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Gulf of Mexico Exploration

Entering the Twilight Zone

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.

Additional Information for Teachers of Deaf Students
In addition to the words listed as key words, the following words should be part of the list.
Photosynthesis
Symbiosis
Hydrothermal vent
Hydrocarbon
Sediment
Polychaete worm
Bacteria
Symbiotic
Trophosome
Hemoglobin
Organic
Inferences

The key words are integral to the unit but will be very difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. Also give the list as a handout to the students to refer to after the lesson.

If these topics have not already been covered in your class you will need to add an additional class period to cover all the material. Additionally, you may want to make stations for each ocean habitat zone. Take the information listed in the Background Information and enlarge it to put on posters. Include pictures. Use these as the starting point for your discussions. Also have copies of the information available as handouts.

Pick two or three of the ocean habitats and gather some reference materials ahead of time and place them at established stations. Since there is a great deal of information to be covered in the second step in the procedure, especially with a small group of students, so instead of dividing the students into groups consider having them work as one or two teams. The students can then pick a habitat from the two or three that you have already gathered materials for. To allow for less frustration and completion in a reasonable timeframe, have students identify four rather than six organisms.

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 four 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

One of the major scientific discoveries of the last 100 years is the presence of extensive deep sea communities that 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. 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.

Other deep-sea chemosynthetic communities 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 is 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.

As is the case with hydrothermal vents, chemosynthetic bacteria are also the base of the food web in cold seep communities. 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 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.

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 among 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 200 m, maximum). Phytoplankton are the dominant primary producers in this zone.

B. The **mesopelagic zone** (about 200 m-1,000 m) 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. Deep-sea organisms are dependent upon production in other zones. The base of bathypelagic food webs 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 the deepest ocean trenches (about 11,000 m).

II. Benthic zones are areas on or in the ocean bottom. Animals that swim near the bottom are 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 webs 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 webs 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. Lead a discussion of the major categories of ocean habitats. Introduce the recently-discovered deep-sea chemosynthetic communities (hydrothermal vents and cold seeps). Empha-size the contrast between communities that depend upon chemosynthesis with those dependent upon photosynthesis. You may want to point out that in both processes, organisms build sugars from carbon dioxide and water. This process requires energy; photosynthesizers obtain this energy from the sun, while chemo-synthesizers 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 webs 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 webs in adjacent habitats.

   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. 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 websites 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://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).

3. 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 organ-

isms in each habitat. When all cards have been attached to the base material, draw lines to indicate trophic (feeding) relationships between and among these organisms.

4. 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

Evaluation

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

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest Gulf of Mexico Expedition discoveries, and to find out what researchers are actually learning about interactions between cold-seep communities and the surrounding deep-sea environment.

Resources

http://oceanexplorer.noaa.gov – Follow the Gulf of Mexico Expedition 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 principal investigator on the Gulf of Mexico expedition

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

http://ridge2000.bio.psu.edu/nonsciencelinks.htm – Links to other deep ocean exploration web sites

http://www-ocean.tamu.edu/education/oceanworld/resources/ – 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.

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

For More Information

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Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
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