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2006 Exploring Ancient Coral Gardens

Big Fleas Have Little Fleas...

(adapted from The Mountains in the Sea 2003 Expedition)

Focus

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

Audio/Visual Materials

- ❒ Overhead projector

Teaching Time

One 45-minute class period

Seating Arrangement

Groups of 4 students

Maximum Number of Students

32

Key Words

Seamount
Octocoral
Fractal
Habitat

Background Information

Seamounts are undersea mountains formed by volcanic processes, either as isolated peaks or as chains that may be thousands of miles long 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 many species of plant, animal, and microbial organisms. Recently, increasing attention is being directed toward deep water coral species found on seamounts. In contrast to shallow-water coral reefs, deep-sea coral communities are virtually unknown to the general public and have received much less scientific study. Yet, deep-water coral ecosystems may have a diversity of species comparable to that of corals reefs in shallow waters. Because many seamount species are endemic (that is, they are found nowhere else), these ecosystems may be a unique feature of seamounts, and are likely to be important for several reasons. First, because of their high biological productivity, these communities are directly associated with important commercial fisheries. Moreover, deep-sea corals have been identified as promising sources for new drugs to treat cancer and other diseases, as well as natural pesticides and nutritional substances. Recent discoveries suggesting that some corals may be hundreds of years old means that these organisms can provide important records of past climactic conditions in the deep ocean. Apart from these potential benefits, deep-sea corals are part of our world heritage—the environment we hand down from one generation to the next.

Despite their importance, there is growing concern about the impact of human activities on these ecosystems. Commercial fisheries, particularly fisheries that use trawling gear, cause severe damage to seamount habitats. Scientists at the First International Symposium on Deep Sea Corals (August, 2000), warned that more than half of the world's deep-sea coral reefs have been destroyed. Ironically, some scientists believe that destruction of deep-sea corals by bottom trawlers is responsible for the decline of major fisheries such as cod.

In addition to impacts from fisheries, deep-sea coral communities can also be damaged by oil and mineral exploration, ocean dumping, and unregulated collecting. Other impacts may result from efforts to mitigate increasing levels of atmospheric carbon dioxide. One proposed mitigation is to sequester large quantities of the gas in the deep ocean, either by injecting liquid carbon dioxide into deep ocean areas where it would form a stable layer on the sea floor or by dropping torpedo-shaped blocks of solid carbon dioxide through the water column to eventually penetrate deep into benthic sediments. While the actual impacts are not known, some scientists speculate that since coral skeletons are made of calcium carbonate, their growth would probably decrease if more carbon dioxide were dissolved in the ocean.

The Davidson Seamount, located about 75 miles southwest of Monterey, CA, was the first geological feature to be described as a "seamount" in 1933. The now-extinct volcanoes that formed this and other nearby seamounts were different from typical ocean volcanoes. While the typical undersea volcano is steep-sided, with a flat top and a crater, seamounts in the Davidson vicinity are formed of parallel ridges topped by a series of knobs. These observations suggest that the ridges were formed by many small eruptions that occurred 3 to 5 million years apart. Typical undersea volcanoes are formed by more violent eruptions that gush out lava more frequently over several hundred thousand years.

Although it was the first recognized seamount and is relatively near the U.S. coast, the Davidson Seamount is still 99.98% unexplored. In 2002, a NOAA-funded expedition to the Seamount found a wide variety of organisms, including extensive deep-water coral communities. Among many intriguing discoveries were observations of animals that had never been seen live before, as well as indications that some coral species may be several hundred years old (visit http://oceanexplorer.noaa.gov/explorations/02davidson/davidson.html and http://montereybay.noaa.gov/reports/2002/eco/ocean.html for more information about the 2002 Expedition).

The 2006 Exploring Ancient Coral Gardens Expedition is focussed on learning more about deep-sea corals at Davidson Seamount, with four general goals:

- to understand why deep-sea corals live where they do on the seamount;
- to determine the age and growth patterns of the bamboo coral;
- to improve the species list and taxonomy of corals from the seamount; and
- to share the exciting experience with the public through television and the Internet.

One of the most conspicuous features of deep-water coral habitats on the Davidson Seamount is spatial variety, with coral branches, sponges, and other animals creating countless "microhabitats" in many sizes. 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.

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. To prepare for this lesson, read the introductory essays for the 2006 Exploring Ancient Coral Gardens Expedition at http://oceanexplorer.noaa.gov/explorations/06davidson/welcome.html, and review the NOAA Learning Object on deep-sea corals at http://www.learningdemo.com/noaa/.

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 Davidson Seamount and the 2002 and 2006 Ocean Exploration expeditions to the area. You may want to show students some images from the 2002 Expedition Web site (http://oceanexplorer.noaa.gov/explorations/02davidson/davidson.html). Tell students that branching corals are conspicuous features of biological communities on the Davidson Seamount, and ask them to speculate on how corals might influence other species by modifying their habitat. Students may suggest that corals 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.

3. 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)

4. 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 corals might have on deep-sea 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

Assessment

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

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest Davidson Seamount Expedition discoveries, and to find out what researchers are learning about deep-water hard-bottom communities.

Resources

NOAA Learning Objects

http://www.learningdemo.com/noaa/ – Click on the link to "Lesson 3 – Deep-Sea Corals" for an interactive multimedia presentation on deep-sea corals, as well as Learning Activities and additional information on global impacts and deep-sea coral communities.

Other Relevant Lesson Plans from the Ocean Exploration Program

Biological Communities of Alaska Seamounts (http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/biocomm7_8.pdf; (5 pages, 108k) (from the Exploring Alaska's Seamounts 2002 Expedition)

Focus: Biological Communities of Alaska Seamounts

Students will be able to infer why biological communities on seamounts are likely to contain unique or endemic species, calculate an index of similarity between two biological communities given species occurrence data, make inferences about reproductive strategies in species that are endemic to seamounts, and explain the implications of endemic species on seamounts to conservation and extinction of these species.

It's OK To Be a Clod (http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/media/03cb_clod.pdf; (5 pages, 252k) (from The Charleston Bump 2003 Expedition)

Focus: Principles of solubility and measurements of water currents (Physical Science/Earth Science)

Students will be able to describe factors that affect the solubility of a chemical substance in seawater and explain how information on the solubility of a substance can be used to measure water currents.

Design a Reef! (http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_aquarium.pdf; (5 pages, 408k) (from the Gulf of Mexico Deep Sea Habitats 2003 Expedition)

Focus: Niches in coral reef ecosystems (Life Science)

Students will compare and contrast coral communities in shallow water and deep water, describe the major functions that organisms must perform in a coral ecosystem, and explain how these functions might be provided in a miniature coral ecosystem. Students will also be able to explain the importance of three physical factors in coral reef ecosystems and infer the fundamental source of energy in a deep-water coral community.

Let's Go to the Video Tape! (http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_letsgo.pdf; (7 pages, 552k) (from the Gulf of Mexico Deep Sea Habitats 2003 Expedition)

Focus: Characteristics of biological communities on deep-water coral habitats (Life Science)

Students will recognize and identify some of the fauna groups found in deep-sea coral communities, infer possible reasons for observed distribution of groups of animals in deep-sea coral communities, and discuss the meaning of "biological diversity." Students will compare and contrast the concepts of "variety" and "relative abundance" as they relate to biological diversity, and given abundance and distribution data of species, will be able to calculate an appropriate numeric indicator that describes the biological diversity of a community.

A Matter of Density (http://oceanexplorer.noaa.gov/explorations/04mountains/background/edu/media/MTS04.density.pdf; (6 pages, 416k) (from the Mountains in the Sea 2004 Expedition)

Focus: Temperature, density, and salinity in the deep sea (Physical Science)

Students will be able to explain the relationship among temperature, salinity, and density; and, given CTD (conductivity, temperature, and density) data, students will be able to calculate density and construct density profiles of a water column. Students will also be able to explain the concept of sigma-t, and explain how density differences may affect the distribution of organisms in a deep-sea environment.

Food Web Mystery (http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_foodweb.pdf; (4 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)

Focus: Food webs in the vicinity of seamounts

Students will be able to describe typical marine food webs, and explain why food is generally scarce in the deep-ocean environment and discuss reasons that seamounts may be able to support a higher density of biological organisms than would appear to be possible considering food available from primary production at the ocean's surface.

Come on Down! (http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_comedown.pdf; (6 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)

Focus: Ocean Exploration

Students will research the development and use of research vessels/vehicles used for deep ocean exploration; students will calculate the density of objects by determining the mass and volume; students will construct a device that exhibits neutral buoyancy.

Biodiversity of Deep Sea Corals (http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_deepseacoral.pdf; (3 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)

Focus: Deep-sea corals

Students will research life found on tropical coral reefs to develop an understanding of the biodiversity of the ecosystem; students will research life found in deep-sea coral beds to develop an understanding of the biodiversity of the ecosystem; students will compare the diversity and adaptations of tropical corals to deep-sea corals.

Treasures in Jeopardy (http://oceanexplorer.noaa.gov/explorations/05deepcorals/background/edu/media/05deepcorals_treasures.pdf; (6 pages, 299k) (from the Florida Coast Deep Corals 2005 Expedition)

Focus: Conservation of deep-sea coral communities (Life Science)

Students will compare and contrast deep-sea coral communities with their shallow-water counterparts and explain at least three benefits associated with deep-sea coral communities. Students will also describe human activities that threaten deep-sea coral communities and describe actions that should be taken to protect resources of deep-sea coral communities.

How Am I Supposed to Eat THAT? (http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/media/03cb_eatthat.pdf; (4 pages, 248k) (from The Charleston Bump 2003 Expedition)

Focus: Feeding adaptations among benthic organisms (Life Science)

Students will be able to describe at least three nutritional strategies used by benthic organisms typical of deep-water coral communities and describe physical adaptations associated with at least three nutritional strategies used by benthic organisms.

Other Links and 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

http://oceanexplorer.noaa.gov/explorations/02davidson/davidson.html – Daily logs, photos, video clips, and backgrounds essays on the 2002 Davidson Seamount Expedition

http://montereybay.noaa.gov/reports/2002/eco/ocean.html – Web page from the Monterey Bay National Marine Sanctuary describing the 2002 exploration of the Davidson Seamount

http://www.mbari.org/ghgases/ – Web page from the Monterey Bay Aquarium Research Institute describing MBARI's work on the Ocean Chemistry of Greenhouse Gases, including work on the potential effects of ocean sequestration of carbon dioxide

http://seamounts.edsc.edu/main.html — Seamounts Web site sponsored by the National Science Foundation

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/Current_Magazine/Current_Magazine.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/Current_Magazine/What_are_DSC.pdf

Reed, J. K. and S. W. Ross. 2005. Deep-water reefs off the southeastern U.S.: Recent discoveries and research. Current 21(4): 33-37; available online at http://www.mcbi.org/Current_Magazine/Southeastern_US.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/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/uploads/oceana_coral_report.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, which provides an easy introduction designed for classroom use

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

http://oceanica.cofc.edu/activities.htm – Project Oceanica Web site, with a variety of resources on ocean exploration topics

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 and Space Science
- Structure of the Earth system

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

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
- *Fundamental Concept b.* An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates.
- *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 c.* Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
- *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.
- *Fundamental Concept f.* Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

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 b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *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.

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

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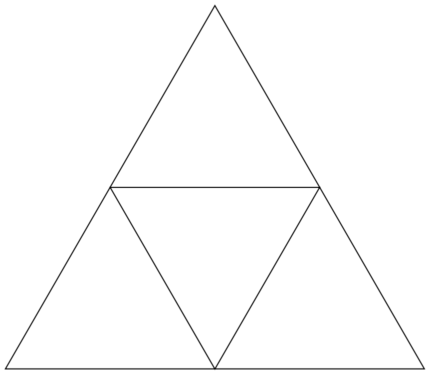
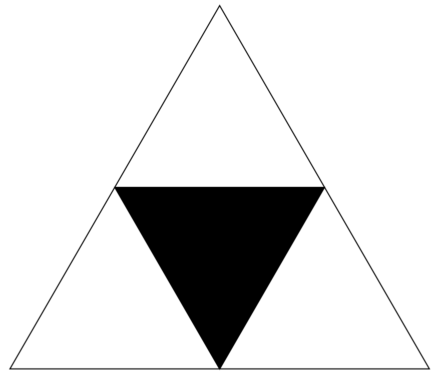
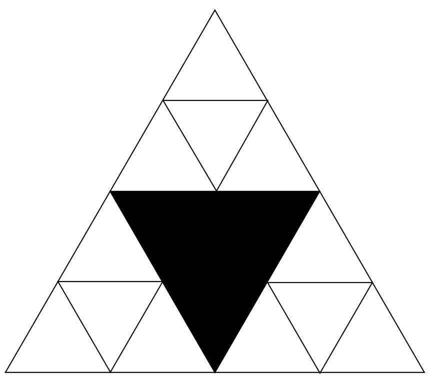
Student Handout
Sierpinski Triangle Construction



Step 1



Step 2



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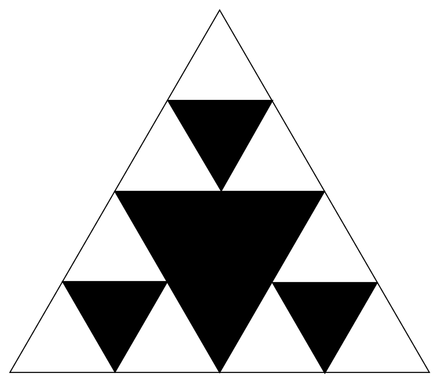
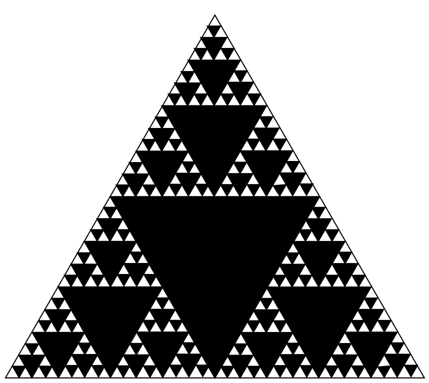


Step 4



Step 5

Student Handout

Hypothetical Ccross Section of A Benthic Habitat