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2006 Gulf of Mexico Expedition

What's in That Cake?

(adapted from the 2004 Estuary to the Abyss Expedition)

Focus
Exploration of deep-sea habitats

Grade Level
5-6 (Life Science)

Focus Question
How can scientists study organisms in deep-sea habitats in the Gulf of Mexico?

Learning Objectives
Students will be able to explain what a habitat is, and describe at least three functions or benefits that habitats provide.

Students will be able to describe some habitats that are typical of the Gulf of Mexico.

Students will be able to describe and discuss at least three difficulties involved in studying deep-sea habitats.

Students will be able to describe and explain at least three techniques scientists use to sample habitats such as those found in the Gulf of Mexico.

Materials
- ❐ At least two cakes or one cake for each student group, approximately 22 cm square or round
- ❐ Icing in various colors
- ❐ Candies or other edible materials for modeling habitat features
- ❐ Cardboard boxes large enough to cover cakes, one for each cake
- ❐ Piece of cardboard or foamcore, approximately 30 cm x 50 cm with a 3 cm x 22 cm "window" cut out of the center, one for each student group
- ❐ Large-diameter drinking straw (6mm or more), one for each student group
- ❐ Tweezers, one for each student group

Audio/Visual Materials
- ❐ None

Teaching Time
Two or three 45-minute class periods, plus time for student research

Seating Arrangement
Classroom style

Maximum Number of Students
30

Key Words
Gulf of Mexico
Chemosynthetic
Deep-sea community

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 pro-

duction 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. 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.

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. Similarly, deep-water coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, but very little is known about the ecology of these communities or the basic biology of the corals that produce them. Most deepwater coral reefs in the Gulf of Mexico were the discovered by explorers investigating hydrocarbon seepage and/or chemosynthetic communities. Scientists studying deep-water reefs on the Norwegian continental shelf have found that many large deepwater coral banks occur at sites where there are relatively high levels of light hydrocarbons present in the sediments. The reason for this correlation is not known, nor is it known whether a similar correlation exists in the hydrocarbon-rich Gulf of Mexico.

Many species found in deepwater bottom communities 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. A major challenge for scientists is how to accurately sample these habitats given the constraints of a hostile environment, as well as the need to minimize damage to the habitats caused by sampling.

In this activity, students will create edible models of Gulf of Mexico habitats, and devise ways to study and sample these habitats under less-than-ideal conditions.

Learning Procedure

[NOTE: Portions of this activity were adapted from "Edible Devonian Marine Ecosystem" by Naturalists at Falls of the Ohio State Park, Clarksville, Indiana, on the Geologic and Paleontologic Cook Book Web site. Visit http://www.uky.edu/KGS/education/cookbook.htm for more edible education ideas!]

1. To prepare for this lesson, review
   - Introductory essays for the 2006 Gulf of Mexico Expedition at http://oceanexplorer.noaa.gov/explorations/06mexico/
   - Prepare cakes and gather decorating materials. You may want to have students volunteer to bring their own cakes (be sure to specify the size!). A standard box of cake mix will make two 22 cm round or square cakes. If cakes are iced, the icing should be uniformly spread over the surface, and be a single color to provide a "clean slate" for the students to work from.

   You may also want to review daily logs and essays about biological communities from previous Ocean Exploration expeditions to the Gulf of Mexico (http://oceanexplorer.noaa.gov/explorations/02mexico/welcome.html and http://oceanexplorer.noaa.gov/explorations/03mex/welcome.html).

2. Briefly review and contrast chemosynthesis with photosynthesis. 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. (You may want to visit http://www.pmel.noaa.gov/vents/home.html for more information and activities on hydrothermal vent communities; http://www.bio.psu.edu/cold_seeps and http://www.bio.psu.edu/hotvents offer virtual tours of cold seep and hydrothermal vent communities.)

Discuss deepwater reefs as an example of another type of deep sea community. Be sure students understand that these reefs have a high diversity of species and large number of individual organisms like coral reefs in shallower water, but are virtually unexplored in the Gulf of Mexico. Visit http://oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup10_lophelia.html for more background on deepwater coral reefs.

Discuss the importance of the Gulf of Mexico to U.S. petroleum resources, as well as the potential importance of deep-sea biological communities that might be adversely affected by exploration and development of petroleum resources. Ask students to brainstorm steps that might be taken to avoid adverse impacts. Tell students that one purpose of the 2006 Gulf of Mexico Expedition is to learn more about the organisms that are found in these communities.

Discuss the concept of habitats. Have students brainstorm what functions or benefits an organism receives from its habitat. The students' list should include food, shelter (protection), and appropriate nursery areas. Tell students that detailed surveys of deep-sea communities in the Gulf of Mexico are just beginning, but we can have a general idea of what to expect based on explorations in other deep-water, hard-bottom habitats. Explain the concept of "microhabitat." Be sure students understand how the combination of various rock formations and organisms with complex physical forms (like branching corals and sponges) can offer many different types of habitat and as a result can provide food, shelter, and nursery space for many different kinds of organisms.

Tell students that one of the challenges faced by scientists studying deep-sea communities is how to obtain information about the organisms living in the habitats without destroying the habitats or the scientists themselves. Point out that early scientific expeditions used dredges or trawls to sample deepwater areas, but that these techniques basically destroy whatever they sample. Being able to use deep-diving submersibles to visit these communities in person has many advantages, but also puts the scientists in greater danger from the extreme conditions in the deep-sea environment. Ask students to list some of these dangers. Their list should include extreme pressure, low temperatures, and darkness.

Tell students that they are going to simulate some of these challenges in their classroom, and devise ways to study unfamiliar habitats under difficult conditions.

3. The first task for exploring new environments is to obtain a general idea of what types of habitats and organisms may be present. Tell student groups that they are to find out what sorts of habitats and organisms the 2002 and 2003 Ocean Exploration Expeditions found in deep-sea communities of the Gulf of Mexico.

   Have students read relevant trip logs from these expeditions at http://oceanexplorer.noaa.gov/explorations/02mexico/welcome.html and http://oceanexplorer.noaa.gov/explorations/03mex/welcome.html, and find pictures or illustrations of these organisms. In addition to printed reference books, the Ocean Explorer Gallery (http://oceanexplorer.noaa.gov/, click on "Gallery") and http://biodidac.bio.uottawa.ca have lots of images suitable for downloading.

4. Have each group present their research findings. Discuss and list the types of habitats found deep-sea communities of the Gulf of Mexico, and the kinds of organisms that may be found in these habitats. Have students describe what functions or benefits organisms receive from each habitat type. Be sure students understand that previous expeditions have only identified a fraction of the organisms that are probably present, so their list should consider habitats that may not have been sampled as yet.

5. Tell students that each group is going to construct an edible model of some of the habitats and organisms found in the Gulf of Mexico. Their model should contain at least three habitat types and at one organism that uses each of the three habitats. The base of the model will be a cake. Have students brainstorm what kinds of edible features can be added to the cake to make the habitat model. Mounds of icing can be used for boulders, and when hardened can be sculpted to form caves and overhangs. Sponges might be modeled with small pieces of sponge cake (of course), and strings of rock candy (made by hanging pieces of string in a saturated sugar solution) could represent branching corals. Of course, there are many more possibilities, and your students will probably have a pretty good idea of potential model elements.

   Each group should prepare a written record of the habitats modeled, the organisms included for each habitat, and where the organisms are located. Be sure each group keeps their work secret from the other groups. When models are finished, they should be placed under a cardboard box so they cannot be seen.

6. Lead a discussion of techniques that could be used to sample organisms living in the eight major habitats found in the Gulf of Mexico. State the following ground rules for sampling:
   - All samples must be collected from the deep-diving submersible.
   - It is important to minimize damage to the habitats being sampled.
   - It isn't possible to sample every centimeter of a habitat, so sampling must be distributed over the entire study area.
   - Time is severely limited, so it is important to get as much information as possible in a short amount of time.

   Photographic and video recordings are one of the most important sampling tools since they can cover large areas, cause no damage to the habitats (although bright lights may cause temporary or permanent blindness to light-sensitive organisms), and provide a permanent record of observations that can be studied in greater detail when scientists return from their dives.

   When sampling unexplored areas, scientists often steer their submersible along a series of pre-determined paths called "transects" that cover the entire area. For example, this would be like sampling a football field at night by walking with a flashlight along every ten-yard line; the entire field would be covered, but only a small fraction would actually be seen. If a site has been previously visited, scientists may concentrate their sampling and observations on features of particular interest.

   Samples of rocks and larger organisms such as corals and sponges can be collected with the submersible's manipulator arm. Scoops, cores, and suction devices may also be used to sample organisms living on living and non-living surfaces, as well as organisms in soft bottom habitats.

   Be sure students realize that regardless of the sampling techniques used, some organisms will almost certainly escape detection, particularly those able to move rapidly away from a source of disturbance, such as fishes, squids, and many burrowing animals.

7. Tell students that their challenge is to sample an unknown environment (cake) to determine the habitats and organisms present. Since we are working with deep-sea environments, there will be some constraints on the sampling:
   - A total of two minutes will be allowed for the entire sampling program.
   - No more than 5% of the model may be damaged.
   - Samples may only be taken through a "window" 3 cm wide.

- No more than 5 windows can be sampled.

Provide each group with a pair of tweezers (simulating the submersible's manipulator arm), a large-diameter drinking straw (simulating a core sampler), and a piece of cardboard with a 3 cm x 23 cm slot (simulating the sampling window). Have each group write down their sampling strategy, indicating which students will be responsible for collecting each type of sample. One or two students may be assigned to record visual observations to simulate video recording.

Working with one group at a time, provide the group with an unknown cake. Signal the start of the two-minute sampling period, and allow the group to begin their sampling program. Be sure that no more than five windows are sampled. Call out elapsed time every 15 seconds so that the group can pace their sampling activities.

When all groups have completed their sampling, have each group prepare a written report on the habitats and organisms discovered in their model environment. Since they won't know what the various modeling materials are supposed to represent, they will have to identify the various features sampled by a description (red boulder, yellow gummy bear, etc).

8. Lead a discussion in which each group presents their report, and compares their findings with the records of the group that created the model. Have students verify that no more than 5% of the model has been damaged by the sampling procedure. Discuss ways in which sampling could be improved. Have students compare and contrast their sampling techniques with those actually used by scientists exploring deep-sea communities of the Gulf of Mexico. Point out that it would have been even more realistic if the entire sampling process were done in total darkness with only a small flashlight to guide the sampling effort.

   Following this discussion (and depending upon the condition of the cakes), invite students to assume the role of top consumers and have a direct interaction with their model environments (they can eat the cake).

The Bridge Connection

www.vims.edu/bridge/ – Click on "ocean science" in the navigation menu to the left, then "Biology," then "Invertebrates," then "Other Inverts," for resources on corals and sponges. Click on "Ecology" then "Deep Sea" for resources on deep sea communities.

The "Me" Connection

Have students write a short essay on how explorations of areas like deep-sea communities of the Gulf of Mexico could be of direct benefit to their own lives.

Connections to Other Subjects

Language Arts, Physical Science, Life Science

Assessment

Reports and records prepared in Steps 4, 5, and 6 provide opportunities for 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

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)

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.

Entering the Twilight Zone (6 pages, 468k)) (from the 2002 Gulf of Mexico Expedition) [http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_twilight.pdf]

Focus: Deep-sea habitats (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 infer probable trophic relationships within and between major deep-sea habitats. Students will also be able to describe in the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, and describe major deep-sea habitats and list at least three organisms typical of each habitat.

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

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)

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.

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://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery

http://www.uky.edu/KGS/education/cookbook.htm – The Geologic and Paleontologic Cookbook

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard C: Life Science
- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science
- Structure of the Earth system

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Populations, resources, and environments

Content Standard G: History and Nature of Science
- Nature of science

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 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 f.* Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
- *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 a.* Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.

- *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 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 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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