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Windows to the Deep Exploration

How Diverse is That?

Focus
Quantifying biological diversity

Grade Level
9-12 (Life Science)

Focus Question
What do ecologists mean when they say a biological community is "diverse?"

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 abundance and distribution data of species in two communities, students will be able to calculate an appropriate numeric indicator that describes the biological diversity of these communities.

Materials
❒ Copies of "Species Distribution in Seep and Non-Seep Areas at Two Sites on the California Slope," one copy for each student group
❒ (Optional) Pieces of colored paper and a coffee-can size container (if you choose to do activities from The Moonsnail Project's mini-lecture on biodiversity)

Audio/Visual Materials
❒ Overhead projector, transparencies, and markers, or marker board, or chalk board

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

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Cold seeps
Methane hydrate
Clathrate
Diversity
Diversity index
Species richness
Species evenness

Background Information
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. 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. These depos-

its are significant for several 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.

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 (or food web). 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 foul-smelling 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. Methane and hydrogen sulfide are produced by the breakdown of organic matter deposited in the sediments. Archea and bacteria gain energy by oxidizing methane (methanotrophs) or hydrogen sulfide (thiotrophs), and then become the base for a "chemosynthetic" food chain, in some cases by being grazed and filtered out of the water and in other cases by functioning as symbionts (for example, with mussels and clams).

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, observed shrimp that appeared to be feeding directly on methane hydrate ices, and documented 16 other numerically abundant groups of invertebrates.

Most studies of unexplored communities in the deep ocean begin with observations of organisms on or near the surface of the sea bottom, because these are the first things scientists see from deep-sea research vehicles and are easiest to sample and photograph on the first dives to a new site. These studies have shown that many of the organisms in deep-sea chemosynthetic communities have distinct adaptations to their environments that make them quite different from organisms in the surrounding ocean, and on almost every dive, these studies find species that are previously unknown to science. Moreover, these communities are often quite extensive, and the presence of an abundant energy source supports much more biological material than is found in other benthic ocean habitats.

Two measurements are frequently used by scientists to describe the abundance of species and individuals within an area (or environment):

- Species Diversity (S) - the number of species in the environment; and
- Species Evenness (or equitability) - a measure of how evenly individuals are distributed

among these species. Evenness is greatest when species are equally abundant.

The simplest measure of species diversity is the number of species present in an environment. This is called species richness. But there is more to diversity than just the number of species in an environment. 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. For example, samples from two separate communities might each contain the same seven species, with distribution of individuals as follows:

Species	**Number of Individuals**	
	Community 1	Community 2
Species a	43	7
Species b	1	7
Species c	1	7
Species d	1	7
Species e	1	7
Species f	1	7
Species g	1	7
Total	**49**	**49**

Our notion of what "diversity" means leads us to consider Community 2 as more diverse than Community 1, even though they both have the same number of species and total individuals.

[NOTE: You can demonstrate this more 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 demonstrating the effect of sample size on diversity estimates].

Because of the importance of both species evenness and species richness to our idea of diversity, some measures of diversity include a way of including both concepts. One commonly used measure of species diversity that includes proportions of individuals is the Shannon-Weaver information function which is:

$H = -\Sigma p_i \ln p_i$

Where:

H is the diversity index

ln is the natural logarithm

i is an index number for each species present in a sample

p_i is the number of individuals within a species (ni) divided by the total number of individuals (N) present in the entire sample

To calculate the diversity index H, you multiply the proportion (p_i) of each species in the sample times the natural log of that same value (ln p_i), then sum (Σ) the values for each species, and finally multiply by -1.

The table below illustrates the calculation:

	Number of Individuals	Proportion (p_i)	$\ln(p_i)$	$p_i\ln(p_i)$
Species a	3	3÷47 = 0.064	-2.749	0.064 • -2.749 = -.176
Species b	5	5÷47 = 0.106	-2.244	0.106 • -2.244 = -.238
Species c	10	10÷47 = 0.213	-1.546	0.213 • -1.546 = -.329
Species d	6	6÷47 = 0.128	-2.056	0.128 • -2.056 = -.263
Species e	12	12÷47 = 0.255	-1.366	0.255 • -1.366 = -.348
Species f	7	7÷47 = 0.149	-1.904	0.149 • -1.904 = -.284
Species g	4	4÷47 = 0.085	-2.465	0.085 • -2.465 = -.123
Total	47			-1.761 (= $\Sigma p_i \ln p_i$)
H				$-1 \bullet \Sigma p_i \ln p_i = 1.761$

So, the diversity index H = 1.761.

Species diversity is often used as a measure of environmental health. A stressed environment typically has a lower number of species with one or two species (those adapted to the stress) having many more individuals than the other species. Species diversity tends to increase at the edges of environments (ecotones) where conditions are more variable. For more background on species diversity, visit the Moonsnail Project's mini-lecture on diversity (referenced above), and the Arbor Project's web page on bird biodiversity at http://www.cees.iupui.edu/Outreach/SEAM/Biodiversity_Exercise.htm.

This activity is based on an investigation to compare the fauna of sediments in methane seep and non-seep environments off the California coast to determine whether the community structure and nutritional sources of seep infauna were distinct from those in non-seep, margin sediments (Levin, et al., 2000).

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 the concept of biodiversity. Show students the sample data given in the "Background Information" and ask them which of the two communities they intuitively feel is most diverse. This should lead to the concepts of species richness and evenness. Say that the Shannon-Weaver information function is a commonly used index of diversity that incorporates both concepts of species richness and evenness. Work through the sample calculation, and be sure students understand the steps involved.

3. Tell students that expeditions to deep-sea communities often discover new and unusual communities of living organisms, and that calculations of diversity indices provide a way to compare various communities. Distribute copies of "Species Distribution in Seep and Non-Seep Areas at Two Sites on the California Slope" to each student group. Tell students that they are to calculate the Shannon-Weaver diversity index for each of the four communities included in the sample, and to use this index to compare the biodiversity of seep and non-seep communities at the two sites (A and B). You may want to divide the assignment among the student groups (each group calculating the diversity index for one or two communities). You may also want to suggest that students use a spreadsheet program to speed the calculation process. One approach is to set up columns in the spreadsheet to make the calculations described in the sample diversity index calculation in the "Background Information," then enter the species data for the appropriate communities.

4. Have student groups summarize their results on an overhead transparency, marker board, etc. This summary should resemble the following:

	Site A		Site B	
	Non-Seep Area	Seep Area	Non-Seep Area	Seep Area
Diversity Index H	1.56	0.57	1.46	1.43

Have each student write an individual analysis of these results. Lead a group discussion of these results. Students should realize that the diversity of seep and non-seep communities differed considerably at Site A, with the seep site having the lower diversity index. Point out that even though the total number of individuals at the seep site was greater than at the non-seep site, the seep site was heavily dominated by one species (*Mediomastus* spp.); consequently, the diversity index was lower. In contrast, there was little difference in diversity between the seep and non-seep communities at Site B. Ask students to speculate on the possible reasons for these results. The investigators who gathered these data concluded that the seep areas sampled were relatively small and possibly transient, and that the fauna in these communities were not highly adapted to or dependent upon the methane-seep environment. Conditions may have been more severe at the seep area in Site A, excluding some species that were found in the surrounding non-seep environment.

Lead a discussion on the significance of biodiversity. The fact that diversity often decreases in stressed environments suggests that high diversity may be "good." On the other hand, it is important to realize that diversity can also be increased by changed or variable conditions (such as those at the boundary of two different types of habitat) or following a major change in a mature ecosystem (such as a forest fire). Encourage pro and con discussion of these questions, but be sure to challenge students to defend their positions. At some point in this discussion, ask students whether "unknown" is the same as "unimportant." You may want to cite examples in which obscure species proved to be directly important to humans (such as the Madagascar periwinkle that provides a powerful cancer treatment).

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 "diversity" in the "Search" box, then click "Search" to display entries on the BRIDGE website for biodiversity.

The "Me" Connection

Have students write a short essay contrasting and comparing the importance of diversity in ocean communities to their own communities.

Connections to Other Subjects

English/Language Arts, Earth Science, Mathematics

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 how the biodiversity of those communities compares with other chemosynthetic communities, as well as with typical deep-sea bottom communities.

Resources

http://oceanexplorer.noaa.gov – Follow the Blake Ridge Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://www.moonsnail.org/Mini_Diversity.htm – The Moonsnail Project's mini-lecture on diversity

http://www.cees.iupui.edu/Outreach/SEAM/Biodiversity_Exercise.htm. – The Arbor Project's web page on bird biodiversity

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

Levin, L. A., et al. 2000. Do methane seeps support distinct macrofauna assemblages? Observations on community structure and nutrition from the northern California slope and shelf. Marine Ecology Progress Series 208:21-39. Available online at http://www.int-res.com/articles/meps/208/m208p021.pdf

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
- Interactions of energy and matter

Content Standard C: Life Science
- Interdependence of organisms

Content Standard D: Earth and Space Science
- Geochemical cycles

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

For More Information

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Student Handout

Species Distribution in Seep and Non-Seep Areas at Two Sites on the California Slope
(Condensed from Levin, et al., 2000)

Species	Site A		Site B	
	Non-Seep Area Total Individuals	Seep Area Total Individuals	Non-Seep Area Total Individuals	Seep Area Total Individuals
Cnidaria				
Obelia sp.	0	2	0	0
Anemone	0	0	6	0
Scolanthus sp.	0	1	0	0
Edwardsid sp.	3	0	0	0
Platyhelminthes				
Turbellaria	0	0	1	0
Polycladida	0	1	0	0
Nemertea				
Unidentified nemertean	1	4	1	1
Cerebratulus sp.	1	0	1	0
Lineus bilineatus	0	1	0	0
Annelida				
Amaeana occidentalis	6	200	8	0
Ampharete arctica	1	0	1	0
Apoprionospio pygmaea	0	0	7	4
Aricidea catherinae	1	4	2	0
Chaetozone cf. *hartmanae*	300	0	0	0
Chaetozone columbiana	0	120	0	0
Eteone cf. *spilotus*	3	0	1	0
Glycera cf. *convoluta*	0	0	3	0
Glycinde sp.	1	2	0	0
Heteromastus filobranchus	150	180	0	0
Levinsenia oculata	0	1	0	0
Magelona sp.	0	1	0	0
Mediomastus spp.	0	10200	0	1
Myriochele sp.	1	0	0	0
Orbinia johnsoni	0	0	1	0
Pholoe glabra	2	5	0	0
Prionospio (Minuspio) lighti	3	140	3	0
Proceraea sp.	0	1	0	0
Scoletoma tetraura	200	190	220	1
Spiochaetopterus costarum	0	1	0	0
Sternaspis fossor	6	7	0	0

Student Handout (continued)

Mollusca				
Epitoniidae	0	1	0	0
Odostomia sp.	0	1	0	0
Rochefortia tumida	230	100	1	0
Gadila aberrans	2	2	0	0
Yoldia sp.	0	1	0	0
Crustacea				
Ampelisca agassizi	0	0	1	0
Atylus tridens	0	1	0	0
Foxiphalus obtusidens	0	0	5	0
Majoxiphalus major	0	0	4	0
Photis brevipes	0	1	0	0
Pleusymtes sp.	0	0	0	0
Rhepoxynius daboius	2	3	590	0
Diastylis quadriplicata	0	0	0	0
Lampropidae	0	2	0	0
Pinnixa occidentalis	0	0	1	0
Synidotea sp. juvenile	0	0	150	0
Sipunculida				
Sipuncula juvenile	0	1	1	0
Echinodermata				
Amphiodia urtica	1	6	330	2
Lovenia cordiformis	0	0	1	0
Chaetognatha				
Chaetognath	0	260	0	0
Total	**914**	**11440**	**1339**	**9**