


Image captions/credits on Page 2.

lesson plan

Lophelia II 2010:
Cold Seeps and Deep Reefs

What's So Special?

Focus
Biology and ecology of *Lophelia* corals and cold-seep ecosystems

Grade Level
7-8 (Life Science)

Focus Question
Why are *Lophelia* corals and cold-seep ecosystems important?

Learning Objectives
- Students will describe the general biology and morphology of *Lophelia* corals.
- Students will explain how *Lophelia* corals and cold seeps contribute to the development of complex biological communities.
- Students will identify ways in which deepwater coral and cold-seep communities are threatened by human activities.
- Students will discuss ways in which deepwater coral and cold-seep communities may be important to humans.

Materials
- Copies of *Deep-Sea Ecosystems and Scientific Posters Inquiry Guide,* one copy for each student group
- Materials for creating scientific posters

Audio-Visual Materials
- (Optional) video projection or other equipment to show images of deep-sea ecosystems from http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/photolog/photolog.html

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

Seating Arrangement
Groups of 2-4 students

Maximum Number of Students
32

Key Words

Gulf of Mexico
Cold seep
Lophelia
Deepwater coral
Conservation

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

For the past four years, NOAA's Office of Ocean Exploration and Research (OER) has sponsored expeditions to locate and explore deep-sea chemosynthetic communities in the Gulf of Mexico. On April 20, 2010, a gas explosion occurred on the mobile offshore drilling unit Deepwater Horizon about 40 miles southeast of the Louisiana coast. The explosion killed 11 workers, injured 17 others, ignited an intense fire that burned until the Deepwater Horizon sunk 36 hours later, and resulted in a massive release of crude oil that is now considered the greatest environmental disaster in U.S. history. The total volume of oil released into the Gulf of Mexico is estimated to have been 205 million gallons (4.9 million barrels), dwarfing the 11-million gallon *Exxon Valdez* spill of 1989. Efforts to prevent the released oil from making landfall included the use of dispersants, some of which were injected at the wellhead to reduce the amount of oil that reached the surface. Extensive media attention has been directed toward the ecological impacts of released oil on beaches, marshes, birds, turtles, and marine mammals. Many scientists, however, are also concerned about how oil and dispersants may affect the unusual and biologically-rich communities of the Gulf of Mexico seafloor.

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. 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 importance is presently unknown.

The Deepwater Horizon blowout highlights the vulnerability of deep-sea ecosystems to impacts from human activity. Increasingly, the biological communities associated with deepwater corals, cold seeps, and

Images from Page 1 top to bottom:
Lophelia pertusa on the seafloor. Note extended polyp on the right. Image courtesy of Ian MacDonald, NOAA.
http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/sept1/media/lophelia_insitu_close.html

Video monitors inside Jason control van allow scientists and Jason crew to see all seafloor operations. Tim Shank (right) records observations using the "Virtual Van" software. Image courtesy Troy Kitch, NOAA.
http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug31/media/controlvan.html

Preserved specimens collected during *Lophelia* II 2009. Image courtesy Troy Kitch, NOAA.
http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug23/media/species_jar.html

Viosca Knoll Wreck: The stempost of the wreck is covered in *Lophelia*, Stalk Barnacles, *Acesta* clams and Anemones. A little *Eumunida picta* is also evident in the lower corner. Image courtesy Stephanie Lessa, NOAA.
http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/sept6/media/7_biostem.html

hydrothermal vents are the focus of efforts to protect these resources that may have enormous value to human well-being. One of the problems confronting these efforts is that it is difficult to build public support for protecting ecosystems that most people will never see. For this reason, a key part of efforts to protect deep-sea ecosystems involves educating the public about these resources and why they are important. In this lesson, students will develop materials that can be used as part of this kind of education activity.

Learning Procedure

1. To prepare for this lesson:
   - Review introductory essays for the *Lophelia* II 2010: Cold Seeps and Deep Reefs Expedition at http://oceanexplorer.noaa.gov/explorations/10lophelia/welcome.html. You may also want to consider showing students some images of deep-sea ecosystems from http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/photolog/photolog.html. You can find a virtual tour of a cold-seep community at http://www.bio.psu.edu/cold_seeps.
   - Review procedures and questions on the *Deep-Sea Ecosystems and Scientific Posters Inquiry Guide*, and make a copy of the *Inquiry Guide* for each student group.
   - Gather materials needed for scientific posters.

2. Briefly introduce the *Lophelia* II 2010: Cold Seeps and Deep Reefs Expedition, and describe, in general terms, cold-seep and deepwater coral communities. If desired, show images from the Web page referenced in Step 1. Lead a brief discussion about the Deepwater Horizon blowout. Tell students that many scientists are concerned about possible impacts from the blowout on deep-sea ecosystems, and ask why these systems might be important enough to justify such concern. Point out that most people have no idea that these ecosystems exist, so there is very little public support for protecting them. For this reason, there is an urgent need for public education as a first step toward protecting the valuable resources.

3. Tell students that their assignment is to develop a scientific poster that could be used as part of efforts to educate the general public about the importance of deep-sea ecosystems in the Gulf of Mexico and the need to protect them. Each poster should address the following questions (students may want to use these questions as headings on their poster):
   - What are the Gulf of Mexico's deep-sea ecosystems?
   - Why are they associated with petroleum deposits?
   - Why are deep-sea ecosystems important?
   - Why are deep-sea ecosystems threatened?
   - What needs to be done to protect them?

Encourage students to use images from deep-water coral and cold-seep communities as part of their poster.

You may want to direct students to the following resources:

- July 2005 issue of *Current: The Journal of Marine Education* which is a special issue on deep-sea corals (available online at http://www.mcbi.org/what/current.htm)
- Article by Fisher *et al.* (2007) on cold-seep communities of the Gulf of Mexico (available online at http://www.tos.org/oceanography/issues/issue_archive/20_4.html)
- Background essays from Ocean Explorer expeditions to the Gulf of Mexico:
  - Chemosynthetic Communities in the Gulf of Mexico (http://oceanexplorer.noaa.gov/explorations/02mexico/background/communities/communities.html) by Erik Cordes, Penn State University
  - Medicines from the Deep-Sea: Discoveries to Date (http://oceanexplorer.noaa.gov/explorations/03bio/background/medicines/medicines.html) by Amy E. Wright, Harbor Branch Oceanographic Institution
  - What is a Natural Product? (http://oceanexplorer.noaa.gov/explorations/03bio/background/products/products.html) by Amy E. Wright, Harbor Branch Oceanographic Institution
  - The Ecology of Gulf of Mexico Deep-Sea Hardground Communities (http://oceanexplorer.noaa.gov/explorations/06mexico/background/hardgrounds/hardgrounds.html) by Erik E. Cordes, Harvard University
  - Conservation in the Deep Sea (http://oceanexplorer.noaa.gov/explorations/07mexico/background/conservation/conservation.html) by Erik E. Cordes, Harvard University

4. Lead a group discussion of students' posters. Each poster should include the following points:
   - There are two types of deep-sea ecosystems in the Gulf of Mexico: chemosynthetic cold-seep communities and deep-sea coral communities.
   - Deep-sea ecosystems in the Gulf of Mexico are often associated with locations where hydrocarbons are seeping through the seafloor.
   - When microorganisms consume hydrocarbons under anaerobic conditions, they produce bicarbonate which reacts with calcium and magnesium ions in the water and forms carbonate rock. This rock provides a substrate for cold-seep and deep-sea coral communities.
   - Organisms found in cold-seep communities include tubeworms, mussels, bacterial mats, snails, eels, starfish, brittle stars, sea

urchins, crabs, lobsters, isopods, sea cucumbers, and fishes.
- Organisms found in deepwater coral communities include soft corals, black corals, sea whips, sea fans, sponges, shrimps, lobsters, crabs, sea urchins, starfish, crinoids, tubeworms, brittle stars, and fishes
- *Lophelia pertusa* is the dominant deep-sea coral in the Gulf of Mexico at depths of 370-900 m.
- The branching morphology of *Lophelia pertusa* creates a complex habitat for many other species.
- Deep-sea corals are found in all of the world's oceans.
- Deep-water corals often lack symbiotic algae (zooxanthellae) that are typical of shallow-water corals.
- Deep-water coral habitats occur at depths of 70 to greater than 1000 m.
- Deep-sea corals grow slowly and may live for centuries.
- Organisms from deep-sea ecosystems are sources of new pharmaceuticals and other natural products that can be directly beneficial to humans.
- Human-caused threats to deep-sea ecosystems include oil and gas development, deep ocean mining, and global warming, but the greatest threat is bottom trawling (a fishing method that drags large, heavily weighted nets across the seafloor to catch fishes and shrimps).

5. Brainstorm ways that information included in students' posters could be communicated to larger audiences. If possible, display some of the posters at events where they might be seen by other students, parents, and members of the general public.

The BRIDGE Connection

www.vims.edu/bridge/ - Type "Gulf of Mexico" in the "Search" box on the left for resources and links about the Gulf.

The "Me" Connection

Have students write an "op-ed" style essay in which they explain why deep-sea ecosystems are personally important and what steps individuals should take to help ensure their protection.

Connections to Other Subjects

Life Science, Social Studies, English/Language Arts, Fine Arts

Assessment

Scientific posters and class discussions provide opportunities for assessment.

Extensions

See http://www.education.noaa.gov/Ocean_and_Coasts/Oil_Spill.html for links to multimedia resources, lessons and activities, data, and background information from NOAA's Office of Education.

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 Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Office of Ocean Exploration and Research

Forests of the Deep Ocean
(from the *Lophelia* II 2008 Expedition)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/forests.pdf

Focus: Morphology and ecological function in habitat-forming deep-sea corals (Life Science)

Students will describe at least three ways in which habitat-forming deep-sea corals benefit other species in deep-sea ecosystems, explain at least three ways in which the physical form of habitat-forming deep-sea corals contributes to their ecological function, and explain how habitat-forming deep-sea corals and their associated ecosystems may be important to humans. Students will also be able to describe and discuss conservation issues related to habitat-forming deep-sea corals.

Monsters of the Deep
(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)

Students will 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
(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)

Students will 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.

Life is Weird
(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)

Students will 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 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://oceanexplorer.noaa.gov/explorations/10lophelia/welcome.html – Web site for the *Lophelia* II 2010: Cold Seeps and Deep Reefs Expedition

http://oceanexplorer.noaa.gov/edu/guide/gomdse_edguide.pdf – *Gulf of Mexico Deep-Sea Ecosystems Education Materials Collection Educators' Guide*

Maxwell, S. 2005. An aquatic pharmacy: The biomedical potential of the deep sea. *Current: The Journal of Marine Education.* 21(4):31-32 (available online at http://www.mcbi.org/what/current.htm)

Morgan, L. E. 2005. What are Deep-Sea Corals? C*urrent: The Journal of Marine Education*. 21(4):2-4 (available online at http://www.mcbi.org/what/current.htm)

http://oceanexplorer.noaa.gov/edu/development/online_development.html – Online professional development opportunities, including *Lessons from the Deep: Exploring the Gulf of Mexico's Deep-Sea Ecosystems*

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 focusing on the exploration, understanding, and protection of Earth as a whole system

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 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

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

Kellogg, C. A., 2009, Gulf of Mexico deep-sea coral ecosystem studies, 2008–2011: U.S. Geological Survey Fact Sheet 2009–3094, 4 pp. available at http://pubs.usgs.gov/fs/2009/3094/

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

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 F: Science in Personal and Social Perspectives

- Personal health
- Populations, resources, and environments
- Risks and benefits
- Science and technology in society

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.

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.
Fundamental Concept a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

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 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 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 f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).
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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Deep-Sea Ecosystems and Scientific Posters Inquiry Guide

Your assignment is to prepare a scientific poster that will provide an introduction to deep-sea ecosystems in the Gulf of Mexico. Here are some tips for producing scientific posters.

Your poster should include the following information:

- What are the Gulf of Mexico's deep-sea ecosystems?
- Why are they associated with petroleum deposits?
- Why are deep-sea ecosystems important?
- Why are deep-sea ecosystems threatened?
- What needs to be done to protect them?

Scientific Posters

Scientific posters are an increasingly popular way to communicate results of scientific research and technical projects. There are a number of reasons for this, including limited time at conferences for traditional public speaking-style presentations, better options for interacting one-on-one with people who are really interested in your work, opportunities for viewers to understand the details of your work (even if you aren't present), and having a more relaxed format for those who dislike speaking in public. In addition, posters are more durable than one-time presentations; once they are created they can be used in many different settings, over and over again. For more discussion of pros and cons, as well as examples of good and bad posters, visit

http://www.swarthmore.edu/NatSci/cpurrin1/posteradvice.htm
http://www.ncsu.edu/project/posters/NewSite/
http://www.the-aps.org/careers/careers1/GradProf/gposter.htm

Scientific posters usually contain the same elements as traditional written reports: title, introduction, materials and methods, results, conclusions, literature cited (key citations only!), acknowledgments, and contact points for further information. Good posters do NOT usually have an abstract, though an abstract is often required as part of the submission process and may be included in a printed program.

Another similarity to traditional reports is that the best posters almost always go through several drafts. You should always expect that the first draft of your poster will change significantly before it emerges in final form. Be sure to allow enough time for others to review your first draft and for you to make needed changes.

An important difference (and advantage) that posters have compared to written reports is that posters can be much more flexible in terms of layout and where the elements appear, as long as there is a clear and logical flow to guide viewers through your presentation. Here are a few more tips for good scientific posters (see the Web sites listed above for many other ideas):

- Posters should be readable from 6′ away;
- Be sure to leave white space (35% is not too much) – densely packed posters can easily repel potential viewers;
- Like real estate, location is key – the top and right columns of your poster are prime areas for vital material, while the bottom edge will receive much less attention;
- Serif fonts (e.g., Times) are easier to read than sans serif fonts (e.g., Helvetica), so use sans serif fonts for titles and headings, and serif fonts for body text (usually no more than two font families on a single poster)
- Text boxes are easiest to read when they are about 40 characters wide