Hook, Line, & Thinker

**Fish Knowledge—
Ecology & Biology**

**People Knowledge—
Social, Political, &
Management Issues**

SPORT FISH RESTORATION

WISCONSIN DEPT. OF NATURAL RESOURCES

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Select a fish that lives in Wisconsin that you would like to learn more about. Use this worksheet to profile the fish as you work through the different sections of this booklet. If each of your classmates selects a different fish, your classroom will know how to catch just about anything!

Profile of a Swimmer

Common Name(s): ______________________________

Scientific Name: ______________________________

SENSE	FEATURE AND DESCRIPTION	IMPORTANCE TO FISH (HIGH, MEDIUM, LOW)
Sight		
Smell		
Hearing		
Taste		
Touch		

Identifying Characteristics: ______________________________

____

Natural Food: ______________________________

Habitat Description: ______________________________

____

Niche (role): ______________________________

Spawning habits and habitat: ______________________________

____

____

Environmental stressors: ______________________________

____

Tackle and Bait: ______________ Bag Limit: ______________

Is there a health advisory for this fish? if so, where? ______________________________

____

Any restoration or stocking efforts for this fish? ______________________________

Good to eat or simple recipes? ______________________________

____

Other interesting facts about this species (list 5): ______________________________

____

____

____

Sources: ______________________________

Welcome, Anglers!

You are holding a guidebook that will help you to better understand our aquatic resources. This booklet is organized into two main sections: **Section A, Fish Knowledge** and **Section B, People Knowledge**. In Fish Knowledge, you will focus on science: fish biology and aquatic ecology. You will build on what you learned in that section as you explore the impact that people can have on fisheries, outlined in People Knowledge. This section looks at problems that humans have caused fisheries, and it addresses the various ways that management can try to solve these problems using science as a tool. In the final activity, Great Conservationists, you will consider your own relationship to fish and our aquatic resources.

We'll be using short scenes at the beginning of each section to guide our investigations. As you read these scenes, think about how fish ecology, management decisions, and personal choices all play roles in the problems described and in their possible solutions.

This booklet can be paired with *Hook, Line, & Thinker: Field Guide,* a booklet that focuses on the technical skills of angling. Even when done together these booklets are not detailed enough to make you an expert angler: that can take a lifetime. These booklets will, however, set you on a path towards discovering some basic principles about aquatic environments and your connection to them as an angler, as a fellow water-dependent being, and as a citizen with the ability to think and choose how you act.

Be sure to thank your teacher and community members for offering you this chance to learn more about Wisconsin's fisheries and the aquatic resources that sustain them.

Grass pickerel

The Scene

A local fishing group wants the Wisconsin Department of Natural Resources to put walleye and yellow perch in Linnie Lake, near Muskego. As a fish biologist, you are responsible for deciding whether or not to stock walleye and/or yellow perch in the lake. What sort of data do you need to collect in order to determine whether or not to stock the fish?

SECTION A

Fish Knowledge

A lake is a lake is a lake, or is it? For those of us who live and breathe on land, it is difficult to comprehend how different each body of water is. But fish can tell the difference! Each species of fish requires certain conditions to survive. To be an informed angler, you need to know these conditions and be able to match the environment to the fish. In this section, you will learn how to recognize different species of fish and how to identify different components of fish habitat.

1

One Fish, Two Fish, Panfish, Catfish

Largemouth bass

The fishing group in the scene requested that both yellow perch and walleye be stocked in Linnie Lake. These are two different species of fish, but how would you tell them apart? In the following section, you will learn what makes an animal a member of the fish family and how to label and identify different species of fish.

What Makes a Fish a Fish?

If you had to describe a fish to someone who had never seen one, what would you say? What makes one species of fish like another species of fish, but different from all other kinds of animals? Scientists struggle with how to appropriately define "fish." All fish are cold-blooded, or **poikilotherms** (animals whose body temperature is that of the environment), but so are reptiles and amphibians. All fish are **chordates** (animals with primitive or well-developed backbones) but so are you. All fish breathe using gills, but so do salamanders. Most fish spend all of their lives underwater, but longnose gar and other species of fish can breathe air. Most fish have scales and fins, but some saltwater eels (which are fish) have neither. Dr. Tim Berra of Ohio State University defines a fish this way, "…poikilothermic, aquatic chordate with appendages (when present) developed as fins, whose chief respiratory organs are gills and whose body is usually covered with scales." Sound confusing?

Poikilotherms
Animals whose body temperature is that of the environment

Chordates
Animals with primitive or well-developed backbones

Fish are hard to define because they have been on earth for so long that they have had time to develop many specialized adaptations. Fish fossils have been found dating back more than 400 million years. Worldwide there are about 21,000 species of fish each adapted through **natural selection** to a particular niche (role) in an aquatic ecosystem. For example, the northern pike's torpedo-shaped body and sharp teeth make it an effective predator. Its markings enable it to hide in the weeds unnoticed while it waits in ambush for its next meal to pass by. Bluegills also rely on coloration for protection instead of predation. The bullhead's keen sense of smell and sensitive barbels (whiskers) compensate for poor vision in the murky water it often inhabits and the **lateral line** senses vibrations as it does in all fish.The more you learn about fish and their habitat, the better angler you'll become.

Natural selection
A process by which only those creatures and plants well adapted to their environment survive

Speaking Anatomically: Scales, Skins and Scutes

Scales are modified skin cells that protect a fish's body from disease and injury. Fish hatch with all the scales they will ever have. They may grow replacement scales, but not additional ones. As fish grow, the scales just get bigger and lay down a growth ring each year. With a microscope, you can count the rings on a scale to determine a fish's age, just like you'd count the rings on the cross-section of a tree trunk. It's a good idea to sample several scales from one fish and go with the highest ring count to ensure that you are not relying on the count from a newer, replacement scale.

Some fish do not have scales at all. Catfish and bullheads have very tough skin and sturgeon have bony plates called scutes for protection.

Diversity Below the Surface

As of 2006, about 156 species of fish lived in Wisconsin waters; 15 of those were non-native, including five non-native game fish stocked by the Department of Natural Resources. Six other fish species are known to have been **extirpated** from Wisconsin since European settlement. Another 12 non-native species have been observed but have not yet become established.

Source: John Lyons, Wisconsin DNR Fisheries Research Biologist

Extirpated
Eliminated from an area

Mucus

Northern pike

A slimy coating helps protect fish from disease, fungi, parasites, and the grasp of would-be predators. Mucus reduces friction, allowing fish to swim 60% faster than they could without it. When you catch a fish, wet your hands before handling to minimize disturbance of this protective coating.

Gills

Brook Trout

Fish breathe every time they take a gulp of water. Water enters a fish's mouth and passes over and out through the gills, where oxygen (the "O" in H_2O) is extracted from water. Carbon dioxide is released from the fish's blood in exchange for oxygen. As a fish swims in moving water, the flow of water through the gills and exchange of gases occur without aid. Injury to the gills is often fatal, so handle fish with care.

Swim Bladder

Swim bladder
An air-tight sac in most fish.

Fish have a **swim bladder**, or gas bladder, that makes it possible for them to remain suspended in water. The bladder is an air-tight sac in most fish; some fish can add or release gas to adjust their depth in the water.

Skeleton

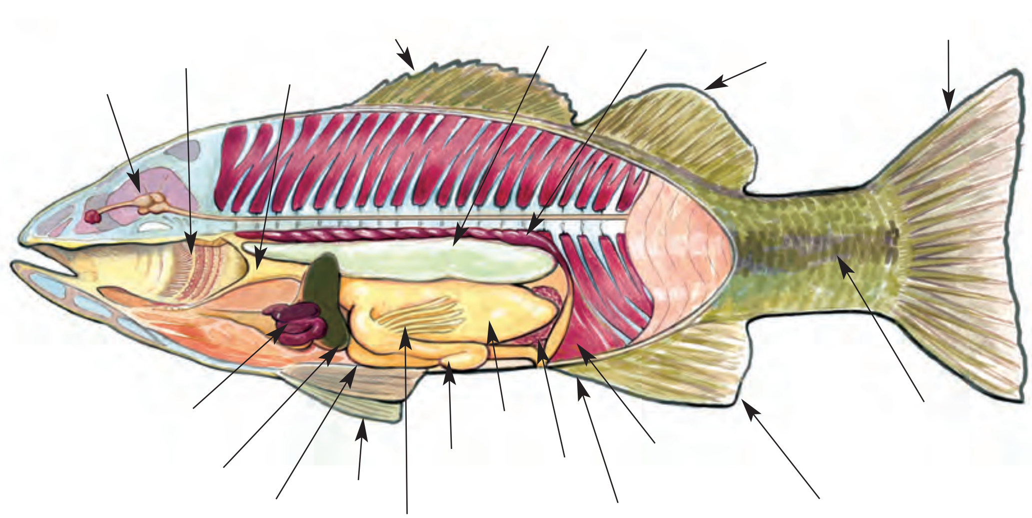
Most fish have a bony skeleton. However, some fish, like lamprey and sturgeon, have skeletons made of cartilage, rather than bone.

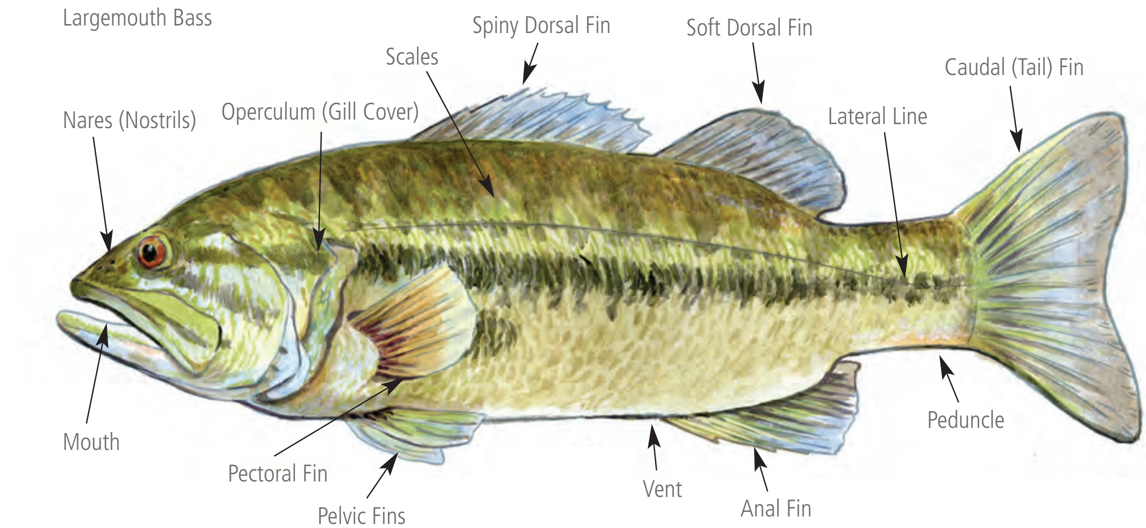
Coloration

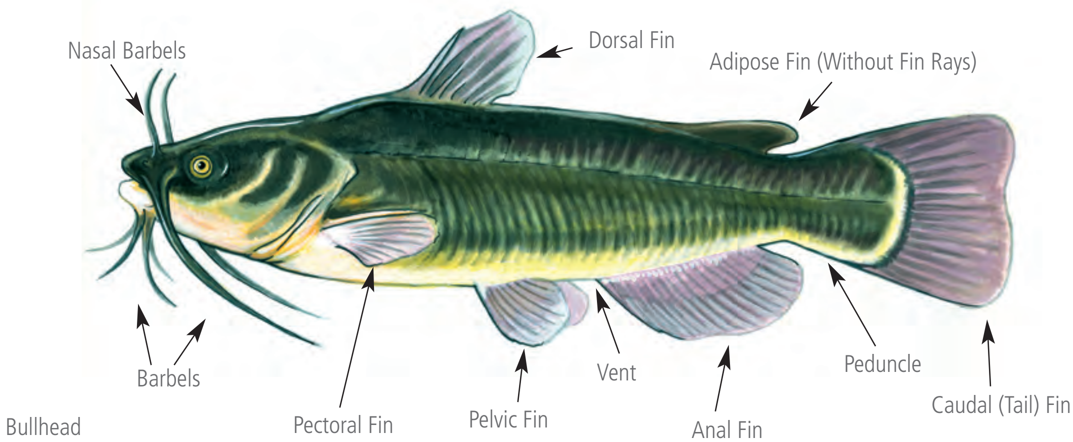
Fish come in a variety of colors and patterns that attract mates or conceal fish from predators or prey, depending on their place in the food chain. Almost every species is counter-shaded, dark across the back and light on the belly to help them stay hidden from above and from below.

Fin-Tastic

Fins are membranes supported by hard, bony spines or soft rays. They provide balance and make it possible for a fish to maneuver through tight spaces and stay upright in water. There are six types of fins, but not all fish have all types. Different species of fish have developed different sizes of fins depending on the fish's niche in the ecosystem. Knowing the size, shape, and location of different species' fins will help you later with identification. What can you know about a fish by its fins?







FIN	FUNCTION	NOTE
Dorsal	Balance and Maneuverability	Some dorsal fins are spiny-rayed and others are soft-rayed. Fish may have one, two, or three dorsal fins that can be a combination of spiny and soft rays. Fins may or may not be connected to each other.
Pectoral	Aim and Positioning	Pectoral fins help the fish aim itself, hover in one place, and dive.
Pelvic	Stability and Balance	Pelvic fins work with the dorsal and anal fins to provide balance.
Caudal or Tail	Locomotion (the propeller)	Species of fish with forked tails are fast swimmers. Those with broad, flat tails are able to turn and start swimming quickly.
Anal	Stability and Balance	Anal fins work best with dorsal and pelvic fins to provide balance.
Adipose	Unclear	The purpose of the small, fatty adipose fin is unclear. It is found on catfish, bullheads, trout,and salmon.

Marked for Research

Fin clipping is a method of marking fish for research. Biologists clip different combinations of fins to identify groups of fish. A specific clipping pattern indicates when and where a fish was stocked. When fish are recaptured, researchers refer to the fin clip records to chart survival and growth rates. The adipose-only fin clip is reserved by the Great Lakes Fishery Commission to be used throughout the Great Lakes on salmonids that are carrying a coded wire tag.

Wall-eyed

The term "walleye" is similar to an old Norse word meaning "a light beam in the eye." Walleye do indeed seem to be shooting light out of their eyes. They have reflective pigments on their retinas that allow them to see in very low light conditions, like at dawn or dusk. For this same reason, walleye avoid bright light. Remember this when seeking them out! Does anatomy play a role in other fish species' common names?

Physiology
The study of how an organism functions

Thermoregulate
Maintain a constant body temperature

Fish-iology

Physiology (the study of how an organism functions) can also be important to an angler. As we learned earlier, fish are poikilotherms.

Fish are not able to **thermoregulate** (maintain a constant body temperature) like mammals. Instead, a fish's body temperature nearly matches the temperature of its environment. How does knowing this help you to be a better angler?

Educated Angler

Use the space below to list five facts you have learned about fish anatomy or physiology and how each could help you catch a fish.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

Which Fish Is This?

What did you catch? What does it matter, anyway? A trout doesn't care if you call it a trout, a carp, or a muskellunge, but conservation wardens do and so should you.

Many fish are subject to **bag limits** (the number of fish you may catch in a day), while others are superior in flavor, and still others can be unhealthy if eaten too frequently. Legal requirements, taste preferences, and health issues are a few important reasons to learn to identify what kind of fish you've caught. The problem is, anglers, conservation wardens, and scientists may all place different labels on the same fish.

Bag limits
The amount you may catch in a day

Surely That's a GamePanMinnow-Fish

The easiest way to identify a fish is to place it in a category based on its purpose.

Anglers group fish by taste and how challenging they are to catch. To an angler, a panfish is generally a fish that is edible, fits in a frying pan, and is legal to keep. A game fish is generally any fish that is caught for sport. But, as you can imagine, definitions as broad as these can include many different fish and might mean something slightly different to each person. Ask around: is a walleye a panfish, a game fish, both, or neither?

To avoid confusion, Wisconsin conservation wardens use the following specific description of fish categories.

By Wisconsin law, **game fish** are defined as all varieties of fish except rough fish and minnows.

Rough fish include: dace, suckers, carp, goldfish, redhorse, freshwater drum, burbot, bowfin, gar, buffalo, lamprey, alewife, gizzard shad, smelt, mooneye, and carpsuckers.

Minnows include: suckers, mud minnow, madtom, stonecat, killifish, stickleback, trout perch, darter, sculpin, and all species of the minnow family (except goldfish and carp).

Wisconsin law is simplifying the identification process by calling *all* panfish game fish. This makes it easier to regulate the catch of the most popular species of fish. You might have noticed that the last sentence of the definition above hints of yet another way of identifying fish: by family.

For legal purposes, goldfish and carp are not considered minnows, but scientifically they are. Biologists identify fish by their **morphology** (structure) rather than by their purpose. Scientists use morphology to classify organisms into **taxonomic groups** (groups of closely related organisms) to build family trees and trace the evolutionary history of everything from plants to bugs to fish.

Morphology
Structure

Taxonomic groups
Groups of closely related organisms

Dichotomous key
An identification tool

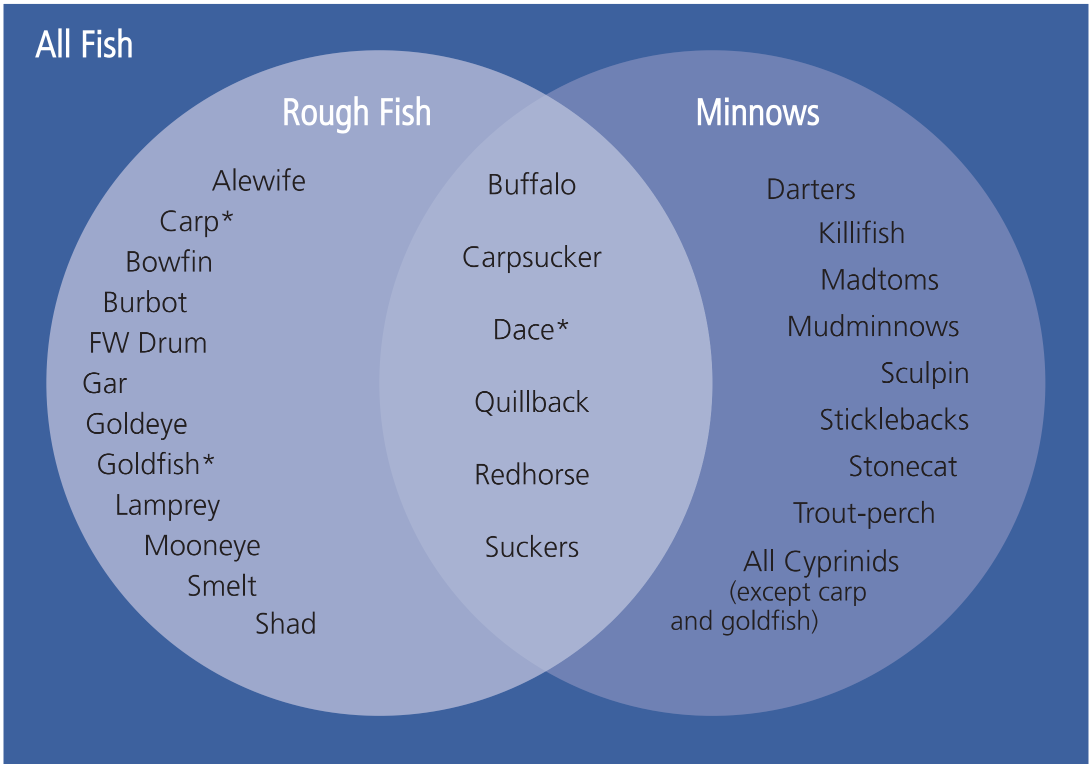
Once a scientist has built a family tree, she can use it to make a **dichotomous** (die-kot-o-mus) **key** (an identification tool). Keys begin with broad differences and work toward specific distinctions.

By scientific identification, no two fish of different structure will have the same name. A brook trout (Salvelinus frontalis) is in a separate taxonomic group from a smallmouth bass (Micropterus dolomieu). Of course anglers and conservation wardens also use this scientific system of identification, but not usually the scientific name.

That's Rough

The term "rough fish" seems to imply that these species have little or no value, but enlightened anglers, biologists, and chefs know better. Rough fish often inhabit a rough neighborhood, the murky bottom, but that doesn't mean they don't taste good. Take a chance and try one sometime!

Game Fish, Rough Fish, Minnows



By state law all fish are "game" fish if not "rough" fish or "minnows." Game fish may not be harvested unless an open season is specified in Administrative Code.

* Taxonomically, carp and goldfish are in the minnow family. Legally, however, they are classified as "rough" fish, but not as "minnows" in Wisconsin. Although dace are also members of the minnow family, legally, they are classified as both a minnow and a rough fish. All members of the sucker family are considered rough fish for legal purposes; they are in the same *order* as minnows. Other fish legally referred to as "minnows," are in several different taxonomic families.

What's That?

What would you expect to see if your friend said, "Hey I just caught an Animalia Chordata Actinopterygii Perciformes Centrarchidae Lepomis gibbosus!"

A Taxonomic Grouping of Esocidae

Identify this fish using the key below.

1. a. Body lacks large bony plates. . . . . Go to #2

   b. Body has large bony plates . . . . **Lake Sturgeon** (not in Esocidae family)

2. a. Dorsal fin is short, much less than half the body length . . . . Go to #3

   b. Dorsal fin is nearly half the body length or longer . . . . . **Bowfin** (not in Esocidae family)

3. a. Teeth are visible and sharp . . . . Go to #4

   b. Mouth is fleshy, teeth are not visible and sucker-like **White Sucker** (not in Esocidae family)

4. a. Tips of tail fin are rounded . . . . Go to #5

   b. Tips of tail fin are pointed . . . . **Muskellunge** (Esocidae family)

5. a. Cheek and gill cover are fully scaled . . . . **Grass Pickerel** (Esocidae family)

   b. Cheek and only upper half of gill cover are scaled . . . . **Northern Pike** (Esocidae family)

Family Ties

Construct your own taxonomic groups of fish.

Notes

2

Survivor

Yellow perch and walleye, like all organisms, are adapted to certain habitats. Before stocking fish, a biologist needs to know the food, water, shelter, and space requirements of the species. If a waterbody does not have the components of habitat a fish needs, stocking it would be a waste of time and money. What would be the right habitat for a walleye? Is it the same as for a yellow perch? In this section you will learn what fish need in order to survive. We'll review some ecological principles, look at how the nature of water affects fish, and explore the different aquatic habitat types in Wisconsin.

Walleye

Fish Food

What fish eat and who they are eaten by plays a major role in the functioning of an aquatic ecosystem. There are predator and prey fish, just as there are predator and prey mammals. The wolf and the coyote are land versions of the salmon and the northern pike, while darters and shiners are the rabbits and mice. Having a healthy aquatic ecosystem means having the right balance of predators and prey in a body of water.

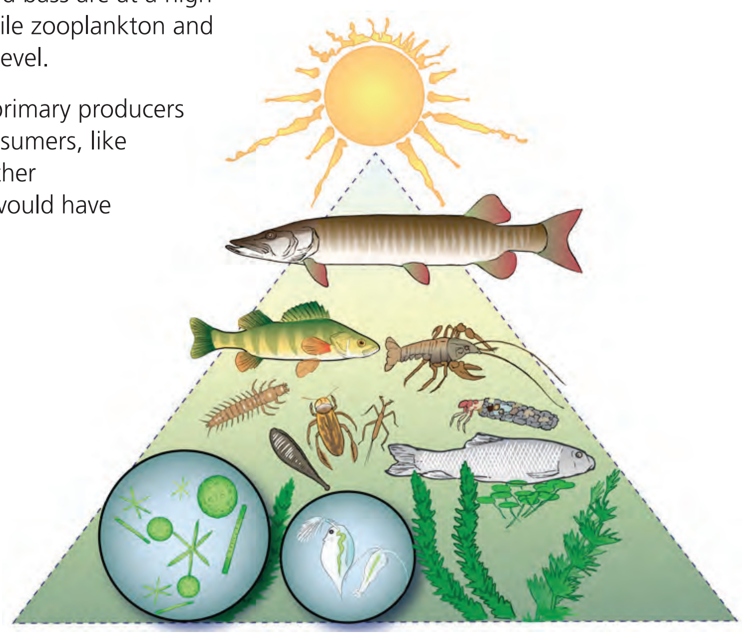
More than a Chain

If you think of the food web as a pyramid, the base of the pyramid would contain many small—even microscopic—plants and animals, while the top would include fewer, larger animals. Thousands of microscopic plants and animals are required to support a few predator fish. Musky and bass are at a high trophic level (feeding position) in the pyramid, while zooplankton and other microscopic organisms are at a low trophic level.

The lowest level on the pyramid is composed of primary producers (those who make their own food, like algae). Consumers, like the bass, feed on the primary producers and on other consumers. Can you think of any organisms that would have a higher trophic level than the musky or bass?

Losing Energy

Within any food web, there is a transfer of energy. When a trout eats a worm, some of the energy stored in that worm is transferred to the trout. Not all of the energy used at each level of the food web, however, is recoverable. As you move up the levels in the pyramid, there is less energy available at each higher level than at the level below.



Energy Pyramid: Thousands of microscopic plants and animals are required to support a few predator fish.

Ecology

From Latin meaning "household" or Greek meaning, "house". When we study ecology, we are studying the relationships between organisms and their environments (homes).

Scientists often refer to this transfer and loss of energy as the "Rule of 10" or the "Ten Percent Law." The primary producers at the very bottom of the pyramid can only store about 10 percent of the radiant energy from the sun as sugars or carbohydrates in their tissues. The microscopic organisms and small fish that feed on the plants, in turn, only store about 10 percent of the energy that the plants provide them, and so on up the pyramid. This creates a broad-based, steep-sided pyramid. Top predators like musky, salmon, and humans are at the pyramid's peak and require a large number of smaller fish to get the energy they need to survive.

Feed Me!

Walleye, for example, require a large amount of space in order to find enough prey to survive. There are fewer walleye in any lake or river compared to smaller fish, simply because a walleye is near the top of the trophic pyramid. A single 10-pound walleye requires about 100 pounds of perch annually to maintain its weight. One hundred pounds of perch depend on one-half ton (1,000 pounds) of minnows. Those minnows rely on five tons (10,000 pounds) of plankton and insects for their survival. The plankton and insects need 50 tons (100,000 pounds) of plants for their support. And at the top of it all is just one well-fed walleye.

A single 10-pound walleye requires about 100 pounds of perch annually to maintain its weight.

You do the Math…

1. What is the total weight of biomass (living plants and animals) required to sustain that 10-pound walleye for a year? Show and label your work.

2. If 7,300 solar units are equal to the amount of energy required to sustain a pound of plants, how many solar units does it take to sustain a 10-pound walleye?

3. What factors influence the amount of energy a fish requires to maintain its weight or grow? In other words, what could cause that 10-pound walleye to starve?

Oligotrophic lakes are usually formed by glacial scouring and have little soil on their bottoms.

Most of the lakes in the southern and central counties of Wisconsin are mesotrophic. These lakes were formed by glacial deposits and tend to be well-vegetated and fertile.

Eutrophic lakes are shallow, very fertile, and loaded with nutrients.

Illustrations by Chris Whalen, Courtesy of University of Wisconsin-Extension Lakes Program

This Lake's Got Class…

Lakes are classified into three trophic categories based on the amount of nutrients found in them and on water clarity.

Oligotrophic lakes have few nutrients and are generally found in the far north of Wisconsin. Lake Superior is a great example of an oligotrophic lake. These lakes were formed by glacial scouring which stripped away the soil. Lack of soil and other nutrients limited the growth of vegetation which allowed clear-water conditions to persist over the ages. Oligotrophic lakes tend to be deep with a high oxygen content that supports prized game fish like lake trout, perch and walleye.

Mesotrophic lakes have a medium amount of nutrients. Most of the lakes in the southern and central counties of Wisconsin are mesotrophic. These lakes were formed by glacial deposits and tend to be well-vegetated and fertile. Mesotrophic lakes are not as deep as oligotrophic lakes, but have a rich assortment of game fish like musky, northern pike, and bass.

Eutrophic lakes are low in oxygen, very fertile, and loaded with nutrients. They are typically shallow and found throughout Wisconsin where older lakes have filled in due to erosion or other factors. Eutrophic lakes will eventually become bogs or marshes. Younger eutrophic lakes host panfish and bass, but catfish, carp, and bullheads begin to dominate as the lake ages. Eutrophication is a natural aging process, but human activities can accelerate it by adding nutrients through erosion, polluted runoff, and leaky septic systems.

Steady State?

Use the worksheet below to fill in your population dynamics results as you participate in a simulated food chain with different limiting factors. Your teacher will provide you with a nutrient game board and cards representing algae, shiners, and smallmouth bass. At the end of a round, record the time that each population crashed and the number of uncovered cards of each color.

1. Each Round lasts exactly five minutes.
2. The Start Time is the time at which a trophic level begins growing (begin laying down cards).
3. The Production Rate is the time interval between laying cards down. It represents the combination of the feeding, growing, and reproducing rates for that trophic level. For example in Round 1, green algae lay down one card at the beginning (t=0) and lay down one card every 5 seconds for the entire 5 minutes. Shiners start after 10 seconds (t=10), and lay down one card every 10 seconds. Bass start after 20 seconds (t=20) and lay down one card every 30 seconds.
4. You may only place your cards on top of the species you consume. If there are no more cards for you to put yours on top of, your species dies of starvation.
5. At the end of five minutes, record the number of cards remaining uncovered (still alive and feeding) and/or when the trophic level crashed.

		ROUND 1		ROUND 2A		ROUND 2B		ROUND 2C	
TROPHIC LEVEL	CARD COLOR	START TIME	PRODUCTION RATE	START TIME	PRODUCTION RATE	START TIME	PRODUCTION RATE	START TIME	PRODUCTION RATE
Green Algae	Green	0	5	0	5	0	5	0	2
Common Shiner	Yellow	10	10	20	3	10	15	10	5
Small-mouth Bass	Purple	20	30	25	20	20	10	20	10

		ROUND 1		ROUND 2A		ROUND 2B		ROUND 2C	
TROPHIC LEVEL	CARD COLOR	CRASH TIME	NUMBER OF CARDS	CRASH TIME	NUMBER OF CARDS	CRASH TIME	NUMBER OF CARDS	CRASH TIME	NUMBER OF CARDS
Green Algae	Green								
Common Shiner	Yellow								
Small-mouth Bass	Purple								

1. Which round of the game does each of these phrases describe?

   Primary Producers are the limiting factor: ____________________

   Predators are the limiting factor: ____________________

   Nutrients are the limiting factor: ____________________

   Steady State: ____________________

2. Which of the rounds describes what can commonly happen in an oligotrophic lake? How would you change the model to reflect a eutrophic lake?

3. What would happen in Round 1 if the round continued for another five minutes? Why?

4. Why did all the trophic levels crash in Round 2A?

5. Name two ways a steady state could be restored for Round 2A:

6. What limits the growth of algae in Round 2C? Predict what would happen to the shiners and the smallmouth bass if this game were to run another five minutes.

7. If you were planning to stock fish in a lake, what could you learn from these rounds?

8. What are some of the assumptions and limitations of this food chain model?

Water of Life

All organisms require water to live. Humans need it to quench thirst, carry boats, and grow food. Fish, of course, rely on clean water simply to breathe and function. Knowing what sort of water conditions a fish requires will help you find the best fishing holes for the species you seek to catch.

"Breathing" Water

Each water molecule is composed of two atoms of hydrogen and one of oxygen. As long as those molecules are bound together, the oxygen molecule is not available to the fish. Fish get the oxygen they need to "breathe" from microscopic bubbles of dissolved oxygen.

Dissolved oxygen comes primarily from air mixed into the water through wind and wave action. In a stream, moving water tumbling over rocks picks up oxygen from the air and carries it along. Plants and algae also contribute oxygen to the underwater world through photosynthesis during daylight hours.

While plants add oxygen to the water during the day, respiration by and decomposition of dead plants and animals remove it.

Polluted runoff also reduces the dissolved oxygen content of a waterbody by adding nutrients that use up oxygen.

Biological Thermostats

Dissolved oxygen content is also tied to water temperature and other factors. Cold water can hold more oxygen than warm water. As weather or thermal pollution warm the water, dissolved oxygen levels drop and fish must work harder to breathe. Thick snow cover on frozen lakes blocks photosynthesis, necessary for the production of oxygen and can lead to "winterkill" conditions. Dissolved oxygen concentrations in a certain stream may be higher in early morning or in mid-winter than they are in the mid-afternoon or summer.

Dry weather can decrease the amount of water in a stream, causing it to move slower and, therefore, pick up less oxygen. Rain, on the other hand, can mix with oxygen on its way down to earth, bringing the oxygen with it when it lands in a body of water.

Most fish require a dissolved oxygen concentration of seven to nine milligrams per liter (mg/l) . Cold-loving trout prefer higher levels of seven mg/l, while bass are adapted to five mg/l. The majority of fish cannot survive at levels below three mg/l. Can you think of some fish that, based on their habitat, might be tolerant of lower levels of oxygen?

Prime Real Estate

Which of the following environments would most likely have good trout habitat based on dissolved oxygen? Which of these could host a catfish?

1. A fast-moving, unpolluted stream ______________________
2. A small pond with lots of vegetation ______________________
3. A large slow-moving, muddy river ______________________
4. Lake Michigan ______________________
5. Lake Superior ______________________

Temperature Tolerances of Common Fish

FISH SPECIES	PREFERRED TEMPERATURE °F										
	40	45	50	55	60	65	70	75	80	85	90
Catfish										XX	??
Bullhead								XX	XX	XX	
Sunfish							XX	XX	XX		
Largemouth Bass						XX	XX	XX			
Muskellunge					XX	XX	XX	XX			
Chinook Salmon		XX	XX	XX							
Lake Trout	XX	XX	XX								

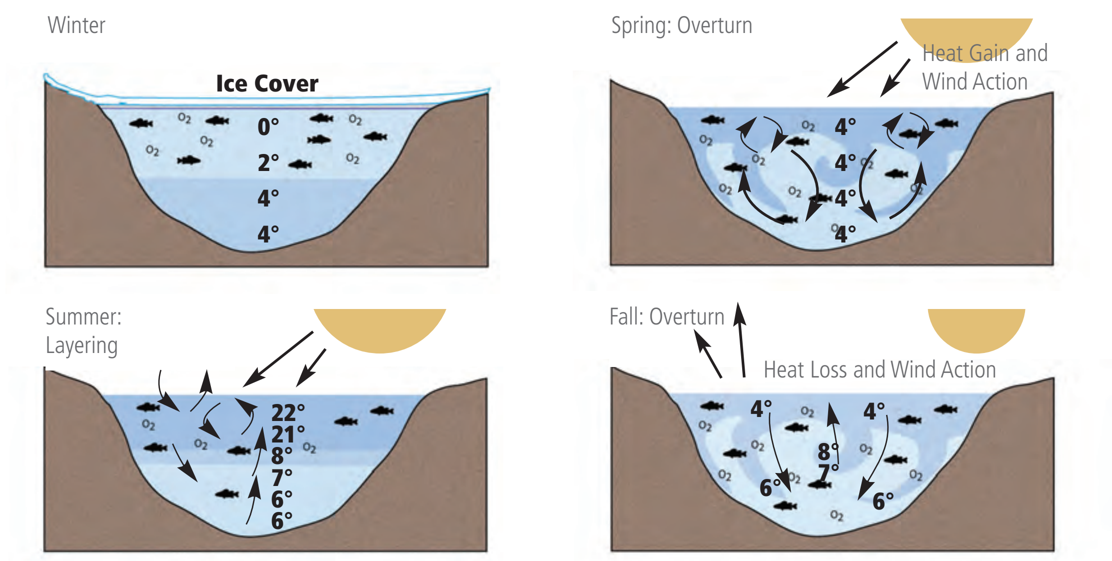
Comfort Zones

Water temperature is perhaps the single most important factor in determining where fish will be and how they will behave. Each species has its own comfort and tolerance level. Fish tend to seek the most comfortable environment, assuming that there is sufficient oxygen, and will migrate from shallow to deep water to find their optimal temperatures.

Like Oil and Vinegar

What sensations do you feel when you dive into a lake during summer? The cool, deep water is often a shock compared to the warmer surface water. Warm and cool water becomes **stratified** (layered) just like the layers of vinegar and oil in a bottle of salad dressing. This is because different temperatures of water have different densities. Warm water is less dense than cold water. The heat of the summer sun warms the **epilimnion** (surface water) until it becomes so warm and light that it cannot mix with the heavier, colder **thermocline** and **hypolimnion** below. The thermocline (also called the **metalimnion** for "middle layer") marks a rapid change in temperature with a small change in depth.

When surface water cools in fall, it sinks until it reaches its maximum density at 4°C (39°F), just above the freezing point. As it continues to cool, it gets lighter and freezes on the surface, indicating that the ice fishing season is just around the corner. If water did not behave this way, lakes would freeze from the bottom up, killing everything in them. Anglers know that as water temperatures shift throughout the seasons, dissolved oxygen, nutrients, and fish distribution shift as well.



By late fall, overturn is complete and temperature is a uniform 4°C* throughout.

*C=Celsius

Coming Up for Air

Watch the demonstration of the layers in a summer lake and then answer the following questions:

1) Where does most of the heating occur in a lake? ______________________________

2) What is the effect of wind on a summer lake? ______________________________

____

3) How does layering affect fish living in the lake?______________________________

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4) Given all that you have learned about temperature and oxygen, what could climate change mean for aquatic species? For anglers?

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5) Design a 10-year experiment that would allow you to determine the layering in your own local lake and whether or not it is changing as a result of climate change. What type of equipment would you need? Where would you take measurements and when? How would you know if you were getting a good sample of the lake? ______________________________

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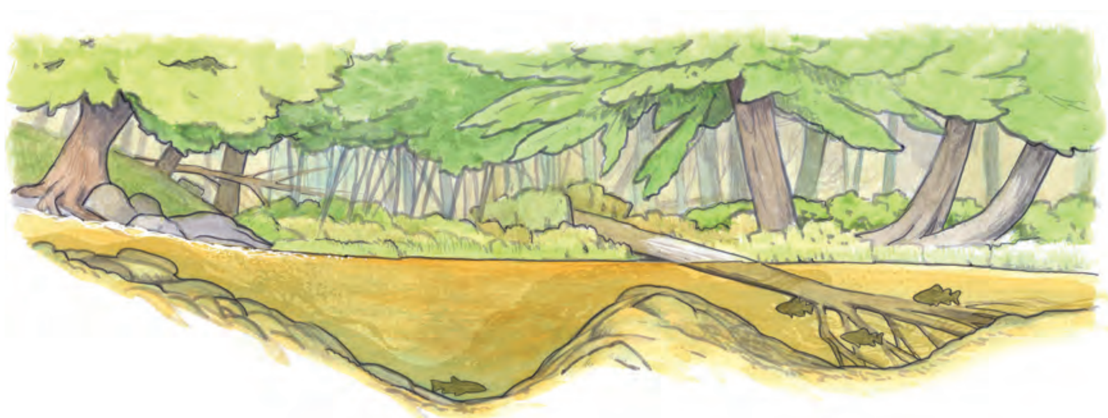
Home Sweet Home

Why do certain fish live deep in lakes, while others can be found in shallow streams, and still others dart in and out of a reedy marsh? Think back to the past two lessons in this section. Fish need to live in waterbodies that can supply enough energy (a small pond cannot support 10-pound walleye) and that will meet their temperature and dissolved oxygen requirements. But fish have more needs than just food and water; they also need places to hide—either to surprise prey or take cover from predators—and places to **spawn** (lay their eggs). A great diversity of aquatic habitats makes for a great diversity of fish species. Woody cover (like fallen logs), aquatic vegetation, rock piles, and overhanging riverbanks are all components of different ideal fish habitats.

Spawn
Lay eggs

Go with the Flow: Rivers and Streams

Rivers and streams provide fish with **dynamic** habitat. Streams dramatically change in depth and flow with the weather, the seasons, and the climate. A flood, for example, can quickly destroy spawning habitat by washing out bottom material. Floods can also make new spawning habitat instantly by felling a log, creating a shady deep pool. Streams are also different from one section to the next—the temperature and current that you find at the **headwaters** of a stream will be different from the temperature and current at the **mouth** of that same stream, and will vary considerably along the stream's entire length from rapids to riffles to pools. Fish travel into, out of, and within stream systems to find the conditions perfect for their food, protection, or spawning needs. As with other habitat types, rivers and streams will warm as our climate changes, which may make them uninhabitable to temperature-sensitive species like trout.



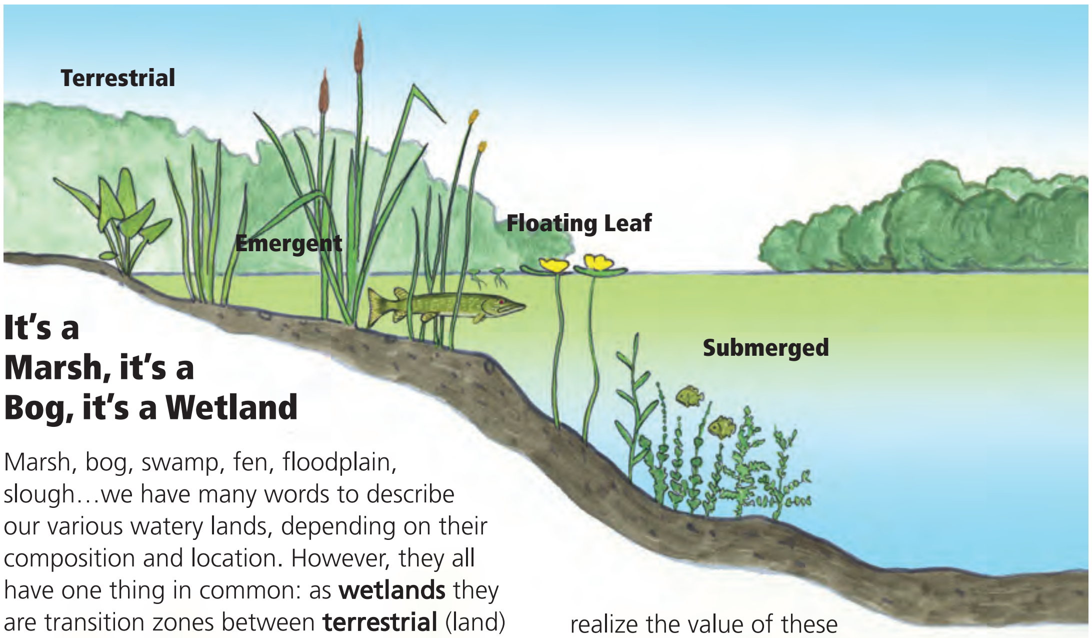
Fish travel into, out of, and within stream systems to find the perfect conditions for their food, protection, or spawning needs.

Wanted

Large, oligotrophic lake with plenty of minnows and other small fish. Cold depths required. Silty bottom preferred. Access to littoral zone a must. Call or email. - A. Sauger

Math Quiz

Wisconsin once had 10 million acres of wetlands and now has only 5.3 million acres. What percent of Wisconsin's wetlands have been lost? Wisconsin was once 28% wetland. What is it today?



A diversity of native aquatic plants are vital to fish habitat and are rooted in the littoral zone of a lake.

It's a Marsh, it's a Bog, it's a Wetland

Marsh, bog, swamp, fen, floodplain, slough…we have many words to describe our various watery lands, depending on their composition and location. However, they all have one thing in common: as **wetlands** they are transition zones between **terrestrial** (land) and aquatic ecosystems. The plants and soils of a wetland are generally saturated with water for at least one season during the year. Like streams, wetlands are very dynamic and change with the weather. During dry spells water might not even soak a wetland's soil. However, during rainy periods wetlands are quick to fill and the water may be over your head. Some fish spend their entire lives in wetlands, while others come only to feed or spawn. Marshes, which are usually wet year-round and filled with shelter-providing grasses, tend to be the most hospitable wetlands for fish. Bogs are typically too acidic for fish.

Wetlands provide important functions available nowhere else on earth. Beyond providing habitat for fish, they are also wildlife nurseries for birds, amphibians, reptiles, and insects. Wetlands also act as great sponges, sopping up floodwaters and filtering out contaminants before they reach groundwater and surface waters. Wetlands keep the effects of erosion in check by holding back silt and preventing it from clogging spawning beds in rivers and streams. Wetlands used to cover 10 million acres or 28% of Wisconsin. Today roughly 5.3 million acres remain. Long after the damage was done, many people came to realize the value of these wetlands and now work to protect and restore them.

In the Zone: Inland Lakes

Lakes have distinct habitat zones that vary in nutrients, oxygen content, temperature and cover. Fish inhabit lake zones when and where the conditions match their needs. The most commonly recognized habitat zones in a lake are the **littoral** (shallow), **limnetic** (open water), **profundal** (deep water), **benthic** (bottom), and **wetland**. The littoral zone extends from the shoreline out as far as emergent, floating, and submerged rooted plants can grow, which is generally about 15 feet, depending on water clarity and lake depth. It is an important zone for females to spawn and for young fish to hide because of the protection underwater plants and fallen trees offer. The limnetic zone (sometimes called the pelagic zone, particularly in ocean environments) begins where water is too deep for rooted plants to get established, but an abundance of sunshine photosynthesizes phytoplankton (microscopic floating plants).

Large, cold-loving fish can be found in the limnetic zone, feeding on free-swimming

Littoral
shallow

Limnetic
open water

Profundal
deep water

Benthic
bottom

Wetland
land-water transition area

Watery Wisconsin

Trace the history of our abundant aquatic resources and you'll be led back about 15,000 years to the ice age. Mountains of glacial ice channeled out many of Wisconsin's 44,000 miles of rivers and streams. Footprints of the glaciers became the Great Lakes as well as most of the 15,081 inland lakes that are splashed across the state.

Many of Wisconsin's wetlands were created where chunks of ice left depressions. The southwest part of Wisconsin, known as the "driftless area," was not glaciated during the last glacial period. Streams in this region have been at work for thousands of years, cutting deep valleys into the soft layers of limestone and sandstone deposited by ancient inland seas. There are few natural lakes and wetlands in this area.

zooplankton like crustaceans and rotifers. The deep, dark profundal zone lies below the limnetic zone and oxygen levels start to drop. The benthic zone is a very low-oxygen environment where decomposers and scavengers roam.

Wetland habitats associated with lakes are marshy transition areas from the water to upland areas. It is common for the littoral zone to also be called a "wetland" in lakes.

Fingerlings
Young fish

Substrate
Bottom material

Superior Habitat: Great Lakes

Wisconsin's eastern and northern borders are nestled against two of the largest freshwater lakes in the world, Lake Michigan and Lake Superior. The extreme depths and cold temperatures of the Great Lakes provide habitat for many of Wisconsin's big game fish. Near-shore rocky reefs attract chinook salmon, coho salmon, and brown trout, while rainbow trout (or "steelhead") live near the surface in open water, often many miles from shore. Lake trout require the coldest waters and generally live in 50 to 200 feet of water, depending on the season. Extensive wetlands and **tributaries** along Lake Superior provide spawning habitat for brown trout, steelhead, chinook and coho, while northern pike head to Chequamegon Bay at spawning time.

Nursery Needs

Wetlands and littoral zones are host to many aquatic plants that serve as protection for fish eggs, **fry** (newly hatched fish), and **fingerlings** (young fish). This makes them a popular site for spawning—but plenty of fish go elsewhere to raise their young. Protection is one consideration for parent fish, but **substrate** (bottom material) is another. Many fish create **redds** (nests) out of a certain bottom material. If that material is not available, the fish will go elsewhere. Other fish deposit their eggs directly on the bottom of a lake or river, while still other fish have eggs that float or that attach to vegetation. Some fish, like salmon, return to the site where they were spawned when it is time to lay their own eggs. Temperature, dissolved oxygen, and food availability are also important indicators of where a fish will spawn.

Follow Your Nose

When salmon are very young, they "imprint" on the stream in which they are stocked or hatched. In spring, the young salmon migrate to the Great Lakes. At spawning time, the salmon are drawn by their strong sense of smell back to their "home" stream.

Spa(wning) Resort

Research the spawning habitat requirements for a fish in order to determine the ideal habitat for the fish's needs. Then design a travel brochure using images and text to lure the fish to your Spa (wning) Resort. As you develop your travel brochure, keep the following questions in mind:

1) What temperature and dissolved oxygen content do the eggs and fingerlings of the species require?

___

2) What types of protection do the eggs need? Do they need to be camouflaged or placed under a structure? Do the parent fish create a redd?

___

___

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3) Who will prey on the eggs or fry? What can the fish parent do to prevent this? What other threats might the eggs and fry encounter?

___

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___

4) What will the fingerlings eat when they hatch? Is it available nearby?

___

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___

5) How far will the fingerlings have to travel to reach the area where they live in maturity?

___

___

___

The Scene

Something is wrong with the Sparkling River. What was once a clear, clean, diverse body of water has become a sluggish, murky eyesore. The residents who moved into the new development along the river are angry that their beautiful riverfront homes are now worth less than when they bought them. Anglers are upset with declining water quality in what used to be an excellent trout stream.

The city has asked you, a fish biologist and expert on **degraded** ecosystems, to come and speak to the angry residents and anglers about what has gone wrong with the river and offer suggestions on how to fix the problems. What do you think could be wrong? What types of surveys would you need to conduct in order to find the culprits? How could the local residents solve the problems you discover?

SECTION B

People Knowledge

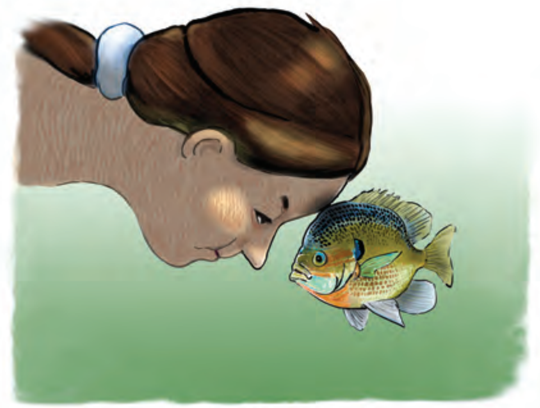
Ecosystems are not perfectly stable machines. Trophic pyramids can crash, dissolved oxygen levels can plummet, temperatures can swing, and shelter can disappear. Sometimes the changing dynamics of an ecosystem are natural fluctuations or disruptions: A volcanic eruption that clouds the sky around the globe can slow photosynthesis and disrupt the trophic pyramid. A long winter that keeps ice on for an extra month can deplete oxygen in a frozen lake. A flood can wash out gravel on the bottom of a stream.

At other times, disruptions to an ecosystem result from human decisions and actions. To be an educated angler, you should be able to recognize some of the actions humans take that can affect fish populations and some steps you can take to improve fishing conditions. In this section, we will discuss some human choices that are changing the environment and several management efforts beneficial to both people and fish.

3

Head to Head

What sorts of decisions do humans make that can affect fish? Sometimes actions that humans take create obvious problems for fish. When a wetland is filled in or a septic tank overflows into a river, the effects on fish populations are immediate and visible. Often, however, we are unaware of the impacts our choices have on aquatic environments. In this section, we'll discuss some environmental **stressors** that affect fish.



In this section, we'll discuss some environmental stressors that affect fish.

To the Point

Water that comes out of our taps at home—the water that we drink and shower in—has been filtered and cleaned. That's not the case for fish. Fish have to swim in whatever water comes their way, even if it is polluted. Water pollution can come from two types of sources: **point** and **nonpoint**. A point source of pollution is a particular, identifiable source of pollution that dumps pollutants directly into a water source. A pulp and paper mill, for example, that discharges **effluent** (waste material) into a nearby stream is a point source and is, therefore, regulated by the Clean Water Act. Many of these sources have been cleaned up over the years. Nonpoint source pollution is much harder to regulate, because it comes from many places across a landscape.

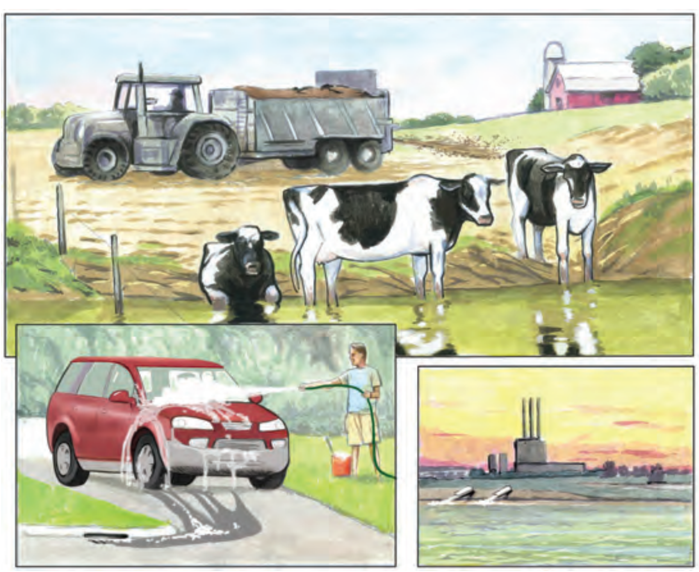
Point source
a particular, identifiable source of pollution that dumps pollutants directly into a water source

Nonpoint source
pollution that comes from many places across a landscape

Effluent
waste material

Runoff

Nonpoint source pollution can come from many places. The oil that drips out from under a car, the salt used to make roads safe in winter, and the dog deposit Spot left on your lawn can all become aquatic pollutants. Rain and snowmelt will carry these items into your local stream or down into the groundwater where they contaminate the water. This polluted **runoff** is the leading cause of water quality problems in Wisconsin and in the United States.



Runoff, atmospheric depostition and erosion can all affect water quality.

Watershed Moment

When rain falls on your roof, where does it go? Down the gutters, off the pavement, into the ground…and then where? The rain that falls on your house will eventually make its way into a large waterbody, like Lake Michigan, the Mississippi, or Lake Superior. On its way, it will travel through a network of streams, rivers and, perhaps, some wetlands and lakes. Each waterbody your water passes through is affected by the decisions you, and those who share your watershed, make. What's your watershed, and who shares it with you?

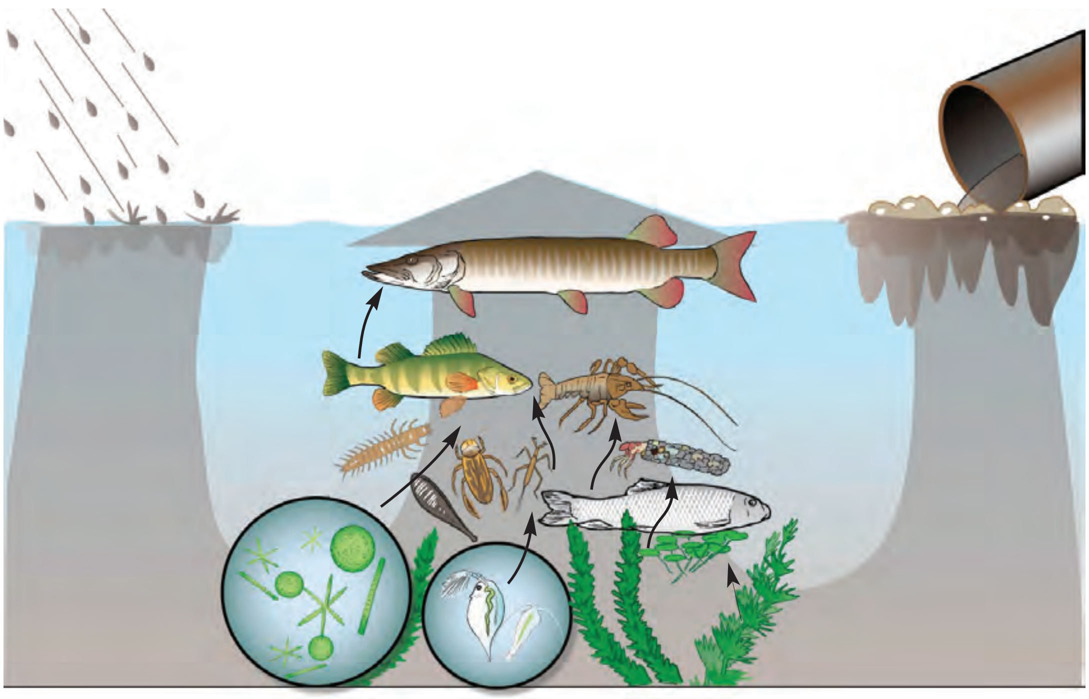
Erosion

Wind, water, and ice movement are natural processes that cause soil erosion, but certain activities can accelerate it. A cow walking into a stream will kick up soil along the bank. A construction worker digging a hole for a new foundation breaks up soil and piles it up. Both actions allow loose soil to more easily wash away in a rainstorm or with melting snow.

Eroded soil that enters the water can bury fish habitat and smother fish eggs. Eroded soil as a nonpoint source pollutant can be a major cause of fish kills and loss of fish habitat.

Atmospheric Deposition

When we burn coal for electricity, when a volcano explodes, and when a waste incinerator operates, the smoke and steam that are emitted carry chemicals with them up into the atmosphere. These chemicals can travel long distances in air currents—crossing city, state, and national borders—and will eventually fall to the ground with rain droplets or snow in a process called **atmospheric deposition**. Atmospheric deposition is another form of nonpoint source pollution that affects the fish in Wisconsin.



Contaminants move up the food chain.

Neurotoxin
A poison that affects the brain and nervous system

Persistent organic pollutants
Contaminants which do not break down in the environment

Bioaccumulation
The build-up of substances such as pesticides or other toxins in an organism

What's in Your Water… Ends Up in Your Fish

Atmospheric deposition and runoff are responsible for two contaminants of particular concern for anglers in Wisconsin: mercury and PCBs, respectively. Both are highly toxic and have properties that allow them to remain in our environment for long periods of time.

Once mercury is in the water, bacteria convert it into methylmercury, which is a powerful **neurotoxin** (a poison that affects the brain and nervous system).

Polychlorinated biphenyls (PCBs) were used in industrial applications like paint and hydraulic equipment until they were banned in 1976 because of their toxicity. They are **persistent organic pollutants** (contaminants which do not break down in the environment) and continue to leak out of contaminated sediments, hazardous waste sites, and old products.

When small fish eat bacteria or plankton that have been exposed to methylmercury, for example, that mercury begins to accumulate in the fish's body. **Bioaccumulation** (the build-up of substances such as pesticides or other toxins in an organism) can have serious implications for fish and angler health.

Toxins aren't the only way that runoff and atmospheric deposition affect fish. When chemical fertilizers and manure, both of which contain phosphorus, are applied to lawns and fields at rates the land cannot absorb, excess phosphorus runs off into waterbodies. Too much phosphorus in the water causes algal blooms that can make water look like pea soup. Not only does a pea soup lake look and smell bad, it can also kill fish and wildlife. When a mat of algae covers the water, it blocks sunlight needed by other aquatic plants and as it decays uses oxygen needed by fish. Massive algal blooms can also produce toxins that sicken wildlife and, occasionally, pets and humans.

Perhaps the most prevalent runoff contaminant is sediment. The sand, dirt, and gravel from construction sites, roadways, backyard gardens, or farm fields become contaminants when they enter the wrong places in the wrong quantities. Sediment in water can alter stream flow, cover important spawning habitat, or make the water murky. Murky water has lower levels of dissolved oxygen and increased water temperatures which both affect fish populations. Murky water also prevents sunlight from reaching submerged plants which stunts their growth.

Fish Consumption Advisory

Certain lakes and rivers have special mercury or PCB advisories. Go to the DNR Website at **dnr.wi.gov/fish/consumption** to investigate which ones. By observing the recommendations in the DNR's "Choose Wisely" fish consumption guide you can enjoy fish as a regular part of your healthy diet.

Making a Difference

Here are a few steps that you can take to reduce your own contribution to nonpoint source pollution:

- Take unwanted household chemicals and medications to hazardous waste collection centers. Do not pour them down the drain or onto the ground.
- Use low-phosphate or phosphate-free soaps and detergents, non-toxic cleaning supplies, and water-based products.
- Clean up after your pets.
- Reduce the amount of chemicals your car releases into the air by driving only when necessary and keeping your car tuned up. Clean up spilled auto fluids and never dump oil or antifreeze into your household trash.
- Support farm practices such as rotational grazing or fencing off streams. These actions will reduce the amount of streambank erosion caused by cattle and the amount of manure that runs off directly into the water.

Prescription for Trouble

Leftover medicine can present problems for aquatic wildlife when it is flushed down the toilet. Sewage treatment plants do not have the ability to remove drugs from the water, so fish end up "taking" leftover prescriptions. To solve this problem, some communities schedule special collection days for citizens to do a "clean sweep" of their medicine chests. This helps to reduce the amount of medication entering the food chain.

Shared Interests

People love living along the shorelines of lakes and rivers. So do fish. The water's edge is a highly diverse environment where people and aquatic species come into contact and often conflict. Fish and humans share an interest in the shoreline, but humans don't always consider fish needs when making shoreline decisions.

On Land

Lakes in Wisconsin today have nine times the number of homes on them as they did in the 1960s. In Vilas County, over half of the new homes built are on lakes. People seek out places with views of water when selecting their vacation cabins or, increasingly, their permanent homes. And why not? It's appealing to have fishing and swimming access right out your front door.

Smaller buildings, less pavement, and more natural landscaping like the home on the left protect water quality and shoreline habitat.

Ecotones
Transition areas where two habitat types meet

Land cover
The forests, highways, water, parking lots, rocks and other visible features on a landscape

Land use
The cultural and economic activities that take place on the landscape

In the Ecotone

Ecotones (transition areas where two habitat types meet) contain greater species diversity than either habitat type alone. The aquatic ecotone of the forest contains an abundance of fish species. It is a patchwork of many micro-habitats, each offering a unique set of niches for a variety of organisms.

The near-shore habitat includes woody cover, bank cover and aquatic plants. Tangles of drooping bank plants, fallen logs, and underwater vegetation are habitat for a rich aquatic insect community. Small fish gather to feed on the insects and hide from predators. Zooplankton feed on tiny underwater plants and are consumed by small fish and young predators. Large fish gather to feed on their prey. The vegetated banks of the lake are important, too: plants hold the soil in place, preventing erosion that could clog spawning habitats. They also provide shelter for a lake's many shoreline species, like frogs and birds.

Conflict in the Clearing

When humans build their waterfront homes, they change the ecosystem. People value their views and want to make sure they can see the water from their homes. Often people also want a sandy beach and a swimming and boating area free of aquatic plants. When waterfront property owners clear their lands of trees, shrubs, fallen logs, and aquatic vegetation, the effects are felt by the animals living nearby. Eighty percent of the plants and animals on Wisconsin's endangered and threatened species list spend all or part of their life cycle within the littoral zone. Clearly, the aquatic ecotone is under pressure from shoreline development.

Land Use for the Future

Satellite images and air photos help scientists and land use planners monitor changes in land use and land cover over time. Historic plat maps are telling, too as they show ownership and reflect changes when land is sold and subdivided. The **land cover** of a region (the forests, highways, water, parking lots, rocks and other visible features on a landscape) often changes as **land use** (the cultural and economic activities that take place on the landscape) changes.

For example, when an agricultural field is converted into a subdivision, the change in land use results in new land cover. But such visible changes are helpful only on a limited scale. A satellite would not be able to see the removal of woody debris and aquatic plants from a lake, a change in land cover that makes a huge difference to a fish. What sort of monitoring method would help scientists understand local, small-scale changes?

Land use decisions at the local level are often regulated by **zoning laws**. City and county governments decide which types of activities (residential, commercial, agricultural, industrial) can take place on a parcel of land. These decisions are based on input from citizens and from environmental assessments. Some cities are moving toward zoning for **sustainability**. These communities are considering the long-term environmental and cultural effects of their land use decisions. They are working to identify ways in which they can enjoy economic growth while preserving the environment and a sense of place. They are designing compact, walk-able communities of mixed land uses that preserve public space in important habitat areas, like along waterfronts.

Historic plat maps can give clues to how changes in land ownership affect land use, water quality, and fish habitat. Left: Bass Lake area, Washburn County, 1915. Right: Bass Lake area, Washburn Co. 1996.

Zoning laws
City and county government regulations concerning which types of activities (residential, commercial, agricultural, industrial) can take place on a parcel of land

Water—Good for the Constitution

The Northwest Ordinance of 1787 is the basis for the Public Trust Doctrine guaranteeing all citizens access to all the navigable waters of the state. It was embedded into the Wisconsin State Constitution of 1848 and states:

> *"The navigable waters leading into the Mississippi and St. Lawrence, and the carrying places between the same, shall be common highways, and forever free...."*

Where can you fish in Wisconsin? Anywhere you can legally gain access to the water! All navigable water (water you can float a canoe, skiff, or kayak down during any time of the year on a recurring basis) is held in trust (protected) by the State of Wisconsin for all Wisconsin citizens, including anglers.

Keep your Feet Wet!

As a wading angler, if you keep your feet in navigable waters, you have the right to be there, regardless if it is a stream or a lake! You may exit the water to portage around an obstruction, water too shallow to boat, or water too deep to wade, but by the shortest route possible. Still, be considerate of riparian landowners when choosing your fishing hole and exercising your water rights.

A Mark of Distinction

The state holds title to all lakebeds; however riparians own the streambeds to the center of the stream. The ordinary high water mark (OHWM) is the point on the bank or shore where the water leaves a distinct mark and establishes the boundary between a public lakebed and private lands. During low water, exposed lakebeds while still part of the public trust are not open to the public. The DNR's Website describes the OHWM in detail: **dnr.wi.gov/waterways/factsheets/PublicPrivateII_OHWM_Brochure.pdf**.

Water rights have been challenged in the courts through the years, building a body of common law that defines your rights as an angler. Watch the video, *Champions of the Public Trust*, available on the DNR's Website to learn more about this important linkage to our history: **dnr.wi.gov/org/water/wm/dsfm/shore/doctrine**.

A Salmo Scenario...Imagine If

Imagine the city of Salmo, in northern Wisconsin. Salmo is a former logging town of 10,000 with an attractive downtown district surrounded by compact neighborhoods and, further out, wooded lots with residences on them.

Salmo has been selected as a possible site for the new headquarters for Icthy, Inc., a rod and reel manufacturer. Icthy would like to relocate to Salmo because of its proximity to Truffa Lake—a known walleye hotspot.

Truffa Lake is a moderately oligotrophic lake, known for its clarity, cool temperatures, and diversity of fish. It is only 10 miles from town.

Three quarters of the lakeshore is surrounded by forest, with a narrow band of coarse sand between the trees and the water. The last quarter is a low-lying wetland that eventually rises to meet the forest.

Icthy is hoping to build its headquarters along the shore of Truffa Lake so that customers can test Icthy's products right out the back door. It is important to Icthy that their building be as close to the lake as possible, and they want a large dock attached to the building's back door to make it easy for customers to test their products.

The company's president, Molly Rose Fish, imagines marketing the headquarters as a business center, a shopping place, and a fishing destination. Ms. Fish dreams that one day she will be able to attach a vacation resort to the headquarters.

Many people in the town of Salmo are excited about the possibility of Icthy moving in. Ever since a nearby paper plant closed, Salmo has been struggling to attract new people to the region. Ms. Fish has promised to bring 85 jobs to the region and hopes to provide even more in the future.

In return for Icthy's selection of Salmo, the county is considering re-zoning the lakefront as "commercial" and giving Icthy a great deal on the entire property surrounding Truffa Lake. This land is currently being leased from the county by a lumber company, which has yet to cut near the lake.

The logging lease will come up for renewal in a few months, and the county is holding a meeting to determine what should be done with the land. Four local groups have arrived at the meeting to discuss their concerns about the possible sale to Icthy. Even though these groups understand the importance of attracting Icthy to Salmo, their organization goals conflict with Icthy's business plan. The groups are:

- **Sustaining Salmo**, a sustainable growth organization. Sustaining Salmo promotes the development of downtown businesses where residents can easily walk or bus to work. The group discourages shoreline development, believing that waterfront property should be used for recreation and conservation.
- **Salmo Spinners**, an angling club. Salmo Spinners works to preserve and restore fish habitat and angling accessibility.
- **Lakeland**, a vacation home real estate group. Lakeland sells vacation homes to people seeking cabins in remote, unspoiled landscapes. Most of their sales are on waterfront property.
- **Truffa Lumber**, the logging company. Truffa Lumber seeks to responsibly and selectively log county land. The company prefers to work on land that is not visible to the public, because people often complain about logging practices.

A Salmo Scenario...Imagine If

Each group has a reason for not wanting Icthy to gain control of the entire lakefront property. Each also has reason to believe that their own proposed uses of the land would serve the community better, while still protecting the landscape and enticing Icthy.

Think back to what you have learned about fish habitat, water pollution, and the aquatic-forest ecotone, as well as your organization's goals, to determine the reasoning behind your group's opposition to the sale. Develop a proposal for an alternate solution to getting Icthy to come to Salmo while also including your own interests. Be sure to anticipate the arguments Icthy will use against you in advocating for ownership of the entire lake. Is compromise possible?

Aquatic Exotics

Invasive species
Exotic species that often rapidly out-compete **native species**, species that live in their natural environments

When you hear of an "exotic vacation," what do you think of? Perhaps a tropical island or maybe a trip to the Himalayas? Regardless of where you go on your imaginary exotic vacation, it will be, by definition, far away from your life here in Wisconsin. So what makes a certain plant or fish or mussel that you can find in your local stream "exotic"?

From Another Land

Exotic plants and animals are species that humans have helped move from a far-away native environment, where these species would naturally live, to a new environment. This happens frequently in the Great Lakes. Since the 1800s more than 100 exotic species have been documented in the Great Lakes bordering Wisconsin. There are many potential pathways for non-native or aquatic exotic species to enter a new waterbody. Can you think of one way they could get here?

There are many potential pathways for non-native or aquatic exotic species to enter a new waterbody.

Competing for Space

Have you heard of people worrying about exotic species? If so, why do you think people are concerned? Why do resource managers count, discuss, and try to control exotic species? Not all exotics are of concern. In fact, some exotic species are still regularly introduced to our lakes and rivers on purpose. Chinook salmon and coho salmon are native to the Pacific Ocean, but the Wisconsin Department of Natural Resources began stocking them in the 1960s to devour an invasive exotic, the alewife, which washed up on Lake Michigan beaches. As an added bonus, they were fun to catch and a new sport fishery was born in Wisconsin. Salmon, brown trout, and rainbow trout are reared at state fish hatcheries and stocked. They are not among the exotics that are considered invasive.

Invasive species are exotic species that often rapidly out-compete **native species** (species that live in their natural environments) for food, prey on native species, and/or take over a native species' niche. These are the exotic species that resource managers and others are concerned about. Many invasive species arrive in the United States without their natural predators, so there is nothing to keep their growth in check.

The spiny water flea, for example, is a tiny crustacean with a sharp, barbed tail. It competes with young perch and other small fish for zooplankton. The spiny water flea arrived in the Great Lakes, and now many inland lakes, without predators and faces little predation from native fish because of its sharp tail. It eats without being eaten, so its population is booming, harming native species.

Resource managers are especially concerned about predator invasive species because these predators can rapidly change an ecosystem when they begin consuming native species. Because native species did not evolve with the exotic predators, they have little natural defense against them.

The sea lamprey, for example, can kill up to 40 pounds of fish in its lifetime—often focusing its efforts on the popular lake trout. The lake trout has no defense against lamprey and was nearly eliminated from the Great Lakes in the 1950s, in part because of lamprey. The diminished population of lake trout, once the Great Lakes' top predator, has had significant effects throughout the ecosystem.

The impact of each exotic species varies, and resource managers cannot work on all of them. Instead, they focus their efforts on the most aggressive and the most controllable species in Wisconsin.

Help is on the way: Chapter NR 40

An administrative rule, Chapter NR 40, was approved by the state legislature in 2009 to establish an invasive species control program. Check the DNR Website to see the full text of this historic document.

Take Action!

Boaters and anglers play an important role in preventing the spread of invasive species in Wisconsin waters.

- INSPECT boat, trailers and equipment and REMOVE plants, animals, and mud.
- DRAIN water from your boat, motor, bilge, live wells, and bait containers.
- DON'T MOVE live fish away from a waterbody. Dispatch your catch and put it on ice.
- DISPOSE of unwanted bait in the trash. Use leftover minnows only under certain conditions outlined on the DNR's Website.
- RINSE boat and equipment with hot or high pressure water OR dry for at least five days

Wisconsin laws prohibit launching a boat or placing a trailer in the water if it has aquatic plants or mussels attached to it. Unauthorized introduction of fish, crayfish, or plants into the wild is illegal—even if you didn't mean to do it! Escaped or dumped exotic pets can also upset the balance of natural systems. Take care and don't be a part of the exotic invasion.

Don't Dump Your Science Projects!

It's great to study living organisms in the classroom, but please do not dump any of them into Wisconsin waters, public or private. Doing so without a permit is illegal and can spread disease, invasive species, and/or undesirable genetic strains.

Very Horrible and Scary

Viral hemorrhagic septicemia (VHS) is an invasive disease that causes fish to bleed to death. It caused large fish kills in the lower Great Lakes in 2005-2006 and was detected in lakes Michigan and Winnebago in May, 2007. VHS spreads easily when a healthy fish eats an infected fish or when fish swim in water carrying the virus. Infected bait (often minnows) is a primary source of the disease. Anglers can make a big difference in preventing VHS from moving into new lakes. In addition to the precautions all boaters must take, anglers are also required to do the following:

- Do not move live fish or fish eggs away from any water.
- Only purchase minnows from a licensed Wisconsin bait dealer. You can use these minnows again on the same water or other waters if no lake or river water or other fish were added to the minnow container.
- You may not harvest minnows from VHS waters. However, suckers can be taken, but may not be transported away while alive. Check the DNR Website for the list of VHS waters.
- Do not use dead fish for bait unless they have been preserved by methods other than refrigeration or freezing.
- Report sick fish to the DNR.

VHS does not harm humans, but it is deadly for fish. Do your part to keep the fishery healthy and check the DNR Website for updates.

News Flash! Asian Carp Approaching Wisconsin!

While resource managers are trying to control the exotic invasive species currently in Wisconsin, others are working their way into our lakes. One of the greatest threats to Wisconsin and the Great Lakes is the Asian carp.

These enormous fish, which can weigh up to 100 pounds, were brought to the United States intentionally by catfish farmers who used them to clean algae out of their ponds. In the 1990s, many rivers near the Mississippi River flooded, connecting the catfish ponds to river systems. Asian carp made their way into the Mississippi River and from there began swimming up the Illinois River toward Chicago and Lake Michigan.

If the carp make it into the Great Lakes, they could significantly change the ecosystem. Asian carp are big eaters and rapid reproducers. They will compete with Great Lakes game fish for food and could end up a dominant species in the Lakes. Managers are trying to stop their advances. Do a quick Internet search: Where is the Asian carp now?

Invasive Aquatic Species

List five aquatic invasive species that live in Wisconsin. What's the impact of each? How are we trying to control them?

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2. ______________________________

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Sea Lamprey Control Methods Survey

Read the article on the next pages to answer the following questions:

1) How do scientists count sea lamprey in their different life stages? Of the three assessment methods described—larval, parasitic-phase, and spawning-phase—which of these do you think provides the most accurate data about the sea lamprey population? Why do you think so?

2) Suppose you are a scientist trying to assess parasitic adult sea lamprey using the help of local commercial and sport fishermen. What kinds of information would you want the fishermen to record for you? Why would it be worth their time to help you?

3) How effective has TFM been at controlling lamprey without hurting other species? Why? State at least three reasons.

4) Describe at least three advantages or benefits of using sea lamprey barriers when compared to the use of TFM.

5) According to the fact sheet, about 25,000 male sea lamprey are caught each year in traps. If you had the choice between destroying these lamprey or sterilizing and then releasing them, which would you choose? State a reason to support your answer.

6) If you were managing the Great Lakes fishery, which method of sea lamprey control would you devote the most time and money to—lampricides, sterile males, or barriers? Why? Make a pie graph showing how you would divide your funds.

7) Do you think it will ever be possible to eliminate all the sea lamprey in the Great Lakes? Why or why not?

8) In 2008 the Great Lakes Fishery Commission spent over $18 million dollars on sea lamprey management. Do you think this is a worthwhile investment? Why or why not?

9) Why is it important for scientists to study other invasive species? Why is it important for us to try to prevent the introduction and spread of new invasive species?

10) Could any of the methods used for sea lamprey control be used on other invasive species? Why or why not?

Sea Lamprey Control Methods

A Summary of Great Lakes Fishery Commission Reports

Sea lamprey are eel-like jawless fish native to the Atlantic Ocean. They entered the Great Lakes system in the 1800s through a series of manmade locks and shipping canals. Sea lamprey were first observed in Lake Ontario in the 1830s. They were discovered in Lake Michigan in 1936 and in Lake Superior in 1938. By the late 1940s, sea lamprey populations had exploded in all of the Great Lakes, causing severe damage to lake trout, salmon, rainbow trout, whitefish, chub, burbot, walleye, and catfish populations. Because Great Lakes fish did not evolve with sea lamprey, the fish do not have defense mechanisms against the aggressive predacious behavior of lamprey. Sea lamprey have no native predators in the Great Lakes.

Lamprey Life Cycle

Sea lamprey begin their lives in tributary streams of the Great Lakes, where they hatch from eggs laid in gravel nests. Once hatched, wormlike larvae are swept downstream until they burrow into sand and silt substrates. The larvae feed on algae and bottom debris for four to six years, until they are six inches long. Once large enough, the larvae transform into their parasitic phase and migrate downstream to the open waters of the Great Lakes. There they attach to large fish with their sucking mouths, rasp through skin and scales, and feed on a fish's bodily fluids. This action often kills the fish. A lamprey can kill 40 or more pounds of fish in its lifetime. After 12 to 20 months of feeding on fish, the lamprey enter their spawning phase and migrate upstream to lay eggs and die.

Control Measures

The Great Lakes Fishery Commission and its agents gather information to assess the population dynamics of sea lamprey. The purpose for collecting and analyzing data is to develop the most efficient and effective sea lamprey control program at the lowest cost and with the least possible negative effects on the environment.

Gathering Information

Larval sea lamprey live in tributary streams and in some offshore areas of the Great Lakes. To estimate the number of larvae that will migrate into the Great Lakes, biologists use a backpack electro-shocker in shallow waters and a deep-water electro-fisher in harder-to-reach waters. The electro-fisher equipment delivers electricity to the water and stimulates (shocks) the larvae out of their burrows to the surface, where they can be counted.

Through a cooperative program, charter boats and commercial fishermen provide government agencies with data on their sightings of parasitic-phase sea lamprey in the open waters of the Great Lakes. To monitor lamprey in their spawning phase, mechanical traps are set in streams to catch the sea lamprey on their spawning migrations. The sex, weight, and length of the trapped sea lamprey are recorded to understand population characteristics. The data collected from all three life phases help scientists determine where and when to apply control measures.

TFM

During the 1950s, scientists tested almost 6,000 compounds to identify one to which sea lamprey were especially sensitive but other aquatic species were not. Through this research, scientists discovered in 1958 that TFM (3-trifluoromethyl-4-nitrophenol) was remarkably effective at controlling lamprey. Sea lamprey are most vulnerable to TFM during their larval phase. For this reason, TFM is applied in streams, not to the open waters of the Great Lakes. A typical treatment takes between 48 and 72 hours to complete, but can take as long as a week. At the levels used, TFM is non-toxic to fish other than lamprey, but it does harm short-lived invertebrates. However, because TFM is applied to a stream in three- to ten-year intervals, populations of these invertebrates can recover between treatments.

TFM does not bioaccumulate in the aquatic environment, and it breaks down in a matter of days. In the Great Lakes, long-term studies have shown no traces of TFM in fish, even in multiply-treated streams in which the fish were caught. Through careful TFM use, the Great Lakes Fishery Commission and its agents have successfully reduced sea lamprey populations in the Great Lakes by 90%.

Sea Lamprey Barriers

Sea lamprey barriers are non-chemical weapons used to control lamprey as they attempt to migrate up streams to spawn. Barriers are constructed across streams in strategic locations throughout the Great Lakes Basin to prevent sea lamprey from getting to their spawning locations, thus reducing the number of streams that produce lamprey. When properly constructed, barriers prevent lamprey passage while still allowing desirable fish species to pass. In some cases, lamprey may spawn below the barriers, but these short stretches of streams are usually much easier and less expensive to treat with TFM than an entire river system. The benefits of barriers include savings in lampricide chemical and application costs and more efficient sea lamprey control. Types of barriers include:

- low-head barriers that create walls across the stream which trout and salmon can jump, but lamprey cannot;
- adjustable-crest barriers, which pop up only during lamprey migration;
- velocity barriers, which make the stream move too swiftly for a lamprey to swim; and
- electrical barriers, which send a current across the stream and are only used during lamprey migration to deter the fish's passage.

Sterile-Male Release Technique

A sterile-male release technique has been used successfully around the world to reduce populations of insect pests. In 1991, scientists began a similar program to control sea lamprey populations in the Great Lakes, starting with Lake Superior. Lamprey are trapped in strategic locations, often at sea lamprey barriers, on Great Lakes tributaries and the males are taken to a sterilization facility where they are injected with a chemical that makes them sterile. These males are in their spawning phase and are no longer feeding on fish.

Once the males are fully sterilized, they are released back into Lake Superior tributaries. Why not just destroy these males? Scientists believe that releasing the sterilized males will actually reduce the number of sea lamprey produced in tributaries, because the sterilized males will compete with normal males to mate with females. None of the eggs produced by the mating of a sterile male and normal female will hatch. Without sterilized males competing during the spawning run, all spawning would be done by normal males and all eggs would be fertilized. The goal of the sterile male release technique is to increase the ratio of sterile to normal males. Early results show success so far.

Source: Great Lakes Fishery Commission Sea Lamprey Control Website: **glfc.org/lampcon.php.php**

4

Buddy System

Musky

Making sure that there is a healthy and sustained fishery for all to enjoy requires resource managers. Managing waterbodies for fish means creating, maintaining, and improving environments favorable to all stages of a fish's life cycle. We all play a role in managing Wisconsin's fisheries, because we all live in watersheds that support fish. Keeping fish in mind when making decisions about when and where we apply fertilizer, how we dispose of hazardous waste, or where we place cattle fences makes us all fish managers. The primary agency for managing fish in Wisconsin is the Department of Natural Resources (DNR). The DNR manages habitat improvement projects; studies, protects and restores fish populations; monitors fish health; staffs hatcheries; stocks fish; and enforces fishing regulations on Wisconsin waters, all of which are public.

Restoration Nation

The Wisconsin DNR Bureau of Fisheries Management protects, maintains, and improves fish habitat. One of the jobs fisheries staff have is to partner with other DNR bureaus and concerned groups, like angler clubs, to improve fish habitat through restoring our streams, lakes, and wetlands.

The Route to Trout: Stream Restoration

Early 20th century farming practices harmed local watersheds in western Wisconsin's Driftless Area, where clean, cold creeks wind through valleys flanked by steep hills. When farmers removed trees and native grasses to plant crops, loose soil flowed downhill, depositing as much as 12 to 15 feet of soil in some creeks over the years. Water quality worsened, stream temperatures increased, and flooding became more frequent and severe.

Gilbert Creek Case Study

One hundred years after farming began in the Driftless Area, a local stream, Gilbert Creek (located twelve miles west of Menomonie), remained choked with silt. Its water was murky and warm, and invasive tree species lined its banks rather than the deep-rooted prairie grasses that once anchored soil in place.

In 2002, brook trout laid eggs in the North Branch of Gilbert Creek, but fish survey crews did not find any newly-hatched trout in 2003. The eggs were likely smothered by silt or killed by high water temperatures. If fishing were to continue in Gilbert Creek, something had to be done. Work with your team to develop a plan to restore trout habitat to Gilbert Creek, using the following questions for direction.

1) Who are the **stakeholders** in the Gilbert Creek restoration, and what do they want?

2) Considering the needs of the stakeholders, what are your goals for the project?

3) What are the constraints?

4) Using the stream improvement techniques on the next page and your own inspiration, decide some of the measures you will take to restore the stream.

5) How will you know if the steps you have taken succeeded in meeting your goals? What might you continue to monitor after your project is done?

No matter what actions your restoration team takes, it is important that your team understands both the habitat needs of a fish during all phases of its life and the root causes of the habitat loss. If your team restores a stream, but does not address the cause of the erosion, for example, the stream will just need to be restored again later.

Lessons Learned

Wisconsin has over 2,700 trout streams with some natural reproduction. The DNR wants to improve and sustain these populations, believing the thrill and challenge wild trout offer will always be valued by anglers. Protecting natural spawning areas is today's biggest challenge for Wisconsin habitat improvement. The ultimate goal of habitat improvement is a completely self-sufficient stream with large populations of wild trout maintaining themselves.

Perhaps the best lesson to learn from all of our restoration work is that it is much easier to prevent habitat loss by making thoughtful land use decisions than it is to restore degraded habitats. We have also learned that it is better to use natural structures and processes to restore streams, lakes, and rivers than it is to install artificial habitat structures. We may never be able to recreate the full complexity of a natural system after it has been altered.

Stream Improvement Techniques

When seeking to improve a trout stream, fishery biologists focus on making habitat meet the needs of the trout. Areas for them to address might include the following: lack of shelter (cover) or living space for fish, lack of sunlight due to overgrowth of vegetation, siltation due to erosion of streambanks, water that is too warm because a stream is too shallow. Fishery experts have developed many solutions to such concerns.

PROBLEM	TECHNIQUE
Bank Erosion	Plant vegetation on bank and buffer. Exclude or modify livestock grazing. Put stabilizing structures in place. Re-grade the slope of the bank.
Lack of Sunlight	Plant native shrubs and grasses. Remove non-native trees and plants.
Over-widened/ Shallow Streams	Use log jams to deepen pools. Use gravel to narrow a stream channel.
No Shelter	Place materials like wood and boulders. Install LUNKERs.

Installing a LUNKERS.

LUNKERS!

Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids are crib-like wooden structures that imitate an undercut bank. LUNKERS provide shelter for fish while stabilizing the streambank. They were developed in Wisconsin by DNR trout stream biologist David Vetrano and work well for restoring fish habitat in Midwestern streams.

Taking Stock

In the first scene of this booklet, you were asked to think about what factors might determine whether or not to stock walleye and yellow perch in Linnie Lake. These decisions are actually a part of the job description of DNR fisheries biologists who manage this resource for the common good (more about that later.) The DNR uses science to determine what goes into (stocking quotas) and comes out of (bag limits) Wisconsin's lakes.

Hatchery
a place where eggs are hatched

Fish Nurseries

Nature provides the best fish **hatchery** (a place where eggs are hatched) and stocking program. In a healthy aquatic ecosystem, all of the elements are in place for a productive fishery: the eggs hatch on their own and fish grow to normal adult sizes in healthy numbers. Not all of our lakes and streams, however, have healthy fisheries. In some instances, we need to supplement and enhance fisheries through artificial hatcheries and wild releases (stocking programs) in order to provide anglers with fish to catch or to reintroduce species after a habitat has been restored. Wisconsin has been stocking hatchery-raised fish since the late 1800s. Today, anglers help fund state-operated hatcheries through license sales, trout and salmon stamps, and taxes on fishing tackle, boats and boat fuel.

Many egg collection facilities, hatcheries, and fish rearing stations are open to the public for tours during certain times of the year. Check the Website for information on locations, hours and visitation policies, **dnr.wi.gov/fish/hatchery/hatcheries.**

Who pays? You do!

Anglers fund a large share of the fisheries habitat work the DNR does through the Sport Fish Restoration (SFR) fund. This fund is generated by a 10% federal tax collected on fishing gear, tackle, baits, motors, and motor boat fuel. The tax money is divided among states for education programs, fisheries habitat work, stocking, and fishing access development. Each state's share of funding is based in part on how much water a state has and how many licenses are sold. Wisconsin is near the top in both categories! Anglers also support fisheries programs through the purchase of licenses and stamps, which you'll learn more about later.

Wisconsin Fish Hatcheries

Wild Rose State Fish Hatchery opened an education center in 2008 as part of a three-phase renovation project.

When stocking a waterbody, a biologist has to consider more than just the physiology and habitat requirements of a species of fish. Ecological balance, cost, and angler needs are also important considerations. Biologists stock a waterbody for one or a combination of the following reasons:

1. **Rehabilitation stocking.** Rehabilitation stocking is a top priority for biologists. In this type of stocking, biologists reintroduce a species of fish that used to exist in a waterbody, but that was extirpated or became too scarce to effectively reproduce. This method of stocking usually follows a catastrophic natural event like a winterkill, disease, or dam failure. It can also follow human-caused events like overfishing or chemical spills. The species is re-introduced to the waterbody with the goal that it will soon become a self-sustaining population again. The DNR is currently using rehabilitation stocking to return lake sturgeon to many rivers and lakes in Wisconsin.

2. **Research and Evaluation stocking.** In this type of high-priority stocking, biologists experiment with putting different species or sizes of fish in a waterbody to determine the most cost-effective or most successful way to manage the lake. For example, biologists are experimenting with stocking small walleye fingerlings (young fish) instead of large walleye fingerlings to see which size is more likely to survive.

3. **Recreation stocking.** Recreation stocking either creates or maintains a fishing opportunity that did not previously exist. A wide array and volume of fish are stocked in urban waters, for example, to provide local residents with the opportunity to fish. If these waters were not stocked, limits on the number of fish caught would have to be lower. Coho and Chinook salmon are stocked in the Great Lakes partly to provide a recreational fishery.

4. **Remediation stocking.** Sometimes an event extirpates or severely lowers a fish population, such as the loss of spawning habitat or the invasion of an exotic species. If the event that caused the problem cannot be readily fixed, the DNR will use remediation stocking to maintain a species of fish that is ecologically or recreationally valuable. For example, the draining of wetlands has greatly reduced northern pike spawning habitat in some areas of Wisconsin. The northern pike are necessary to maintain a predator/prey balance in many inland lakes. Even if the drained wetlands will not be restored, the DNR will continue to stock northern pike as a last resort to maintain a fishery. The stocking of once-abundant lake trout along the offshore reefs of Lake Michigan is also an example of remediation stocking.

Photo: Alisa Santiesteban, July 2009.

Wisconsin DNR Fisheries technician Tom Burzynski stocks young lake sturgeon into the Milwaukee River, a tributary of Lake Michigan, below the Thiensville Dam. The sturgeon were raised at a streamside rearing facility, located at Riveredge Nature Center in Newburg, Wisc. Learn more about this exciting rehabilitation project and take a tour of the facility on the DNR's Website: **dnr.wi.gov/fish/lakemich/LakeSturgeon**.

5. **Introduction stocking.** When a fish is placed in a newly created waterbody, like a small pond or reservoir, or when a species is put in a waterbody it has not previously inhabited, the DNR has conducted an introduction stocking. The DNR generally discourages introductions unless done on a new pond or reservoir where the species could soon develop a self-sustaining population. Stocking of muskellunge into southern Wisconsin lakes to expand musky range could be considered introduction stocking, because it is unlikely muskies occurred in these lakes prior to European settlement.

Managing the Commons

Moratorium
a period of time when a certain activity is not allowed

Fish, like air and water, are a resource held in common by all citizens. In other words, no one person owns it, but all share it. The "tragedy of the commons, "a phrase coined by Garrett Hardin in 1968, refers to unsustainable rates of use or abuse of a resource held in common. Fisheries biologists attempt to manage the commons by considering how many fish anglers and commercial fishermen should be allowed to harvest (keep) from Wisconsin's waters to ensure a fair, equitable and sustainable distribution of the resource.

Sustainable Harvest Rates

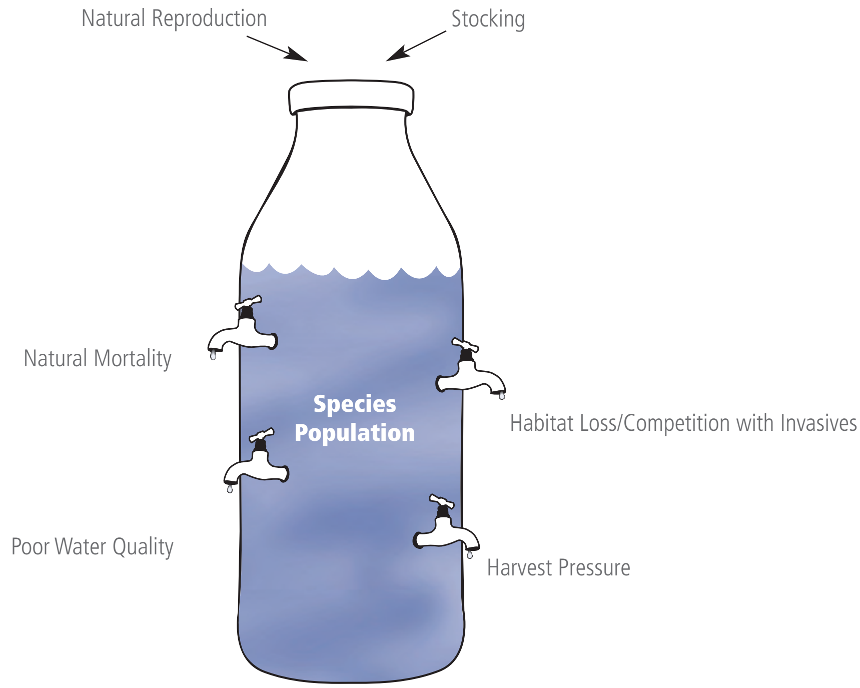
Imagine if every single angler and commercial fishermen were able to harvest as many fish as they wanted, regardless of species. Overfishing, especially on smaller lakes and with popular fish, could rapidly eliminate certain fish populations. Historically, many species of fish suffered because of overharvest. To sustain our diverse fish populations, and the ecosystems they are a part of, the DNR makes. Although some lakes, regions, and fish have special **regulations**, in general the DNR defines how many fish of a certain species you may catch in one day from all waters as the "total daily bag limit."

Occasionally fisheries managers may recommend a **moratorium** (a period of time when a certain activity is not allowed) on fishing for a certain species of fish in a certain lake to allow its population to grow. Whether fish managers are restoring streams, putting fish in the water, or regulating how you take them out, they have a fascinating job that mixes science and policy to help create a sustainable fishery.

The Dam Problem

Dams have had an enormous effect on stream habitats; about 3,700 were built in Wisconsin to grind flour, saw lumber, and power other early Wisconsin industries. Dams **fragmented** (divided) fish communities and blocked fish movement essential for reproduction during spawning time. Paddlefish, sturgeon, and other river species that swim upstream to spawn declined in population, partly as a result of dam construction. Dams also created stagnant millponds that became clogged with algae. To remedy some of these problems, Wisconsin has been leading the nation in dam removal. As of 2008, about 100 dams have been removed. Dam removal projects are major community efforts the DNR supports. Once a community removes a dam, it is rewarded with a return of cool sparkling waters and native catchable fish.

Bottle Model



Look at the Bottle Model diagram above. This model represents the interaction among ways in which species are removed from and added back to Lake Michigan.

1) Explain what you think the model illustrates about the factors that bring fish into the lake and that take fish out of the lake.

2) Describe an event that could make one faucet flow faster, and name the affected faucet.

3) If the event you described above did happen, what would happen to the population level in the bottle? Would the population be able to return to its original level after the event? How?

Balancing Act

Your teacher will provide you with instructions to play a game that illustrates the way that people, fish populations, and laws interact and influence each other. In the game, you will represent some of the people—lawmaker, scientist, anglers, and commercial fishermen—who influence and are affected by fisheries regulations. You can play a similar on-line version, The Fish Game, by the Cloud Institute, that demonstrates how individual actions affect a resource held in common, **sustainabilityed.org/games/**.

After you have played 10 rounds of Balancing Act, answer the following questions.

1) Summarize the results of the game. What trends did you see in the beanfish population over time?

2) Of the factors that increase and reduce species in the water, which can we control? Look back at the Bottle Model and record here the factors that people can control. Under each factor, provide an example of an action that you, or others, do or could do to decrease the flow of the faucet.

3) What would happen to the fishery if commercial fishermen or anglers "cheated" on their fish counts when fisheries scientists weren't watching?

4) Describe three events, actions, or decisions in the game that most influenced the health of your fishery.

5) List and explain three things that you would do differently if you were to play Balancing Act again. How do you believe these actions would affect the outcome of the game?

6) Because this was a game, or a model of a real-life process, there were many things that were not quite realistic. Even so, this game should have given you a good sense of the challenges, cooperation, and compromise involved in fisheries management. What other factors might influence populations and catches in real life that this model does not account for?

7) This game deals with a very real issue: the role of laws in fisheries management. Think about how laws or regulations affected the commercial fishermen and anglers in your game. How did the regulations affect the fish population? Write a persuasive paragraph to a classmate explaining whether or not you think we need laws, such as those you saw in the game, to manage fisheries. Use examples and evidence from the Bottle Model, the game, and any other knowledge you have to support your perspective.

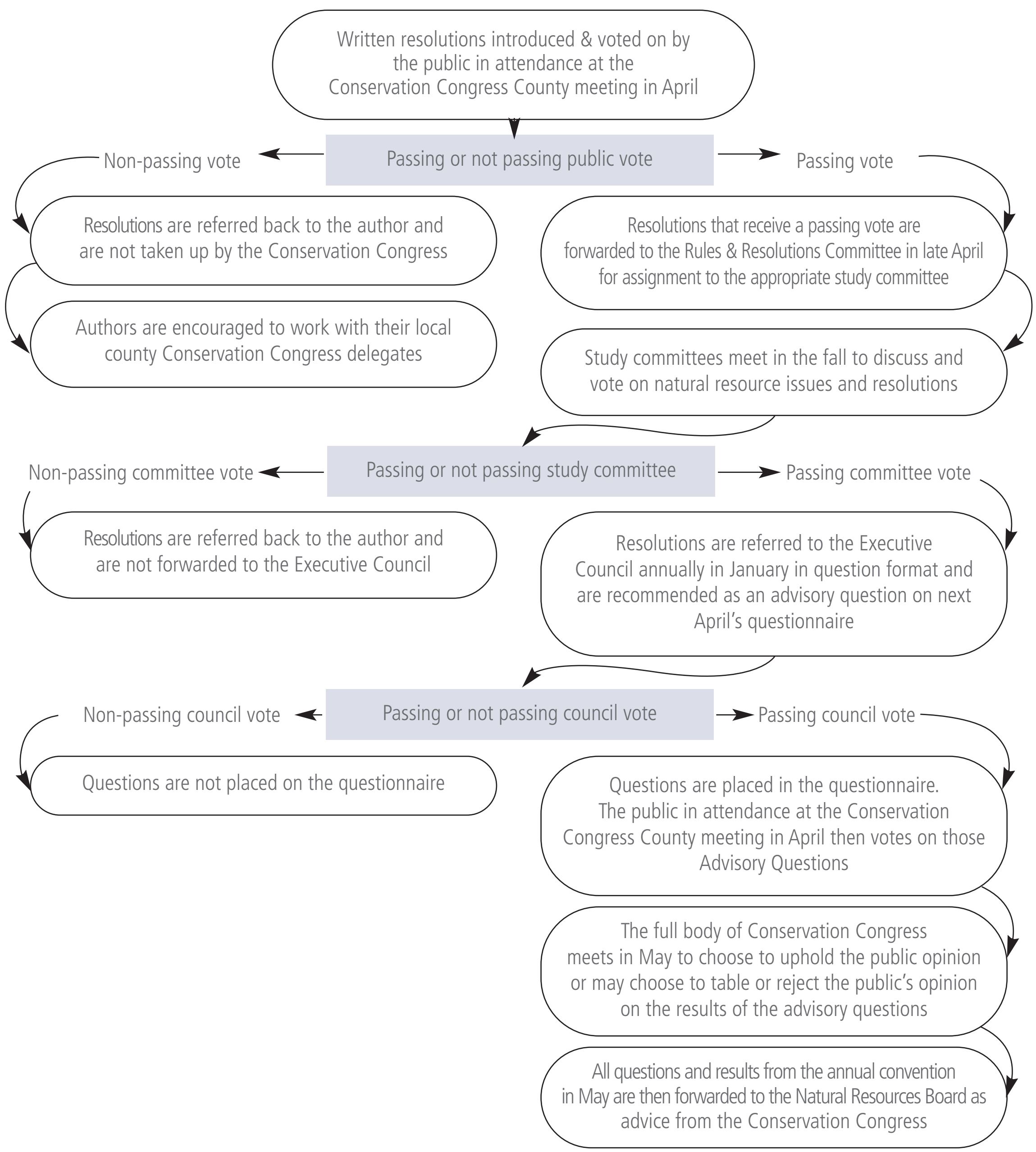
Making Decisions

Who is responsible for making sure that our fisheries stay healthy? We all are—through our daily actions and the power of our vote. We choose the legislators who create laws that affect natural resources. But who actually determines, for example, whether a bottled water business can be built at the headwaters of a trout stream? That would be the **Natural Resources Board** (NRB) based on input from DNR staff and citizens. The NRB makes policy decisions for the Department of Natural Resources. The governor appoints the board's seven members, whom the state Senate must approve. After hearing from scientists and citizens, the NRB members make environmental and natural resource decisions, within the confines of law.

Policy Process

The **Wisconsin Conservation Congress**, an independent citizen advisory body defined in state statutes, advises the NRB on natural resource issues. Wisconsin citizens elect delegates to serve on the Conservation Congress. You must be 18 years old to be a delegate or to vote for a delegate to the Congress, but people of any age may propose and vote on rule changes. Hearings where these proposals are brought to a vote occur the second Monday in April in every Wisconsin county every year. If you feel strongly about a natural resource issue, use Wisconsin's citizen input opportunities to help the NRB make a decision to present to legislators!

The Conservation Congress Resolution Process



How to Write a Resolution

Each year the Conservation Congress accepts written resolutions from the public in each county regarding natural resource issues of statewide concern. The public introduces these resolutions during the Conservation Congress county meeting held annually in conjunction with the DNR Spring Fish and Wildlife Rules Hearings in April.

1. Resolution Content

In order for a resolution to be accepted for further consideration by the Conservation Congress and for public vote at the annual Conservation Congress county meeting, all resolutions introduced must meet the following requirements:

1. The concern must be of statewide impact.
2. The concern must be practical, achievable and reasonable.
3. The resolution must have a clear title.
4. The resolution must clearly define the concern.
5. Current state statutes and laws must be considered, with reasonable cause for change being presented.
6. The resolution must clearly suggest a solution to the concern and a description of further action desired.

NOTE: If the resolution defines an unresolved concern at the local county level, or district level within your Congress district, please make sure to indicate whether or not you have already spoken with local department staff and your local county congress delegates.

2. Resolution Format

- Resolutions must total 250 words or less and be typed or legibly hand-written on one side of an 8 ½ x 11 sheet of white paper. No attachments or additional sheets will be accepted for the same resolution.
- The author's name, mailing address, county, telephone number and signature are required at the bottom of the resolution.
- Only the individual author or designated representative may present the resolution within the county. The author or designated representative must be present at the time the resolution is introduced.
- No one may introduce more than two resolutions during the Congress portion of the Spring Hearings.
- Written resolutions not meeting the above criteria and/or verbal resolutions will not be accepted.
- Provide the Congress County Chair with TWO COPIES of the resolution for submission at the beginning of the evening, one to be part of the official record and the other to be posted for public viewing.
- Individuals attending the meeting may vote on the resolution being introduced within the county.

3. Sample Resolution

Title: Spring Dinosaur Hunting Season

The Problem: Dinosaurs are a threat to agriculture across the state, especially in April and May, because they make deep footprints in newly planted farm fields, damaging the emerging crops. The problem is aggravated in southern Wisconsin, because dinosaurs are migrating across the state line to avoid hunting pressure in Illinois. There is already an overpopulation of dinosaurs in Wisconsin. At present, state law does not permit dinosaur hunting at any time during the year. We feel that Wisconsin law should be consistent with Illinois, which permits dinosaur hunting in the spring. Wisconsin farmers are suffering significant crop damage because of dinosaur incursions.

BE IT RESOLVED, that the Conservation Congress at its annual meeting held in Buffalo County on April 16, 2007 recommends that the Conservation Congress work with the Department to take action to correct this situation by introducing rule change allowing a spring dinosaur hunting season.

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4. DNR Rules Process

A lengthy internal process begins at this point that includes an environmental analysis, legal review, public hearings, a public comment period, review by the Natural Resources Board, and finally, action by the Legislature where it is made law or rejected.

Hot Topics

Resource policy is rarely developed or changed without controversy. Wisconsin citizens often feel strongly about how natural resources should be managed. Every year the Conservation Congress hears debates about several hot topics. In the past, citizens have debated manure management, large livestock operation site approval, and, as mentioned above, bottling spring water near the headwaters of a trout stream. Check out the Conservation Congress on the DNR's Website to discover some of this year's topics. Citizen resolutions, Advisory Committees' notes, and the annual Spring Hearing Questionnaire describe the topics.

Choose a hot topic, research it, and develop a resolution on it that could be introduced to the Conservation Congress in the spring. Use the outline on the next page to guide the process. Keep the following questions in mind: Who are the stakeholders? What role should science have in determining policy? Who and what will be affected by this resolution?

As you work through your resolution, consider this quote from the Wisconsin Conservation Congress publication, *Democracy in Wildlife Regulations*, "In the final analysis, no matter what the commission or the department believes to be in the best interest of the state, if the citizenry is not in accord, any program set up would eventually be doomed to failure. The birds, animals and fish belong to the people of the state." Do you agree or disagree with this quote? How does your opinion of this quote relate to your resolution?

Forward Thinking

At the start of Iroquois council meetings council members would invoke this declaration: "In every deliberation we must consider the impact on the seventh generation." When making a decision, a representative spoke for the needs of those who would follow 150 years, or seven generations, from that moment. How can we learn from this idea?

Great Conservationists

Fishing is an amazing way to enjoy the outdoors, learn about the natural world, spend time with family and friends, explore the state, and catch fabulous food. But maintaining a healthy fishery requires our attention and care. The future of fishing in this state rests in the hands of those who regularly use it. If you think fishing is a valuable and important pastime, it's up to you to make your voice heard and your opinions matter.

Through the ages individuals have made decisions and developed personal ethics that are helpful in guiding our own decisions today. Great thinkers since ancient times have heard a call for stewardship of the earth and all of its inhabitants. Native Americans and leaders of religious movements continue to reflect on the spiritual aspects of water resources and fish and recognize that the health of the water is linked to humankind's existence. Modern leaders from around the world have stepped on the path of environmental activism, bringing awareness of natural resources to a society increasingly unaware of them, yet just as dependent on them.

Through the Eyes of Another

Research the environmental views of an artist, or a scientific, civic, or spiritual leader. What were his or her contributions to the environment? What evidence did you find to support these contributions (art, books, speeches, projects, public service)? What struggles or challenges did he or she encounter in protecting natural resources? Did his or her commitment to the environment erode or strengthen over time? In what way? Explain his or her beliefs about what responsibility people have to protect the environment.

Wise Elders

Each of the following leaders had different viewpoints about why and how we should care for the earth. As a caretaker of the earth yourself, you can learn from their experiences. Choose one of the quotes below to reflect on in a one-page response. Do you agree or disagree with the quote? Why? If you disagree with the quote, do you know of another quote that better matches your feelings about conservation? If you agree with the quote, what can you do in your own life to support it?

1) *"We abuse the land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."* - Aldo Leopold, Wisconsin ecologist, wildlife biologist, angler, and hunter.

2) *"The human race is challenged more than ever before to demonstrate our mastery—not over nature but of ourselves."* - Rachel Carson, marine biologist and nature writer.

3) *"We all have to take responsibility for the direction we are going. In our schools we are focusing on numbers and letters but we need, from the earliest times, to get across the concept that we are connected to nature and that we are trying to find a space to sustain ourselves."* - Sylvia Earle, marine biologist, National Geographic Explorer-in-Residence and *Time Magazine*'s first Hero for the Planet.

4) "*The most important environmental issue is one that is rarely mentioned, and that is the lack of a conservation ethic in our culture."* - Gaylord Nelson, Governor and State Senator of Wisconsin and founder of Earth Day.

5) *"The conservation of natural resources is the fundamental problem. Unless we solve that problem, it will avail us little to solve all others."* - Teddy Roosevelt, U.S. President, Nobel Prize winner, conservationist, and rancher.

The Wealth of Nature

> "The economy is a wholly-owned subsidiary of the environment, not the other way around." Gaylord Nelson

Swimming Upstream

You too can be a great conservationist! There are direct and indirect paths to helping protect our natural resources. Some people choose to dedicate their lives to natural resources in careers at conservation organizations like the DNR.

The future of fishing in this state rests in the hands of those who regularly use it.

If you are planning a career in natural resources, check the DNR Website for a sampling of jobs in the field. If you see one that looks great, interview someone in that job to find out what skills you should be getting while still in school.

You can also check university Websites to see what types of courses they offer for people interested in our natural resources.

You don't need a career in conservation to be a conservationist. No matter what career you choose, artists, economists, cashiers, mathematicians, and flight attendants, to name a few, can all advocate and volunteer on behalf of our natural resources. There are many ways to stay involved with and learn more about Wisconsin's fish and waters. Here are a few suggestions:

- Take a friend fishing. One of the best ways to gain support for the resource is to introduce others to it.
- If you like trout fishing, or are interested in starting, contact Trout Unlimited to see if they have a chapter near you. You could help with a restoration effort or meet others who want to help trout.
- Start a fishing club at your school or join one in your community.
- Speak up! Write letters to your representatives and senators about your resource concerns and vote as soon as you are eligible.
- Get outside. Being an active observer is the first step to working for the changes you would like to see.

It's not always easy to improve our natural resources, but neither is it to swim upstream and plenty of fish do it every year. Keep your eyes on the water and your mind open. Even if you don't continue fishing, you will continue to live in a world where water resources and aquatic wildlife will play a role in the health and stability of our planet. Don't lose touch with the water in your world!

Cheap Date

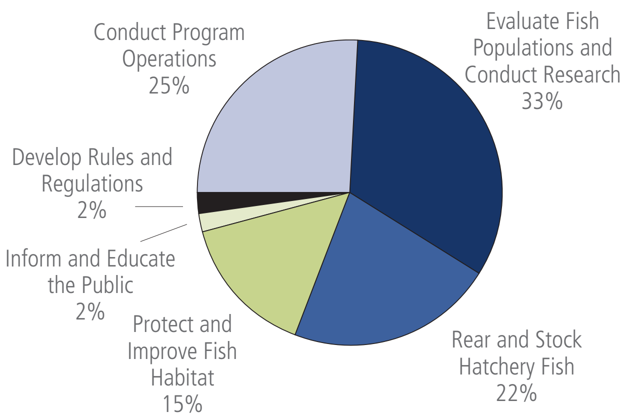
Take your date or a pal fishing! After a small annual investment, you can fish 365 days a year with whomever you want. Many Wisconsin communities are situated on or near fishable waters. Pack a picnic, call a friend or two, hop on your bike, and head for the water's edge.

Compare the cost of a day of fishing to other leisure activities.
Consider total costs of participation and how often you can use your investment. Here are some examples:

ACTIVITY	MINIMUM REQUIREMENTS	COST	ONE-TIME USE OR OPPORTUNITY	MULTIPLE USES OR OPPORTUNITIES
Fishing	License & Stamps Rod Reel Bait Tackle Other:			
Prom	Ticket Clothes Dinner Flowers Special Transportation Other:			
A night out Several options: movie, food, gasoline. List what you would do.				
A night at home Several options: games, music, snacks. List what you would do.				

Where does your license money go?

Money collected through the Sport Fish Restoration Fund and fish license fees funds the fisheries program at the Department of Natural Resources. Within the fisheries program, the money gets divided into many different projects, illustrated in the pie chart below:



All that for less than the cost of one night on the town!

Data from 2006 DNR Fishing Report

A love of fishing has inspired generations of anglers to pay close attention to natural resources. Invite a friend to join you in enjoying the beauty and excitement that fishing offers. Maybe he or she will become a *great conservationist*.

Glossary

Adaptation
a physical, chemical, or behavioral change made by a species or an individual organism which improves its relationship to its environment

Assessment
the action of determining the amount or value of something

Atmospheric deposition
nonpoint source pollution that travels through the air and is deposited on land and water

Bag limit
the number of fish of a certain species from a certain body of water that an angler can keep on a single day

Barbels
slender, whisker-like taste receptors found on certain fish, such as catfish, bullheads, and sturgeon; used to find food

Benthic Zone
the bottom of a lake

Bioaccumulation
the build-up of substances, such as pesticides or other toxins, in an organism

Biomass
the total mass of live plants and animals in a given area

Chordate
animal that belongs to the phylum Chordata (has a notochord for at least part of its life cycle)

Conservation Congress
the citizen group that suggests regulation changes to the Natural Resources Board

Consumer
an organism that cannot produce its own food and must eat other organisms to survive

Degraded
lowered to a less desirable or less diverse level

Dichotomous key
a system of classification used to identify organisms by moving from broad differences to specific distinctions

Dissolved oxygen
molecules of oxygen mixed into water

Distal
located away from the central point or origin

Distribution
the range, or geographic locations, of an organism

Dorsal
located on the back of an animal

Dynamic
continually changing

Ecology
the study of the interrelationship between environments and organisms

Ecotone
a transition area between two different ecological communities

Ecosystem
closed communities of interdependent plants, animals, and non-living factors

Effluent
waste material released into the environment

Emergent
near-shore plants rooted in shallow water with most vegetative growth above water

Epilimnion
the top layer of lake water, often warmest in the summer and frozen in winter

Erosion
the process of soil and other natural materials being worn away

Eutrophic
characterized by having a high level of nutrients; often used to describe a lake or pond with low oxygen and thick plant growth

Eutrophication
the process of adding nutrients to a waterbody

Exotic species
species that live in environments where they are not native

Extirpate
a species that has disappeared from part of its native environment, but is not extinct

Fingerling
a young fish

Floating leaf
plants rooted in the lake bottom; their leaves and flowers float on the water surface

Fragmentation
the process of dividing landscapes or watersheds into parcels that are isolated

Fry
newly-hatched fish

Harvest
to gather, catch, hunt, or kill for human use, sport, or recreation

Hatchery
a place where eggs are hatched, either human-made or natural

Headwaters
the origin, or beginning, of a stream or river

Hypolimnion
The bottom layer of lake or pond water

Inferior
located nearer the lower extremity of a body

Invasive species
an exotic species that tends to spread, causing environmental or economic harm

Land cover
the visible features on a landscape

Land use
the cultural and economic activities that take place on a landscape

Lateral
located on or near the side of the body

Lateral line
a canal along the side of a fish containing pores with sensory organs that detect vibrations

Limiting factor
a factor in the environment that limits the growth, abundance, or distribution of organisms in an ecosystem

Limnetic zone
the open-water zone away from shore where light is abundant

Littoral zone
the shallow area of a lake or pond where plants are able to grow

Marsh
a wetland that is rich in plant life, especially grasses and cattails; excellent fish spawning habitat

Medial
located near the middle (mid-line) of the body

Mesotrophic
characterized by having a moderate amount of nutrients

Moratorium
the suspension of an activity for a period of time

Morphology
the shape or structure of an organism

Mouth
the end of a stream or river, where it empties into another waterbody

Native species
a species that lives in its natural environment

Natural Resources Board
a group of citizens selected by the governor which makes policy decisions for the Wisconsin DNR

Natural selection
the process that results in the survival and reproductive success of individuals or groups best adapted to their environment

Neurotoxin
a poison which affects the brain or nervous system

Niche
the specific role an organism or a population plays within an ecosystem

Nonpoint source pollution
contamination that comes from many sources across a landscape; often carried into waterbodies by runoff

Notochord
a flexible, primitive backbone that provides support in chordate embryos. As vertebrates (the highest class of chordates) develop, the notochord is replaced by spinal vertebrae.

Oligotrophic
characterized by having few nutrients

Persistent organic pollutant
a contaminant that does not break down easily or quickly in the environment

Physiology
the study of the functions of living organisms

Phytoplankton
microscopic floating plants

Poikilotherm
an organism that cannot regulate its own body temperature; the temperature of the organism matches that of the surrounding environment

Point source pollution
a particular, identifiable source of contamination

Primary producer
an organism which creates its own food through photosynthesis

Profundal
deep dark lake zone below the limnetic zone

Proximal
located near the center of the body

Public Trust Doctrine
a body of common law that protects navigable waters for the common good

Redd
the nest or spawning ground of a fish

Regulation
a rule dealing with details or procedures

Restore
to repair damage (in this case, to an ecosystem)

Rheotactic
orienting upstream

Rule of 10
a law of nature that says that approximately 10 percent of available energy passes from one trophic level to the next and the rest is lost as heat

Runoff
precipitation not absorbed by the soil; often carries nonpoint source pollution with it into a waterbody

Spawn
to produce and deposit eggs (generally refers to fish, amphibians, and mollusks)

Stakeholder
a person who has an interest in a decision, but is not responsible for making that decision; for example, a private landholder may be a stakeholder in a decision the county makes about the stream running through her property

Stewardship
the careful and responsible management of something

Stock
the act of putting quantities of fish in a lake, stream, or other waterbody for recreational or scientific purposes

Stratify
to become layered; lakes are stratified by temperature

Stressor
an action or agent that puts stress on an organism

Submerged
rooted plants that grow entirely underwater, although some leaves may float above water. They grow from near shore to the deepest part of the littoral zone.

Substrate
the layer of material, such as clay or gravel, found on the bottom of a waterbody

Superior
located higher on a body, nearer the upper extremity

Sustainable practices
the use and management of a resource that meets the needs of the present generation without compromising the ability of future generations to meet their own needs

Swim bladder
the swim bladder (also gas bladder or air bladder) is an internal gas-filled organ allows a fish to control its buoyancy and depth in the water.

Taxonomic groups
a group of closely related plants or animals

Terrestrial
land-based, not aquatic; as in a terrestrial organism or habitat

Thermocline
a layer of water in a lake in which the temperature change is most abrupt; found below the epilimnion

Thermoregulate
to maintain a constant body temperature; humans thermoregulate, fish do not

Tragedy of the Commons
unsustainable rates of use or abuse of a resource held in common

Tributary
a stream or river that flows into a larger stream or waterbody

Trophic level
feeding position in the food pyramid; primary producers are the lowest trophic level

Ventral
located opposite the back, on the front or belly

Vertebrates
animals with backbones

Watershed
a region or area that all drains to the same body of water

Wetland
an area that is a transition between an aquatic and a terrestrial environment; saturated for at least one period of time each year

Zoning
division of a city (or other region) into sections reserved for certain purposes (homes or businesses)

Notes

Hook, Line, & Thinker: Science Guide

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Special thanks to the many angler education instructors who have helped to guide our program efforts over the years and have taken the time to introduce youth to Wisconsin's fishery.

With all due respect to 19th Century French sculptor, Auguste T. Rodin, we are using playful renditions of his masterpiece, *The Thinker* to lead us through these guides. The Philadelphia Museum of Art houses the original sculpture and notes on their Website that "Rodin was faithful to nature in his work."
We hope these words and your experiences outdoors will inspire you to do the same in your work and play.

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