Next Generation of Scientists & Engineers:

Examining Stability and Change

Grade Level: 3-8

Activity Duration:
Warm-up: 10 minutes
Activity: 30 minutes
Wrap-up: 10-20 minutes

Overview:
Warm-Up: Defining Dissolved Oxygen
Activity: Surviving the winter & understanding limiting factors
Wrap-Up

Tools for building science literacy and understanding the nature of science

http://undsci.berkeley.edu/

YouTube Video Series Introducing the Next Generation Science Standards
http://tinyurl.com/ajy3fhq

Summary: In a simulation game, students play the role of fish attempting to survive a Minnesota winter. 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. Students revise their behaviors just as fish do, to increase their chance of survival.

Topic: Fish Survival in Winter

Theme: Stability and Change in Natural Systems

Objectives:

The students will:

1. Identify oxygen as 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 dissolved oxygen levels to decrease in a body of water during Minnesota winters.
4. Describe the behavior shifts in fish that allow for survival in low oxygen environments.

*This lesson is adapted from "**Fishing: Get in the Habitat! Leader's Guide,** Lesson 2:8 – Fish in Winter" with permission from the MN DNR MinnAqua Program.* http://tinyurl.com/minnaqua-fish-winter

Great Lakes Aquarium

MinnAqua
Fishing: Get in the Habitat!

Next Generation Science Standards

Crosscutting Concepts: Stability and Change

Stability and change are the primary concern of many, if not most, scientific and engineering endeavors. Stability denotes a condition in which some aspects of a system are unchanging, at least at the scale of observation. Stability means that a small disturbance will fade away-that is, the system will stay in, or return to, the stable condition.

Progression at Grades 3-5

Students measure change in terms of the differences over time and observe that change may occur at different rates. Students learn that some systems appear stable, but over long periods of time they will eventually change.

Progression at Grades 6-8

Students explain stability and change in natural or designed systems by examining changes over time and considering forces at different scales, including the atomic scale. Students learn that changes in one part of a system might cause larger changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time.

Suggested MN Science Standards:

This lesson may partially or fully address the following standards.

Grade 3:

3.1.1.2.4 – Construct reasonable explanations based on evidence collected from observations or experiments.
3.1.3.2.1 – Understand that everyone can use evidence to learn about the natural world, identify patterns in nature, and develop tools.

Grade 4:

4.2.1.2.2 – Describe how the states of matter change as a result of heating and cooling.

Grade 5:

5.1.1.1.4 – Understand that different models can be used to represent natural phenomena and these models have limitations about what they can explain.
5.3.4.1.3 – Compare the impact of individual decisions on natural systems.
5.4.2.1.1 – Describe a natural system in Minnesota, such as a wetland, prairie, or garden, in terms of the relationships among its living and nonliving parts, as well as inputs and outputs.
5.4.2.1.2 – Explain what would happen to a system such as a wetland, prairie or garden if one of its parts were changed.

Grade 6:
6.1.3.1.1 – Describe a system in terms of its subsystems and parts, as well as its inputs, processes and outputs.
6.2.1.2.1 – Identify evidence of physical changes, including changing phase or shape, and dissolving in other materials.

Grade 7:
7.4.1.1.2 – Describe how the organs in the respiratory, circulatory, digestive, nervous, skin and urinary systems interact to serve the needs of vertebrate organisms.
7.4.2.1.3 – Explain how the number of populations an ecosystem can support depends on the biotic resources available as well as abiotic factors such as amount of light and water, temperature range and soil composition.
7.4.2.2.2 – Describe the roles and relationships among producers, consumers, and decomposers in changing energy from one form to another in a food web within an ecosystem.
7.4.4.1.2 – Describe ways that human activities can change the populations and communities in an ecosystem.

Grade 8:
8.1.3.3.1– Explain how scientific laws and engineering principles, as well as economic, political, social, and ethical expectations, must be taken into account in designing engineering solutions or conducting scientific investigations.
8.1.3.3.3 – Provide examples of how advances in technology have impacted how people live, work and interact.
8.2.1.2.1 – Identify evidence of chemical changes, including color change, generation of a gas, solid formation and temperature change.
8.3.4.1.2 – Recognize that land and water use practices affect natural processes and that natural processes interfere and interact with human systems.

Environmental Literacy Scope and Sequence

- 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)
- Social and natural systems can include processes as well as things. (6-8)

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

Materials:

- 200 Oxygen Markers, Options include:
  - 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
- Six **Lake Habitat Signs**
  - 8.5" x 11" (or larger) sheets of paper
  - Labeled: Waterfall, incoming stream, spring, decaying plants, shallow area, and pollution
- Whiteboard (not provided) or graph paper (teacher copy included) – optional extension
- Pen or pencil per student – optional extension
- Colored Pencils (7 colors per group) – optional extension
- Whistle or other noisemaker (to signal the beginning and ends game rounds)
- **Playing Area Diagram**

Vocabulary:

Adaptation: A physical characteristic or behavior developed by a plant or animal that makes it better suited to its environment and enables it to survive particular conditions.

Aeration System: A mechanical device used to add or mix oxygen into the water of a lake or pond.

Anaerobic: The state of being, living, or occurring without oxygen.

Cold-blooded/Ectothermic: Animals, such as fish and amphibians that require the sun's warmth for heat and have an internal body temperature that varies according to the temperature of their surroundings.

Diapause: A suspended state in which an organism exhibits an extremely slow heart rate; a behavioral adaptation that helps an organism survive a seasonal or limited period of extreme or harsh environmental conditions.

Dissolved Oxygen: Oxygen gas dissolved in water.

Hibernation: A survival strategy for spending part or all of the cold season in a basically dormant state of inactivity brought about by short daylight hours, cold temperatures, and limited food.

Limiting Factor: A condition that influences the survival of an organism, population, or species.

Microclimates: Term used to describe climates within a small, defined area, possibly different from the area directly surrounding it.

Migrate: The annual or seasonal movement of an organism from one habitat to another; typically involves a return trip to the original habitat.

Respiration: The physical and chemical process of supplying the cells and tissues of an organism with oxygen for the processes of metabolism and releasing carbon dioxide.

Warm-blooded/Endothermic: Organisms that produce body heat and regulate body temperature from within their bodies using energy from the food they eat. Warm-blooded animals maintain a relatively constant body temperature independent of the outside temperature.

Winterkill: When fish under ice cover die due to lack of oxygen during winter.

Instructor 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.

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 is 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 (ectothermic)** 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.

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 in the winter 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.

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 areas 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.

Winter Suspense

Winter in Minnesota is a challenging time for fish. To survive, fishes 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?

Preparation

1. In large letters, write each of the following words on sheets of paper: (Optional: Print out one copy of each of the **Lake Habitat Signs**.)

    a. waterfall
    b. incoming stream
    c. spring
    d. decaying plants
    e. shallow area
    f. pollution

2. Place these labels around the classroom or playing area to indicate oxygen-rich and oxygen-poor areas in the lake. (See **Playing Area Diagram**.)

3. Make 200 oxygen markers. (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.")

4. Scatter the 200 oxygen markers around the room, clustering more of them in oxygen-rich locations (waterfall, stream, spring) and fewer in oxygen-poor areas (decaying plants, shallow area, pollution). (See **Playing Area Diagram**.)

5. You may need to start out with less markers depending on your class size – 200 markers is ideal for classes with 25 or more students. You can adjust your markers during the game as well if you are not able to create a winterkill in the first two rounds.

Warm-Up: Defining Dissolved Oxygen

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.

2. Ask the students to describe something that can be dissolved into water. If students are struggling, ask them to think about what happens when sugar is added to water. (Sugar looks like it disappears – it is dissolved. If the water is evaporated, the sugar is left behind in the container.)

3. Ask the students how oxygen gets mixed/dissolved into a lake or stream.

    a. Aquatic plants produce oxygen through photosynthesis
    b. Waves, wind, and currents also mix oxygen from the air into the water

4. Compare the respiration of fish with that of the students.

a. Have students hold their breath.
b. 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.
c. Now let the students breathe.
d. What would it be like for a fish to try and swim in a lake without oxygen?

5. Let the participants know that they are going to become fish and the area where the markers are on the floor is their lake.

6. Point out the signs hanging in the room around the lake.

7. Explore with students what might create more oxygen in one place in the water than elsewhere in a lake. List their ideas. Guide students to include:

    a. waterfalls
    b. incoming streams
    c. springs

8. Explore with the students what might reduce the amount of oxygen in place in the water than elsewhere in the lake. List their ideas. Guide the participants to include:

    a. pollution
    b. decaying/decomposing plants
    c. shallow water

Activity: Surviving the Winter

Round One: Spring, Summer, and Fall

1. Students will play the roles of fish.

2. For this first round, announce that the participants are going to try and survive for one year in this lake.

3. Explain that the paper circles, quartered sheets, small paper plates, or poker chips scattered around the room represent dissolved oxygen in a lake.

4. Have the students review the six areas around the lake that may affect oxygen levels in the lake.

5. Ask the participants to list the ways oxygen is being mixed into the water:

    a. wave action
    b. photosynthesis
    c. moving water from a waterfall, stream or seep

6. Each fish must touch a marker in order to take a breath—they don't have to remain touching the oxygen as they inhale. Note:

    a. They can only take one breath per oxygen marker.
    b. They must take ***five or more*** steps before they stand on a new marker to take another breath.
    c. The oxygen markers can be used, or touched by the students to breathe over and over because new oxygen is being mixed into the system at this time.
    d. During this game, students must walk, not run.
    e. The students must keep moving around the lake and breathing until you signal them to stop in place.

7. Start the round. Announce the changing of the months – starting with April. Give a little wait time between each month for the fish to swim around.

8. You may notice the "fish" clustering around the oxygen-rich areas in the lake.

9. Pause the game (in June or July), and have students note the distribution of fish.

    a. Are there more fish in some areas of the lake than in others?
    b. What is causing fish to congregate in certain areas of this lake?

10. Continue the game until you reach October and then pause the game again.

Round Two: Winter Trial 1 (November – March)

1. Ask the students to think about what usually happens to Minnesota lakes in late November or December. (*Lakes freeze over and snow accumulates on top of the ice.*)

    A. Ask students to think about how will oxygen be mixed into the water once the lake is frozen over? (*For the most part oxygen won't be mixed into the water.*)
    B. What does a heavy snow cover mean for aquatic plants? (*Lack of sunlight means they will die off and start to decompose.*)
    C. What does this mean for fish? (*Oxygen may be hard to come by in the winter. Students may also note that food sources may be reduced.*)

2. Explain that, this time, the students will pick up and collect each oxygen marker, "using it up" as they take a breath.

3. Again, they must take at least <u>five steps</u> before they stand on a new oxygen marker.

4. When they can't reach another marker before they need to take another breath, they must sit down in that part of the lake, having "suffocated" from lack of oxygen.

5. Start the round. Have students be fish in the newly ice-covered lake starting in November. You may need to remind participants to:

    A. Move from marker to marker, taking at **least 5 steps** before standing on a marker.
    B. Breathe once at each oxygen marker.
    C. Pick it up before they move on to the next marker.
    D. Sit down where you run out of oxygen.
    E. Stay in the lake.

6. Continue to have the time pass by announcing the months changing starting with November. Give a lot more time before announcing the next month to allow the fish to reduce the amount of oxygen in the water.

7. Pause the game before any fish sit down, (approximately January).

8. Ask the students to describe what's happening to the oxygen in the lake. (*It's getting used up.*)

9. Have students observe where they are located in the lake. Which areas of the lake are most of the fish located? (*Near the waterfall, incoming stream, and spring.*) Why are the fish beginning to cluster into these areas? (*This is where the oxygen is concentrated.*)

10. Ask students to describe how the fish are affected as oxygen is used up in the lake.

11. 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.*)

12. Discuss other limiting factors caused by Minnesota winters, including decreased food supplies, heavy snow, and cold temperatures.

13. Restart the game. Continue from January and play until students start sitting down due to lack of oxygen (before April).

14. Ask the students if anyone knows the term used to describe the phenomena of a lot of fish dying in the winter due to lack of oxygen. (*Winterkill*) This is what happened in our lake.

15. Note where the students that died are sitting in the lake.

    A. What is happening in the lake near where the dead fish are located? (*Shallow area, pollution, decaying plants*)

B. Why/how is the oxygen being reduced in these areas? (*See background information for complete explanations on how these three things reduce or oxygen in the winter.*)

16. Ask the students to start thinking about why it would matter if a lot of fish are dying in a lake over the winter.

Round 3: Winter Trial 2 (December – March)

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.
2. This time, hold back 50 oxygen markers from the oxygen-poor areas to represent the oxygen that was used up in December.
3. Ask the students to think about how fish may change in order to survive the winter.
4. Have the participants run in place for 30-seconds and then assess their breathing and heart rates.
5. Ask the participants to turn to another person and discuss what fish may do to help them survive the winter with a limited amount of oxygen in the water.
6. After about a minute regroup and ask a participants to explain one thing a fish might do that will help them survive the winter. (*Answers may include: swim slower, eat less, migrate, or they can't change.*)
7. Let the participants know that the fish cannot migrate out of this body of water but they can change their behavior during the winter so they can survive. Tell the students that, during the winter, fish move more slowly to conserve energy and decrease their rate of oxygen use.
8. 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.)
9. Remind the students that:

    a. They will collect each oxygen marker as they take their two breaths.
    b. They need to take at **least five steps** between markers.
    c. They must sit down in the lake if they can't get to another marker before they need to take another breath.
    d. During this game, students must walk, not run.
    e. The students must keep moving around the lake and breathing until you signal them to stop in place.

10. Start the game resetting back to December.

11. Call out the months, giving enough time between each to see a marked decrease of oxygen in the water.

12. Monitor activity in the lake, and before any fish sit down, pause the game before you announce February.

13. 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.*)

14. In which areas of the lake are most of the fish concentrated? Why? (*The moving water from the stream, waterfall and underground spring are mixing oxygen into it and/or keeping the ice off of that area so oxygen can enter the water.*) When oxygen levels are low in winter, fish move to oxygen-rich areas.

15. Restart the game and play until about half of the fish are sitting down (slow down your timing so this begins to happen before you call out April).

16. What is happening to the fish in the lake? (*Oxygen can still be a limiting factor, more changes are needed.*)

17. Why is understanding what is causing a winterkill important?

18. What else may be impacted by a winterkill, besides the fish? List the participants ideas which may include:

    a. *Other animals that eat fish*
    b. *Animals that are eaten by fish*
    c. *People that live by the lake (smelly!)*
    d. *People that depend on the lake for fishing.*

Round 4: Winter Trial 3 (January – April)

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, December - January (there should only be 100 markers left.) As you begin this round, there should be little or no oxygen in the oxygen-poor areas.

2. Ask the students to turn to another student and discuss another way they can conserve oxygen in this game.

3. Regroup and ask for ideas on how the participants can change to survive the winter with low oxygen. (*Slow down, do nothing, reduce the population*)

4. Let the participants know that the goal is to have almost all of the fish survive and focus the group on the idea of slowing down.

5. Ask for a volunteer to demonstrate how a slow fish might look in this activity. (*Take a long time between each step, wait a long time before taking a second breath when on an oxygen marker.*)

6. Start the game in January.

7. Remind the students that:

    a. They will collect each oxygen marker as they take their two breaths.
    b. They need to take at **least five steps** between markers.
    c. They can take slower steps.
    d. They must sit down in the lake if they can't get to another marker before they need to take another breath.
    e. During this game, students must walk, not run.
    f. The students must keep moving around the lake and breathing until you signal them to stop in place.

8. If the students start to sit down, pause the game and ask them to explain what is happening to the fish. Challenge them to stay alive for the winter. You can also have the participants breathe normally while they are slowing down their steps for this round because we cannot actually slow down our respiration the same way a fish does.

9. When you get to March, pause the game again.

10. Ask the students to observe where fish are concentrating in the lake.

    a. Why are fish concentrating in certain areas of the lake?
    b. What natural features are in the areas where fish are concentrating? What may be happening to the oxygen levels in these areas?
    c. What natural or unnatural features are in the areas where there are no fish? What may be happening to the oxygen levels in these areas?

11. Complete the game through April and celebrate a successful year of survival!

Wrap Up:

1. Review the term limiting factor.

2. 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:

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

3. Review the adaptations (physical, behavioral, physiological) that fish possess that help them survive a Minnesota winter.

4. What could happen to a community that relies on tourism from anglers for their primary income if there is a winterkill? You can note that the fishing industry including the impacts from anglers eating at restaurants, staying at hotels and using gasoline brings $2.5 billion dollars into our economy every year.

5. Reinforce 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, 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.

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

7. What do you think we can do to prevent a winterkill?

    a. Prevent pollution that causes excessive plant growth in the summer, (phosphorous from fertilizers and soaps), which cause more plants to decay in the winter – ultimately reducing oxygen levels
    b. Prevent organic pollution (human waste, animal waste, leaves that are raked up from yards, wood chips, etc.) from entering the lake and streams around the lake

c. Use technology like an aeration system to help mix oxygen into the lake during the winter

Extensions:

1. During each round of the game have the students count the number of fish near each of the six signs around the lake and record the data in a chart.

    a. Using the data collected during the game, make a graph as a large group or individually.

        i. On the x-axis, note the months of the year.
        ii. On the y-axis, note numbers of fish.
        iii. Use a different symbol to graph the points for each location – using different colors can also be helpful in seeing the different locations clearly.

    b. Have the participants tell you the numbers to plot or call on participants to come up and plot one point until all data from the chart is plotted.
        i. Create a key showing what each symbol/color represents on the graph

    c. Have students write an appropriate title on the graph and include a key to explain symbols and data in the graph.

    d. 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. 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.

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. 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.

5. Visit a site with an aeration system. Ask a community resource person to explain how and why the system is used.

6. 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.

7. 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.

K-2 Option

The game is appropriate for this age group. The following are suggestions to help with participants understanding of how fish breathe and how oxygen is mixed into the water.

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.

Brought to you by Great Lakes Aquarium and MN DNR MinnAqua Program, funded in part by the US Sport Fish Restoration Fund.

Game play at a glance

General Rules:

A. They must take *five or more* steps before they stand on a new marker to take another breath.
B. During this game, students must walk, not run.
C. The students must keep moving around the lake and breathing until you signal them to stop in place or they run out of oxygen.

Round 1: Spring, Summer, Fall (April – October)

A. They can only take one breath per oxygen marker.
B. The oxygen markers can be used, or touched by the students to breathe over and over because new oxygen is being mixed into the system at this time.
C. Pause game mid-summer to observe where fish are located in the lake.

Round 2: Winter Trial 1 (November – March)

A. Breathe once at each oxygen marker.
B. Pick it up before they move on to the next marker.
C. Sit down where you run out of oxygen.
D. Stay in the lake.
E. Pause game in January to note where fish are located in the lake
F. Define Limiting Factor
G. Pause game when fish start to sit down and define winterkill, note where in the lake the dead fish are located

Round 3: Winter Trial 2 (December – March)

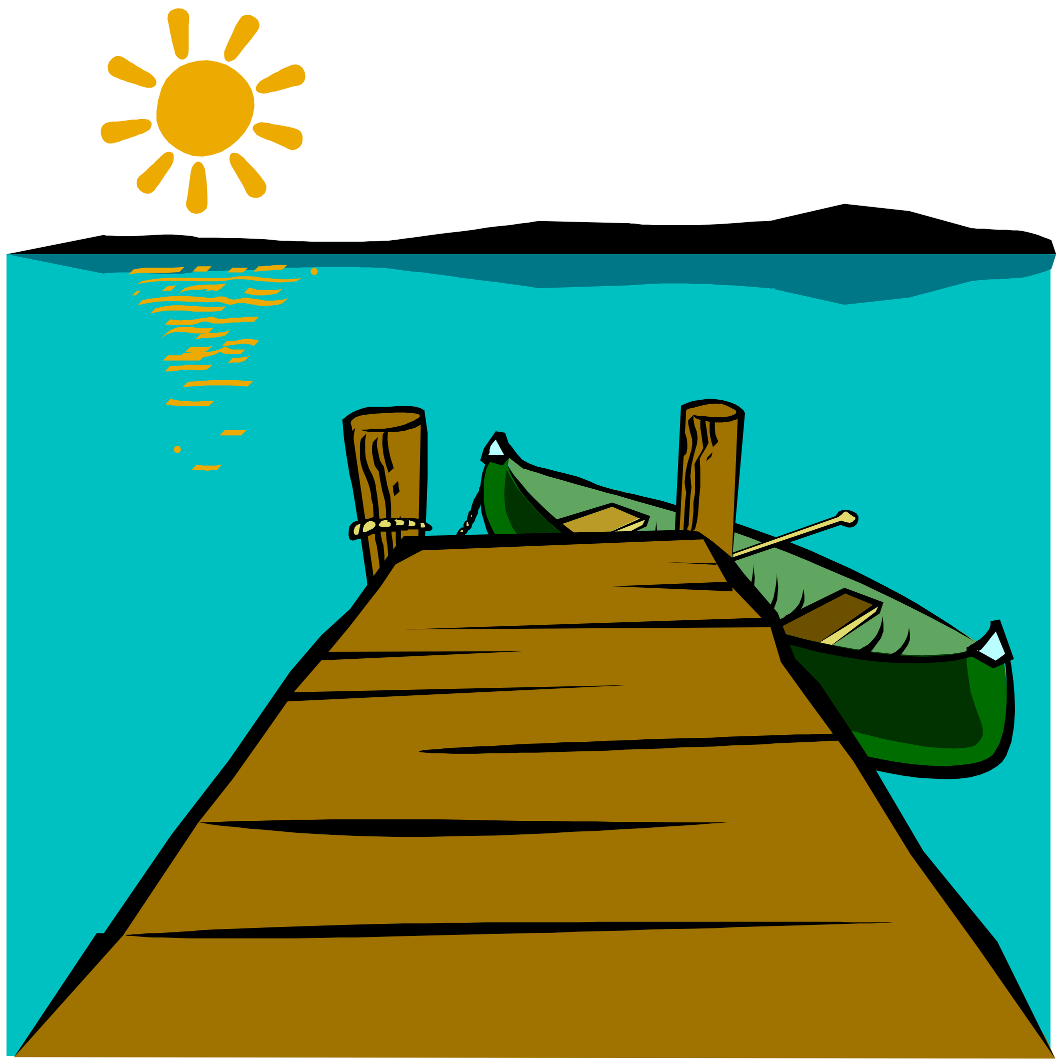
A. Reduce number of O2 in water by 50, taking away from low oxygen areas (shallow area, decaying plants, pollution)
B. Return rest of O2 to the lake
C. Run in place to illustrate O2 needs, brainstorm ideas to conserve O2
D. Students take two breaths at each marker before collecting it and moving on.
E. A second winterkill may happen or not – you can force it to happen by lengthening time between months

Round 4: Winter Trial 3 (January – March)

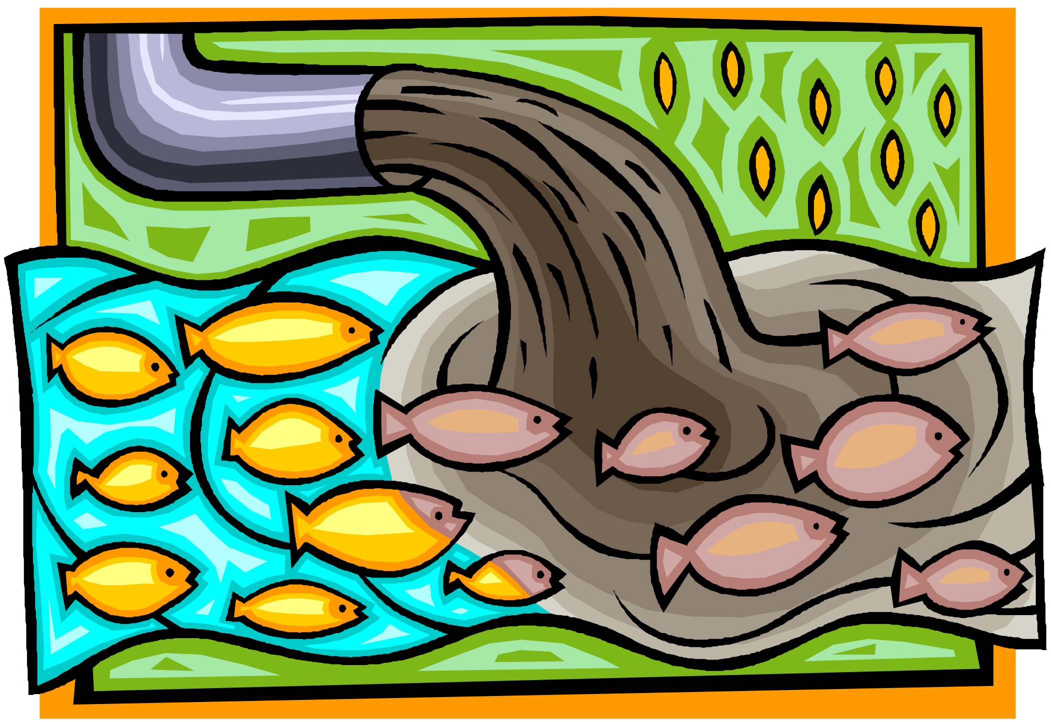
A. Reduce number of O2 by 50 again (leaving only 100 in the lake)
B. Return rest of O2 to the lake concentrating it in the high O2 areas (incoming stream, waterfall, seep/spring)
C. Brainstorm another way to conserve O2 – slow down movement, have student demo super slow walking.
D. Try to keep from having a winterkill – pause game if winterkill is happening and ask students to ID how to keep it from happening.
E. Continue game into April when the ice melts.

Waterfall

Shallow Area



Pollution

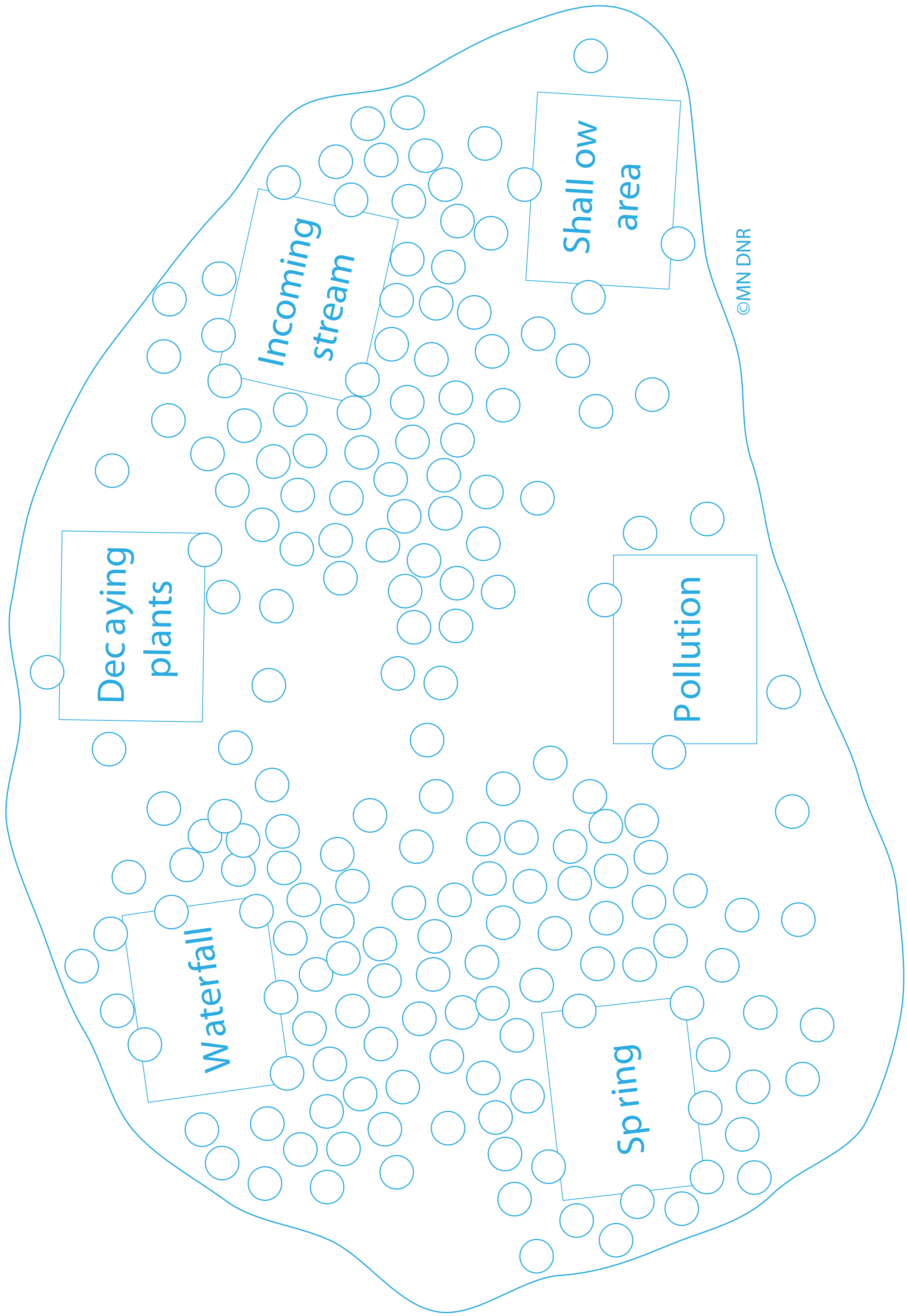


Decaying Plants

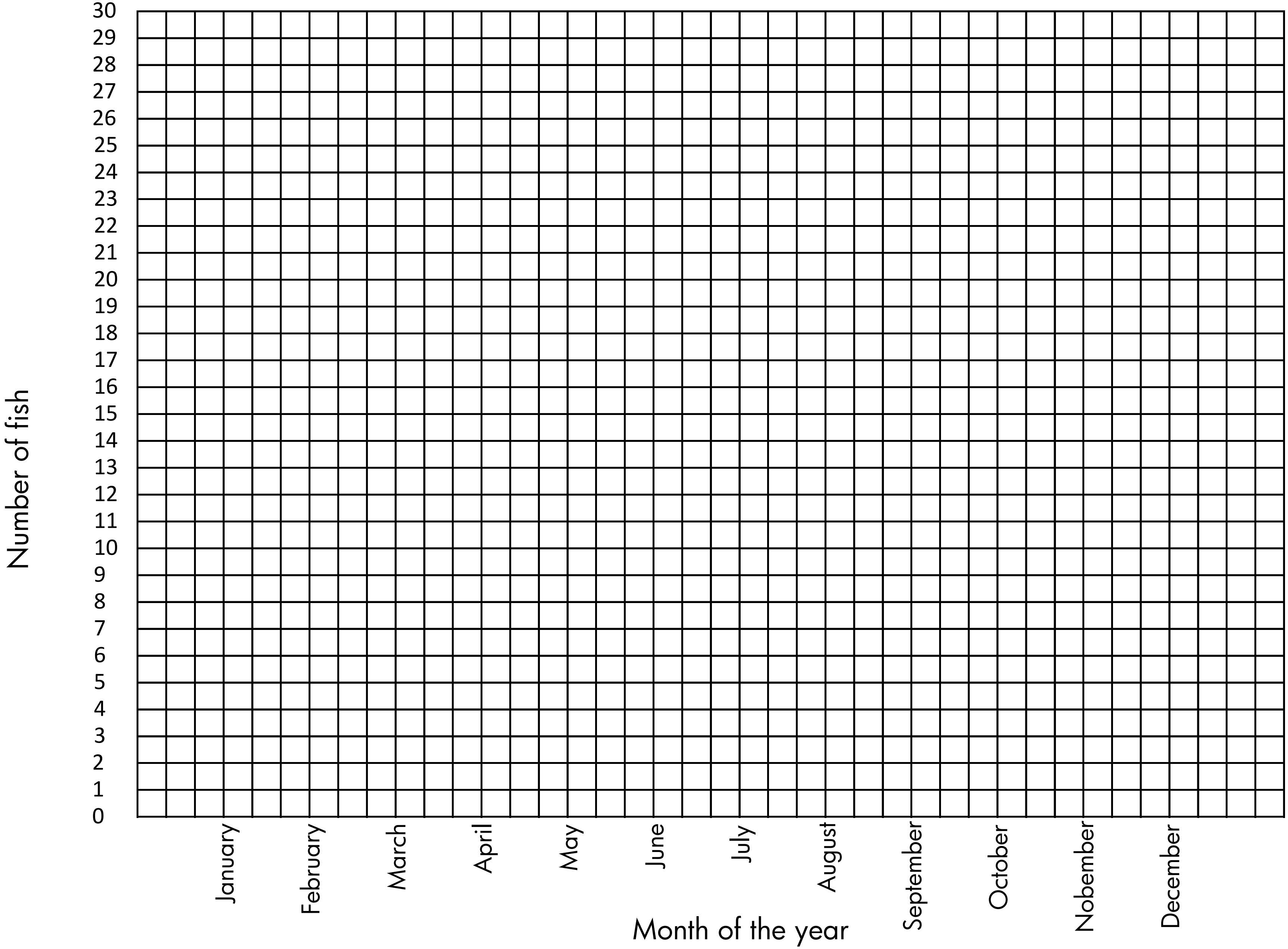
Incoming Stream

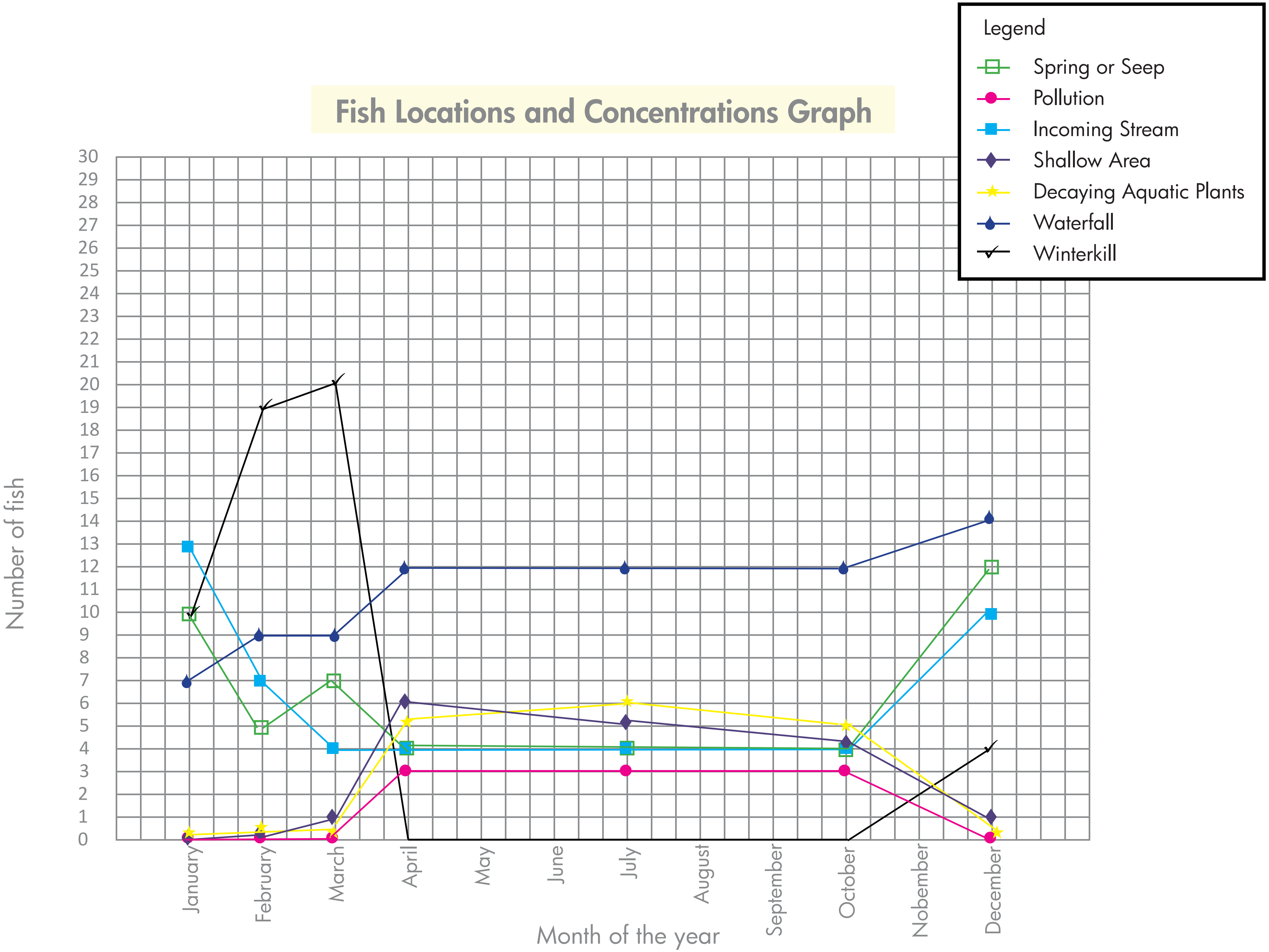
Spring

Playing Area Diagram



Fish Locations and Concentrations Graph




Fish Locations and Concentrations Graph
Legend
Spring or Seep
Pollution
Incoming Stream
Shallow Area
Decaying Aquatic Plants
Waterfall
Winterkill
Number of fish
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
Nobember
December
Month of the year