Water Scarcity and Conservation

Introduction — Time: 10 minutes

One of the key factors in sustainable food production systems is to **protect and conserve the natural resources on which food production depends.** Water is a critical resource for all aquacultural production. It must be available in sufficient quantity, at a high enough quality, and at a cost that makes its use for aquacultural production possible. This lesson will focus on where water comes from, how we use it for many purposes, and how aquaculture farmers can help conserve water.

Read the *Background Material on Water Use in Aquaculture* (pages 5-8). This material will help you become familiar with the key sources of water used in the U.S. and in the aquaculture industry and the ways it can be conserved. You may want to make transparencies of pages 9-15 to help explain the ideas included in this material. You can also assign these pages as a homework assignment for students with a ***9th grade or higher reading level***, but we suggest that you explain the concepts yourselves for students with lower reading levels.

Getting Ready — Time: 30 minutes

Write on the chalk board: ***Water is a critical natural resource.*** Now ask the students how we use water. Use a circular whip technique in which every student must quickly explain at least one important use of water. Write down the responses on the board in two columns.

Group the students into two teams assigning each team half of the list of water uses written on the board. Have each team nominate a recorder to write their ideas for conserving water (ways to use less or save water) as quickly as possible on the board next to each water use. The winners are the team that generates the most conservation methods in 10 minutes.

Select the three water use categories that have the most conservation practices listed next to them. Tally the number of students in the class that are doing or know someone who is doing that particular practice by asking the students to raise their hands. Record the number doing the practice and divide by the number of students in the class to get a percentage. Now ask the students to discuss their ideas why people do or do not use more water conservation practices.

Doing the Activity — Time: 2 hours of class time and a four day experiment

Hand out the student page *Testing a Water Conservation Practice.* Explain that this will be a four day experiment to see how much water could be conserved in North America.

Purpose

To explore where water comes from, its use and how it can be conserved in aquaculture production

Key Concepts

Sustainable food production systems must conserve the natural resources on which food production depends.

Learning Objectives

Students will be able to:

- Describe the water cycle
- Compare how much water is used by different sources
- List several water conservation practices for domestic, industrial or agricultural purposes
- Test one water conservation practice and calculate savings in both water and money from using the practice

Subjects

Science
Mathematics

Students can choose any water saving practice to test. Alternatives suggested by teachers include: (1) water used to brush teeth, (2) time and flow rates for showers, (3) giving students a one gallon jug of water and having them record what they can use it for and (4) calculating the evaporation from the school's fish tanks. As an example, we describe a way to test the water that can be saved in flushing toilets.

Families in North America use the most water to flush the toilet. For the first two days, students will record the number of times they use the toilet and the amount of water used. During this time they should be collecting milk jugs or soda containers in order to have enough of them to place one in each of the different toilets they usually use. During days three and four of the study, students will fill the selected containers with water and place them in the water storage tank of the toilets that they normally use. They will then record the number of times they use the toilet and the amount of water used for this conservation practice. If, for some reason, they cannot actually place the container in the toilet, they should estimate how much water they would have saved if the container had been in place.

If students live in homes with low-flow toilets (3 gallons or less), or if students want to evaluate the water saved by other conservation practices as well, we suggest the following possibilities. Compare the water used if water is left running while brushing teeth to the amount used if the water is turned off while brushing. Compare the water used in washing dishes by hand to that used by a dishwasher. Compare taking a shower vs taking a bath.

After completing the experiment, students should calculate the total amount of water used with and without the conservation practice, find the difference between the two, and calculate the value of the water that was saved by using the conservation practice. To calculate the value, students will have to find out the cost of water in their community (usually indicated per 1,000 gallons). Tally the results from the entire class and calculate the amount of water saved and its value.

Key Points for the Discussion Questions

Bring closure to the lesson by having the students discuss the following questions.

- How much water was saved by using the conservation practice? What was the dollar savings?
- What difficulties did you have in doing the conservation practice? Did it make you more aware of how you use water at other times?
- What natural resources could be conserved at your school's aquaculture facility?
- List several ways that aquaculture producers conserve water or other natural resources.

Materials

Pencils
Calculato:
Half gallon or gallon milk jugs or soda containers with lids
Transparencies of 9-15.
Copies of Student Pages 16 and 17

Extensions

Can We Save Water in Our System?
Students can brainstorm ways to save water in their aquaculture system. Discuss what the possible impacts would be on the fish and the water quality of the system. Students can research how commercial aquaculture producers conserve water either through a telephone survey or visit to a producer or extension agent or through a library or Internet search. Would any of the ways commercial producers conserve water work in their aquaculture system? Have them discuss why or why not.

Possible Answers. (1) Control evaporation. (2) Integrate - reuse water in a greenhouse, for example. (3) Recycle (closed loop system). (4) Minimize the sump. (5) Don't fill the pond completely full, leave some space to hold rainfall. (6) Cover tanks to minimize splash and evaporation.

Quiz Questions

- Describe where we get most of the fresh water that we use.

Answer: Rainwater is where most of our fresh water comes from.

- Who uses more water for domestic consumption (toilet flushing, washing dishes, etc.), the U.S., Mexico, or Canada?

Answer: The U.S.

- Describe the relationship between the price of water and consumption of water. Why is this important?

Answer: In general, consumption goes down when the price of water goes up. This implies that one very effective way to get people to reduce water use is to increase the cost of water.

- What is the biggest use of water in agriculture? How can farmers conserve water resources?

Possible Answers: Irrigation is the biggest use in agriculture. Farmers can save water by using more efficient irrigation systems, recycling water, or growing crops that need less water.

- Explain how water is lost in aquaculture pond systems. List two ways that fish farmers can conserve water?

Possible Answers: Evaporation, seepage, and release of pond water cause water loss in aquaculture systems. Ways to conserve water include sealed ponds, covered ponds, and recycling water.

Want More Information?

Hartman, M.C. 1989. *Manual for the Design and Operation of a Low Budget Hatchery for the Hard Clam* Mercenaria mercenaria *in Florida.* Florida Department of Agriculture and consumer Services, Division of Marketing, Tallahassee, FL. 28 p. NAL Call No. SH373.2.F6H37 1988.

Pote, J.W.; Wax, C.L. and Tucker, C.S. 1988. *Water in Catfish Production: Sources, Uses and Conservation.* Mississippi Agricultural and Forestry Experiment Station Special Bulletin 88-3. Mississippi State University, Starksville, MS. 20 p. NAL Call No. S541.5.M8S7.

Rogers, G.L. and Klemetson, S.L. 1981. Evaluation of a Biofilter Water Reuse System for *Macrobrachium rosenbergii* Prawn Aquaculture Ponds. P. 908-923 in *Proc. of the Water Reuse Symposium II,* August 23-28, 1981. National Technology Information Service, Springfield, VA. NAL Call No. TD429.W3 1981.

Tucker, C.S.; Steeby, J.A.; Waldrop, J.E. and Garrard, A.B. 1992. *Effects of Cropping System and Stocking Density on Production of*

Build a Micro-Ecosystem

The objective of this extension is to illustrate to students the concept that the earth is a closed ecosystem for materials. With the exception of some minor gains (from meteorites, for example) and losses (space probes that never return), all materials, including the molecules that make up water, must recycle over and over again through the planetary ecosystem. Students design a micro-ecosystem in a ten gallon aquarium tank. They seal the system and watch how well it functions. We got this idea from Nora C. Doerder of C.F. Brush High School in Lyndhurst, OH. You can get all the details on how to build and use the living laboratory at: http://www.gene.com/ae/AE/AEC/AEF/1996/doerder.html

Non-Formal Assessment

Have students do a water use assessment of the school facilities. Some of the questions they may want to try to answer are: Where does the water come from? Where is it wasted? How does water return to the water cycle? What conservation practices could be used? What benefits would there be to using conservation practices?

Channel Catfish in Ponds. Mississippi Agricultural and Forestry Experiment Station Bulletin 988. Mississippi State University, Starksville, MS. 25 p. NAL Call No. S79.E3.

Notes

Web Site:

Find out all about water use in the U.S. from the United States Geological Survey at:
http://h2o.er.usgs.gov/public/watuse/index.html

The *WaterWise* site, put together by the American Water Works Association, Environmental Protection Agency, and U.S. Bureau of Reclamation, focuses on water conservation. You can search an extensive bibliography, download documents, and join a discussion group:
http://www.waterwiser.org/watuse.html

Where Does Our Water Come From?

Do you know that 97% of the earth's water resources are in the oceans? Only 3% is fresh water and most of that is found in the polar ice caps (Table 1). The fresh water that we use comes from rainwater. Therefore, the weather forecast that we hear every night is critical to maintaining our water supplies.

The amount of water available for people to use varies widely around the world (Table 2). Available or renewable water is **runoff -- the excess of precipitation over evaporation into the air and infiltration into the ground.** South America is best off in terms of the amount of available water per person. This continent has only 6 percent of the world's population, but 27 percent of the world's runoff. Kuwait, on the other hand, has *no* renewable water supply. Runoff in the U.S. averages 2.7 million gallons (10,430 cubic meters) per person per year (Cunningham and Saigo, 1995:406-407).

The sun supplies the energy needed to move water through the cycle. Therefore, the amount of water available fluctuates throughout the year depending on the weather. Scientists have studied these natural cycles and fluctuations in water availability and have not been able to predict exactly how much water we will have available at any one time in the future. This presents a dilemma for anyone needing to use water on a regular basis because you do not know how much you can use before creating a shortage.

Who Competes for the Available Fresh Water?

In the U.S., we use about one-fifth of the runoff available to us each day (Cunningham and Saigo, 1995:407). In 1990, average per capita use of freshwater was 1,340 gallons per day (USGS). Per capita use varies greatly from state to state. Some thinly populated states with large acreages of irrigated land have some of the highest per capita use. Examples are Idaho (population of 1,007,000 and per capita use of 19,600 gallons of fresh water per day), Montana (population of 799,000 and per capita use of 11,600 gallons per day) and Wyoming (population of 454,000 and per capita use of 16,700 gallons per day). On the other hand, small states in the northeast have the highest withdrawal of fresh water per area of land.

> Find out all about water use in the U.S. from the **United States Geological Service** at: http://h2o.er.usgs.gov/public/watuse/index.html

Where is all this water being used? Figure 1 indicates how water was used in the U.S. in 1990. Almost all of the water that we use is fresh water, although mining, industry, and thermoelectric power generation are using some saline water. As the graph shows, irrigation and thermoelectric power generation are by far the two largest water users in the country. Domestic supply refers to those of us who provide our own water -- from a well, usually. Public supply includes all of the water that utility companies provide to users. A large percentage of the public supply category is for water use in home. If we add the public supply and domestic categories, we can see that use of water in the home is the third major use category. Table 3 shows some examples of water use.

The Need to Conserve

Conserving water is increasingly important. The USGS (1996) says the following:

> "The era of building large dams and conveyance systems is drawing to a close; as we approach the 21st Century, the relatively limited water supply and established infrastructure must be managed more effectively to meet increasing demands. 'New' future supplies likely will be from conservation, recycling, reuse, and improved water-use efficiency rather than from ambitious development projects. It is apparent that the Nation no longer can try to meet insatiable water demands by continuously expanding a supply that has

physical, ecological, and economic limits."

Agricultural use of water, for irrigation and livestock, is the largest single user of ***fresh water*** in the U.S. It is not surprising that increasing attention is being paid to conserving water use for farming. Fish farming is no exception. In 1990, the USGS began to separate out use for "animal specialities," which includes fish in captivity, furbearing animals in captivity, horses, rabbits and pets because of "the large increase in fish farming water use" (USGS, 1996).

However, total water use is not the only question. It is also important to consider where the water comes from -- fresh or saline waters -- and whether the use is **consumptive** or **non-consumptive**. Uses that return water to the water cycle are called **non-consumptive uses**. In contrast water used in industrial processes tends to **consume water**. The United States uses more water for thermoelectric power production than for any other purpose. However, one-third of the water used comes from saline sources. Of the fresh water used, ninety-eight percent is returned to lakes and rivers. In comparison, 68 percent of the water used for livestock is consumptive use.

Industry has responded to the need to conserve water by decreasing water use by 19% since 1950. Today, it takes less water to make paper, manufacture paint, or forge steel than it once did. Conservation measures include the development of manufacturing processes that require less water or re-use the same water several times.

Like industry, homeowners are using less water. However the change is more recent. Water use in homes increased between 1960 and 1985 and then started to decline. Water conservation campaigns, increased price, new building codes, and federal laws have all resulted in less domestic water use. For example, manufacturers are now required to produce only water-saving toilets that use 1.5 to 3.5 gallons of water instead of 5 to 7 gallons. Restrictions on watering lawns combined with landscaping techniques designed to reduce water use all help save water.

Irrigation uses the most water in the agriculture sector. Farmers in the West use irrigation in desert areas to produce cotton in Arizona, potatoes in Idaho and tomatoes in California. Irrigated lands are more productive than non-irrigated lands. Although they account for only a small percentage of all U.S. farmland, irrigated farms account for 20% of the value of all farm products we consume. Although some irrigation water returns to the water cycle, irrigation is a largely consumptive use of water because water is lost to the atmosphere by evaporation and transpiration.

Farmers can do many things to conserve water. They can plant less water demanding crops such as wheat, sorghum, or soybeans in dry areas. **Trickle irrigation** provides a very small amount of water directly to the roots of the plant instead of spraying water over large areas and into the air. Farmers are adopting many of these practices. Over 90% of all tomatoes grown in Florida, for example, use trickle irrigation. Water shortages, increased costs for pumping water over long distances, changes in government subsidies for irrigation and an increase in the cost of water itself has stimulated the search for ways to conserve water by farmers just as it does for homeowners.

Water Use in Aquaculture

Farm ponds number in the millions in the United States, but they only account for about 3% of agricultural water use. Nonetheless, in some states water use for fish farming is significant. The 1996 USGS report notes that "Several States, including Louisiana and North Carolina, reported a significant increase in animal specialties water use, primarily fish farming." They also point out that "Louisiana, Idaho, and Mississippi accounted for 64 percent of the Nation's animal specialties water use, largely because of fish farming."

Water is critical to commercial aquaculture production. There must be a watershed of sufficient size draining into a pond to provide enough water to fill it. The amount of water produced by a watershed depends on where it is. Climate, soil, and vegetation all influence how much water is available to fill a pond. For example, in the humid eastern states, only two to three acres of watershed would be needed for each acre-foot of pond water. For an average pond depth of 5 feet, this means 10 to 15 acres of watershed per acre of pond surface area are needed. In contrast, in the arid west, often 100 acres of watershed are needed per acre-foot.

For levee ponds where there is no run-off water available from a watershed, another water source is needed such as a well, spring, or reservoir. Usually one well with a capacity of 2,000 to 3,000 gallons per minute will work to fill four 20 acre ponds. There must be enough water available to fill the pond in ten days or else there could be problems with growth of unwanted vegetation or water quality.

One of the benefits of farm ponds is that they trap water and make it available for other uses, such as watering livestock or recreation, along with raising fish. However, open ponds lead to increased loss of water to the atmosphere through evaporation. That's the water cycle in motion again.

Figures 3, 4 and 5 show a water budget for a catfish pond in Auburn, Alabama. What sources of water fill the pond? Where does most water loss occur? How do gains and losses vary during the year? This is a water budget for this pond of one single year. Look at the graph on page 11. Did the pond make a net gain or a net loss in water during this year? What would happen if the same thing occurred for many years in a row?

Conservation in Aquaculture

Water pumping restrictions are being enacted in some areas because of the potential impact of aquaculture operations on lowering the underground water table. As we saw in the catfish example above, most of the water used to fill the pond came from underground sources. The aquaculture industry appears to be headed towards no release of pond water into the environment off the farm. Farmers will reuse water as it becomes scarce and more expensive.

In simple systems of water recycling, the main treatments may be aeration of water, disease control, or mechanical filtration to remove solids. For completely closed systems in which water is only used to initially fill the system and to replace losses due to evaporation, more sophisticated methods are being developed. Methods to improve sedimentation, mechanical or biological filtration, sterilization, oxygenation, aeration, degassing, cooling or heating, and pH control are being studied to see whether they will be an economical way to reduce water use.

Loss of water from ponds through seepage into the ground is another area that is being explored. Seepage is like a bucket with lots of little holes in the bottom. You have to constantly be adding more water to keep the water level steady. Scientists classify water seepage rates as low, medium and high as shown in the chart below. In sandy soils seepage is much higher (0.51 cm/day) than for ponds built in clay soils (0.05 cm/day). Farmers concerned about water conservation will take into consideration the type of soil in the area where they want to construct future ponds.

Seepage Category	Water Lost (Cm/day)
Low	Less than 0.51
Medium	0.51 to 1.0
High	More than 1.0

Discussion Questions

- Where is most water used in agriculture in the United States? List three ways that we can conserve water resources in agriculture.
- What affect does water price have on the use of conservation practices?
- How do aquaculture producers conserve water? How could you conserve water in your school's aquaculture facility?

References

Cunningham, W.P. and Saigo, B.W. 1995. *Environmental Science: A Global Concern.* Wm. C. Brown Publishers, Dubuque, IA.

United States Geologic Survey. 1996. *Estimated Use of Water in the United States in 1990.* USGS National Circular 1081. United States Geologic Survey, Washington, D.C.

Table 1. Where Is the Earth's Water Stored?

	Volume 1000 of km^3	% of Total Water	Average Residence Time
Total	1,403,377	100.00	2,800 years
Ocean	1,370,000	97.60	3,000 years to 30,000 years
Ice and Snow	29,000	2.07	1 to 16,000 years
Groundwater down to 1 km	4,000	0.28	Days to 1000's of years
Lakes and Reservoirs	125	0.009	1 to 100 years
Saline Lakes	104	0.007	10 to 1,000 years
Soil Moisture	65	0.005	2 weeks to a year
Moisture in Plants and Animals	65	0.005	1 week
Atmosphere	13	0.001	8 to 10 days
Swamps and Marshes	3.6	0.003	Months to years
Rivers and Streams	1.7	0.0001	10 to 30 days

Adapted from: W.P. Cunningham and B.W. Saigo. 1995. Environmental Science: A Global Concern. Wm. C. Brown Publishers, Dubuque, IA. P. 402

Table 2. Where Are the World's Water Shortages?

Region	% of Population Living in Countries with Less than 2,000 Cubic Meters per Person per Year
Sub-Saharan Africa	26
East Asia & Oceania	7
South Asia	0
East Europe & Former USSR	22
Other Europe	20
Middle East & North Africa	71
Latin America & Caribbean	5
Canada & United States	0

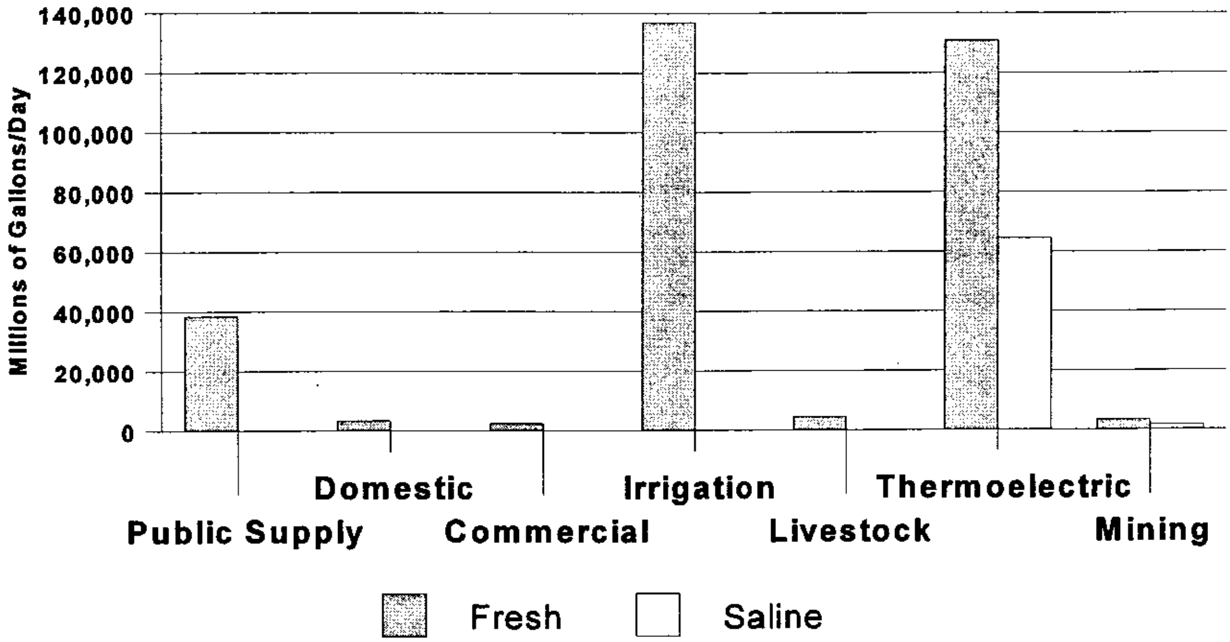
Adapted from: W.P. Cunningham and B.W. Saigo. 1995. Environmental Science: A Global Concern. Wm. C. Brown Publishers, Dubuque, IA. P. 409. .

Table 3. Some Examples of Water Use

Type of Use	Gallons
Home Use	
Bath	30-40
Shower	5 per minute
Washing Clothes	20-30
Cooking	8
Flushing Toilet (once)	3-4
Watering Lawn	10 per minute
Agriculture & Food Processing	
1 Egg	40
1 Ear Corn	80
1 Loaf Bread	160
1 Pound Beef	2,500
Industry	
1 Sunday Paper	280
1 Pound Steel	32
1 Pound Synthetic Rubber	300
1 Pound Aluminum	1,000
1 Automobile	100,000

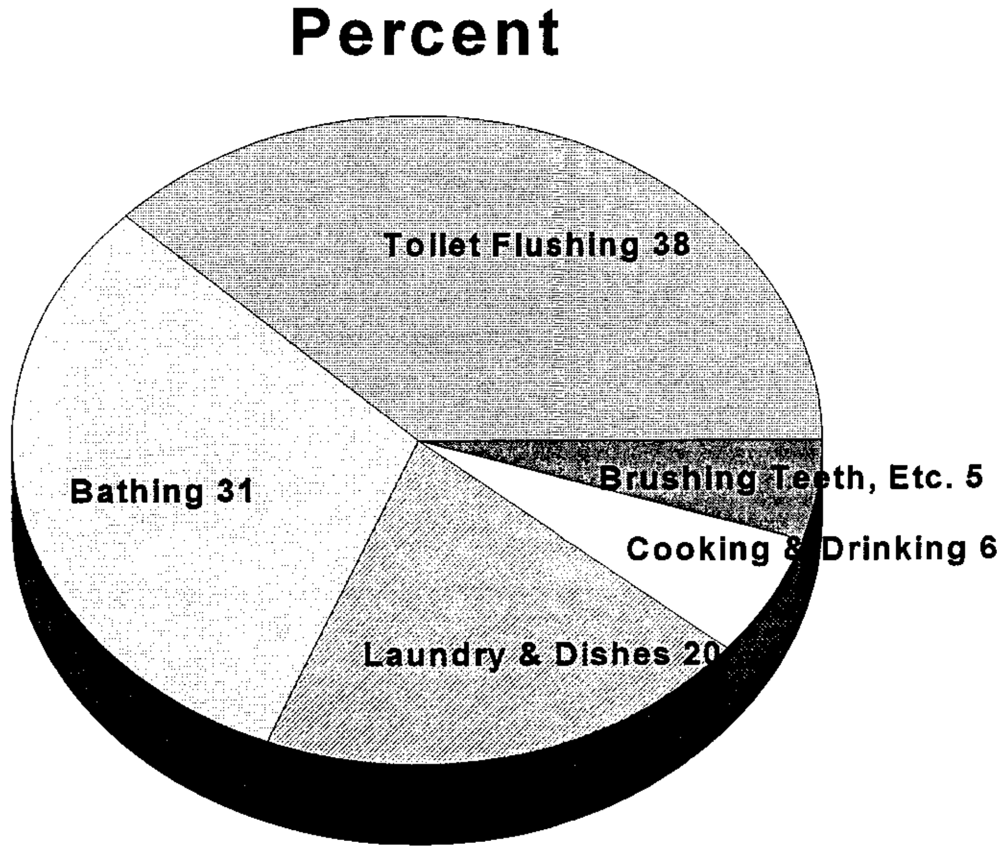
Adapted from: W.P. Cunningham and B.W. Saigo. 1995. Environmental Science: A Global Concern. Wm. C. Brown Publishers, Dubuque, IA. P. 408.

Fig. 1. Estimated Use of Water In the United States in 1990



Source: United States Geologic Survey, 1996. Estimated Use of Water in the United States in 1990. Total Water Withdrawals by Water-Use Category.

Fig. 2. Water Use at Home



Adapted from: W.P. Cunningham and B.W. Saigo. 1995. Environmental Science: A Global Concern. Wm. C. Brown Publishers, Dubuque, IA. P. 416.

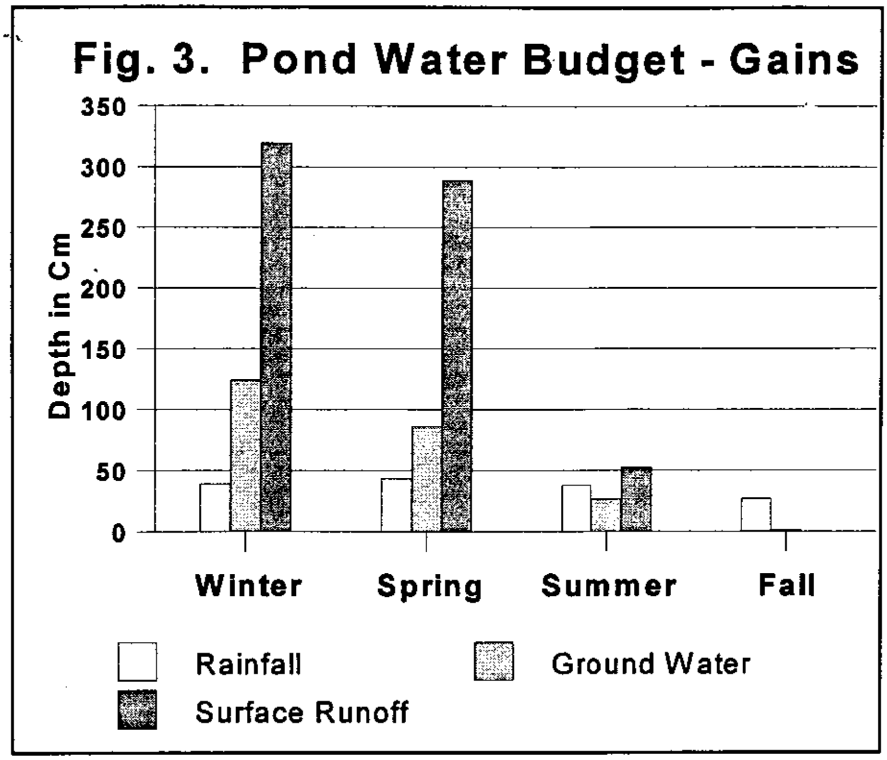


Fig. 3. Pond Water Budget - Gains
Depth in Cm
350
300
250
200
150
100
50
0
Winter
Spring
Summer
Fall
Rainfall
Ground Water
Surface Runoff

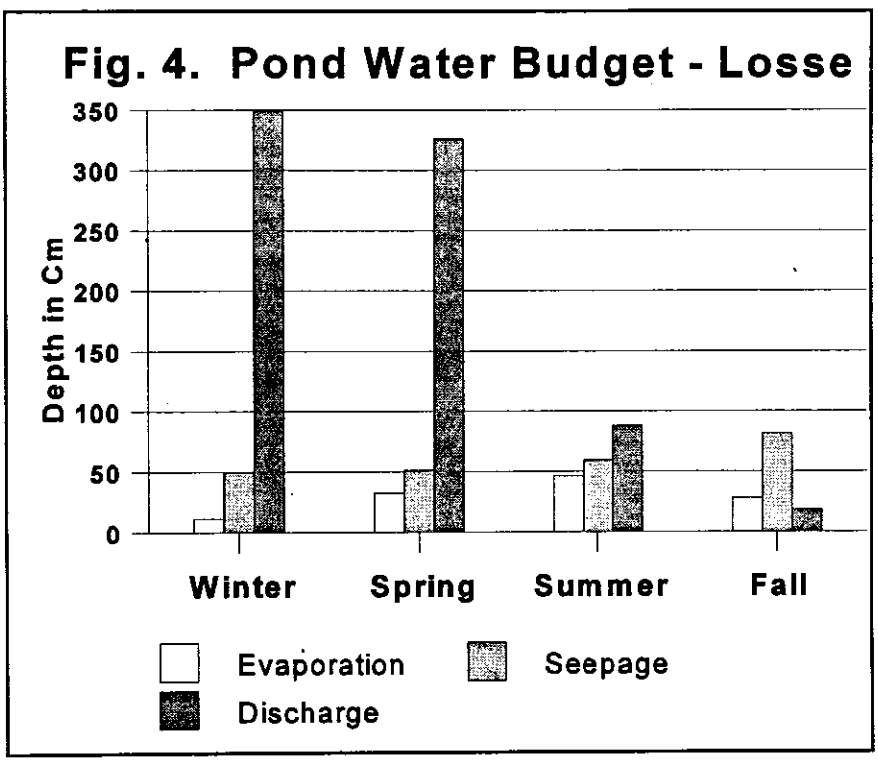


Fig. 4. Pond Water Budget - Losse
Depth in Cm
350
300
250
200
150
100
50
0
Winter
Spring
Summer
Fall
Evaporation
Seepage
Discharge

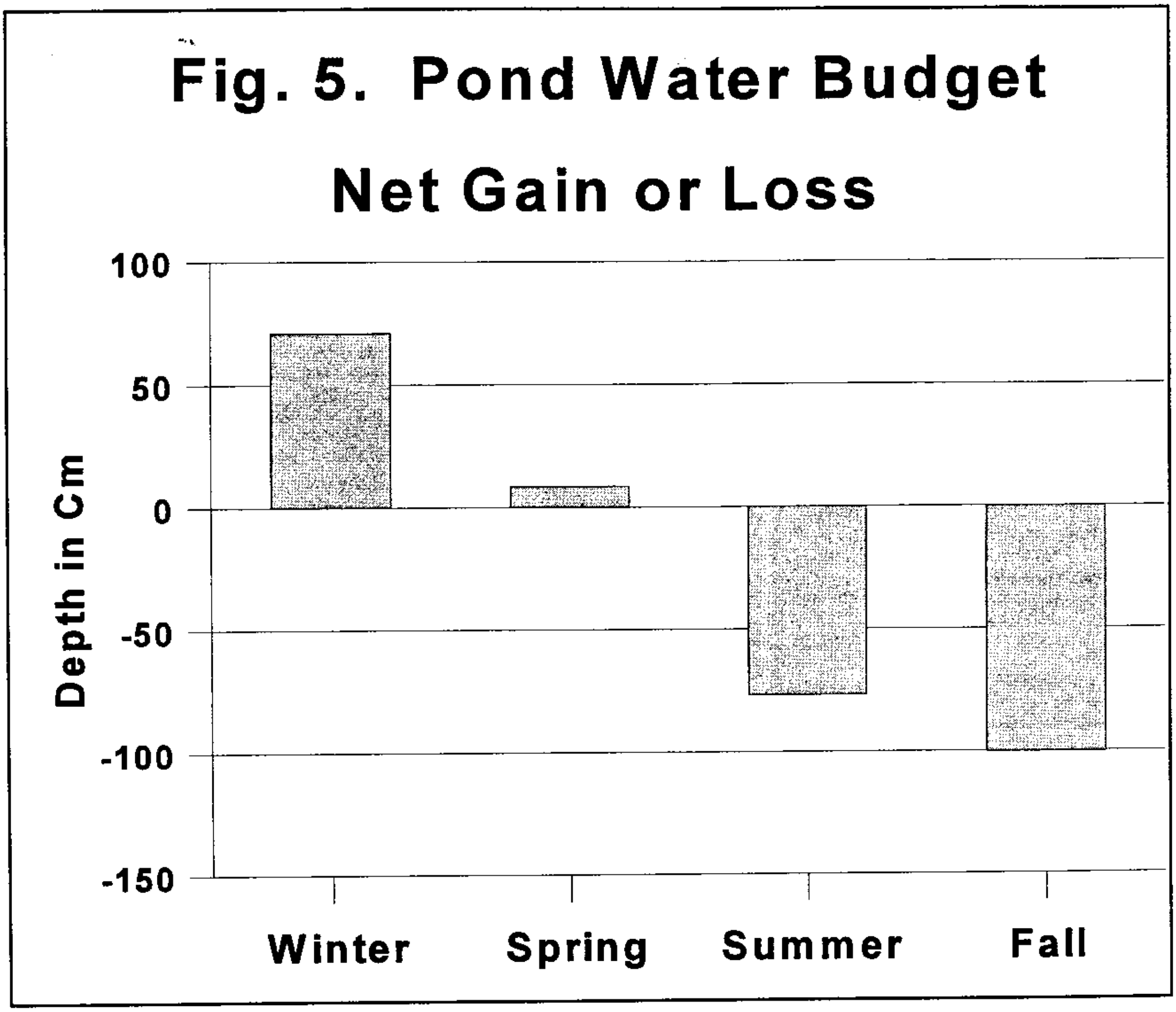
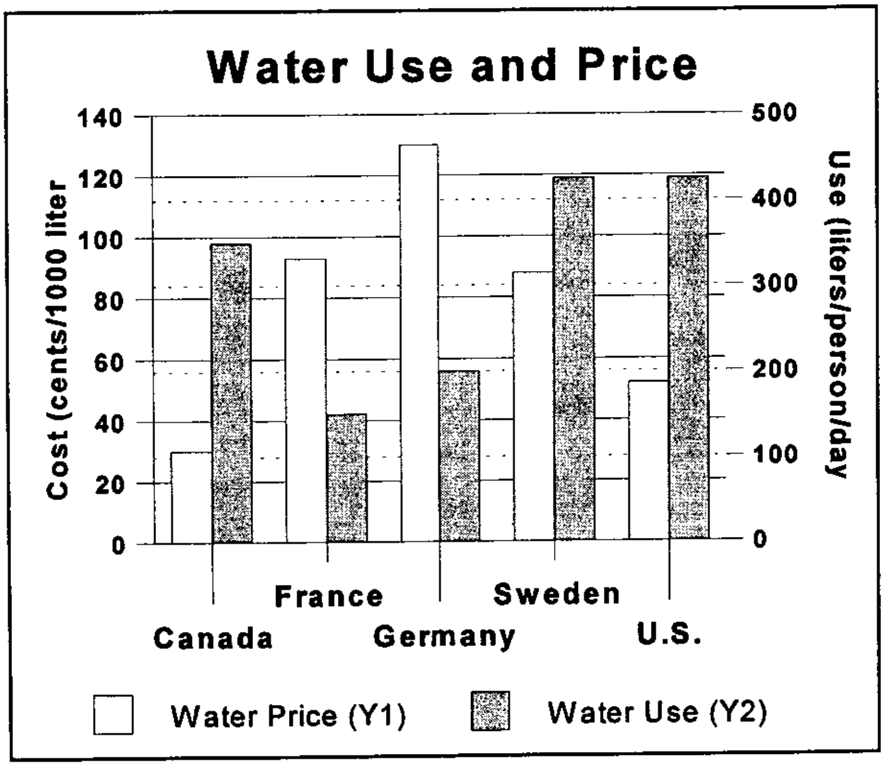


Fig. 5. Pond Water Budget
Net Gain or Loss
100
50
0
-50
-100
-150
Depth in Cm
Winter
Spring
Summer
Fall

The Water Watchers

It's clear that we need to conserve water. What can people do to save water? How are we going to get people to use water conserving practices?



Studies have shown that people tend to use less water as the prices of water increases. For example, in Canada and the U.S. the cost of water is low in most cities, 30 to 60 cents per 1,000 liters of water. Consumption is high -- 350 to 425 liters per person per day (*1 gallon = 3.78 liters*). In contrast, the cost of water is high, 95 to 130 cents per 1,000 liters of water, in France and German. Consumption in those countries is much lower, only about 150 to 200 liters per person per day. We're going to conduct an experiment over the next few days. As you do the experiment, think about the impact it would have on how you use water if the price were as high as it is in France and Germany. How would you use water differently if you lived in France or Germany?

We will conduct an experiment to study the effects of conserving water.

Choose one thing that you do every day that uses water, such as brushing your teeth or flushing the toilet. We will measure how much water can be saved and the value of the water. Think of a way you could save water. For example, you could use a glass of water to brush you teeth instead of letting the tap run. For two days, record how much water you normally use. Then put your conservation idea into practice for the next two days and record how much water you use with this water-saving practice. Use the form on the next page to calculate how much water you save and how much it is worth. Answer the discussion questions.

My Water Use

My Conservation Practice Is: ______________________________

Normal Water Use Day 1: _____ + Day 2: _____ = Total _____

Conservation Water Use Day 1: _____ + Day 2: _____ = Total _____

Total Water Saved? (Day 1 - Day 2) _____

Average Water Saved (Total Divided by 2) _____

Value of Water Saved

Average Water Saved	X	$0.004 per gallon	=	Average Money Saved
___________		______________		____________

Things to Think About:

How hard or easy was it to conserve water?

If you saved the same amount of water every day as you did during the experiment, how much water could you save in a year? How much money could you save? (To find out, multiply the average water or money saved by 365.)

Add everyone's average water and money savings during the experiment together. Multiply by 365 to get a yearly total. How important are water conservation practices.

What other resources in your area could you conserve?

Should you wait until a resource is scarce or expensive before you conserve it? Why or why not?

____

____

Water Quality

Introduction — Time: 10 minutes

Protecting and conserving the natural resources on which food production depends is a key feature of sustainable food production systems. Aquaculture requires water resources of high quality. Aquaculture can also have impacts on water quality. In this lesson we will explore the parameters of water pollution, how water quality affects aquaculture, and how aquaculture can affect water quality.

Read the *Background Material on Water Quality* (pages 5-6). This will provide you with information that you can share with your students about water quality. For students with a ***9th grade or higher reading level,*** you can assign the reading as a homework assignment. For students with an ***8th grade or lower reading level,*** we suggest that you present the ideas included in this reading yourself. You can make a transparencies of pages 8 and 9 to help explain the key points in the reading.

Getting Ready — Time: 30 minutes the first day, 20 minutes for each of 3 or 4 days, 30 minutes the last day

Fill several containers with water taken from your aquaculture facility if you have one. If not, just use plain tap water. ***If you do not mind running the risk of losing some fish,*** you could put one or two fingerlings or goldfish in each container.

- Give students small containers of several common substances, such as dish detergent, oil, molasses, vinegar, potting soil, baking soda and organic material. Have them add small amounts of the different substances to one or more of the containers. Explain that this is a simulation of non-point source pollution where small amounts of different substances from many places enter a water body.

- Have students predict what they think will happen to the water quality, introducing concepts like pH and dissolved oxygen. Ask students to make a list of as many different characteristics of water quality as they can identify. For each item, have students determine how they might test water for that characteristic, including both tests with laboratory equipment and things they can measure with their own senses. If you are including fish, have students predict the impact of the different pollutants on the fish.

- Leave the containers for a few days. Have students examine the containers each day (especially if you want to observe fish). After a

Purpose

To explore where water pollution comes from, its impact on aquaculture, and the potential impacts of aquaculture on water quality.

Key Concepts

Sustainable food production systems must protect the natural resources on which food production depends.

Learning Objectives

Students will be able to:

- List several ways to measure water quality
- Explain the role of dissolved oxygen in fish survival
- Describe types of water quality problems that can occur in aquaculture
- Compare differences in water quality between natural streams, fish ponds, and treated sewage water

Subjects

Science
Mathematics

few days, have students test all of the water quality characteristics that they can and, if fish are present, determine the impact of the pollution on the fish.

Doing the Activity — Time: 45 minutes

- Use a transparency of *Graphic Method for Predicting Oxygen Depletion* to demonstrate how to graph oxygen readings (page 9). Discuss the key causes of low dissolved oxygen in fish ponds.

- Have students read the Student Page *Gasping for Air* (page 10). Students should complete the Student Page *Keeping the Fish Alive* (page 11) as homework assignments. Provide students with copies of Student Pages 12 and 14 to help them prepare their arguments.

- Divide the class into two teams for a debate. Give the students five to ten minutes to share their results from the homework assignment and agree upon a course of action. For round one of the debate, one team will act as Farmer Careless. For two minutes, the other team of students should try to convince Farmer Careless about what should be done for his fish pond. The Farmer Careless group must record every valid point raised or piece of data presented. The two groups should switch roles for the next two minutes. Round two should continue in the same pattern, but shorten the time to only one minute. The team that has the most valid points at the end wins the debate. You should act a referee.

Alternative if You Have a Tank

Teachers suggested the following alternative if you have a tank, but ***BE CAREFUL!!! This experiment can kill fish.*** Turn off the aerators in a recirculating tank system. Have students record and graph DO every few minutes and predict when the system must be re-connected to avoid fish kill. ***Note that, depending on stocking and feeding rates, the time that will elapse before fish start to die can be as little as 30 MINUTES!***

Quiz Questions

- Give an example for both point source and non-point source pollution.

Possible Answers: Point source: pipes discharging contaminated water, electrical power plants, untreated sewage outflow. Non-point source: oil and chemicals from streets in urban areas or sediment or pesticides from agricultural lands.

- Describe why non-point source pollution is important in agriculture.

Answer: Non-point source pollution is by far the most common type of pollution from agriculture.

- List one type of water pollution and its effect on fish production.

Materials

Three clear plastic glasses (16 oz) or clear soda containers
Three water samples (see Getting Ready)
Copies of Student Pages
Pencil
Graph Paper
Ruler
Transparencies of pages 7-10

Extensions

Comparing Water Quality
Students can measure the water quality parameters for which you have the test equipment. Take samples for comparison from both the aquaculture facility and the stream, river or other water source that receives waste water from the school. It would be more interesting to have students vary their sample collection either by time of day (i.e. several samples at night and several at the same time during the day) or by season for a comparison of how these parameters change in the same location over time. Have students discuss the influence of water quality on fish production as well as the impact of waste from aquaculture on waterways.

Build a Water Filter
Have students use PVC, plastic one-liter containers, or other containers and common materials such as charcoal, sand, and cotton balls to make a water cleaning filtration system. Have students devise different

Possible Answers: Nutrients can kill fish and lower oxygen due to algae blooms. Heat can cause heat stress and lower oxygen levels. Toxic chemicals reduce growth and survival of fish eggs and make fish more susceptible to disease. Disease organisms (from sewage or runoff from feedlots) can infect fish. Sediments clog gills and filters and cover spawning sites.

- Explain what increases and reduces dissolved oxygen in a fish pond.

Possible Answers: Phytoplankton are the major producers of oxygen in ponds. Farmers use aeration -- mixing air with the water -- to further increase dissolved oxygen. Many factors can reduce dissolved oxygen, including excess growth of algae at night, increased temperature, inadequate aeration and high stocking and feeding rates.

- When fish wastes are released what kinds of pollutants may they contain?

Possible Answers: Excess nutrients and chemicals.

Want More Information?

Chisholm, P.S. and Farrell, J.B. 1989. Waste Production, Land Based Rainbow Trout Culture. *American Society of Agricultural Engineers No. 89-7526.* The Society, St. Joseph, MI. 18 p. NAL Call No. 290.9 AM32P.

De la Bretonne, L.W., Jr. and Romaire, R.P. 1990. *Crawfish Culture: Site Selection, Pond Construction and Water Quality.* Southern Regional Aquaculture Center No. 240, Ada, OK. 4 p. NAL Call No. SH151.S62.

Eversole, A.G. and Bellinger, R.G. Feb., 1990. *Protect Crawfish from Pesticides.* South Carolina Cooperative Extension Service Pesticide Information Program Information Sheet No. 17. Clemson University, Clemson, SC. 2 p. NAL Call No. SB950.2.S6P47.

Murphy, D.L. 1990. *Contaminant Levels in Oysters and Clams from the Chesapeake Bay, 1981-1985.* Maryland Water Management Administration, Department of the Environment, Water Management Administration, Water Quality Programs, Technical Report No. 102, Baltimore, MD. 2 p. NAL Call No. QL430.7.O9M87.

Robichaux, D.M. and Wang, J.K. 1989. Managing Algae and Suspended Solids in Shrimp-Oyster Joint Production. *American Society of Agricultural Engineers No. 89-7525.* The Society, St. Joseph, MI. 12 p. NAL Call No. 290.9 AM32P.

Steeby, J.A. and Tucker, C.S. 1988. *Comparison of Nightly and Emergency Aeration of Channel Catfish Ponds.* Mississippi Agricultural

systems for cleaning up dirty water. You may want to have a contest between different groups. Put water from your aquaculture facility, dirty or polluted water that you find, or make your own polluted water to put through the system. Have students evaluate the quality of the water that comes out of each system. You can use water quality test equipment that you have. If you do not have equipment, have students think of ways that they can judge the relative quality of samples of water from the different systems.

Do Plants Produce CO_2? A common misperception of students is that plants produce oxygen and animals produce carbon dioxide. As you know, this is not true. Plants respire continuously, just as animals do, and in the dark when photosynthesis is not occurring, plants will contribute to the build-up of carbon dioxide in a closed system. Set up one or more closed systems with aquatic plants and fish or other aquatic animals in them. Use Bromthymol blue to test for the presence of carbon dioxide during periods when the system is exposed to daylight and when it is sealed off from light. We got this idea from two teachers, Bob Culler at Avon Lake High School in Avon Lake, OH,

and Forestry Experiment Station, Vol. 13, No. 8. Mississippi State University, Starksville, MS. 4 p. NAL Call No. S79.E37.

Web Sites:

There are many great Web sites dealing with water quality.

For a general profile on U.S. water quality in 1994, try the EPA's site:
http://www.epa.gov/OWOW/sec1/profile/

If you go to this EPA site, you can search for water quality data on specific watersheds:
http://www.epa.gov/OW/sec1/index.html.

The National Council on Agricultural Science and Technology has a good description of agriculture's impact on water quality at:
http://www.netins.net/showcase/cast/watq_sum.htm

Purdue has a site that lets you search for specific information -- and they have information on aquaculture and water quality:
http://hermes.ecn.purdue.edu:8001/server/water/water.html

U.S. Water News On-Line has lots of good information and students can join a water quality discussion group:
http://www.mother.com/uswaternews/welcome.html

Another Purdue University site lets you click on your watershed on a map of the U.S. and get information about water quality in your area:
http://www.ctic.purdue.edu/KYW/KYW.html

Want some great ideas for classroom activities? Check out the Access Excellence Activities Exchange at:
http://www.gene.com/ae/AE/AEC/AEF/

and James Linhares from Forest Grove High School in Forest Grove, OR. You can find full descriptions of their classroom experiments at:

http://www.gene.com/ae/AE/AEC/AEF/1996/culler.html

or

http://www.gene.com/ae/AE/AEC/AEF/1996/linhares.html

What Comes Off a Parking Lot?
Teachers suggested this Extension. Have students pace off a parking lot and determine it's size. Have them calculate how much water runs across the lot in a ½-inch rainfall. You can add visiting this web site:

http://www.txdirect.net/users/eckhardt/glossary.html

It gives the definition of many terms used in water quality discussions, including, for example, that one acre-foot of water equals 325,851 gallons.

Tell students to assume that a car leaks one quart of oil on the lot before the rainfall. Have them calculate the oil in the water that runs across the lot during the rainfall in parts per million.

Where does water pollution come from? Do you picture in your mind an oil spill from a tanker wrecked in the ocean or a big factory? Both of these are examples of what is **called point source pollution** -- pollution for which we know exactly where the pollution comes from. We can measure and treat point-source pollution relatively easily because we know where it comes from. The United States has made many changes to regulate and control point source pollution.

Today, the biggest threat to water quality comes from **non-point source pollution.** Non-point source pollution comes from many sources spread over a large area. For example, when you spill oil on your driveway and hose it into the storm sewer drain, it finds its way into lakes, streams or ponds. Non-point source pollution is more difficult to trace and treat than point-source pollution. It is harder to locate pollution sources such as soil erosion or pesticides washing off urban lawns than pollution coming from a factory drain pipe.

Agriculture does contribute to non-point source pollution. The Environmental Protection Agency has estimated that 58 percent of the miles of streams in our country are being polluted from agricultural activities.

However, urban areas cause just as much non-point source pollution. Just think about all the different ways your family contributes to non-point source pollution. When was the last time you washed oil or something else out of your driveway?

How Aquaculture Affects Water Quality

Aquaculture can contribute to water pollution, too. Ponds have fish, fish wastes, excess feeds and fertilizers in them, as well as bacteria. In the majority of aquaculture ponds, waste water called **effluent** is discharged when fish are harvested. This effluent can be a pollutant if it decreases the water quality in natural waterways.

The water quality of effluent depends on the stocking and feeding rates, use of aeration, water flow, other chemicals used to disinfect or control pests, and the amount of water discharged. The timing of harvesting can vary between one and three years, depending on the management of the pond. This, too, will affect the water quality in the effluent. In addition, the size, flow, and water quality of the stream, lake or river that the effluent is discharged into is critical. Rivers and streams have the natural capacity to use biological processes and recover from pollution depending on time, distance and species living in them. Some streams will therefore be more able to absorb effluent without suffering damage than others. This is called **absorptive capacity.** We often hear people say that something is "biodegradable." This means that the natural processes in water and land can absorb and decompose the substance.

Table 1 shows the average concentration of water quality variables in 25 channel catfish ponds and in 24 streams in West-Central Mississippi. The impact of water discharged from ponds on receiving streams will depend upon the differences in concentrations of water quality variables between pond waters and stream waters and on the ratio of pond discharges to stream discharge. Catfish pond water qualities and stream water in the Mississippi catfish-producing region were not greatly different, although pond waters were higher in total nitrogen and chemical oxygen demand. Why were the differences not greater? Stream water in this area of Mississippi are not considered of high quality and pond waters were not extremely polluted relative to these stream waters. Very different results could occur in other regions.

Waste treatment from aquaculture ponds includes **sedimentation** to remove the large amount of the particles in the water. Sedimentation alone results in low concentrations of pollutants in a high volume of water. If farmers also use biological nutrient removal methods such as varying the amount of time the effluent is in a settling pond, solids are removed and BOD levels can be lowered.

How Water Quality Affects Aquaculture Production

Aquaculture farmers are very concerned about water quality. Water pollution can have a severe impact on fish production.

Dissolved oxygen is probably the most important water quality factor that fish producers must understand. The primary source of dissolved oxygen in ponds is from the microscopic plants called "phytoplankton" or "algae blooms." In the presence of sunlight, algae produce oxygen through photosynthesis. However, at night and on very cloudy days, phytoplankton only consume oxygen -- as much as three to five times the amount of oxygen that the fish consume. Low oxygen is often the result of an imbalance in the amount of phytoplankton present in a pond. Sometimes low dissolved oxygen can be predicted before it occurs, but it may also develop suddenly without warning. If dissolved oxygen levels go too low, supplemental aeration can help raise dissolved oxygen levels.

Different aquaculture species tolerate different levels of dissolved oxygen in the tank or pond. According to Popma and Lovshin (1996: 5), "Commonly cultured species of tilapia survive routine dawn dissolved oxygen (DO) concentration less than 0.5 mg/L, levels considerably below the tolerance levels for most other cultured fish. Survival in water with low DO is due, in part, to their ability to extract dissolved oxygen from the film of water at the water-air interface when DO is below 1 mg/L."

Other important water quality considerations for aquaculture are temperature, carbon dioxide, total gas pressure, salinity, hardness, alkalinity, pH, ammonia, nitrate, iron and hydrogen sulfide. Table 2, *Sources of Water Pollution and Their Impact on Both Fish and the Environment*, shows how different kinds of pollution present in water can affect aquaculture production.

References

Popma, T.J. and Lovshin, L.L. 1996. *Worldwide Prospects for Commercial Production of Tilapia.* Southern Regional Aquaculture Center, Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

Boyd. F.L. 1990. *Water Quality in Ponds for Aquaculture.* Southern Regional Aquaculture Center, Alabama Cooperative Extension Service, Auburn University, Auburn, AL. P. 11.

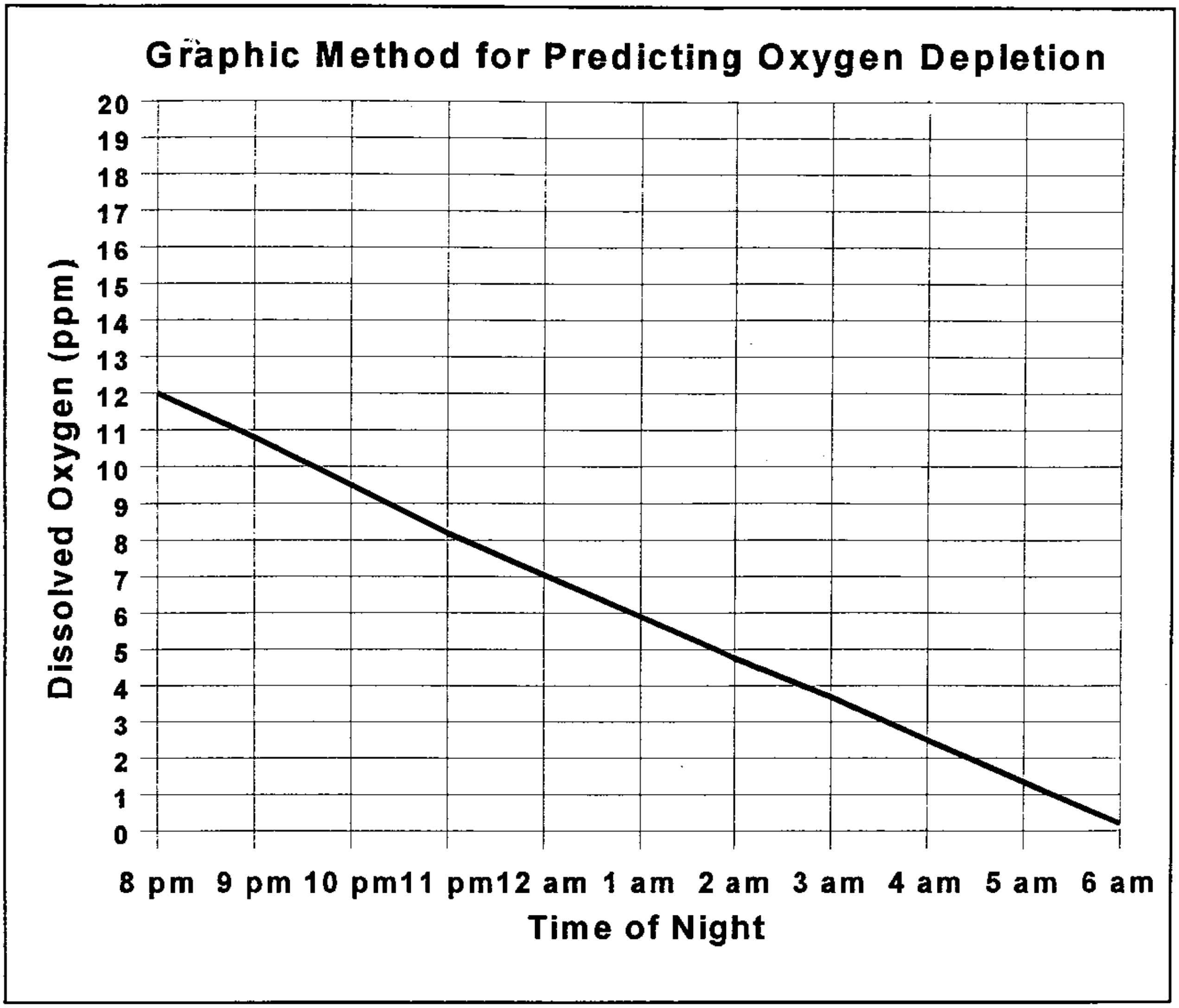
Table 1. Average Concentrations of Water Quality Variables in 25 Channel Catfish Ponds and 24 Streams in West-Central Mississippi

Variable	Ponds		Streams	
	Spring	Summer	Spring	Summer
Total solids (mg/liter)	481	500	499	344
Total volatile solids (mg/liter)	149	162	123	66
chemical oxygen demand (mg/liter)	61	97	32	33
Dissolved inorganic phosphorus (mg/liter as P)	0.07	0.16	0.18	0.25
Total phosphorus (mg/liter)	0.56	0.86	0.63	0.58
Total ammonia nitrogen (mg/liter)	0.93	0.42	0.62	0.13
Nitrite and nitrate (mg/liter as N)	0.05	0.24	0.26	0.19
Total nitrogen (mg/liter)	4.41	5.55	2.07	1.47

Source: Boyd, F.L. 1990. Water Quality in Ponds for Aquaculture. Southern Regional Aquaculture Center, Alabama Cooperative Extension Service, Auburn University, Auburn, AL. P. 13.

Table 2. Sources of Water Pollution and Their Impact on Both Fish and the Environment

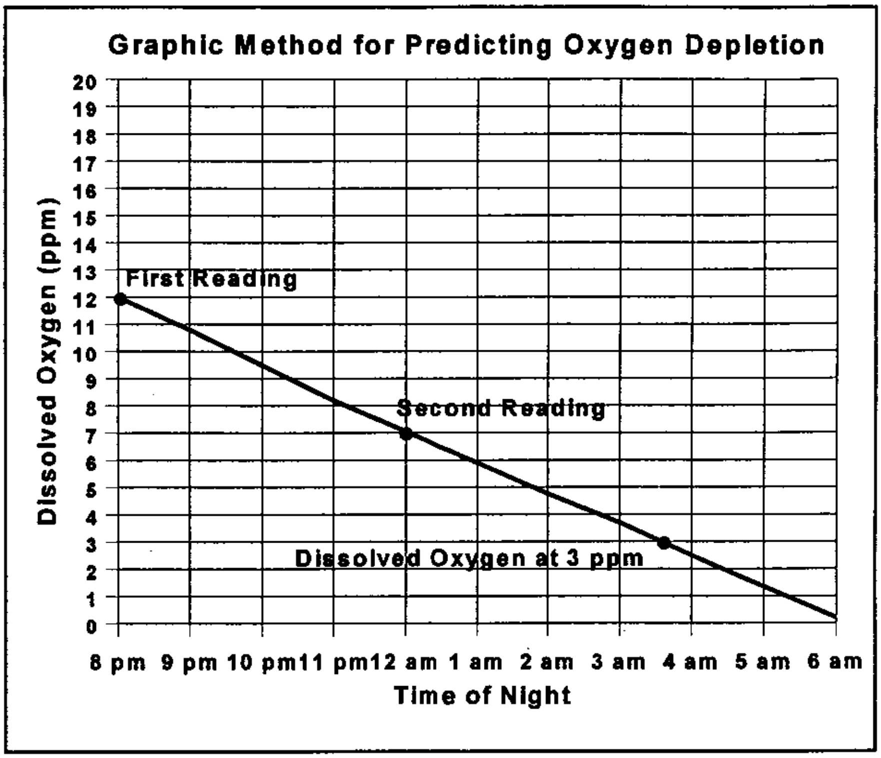
Type of Water Pollution	Effect on Fish and the Environment
Nutrients from yard waste, sewage, food processing, agriculture, livestock, and industry	Fish kills, low oxygen due to algae blooms, and reduced diversity of animals and plants
Heat from cities, power plants, industrial discharges, and the sun	Cold water fish cannot survive, more disease occurs because of heat stress and lower oxygen levels
Toxic Chemicals from landfills, agricultural and urban runoff, and industrial discharges	Reduced growth and survival of fish eggs; fish diseases and death of carnivores from chemicals being passed through the food chain
Disease Organisms from raw or partially treated sewage and runoff from feedlots	Infection of fish and contamination of the environment
Sediments from agricultural fields, logged areas, feedlots, degraded stream banks, and road construction	Clogging of gills and filters, covering of spawning sites, reduced insects and plant growth


Graphic Method for Predicting Oxygen Depletion
Dissolved Oxygen (ppm)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
8 pm
9 pm
10 pm
11 pm
12 am
1 am
2 am
3 am
4 am
5 am
6 am
Time of Night

GASPING FOR AIR

Low levels of dissolved oxygen is the largest cause of fish kills. It often results from the wrong number of microscopic organisms called phytoplankton or algae blooms in a pond. How could lots of little phytoplankton kill fish? In the presence of sunlight, algae blooms produce oxygen through photosynthesis. However, at night and on very cloudy days, phytoplankton consume oxygen. In fact, they use three to five times as much oxygen as fish do.

The other source of oxygen for fish is through diffusion from the atmosphere, but this is a very slow process. Farmers use aeration or the mixing of air and water to put oxygen back into the pond. It is very important to monitor and predict low oxygen levels before fish start to become stressed or die.



Low dissolved oxygen can be predicted using the graphic projection method. This method relies on the fact that oxygen generally declines at a constant rate throughout the night. Low oxygen can be predicted by graphing the rate of decline and projecting the trend on through morning. To use this method, oxygen readings must be taken near dusk and two to four hours later using either electronic or chemical measurements. Look at the example pond to the right. The two oxygen readings (Dissolved Oxygen ppm) are entered onto the graph when they are taken. In this case the first reading (12 ppm) was taken at 8:00 p.m and the second (7 ppm) at midnight. Then a straight line is drawn connecting them to the point where the line crosses the x-axis (Time of Night). In this case, 3 ppm dissolved oxygen is the critical value. The fish cannot survive at lower oxygen levels. The line that we have drawn crosses the 3 ppm value for the y-axis at about 3:30 a.m. If the line crosses at a time before sunrise, then the farmer needs to turn on the aerators in his or her pond. In our example, the farmer will need to aerate the ponds during the night or else the fish could die.

Somebody, Help, Help!!!

You are helping a Mississippi catfish farmer maintain his ponds for the summer. You know that most oxygen problems occur between May and September because:

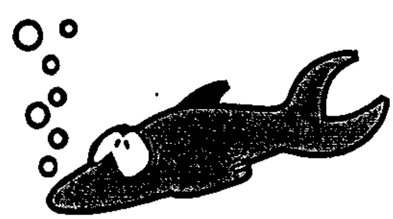
Temperatures are higher -- there is less oxygen in water as the temperature increases.

Feeding rates are high-- which means there is lots of extra waste in the water which also demands oxygen for bacteria to decompose it.

Algae blooms are heavy--phytoplankton use three to five times as much oxygen as fish do.

Fish are growing rapidly--higher oxygen demands on the pond.

Farmer Careless has a large pond that is heavily stocked with catfish because he has not gotten around to harvesting the fish yet. His land lies adjacent to a large dairy. It's been cloudy and windy all day, so when Farmer Careless took an oxygen reading in his pond at 7 pm and it was 15 ppm, he decided to go play cards with his friends. He told you that there should not be any problems with his pond for the night, but its your responsibility to care for the fish while he is gone. When you go to the pond you notice that there is lots of excess feed in one corner , the wind has died down and it's hot. You sit and listen to music for a few hours. At 10 pm, you take an oxygen reading and its 6 ppm which is still double what it needs to be. What do you do? If you decide to turn on the aerators you have to first convince Farmer Careless why it is necessary.



Write as convincing an argument as you can for your actions using as much data as you can produce.

What Does the Fish Say?

The Fish	Possible Cause	Possible Management
Excitable, darting, erratic swimming	Excess of intense sounds or lights Parasite High ammonia High carbon dioxide	Reduce sound levels, pad sides of tank, reduce light intensity Examine fish with symptom* Check ammonia concentration Check carbon dioxide level
Flashing, whirling	Parasite	Examine fish with symptom
Discolorations, sores	Parasite or bacteria	Examine fish with symptom
Bloated, eyes bulging out	Virus or bacteria Gas bubble disease	Examine fish with symptom Check for supersaturation and examine fish with symptom
Laying at surface, not swimming off	Parasite Low oxygen High ammonia or nitrite Bad feed	Examine fish with symptom Check dissolved oxygen in tank Check ammonia and nitrite concentrations Check feed for discoloration or clumping and check blood of fish
Crowding around water inflow or aerators	Low oxygen Parasite or disease High ammonia or nitrite Bad feed	Check dissolved oxygen in tank Examine fish with symptom Check ammonia and nitrite concentrations Check feed for discoloration or clumping and check blood of fish
Gulping at surface	Low oxygen Parasite or disease High ammonia or nitrite High carbon dioxide Bad feed	Check dissolved oxygen in tank Examine fish with symptom Check ammonia and nitrite concentrations Check carbon dioxide level Check feed for discoloration or clumping and check blood of fish
Reduced feeding	Low oxygen Parasite or disease High ammonia or nitrite Bad feed	Check dissolved oxygen in tank Examine fish with symptom Check ammonia and nitrite concentrations Check feed for discoloration or clumping and check blood of fish
Stopped feeding	Low oxygen Parasite or disease High ammonia or nitrite	Check dissolved oxygen in tank Examine fish with symptom Check ammonia and nitrite concentrations

The Fish	Possible Cause	Possible Management
Discolored Blood Brown Clear (no blood)	 High nitrite Vitamin deficiency	 Examine fish with symptom; add 5 to 6 ppm chloride for each 1 ppm nitrite; purchase new feed and discard old feed Examine fish with symptom; check feed for discoloration and clumping; purchase new feed and discard old feed
Broken back or "S" shaped backbone	Vitamin deficiency	Examine fish with symptom; purchase new feed and discard old feed

* Have fish examined by a qualified fish diagnostician

Source: M.P. Masser, J.Rakocy, and T.M. Losordo. 1993. Recirculating Aquaculture Tank Production Systems. Southern Regional Aquaculture Center, Alabama Cooperative Extension Service, Auburn University, Auburn, AL. P. 10.

Possible Management Options Based on Water Quality and Feed Observations

Observation	Possible Management
Low dissolved oxygen (less than 5 ppm)	Increase aeration Stop feeding until corrected Watch for symptoms of new parasite or disease
High carbon dioxide (above 20 ppm)	Add air stripping column Increase aeration Stop feeding until corrected Watch for symptoms of new parasite or disease
Low pH (less than 6.8)	Add alkaline buffers (sodium bicarbonate, etc.) Reduce feeding rate Check ammonia and nitrite concentrations
High ammonia (above 0.05 ppm as un-ionized)	Exchange system water Reduce feeding rate Check biofilter, pH, alkalinity and hardness, and dissolved oxygen in the biofilter Watch for symptoms of new parasite or disease
High nitrite (above 0.5 ppm)	Exchange system water Reduce feeding rate Add 5 to 6 ppm chloride per 1 ppm nitrite Check biofilter, pH, alkalinity and hardness and dissolved oxygen in the biofilter Watch for symptoms of new parasite or disease
Low alkalinity	Add alkaline buffers
Low hardness	Add calcium carbonate or calcium chloride
Discolored or clumped feed	Purchase new feed and discard old feed Watch for symptoms of new parasite or disease

Source: M.P. Masser, J.Rakocy, and T.M. Losordo. 1993. Recirculating Aquaculture Tank Production Systems. Southern Regional Aquaculture Center, Alabama Cooperative Extension Service, Auburn University, Auburn, AL. P. 11.

Who's Eating the Fish?

Introduction — Time: 15 minutes

One objective of sustainable agriculture is to **protect natural resources.** These resources include not only water and soil, but living organisms. Normally, when we discuss human alterations of natural systems, we hear about decreases in the numbers and kinds of natural organisms living in an area. Many have voiced criticisms of agriculture's impact on biological diversity and sustainable agriculture generally seeks to protect and enhance the diversity of organisms in agricultural ecosystems. In this lesson, we will look at what happens when agriculture ***increases*** the presence of natural organisms. This can result in conflict as farmers seek both to protect biological diversity -- and protect their farm animals and crops. In this lesson we will examine how aquaculture production has increased bird populations in some parts of the Southern United States and what fish farmers have done to try to both protect the birds and protect their fish.

Read the *Background Material on Who's Eating the Fish* (pages 5-6). This reading explains the situation that has developed with regard to aquaculture and increased bird populations in some parts of the Southern United States. For students with a ***9th grade or higher reading level,*** you can assign these pages as a homework assignment. For students with an ***8th grade or lower reading level,*** we suggest that you explain the ideas in the readings to your students yourself.

Getting Ready — Time: 5 minute observations over a one-week period

This is a discovery exercise to involve the students and capture their interest in the relationship between migration patterns and food resources. Make two bird feeders out of a plastic soda jugs by cutting an oval section out of the center of each jug large enough for a bird to use for feeding. Hang the feeders from a window outside your classroom or glue two suctions cups to the uncut side of each feeder and attach the feeder to a window. Place one cup of birdseed in one feeder and another food of the students' choice in the other. Tape a piece of paper or a larger sheet of newsprint next to the window where the feeders are mounted for recording the students' observations. Have students observe and record

Purpose

To explore the interaction between aquaculture production and the natural environment

Key Concepts

Sustainable agriculture protects natural resources, including biological resources

Learning Objectives

Students will be able to:

- List at least three factors that influence bird population changes;
- Find examples of different migratory birds for their local area; and
- Graph and interpret trends in bird populations in relation to catfish and crawfish production over time.

the number and kinds of birds present at each feeder at roughly the same time every day for a week. They should also record any other animals that visit each feeder and what how much of the food supply is consumed each day. Encourage students to take detailed observations on factors that may affect feeding behavior, such as temperature, cloud cover, weather, etc. Have them quantify as many of the observations as possible.

Doing the Activity Time: 30 minutes of class time and several days of student research

Hand out the Student Page (7) *Fish Farmers Fight Fowl in Louisiana*. Explain that the students will be researchers for this activity. They have been provided with data on population trends for several bird species (Student Pages 8 and 9). Divide students into teams of four or five.

- Each team should analyze and interpret the data on bird populations, using the data in the tables on Student Pages 8 and 9 to determine whether they think these birds are actually eating fish in aquaculture ponds.
- If so, they should develop alternative solutions for fish farmers by searching in the library, looking on the World Wide Web, calling fish farmers, or contacting their local Cooperative Extension Service.
- Have each team present their analysis and solutions to the class as a whole.
- Compare the different analyses and solutions.

Quiz Questions

- List three reasons why bird populations have decreased in some areas of the country since 1950.

Possible Answers: Hunting, habitat loss, pollution, and pesticide contamination.

- Describe how data on bird populations are collected.

Possible Answers: The Audubon Society collects data on bird populations by observing birds all over the United States during the Christmas Bird Count. The Breeding Bird Survey is conducted by the National Biological Service.

Subjects

Science
Mathematics
Environmental Studies

Materials

Copies of Student Pages (7-9)
Pencil and Ruler
Peterson's Guide to Birds or any other local bird guide with pictures and descriptions or go to Peterson's on-line at: http://www.fastfwd.com/bird/peterson/home.html
Optional Transparency (some bird pictures with a little bit of information about the bird)

Extensions

It's for the Birds!
Conduct a role play where students play the roles of bird watchers, environmentalists, farmers, government officials responsible for resource management, politicians, and others with a stake in the bird issue.

Food Abundance a Micro-Ecosystem
We got this idea from Sharon T. Deal, a teacher at Ridge View High School in Columbia, SC. Find a full description of her experiment on the Web at: http://www.gene.com/ae/AE/AEC/AEF/deal.html We suggest some modifications for you on the next page.

- True or False. All bird species are pests for aquaculture production.

Answer: False.

Want More Information?

Abatiello, V. And Flimlin, G.E. 1989. *Construction of Shellfish Predator Control Net.* Cooperative Extension Service, Rutgers University. Videocassette. Rutgers University, New Brunswick, NJ. NAL Call No. Videocassette No. 897.

Glahn, J.F. Sept., 1990. *Cormorant Diet and Its Impact on Mississippi Catfish Farms.* Mississippi Cooperative Extension Service, Mississippi State University, Starksville, MS. 2 p. NAL Call No. SH222.M7F47.

Martin, R.P. and Hamilton, R.B. 1985. *Wading Bird Predation in Crawfish Ponds.* Louisiana Agricultural Experiment Station, Vol. 28, No. 4. Louisiana State University, Baton Rouge, LA. 2 p. NAL Call No. 100 L939.

May, J.A. April, 1992. *An Experiment "Wire" Grid for Exclusion of Double-Crested Cormorants from Commercial Catfish Ponds.* Mississippi Cooperative Extension Service, Mississippi State University, Starksville, MS. 2 p. NAL Call No. SH222.M7F47.

Mississippi Cooperative Extension Service. Oct., 1989. *Control of Fish-Eating Bird Damage on Catfish Ponds.* Mississippi State University, Starksville, MS. 2 p. NAL Call No. SH222.M7F47.

Naves, R.J. and Odom, M.C. Oct., 1989. Muskrat Predation on Endangered Freshwater Mussels in Virginia. *Journal of Wildlife* 53(4):934-941. NAL Call No. 410 J827.

Stickley, A.R. and Andrews, K.J. July, 1989. *Survey of Mississippi Catfish Farmers on Costs of Repelling Fish-Eating Birds from Ponds.* Mississippi Cooperative Extension Service, Mississippi State University, Starksville, MS. 2 p. NAL Call No. SH222.M7F47.

Web Sites:

The University of Michigan provides excellent, detailed information on many bird species at:
http://www.nceet.snre.umich.edu/Curriculum/birdfacts.html

For specific information on the feeding habits of birds of prey go to:
http://crusher.bev.net//education/SeaWorld/birds/birddiet.html

Want to know what these birds we're talking about look like? Peterson's Field Guides are now on-line at:
http://www.fastfwd.com/bird/peterson/home.html

Use samples of water from your aquaculture facility. If you do not have one, any sample of water from a stream, pond, or ditch will do. Or, if you want to, purchase cultures of common aquatic microor-ganisms. Use microscopes to identify the microor-ganisms in the water. If you purchased cultures, this will be easy. If you are using tank or other water, you will need to find a guide or get some help to identify the organisms. Make sure students become adept at identifying at least the most common organisms.

Roughly calculate the number of each kind of organism in one small drop of water. Or you can simply rank them by apparent frequency. Fill several petri dishes about half full of the water. Add different food sources such as sugar, organic matter, and starch to different dishes, leaving one dish without added food source. Leave the dishes for a week. Examine a drop of water from each dish under the microscope once again. See how the abundance of organisms has changed over time, depending on the food source available. Discuss the concepts of population change and dynamics.

You can learn all about the Audubon Society, plus take a virtual walk in Corkscrew National Sanctuary at:
http://www.audubon.org/audubon/contents.html

Birds show up everywhere. To see and read about the many birds that show up at the Fermilab linear accelerator site outside Chicago, go to:
http://fnnews.fnal.gov/ecology/wildlife/list.html

Want to know more about how the bird inventories are done? The National Biological Service has the information. Go to:
http://www.im.nbs.gov/birds.html

Notes

Background Material on Who's Eating the Fish?

What do wading and diving birds eat? They eat aquatic organisms, regardless of whether they're in the wild or in your pond! Bird species that include fish and crawfish in their diet are cormorants, pelicans (white and brown), herons (great blue, little blue, tricolor, green-backed, yellow-crowned night heron and black-crowned night heron), egrets (great, snowy, reddish and cattle) bitterns (American and least), ibises (white, glossy and white-faced) and Roseate spoonbills.

The populations of many of these species plummeted in the nineteenth and early twentieth centuries because of plume hunting, habitat loss, pollution, and pesticide contamination. Laws were enacted by Congress to protect these species from plume hunters in 1900 (Lacey Act) and the Migratory Bird Treaty of 1916 established laws that protected all species of migratory waterfowl. Since that time many of these bird populations have bounced back or increased, some even dramatically.

One problem is that we do not know exactly what the populations of these birds were historically, before they were exploited in the 1800's. Since 1949, we do have some data on bird populations based on the Christmas Bird Counts (CBC). These counts are done by the Audubon Society, a national environmental organization of bird watchers and environmentalists that organize in local or state groups. These groups go out one day every year around Christmas (between December 15 and January 5) and identify birds by species and count the numbers of each species that they see within a 15-mile diameter circle for that one day. This is valuable data that sets trends in populations. It records both resident and migrating populations.

> Visit the **Audubon Society** on the Web at: http://www.audubon.org/audubon/contents.html

Since 1966, the U.S. Fish and Wildlife Service (now the National Biological Service) has also conducted surveys called Breeding Bird Surveys. The National Biological Service is a branch of the federal government. The Breeding Bird Surveys are done by trained biologists during the summer. This survey looks only at breeding bird populations in specific areas (i.e., resident populations).

> Visit the **National Biological Service** on the Web at: http://www.im.nbs.gov/

The data gathered from both these sources is used to determine whether bird populations are increasing or decreasing.

Many of the bird populations have actually increased or rebounded since the 1950s. Some of the reasons scientists give for these increases are:

- long-term recovery from the effects of hunting;
- preservation of critical habitat in breeding areas;
- protection and expansion of wetlands (including artificial wetlands like aquaculture ponds);
- recovery from pesticides like DDT; and
- regional concentrations due to migration caused by habitat loss in other areas.

Long-term protection from hunting has certainly helped many bird species recover. So has the preservation of critical habitat like breeding areas and wetlands. Banning the use of pesticides that either directly killed or slowed reproductive success started in the 1960s and has continued as scientific studies have shown certain chemicals do not biodegrade quickly or are harmful by bioaccumulating over time. **Biodegrade** means that the substance will not decompose and leave harmful residues in the environment. Many products we see today are labeled as biodegradable. **Bioaccumulation** is the process by which a chemical can build up to higher levels at each step in the food chain. DDT is a classic example of a pesticide that bioaccumulates.

In some cases, bird populations have actually declined in one area while increasing in another. For example, many of the wading bird populations have decreased in Florida while increasing in Louisiana. In this case, many blame drought, increased human populations, the draining and pollution of estuaries, and the man-induced changes in the Everglades as causes for Florida's declining wading bird populations. Some of these problems exist in Louisiana, yet the wading bird populations are generally increasing. Many people think the increase in Louisiana is due to aquaculture.

Fish Farmers Fight Fowl in Louisiana

Louisiana is famous for its water resources, such as the Mississippi River, the Atchafalaya basin, Lake Pontchartrain and all those alligator-infested swamps. Louisiana is also famous for its unique and spicy cajun or creole food -- like etouffe, jambalaya, and crawfish pie. Have you ever tried any of these?

Louisiana swamps and crawfish just naturally go together. In fact, Louisiana harvests from the wild or produces about 85 percent of all the crawfish in the U.S. The acreage in Louisiana devoted to crawfish aquaculture exceeds 100,000 acres of ponds. Almost all of this acreage has been developed in the last 30 years. Louisiana has also built over 10,000 acres of catfish ponds in the last 15 years. This rapid increase in aquaculture acreage has coincided with a rapid increase in wading bird populations. Many crawfish and catfish farmers believe that the bird increases are because of the development of their aquaculture industry. Is it?

You be the researcher. Your job is to analyze the data presented in the tables on the following pages. Decide whether there is a relationship between bird population size and aquaculture ponds in Louisiana. If you decide that there is a relationship, devise solutions for Louisiana's fish and crawfish farmers.

First, do wading birds really eat crawfish? Table 1 gives some data on the percentage of crawfish and other crustaceans in the diets of a few species of these wading birds. It should be noted that this data is not from one scientific study, but many studies done over a 60-year period. The other major part of the diet of most of these birds is fish.

Next, what about the acreage of crawfish and catfish ponds and the increase in this acreage over time? Table 2 gives information on the pond acreage devoted to crawfish and catfish production since 1970.

Finally, how rapidly have these species increased in population? Table 3 gives Christmas Bird count (CBC) and Breeding Bird Survey (BBS) data as a percentage of change from 1966 through 1989. Table 4 gives examples of CBC data for five species of wading birds between 1969 and 1987.

How can you analyze all this data? Try drawing a graph that shows the increase in population of any wading bird species on the Y-axis and acreage in aquaculture on the X-axis over time. Do you think these wading birds are using aquaculture ponds as a source of food? Why or why not? Go to your library, or try some of the World Wide Web sites your teacher can tell you about to get more information. Have any of the species described here had a negative population trend? What are the possible reasons? What studies need to be done to help better understand this issue?

If you think the birds are the culprits, make your recommendations to Louisiana's fish and crawfish farmers.

Table 1. Percentage of Crawfish in the Diet of Juvenile and Adult Wading Birds in Louisiana

Species	% of Crawfish in Diet	
	Adult	Juvenile
Herons		
Great Blue	9-14[1]	No Data
Black-Crowned Night	22	8
Yellow-Crowned Night	74-97	No Data
Little Blue	11-73	5-8
Egret		
Great	9	30
Snowy	16-39	1-3
Ibis		
White	52-72	46
Glossy	Great[2]	37-40
White-Faced		

1. A range of percentages means that more than one scientific study was conducted and slightly different results were found in the different studies (usually over different years).
2. Great means that studies have shown that crawfish are a high percentage of the diet, but did not quantify the results.

Table 2. Increase in Crawfish and Catfish Aquaculture Pond Acreage, 1970-1995

Year	Crawfish	Catfish
1970	24,710	No Data
1975	45,466	No Data
1980	50,161	988
1990	120,659	15,963
1995	115,050	18,038

Table 3. Christmas Bird Count (CBC) and Breeding Bird Survey (BBS) Trends in Louisiana as a Percent of Annual change from 1966-1989

Species	CBC	BBS
Heron		
Great Blue	8.8	1.7
Black-Crowned Night	20.3	3.3
Yellow Crowned Night	4.0	9.1
Little Blue	1.2	-2.2
Egret		
Great	9.7	15.5
Snowy	15.1	24.8
Ibis		
White	25.4	18.5
Glossy	24.9	No Data
White-Faced	24.9	58.8

Table 4. Number of Individual Birds Counted During CBC in Louisiana, Selected Years (1969-1987)

Year	Great Blue Heron	Great Egret	White Ibis	Snowy Egret	Little Blue Heron
1969	20	60	70	45	390
1971	32	100	98	80	82
1973	26	125	88	115	88
1975	28	129	200	106	93
1977	42	158	196	140	89
1979	45	178	380	120	98
1981	63	196	510	148	68
1983	71	390	715	480	138
1985	82	410	1200	460	175
1987	86	242	990	300	100