oceanexplorer.noaa.gov

2005 Lost City Expedition

Where's Dinner?

Focus
Trophic relationships in biological communities of the Lost City Hydrothermal Field

Grade Level
9-12 (Life Science)

Focus Question
What are the nutritional strategies employed by living organisms at the Lost City Hydrothermal Field?

Learning Objectives
Students will be able to compare and contrast primary production in biological communities at cold seeps and hydrothermal vents.

Students will be able to describe and discuss probable primary production processes in biological communities of the Lost City Hydrothermal Field.

Students will be able to infer probable trophic relationships among macrofauna of the Lost City Hydrothermal Field.

Materials
❒ Copies of "Preliminary List of Species Groups found at the Lost City Hydrothermal Field," one copy for each student group

Audio/Visual Materials
❒ (Optional) equipment for viewing online or downloaded video of vent communities

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

Seating Arrangement
Groups of two to four students

Maximum Number of Students
30

Key Words
Lost City
Hydrothermal vent
Cold seep
Chemoautotroph

Background Information
In 1977, scientists in the deep-diving submersible Alvin made the first visit to an oceanic spreading ridge near the Galapagos Islands, and made one of the most exciting discoveries in 20th century biology. In the middle of deep, cold ocean waters, they found hot springs and observed black smoke-like clouds billowing from chimneys of rock; and nearby were communities of animals that no one had ever seen before.

These hot springs came to be known as hydrothermal vents, and since that first discovery, more than 200 similar vent fields have been documented in the world's ocean. These systems are formed when seawater flowing through cracks in the seafloor crust enters magma-containing chambers beneath a spreading ridge. Intense heat from the molten rock causes a variety of chemical changes and many substances from the rocks become dissolved in the fluid. The heated fluid becomes less dense, rises upward, and emerges onto the sea floor to form a hydrothermal vent. When the heated fluid is cooled by cold water of the deep ocean, many of the dissolved materials precipitate, creating black clouds and chimneys of rock-like deposits. The hydrothermal fluid emerging from the vents is rich in sulfide, which is used as an energy source by chemosynthetic bacteria to produce essential organic substances. These autotrophic bacteria are the base of a diverse food web that includes large tubeworms (vestimentiferans), clams, mussels, limpets, polychaete worms, shrimp, and crabs.

In 2000, a different sort of vent field was serendipitously discovered on an underwater mountain called the Atlantis Massif near the Mid-Atlantic Ridge. This new field also had hot fluids venting from rocky chimneys. But these chimneys towered as much as 200 feet above the seafloor, much larger than chimneys found in other vent fields. In fact, the vent field was located 15 kilometers away from the spreading axis of the Mid-Atlantic Ridge and the chimneys looked so much like towers and spires of a fantastic city that the new vent field was named "Lost City." And the fluids emerging from the chimneys, as well as the surrounding biological communities, were unlike any other known hydrothermal system. Subsequent investigations have shown that the newly-discovered hydrothermal fields are not formed by seawater reacting with molten magma. Instead, these fields are formed when seawater reacts with solid mantle rocks. These rocks, called peridotites, are formed deep inside the Earth, but a unique type of faulting can bring them close to the seafloor. Cracks in the seafloor can allow seawater to percolate down to the up-lifted peridotites. When this happens, numerous chemical reactions occur between seawater and minerals in the rock (a process called serpentinization). These reactions produce a large amount of heat that causes the fluids to rise and eventually vent at the surface of the seafloor. Mixing between the heated fluids and cold surrounding seawater causes additional reactions that include precipitation of calcium carbonate (limestone), which forms the towering chimneys of Lost City. Because the reactions of seawater with peridotites are essential to these formations, the Lost City is called a "peridotite-hosted ecosystem."

In contrast to the abundant biological communities of hydrothermal vents formed by volcanic activity, the Lost City Hydrothermal Field (LCHF) initially appeared to be devoid of living organisms. But when scientists took a closer look at the surface of the chimneys (they actually vacuumed the surface), they found large numbers of tiny shrimps and crabs. Because most of these animals are less than one centimeter in size, transparent or translucent, and tend to hide in small crevices, they were easily overlooked when the LCHF was first discovered. While the total biomass around the LCHF vents appears to be less than at other hydrothermal vents, scientists believe there is just as much diversity (variety of different species). Like previously discovered vent communities, the LCHF ecosystem is based on microorganisms that are able to use chemicals in the vent fluids as an energy source for producing complex organic compounds that are used as food by other species (chemosynthesis). But again, the LCHF differs in that the fluids emerging from the chimneys has very little of the hydrogen sulfide and metals that are typical in hydrothermal fluids of other vent. Instead, LCHF vent fluids contain high concentrations of methane and hydrogen, and these chemicals appear to provide the energy source for chemosynthetic microbes.

Learning Procedure

1. To prepare for this lesson, visit the Lost City expedition's Web pages (http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html; http://www.lostcity.washington.edu/; and http://www.immersionpresents.org) for an overview of the expedition and background essays.

You may also want to review background information on biological communities associated with hydrothermal vents and cold seeps (http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html and http://www.bio.psu.edu/hotvents offer virtual tours of hydrothermal vent communities; http://www.bio.psu.edu/cold_seeps provides a virtual tour of a cold seep community in the Gulf of Mexico; http://www.soc.soton.ac.uk/chess/edumain.html offers background information and virtual tours of both communities; http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML.ps_vents.html has links to many other Web sites with information about hydrothermal vents).

2. Briefly review:
   (a) The concepts of plate tectonics, being sure that students understand the processes that take place at convergent and divergent boundaries, and why these boundaries are often the site of volcanic activity; and
   (b) Hydrothermal vents, cold seeps, and the Lost City Hydrothermal Field emphasizing the characteristics and origin of vented fluids. Point out that each of these habitats is associated with distinct living communities, and many of the organisms found in these communities are not found anywhere else. These communities have at least one thing in common, however: they are all based on chemosynthetic processes that use substances in vent fluids as energy sources for the synthesis of essential compounds needed by living organisms.

3. Provide each student group with "Preliminary List of Species Groups found at the Lost City Hydrothermal Field." Tell students that their assignment is to
   (a) Research food webs at hydrothermal vents and cold seeps;
   (b) Use this information to develop hypotheses about trophic relationships between LCHF species; and
   (c) Prepare a written summary of their results.

   These reports should identify the energy sources and primary producers in each of the three communities, and the nutritional strategy employed by the dominant species. It may not be possible to precisely determine specific foods for all groups, 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. Tell students that to date, biological studies at LCHF suggest high diversity but low biomass, and they should consider this observation when developing their hypotheses.

   In addition to written reference materials and resources referenced in Step 1, the following Web sites contain useful information:
   http://www.bio.psu.edu/cold_seeps
   http://biodidac.bio.uottawa.ca/
   http://www.geomar.de/projekte/sfb_574/abstracts/vanDover_et_al_2003.pdf

4. Have each student group present an oral summary of their results, then lead a discussion of the proposed hypotheses. The following points should be included:
   - Sulfide and methane are energy sources commonly used by chemoautotrophic organisms in hydrothermal vent and cold seep communities. Note that methane and sulfide may be produced by decomposition of organic material, as well as by inorganic hydrothermal processes. At LCHF, hydrogen and methane result from reducing conditions caused by serpentinization reactions.

   - The primary chemoautotrophic organisms in hydrothermal vent and cold seep communities are Archaea and bacteria that oxidize methane (methanotrophs) or hydrogen sulfide (thiotrophs). These organisms are found both free living and in symbiotic associations.

- Free-living chemoautotrophs may be grazed (in the case of bacterial mats) or filtered out of the water by other species.

- Some of the best studied vent organisms are the large tubeworms (phylum Pogonophora) known as vestimentiferans. These unusual animals do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome, that contains chemosynthetic bacteria. Vestimentiferans have tentacles that extend into the water. The tentacles are bright red due to the presence of hemoglobin which can absorb hydrogen sulfide and oxygen which are transported to the bacteria in the trophosome. The bacteria produce organic molecules that provide nutrition to the tube worm. A similar symbiotic relationship is found in clams and mussels that have chemosynthetic bacteria living in their gills.

- In addition to obligate species that obtain all or most of their nutrition from chemosynthetic production by Archaea and bacteria, cold seep and hydrothermal vent communities also include a second category of species such as anemones, crabs, gastropods, and soft corals that utilize seep-derived production but are also found in other habitats.

- A third category of species includes cosmopolitan benthic fauna that foraging around hydrothermal vents and cold seeps.

- While specific trophic relationships have not been established among the macrofaunal organisms found at the LCHF, it is reasonable to suppose that chemoautotrophic organisms using methane and/or hydrogen are an important part of LCHF food webs.

- Based on knowledge of cold seep and hydrothermal vent communities, it would also be reasonable to suppose that Archaea and/or bacteria are the primary chemoautotrophs at LCHF. This inference is supported by microbial analyses indicating that Archaea are abundant at LCHF.

- Possible nutritional strategies at LCHF include:
  Symbiotic relationship with chemoautotrophs;
  Direct feeding on chemoautotrophs (primary consumption);
  Feeding on other organisms (secondary or tertiary consumption).

- Many of the macrofaunal organisms found at LCHF are most likely grazers, filter feeders, or deposit feeders.

- High diversity and low biomass in biological communities often signifies a limitation in some critical resource, such as food. Organisms in these communities are either highly specialized to specific food resources (hence a high diversity among species) or are omnivorous, taking advantage of small quantities of many different types of food. If food resources are limited at the LCHF, food chains are likely to be fairly short, since a given biomass of primary producers can generally support only about one-tenth that biomass of primary consumers, one one-hundredth that biomass of secondary consumers, etc.

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click "Ocean Science Topics," then "Habitats," then "Deep Sea" for links to resources about hydrothermal vents and cold seep communities.

The "Me" Connection

Have students write a brief essay speculating on how knowledge of chemosynthetically-based food webs could be of personal importance.

Connections to Other Subjects

English/Language Arts, Earth Science

Evaluation

Student reports and group discussions provide opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html to keep up to date with the latest Lost City Expedition discoveries.

Resources

http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html – Web site for the 2005 Lost City expedition.

http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html – Virtual tour of Magic Mountain, a hydrothermal vent site located on Explorer Ridge in the NE Pacific Ocean, about 150 miles west of Vancouver Island, British Columbia, Canada.

http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html – 3-dimensional structure of a "mid-ocean ridge," where two of the Earth's tectonic plates are spreading apart

http://www.bio.psu.edu/hotvents – Virtual tour of hydrothermal vent communities

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML.ps_vents.html – links to many other Web sites with information about hydrothermal vents

Tunnicliffe, V., 1992. Hydrothermal-vent communities of the deep sea. American Scientist 80: 336-349.

Corliss, J. B., J. Dymond, L.I. Gordon, J.M. Edmond, R.P. von Herzen, R.D. Ballard, K. Green, D. Williams, A. Bainbridge, K. Crane, and T.H. Andel, 1979. Submarine thermal springs on the Galapagos Rift. Science 203:1073-1083. – Scientific journal article describing the first submersible visit to a hydrothermal vent community

National Science Education Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science
- Interdependence of organisms

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality

Content Standard G: History and Nature of Science
- Nature of scientific knowledge

For More Information

Paula Keener-Chavis, Director, Education Programs
NOAA Office of Ocean Exploration
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (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

Preliminary List of Macrofaunal Species Groups found at the Lost City Hydrothermal Field

Annelida
- Glyceridae
- Amphinomidae
- Polynoidae

Cnidaria
- anemones
- gorgonians
- hydroids
- *Lophelia sp.*

Porifera
- five different types of sponges

Mollusca
- gastropods
- *Bathymodioilus azoricus*
- limpets

Arthropoda
- amphipods (*Bouvierella curtirama* and *Primno evansi* most abundant fauna)
- copepods
- ostracods
- tanaidaceans
- brachyuran crabs
- galatheid crabs
- isopods
- barnacles
- pycnogonids

Echinodermata
- urchins
- asteriods
- ophiuroids

Osteichthyes
- *Polyprion americanus*
- *Synaphobranchus kaupi*