oceanexplorer.noaa.gov

Mountains in the Sea Exploration

Big Fleas Have Little Fleas!

Physical structure in benthic habitats

Grade Level
7-8 (Life Science)

Focus Question
How can we model the physical complexity that is typical of natural structures and systems?

Learning Objectives
Students will recognize that natural structures and systems often display recurrent complexity over many scales of measurement.

Students will be able to infer the importance of structural complexity to species diversity and abundance in benthic habitats.

Students will be able to discuss ways that octocorals may modify seamount habitats to make these habitats more suitable for other species.

Materials
- ❒ Overhead transparency of "Sierpinski Triangle Construction"
- ❒ Copies of "Hypothetical Cross Section of A Benthic Habitat," one copy for each student group
- ❒ Pair of dividers for each student group
- ❒ Drawing paper or triangle grid paper (download from http://math.rice.edu:80/~lanius/fractals/)
- ❒ Ruler for each student group
- ❒ Pencils or markers

A sual Mate
- ❒ Overhead projector

Teaching Time
One 45-minute class period

Seating Arrangement
Groups of four students

Maximum Number of Students
32

Key Words
Seamount
Octocoral
Fractal
Habitat

Background Information
Seamounts (also called "guyots") are undersea mountains that rise from the ocean floor, often with heights of 3,000 m (10,000 ft) or more. Compared to the surrounding ocean waters, seamounts have high biological productivity, and provide habitats for a variety of plant, animal, and microbial species. Seamounts are formed by volcanic processes, either as isolated peaks or as chains that may be thousands of miles long. In the Atlantic Ocean, the New England Seamounts form a chain of more than 30 peaks that begins near the coast of New England and extends 1,600 km to the southeast. Some of the peaks are more than 4,000 m above the deep-sea floor, similar to the heights of major peaks in the Alps.

Bear Seamount is the closest of the New England Seamounts to the coast of the United States, and rises from a depth of 2,000 - 3,000 m to a summit that is1,100 m below the sea surface. Previous investigations have found numerous invertebrates, including cephalopods, crustaceans, and more than a hundred other species in 10 different phyla. These investigations also found more than 100 species of fishes, some of which are commercially important. Several species discovered at Bear Seamount were previously unknown to science. Because the biological communities of seamounts have not been well-studied, these communities are likely to contain significant numbers of species that are not yet known to science. Some of these species may provide drugs that can directly benefit human beings.

Deep-sea corals appear to be the primary factor that forms the physical structure of habitats on Bear Seamount and in many other deep sea communities. Photographs from previous submersible dives on Bear Seamount show that the habitat is mostly bare rock except in areas where corals are present. Most of these corals are octocorals (soft corals), rather than the scleractinian corals (hard corals) that are familiar habitat formers in shallow water environments.

Scientists have found that physical structure in many habitats (for example, forests, coral reefs, and rocky shorelines) has a strong influence on the diversity and abundance of species that live in these habitats. When organisms (such as corals) increase the physical complexity of their environment, they may provide many additional habitats for other species.

Most natural objects have complex physical structures, and this complexity exists at multiple scales. A tree, for example, usually appears to have a somewhat irregular shape when viewed from a distance of 10 meters. If we move closer and observe the tree from a distance of 1 meter, we see more irregularities in the patterns of the bark and leaves. If we move even closer and observe the bark with a magnifying lens, we see tiny crevices and protrusions in the bark structure. If we continue this process, we continue to see structures that are increasingly small—but still complex—even at the level of individual cells. Although this complexity has been traditionally ignored to make simple or "approximately correct" explanations about nature, many scientists now realize that physical complexity has a significant influence on many biological systems.

Fractal geometry is a relatively recent (less than 30 years old) development in the field of mathematics that helps scientists describe the physical complexity of natural systems. In this lesson, students will explore the idea of fractals, and will make inferences about the importance of physical complexity to a biological community.

Learning Procedure

1. Explain that seamounts are the remains of underwater volcanoes, and that they are islands of productivity compared to the surrounding environment.

   Although seamounts have not been extensively explored, expeditions to seamounts often report many species that are new to science. If students are already familiar with corals, have them contrast octocorals (soft corals) with scleractinian corals (hard corals). Tell students that in deepsea habitats, hard corals generally occur as isolated colonies, while octocorals are much more abundant. You may want to visit http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean.html to see pictures of octocorals and deepsea habitats. Ask students to speculate on how octocorals might influence other species by modifying their habitat. Students may suggest that octocorals may serve as a source of food for other species, that they may occupy space that might otherwise be used by other species, that they may modify currents flowing over the seamount, and that they may provide shelter for other species. Tell students that we will focus on the physical structure of seamount communities, which appears to be significantly changed by the presence of octocorals.

2. Tell students that simple geometric forms, such as circles or smooth surfaces, are rare in nature. Use the tree analogy described above to introduce the idea of complexity at multiple scales. Tell students that we are going to create a Sierpinski triangle, a simple example of a structure that can be increasingly complex at an infinite number of scales.

   Instruct students to begin by drawing an equilateral triangle measuring 16 cm on each side (you may want to download triangle graph paper from the site referenced in the next paragraph to assist with constructing the Sierpinski triangle). Next, find the midpoint of each side (8 cm), and join these midpoints as shown in Step 1 of "Sierpinski Triangle Construction." Shade the triangle in the middle as shown in Step 2. Now find the midpoints of each side of the three outer triangles (4 cm), and join these as shown in Step 3. Shade each of the middle triangles as shown in Step 4. Continue this process for three more iterations, until the midpoints measure 0.5 cm, shading the middle triangles after each iteration until the drawing appears similar to Step 5.

   Explain that the Sierpinski triangle is one example of a class of geometric forms known as fractals: forms that can be infinitely repeating and infinitely complex (we stopped constructing our triangle after only five iterations, but theoretically the process could continue indefinitely; if you wanted to add more iterations, you could start with a larger piece of paper). You may want to visit http://math.rice.edu:80/~lanius/fractals/sierjava.html for an interactive program to construct Sierpinski triangles and several other fractals, as well as easy to understand discussions of fractals and links to other sites.

   Ask students to imagine that the shaded areas represent holes in a surface. The Sierpinski triangle is a good illustration of how a simple process of repeated division can produce an extremely complex structure. Ask students to think of examples in nature where this sort of process occurs, and to infer how such a process might affect habitats. Students should realize that natural objects are not really fractals, but are fractal-like because they do not operate over an infinite range of scales.

   You may want to use the familiar rhyme that comments on the fractal aspect of nature:

   "Great fleas have little fleas upon their backs to bite 'em,
   And little fleas have lesser fleas, and so *ad infinitum*"
   (De Morgan: A Budget of Paradoxes, p. 377)

3. Have each student group measure the length of line A-B on "Hypothetical Cross Section of A Benthic Habitat" using a pair of dividers. Have each group set their dividers to a spacing of 0.5 cm, 1 cm, 2 cm, or 4 cm. Measurements should be made by placing one of the divider pins on point A, then pivoting the dividers until the other pin intersects line A-B. Keeping the divider pin on this intersection, pivot the dividers again until the swinging pin again intersects line A-B. Repeat this process, counting the number of intervals needed to reach point B.

   Summarize results from all groups on an overhead transparency or marker board. Ask students to infer the significance of these results to a biological community that might exist on this hypothetical habitat. Students should realize that there is considerably more habitat available for small organisms (say, less than 0.5 cm) than for larger ones, and that the structure of the hypothetical habitat would provide refuges for smaller organisms. Students should recognize the importance of measurement scales in ecological investigations: large scales tend to obscure details that can be very important to biological diversity within natural communities. Ask students to speculate on the influence that octocorals might have on deepsea biological communities. In many biological communities, there is evidence that spatially heterogeneous habitats support more complex ecological communities than more homogenous habitats.

The BRIDGE Connection

www.vims.edu/bridge/ - On the home page, type "seamount" into the "Search" box and press "return."

The "Me" Connection

Have students write a brief essay comparing simple models of biological systems to fractal models, and stating which approach they believe is most useful, and why.

Connections to Other Subjects

Mathematics, Earth Science

Evaluation

Have students identify and describe three other examples of fractal-like structures in nature.

Extensions

Have students visit http://oceanexplorer.noaa.gov to find out more about research on the New England Seamounts and opportunities for real-time interaction with scientists on current Ocean Exploration expeditions. Suggest that students ask scientists if they have observed examples of fractal structures or processes on seamounts.

Resources

http://math.rice.edu:80/~lanius/fractals/ - Introduction to fractals for kids by Cynthia Lanius at Rice University

http://math.bu.edu/DYSYS/chaos-game/chaos-game.html - Introduction to fractals and chaos by Robert Devaney, Boston University

http://www.umanitoba.ca/faculties/science/botany/labs/ecology/fractals/ - Paper on fractals in the biological sciences

Schmid, P. E., 2000. Fractal properties of habitat and patch structure in benthic ecosystems. Advances in Ecological Research 30:339-402 - Journal article on the application of fractals in ecological investigations

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
- Properties and changes in matter

Content Standard C: Life Science
- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations

Content Standard D: Earth Science
- Structure of the Earth system

Content Standard G: History and Nature of Science
- Nature of science

For More Information

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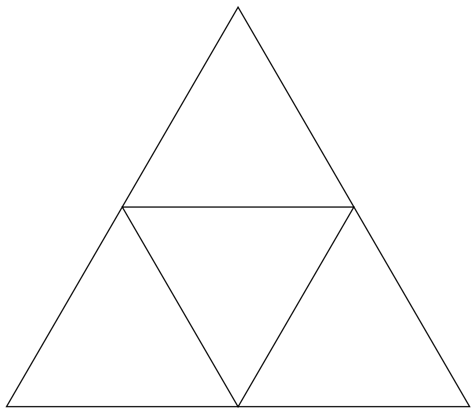
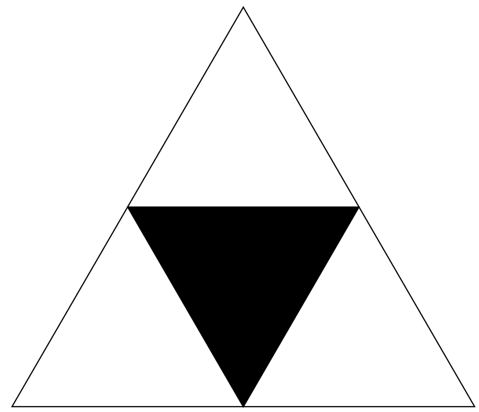
http://oceanexplorer.noaa.gov

Student Handout

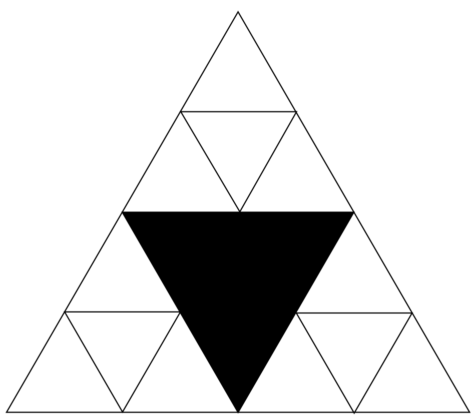
Sierpinski Triangle Construction



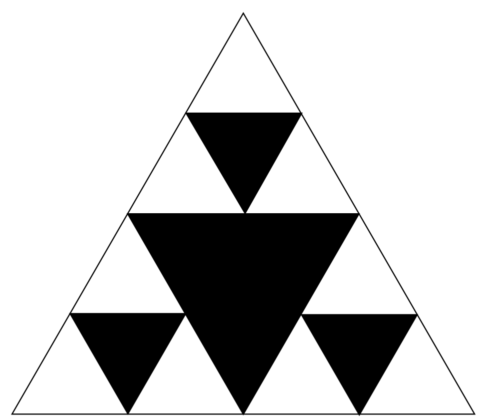
Step 1



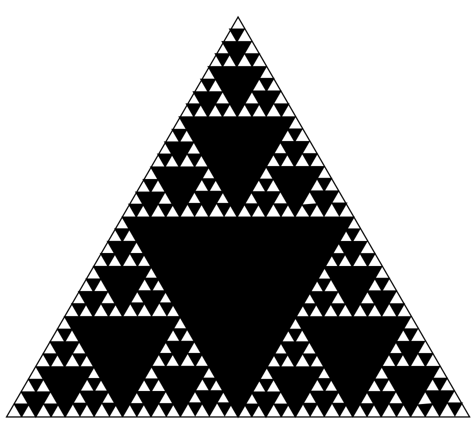
Step 2



Step 3

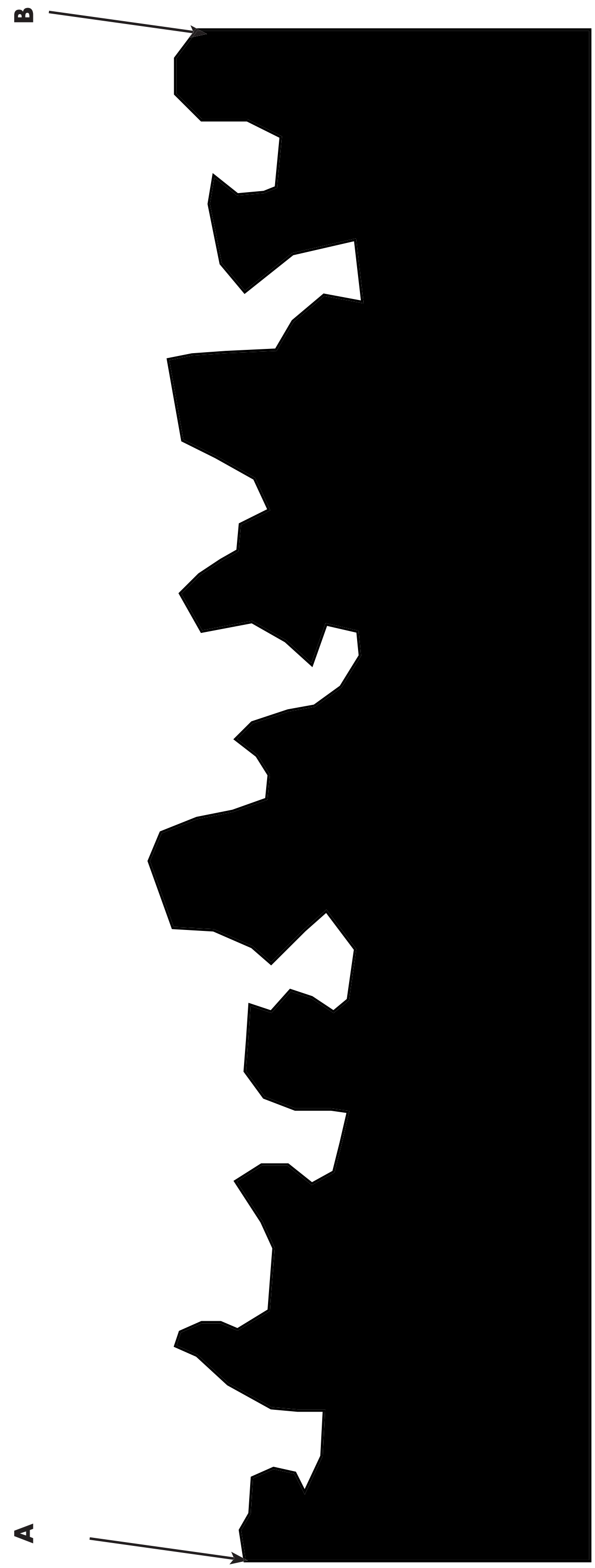


Step 4



Step 5

Student Handout



Hypothetical Cross Section of A Benthic Habitat