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Expedition to the Deep Slope 2007

Animals of the Fire Ice

[adapted from the 2003 Windows to the Deep Expedition]

Focus
Methane hydrate ice worms and hydrate shrimp

Grade Level
5-6 (Life Science)

Focus Question
What are animals that have been found feeding on methane hydrates, and how may they interact with other species?

Learning Objectives
Students will be able to define and describe methane hydrate ice worms and hydrate shrimp.

Students will be able to infer how methane hydrate ice worms and hydrate shrimp obtain their food.

Students will be able to infer how methane hydrate ice worms and hydrate shrimp may interact with other species in the biological communities of which they are part.

Materials
None

Audio/Visual Materials
None

Teaching Time
One or two 45-minute class periods plus time for student research

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Cold seeps
Methane hydrate
Clathrate
Methanogenic Archaeobacteria
Polychaete
Alvinocarid shrimp
Ice worm
Hydrate shrimp

Background Information
> "For kicks, oceanographer William P. Dillon likes to surprise visitors to his lab by taking ordinary-looking ice balls and setting them on fire.
>
> 'They're easy to light. You just put a match to them and they will go,' says Dillon, a researcher with the U.S. Geological Survey (USGS) in Woods Hole, Mass.
>
> If the truth be told, this is not typical ice. The prop in Dillon's show is a curious and poorly known structure called methane hydrate."

from "The Mother Lode of Natural Gas" by Rich Monastersky, http://www.sciencenews.org/sn_arch/11_9_96/bob1.htm

Methane hydrate is a type of clathrate, a chemical substance in which the molecules of one material (water, in this case) form an open lattice that encloses molecules of another material (methane) without actually forming chemical bonds between the two materials. Methane is produced in many environments by a group of Archaea known as the methanogenic Archaeobacteria. These Archaeobacteria obtain energy by anaerobic metabolism through which they break down the organic material contained in once-living plants and animals. When this process takes place in deep ocean sediments, methane molecules are surrounded by water molecules, and conditions of low temperature and high pressure allow stable ice-like methane hydrates to form. Besides providing entertainment for oceanographers, methane hydrate deposits are significant for several other reasons:

- The U.S. Geological Survey has estimated that on a global scale, methane hydrates may contain roughly twice the carbon contained in all reserves of coal, oil, and conventional natural gas combined.
- Methane hydrates can decompose to release large amounts of methane which is a greenhouse gas that could have (and may already have had) major consequences to the Earth's climate.
- Sudden release of pressurized methane gas may cause submarine landslides which in turn can trigger catastrophic tsunamis.
- Methane hydrates are associated with unusual and possibly unique biological communities containing previously-unknown species that may be sources of beneficial pharmaceutical materials.

Methane hydrates are one of the chemicals that are often found in areas where gases (such as methane and hydrogen sulfide) and oil seep out of sediments. These areas, known as cold seeps, 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 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.

Earlier Ocean Exploration expeditions to other cold-seep communities in the Gulf of Mexico found polychaete worms that appeared to be actively sculpting methane hydrate ices, and expeditions to other areas (such as the 2001 Deep East Expedition) observed shrimp that appeared to be feeding directly on methane hydrate ices (visit http://oceanexplorer.noaa.gov/explorations/03mex/welcome.html, http://oceanexplorer.noaa.gov/explorations/02mexico/welcome.html, and http://oceanexplorer.noaa.gov/explorations/deepeast01/deepeast01.html for more information). What are these "fire ice animals" doing? Are they actually consuming methane hydrate ices for food? Until more detailed studies are done on these animals, we won't know for sure. But we can use what is already known about other shrimps and polychaete worms to infer some possible answers. These inferences can lead to hypotheses about the relationships between the animals and methane hydrate ices, and can form the basis for experiments to find out more about these strange deep-sea animals.

In this activity, students will research cold-seep communities and typical feeding habits of polychaetes and shrimp to make inferences about the relationships between fire ice animals and methane hydrates.

Learning Procedure

1. Visit http://oceanexplorer.noaa.gov/explorations/07mexico/welcome.html for information about Expedition to the Deep Slope 2007, as well as http://oceanexplorer.noaa.gov/explorations/deepeast01/logs/oct1/oct1.html and http://oceanexplorer.noaa.gov/explorations/03windows/welcome.html for background on the 2001 Ocean Exploration Deep East expedition to the Blake Ridge and the 2003 Windows on the Deep Ocean Exploration expedition. Lead an introductory discussion about these expeditions, briefly describing methane hydrates and why these substances are potentially important to human populations. You may also want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold-seep community in the Gulf of Mexico, and http://www.pmel.noaa.gov/vents/ for more information and activities on hydrothermal vent communities.

2. Lead a discussion about 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 throughboth 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 or webs, emphasizing that the entire chain or web depends upon primary producers at the base of the chain (or web) that are able to create energy-rich food from non-living components in the surrounding environment.

3. Tell students that expeditions to deep-sea communities often discover new and unusual types of living organisms. Two of these organisms are a type of polychaete called "ice worms" and a type of crustacean called "hydrate shrimp." Say that the "ice worms" make burrows in methane hydrate ices, and that hydrate shrimp have been seen crawling on top of methane hydrate ices, possibly feeding on the ice surface. Explain that scientists are not certain about the relationships between these animals and methane hydrates, nor how the fire ice animals obtain their food. To plan investigations to answer these questions, we need to use existing knowledge about other types of shrimp, polychaetes, and chemosynthetic communities to make hypotheses that are the basis for experiments and observations to learn more about these animals.

   Tell students that their assignment is to find out what is known about polychaetes and shrimps in cold-seep communities, how other polychaetes and shrimps obtain their food, and to make hypotheses about the relationships between methane hydrates, ice worms, and hydrate shrimp. Each student group should prepare a written report that answers the following questions:

- What is the basis of food webs in cold-seep communities?
- What have explorers to cold-seep communities observed about ice worms and hydrate shrimp?
- How do polychaetes and shrimps, in general, obtain their food?
- What are the relationships that you hypothesize between ice worms, hydrate shrimp, and methane hydrates?

Direct students to encyclopedias and general biology books to obtain information on feeding habits of shrimps and polychaetes in general. Information at http://www.wetwebmedia.com/marind5_5.htm may also be useful, although the emphasis of this site is on aquaria. There is not much information presently available on hydrate shrimp, other than the fact that they have been observed on methane hydrates at the Blake Ridge. Two good sources of information on ice worms are http://www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html and http://nai.arc.nasa.gov/news_stories/news_detail.cfm?ID=86. If students do keyword searches to find additional references, be sure they understand that the name "ice worm" has also been used to describe animals that inhabit glaciers and similar environments, so students should also include "methane" in their search query.

4. Have each student group present the results of their research, then lead a discussion of students' hypotheses. Encourage imagination and creativity, but challenge students to explain how their hypotheses are consistent with existing knowledge. Possible relationships could include:
   - Shrimp and/or worms are directly using methane hydrate as a source of food (this is not particularly likely, since other shrimps and polychaetes are heterotrophic).
   - Shrimp and/or worms are consuming methane hydrate which is used by symbiotic chemosynthetic bacteria living inside the animals (this would be analogous to many similar symbioses, and a variety of bacteria have been found to be closely associated with ice worms).
   - Shrimp and/or worms are grazing the surface or interior of methane hydrate ices, and are eating chemosynthetic bacteria that use methane hydrate as an energy source (bacterial mats have been found in cold-seep communities, and grazing or deposit-feeding is common among other shrimps and polychaetes).
   - Ice shrimp that burrow into methane hydrate ices could be deriving protection from predators (burrowing behavior is typical among many other polychaetes).

   Have students discuss what sort of investigations might be undertaken to test their hypotheses.

The Bridge Connection

www.vims.edu/bridge/ – Enter "cold seep" in the "Search" box, then click "Search" to display entries on the BRIDGE Web site for cold-seep communities; enter "ice worm" in the "Search" box, then click "Search" to display entries on the BRIDGE Web site for ice worms; enter "shrimp" in the "Search" box, then click "Search" to display entries on the BRIDGE Web site for shrimps.

The "Me" Connection

Have students write a short essay on how additional knowledge about "fire ice animals" could be important to their own lives.

Connections to Other Subjects

English/Language Arts, Earth Science, Physical Science

Assessment

Written and oral group reports provide opportunities for 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.

Van Dover, C.L., et al. 2003. Blake Ridge methane seeps: characterization of a soft-sediment, chemosynthetically-based ecosystem. Deep-Sea Research Part I 50:281–300. (available as a PDF file at http://www.mbari.org/staff/vrijen/PDFS/VanDover_2003DSR.pdf)

http://www.resa.net/nasa/ocean_methane.htm — Links to other sites with information about methane hydrates and associated communities

http://www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html – Article on cold-seep communities and ice worms

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

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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Please send your comments to:
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For More Information

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