8 Water quality

"Like swift water, an active mind never stagnates."
— Author unknown

Defining water quality depends on its intended use. A particular body of water might be clean enough for farm irrigation and yet too polluted for drinking water. Water could be clean enough for drinking water, and yet still be too warm for some aquatic organisms to live in it.

Natural conditions sometimes make water unsuitable for use. High levels of some inerals and salts are common in some areas, making water unfit for drinking. In other places the natural quality of the water has been degraded. We call this water polluted. Guidelines from the Environmental Protection Agency (EPA) for surface waters often refer to a goal of being "fishable and swimmable." While this does not provide precise values for various pollutants it does give a general goal. Water must be clean enough to allow aquatic life to live and not be a hazard to public health. Several types of water pollutants are discussed below.

Bacteria

Bacteria can come from improperly or incompletely treated sewage, failing septic systems, and livestock manure. High levels of bacteria indicate the presence of micro-organisms that can cause disease. Tests are often done to determine the concentrations of fecal coliform bacteria. Fecal coliform counts are used as an indicator of water quality.

Sediments

Sediments are small soil particles carried by surface runoff from logging, forestry, construction, mining, or agricultural sites. Sediments can carry nutrients and pesticides that degrade water quality. Sediments may settle to the bottom of streams, smothering aquatic life and fish spawning areas.

Toxics

Toxics can include pesticides, heavy metals, petroleum products from leaking underground storage tanks, solvents, and water runoff from hazardous waste disposal sites and landfills. The greatest sources of toxics are sewage and industrial wastewater. Toxics are also found in runoff from forests, farms and urban areas.

Nutrients

Nutrients, such as nitrogen and phosphorus, increase the growth of aquatic plants. When the plants die and decay they may make the water

Vocabulary

bacteria	toxics
beneficial uses	nutrients
Clean Water Act	dissolved oxygen
coliform	non-point source pollution
eutrophication	point source pollution
groundwater	pollution
surface water	
sediments	

unsuitable for other uses. Excess nutrients may be washed into streams and lakes from sewage and septic systems, livestock and pet wastes, and fertilizers.

Heat

Water temperature is critical to many kinds of aquatic life. Water temperature can be increased when warmer water, from industrial processes or irrigation returns, is added to streams. But the most important factor in raising water temperatures in Oregon streams and rivers is a lack of shade. Without a canopy of vegetation, solar radiation heats water in streams. Shade does not cool water. It helps prevent it from heating.

Dissolved oxygen

It is not dissolved oxygen, but the lack of it that results from pollution. Dissolved oxygen is essential for the survival of fish and aquatic life. The decay process—for organic materials washed into streams or the increased plant growth that goes along with the addition of extra nutrients—uses oxygen, making it unavailable for fish or other aquatic life.

Clean Water Act

The Clean Water Act includes federal water quality standards. The standards vary from stream to stream and are based on research data. These standards are set according to the natural, or background, conditions for each body of water. A stream fed by hot springs is not expected to have the same temperature as one fed solely by melting snow. The standards are also based on the **beneficial uses** for that particular body of water. The list of beneficial uses is defined by law and includes things as drinking water, recreation, preserving healthy conditions for aquatic life, fisheries, aesthetics, and irrigation. When there are competing beneficial uses in a river or stream, the Department of Environmental Quality (DEQ) is required to protect the beneficial uses that are most sensitive.

When a particular body of water is identified as below the water quality standards for its beneficial uses, **point sources of pollution**—those that come from an identifiable source such as a pipe—are controlled first. These sources of pollution are the easiest and generally least expensive to find and control. If controlling point sources is not enough to achieve water quality standards, then **non-point sources of pollution**, those that come from wide areas, such as soil eroded from uplands, are included in efforts to clean up the water. (See Table 2.)

Section 303(d) of the Clean Water Act requires that bodies of water that cannot achieve the standards by controlling point source pollution alone are placed on a special list—the 303(d) list—and additional measures must be taken to help them achieve the standards. Although the Clean Water Act is a federal law, individual states have responsibility for determining which bodies of water should be on the 303(d) list. In Oregon, the Department of Environmental Quality (DEQ) is responsible for this list. It is compiled using the best scientific and technical information available. In the past several years many more lakes and segments of streams and rivers have been added to the list. Recent additions do not mean that water quality in Oregon is getting worse, but instead reflects more information and knowledge about waters in the state. Currently there are 1,067 streams and rivers, 32 lakes and 1,168 stream segments on the list.

Groundwater

When we think of water pollution we most often connect it with rivers, streams, lakes, and other bodies of surface water. Groundwater can also suffer from pollution. Groundwater is a precious resource. Each day in Oregon 700 million gallons of groundwater are used. The drinking water supply for almost 77% of Oregonians comes, at least partially, from groundwater. Groundwater supplies some or all of the drinking water to 3,100 public water systems.

Groundwater is easily contaminated by pollutants. Pollutants dissolved in water can percolate through the soil and become part of groundwater. Groundwater contamination is often caused by leaking landfills, failing septic systems, runoff from animal feed yards, leaking underground storage tanks, and the improper use of fertilizers and pesticides. Nitrates are the most common form of groundwater pollution. Nitrates come from fertilizers and human and animal wastes. Drinking water contaminated with high levels of nitrates can be harmful to humans and livestock. Contaminated groundwater is very difficult, sometimes impossible, to clean up. As of March 1993, DEQ had identified 1,359 groundwater contamination sites in Oregon.

Sources of pollutants

Generally we associate water pollution with pollutants that come from a pipe, such as discharges from factories and sewage treatment plants. Point source pollutants include heavy metals, toxic chemicals, heated water, sewage, radioactive materials and other pollutants from industrial or municipal sources. Often, point source pollutants are the most dangerous. But they are not the only pollutants.

In terms of the volume of pollutants the largest source is non-point source pollution in the form of surface water runoff. Rainwater and melting snow pick up and carry soil, garbage, and various toxics as they wash over streets, roofs, lawns, constructions sites, logging sites, and farm fields. It is estimated that non-point sources are responsible for half or more of all nitrogen, coliform bacteria, iron, phosphorus, oil, zinc, lead, chromium, and copper that enter the surface waters of the United States. Sediments from non-point sources alone are responsible for an estimated $6 billion in damage per year. Even though many non-point source pollutants are less toxic than some industrial wastes, they still damage fish and wildlife and their habitats, degrade drinking water supplies, promote eutrophication, and damage the aesthetics and the recreation potential of Oregon's waters.

Non-point source pollution carried with surface water runoff is hard to detect and control because it does not come from a single source. It is hidden in many everyday activities. Non-point source pollutants come from farm fields, pastures, backyards, parks, streets, roads, mines, and construction sites. Anything on the surface of the land can be carried with surface runoff to gutters, storm drains, or ditches and then on to streams and rivers. Some common sources of non-point source pollutants include:

- household chemicals and soaps from driveways, roofs, and yards;
- fertilizers and pesticides from farm fields, yards, parks, golf courses, and landscaped areas;
- oil, anti-freeze, and other toxic materials from streets and roads;
- eroded soil from farm fields, logging areas, and construction sites;
- failing septic tanks; and
- manure from livestock and pets.

Controlling water pollution

It is easier and cheaper to prevent pollution than it is to clean it up. It is illegal to discharge pollutants into Oregon waters without a permit from DEQ. Some pollution, such as treated effluent from sewage treatment plants, is allowed when a stream is able to process it without degrading its quality. DEQ has responsibility for seeing that pollution problems are addressed. This agency works with other agencies to ensure that the job of controlling pollution, both point and non-point, progresses. Agencies responsible for forestry, urban areas, and agriculture all play a part in controlling pollution. Individual cities are responsible for overseeing their municipal wastes.

The Oregon Department of Forestry is responsible for designing and enforcing measures in the Oregon Forest Practices Act to prevent and control non-point source pollution from forest lands. Responsibility for non-point source pollution from rural and agricultural lands rests with the Oregon Department of Agriculture. Other state agencies involved in various aspects

continued, p. 238

Table 2. Some Non-point Source Pollutants, Their Sources, and Water Quality Impacts

Pollutant	Sources	Water Quality and Related Impacts
Sediment	Agriculture—crops and grazing Forestry Urban runoff Construction Mining	• decreases water clarity and light transmission through water, which: —causes a decrease in aquatic plant production —obscures sources of food, habitats, refuges, and nesting sites of fish —interferes with fish behaviors which rely on sight, such as mating activities • adversely affects respiration of fish by clogging gills • fills gravel spaces in stream bottoms, smothering fish eggs and juveniles • inhibits feeding and respiration of macroinvertebrates, an important component of fish diets • decreases dissolved oxygen concentration • acts as a substrate for organic pollutants, including pesticides • decreases recreational, commercial and aesthetic values of streams • decreases quality of drinking water
Pesticides Herbicides	Agriculture Forestry Urban runoff	• kill aquatic organisms that are not targets • adversely affect reproduction, growth, respiration, and development in aquatic organisms • reduce food supply and destroy habitat of aquatic species • accumulate in tissues of plants, macroinvertebrates and fish • some are carcinogenic (cause cancer), mutagenic (induce changes in genetic material –(DNA), and/or teratogenic (cause birth defects) • create health hazards for humans consuming contaminated fish or drinking water lower organisms' resistance and increase susceptibility to diseases and environmental stress • decreases photosynthesis in aquatic plants • reduces recreational and commercial activities
Polycholorinated biphenyls (PCBs)	Urban runoff Landfills	• accumulate in tissues of plants, macroinvertebrates and fish • toxic to aquatic life • adhere to sediments; persist in environment longer than most chlorinated compounds
Polycyclic aromatic hydrocarbons	Urban runoff	• accumulate in tissues of plants, macroinvertebrates and fish • when digested, create substances which are carcinogenic (cancer-causing) • toxic to aquatic life • toxicity is affected by salinity; estuaries with low salinities may be the most biologically sensitive
(PAHs) Petroleum	Urban runoff	• water soluble components can be toxic to aquatic life • portions may adhere to organic matter and be deposited in sediment • may adversely affect biological functions
hydrocarbons Pathogens and fecal	Agriculture Forestry Urban runoff	• create human health hazard • increase costs of treating drinking water • reduce recreational value

Pollutant	Sources	Water Quality and Related Impacts
bacteria Nutrients (phosphorous,	Agriculture Forestry Urban runoff Construction	• overstimulate growth of algae and aquatic plants, which later, through their decay, cause: —reduced oxygen levels that adversely affects fish and other aquatic organisms —turbid conditions that eliminate habitat and food sources for aquatic organisms —reduced recreational opportunities —reduced water quality and increased costs of treatment —a decline in sensitive fish species and an overabundance of nutrient-tolerant fish species, decreasing overall diversity of the fish community —premature aging of streams, lakes and estuaries • high concentrations of nitrates can cause health problems in infants
nitrogen)	Urban runoff Industrial runoff Mining Automobile use	• adversely affect reproduction rates and life spans of aquatic organisms • adversely disrupt food chain in aquatic environments • accumulate in bottom sediments, posing risks to bottom feeding organisms • accumulate in tissues of plants, macroinvertebrates, and fish • reduce water quality
Metals	Mining Industrial runoff	• lower pH (increase acidity) in streams which stresses aquatic life and leaches toxic metals out of sediment and rocks. • High acidity and concentrations of heavy metals can be fatal to aquatic organisms, may eliminate entire aquatic communities
Sulfates	Mining and ore processing Nuclear power plant fuel and wastes Commercial/industry	• release radioactive substances into streams • some are toxic, carcinogenic (cancer causing) and mutagenic (induce change in genetic material-DNA) • some break down into "daughter" products, such as radium and lead, which are toxic and carcinogenic to aquatic organisms • some persist in the environment for thousands of years and continue to emit radiation • accumulate in tissues, bones and organs where they can continue to emit radiation
Radionuclides Salts	Agriculture Mining Urban runoff	• eliminate salt intolerant species, decreasing diversity • can fluctuate in concentration, adversely affecting both tolerant and intolerant species • impact stream habitats and plants which are food sources for macroinvertebrates • reduce crop yield • decrease quality of drinking water • reduce recreation values through high salinity levels and high evaporation rates

Table provided courtesy of the Adopt-A-Stream Foundation from the *Streamkeeper's Field Guide*, of controlling water pollution in Oregon include the Division of State Lands, the Department of Geology and Mineral Industries, the Department of Transportation, and the Water Resources Department.

State agencies are not the only ones with control over pollutants and water quality. The actions of local governments, businesses, and private individuals all have an effect on water quality in Oregon. An effort to control water pollution through cooperative efforts, called the Healthy Streams Partnership, was instituted by Oregon Governor John Kitzhaber and approved and funded by the Oregon Legislature in 1997. This partnership includes representatives from agriculture, forestry, environmental groups, local governments, state agencies, and the governor's office. Its goal is to restore water quality in Oregon's rivers, streams, lakes, and estuaries so they can support salmon and other beneficial uses.

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Nutrients

8.1

"Slime is the agony of water."
— Jean-Paul Sartre

The uplands, riparian corridors and streams of a watershed are all connected to each other. None is separate or distinct from the others. Each is an integral part of the ecosystems in a watershed. When water passes through the uplands and riparian corridors it picks up and carries materials to the stream. Some may be carried intact, such as small pieces of soil or organic material. But water is also an effective solvent, so some materials are dissolved and carried in solution. Even under the most pristine conditions, water in streams carries a complex mix of chemicals, many of which are nutrients necessary to support aquatic life. In small concentrations many of these nutrients are beneficial. But if concentrations are high, then the stream may be considered polluted.

Two nutrients that often create water quality problems are **nitrogen (N)** and **phosphorus (P)**. Much as a weed is a plant in the wrong place, nitrogen and phosphorus, as pollutants, are nutrients in the wrong place. Both are essential for life and occur naturally in all living cells and in every ecosystem. The problem they pose for water quality is not their presence, but how much is present.

Nitrogen and phosphorus are the two elements most critical to the growth of plants. While increased plant growth might seem desirable, in aquatic environments the effects of that growth can be far from desirable. Slightly increased water fertility can have beneficial effects on fisheries, but most aquatic ecosystems evolved with low nutrient levels. A shift to higher nutrient levels causes aquatic plants, in general, and algae, in particular, to reproduce and grow at high rates. These rapid growth conditions can have widespread effects on aquatic systems. An increase of surface plants reduces light penetration, which in turn reduces or eliminates plant growth at greater depths. This, combined with competition for other essential needs and the relatively short life span of many of the individual plants, produces a large amount of dead organic material. Decaying plants increase the **biochemical oxygen demand (BOD)** in water, reducing the amount of oxygen available for fish and other aquatic life.

This demand for oxygen, along with the rotting vegetation, can create bad tastes in drinking water, even after it passes through water purification systems, and foul smells in water used for recreation or drinking. During periods of high **photosynthesis** the withdrawal of carbon dioxide for plant respiration may cause the water to become more alkaline. The change in **pH** and loss of oxygen from increased BOD can result in the death of other aquatic organisms or a change in the species composition of the aquatic community. This process, known as **eutrophication**, may affect the potential uses of water. Eutrophic waters may be unsuitable for boating, fishing,

Vocabulary

alkaline
biochemical oxygen demand (BOD)
eutrophication
nitrates
nitrogen (N)
pH
phosphorus (P)
photosynthesis

swimming, drinking, irrigation, or other beneficial uses.

Nitrogen

In most undisturbed watersheds, upland areas tend to generate nitrogen, particularly nitrogen compounds called **nitrates**. Nitrogen makes up a large part of our atmosphere, and some bacteria and plants have the ability to fix nitrogen in their tissues. Small amounts of nitrogen may also come from the weathering of rocks. Much nitrogen from the uplands—carried in organic material or dissolved in rainwater—moves through the watershed to **riparian areas**. A riparian area tends to accumulate excess nitrogen in its lush vegetation and rich soils, denitrifies it over time, and releases it back to its gaseous form in the atmosphere.

Human activities in the watershed can affect the amount of nitrogen in the system, sometimes increasing nitrate concentrations to levels higher than the land portion of the ecosystem can effectively process. Septic tanks, livestock wastes, and runoff from intensively fertilized lawns, gardens, and golf courses are all potentially rich sources of nitrogen that can increase nitrate-N concentrations in water. When groundwater used for drinking water becomes enriched with nitrogen it can cause health problems for humans and livestock. In humans, nitrate levels above 10 mg/l can cause methemoglobinemia, or "blue baby syndrome," which robs the blood cells of their ability to carry oxygen. This potentially fatal condition is generally only found in infants under six months of age. However both adult and young cows and sheep, baby pigs, and chickens can also suffer from the same condition.

Human activities in the watershed can also increase nitrate-N concentrations in surface waters, and these high concentrations can stimulate the growth of algae and other aquatic plants. Some fish are also directly affected by nitrate-N concentrations above 4.2 mg/l. But nitrogen in aquatic ecosystems—even in relatively high concentrations—may have relatively little effect on plant growth unless phosphorus is also present. When phosphorus is present, as little as 0.30 mg/l of nitrogen in the form of nitrates may cause algal blooms.

Phosphorus

Unlike nitrogen, phosphorus does not occur as a gas in its biogeochemical cycle. This means that virtually all phosphorus in aquatic environments was carried there by water. Unless it is physically removed, accumulated phosphorus is stored in the system and available for repeated aquatic growth cycles. Phosphorus is the single most limiting factor for aquatic plant growth. Other nutrients may play a role in eutrophication, but phosphorus is the nutrient most easily controlled through management. In general, relatively undisturbed lakes and streams have levels of phosphorus too low (below 0.7 mg/l) for the rapid algal growth characteristic of eutrophication.

Sources of phosphorus in a watershed may include rock, and the soils created by weathering actions on those rocks. Most ecosystems evolved with these relatively low levels of phosphorus. Accumulations above historic background levels are mainly from human activities. Soil, in the form of erosion sediments, can be a rich source of phosphorus for aquatic ecosystems. Even soils with relatively low levels of phosphorus can be rich by aquatic standards. This means any human activity that increases soil erosion has the potential to increase phosphorus concentrations in surface waters. Industrial discharges, fertilizers, phosphorus detergents, organic materials—including animal wastes, sewage, leaves and lawn clippings—are all rich sources of phosphorus.

Soil disturbance and fertilization occurring as part of agricultural and forest practices can influence the amount of phosphorus in surface waters, but urban runoff is also an important source. A study in Seattle, Washington, found phosphorus concentrations in storm-water runoff as high as 200 times the accepted background level for streams. In part, this is because urban and suburban lawns and gardens are often heavily fertilized, and organic materials such as leaves and lawn clippings are often carried to streams with surface runoff that enters storm drains. Most storm drain systems dump directly into streams without passing through a riparian area. A healthy riparian corridor could filter and delay phosphorus-rich materials so they could be used by other terrestrial plants.

Controlling nutrient pollution

The easiest and most effective way to control water pollution from nutrients is to prevent nutrients from entering streams. Nutrients may be carried with soil sediments, organic material, or carried in solution as surface runoff or through the soil to groundwater. To prevent nutrients from reaching surface or ground water:

- keep pet wastes, leaves, lawn clippings, and debris out of street gutters and storm drains;
- apply only as much fertilizer as plants need, and only when they need it;
- control soil erosion in urban areas by planting ground cover and stabilizing erosion-prone areas;
- use proper logging and erosion control practices on forest lands;
- use proper construction, maintenance, and closure of farm and logging roads;
- manage animal waste to minimize contamination of surface water and groundwater;
- reduce soil erosion on farms by using sound conservation; and
- manage grazing on pasture and rangeland to maintain a healthy stand of plants covering the soil.

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Too much of a good thing

Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

The student will (1) observe, (2) record, and (3) analyze the effects of nutrients on aquatic plants.

Method

Students grow aquatic plants in nutrient solutions to observe the effects of nutrients on aquatic plant growth.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.

Materials

- copies of student sheets (pp. 249-252)
- water containers (2-liter used plastic drink bottles)
- ammonium nitrate fertilizer
- TSP (trisodium phosphate)
- aquatic plants such as Elodea
- paper towels
- scale or balance

For each team:

- four 2.0 liter soda bottles
- deionized water (preferred)
- measuring spoons
- aquatic plants
- ammonium nitrate fertilizer
- TSP
- funnel for filling bottles
- scale or balance (may be shared between teams)

Note to the teacher

Deionized water is not only distilled, but demineralized. If it is not readily available, distilled water can be used.

The nutrient content of commercial fertilizer or plant food is generally shown by a series of three numbers, for example 10-10-20. This shows, in order, the relative amounts of nitrogen, phosphorus, and potash. For this experiment you need a fertilizer with only nitrogen, for example 10-0-0.

This lends itself well to an independent study project. Two weeks may not be enough time for changes to occur. Take this into consideration when planning the activity.

Students may need to experiment with the amounts of nitrogen and phosphorous to notice growth changes.

Background

Do you know . . .

Most aquatic life developed in environments with low levels of nutrients. When nutrients are available in amounts greater than this natural background level, plants may grow very rapidly. In lakes and streams, this rapid growth can cause

Vocabulary

alkaline
biochemical oxygen demand (BOD)
eutrophication
nitrates
nitrogen (N)
pH
phosphorus (P)
photosynthesis

serious problems. Plants may grow so fast and in such abundance they shade out the plants below them. Without light the shaded plants die and begin to decay. The decay process requires oxygen, sometimes removing so much from the water that other aquatic organisms cannot live. The decaying plants may also make the water smell and taste bad, making it unsuitable for drinking or swimming.

Nitrogen and phosphorus are vital for the growth of aquatic plants. Much as a weed is a plant in the wrong place, nitrogen and phosphorus as pollutants are nutrients in the wrong place. Both are essential for life and occur naturally in all living cells and in every ecosystem. The problem they pose for water quality is not their presence, but how much is present.

Nitrogen is naturally found in watersheds. Our atmosphere contains more nitrogen gas than any other substance. Large amounts of nitrogen are also tied up in plant and animal tissues. Some bacteria and plants also have the ability to "fix" nitrogen from the air and incorporate it into their tissues. Human activities in the watershed can affect the amount of nitrogen in the system. Septic tanks, livestock wastes, and runoff from heavily fertilized lawns, gardens and golf courses are all potentially rich sources of additional nitrogen.

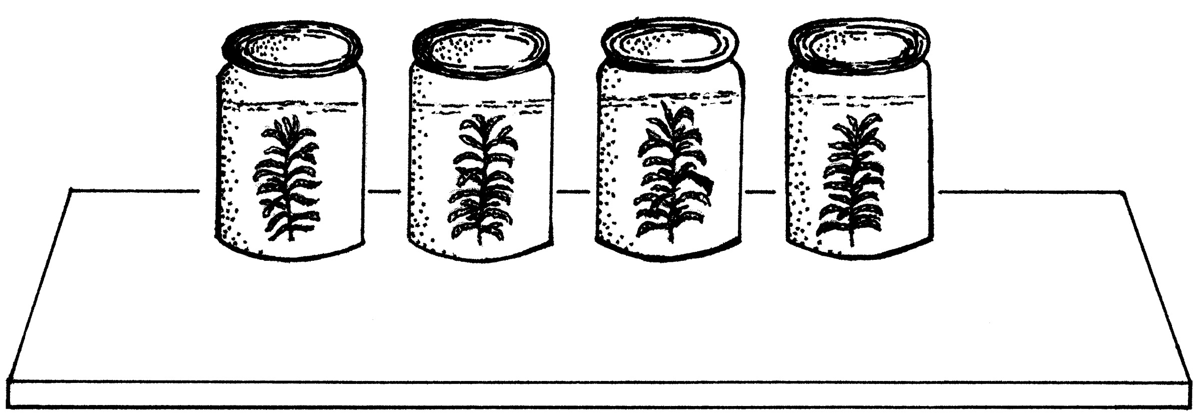
Phosphorus is a normal component of most rocks. As a result, phosphorus is commonly attached to soil particles created from the weathering of those rocks. This means that any human activity that increases soil erosion has the potential to increase phosphorus concentrations in surface water. Industrial discharges, fertilizers, detergents high in phosphates, organic materials—including animal wastes, sewage, leaves, and lawn clippings—are also rich sources of phosphorus.

Procedure

Now it's your turn . . .

How do nitrogen and phosphorus affect plant growth in an aquatic environment? Do they work better together or separately? Set up the following investigation to test your ideas.

1. Label each container with the date, the name of your team, plus:
   a. label the first container "control,"
   b. label the second container "nitrogen,"
   c. label the third container "phosphorus," and
   d. label the fourth container "nitrogen and phosphorus."
2. Add nutrients to the containers as follows:
   a. do not add any nutrients to "control"
   b. add one-quarter teaspoon ammonium nitrate fertilizer to "nitrogen"
   c. add one-eighth teaspoon TSP to "phosphorus"
   d. add one-quarter teaspoon ammonium nitrate fertilizer *and* one-eighth teaspoon TSP to "nitrogen and phosphorus"
3. Add one liter of deionized water to each of the four containers. Screw the caps on and



	Control	Nitrogen	Phosphorus	Nitrogen and Phosphorus
Final weight of plants				
Original weight of plants				
Weight gained (subtract original weight from final weight)				

shake the bottles until the fertilizers dissolve. Then add one more liter of deionized water to each botttle.

4. Take four samples (strands) of *Elodea* and blot gently with paper towels. Remove any snails you find. To add an equal weight of plants to each container, weigh the shortest strand. Carefully snip off pieces of each of the remaining samples until all are as close as possible to the same weight as the first. Record the weight of each sample on the chart and place it in the correct water container.
5. Place all samples where they get plenty of light, but not exposed to direct sunlight. Let the samples grow for two weeks. At the end of two weeks:
   a. Remove the plant from the "control" container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   b. Remove the plant from the "nitrogen" container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   c. Remove the plant from the "phosphorus" container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   d. Remove the plant from the "nitrogen and phosphorus" container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
6. Complete the chart by subtracting the original weight from the final weight to get weight gained.

Questions

1. Which container had the greatest increase in plant growth? Based on your results, was a single nutrient or a combination of nutrients most effective in increasing growth? If a single nutrient, which one?
   Answers will vary, but the expected result would be greatest growth from the combination of nitrogen and phosphorus.
2. Why is it important to remove any snails from the strands of plant material used in your experiment?
   Snails feed on aquatic plants as well as microorganisms living on the plant material. If the snails consumed a significant amount of the plant material, it could affect the results. The weight of the snails, although small, and their waste could also affect the results. It is always better to remove as many variables as possible when conducting an experiment.

3. Besides nutrients, what environmental factors might affect the growth of aquatic plants in your experiment and in nature?

   Factors identified might include light, temperature, other nutrients, the effects of grazing by aquatic herbivores (snails), competition with other plants, and others.

4. How might the rapid growth of aquatic plants affect the rest of the aquatic ecosystem?

   Plants with the most rapid growth rate can more effectively compete for nutrient resources. As a result, other plants may decline or disappear. As plants die, dissolved oxygen is used in the decay processes. Oxygen levels may become so low other aquatic organisms, such as fish, can no longer live.

5. If excess nutrient levels cause aquatic plants to grow unchecked, eventually creating water quality problems, what are some ways to control the amount of nutrients in water? How can we remove nutrients from water?

   Answers will vary. Removing nutrients from water may require water treatment, such as in a sewage treatment plant. Removing plants will also remove the nutrients in their tissues, although as a practical matter this method is expensive and may not remove enough nutrients to be effective. Preventing nutrients from entering water is the most effective and economical means of controlling nutrients.

6. How can we prevent nutrients from entering water?

   Preventing nutrients from entering water is the most effective and economical means of controlling nutrients. Answers should include various methods to control non-point source pollution.

Going further

1. Add a fifth treatment using tap water. How does plant growth in tap water alone compare to deionized water alone? Is it likely your tap water contains nutrients?
2. Use different amounts of nutrients. Is there a threshhold level where accelerated plant growth begins or when growth ceases to occur?
3. Add other combinations of plant nutrients. Which has the greatest effect on aquatic plant growth?
4. Add a similar set of treatments using terrestrial plants, such as beans or tomatoes, grown hydroponically in sand with nutrient solutions. Do terrestrial plants show the same response to nutrients as aquatic plants?
5. To demonstrate eutrophication, let a container with rapid growth continue to grow until the plants begin to die and decay. Measure and discuss the effects this has on water quality.

Name

Too much of a good thing

Do you know . . .

Most aquatic life developed in environments with low levels of nutrients. When nutrients are available in amounts greater than this natural background level, plants may grow very rapidly. In lakes and streams, this rapid growth can cause serious problems. Plants may grow so fast and in such abundance they shade out the plants below them. Without light the shaded plants die and begin to decay. The decay process requires oxygen, sometimes removing so much from the water that other aquatic organisms cannot live. The decaying plants may also make the water smell and taste bad, making it unsuitable for drinking or swimming.

Nitrogen and phosphorus are vital for the growth of aquatic plants. Much as a weed is a plant in the wrong place, nitrogen and phosphorus as pollutants are nutrients in the wrong place. Both are essential for life and occur naturally in all living cells and in every ecosystem. The problem they pose for water quality is not their presence, but how much is present.

Nitrogen is naturally found in watersheds. Our atmosphere contains more nitrogen gas than any other substance. Large amounts of nitrogen are also tied up in plant and animal tissues. Some bacteria and plants also have the ability to "fix" nitrogen from the air and incorporate it into their tissues. Human activities in the watershed can affect the amount of nitrogen in the system. Septic tanks, livestock wastes, and runoff from heavily fertilized lawns, gardens and golf courses are all potentially rich sources of additional nitrogen.

Phosphorus is a normal component of most rocks. As a result, phosphorus is commonly attached to soil particles created from the weathering of those rocks. This means that any human activity that increases soil erosion has the potential to increase phosphorus concentrations in surface water. Industrial discharges, fertilizers, detergents high in phosphates, organic materials—including animal wastes, sewage, leaves, and lawn clippings—are also rich sources of phosphorus.

Now it's your turn . . .

How do nitrogen and phosphorus affect plant growth in an aquatic environment? Do they work better together or separately? Set up the following investigation to test your ideas.

1. Label each container with the date, the name of your team, plus:
   a. label the first container "control,"
   b. label the second container "nitrogen,"
   c. label the third container "phosphorus," and
   d. label the fourth container "nitrogen and phosphorus."
2. Add nutrients to the containers as follows:
   a. do not add any nutrients to "control"
   b. add one-quarter teaspoon ammonium nitrate fertilizer to "nitrogen"
   c. add one-eighth teaspoon TSP to "phosphorus"
   d. add one-quarter teaspoon ammonium nitrate fertilizer *and* one-eighth teaspoon TSP to "nitrogen and phosphorus"
3. Add one liter of deionized water to each of the four containers. Screw the caps on and shake the bottles until the fertilizers dissolve.

Vocabulary

alkaline	nitrogen (N)
biochemical oxygen demand (BOD)	pH
eutrophication	phosphorus (P)
nitrates	photosynthesis

Student sheet

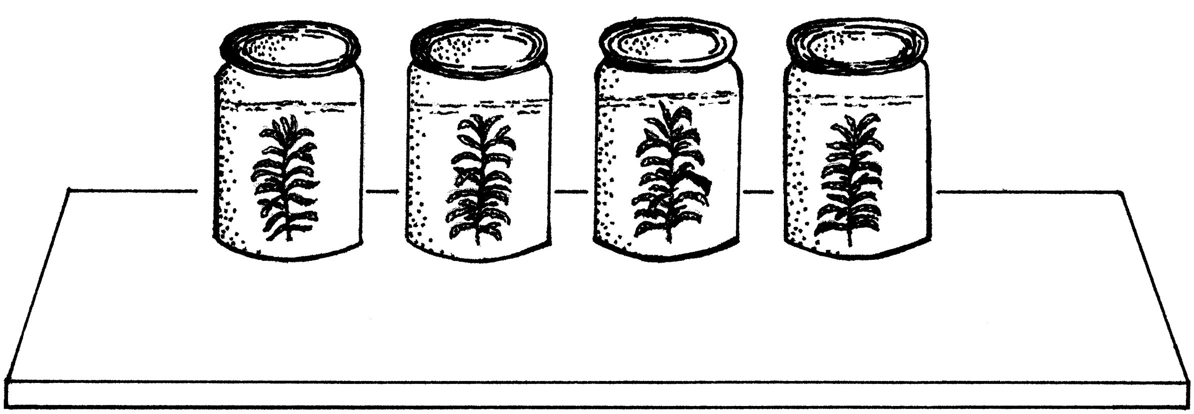
Then add one more liter of deionized water to each botttle.

4. Take four samples (strands) of *Elodea* and blot gently with paper towels. Remove any snails you find. To add an equal weight of plants to each container, weigh the shortest strand. Carefully snip off pieces of each of the remaining samples until all are as close as possible to the same weight as the first. Record the weight of each sample on the chart and place it in the correct water container.

5. Place all samples where they get plenty of light, but not exposed to direct sunlight. Let the samples grow for two weeks. At the end of two weeks:
   a. Remove the plant from the "control" container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   b. Remove the plant from the "nitrogen" container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   c. Remove the plant from the "phosphorus" container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   d. Remove the plant from the "nitrogen and phosphorus" container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.

6. Complete the chart by subtracting the original weight from the final weight to get weight gained.

	Control	**Nitrogen**	**Phosphorus**	**Nitrogen and Phosphorus**
Final weight of plants				
Original weight of plants				
Weight gained (subtract original weight from final weight)				



Student sheet

Questions

1. Which container had the greatest increase in plant growth? Based on your results, was a single nutrient or a combination of nutrients most effective in increasing growth? If a single nutrient, which one?

2. Why is it important to remove any snails from the strands of plant material used in your experiment?

3. Besides nutrients, what environmental factors might affect the growth of aquatic plants in your experiment and in nature?

4. How might the rapid growth of aquatic plants affect the rest of the aquatic ecosystem?

5. If excess nutrient levels cause aquatic plants to grow unchecked, eventually creating water quality problems, what are some ways to control the amount of nutrients in water? How can we remove nutrients from water?

6. How can we prevent nutrients from entering water?

Water temperature

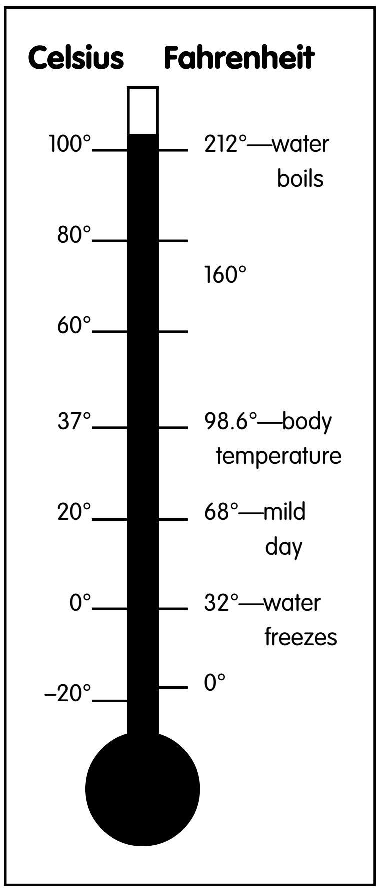
8.2

"Worsewick Hot Springs was nothing fancy . . . . There were dozens of dead fish floating in our bath."
— Richard Brautigan

Water temperature is one of the most important factors for survival of aquatic life. Most aquatic organisms become the temperature of the water that surrounds them. Their **metabolic rates** are controlled by water temperature. This metabolic activity is most efficient within a limited range of temperatures. If temperatures are too high or too low, productivity can decrease or metabolic function cease. The organism can die. These extremes, or lethal limits, vary for different species.

Lethal limits

Within the lethal limits there is an ideal range of temperatures. In this range, an organism is more efficient, and the species has a greater chance of success. Various species of fish have adjusted to upper and lower levels of an optimum temperature range. Spawning, hatching and rearing temperature ranges vary from species to species.



Vocabulary

metabolic rates
riparian
streamflow

In this way, temperature determines the character and composition of a stream community.

In the Pacific Northwest, most streams have had populations of salmon and trout, which prefer temperatures between 40.5°F and 65.5°F. In the summer, when temperatures are highest and water flows lowest, juvenile fish live in the pools of smaller streams. Pools offer deeper, cooler, oxygen-rich water and increased protection from predators. Because of low water flows, fish can be confined to a limited area. A temperature rise in a rearing pool can kill fish by exceeding their lethal temperature limits.

Plant cover's role

With the exceptions of hot springs and thermal pollution, solar radiation is the cause of increased water temperatures. Shade from **riparian** vegetation plays a major role in keeping streams cool. During midsummer, adequate shade will keep a stream 7.5°F to 12.5°F cooler than one exposed to direct sunlight.

One example of the effects of vegetation in keeping water cool is what happened on Cedar Creek, a tributary of Steamboat Creek in Oregon's Umpqua Basin. The site was clearcut in 1969. A 25-year temperature study followed the clearcut. Immediately after the clearcut the 14 warmest daily temperature measurements averaged 78°F. By 1995, after trees had more than 20 years to regrow, the temperature on the warmest 14 days was between 64°F and 65°F.

Water temperature is one of the most important factors for suvival of aquatic life.

Even the shade from floating debris in water will help keep temperatures low. If there is enough debris, temperatures can be 3°F to 8°F cooler than if there was no shade. Once water has warmed, it does not cool rapidly, even if it flows into a shady stretch.

It is important to recognize that water temperatures change from day to night and that cool-water areas exist in a stream.

Warmer temperatures encourage the growth of life forms that adversely affect fish and human health. Pathogens such as bacteria, as well as several parasitic organisms, thrive in warmer waters.

Air temperature, surface area

As water in a stream mixes with air through exposure and turbulence at the surface, water is influenced by the air temperature. This mixing action can also increase the evaporation rate.

The greater the surface area of a body of water, the greater its exposure to both solar radiation and air. Because of its increased surface area a wide, shallow stream will heat more rapidly than a deep, narrow stream.

Streambed, streamflow, orientation and sediments

Color and composition of a streambed also affect how rapidly stream temperature rises. A dark bedrock channel will gain and pass to the stream more solar radiation than a lighter-colored channel. Similarly, solid rock absorbs more heat than gravel.

The streamflow, or volume of water in a stream, influences temperature. The larger a body of water, the slower it will heat. Rivers and large streams have more constant temperatures than smaller streams.

The direction a stream flows also affects how much solar radiation it will collect. Because of the angle of the sun's rays, southerly flowing streams receive more direct sunlight than streams flowing north. Eastward or westward flowing streams receive shading from adjacent ridges, trees and riparian vegetation.

Sediments suspended in water can absorb, block or reflect some of the sun's energy depending on their color and position in the water. Particles on or near the surface can have a beneficial influence through reflection, but those with a dark color increase the total energy absorbed from the sun.

Table 3. Temperature Ranges (approx.) Preferred by Certain Organisms

Temperature (Fahrenheit)	Examples of life
Greater than 68° (warm)	Redside shiner, crappie, bluegill, carp, catfish, caddisfly, dragon fly, and much plant life
Middle range (55°-68°)	Brown trout, rainbow trout, stonefly, mayfly, caddisfly, water beetles, sculpins, and some plant life
Low range (cold, less than 55°)	Brook trout, sculpins, caddisfly, stonefly, mayfly, and some plant life

Adapted from Claire Dyckman and Stan Garrod, eds., *Small Streams and Salmonids,* p. 73.

Effects of thermal pollution

Thermal pollution occurs when heated water is discharged into cooler streams or rivers. This heated water generally has been used to cool power plants or industrial processes and can be as much as 20ºF warmer than the water into which it is discharged. This increase in temperature can have drastic effects on downstream aquatic ecosystems.

Extensions

1. "Water Canaries," *Aquatic Project WILD*, pp. 24. Grades 4-12.
2. "What's in the Water," *Aquatic Project WILD*, pp.140. Grades 3-12.

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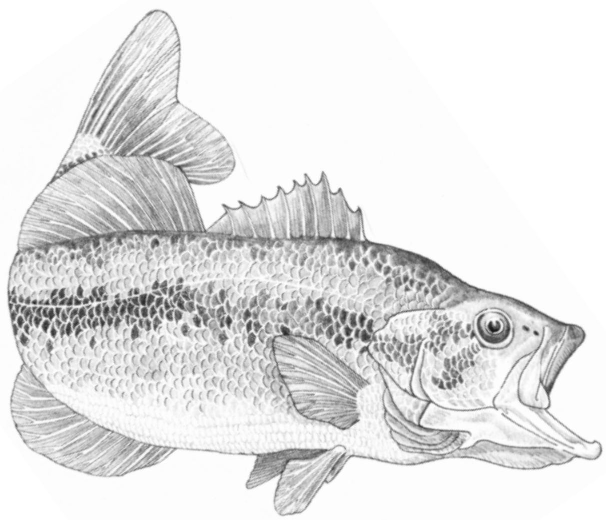
When it's hot . . .

Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

The student will (1) analyze temperature tolerance data of various fish species, (2) graph and compare temperature tolerance information for several fish species, and (3) respond to questions analyzing information presented on the graph.



Method

The student will graph, compare, and analyze the temperature tolerance data presented in the table.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Use as a demonstration activity, rephrase some questions or answer questions as part of a group discussion.

Acitivity adapted from: Daniel Stoker, et al., *A Guide to the Study of Freshwater Ecology,* 1972, p. 159.

Materials

- copies of student sheets (pp. 261-264).

Background

Do you know . . .

Some fish can live in warm water while other fish require colder water. By experimenting with different kinds of fish, and raising the water temperature of the water a little bit at a time, biologists have learned a lot about how fish respond to changes in temperature in their environment.

One way to measure temperatures a fish can tolerate or live through is called the 24-hour tolerance limit median (24-hour TLm). Why do biologists need to know this? What does it mean? Let's look at an example.

A biologist collects several largemouth bass, all about the same size. They are put into a tank and held for 24 hours. The temperature of the water in the tank is slowly raised. At a certain point the water will become so warm that one-half (or 50%) of the fish will not be able to tolerate the temperature and will die. If that temperature was 84°F, we can say the 24-hour TLm is 84°F.

If the temperature continued to rise, a point would be reached where half the fish would die in only 12 hours. This temperature is called the 12-hour TLm.

The table on the next page lists some of the fish species found in streams and rivers. Because their TLm values are close to the same, we can assume these different kinds of fish could, but may not, live together in one body of water.

Procedure

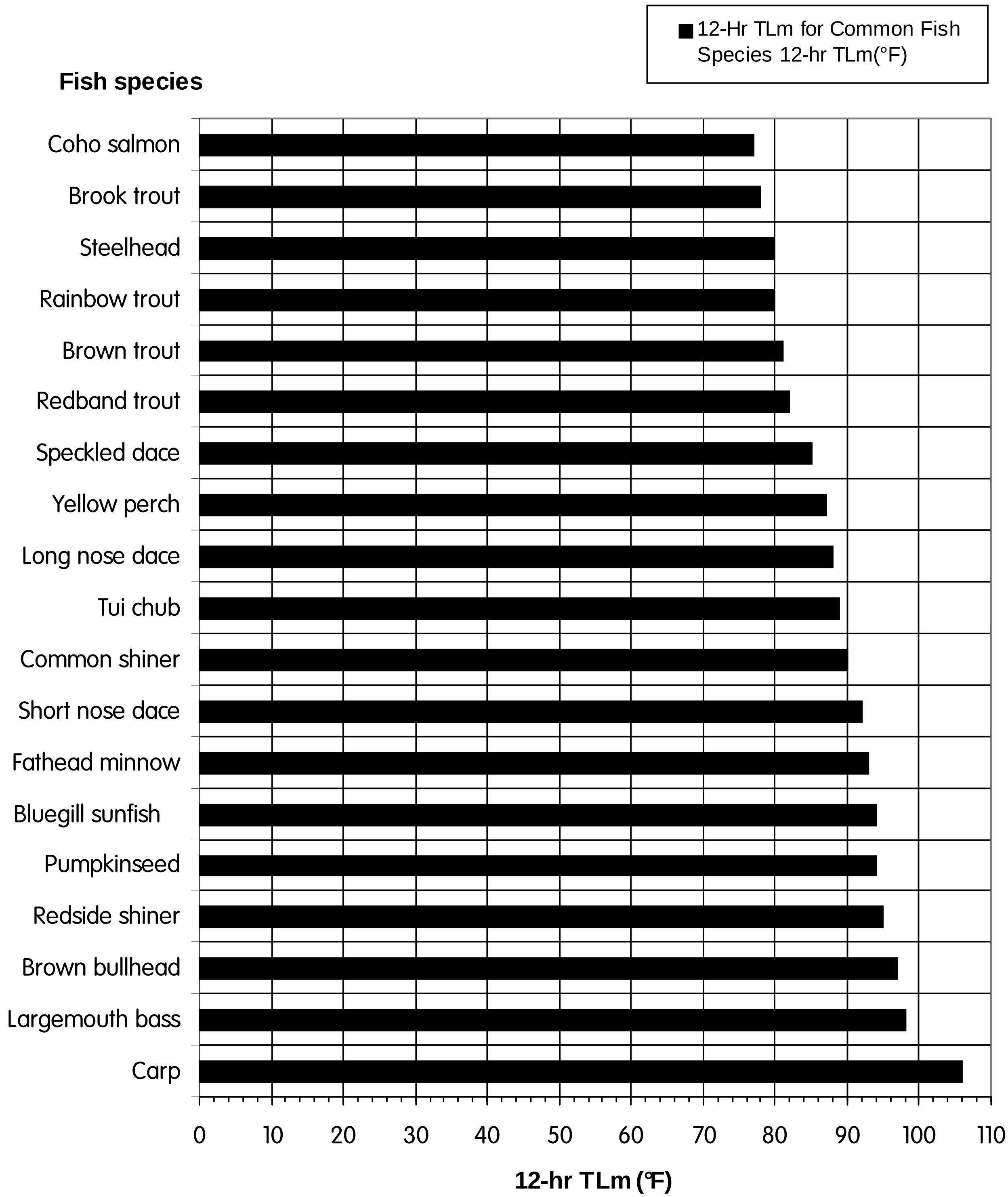
Now it's your turn . . .

Look at the data in the table below. It is sometimes easier to compare this kind of information when seen in a different form. Using the one provided, create a bar graph showing the 12-hour TLm for each species on the table. Working from **top to bottom** on the vertical axis, start with the lowest temperature (77°F for cutthroat and coho salmon) and plot the values in order from **lowest to highest temperature**. Carp (106°F) should be the last fish listed at the bottom of the vertical axis.

Answer the questions that follow.

Common name	12-hr. TLm (°f)	Common name	12-hr. TLm (°f)	Common name	12-hr. TLm (°f)
Common shiner	90	Brook trout	78	Pumpkinseed	94
Long nose dace	88	Carp	106	Redband trout	82
Steelhead	80	Rainbow trout	80	Largemouth bass	98
Bluegill sunfish	94	Speckled dace	85	Coho salmon	77
Brown bullhead	97	Brown trout	81	Yellow perch	87
Redside shiner	95	Cutthroat trout	77	Fathead minnow	93
Tui chub	89	Short nose dace	92		

12-Hr TLm for Common Fish Species 12-hr TLm (°F)



Questions

Suppose an industry pumped very hot waste water into a river, raising the water temperature by many degrees.

1. Which would be the first five fish species to die from the increased water temperatures (thermal pollution)?
   Cutthroat trout, coho salmon, brook trout, steelhead, rainbow trout, and brown trout.
2. Which five species would be most tolerant or able to survive the higher temperatures?
   Largemouth bass, carp, brown bullhead, redside shiner, pumpkinseed, and bluegill sunfish.
3. Looking at the graph, how would you classify these fish species according to their ability to tolerate temperature changes? Explain.
   Fish can be classified as warm water fish and cool water fish. Those with a shorter bar are less tolerant of warm water, and those with longer bars are more tolerant.
4. Compare the salmon and trout with the other species listed. Based on what is shown on the graph, what specific habitat requirements could be indicated for salmon and trout by the information portrayed?
   Answers will vary, but they should include information about cooler and deeper water, shaded streams, and cover.
5. Compare the salmon and trout with each other. Which species would be most tolerant of warmer waters? Which would be least tolerant?
   Redband trout are most tolerant of warmer water. Cutthroat and brook trout are least tolerant.
6. Which of the other species is most tolerant of warmer waters? What would this tell you about their habitat needs?
   Carp are most tolerant and would survive in a wider range of conditions.

Going further

1. Design an experiment to test which factors most affect water temperature (soil temperature, air temperature, shading, substrate types, or others) at a specific site in your watershed. Can this information be applied to other watersheds or even other areas within your own watershed? Why or why not? Prepare a report summarizing your findings and share with the class.
2. Contact your local department of fish and wildlife, watershed council, or department of environmental quality office. Volunteer to assist with temperature monitoring on streams in your area. Ask local experts to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

Name

When it's hot . . .

Do you know . . .

Some fish can live in warm water while other fish require colder water. By experimenting with different kinds of fish, and raising the water temperature of the water a little bit at a time, biologists have learned a lot about how fish respond to changes in temperature in their environment.

One way to measure temperatures a fish can tolerate or live through is called the 24-hour tolerance limit median (24-hour TLm). Why do biologists need to know this? What does it mean? Let's look at an example.

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If the temperature continued to rise, a point would be reached where half the fish would die in only 12 hours. This temperature is called the 12-hour TLm.

The table below lists some of the fish species found in streams and rivers. Because their TLm values are close to the same, we can assume these different kinds of fish could, but may not, live together in one body of water.

Now it's your turn . . .

Look at the data in the table below. It is sometimes easier to compare this kind of information when seen in a different form. Using the one provided, create a bar graph showing the 12-hour TLm for each species on the table. Working from **top to bottom** on the vertical axis, start with the lowest temperature (77°F for cutthroat and coho salmon) and plot the values in order from **lowest to highest temperature**. Carp (106°F) should be the last fish listed at the bottom of the vertical axis.

Answer the questions that follow.

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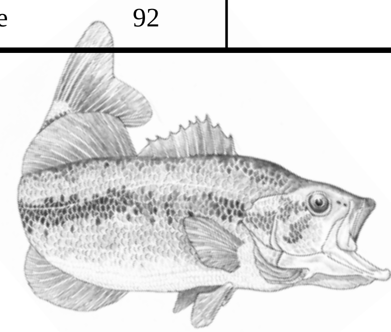
Acitivity adapted from: Daniel Stoker, et al., *A Guide to the Study of Freshwater Ecology*, 1972, p. 159.



Student sheet

12-Hr TLm for Common Fish Species 12-hr TLm (°F)

Student sheet

Questions

Suppose an industry pumped very hot waste water into a river, raising the water temperature by many degrees.

1. Which would be the first five fish species to die from the increased water temperatures (thermal pollution)?

2. Which five species would be most tolerant or able to survive the higher temperatures?

3. Looking at the graph, how would you classify these fish species according to their ability to tolerate temperature changes? Explain.

4. Compare the salmon and trout with the other species listed. Based on what is shown on the graph, what specific habitat requirements could be indicated for salmon and trout by the information portrayed?

5. Compare the salmon and trout with each other. Which species would be most tolerant of warmer waters? Which would be least tolerant?

6. Which of the other species is most tolerant of warmer waters? What would this tell you about their habitat needs?

Temperature and respiration rate

Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

The student will demonstrate (1) the inverse relationship between water temperature and dissolved oxygen levels, and (2) its effect on the respiration rates of fish.

Method

Fish respiration rates can be estimated by counting the number of gill plate (opercula) beats per minute at different water temperatures.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. It is necessary for you to gather supplies and closely monitor student work with this activity. Simply questions. Students must know how to read a thermometer.

Materials

- copies of student sheets (pp. 269-272)
- fahrenheit/celsius conversion formulas (Chapter 14.2)
- an aerated aquarium at room temperature with enough fish to supply all teams; all fish should be of similar size; goldfish are hardy and inexpensive

For each team

- fish
- dip net
- thermometer
- ice
- warm water (without chlorine)
- watch or clock with second hand
- small container (less than one-half full of water)
- large container (at least 2" in diameter larger than the small container)

Background

Do you know . . .

Aquatic life must deal with a very different set of environmental conditions than terrestrial (land) life. For example, temperatures on land can move quickly from hot to very cold while water temperatures usually are slow to change. Water has the ability to absorb weather extremes and other environmental factors, so water temperature remains within a narrow range.

Water temperatures have an effect on the amount of dissolved oxygen (DO) available to fish. As water warms, it cannot hold as much DO. In contrast, air temperature has little effect on the amount of oxygen in the air we breathe.

A fish must pump water across its gills to meet its oxygen needs. If DO in the water is low, the gills must move faster to get enough oxygen for the fish to survive. We can count these gill movements to estimate the DO requirements of fish.

Note to teacher

Refer to the dissolved oxygen saturation charts in the next chapter to encourage students to make the connection between water temperature and the dissolved oxygen content of the water.

Procedure

Now it's your turn . . .

Divide into teams of three students each. Each team member will have a specific job as outlined below.

1. **Gill beat counter**
   Count and record the number of gill beats/ minute every time the water changes by 5°F.
2. **Time counter**
   Tell the gill plate counter when to start and end (one-minute counting intervals).
3. **Temperature guardian**
   Announce the temperature changes by approximately 5°F intervals (but no more than 10°F intervals). It is not essential to be exact. Make sure the water changes happen slowly to avoid harming the fish.

Place the fish in a small container with water as close to the aquarium's temperature as possible. Water in the small container must be either spring water or treated to remove the chlorine. ***These two steps are very important to avoid shocking or killing the fish.*** Each team's container should have the same amount of water to control the variables and increase accuracy in later comparisons of results.

Now you are ready to begin changing the water temperature. As the temperature changes, make a total of six observations, recording the results in the chart at right.

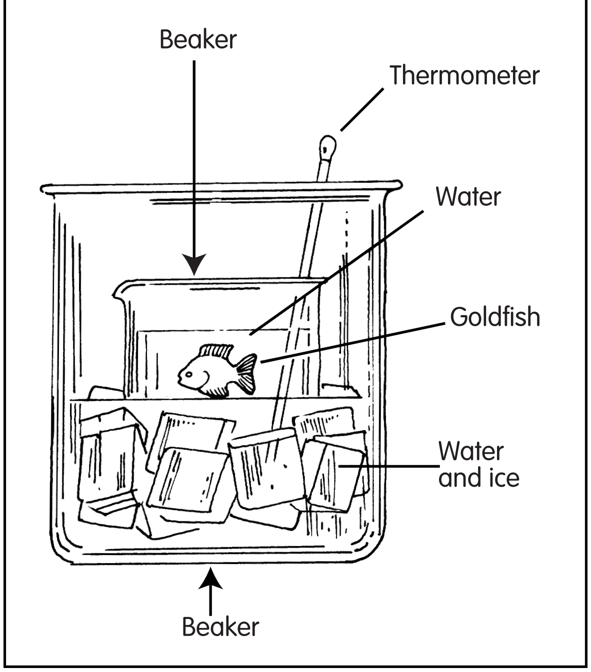
Temperature guardian

Add ice or cold water to the large container. When the water temperature of the large container is well below room temperature (**but no lower than 55°F**), place the small container with the fish into the larger one (see drawing). Once the fish has calmed down, measure the water temperature in the small container. All other water temperature measurements should be taken from the small container. **Do not allow the temperature of the small container to drop below 55°F.**

After the count has been completed at the 55°F reading, change the water temperature (**slowly, remember!**) by adding warm water near the outside of the outer container. **Do not add ice or warm water to the smaller container with the fish.** At each 5°F interval, signal the time and gill beat counters to do their counts.

Do not allow the temperature of the smaller container to exceed 80°F.

Observation No.	Temperature	Gill beats/minute
1		
2		
3		
4		
5		
6		



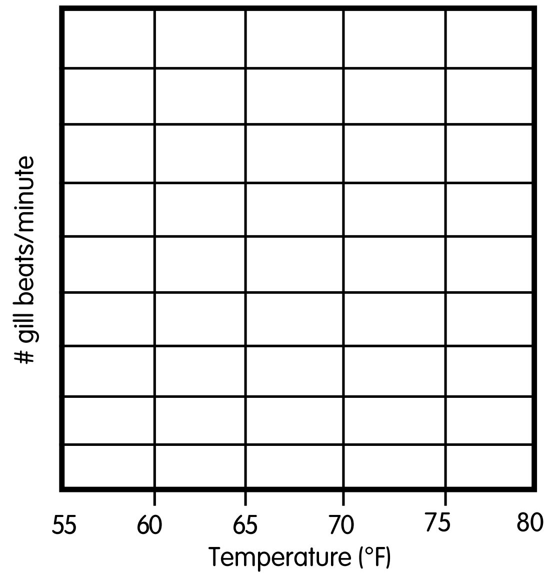
Gill beat and time counters

Once the Temperature Guardian has indicated the starting temperature, begin your counts. Count for one minute and record the results.

Make your counts at 5°F intervals.

If the fish is to be returned to the aquarium, the temperature of the water in the fish's container and the aquarium should be within 5°F of each other. Remove the fish from the jar with a dip net. Do not dump water from the beaker into the aquarium.

Transfer your results to the graph at right. Compare your results with those of another team by recording their measurements on your graph in another color.



Questions

1. The amount of oxygen water can hold is directly related to the temperature of the water (the higher the temperature, the less oxygen it can hold). The amount of oxygen water can hold is also related to the pressure (the higher the pressure, the more oxygen the water can hold). How might the combined effects of temperature and pressure affect the number of gill beats?

   If the temperature of the water is cool and the pressure is high, water has the greatest potential to hold oxygen. If the temperature is cooler, but the pressure is low, the water could not hold as much oxygen as would be expected. The amount of oxygen available in the water would affect the number of times the gills would have to open and close to meet the oxygen needs of the fish.

2. What could account for unexpected results in the data? For example, why would the number of gill cover beats be lower than expected at a certain temperature when the trend appeared to show a larger number of beats as the temperature increased?

   Person doing the counts may have counted incorrectly, or other variables such as pressure or fish using up available oxygen may be influencing the results.

3. List several factors that would affect the amount of sunlight reaching a stream and the effect each factor would have on the temperature of the stream, thus affecting its aquatic life.

   Many answers are possible. Acceptable answers might refer to the amount of shading from the riparian area; instream structure or debris; the amount of surface area of the stream; the color and composition of the streambed; the volume of water in a stream; the direction the stream is flowing; the amount and kind of sediments suspended in the water; or the human activities occurring in the riparian area that might be affecting any of the above. A correct answer should refer to how the above factors would affect the water's temperature and subsequently the fish and other aquatic life present in the stream.

4. How might seasonal temperature changes affect fish?
   Warmer air temperatures during the summer would generally create warmer water conditions with lower oxygen levels. Those fish with high oxygen needs would have more difficulty obtaining the necessary oxygen from the water. These fish would possibly move to cooler water areas. During cold weather, the formation of ice in some streams would require movement of fish to open water areas.

5. How could the presence of fish affect the amount of oxygen in the water?
   Fish are depleting the available oxygen in the water through the respiration process. This introduces another variable to be considered in the experiment. The usage of oxygen by the fish and the amount of oxygen available in the water as a function of the temperature and pressure could both be influencing the number of gill beats.

Going further

1. Following the end of the experiment, place food coloring near the mouth of the fish with a dropping pipette. Observe the flow of water as shown by the dye. Describe what you see. Discuss the implications of this discovery if the water in which the fish lives is polluted or full of sediment.

2. Repeat the experiment using other species of fish (some warm water species and some cold water species). Compare the results. Based on your results, discuss why different species are found in completely different environments or different parts of the same stream.

3. Design an experiment to test factors other than temperature which may affect the dissolved oxygen content of water.

4. Contact your local department of fish and wildlife, watershed council, or department of environmental quality office. Volunteer to assist with temperature monitoring on streams in your area. Ask local experts to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

Name

Temperature and respiration rate

Do you know . . .

Aquatic life must deal with a very different set of environmental conditions than terrestrial (land) life. For example, temperatures on land can move quickly from hot to very cold while water temperatures usually are slow to change. Water has the ability to absorb weather extremes and other environmental factors, so water temperature remains within a narrow range.

Water temperatures have an effect on the amount of dissolved oxygen (DO) available to fish. As water warms, it cannot hold as much DO. In contrast, air temperature has little effect on the amount of oxygen in the air we breathe.

A fish must pump water across its gills to meet its oxygen needs. If DO in the water is low, the gills must move faster to get enough oxygen for the fish to survive. We can count these gill movements to estimate the DO requirements of fish.

Now it's your turn . . .

Divide into teams of three students each. Each team member will have a specific job as outlined below.

1. **Gill beat counter**
   Count and record the number of gill beats/minute every time the water changes by 5°F.
2. **Time counter**
   Tell the gill plate counter when to start and end (one-minute counting intervals).
3. **Temperature guardian**
   Announce the temperature changes by approximately 5°F intervals (but no more than 10°F intervals). It is not essential to be exact. Make sure the water changes happen slowly to avoid harming the fish.

Place the fish in a small container with water as close to the aquarium's temperature as possible. Water in the small container must be either spring water or treated to remove the chlorine. ***These two steps are very important to avoid shocking or killing the fish.*** Each team's container should have the same amount of water to control the variables and increase accuracy in later comparisons of results.

Now you are ready to begin changing the water temperature. As the temperature changes, make a total of six observations, recording the results in the chart at right.

Observation No.	Temperature	Gill beats/minute
1		
2		
3		
4		
5		
6		

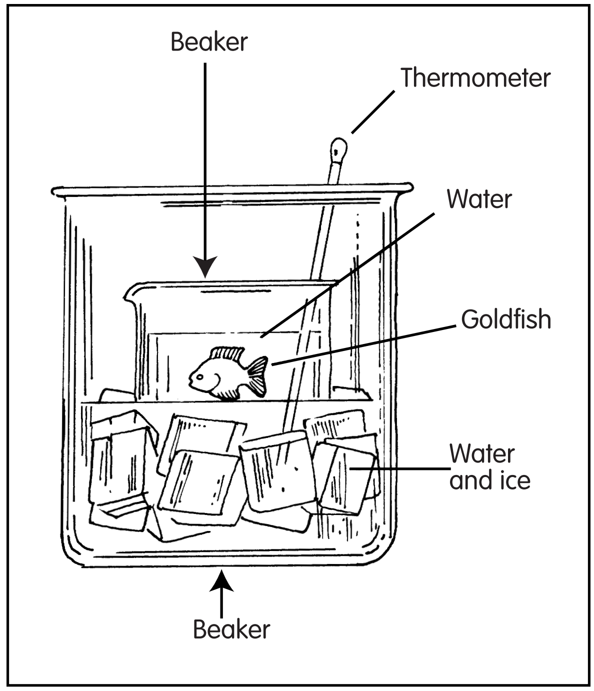
Student sheet

Temperature guardian

Add ice or cold water to the large container. When the water temperature of the large container is well below room temperature (**but no lower than 55°F**), place the small container with the fish into the larger one (see drawing). Once the fish has calmed down, measure the water temperature in the small container. All other water temperature measurements should be taken from the small container. **Do not allow the temperature of the small container to drop below 55°F.**

After the count has been completed at the 55°F reading, change the water temperature (**slowly, remember!**) by adding warm water near the outside of the outer container. **Do not add ice or warm water to the smaller container with the fish.** At each 5°F interval, signal the time and gill beat counters to do their counts.

Do not allow the temperature of the smaller container to exceed 80°F.



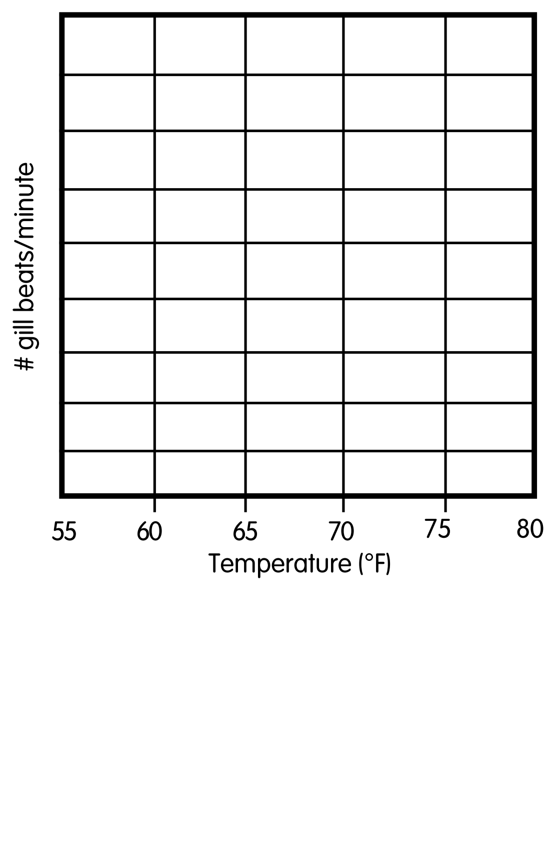
Gill beat and time counters

Once the Temperature Guardian has indicated the starting temperature, begin your counts. Count for one minute and record the results.

Make your counts at 5°F intervals.

If the fish is to be returned to the aquarium, the temperature of the water in the fish's container and the aquarium should be within 5°F of each other. Remove the fish from the jar with a dip net. Do not dump water from the beaker into the aquarium.

Transfer your results to the graph provided. Compare your results with those of another team by recording their measurements on your graph in another color.



Student sheet

Questions

1. The amount of oxygen water can hold is directly related to the temperature of the water (the higher the temperature, the less oxygen it can hold). The amount of oxygen water can hold is also related to the pressure (the higher the pressure, the more oxygen the water can hold). How might the combined effects of temperature and pressure affect the number of gill beats?

2. What could account for unexpected results in the data? For example, why would the number of gill cover beats be lower than expected at a certain temperature when the trend appeared to show a larger number of beats as the temperature increased?

3. List several factors that would affect the amount of sunlight reaching a stream and the effect each factor would have on the temperature of the stream, thus affecting its aquatic life.

4. How might seasonal temperature changes affect fish?

5. How could the presence of fish affect the amount of oxygen in the water?

Dissolved oxygen

8.3

"And the boiling voice of the waters…"
— Thomas Hardy

Oxygen is as essential to life in water as it is to life on land. Oxygen availability determines whether an aquatic organism will survive and affects its growth and development. The amount of oxygen found in water is called the **dissolved oxygen concentration (DO)** and is measured in milligrams per liter of water (mg/l) or an equivalent unit, parts per million of oxygen to water (ppm).

DO levels are affected by:

- altitude,
- water agitation,
- water temperature,
- types and numbers of plants,
- light penetration, and
- amounts of dissolved or suspended solids.

As water low in oxygen comes into contact with air, it absorbs oxygen from the atmosphere. The turbulence of running water and the mixing of air and water in waterfalls and rapids add significant amounts of oxygen to water.

Effects of temperature on DO

Temperature directly affects the amount of oxygen in water—the colder the water, the more oxygen it can hold. Bodies of water with little shading can experience a drop in DO during periods of warm weather.

Thermal pollution, the discharge of warm water used to cool power plants or industrial processes, can reduce DO levels. The area immediately downstream from the entry of warm water can be altered drastically. Thermal pollution generally occurs in larger streams. However, dilution will temper these effects as warm water mixes with colder water downstream.

Temperature alterations are occasionally used to increase fish productivity, such as at a hatchery.

Temperature directly affects the amount of oxygen in water.

At higher altitude (elevation), the dissolved oxygen saturation point is lower than under the same conditions at lower altitude. Shown below are maximum amounts, or saturation levels, of dissolved oxygen (in ppm) in fresh water at sea level for different temperatures:

DO ppm	5	6	7	8	9	10	11	12	13	14	15
Temp°F	117	92	90	77	68	59	50	45	39	36	32

When aeration is high, DO levels can temporarily be higher than the saturation level. This extra oxygen is not stored in the water.

Vocabulary

biochemical oxygen demand (BOD)
dissolved oxygen concentration (D)
salmonid

Photosynthesis, oxidation and decomposition

Oxygen can also be added to water as a result of plant photosynthesis. During the day, plants can produce oxygen faster than it can be used by aquatic animals. This surplus is temporarily available throughout the night for plant and animal respiration. Depending on individual stream conditions, high daytime DO levels and low nighttime DO levels can occur.

Photosynthesis can be inhibited by sediments. Suspended sediments make water look murky or cloudy and block or reflect much of the sunlight that would otherwise be available for photosynthesis. Sediments can also settle onto the leaves of plants, further blocking their efficiency as oxygen producers.

Most DO problems occur when temperatures are at their highest and streamflows at their lowest.

The chemical oxidation and decomposition of dissolved, suspended and deposited sediments remove oxygen from the water. The amount of oxygen needed for these processes is called **biochemical oxygen demand (BOD)** and is oxygen that is unavailable for aquatic life. If the quantity of these sediments is large, remaining oxygen can be insufficient to support many forms of aquatic life.

Most DO problems in Oregon streams occur when temperatures are at their highest and streamflows at their lowest. Salmon and trout are especially at risk during this time. Fry are often limited to small spawning streams during these "pinch periods" and DO is critical to their development. While a juvenile **salmonid** can withstand 1-2 ppm of DO for short periods, its growth rate drops sharply below 5 ppm, especially if the temperature is high.

Fish die-offs in shallow, warm ponds are a fairly common occurrence during the summer. During a long period of warm sunshine, algae grow profusely. A summer storm can result in several days of cloudy weather. The reduced sunlight can cause a massive die-off of the algal bloom. As dead algae decompose, available oxygen is depleted. The amount of DO drops to lethal levels, causing a subsequent die-off of fish and other aquatic organisms.

Maintaining productive DO levels

To maintain productive DO levels in a stream, shade should be provided to keep water temperatures cool. The presence of instream structures ensures mixing of water and air. Materials that can increase BOD, such as manure from feedlots or untreated municipal waste, should not be introduced.

Extensions

1. "Water Canaries," *Aquatic Project WILD*, pp. 24. Grades 4-12.
2. "The Glass Menagerie," *Aquatic Project WILD*, pp. 155. Grades 7-12.
3. "What's in the Water," *Aquatic Project WILD*, pp.140. Grades 3-12.

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A South Twin story

Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

The student will (1) graph DO and temperature changes for various depths of South Twin Lake, and (2) describe the relationship between temperature and dissolved oxygen in water.

Method

The student will graph and analyze the relationship between temperature and DO information and how it relates to aquatic life.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Students need the experience with the activity "Temperature and Respiration Rate" (pp. 265-268) before proceeding with this activity. Students must know how to read a thermometer. Prior graphic experience is helpful. Simply questions.

Materials

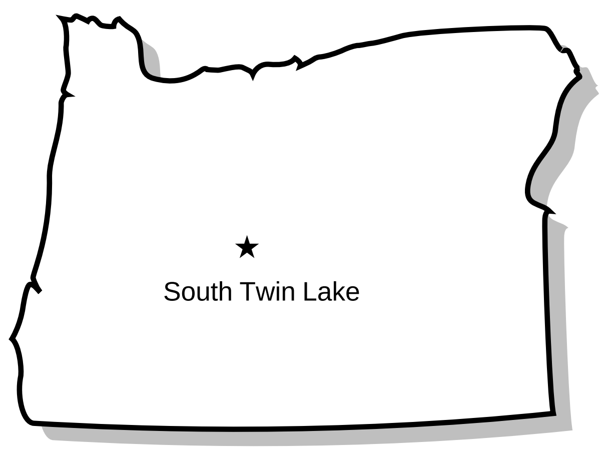
- colored pencils or markers
- rulers
- copies of student sheets (pp. 279-282)

Background

Do you know . . .

Oxygen is as important to life in water as it is to life on land. Aquatic life needs a minimum amount of oxygen to survive, grow and develop. The oxygen found in water is called the **dissolved oxygen concentration (DO)** and is measured in milligrams per liter of water (mg/l) or parts per million of water (ppm). The two measurements are equal.

DO levels can be changed by water movement, water temperature and the growth of aquatic plants. The *amount* of oxygen put into the water by these plants can also be changed by water temperature, the amount of light (cloudy vs. sunny days), and water depth (plants can only photosynthesize at depths to which light can penetrate). Clearness of the water can affect oxygen levels, too. Muddy water will block the sunlight needed by plants to make food and produce oxygen.



Vocabulary

dissolved oxygen concentration (DO)

Water temperature directly affects the amount of oxygen water can hold. The colder the water, the more oxygen it can hold. The chart belows shows how much dissolved oxygen (in ppm) fresh water (at sea level) can hold at different temperatures.

DO ppm	5	6	7	8	9	10	11	12	13	14	15
Temp°F	117	92	90	77	68	59	50	45	39	36	32

The saturation level is the maximum amount of DO that water can hold. This saturation level can be temporarily exceeded when many plants are growing in the water, or if the water is very turbulent (tumbling water caused by rocks). This extra oxygen is not stored in the water.

Most DO problems in Oregon streams occur between April and October. During this time, temperatures are at their highest levels and streamflows are at their lowest. Fish, especially salmon and trout, have problems surviving during this time. Fry are often found only in small spawning streams during these "pinch periods," and DO is necessary for their development. Even though a young fish can survive 1-2 ppm of DO for short periods, their growth rate drops sharply below 5 ppm, especially if the temperature is high.

Procedure

Now it's your turn . . .

How does temperature affect the amount of DO in a body of water? To answer this question, you will graph temperature and dissolved oxygen data gathered from South Twin Lake in the Oregon Cascades. Make the graph as instructed, then answer the questions about the relationship of dissolved oxygen (DO) and temperature.

The information in the table at right is from a 1982 survey of South Twin Lake near Bend, Oregon. Fish found in the lake include rainbow trout, chub, brown trout, brook trout, and kokanee (land-locked sockeye salmon). Aquatic plants found in the lake include water milfoil and algae.

South Twin Lake, July 1982

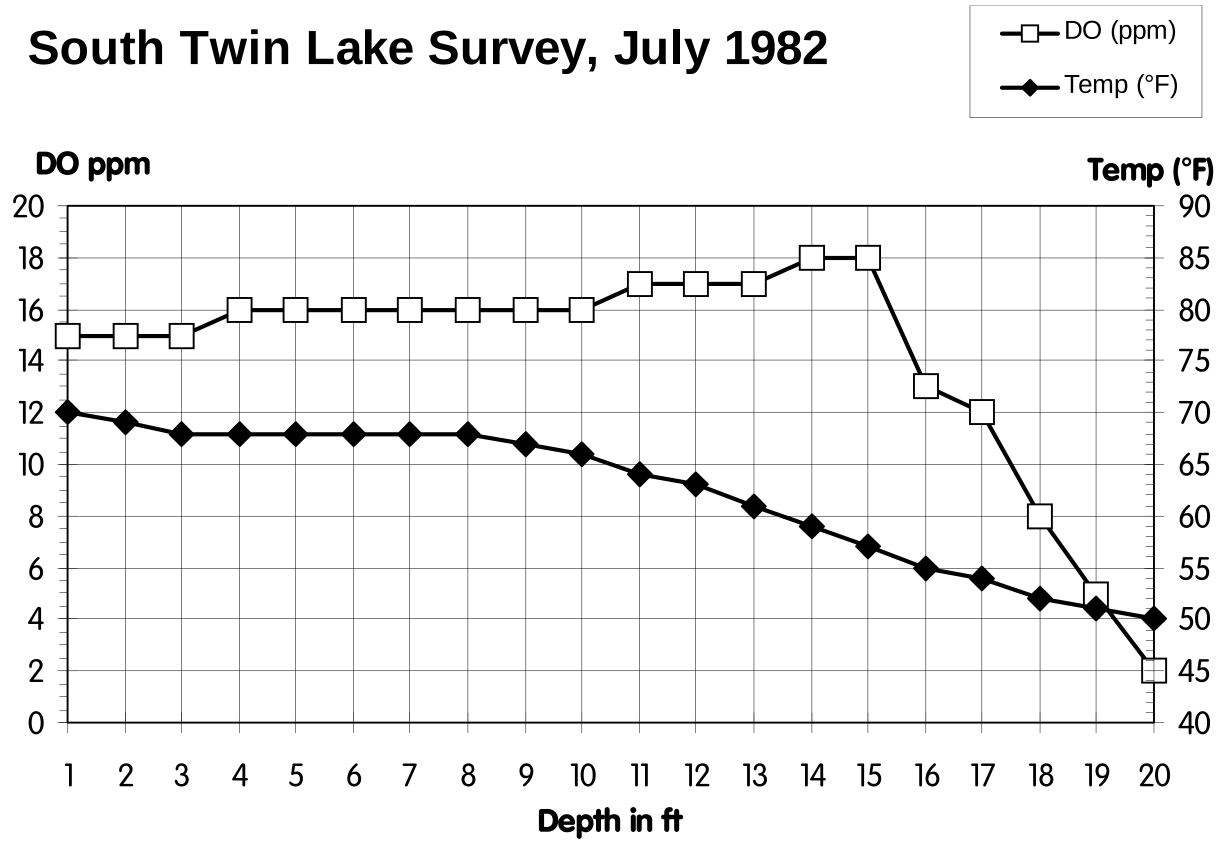
Depth (ft.)	DO (ppm)	Temp (°F)	O_2 Saturation (ppm)
0	—	—	
2	15	70	
4	15	69	
6	15	68	9
8	16	68	
10	16	68	
12	16	68	
14	16	68	
16	16	68	
18	16	67	
20	16	66	
22	17	64	
24	17	63	
26	17	61	
28	18	59	10
30	18	57	
32	13	55	
34	12	54	
36	8	52	
38	5	51	
40	2	50	11

Graph

Plot depth versus dissolved oxygen (DO) and temperature on the following graph.

Going further

1. Design an experiment to test oxygen production by plants under different light and temperature conditions. Produce a display to summarize your results.
2. Contact your local department of fish and wildlife, watershed council, or department of environmental quality office. Volunteer to assist with temperature monitoring on streams in your area. Ask local experts to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.



Questions

1. At what depths would you expect to find the greatest number of salmon or trout? Why?
   Between 22 feet and 30 feet. (Students may need to refer to water temperature background information on page 253 to make a better determination.) Salmon and trout prefer temperatures between 40°F and 65°F, and water can hold the greatest amount of oxygen at these temperatures.

2. List as many reasons as you can why more dissolved oxygen is present in the water between the depths of 20 and 30 feet?
   Cold water at these depths holds more oxygen, and enough light is present for food and oxygen production by plants.

3. According to the graph, what effect does temperature appear to have on dissolved oxygen saturation?
   Cold water holds more oxygen, except at depths below 30 feet.

4. At depths less than 36 feet, the DO level is higher than saturation level. Why?
   At less shallow depths, light penetration allows more oxygen production by photosynthetic plants. (Students may need additional information to answer this question.)

5. Why does the DO level drop between 30 feet and 40 feet?
   Available light is limited, reducing photosynthesis and the amount of oxygen produced by that process.

Name

A South Twin story

Do you know . . .

Oxygen is as important to life in water as it is to life on land. Aquatic life needs a minimum amount of oxygen to survive, grow and develop. The oxygen found in water is called the **dissolved oxygen concentration (DO)** and is measured in milligrams per liter of water (mg/l) or parts per million of water (ppm). The two measurements are equal.

DO levels can be changed by water movement, water temperature and the growth of aquatic plants. The *amount* of oxygen put into the water by these plants can also be changed by water temperature, the amount of light (cloudy vs. sunny days), and water depth (plants can only photosynthesize at depths to which light can penetrate). Clearness of the water can affect oxygen levels, too. Muddy water will block the sunlight needed by plants to make food and produce oxygen.

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Temp°F	117	92	90	77	68	59	50	45	39	36	32

The saturation level is the maximum amount of DO that water can hold. This saturation level can be temporarily exceeded when many plants are growing in the water, or if the water is very turbulent (tumbling water caused by rocks). This extra oxygen is not stored in the water.

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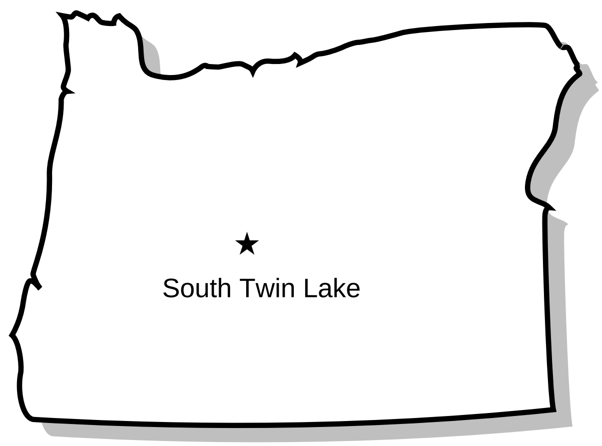


Vocabulary

dissolved oxygen concentration (DO)

Student sheet

Now it's your turn . . .

How does temperature affect the amount of DO in a body of water? To answer this question, you will graph temperature and dissolved oxygen data gathered from South Twin Lake in the Oregon Cascades. Make the graph as instructed, then answer the questions about the relationship of dissolved oxygen (DO) and temperature.

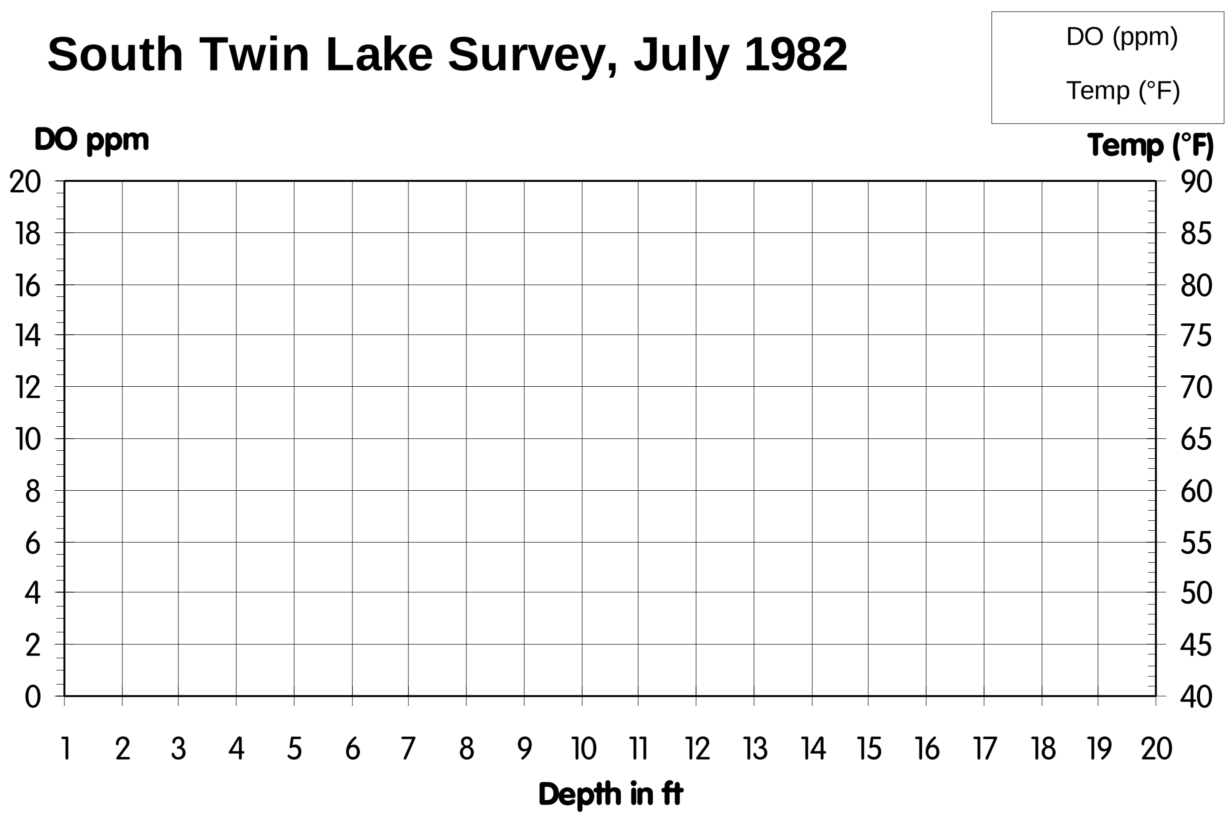
The information in the table at right is from a 1982 survey of South Twin Lake near Bend, Oregon. Fish found in the lake include rainbow trout, chub, brown trout, brook trout, and kokanee (land-locked sockeye salmon). Aquatic plants found in the lake include water milfoil and algae.

South Twin Lake, July 1982

Depth (ft.)	DO (ppm)	Temp (°F)	O_2 Saturation (ppm)
0	—	—	
2	15	70	
4	15	69	
6	15	68	9
8	16	68	
10	16	68	
12	16	68	
14	16	68	
16	16	68	
18	16	67	
20	16	66	
22	17	64	
24	17	63	
26	17	61	
28	18	59	10
30	18	57	
32	13	55	
34	12	54	
36	8	52	
38	5	51	
40	2	50	11

Graph

Plot depth versus dissolved oxygen (DO) and temperature on the following graph.



Student sheet

Questions

1. At what depths would you expect to find the greatest number of salmon or trout? Why?

2. List as many reasons as you can why more dissolved oxygen is present in the water between the depths of 20 and 30 feet?

3. According to the graph, what effect does temperature appear to have on dissolved oxygen saturation?

4. At depths less than 36 feet, the DO level is higher than saturation level.Why?

5. Why does the DO level drop between 30 feet and 40 feet?

pH

8.4

"There was, at this time, a small alkaline water hole at the desert's edge.… No one but crows would drink there."
— Barry Holstun Lopez

The concentration of hydrogen ions in a solution is called **pH** and determines whether a solution is acid or alkaline. A pH value shows the intensity of acid or alkaline conditions. In general, acidity is a measure of a substance's ability to neutralize bases, and alkalinity is a measure of a substance's ability to neutralize acids.

The pH scale ranges from 1 (acid) to 14 (alkaline or basic) with 7 as neutral. The scale is logarithmic so a change of one pH unit means a tenfold change in acid or alkaline concentration. A change from 7 to 6 represents 10 times the concentration, 7 to 5, 100 times, and so on.

Most organisms have a narrow pH range in which they can live (Figure 10). While some fish can tolerate a range of 5 to 9, others cannot tolerate a change of even one pH unit. Because of this narrow range of tolerance, pH limits where many organisms can live and the composition of a community.

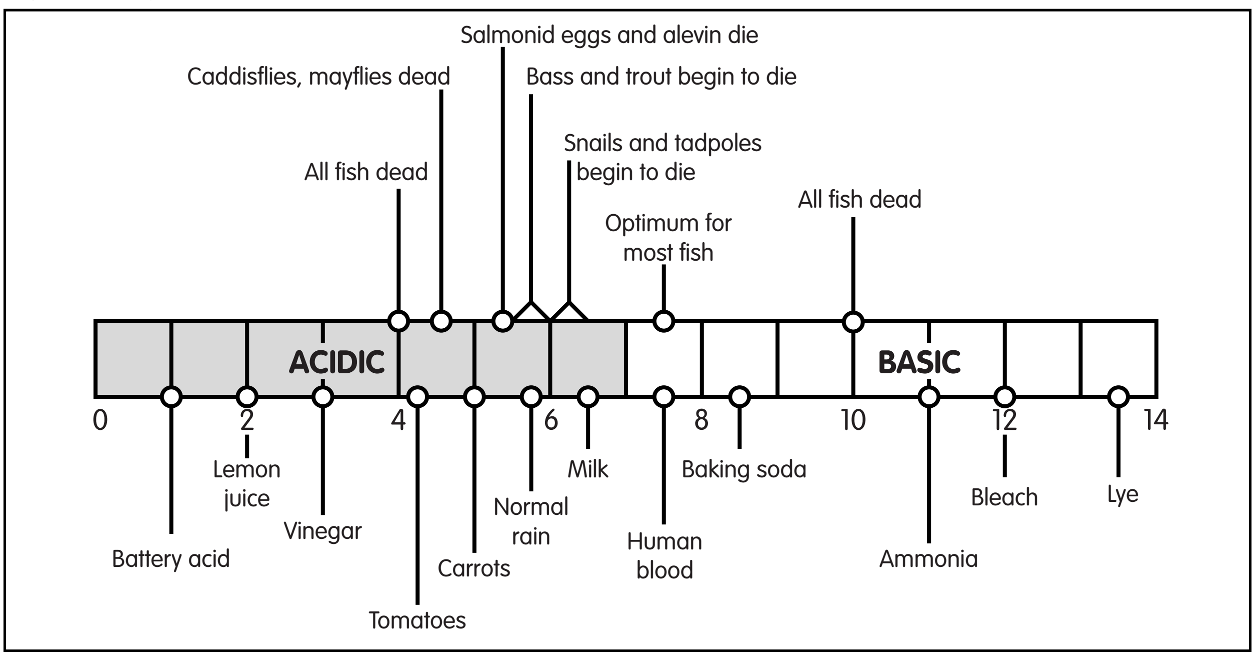
Although pure distilled water has a pH of about 7, any minerals dissolved in water can change the pH. These minerals can be dissolved from a streambed, the soil in a watershed, sediments washed into a stream, or the atmosphere.

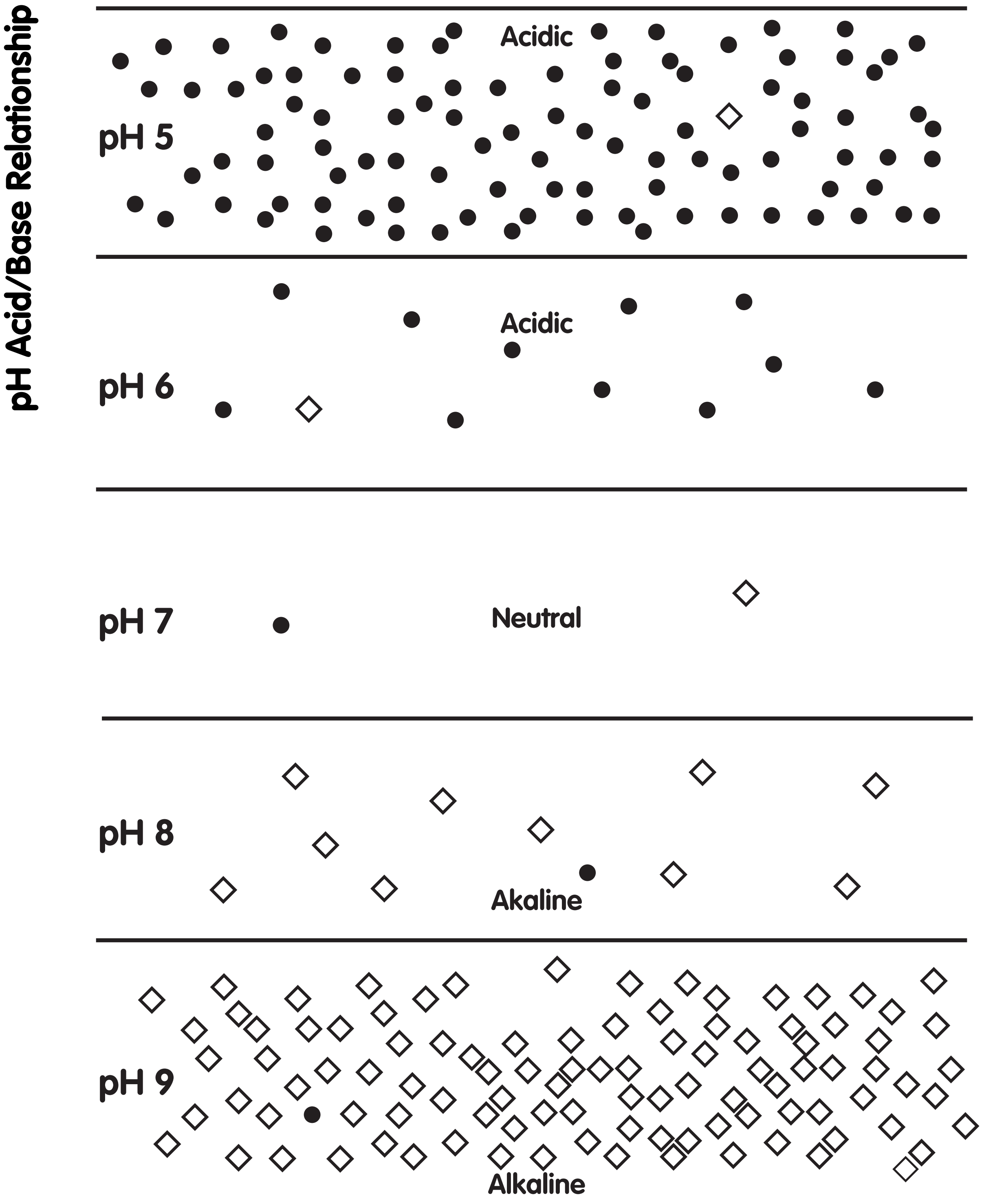
In eastern Oregon, where many soils have a high alkaline content, pH levels of some water bodies can rise above 10. Forest soils tend to

Vocabulary

pH

Figure 10. pH Scale





Each pH increment changes the pH factor 10 times

Adapted from materials prepared by Stephanie Gunckel, Andrew Talabere, and Art McEldowney and used with permission.

be slightly acid and many lakes or streams in forested regions of Oregon can approach a pH of 6.

The age of a lake can also influence pH. Young lakes are often basic. As organic materials build up, decomposition forms organic acids and releases carbon dioxide. Carbon dioxide mixed with water forms carbonic acid, making the lake more acidic.

Rainfall measuring just under 2.0 fell on Wheeling, WV, in 1978.

When rain falls through the atmosphere, the gases it contacts come into solution. As rain absorbs carbon dioxide it becomes slightly acidic, but reaches a natural lower limit of pH 5.6.

Air pollution, primarily from automobile exhaust and fossil fuel burning, has increased concentrations of sulfur and nitrogen oxides in the air. These fall with rain as weak sulfuric and nitric acids causing an “acid rain.” Currently in portions of the eastern United States, the mean pH for rainfall is 4.3, approximately ten times more acidic than normal. Rainfall measuring just under pH 2.0 fell on Wheeling, West Virginia, in 1978. This was approximately 5,000 times the acidity of normal rainfall and is the most acidic rainfall on record.

Increased acidity has caused pH to exceed lethal levels for fish in many lakes. A U.S. government study estimated that 55 percent of the lakes and 42 percent of stream miles in the eastern United States are currently being subjected to acidic deposition, which will eventually lead to their deterioration. In addition, acid build-up in soils can have detrimental effects on forests and crops, and hinders natural nutrient recycling processes.

Because rain can fall a considerable distance from a pollution source, acid rain is a regional and global problem.

Factors that determine the pH of a body of water can be far removed from a particular site, making it difficult to directly manage the pH. Because pH is a limiting factor, it is important to have a measurement to determine which organisms can survive and prosper. This measurement also serves as a baseline measurement and can assist in the monitoring of future changes.

Note: Use the graphic on p. 284 as an overhead transparency to demonstrate the concept that each pH increment changes the pH by a factor of 10.

Extensions

1. “What’s in the Air,” *Aquatic Project WILD,* pp. 136. Grades 1-12.
2. “Water Canaries,” *Aquatic Project WILD*, pp. 24. Grades 4-12.
3. “What’s in the Water,” *Aquatic Project WILD* pp. 140. Grades 3-12.
4. “How the Soil Affects Acid Rain,” *Earth: The Water Planet*, pp. 73-78. Grades 4-8.
5. “Acid Rain—How Acid Is It?” *Groundwater: A Vital Resource*, pp. 31-34. Grades 7-12.
6. “Does Acid Rain Affect Groundwater?” *Groundwater: A Vital Resource*, pp. 39. Grades 8-12.
7. “Making Acid Rain,” *Groundwater: A Vital Resource*, pp. 40-41. Grades 4-8.
8. Take comparably aged leaves from several different tree species. Set up separate containers for each species with 16 oz. of water each. Measure the pH.

   Strip the leaves from the stems and soak 1 oz. of the leaf material in the water overnight. Test the pH the next day. Note the differences in pH from naturally occurring materials in the leaves.

   Discuss how plant materials falling into a stream can change the water quality for stream organisms. A good choice of species includes Douglas-fir, alder, willow and oak. (Contributed by Mary Roberts, 1989.)

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Lakes and pH

Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

The student will (1) compare the pH differences of two lakes, and (2) answer questions analyzing the reasons for and effects of those differences.

Method

The student will compare and analyze the pH differences of two Oregon lakes.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Provide sufficient background information about pH using common products students recognize (baking soda, vinegar, coke, lemon juice, etc.).

Materials

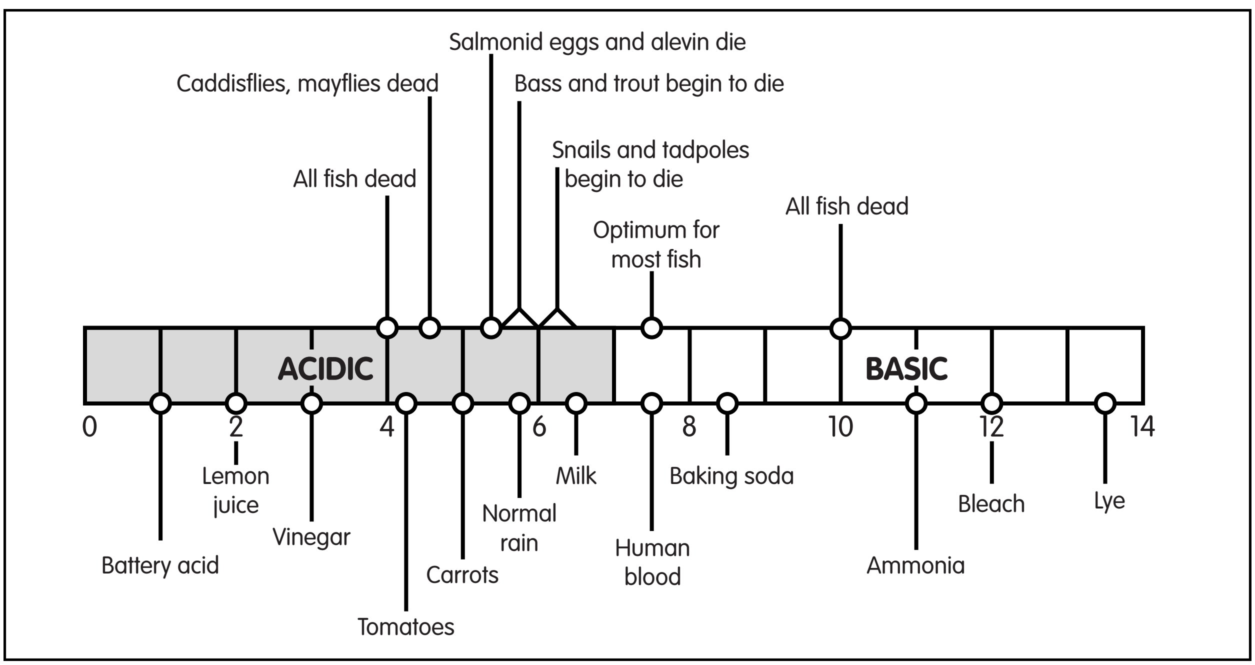
- copies of student sheets (pp. 291-294)

Background

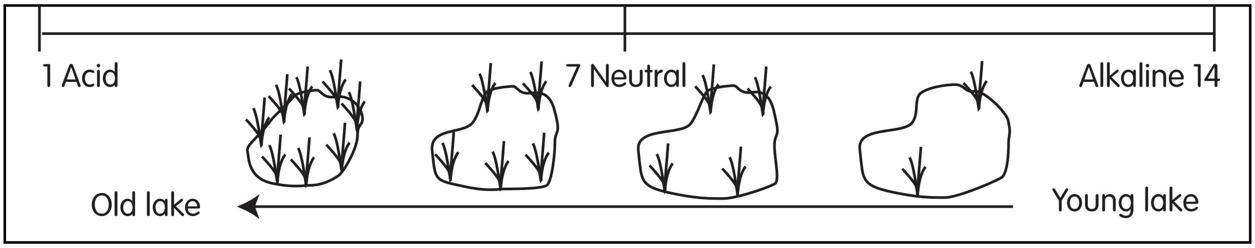
Do you know . . .

Water has an important chemical nature. We measure this chemical nature with a pH scale. If you look at the pH scale below, you will see this watery environment can be very acid (0 on the pH

pH Scale



pH Scale



scale) or very alkaline (14 on the pH scale) or anywhere in between. We meet these extremes every day in our foods—vinegar is very acid and baking soda or antacid pills are very alkaline. Pure distilled water has a neutral pH of about 7.

Each increase in value away from the neutral point of 7 is 10 times greater than the previous value. Small changes in the acidity or alkalinity of water can have big impacts on aquatic life, most of which require a pH level ranging from 6.0 to 8.5. Even if fish could survive changes in pH, insects on which they feed and aquatic plants cannot. The food chain can collapse if the pH goes beyond these narrow boundaries.

Acid rain results when water vapor in the air becomes acidified through chemical reactions with pollution coming from refineries and factories, coal- or oil-fired power plants, and cars. It falls to earth as acid rain. Acidified water can be very harmful to living organisms.

Soils also have a chemical nature. When soils are mixed with water, the pH may change. In eastern Oregon, where soils are high in alkali content, the pH of many lakes and streams can be greater than 10—or very alkaline. Forested soils are usually slightly acidic. Their influence creates a pH near 6 in the streams and lakes near them. Natural rainfall has a pH of 5.7.

Some areas of the country have a major problem with acid rain while in other areas the threat is not as great. The degree to which acid rainfall affects a watershed depends on the system's natural "buffering capacity." In areas with alkaline soils, natural runoff is enough to keep the water from becoming too acidic. In forested areas, soils have far less ability to buffer the effects of acid rain.

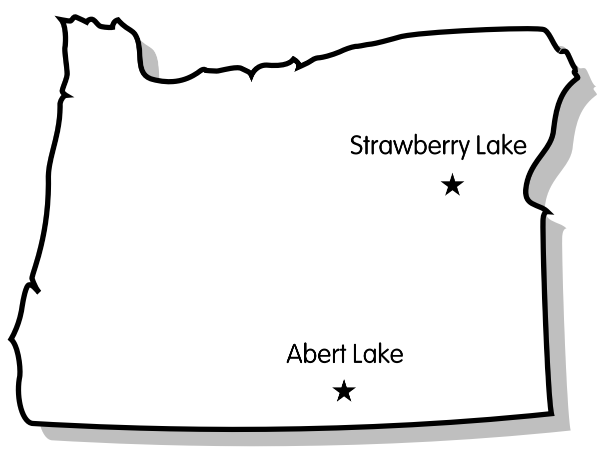
The age of a lake influences the pH of the water in the lake. The drawing above illustrates how this happens.

As trees and other plants grow, die and decompose, they release carbon dioxide (CO_2) into the water. This succession forms carbonic acid and makes the lake more acidic as time passes.

Procedure

Now it's your turn . . .

Does Oregon have acidic or alkaline lakes? In this exercise you will study the descriptions of two Oregon lakes. Compare the factors that may influence their pH and answer the questions that follow.



Description

Strawberry Lake is found in the Strawberry Mountains of eastern Oregon. Forest covers more than 75% of its steeply sloped watershed. A survey of Strawberry Lake found the following information:

	Depth	Dissolved Oxygen	Temp	pH
Maximum	27 ft.	8.4 ppm	64.8°F	6.5
Average	9 ft.			

Abert Lake has no outlet, and is found in an arid, highly mineralized area of southeastern Oregon. Forest covers 30 percent of its moderately sloped watershed. A survey of Abert Lake found the following information:

	Depth	Dissolved Oxygen	Temp	pH
Maximum	11 ft.	9.5 ppm	65.3°F	10.1
Average	7 ft.			

Notes to the teacher

An apparent discrepancy exists between depth, temperature and dissolved oxygen between the two lakes. This discrepancy could be a result of specific conditions on the day measurements were taken or sampling error. The discrepancy does not affect the questions in this activity but may be used to generate discussion with the students.

Questions

1. Why is the pH different in the two lakes?
   The alkaline soils in the Abert Lake drainage account for its high pH, while the forested drainage of Strawberry Lake contributes organic material to make it more acidic.
2. Which lake could support the most life? Why?
   Strawberry Lake. More species are tolerant of its pH range.
3. If both lakes dried up, which lake bed would likely have the best chemical environment to become colonized by plants? Why?
   Strawberry Lake. Fewer plant species are tolerant of alkaline soils.
4. If acid rain becomes a problem in Oregon, predict what could happen to Strawberry Lake.
   Because Strawberry Lake is already near the lower limit for many fish, an increase in acidity would make it uninhabitable for most species.
5. What could happen to Abert Lake?
   If the increase in acidity is great (bringing it closer to neutral), Abert Lake could support a greater number of species.

Going further

1. Collect water samples from several sites in your local community or watershed. Test their pH. Hypothesize about the quality of each of the collection sites with respect to suitable aquatic habitat for living organisms. Research whether or not the pH levels in these areas have changed over the past several years. Prepare a report to summarize your findings and present the results to the class.
2. See “Deadly Skies,” *Aquatic Project Wild*, pp. 142-145.
3. Design an experiment to test how soil types affect acid rain. See “How The Soil Affects Acid Rain,” *Earth: The Water Planet*, pp. 73-78. Prepare a report to summarize your findings and present the results to the class.
4. Design an experiment to test the effect naturally occurring materials in leaves and twigs have on the pH of water during autumn when large amounts of organic material fall into the water. A good choice of species to compare includes Douglas fir, alder, willow, and oak. Prepare a report summarizing your findings and present it to the class.
5. Contact your local department of environmental quality office. Volunteer to assist with water quality monitoring on streams in your area. Ask local experts to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

Name

Lakes and pH

Do you know . . .

Water has an important chemical nature. We measure this chemical nature with a pH scale. If you look at the pH scale below, you will see this watery environment can be very acid (0 on the pH scale) or very alkaline (14 on the pH scale) or anywhere in between. We meet these extremes every day in our foods—vinegar is very acid and baking soda or antacid pills are very alkaline. Pure distilled water has a neutral pH of about 7.

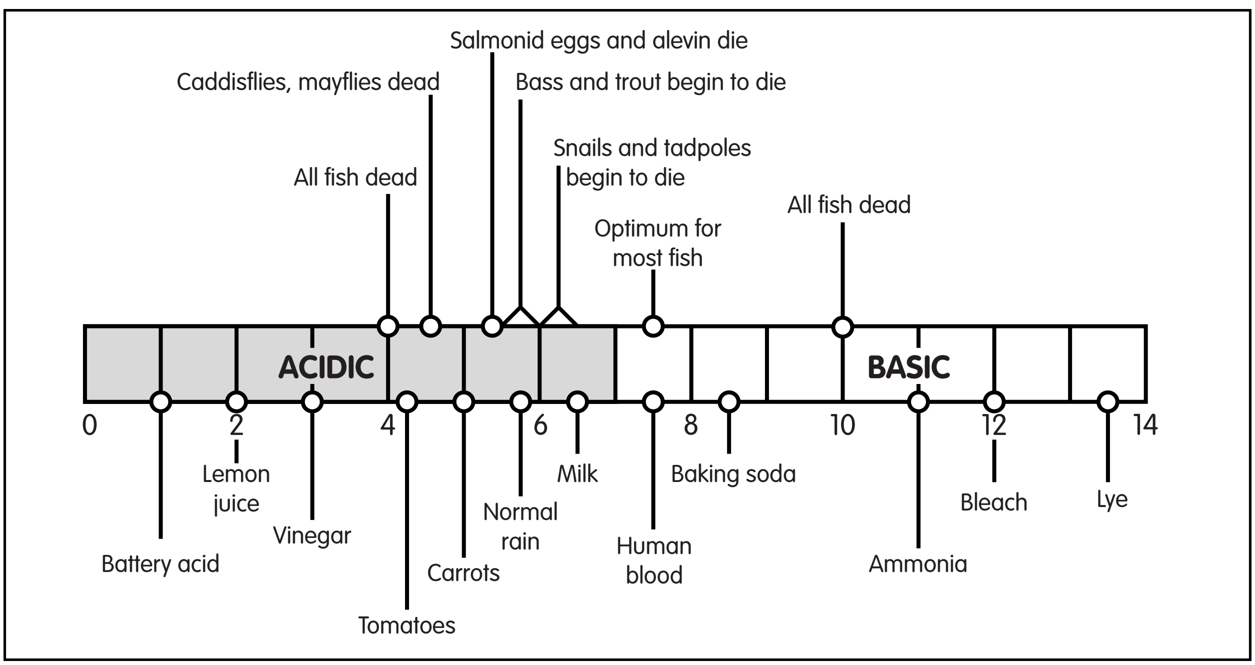
Each increase in value away from the neutral point of 7 is 10 times greater than the previous value. Small changes in the acidity or alkalinity of water can have big impacts on aquatic life, most of which require a pH level ranging from 6.0 to 8.5. Even if fish could survive changes in pH, insects on which they feed and aquatic plants cannot. The food chain can collapse if the pH goes beyond these narrow boundaries.

Acid rain results when water vapor in the air becomes acidified through chemical reactions with pollution coming from refineries and factories, coal- or oil-fired power plants, and cars. It falls to earth as acid rain. Acidified water can be very harmful to living organisms.

Soils also have a chemical nature. When soils are mixed with water, the pH may change. In eastern Oregon, where soils are high in alkali content, the pH of many lakes and streams can be greater than 10—or very alkaline. Forested soils are usually slightly acidic. Their influence creates a pH near 6 in the streams and lakes near them. Natural rainfall has a pH of 5.7.

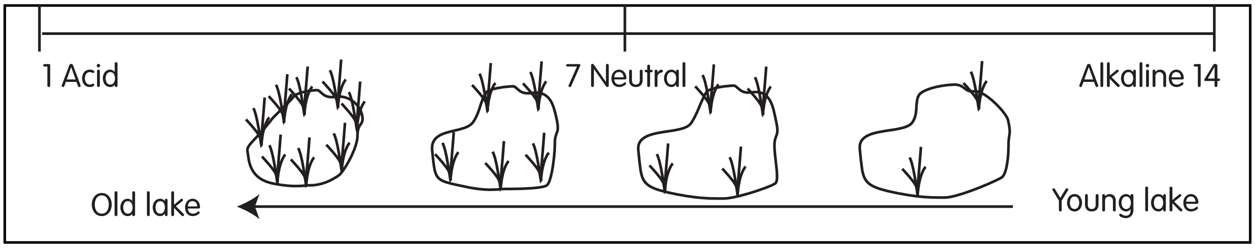
Some areas of the country have a major problem with acid rain while in other areas the threat is not as great. The degree to which acid rainfall affects a watershed depends on the system's natural "buffering capacity." In areas with alkaline soils, natural runoff is enough to keep the water from becoming too acidic. In forested areas, soils have far less ability to buffer the effects of acid rain.

pH Scale



Student sheet

pH Scale



The age of a lake influences the pH of the water in the lake. The drawing below illustrates how this happens.

As trees and other plants grow, die and decompose, they release carbon dioxide (CO_2) into the water. This succession forms carbonic acid and makes the lake more acidic as time passes.

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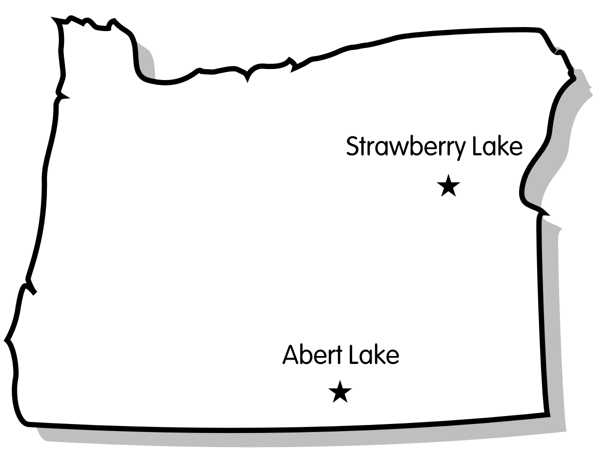

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3. If both lakes dried up, which lake bed would likely have the best chemical environment to become colonized by plants? Why?

4. If acid rain becomes a problem in Oregon, predict what could happen to Strawberry Lake.

5/ What could happen to Abert Lake?

Sediments

8.5

"Mud, mud, glorious mud, mud, mud, mud."
— Outdoor School song

As long as there has been water, it has carried solid particles called **sediments**. Sediments occur naturally as products of weathering and erosion. Wind, water or frost action on rock surfaces result in gradual breakdown of large, solid rock pieces to finest sand. Nutrients necessary to life are transported as sediments, using rivers and streams as pipelines.

Ecosystems depend on sediments for their health, but excessive amounts are harmful. Erosion and sediment transport are natural phenomena that can improve as well as degrade habitats within a watershed. Water erodes gravel banks to provide a continuing source of gravel for a stream, shifts gravel bars, and forms or deepens pools, all of which benefit spawning and rearing fish. However, erosion of fine-textured soils such as clays, silts, and fine sand can reduce habitat quality by compacting gravel or lowering water quality.

Sediment types

There are several types of sediments. **Bedload sediments** are too heavy to be constantly suspended. They are rolled and bounced along the bottom of a stream. The size of a particle of bedload sediment will vary with the volume and speed of the water. Spawning gravel is often transported as bedload sediment during high winter streamflow. Periodic fluctuations in the amount of sediment and bedload being transported naturally occur.

Suspended sediments are those carried in suspension. Rapidly flowing water can carry more suspended sediments than slow-moving water.

A gradient of deposition exists and is determined by streamflow velocity and volume and sediment size. Heavier sediments settle out first, followed by successively lighter materials. As velocity decreases, as from the center of the stream out toward its edges, or in slow water areas, the finest sediments settle to the bottom, no longer suspended by the action of water.

Total suspended sediment (TSS) is a measure of how much sediment a stream is carrying.

Nutrients necessary to life are transported as sediments, using rivers and streams as pipelines.

Suspended sediments can give water a murky or cloudy appearance by reducing light penetration. **Turbidity** is the term used to describe and measure the degree to which light is blocked.

Vocabulary

bedload sediments
sediments
suspended sediments
total dissolved solids (TSD)
total suspended sediment
turbidity

Helpful and harmful sediments

Sediments dissolved in water can be beneficial or harmful to the aquatic community. Some are nutrients essential to life. Others can be minerals or salts that change water pH or are poisonous to life. The measure of solids dissolved in water is called **total dissolved solids** (**TDS**). TDS levels higher than 500 ppm make water unfit for consumption.

In western Oregon, 200 communities get at least a part of their water supply from municipal watersheds. Currently, because of its high quality, little treatment is needed to make most of this water fit for domestic use.

Manufacturing of high-quality paper products and beer depend on availability of clear, clean water. High concentrations of sediments make water unfit for these processes without expensive filtering.

Sediments are the nations primary water pollutant, even though industrial and municipal wastes receive more attention.

Suspended sediments can block or reflect sunlight before it reaches aquatic plants. Heavier sediments can cover leaves, inhibiting photosynthesis, or even bury plants.

Sediments affect insect life in a body of water. Large amounts of sediments can smother some species. A change in the bottom material and the type, number, and health of plants changes the habitat, and, therefore, the species composition of the insect community.

Today, even though industrial and municipal wastes receive more attention, sediments are the nation's primary water pollutant. Erosion is the source of most sediments. Agriculture is responsible for more erosion than any other single activity, but road construction and use, timber harvest, forest fires and other sources contribute. Heavy concentrations of sediments increase the cost of municipal water treatment, can be harmful or fatal to aquatic life, and are indicators of excessive erosion.

Fish are also adversely affected by high sediment levels. Very high concentrations of suspended sediments can irritate and actually clog gill filaments, causing fish to suffocate.

Bedload sediments deposited in the channel change the composition of gravel beds used for spawning. This can reduce the amount of oxygen available to the eggs by blocking water circulation, trap fry in the gravel, or reduce the amount of suitable spawning habitat. Changes in plant and insect composition can also reduce amount and types of food needed during different stages of development.

Importance of vegetation

Excessive sedimentation and the problems it causes can be controlled by reducing erosion. Surface runoff is the primary cause of erosion and can be prevented with adequate plant cover during periods of runoff. Plants and the organic material they add to soil lessen the force of falling rain, add structure to the soil, and increase the soil's ability to absorb and hold water. When surface runoff does take place, leaves and stems of plants trap much debris and sediment that would otherwise be carried into streams.

As a stream meanders across a floodplain, it moves sediments and deepens its channel. Riparian vegetation is especially important in the control of these sediments. Plants along streams help prevent bank erosion.

Death of a stream

If these plants are lost, a devastating chain of events can begin. The banks become eroded, undercut, and frequently collapse, destroying more plants and exposing more soil to weathering and erosion. Sedimentation increases. Heavy flows scour the channel, moving even greater quantities of sediments. The stream channel continues to downcut, interfering with the re-deposition of sediments. This lowers the water table and decreases water retention in the area around the stream. Decreased water retention in the area around a stream means higher flows that will accelerate erosion.

During the summer months, a wide, shallow stream, shaded only by its deep cutbanks, will be warm and have limited quantities of dissolved oxygen. At this point, it is no longer a productive or healthy stream. Control of excessive sedimentation and the health of streams depend on vegetation, especially in riparian areas.

Extensions

1. "Where Does Water Run?"
   Aquatic Project WILD, pp. 21.
   Grades 6-12.
2. "What's in the Water," *Aquatic Project WILD,* pp. 140. Grades 3-12.
3. "The Invisible Load," *Groundwater: A Vital Resource*, pp. 28-28. Grades 8-12.
4. "How Raindrops Erode The Soil," *Earth: The Water Planet*, pp. 63-68. Grades 4-8.
5. "How Can Farmers Reduce Erosion Caused by Rain?" *Earth: The Water Planet*, pp. 69-72. Grades 4-8.
6. The following demonstration shows the effects of raindrop impact on various soil surfaces:
   - Obtain several dowels and wrap a piece of filter paper around each one, securing it with a rubber band.
   - Choose several sites (for example, bare soil, sod-covered soil, or soil covered with forest litter).
   - At each site, make a hole in the ground sufficient to hold the dowel upright with its filter paper covering above the soil's surface.
   - Use a sprinkling can to simulate rainfall or allow the dowels to remain at the sites during a storm.
   - Raindrop impact and splash will deposit sediment and organic material on the filter paper.
   - Collect the dowels.
   - Carefully remove the filter paper.
   - Dry and weigh the paper to compare the sites.
   - Take note of what sticks to the filter paper.
   - Discuss the implications of the results as they relate to riparian area health and sedimentation.

(Contributed by Bruce Anderson, 1988.)

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Don't runoff

Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

The student will (1) demonstrate how sediments enter a stream and (2) describe the effect of sediments on stream dynamics, plants and animals.

Method

The student will use sod-covered soil and bare soil samples to demonstrate how ground cover reduces erosion.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Teacher should set up activity prior to student use, or use as a demonstration activity. Simply the questions.

Materials

- copies of student sheets (pp. 303-306)
- 2 boxes about 12" wide, 24" long, and 2" to 4" deep. A plastic tray used for starting plants makes a good box. The boxes should be water tight. At one end, cut a "V" notch about half the depth of the tray. Fit a spout (of tin or other material) at the notch to draw running water off into a container.
- 2 sprinkling cans, or make your own with two, 1-gallon plastic milk jugs. (With a hot straight pin, melt the same number of holes in each jug in an area near the top and opposite of the handles. Melt an eighth-inch hole in the jug at the top of the handle.)
- Soil to fill each container. Make sure the soil for both containers is gathered from the same spot. The soil need not be completely dry, but avoid waterlogged soil.
- Piece of sod from a pasture, lawn, or fence row, cut to fit one of the boxes (trim grass to one inch in height). Grass clippings or other mulch to cover the soil in one container could also be used.
- 2, ½-gallon or larger, wide-mouth glass jars
- 2 sticks of wood about 1 inch thick
- ½ gallon of water for each sprinkler (1 gallon total)
- 2 stools (to support jars collecting runoff water)

Source: U.S. Department of Agriculture, Soil Conservation Service, *Soil and Water Conservation Activities for Scouts,* PA-978, 1977.

Background

Do you know . . .

Ground cover (grass, herbs, shrubs, etc.) actually protects the soil from a real pounding. Raindrops that hit bare soil break it down and reduce the amount of water it can absorb (store). Unprotected soil can also be easily washed into a stream. This is why plants are so important to soil, riparian areas and watersheds.

The soil in a healthy area would contain large amounts of decomposed organic matter (**humus**). Humus can absorb lots of water—like a sponge. Water is also held in the pores between the soil particles. The make-up of a soil determines how much water it can absorb.

Healthy soils can absorb most

Vocabulary

humus

rain and snowmelt until saturated (full of water). This means water seeps into streams more slowly, reducing erosion and sediments. It also means flooding is less likely, because most of the water is stored in the soil.

Plants benefit, too. Plants can use the stored water over a longer time period, increasing their growth rates. Plant roots open up channels allowing water to enter the soil easily. Plant stems and leaves also slow water, greatly reducing erosion and sediments in streams. Streams run clear in a healthy system.

A riparian area with little or no cover is exposed to the force of raindrops. Raindrops soften binding material that holds soil particles together, breaking them into fine particles. The impact of the drops splashes the fine particles into the air. These fine particles collect on the soil surface and fill the spaces between the larger soil particles. The result is a "seal" over the surface that prevents much of the rain from entering the soil. The water has no choice but to run off quickly, carrying sediments that end up in the stream. River systems with poor soils in the riparian area and uplands experience high sediment loads and heavy flooding.

Sediments that end up in a stream can harm aquatic plants and animals. Muddy or murky water blocks sunlight, which plants need to make food. Sediments also settle on plant leaves, further reducing their ability to produce food and oxygen. Extremely heavy sediment loads can even bury plants.

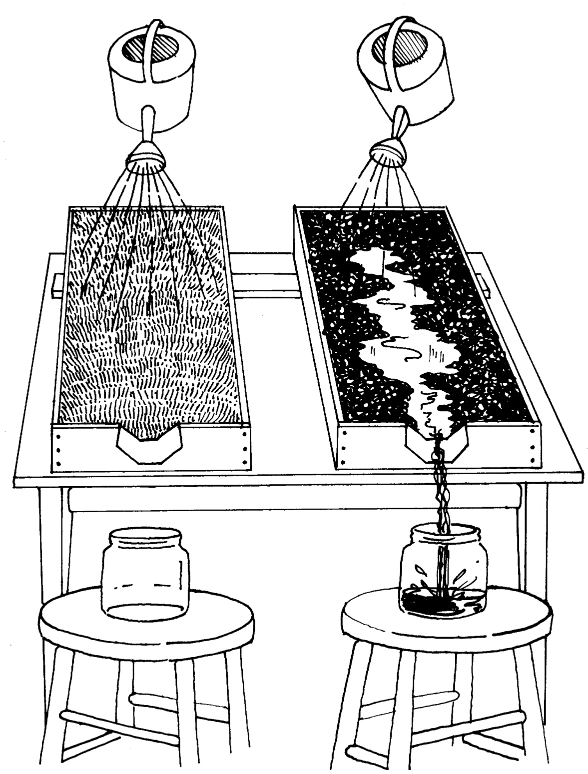
Large amounts of sediments suspended in the water can clog a fish's gills, causing it to suffocate. Sediments sift into spaces among the gravel. This can reduce oxygen flow to developing fish eggs, trap fry in the spawning gravel, and make aquatic insect habitat unsuitable.

Procedure

Now it's your turn . . .

Will vegetation protect the soil's surface from erosion? In this investigation you will demonstrate how ground cover affects erosion by comparing the effects of falling water on vegetated and nonvegetated soils.

1. Prepare two boxes as directed by your teacher. Refer to the diagram at right.
2. Set both boxes on a table so the spouts extend over the edge. Place sticks under the opposite end to give the boxes slope. Both boxes should have the same slope.
3. Fill both trays with soil from the same place—no grass, just soil. The idea is to have the same kind of soil in both boxes.
4. Place the empty jars on stools placed beneath the spouts of the boxes.
5. Cover the soil in one tray with sod (or grass clippings).
6. Fill two sprinkling jugs with ½ gallon of water each. Holding each jug about one foot above the boxes, sprinkle water onto the soil at the upper end of both boxes. It is important to pour the water from the same height and at the same steady rate.
7. Collect water in both jars for five minutes. If necessary, adjust the collection time for the soil and slope you are using.
8. Compare the amounts and clarity of water in each jar.



Questions

1. Describe the water in the runoff jars from each box. Is the same amount of runoff found in each jar? Why or why not?
   There should be less water from the tray with grass clippings or sod. The mulch has held the soil and slowed the water velocity allowing greater infiltration.
2. Why is it important to use the same amount of water and pour it from the same height and at the same rate when conducting this activity? What would happen if the height at which the water was being poured was increased? How would this have affected the runoff rate?
   To keep the runoff rates even. Increasing the height from which the water is poured will increase "splash" erosion and water velocity. This will increase the amount of soil carried away and the speed of runoff.
3. What conclusion can be drawn about the influence of vegetation on the amount of sedimentation in a stream?
   Vegetation reduces the amount of sediments carried to a stream.
4. How important is vegetation to stream quality?
   Very important. A healthy riparian area acts as a filter to keep the water clean.
5. How might excessive sedimentation in streams affect aquatic plants?
   Excessive sedimentation makes water murky. This reduces light for photosynthesis. Silt may also smother or bury plants.
6. How might excessive sedimentation in streams affect aquatic animals, especially fish?
   Fish eggs and aquatic insects may be buried or smothered. Silty water may also make it harder for aquatic animals to filter water for breathing. Reduced insect populations make it harder for fish to get enough to eat.
7. What does the accumulation of excessive sediments in a stream indicate about the water flow of a stream?
   For small sediments to settle out, water velocity must be slow.
8. How does organic material affect water retention in riparian areas?
   Organic material adds structure and helps hold the soil. It also creates spaces in the soil so that the soil can act as a giant sponge.
9. Specifically, how does vegetation protect the soil's surface?
   Vegetation breaks the force of raindrops and reduces "splash" erosion. Roots help hold the soil surface.
10. How could removing streamside vegetation influence sedimentation?
    It would increase erosion and reduce the amount of debris trapped and collected by the riparian vegetation.
11. How might roadbuilding, building construction, livestock grazing, and farming influence stream sedimentation?
    All create soil disturbance, exposing bare soils to the effects of water and wind, contributing a source of sediments to an adjacent stream system.

12. What preventive measures might be taken to reduce the effects of sedimentation created by the disturbances mentioned in the two previous questions?

Many specific answer are possible. A correct answer should include the retention of vegetation along streambanks to trap sediments transported from upland areas.

Going further

1. See "How Can Farmer's Reduce Erosion Caused By Rain?" *Earth: The Water Planet*, pp. 69-72.
2. Design an experiment to demonstrate the effects of "splash erosion" caused by raindrops falling on different soils and vegetative cover. See "How Raindrops Erode The Soil," *Earth The Water Planet*, pp. 63-68. Suggest ideas for reducing the effects of splash erosion. Prepare a display to present your findings.

Name

Don't runoff

Do you know . . .

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Source: U.S. Department of Agriculture, Soil Conservation Service, *Soil and Water Conservation Activities for Scouts,* PA-978, 1977.

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5. Cover the soil in one tray with sod (or grass clippings).

Vocabulary

humus

Student sheet

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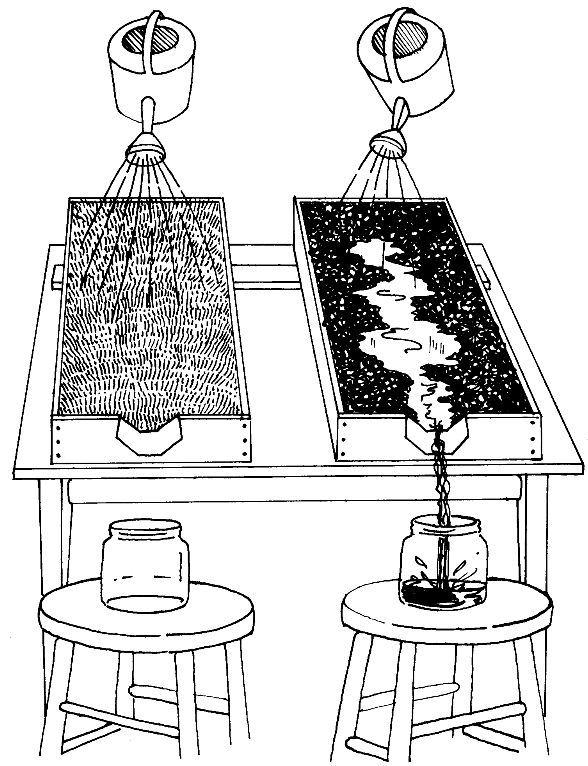

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5. How might excessive sedimentation in streams affect aquatic plants?

6. How might excessive sedimentation in streams affect aquatic animals, especially fish?

7. What does the accumulation of excessive sediments in a stream indicate about the water flow of a stream?

8. How does organic material affect water retention in riparian areas?

9. Specifically, how does vegetation protect the soil's surface?

10. How could removing streamside vegetation influence sedimentation?

11. How might roadbuilding, building construction, livestock grazing, and farming influence stream sedimentation?

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