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2006 Gulf of Mexico Expedition

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
- ❒ Painting tape or sticky notes

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
30

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

Background Information

On August 28, 2005, Hurricane Katrina swept across the Gulf of Mexico, gathering strength to become a Category 3 storm that proved to be the most costly—and one of the most deadly—hurricanes in U.S. history. Four days later, the Department of the Interior's Minerals Management Service (MMS) reported that oil production in the Gulf of Mexico had been reduced by over 90 percent, and that natural gas production had been reduced by more than 78 percent. In the weeks that followed, fuel shortages and soaring prices underscored the importance of the Gulf of Mexico to petroleum supplies in the United States.

In fact, the Gulf of Mexico produces more petroleum than any other region in the nation, even though its proven reserves are less than those in Alaska and Texas. The San Francisco *Chronicle* reports that oil companies are spending billions to find more crude oil and drill more wells. Even with the threat of more hurricanes, the Gulf of Mexico has advantages: oil workers are not in danger of being kidnapped by armed insurgents as is the case in Nigeria; no foreign president threatens to raise oil companies' taxes, as has happened in Venezuela; and OPEC doesn't control oil production in the Gulf of Mexico. As of August 1, 2005, a total of 41,188 wells had been drilled in the Gulf, and 1,259 petroleum fields had been discovered.

Much of this new exploration is focussed on some of the deepest regions of the Gulf, made possible by improved technology and increasing crude oil prices (which have doubled in the last three years). In addition to new petroleum fields, this exploration has led to other discoveries as well. Some of the same conditions responsible for petroleum deposits also provide the basis for biological communities that receive energy from chemicals through a process called chemosynthesis (in contrast to photosynthesis that provide energy to terrestrial and shallow-water communities through processes in which sunlight is the basic energy source).

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. Hydrogen sulfide is abundant in the water erupting from hydrothermal vents, and is used by chemosynthetic bacteria that are the base of the vent community food chain. These bacteria obtain energy by oxidizing hydrogen sulfide to sulfur:

$$CO_2 + 4H_2S + O_2 > CH_2O + 4S + 3H_2O$$

(carbon dioxide plus sulfur dioxide plus oxygen yields organic matter, sulfur, and water). Visit http://www.pmel.noaa.gov/vents/home.html 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 areas where hydrocarbon gases (often methane and hydrogen sulfide) and oil seep out of sediments. These areas, known as cold seeps, are commonly found along continental margins, and (like hydrothermal vents) are home to many species of organisms that have not been found anywhere else on Earth. 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. 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.

Where hydrogen sulfide is present, large tube-worms (phylum Annelida) known as vestimentiferans are often found, sometimes growing in clusters of millions of individuals. These unusual animals do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome that contains chemosynthetic bacteria. Vestimentiferans have a structure called a plume that consists of filaments (sometimes referred to as "tentacles") that extend into the water. The tentacles are bright red due to the presence of hemoglobin which can absorb hydrogen sulfide and oxygen which are transported to the bacteria in the trophosome. The bacteria produce organic molecules that provide nutrition to the tube worm. A similar symbiotic relationship is found in clams and mussels that have chemosynthetic bacteria living in their gills. Bacteria are also found living independently from other organisms in large bacterial mats A variety of other organisms are also found in cold seep communities, and probably use tubeworms, mussels, and bacterial mats as sources of food. These include snails, eels, starfish, crabs, lobsters, isopods, sea cucumbers, and fishes. Specific relationships between these organisms have not been well-studied.

Deepwater chemosynthetic communities are fundamentally different from other biological systems, and there are many unanswered questions about the individual species and interactions between species found in these communities. These species include some of the most primitive living organisms (Archaea) that some scientists believe may have been the first life forms on Earth. Many species are new to science, and may prove to be important sources of unique drugs for the treatment of human diseases. Because their potential importance is not yet known, it is critical to protect these systems from adverse impacts caused by human activities.

Ironically, one of the most likely sources of such impacts is the same activity that led to the discovery of these systems in the first place: exploration and development of petroleum resources. MMS has the dual responsibility of managing these resources as well as protecting the environment from adverse impacts that might result from development activities. In 1988, MMS issued regulations specifically targeted toward protecting deepwater chemosynthetic communities. An essential part of the protection strategy requires identification of seafloor areas that could support chemosynthetic communities. These areas must be avoided by drilling, anchoring, pipeline installation, and other activities that involve disturbing the seafloor. Describing deepwater biological communities and evaluating their sensitivity to impacts from human activities are key objectives of the 2006 Gulf of Mexico Expedition.

This activity focuses on relationships between some inhabitants of cold-seep communities in the Gulf of Mexico.

Learning Procedure

1. To prepare for this lesson, review
   - Introductory essays for the 2006 Gulf of Mexico Expedition at http://oceanexplorer.noaa.gov/explorations/06mexico/

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 until recently it was well-accepted that photosynthesis was the basis of all major biological communities on Earth. Recognition of chemosynthetic communities has changed this view dramatically; indeed, many biologists now favor the idea that life on Earth may have begun in communities like those found near hydrothermal vents and cold seeps. Contrast hydrothermal vent communities with cold-seep communities. Visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community in the Gulf of Mexico.

Review the concepts of food chains and 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 Granuloreticulosa, genus Syringammina)
   Anthozoa (sea anemones)
   Turbellaria (a flatworm (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 crustacean)
   Alvinocaris (a crustacean)
   Nematoda (a roundworm)
   Sarsiaster greigi (a species of sea urchin)
   Chiridota (a genus of sea cucumber)
   Ophioctenella (a genus of brittle star)
   Brisingia (a genus of starfish)

   In addition to written reference materials (encyclopedia, periodicals, and books on the deep-sea), the following websites contain useful information:
   http://www.bio.psu.edu/cold_seeps
   http://biodidac.bio.uottawa.ca/
   http://www.fishbase.org/search.cfm
   http://www.geomar.de/projekte/sfb_574/abstracts/vanDover_et_al_2003.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 between 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 "Biology" in the navigation menu to the left, then "Plankton," then "Phytoplankton" for resources on ocean food webs. Click on "Ecology" 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.

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

1. Visit http://oceanexplorer.noaa.gov/explorations/06mexico/ for daily logs and updates about discoveries on the 2006 Gulf of Mexico Expedition.

Resources

NOAA Learning Objects

http://www.learningdemo.com/noaa/ Click on the links to Lessons 3, 5, and 6 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from the Ocean Exploration Program

Monsters of the Deep (6 pages, 464k)) (from the 2002 Gulf of Mexico Expedition)
[http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_monsters_gr78.pdf]

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

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

One Tough Worm (8 pages, 476k)) (from the 2002 Gulf of Mexico Expedition)
[http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_toughworm.pdf]

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

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

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

Focus: Ocean Exploration

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

Let's Go to the Video Tape! (7 pages, 552k) (from the 2003 Gulf of Mexico Deep Sea Habitats Expedition)
[http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_letsgo.pdf]
Focus: Characteristics of biological communities on deep-water reef habitats (Life Science)

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

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

Focus: Functions of cell organelles and the genetic code in chemical synthesis (life science)

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

Mapping Deep-sea Habitats in the Northwestern Hawaiian Islands (7 pages, 80kb) (from the 2002 Northwestern Hawaiian Islands Expedition)
[http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf]
Focus: Bathymetric mapping of deep-sea habitats (Earth Science - This activity can be easily modified for Grades 5-6)

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

Other Resources and Links

http://www.gomr.mms.gov/index_common.html – Minerals Management Service Web site

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

http://www.gomr.mms.gov/homepg/lagniapp/lagniapp.html – Kids Page on the Minerals Management Service Web site, with posters, teaching guides and other resources on various marine science topics

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

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

http://www.energybulletin.net/4901.html – Article "Out of Gas: Sediments in Northern Gulf of Mexico Not Right for Methane Gas Hydrate Formation, Study Shows" published by Georgia Research Tech News, 21 Mar 2005

http://www.ridge2000.org/eo/index.html – Links to other deep ocean exploration Web sites

http://www-ocean.tamu.edu/education/oceanworld-old/resources/general_links.htm – Links to other ocean-related web sites

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://dbhs.wvusd.k12.ca.us/webdocs/ChemTeamIndex.html – Web site for help with basic chemical concepts including oxidation-reduction reactions

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

Van Dover, C.L., et al. 2003. Blake Ridge methane seeps: characterization of a soft-sedime nt,chemosynthetically based ecosystem. Deep-Sea Research Part I 50:281–300. (available as a PDF file at http://www.geomar.de/projekte/sfb_574/abstracts/vanDover_et_al_2003.pdf)

http://www.accessexcellence.org/BF/bf01/arp/bf01p1.html – Verbatim transcript of a slide show on coping with toxic sulfide environments

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 4.
The ocean makes Earth habitable.

- *Fundamental Concept b.* The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

- *Fundamental Concept a.* Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.
- *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 g.* There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

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

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

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

Essential Principle 7.
The ocean is largely unexplored.

- *Fundamental Concept a.* The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
- *Fundamental Concept b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *Fundamental Concept c.* Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
- *Fundamental Concept d.* New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- *Fundamental Concept f.* Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

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