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Expedition to the Deep Slope 2007

Monsters of the Deep
[adapted from the 2002 Gulf of Mexico Expedition]

Focus
Predator-prey relationships between cold-seep communities and the surrounding deep-sea environment

Grade Level
7-8 (Life Science)

Focus Question
What deep-sea predators may visit cold-seep communities in search of food?

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.

Students will be able to describe at least five deep-sea predator organisms.

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
30

Key Words
Cold seeps
Methane hydrate ice
Chemosynthesis
Brine pool
Polychaete worms
Vestimentiferans
Chemosynthetic bacteria
Mussels
Sea stars
Eels
Squat lobsters
Snails
Isopods
Spider crabs
Anglerfishes
Pelican eel
Pancake bat fish
Viperfish
Fangtooth
Squids
Football fish

Hatchet fish
Trophic level

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. Unlike biological communities in shallow-water ocean habitats, cold-seep communities do not depend upon sunlight as their primary source of energy. Instead, these communities derive their energy from chemicals through a process called chemosynthesis (in contrast to photosynthesis in which sunlight is the basic energy source). Some chemosynthetic communities have been found near 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 and http://www.divediscover.whoi.edu/vents/index.html for more information and activities on hydrothermal vent communities.

Typical features of the cold seep chemosynthetic 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. The base of the food chain in cold seep communities is chemosynthetic bacteria that are able to obtain energy from some of the chemicals seeping out of the ocean floor. Bacteria may form thick bacterial mats, or may live in close association with other organisms.

One of the most conspicuous associations exists between chemosynthetic bacteria and large tubeworms that belong to the group Vestimentifera (formerly classified within the phylum Pogonophora; recently Pogonophora and Vestimentifera have been included in the phylum Annelida). Pogonophora means "beard bearing," and refers to the fact that many species in this phylum have one or more tentacles at their anterior end. Tentacles of vestimentiferans are bright red because they contain hemoglobin (like our own red blood cells). Vestimentiferans can grow to more than 10 feet long, sometimes in clusters of millions of individuals, and are believed to live for more than 100 years. They do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome that contains chemosynthetic bacteria. Hemoglobin in the tubeworm's blood absorbs hydrogen sulfide and oxygen from the water around the tentacles, and then transports these raw materials to bacteria living in the trophosome (the tentacles also absorb carbon dioxide, which is also transported to the bacteria). The bacteria produce organic molecules that provide nutrition to the tubeworm. Similar relationships are found in clams and mussels that have chemosynthetic bacteria living in their gills. 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, sea stars, crabs, isopods, sea cucumbers, and fishes. Specific relationships between these organisms have not been well-studied.

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 focused 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 deep-sea environment that contains a variety of unusual creatures with names like viperfish, football fish, and vampire squid. Very little is known about interactions between cold-seep communities and organisms from the surrounding deep-sea. It seems likely, though, that deep-sea predators visit cold-seep communities in search of food, since these communities produce large amount of biological material. This activity focuses on cold-seep communities and deep-sea predators that may use these communities for food.

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 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 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 organisms to research:
   Cold-Seep Groups:
   - Polychaete worms
   - Vestimentiferans
   - Chemosynthetic bacteria
   - Mussels
   - Sea stars
   - Eels
   - Squat lobsters
   - Snails
   - Isopods
   - Spider crabs

   Deep-Sea Groups:
   - Anglerfishes
   - Pelican eel
   - Pancake bat fish
   - Viperfish
   - Fangtooth
   - Squids
   - Football fish
   - Hatchet fish

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://www.pbs.org/wgbh/nova/abyss/life/bestiary.html
http://biodidac.bio.uottawa.ca/
http://www.fishbase.org/search.cfm
http://www.learningdemo.com/noaa/ Lesson 5, Hydrothermal Vent Food Web activity

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 (for example, deep-sea predators might be feeding in other areas besides the cold-seep communities).

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 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.

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 Lessons from the Ocean Exploration Program

Let's Go to the Video Tape! (11 pages; 327kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition) http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/videotape.pdf

Focus: Characteristics of biological communities on deep-water coral habitats (Life Science)

In this activity, students will recognize and identify some of the fauna groups found in deep-sea coral communities, infer possible reasons for observed distribution of groups of animals in deep-sea coral 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.

Treasures in Jeopardy (8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition) http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/treasures.pdf

Focus: Conservation of deep-sea coral communities (Life Science)

In this activity, students will compare and contrast deep-sea coral communities with their shallow-water counterparts and explain at least three benefits associated with deep-sea coral communities. Students will also describe human activities that threaten deep-sea coral communities and describe actions that should be taken to protect resources of deep-sea coral communities.

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

In this activity, 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.

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)

In this activity, 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)

In this activity, 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.

Life is Weird (8 pages, 268k) (from the 2006 Expedition to the Deep Slope) http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Weird.pdf

Focus: Biological organisms in cold-seep communities (Life Science)

In this activity, students will be able to 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 will be able to contrast chemosynthesis and photosynthesis.

It's a Gas! Or Is It? (12 pages, 276k) (from the 2006 Expedition to the Deep Slope) http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Gas.pdf

Focus: Effects of temperature and pressure on solubility and phase state (Physical Science/Earth Science)

Students will be able to describe the effect of temperature and pressure on solubility of gases and solid materials; describe the effect of temperature and pressure on the phase state of gases; and infer explanations for observed chemical phenomena around deep-sea volcanoes that are consistent with principles of solubility and phase state.

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.

http://www.bio.psu.edu/People/Faculty/Fisher/fhome.htm – Web site for the senior biologist on Expedition to the Deep Slope 2007

http://www.rps.psu.edu/deep/ – Notes from another expedition exploring deep-sea communities

http://www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html – Aarticle on cold-seep communities

http://nai.arc.nasa.gov/news_stories/news_detail.cfm?ID=86 – "Cafe Methane," another article on cold seep communities

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.divediscover.whoi.edu/vents/index.html – "Dive and Discover: Hydrothermal Vents;" another great hydrothermal vent site from Woods Hole Oceanographic Institution

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.

Send Us Your Feedback

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