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2006 Gulf of Mexico Expedition

Keep Away

(adapted from the 2003 Gulf of Mexico Deep Sea Habitats Expedition)

Focus
Effects of pollution on diversity in benthic communities

Grade Level
5-6 (Life Science)

Focus Question
How does pollution affect biological diversity in benthic communities?

Learning Objectives
Students will be able to discuss the meaning of "biological diversity," and will be able to compare and contrast the concepts of "variety" and "relative abundance" as they relate to biological diversity.

Given information on number of individuals, number of species, and biological diversity at a series of sites, students will be able to make inferences about the possible effects of oil drilling operations on benthic communities at these sites.

Materials
- ❒ Copies of "Biological Data from Grab Samples Collected in the Vicinity of the Ekofisk Oilfield, North Sea," one copy for each student group
- ❒ Graph paper

Audio/Visual Materials
- ❒ Chalkboard, marker board with markers, or overhead transparencies for group discussions

Teaching Time
One 45-minute class period

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Diversity
Diversity index
Species richness
Species evenness
Pollution

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. 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.

Deep-water 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 deep-water 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 deep-water 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 deep-water 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 deep-water 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 deep-water biological communities and evaluating their sensitivity to impacts from human activities are key objectives of the 2006 Gulf of Mexico Expedition.

In this activity, students will graph data from an investigation of the effects of oil drilling on marine benthic communities, and use these graphs to make inferences about these effects.

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/

   You may also want to review one or more of the Web sites listed in Steps 2 and 3.

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 deep-water 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 deep-water 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 the overall purposes of the 2006 Gulf of Mexico Expedition are to develop ways to more easily locate such communities, and to learn more about how these communities work.

3. Review the concept of biological diversity. Scientists often use the term "species diversity" to describe the abundance of species and individuals within an area (or environment). The simplest measure of species diversity is the number of species present in an area. This is called species richness. But there is more to diversity than just the number of species present. A community that has more or less equal numbers of individuals within the species present is usually thought of as more diverse than a community that is dominated by one species. [NOTE: You can demonstrate this tangibly with an activity from The Moonsnail Project's mini-lecture on diversity at http://www.moonsnail.org/Mini_Diversity.htm; this site also has a related activity demonstrat-

ing the effect of sample size on diversity estimates.]

Species diversity tends to increase at the edges of environments (ecotones) where conditions are more variable. Species diversity is often used as a measure of environmental health; diversity is generally expected to decline in a stressed environment. For more background and activities on species diversity, visit the Moonsnail Project's mini-lecture on diversity http://www.moonsnailproject.org/Mini_Diversity.htm), and the Arbor Project's Web page on bird biodiversity at www.cees.iupui.edu/Education/Workshops/Project_Seam/Exercises/bird_biodiversity_exerciese.htm.

4. Tell students that they are going to analyze data from an investigation of the effects of oil drilling on marine benthic communities. Their assignment is to use their analyses to make inferences about these effects.

   Provide each student group with a copy of "Biological Data from Grab Samples Collected in the Vicinity of the Ekofisk Oilfield, North Sea" (grab samples are samples collected from the sea bottom with a device that resembles a giant clam shell). Have students sort the data into four groups: samples collected less than 500 m from the drilling platform, samples collected between 500 and 1,000 m, samples collected between 1,000 and 3,000 m, and samples collected more than 3,000 m from the platform. For each of these four groups, student should find the mean number of individuals, mean number of species, and mean diversity. Students should then construct three bar graphs, one each for mean number of individuals, mean number of species, and mean diversity, with the distance interval on the horizontal axis.

5. Lead a discussion of students' results. Means for each interval should be:

Distance from Drilling Platform (meters)	Mean Number of Individuals	Mean Number of Species	Mean Diversity
0-500	412	57	1.73
500-1,000	294	104	2.20
1,000-3,000	254	148	2.05
>3,000	152	113	2.05

   Ask students which of the four groups they would expect to be most affected by drilling operations, and how this group differs from the other groups. Students should identify the group of samples collected less than 500 m from the platform as the most likely to be affected, and should notice that this group has more individuals, fewer species, and lower diversity than the other groups. A probable explanation for these observations is that fewer species were able to tolerate effects produced by drilling operations, so the number of species and diversity were decreased; but individuals belonging to species that could tolerate these conditions faced less competition from other species, and so there were more individuals of the tolerant species.

   Ask students to infer what is happening at sites 500 – 1,000 m from the drilling platform. Here the number of species is less than at sites farther away from the platform, but more than at sites closer to the platform. This suggests that conditions at the 500 – 1,000 m sites were unfavorable to some species found at more distant sites, but still tolerable to others that are missing from sites closer to the platform. The number of individuals at the 500 – 1,000 m sites was higher than any of the other sites, perhaps because of reduced competition. Since the number of species was still fairly high, this increase in individuals caused the diversity to be higher (remember that diversity considers numbers of individuals as well as number of species).

Ask students to interpret results from the groups that were 1,000 – 3,000 m and >3,000 m from the drilling platform. The diversity of these two groups is identical, yet the more distant group has fewer species and fewer individuals. One possible explanation is that low levels of pollution at the 1,000 – 3,000 m sites caused some species to disappear, but this allowed other species to come into the area. Another possibility is that these sites in these two groups were influenced by one or more factors other than the drilling platform.

Emphasize that one of the primary reasons for the 2006 Gulf of Mexico Expedition is to locate deep-sea bottom communities so that they can be protected. Be sure students understand that MMS regulations require petroleum development companies to locate potentially sensitive biological communities and avoid these during exploration and development activities.

The Bridge Connection

http://www.vims.edu/bridge/reef.html; www.vims.edu/bridge/vents.html; and www.vims.edu/bridge/geology.html

The "Me" Connection

Have students write a short essay describing how biological diversity is important to their own lives.

Connections to Other Subjects

English/Language Arts, Mathematics

Assessment

Graphs prepared in Step 4 provide an opportunity for assessment. In addition, you may want to have each group prepare a written interpretation of their results prior to the group discussion in Step 5.

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://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

Gray, J. S., K. R. Clarke, R. M. Warwick, and G. Hobbs. 1990. Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Eldfisk oilfields, North Sea. Marine Ecology Progress Series 66:285-299 – Technical journal article upon which this activity is based.

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
- Populations and ecosystems

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

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 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.

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Student Handout

Biological Data from Grab Samples Collected in the Vicinity of the Ekofisk Oilfield, North Sea

(from Gray, et al., 1990)

Distance from Drilling Platform (meters)	Number of Individuals	Total Number of Species	Diversity
120	362	47	1.60
235	462	67	1.86
340	392	42	1.63
450	432	72	1.83
600	274	84	2.00
720	314	124	2.40
850	289	99	2.10
950	299	109	2.30
1150	260	140	2.01
1250	248	156	2.09
2375	244	138	2.04
2800	264	158	2.06
3100	140	105	2.03
3800	164	121	2.07
4200	148	118	2.10
4900	156	108	2.00