Mountains in the Sea Exploration

Food Web Mystery

Focus
Food webs in the vicinity of seamounts

Grade Level
7-8 (Life Science)

Focus Question
How are orange roughy able to obtain sufficient food in the deep ocean environment?

Learning Objectives

Students will be able to describe typical marine food webs, and explain why food is generally scarce in the deep-ocean environment.

Students will be able to 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.

Materials
❒ Blackboard, overhead projector, or marker board for presenting nutritional data on orange roughy (Learning Procedure Step #2)

Audio/Visual Materials
None

Teaching Time
One 45-minute class period

Seating Arrangement
Classroom style

Maximum Number of Students
30

Key Words
Seamount
New England Seamounts
Primary production
Orange roughy
Oreo
Food web
Phytoplankton
Zooplankton
Trophic level

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 is 1,100 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.

One of the challenges for animals living in the deep sea is a general scarcity of food. Most primary production in the ocean takes place in the upper 100 meters of the water column. Consequently, primary consumers (zooplankton) and higher predators are much more abundant in this near surface region than in deeper waters. Most deep-water fishes are not considered commercially important because their flesh lacks protein and has a watery consistency that makes them unattractive as food for humans. In the 1980's, however, fishermen discovered large populations of a very different type of deep water fish living between depths of 700 - 1,200 m. These fishes had firm, tasty flesh and high content of protein and lipids. Moreover, these fishes occurred in large aggregations around seamounts and plateaus near Australia and New Zealand. The biomass of fishes in these aggregations was typically more than ten times the biomass of other deep-water fishes in surrounding areas, making the aggregated fish much easier to harvest than fishes spread out over large areas of the deep sea. One of these fishes, the orange roughy (*Hoplostethus atlanticus*), is now common in North American markets.

How are large populations of muscular, active fish like the orange roughy able to obtain enough food from the deep-sea environment to meet their energy requirements? In this activity, students will compare the food needs of orange roughy with a more "typical" deep-water fish, and will estimate the amount of food actually available to these fishes in the deep-sea environment, and hypothesize what strategies may be used by orange roughy to meet their nutritional needs.

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 and many that appear to be endemic to a particular group of seamounts. Review the concept of food webs, and discuss the paths of energy from sunlight at the sea surface to organisms in the deep ocean. Students should state that a portion of the solar energy at the sea surface is captured by phytoplankton through photosynthesis (primary production), and that this energy is then transferred to other organisms along many pathways.

   Explain that most photosynthesis in the ocean takes place in the upper 100 meters of the water column. A portion of this primary production is consumed by zooplankton. Some zooplankton are consumed by planktivorous species, and a portion of the planktivorous organisms are in turn consumed by carnivores. Each stage in this "chain" is called a trophic level; primary producers are the first trophic level, zooplankton that consume phytoplankton are the second trophic level, planktivorous organisms are the third trophic level, and carnivorous species that consume the planktivores are the fourth and higher trophic levels. In general, the amount of energy available at a given trophic level is about one-tenth of the energy supplied by the previous trophic level. Be sure students realize that many species (including our own) feed at more than one trophic level.

2. Give students the following information:
(a) Primary production at the sea surface above seamounts where orange roughy are found is approximately 200 grams of carbon per square meter per year.

(b) Orange roughy are typically found in densities that are equivalent to 5 grams of carbon per square meter per year.
(c) Orange roughy consume approximately 1% of their body weight daily.
(d) Orange roughy feed primarily on small fishes and squid, which prey on small crustaceans, primarily zooplankton.

Have the students estimate (a) the amount of food (in grams of carbon per square meter per year) available to orange roughy populations, and (b) the amount of food required by these populations (also in grams of carbon per square meter per year).

The calculations are:
(a) Orange roughy are feeding at the fourth trophic level. So, the amount of food available is the amount provided by primary production, multiplied by one-tenth available from the second trophic level, multiplied by one-tenth available from the third trophic level:
(200 grams per square meter per year) • (0.1) • (0.1) = 2.0 gr/m2/yr

(b) Orange roughy consume 1% of their body weight daily, so in one year they consume 1% • 365 = 365% of their body weight.

If the density of orange roughy is 5 grams of carbon per square meter, then they require (5 grams carbon per square meter) •365% = (5) • (3.65) = 18.25 grams of carbon per square meter per year.

So, the orange roughy populations around seamounts require nearly ten times more food than is available from primary production!

3. Lead a discussion of how orange roughy are able to survive, assuming that these calculations are valid. Ask students to speculate on how seamounts may alter physical conditions of the surrounding water, thinking of the kinds of effects mountains have on nearby air masses. One such effect is that seamounts greatly alter current patterns, causing upwellings and circulation cells. At some point in the discussion, students should realize that the calculations in Step #2 only consider the water column directly above the seamount as a source of food. In fact, of course, ocean currents could bring potential food from a much larger area and the physical effect of seamounts on these currents could cause the food to become concentrated and thus more available to organisms such as orange roughy.

Some students may be aware that there are other sources of primary production in the deep ocean that are fundamentally different from those discussed in this lesson. Cold seeps and hydrothermal vents, for example, support chemosynthetic bacteria that are the base of extensive food webs in deep waters where these features occur; but this has not been found to be a source of food on the New England Seamounts.

The BRIDGE Connection

www.vims.edu/bridge/ - In the Navigation toolbar, click on "Ocean Science Topics." In the "Ocean Science Topics" menu, click on "Biology," then on "Bony Fishes" or "Plankton."

The "Me" Connection

Have students describe their position in a food web, and estimate the amount of primary production required to support their feeding habits for one year.

Connections to Other Subjects

Language Arts, Mathematics, Earth Science

Evaluation

Have students complete the calculations in Step #3 independently, and/or prepare a written discussion of possible explanations for the apparent discrepancy prior to group discussion of these results.

Extensions

Have students visit http://oceanexplorer.noaa.gov to find out more about the Census of Marine Life and Ocean Exploration programs, including opportunities for real-time interaction with scientists on current Ocean Exploration expeditions.

Resources

http://www.fishbase.org - a searchable database of life history information on more than 24,000 fish species.

Koslow, J. A. 1997. Seamounts and the ecology of deep-sea fisheries. American Scientist 85: 168-176. The journal article on which this activity is based.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard C: Life Science

- Populations and ecosystems

For More Information

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