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Expedition to the Deep Slope 2007

Entering the Twilight Zone

[adapted from the 2002 Gulf of Mexico Expedition]

Focus
Deep-sea habitats

Grade Level
5-6 (Life Science)

Focus Question
What organisms are typical of major deep-sea habitats, and how do they 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 within and between major deep-sea habitats.

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

Students will be able to describe major deep-sea habitats and list at least three organisms typical of each habitat.

Materials
- ❒ 5 x 7 index cards
- ❒ Drawing materials
- ❒ Corkboard, flip chart, or large poster board
- ❒ "Generalized Ocean Habitats" diagram

Audio/Visual Materials
None

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

Seating Arrangement
Groups of 4 students

Maximum Number of Students
32

Key Words
Cold seeps
Methane hydrate ice
Chemosynthesis
Brine pool
Trophic level
Pelagic zone
Epipelagic zone
Mesopelagic zone
Bathypelagic zone
Hadopelagic zone
Benthic zone
Intertidal zone
Subtidal zone
Bathyal zone
Abyssal zone
Hadal zone
Hydrothermal vent

Background Information
Cold seeps are areas of the ocean floor where gases (such as methane and hydrogen sulfide) and oil seep out of sediments. These areas are commonly found along continental margins, and are home to many species of organisms that

have not been found anywhere else on Earth. Recently, increasing attention has been focused on cold seeps in the Gulf of Mexico, an area that produces more petroleum than any other region in the United States. Responsibility for managing exploration and development of mineral resources on the Nation's outer continental shelf is a central mission of the U.S. Department of the Interior's Minerals Management Service (MMS). In addition to managing the revenues from mineral resources, an integral part of this mission is to protect unique and sensitive environments where these resources are found. MMS scientists are particularly interested in finding deep-sea chemosynthetic communities in the Gulf of Mexico, because these are unique communities that often include species that are new to science and whose potential importance is presently unknown. In addition, the presence of these communities often indicates the presence of hydrocarbons at the surface of the seafloor.

The 2006 Expedition to the Deep Slope was focussed on discovering and studying the sea floor communities found near seeping hydrocarbons on hard bottom in the deep Gulf of Mexico. The sites visited by the Expedition were in areas where energy companies will soon begin to drill for oil and gas. A key objective was to provide information on the ecology and biodiversity of these communities to regulatory agencies and energy companies. Dives by scientists aboard the research submersible ALVIN revealed that hydrocarbons seepage and chemosynthetic communities were present at all ten sites visited by the Expedition. The most abundant chemosynthetic organisms seen were mussels and vestimentiferan tubeworms. Expedition to the Deep Slope 2007 is focused on detailed sampling and mapping of four key sites visited in 2006, as well as exploring new sites identified from seismic survey data.

Cold-seep communities are surrounded by a much larger ocean environment. Very little is known about interactions between cold-seep communities and organisms in other ocean habitats. This activity focuses on major ocean habitats, organisms typically found in these habitats, and the interactions that take place within and between these habitats.

Ocean habitats are usually categorized into zones:

I. Pelagic zones are found in the water column above the bottom. Organisms that inhabit pelagic zones are divided into plankton that drift with the ocean currents and nekton that can swim and control their motion in the water (at least to some extent).

   A. The Epipelagic zone includes surface waters where light is adequate for photosynthesis (about 200m, maximum). Phytoplankton are the dominant primary producers in this zone.

   B. The Mesopelagic zone (about 200m-1000m) is the twilight zone. Because there is not enough light for photosynthesis, much less energy is available to support animal life. Bacteria and detritus (pieces of dead plants and animals that slowly settle to the bottom) are the primary sources of food for animals like jellyfishes that are confined to this zone. Other animals, including squids, fishes, and shrimps can move up and down through the water column, and have a wider range of food available to them.

   C. The Bathypelagic zone (sometimes divided further into an additional Abyssopelagic Zone) has no light at all, with the exception of light produced by bioluminescent organisms. Deep-sea organisms are dependent upon production in other zones. The base of bathypelagic food chains may be primary production in shallower water (obtained by feeding on detritus or on other animals feeding in shallower water) or chemosynthetic communities like hydrothermal vents or cold-seeps.

D. The Hadopelagic zone is sometimes used to include the water column in deepest ocean trenches (about 11,000 m).

II. Benthic zones are areas on or in the ocean bottom. Animals that swim near the bottom and called "benthopelagic."

A. The Intertidal zone is on the shore between the level of high and low tide.

B. The Subtidal zone includes the ocean bottom on continental shelves down to about 300 m. Green plants are the base of food chains in shallower waters, but bacteria and detritus are the primary energy source below about 200 m.

C. The Bathyal zone includes the rest of the continental shelf (between about 300 m and 3,000 m).

D. The Abyssal zone is the ocean bottom between 3,000 m and 6,000 m. The bottom is primarily muddy and flat in most places (hence the common term "abyssal plain"). This is the largest benthic zone and covers about half of the Earth's surface.

E. The Hadal zone is sometimes used to describe the very deep ocean bottom between 6,000 m and 11,000 m

F. Vents and seeps are unusual deep-water habitats that support communities of living organisms whose food chains are based on chemosynthetic bacteria, rather than photosynthetic activity near the surface. Vent and seep communities may, in turn, be a significant energy (food) source for organisms living in other benthic habitats nearby.

Learning Procedure

1. To prepare for this lesson, visit http://oceanexplorer.noaa.gov/explorations/07mexico/welcome.html for information about Expedition to the Deep Slope 2007. You may want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community, and http://www.bio.psu.edu/hotvents for a virtual tour of a hydrothermal vent community.

2. Lead a discussion of the major categories of ocean habitat. Introduce the recently-discovered deep-sea chemosynthetic communities (hydrothermal vents and cold seeps). Emphasize the contrast between communities that depend upon chemosynthesis with those dependent upon photosynthesis. You may want to point out that through 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. Review the concepts of food chains and food webs, including the concept of trophic levels (primary producer, primary consumer, secondary consumer, and tertiary consumer). Be sure students understand that food chains in most of the habitats are largely based upon photosynthetic production, either directly (primary consumers obtain energy from photosynthetic plants) or indirectly (primary consumers obtain energy from detritus). This situation is fundamentally different in deep-sea chemosynthetic communities, which may also provide an alternative basis for food chains in adjacent habitats.

3. Assign each student group one or more of the following deep ocean habitats to research:
   - Mesopelagic zone
   - Bathypelagic zone
   - Hadopelagic zone
   - Bathyal zone
   - Abyssal zone
   - Hadal zone
   - Hydrothermal vents
   - Cold seeps

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://people.whitman.edu/~yancey/deepsea.html
http://oceanlink.island.net/
http://www.pbs.org/wgbh/nova.abyss/life.bestiary.html
http://www.pbs.org/wgbh/nova/abyss/life/bestiary.html
http://biodidac.bio.uottawa.ca/
http://www.fishbase.org/search.cfm

Each student group should identify six organisms typical of their assigned habitat, and determine the energy (food) source(s) of each of these organisms. It may not be possible to precisely determine specific foods in all cases, 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 draw a general profile of ocean habitats (see "Generalized Ocean Habitats" diagram), and arrange the cards to show representative organisms in each habitat. When all cards have been attached to the base material, draw lines to indicate trophic (feeding) relationships between these organisms.

5. Lead a discussion of the food web the students have created. What is the source of primary production in each habitat? 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 (for example, some secondary or tertiary predators may feed in more than one habitat. Considering that the abyssal plain covers about half of the Earth's surface, and is largely unexplored, how might the students' ocean food web change with further exploration?

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 describing their personal position in a food web, and how they could adapt if their source of primary production were no longer available.

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 4 to provide a means of individual assessment.

Extensions

Visit http://oceanexplorer.noaa.gov/explorations/07mexico/welcome.html to keep up to date with the latest Expedition to the Deep Slope 2007 discoveries, and to find out what researchers are learning about cold-seep communities.

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ Click on the links to Lessons 3, 5, 6, 11, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, Energy from the Oceans, and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from the Ocean Exploration Program

A Piece of Cake (7 pages; 282kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition) http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/cake.pdf

Focus: Spatial heterogeneity in deep-water coral communities (Life Science)

In this activity, students will be able to explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of deep-water hard bottom communities. Students will also be able to explain how organisms, such as deep-water corals and sponges, add to the variety of habitats in areas such as the Cayman Islands.

Deep Gardens (11 pages; 331kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition) http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/deepgardens.pdf

Focus: Comparison of deep-sea and shallow-water tropical coral communities (Life Science)

In this activity, students will compare and contrast deep-sea coral communities with their shallow-water counterparts, describe three types of coral associated with deep-sea coral communities, and explain three benefits associated with deep-sea coral communities. Students will explain why many scientists are concerned about the future of deep-sea coral communities.

Let's Make a Tubeworm! (6 pages, 464k) (from the 2002 Gulf of Mexico Expedition) http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_tube_gr56.pdf

Focus: Symbiotic relationships in cold-seep communities (Life Science)

In this activity, students will be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, describe major features of cold-seep communities, and list at least five organisms typical of these communities. Students will also be able to define symbiosis, describe two examples of symbiosis in cold-seep communities, describe the anatomy of vestimentiferans, and explain how these organisms obtain their food.

Journey to the Unknown & Why Do We Explore (10 pages, 596k) (from the 2002 Galapagos Rift Expedition) http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr5_6_l1.pdf

Focus: Ocean Exploration

In this activity, students will experience the excitement of discovery and problem-solving to learn about organisms that live in extreme environments in the deep ocean and come to understand the importance of ocean exploration.

Chemists with No Backbones (4 pages, 356k) (from the 2003 Deep Sea Medicines Expedition) http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_ChemNoBackbones.pdf

Focus: Benthic invertebrates that produce pharmacologically-active substances (Life Science)

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

Keep Away (9 pages, 276k) (from the 2006 Expedition to the Deep Slope) http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20KeepAway.pdf

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

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

What's In That Cake? (9 pages, 276k) (from the 2006 Expedition to the Deep Slope) http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Cake.pdf

Focus: Exploration of deep-sea habitats

In this activity, students will be able to explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of the Gulf of Mexico. Students will also be able to describe and discuss at least three difficulties involved in studying deep-sea habitats and describe and explain at least three techniques scientists use to sample habitats, such as those found on the Gulf of Mexico.

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/explorations/07mexico/welcome.html – Follow Expedition to the Deep Slope 2007 daily as documentaries and discoveries are posted each day for your classroom use.

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.

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
- Diversity and adaptations of organisms

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 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 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.

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Please send your comments to:
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Student Handout

Generalized Ocean Habitats