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2007 Cayman Island Twilight Zone Expedition

Deep Gardens
(adapted from the Florida Coast Deep Corals 2005 Expedition)

Focus
Deep-sea coral reefs

Grade Level
5-6 (Life Science)

Focus Question
How do deep-sea coral reefs compare to coral reefs in shallow tropical waters?

Learning Objectives
Students will be able to compare and contrast deep-sea coral reefs with their shallow-water counterparts.

Students will be able to describe three types of coral associated with deep-sea coral reefs.

Students will be able to explain three benefits associated with deep-sea coral reefs.

Students will be able to explain why many scientists are concerned about the future of deep-sea coral reefs.

Materials
- ❒ Access to the internet, or copies of materials cited in "Learning Procedure"
- ❒ Copies of "Deep-Water Coral Reefs Report Guide," one copy for each student or student group
- ❒ Bulletin board or poster board

Audio/Visual Materials
- ❒ None

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Classroom style

Maximum Number of Students
30

Key Words
Deep-sea coral
Lophelia pertusa
Cnidaria

Background Information
Coral reefs provide habitats for some of the most diverse biological communities on Earth. Most people have seen photographs and video images of shallow-water coral reefs, and many have visited these reefs in person. Historically, scientists have believed that reef-building corals were confined to relatively shallow depths because many of these corals have microscopic algae called zooxanthellae (pronounced "zoh-zan-THEL-ee") living inside their soft tissues. These algae are often important for the corals' nutrition and growth, but require sunlight for photosynthesis. The maximum depth for reef-building corals was assumed to be about 150 m, since light levels below this depth are not adequate to support photosynthesis. Recently, though, ocean explorers have discovered extensive mounds of living coral in depths from 400 m to 700 m – depths at which there is virtually no light at all! These deep-water corals do not contain zooxanthellae, and

do not build the same types of reef that are produced by shallow-water corals. But branches of deep-water coral species such as *Lophelia pertusa* grow on mounds of dead coral branches that can be several meters deep and hundreds of meters long. Recent studies indicate that the diversity of species in deep-water coral ecosystems may be comparable to that of coral reefs in shallow waters, and that there are just as many species of deep-water corals (slightly more, in fact) as there are species of shallow-water corals.

Because of the high species diversity found on shallow- and deep-water reefs, these ecosystems are proving to be very promising sources of powerful new antibiotic, anti-cancer and anti-inflammatory drugs. In addition, these reefs provide habitat for important food resources, and shallow reefs are an important part of coastal recreation and tourism industries and protect shorelines from erosion and storm damage. Despite the direct importance of coral reefs to many aspects of human well-being, shallow- and deep-water reefs are both threatened by human activities. Shallow-water reefs are damaged by sewage, chemical pollution, careless tourists, boat anchors, and abnormally high temperatures that result in thermal stress. Commercial fisheries, particularly fisheries that use trawling gear, cause severe damage to both shallow and deep-water habitats. Deep-sea coral communities can also be damaged by oil and mineral exploration, ocean dumping, and unregulated collecting.

Around the world, shallow water coral reefs have been intensively studied by scientists using self-contained underwater breathing (SCUBA) equipment, while deep coral systems are being investigated with submersibles and remotely operated underwater vehicles (ROVs). Recent explorations have found a third type of coral ecosystem between depths of 50 m and 150 m: light-limited deep reefs living in what coral ecologists call the "twilight zone." These reefs have been studied much less than shallow and deep-water reefs because they are beyond the safe range of conventional SCUBA equipment, yet are too shallow and close to shore to justify the use of expensive submersibles and ROVs. The few studies of twilight zone reefs suggest that these ecosystems not only include species unique to this depth range, but may also provide important refuges and nursery habitats for corals and fishes that inhabit shallower reefs. This is particularly important in areas where shallow reefs are severely stressed, since twilight zone coral ecosystems may provide a natural option for recovery.

Scientific exploration of twilight zone coral reef ecosystems is urgently needed to provide information for their protection, as well as to identify potentially important sources of drugs and other biological products from organisms that are endemic to these systems. Helping to meet this need is the primary focus of the 2007 Ocean Explorer Cayman Island Twilight Zone Expedition. In this lesson, students will explore the variety of corals found on deep-water coral reefs, potential benefits that these reefs offer, and why scientists are concerned about their future.

Learning Procedure

1. To prepare for this lesson, review the introductory essays for the 2007 Cayman Island Twilight Zone Expedition at http://oceanexplorer.noaa.gov/explorations/07twilightzone/welcome.html.

   If you are not already familiar with coral reefs, you may also want to review the coral reef tutorials at nos.noaa.gov/education/kits/corals/.

2. Briefly review the basic biology and classification of the phylum Cnidaria (for an easy introduction to the phylum, check out http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html). You may want to show part or all of a video by Peter Etnoyer from the 2002 Ocean Explorer Gulf of Alaska Expedition, which includes many images of deep-water corals (http://www.oceanexplorer.noaa.gov/explorations/02alaska/logs/summary/media/movies/deepsea-coral_video.html).

Alternatively, you may want to have students research answers to a series of questions based on the following list. Here are some points that you may want to include in this review:

- 'Cnidaria' means 'stinging nettle' in Greek; the name comes from the stinging cells called nematocysts, which are the primary distinguishing characteristic of the phylum; nematocysts often contain toxins; some box jellies have toxins powerful enough to kill humans.
- All Cnidarians live in water.
- Cnidarians are radially symmetrical.
- There are two body plans among the Cnidaria: the "jellyfish plan" is called a medusa, which has an umbrella-shaped body with the mouth facing downwards, surrounded by tentacles; the "flower plan" is called a polyp, which has a body resembling the trunk or stem of a plant with its mouth facing upwards, also surrounded by tentacles; the other end of the polyp is usually attached to a fixed surface.
- Cnidarians have nerve cells and muscles, but do not have organs such as brains, hearts, circulatory or excretory systems.
- Cnidarians have simple digestive systems without an anus; the mouth is used for output as well as input.
- Most cnidarians are carnivorous; many feed on small particles of detritus and plankton, but others are able to capture and eat large prey.
- Some cnidarians, including many corals, have symbiotic single-celled algae called zooxanthellae that use photosynthesis to produce food that their cnidarian hosts are able to use; corals that do not have zooxanthellae are called azooxanthellate.
- Many cnidarians, including many corals, are colonial, with many individual animals living together as one organism.
- Cnidarians maintain their shape with fluids inside their bodies (this is called a hydrostatic skeleton).
- Some cnidarians also produce a hard internal skeleton of limestone (this is what makes some of the hard structures that form coral reefs).
- Some corals are used to make jewelry; coral reefs protect many coastal areas from erosion and storm damage, provide habitat and nursery areas for fishes that provide food for many people around the world, and support tourist industries in many countries; some reef-dwelling organisms are the source for important pharmaceuticals.
- The phylum Cnidaria is divided into four classes (there more classes, but they only contain extinct species): class Anthozoa includes the corals, anemones, and sea pens; class Cubozoa includes the highly toxic box jellies; class Hydrozoa includes hydroids, fire corals, and animals resembling jellyfish like the Portuguese man-of-war; class Scyphozoa includes the true jellyfish.
- The life cycle of many cnidarians includes a polyp phase as well as a medusa phase, but there is never a medusa phase in the Anthozoa (for more about cnidarian reproduction, see the lesson plan, "Architects of the Deep Reef" at http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_architects.pdf).

3. Assign one of the following coral species or groups to each student:
   Acanella sp.
   Antipatharia
   Callogorgia sp.
   Gorgonia sp.
   Hydrocoral
   Lophelia pertusa
   Madrepora occulata
   Octocoral
   Oculina varicosa
   Paragorgia
   Primnoa
   Scleractinia

   Tell students that their assignment is to find, copy, and label (with the name of the coral) a photograph of their assigned coral, and prepare a brief report (three to five paragraphs) that includes answers to questions on the "Deep-Water Coral Reefs Report Guide." You may choose to provide copies of the following articles, or provide the url links, or allow students to discover these (or others) on their own:

"What are deep-sea corals?" by Lance Morgan; Current 21(4):2-4; available online at http://www.mcbi.org/what/what_pdfs/Current_Magazine/What_are_DSC.pdf

"Trawlers Destroying Deep-Sea Reefs, Scientists Say," by John Pickrell; National Geographic News, February 19, 2004 (http://news.nationalgeographic.com/news/2004/02/0219_040219_seacorals.html)

4. Create a collage of deep-sea corals by having each student place the labeled photograph of their assigned coral on a bulletin board or a piece of poster board. Some notes about classification and common names are provided below (note that some authorities use Alcyonaria instead of Octocorallia):

Acanella sp. (common name: bamboo coral; class Anthozoa, subclass Octocorallia)

Antipatharia (common name: black coral; class Aanthozoa, subclass Hexacorallia, order Antipatharia)

Callogorgia sp. (common name: gold coral; class Anthozoa, subclass Octocorallia)

Gorgonia sp. (common name: sea fan; class Anthozoa, subclass Octocorallia)

Hydrocoral (common name: fire coral; class Hydrozoa, order Milleporina)

Lophelia pertusa (class Anthozoa, subclass Zoantharia, order Scleractinia)

Madrepora occulata (class Anthozoa, subclass Zoantharia, order Scleractinia)

Octocoral (common name: soft coral; class Anthozoa, subclass Octocorallia)

Oculina varicosa (common name: ivory tree coral; class Anthozoa, subclass Zoantharia, order Scleractinia)

Paragorgia (common name: bubblegum coral; class Anthozoa, subclass Octocorallia)

Primnoa (common name: red trees; class Anthozoa, subclass Octocorallia)

Scleractinia (common name: stony coral; class Anthozoa, subclass Zoantharia, order Scleractinia)

5. Lead a discussion of students' answers to worksheet questions. Be sure students understand that deep-sea coral reefs:
   - Are at least as diverse as their shallow-water counterparts;
   - Provide habitat for many other species (some of which are important human food species);
   - Probably include organisms that can provide useful drugs to treat human diseases; and
   - Are severely threatened by human activity, particularly bottom trawling and longlining.

   The following points should be included:
   - The majority of coral species live in colder, deeper waters.
   - *Lophelia pertusa* is found on deep-sea reefs on continental margins worldwide.
   - Because deep-sea exploration is difficult, our knowledge of deep-sea environments is very limited, and this has led to the widespread assumption that coral reefs are confined to shallow waters.
   - Gorgonians, alcyonaceans, pennatulaceans, and stoloniferans belong to the subclass Alcyonaria or Octocorallia and are collective-

ly referred to as octocorals or soft corals.
- Only members of the order Scleractinia actually form true coral "reefs."
- Some deep-sea reefs in the North Atlantic have been found to harbor as many as 1,300 invertebrate species.
- Growth and reproduction in deep-sea corals is very slow.
- Some deep-sea corals may be hundreds of years old; one individual has been dated at 1,800 years old.
- At present, the greatest threat to deep-sea coral communities is bottom trawling.
- In addition to deep-sea corals, sponges also form highly diverse communities in the deep ocean.

The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Biology," then "Invertebrates," then "Other Inverts" for links to more information about Cnidaria

The "Me" Connection

Have students write a short essay on how deep-sea coral reefs could be of personal importance, and how they might be personally affected by the widespread destruction of these reefs.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Written reports and discussions in Steps 3 and 4 provide opportunities for assessment.

Extensions

1. Visit oceanexplorer.noaa.gov to keep up to date with the latest Cayman Island Twilight Zone Expedition discoveries, and to find out what researchers are learning about deep fore reef communities.
2. See the July 2005 issue of Current: the Journal of Marine Education for a special issue on deep-sea corals (available online at http://www.mcbi.org/Current_Magazine/Current_Magazine.htm), including three lesson plans for grade 5 - 12.

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 3 and 12 for interactive multimedia presentations and Learning Activities on deepsea corals and biotechnology.

Other Relevant Lesson Plans from the Ocean Exploration Program

Easy as Pi [http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/media/03cb_pi.pdf] (4 pages, 252k) (from the 2003 Charleston Bump Expedition]

Focus: Structural complexity in benthic habitats (Life Science/Mathematics)

In this activity, students will be able to describe the importance of structural features that increase surface area in benthic habitats and quantify the relative impact of various structural modifications on surface area in model habitats. Students will also be able to give examples of organisms that increase the structural complexity of their communities.

Friend, Foe, or . . . [http://oceanexplorer.noaa.gov/explorations/05stepstones/background/education/ss_2005_friend-foe.pdf] (5 pages, 331k) (from the North Atlantic Stepping Stones 2005 Expedition)

Focus (Life Science) - Symbiotic relationships with corals

In this activity, students will be able to define and describe symbiotic, mutualistic, commensal, parasitic, facultative and obligatory relationships between organisms; describe at least three species that have symbiotic relationships with corals;

and discuss whether these relationships are mutualistic, commensal, or parasitic.

Architects of the Deep Reef [http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_architects.pdf] (5 pages, 388k) (from the Gulf of Mexico Deep Sea Habitats 2003 Expedition)

Focus: Reproduction in Cnidaria (Life Science)

In this activity, students will be able to identify and describe at least five characteristics of Cnidaria coral, compare and contrast the four classes of Cnidaria, and describe typical reproductive strategies used by Cnidaria. Students will also be able to infer which of these strategies are likely to be used by the deep-sea coral Lophelia pertusa, and will be able to describe the advantages of these strategies.

Chemists Without Backbones [http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_ChemNoBackbones.pdf] (4 pages, 356k) (from the 2003 Deep Sea Medicines Expedition)

Focus: Benthic invertebrates that produce pharmacologically active substances (life science)

In this activity, students will be able to identify at least three groups of benthic invertebrates that are known to produce pharmacologically active compounds and will describe why pharmacologically active compounds derived from benthic invertebrates may be important in treating human diseases. Students will also be able to infer why sessile marine invertebrates appear to be promising sources of new drugs.

Keep Away [http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_keepaway.pdf] (5 pages, 424k) (from the 2003 Gulf of Mexico Deep Sea Habitats Expedition)

Focus: Effects of pollution on diversity in benthic communities (Life Science)

In this activity, students will discuss the meaning of 'biological diversity' and compare and contrast the concepts of 'variety' and 'relative abundance' as they relate to biological diversity. Given information on the number of individuals, number of species, and biological diversity at a series of sites, students will make inferences about the possible effects of oil drilling operations on benthic communities.

Other Links and 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.

oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration program

oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer image gallery

http://www-biol.paisley.ac.uk/courses/Tatner/biomedia/units/cnid1.htm – Phylum Cnidaria on Biomedia of the Glasgow University Zoological Museum on the Biological Sciences, University of Paisley, Scotland Web site; includes explanations of the major classes, a glossary of terms and diagrams and photos

http://www.calacademy.org/research/izg/calwildfall2000.pdf – Article from California Wild: "Stinging Seas - Tread Softly In Tropical Waters" by Gary C. Williams; an introduction to the venomous nature of tropical cnidarians, why and how they do it

http://www.mcbi.org/publications/pub_pdfs/Deep-Sea%20Coral%20issue%20of%20Current.pdf – A special issue of Current: the Journal of Marine Education on deep-sea corals.

http://www.mesa.edu.au/friends/seashores/index.html – "Life on Australian Seashores" by Keith Davey on

the Marine Education Society of Australasia Web site, with an easy introduction to Cnidaria, including their method of reproduction

http://www.oceanicresearch.org/ – The Oceanic Research Group Web site; lots of photos, but note that they are very explicit about their copyrights; check out "Cnidarians: Simple but Deadly Animals!" by Jonathan Bird, which provides an easy introduction designed for classroom use

http://www.science.fau.edu/drugs.htm – An overview article on drugs from the sea

http://spikesworld.spike-jamie.com/science/index.html — Web site with lots of background and activities on multiple science topics, including microorganisms

http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html – Introduction to Cnidaria from the University of California Museum of Paleontology

http://www.uky.edu/KGS/education/cookbook.htm – The Geologic and Paleontologic Cookbook

http://www.wwf.org.uk/filelibrary/pdf/darwin_mounds.pdf – Report on the Darwin Mounds, a recently-discovered group of hard-bottom habitats in the United Kingdom's 200 nm offshore zone

Maxwell, S. 2005. An Aquatic Pharmacy: The Biomedical Potential of the Deep Sea. Current 21(4):31-32; available online at http://www.mcbi.org/what/what_pdfs/Current_Magazine/Pharmacy.pdf

Frame, C. and H. Gillelan. 2005. Threats to deep-sea corals and their conservation in U.S. waters. Current 21(4):46-47; available online at http://www.mcbi.org/what/what_pdfs/Current_Magazine/Threats_Conservation.pdf

Morgan, L. E. 2005. What are deep-sea corals? Current 21(4):2-4; available online at http://www.mcbi.org/what/what_pdfs/Current_Magazine/What_are_DSC.pdf

Pickrell, J. 2004. Trawlers Destroying Deep-Sea Reefs, Scientists Say. National Geographic News. http://news.nationalgeographic.com/news/2004/02/0219_040219_seacorals.html

Reed, J. K. and S. W. Ross. 2005. Deep-water reefs off the southeastern U.S.: Recent discoveries and research. Current 21(4):33-37; available online at http://www.mcbi.org/what/what_pdfs/Current_Magazine/Southeastern_US.pdf

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://www.oceana.org/fileadmin/oceana/uploads/reports/oceana_coral_report_final.pdf — Background on deep-water coral reefs

National Science Education Standards

Content Standard A: Science as 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 E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal & Social Perspectives
- Populations, resources, and environments
- Risks and benefits
- Science and technology in society

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of science

Ocean Literacy Essential Principles and Fundamental Concepts

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

- *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 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.

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 c.* The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *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 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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Student Handout

Deep-Water Coral Reefs Report Guide

1. Are more coral species found in warm, shallow water or cold, deep water?

2. What is one species of deep-sea coral that is found in large reefs on the European continental margin from Norway to Portugal?

3. Why have coral reefs been considered to be confined to shallow waters?

4. Gorgonians, alcyonaceans, pennatulaceans, and stolonifer-ans belong to the subclass __________ and are collectively referred to as __________.

5. Only members of the order __________ actually form true coral "reefs."

6. Some deep-sea reefs in the North Atlantic have been found to harbor __________ invertebrate species.

7. How rapidly do deep-sea corals grow and reproduce?

8. How long do deep-sea corals live?

9. At present, what is the greatest threat to deep-sea coral communities?

10. In addition to deep-sea corals, what other invertebrates form highly diverse communities in the deep ocean?

Teacher Answers

Deep-Water Coral Reefs Report Guide

1. Are more coral species found in warm, shallow water or cold, deep water?
   - The majority of coral species live in colder, deeper waters.
2. What is one species of deep-sea coral that is found in large reefs on the European continental margin from Norway to Portugal?
   - *Lophelia pertusa* is found on deep-sea reefs on continental margins worldwide.
3. Why have coral reefs been considered to be confined to shallow waters?
   - Because deep-sea exploration is difficult, our knowledge of deep-sea environments is very limited, and this has led to the widespread assumption that coral reefs are confined to shallow waters.
4. Gorgonians, alcyonaceans, pennatulaceans, and stoloniferans belong to the subclass _________ and are collectively referred to as _________.
   - Gorgonians, alcyonaceans, pennatulaceans, and stoloniferans belong to the subclass Alcyonaria or Octocorallia and are collectively referred to as octocorals or soft corals.
5. Only members of the order _________ actually form true coral "reefs."
   - Only members of the order Scleractinia actually form true coral "reefs."
6. Some deep-sea reefs in the North Atlantic have been found to harbor _________ invertebrate species.
   - Some deep-sea reefs in the North Atlantic have been found to harbor as many as 1,300 invertebrate species.
7. How rapidly do deep-sea corals grow and reproduce?
   - Growth and reproduction in deep-sea corals is very slow.
8. How long do deep-sea corals live?
   - Some deep-sea corals may be hundreds of years old; one individual has been dated at 1,800 years old.
9. At present, what is the greatest threat to deep-sea coral communities?
   - At present, the greatest threat to deep-sea coral communities is bottom trawling.
10. In addition to deep-sea corals, what other invertebrates form highly diverse communities in the deep ocean?
    - In addition to deep-sea corals, sponges also form highly diverse communities in the deep ocean.