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2006 Olympic Coast Deep Corals Expedition

Keep It Complex!
(adapted from the 2003 Charleston Bump Expedition)

Focus
Effects of habitat complexity on biological diversity

Grade Level
9-12 (Life Science)

Focus Question
How does structural complexity of benthic habitats affect biological diversity of species living in those habitats?

Learning Objectives
Students will be able to describe the significance of complexity in benthic habitats to organisms that live in these habitats.

Students will be able to describe at least three attributes of benthic habitats that can increase the physical complexity of these habitats.

Students will be able to give examples of organisms that increase the structural complexity of their communities.

Students will be able to infer and explain relationships between species diversity and habitat complexity in benthic communities.

Materials
- ❒ Copies of "Species Distribution in Benthic Habitats," one for each student group

Audio/Visual Materials
- ❒ Chalk board, marker board, or overhead projector with transparencies for brainstorming sessions

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
Habitat
Diversity
Diversity index
Species richness
Species evenness
Structural complexity

Background Information
For hundreds of years, fishermen have harvested coastal waters of the Pacific Northwest. Yet, the deepwater habitats that support these fisheries are poorly studied and in many cases completely unknown. On deeper portions of the continental shelves, hard or "live" bottom habitats support diverse biological communities that provide the foundation for the food web of many commercially-important species. Deep-water corals, particularly corals belonging to the genus *Lophelia*, form reefs that may have a diversity of species

comparable to that of corals reefs in shallow waters. Often, sponges and soft corals are important parts of these reefs as well. But although shallow coral reefs have been studied extensively, scientists know very little about about the ecology of coral communities in depths beyond the range of SCUBA gear.

The Olympic Coast National Marine Sanctuary (OCNMS) is an area of 3,310 square miles off of Washington State's Olympic Peninsula, as well as 135 miles of shoreline that includes some of the last remaining wilderness coastline in the lower 48 states. The seaward boundary of the Sanctuary extents 40 miles offshore to depths of 1,400 m, and encompasses most of the continental shelf, as well as a variety of marine habitats including kelp beds, subtidal reefs, rocky and sandy intertidal zones, submarine canyons and plankton-rich upwelling zones. Acoustic surveys between 2001 and 2004 revealed deep, hard-bottom areas that scientists believe may include extensive coral and sponge communities. These habitats are part of one of the most productive marine ecosystems in North America, and support many commercial fisheries, including halibut, hake, salmon, and rockfish. The overall mission of the OCNMS was to protect the Olympic Coast's natural and cultural resources by conserving its resources as well as encouraging uses that are compatible with conservation.

A growing concern among managers of the OCNMS was the impact of bottom-fishing on deep-water coral and sponge habitats. Species that form deep-water habitats typically have long life-spans, slow growth rates, and fragile structures that make them particularly vulnerable and slow to recover from physical damage. Many investigations have reported large-scale damage to deepwater reefs caused by commercial fishing trawlers. There is also concern about damage that might result from other activities such as exploration and extraction of fossil fuels, and trenching for installation of submarine cables.

Because the mission of the OCNMS is to protect the Olympic Coast's resources for the use and enjoyment of future generations, there is an urgent need to locate deep-sea coral and sponge communities so appropriate protective actions can be taken.

The central objective of the Olympic Coast Deep Corals Expedition was to document the location and condition of deep-sea coral and sponge communities in the Olympic Coast National Marine Sanctuary. The Expedition used an underwater robot called ROPOS (Remotely Operated Platform for Ocean Science) owned by the Canadian Scientific Submersible Facility to obtain video and photographic documentation of deep-sea coral and sponge communities, as well as to collect biological samples from these communities for species identification. Specific objectives of the Expedition included:

- Locating and mapping deep-sea coral and sponge communities in the Sanctuary;
- Characterizing diversity, abundance, and health of living marine resources associated with these communities; and
- Documenting the impact of fishing activities on these communities.

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. 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	44	8
Species b	2	8
Species c	2	8
Species d	2	8
Species e	2	8
Species f	2	8
Species g	2	8
Total	**56**	**56**

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: For another activity about biodiversity and how it applies to nature preserves, visit http://www.ecostudies.org/syefest/ap1res7.htm.]

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 divided by the total number of individuals) 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 logarithm of that same value ($\ln p_i$), then sum (Σ) the values for each species, and finally multiply by minus 1.

[Note: the logarithm of a number x is the power to which another number b (the base) must be raised to equal x. In other words, $x = b^n$, where n is the logarithm of x in base b. This relationship can also be written $\log_b x = n$. If a base of 10 is used, then the logarithm of 1 is zero, since $10^0 = 1$; the logarithm of 100 is 2, since $10^2 = 100$; and so on. Natural logarithms use a mathematical constant known as "e" as the base. The constant e is equal to 2.718281828459... (the number continues infinitely). Natural logarithms are abbreviated $\log_e$ or simply ln, and can be found in published tables or as a function on most electronic calculators.]

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 • $\Sigma p_i \ln p_i$ = 1.761

So, the diversity index H = 1.761.

For more background on species diversity, visit the Arbor Project's web page on bird biodiversity at http://www.cees.iupui.edu/Education/Workshops/Project_Seam/Exercises/bird_biodiversity_exerciese.htm.

This activity is based on an investigation of the relationship between physical factors and biological diversity in a deep-sea benthic community.

Learning Procedure

1. To prepare for this lesson, read the introductory essays for the Olympic Coast Deep Corals Expedition at http://oceanexplorer.noaa.gov/explorations/06olympic. You may also want to view and possibly download the video of deep-sea corals from http://oceanexplorer.noaa.gov/explorations/02alaska/logs/summary/media/movies/deepseacoral_video.html.

2. Review the concept of habitats. Have students brainstorm what functions or benefits an organism receives from its habitat. The students' list should include food, shelter (protection), and appropriate nursery areas. Lead an introductory discussion of the Olympic Coast Deep Corals Expedition. Tell students that detailed surveys of deep-sea reef communities in the Olympic Coast National Marine Sanctuary are just beginning, but we can have a general idea of what to expect based on explorations in other deep-water, hard-bottom habitats.

   Explain the concept of "microhabitat." Be sure students understand how the combination of physical conditions such as currents, sediment type, various rock formations and organisms with complex physical forms (like branching corals and sponges) can create numerous microhabitats and as a result provide food, shelter, and nursery space for many different kinds of organisms. Using images from the Ocean Explorer Web site (http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean.html), prepare a list of organisms that might increase the structural complexity of deep-sea reef communities in the Olympic Coast National Marine Sanctuary.

3. 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.

4. Tell students that a key objective of the Olympic Coast Deep Corals Expedition is to characterize the diversity of living marine resources associated with deep-sea coral and sponge communities. Distribute copies of "Species Distribution in Benthic Habitats" to each student group. Tell students that they are to calculate the Shannon-Weaver diversity index for each of the habitats included in the study, and use this index to compare the biodiversity of the habitats. You may want to divide the assignment among the student groups (each group calculating the diversity index for one or two groups of data). You may also want to suggest that students use a spreadsheet program to speed the calculation process.

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

	Mixed #1	Mixed #2	Mud #1	Mud #2	Cobbles & Boulders #1	Cobbles & Boulders #2
Diversity Index H	1.34	1.15	1.18	0.72	1.64	1.35

Have each student write an individual analysis of these results, including inferences and explanations about relationships between species diversity and habitat complexity in benthic communities. Lead a group discussion of these results. Students should recognize that species groups on the most spatially complex substrates (cobbles and boulders) had the highest diversity, groups on the most uniform substrate (mud) had the lowest diversity, and groups on mixed substrates had diversities in between the other two groups. Students should realize (you may have to point this out), however, that this study only included species living on the surface of the three substrate types. If organisms living beneath the surface were included, the results might have been quite different, since the infauna of many benthic communities on the deeper portions of the continental shelf can be quite diverse.

Discuss the importance of spatial variety to biological diversity in benthic communities. Branched shapes, highly folded surfaces, and porous structures such as sponges, gravel, or loose sediment can multiply available surface area by orders of magnitude, and are an important feature of many biological structures (such as lungs, gills, and other surfaces where diffusion takes place). Surface area is significant to many organisms as a point of attachment or from which to graze microbial films. The same shapes and structures also often create a variety of enclosed spaces that increase the diversity of shelter types available within the community. Based on this discussion, have students describe the features of the most diverse benthic habitat they can imagine, and compare this hypothetical vision to what scientists actually found during the Olympic Coast Deep Corals Expedition.

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Biology," then "Invertebrates," then "Other Inverts," for resources on corals and sponges. Click on "Ecology" then "Deep Sea" for resources on deep sea communities.

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

Assessment

Individual and group reports in Step 4 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/06olympic to explore the discoveries made during the Olympic Coast Deep Corals Expedition.

2. See the July 2005 issue of *Current: The Journal of Marine Education* — a special issue on deep-sea corals (available online at http://www.mcbi.org/what/current.htm).

Resources

http://oceanexplorer.noaa.gov/explorations – Web site for NOAA's Ocean Exploration Program

Pickrell, J. 2004. Trawlers Destroying Deep-Sea Reefs, Scientists Say. *National Geographic News*. http://news.nationalgeographic.com/news/2004/02/0219_040219_seacorals.html

http://www.mcbi.org/what/current.htm – A special issue of *Current: the Journal of Marine Education* on deep-sea corals.

Morgan, L. E. 2005. What are deep-sea corals? *Current* 21(4):2-4; available online at http://www.mcbi.org/what/what_pdfs/Current_Magazine/What_are_DSC.pdf

Frame, C. and H. Gillelan. 2005. Threats to deep-sea corals and their conservation in U.S. waters. *Current* 21(4):46-47; available online at http://www.mcbi.org/what/what_pdfs/Current_Magazine/Threats_Conservation.pdf

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://www.oceana.org/fileadmin/oceana/uploads/reports/oceana_coral_report_final.pdf — Background on deep-water coral reefs

http://www.oceanicresearch.org/ – The Oceanic Research Group Web site; lots of photos, but note that they are very explicit about their copyrights; check out "Cnidarians: Simple but Deadly Animals!" by Jonathan Bird (http://www.oceanicresearch.org/cnidarian.html), which provides an easy introduction designed for classroom use

http://www.mesa.edu.au/friends/seashores/index.html – "Life on Australian Seashores" by Keith Davey on the Marine Education Society of Australasia Web site, with an easy introduction to Cnidaria, including their method of reproduction.

http://www-biol.paisley.ac.uk/courses/Tatner/biomedia/units/cnid1.htm – Phylum Cnidaria on Biomedia of the Glasgow University Zoological Museum on the Biological Sciences, University of Paisley, Scotland Web site; includes explanations of the major classes, a glossary of terms and diagrams and photos.

http://www.calacademy.org/calwild/2000fall/stories/seavenoms.html – Article from California Wild: "Stinging Seas - Tread Softly In Tropical Waters" by Gary C. Williams; an introduction to the venomous nature of tropical cnidarians, why and how they do it

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery

http://oceanexplorer.noaa.gov/explorations/02alaska/logs/summary/media/movies/deepseacoral_video.html – Online video of deep-sea corals from the Ocean Explorer 2002 Gulf of Alaska Expedition

http://olympiccoast.noaa.gov/ – Web site for the Olympic Coast National Marine Sanctuary

http://www.nccos.noaa.gov/ – Web site for the NOAA's National Centers for Coastal Ocean Science, which conduct and support research, monitoring, assessments, and technical assistance for coastal stewardship and management; and participated in the Olympic Coast Deep Corals Expedition

http://www.nurp.noaa.gov/ – Web site for the National Undersea Research Program, which provides scientists with the tools and expertise for investigations in the undersea environment, including submersibles, remotely operated vehicles, autonomous underwater vehicles, mixed gas diving gear, underwater laboratories and observatories, and other cutting-edge technologies

http://www.nwfsc.noaa.gov/ – Web site for the Northwest Fisheries Science Center, which studies living marine resources and their habitats in the Northeast Pacific Ocean and in freshwater rivers and streams in Washington, Oregon, Idaho, and Montana.

http://pubs.usgs.gov/of/of01-154/index.htm – U. S. Geological Survey Open-File Report 01-154 "Sea-Floor Photography from the Continental Margin Program"

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
- Motions and forces

Content Standard C: Life Science

- Interdependence of organisms
- Behavior of organisms

Content Standard F: Science in Personal and Social Perspectives

- Environmental quality

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 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 e*. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

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 c*. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *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 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
Species Distribution in Benthic Habitats

(adapted from Hecker, 1990; data from the continental shelf south of New England, depth range approximately 650 – 1150 meters)

	Number of Individuals per 100 m²					
Substrate Type	**Mixed #1**	**Mixed #2**	**Mud #1**	**Mud #2**	**Cobbles & Boulders #1**	**Cobbles & Boulders #2**
Species						
Hyalinoecia artifex	2		8			
Dasmosmilia lymani			1			
Amphilimna olivacia	19			1		
Geryon quinquesidens			4	2		
Synaphobranchus spp.	12	4	9	9	2	
Acanella arbuscula	2	47			63	6
Stalked Crinoid	4	9			53	29
Anthomastus agassizii		1			7	60
Distichoptilum gracile		2			7	6
Cerianthid	1	5			4	6
Ophiomusium lymani		2			19	85
Echinus affinis					1	
Total	**40**	**70**	**22**	**12**	**197**	**402**