VOICES of the BAY

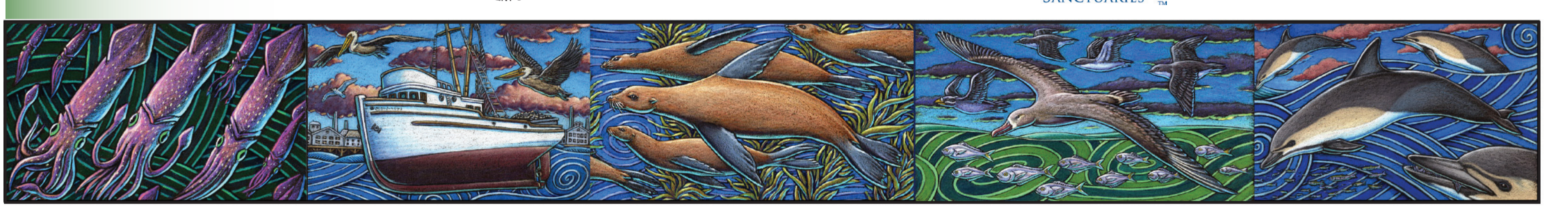
Balance in the Bay

In this activity, students will take part in a simulated fishery, harvesting California market squid - *Doryteuthis opalescens* (formerly *Loligo opalescens*) - that are common in Monterey Bay and the Pacific Ocean. Because of their quick response time to environmental conditions, market squid can provide an interesting example of ecosystem-based management at work. Student groups will take on various roles in a simulated fishing community, making decisions while also facing a range of natural and man-made challenges. These decisions will impact their own well-being in addition to the well-being of the natural squid population as a shared or "common" resource. Maintaining a balance that sustains both the squid population and the squid fishery that relies on that population will prove to be challenging. Students will analyze their decisions and recognize the difficulty associated with maintaining a healthy "balance in the bay."

NOAA · NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · U.S. DEPARTMENT OF COMMERCE

PRESERVE AMERICA
Explore and Enjoy Our Heritage

NATIONAL MARINE SANCTUARIES ™



Grade Level: 8-12, Community College

Time Frame

Preparation:

- 30 minutes to review complete module and prepare student materials.

Facilitation:

- One 50-minute period to conduct the initial fishing simulation, discuss the outcomes, and challenge students to devise strategies for a better "balance in the bay."
- One 50-minute period to view Balance in the Bay PowerPoint slides, reach consensus on student devised strategies for sustainability, and introduce added roles for a Marine Scientist and Regulatory Agency Representative.
- One 50-minute period to conduct second round of simulation and discuss how sustainable strategies and **ecosystem-based management** practices help maintain a better "balance in the bay."
- Additional 1-2 class periods for optional extensions.

Brief Overview

The Monterey Bay National Marine Sanctuary, and the Pacific Ocean beyond, are rich and valuable resources shared by many. The living organisms that populate these vast ocean **ecosystems** are also a shared resource, as well as being biologically interconnected for their own survival and sustainability. Managing these resources on behalf of the many individuals, businesses, states, and nations that share them can be a challenge. Maintaining a balance between the health and long-term **sustainability** of the natural resources as well as the health and economic vigor of the individuals and communities that depend on these resources makes the challenge even more complex. **Ecosystem-based management** is an exciting new approach to resource management that addresses these challenges. Looking at an entire **ecosystem**, usually containing many interrelated and interdependent resources and users, is becoming a more common approach for measuring and maintaining balance within an **ecosystem** and the communities supported by that **ecosystem**.

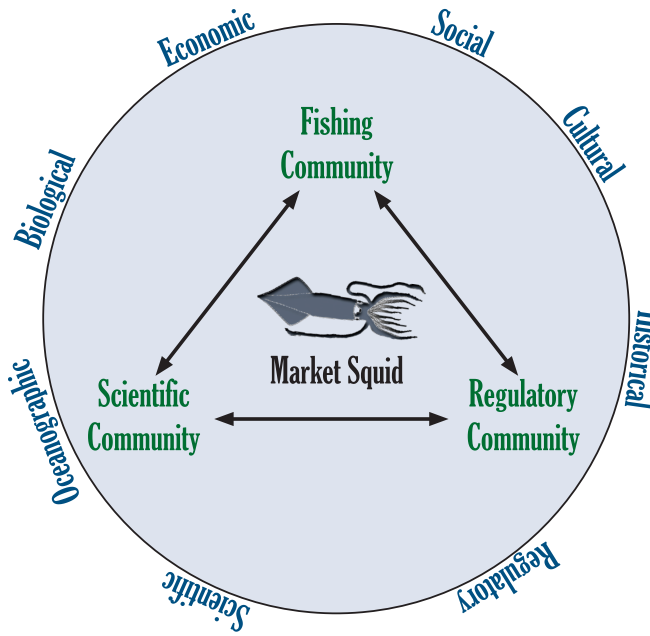


Figure 1. Ecosystems-based factors influencing squid fisheries management.

Skills/Outcomes

- Students will gain an understanding of some of the inter-related factors involved in the **ecosystem-based management** of a marine resource.
- Students will learn to effectively apply critical thinking and problem-solving skills to respond to natural and man-made challenges.
- Students will learn how to apply **ecosystem-based management** principles to find solutions.
- Students will learn to use basic arithmetic to calculate and record numerical values, prepare and interpret graphs and charts, and make decisions based on their understanding of these numbers.

Purse seiner spreading a net for squid, 1957. (J. B. Phillips photograph; courtesy Tim Thomas, Monterey Maritime and History Museum.)

Key Subjects/Standards

Biology, economics, mathematics, ecosystem-based management.

National	<u>Science:</u> NS.9-12.1 Science as Inquiry. NS.9-12.6 Personal and Social Perspectives: population growth, natural resources, environmental quality. <u>Math:</u> NM-NUM.9-12.3 Number and Operations: compute fluently and make reasonable estimates. NM-PROB.CONN.PK-12.3 Connections: recognize and apply mathematics in contexts outside of mathematics. <u>Economics:</u> NSS-EC.9-12.1 Scarcity. NSS-EC.9-12.11 Role of Money. NSS-EC.9-12.13 Role of Resources in Determining Income. <u>Social Sciences:</u> NSS-G.K-12.2 Places and Regions. NSS-G.K-12.3 Physical Systems.
California	<u>Science:</u> Grade 9-12, Ecology (6): Sustainability in an ecosystem is a balance between competing effects. Grade 9-12, Investigation & Experimentation (1): Scientific progress is made by asking meaningful questions and conducting careful investigations. <u>Math:</u> Algebra I (3.0): Students solve equations and inequalities involving absolute values. Algebra I (5.0): Students solve multi-step problems, including word problems, involving linear equations and linear inequalities in one variable and provide justification for each step.
Ocean Literacy	1. The Earth has one big ocean with many features (h). 5. The ocean supports a great diversity of life and ecosystems (f). 6. The ocean and humans are inextricably interconnected (b, c, e, g).

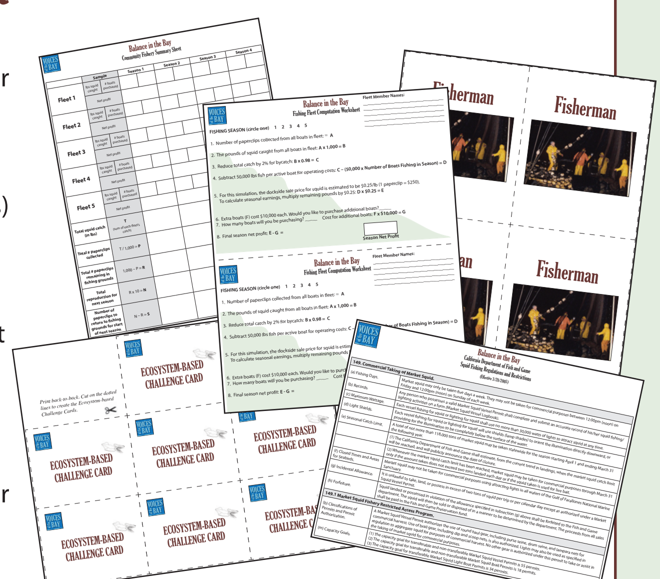
Teacher Preparation

1. Read entire activity and review all student handout materials and the Balance in the Bay PowerPoint in advance.
2. Print/copy materials as listed in the Materials List section.
3. Locate a relatively open space that is approximately 20ft x 20ft square. A school cafeteria, courtyard, parking lot, gymnasium, large classroom, or hallway will work. Arrange exclusive use of this space for at least two 50-minute class periods.
4. If using an overhead projector, make a transparency of the Community Fishery Summary Sheet chart for recording fishing season results. Otherwise, reproduce the chart on a large white board or on paper to facilitate sharing group results with the entire class.

Materials List

For a classroom of 30 students:

- ☐ Squid Fisheries PowerPoint slides, pre-loaded into presenting computer or printed out for each student for use on Day 2
- ☐ 1,000 standard paperclips (each paperclip = 1,000 pounds of market squid)
- ☐ A relatively open area roughly 20ft x 20ft square (ocean fishing grounds)
- ☐ Pencil/pen for each fishing fleet of five students
- ☐ 30 paper cups (representing purse seine boats)
- ☐ 60 Fishing Fleet Computation Worksheets, ten for each fishing fleet
- ☐ 8 calculators, one per fishing fleet and two extras for Marine Scientist and Regulatory Agency Representative roles for Day 3 simulation
- ☐ 1 set of Role Cards (includes 6 Fisherman, 1 Marine Scientist, and 1 Regulatory Agency Representative)
- ☐ 1 set of Ecosystem-based Challenge Cards
- ☐ 2 Community Fishery Summary Sheets, as overhead transparencies or large wall chart
- ☐ 30 California Department of Fish and Game (CDFG) Squid Fishing Regulations and Restrictions handouts



Instructional Strategies/Procedures

For a classroom of 30 students:

Fishing for Market Squid

1. Randomly scatter the 1,000 paperclips throughout the designated 20 ft x 20 ft area which will serve as the "fishing grounds" for the simulation. It is ok if they are clustered or unevenly distributed as this, in itself, models how squid naturally congregate in massive schools.

2. Explain to students that they will be participating in a multi-day activity that explores some of the challenges associated with balancing multiple factors – biological, economic, cultural – in a fishery using a fishery simulation modeled on the market squid fishery in the Monterey Bay National Marine Sanctuary.

3. Divide class into five "fishing fleets" of six students each (hereafter called student fleet).

4. Evenly position student fleets along the edge of the 20ft x 20ft fishing grounds. Provide each fisherman with a paper cup (boat hold). Provide a "Fisherman" role card to each student fleet.
   a. Have them read aloud the text on the back of the card.
   b. Then, have them select one fisherman from their fleet who will be the only boat to fish in the first season.
   c. Tell the students to imagine that the designated area represents a portion of the market squid's habitat: an open-water space, within 200 miles of the central California coastline.
   d. Announce that each student fleet will be allowed to send one boat (one student) in the first season (1 minute) to harvest squid (paperclips).
   e. Each paperclip will represent 1,000 pounds of market squid. Each student fleet needs at least 50 paperclips (50,000 pounds of squid) per boat per season just to feed their families and pay their bills. Financially, each paperclip is worth $250 in the simulation (1,000 pounds of squid at $0.25/lb).

Boat fishing for squid off the Monterey coast. (Photo: Sabrina Beyer.)

5. Announce the start of the first season. One fisherman from each student fleet should enter the fishing grounds to collect squid (paperclips), storing them in their paper cup. At the end of 1 minute, shout "stop." Fishermen return to their fleet's port to count their catch.

6. Hand out 5 Fishing Fleet Computation Worksheets to each student fleet. Instruct students to follow the instructions on their worksheet to calculate their squid catch (in pounds) and their net profit after expenses and re-investments. Allow students 5-10 minutes to complete their calculations.

7. Ask each student fleet to report the following numbers from Season 1. Record these numbers on the Community Fishery Summary Sheet:
   - Pounds of squid caught (#2 Fishing Fleet Computation Worksheet)
   - Number of new boats purchased (#6 Fishing Fleet Computation Worksheet)
   - Net profit (#8 Fishing Fleet Computation Worksheet)

8. Using the numbers reported by each student fleet, calculate the number of paperclips to return to the fishing grounds for the next season (S on the Community Fishery Summary Sheet). Note: for this simulation it is assumed that the reproduction rate will be 10x annually. This means that if, after the first fishing season, there were 85 paperclips left in the fishing grounds, the number to start the next season with should be 850. The maximum number of paperclips in the fishing grounds at any one time is 1,000. If the calculated number of paperclips to return (S from the Community Fishing Summary Sheet) is over 1,000, introduce the concept of **carrying capacity**.

9. Collect all the paperclips from each student fleet. Randomly scatter the appropriate number of paperclips to the fishing grounds (S from the Community Fishing Summary Sheet) and set aside the remaining paperclips.

10. Repeat steps 5-10 for two more seasons of fishing, adding additional fishermen if new boats are purchased within a student fleet.

11. After three seasons have passed and all calculations completed, ask each student fleet to make a prediction about the squid population and their fleet's on-going profits and success based on their data so far. If time allows, have each group share their predictions with the entire class.

12. If time allows, have the students complete a fourth season and record their data.

13. *Class Discussion*: At this juncture, various trends may be emerging. Complete the Community Fishery Graph. Gather the students and discuss the following questions:
    a. Which student fleet was the most profitable?
    b. What happened to the catch numbers as the seasons progressed?
    c. What were the effects of having more boats fishing in the **common** waters?
    d. What happened to the total number of available squid as the seasons progressed?

14. Inform the students that they will repeat the fishing simulation with a new goal: sustaining the greatest number of boats for the longest period of time while maintaining a healthy squid population season to season. Ask them to think about strategies that their community might put in place in order to realize such a goal.

Seeking Balance in the Bay

1. Ask the students to share some of their ideas for sustaining the market squid fishery simulated the previous day. Record these potential strategies for the class to reference later.

2. Show students the Balance in the Bay PowerPoint presentation. These slides will introduce the students to some basic squid biology, fishery history, and economic factors that can impact the fishery. Students will be introduced to additional members of the community - Marine Scientists and Regulatory Agency Representatives - who can help sustain a fishery through the application of **ecosystem-based management** practices.

3. Remind students of their new community-wide challenge: sustaining the greatest number of boats for the longest period of time while maintaining a healthy squid population season to season.

4. Appoint one student from the class to serve as a Marine Scientist and another student to serve as a Regulatory Agency Representative in the up coming rounds of the simulation. Provide role cards to these two students and have them read their duties aloud to the class.

Leeanne Laughlin, Marine Scientist for CDFG, dissecting squid. (Photo: Briana Brady.)

5. Ask the students to brainstorm within their student fleets preferred strategies for sustaining the squid population. Brainstormed ideas may include: limiting the number of fishing boats, shortening the fishing seasons, closing off areas to fishing, etc. Encourage students to be creative in brainstorming strategies for **sustainability**. Once each student fleet has a few ideas, instruct all the student fleets to cooperate and agree to a community-wide strategy or set of strategies before repeating the multi-season simulation. Have the Regulatory Agency Representative help facilitate this discussion and ask the Marine Scientist to propose ideas based on his/her role and responsibility in the community.

Sicilian squid fisherman asleep on his boat. The Sicilians first came to Monterey, circa 1905, bringing with them the lampara net. At this time in America, squid was considered a junk fish, so the Sicilians sold it to the Chinese. (Courtesy Tim Thomas, Monterey Maritime and History Museum.)

Ecosystem-based Management in Action

1. Review with the students the **sustainability** strategies they agreed to previously. Also, remind them of the two additional community roles that were added – Marine Scientist and Regulatory Agency Representative.

2. Introduce them to a third parameter that they will need to address: Ecosystem-based Challenges. These challenges, introduced at the start of each season by cards drawn randomly by the Marine Scientist, will provide an additional, realistic dimension to the simulation.

3. Provide each student fleet with five more blank Fishing Fleet Computation Worksheets. Using a fresh Community Fishery Summary Sheet for recording, conduct another multi-season simulation adding the new community roles (Marine Scientist and Regulatory Agency Representative), Ecosystem-based Challenge Cards, and **sustainability** strategies agreed to by the whole community. Remind the Regulatory Agency Representative to choose a student fleet each fishing season and count their catch when they return to port. Remind the Marine Scientist to record data on the Community Fishery Summary Sheet.

4. *Class Discussion:* After four seasons have been recorded, gather the students to discuss their observations and to what extent they were able to maintain a better balance applying their chosen strategies. Ask the following questions:
   a. What are the factors now affecting the availability of squid?
   b. Were the student fleets still profitable?
   c. How did the agreed upon strategies affect fishing? Student fleet profitability? Numbers of squid returning each season? Number of seasons with strong squid populations available?
   d. How did certain Ecosystem-based Challenges affect the above?

5. Hand out copies of the California Department of Fish and Game Squid Fishing Regulations and Restrictions. Ask students to read these and compare them to their own agreed upon strategies for **sustainability**. Which strategies, regulations, and restrictions do they think contribute most to maintaining a "balance in the bay"?

"Squid Mountain," circa 1930. The Chinese bought the squid from the Sicilian fishermen and trucked it away from the city to drying fields located off the Monterey-Salinas Highway (across from what is now the Monterey Airport) because of the strong smell. (J. B. Phillips photograph; courtesy Tim Thomas, Monterey Maritime and History Museum.)

Extensions & Connections

1. Have students read Garrett Hardin's paper titled "Tragedy of the **Commons**" published in Science Magazine in 1968. Or, simply read them the excerpt in the Background section of this module. After reading the paper, have students discuss how the fishing simulation relates. What was the **commons**? What was the tragedy? Did the particular strategies described in the article help prevent the tragedy from happening? How does this article relate to their own experience trying to maintain a "balance in the bay"?

2. Allow students time to discuss additional (or different) **ecosystem-based management** strategies to apply to their squid fishery simulation. Repeat the simulation 1-2 more times to test their ideas even while accommodating new ecosystem-based challenges. The ultimate goal is to settle on a set of cooperative strategies that result in true **sustainability** regardless of the challenges faced.

3. Have students select a particular fishery and research its history. Over a 50-100 year period, what happened to the number of fish landed, or the number of boats/fishermen supported by the fishery? Were there strategies put in place to sustain a healthy balance? Was the balance sustained?

4. Have the students research the different fisheries found in Monterey Bay (sardine, salmon, rockfish, crab, etc.). Have them adapt the Balance in the Bay activity to simulate one or more of these fisheries or accommodate multiple fisheries in a single simulation. Keep in mind species-specific reproductive rates, fishing methods, boat costs, economic value, typical landings, etc. Allow the students to try their ideas in a future class period.

Background

The ocean waters around the United States (out to 200 miles, the limit of our **Exclusive Economic Zone**, **EEZ**) are common property – every citizen "owns" a share in those resources, with the government managing it for the common good. However, history has shown us that communal resources are often maximized to individual benefit, sometimes to the detriment of the resource as a whole. This is referred to as "the tragedy of the **commons**." In "The Tragedy of the **Commons**," Garrett Hardin reminds the reader that "a finite world can support only a finite population."

> In Garrett Hardin's own words:
>
> *The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the* ***commons****. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the* ***carrying capacity*** *of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the* ***commons*** *remorselessly generates tragedy.*
>
> *As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component.*
>
> *1. The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly + 1.*
>
> *2. The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of - 1.*
>
> *Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another.... But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit -- in a world that is limited.*
>
> (Hardin, 1968)

To prevent this "tragedy," fisheries are managed by both the state and federal governments for the benefit of all citizens. The legislation that directs how our federal government manages fishery resources is the **Magnuson-Stevens Fishery and Conservation Management Act** (MSA, 1976). This act was first revised in 1996 with the Sustainable Fisheries Act, and was revised again in 2006, reaffirming America's commitment to fishery protection.

Generally speaking, the state (in California, the California Resources Agency, California Department of Fish and Game, and the Fish and Game Commission) is responsible for managing fisheries within three miles of shore while the federal government, National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries) is responsible for managing fisheries between 3-200 miles from shore. In California, many fisheries are managed jointly by state and federal agencies. A result of the **MSA** was the creation of eight regional fishery management councils. These councils create Fishery Management Plans (FMPs). The FMPs describe the nature of a fishery, including an assessment of a fish population, and provide recommendations on how the fishery should be managed. The Pacific Fishery Management Council develops management measures for the **EEZ** off the coasts of Washington, Oregon, and California.

Those working in the fishing industry have the responsibility to comply with state and federal regulations. In the late 1990s, amendments to the **MSA** were passed that mandated more conservative management of marine resources. Working to minimize the negative effects posed by the "tragedy of the **commons**," the full implementation of these new laws often results in more restrictive regulations to prevent overfishing, limit **bycatch**, preserve essential fish habitat, and whenever possible, rebuild depleted fish stocks. More restrictive regulations have led to shorter seasons and lower quotas for many species, thus reducing the flexibility and economic viability of many fishing enterprises.

Scientific research performed on specific fish species provides an understanding of the nature and biology of that particular species. For successful and effective management, however, resource managers must have an understanding of the entire marine environment while also accounting for the rights and success of those in the fishing industry. **Ecosystem-based management** is a comprehensive method for managing and assessing the biological, ecological, economic, political, and social aspects of fisheries and environmental quality. **Ecosystem-based management** accounts for many elements including water quality, climate, predator/prey interactions, harvest pressure, regulatory policy, and the economic and social factors that result from harvesting the resource. For those reasons and more, it is critical to have an effective, contemporary, and dynamic approach to fisheries management. The Monterey Bay National Marine Sanctuary is one of the most diverse marine environments in the world, with 345 species of fish, 33 species of marine mammals, 94 species of seabirds, and home to the largest kelp forest in the nation. **Ecosystem-based management** practices are increasingly being used in the Monterey Bay National Marine Sanctuary and other sensitive and productive fishing grounds around the globe.

Resources for Teachers

Hardin, G. 1968. The Tragedy of Commons. *Science* 162: 1243-48.

Monterey Bay National Marine Sanctuary. Available from: http://montereybay.noaa.gov/

References Specific to this Activity

California Department of Fish and Game. 2008. Status of the Fisheries Report - an Update Through 2006. Available from: http://www.dfg.ca.gov/marine/status/.

Magnuson-Stevens Fishery Conservation and Management Act. 1996. Public Law 94-265. Available from: http://www.nmfs.noaa.gov/sfa/magact/

Market Squid Fishery Provisions. 2005. California Department of Fish and Game. [cited 2008 Sep] Available from: http://www.dfg.ca.gov/licensing/pdffiles/fg1341.pdf

Market Squid Fishery Management Plan. 2005. California Department of Fish and Game. [cited 2008 Sep] Available from: http://www.dfg.ca.gov/marine/msfmp/index.asp

National Oceanic and Atmospheric Administration. 2007. Ecosystem-based Management. [cited 2008 Jul 8] Available from: http://celebrating200years.noaa.gov/magazine/chesapeake_fish_mgmt/side1.html

Acknowledgments

Curriculum Development and Design

David Heil & Associates, Inc., Portland, Oregon
David Heil
Lauren Seyda

Research and Review

NOAA's Monterey Bay National Marine Sanctuary
Sabrina Beyer
Kristin Hunter-Thomson
Lisa Uttal

NOAA's Office of National Marine Sanctuaries
Seaberry Nachbar

Additional Credit

The simulation part of this activity was adapted with permission from a previous activity titled Tragedies in the Commons developed by the Biological Sciences Curriculum Study (BSCS) to celebrate National Science & Technology Week. April, 1990.

Original Artwork

© Ray Troll & NOAA Fisheries Service's "Green Seas/Blue Seas Project" (http://swfsc.noaa.gov/GreenSeas-BlueSeas)

Market squid drawing. © Lynn McMaster, 1996.

Vocabulary

Bycatch: Living creatures that are caught unintentionally by fishing gear and are often unmarketable and unused. An example of bycatch is dolphins caught in tuna nets.

Carrying Capacity: The carrying capacity of a particular environment is the greatest number of individuals of a given species that can be supported with the environment's available resources.

Commons: Belonging to, or shared equally by two or more individuals or populations.

Ecosystem: A geographically specified system of organisms, including humans, the environment, and the processes that control its dynamics.

Ecosystem-based Management: A broader more comprehensive management approach that takes into account the interaction of ecological, economic, cultural, and regulatory factors impacting the overall health of an ecosystem and the communities dependent upon that ecosystem. Specific factors may include pollution, coastal development, harvest pressure, predator/prey, and other ecological interactions, as well as nearby watershed management.

Exclusive Economic Zone (EEZ): An area along a country's coastline, extending from the shore to 200 nautical miles from shore, to which a country claims exclusive rights for economic activities.

Limited Entry: A strategy used to control the size of fishing fleets by limiting the number of fishing vessels allowed to legally harvest seafood.

Magnuson-Stevens Fishery Conservation and Management Act (MSA): This act provides for the conservation and management of fishery resources found off the coasts of the United States. The act established a national fishery conservation zone (EEZ) extending from shore to 200 nautical miles off the coast of the United States, set up a council system, mandated fishery management plans, and set standards for fishery conservation and management practices.

Sustainability: A state that can be maintained at a certain level indefinitely. The potential longevity of ecological systems, such as the planet's climatic system, systems of agriculture, industry, forestry, fisheries, and the ecological infrastructure on which they depend.