OCEAN EXPLORATION & RESEARCH

Lessons from the Deep:

Exploring the Gulf of Mexico's Deep-Sea Ecosystems

Education Materials Collection

Image captions/credits on Page 2.

lesson plan

Cool Corals

(adapted from the 2003 Life on the Edge: Exploring Deep Ocean Habitats Expedition)

Focus

Biology and ecology of *Lophelia* corals

Grade Level

7-8 (Life Science)

Focus Question

What do scientists know about the basic biology and ecology of *Lophelia* corals?

Learning Objectives

- Students will be able describe the basic morphology of *Lophelia* corals and explain the significance of these organisms.

- Students will be able to interpret preliminary observations on behavior of *Lophelia* polyps, and infer possible explanations for these observations.

- Students will be able to explain why biological communities associated with *Lophelia* corals are the focus of major worldwide conservation efforts.

Materials

- For Optional Activity: Copies of *Preliminary Studies of* Lophelia pertusa *Polyp Behavior*, one for each student group

Audio/Visual Materials

- Chalkboard, marker board, or overhead projector with transparencies and markers for group discussion

Teaching Time

One 45-minute class period, plus time for student research

Seating Arrangement

Groups of 4-6 students

Maximum Number of Students

30

Key Words

Gulf of Mexico
Hard bottom
Cold seep
Lophelia pertusa
Deep-water coral

Background Information

Deepwater ecosystems in the Gulf of Mexico are often associated with rocky substrates or "hardgrounds." Most of these hard bottom areas are found in locations called cold seeps where hydrocarbons are seeping through the seafloor. Microorganisms are the connection between hardgrounds and cold seeps. 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. Two types of ecosystems are typically associated with deepwater hardgrounds in the Gulf of Mexico: chemosynthetic communities and deep-sea coral communities. Hydrocarbon seeps may indicate the presence of undiscovered petroleum deposits, so the presence of these ecosystems may indicate potential sites for exploratory drilling and possible development of offshore oil wells. At the same time, these are unique ecosystems whose full importance is presently unknown.

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. These corals are usually found on hardbottom areas where there are strong currents and little suspended sediment (but extremely strong currents may interfere with feeding and cause breakage). *Lophelia pertusa*, the best-known deepwater coral species, prefers water temperatures between 4-12 °C, dissolved oxygen concentrations above 3 ml/l, and salinity between 35 and 37 ppt. The influence of other factors, including pH, is not known. Recent studies suggest that deepwater reef ecosystems may have a diversity of species comparable to that of corals 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

Images from Page 1 top to bottom:
A close-up mussel aggregation with *Chirodota heheva* sea cucumbers. Image courtesy of Expedition to the Deep Slope 2007.
http://oceanexplorer.noaa.gov/explorations/07mexico/logs/july3/media/cuke_600.html

A CTD rosette being recovered at the end of a cast. Note that the stoppers on the sample bottles are all closed. Image courtesy of INSPIRE: Chile Margin 2010.
http://oceanexplorer.noaa.gov/explorations/10chile/logs/summary/media/2summary.html

A methane hydrate mound on the seafloor; bubbles show that methane is continuously leaking out of features like this. If bottom waters warmed, this entire feature may be destabilized and leak methane at a higher rate.
http://oceanexplorer.noaa.gov/explorations/10chile/background/methane/media/methane4.html

Lophelia pertusa create habitat for a number of other species at a site in Green Canyon. Image courtesy of Chuck Fisher.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

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. Sulak (2008) provides extensive information on deepwater hard bottom coral communities at Viosca Knoll in the Northern Gulf of Mexico, including illustrations of fishes, benthic invertebrates, and typical biotopes associated with these communities.

Lophelia pertusa create habitat for a number of other species at a site in Green Canyon. Image courtesy of Chuck Fisher.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

The major deepwater structure-building corals 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.

An example of the Viosca Knoll 906 habitat. In part of this site, there are a series of mounds that appear to be composed primarily of dead *Lophelia pertusa* rubble. Image courtesy of Lophelia II Team 2009, NOAA-OER.
http://oceanexplorer.noaa.gov/explorations/09lophelia/background/plan/media/image_4.html

Why are deepwater coral reefs in the Gulf of Mexico so often associated with hydrocarbon seeps? One reason is that the carbonate rock resulting from microbes feeding on hydrocarbons provides a substrate where larvae of many other bottom-dwelling organisms may attach, particularly larvae of corals. It has also been suggested that microorganisms that feed on hydrocarbons could also provide a food source for corals, many of which obtain their nutrition through filter-feeding. Recent research, however, has shown that the skeletons of corals from seep communities do not have a chemical composition that supports this hypothesis (Becker, *et al.*, 2009).

Lophelia pertusa coral, with opened polyps, attached to an authigenic carbonate rock. Seep-dependent tubeworms are visible behind the coral. Image courtesy of, *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs and Wrecks.
http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug25/media/lophelia_insitu_.html

In this activity, students will research basic information on *Lophelia pertusa* and interpret results of a preliminary study of polyp behavior in this species.

Learning Procedure

1. To prepare for this lesson:
   (a) Review the following essays:

Chemosynthetic Communities in the Gulf of Mexico (http://oceanexplorer.noaa.gov/explorations/02mexico/background/communities/communities.html); and
The Ecology of Gulf of Mexico Deep-Sea Hardground Communities (http://oceanexplorer.noaa.gov/explorations/06mexico/background/hardgrounds/hardgrounds.html).
Geological Setting (http://oceanexplorer.noaa.gov/explorations/02mexico/background/geology/geology.html)
Diversity of Deep-sea Corals (http://oceanexplorer.noaa.gov/explorations/03mex/background/coral_diversity/coral_diversity.html)

(b) You may also want to review the following visual resources and consider presenting some of these to your students:

- Image collections from Sulak, *et al.* (2008). Master Appendix D of this large report contains many images of deep-water coral communities. Download the PDF files "Master Appendix D - Megafaunal Invertebrates of Viosca Knoll, *Lophelia* Community Investigation," and "Key to Plates in Master Appendix D" from http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html

- Video showing some of the extraordinary biological diversity of the Gulf of Mexico (http://oceanexplorer.noaa.gov/explorations/03mex/logs/summary/media/ngom_biodiversity_cm3.html)

- Videos of deepwater corals and coral communities (http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/photolog/photolog.html)

- Virtual tour of a cold-seep community (http://www.bio.psu.edu/cold_seeps)

- Slideshow of highlights from Expedition to the Deep Slope 2006 (http://oceanexplorer.noaa.gov/explorations/06mexico/background/media/slideshow/slideshow.html)

- Slideshow of images from the Expedition to the Deep Slope 2007 (http://oceanexplorer.noaa.gov/explorations/07mexico/logs/summary/media/slideshow/html_slideshow.html)

(c) Review Learning Procedure Step 4, and decide whether to include this optional activity.

2. Lead a discussion of deep-sea coral communities. Briefly describe the association of these communities with hardgrounds and cold-

seeps. Tell students that their assignment is to prepare a written report on *L. pertusa* which should include:

- a brief summary of the biology of this species (what kind of animal is it and what its general characteristics are);
- preferred habitat (where is it found, and what the general physical conditions in this habitat are);
- associations with other species;
- significance to humans; and
- interactions with humans.

3. Lead a group discussion about *Lophelia pertusa*. Student reports should include most of the following points:
   - *L. pertusa* is a scleractinian (stony) coral with a branched growth form; live corals are often found growing on mounds of dead branches that form deep-water reefs.
   - About 20 of 703 known species of deep-sea scleractinians build reef structures.
   - *L. pertusa* is distributed throughout the Earth's ocean except in polar regions, usually in depths ranging from 200 m to 1,000 m at temperatures between 6° C and 8° C; live *L. pertusa* reefs have been reported from depths greater than 3,000 m.
   - Growth rates of *L. pertusa* have been estimated at 4 – 5 mm per year, which is slower than that of reef-building corals in shallow water.
   - Deep-sea corals often are long-lived and may be hundreds of years old.
   - The branching growth form of *L. pertusa* provides a variety of habitats for other species.
   - Complex biological communities are associated with *L. pertusa* reefs on continental shelves, slopes, and seamounts.
   - Biological diversity on *L. pertusa* reefs has been reported to be about three times greater than on surrounding soft bottom habitats.
   - About 800 species have been reported to be associated with these reefs in the North Atlantic.
   - Very little is known about reproduction in *L. pertusa*, but colonies of the coral have been found on oil rigs that are far away from known locations of natural reefs, suggesting that this species may have long-lived planktonic larvae (this would be advantageous for the potential recolonization of damaged areas).
   - *L. pertusa* reefs have been known to fishermen for centuries and are considered good fishing areas, especially for gillnets and longlines.
   - Scientists paid little attention to reports of *L. pertusa* reefs until the 1990's, at least partially because the deep-sea environment was very difficult to explore prior to that time.
   - Use of heavy bottom trawls in recent years has greatly

increased damage to *L. pertusa* reefs from fishing activities.
- Trawling causes mechanical damage to *L. pertusa* reefs, and stirs up large quantities of silt; siltation is believed to be a major cause of *L. pertusa* reef degradation on a global scale.
- Silt has been reported to suppress growth rates of adult *L. pertusa* polyps and to reduce the diversity of associated species.
- Oil exploration and extraction activities can also damage *L. pertusa* reefs by increasing sedimentation and discharging toxic chemicals.

In the course of the discussion, ask why so much attention is suddenly being directed toward *L. pertusa* reefs. Students should recognize that the extent and diversity of these reefs (like many other biological communities in the deep ocean) simply wasn't known until recently, and the potential benefits of other species associated with these reefs are still unknown. The availability of deep-sea exploration technology has been critical to gaining a better understanding of these systems and the extent to which they are threatened. The relationship of these reefs to productive fisheries has been known to fishermen for many years, and the recent introduction of heavy "rock hopping" trawl gear poses a new threat of major destruction. Apart from ethical or moral considerations, it is simply in our best interest to protect potentially useful resources.

4. **Optional data analysis and interpretation activity**

(a) Provide each student group with a copy of *Preliminary Studies of* Lophelia pertusa *Polyp Behavior*. Each group should graph the data and answer the questions in the handout.

(b) Lead a discussion of students' answers to questions on the handout. The following points should be included:

- Scientists wanted to avoid exposing corals to visible light because this would be an unnatural physical factor (light) that might affect their behavior, since these corals normally live in very deep waters where there is virtually no light.

- Scientists did not control their experiment for possible effects of infrared light.

- In the second experiment, scientists did not expose one colony to sand to provide a control for the experimental treatment.

- Data from this study no not support the idea that *L. pertusa* polyps are permanently expanded.

- *L. pertusa* polyps do not extend and retract at the same rate; the rate of extension is slower than the rate of retraction.

- Some reasons (students may describe others) that *L. pertusa* polyps suddenly retract include disturbance by some external factor; or because a rapid retraction could produce a more vigorous water movement (possibly useful for exchanging water in the coelenteron cavity or for expelling waste products of metabolism).

- Some reasons (students may describe others) *L. pertusa* periodically extend and contract are to exchange water in the coelenteron cavity or expel waste products of metabolism.

- Sand appears to have an effect on *L. pertusa* polyps; it appears to reduce extension of the polyps.

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Habitats," then "Deep Sea" for resources on deep-sea communities.

The "Me" Connection

Have students write a short essay on how *L. pertusa* reefs might be potentially important to their own lives.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Students' reports and class discussions provide opportunities for assessment.

Extensions

See the "Resources" section of *Lessons from the Deep: Exploring the Gulf of Mexico's Deep-sea Ecosystem Education Materials Collection Educators Guide* for additional information, activities, and media resources about deepwater ecosystems in the Gulf of Mexico.

Multimedia Discovery Missions

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

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

From the Gulf of Mexico to the Moons of Jupiter (6 pages, 207 KB)

http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_moons.pdf

Focus - Adaptations to unique or "extreme" environments (Earth 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 will be able to compare physical conditions in deep-sea "extreme" environments to conditions thought to exist on selected moons of Jupiter. Students will also discuss the relevance of chemosynthetic processes in cold seep communities to the possibility of life on other planetary bodies.

Biochemistry Detectives (8 pages, 480 K)

http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_biochem.pdf

Focus - Biochemical clues to energy-obtaining strategies (Chemistry)

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 energy-obtaining strategies used by organisms in cold-seep communities. Students will also be able to interpret analyses of enzyme activity and ^{13}C isotope values to draw inferences about energy-obtaining strategies used by organisms in cold-seep communities.

This Old Tubeworm (10 pages, 484 KB)

http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/old_worm.pdf

Focus - Growth rate and age of species in cold-seep communities (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 construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age specific growth in individuals of the same species.

C.S.I. on the Deep Reef (Chemotrophic Species Investigations, That Is) (6 pages, 444 KB)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/gom_06_csi.pdf
Focus: Chemotrophic organisms (Life Science/Chemistry)
In this activity, students will describe at least three chemotrophic symbioses known from deep-sea habitats and will identify and explain at least three indicators of chemotrophic nutrition.

Gellin (4 pages, 372 KB)
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_gellin.pdf
Focus - DNA analysis (Life Science)
In this activity, students will explain and carry out a simple process for separating DNA from tissue samples, explain and carry out a simple process for separating complex mixtures, and explain the process of restriction enzyme analysis.

Hot Food (4 pages, 372 KB)
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_hotfood.pdf
Focus - Energy content of hydrocarbon substrates in chemosynthesis (Chemistry)
In this activity, students will compare and contrast photosynthesis and chemosynthesis as processes that provide energy to biological communities, and given information on the molecular structure of two or more substances, will make inferences about the relative amount of energy that could be provided by the substances. Students will also be able to make inferences about the potential of light hydrocarbons as an energy source for deep-water coral reef communities.

How Does Your (Coral) Garden Grow? (6 pages, 456 KB)
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_growth.pdf
Focus - Growth rate estimates based on isotope ratios (Life Science/Chemistry)
In this activity, students will identify and briefly explain two methods for estimating the age of hard corals, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals.

What's the Difference? (20 pages, 300 kb)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/difference.pdf
Focus - Identification of biological communities from survey data (Life *Science)*
In this activity, students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas, describe similarities between groups of organisms using a dendrogram, and infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

The Big Burp: Where's the Proof? (5 pages, 364 KB)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/burp.pdf
Focus - Potential role of methane hydrates in global warming (Earth Science)
In this activity, students will be able to describe the overall events that occurred during the Cambrian explosion and Paleocene extinction events and will be able to define methane hydrates and hypothesize how these substances could contribute to global warming. Students will also be able to describe and explain evidence to support the hypothesis that methane hydrates contributed to the Cambrian explosion and Paleocene extinction events.

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.

http://oceanexplorer.noaa.gov/ – Ocean Explorer Web site

Sulak, K. J., M. T. Randall, K. E. Luke, A. D. Norem, and J. M. Miller (Eds.). 2008. Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral - *Lophelia* Reef Megafaunal Community Structure, Biotopes, Genetics, Microbial Ecology, and Geology. USGS Open-File Report 2008-1148; http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html

http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/maincontent.htm – Web site for the National Methane Hydrate Research and Development Program http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html – Gas (Methane) Hydrates—A New Frontier; Web page from the U.S. Geological Survey's Marine and Coastal Geology Program

Van Dover, C.L., P. Aharon, J.M. Bernhard, E. Caylord, M. Doerriesa, W. Flickinger, W. Gilhooly, S.K. Goffredi, K.E. Knick, S.A. Macko, S. Rapoport, E.C. Raulfs, C. Ruppel, J.L. Salerno, R.D. Seitz, B.K. Sen Gupta, T. Shank, M. Turnipseed, R. Vrijenhoek. 2003. Blake Ridge methane seeps: characterization of a soft-sediment, chemosynthetically-based ecosystem. Deep-Sea Research Part I 50:281–300. (Available as a PDF file at http://www.mbari.org/staff/vrijen/PDFS/VanDover_2003DSR.pdf)

MacDonald, I. and S. Joye. 1997. Lair of the "Ice Worm." Quarterdeck 5(3); http://www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html; article on cold-seep communities and ice worms

Siegel, L. J. 2001. Café Methane. http://nai.arc.nasa.gov/news_stories/news_detail.cfm?ID=86; article on cold-seep communities and ice worms from NASA's Astrobiology Institute

Kirschvink, J. L. and T. D. Raub. 2003. A methane fuse for the Cambrian explosion: carbon cycles and true polar wander. Comptes Rendus Geoscience 335:65-78. Journal article on the possible role of methane release in rapid diversification of animal groups. Also available on-line at http://www.gps.caltech.edu/users/jkirschvink/pdfs/KirschvinkRaubComptesRendus.pdf

Simpson, S. 2000. Methane fever. *Scientific American* (Feb. 2000) pp 24-27. Article about role of methane release in the Paleocene extinction event

http://www.piersystem.com/go/site/2931/ – Main Unified Command Deepwater Horizon response site

http://response.restoration.noaa.gov/deepwaterhorizon – NOAA Web site on Deepwater Horizon Oil Spill Response

http://docs.lib.noaa.gov/noaa_documents/NESDIS/NODC/LISD/Central_Library/current_references/current_references_2010_2.pdf – Resources on Oil Spills, Response, and Restoration: a Selected Bibliography; document from NOAA Central Library to aid those seeking information concerning the Deepwater Horizon oil spill disaster in the Gulf of Mexico and information on previous spills and associated remedial actions; includes media products (web, video, printed and online documents) selected from resources available via the online NOAA Library and Information Network Catalog (NOAALINC) http://www.gulfallianceeducation.org/ – Extensive list of publications and other resources from the Gulf of Mexico Alliance; click "Gulf States Information & Contacts for BP Oil Spill" to download the Word document

http://rucool.marine.rutgers.edu/deepwater/ – Deepwater Horizon Oil Spill Portal from the Integrated Ocean Observing System at Rutgers University

http://www.darrp.noaa.gov/southeast/deepwater_horizon/ index.html – Information about damage assessments being conducted by NOAA's Damage Assessment Remediation and Restoration Program

http://response.restoration.noaa.gov/ – Click "Students and Teachers" in the column on the left for information, fact sheets, and activities about oil emergencies, habitats, and other ocean issues

http://www.noaa.gov/sciencemissions/bpoilspill.html – Web page with links to NOAA Science Missions & Data relevant to the Deepwater Horizon/BP Oil Spill

http://ecowatch.ncddc.noaa.gov/jag/data.html – Data Links page on the Deepwater Horizon Oil Spill Joint Analysis Group Web site

http://ecowatch.ncddc.noaa.gov/jag/reports.html – Reports page on the Deepwater Horizon Oil Spill Joint Analysis Group Web site

http://www.education.noaa.gov/Ocean_and_Coasts/Oil_Spill.html - "Gulf Oil Spill" Web page from NOAA Office of Education with links to multimedia resources, lessons & activities, data, and background information

http://www.geoplatform.gov/gulfresponse/ - Web page for GeoPlatform.gov/gulfresponse—an online map-based tool developed by NOAA with the EPA, U.S. Coast Guard, and the Department of Interior to provide a "one-stop shop" for spill response information; includes oil spill trajectory, fishery area closures, wildlife data, locations of oiled shoreline and positions of deployed research ships

Fisher, C., H. Roberts, E. Cordes, and B. Bernard. 2007. Cold seeps and associated communities of the Gulf of Mexico. Oceanography 20:118-129; available online at http://www.tos.org/oceanography/issues/issue_archive/20_4.html

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard C: Life Science
- Interdependence of organisms
- Behavior of organisms

Content Standard D: Earth and Space Science
- Geochemical cycles

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality

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 3.
The ocean is a major influence on weather and climate.
Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
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 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 g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustainthe 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 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 e-mail your comments to: oceanexeducation@noaa.gov

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Preliminary Studies of *Lophelia pertusa* Polyp Behavior

(adapted from Roberts and Anderson, 2000)

Scientists who conducted this study used time-lapse video recording to study polyp behavior. The recordings were made using infrared light to avoid potential effects of exposing the corals to visible light. Light from an infrared-emitting diode was diffused through a translucent screen. A coral branch in an aquarium was placed between the video camera and the screen so that the branch produced a silhouette. This allowed the scientists to see when polyps were extended and when they were retracted into the calices (a calyx is the "cup" formed by the coral skeleton that shelters the individual coral polyps).

At the beginning of the first experiment, the corals were gently tapped to cause them to retract. An image of the coral branch was recorded at 20-minute intervals. When the experiment was completed, the scientists measured the diameter of each calyx recorded at the beginning of the experiment, and compared this measurement to the diameter of the same calyx at 20-minute intervals. If the polyps were extended or partially extended, the diameter would appear larger than if the polyps were retracted (and hence out of sight in the silhouette). To compensate for size differences among the polyps, a "corrected index of extension" was calculated by dividing the amount of extension by the calyx diameter:

Corrected Index of Extension =
(Extended Diameter - Calyx Diameter) ÷ Calyx Diameter

A second experiment was conducted to investigate the effect of sand deposition on polyp behavior; the scientists used a pump to drop sand onto one colony while a second colony was left undisturbed. Time-lapse video recordings were made of both colonies at 20-minute intervals for 24 hours.

Table 1 contains data from a single polyp in the first experiment.
Data from the second experiment are summarized in Table 2.

Graph the data from Tables 1 and 2 as directed by your teacher, and answer the following questions:

1. Why did scientists want to avoid exposing the corals to visible light?

Preliminary Studies of *Lophelia pertusa* Polyp Behavior - 2

2. How did the scientists control their experiment for possible effects of infrared light?

3. In the second experiment, why did the scientists have one colony that was not exposed to sand?

4. Other researchers have suggested that L. pertusa polyps are permanently expanded. Do data from this study support this idea?

5. Do L. pertusa polyps extend and retract at the same rate?

6. Why might L. pertusa polyps suddenly retract?

7. Why might L. pertusa periodically extend and contract?

8. Does sand appear to have an effect on L. pertusa polyps? If so, what is the effect?

Preliminary Studies of *Lophelia pertusa* Polyp Behavior - 3

Table 1

Time	Corrected Index of Extension	Time	Corrected Index of Extension	Time	Corrected Index of Extension
1900	0.41	0020	0.43	0540	0.04
1920	0.44	0040	0.45	0600	0.07
1940	0.46	0100	0.47	0620	0.14
2000	0.47	0120	0.02	0640	0.16
2020	0.39	0140	0.00	0700	0.23
2040	0.42	0200	0.03	0720	0.29
2100	0.44	0220	0.06	0740	0.35
2120	0.47	0240	0.08	0800	0.28
2140	0.50	0300	0.11	0820	0.28
2200	0.48	0320	0.10	0840	0.32
2220	0.42	0340	0.00	0900	0.40
2240	0.43	0400	0.02	0920	0.43
2300	0.45	0420	0.04	0940	0.34
2320	0.47	0440	0.07	1000	0.35
2340	0.47	0500	0.10		
0000	0.48	0520	0.02		

Table 2

Polyp Number	Treatment	Mean Corrected Index of Extension Over 24 hours
1	sand	0.07
3	no sand	0.35
4	sand	0.08
6	sand	0.05
8	no sand	0.36
12	no sand	0.39
13	sand	0.03
15	no sand	0.40
19	sand	0.11