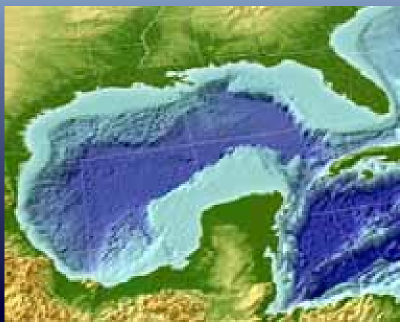


Lessons from the Deep:
Exploring the Gulf of Mexico's Deep-Sea Ecosystems
Education Materials Collection

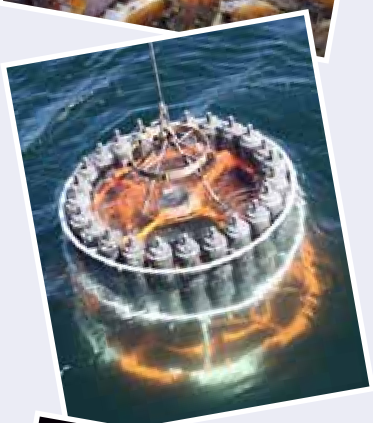


Image captions/credits on Page 2.

lesson plan

Life is Weird!

(adapted from the 2003 Windows to the Deep Expedition)

Focus
Biological organisms in cold-seep communities

Grade Level
7-8 (Life Science)

Focus Question
What organisms are typically found in cold-seep communities, and how do these organisms interact?

Learning Objectives
- Students will be able to describe major features of cold-seep communities, and list at least five organisms typical of these communities.

- Students will be able to infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment.

- Students will be able to describe in the process of chemosynthesis in general terms, and will be able to contrast chemosynthesis and photosynthesis.

Materials
- 5 x 7 index cards
- Drawing materials
- Corkboard, flip chart, or large poster board

Audio/Visual Materials
- None

Teaching Time
Two 45-minute class periods, plus time for individual group research

Seating Arrangement

Groups of four students

Maximum Number of Students

32

Key Words

Cold seeps
Methane hydrate ice
Chemosynthesis
Brine pool
Polychaete worms
Chemosynthetic
Methanotrophic
Thiotrophic
Xenophyophores
Anthozoa
Turbellaria
Polychaete worm
Sipunculida
Mussel
Clam
Octopus
Crustacean
Alvinocaris
Nematoda
Sea urchin
Sea cucumber
Brittle star
Sea star

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 importance is presently unknown.

Images from Page 1 top to bottom:

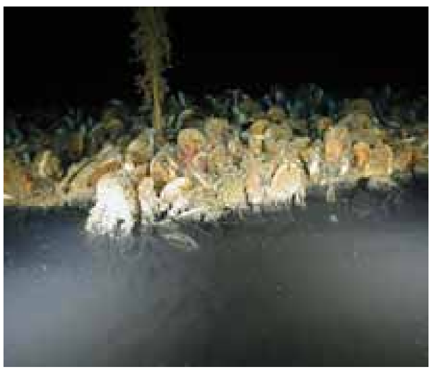
A close-up mussel aggregation with *Chirodota heheva* sea cucumbers. Image courtesy of Expedition to the Deep Slope 2007.
http://oceanexplorer.noaa.gov/explorations/07mexico/logs/july3/media/cuke_600.html

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

A close-up of the mussel *Bathymodiolus brooksi*, with one of the common species found in tubeworm and mussel habitats — the shrimp *Alvinocaris muricola*. Image courtesy of AquaPix, Chuck Fisher, Expedition to the Deep Slope 2006. http://oceanexplorer.noaa.gov/explorations/07mexico/background/conservation/media/mussels_600.html



These methane mussels (Bathymodiolus childressi) live at the edge of Brine Pool NR1 at 650 m depth in the Gulf of Mexico. The pool of brine in the foreground is nearly four times as salty as seawater and is so dense that the submarine can float on the pool to take pictures such as this. Image courtesy Stephane Hourdez. http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/mussels_600.html

Iceworms (Hesiocaeca methanicola) infest a piece of orange methane hydrate at 540 m depth in the Gulf of Mexico. During the Paleocene Epoch, lower sea levels could have led to huge releases of methane from frozen hydrates and contributed to global warming. Today, methane hydrates may be growing unstable due to warmer ocean temperatures. Image courtesy Ian MacDonald. http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/iceworms_600.jpg

The first chemosynthetic communities were discovered in 1977 near the Galapagos Islands in the vicinity of underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates (visit http://www.pmel.noaa.gov/vents/ for more information and activities on hydrothermal vent communities). Chemosynthetic communities in the Gulf of Mexico were found by accident in 1984. These communities are similar in that they are based upon energy produced by chemosynthesis; but while energy for the Galapagos communities is derived from underwater hot springs, deep-sea chemosynthetic communities in the Gulf of Mexico are found in the vicinity of cold seeps. Typical features of communities that have been studied so far include mounds of frozen crystals of methane and water called methane hydrate ice, that are home to polychaete worms and shrimp. Brine pools, containing water four times saltier than normal seawater, have also been found. Researchers often find dead fish floating in the brine pool, apparently killed by the high salinity.

This activity focuses on relationships between some inhabitants of cold-seep communities.

Learning Procedure

1.To prepare for this lesson:

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).

You may want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community.

2. Lead a discussion of deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis. In both processes, organisms build sugars from carbon dioxide and water. This process requires energy; photosynthesizers obtain this energy from the sun, while chemosynthesizers obtain energy from chemical reactions. Point out that there are a variety of chemical reactions that can provide this kind of energy. Contrast hydrothermal vent communities with cold-seep communities.

Review the concept of food webs, including the concept of trophic levels (primary producer, primary consumer, secondary consumer, and tertiary consumer).

3. Assign each student group one or more of the following groups to research:
   Methanotrophic bacteria
   Thiotrophic bacteria
   Xenophyophores (see also genus *Syringammina*)
   Anthozoa (sea anemones)
   Turbellaria (a flatworm of the genus *Platyhelminthes*)
   Nautiliniella (a genus of polychaetes)
   Maldanidae (a family of polychaetes)
   Chaetopteridae (a family of polychaetes)
   Capitellidae (a family of polychaetes)
   Sipunculida (peanut worms)
   Bathymodiolus heckerae (a species of mussel)
   Vesicomya (a genus of clams)
   Octopoda (octopus)
   Munidopsis (a genus of crustacean)
   Alvinocaris (a genus of crustacean)
   Nematoda (a round worm)
   Sarsiaster greigi (a species of sea urchin)
   Chiridota (a genus of sea cucumber)
   Ophioctenella (a genus of brittle star)
   Brisingia (a genus of sea star)

   In addition to written reference materials (encyclopedia, periodicals, and books on the deep sea), the following Web sites contain useful information:
   http://www.bio.psu.edu/cold_seeps
   http://biodidac.bio.uottawa.ca/
   http://www.fishbase.org/search.cfm
   http://www.mbari.org/staff/vrijen/PDFS/VanDover_2003DSR.pdf
   (this document also contains a food web model for the Blake Ridge, so you may want to provide only selected portions of this reference!)

   Each student group should try to determine the energy (food) source(s) of their assigned organisms. It may not be possible to precisely determine specific foods for all groups, but students should be able to draw reasonable inferences from information about related organisms and anatomical features that may give clues about what the animals eat. Students should prepare a 5 x 7 index card for each organism with an illustration of the organism (photocopies from reference material, downloaded internet pictures, or their own sketches), notes on where the organism is found, approximate size of the organism, and its trophic level (whether it is a primary producer, primary consumer, secondary consumer, or tertiary consumer).

4. Have each student group orally present their research results to the entire class. On a corkboard, flip chart, or piece of poster board, arrange the cards to show organisms that inhabit cold-seep communities, organisms from deep-sea environments outside cold-seep communities, and the trophic (feeding) relationships among these organisms. You may want to arrange the organisms by habitat first, then draw lines indicating which organisms probably provide an energy source (food) for other organisms. Painting tape or sticky notes can be used to temporarily anchor the cards until you have decided on the best arrangement, then tape or glue the cards in place.

5. Lead a discussion of the food web the students have created. Which groups show the greatest variety of anatomical types and feeding strategies? Which groups are responsible for primary production? What would the students infer about the relative abundance of each trophic level? In the simplest analysis, organisms at lower trophic levels (primary producers and primary consumers) must be more abundant than those on higher trophic levels. If this does not appear to be true, then there must be additional energy sources for the higher trophic levels.

The Bridge Connection

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

The "Me" Connection

Have students write a short essay on their favorite deep-sea or cold-seep community organism, stating why they like it and at least three interesting facts about it. Have students discuss how deep sea communities may someday affect their lives.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Results and presentation of the research component of this activity provide a basis for group evaluation. In addition, individual written interpretations of the pooled results may be required prior to Step 5 to provide a means of individual 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://www.learningdemo.com/noaa/ 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

Monsters of the Deep (6 pages, 464 KB)

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 describe major features of cold seep communities, list at least five organisms typical of these communities, and infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment. Students also 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, 476 KB)

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

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

Students 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 also describe the problems posed by hydrogen sulfide for aerobic organisms, and explain three strategies for dealing with these problems.

Who Has the Light? (7 pages, 200 KB)

http://oceanexplorer.noaa.gov/explorations/04deepscope/background/edu/media/whohaslight.pdf

Focus - Bioluminescence in deep-sea organisms (Life Science)

Students compare and contrast chemiluminescence, bioluminescence, fluorescence, and phosphorescence. Students also explain at least three ways in which the ability to produce light may be useful to deepsea organisms and explain how scientists may be able to use light-producing processes in deep-sea organisms to obtain new observations of these organisms.

Twisted Vision (7 pages, 303 KB)

http://oceanexplorer.noaa.gov/explorations/05deepscope/background/edu/media/now_u_see_me.pdf

Focus - Polarization vision (Life Science/Physical Science)

Students explain the meaning of 'polarized light,' and identify three ways in which unpolarized light can become polarized; explain why some animals have polarization vision, and why humans do not have this ability; and discuss three ways in which polarization vision may be useful to marine organisms.

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

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)

http://www.geol.ucsb.edu/faculty/valentine/Valentine%202002.pdf – Review of methane-based chemosynthetic processes

Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. Science 226:965-967 – early report on cold seep communities.

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

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
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Transfer of energy

Content Standard C: Life Science

- Structure and function in living systems
- Populations and ecosystems

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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