Introduction to Aquaculture

KEY CONCEPTS
Aquaculture is the controlled cultivation and harvest of aquatic animals and plants. There are many similarities between aquaculture and agriculture, but there are some important differences as well. Aquaculture, like agriculture, is necessary in order to meet the food demands of a growing global population with diminishing natural fisheries stocks. Unlike land under cultivation, the world's oceans, lakes, rivers, and streams are usually public or common resources. Managing these common resources is often problematic.

LESSON OVERVIEW
Students will read a handout which introduces them to the topic of aquaculture. The class will conduct an aquaculture brainstorming session. Cooperative learning groups will explore the "commons dilemma" through a hands-on activity. Students will connect what they learned in the "Aquaculture and the Global Commons" activity to what they know about aquaculture.

LEARNING OBJECTIVES
After completing this chapter, the student will be able to:
- Define aquaculture.
- Distinguish between aquaculture and agriculture.
- Explain different types of aquaculture.
- Distinguish between warmwater, coldwater, and maricultured species.
- Describe the outcomes of a self-interest strategy vs. a cooperative strategy for managing a renewable resource.
- Enumerate the complex factors involved in managing a global public resource.
- Apply math skills to natural resource management problems.
- Apply analytic skills to natural resource management problems.

LEARNING RESULTS
AQUACULTURE AND THE GLOBAL COMMONS
B. Ecology: Students will understand how living things depend on one another and on non-living aspects of the environment.
   3. Analyze the effect of reproductive and survival rates on population size.
   4. Analyze the impact of human and non-human activities on the type and pace of change in ecosystems.
J. Inquiry and Problem Solving: Students will apply inquiry and problem solving approaches in science and technology.
   2. Verify, evaluate, and use results in a purposeful way. This includes analyzing and interpreting data, making predictions based on observed patterns, testing solutions against the original problem conditions, and formulating additional questions.
K. Scientific Reasoning: Students will learn to formulate and justify ideas and to make informed decisions.
   3. Develop generalizations based on observations.
   5. Produce inductive and deductive arguments to support conjecture.
L. Communication: Students will communicate effectively in science and technology.
   5. Critique models, stating how they do and do not effectively represent the real phenomenon.

MATERIALS
Copies of student handout, chart paper, and markers (brainstorming session); 2 pounds of peanuts
in the shell* or styrofoam packing material and one large bowl for every cooperative learning

group made up of approximately four students ("Aquaculture and the Global Commons" activity).
(*Keep in mind that some students may have food allergies or dietary restrictions.)

BACKGROUND
What is aquaculture?
   Word breakdown: Aqua (water) culture (to grow)
Aquaculture is:
   • The art, science, and business of producing aquatic plants and animals useful to humans.
   • The controlled cultivation and harvest of aquatic animals and plants.
Mariculture is:
   • The raising of such crops in the sea.

Are aquaculture and agriculture similar?
Aquaculture can be viewed as a type of agriculture. Aquaculture, like agriculture, is the cultiva-
tion and harvest of plants and animals for human use. In essence, aquaculture and agriculture are
both farming. However, aquaculture is farming in water and therefore requires a different set of
knowledge, skills, and technology.

Which aquatic species are cultured in which environments?
Aquaculture takes place in three general aquatic environments:
1. Warmwater aquaculture is culturing plants and animals which thrive in warm, fresh water
   such as catfish, crayfish, baitfish, sportfish, and ornamental fish.
2. Coldwater aquaculture is culturing species which thrive in cool, fresh water such as trout and
   salmon.
3. Mariculture (marine culture) is culturing plants and animals which are accustomed to living in
   a saltwater or brackish environment. Species include clams, oysters, seaweed, mussels and
   shrimp, salmon, and steelhead trout.

Who practices aquaculture and why?
Aquatic plants and animals are cultured for a variety of reasons. For simplicity, let's separate
aquaculture into two broad categories: public sector and private sector aquaculture.

Public sector/restoration aquaculture is generally aimed at replenishing depleted fishery stocks
to benefit all. It tends to be conducted by non-profit organizations, or by the state and federal
government. Motivations for public sector aquaculture vary. Sometimes officials are attempting
to protect a potentially threatened species such as the Atlantic salmon. When fish are raised to
restock depleted waters, we will refer to it as restoration aquaculture. Another motivation for
public sector aquaculture initiatives are to replenish depleted commercial fishery stocks to en-
hance the local fishing economy.
Private sector aquaculture has profit as its main motive. Aquaculture entrepreneurs range from individuals to large corporations. Their goal is to sell their product for a profit. The product may be fish or shellfish for a local, regional, or national market; seaweed for a global market; or ornamental fish for aquaria.

What are the different stages of aquaculture?
For finfish...
Hatchery: Place where young are produced and often parental broodstock are maintained.
Nursery: Place where newly hatched fry are housed and cared for.
Grow-out facility: Place where young are grown to market size in a variety of holding facilities which include ponds, tanks, raceways, cages, vats, and pens.
Harvesting: Gathering or capturing the cultured aquatic species for marketing or processing.
Processing: Converting the raw product to final form for sale, ranging from minimal to value-added.
Marketing: Getting the product from the producer to the consumer.

For shellfish...
Hatchery: Place where broodstock are maintained and spawning and fertilization are initiated.
Nurseries: Place where juvenile shellfish are raised, often in floating trays where they are fed marine algae.
Grow Out: Process whereby young shellfish are seeded on mud flats, placed on the bottom, or suspended in the water column.
Harvesting: Gathering or capturing the cultured aquatic species for marketing or processing.
Processing: Converting the raw product to final form for sale, ranging from minimal to value-added.
Marketing: Getting the product from the producer to the consumer.

ACTIVITY: AQUACULTURE AND THE GLOBAL COMMONS
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Information
Although aquaculture has been around for thousands of years, many people are still unclear about the nature of aquaculture and its place in society. Only a small percentage of global fish production stems from aquaculture; the overwhelming majority is wild capture. Now, with many commercial fisheries in decline, we must turn to alternative food technologies. Aquaculture research and development may provide a partial answer to the difficult problem of managing a dwindling natural resource. In order to understand how our fisheries predicament evolved, we must turn to the global commons. As global population increases, more and more pressure is put on our diminishing natural fish stocks because the oceans are a common public resource to which everyone has access.

The interrelated problem of population growth and dwindling resources is illustrated in this demonstration of the “commons dilemma.” Christened by Garrett Hardin, the commons dilemma is derived from The Tragedy of the Commons written by William Forester Lloyd in 1833. The commons described by Lloyd is a pasture open to all. Herdsman bring cattle to the commons to graze. Over time, each herdsman seeks to maximize his economic gain and adds cattle to his
herd. The positive component, the increased profit, is realized by the individual herdsman. The negative component, the resultant overgrazing, is shared by all who use the commons. As each seeks to maximize his gain, the commons resource declines until overgrazing leads to its destruction. The dilemma: self-interest versus cooperation, or maximizing individual gain versus cooperative stewardship of a resource.

Preparation
Photocopy and distribute the student handouts entitled Aquaculture: What Is It All About? to the students the day before so that your students will have a chance to read them prior to class.

Procedure
1. Introduce the unit or lesson with a brainstorming session to engage students in the topic and to determine their current level of knowledge about aquaculture. This could be done as a whole-class activity or in cooperative learning groups. Explore ways in which aquaculture connects with their lives. Some students might have relatives working in aquaculture, or live near an aquaculture facility. The goal is to have your class generate a concept map or descriptive list about aquaculture which can be reproduced, distributed, and revisited at the end of the unit.

2. Invite students to consider water resource issues associated with aquaculture. Who owns the oceans, bays, or rivers of the world? The people or nations that surround them? The organisms that occupy them? What happens to the fisheries as the human population rises?

3. Facilitate the commons dilemma demonstration. In this simulation, your students will have an opportunity to demonstrate their response as consumers of a resource in a commons. A large bowl (the commons) represents the sea, and peanuts or styrofoam packing material represent fish (the resource).

4. Introduce the demonstration with a discussion of the ground rules, supplying only the information needed to get the students started. The dilemma and a discussion of the various strategies should surface at the outcome of the activity. Divide students into groups of four and give each a bowl with 16 “fish.”

Ground Rules
- The object of the game is to harvest as many fish as possible from the sea.
- At carrying capacity, there are 16 fish (peanuts) in this sea (bowl). For every four fish each student harvests, he/she will receive one point. The more fish you harvest, the more points you will receive.
- When the game begins, you may harvest all of the fish, some of the fish, or none.
- You will have four, 20-second trials in which to harvest fish. You will be notified when to start and stop each trial.
- If fish remain in the sea after each trial, a new fish will be added for each one remaining. If there are four fish left, four more can be added. But for each new trial, the total number of fish in the sea cannot be more than the carrying capacity of 16 fish.
5. Repeat the demonstration with eight students in each group to simulate population growth. Keep all other factors constant.

6. Engage the students in the following discussion of their experience.

**Discussion**
1. What were the maximum number of points achieved by any individual? Any group?
2. Why were fish only replaced if some remained in the bowl after the trial?
   - It simulates natural conditions; if all fish are harvested, no additional fish will be born.
3. Why is the population of the “sea” limited to 16 fish?
   - Carrying capacity represents the maximum number of organisms that can be supported by an ecosystem.
4. What happens when members of a group do not use a cooperative strategy?
5. What was the best strategy for harvesting from this commons?
   - Harvest eight from each trial.
6. Does this model realistically represent the real phenomenon of fishing within our oceans?
   - Other variables may affect the population of fish, including non-human predators, dissolved oxygen, water temperature, food supply, and disease.
7. What other human activities threaten the oceans and its inhabitants?
   - Ocean dumping of municipal, industrial and hazardous waste
   - Oil spills and oil drilling
   - Fishing practices which harm other marine wildlife such as whales, dolphins, and sea turtles
   - Nonpoint source pollution such as stormwater runoff
   - Coastal development
   - Industrial and municipal sewage
8. How does aquaculture relate to the commons dilemma?
   - If we culture more aquatic species and catch less wild species, depleted fish stocks will begin to recover.
9. Aquaculture alone will not solve the commons dilemma. Why?
   - Global population is still rising.
   - Cooperation is needed between different nations, corporations, fisherman, and aquaculturists.
   - National and international regulations are needed.
   - Many aquatic species which are being overharvested are not currently being cultured.
Aquaculture: What Is It All About?

The practice of “farming” aquatic plants and animals (or aquaculture) has been going on for many centuries. Since prehistoric times, obtaining food has been a struggle and a necessity for humans. Early humans were hunter-gatherers, which meant that members of the community would venture into the wild to hunt animals such as bear, moose, deer, beaver, fish, and other small mammals and reptiles, while others would gather food including fruits, berries, nuts, herbs, roots and grubs (insect larvae).

Many societies moved from hunting and gathering to culturing their food. In addition to domesticating and cultivating terrestrial plants and animals, aquatic species were cultured as well. The culture of plants and animals useful to humans is called agriculture; when it takes place in water, it is called aquaculture. Therefore, aquaculture is a type of agriculture. The method, equipment, and technology is quite different, but the rationale is similar. It is more convenient to choose particular wild species to domesticate, cultivate, and harvest.

Just as animals have been over-hunted in the past, fish and shellfish have been overfished as well. If an animal is hunted beyond a sustainable level, it is said to be depleted, overharvested, or overexploited. Throughout the world, marine fisheries are in trouble. While the world’s population and its appetite for fish are growing, wild fish stocks are shrinking. According to the U.N. Food and Agricultural Organization (FAO), about 60% of the commercial species in every ocean and sea are either depleted or fully exploited today. “It’s like deforestation, but you can’t see it under the ocean,” explained a World Bank fisheries advisor in a recent article in National Fisherman.

Between 1950 and 1988, the human population has doubled from 2.5 billion to 5 billion. In response to this increase in mouths to feed and people to employ, world fish production has more than quadrupled from 21 million metric tons (mmt) to 98 mmt. Of the 98 mmt of fish production, only 14 mmt came from aquaculture; the remaining 84 mmt came from wild capture. As we take more and more fish from our waters, there are less fish left behind to produce the next generation of fish. By the year 2000, the global human population is expected to reach 6 billion and annual fish production to reach 138 mmt. With global fisheries in decline, aquaculture is the only way we can attempt to make up the difference and meet the seafood demands of a growing population.

As the total worldwide marine catch continues to fall, the harvest from aquaculture is rising. By the 21st century, aquaculture will be a major new agricultural growth industry. If managed properly, aquaculture can help overfished species recover, employ people, feed a growing population, and help our local, regional, and national economy.
MAKING CONNECTIONS: ADDITIONAL ACTIVITIES AND EXTENSIONS

• Taking Action

Is there a commons dilemma to be resolved in your community? Have students (or groups of students) select a local commons issue to investigate. Once students have identified the problem and collected data, they should determine which laws exist to protect the resource they are investigating, and then try to come up with a solution to the problem.

• Local Fishery Resources

Many of the fish that once inhabited the Gulf of Maine have been overharvested. Have students, or a group of students, choose a local species which has been overharvested and determine its past and present status, management, and whether it is being cultured or considered for culture.

• Global Planning

There have been successful international efforts to solve some of our global environmental problems. One example is the Montreal Protocol on Substances that Deplete the Ozone Layer—referring to the beneficial ozone found in the upper atmosphere that protects us from the harmful rays of the sun. Another largely successful international effort has been the establishment of the International Whaling Commission (IWC) which seeks to end the global slaughter of whales. Have students devise an international management plan for the oceans which would protect species from being overharvested.

GLOSSARY

**Agriculture:** The art, science, and business of producing every kind of plant and animal useful to humans.

**Aquaculture:** The art, science, and business of producing aquatic plants and animals useful to humans. The controlled cultivation and harvest of aquatic animals and plants.

**Aquatic:** An organism that lives in, on, or near the water.

**Brackish:** Water that contains some salt, but not as much as the ocean.

**Carrying Capacity:** The maximum number of individual organisms that can be supported by an ecosystem.

**Coldwater Species:** Aquatic animals that spawn at temperatures below 60° F (15° C).

**Commercial:** Those fish species which are raised or harvested for market sale.

**Cultivate:** To grow or tend a plant or crop.

**Deforestation:** The practice of cutting down or clearing away trees from a forest.

**Depleted:** Decreased, used up, or emptied out.

**Domesticate:** To train or adapt a plant or animal to live in a human environment for human use.

**Exploit:** To utilize for personal gain.

**Extinction:** The complete elimination of a species.

**Finfish:** Any true fish (bony, cartilaginous, or jawless) which has a spindle-shaped body and fins.

**Grow-out:** Place where young are raised to market size.

**Harvest:** To gather or capture aquatic species for marketing or processing.

**Hatchery:** Place where seed or young fish produced.

**Hunter-Gatherers:** Humans who hunt wild animals and gather wild plants for food.

**Mariculture:** A type of aquaculture which cultures animals and plants in seawater.

**Marine:** Having to do with salt water.

**Organism:** An individual form of life, such as a plant, animal, bacterium, protist, or fungi.

**Overexploited:** To utilize a resource beyond a sustainable level.
Overfish: To collect so many fish from the wild that the population can no longer sustain itself.
Overharvest: To gather so many plants and animals from the wild that the population can no longer sustain itself.
Marketing: The process of getting the product from the producer to the consumer.
Nursery: Place where newly hatched fry are housed and cared for.
Prehistoric: Of, relating to, or belonging to the era before recorded history.
Processing: Conversion of raw product to final saleable form.
Shellfish: An aquatic invertebrate animal with a shell. Especially an edible mollusk or crustacean.
Spawn: The mixing of sperm and eggs to produce young. (i.e., fertilization)
Species: A group of organisms that resemble one another closely.
Sustainable: Economic development that takes full account of the environmental consequences of economic activity and is based on the use of resources that can be renewed or replaced and therefore are not depleted.
Traditional Fisheries: Business of harvesting wild aquatic organisms for sale.
Terrestrial: Living on land.
Warmwater Species: Aquatic animals that spawn at temperatures above 60° F (15°C).
Wild: Occurring, growing, or living in a natural state; not domesticated, cultivated, or tamed.

ADDITIONAL RESOURCES
Aquaculture Around the World: Where Did It Come From and Where Is It Going?

KEY CONCEPTS
Aquaculture may seem to us like a relatively new scientific venture, but it has a very long and rich history. The roots of aquaculture can be traced back to 3500 B.C. in China. Asia is still, by far, the leader in aquaculture production. In the United States, aquaculture is a small, yet growing, industry. U.S. national policy encourages this growth for the dual purpose of reducing the U.S. trade deficit and for replenishing depleted wild fish stocks.

LESSON OVERVIEW
Students will learn about the history of aquaculture around the world and construct a timeline which will place aquaculture milestones in context with key world events. Students will calculate figures and construct graphs and charts based on global aquaculture production statistics. Students will research different countries and their contribution to global aquaculture production.

LEARNING OBJECTIVES
After completing this chapter, the student will be able to:
- Describe the history of aquaculture around the world.
- Explain the current global status of aquaculture.
- Describe the production status of individual countries.
- Identify several countries and continents critical to aquaculture production and locate them on a map of the world.
- Enumerate the important contributions that many different cultures have made to aquaculture.
- Demonstrate math skills such as adding, subtracting, multiplying, dividing, calculating proportions and percentages and applying basic algebra.
- Demonstrate analytical math skills and apply them to real global aquaculture statistics.
- Develop a pie chart and a bar graph based on global aquaculture statistics.
- Analyze and interpret data.
- Demonstrate research skills.

LEARNING RESULTS
AQUACULTURE TIMELINE
M. Implications of Science and Technology: Students will understand the historic, social, economic, environmental, and ethical implications related to science and technology.
   5. Examine the historic relationships between prevailing cultural beliefs and breakthroughs in science and technology.

GLOBAL GRAPHING
M. Implications of Science and Technology
   1. Examine the impact of political decisions on science and technology.
MATERIALS
World map, overhead of *Aquaculture Timeline*, overhead projector, index cards, markers, flags or pushpins, copies of student handouts, map of the world, graph paper, calculators (optional), computer spreadsheet/graphing program (optional), world almanac, research materials.

BACKGROUND
Based on written documents, it is believed that aquaculture began in China around 3500 B.C. Culturing fish may have evolved from the practice of storing fish in ponds until they are ready to be eaten. The Chinese developed the use of polyculture, the art of growing more than one species at a time. They determined that many different species of *carp* could coexist in the same pond because they lived in different parts of the water and fed on different organisms. With polyculture, more fish could be raised in a given area. Originally, aquaculture was designed only for the wealthy elite who wished to have fresh fish all year long. Later, it became a way to provide food for the masses.

Based on drawings which date back to 2000 B.C., historians determined that Egyptians cultured *tilapia*. It is likely that the practice of aquaculture evolved from their advanced system of irrigation. Mayan Indians trapped and culture fish between 500 and 800 B.C. By 100 B.C., wealthy members of the Roman empire enjoyed mullet and trout reared in ponds called “stews.” They were the first to experiment with both saltwater and freshwater culture. As far back as 400 A.D., Hawaiians utilized extensive pond systems for aquaculture. They raised species in fresh, salt, and brackish water. It was not until the end of the 11th century that aquaculture took hold in Europe. In the United States, culturing trout began in earnest in the mid 1800s. To this day, the United States lags behind much of the world in aquaculture production. China is still the leader in aquaculture production. All of Asia makes up around 85% of the total global aquaculture production. In contrast, the U.S. produces only 2% of the world’s total aquaculture production.

A variety of experts are needed to unravel the history of aquaculture, which may include deciphering ancient writings and pictures, archaeological excavation, and carbon-dating. “Modern” aquaculture usually involves sophisticated technology, but does not necessarily imply “better” aquaculture. Many less developed countries still practice very successful, low technology aquaculture.

ACTIVITY 1: AQUACULTURE TIMELINE
Preparation
Student groups will need index cards and access to a world map and a world almanac.

Procedure
1. Using a map of the world and the overhead provided, trace the evolution of aquaculture through time. Point out that these dates are approximate. Determine whether students understand the B.C./A.D. distinction. Try to get students thinking about how timelines are created. How did historians trace the history of aquaculture back 3500 years?

2. Divide the class into three groups. Assign each group a particular area of the world such as the Americas, Europe, and Asia/Africa. Give each group a world almanac. Have each group brainstorm (with the help of the almanac and teacher) pivotal events in history in their region. Then choose five pivotal historical events and write down the event and date on an index card. Each group will also fill out an index card for any relevant aquaculture event in their region.
3. As a class, create a “History of the World Timeline” by pasting, taping, or stringing the various index cards from the three groups in sequence, to be displayed in the classroom or hall. Students will see the history of aquaculture in context with general events in history.

4. After the classroom timeline is complete, have the students from each group apply a “flag” or pushpin to a world map identifying their country or region and the date which reflects that country’s milestone in aquaculture history (e.g., Egypt, 2000 B.C.)

Discussion
1. How do the aquaculture systems and practices of the different area and time periods differ?
2. Is there a relationship between any historic event and a breakthrough in aquaculture?
3. What cultural beliefs might account for the acceptance of aquaculture in one area and not in another?
4. What predictions might you make for the future of aquaculture?
OVERHEAD
Aquaculture Timeline

3500 B.C. Aquaculture began in China. They raised carp, a hardy freshwater species, which is still raised in many parts of the world today. They also developed the use of polyculture, the art of growing different species together.

2000 B.C. Drawings dated back to 2000 B.C. indicate that Egyptians practiced aquaculture. They cultured tilapia, a warmwater species which is still cultured in many countries today.

800 B.C. Archeological evidence indicates that the Mayan Indians of Central America cultured fish in ponds and canals.

100 B.C. Romans practiced both freshwater and saltwater aquaculture. Fish such as trout and mullet were raised in ponds called “stews.”

400 A.D. Hawaiian Natives established an organized system of aquaculture which consisted of a variety of fresh and saltwater systems to raise several species.

1100 A.D. Aquaculture began in Central Europe with the culture of carp.

1800 A.D. France began experimenting with modern aquaculture techniques. By the mid 1800s, coldwater trout and salmon were cultured in France and other European countries.

1850 A.D. Trout and salmon were cultured in the United States for the purpose of restocking lakes and streams for anglers.

*Within the last century, aquaculture has expanded nationally and globally. A huge selection of fish, shellfish, and plants are cultured for a variety of purposes.*
ACTIVITY 2: GLOBAL GRAPHING

Information
Depending on the level of your students, the following activity can be modified to make it more or less challenging. For younger students, who may not be familiar with algebra, figures can be rounded to whole numbers, estimated, or given in proportions. This activity can work as an individual student exercise, as a take-home assignment, but ideally as a cooperative learning activity.

Preparation
Familiarize students with the countries and geographic areas for which they will be calculating aquaculture productivity: Asia, East Asia, West Asia, Africa, Eastern Europe, Western Europe, Western Hemisphere, etc. Review computational skills and graphing if needed.

Procedure
1. Divide students into cooperative learning groups. Give each student a copy of the student handout entitled *Global Graphing*.

2. Have students work through the mathematical problems and construct graphs.

3. Go over the problems as a class, inviting groups to provide answers.

4. Pass out a copy of the handout *Aquaculture Policy in the U.S.* This may be read in, before, or after class.

Discussion
- What role has the U.S. played in aquaculture in the past, present, and future?
- How does this relate to global aquaculture statistics and the aquaculture timeline?
STUDENT HANDOUT

ACTIVITY: GLOBAL GRAPHING

In 1988, the Food and Agricultural Organization (FAO) gave the following statistics for global aquaculture production:

1. In 1988, global aquaculture yield reached 14 million metric tons (mmt). If global fish production was 98 mmt, what percentage of this fish production was cultured?

   East Asian Countries (China, Japan, North and South Korea, Taiwan and the Philippines) produce three-fourths of the world's aquaculture production. China produces one-half of all East Asian aquaculture production.

2. How many mmt does East Asia produce?

3. How many mmt does China produce?

   West Asian Countries (Indonesia, Vietnam, Thailand, India and Bangladesh) together produce almost 1.5 mmt, bringing the Asian total to 12 mmt.

4. What percentage of global aquaculture production is made up by all of Asia?

5. Europe and the former USSR make up 10% of world aquaculture production. How many mmt does that work out to be?

6. Aquaculture in Africa makes up 0.5% of total aquaculture production. How many mmt is Africa producing?

7. The entire western hemisphere produces less than 5% of the total world aquaculture production. How many mmt does the Western Hemisphere produce?
8. The U.S. produces 0.3 mmt of cultured fish. What percentage of total aquaculture production does this amount to?

9. Draw a pie chart which shows the percentages of global aquaculture production for the following countries or areas: (Asia, Europe and former USSR, U.S, Africa, other)

10. Construct a bar graph (on the graph paper provided) of aquaculture production in mmt for the following countries or areas: (Asia, Europe and former USSR, U.S, Africa, other)

11. Based on your answers above, shown by the pie chart and the bar graph you generated, briefly assess global aquaculture production. Do you think it will change? Why do you think that countries within the Eastern Hemisphere culture more fish than the Western Hemisphere?

12. Of the species cultured globally, 4 mmt are algae, 3 mmt are mollusks (oysters, clam, mussels, and scallops) and 7 mmt are finfish. Of the finfish, most are freshwater carp and tilapia raised in Asia. Less than 1 mmt of all finfish cultured are marine. Determine the percentages of algae, mollusks, and finfish cultured and draw a pie diagram to represent the total.

   Algae:
   Mollusks:
   Finfish:

13. In the U.S., the species listed below are cultured. Construct a bar graph and/or pie chart which represents the distribution of species cultured in the U.S.

   Catfish - 49%
   Bait/tropical fish - 6%
   Others - 10%
   Salmon - 10%
   Trout - 9%
   Oysters - 5%
   Crawfish - 11%
HANDOUT (TEACHER COPY)

ACTIVITY: GLOBAL GRAPHING

In 1988 the Food and Agricultural Organization (FAO) gave the following statistics for global aquaculture production:

1. In 1988, global aquaculture yield reached 14 million metric tons (mmt). If global fish production was 98 mmt, what percentage of this fish production was cultured?

\[
(14/98 = X/100) = 14.3\% \text{ (of total global fish production came from aquaculture)}
\]

*East Asian Countries (China, Japan, North and South Korea, Taiwan and the Philippines) produce three-fourths of the world's aquaculture production. China produces one-half of all East Asian aquaculture production.*

2. How many mmt does East Asia produce?

\[
(14) (3/4) = 10.5 \text{ mmt}
\]

3. How many mmt does China produce?

\[
(10.5) (1/2) = 5.25 \text{ mmt}
\]

*West Asian Countries (Indonesia, Vietnam, Thailand, India and Bangladesh) together produce almost 1.5 mmt, bringing the Asian total to 12 mmt.*

4. What percentage of global aquaculture production is made up by all of Asia?

\[
(12/14) = X/100 = 85.7\%
\]

5. Europe and the former USSR make up 10% of world aquaculture production. How many mmt does that work out to be?

\[
(14) (.1) = 1.4 \text{ mmt}
\]

6. Aquaculture in Africa makes up 0.5% of total aquaculture production. How many mmt is Africa producing?

\[
(14) (.005) = .07 \text{ mmt}
\]
7. The entire western hemisphere produces less than 5% of the total world aquaculture production. How many mmt does the Western Hemisphere produce?

\[ (14)(.05) = 0.7 \text{ mmt} \]

8. The U.S. produces 0.3 mmt of cultured fish. What percentage of total aquaculture production does this amount to?

\[ (.3)(14) = X/100 = 2.1\% \]

9. Draw a pie chart which shows the percentages of global aquaculture production for the following countries or areas: (Asia, Europe and former USSR, U.S, Africa, other)

10. Construct a bar graph (on the graph paper provided) of aquaculture production in mmt for the following countries or areas: (Asia, Europe and former USSR, U.S, Africa, other)

11. Based on your answers above, shown by the pie chart and the bar graph you generated, briefly assess global aquaculture production. Do you think it will change? Why do you think that countries within the Eastern Hemisphere culture more fish than the Western Hemisphere?

12. Of the species cultured globally, 4 mmt are algae, 3 mmt are mollusks (oysters, clam, mussels, and scallops) and 7 mmt are finfish. Of the finfish, most are freshwater carp and tilapia raised in Asia. Less than 1 mmt of all finfish cultured are marine. Determine the percentages of algae, mollusks and finfish cultured and draw a pie diagram to represent the total.

<table>
<thead>
<tr>
<th>Species</th>
<th>Production (mmt)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>(4)/(14)</td>
<td>28.6%</td>
</tr>
<tr>
<td>Mollusks</td>
<td>(3)/(14)</td>
<td>21.4%</td>
</tr>
<tr>
<td>Finfish</td>
<td>(7)/(14)</td>
<td>50%</td>
</tr>
</tbody>
</table>

13. In the U.S., the species listed below are cultured. Construct a bar graph and/or pie chart which represents the distribution of species cultured in the U.S.

<table>
<thead>
<tr>
<th>Species</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catfish</td>
<td>49%</td>
</tr>
<tr>
<td>Bait/tropical fish</td>
<td>6%</td>
</tr>
<tr>
<td>Others</td>
<td>10%</td>
</tr>
<tr>
<td>Salmon</td>
<td>10%</td>
</tr>
<tr>
<td>Trout</td>
<td>9%</td>
</tr>
<tr>
<td>Oysters</td>
<td>5%</td>
</tr>
<tr>
<td>Crawfish</td>
<td>11%</td>
</tr>
</tbody>
</table>
Charts and Graphs

9. Global Aquaculture Production (in %)
10. Global Aquaculture Production (in mmt)
1 = Asia    2 = Europe    3 = Former USSR    4 = United States    5 = Africa & others

12. Species cultured in the U.S. (in %)
1 = Catfish    2 = Crawfish    3 = Salmon    4 = Trout    5 = Bait/tropical fish    6 = Oysters
7 = Others
Aquaculture Policy in the U.S.

In 1980, The National Aquaculture Act (P.L. 96-362) made aquaculture a national priority in the United States. The law was enacted because so many commercial fish had been depleted and our national fisheries trade deficit was rising. A trade deficit occurs when a nation imports more than it exports. The U.S. is the second largest importer of seafood in the world. Over the last 20 years, people in the U.S. have demanded more seafood, largely due to the health benefits associated with eating seafood. Less than 40% of the seafood we consume has been caught, harvested, or raised in the U.S. Therefore, the majority of the seafood we, as a nation, consume is imported from other countries. Between 1980 and 1990, aquaculture production in the U.S. tripled, making aquaculture the fastest growing type of agriculture in the U.S. However, the U.S. fishery trade deficit rose from 2.6 billion in 1980 to 5.5 billion in 1990, so we still have a long way to go if we want to reverse our trade deficit. We can no longer turn to traditional fisheries to solve the problem since they are in decline throughout the world, due to management problems, overfishing, and environmental problems. Instead, the U.S. could seize this major opportunity to develop an internationally competitive aquaculture industry.

Mariculture: An Unrealized Potential

Of the 0.3 mmt of fish cultured in the U.S., nearly three-fourths is grown in fresh water. These freshwater species include catfish, crayfish, rainbow trout, ornamental fish and baitfish for commercial, recreational, and stocking purposes. Marine aquaculture, or mariculture, makes up the remaining one-fourth of all cultured fish in the U.S. Oyster culture makes up the bulk of all maricultured species (80%). Clams, mussels, salmon, and shrimp make up the rest (20%).
MAKING CONNECTIONS: ADDITIONAL ACTIVITIES AND EXTENSIONS

- Have each cooperative learning group research aquaculture in a particular country, region, or continent. This research would give the students an opportunity to compare and contrast the way different countries practice aquaculture, and how it relates to their culture and politics. This group project could culminate in a research paper and/or a class presentation.

GLOSSARY

Aquaculture: The art, science, and business of producing aquatic plants and animals useful to humans. The controlled cultivation and harvest of aquatic animals and plants.

Carp: Hardy, freshwater fish cultured throughout much of the world.

Commercial: Those fish species which are raised or harvested for market sale.

Depleted: Decreased, used up, or emptied out.

Export: To send or transport a product to another country for trade or sale.

Harvest: To gather or capture fish for marketing and processing.

Import: To bring a product from a foreign country for trade or sale.

Mariculture: A type of aquaculture which cultures animals and plants in seawater.

Polyculture: Raising two or more species in the same pond or enclosure.

Tilapia: A warm, freshwater fish native to Africa, which is cultured throughout much of the world.

Trade Deficit: When a nation spends more money importing a product than it gains from exporting that product.

Traditional Fisheries: Business of harvesting wild aquatic organisms for sale.

ADDITIONAL RESOURCES


Aquaculture in Maine

KEY CONCEPTS
For many reasons, Maine is an ideal place for certain kinds of aquaculture, particularly mariculture. Since the 1970s, there have been many advances in culturing finfish, shellfish, and sea vegetables in Maine.

LESSON OVERVIEW
Students will read about and discuss the practice of aquaculture in Maine. Aquaculture sites in Maine will be identified and marked on a map. The class will collaborate on a class newsletter which focuses on aquaculture in Maine. Students will conduct an aquaculture survey at a local fish market and tour a local aquaculture facility.

LEARNING OBJECTIVES
After completing this chapter, the student will be able to:
- Explain major events in the history of aquaculture in Maine.
- Identify the three broad groups cultured in Maine (finfish, shellfish, sea vegetables).
- Identify the species cultured within the three groups.
- Locate aquaculture sites on a map of Maine.
- Explain the important cultural aspects of aquaculture in Maine.
- Identify environmental factors influencing aquaculture site locations.

LEARNING RESULTS
MAPPING MAINE'S AQUACULTURE SITES
K. Scientific Reasoning: Students will learn to formulate and justify ideas and make informed decisions.
   3. Develop generalizations based on observations.
L. Communication: Students will communicate effectively in science and technology.
   3. Make and use appropriate symbols, pictures, diagrams, scale drawings, and models to represent and simplify real-life situations and solve problems.

AQUACULTURE NEWSLETTER
L. Communication
   2. Use journals and self-assessment to describe and analyze scientific and technological experiences and to reflect on problem-solving processes.
   6. Evaluate the communication capabilities of new kinds of media.

FISH MARKET AQUACULTURE SURVEY
J. Inquiry and Problem Solving: Students will apply inquiry and problem-solving approaches in science and technology.
   1. Make accurate observations using appropriate tools and units of measure.
K. Scientific Reasoning
   3. Develop generalizations based on observations.
   4. Recognize the need to revise studies to improve their validity through better sampling controls or data analysis techniques.
MATERIALS
Large classroom map of Maine, map “flags” (colored pushpins) and labels (paper cut into small strips), copies of student handout Aquaculture in Maine, four copies of the Aquaculture Map, copies of student handout Fish Market Survey, copy of List of Aquaculture Facilities in Maine.

BACKGROUND
(The following information is an excerpt from The Maine Seacoast, Sherman Hasbrouck and Kathleen Lignell, a University of Maine Sea Grant publication, 1994.)

The Gulf of Maine
The Gulf of Maine is a body of water 70% enclosed by New England and Canadian land masses. It is really a “sea within a sea,” a 36,000 square-mile basin bounded on the ocean side by Georges Bank and other submerged shelves off Nova Scotia. (These shelves were mainly formed by glacial ice sheets that dredged huge amounts of materials from the mainland and deposited them on the ocean floor.)

The Gulf is a unique body of water because of its size, tidal action, and other characteristics. Its water circulation pattern—called the “Gulf of Maine gyre” is shown on the illustration below. Cold ocean water from the Scotian Shelf off Nova Scotia, runoff from rain and spring snowmelt, and winds and strong tides all contribute to the circulation pattern. (As satellite photographs show, areas of high biological production tend to occur where water movement is strong, especially along the coast and over Georges Bank.)

![Gulf of Maine illustration]

GULF OF MAINE

Tides currents, salinity (salt) levels, sedimentation, freshwater input, and cool temperatures all provide the special conditions that contribute to the abundant marine life in the Gulf. Especially important is the process of vertical mixing of bottom waters with surface waters.
The Gulf contains a number of diverse biological habitats and ecosystems that are linked and partially interdependent. The two primary habitat regions are the coastal region and the central gulf.

The coastal region consists primarily of rocky headlands, coves, bays, islands, and occasional sand beaches. Near-shore waters contain many fish species and marine mammals (including whales and harbor seals). The sea bottom in this region is composed of rocks and soft sediments on and in which an array of "benthic" (bottom-dwelling) organisms live (i.e., marine worms and other detritus-feeding organisms). There is also an abundance of rock crabs, sea scallops, ocean quahogs, and surf clams. The most familiar benthic creature is the American lobster.

In the central gulf region, the relatively warm bottom waters and moderate depths (around 500 feet) support a wide variety of fish: e.g., cod, haddock, pollock, swordfish, and redfish (ocean perch).

The Maine Seacoast
It is ironic that rising sea levels are now a matter of concern, since rising sea levels helped create Maine’s rugged sea coast. However, historic sea-level changes have been extremely gradual and hardly noticeable.

Yet those changes have had much to do with forming the physical, biological, and social character of Maine’s seacoast. Scientists call that coast a “drowned coastline.” As a geologically young coast, the sea has not yet had time to pound Maine’s seacoast flat. There has not been time for the shore to be weathered into a relatively smooth edge, where shifting sand deposits absorb much of the brunt of the ocean’s force. Rather Maine’s coast is a place where hard upland bedrocks meet the fury of the rising, incoming sea in full force.

There are, nevertheless, considerable differences in coastal areas in Maine, differences in physical character, marine life, and human settlement. To understand the Maine coast more fully, we must look at three coastal zones: the eastern coast, the midcoast, and the southern coast.

Maine’s southern coast extends from Casco Bay to the New Hampshire border. Although some sections are rocky, the southern coast is noted for its sand beaches. The sand was deposited by the glaciers of the last ice age over a large area. (In contrast, the sands of coastal areas below Cape Cod were created by thousands of years of shoreline erosion and weathering.) We thus find, in the southern coast, a shorter, more regular seacoast and

- fewer fish and shellfish areas than those elsewhere in coastal Maine;
- warmer waters than those elsewhere in Maine;
- little contamination of coastal waters; and
- intensive recreational use and tourism.

Maine’s midcoast extends from Penobscot Bay to Casco Bay. This coastal area is irregular, like the eastern coast, but shaped more by the rivers that flow southward into the Gulf of Maine. (These rivers drain well over half of Maine’s land area.) We find in the midcoast:

- river corridors, like the Kennebec, that historically linked Maine’s seacoast with interior forests, agricultural lands, and urban communities;
- Merrymeeting Bay, a large inland tidal area of water and wetland, where the Androscoggin River joins the Kennebec before the combined river flows to the sea;
• superb saltwater boating areas and dozens of protected harbors;
• competing space demands, in those same harbors, by commercial fishermen, recreational boaters, and tourism businesses;
• some pollution of bays and shellfish areas; and
• excellent aquaculture sites (though not comparable, in number and size, to those on Maine's eastern coast).

The eastern coast extends from Passamaquoddy Bay in the east to Penobscot Bay. On this coast we find:
• tides nearly twice as strong and high as those along the southern coast;
• a most irregular coastline with rocky headlands, thousands of islands, and many tidewater bays and salt marshes;
• cold waters and, especially toward the east, frequent foggy days;
• abundant fish, shellfish, seabirds, and other marine life;
• the prime habitat in the world of the American lobster;
• Cobscook Bay, a bay complex with unusually high, strong tides (and some of the best aquaculture sites in the world);
• relatively little urban development and tourism (aside from Mount Desert Island); and
• the largest extent of undeveloped coast remaining in the lower United States—the "bold coast" extending eastward from Machias Bay.

ACTIVITY 1: MAPPING MAINE'S AQUACULTURE SITES

Preparation
Distribute the two student handouts on Aquaculture in Maine prior to class.

Procedure
1. Have the students review the Aquaculture in Maine handouts at the beginning of class. Based on the student handouts, conduct a brainstorming session on aquaculture in Maine with your class. This could be done as a class activity or in cooperative learning groups. The goal is to have the class generate a list that describes Maine aquaculture which can later be reproduced and distributed. One way to facilitate the brainstorming session is to ask the class a series of questions to introduce the topic such as:
   • What makes the coast of Maine suitable for aquaculture?
   • What species are suitable for aquaculture in Maine?
   • How do fisheries and aquaculture complement each other?
   • How does technology influence aquaculture?
   • Why is it becoming so important to learn how to aquaculture cod, haddock, or halibut?

2. Divide the class into three teams and give each team a copy of the Aquaculture Map. As a class, go through the student handout and pick out all the aquaculture operations mentioned. Then locate them on a large class map of Maine. Mark each location with a clear pushpin and a label identifying the name of the aquaculture operation.
3. Under “Additional Resources,” there is a comprehensive list of current aquaculture operations in Maine. Copy and distribute the list to each student. Assign each of the three teams to one of the following categories: 1. finfish, 2. shellfish, and 3. freshwater hatcheries and sea vegetables. Distribute 25 pushpins (of one color) to each team, which will be named after the color of the pushpins they receive (i.e., blue team, red team, and green team).

4. Have each group identify the species cultivated within their category.

5. Have each group locate the aquaculture operations they are responsible for on their own map. Call on members of each group to come up and label aquaculture operations on the large class map. Students will label each site with a paper strip which will have the name of the aquaculture operation, and a colored pushpin.

Discussion
1. Where do you tend to see a concentration of finfish operations, shellfish operations, freshwater hatcheries, or sea vegetable growing sites?
2. What factors influence the locations of a particular type of aquaculture?
STUDENT HANDOUT
Aquaculture in Maine

In the early 1970s, a few entrepreneurs first experimented with commercial mussel, oyster, coho salmon, and rainbow trout farming in Maine. Since then, aquaculture has grown into a technologically advanced industry worth $57.5 million to harvesters in 1996. There are 1,282 acres of ocean leased for farming at 80 different sites. More than 690 people work full time on 25 aquafarms in Washington, Hancock, Lincoln, Knox, and York counties where they raise Atlantic salmon, steelhead trout, mussels, and oysters. In finfish culture, the harvest has grown from a 1988 landing of 1 million pounds to over 22 million pounds in 1996. Research conducted by Maine scientists may make raising cod, haddock, and halibut practical and cost-effective in the future.

Because Maine has protected bays with generally clean and nutrient-rich waters with large tides, the entire coast is suitable for aquaculture in one form or another. The greatest concentration of finfish operations is in Downeast Maine where winter water temperatures tend to be higher than the deep narrow estuaries west of Penobscot Bay. Most shellfish farms are in the midcoast region. Maine’s lakes, with their abundance of clean water, are also ideal places for freshwater finfish hatcheries.

Although sometimes seen as rivals, aquaculture and traditional fisheries can complement each other. Several projects in the state prove the beneficial relationship between the two. Aquaculture can provide off-season or additional jobs for people involved in traditional fisheries, and fishermen can apply their skills and know-how to aquaculture.

Maine’s strategy for developing aquaculture in the state has included promoting cooperation among university and technical college researchers, industry and government personnel, and those involved in traditional fisheries and aquaculture. Maine is committed to encouraging the development and distribution of information on aquaculture, developing a positive investment climate for small entrepreneurs, coordinating aquaculture and traditional fisheries, and ensuring efficient and effective regulations while monitoring and preserving coastal water quality.

Maine’s Aquaculture History: A Closer Look

Finfish

Commercial finfish aquaculture began in Maine in 1970 near the midcoast town of Wiscasset. Richard Gower, Evelyn Sawyer, and Gary Towle formed Maine Salmon Farms, the first commercial salmonid pen culture operation on the east coast, and the second in the U.S. They raised rainbow trout and coho salmon in floating net pens and fed them a homemade concoction of shrimp and herring waste from a local fish meal plant. High water temperatures during the summer and low water temperatures during the winter were factors in the collapse of their business.

Also in the 1970s, Robert Mant started Maine Sea Farms on Cape Rosier. He raised coho salmon and rainbow trout in pens that floated in the flooded pit of a former 300-foot-deep, open-pit, copper and zinc mine. In another part of Penobscot Bay in 1973-74, Spencer Fuller started a Vinalhaven-based company, Fox Island Fisheries, which was probably the first strictly marine salmon pen operation in the Northeast. By 1975, Fuller’s company was producing 40,000 pounds of fish in Hurricane Sound. The combination of the 1976 superchill, when the seawater temperature at the site dropped to 29.5°F, and the low price for fish caused the company to close by 1979.

In 1981, Edward Myers of Abandoned Farm, Inc. on the Damariscotta River, obtained the
first lease from the Maine Department of Marine Resources, allowing the culture of salmon and shellfish at his site. Using 5,000 coho salmon, Myers set up pens about eight miles from the open sea. That winter, water temperatures fell to 28°F. and only 150 fish survived. Myers abandoned finfish cultivation to concentrate on mussel culture.

By the early 1980s, pen-rearing techniques improved, and raising salmon and rainbow trout became a promising new business in Downeast Maine. In Eastport, where the decline of the local herring fishery made salmon aquaculture a welcomed new industry, Ocean Products Inc. (OPI) was established in 1982. By 1984, the company had 12 pens holding about 63,000 fish. Some of the fish were smoked and sold through L.L. Bean's mail-order catalog.

A second generation of sea farmers in the Eastport area came mostly from former employees of OPI, local families formerly involved in herring fishing, or were graduates of an aquaculture training course at Washington County Technical College. These people formed small, mostly family-run businesses in 1986-87. Their examples were soon followed by large firms, some of them multinational, including Maine Coast Nordic Enterprises, Sea Farm Lubec, Atlantic Salmon Maine, and Mariculture Products, Ltd.

Currently, 12 companies along the Maine coast, from the Canadian border to Muscongus Bay in the midcoast region, raise about 22 million pounds of salmon each year. Maine fish farmers and scientists are researching nutrition and feeding methods, predator controls, and alternative species of fish for culture.

Shellfish

In the 1970s, a few small oyster and mussel farms pioneered raising shellfish. The industry grew slowly, but the 1980s brought promising changes. In mussel and oyster farming, bottom culture techniques were developed to allow growers to produce their crops more efficiently. According to 1989 data, for every 1,000 acres of ocean bottom planted with oysters, about $35 million worth of shellfish could be harvested each year. Also in the 1980s, the Beals Island Regional Shellfish Hatchery began to spawn soft-shell clams and educate clam diggers and the public about the life cycle of clams and ways to restock depleted clam flats.

Sea Vegetables

Aquaculturists in the 1990s began to investigate the culture of nori, a species of algae native to the Pacific and most familiar as the seaweed wrappers for sushi. Japanese delicacies made of raw fish, vegetables, and rice. In Cobscook and Penobscot bays, large nets seeded with nori were placed in areas where strong currents could provide the necessary nutrients and oxygen-carbon dioxide exchange needed by the seaweed. The harvested seaweed is sent to Eastport for processing on a press (the only one of its kind in the Western Hemisphere) that turns out paper-like sheets of dried nori, for the growing U.S. market.
ACTIVITY 2: AQUACULTURE NEWSLETTER

Information

A class newsletter provides an excellent opportunity to engage students of all abilities in a class project. The newsletter should concentrate on local events which are more relevant to the students and the community. The following could be included: personal interviews with members of the community, summaries of articles from local papers and magazines, photographs, artwork, poetry, editorials, comics, supermarket inventories of aquaculture products, recipes, web site reviews, etc. The newsletter can be an ongoing project throughout the unit. After it is completed, it can be displayed in the school or distributed throughout the local community to educate others.

Depending on the age and ability of your students and your teaching objectives, the format of the aquaculture newsletter activity can be modified to suit your needs. It could simply be a teacher compilation of student work, a sophisticated newspaper, or a magazine. Access to a personal computer would provide a good opportunity to experiment with some simple graphic design, graphing, and word processing.

Procedure
1. Introduce the idea of a class newsletter about aquaculture.

2. As a class, generate a list of various components which ought to be included in the newsletter.

3. Have students choose which areas of the newsletter they would like to be responsible for and divide the students up into groups based on their interests.

4. Have groups work on their part of the newsletter.

5. As a class, discuss the design of the newsletter and how to incorporate everyone’s work into a final product.

6. Compile and merge the various components to form the class newsletter.

7. Publish and distribute the newsletter.

ACTIVITY 3: FISH MARKET AQUACULTURE SURVEY

Preparation

Locate a few local fish markets and inform them that students will be stopping by to ask them questions about their fish and shellfish products. Students may visit these fish markets individually, with their family, or as a class.

Procedure
1. Distribute and explain the student handout Fish Market Survey.

2. Have students discuss the purpose in conducting this survey.

3. Have students visit a local fish market. If possible, encourage students to survey different fish markets for comparison.
4. At the fish market, have the students fill out the inventory sheet so that they can distinguish between products that are coldwater, warmwater, marine, cultured or wild caught. They can also record the packaging of the product (fresh, frozen, canned, etc.) Students should also be aware of price and quality differences between cultured and wild caught fish products.

5. Share and compile students' findings in class.

Discussion
1. In what ways does aquaculture impact the economics of the fish market?
2. What influences might a producer, a retailer, or a consumer have on the market?
3. Does the fish market sample represented by the class results adequately represent fish markets in the State of Maine? How might the study be revised to improve its validity?
# STUDENT HANDOUT

## Fish Market Survey

<table>
<thead>
<tr>
<th>Product Name (Species)</th>
<th>Freshwater (Cold/Warm)</th>
<th>Marine</th>
<th>Wild Caught</th>
<th>Aquacultured</th>
<th>Price /lb</th>
<th>Origin</th>
<th>Packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flounder</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>Gulf of Maine</td>
<td>Frozen at sea</td>
</tr>
</tbody>
</table>

Name/Location of Fish Market:

**Questions:**

1. How many species were wild caught?

2. How many species were produced by aquaculture?

3. What is the proportion of wild caught species to aquacultured species?

4. How many species were produced locally (in Maine)?

5. Why does one species of a fish cost so much more than another?

6. Are aquacultured products more or less expensive than products caught in the wild?

7. What time of year did you visit the market? How would prices change at another time of year? Are there any species that are only available at a certain season?
<table>
<thead>
<tr>
<th>TYPE</th>
<th>SPECIES</th>
<th>CULTURE</th>
<th>COMPANY</th>
<th>LOCATION</th>
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</thead>
<tbody>
<tr>
<td>Shellfish</td>
<td>M</td>
<td>S,P</td>
<td>Abandoned Farm</td>
<td>South Bristol</td>
</tr>
<tr>
<td>Shellfish</td>
<td>O,C</td>
<td>B</td>
<td>Associated Sea Farms</td>
<td>Newcastle</td>
</tr>
<tr>
<td>Shellfish</td>
<td>M</td>
<td>B</td>
<td>Beal, Isaac</td>
<td>Beals</td>
</tr>
<tr>
<td>Shellfish</td>
<td>C</td>
<td>F</td>
<td>Beals Is, Reg. Shellfish Hatchery</td>
<td>Beals</td>
</tr>
<tr>
<td>Shellfish</td>
<td>M,O,C,Sc</td>
<td>F,B</td>
<td>Chance Along Farm</td>
<td>Freeport</td>
</tr>
<tr>
<td>Shellfish</td>
<td>O</td>
<td>S</td>
<td>Dodge Cove Marine Farms</td>
<td>Damariscotta</td>
</tr>
<tr>
<td>Shellfish</td>
<td>C</td>
<td>B</td>
<td>Federal Harbor Farms</td>
<td>Lubec</td>
</tr>
<tr>
<td>Shellfish</td>
<td>O</td>
<td>S</td>
<td>Glidden Point Oyster Co.</td>
<td>Newcastle, S. Bristol</td>
</tr>
<tr>
<td>Shellfish</td>
<td>M</td>
<td>B,S</td>
<td>Great Eastern Mussel Farms</td>
<td>Jonesport, Deer Isle, Lamoine</td>
</tr>
<tr>
<td>Shellfish</td>
<td>O</td>
<td>F,B</td>
<td>Hog Island Shellfish Inc.</td>
<td>Newcastle</td>
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<tr>
<td>Shellfish</td>
<td>O,C</td>
<td>B,S</td>
<td>Marine Bioservices Co.</td>
<td>Damariscotta</td>
</tr>
<tr>
<td>Shellfish</td>
<td>O,C,Sc</td>
<td>F,B</td>
<td>Mook Sea Farms, Inc.</td>
<td>Newcastle</td>
</tr>
<tr>
<td>Shellfish</td>
<td>O</td>
<td>B</td>
<td>Pemaquid Oyster Co.</td>
<td>Damariscotta, Newcastle</td>
</tr>
<tr>
<td>Shellfish</td>
<td>O,C</td>
<td>B</td>
<td>Spinney Creek Shellfish</td>
<td>Eliot</td>
</tr>
<tr>
<td>Shellfish</td>
<td>M</td>
<td>S,B</td>
<td>Thompson, Paul</td>
<td>Cutler</td>
</tr>
<tr>
<td>Shellfish</td>
<td>O</td>
<td>B</td>
<td>York Harbor Oyster</td>
<td>York</td>
</tr>
<tr>
<td>Finfish</td>
<td>S</td>
<td>S,P</td>
<td>Atlantic Aquafarms</td>
<td>Sorrento, Eastport, Machiasport, Cutler, Harrington</td>
</tr>
<tr>
<td>Finfish</td>
<td>S</td>
<td>P</td>
<td>Atlantic Salmon of Maine</td>
<td>Perry</td>
</tr>
<tr>
<td>Finfish</td>
<td>S</td>
<td>P</td>
<td>Birch Point Fisheries</td>
<td>Lubec, Eastport</td>
</tr>
<tr>
<td>Finfish</td>
<td>S</td>
<td>P</td>
<td>Connors Aquaculture, Inc.</td>
<td>Lubec, Eastport</td>
</tr>
<tr>
<td>Finfish</td>
<td>S</td>
<td>P</td>
<td>Cooke Aquaculture U.S., Inc.</td>
<td>E. Orland</td>
</tr>
<tr>
<td>Finfish</td>
<td>S</td>
<td>T</td>
<td>Craig Brook National Fish Hatchery</td>
<td>Lubec</td>
</tr>
<tr>
<td>Finfish</td>
<td>S</td>
<td>P</td>
<td>D.E. Salmon Company</td>
<td>Lubec, Pembroke</td>
</tr>
<tr>
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1 M - mussel  O - oyster  C - clam  S - salmon  T - trout  A - arctic char  N - nori
2 B - bottom  F - floating  S - suspended  P - pen  T - tank

This chart was compiled by the project's curriculum consultants from data provided by the Maine Department of Marine Resources, Maine Aquaculture Innovation Center, extension agents, and industry contacts.
To Culture or Not to Culture:  
The Controversy Continues

KEY CONCEPTS
Aquaculture, like any other industry, has its costs and benefits, as well as its proponents and opponents. As a result, there are impediments to aquaculture development in Maine. Some of the concerns expressed about aquaculture are valid, while others are steeped in misconceptions and misunderstandings about the nature of aquaculture in Maine. An active, involved, and informed community is needed to determine whether or not aquaculture is suitable for their community and coastal waters. Comprehensive federal and state regulations are necessary to insure that an aquaculture venture does not compromise the integrity of the community and the natural environment.

LESSON OVERVIEW
Students will discuss some of the pros and cons related to aquaculture. As a class, the students will discuss the hypothetical case studies provided. In cooperative learning groups, students will engage in an aquaculture debate in the style of a town meeting.

LEARNING OBJECTIVES
After completing this chapter, the student will be able to:

- Describe the impediments to aquaculture development in Maine.
- Describe the pros and cons of an aquaculture industry in their community.
- Describe the position of several community groups regarding aquaculture development.
- Work cooperatively in groups to solve real life problems.
- Adopt a position and defend it effectively.
- Demonstrate critical thinking skills.
- Demonstrate public speaking skills.

LEARNING RESULTS
AQUACULTURE DEBATE/TOWN MEETING

B. Ecology: Students will understand how living things depend on one another and on non-living aspects of the environment.

1. Analyze the impact of human and non-human activities on the type and pace of change in ecosystems.

K. Scientific Reasoning: Students will learn to formulate and justify ideas and to make informed decisions.

1. Judge the accuracy of alternative explanations by identifying the evidence necessary to support them.
2. Show that agreement among people does not make an argument valid.
3. Produce inductive and deductive argument to support conjecture.
4. Analyze situations where more than one logical conclusion can be drawn.

L. Communication: Students will communicate effectively in science and technology.

1. Debate opposing points of view using a common set of information.

M. Implications of Science and Technology: Students will understand the historic, social, economic, environmental, and ethical implications related to science and technology.

3. Evaluate the ethical use or introduction of new scientific or technological developments.
MATERIALS
Copies of student handout To Culture or Not to Culture, overhead Aquaculture: Arguments For and Against, overhead projector.

BACKGROUND
Why does the U.S. lag behind so many other nations in aquaculture production?

Even though national policy is aimed at encouraging aquaculture initiatives, there are still many barriers to starting new aquaculture ventures including:

- **Economics**
  Starting a new aquaculture venture is expensive, it requires a large initial capital investment, and it may be quite some time before entrepreneurs begin to see a profit. Banks may be skeptical about loaning out large sums of money to small aquaculture entrepreneurs. As a result, new aquaculture enterprises often favor large businesses over smaller, community operations.

- **Environmental issues**
  Not every body of water can serve as a site for an aquaculture facility. There are very specific requirements which must be met. For example, to raise freshwater trout, you must have a continuous supply of very cold water. For salmon, or other mariculture finfish, you must have very strong tides to disperse the waste produced from the finfish or you risk polluting the surrounding waters. For mollusks, you must have nutrient-rich water. Culturing shellfish and sea vegetables rarely have any negative environmental consequences.
  Mariculture operations are always at the mercy of mother nature. Storms and other oceanographic and meteorological conditions can wreak havoc on one's culturing operation. A specific threat to mariculture shellfish is a tiny organism called fecal coliform bacteria which can enter the water via sewage, particularly during times of flooding. In spite of all these hazards, Maine has an excellent marine environment for raising mariculture fish, shellfish, and algae because of its high tides, strong currents, and nutrient-rich water.

- **Opposition**
  Probably the biggest barrier to starting new aquaculture ventures is local public opposition. Although there are many people who support and encourage a growing aquaculture industry, there are others who oppose such growth.

*In 1990, the Maine Coastal Program at the State Planning Office published An Aquaculture Development Strategy for the State of Maine which listed several impediments to aquaculture development in Maine:*

1. Lack of information about aquaculture development such as production technology.
2. Lack of a lead state agency to coordinate action and state services to provide programs in training, inspection, and grading (sorting fish by size).
3. Lack of research and development coordination between federal, state and university research organizations.
4. Lack of public understanding about the nature of aquaculture, specifically that success of aquaculture ventures depends on good environmental quality in Maine’s coastal waters.
5. Lack of adequate organized market institutions for sale of cultured seafood.
In response to these impediments, a strategy was developed which was designed to reduce or remove the impediments listed above. The strategy included the following goals:

1. Develop and disseminate information about aquaculture.
2. Cultivate a positive investment climate for small entrepreneurs.
3. Designate a lead state agency to support development of aquaculture.
4. Develop a comprehensive regulatory process.
5. Include traditional fisheries.
6. Protect, preserve, and enhance coastal water quality.
7. Develop a comprehensive plan for use of coastal waters.

Since 1990, state officials have been working to achieve the above goals and encourage the growth and development of aquaculture in Maine. Many Maine organizations have helped realize this goal such as: Maine Department of Marine Resources, Maine Aquaculture Innovation Center, Sea Grant College Program, and the University of Maine system.

**Economic issues include:**

- Regulatory/permitting costs
- Capital costs
- Operating costs
- Marketing factors
- Foreign competition and trade

To be economically successful, feed and feeding practices must be cost-effective to yield more growth with minimal pollution impacts. An aquaculture operation must maintain a clean environment if it is to survive.

**Environmental Issues include:**

- Waste from cages or ponds
- Introduction of non-native species and/or disease
- Culture operation infrastructure in public waters
- Genetic alteration of wild stocks through escapement of cultured animals or intentional releases for stock enhancement
- Dealing with fish predators which are protected by law such as seals and eagles

**Benefits of a healthy U.S. marine aquaculture industry include:**

- Healthy food to replace diminishing wild stocks
- Export crop to decrease trade deficit
- Enhancement of commercial and recreational fisheries
- Economic opportunities for rural communities
- New jobs for skilled workers
ACTIVITY 1: AQUACULTURE DEBATE/TOWN MEETING

Preparation
Prior to class, have the students read the hypothetical case study about the two island communi-
ties.

Procedure
1. As a class, or in cooperative learning groups, develop a possible pros and cons list for aquacul-
ture or use the overhead provided.

2. Give the students a chance to review the student handout To Culture or Not to Culture describ-
ing the hypothetical case study of Gull and Tern Islands. Engage the class in a discussion about
the case study. How and why did each community reach such different conclusions about the
issue of salmon farming?

3. Introduce the idea of a town meeting or debate in which various members of the community
come together to reach a consensus on an issue or proposal which will affect their community.
Explain that the class will conduct their own town meeting to decide whether to permit the
establishment of an aquaculture venture in their community.

4. The class must first set the parameters of the aquaculture site that is being proposed:
   • Will the company be culturing finfish, shellfish, or sea vegetables? What species?
   • Will the site be warmwater, coldwater, or marine? A river, estuary, shorefront, or deepwater?
   • Is the area already used by others? By whom?

5. In the aquaculture debate, groups of students will adopt a position on aquaculture (role-play-
ing) and defend it in a town meeting. Possible roles include: fisherman, lobsterman, coastal
homeowner, vacationer, local/state politician, small aquaculture entrepreneur (local), large aqua-
culture entrepreneur (international), or conservation group. Before the debate, stress the pro-
fessionalism and decorum which ought to take place in a town meeting. Establish a set of
guidelines based on mutual respect so that the debate does not degenerate into a shouting match.
Positions can include stipulations such as: “I support aquaculture in the community if x, y, and z
are included.” You may need to stress that the point of a debate is to adopt the position of the
group and defend that position. The position may or may not reflect the students’ own opinions.
Therefore, students ought not to feel personally attacked and have the advantage of learning
how to argue positions other than their own. Students should gain an understanding of the
complexity of community issues.

6. Break the class up into as many groups as there are roles. Assign (or let the groups choose for
themselves) a different role for each cooperative learning group. You may want to provide a
“blurb” describing each group’s general position on aquaculture. However, be careful not to
pigeonhole groups into black and white categories. There can be advantages to letting the
students struggle with defining the roles of these groups themselves, rather than providing
them with a predetermined “script.” Encourage groups to approach this as a real-life scenario.
7. Give students some time to prepare their case. Each group will be given 2-3 minutes to present their case. After all groups have spoken, any group is entitled to "counter" or challenge another group's argument. It is important that the group that is challenging another group be given a time limit and that the group being challenged has the opportunity to respond to that challenge. Stick to one challenge and response per group.

8. After the debate is over, individuals will be asked to vote on whether or not they want to start an aquaculture venture in their community and any stipulations. Write the final decision on the board or overhead and then list the reasons and/or stipulations for the decision.

Discussion
What would you do to encourage aquaculture if you were on a special governor's committee?
Aquaculture: Arguments For and Against

FOR

Aquaculture...

1. Can increase employment in your community.
2. Can increase revenue in your community, resulting in better schools, parks, community programs, etc.
3. Can increase state and national revenue.
4. Can reduce the seafood trade deficit.
5. Can restore depleted native fish populations.
6. Can feed a growing population.
7. Can encourage local investment.
8. Can increase scientific knowledge and technology.
9. Can place more emphasis on protecting coastal waters from pollution.

AGAINST

Aquaculture...

1. Can occupy bottom formerly utilized by lobstermen and fishermen.
2. Can compromise the aesthetic beauty of our coastline.
3. Can alter the benthic (bottom) communities under coastal finfish pens.
4. Can add excess nutrients (fish feed and wastes) to coastal waters.
5. Can add chemicals and antibiotics to coastal waters.
6. Can be too expensive for small local companies because of large start-up costs.
7. Can compromise native gene pools if cultivated and native species interbreed.
8. Can threaten the livelihood of fishermen and lobstermen.
9. Can be an unpredictable enterprise for small local communities due to its susceptibility to severe weather, predators, disease, and global competition.
To Culture or Not to Culture . . . That Is the Question

Two island communities in Maine were approached by salmon farming entrepreneurs. One community said yes the other said no. Why?

In the late 1980s, both Gull Island and Tern Island were approached by separate companies wishing to establish net-pen salmon farming operations off their islands. The majority of the year-round residents on Gull Island and Tern Island make their living lobstering. While the residents of Tern Island fiercely rejected the proposal for net pen salmon farming off their island, the residents of Gull Island grappled with the proposal for some time and eventually decided to accept it and try salmon farming, hoping to supplement their traditional fishing income. What prompted these two similar communities to have such different responses to salmon farming in their coastal waters? Let’s take a look at these two different approaches.

Tern Island

In 1987, a representative from Salmon Servers Inc. submitted a proposal for a 10-year lease of 25 acres of ocean bottom off Tern Island. The residents of Tern Island were first introduced to the proposal at a public hearing. No attempt was made to introduce the idea to Tern Island’s residents prior to the hearing, and the people of Tern Island were not pleased about being left in the dark.

The proposed 25-acre lease area was prime lobster and scallop area, used heavily by the lobstermen and fishermen of the island. The fishing community was concerned about not having access to those 25 acres and also about the effect the net pens would have on the surrounding bottom. They feared contamination of the bottom and the surrounding coastal water from fish food and waste, antibiotics used in the pens, chemicals used in the fish foods, and diseases spread by the cultured salmon. Another fear was that escaped salmon could mix with wild salmon and negatively affect the local native salmon species. Many of these fears were valid, while others were not. Many of the contamination issues which had been problems in past net-pen ventures in Norway and Sweden, had since been resolved.

The effect of aquaculture on the local economy was another issue for the residents of Tern Island. While Salmon Servers Inc. promised economic gain, residents feared that the big corporation would bring workers from off-island. Residents researched the job total and determined that there would be only three to five jobs available per farm which might not make up for the money lost from the 25 acres of bottom leased to Salmon Servers Inc.

Another issue was tourism. Tourists and summer residents alike are attracted by the beauty of the island. In the summer, the size of the island swells from 1,200 to 6,000. Islanders feared the salmon pens would be an eyesore which would compromise the natural beauty of the island, deter tourists, and reduce the property value of their homes. Due to community opposition, Salmon Servers Inc. withdrew its proposal.

Gull Island

Soon after the Tern Island aquaculture fiasco, Gull Island was approached with a different salmon culturing proposition. Initially, a representative of Salmon Lovers Ltd. came to the island to speak with members of the Gull Island Fisherman’s Coop. Members of the community were invited to several informative discussions to decide whether they were interested in exploring salmon
farming as an option. Although there was a great deal of negative aquaculture propaganda floating around the community, there was little concrete information. Keeping an open mind, the Gull Island Fisherman's Coop thoroughly researched salmon farming, and visited salmon farms in New Brunswick.

Many of the salmon farms that Gull Island residents visited were small operations run by former and current fishermen and lobstermen. Because of the strong tidal action in the Gulf of Maine, there was no buildup of feed or waste under the pens, and scallop and lobster populations in and around the pens were healthy. The two antibiotics which were used in the salmon pens were both approved by the U.S. Food and Drug Administration (FDA) and were commonly used in lobster pounds. The contamination problems such as those experienced in Norway had resulted from overcrowding, shallow sea pens, and inadequate tidal current. These problems were remedied once the sea pens were moved from the still water fjords to the open oceans. Salmon farmers frequently commented that if the net-pen salmon were to contaminate the surrounding water or bottom in any way, the salmon themselves would be the first ones to suffer.

Although the Gull Island fishing community was sufficiently convinced about the merits of aquaculture to continue exploring salmon farming as an option, there was still opposition from members of the community. Some residents were concerned about the potential environmental problems associated with aquaculture. Other members were concerned with the aesthetic value of their coastline and the affect that salmon farms could have on the property value of their homes. Much of the opposition came from summer residents and tourists.

Ultimately, there was greater support for salmon farming than there was opposition to it. Salmon Lovers Ltd. offered to help set up any member of the community who wanted to get involved in salmon farming, so a mutually beneficial partnership was established. Gull Island began salmon farming very conservatively, with seven, well-spaced pens on 18 acres. They purposefully understocked the pens to avoid problems associated with overcrowding. As a result of their caution, no antibiotics were necessary and the salmon and the surrounding bottom community were healthy.
GLOSSARY
Antibiotic: A chemical compound which can inhibit reproduction or cause the destruction of bacteria.
Benthic: Bottom-dwelling organisms in an ocean community.
Compromise: An agreement between two parties in which each side makes concessions.
Contamination: Polluted or impurity caused by contact with another substance.
Deficit: The quantity by which an amount is less than the needed amount.
Entrepreneur: A person who takes on the risk of a business venture hoping to profit.
Fecal Coliform Bacteria: A rod-shaped microorganism found in the solid waste of humans and some other animals. These bacteria render water supplies unusable.
Investment: The money put into a business.
Pelagic: Organisms living in ocean waters away from the shore or bottom.
Public Hearing: A meeting to discuss or resolve an issue. The general population is invited.
Net-pen Salmon Farming: An aquaculture technique using nets to form holding pens for salmon.

MAKING CONNECTIONS: ADDITIONAL ACTIVITIES AND EXTENSIONS
  • Survey/Questionnaire
    Have students create a survey/ questionnaire to determine how members of the community would feel (or do feel) about having an aquaculture facility in their community. Have them survey family, friends, and members of the community and share their results with the class. Students may also choose to tape a personal interview with someone who has an interesting point of view.
  • Marine Issues
    Divide students into groups and have each group monitor one local marine issue or controversy involving fisheries and/or aquaculture.

ADDITIONAL RESOURCES