oceanexplorer.noaa.gov

Mountains in the Sea Exploration

Boom and Bust

Focus
Fishery management

Grade Level
7-8 (Life Science)

Focus Question
How can fishery managers detect overfishing in time to prevent "crashes" in commercially-important fish populations?

Learning Objectives
Students will be able to describe stages in a commercial fishery that eventually becomes severely depleted.

Students will be able to interpret basic data to predict when a fishery stock is beginning to show signs of overexploitation.

Students will be able to describe the potential consequences of overexploitation on fish populations, marine habitats, and fishing businesses.

Students will be able to described and discuss potential management policies that could avoid or remediate overexploitation in commercial fisheries.

Materials
❒ Copies of "Orange Roughy Landings Data," one for each student or student group

Audio/Visual Materials
❒ Blackboard, overhead projector, or marker board for discussing landings data on orange roughy (See Learning Procedure Step #2)

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Classroom style or in groups of up to four students

Maximum Number of Students
No limit

Key Words
Seamount
Orange roughy
Fishery
Overexploitation
Aggregation
Catch per unit effort
Habitat destruction
Closed season
Minimum size
Limited entry

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.

The flesh of many deep-water fishes is unattractive as food for humans, because it contains less protein and a higher proportion of water than fish species from shallower waters. Consequently, many deep-water fishes are not considered commercially important. In the 1980's, though, 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 fishes much easier to harvest than fishes spread out over large areas of the deep sea. One of these fishes, the orange roughy (*Hoplostethus atlanticus*), has become common in North American markets. Scientists who have studied populations of orange roughy around seamounts believe that the large populations are made possible by current patterns around seamounts that tend to concentrate food organisms.

Fishes that form large aggregations are particularly susceptible to over-harvesting, and many deep-water fisheries go through a "boom and bust" cycle in which landings from newly-discovered fisheries are initially high, then rapidly decline to very low levels. To protect such fisheries from overexploitation, fishery managers need to be able to recognize the early signs of overfishing before fish populations go into rapid decline. In this activity, students will examine data from a commercial fishery and search for trends that could be used as early warning signs of severe overfishing.

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 explain that seamount ecosystems support a greater abundance of biological organisms than the surrounding deep ocean environment. Point out that some of these organisms are commercially important fishes, and that their habit of aggregating around seamounts makes them easy to harvest (and overharvest). Explain that fishery managers need to be able to recognize early signs of overfishing so that fish stocks can be protected before drastic declines in landings take place.

2. Provide each group with a copy of "Orange Roughy Landings Data." Tell students that they are to examine these data to identify trends that might be used as early warning signs of overfishing. Have the students begin by graphing Total Landings in tons (y-axis) vs. Year (x-axis). On the same graph, plot Total Number of Fish Landed vs. Year. Add a third plot to the same graph for Number of Full-time Fishing Boats.

3. Lead a discussion of the graphs. Students will notice a sharp increase in landings during the first nine years of the fishery to a maximum in 1991, followed by a steady decline that plummets even more during 1998 and 1999. Assuming that there was no natural disaster

that affected the fishery, overfishing is a plausible explanation for these results.

4. Draw students' attention to data for 1992-1994. Total landings declined during these years, even though the number of boats increased. Remind the students that we are looking for clues that may signal problems for the fishery before there is a drastic decline in landings. Lead the students to the idea of calculating the average catch per boat (known generally as "catch per unit effort" or CPUE) by dividing Total Landings in tons by Number of Full-Time Fishing Boats for each year. Plot these data, either on the same graph prepared in Step #2, or on a new graph. Discuss the results. Students should notice that CPUE declines steadily from 1987 on, five years before total landings begin to decline. The point here is that increasing fishing effort (more boats) resulted in increased landings (for a few years), masking the fact that each boat was catching fewer fish. So, CPUE might be a good indicator for an early warning sign of overfishing.

5. Draw students' attention to data for 1985 and 1994. Total landings in tons were the same in these two years, but the total number of fish landed in 1994 was almost twice as high as in 1985! Discuss the significance of this. Students should realize that these data indicate that the average weight of individual fish landed decreased between these two years. Lead the students to the idea of calculating the average weight of fish landed by dividing Total landings in tons by total number of fish landed for each year. Plot these data on the same graph prepared in Step #3. Discuss the results.

   Students should notice that average weight of fish landed declines steadily from 1985 on, seven years before total landings begin to decline. So average size of fish landed could also be a promising early warning sign of overfishing.

   The implication of a trend of declining size in landed fish is that fish are being caught before they have a chance to reach a large size. If this trend continues, a point will be reached at which significant numbers of fish are captured before they have a chance to reproduce. When this happens, the fishery will go into rapid decline.

6. Have students imagine that they are managers for the orange roughy fishery, and that they wisely kept records of CPUE and average size of fish landed since 1980. What actions would they take to avoid the crash of the orange roughy fishery in the late 1990's, and when would they take those actions? Some commonly used fishery management controls are setting minimum sizes (to allow fish to grow large enough to reproduce), restricting fishing to certain seasons of the year (to allow reproductively mature fishes to spawn), limiting the number of fishing vessels allowed to fish a particular area (limited entry), and complete closure of a fishery (prohibiting any fishing at all for some period of time). Students should recognize the need to assess the effectiveness of whatever actions they recommend; i.e., the fishery must be monitored.

Suppose the population size of the orange roughy fishery continued to decline, even if fishing were stopped completely? In this circumstance, managers might look for other causes for the decline. Habitat destruction is one of the common impacts caused by humans that adds to the problems of direct overfishing. This is a particular concern in the case of fisheries that operate on seamounts, since trawling equipment used to harvest fishes can be extremely destructive to bottom-dwelling organisms (such as corals) that form an important part of seamount habitats.
Graphs prepared in this lesson model a story that unfortunately is quite close to the real history of

many commercial fisheries. The discovery of a new commercially-valuable fish stock is followed by rapid development as more and more fishermen try to exploit the stock; landings begin to level off, then drop drastically. At this stage the fishery is not only depleted from its orginal size, but its reproductive capacity is even more reduced because larger sexually mature fish have been selectively removed from the population. The fish population is no longer able to support an extensive fishing effort, many fishermen may be forced out of business, and a once-productive fishery has disappeared for many years, or possibly forever.

The problem is even worse for fish species that form large aggregations for reproductive purposes. When fishermen target these aggregations, the impact on the ability of the fish population to replenish itself is severe. Some species, such as Nassau grouper, have been severely depleted for this reason. The negative impacts extend to many other species when fish are harvested with gear that damages the bottom habitat.

These problems do not mean that all commercial fishing should be banned, but they show how disaster can "sneak up" on fishermen and resource managers alike. This case study also illustrates why thoughtful management based on good data and analysis are needed from the very beginning.

The BRIDGE Connection

www.vims.edu/bridge/

From the opening screen, navigate to Ocean Science Topics, then Human Activities, then Fisheries. Here are links to many other student activities related to fisheries.

The "Me" Connection

Have students select a species of fish that is available in local grocery stores (perhaps their favorite fish), and prepare a short report on what management practices (if any) are being used to ensure that populations of this species are not being depleted by overfishing.

Connections to Other Subjects

Language Arts, Mathematics, Geography, Earth Science

Evaluation

Have students prepare individual written responses to questions in Step #6 prior to group discussion. Graphs prepared in Steps #2, 4, and 5 can be evaluated for thoroughness and accuracy in graphings and calculations.

Extensions

Have students visit http://oceanexplorer.noaa.gov to find out more about opportunities for real-time interaction with scientists on current Ocean Exploration expeditions.

Resources

http://www.oar.noaa.gov/k12/html/fisheries.html
Includes background information, data, applications, and student activities in fisheries management

http://www.npaci.edu/online/v5.15/seamounts.html
General introduction to research on seamounts with links to other sites

http://seamounts.sdsc.edu/main.html
Website sponsored by the National Science Foundation to archive data from seamount exploration expeditions

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

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

Content Standard F: Science in Personal and Social Perspectives
- Populations, resources, and environments

For More Information

Paula Keener-Chavis, National Education Coordinator/Marine Biologist
NOAA Office of Exploration
2234 South Hobson Avenue
Charleston, SC 29405-2413
843.740.1338
843.740.1329 (fax)
paula.keener-chavis@noaa.gov

Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
http://oceanexplorer.noaa.gov

Student Handout

Orange Roughy Landings Data

Year	Total Landings in Metric Tons (=1,000 kg)	Number of Fish Landed	Number of Full-time Fishing Vessels
1980	5,000	116,000	10
1981	25,200	600,000	28
1982	39,600	900,000	36
1983	100,000	2,500,000	100
1984	250,000	6,584,200	278
1985	300,000	7,692,307	300
1986	350,000	9,459,459	350
1987	369,900	10,568,571	411
1988	379,950	11,873,437	447
1989	359,800	11,993,333	514
1990	339,600	12,128,571	566
1991	380,000	15,200,000	760
1992	360,000	17,412,857	720
1993	340,200	15,463,636	756
1994	300,000	14,285,714	750
1995	239,750	11,987,500	685
1996	159,900	7,614,286	533
1997	110,000	5,500,000	550
1998	40,000	1,818,182	400
1999	20,000	1,111,111	200