Water of Life

OBJECTIVES: Students will be able to:

- explain the process of stratification in lakes
- describe how lake stratification affects fish
- make predictions about the effects of climate change on fish distribution

METHOD: Students will watch a demonstration of summer lake stratification, showing the epilimnion, thermocline (metalimnion), and hypolimnion. Students will discuss oxygen and temperature changes in lakes during other seasons. Students will answer questions about the demonstration and work in partners to design an experiment.

MATERIALS:

1) Distilled water
2) Salt
3) Three 400 ml glass beakers or pint-sized canning jars
4) 25 x 200 mL tube with screw cap (ideal) or a large, clear container with limited surface area for a demonstration container
5) Large syringe
6) Drinking straw
7) Blue, yellow, and red food coloring
8) Microwave, hot plate or stove
9) Ice or refrigerator

ALTERNATE DEMONSTRATION MATERIALS LIST

1) Salad or olive oil
2) Vinegar
3) Grape juice concentrate
4) Honey
5) Herbs
6) Pint-sized canning jar

PREPARATION: Make the dense "cold" hypolimnion by supersaturating 250 ml (approximately I cup) of water with salt. Add at least 50 ml (1/4 cup) of salt until the water will hold no more. Aid this process by heating the water so it will hold more salt. Pour off the saltwater into a separate container and chill. Once the salt solution is cold, make the thermocline by mixing a portion of it with distilled or tap water in a 1/3 to 2/3 proportion.

Dye it yellow and heat. Dye the remainder of the cold salt solution blue. The epilimnion consists of pure, distilled water. Dye it red and heat it up, too. Now you are ready to do the demonstration in the main activity.

An alternative preparation would involve pouring equal proportions of honey, vinegar dyed with a tablespoon of grape juice concentrate, and oil; sprinkle in herbs to represent phytoplankton. Use quality ingredients and save to enjoy on a salad with your fish fry later in the unit.

SETTING: Indoors

DURATION: One 45-minute period

VOCABULARY: Dissolved oxygen, stratified, distribution, epilimnion, hypolimnion, thermocline, winterkill

STANDARDS: Science: E 12.2.
Environmental Education: A 8.4, 8.5, 12.3; B 8.1, 8.2, 8.4, 12.1, 12.2, 12.3, 12.4, 12.6.

BACKGROUND: The layers of warm and cool water in a lake change with the seasons as the water heats and cools, causing the epilimnion, thermocline, and hypolimnion to change in size and width. Stratification occurs in summer when the sun warms the top layers of water and the epilimnion grows to its maximum thickness. Under the heat of the strong summer sun, the warmer, less dense, water "floats" on the denser, cooler water below. Wind and wave action are not strong enough to overcome these different densities of water. Warm water and oxygen circulate freely in the surface layer, but the cold, denser water in the hypolimnion does not mix with the water above it. Oxygen content is slowly reduced in the hypolimnion, and fish are forced to more favorable conditions nearer the surface.

In fall, surface waters cool. The epilimnion shrinks as cooling water sinks to the bottom, carrying oxygen with it. As the different layers get close to the same temperature and density, wind and waves provide mixing action and the water temperatures become fairly uniform from the top to the bottom of the lake. The epilimnion becomes a very narrow band in fall and fish can more easily circulate between shallow and deep waters.

In winter, ice prevents wind from mixing lake water. The coldest water remains just below the ice at between 32°F (0°C) and 39°F (4°C) while the rest of the lake is 39°F (4°C) or warmer. Thick snow cover prevents sunlight from penetrating the ice and halts photosynthesis, which is necessary for the production of oxygen. Decaying plants consume oxygen and can help set the stage for anoxic (absence of oxygen) conditions. Winterkills (massive die-offs of fish) occur under anoxic conditions. Shallow, heavily-vegetated, snow-blanketed lakes are particularly susceptible to high winterkills. In Wisconsin, deeper lakes that are frozen over and snow-covered usually have enough oxygen for aquatic life to survive the winter.

As the ice melts in the spring, wind and waves mix the water. Lakes once again become uniform in temperature and the process of stratification starts over.

Increasing water temperature due to climate change concerns fish biologists. Many species of freshwater fish, like trout and salmon, require high concentrations of oxygen and cool water to survive. As the climate warms, the epilimnion increases in thickness, making it more difficult for fish to find cool water without swimming deep into lakes. In the deep water, however, fish can suffocate. Anglers, too, may have difficulty catching fish that have gone deep in search of cold waters.

OPENING: Ask students to read the **Water of Life** section. Have them answer the Prime Real Estate questions in a discussion.

MAIN ACTIVITY: Demonstrate summer lake stratification. Begin by pouring the dense blue "hypolimnion" saltwater into the demonstration container. On top of the hypolimnion, **carefully** add the yellow "thermocline" using a syringe. Finally, add the red "epilimnion." You should end up with a blue band of water on the bottom, a yellow middle band, and a red surface band. Ask students which season they think this lake represents. Explain the different seasons and how the demonstration would look different in winter (epilimnion would be thin, blue and frozen), and in spring and fall (water would be mixed, with no bands of color).

To demonstrate wind mixing, blow across the surface of the water using a straw. Mixing may occur in the epilimnion, but the layers should not mix, showing that once a lake is stratified, wind and wave action do not usually cause mixing between the epilimnion and hypolimnion. Ask students where they think fish would be in this demonstration. In early summer, the fish should be well distributed, but as oxygen is depleted from deeper waters, fish will move up to shallower, warmer waters.

A simpler project that requires no advanced preparation is to fill a mason jar with hot tap water and add a few drops of red food coloring to it. Take another mason jar with the same size mouth, fill it with cold tap water, and dye it blue. Hold a 3 x 5 index card over the warm jar and flip it upside down. Place it on top of the cold jar and slowly remove the card. Watch what happens, then repeat the experiment by putting the cold water on top. This version demonstrates water density more than lake stratification.

CLOSING: Have students work in partners to answer the final questions in Coming Up for Air. Alternatively, assign the questions as a take-home project and allow students to use the internet to find answers.

ASSESSMENT QUESTIONS: Name three factors that affect dissolved oxygen levels in waterbodies. Do these factors increase or decrease the amount of oxygen available to fish?

ANSWERS: Increase: rain, moving water, waves, wind, photosynthesis, colder water. Decrease: warmer water, decomposition, dry weather, respiration, pollution.

EXTENSIONS:

Field: Take your students on a field trip to a local waterbody. Measure the dissolved oxygen and temperature at various depths or in different locations.

In Depth: Direct students to these websites for more information on how climate change may affect Wisconsin fisheries: Wisconsin Initiative on Climate Change Impacts, **wicci.wisc.edu** and Paradise Lost, **cbe.wisc.edu/K12/paradiselost**.

● **See Appendix E** for a PowerPoint Presentation: Responses of Wisconsin's Coolwater and Warmwater Fishes to Climate Change

● **See Appendix E** for the Field Trip Record Sheet options.

● *If you have downloaded this booklet, please see the appendix that follows for additional materials.*

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?

Catfish, bullhead, and carp all inhabit low oxygen lake bottoms.

PLEASE SEE APPENDIX E
Water of Life: Lake Monitoring Field Record Sheet

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INSTRUCTORS: Underlined content is not provided in student manual.

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 ______ trout
2. A small pond with lots of vegetation ______ catfish
3. A large slow-moving, muddy river ______ catfish
4. Lake Michigan ______ both! but in different areas
5. Lake Superior ______ trout

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

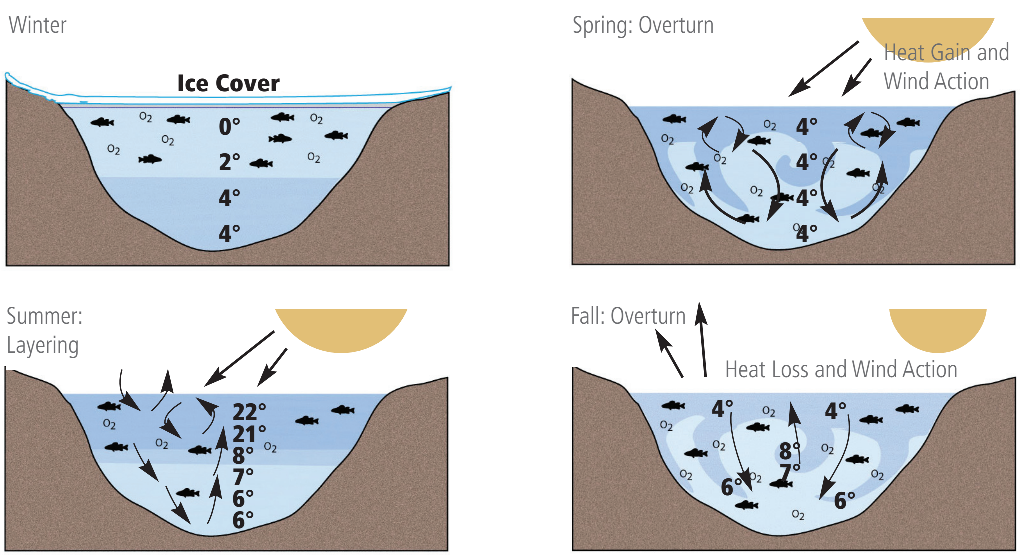
Water temperature is perhaps the single most important factor in determining where fish will be and how they will behave. Each species has its own comfort and tolerance level. Fish tend to seek the most comfortable environment, assuming that there is sufficient oxygen, and will migrate from shallow to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

INSTRUCTORS: Underlined content is not provided in



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? At the surface (epilimnion)

2) What is the effect of wind on a summer lake? Water in the epilimnion is mixed and oxygenated, but the layers stay intact until seasonal temperature changes aid mixing.

3) How does layering affect fish living in the lake? Fish distribution is dependent on temperature and dissolved oxygen content which changes with the weather, from day to day and season to season. In late summer, the epilimnion may hold more oxygen, but be too warm for some species seeking the proper balance.

4) Given all that you have learned about temperature and oxygen, what could climate change mean for aquatic species? For anglers? Climate change may increase stream temperatures and make it difficult for coldwater species, like trout, to get the oxygen they need. Coolwater species, like bass, may expand their ranges to the north. Climate change could lead to a disruption of aquatic food chains.

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?

Dissolved oxygen (DO) meter and thermometer. Boat. Where would you take measurements and when? At least once a month, sampling every 10 feet or less, from several different locations on the lake. How would you know if you were getting a good sample of the lake? Check many locations on a lake and take an average. Test your temperatures against fish you catch in that depth.

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INSTRUCTORS: Underlined content is not provided in