ocean explorer
oceanexplorer.noaa.gov

Windows to the Deep Exploration

Animals of the Fire Ice

Focus
Methane hydrate ice worms and hydrate shrimp

Grade Level
5-6 (Life Science)

Focus Question
What animals 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 a 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
Blake Ridge
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. 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.

The Blake Ridge is a large sediment deposit located approximately 400 km east of Charleston, South Carolina on the continental slope and rise of the United States. The crest of the ridge extends in a direction that is roughly perpendicular to the continental rise for more than 500 km to the southwest from water depths of 2,000 to 4,800 m. Over the past 30 years, the Blake Ridge has been extensively studied because of the large deposits of methane hydrate found in the area. In September, 2001, the Ocean Exploration Deep East Expedition conducted four DSV Alvin dives to explore chemosynthetically-based communities on the crest of the Blake Ridge at a depth of 2,154 m. The expedition recovered some of the largest mussels (up to 364 mm) ever discovered and documented 16 other numerically abundant groups of invertebrates, some of which are probably new to science.

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. 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 such as the Blake Ridge 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. As is the case with hydrothermal vents, chemosynthetic bacteria are also the base of the food chain in cold seep communities. Bacteria may form thick bacterial mats, or may live in close association with other organisms. Specific relationships between these organisms have not been well-studied.

The 2001 Ocean Exploration Deep East Expedition observed shrimp (similar to other shrimps in chemosynthetic communities called "alvinocarid shrimp") that appeared to be feeding directly on methane hydrate ices. Expeditions to other cold seep communities in the Gulf of Mexico found polychaete worms that appeared to be actively sculpting methane hydrate ices. 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 these hypotheses 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/deepeast01/logs/oct1/oct1.html and http://oceanexplorer.noaa.gov/explorations/03windows/welcome.html for background on the 2001 Ocean Exploration Deep East Expedition and the 2003 Windows to the Deep Expedition to the Blake Ridge. 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.

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 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. 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 (or chains) 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 hypoth-

esize 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 worms 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 website for cold seep communities; enter "ice worm" in the "Search" box, then click "Search" to display entries on the BRIDGE website for ice worms; enter "shrimp" in the "Search" box, then click "Search" to display entries on the BRIDGE website 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

Evaluation

Written and oral group reports provide opportunities for assessment.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest Blake Ridge Expedition discoveries, and to find out what researchers are learning about cold-seep communities. Ask researchers what their hypotheses are about the relationships between methane hydrates and hydrate shrimp, and what they are doing to test these hypotheses.

Resources

http://oceanexplorer.noaa.gov – Follow the Blake Ridge Expedition 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.geomar.de/projekte/sfb_574/abstracts/vanDover_et_al_2003.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 – Another article on cold seep communities, and ice worms

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

For More Information

Paula Keener-Chavis, National Education Coordinator/Marine Biologist
NOAA Office of Exploration
2234 South Hobson Avenue
Charleston, SC 29405-2413
843.740.1338
843.740.1329 (fax)
paula.keener-chavis@noaa.gov

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: http://oceanexplorer.noaa.gov