Fish in Winter

In the short, cold days of winter, lakes and rivers freeze. What happens to the fish?

Courtesy of Bill Linder

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Please note: Academic Standards are updated regularly and our alignments will be updated on the DNR Academic Standards Website at: www.mndnr.gov/education/teachers/edstandards_intro.html

Fish in Winter

Minnesota Academic Standards

◒ Lesson *introduces* this Benchmark.
◒ Lesson *partially* addresses this Benchmark.
● Lesson *fully* addresses this Benchmark.

Language Arts

Grades 3, 4, 5
I. Reading and Literature
B. Vocabulary Expansion:
Benchmark 1—The student will acquire, understand, and use new vocabulary through explicit instruction and independent reading. ◒ (no reading)
III. Speaking, Listening, and Viewing
A. Speaking and Listening:
Benchmark 1—The student will participate in and follow agreed-upon rules for conversation and formal discussions in large and small groups. ●
Benchmark 2—The student will demonstrate active listening and comprehension. ●

Math

Grade 3
I. Mathematical Reasoning
Benchmark 1—The student will communicate, reason, and represent situations mathematically. ●
II. Number Sense, Computation, and Operations
A. Number Sense:
Benchmark 1—The student will read, write with numerals, compare, and order whole numbers to 9,999. ◒
IV. Data Analysis, Statistics and Probability
A. Data and Statistics:
Benchmark 2–The student will collect data using observations or surveys and represent the data with pictographs and line plots with appropriate title and key. ●

Grade 4
I. Mathematical Reasoning
Benchmark 1—The student will communicate, reason, and represent situations mathematically. ●
Benchmark 3—The student will evaluate the reasonableness of the solution by considering appropriate estimates and the context of the original problem. ◒
III. Patterns, Functions, and Algebra
A. Patterns and Functions:
Benchmark 1—The student will examine and describe patterns in tables and graphs. ●
IV. Data Analysis, Statistics and Probability
A. Data and Statistics:
Benchmark 1—The student will collect data using observations or surveys and represent the data using tables and graphs with labeling. ●
Benchmark 2—-The student will use mathematical language to describe a set of data. ◒

Grade 5
I. Mathematical Reasoning
Benchmark 1—The student will communicate, reason and represent situations mathematically. ●
Benchmark 3—The student will evaluate the reasonableness of the solution by considering appropriate estimates and the context of the original problem. ◒
Benchmark 7—The student will organize, record and communicate math ideas coherently and clearly. ●
III. Patterns, Functions, and Algebra
A. Patterns and Functions:
Benchmark 1—The student will examine and describe patterns in tables and graphs and explain how to extend those patterns. ●
IV. Data Analysis, Statistics, and Probability
A. Data and Statistics:
Benchmark 1—The student will determine whether or not a given graph matches a given data set. ●
Benchmark 3—The student will collect data using measurements, surveys, or experiments and represent the data with tables and graphs with labeling. ●

History and Social Studies

Grades K-3
IV. Historical Skills
B. Historical Resources:
Benchmark 1—Students will define and use terms for concepts of historical time. (Seasons)

Science

Grade 3
II. Earth and Space Science
C. The Universe:
Benchmark 3—The student will observe that the sun supplies heat and light to the Earth.
IV. Life Science
B. Diversity of Organisms:
Benchmark 1—The student will describe the structures that serve different functions in growth, survival, and reproduction for plants and animals.
C. Interdependence of Life:
Benchmark 2—The student will know that changes in a habitat can be beneficial or harmful to an organism.

Grade 4
II. Physical Science
A. Structure of Matter:
Benchmark 1—The student will observe that heating and cooling can cause changes in state.
Benchmark 2—The student will describe the changes in the properties of a substance when it is heated or cooled.

Grade 5
IV. Life Science
E. Biological Populations Change Over Time:
Benchmark 1—The student will recognize that individuals of the same species differ in their characteristics and that sometimes the differences give individuals an advantage in surviving and reproducing.

Environmental Literacy Scope and Sequence

Benchmarks

- Social and natural systems are made of parts. (PreK-2)
- Social and natural systems may not continue to function if some of their parts are missing. (PreK-2)
- When the parts of social and natural systems are put together, they can do things they couldn't do by themselves. (PreK-2)
- In social and natural systems that consist of many parts, the parts usually influence one another. (3-5)
- Social and natural systems may not function as well if parts are missing, damaged, mismatched or misconnected. (3-5)

For the full Environmental Literacy Scope and Sequence, see:
www.seek.state.mn.us/eemn_c.cfm

Chapter 2 • Lesson 8

Fish in Winter

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Grade Level: 3–5
Activity Duration: 45 minutes
Group Size: up to 30
Subject Areas: Language Arts, Math, Science
Academic Skills: drawing conclusions, graphing, kinesthetic concept development, large group skills, role-playing
Setting: large indoor or outdoor open area
Vocabulary: aeration system, anaerobic, cold-blooded, diapause, dissolved oxygen, hibernation, limiting factor, microclimates, migrate, respiration, warm-blooded, winterkill
Internet Search Words: fish in winter, winter adaptations

Instructor's Background Information

In winter, Minnesota's snow-covered landscape can often look lifeless and empty. But if you go outside for a closer look, you'll see plants and animals alive and thriving under the ice and snow. But unlike summertime when, as the song says, "the livin' is easy," winter does pose some survival challenges.

Winter can be the most stressful season for living things in the north, posing hardships, or limiting factors, that impact chances of survival for plants and animals. A **limiting factor** is anything that restricts the living conditions for an organism, species, or population. Some limiting factors caused by Minnesota winters include decreased food supplies, heavy snow, and cold temperatures.

Fish must cope with water temperatures that rarely rise above 35° F under the ice. But one of the primary limiting factors for fish in lakes under ice and snow is not the cold or even shortage of food, but lack of oxygen.

Summary

In a simulation game, students play the roles of fish attempting to survive a Minnesota winter. They discover how ice and snow cover can affect dissolved oxygen levels in the water, and why oxygen is the most important limiting factor for fish in climates with cold winters.

Student Objectives

The students will:

1. Become fish in a role-playing activity, and discover how oxygen is a limiting factor for fish during the winter.
2. Define dissolved oxygen and describe how oxygen dissolves in a lake or river.
3. Identify at least two natural factors that can cause a water body's dissolved oxygen levels to decrease during Minnesota winters.
4. Write a story to describe how fish survive in winter.

Materials

- 200 six-inch-diameter paper circles or 50 sheets of 8.5" x 11" paper cut in quarters or 200 poker chips or 200 small paper plates, to use as oxygen "markers"
- 8.5" x 11" (or larger) sheets of paper, six
- Whiteboard or graph paper
- Pen or pencil
- Marker
- Whistle or other noisemaker (to signal the beginning and ends game rounds)
- **Playing Area Diagram**

In winter, less food is available in lakes and streams. The winter season brings a reduction in aquatic plant activity and availability. Fewer daylight hours and the increased angle of the sun's rays reduce the photosynthetic performance of aquatic plants. Many aquatic animal species are also less active—some even hibernate during the winter.

The air has approximately 26 times more oxygen than the amount dissolved in an average, well-oxygenated body of water.

Dissolved Oxygen

Oxygen is a gas that we usually think of as the air that we breathe. Oxygen gas also exists in water, much like the carbonation bubbles in soda pop, although the "bubbles" are much smaller. Most living things require oxygen for survival whether they live on land or in the water. Fish use gills to obtain oxygen from the water. They take in water through their mouths. The water flows over their gill tissues, which draw oxygen from the water into the fish's bloodstream. Carbon dioxide waste (a by-product of cell respiration) is released from the bloodstream, through the gills, and into the water as it flows outward over the gill tissues.

Dissolved oxygen is oxygen gas dissolved in water. Gases, such as oxygen, nitrogen, and carbon dioxide, can dissolve in water, just as salt does. The oxygen available to fish is dissolved or mixed into the water by turbulence (wave action, currents, waterfalls, riffles, and rapids). Oxygen is also released into the water during photosynthesis—aquatic plants use the sun's energy and carbon dioxide to make food energy, releasing oxygen. Although oxygen occurs in much lower concentrations in water than it does in air, most water bodies have enough dissolved oxygen to support aquatic life.

The amount of oxygen that can dissolve in water depends on the temperature of the water. Cold water holds more dissolved oxygen than warm water.

But, if cold water holds more oxygen than warm water, why is oxygen availability a limiting factor for fish in winter? The amount of dissolved oxygen in lakes can vary greatly for a number of reasons. In warmer seasons, when the water isn't frozen, the wind, waves, and current constantly mix air into the water, dissolving oxygen into it. Underwater plants also produce oxygen through photosynthesis. But in winter, lakes blanketed by ice and snow can have lower oxygen levels because the ice seals off the surface air as a source of oxygen, and because the snow blocks sunlight, making it hard for underwater plants to photosynthesize. No new oxygen is being added into the water as fish and other aquatic organisms continue to breathe beneath snow-covered ice. They gradually use more and more of the available oxygen in the water as winter progresses. Oxygen levels in the water can potentially decline to dangerously low levels, depending on the depth of the water body and the duration of ice and snow cover.

Water Temperature

Water temperature also has an effect on fish **respiration** (breathing, or the physical and chemical process of supplying the fish's cells and tissues with oxygen for the processes of metabolism and release of carbon dioxide). Fish are cold-blooded animals, and their rates of metabolism increase in warmer water temperatures. As their respiration rates increase in warmer temperatures fish use more oxygen. Conversely,

the rate of respiration decreases in cold water—even though the water may contain higher concentrations of dissolved oxygen. This is because fish require less oxygen as their metabolism slows in cold water and as a result, they don't need to work as hard to pass water over their gills to get the oxygen they need.

Winter Survival: A Balancing Act
If fish are to survive a Minnesota winter, a balance of factors determining the availability of oxygen are key. These include water temperature, ice and snow cover, the number of daylight hours, plant activity, and respiration rates.

Fish Winter Survival Strategies
Beneath the ice, in semi-darkness, fish and other aquatic animals must use the dwindling oxygen and food supply for as long as six months. It's a challenge to adjust to difficult winter conditions, and fish rely on a number of strategies to help them adapt. Conserving energy is the key to survival. Fish conserve energy in various ways, primarily through a combination of physical attributes (morphology or body parts), habitat, behavior or habits, and physiological capabilities (body chemistry and metabolic factors).

One behavior strategy fish employ to survive winter conditions involves changing their normal living habits. Cold weather triggers a physiological change. Metabolic rates slow and fish decrease their activity level, appearing to become more lethargic or sluggish. Because they become less active, fish can survive longer with the reduced amounts of food and oxygen in the water under ice and snow. Some fish spend winters in a state of dormancy. Fish can do this because they are **cold-blooded** like reptiles and amphibians. The body temperatures of cold-blooded animals are about the same as those of their surrounding environment because they absorb heat from the surrounding air, ground, or water. Cold-blooded animals reduce activity levels in winter conditions because the chemical activity that controls muscular activity occurs more slowly when their body temperatures are lowered.

Factors Affecting Oxygen Content of Aquatic Systems

Temperature—Cold water holds more oxygen than warm water. Shaded streams tend to be cooler than similar streams that aren't shaded. The cooler streams have relatively higher dissolved oxygen levels.

Depth—Shallow lakes don't hold as much water as deeper lakes of the same size, decreasing the overall oxygen content. Shallow lake systems also tend to have warmer water temperatures than deep lakes. Warm water doesn't hold as much dissolved oxygen as cold water, decreasing the amount of oxygen available to fish.

Competition—Fish aren't the only aquatic organisms that require oxygen. Aquatic vegetation is a crucial component of any aquatic system. It provides essential cover for fish and invertebrates. Plants also are a vital link in the food chain, producing food energy directly from the sun's light energy. Plants produce oxygen during photosynthesis, but also they *use* oxygen during respiration. If excessive amounts of vegetation grow in very small, shallow bodies of water, plants can eventually compete with fish for available oxygen. When many plants die suddenly, the bacteria that break down the plants also use oxygen.

Wind—Wind blowing across the surface of a lake or pond increases the amount of dissolved oxygen. If a body of water is covered with ice in winter, or if there are several calm days in summer, the amount of dissolved oxygen decreases.

—Michigan DNR information

Mammals (including people) and birds are **warm-blooded**. Their body heat comes from inside of their bodies from energy provided by the food they eat. Warm-blooded animals maintain a relatively constant body temperature independent of surrounding temperatures.

During hibernation, an animal's body temperature drops—its heartbeat, breathing, and other body activities are slowed and it uses very little energy. Hibernating animals prepare for their winter sleep by eating extra food and storing it as body fat. This body fat is the energy that will carry them through the winter. During hibernation, animals don't grow.

Some species of fish require more oxygen than others, depending upon their activity levels. Small, active fish, such as the brook trout, prefer fast-running cold streams with high oxygen levels. Other fish, such as carp, sticklebacks, and bullheads, can survive in warm, still waters with very little oxygen.

The body temperatures of cold-blooded animals are high when outside temperatures are hot and lower when their environments are cold. The body temperatures of fish can vary with the temperature of the water in which they swim. Because their body heat doesn't come primarily from the food they eat, fish require less food than mammals; they also convert a larger percentage of their food into body mass. Even though food is scarce in winter, fish are moving more slowly and expending less energy to obtain food, so they require less food during the winter. This is why decreased food supply is a much less serious wintertime limiting factor than oxygen shortage.

When temperatures start to get too cold, many animals **migrate,** or move to places with warmer temperatures for the winter season. Some fish, like many birds, migrate down rivers to warmer climates or, if that isn't possible, move to deeper water. Stress caused by predators, reduced oxygen levels, and extreme cold can increase fish activity levels and respiration rates, threatening their chances of surviving the winter.

For some aquatic animals, such as painted turtles and frogs, **hibernation** is the strategy of spending part or all of the cold season in a basically dormant state. In Minnesota winters, fish slow their metabolism, but they're not true hibernators. When temperatures drop, many fish move to the bottom of lakes and seek shelter under logs, rocks, and fallen leaves in the water. Some even burrow into the mud. They are quiet but awake. Some go into diapause, a suspended state with an extremely slow heart rate. These fish don't eat or release bodily wastes, but unlike true hibernators, they can be roused. One type of fish that enters diapause is the carp, which uses its tail to cover itself with mud from the bottom of the lake, river, or pond. Carp spend the winter partly buried in the mud on the bottom while northern pike and other fish move to deep water. The smallmouth bass dramatically slows its metabolism and rarely feeds when water temperatures drop below 40° F. In winter, fish metabolism slows as temperatures drop, and some fish even stop growing. But no matter how much fish slow down or stop growing, they still need some oxygen to survive.

Microclimates

Microclimates are climates within a small, defined area, possibly different than those of the immediate surrounding area. For example, places in a lake or stream with plants, logs, dead trees, snags, crevices, holes, and caves provide cover from predators, help reduce stress, and offer resting places and shelter. These places are critical for winter survival of fish.

The amount of dissolved oxygen varies, too, in the different microclimates within a lake or stream. Areas with turbulent water contain higher oxygen levels than less turbulent areas. Oxygen-rich locations include waterfalls, rapids, incoming streams, and springs.

In winter, when ice covers a lake, shallow areas contain less oxygen than deeper areas simply because they hold a smaller volume of water.

When deep snow cover doesn't keep sunlight from reaching aquatic plants through the ice in shallow areas, the plants can photosynthesize and produce oxygen. (Aquatic plants typically grow in the shallow areas of a lake, from shore to a depth of approximately fifteen feet.) In this case, shallow areas can contain much more oxygen than deep areas.

The areas of a lake deeper than fifteen feet are darker, without plants to produce oxygen. These areas can become **anaerobic** (meaning the state of being, living, or occurring without oxygen) as fish and other organisms deplete the available oxygen.

Frequent, heavy snows blanketing ice-covered lakes prevent sunlight from reaching the aquatic plants. Not only do the plants fail to photosynthesize, but they may begin to die and decay. Bacterial decomposers then go to work on the plants, multiplying and consuming more oxygen from the water in these areas of a lake.

Oxygen-rich Areas	Oxygen-poor Areas
Waterfall	Area of decaying plants
Incoming stream	Shallow area
Spring	Areas with pollution

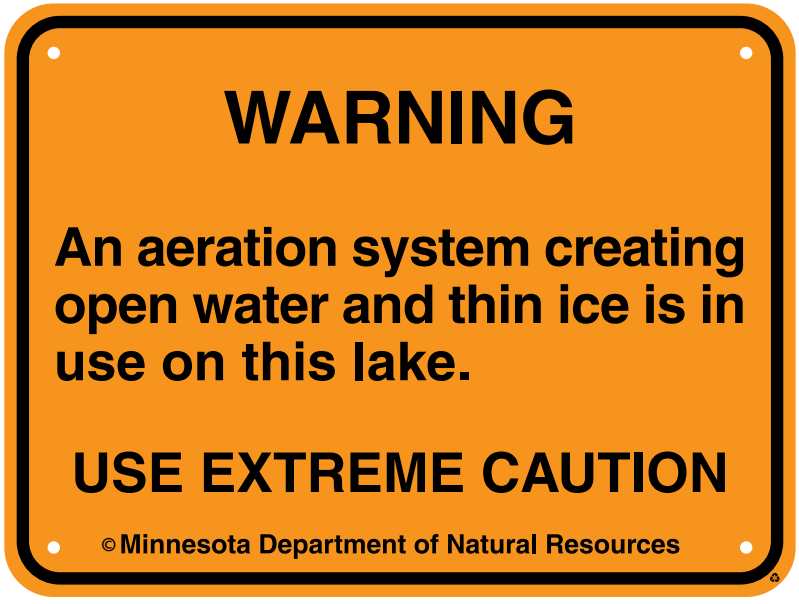
Winterkill
As winter progresses in some water bodies, dissolved oxygen levels can drop too low for fish to survive. Fish dying due to lack of oxygen is called **winterkill**. In many shallow lakes, most or all fish die every few winters due to winterkill, depending on the severity of the winter and the amount of snow cover on the ice. Usually it takes three or four years for a lake's fish population to recover after a winterkill.

Aeration Systems
To prevent winterkill, an **aeration system** can be used to keep an area free from ice, and allow oxygen from the air to mix with the open water. One type of aeration system is a subsurface unit known as a "bubbler." Bubblers force air through a hose located at the bottom of a lake, creating air bubbles. The air bubbles cause upward currents that bring the warmer water up from the bottom of the lake and melt the ice. Another popular system is called a surface agitator. Surface agitators float on the water and contain a propeller or a sprayer that sprays water onto the ice. The propeller or sprayer creates a current that circulates the water to keep the ice open.

In some lakes, dissolved oxygen levels can become dangerously low due to certain summer conditions, too. Fish dying from lack of oxygen in the summer is called a **summerkill.**

An aeration system keeps water open on a frozen lake within a posted thin-ice area.

An aeration system is expensive to operate and is recommended primarily for waters used extensively by anglers. To ensure safe and appropriate use, permits are required for aeration systems. The Aeration Program of the Minnesota DNR has existed since 1974. The program has grown from issuing a handful of aeration permits annually to approximately 250 aeration permits statewide per year. Aeration is primarily used to prevent the winterkill of fish, but in recent years, its use has expanded to include shoreline protection, providing open water areas for captive waterfowl, and to some extent, water quality improvement.



A sign must be posted at the public access to indicate that an aeration system is operating on a lake.

It's important to know and remember that winter ice can be thin and weak for many yards surrounding areas of open water. If you venture onto the ice for any reason, always stay well outside fenced areas indicated by thin ice signs.

Watch for these diamond-shaped signs out on the ice. They signify thin ice caused by many factors, including aeration systems.

Winter Suspense

Winter in Minnesota is a challenging time for fish. To survive, fish slow down, migrate, or make other changes in their lifestyle. Lakes under ice and snow have a decreasing supply of dissolved oxygen to offer as the long winter months progress. The story of fish in winter is a cliffhanger—will the snow and ice melt in time for wave action to renew the oxygen before the winter supply is completely expended?

Procedure

Preparation

1. In large letters, write each of the following words on sheets of paper: waterfall, incoming stream, spring, decaying plants, shallow area, and pollution. Place these labels around the classroom or playing area to indicate oxygen-rich and oxygen-poor areas in the lake. (See **Playing Area Diagram**.)
2. Cut out 200 six-inch-diameter paper circles or the one-quarter sheets of 8.5" x 11" paper or collect 200 poker chips or 200 small paper plates to use as oxygen "markers." Scatter these oxygen markers around the room, clustering more of them in oxygen-rich locations and fewer in oxygen-poor areas. Hang onto at least 30 oxygen markers for the warm-up part of the lesson. These markers will be placed in the lake after the warm-up

Activity

Warm-up

1. Like people, fish breathe oxygen, but it is mixed, or dissolved, into the water. Fish use their gills to get oxygen from the water. Ask the students how oxygen gets mixed into a lake or stream. (Aquatic plants produce oxygen through photosynthesis; waves, wind, and currents also mix oxygen into the water.)
2. Compare the respiration of fish with that of the students. Have students hold their breath. As they do this, ask them to think about whether they've ever been in a situation where oxygen was difficult to come by. Have them imagine what it would be like if they had to run to the other side of the school before being able to take another breath. Now let the students breathe. Invite them to tell about a situation in which they lacked oxygen.
3. Explore with students what might create more oxygen in one place and less in another. List their ideas. Guide students to include waterfalls, incoming streams, and springs. Have students write these items on the oxygen markers that will be used in the lesson. Make sure there are at least ten oxygen markers labeled waterfall, at least ten markers labeled incoming stream, and at least ten markers labeled spring. Scatter the remaining 30 oxygen markers in the appropriate places on the lake that you have set up as the playing area.

Students with breathing problems, such as asthma, may have difficulty with this lesson, which requires students to hold their breath for periods of time. Check with parents or the school nurse to make sure any students with asthma or other respiratory considerations will be able to participate in this lesson.

Lesson

Explain that fish don't always have plenty of oxygen available, and that lack of oxygen may affect them far more often than it affects us.

Round One: Spring, Summer, and Fall

1. Students will play the roles of fish. The oxygen markers (paper circles, quartered sheets, small paper plates, or poker chips) scattered around the room represent dissolved oxygen in a lake. Each fish must touch a marker in order to take a breath—they don't have to remain touching the oxygen as they inhale. But they can only take one breath per oxygen marker, and must take *five or more* steps before they stand on a new marker to take another breath. During this game, students must walk, not run. For this first round, announce that it is spring, summertime, and fall, and wave action and photosynthesis are mixing more oxygen into the water as the fish are breathing. The oxygen markers can be used, or touched by the students to breathe over and over. The students must keep moving around the lake and breathing until you signal them to stop in place.
2. Start the round. You may notice the "fish" clustering around the oxygen-rich areas in the lake.
3. Stop the game, and have students note the distribution of fish. Are there more fish in some areas of the lake than in others? Is there more oxygen in these same areas than in other areas of the lake? Have students count the number of fish in each location of the lake.

Record these numbers on a whiteboard or on graph paper. Students will make a graph to represent this data after the game.

4. Review that fish don't always have plenty of oxygen available, and that lack of oxygen may affect them far more often than it affects us.

Round Two: Early Winter

1. Ask the students to think about what usually happens to Minnesota lakes in December. (Lakes freeze over and snow accumulates on top of the ice.) How will oxygen be mixed into the water? Explain that oxygen isn't replenished in a lake that's under ice and snow.
2. Explain that, this time, the students will pick up and collect each oxygen marker, "using it up" as they take a breath. Again, they must take at least five steps before they stand on a new oxygen marker. When they can't reach another marker before they need to take another breath, they must sit down, having "suffocated" from lack of oxygen.
3. Start the round. Have students be fish in the ice-covered lake again, moving from marker to marker, breathing once at each oxygen marker, and picking it up before they move on to the next marker.
4. Stop the game before any fish sit down. Ask the students to explain what's happening to the oxygen in the lake. (It's getting used up.) Have students count the number of fish in each location of the lake. Record numbers for Round Two on the whiteboard or on graph paper. Students will make a graph to represent this data after the game.
5. Introduce the term limiting factor by asking students to describe how the fish are affected as oxygen is used up in the lake. If oxygen is impacting fish survival, it's a limiting factor in the lake. Define limiting factor. (A limiting factor is anything that restricts the living conditions for an organism, species, or population.) Discuss other limiting factors caused by Minnesota winters, including decreased food supplies, heavy snow, and cold temperatures.
6. Restart the game and play until students start sitting down due to lack of oxygen. What happens when a fish can't get the oxygen it needs?

Round 3: Midwinter

1. Collect the oxygen markers from the students and put them back in the lake, again concentrating more of them in the oxygen-rich areas. This time, hold back 50 oxygen markers from the oxygen-poor areas to represent the oxygen that was used up in December.
2. Tell the students that, during the winter, fish move more slowly to conserve energy and decrease their rate of oxygen use. During this round, students may take two breaths per oxygen marker, allowing them to spend more time at each marker. This will represent the fish slowing down and using the oxygen at a slower rate. Remind the students that they will collect each oxygen marker as they take their breaths, need to take at least five steps between markers, and that they must sit down if they can't get to another marker before

they need to take another breath.

3 Start the game. Monitor activity in the lake, and before any fish sit down, stop the game again. Have students stop where they are, and ask them what's happening to the oxygen in the lake. Even though there's less oxygen in the lake, the fish are surviving because they've slowed down and aren't using the oxygen as quickly. In which areas of the lake are most of the fish concentrated? Why? When oxygen levels are low in winter, fish move to oxygen-rich areas. Have students count the number of fish in each location of the lake for Round Three. Record these numbers on a whiteboard or graph paper for Round Three. Students will make a graph to represent this data after the game.

4 Restart the game and play until about half of the fish are sitting down. What is happening to the fish in the lake? Describe how oxygen can be a limiting factor.

Round 4: Late Winter

1 Collect the oxygen markers from the students and put them back in the lake, again concentrating more of them in the oxygen-rich areas. This time, remove 50 more oxygen markers from the lake to represent the oxygen that was used in midwinter. As you begin this round, there should be little or no oxygen in the oxygen-poor areas.

2 Start the game as in the last round. As the students start to sit down, stop the game and ask them to explain what is happening to the fish. Why are fish concentrating in certain areas in the lake? Have students count the number of fish in each location of the lake for Round Four. Record these numbers on a data sheet for this round. Students will make a graph to represent this data after the game.

3 Tell students that fish don't usually use up all of the oxygen in Minnesota lakes every winter. This does happen in some lakes during some winters, however. In what situations might the fish use all of the oxygen in a lake? Brainstorm a list, which may include:

- winter lasts too long, with continuous ice and snow cover
- there are no waterfalls, springs, or incoming streams (oxygen-rich areas)
- the lake is very shallow
- there are a lot of decaying plants, pollution, or both (oxygen-poor areas)
- a drought year has made the lake shallower, so it holds less oxygen
- snow cover blocks sunlight that would otherwise penetrate uncovered ice to reach aquatic plants; this prevents photosynthesis
- there are too many fish breathing the limited available oxygen

If fish don't use up all of the oxygen in a lake, is oxygen still a limiting factor?

4 Discuss the fact that when fish die in a lake during winter, it is not because the lake has frozen solid all the way to the bottom. Instead,

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winterkill usually occurs because all of the oxygen in the water has been used. Fish species that require more oxygen than others will die off first. Lack of oxygen is a key limiting factor for fish survival in winter. The oxygen level in a lake in winter is one of the most important factors determining whether the fish in a lake will survive the season. Fish that can survive in water with lower oxygen levels, such as bullheads, may be able to survive until spring. Fish that require more oxygen probably won't. When ice and snow melt in the spring, wave action and increased photosynthesis replace dissolved oxygen lost during the winter.

Wrap-up

1. Have students make bar graphs for each of the four rounds. On the x-axis, have students note the different locations in the lake. On the y-axis, note numbers of fish. Have students write an appropriate title on the graph and include a key to explain symbols and data in the graph. Ask students to determine which areas of the lake had the highest oxygen levels in each round and note that below each graph. (Areas with the most fish as noted on the graphs should correlate to areas of the lake with highest oxygen levels.)
2. Review the term limiting factor. Have students identify at least three natural factors that result in lower dissolved oxygen levels in aquatic environments in winter. Discuss what it means to be cold-blooded. What happens to a lake in the winter? What does a heavy snow cover mean for aquatic plants? What does this mean for fish? Discuss the adaptations (physical, behavioral, physiological) that fish possess that help them survive a Minnesota winter.
3. Have students do research on the Internet to find the oxygen requirements for several Minnesota fish species, including black bullheads, carp, brook trout, walleye, smallmouth bass, and bluegill sunfish. Play the game with a different species of fish each time. Depending on the oxygen required by each species, have students determine how each fish species will move between oxygen markers. Discuss how the adaptations of different species can cause each species to require more or less oxygen to survive. Make a graph comparing the oxygen requirements of different types of fish. List oxygen requirement levels in ascending order on the y-axis, and species of fish along the x-axis of the graph. Have students write an appropriate title on the graph and include a key to explain symbols and data in the graph. Note overlaps and discuss factors that make setting minimum oxygen requirements for fish difficult and variable. (These include water temperature, plant activity, winter conditions, metabolic rates, and respiration rates.)
4. Suppose that some of the fish in a lake are stressed or sick. Discuss what might happen to those fish over the winter.

Graphic organizers can take the form of a concept map, tree, star, or web showing definitions, attributes, examples, classifications, structures, examples, relationships, and brainstorming. Charts and tables show attributes, characteristics, comparison, and organization. A chain or timeline illustrates processes, sequences, cause and effect, and chronology. Diagrams, charts, and drawings show physical structures, spatial relationships, and concrete objects. Cut and folded paper can be fashioned into flaps that, when lifted, reveal details, definitions, descriptions, or explanations.

Assessment Options

1. After the simulation activity, have students construct a graphic organizer to include the following information:
   - Fish are cold-blooded. How do they maintain their body temperature?
   - What is usually the most important limiting factor for fish in winter?
   - Define dissolved oxygen and describe how oxygen enters and mixes into a lake or river.
   - Identify at least two natural factors that cause a decreased dissolved oxygen levels in a water body during Minnesota winters. (Answers include ice cover, snow cover on ice that blocks sunlight, shorter days, less photosynthesis performed by plants, lack of wave action to mix more oxygen into the water.)
2. Have students use the information in their graphic organizers to write a story from the perspective of a fish, explaining how they survive the winter in Minnesota. They can consider:
   - What are the limiting factors that concern them during the winter? (The limitations should include low oxygen levels and less available food.)
   - What strategies—behaviors or body functions—help them survive low oxygen levels in winter?
   - Explain how they prepare for winter. (Answers could include slowing metabolism, stopping growth, finding deeper water, finding an area with higher oxygen levels, and finding a sheltered location.)
3. As an alternative to having students create graphic organizers for Assessments 1 and 2, you may wish to have students write and illustrate a story about fish in winter that includes this information. Then have them present the story to a class of younger students. Or have students perform scenes from their story to answer the questions in Assessments 1 and 2. Or have the students simply prepare a list that includes the requested information.
4. Have students do research comparing the oxygen requirements of different fish species such as such as walleye, sunfish, bass, and northern pike. Play the game again, but in addition to the fish in the lake, add some other species (about one-quarter of the students). These could be carp or bullheads, fish that require less oxygen than the other types of fish. The carp or bullheads can take two breaths each time they step on an oxygen marker, and can take two breaths as they walk from one oxygen marker to another. Discuss what happens to the different species as the fish move around the lake throughout the winter during the various rounds. Graph population densities of the different types of fish as winter progresses during the four rounds of the game.
5. Assessment options include the Checklist and Rubric on the following pages.

Fish in Winter Checklist

Possible Points	Points Earned Student	Points Earned Instructor	
2	_____	_____	Student's story explains that oxygen is important to fish.
4	_____	_____	Student's story clearly explains two ways that oxygen is depleted from water in a lake in winter.
3	_____	_____	Student's story shows an understanding of the definition of *limiting factor*.
2	_____	_____	Student's story notes that oxygen is the most important limiting factor for fish in winter.
2	_____	_____	Student describes two additional limiting factors for fish in winter.
3	_____	_____	Student's story describes how wind, waves, and plants oxygenate the water.
2	_____	_____	Student explains that when ice and snow block sunlight, plants don't make oxygen that fish need.
4	_____	_____	Student identifies four locations or features of a lake that result in higher oxygen levels in winter.
Total Points			
22	_____	_____	**Score** _____

Checklists are tools for students and instructors. Checklists involve students in managing their own learning. They help students understand and set learning goals before the lesson begins, and help them monitor their progress during the lesson, ensuring that they meet learning goals and objectives by the end of the lesson. Students can also use checklists to discover areas that may need improvement. Checklists help instructors monitor each student's progress throughout the lesson, facilitating appropriate adjustment of instruction to ensure learning by the end of the lesson. The instructor may wish to have students add several of their own learning goals to the checklist to personalize it, and to accommodate varied learning needs and styles.

Grade

20–22 points = A
Excellent. Work is above expectations.

17–19 points = B
Good. Work meets expectations.

14–16 points = C
Work is generally good. Some areas are better developed than others.

10–13 points = D
Work does not meet expectations; it's not clear that student understands objectives.

0–9 points = F
Work is unacceptable.

Fish in Winter Scoring Rubric

Story Criteria	4 Excellent	3 Good	2 Fair	1 Poor	0 Unacceptable
Oxygen	Story clearly mentions oxygen mixed into water and why oxygen is important to fish.	Story mentions oxygen mixed into water and why oxygen is important to fish, but concepts aren't clearly stated.	Story mentions oxygen mixed into water, but not the importance of oxygen to fish.		Story doesn't mention oxygen in water or the importance of oxygen to fish.
How oxygen is depleted from water in winter	Story clearly explains two ways oxygen is depleted from the water of a lake in winter.	Story explains two ways oxygen is depleted from the water of a lake in winter, but lacks clarity.	Story clearly explains one way that oxygen is depleted from the water of a lake in winter.	Story incorrectly explains how oxygen is depleted from the water of a lake in winter.	Story doesn't mention how oxygen is depleted from the water of a lake in winter.
Limiting factor	Understands definition of limiting factor and that oxygen is the most important limiting factor for fish in winter. Describes two additional limiting factors other than oxygen for fish in winter.	Understands definition of limiting factor and that oxygen is the most important limiting factor for fish in winter.	Understands definition of limiting factor and that oxygen is a limiting factor for fish in winter.	Understands that oxygen is a concern for fish in winter.	Doesn't mention oxygen as a concern for fish in winter.
How oxygen mixes into the water	Story describes how wind, waves, and plants mix oxygen into the water. Explains that when ice and snow cover block sunlight, plants don't make oxygen. Identifies four locations or features of a lake that result in higher oxygen levels in winter.	Story describes how wind, waves, and plants mix oxygen into the water. Explains that plants don't receive sunlight under ice and snow cover. Identifies three locations or features of a lake that result in higher oxygen levels in winter.	Story identifies that wind, waves, and plants mix oxygen into the water. Identifies three locations or features of a lake that have higher oxygen levels.	Story identifies that wind, waves, or plants mix oxygen into the water. Identifies two locations or features of a lake that have higher oxygen levels.	Story doesn't identify wind, waves, or plants mixing oxygen into the water. Identifies fewer than two locations and features of a lake that have higher oxygen levels.

Score _____ (Calculate score by dividing total points by number of criteria.)

Diving Deeper

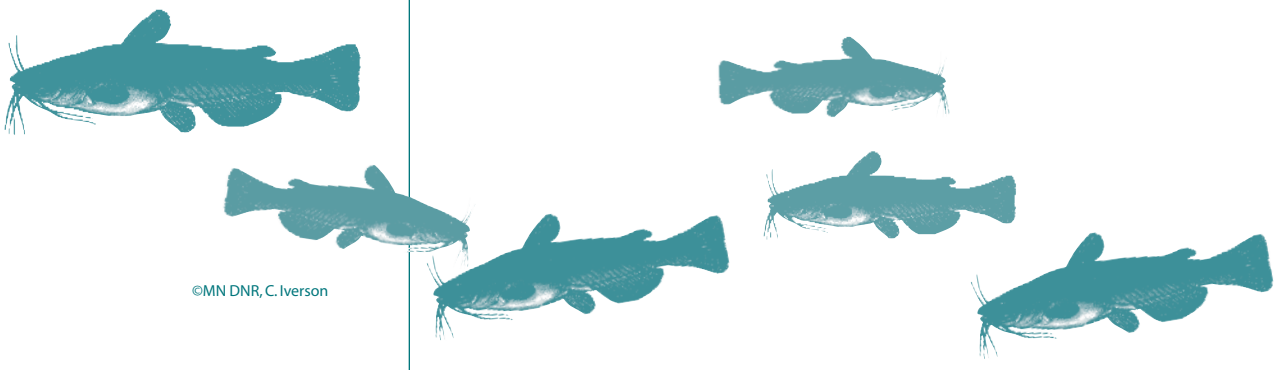
Extensions

1. Add additional rounds to the game to illustrate how people's activities contribute to reduced oxygen levels in the lake or how installed aeration systems increase oxygen levels of lakes.
2. In early fall, have students predict when "ice-on" will occur at a local lake or pond. In late winter, they can try to predict when "ice-off" will occur. (Ice-on is when the lake or pond freezes over for the winter; ice-off is the day that a lake or pond loses its winter ice cover in the spring.) To make these predictions, students can work individually or in groups to make observations, gather information, and record data about the seasonal changes and conditions they observe at the lake or pond. Have them continue to record their observations until the actual ice-off date. This information can be included in a class record or calendar of natural occurrences at the lake or pond, along with their observations at the site. Students can also record conditions such as daily temperatures, winter snowfall, cloud conditions, and whether the ice gradually disappears from the lake or melts all at once. They might also observe and record the activities of animals and plants. This type of record or calendar is called a phenology chart. The students can make their phenology chart available to next year's class so those students can continue the school's recording of ice-on, ice-off, weather conditions, plant and animal sightings, and the like. Students can compare the actual ice-on or ice-off dates with their prediction dates and discuss any differences.
3. Visit a site with an aeration system. Ask a community resource person to explain how and why the system is used.
4. Has there been a winter fish kill in your area? Save newspaper articles about local fish kills to share and discuss with your students. Get additional information about a local fish kill from your area DNR office.
5. Visit the DNR website and search for the *Minnesota Conservation Volunteer* article "Life Under Ice and Snow," by Larry Weber to find out how other animals adapt to Minnesota winter conditions.

For the Small Fry

K-2 Option

1. Have students observe a fish breathing in the water. Watch the mouth and gill covers open and close. Discuss how fish use their gills to obtain oxygen from the water.
2. Visit a body of water near your school. Look for aquatic plants, inlets, and waves. As you discover these items, discuss how they put oxygen in the water for fish to breathe. If you're visiting the water body in the winter, note how the ice covers the water and prevents waves. Look for plants under the ice. Can you see them? Are they still green? Discuss how these things prevent oxygen from getting into the water. If a lake visit isn't feasible, use seasonal photos of lakes to show the vegetation and wave differences at different times of the year.
3. Have students create (by drawing or building a model) a summer lake habitat showing the areas where oxygen enters and mixes into the water. Create a second winter lake habitat, demonstrating the changes that allow less oxygen to enter and mix into the water.



Playing Area Diagram