Interactive Lake Ecology
Student Workbook

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Table of Contents

Title Page #

List of Figures i

List of Tables ii

Acknowledgements iii

Introduction iv

Chapter 1: How Our Lakes Were Formed 1

Chapter 2: Water Properties 9

Chapter 3: Water Cycle 15

Chapter 4: Food Chain 19

Chapter 5: Watersheds 23

Chapter 6: Pollution 29

Chapter 7: Non-Native Species 37

Chapter 8: Testing a Lake 45

Chapter 9: Classifying Lakes 55

Chapter 10: Conclusions 61

Appendix

Exercises A-1
Experiments A-13
Glossary A-31
Illustration acknowledgments A-39

List of Figures

Figure #	Title	Page #
1-1	Glacial lake formation	2
1-2	Oxbow lake formation	4
1-3	Animal-made lake	5
1-4	Volcanic lake formation	6
1-5	Landslide lake formation	7
1-6	Tectonic lake formation	7
2-1	The water molecule	9
2-2	A water strider exhibiting surface tension	10
2-3	Thermal layers	12
2-4	Lake turnover	13
3-1	The water cycle	15
4-1	Examples of phytoplankton and zooplankton	19
4-2	Example of a fresh water food chain	21
5-1	A watershed	23
5-2	An example of blue-green algae	25
6-1	Stop pollution	30
6-2	The pH scale	31
6-3	Point source pollution	32
6-4	Nonpoint sources of pollution	33
7-1	Examples of 6 non-native species	37
7-2	Native vs. non-native vegetation growth	38
7-3	Birds find shelter in a natural marsh habitat	39
7-4	Always check your boat for non-native species	41
8-1	Kemmerer bottle	46
8-2	Secchi disk	49
8-3	Flow meter	50
8-4	Fathometer	51
8-5	Bathymetric map	51
8-6	Plankton net	52
8-7	Integrated sampler	53
9-1	Eutrophic lake	55
9-2	Oligotrophic lake	56
9-3	Mesotrophic lake	57
9-4	A sample graph showing x and y axes	58
9-5	Lake Clear chlorophyll-a levels	59
9-6	Number of shoreline houses	59
9-7	Lake Clear total phosphorus	60

List of Tables

Table #	Title	Page #
8-1	New Hampshire pH ranges	47
8-2	New Hampshire total phosphorus ranges	48
9-1	Measurement ranges for lake classification	57

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Introduction

This workbook will introduce you to the most important elements of a lake ecosystem. We will discuss basic scientific concepts of water, the water cycle, how lakes are formed, food chains and watersheds. In addition we will introduce you to some of the pollution problems facing lakes today, such as nutrient loading, exotic plants and animals, and acid rain. Also, we'll look at how lakes are tested, classified and monitored for water quality. Lastly, we'll present some ways that you can educate your community about the critical problems lakes are facing.

We hope that you enjoy this journey of discovery, and that you will come away from this experience with a greater appreciation for the complexity and diversity of life in freshwater lakes. By the end of this learning process you will have an understanding that everyone, even you, can play a role in lake protection.

• • • •

Chapter 1. How Our Lakes Were Formed

Have you ever wondered why lakes have so many different shapes, or why some are so deep and others are so shallow? Have you wondered why some lakes are so big you can't see the other side, but some are so small you can throw a rock across? The answer to these questions, in part, is that all lakes were not created in the same way or by the same forces of nature. Also, lakes age at different rates depending on the characteristics of the land by which they are surrounded.

Events that occurred on or beneath the Earth's surface thousands of years ago formed many of our lakes. As a result, lakes are usually concentrated into areas that have a large number of waterbodies. Most lakes can be found in the Northern Hemisphere, where large areas were covered by huge ice formations.

On a scale of human life spans, lakes seem to be permanent features of our landscape, but they are really only geologically temporary. They are created, mature (fill-in) and eventually disappear.

The origins of the lake basins and their characteristics ultimately reflect the physical, chemical and biological events taking place within the area surrounding them. These events play an important role in how the lake responds to surrounding activities.

The shape of the lake basin often determines how much plant and algae growth occurs. Steep sided U- or V-shaped basins, often formed by our shifting earth, are usually deep and don't have many plants or algae. These lakes may be very clear. Shallow lakes have a greater area of water that touches the bottom sediments. These lakes may have a greater number of aquatic plants, algae and less visibility, or ***clarity***.

Less than 2 percent of the earth's surface is covered by fresh water, and much of the volume of this is contained in about 20 large, deep lakes. In fact, one lake, Lake Baikal in Siberia, contains about 20 percent of the world's fresh water.

The following is a summary of how lakes are formed. Although lakes are continually forming, these new lakes are generally shallow in nature and are highly exposed to nutrients from man-made sources.

TYPES OF LAKES

1. Glacial Lakes

By far the most important agents in the formation of lakes are the catastrophic effects of glacial ice movements that occurred 10,000 to 12,000 years ago. Gigantic sheets of ice and snow are created in climates

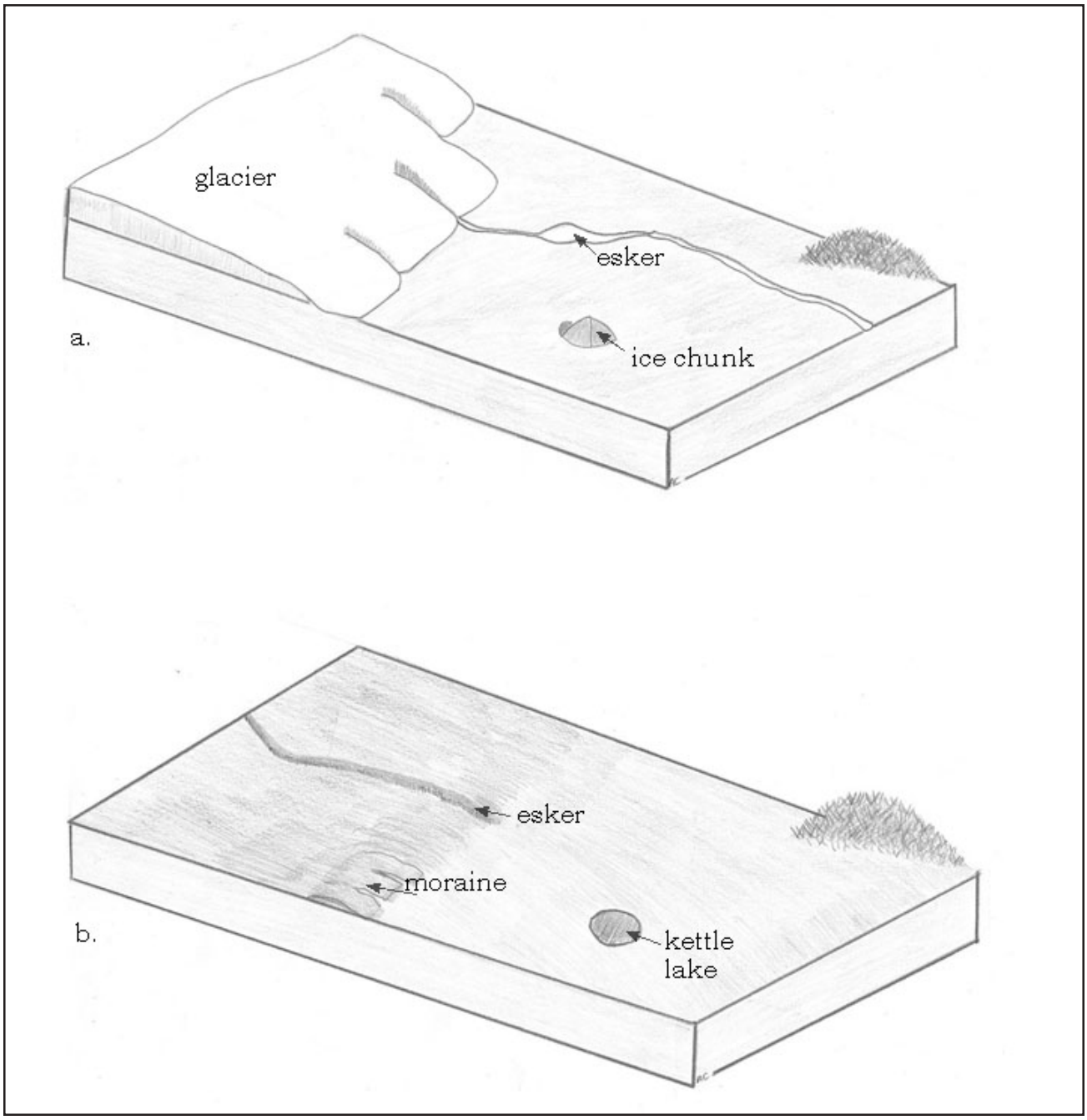


Figure 1-1. Glacial lake formation. In a., glacier is retreating, leaving ice chunks and sediments behind. In b., the moraine formed from sediments and the kettle lake from the ice chunk.

where snow falls but does not melt. They can cover entire continents, as can be seen today in Greenland and Antarctica. These sheets of ice are called ***glaciers***.

As the glaciers grow, they become very heavy. The ice on the bottom has so much weight that it is compressed and pushed out from underneath the ice mass. This pushing motion makes the glacier spread and move across the countryside. For

the most part, glaciers move at a rate of about one inch per day.

The glaciers covered an area from the Atlantic Ocean to the Rocky Mountains in ice that was more than a mile high. Although these glaciers did eventually melt, ten percent of the earth is presently covered with glaciers. Some of these glaciers can still be seen in the mountainous areas of the United States and Canada. Scientists believe that glaciers could actually surround us again someday.

As a glacier moves back and forth across the land, scraping off the tops of hills and bluffs and taking rocks with it, lakes are formed. The material picked up by the glacier is later dropped off at other sites. This back and forth and stop and go movement of the glaciers permanently alters the landscape. This movement creates several important landforms.

When the glacier stops, it leaves behind piles of rocks and materials that it carried over time, called ***moraines***. These dam up rivers and smaller streams to form lakes.

Sometimes, huge blocks of ice are broken off and covered by sand and gravel. When the ice melts, the sand and gravel cave in, leaving a large hole behind. These ***kettles*** may form large marshes or lakes.

As the large mass of ice melts, rivers form beneath the glaciers. The rivers carve out tunnels in the bottom of the glacier. Rocks and debris that have collected in the glacier fall into these tunnels. As the tunnels fill up, they form ***eskers***. Eskers look like huge snakes winding across the landscape. Glacial lake formations are depicted in *Figure 1-1*.

2. Solution Lakes

Lakes can form when underground deposits of soluble rocks are dissolved by water running through the area, making a depression in the ground. Rock formations made of sodium chloride (salt), or calcium carbonate (limestone), are most likely to be dissolved by acidic waters.

Once the groundwater has dissolved the rocks below the surface, the top of the land caves in, usually forming a round-shaped lake, called a ***solution lake***. Typically, the depressions are deep enough to extend below the groundwater table and are permanently filled with water. Solution lakes are common in Michigan, Indiana, Kentucky and particularly in Florida.

3. Oxbow Lakes

The flow of water from rivers has a great deal of energy and

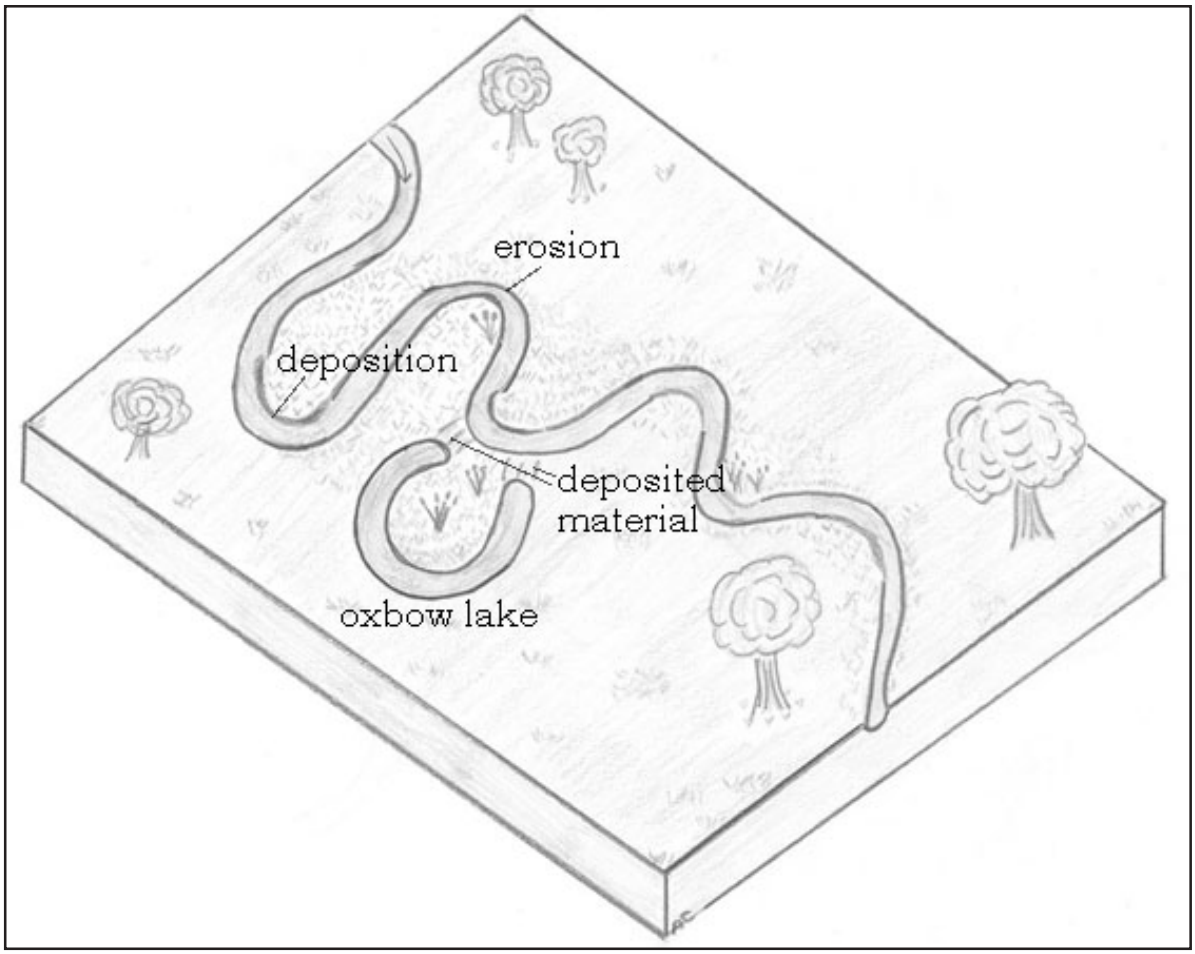


Figure 1-2. Oxbow lake formation. Erosion occurs at the outer edge of a river, where the flow is fastest. Depositing of materials then occurs at the inner edge of a river.

erosive strength that may create lake basins.

As a river winds over the earth's surface, a greater amount of erosion occurs on the outer river bend, where the flow of water is the fastest. Materials carried by the river are deposited on the inner portion of the bend, where currents are reduced. As time passes, erosion continues and more materials are left off until the U-shaped meander of the river closes in. The main course of the river cuts a new channel to the inner end of the meander. Oxbow lakes are usually shaped like the letter C (*Figure 1-2*).

4. Man-made or Animal-made Lakes

Many small lakes in North America have been formed by the activities of the American beaver (*Figure 1-3*). Sticks, aquatic plants and mud are used to build dams across small streams to form an impoundment of the water. These ponds are usually very shallow and are rich in nutrients and plant life.

Humans have constructed

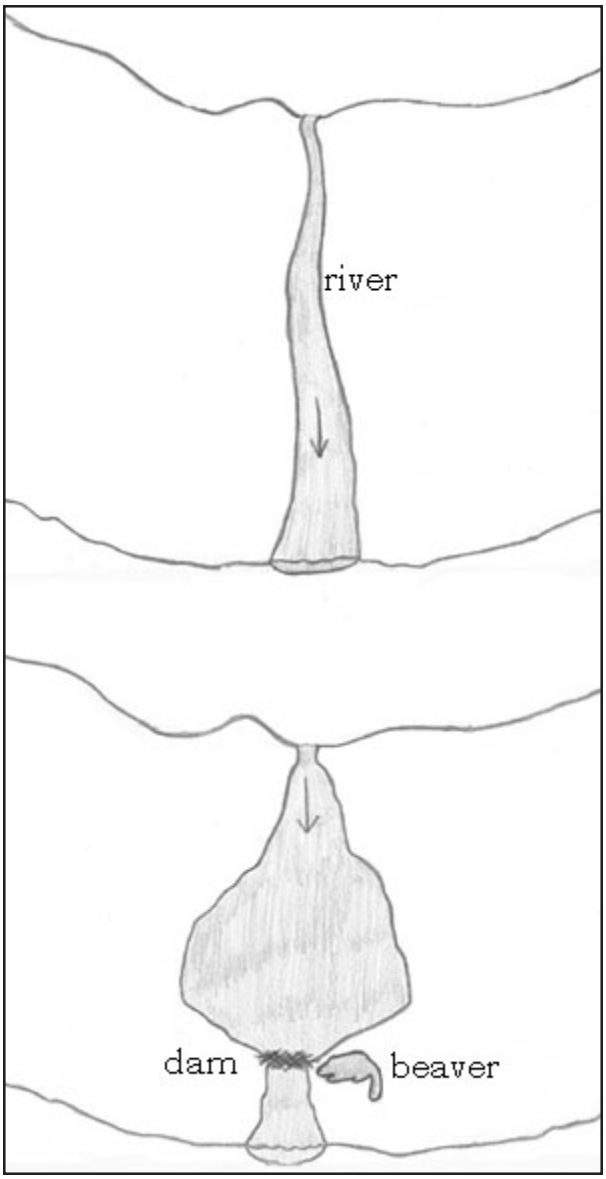


Figure 1-3. Animal made lake. The American beaver builds a dam with sticks and other materials and creates a pond from an existing river.

artificial lakes (reservoirs) to supply drinking water to the public, to provide power, to aid in navigation, to provide flood control and for recreational purposes. These reservoirs are usually well engineered by humans to hold back a certain quantity of water with the use of dams.

5. Volcanic Lakes

Sometimes, disastrous events associated with volcanic activity form lake basins. The formation of volcanic lakes can occur in different ways. As volcanic material, including magma, is discharged out of the volcano, empty depressions or cavities are formed within the volcano. Some of these depressions cannot drain and become sealed holes on top of the volcano. Rainfall and runoff eventually fill the depression with water and a new lake is formed. Because of the type of rock base in which these lakes are formed and the small drainage area that surrounds these basins, these lakes are usually low in nutrients and have little plant and algae growth. Lakes that form in the craters of volcanoes, or ***crater lakes***, are more common in areas that are subject to volcanic activity.

Lakes formed by the caving in of a roof of a partially empty magmatic chamber are termed ***calderas*** (*Figure 1-4*). One of the most spectacular lakes formed in this way is Crater Lake in Oregon. Crater Lake is the seventh deepest lake in the world with a maximum depth of 608 m (2006 ft). Volcanic basins, like Crater Lake, are usually very round in shape.

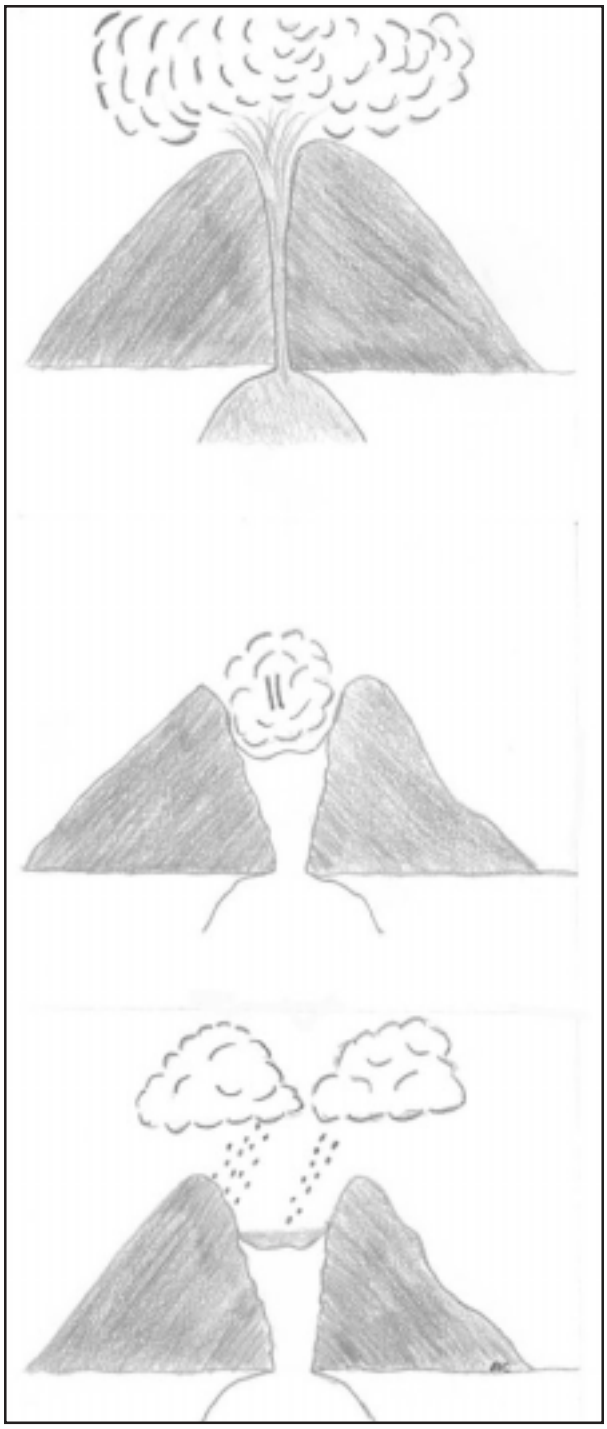


Figure 1-4. Volcanic lake formation. Eruption occurs, followed by collapse (cave-in) and filling.

Lava flows from volcanic activity can also form lakes. The surface lava cools, and becomes solid, while the inside of the lava flow remains hot enough to continue moving. Eventually, the surface of the hardened lava collapses, forming a depression. These depressions eventually fill with water to form smaller lakes. Lava streams also flow into existing river valleys and solidify into a dam. This solid mass of rock backs up the river water into a new lake.

6. Landslide lakes

Large quantities of materials that fall from the sides of steep valleys into the floors of stream valleys can cause dams that create new lakes (*Figure 1-5*). Such landslides usually occur as a result of abnormal meteorological events, such as excessive rains acting on an unstable slope. Landslide dams may be a result of rockfalls, mudflows or even iceslides. Lakes that are formed by landslides are usually only temporary because they may be susceptible to erosion by the flow of the river or stream. If the dam is very large, the lake may become permanent.

7. Tectonic lakes

Tectonic basins are depressions formed by the movements of the earth's crust deep underground. The major types of tectonic basins are formed from faulting. A depression forms when a weak

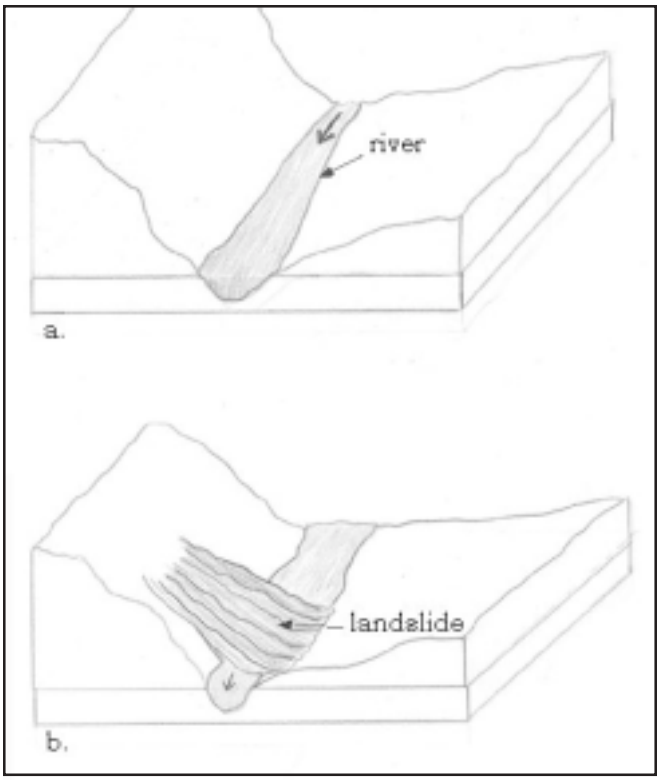


Figure 1-5. Landslide lake formation. A landslide occurs and dams an existing river.

section of the earth's crust separates, resulting in an earthquake. Rainfall and groundwater may collect in this depression, forming a lake. This type of basin is referred to as a ***graben*** and is the mode of origin of a large number of the most spectacular relic lakes in the world containing a vast number of native plant and animal species. The deepest lake in the world, Lake Baikal in Siberia, was formed from tectonic activity. In the United States, Lake Tahoe in California and Nevada was formed by tectonic activity.

LAKE MORPHOLOGY

Experiment 2

The formation of a lake and the structure and form, or ***morphology***, of the lake basin affects how the lake functions throughout its life stages.

Lake morphology is best examined by creating a map of the lake's depths. These maps will be discussed in greater detail in Chapter 8.

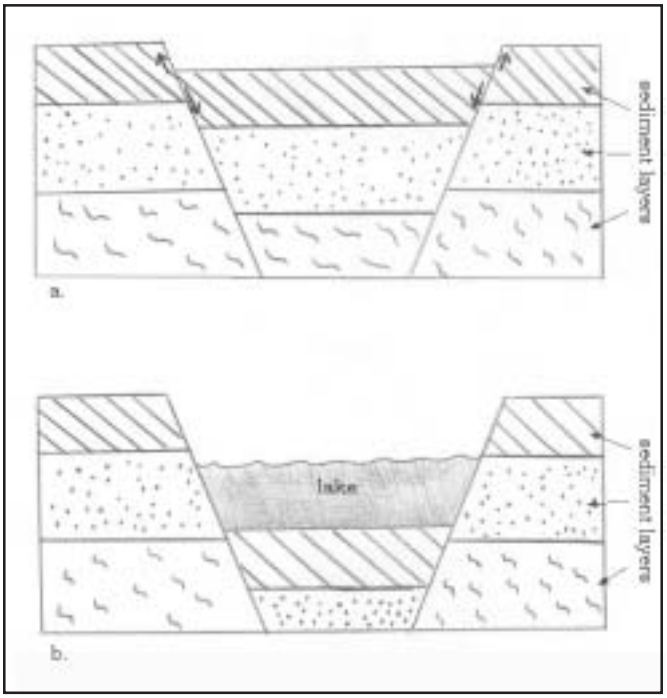


Figure 1-6. Tectonic lake formation. As the tectonic plates move, a depression is formed. This is later filled with water.

Many of the characteristics determined by these maps are used to construct lake models that determine how the lake will react to various changes in the aurrounding land area. Characteristics like the lake length, width, depth, area and volume are all important to how the lake water quality may be affected by changes to the land. As humans develop the land surrounding the lake, they disturb the soils, exchange trees for driveways or rooftops and replace the natural vegetation. These changes result in an increased flow of surface runoff and an increase in the amount of nutrients to the lake.

The lake structure dictates how the lake will react to these cultural changes in the surround lands. Knowing the lake morphology and how the lake was formed are important tools used by scientists to help protect our lakes from pollutants that can deteriorate their health.

Summary

Knowing how a lake was formed is important in determining both its age and its potential for aging quickly. Most lakes are formed through earth movements or other natural events. Other lakes, like oxbows, are formed through long-term forces of flowing water. Still, other lakes are formed through animal activities and planned human interventions.

Lake depths can be mapped for a better understanding of the lake's shape and aging process.

Quiz Yourself

1.How are most of the lakes in the northern United States formed?

2. List the types of lakes not created by forces of the earth.

3. Blue Lake is a glacially formed basin that is steep-sided and deep. Is this lake likely to age more or less quickly?

Vocabulary

caldera
crater lake
esker
glacier
graben
kettle
moraine
morphology
solution lake

Complete Chapter 1 Exercises, located on page A-1. Also, Experiments 1 and 2 should now be completed.

There are several very important ideas about the nature of water that must be understood before we begin our study of lakes. Some of these concepts may be a review, while others will be new to you.

PHYSICAL CHARACTERISTICS

A ***molecule*** of water is made up of two elements, hydrogen and oxygen. Two atoms of hydrogen and one atom of oxygen create the well-known formula H_2O.

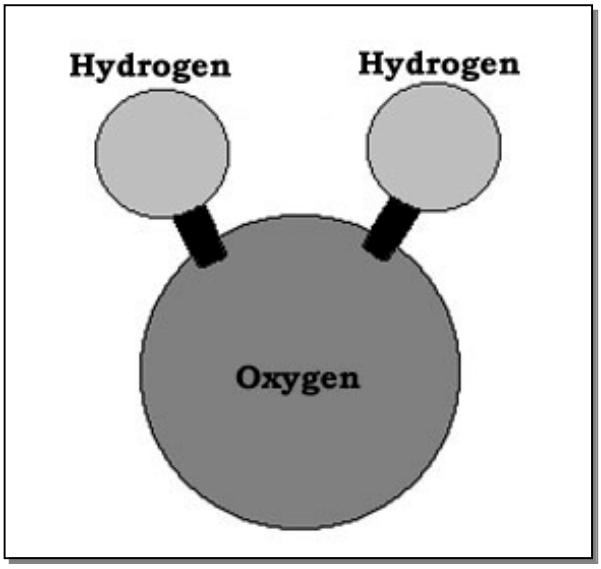


Figure 2-1. The water molecule.

Water is found in three forms: solid, liquid and gas (vapor). Water vapor cools to form a liquid, a process known by the term ***condensation***. When liquid changes form to a gas, ***evaporation*** occurs; solids change to form liquids, known to you as ***melting***. ***Freezing*** occurs when a liquid becomes cold enough to change to a solid.

All of these natural properties are frequently observed as they occur in any home, particularly in the kitchen. Can you think of any examples that you have seen in your house?

Experiment 3

Now that you have a better idea of how surface tension works, can you think of any plants or animals that live on a lake that take advantage of surface tension to move, eat or reproduce?

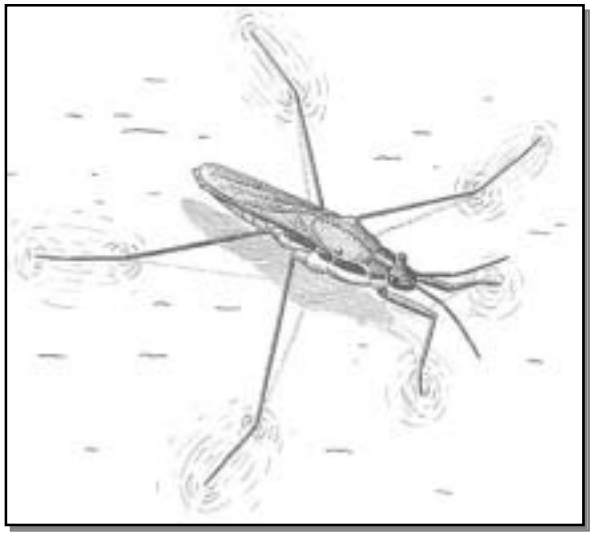


Figure 2-2. A water strider exhibiting surface tension.

Have you ever seen water bugs skimming over the surface of the water? Have you noticed water lilies with their leaf pad occupied by a croaking frog? Maybe you've seen algae floating on the surface of a pond. All of these are examples of pond life utilizing a special quality of water: ***surface tension.***

Even many adults surprisingly misunderstand the next concept that is essential to a full understanding of lake ecology: water is the only liquid on earth that *expands when freezing!*

Experiment 4

When water molecules are a vapor they are in their least dense state (think of fog). As they cool, the molecules move closer together and they form a liquid (rain). As the temperature continues to drop the molecules move closer together until they reach 4 degrees Celsius. At this point, the water molecules can no longer move closer together. The water is now at its greatest density. If the temperature continues to decline, the water cools towards its freezing point of zero degrees Celsius. As this happens, the molecules once again move apart, forming ice. Air trapped between the molecules provides ice with the ability to float on top of water. If ice were denser, it would sink to the bottom.

WATER PROPERTIES OF LAKES

You have probably learned that warm air rises in relation to the cooler air around it. The same is true of water. Warmer water is generally found at the top layer of the lake, and the deeper down you go, the cooler the water becomes. The coldest water lies at the bottom of any lake or pond during the summer months.

Maybe you have noticed this temperature layering when swimming. As you dive, you feel the temperature of the water grow colder as you approach the bottom. Then why, you might ask, does ice form at the surface?

That is precisely the question we want to raise. Do you have any ideas why this may be true? Discuss this with your teacher and see if you or your class can brainstorm some reasons why this is true. Why is it beneficial to the lake ecosystem for ice to form on the surface?

In addition to these ideas

about water, you need to know at least one more. (In order to understand this concept clearly, we will do an experiment after discussing the idea.) Water, air and soil change temperature at different rates. If the water temperature is 17° C (62° F) and the soil is 4° C (39° F), which temperature will rise faster, water or soil, when the air temperature is increased by twenty degrees? (Make a guess or hypothesis.)

The amount of heat required to raise the temperature of a unit of a substance is called ***specific heat.***

Experiment 5

Remember, we discussed earlier that the temperature of the lake water in northern areas of the country becomes cooler as we travel from the surface to the bottom. During the summer there is a difference between the temperature at the top of the water column and the temperature at the bottom. Some lakes, due to these temperature differences, form distinct layers in the summer, each successively cooler than the one closer to the surface.

In addition, certain living things spend most of their lives at a particular depth. Algae, for instance, are dependent on heat and light for their existence. Where do you think most algae might be found?

Trout and salmon need cold-water temperatures in order to survive. Where do you think you will find them most of the time? Bass, perch and sunfish can live in much warmer waters and need the support of plants and rocky shores for cover and food supply. Where do you think they can be located most of the time?

So, we can say that there are layers of temperature, called ***thermal layers,*** in many deeper lakes and ponds. Each layer supports various animal and plant species and contributes to the pond ecosystem as a whole.

This thermal layering takes place during the summer months. The warm June sun heats the top layer of water to toasty temperatures of 21° C to 27° C (70° – 80° F).

Diving into a deep lake during the summer can be a chilling reminder that the warm rays of the sun fail to reach the bottom. The cold, dense water remains separated from the warm

upper water by a barrier. This barrier, called the ***thermocline***, is the zone of rapidly changing temperatures between the warm surface water and the colder deep waters of a lake. The cross-section illustration of Dan Hole Pond (*Figure 2-3*) shows a three-layered water column that is typical of deep lakes and ponds in the summer. The top layer remains at a stable temperature somewhere around 21° C. The cold, bottom layer hides below at a chilling temperature of about 4° C (39° F).

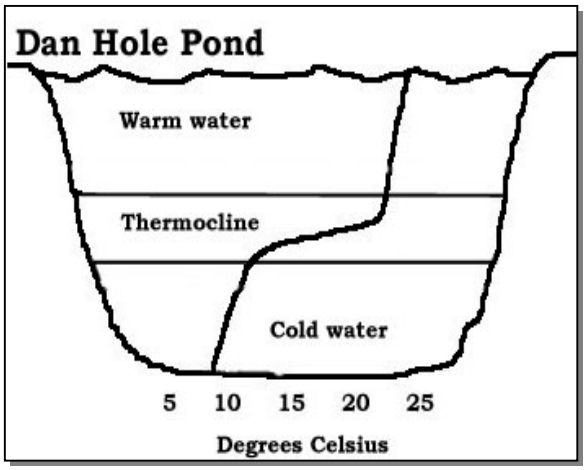


Figure 2-3. Thermal layers.

These thermal layers change as the cool winds of autumn send a chill through the top water layer. The wind cools the water and the colder molecules sink.

As this water sinks, it pushes the bottom water towards the surface and mixes the water in the lake. This process is called ***lake turnover.*** The bottom layer brings accumulated nutrients and oxygen upwards as the cool upper water displaces it. Nutrients, minerals and oxygen become mixed along the entire water column during lake turnover.

In cooler climates, as autumn gradually progresses into winter, the lake water remains at a fairly consistent temperature from top to bottom. The temperature range is very small, but important. The less dense water freezes on the surface at 0°C (32° F), forming the ice. The water actually becomes warmer nearer the lake bottom. In a deep lake, the bottom water temperature is 4°C , the densest water. Ice and snow cover the lakes during the winter forming an insulating blanket (*Figure 2-4*). In areas that don't experience a lot of temperature change through different seasons, lakes may mix year round, or several times a year with varying weather conditions.

Take a minute to consider the individual nature of each lake. A lake has depths, a shoreline and tributaries unique to itself. And all lakes are found in different climates. Therefore, lakes in different regions will respond to forces of nature in a slightly different manner.

Spring turnover, the second of the two yearly turnovers in the northern lakes, is the mixing of the entire water column. But

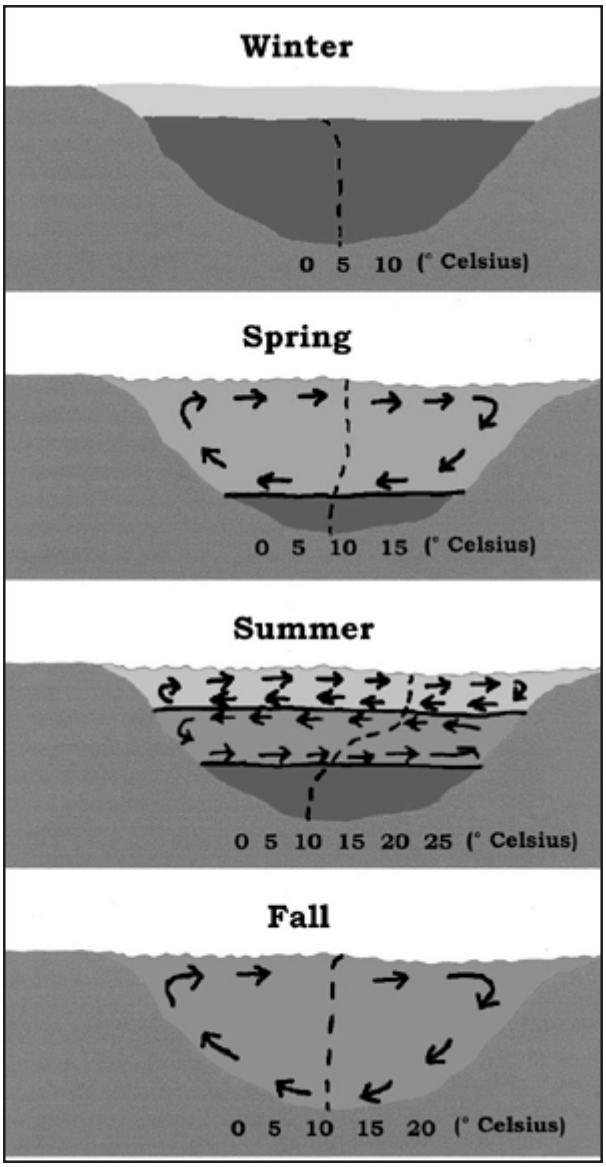


Figure 2-4. Lake turnover.

each lake follows a slightly different path to spring turnover.

In a shallow lake, wind plays a decisive role in lake turnover. Wind forces break up the ice and help to freely mix water from all depths.

However, in a deep-water lake, several forces are at work in spring turnover. The sun, wind, currents, tributaries and groundwater all join together to mix the huge volumes of water in a deep-water lake. As in fall turnover, nutrients are again mixed throughout the water column and provide food for algae. This cycle continues every year. Without this mixing, a lake could become stagnant, which would cause the water quality to decline.

Experiment 6

Summary

We have touched upon a range of topics in this second chapter. We've discussed the structure of a water molecule, and how water changes from a solid to a liquid to a gas. Can you remember the names for those changes?

We explained surface tension and how that characteristic of water helps support much aquatic life.

Later, we discussed the unique idea that water actually expands as it freezes! Water, as you recall, is denser at 4° C than it is at 0° C, its freezing point. It is this fact that allows ice, which

is less dense, to float on a lake.

Additionally, we examined how water behaves a bit like air in that warm water floats and cooler water sinks.

We also talked about the difference in the rate at which the ground and a lake change temperature. This was followed by a discussion of layering and how certain species of plants and animals live at certain levels in a pond or lake.

Lastly, there was an explanation of seasonal lake turnover. The warm sun of summer slowly heats the upper layer, leaving the deep layers in cold isolation. The thermocline effectively separates the upper and lower layers. Fall winds cool the surface water and cause a turnover. The cold temperatures of winter freeze the surface waters to form ice. The denser water then sinks to the bottom. Spring warms the surface and the lake mixes, causing spring turnover.

Quiz Yourself

1. Describe surface tension. Name some plants or animals that take advantage of surface tension.

2. What is the only substance on earth that expands when freezing?

3. What property of water describes water vapor changing to a liquid?

4. What property of water describes a liquid changing form to a vapor?

5. When water is at 4 degrees Celsius its molecules are closer together than at 100 degrees Celsius. What word describes this difference?

6. What happens to a northern lake when the autumn winds and shorter days cool the lake's surface waters? What is this process called?

7. In what type of water do salmonoid fish such as trout and salmon primarily live, cold or warm?

8. Name some animals and describe the layer of the lake they inhabit.

Vocabulary

condensation
evaporation
freezing
lake turnover
melting
molecule
specific heat
surface tension
thermal layers
thermocline

Complete Chapter 2 Exercises, located on page A-2. Also, Experiments 3, 4, 5 and 6 should now be completed.

Chapter 3. Water Cycle

Now that you have a basic understanding of some very important concepts about water, we can look directly at a process that is essential to continued life on earth: the ***water cycle***. Simply stated, the water cycle is the ***circulation*** of water from the ***atmosphere*** to the earth, powered by the sun. As indicated by its name, the water cycle is a series of events linked together by physical forces so that a defined start point and end point cannot be defined.

THE CYCLE OF WATER

Three quarters of the earth's surface is made up of water, primarily ocean water. The evaporation and condensation of ocean water drives most of the earth's water cycle. The waters of the Atlantic and Pacific Oceans evaporate thousands of tons of water into the atmosphere, where it is then pushed by air currents to contribute moisture to the North American mainland. So, we depend not only on the quality of local surface water, but also on the quality of the water that falls to earth in our area. This idea is clearly demonstrated by the problem of acid rain, which is caused by air pollution. Acid rain will be discussed more completely in Chapter 6.

Water circulates from the atmosphere to the ground and from the ground to the atmosphere depending on the

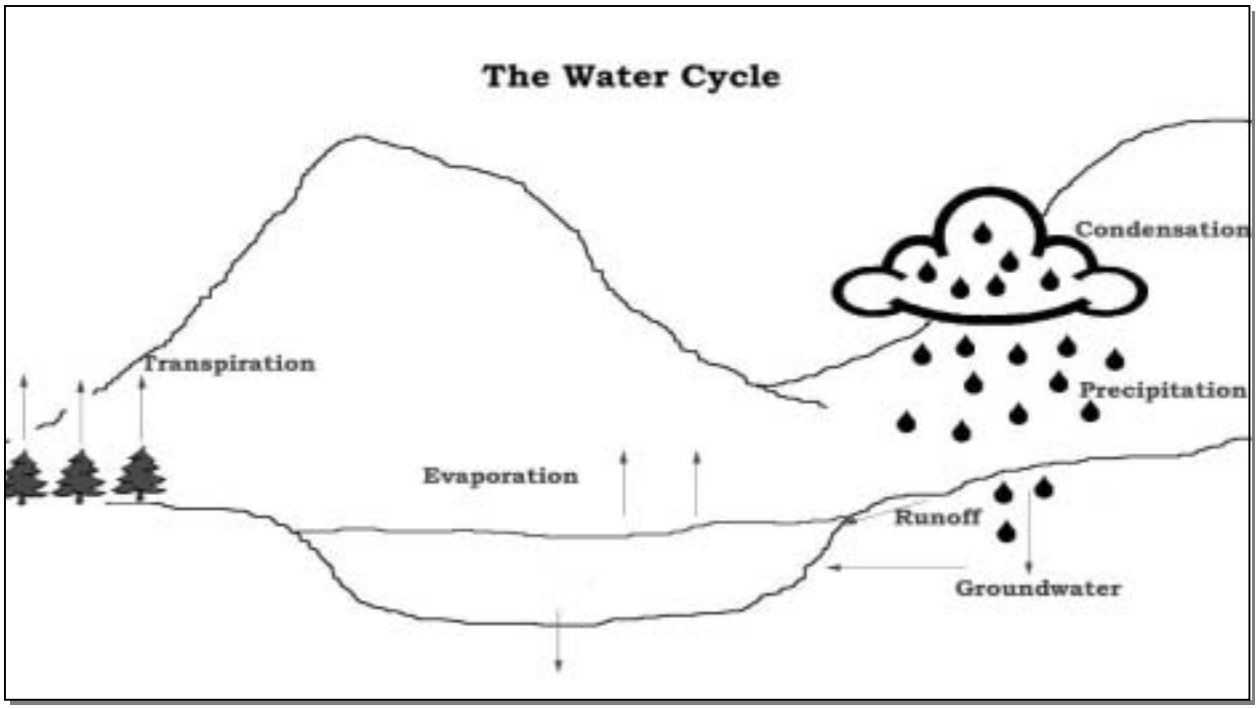


Figure 3-1. The water cycle.

temperature and the pressure of the surrounding air.

As the temperature increases, water evaporates from the surface of lakes, ponds, puddles and other sources of open water. The water vapor rises to the upper levels of the atmosphere where it cools (remember condensation from the previous chapter?) and condenses to form tiny water droplets. When the conditions are right, those water droplets return to the earth's surface in the form of rain, snow, hail, and sleet, otherwise known as ***precipitation***. Water is once again evaporated into the

Experiment 7

atmosphere from the surface water, and the cycle continues.

There are several more ideas that you must understand in order to account for all the water that is in the cycle. Scientists divide the water cycle into two parts, ***inputs*** and ***outputs***. The term for water entering a lake is called an input. The word for water that is exiting a lake is output.

Can you list some ways that water enters a lake? Think of a lake or pond that you know well. How does that lake or pond get filled with water? Where does the water come from? Try to brainstorm a list before going on to the next section. Then do the same with outputs. List all the ways water leaves a pond.

Inputs:

precipitation
groundwater discharge
surface streams/rivers
surface runoff

Outputs:

surface discharge streams
evaporation
groundwater discharge
domestic use
agriculture/industry
transpiration

Before we begin to talk about these ideas, let's discuss some new vocabulary that we'll be using in order to describe the water cycle. Evaporation and condensation have already been explained in the water properties section. Do you remember their definitions? ***Groundwater*** is water that is absorbed by the soil and still is flowing downhill. The word that describes water being absorbed by the soil (thus

becoming groundwater) is ***infiltration***. ***Runoff*** describes water that has come down from the sky as precipitation and is running downhill on the earth's surface.

Precipitation is the major input to the whole system. ***Surface streams*** are any rivers, streams, brooks or creeks that are flowing across the earth's surface. ***Transpiration*** occurs when soil moisture is taken up by plant roots, moves through the plant and passes through the leaves as a vapor.

The main outputs in a lake's water cycle are the outflow of water from the lake into an outlet stream (***surface discharge***) and the evaporation of the water into the atmosphere. Additionally, water percolates down through the lake floor (***groundwater recharge***). Another way that a lake loses water, however, is from human use. In some towns, the local lake serves as the supplier of water to all homes. This is called ***domestic use***. Also local businesses and some local factories use large amounts of water for production, called ***industrial use.***

This description of a water cycle is intended to focus your understanding of the process on a particular lake or pond. Let's look at Lake Clear, a typical lake in the United States. During the summer, Lake Clear receives its majority of precipitation in the form of rain. Also, the streams and brooks that run into the lake add more water. Additionally, groundwater adds water into the bottom of the lake. Together, these are the major inputs to Lake Clear during the summer. The outputs are surface discharge, water drawn for public and private use, evaporation and groundwater recharge.

If there had been little or no rain during the summer, the lake's water level would drop daily because of evaporation and reduced stream water input. The outputs of water from the lake would be greater than the inputs. The amount of water it contributed to the next lake downstream through its surface discharge would also be reduced. So we can see that drought conditions hundreds of miles away can impact water levels locally. If, on the other hand, we look at the springtime, when precipitation in the form of rain and snow (in the northern U.S.) is plentiful and runoff increases from snow and ice melt, lakes are filled to capacity and contribute a lot to downstream flows.

Summary

To summarize, the water cycle is the circulation of H_2O in

its various forms, powered by the sun's energy. Water in the form of precipitation falls from the clouds to the earth's surface. The sun's energy evaporates the water, the vapor rises to the atmosphere where it collects, cools, and eventually condenses into water and falls to Earth as precipitation. Water that does not infiltrate is runoff and it gradually moves downhill to the nearest surface stream.

To relate that process to a lake or a pond means understanding the kinds of inputs and outputs a lake possesses. On the input side, we have precipitation, runoff, groundwater and surface streams. These are all the ways water can enter a lake.

Then on the output side we have evaporation, surface discharge, transpiration and recharge to groundwater. Additionally, water withdrawn by human activity for use in the home as well as for commercial and industrial purposes accounts for a major water loss. In communities where drought conditions exist, towns may impose water restrictions in order to control the output side of the delicate balance. These are all the ways that water may exit a lake.

When the inputs exceed the outputs, water is stored in the lake. In times of drought, evaporation, tributary outflow and groundwater discharge result in a reduction of the lake water level.

Quiz Yourself

1. Name several inputs and describe how these inputs combine to add water to a lake.

2. Name some outputs and explain how lake water levels might be affected by these outputs.

3. What is the process by which plants return soil moisture to the atmosphere?

4. Draw a miniature water cycle. Label all parts of the cycle.

Vocabulary

atmosphere
circulation
domestic use
groundwater
groundwater recharge
industrial use
infiltration
input
output
precipitation
runoff
surface discharge
surface streams
transpiration
water cycle

Complete Chapter 3 Exercises, located on page A-3. Also, Experiment 7 should now be completed.

Chapter 4. Food Chain

An essential element of a ***food chain*** is that each individual organism is of equal importance to the ecosystem. The term to describe this concept is ***interdependence***. You may have already learned of ideas related to a food chain, such as a food web or a food pyramid. A food web is made up of several food chains. A food pyramid describes the energy that is exchanged when an animal eats a plant or another animal.

We will describe the food chain of a typical lake, Lake Clear. In Lake Clear, the food chain begins with a very productive element in the total chain, that of ***primary producers***. Primary means first in order. These are plants and plant-like algae, or ***phytoplankton,*** that take in carbon dioxide and water and, with the sun's energy, produce their own food in the form of a sugar. They then give off oxygen, an extremely important element for all aquatic animals. This process is known as ***photosynthesis***. Can you think of a reason why they are called primary producers?

Next in the chain are the ***primary consumers***, otherwise known as ***herbivores***. These animals, as small or as large as they may be, eat plants. The most populous of these consumers are the ***zooplankton***. These tiny animal-like organisms consume phytoplankton in large quantities. A common species found in Lake Clear is *Daphnia*. It is among the largest of the zooplankton. *Daphnia* are easily seen without the aid of a microscope. Simply

Figure 4-1. Examples of phytoplankton (top) and zooplankton (bottom).

Experiment 8

taking a large container and dipping it into the lake may yield some of these creatures. Tadpoles and insects in the lake also eat plants.

Following the primary consumers are the ***secondary consumers*** (meaning, second in order). They eat other animals, and are thus called ***carnivores***. Small fish such as minnows, crayfish, and the young of larger species consume zooplankton and insects as their source of energy.

In addition to secondary consumers, there is yet another level referred to as ***tertiary consumers***. Tertiary means third in order. These consumers may be carnivores, such as salmon, trout, bass and otter, and also include the ***omnivores*** (eat meat and plants), such as humans.

Lastly, an essential element in the food web is the ***decomposers***. Decomposers grow as they break down dead and decaying organisms into the essential elements of life, the ***nutrients*** required to sustain life itself. These nutrients, such as ***nitrogen***, ***phosphorus*** and other elements, are then accessible to many forms of life around them. The primary producers are the greatest immediate beneficiaries of this process, but the effects of the decomposition process are felt throughout the food chain. The primary producers, with help from the sun, use the nutrients to produce their own food, reproduce, and are then ingested by the primary consumers. These, in turn, are eaten by the secondary consumers. The cycle is continuous, and all forms of life are affected when population changes occur in any part of the chain.

Decomposers in Lake Clear live primarily at the bottom, generating the much-needed nutrients for the primary producers. ***Bacteria*** make up a large segment of the decomposer population in lakes. These bacteria basically reverse the equation of photosynthesis, taking the food and breaking it down while they use oxygen.

Let's take a look at an example of a lake food chain (below and *Figure 4-2*):

Primary Producer:	*Asterionella*
Primary Consumer:	*Daphnia*
Secondary Consumer:	yellow perch
Tertiary Consumers:	Large mouth bass
Decomposer:	bacteria

Try to generate food chains of your own. You can create some for marine life, life in the desert, life on the African plains, and so on. In each case the

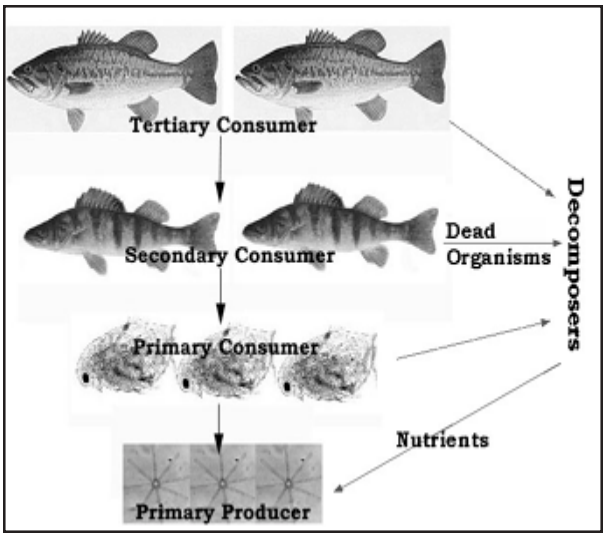


Figure 4-2. Example of a fresh water food chain.

interdependency of all the organisms in the food chain is apparent.

Experiment 9

In aging lakes, when the populations of algae and plants increase so rapidly that there are insufficient nutrients to sustain them, many algae and plants die and sink to the bottom. Bacterial action to decompose the algae reduces the amount of oxygen available to the larger fish, such as trout, and, as a result, many may die. Also, the plants may take up some toxic substances, where they can work their way up the food chain to harm tertiary consumers.

Experiment 10

Summary

In the food chain, the primary producers are the green plants. Photosynthesis plays an essential role in this process. Primary consumers are herbivores. Secondary and tertiary consumers are carnivores or omnivores. All life in a food chain is interdependent.

Quiz Yourself

1. In your own words, describe interdependency.

2. In your library, research the topic of decomposers. Try to illustrate two or three decomposers of your choice.

3. Which of the organisms in the food chain are the most productive? Give reasons for your response.

4. Explain how toxic substances might enter a lake food chain and eventually affect humans.

Vocabulary

bacteria
carnivores
decomposers
food chain
herbivores
interdependent
nitrogen
nutrients
omnivores
phosphorus
photosynthesis
phytoplankton
primary consumers
primary producers
secondary consumers
tertiary consumers
zooplankton

Complete Chapter 4 Exercises, located on page A-4. Also, Experiments 8, 9 and 10 should now be completed.

Chapter 5. Watersheds

The geographic region where all of the water in the area flows down hill to a particular body of water, be it a lake, a pond, a river, or a marsh, is known as a ***watershed*** (*Figure 5-1*).

If you were to look at the land surrounding a lake or a pond, you would see high and low spots. The high points of elevation surrounding a watershed form its boundaries. Scientists use ***topographic maps*** to determine the elevation of the land surrounding a pond or lake. Using these maps they can locate the boundaries of a particular watershed.

You can imagine a watershed as an enormous funnel. As you pour water into the funnel, its sides direct the water to the bottom of the funnel. The top edges of the funnel are like the boundaries of the watershed, or the mountains and hills surrounding the body of water. Because of gravity, all precipitation flows over the land and down to the watershed's body of water, like the bottom of a funnel.

Watersheds are not separated, but are interconnected. Rain may fall on top of a high mountain. The water will flow downhill to a lake or river. Some will move as surface runoff and some will percolate into the ground and arrive at the body of water in the form of groundwater. The water will continue to flow

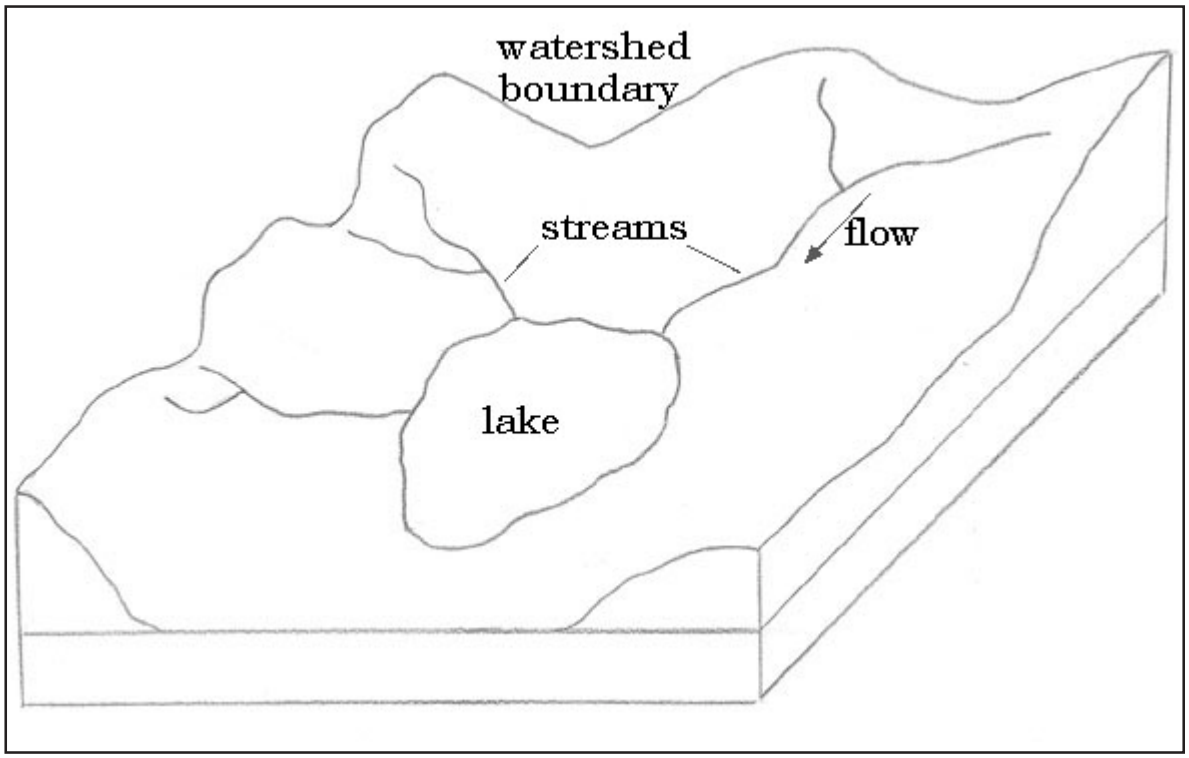


Figure 5-1. A watershed, with high and low points, surface streams and a lake.

through the lake, exiting by surface discharge at the lake's outlet, which may, in turn, be a tributary for another watershed downstream, and so on. Ultimately, all water will make its way to the sea, with some evaporating along the way.

In order to monitor the health of a particular body of water, scientists will measure the flow of water into a lake and run tests on that water that may help indicate the relative health of the lake or stream.

Because of the "funnel effect," anything that happens in a watershed may eventually affect the quality of a lake. In some instances, a lake may serve as a community's water supply. In such a case, it is imperative that all people understand that if you pour a substance into the ground it does not go away...it ultimately ends up in a body of water!

The idea of any activity eventually affecting a body of water within a watershed does not only apply for toxic materials. Trees, shrubs and plants help to hold soil in place with their roots and take in any nutrients or pollutants that may be washing over the land. If there is removal, or ***clear-cutting***, of trees occurring within the watershed, how do you think sediments in the form of soil and sand and their associated nutrients will be washed down the drainage basin and into the lake?

Sedimentation can stifle plant growth, cover up eggs, kill fish and other lake wildlife, and reduce the quality of the water in the lake. The color and odor of the water will be affected as well.

All the septic systems that exist in a particular watershed drain the wastewater towards a body of water. This wastewater, although clear of any solids, contains phosphorus and nitrogen. These nutrients can drastically change the nature of a lake.

Another way that nutrients can make their way into the watershed is through the fertilization of crops by farmers. Corn, for example, requires very high amounts of nutrients. Therefore, if a lake is surrounded by farmland, controlling the amount of nutrients that reach the lake can be very difficult. In particular, chemical granulated fertilizer, a type that most farmers use, very quickly finds its way into surface streams and groundwater, eventually ending up in the lake or pond.

Property owners who live on or near a waterbody may fertilize their lawns each spring and fall. This practice will contribute an excessive amount of nutrients to that lake. So, if you are riding in your boat past lake front homes

and you notice that the lawns are a rich, green color, keep in mind that green lawns can lead to green lakes!

In many states, laws have been passed to limit the amount of phosphates in laundry detergents.

Why, you may ask, are nutrients in particular a problem? [After all, all living things need nutrients.] In a small pond or lake with shallow depths, the addition of extra nutrients causes a remarkable increase in the production of algae and other aquatic plants. Aquatic plants, such as milfoil, water lilies, and other plants, multiply much more rapidly than normal. This can be bad for the animals and other plants that live in the water. More plants means less room for the animals to swim and move around, more shade that can stop sunlight from reaching bottom-dwelling plants, and less oxygen in the water when the plants die and are decomposed.

In some cases, depending on the right conditions, too many nutrients may actually cause an ***algal bloom***. An algal bloom is an abnormal increase in the population of algae.

There is one particular type of bloom you may have seen in lakes near your town. It appears as a thick, green carpet over the surface of the water. This is commonly caused by ***blue-green algae***. Once the algae have reproduced beyond their ability to sustain themselves, a large number of the algae begin to die off and the resulting odor can best be described as similar to rotting eggs.

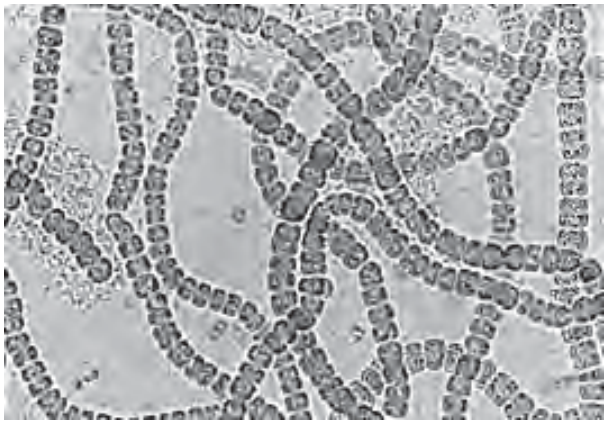


Figure 5-2. An example of blue-green algae: Anabaena.

Even when not carried to this extreme, excessive amounts of nutrients leaching into a lake or pond may gradually, over a number of years, cause the lake to age prematurely. We will discuss the aging process of lakes in Chapter 8.

Experiment 11

Summary

A watershed is a region of land surrounding a body of water where all the precipitation that falls into the area eventually ends up in the bottom of the watershed at a lake, pond, river or wetland. Watersheds are connected.

The water quality of the body of water is a direct indicator of the kinds of activities that are taking place in a watershed. Any material that is poured into the ground or into surface waters will eventually flow to the lake.

For example, if toxins are being buried in open or leaky containers, the material will end up in the lake through the groundwater. If there is clear-cutting of trees within the watershed, an excessive amount of sediments in the form of soil, sand and debris will wash into the lake. Malfunctioning septic systems leach nutrients and other materials into the lake. When crops and lawns are fertilized, especially when done with chemical granulated fertilizers, the aging process is sped up.

So, we now are aware that a watershed is like an immense funnel that directs the flow of all materials to the bottom of its basin and pollutants follow the same path. Everybody lives in a watershed!!

Quiz Yourself

1. What common object is used to describe the idea of a watershed? In what ways does this object compare to a watershed?

2. What happens to precipitation that falls within a particular watershed?

3. What if a person happened to dispose of his automobile oil by dumping it into a pit that he has dug in his back yard? Where would it eventually go?

4. Joe Haphazard is having trouble with his septic system. He has hired a company to pump out the tank several times this year. However, Joe still has a problem. He decides that it really wouldn't do any harm to put the sewer directly into the fast moving stream on his property. He rationalizes that since the water is moving fast, the sewer water can't harm the stream. Is he right? What is the problem with his logic? Hint: Try to imagine where that stream flows.

5. What is phosphorus? What is nitrogen? In what way may these actually pollute a lake? Can you imagine ways, other than those listed in the text, that excess amounts of these might create problems in a watershed?

Experiment 12

Vocabulary

algal bloom
blue-green algae
clear-cutting
topographic map
watershed

Complete Chapter 5 Exercises, located on page A-5. Also, Experiments 11 and 12 should now be completed.

Chapter 6. Pollution

There are many kinds of ***pollution*** that may be a problem to a lake and its wildlife. Pollution is defined as the introduction of harmful substances or products into the environment. Using that as a definition will lead us to consider a host of pollutants in this chapter. As we discussed in the preceding chapter, phosphorus and nitrogen, even though they occur naturally, can be serious contaminators of lakes.

In addition, we will discuss some of the ways that human activities can negatively impact water quality in a watershed. We will examine various sources of pollution. Lastly, we will introduce you to some of the ways a community as a whole may be adding pollutants to the environment. Popular notions of pollutants as only hazardous wastes and dangerous chemicals are a part of the overall problem.

Interestingly enough, many people who pollute our fragile ecosystems have no idea that what they are doing is harming the environment. Sometimes, awareness that certain activities are environmentally harmful is all that is needed to correct a problem. For example, some people are not aware that dumping hazardous wastes such as paint, pesticides, and petroleum products down the toilet or sink can be harmful to the nearest lake or river, in addition to damaging the septic system. If the person has a septic system and leach field, then the material will eventually end up at the bottom of the watershed. In this case, simply explaining the problem to the individual and what to do to solve that problem correctly may be all that is needed.

In other cases, however, the polluting activities are economically beneficial to the parties involved. In other words, someone might stand to make money by polluting. In this instance, there may be an owner of a company that generates hazardous wastes who does not want to pay the large fee for dumping his toxic materials at a regulated hazardous waste disposal facility. Instead, he sends off one of his employees to dump it at a remote location. Here, a simple explanation will not stop the problem. There must be law enforcement officials involved in prosecuting these individuals.

Unpermitted clear-cutting of forests within the watershed is another example of damage to the environment for the sake of short-term profit. Anyone observing such activity should report it to the nearest environmental protection agency.

As a result of these and

Figure 6-1. Stop pollution!

other activities, there must be vigorous efforts to educate the public concerning the kinds of activities that can be harmful to the water. Let's look at some of those activities now.

Development of hotels, condominiums or homes of any type usually involves disturbances of the land. Sometimes that may be a bulldozer moving earth to accommodate the design of the home and the surrounding land. Generally, it also involves the cutting of at least some trees. In each case, the results will be the same: erosion, which leads to an increase in the amount of sediments that wash down into a nearby lake.

These sediments carry large amounts of nutrients. The erosion that results from tree cutting activity can be detrimental to the health of the lake as well. It is a very common feeling for most people when they buy their property to look out the window, see their view blocked by some trees and think, "Gee, those trees are old and lovely, but wouldn't the view be wonderful without having to look between the limbs?".

What might be your response to that thought? What do you predict will happen if the owner does remove the trees? You know the right answer...those trees prevent the shoreline from eroding, soak up nutrients before they reach the lake and help protect the lake from contamination. A favorable argument to save the trees, besides the obvious, is that the trees provide privacy. There are ways to cut limbs so as to provide a view, but leave the tree trunks in place.

Another notion that a lake front owner may have is to make a sandy beach where there was none before. Sand reduces the depth of the lake when it is placed in the water, smothers bottom habitat for wildlife, and also adds nutrients, which stick to sediment particles.

If you have a septic system, please be aware of the following: You shouldn't put anything into the system other than what was intended. Flushing paint,

kerosene, gasoline, pesticides or other hazardous wastes into your system is illegal, as well as harmful to the system. These materials will also contaminate groundwater supplies and, eventually, the nearest waterbody.

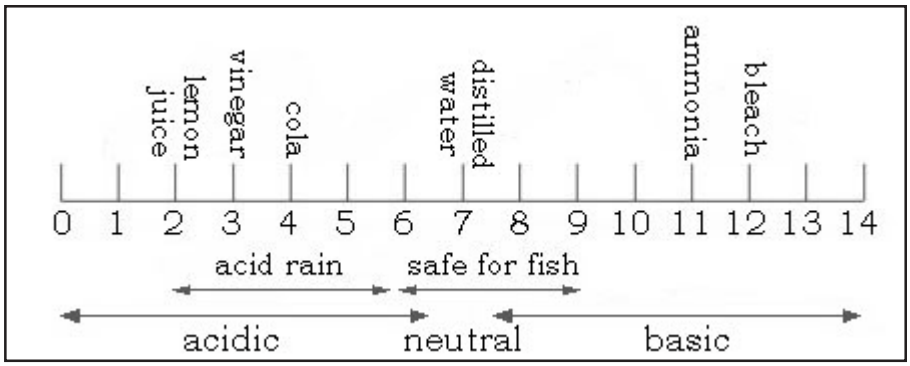


Figure 6-2. The pH scale.

Acid rain continues to be a major environmental problem in various areas of the country, like the Northeast.

Acid rain is made up of sulfur dioxide (SO_2) and nitrogen oxides (NOx). Sulfur dioxide is primarily produced by fossil fuel burning plants that generate electricity. Nearly 50% of the nitrogen oxides are generated by fuel burning vehicles. Everyone who drives and rides in an automobile, as well as buses, trucks and other forms of motorized transportation are contributing to this pollution. Automobile gas vapors rise into the atmosphere where winds carry them along natural weather lanes. The sun, meanwhile, acts on these chemicals, and when moisture is added, acid rain falls. What qualifies precipitation to acquire the dubious distinction of "acid rain"? Refer to *Figure 6-2*.

Experiment 13

Acid rain falls as precipitation regularly in certain areas of the United States and the world. Trees have been damaged in many parts of the Northeast U.S. and Europe. Even seemingly durable materials such as stone

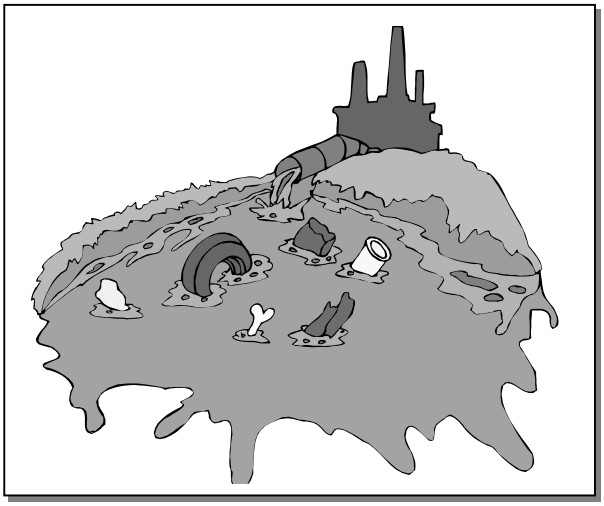


Figure 6-3. Point source pollution.

statues and metal parts of buildings have deteriorated as a result of acid rain. The degradation of the Statue of Liberty in New York City is one example of the damage that is a consequence of acid rain.

The effects on lakes have been profound. In the Adirondack Mountains in upstate New York, many lakes no longer have fish due to low pH waters. The species of fish that can survive or reproduce in high acidity (low pH) conditions are few.

As we mentioned earlier, farms and businesses as well as towns and cities may also be contributing to the pollution of our lakes and ponds. One of the ways scientists classify pollutants is to refer to them as either ***point*** or ***nonpoint sources*** of pollution. A point source is the addition of a pollutant directly into a lake, river or other body of water. Point source examples include wastewater treatment facilities, industrial waste discharge and a septic pipe that dumps straight into a body of water. These are sources that are usually traced to a pipe. These point sources were the greatest threat about 30 years

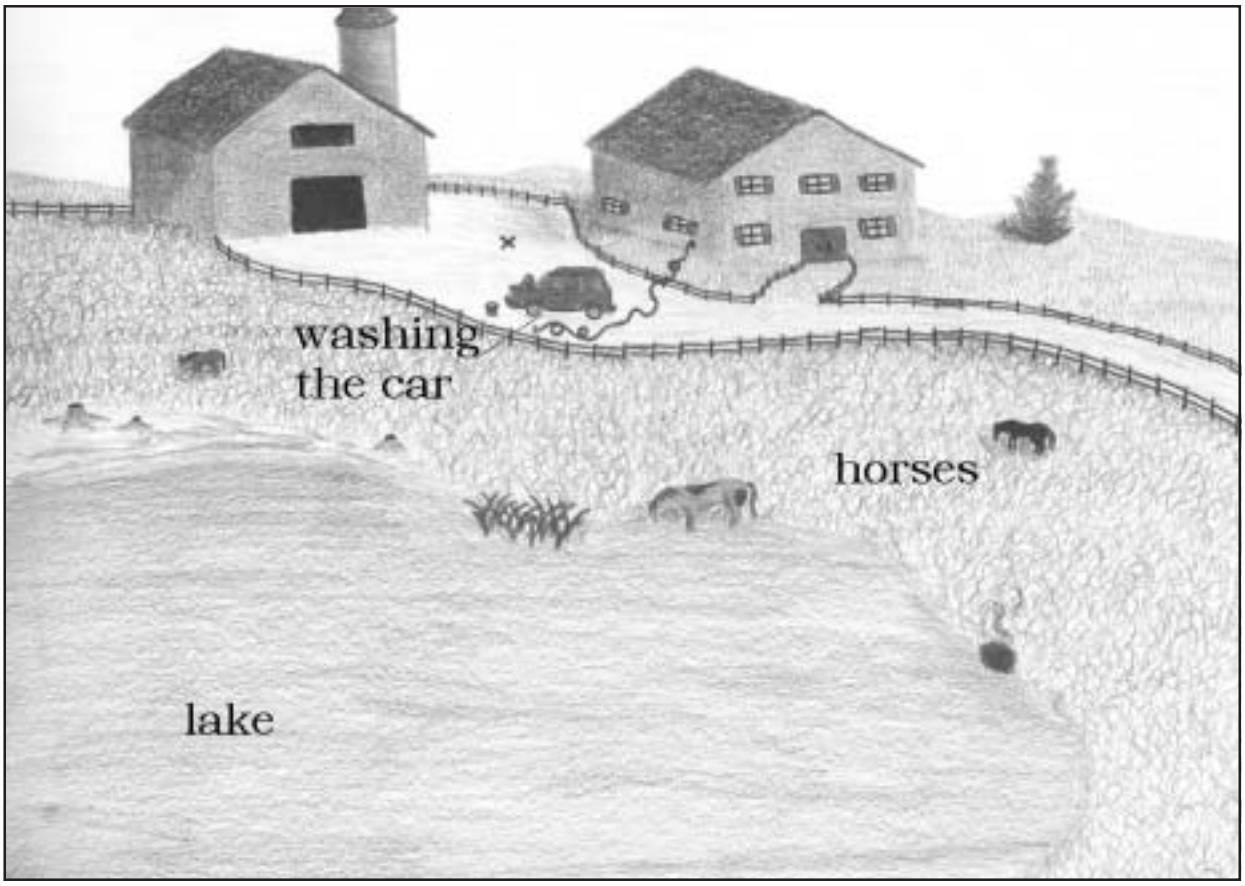


Figure 6-4. Nonpoint sources of pollution.

ago (1960s and 1970s). Generally, these sources are now known and regulated by law. It is the nonpoint sources of pollution that are most difficult to find.

Nonpoint sources of pollution are those that can't directly be pinpointed. They are released from many activities, including runoff from farm fields, leaching septic systems, fertilized lawns, roads, and almost every other type of land use. This is where communities find themselves having to make choices concerning the treatment and removal of the sources of pollution. The answers and the decisions are not always easy.

With nonpoint sources in mind we'll talk about an example using sanitary landfills as a method of disposing solid waste (otherwise known as garbage). In the past, many towns, particularly the smaller ones, maintained their landfill sites in an uncovered state. In this situation, each time it rains, any hazardous materials leach (infiltrate) into the soil and make their way into the groundwater. Just think of all the things we put in the trash, food, chemicals, diapers, soap and all sorts of other things. Now, picture these things decaying and mixing with rainwater and finding their way into the water cycle.

Communities are now required to set up regional transfer stations where all of an area's waste may be incinerated or disposed of in a less harmful manner. Encourage local officials to move to the regional disposal method. Your lake will demonstrate its appreciation!

Another way local towns contribute to diminished water quality is by heavily salting the roads and dumping snow into rivers or streams during the winter months. Why, do you think, would these activities negatively impact a water body?

Other nonpoint sources of pollution include stormwater runoff from town drainage storm lines, as well as fertilizers used for gardens, lawns and crops. These sources account for additional nutrients within a watershed. Soil erosion from poorly maintained dirt roads or road ditches and culverts can add sediments, as well as nutrients and other pollutants, to a water body. Lastly, marinas along a lake can add pollution to the lake in the form of gasoline, oil, and phosphate-based cleaners.

As you can see, much of our modern life and seemingly innocent activity can have a detrimental impact on the water quality of a lake. Remember, a lake is a delicate balance of nutrients. Its waters move much

more slowly than a river. Therefore, more nutrients enter a lake than leave, making a lake a

Experiment 14

"sink" of sorts where nutrients settle out. Whatever is put in the lake will take time and money to correct. It's far more cost effective to preserve a lake than to restore it once it has been damaged.

Summary

Pollution can take many forms, whether it's household products being dumped down a sink, erosion from a recently clear cut hillside or gas vapors from automobiles. All of these examples may negatively affect a body of water. Chemicals from household products will poison fish and other aquatic organisms; sediment from erosion will cover important lake bottom-dwelling organisms; and, gas vapors will reach the atmosphere and, eventually, return to the earth as acid rain.

There are two types of pollution sources: nonpoint and point source pollution. Most point sources have been identified and are now being regulated. These include waste water treatment facilities and industrial plants. Nonpoint sources are more difficult to find. This type of pollution comes from land uses, like a farm (pesticides and fertilizers may run off into a stream), septic systems (nutrients can leach into the groundwater) and landfills. Educating the public about these and other pollution sources is the best way to reduce the polluting of our fresh waters.

Quiz Yourself

1. Imagine yourself spending your first summer at your family's new lakefront home. You are sunning yourself on the deck and you notice your next-door neighbor backing a dump truck to the water's edge. He's about to dump a load of sand on the shore. Why shouldn't he?

2. Name some of the ways in which a town or city may contribute to water pollution.

If you live in an area where it snows, check with your local public works department to see if they dump excess snow into a lake or river.

3. What can a family do to reduce nitrogen oxide emissions into the atmosphere? What can a family do to reduce the amount of nutrients they contribute to the environment?

4. Think back to Chapter 1 regarding the formation of lakes. Do think that with increases in acid rain more solution lakes may be formed?

5. Find out what type of sewage disposal system is used for your home. If your home is connected to a municipal treatment plant, ask if the plant will give a tour to your family or class. If your home is supplied by a septic system, discuss with your family how often it is pumped. Identify where the leachfield is located and check for soggy or wet areas periodically.

Experiment 15

Vocabulary

acid rain
non-point sources
point sources
pollution

Complete Chapter 6 Exercises, located on page A-6. Also, Experiments 13, 14 and 15 should now be completed.

Chapter 7. Non-Native Species

As we mentioned in the last chapter on pollution, there can be many different substances that can affect the health of a lake. These may not only be things like the chemicals and sediment particles that we just discussed, but they can actually be the aquatic plants and animals in the lake.

Most lakes have a wide variety of plants and animals that make up the food chain. Both microscopic and larger-sized aquatic plants and animals are an important part of any healthy lake. The aquatic plants provide a food source and habitat for many animals. The animals in the lake are important for eating the plants and for providing food for other animals.

Many of the plants and animals found in a lake or pond can be considered ***native*** to that waterbody, meaning that they have been in that system since it was created. When either a plant or animal is introduced into a lake or pond from outside of that system or region, it is called a ***non-native species***.

Occasionally non-native species can be beneficial to a lake or pond. For example, different types of fish stocked into a waterbody enhance the fish populations for fishermen and

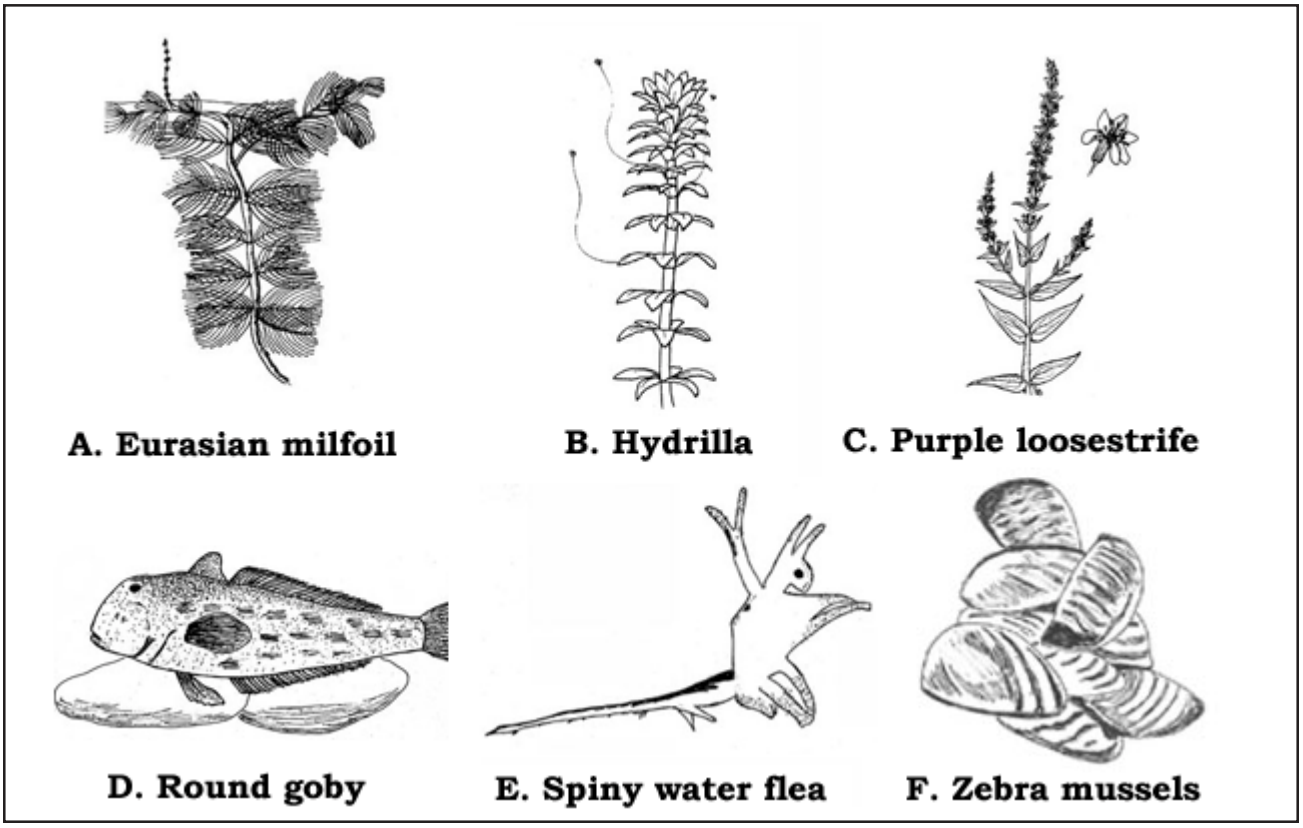


Figure 7-1. Examples of 6 non-native species.

anglers. In most other cases, however, non-native species are considered nuisance species and should be kept out of a lake.

Non-native species can be found in many shapes and varieties. Most non-native species that plague lakes and ponds are of the plant variety, but there are some nuisance animals such as fish, zooplankton and mussels. Some examples of these non-native species are pictured in *Figure 7-1*.

So why are non-native species a problem? You may have learned that a diversity of plants and animals enriches a habitat. What harm could a new species cause?

Non-native species can negatively impact a waterbody because these plants and animals can literally take over a lake, leaving less habitat and food for native species. If they grow thickly, they may even cause a safety hazard that would affect people's swimming. These ***invasive species*** don't have any natural ***predators*** to keep them under control.

Our native plants and animals, because they have evolved with the lake, have an established set of predators, such as animals, bacteria and diseases, that will keep them from taking over a waterbody.

Because non-native plants have not evolved with the lake, they do not have any predators present in this new environment to keep them in check. Additionally, many of these non-native animals have the ability to reproduce quickly, far faster than native species. Because of increasing numbers of non-native and invasive species, the food chain of the lake may be irreversibly affected.

For example, non-native aquatic plants have grown to be a large problem in waterbodies

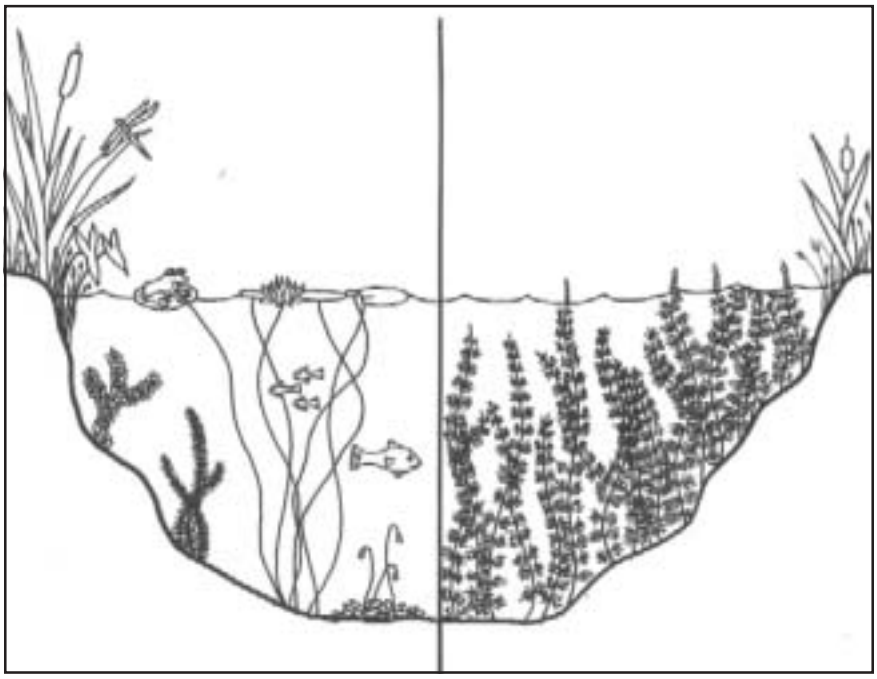


Figure 7-2. Native vs. non-native vegetation growth.

across the country. Each region of the country may have a different plant that is more problematic than in other areas, but for the most part, the impacts that these species have on lakes is devastating.

Many of these non-native plants are used in water gardening or in home aquariums. They can be bought at local stores and through mail order catalogs.

Common non-native and invasive plants like ***Eurasian milfoil*** or Hydrilla can grow quickly in a lake if favorable conditions exist. Some researchers have estimated that these non-native plants can grow an inch a day during the growing season. This is much faster than most native plants. Because of this fast growth rate and lack of predators, milfoil or Hydrilla can take over a lake in a manner similar to what is shown in *Figure 7-2*.

On the left side of the picture there is a healthy mix of plants and animals in a lake. On the right side of the picture the lake is dominated by non-native plant growth. Fish, frogs and other wildlife populations are reduced due to the lack of habitat. The food chain is ultimately impacted, resulting in a lake that is in poor health.

Another plant that has spread across the United States

Figure 7-3. Birds find shelter in a natural marsh habitat.

is ***purple loosestrife***. This plant has a pretty purple or dark pink flower that blooms in mid to late summer, and can be found along the edges of streams, lakes and throughout wetland habitats.

Because it is so pretty, this non-native plant was popular in the gardening trade for a long time. In fact, the plant was brought over from Europe for just that purpose in the late 1800s.

Each purple loosestrife plant can produce more than two million seeds that are the size of pepper grains. Try putting a small pinch of pepper grains in your hand and blowing them into the air. Purple loosestrife seeds, like the pepper, can be easily blown across the land, allowing them to spread very quickly.

But purple loosestrife is so pretty, why should we be concerned? Purple loosestrife is an invasive species that takes over native marsh habitats where cattails and other native plants grow. Many species of birds and mammals that used these

habitats when they were in their native condition are left homeless after the purple loosestrife takes over. This non-native plant does not provide good shelter or food for the animals that once lived in the marsh habitat.

Aquatic nuisance animals can also pose a serious threat to our lakes. Many different species of fish and ***invertebrates*** (animals without backbones), like zooplankton and mussels, are becoming problematic in our lakes and ponds.

Several of these non-native animals were brought in from other countries in ballast water of large ships that crossed the ocean. Ballast water is used to weigh down and stabilize large ships when they have no cargo on board. As ships are unloaded they take on ballast water to stabilize them on the ocean. As they come into a new port they empty their ballast into the water, including any organisms that may have been picked up from the water in another area of the world. It is estimated that thousands of non-native species are introduced into the United States each year.

Once these organisms enter our waters, possibilities abound for them to become nuisance species. ***Zebra mussels***, for example, have proven to be a costly and ecological threat. These black and white striped mussels, about the size of a pistachio nut, have sticky strands that are secreted from their shells. These sticky strands allow the mussels to adhere to surfaces in the water such as buoys, boat hulls and water pipes. Factories and power plants that may draw water in for use in cooling engines or for drinking water may not be able to bring water in due to clogged pipes. The shells of the mussels also wash up on beaches and can be so sharp that they cut the feet of people using the beach.

Zebra mussels not only stick to foreign surfaces, but they can stick to each other, forming mats of mussel growth more than three feet thick on surfaces. Imagine going to the lake one day to enjoy a boat ride and your boat is missing. No, it wasn't stolen, but it was sunk under the weight of all of the zebra mussels that were growing on the bottom of the boat. This actually happens!

Other invasive and non-native animals include species of fish. Brought in by ballast water, the ***round goby***, a native of the Black and Caspian Sea in Europe, has proven to be a nuisance in the Great Lakes Region of the United States.

The round goby threatens native fish populations because it is a ***competitive feeder*** with native fish, eating available food so quickly that there is none left

for native fish. Additionally, the round goby lives in the prime egg laying areas of native fish species, ultimately reducing the number of native fish due to lowered reproduction.

Yet another non-native species causing problems is the ***spiny water flea***. This *Daphnia*-like member of the zooplankton, which is a native to Great Britain and northern Europe, is much larger in length than the native *Daphnia* that is an important member of our native food chain. Because of this, the spiny water flea eats the native *Daphnia*, thereby disrupting the food chain.

The next step of the native food chain is for small fish to eat the native zooplankton. Due to the larger size and long spike-like tail of the spiny water flea, small fish are unable to eat this non-native species, allowing this invader to keep growing and eating the native *Daphnia*. What happens? Over time, the fish populations will be impacted because the smaller fish will not get enough food, and if the smaller fish decline in numbers, the food source of the larger fish will decline as well. There is ultimately a short-circuit in the native food web, permanently altering the waterbody in countless ways.

Unfortunately, once in a waterbody these non-native species don't always stay put. Recreational boating can bring these invasive species from lake to lake, spreading the problem throughout states, regions, and across the country.

To prevent further damage to our lakes from these and other species, many states are beginning to regulate activities that are conducted with non-native species. Ports of entry into the United States are putting restrictions on ballast water dumping, while many plant nurseries and aquarium retailers are restricted from selling certain invasive plants like milfoil and Hydrilla. Bait dealers must also be careful not to introduce non-native species into lakes.

The recreational boater is also facing more regulations on how to appropriately remove these non-native plants and animals from boats, fishing equipment, and other recreational gear after exiting a lake that has invasive species (*Figure 7-4*). Many states are investigating the use of boat washing stations at or near boat launch sites. Boat washing

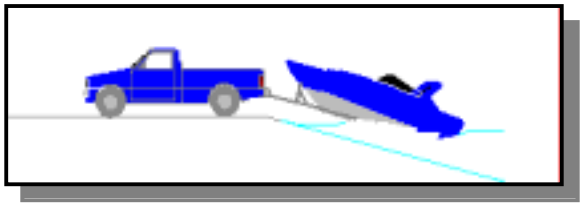


Figure 7-4. Always check your boat for non-native species!

stations may help to remove zebra mussels and aquatic plants from boats and trailers before launching and after pulling out.

Contact your local state government to see which invasive species are affecting the lakes in

Experiment 16

your area and what regulations your state has on these species that are threatening to disrupt whole lake environments.

Summary

Non-native and invasive plants and animals can be considered a type of biological pollution in a lake. These non-native species are introduced into a waterbody where they have no natural predators. This allows them to quickly take over the lake, changing the food web and affecting native species of plants and animals.

Quiz Yourself

1. You are helping your parents plant a summer flower garden. In a wildflower seed mix you read that purple loosestrife is one of the plants that is in the packet. Should you put those seeds in the garden? Why or why not?

2. You are out fishing on a lake one day when you notice that there are a lot of tiny black and white striped mussels growing on some rocks. When you leave the lake you decide that it is still early and you want to continue fishing, but on another lake. Is there something you should do when you pull your boat out of the water? Should you immediately launch your boat in another nearby lake?

Experiment 17

Vocabulary

competitive feeder
Eurasian milfoil
invasive species
invertebrate
native
non-native species
predator
purple loosestrife
round goby
spiny water flea
zebra mussel

Complete Chapter 7 Exercises, beginning on page A-7. Also, Experiments 16 and 17 should now be completed.

Chapter 8. Testing Lakes

In Chapters 6 and 7, we explained some of the ways in which a lake may be polluted. In this chapter we will look at the techniques and tests that scientists perform on lake water in order to determine the health of a lake. Lake water monitoring is the primary job of many fresh water biologists, or ***limnologists***, across the country.

Furthermore, volunteers who live on or near lakes serve in that capacity also. They are referred to as volunteer or ***lay monitors***. You can become a monitor for a nearby lake; find out more in the "Conclusions" section of this workbook.

We will begin with an introduction of the testing equipment that limnologists use to determine the quality of a lake as well as to ***classify*** that lake into one of three categories (this will be discussed in greater detail in Chapter 9). These pieces of equipment and the ways in which they are used are an essential part of the job of the limnologist.

In many ways, the work of a limnologist testing a lake is similar to a doctor examining a patient. The doctor seeks to determine the overall health of a patient by administering a series of tests. He or she draws blood, takes the patient's temperature, listens to the heartbeat, and takes a blood pressure reading, among other things. The doctor is a scientist as well, using very accurate measuring instruments and equipment to collect information on his or her patient. He or she is able to ***analyze*** all this information to determine the condition of the patient.

In very much the same way, a limnologist tests lakes. In this case, the lake is the patient, and although the lake itself is not alive, it is the home of many different living organisms. The limnologist uses precise scientific equipment to collect information about a lake. The limnologist, as the doctor, then determines the "health" of a lake. If something is wrong, then he or she can suggest a series of steps that will eventually improve the water quality (or health) of the lake. Limnologists use the following instruments:

Kemmerer Bottle (or Van Dorn sampler)
Secchi Disk
Flow Meter
Fathometer
Dissolved Oxygen Meter
Plankton Net
Integrated Sampler

Although they do use other, more sensitive instruments, our discussion will focus on those tools mentioned above.

Kemmerer Bottle or Van Dorn Sampler: This is a long, hollow, plastic bottle. It is the primary tool that a limnologist uses to collect water from a lake. Its unique design allows the limnologist to collect water samples from the various layers of the lake (refer to Chapter 2).

Some lakes have distinct layers because the temperature and the amount of light each layer receives is very different. Each of these different layers has a different chemical and biological makeup. As a result, it is very important that the scientist collects a sample from each layer of the lake.

Temperature plays a very important role in determining the boundaries of the various layers. In deeper lakes, as a person swims from the surface to the bottom, they can experience a drastic change in temperature as the water becomes colder and colder.

We can probably all imagine the differences in aquatic life from layer to layer. Remember, plants need heat, nutrients, and light to live and grow. Do you think there will be many plants at the bottom of a very deep lake? How about for a pond that is only two or three feet deep? Which do you think is

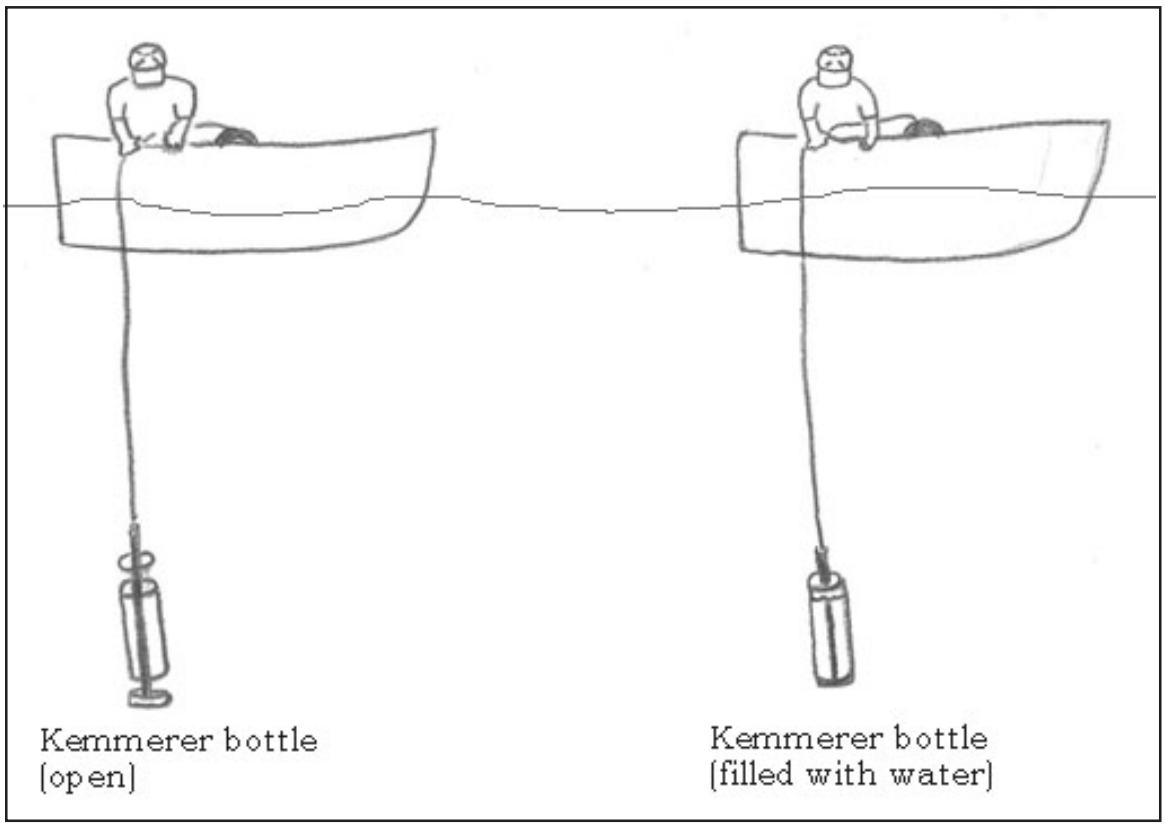


Figure 8-1. Kemmerer bottle, open and filled with water.

more likely to have plants or high populations of algae? Can you give reasons for your answer? Are there other factors besides depth that contribute to these high populations of algae?

As you can see, if some scientists took samples at the bottom and some at the surface, the results of their tests would be inconsistent. As a result, samples are taken with the Kemmerer bottle from the middle of each layer every time. These water samples are then bottled and transported back to the laboratory for a series of tests. These tests include an analysis of color, a pH test and a test for total phosphorus, or other nutrients.

Color is an actual visual measure of the color of the water. Color can be caused by naturally occurring metals like iron. Dead and decaying plants and animals can also stain the water. Limnologists use a scale to determine color. The lower the number, the clearer the water. The color scale includes light tea color, tea color and highly colored. Highly colored waters usually have mucky bottoms and are relatively shallow.

Some of the water sample is also used to determine the ***pH*** of the lake. As was illustrated earlier in the pollution chapter, a low number on the pH scale means high acidity. A pH reading of 7.0 is neutral and higher numbers are more alkaline, or basic. Each whole unit that pH decreases indicates an increase of ten times in acidity. That means a pH reading of 4.0 is ten times more acidic than a pH of 5.0, and one hundred times more acidic than a pH of 6.0. Acid rain has contributed to an increasing level of acidity in many lakes and ponds. Any pH reading below 5.6 is considered critical (see *Table 8-*

Category	pH (units)
Acidified	<5.0
Critical	5.0-5.4
Endangered	5.6-6.0
Satisfactory	6.1-8.0

Table 8-1. New Hampshire pH ranges.

Category	Total Phosphorus (ug/L)
Low (good)	1-10
Average	11-20
High	21-40
Excessive	>40

Table 8-2. New Hampshire total phosphorus ranges.

1). At these high levels of acidity, aluminum, a metal that is extremely toxic to fish, is activated and results in damage to the gills of some fish. Readings between 5.6 and 6.0 are rated as endangering because this level of acidity is toxic to some aquatic organisms. Any reading between 6.1 and 8.0 is thought to be satisfactory.

Total phosphorus is also measured in the water collected in the Kemmerer bottle. The word "total" is used in the description because phosphorus comes from living and nonliving organisms. It can be found in the sediments that flow into a lake as surface runoff. It can also be found in live or decaying plants and animals in the lake. This measurement includes all the phosphorus found in the lake, thus "total phosphorus" (*Table 8-2*).

The instruments used to measure phosphorus are extremely sensitive and are able to measure very small quantities of this nutrient, up to one part per billion (ppb) of each sample tested. That is comparable to one pinch of salt for every ten tons of potato chips or one drop of water in five hundred barrels of soft drink.

Can you remember our detailed discussion of nutrients in the chapter on pollution? How can a nutrient also act as a pollutant? What might large amounts of phosphorus and nitrogen do to a lake or pond? Take the time to write out a list of problems that can be caused by excess nutrients in lakes and also write down a list of potential sources of an excessive amount of these nutrients.

You will learn in Chapter 9 that lakes are referred to as "young", "middle aged", or "old" just like humans. When phosphorus and nitrogen enter into a lake from the watershed, or through the sediments in the lake itself, limnologists call this ***nutrient loading***. Nutrient loading can cause a lake to age before its time. The process by which a lake ages or evolves is called ***eutrophication***. A scientist needs to know the precise levels of nutrients in the lake and has to be aware of any increases. Usually, a large increase is evidence of additional point or nonpoint sources of these potentially harmful nutrients.

The scientist will then investigate the problem to determine the general location of the nutrient source and look for ways to reduce or eliminate the levels of loading.

Secchi Disk Transparency Test: In this test, the biologist uses a black and white plastic disk,

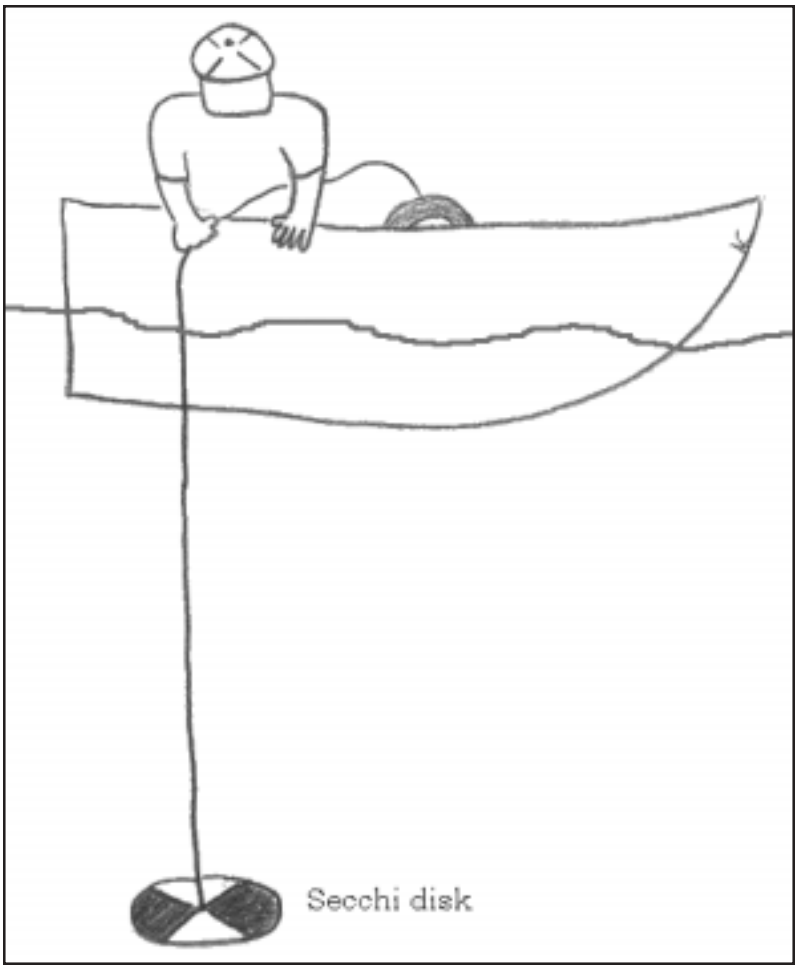


Figure 8-2. Secchi disk.

twenty centimeters in diameter, that is observable in the water (*Figure 8-2*). The scientist will lower the disk into the water over the side of the boat and note the depth at which the disk is last visible. This is a measure of water ***clarity***. A depth of less than 4 feet is considered poor, any depth between 5 and 15 feet, good and anything beyond 15 feet, exceptional.

Interestingly, many high quality lakes have Secchi disk readings greater than 35 feet. Not all lakes with high clarity readings are clean, however. Some are highly acidified and are not biologically productive. In addition to natural factors, poor Secchi disk readings are sometimes due to high populations of algae caused by high nutrient loading, or increased levels of sedimentation due to development activities within the watershed.

Flow Meter: A flow meter is used to measure the amount of water entering a lake through its surface streams and the amount of water leaving a lake through its outlets. The flow can be measured in cubic meters of water. The flow meter has a long rod with a probe at the base (*Figure 8-3*). The probe can be adjusted to the correct height (usually the mid depth of the sample location). The limnologist will choose a point in the stream where there is an unobstructed flow of water. The presence of rocks or debris could make the measurements inaccurate. He takes readings at intervals across the stream and determines the amount of water moving into the lake every minute. From that, he can easily compute the total for the day by

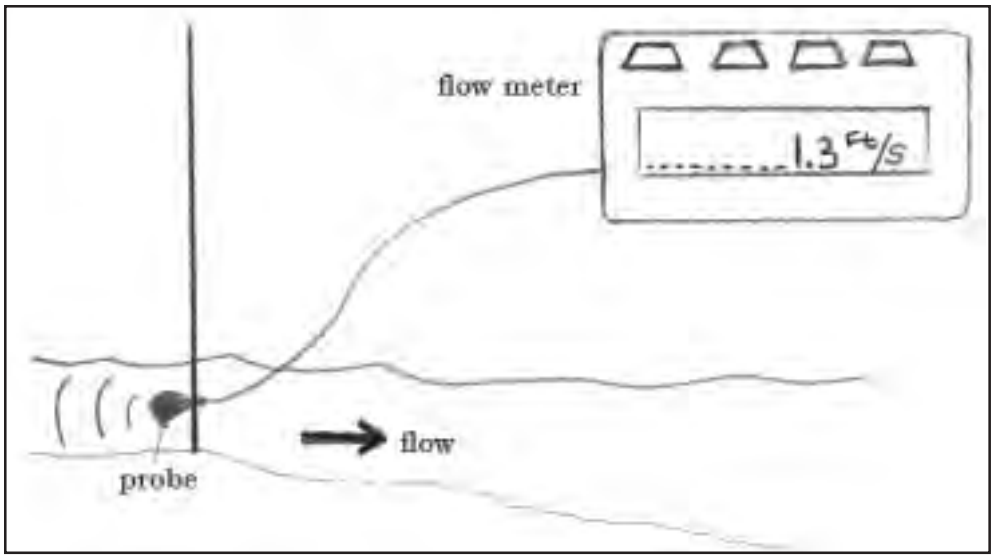


Figure 8-3. Flow meter. A flow meter is used to determine the rate of flow of a stream or river.

using simple multiplication.

In actuality, the time it takes for a volume of water equal to the lake's volume to pass through the lake is called the ***flushing rate***. As you might imagine, the more time that nutrients spend in a lake and increase algal and plant growth, the greater chance the overall quality of water will be affected. The lake that has large amounts of water moving through in a relatively short period of time will, in the long run, avoid more problems than the lake that is slow to flush out nutrients.

Fathometer: In previous readings you may have come across the word "fathom". Historically, sailors used to measure rope by holding a rope in both hands and stretching out their arms fully. This length is approximately six feet. Sailors estimated the depth of the water by tying a heavy object onto the rope and throwing a known length of rope into the water. When the rope slackened, they knew the depth of the water. Although anyone can still use that ancient method to measure depth, modern scientists use a ***fathometer*** (*Figure 8-4*). This is an electronic device that sends signals to the bottom of the lake; the signals bounce off the bottom and return to the surface. The instrument is calibrated to measure the amount of time it takes for the signal to travel a certain distance. In this way, the fathometer is able to give the user a read-out in feet or meters. The limnologist constructs a

Experiment 18

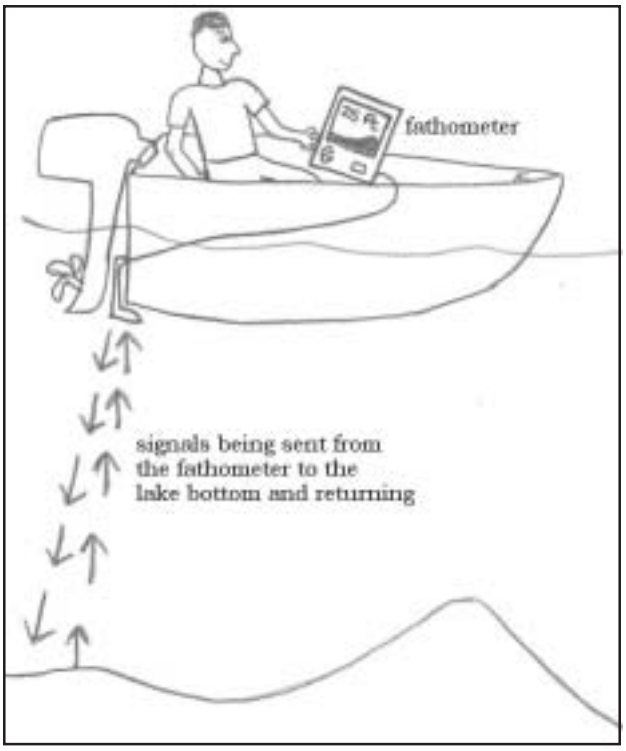


Figure 8-4. Fathometer. A fathometer is used to determine depth in a lake or pond.

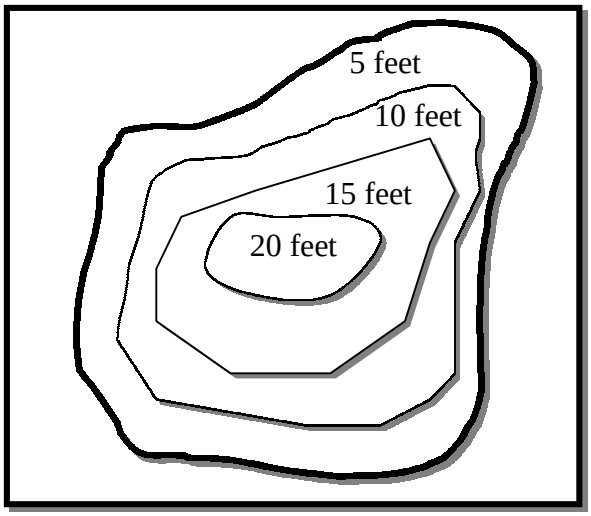


Figure 8-5. Bathymetric map.

bathymetric map (*see Figure 8-5*) to show the various depths of the lake in different locations. The depths are then recorded on an outline map of the lake. From these, the biologist can "see" the depths in a pond or lake.

Dissolved oxygen meter: This instrument, which has a probe on a cable, is used to measure the amount of oxygen in a lake as well as the temperature at the lake's deepest spot. This is a very important instrument in determining the overall water quality of a lake. When a large population of algae dies and settles to the bottom the decaying action of the bacterial decomposers uses up much of the available oxygen (remember the food chain). When the bottom layer becomes devoid of oxygen, bottom-dwelling organisms such as scavengers and decomposers die off.

If a lake has a mucky bottom, it is more likely to have low levels of oxygen at the bottom. Why is that important, you might ask? The answer is that fish need oxygen to breathe. Some fish need very high levels of oxygen if they are to survive. Salmon and trout are two of the more important species that need that kind of oxygen availability. In addition, these fish also require temperatures of less than 70°F and like to swim in waters with a temperature range of 50˚F – 60°F.

Sandy bottoms have low bacteria and decaying matter and, as a result, high amounts of oxygen. It is the decaying of

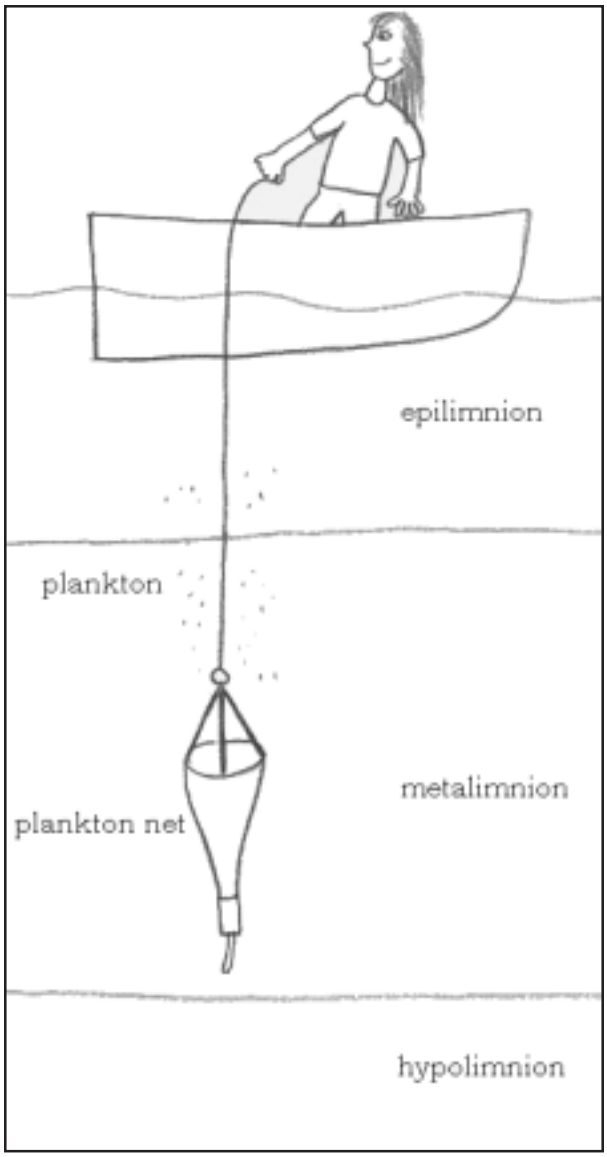


Figure 8-6. Plankton net. A plankton net collects zooplankton and phytoplankton, typically from the mid-metalimnion to the surface.

plants and animals in the mucky bottomed lakes that uses up the available oxygen. These lakes generally are shallower and have warmer temperatures. Fish such as perch and bass are more common in these warm water lakes.

Plankton net: This fine mesh net is slowly pulled from the middle layer up to the surface, collecting phytoplankton and zooplankton along the way. Because plankton need light to grow, most of the plankton in a pond lives at the upper levels of the pond. If the population of plankton is high, a lake is said to be ***productive***.

In a lake, however, being productive isn't necessarily beneficial. Based on what you've learned so far, why do you think this is true?

Integrated sampler: One measure of a lake's production is the amount of chlorophyll-a, which a pigment found in phytoplankton. The limnologist lowers a long tube, called an ***integrated sampler,*** down to the middle layer of the lake. The tube is then pulled up to the surface and the water in the tube is collected in a sample bottle. Because the chlorophyll-a is found within the phytoplankton, this test yields an accurate measure of the phytoplankton within a lake.

We will see that increased levels of plant growth, vascular as well as algal, are signs of aging. What did we call this aging process? Generally, as lakes age, the quality of the water in the lake is reduced. The bottom gradually turns from sandy to mucky. Why do you think this occurs? What

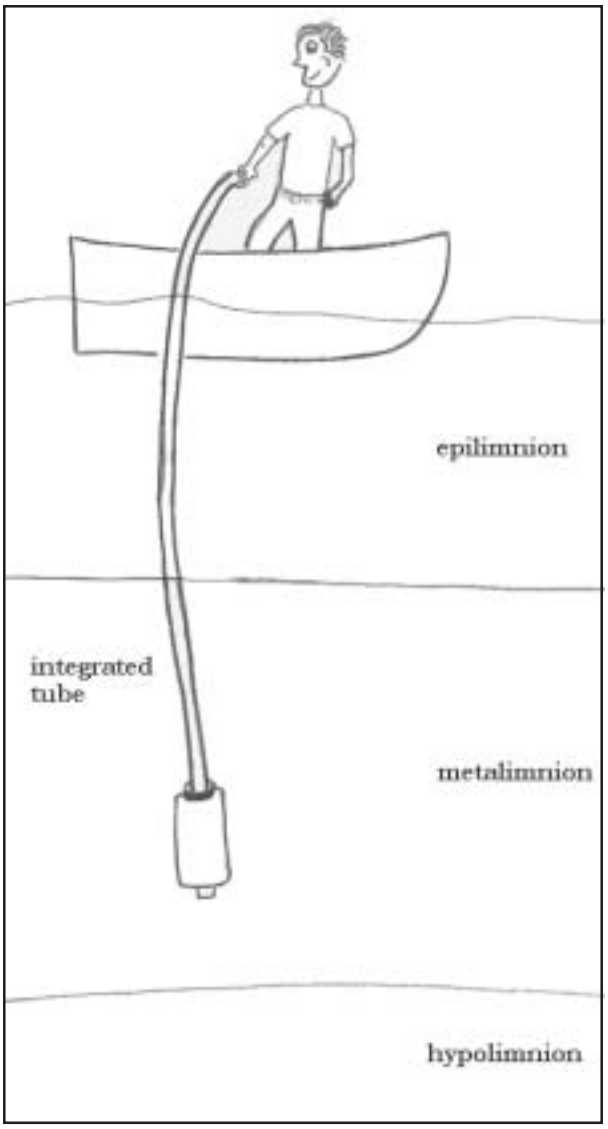


Figure 8-7. Integrated sampler. An integrated sampler collects water samples to determine the amount of chlorophyll-a present in a lake or pond. The sample is typically collected from the surface to the mid-metalimnion.

if this continues for many years?

The amount of bacterial action on the decaying plants and animals is increased and the levels of oxygen are reduced, thereby limiting the number and species of fish that can live in the lake.

The lake gradually begins to "fill-in". This process may take hundreds of years, but the artificial introduction of nutrients, typically total phosphorus and nitrogen, and sediments can speed up this process.

Scientists conduct the tests mentioned in this chapter and many others on a lake to determine its health, as well as to see any changes in the lake over time. They use a variety of instruments to gather information about the lake. They analyze the data collected from the lake in the laboratory and record the information in logbooks. Why do you think they record this information? How do records help them do their work?

Summary

To summarize, a limnologist is concerned about a number of factors when assessing a lake. These factors include: depth, the level of dissolved oxygen, the temperature, the amount of nutrients in the surface streams and lake, the transparency of the water and the production within the lake.

Limnologists utilize a variety of instruments to obtain data on each of these factors. The results of these tests are compared to the lake over time and to other lakes.

All of this information is put

together and forms the basis for a classification system. In the same way that animals, plants, insects and minerals are classified, so are lakes. As we talked about earlier, these three groups represent the lake aging process: young, middle aged, and old.

In the next chapter we will look at the names for these three classes of lakes and we shall see how the results of the testing lead to the classification of a lake.

Quiz Yourself

1. Now that you have the background to think about eutrophication, can you explain why increasing the amount of nutrients and sediments that enter a lake would cause that lake to age prematurely?

2. Why do you think it is important to know how much water is flowing into and out of a lake? What if nutrients such as phosphorus and nitrogen were to remain in a lake for extended periods of time? What if those nutrients were to quickly move through the lake and into the outlet?

Vocabulary

analyze
bathymetric map
clarity
color
eutrophication
fathometer
flushing rate
integrated sampler
lay monitor
limnologist
nutrient loading
pH
productive

Complete Chapter 8 Exercises, beginning on page A-9. Also, Experiment 18 should now be completed.

Chapter 9. Classifying Lakes

Now that we have collected our data, we can begin to evaluate the lake based on a widely used lake classification system. This point system allows the scientist to assign a certain value for each of the systems' categories. Although different limnologists use different classification systems, this text will focus primarily on four measurements:

1. **Bottom dissolved oxygen**
2. **Secchi disk Transparency**
3. **Vascular aquatic plant growth**
4. **Chlorophyll-a**

Some scientists also use total phosphorus as a measurement for classification.

These tests are conducted on the lakes and allow the scientist to evaluate the "age" of the lake. More points are given to lakes with lower dissolved oxygen levels, a shallow transparency reading, and also abundant vascular aquatic plants. Lastly, those lakes with high levels of chlorophyll-a (signifying high plankton populations) receive more points as well. So we can see that highly productive lakes are given more points. These lakes are termed "old", or ***eutrophic***.

Remember our discussion of eutrophication? The introduction of new sources of phosphorus and nitrogen can intensify the aging process. We can now say that a lake that possesses a large and varied population of vascular aquatic plants, a high plankton

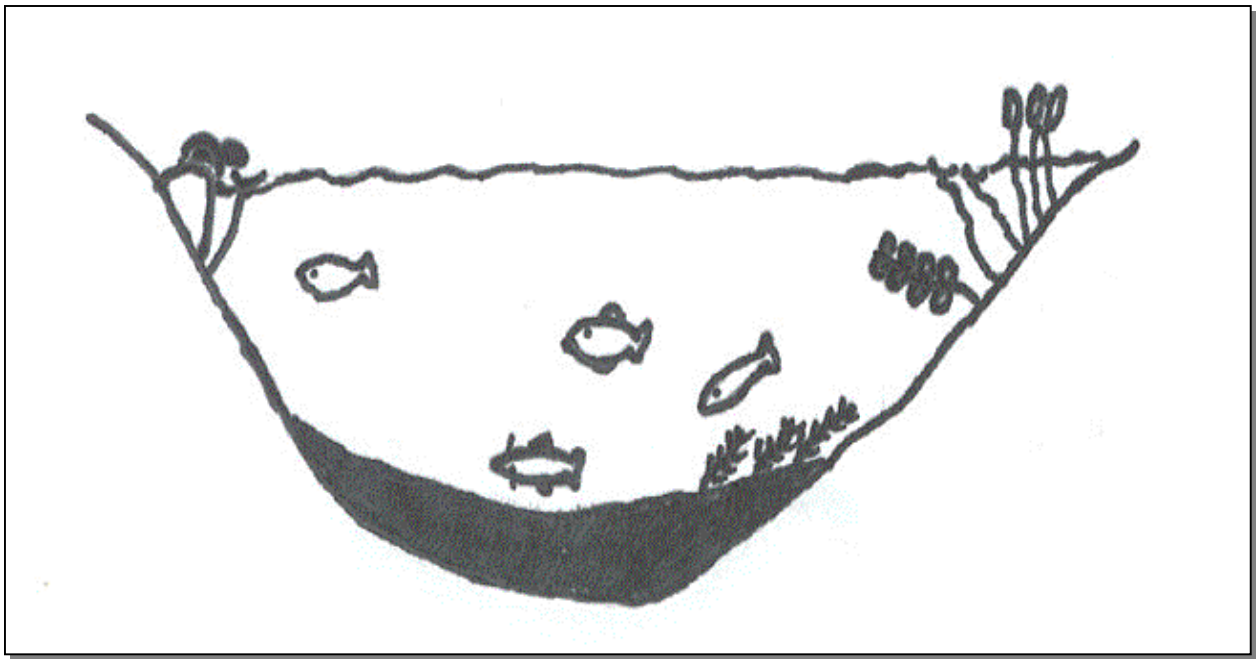


Figure 9-1. Eutrophic lake.

count, a low Secchi disk transparency (below 0.5 meters) and low levels of dissolved oxygen all add up to a eutrophic classification.

On the other hand, if a lake possessed very high levels of dissolved oxygen, a high transparency reading (greater than 4 meters), had sparse vascular plant growth and relatively low levels of plankton growth, the lake would be classified as ***oligotrophic***, or a "young" lake.

The third classification is a lake that falls between the two extremes of eutrophic and oligotrophic. It is referred to as ***mesotrophic***. This stage of lake development can best be termed "middle-aged". Most of the data collected falls between that gathered for oligotrophic and eutrophic. Mesotrophic lakes have fewer vascular plants than do eutrophic lakes, but generally more than oligotrophic lakes. The Secchi disk transparency of most mesotrophic lakes falls between two and three meters (six and nine feet).

If this is the pattern for most lakes of this type, what might you conclude about dissolved oxygen levels and plankton populations in mesotrophic lakes in general? How would measurements of plankton populations and oxygen levels compare with an oligotrophic and a eutrophic lake? Use *Table 9-1* to help you

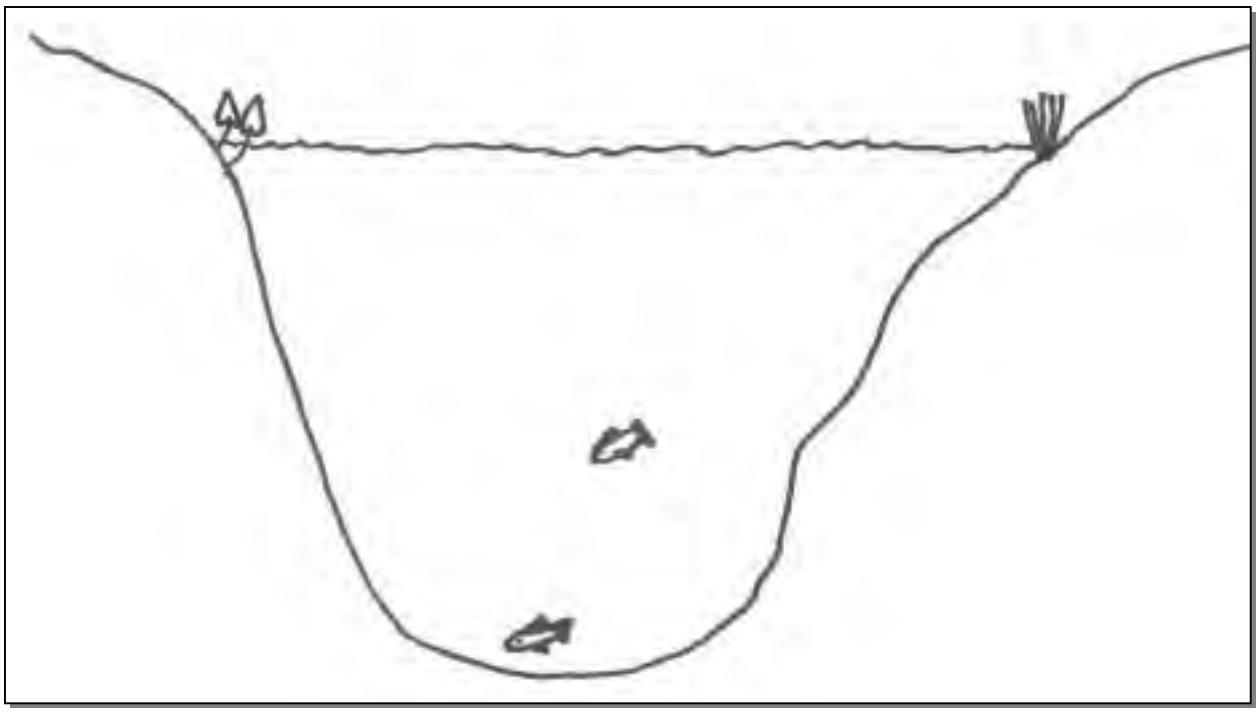


Figure 9-2. Oligotrophic lake.

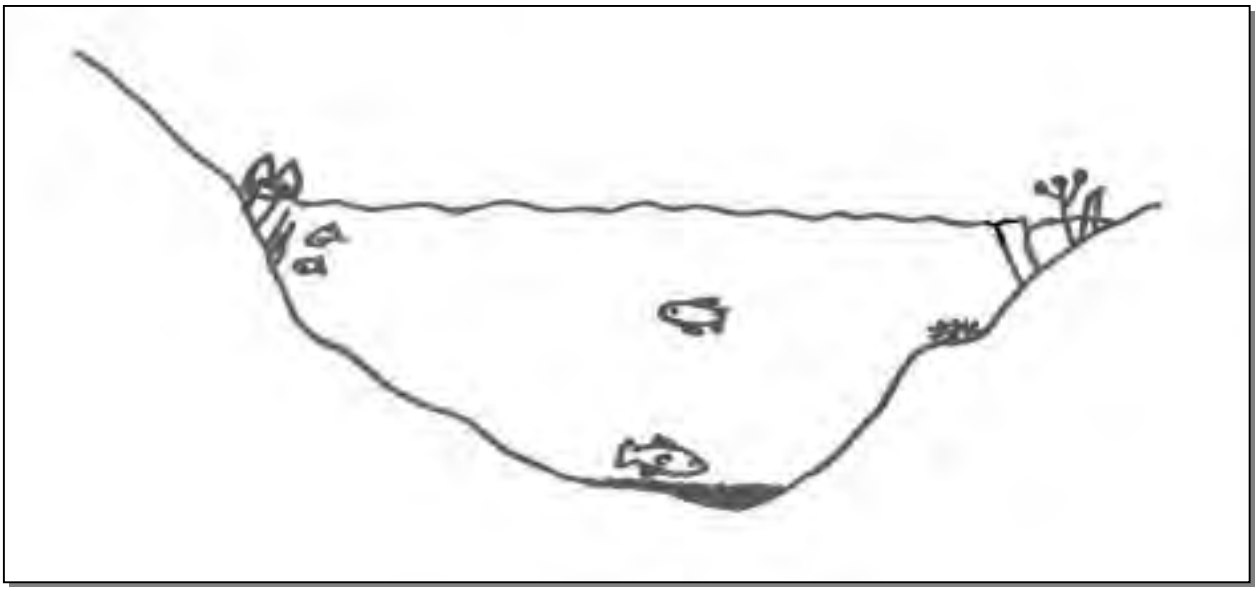


Figure 9-3. Mesotrophic lake.

compare.

Certainly, if you were to refer back to the information at the beginning of the chapter, you would see that plankton populations and oxygen levels for most mesotrophic lakes would fall between those commonly found in oligotrophic and eutrophic lakes. A moderate population of plankton, common but not abundant vascular aquatic plants, and lastly, moderate levels of dissolved oxygen are characteristic of most mesotrophic lakes.

Some of the tests may not yield mid-range results. For example, it may be that Secchi disk transparency readings are particularly low for a certain mesotrophic lake because of recent shoreline development. The subsequent flow of sediments into the lake may have clouded the water column to the degree that results look more like eutrophic readings. Or a shallow eutrophic lake may have higher dissolved oxygen due to mixing by wind. Similarly, certain lakeside activities that were discussed in the chapter on pollution may lead to increased aquatic weed and plankton growth.

Limnologists also use water quality data to create graphs to

Experiment 19

Classification	Bottom Dissolved Oxygen	Secchi Disk	Vascular Plants	Chlorophyll *a*
Oligotrophic	>5 ppm	>4 meters	Few to sparse	<4 mg/m^3
Mesotrophic	2-5 ppm	2-4 meters	Moderate to Common	4-10 mg/m^3
Eutrophic	<2 ppm	<2 meters	Abundant	>10 mg/m^3
">"=Greater Than	"<"=Less Than	"ppm"= parts per million		mg/m^3=milligrams per cubic meter

Table 9-1. Measurement ranges for lake classification.

analyze and compare the data collected. Graphs allow data to be seen in a different format. These graphs come in many varieties including simple line graphs, bar graphs and pie charts. We'll take a look at each of these graphing styles using some data from Lake Clear.

First of all, it is important to know that most graphs have two sides, called axes. The horizontal side is the 'x' axis and the vertical side is the 'y' axis (*Figure 9-4*). Usually for lake data, the 'x' axis shows the date, sample location, or time interval. The 'y' axis shows the results of the test that was conducted on that date, sample location or time interval.

Let's first look at a simple line graph. This type of graph is appropriate for looking at trends over time. For example, let's look at the trend in chlorophyll-a levels in Lake Clear (*Figure 9-5*). As you can see, from 1990 to 1995 the chlorophyll-a levels in Lake Clear were roughly the same, which means the trend was stable. In 1996 there was a sudden increase in chlorophyll-a, and it has steadily increased since 1996. A limnologist would wonder what happened between 1995 and 1996 to cause such an increase of chlorophyll-a.

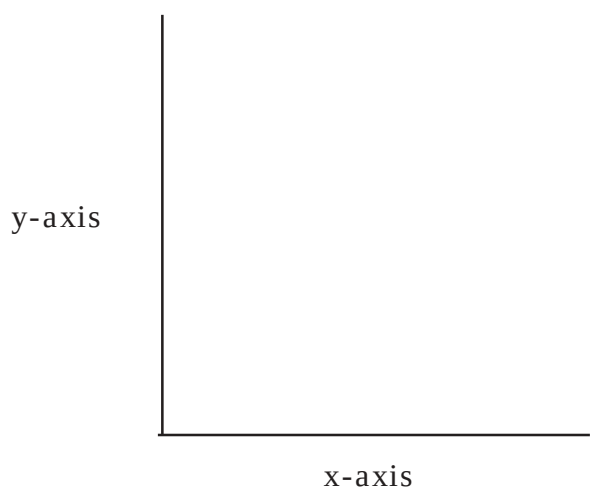


Figure 9-4. A sample graph showing x- and y-axes.

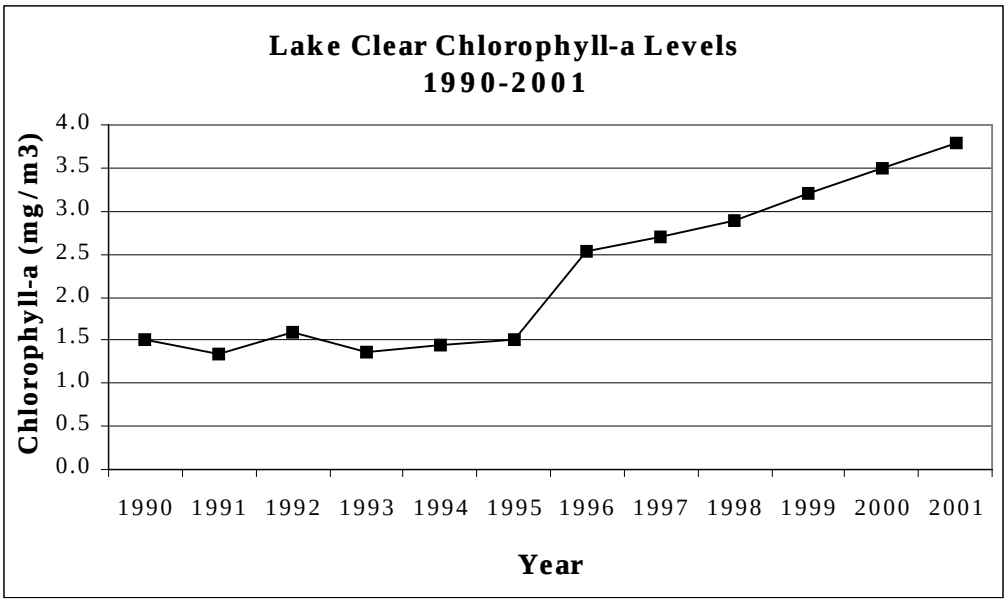


Figure 9-5. Lake Clear chlorophyll-a levels.

comparison between many factors of the whole. You will notice that this graph looks different than the first two; most notably it lacks the 'x' and 'y' axes. This method of graphing totals the whole set of data and then determines the percentage of each contributing factor. For example, if we wanted to evaluate the sources of total phosphorus entering Lake Clear and their corresponding amounts we would create a pie chart, as in *Figure 9-7*.

Bar graphs are used to compare data sets. For example, if we wanted to compare the number of shoreline houses on three different lakes, a bar graph would be a suitable choice (*Figure 9-6*). By looking at the graph you can easily see that Pickerel Lake has the most shoreline houses in relation to the other two lakes. Bass Lake has the next greatest number of houses, and Lake Clear has the fewest houses on its shoreline.

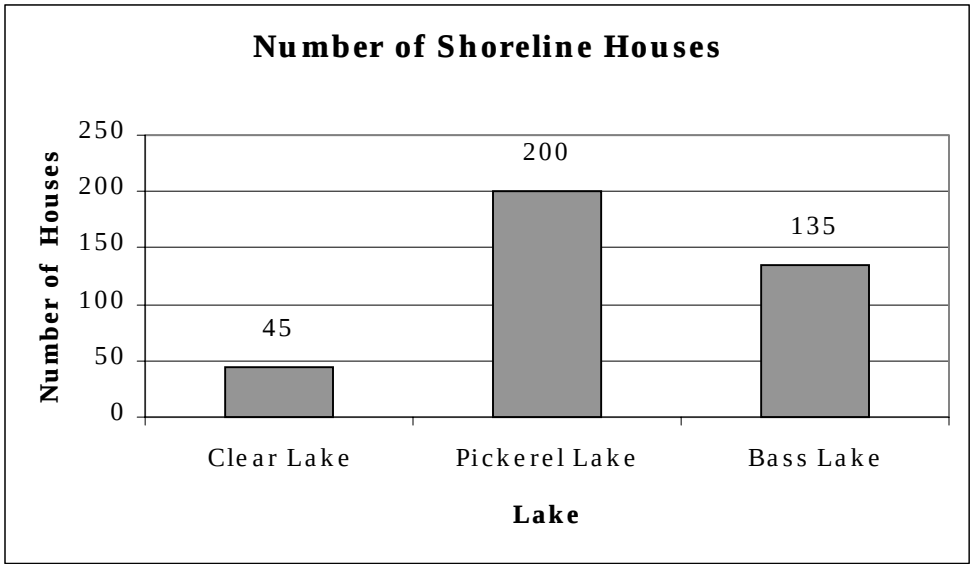


Figure 9-6. Number of shoreline houses.

Another type of graph, the pie chart, can show a

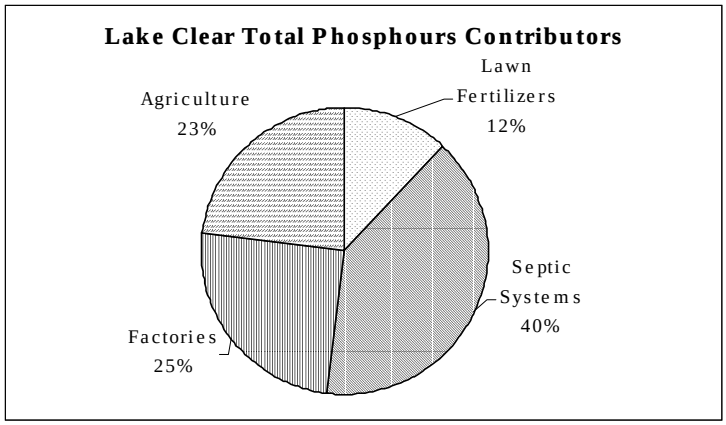


Figure 9-7. Lake Clear total phosphorus

Just think of a pie chart as a pie; each component is a different sized slice of the pie. *Figure 9-7* shows us that 40% of the phosphorus that enters Lake Clear comes from septic systems. This is the greatest contributor (it's the largest piece of the pie). Lawn fertilizers contribute the smallest amount, with only 12% of the phosphorus coming in from this source. In this case, a pie chart like *Figure 9-7* can help a limnologist visualize which pollution source in the watershed should first be targeted to reduce the input of nutrients.

Experiment 20

Summary

Lakes are classified using a point system based on results from field observations and laboratory measurements. These usually include bottom dissolved oxygen, Secchi disk transparency, vascular plant abundance and chlorophyll-a. The three main classification categories used by limnologists to evaluate the aging process of lakes and ponds are oligotrophic, mesotrophic and eutrophic.

Limnologists use graphs, such as line graphs, bar graphs, and pie charts to help them visualize data.

Quiz Yourself

1. Explain the difference between oligotrophic and eutrophic lakes.

2. Why do you think plant and algae abundances are used to classify lakes? Use what you learned in previous chapters to complete your answer.

3. If there were many algae in a lake would you expect the clarity to be high or low?

Vocabulary

eutrophic
mesotrophic
oligotrophic

Complete Chapter 9 Exercises, located on page A-11. Also, Experiments 19 and 20 should now be complete.

Chapter 10. Conclusions

You have learned a considerable amount of information about freshwater lakes and ponds. It began with a chapter on the formation of lakes, then physical properties of water, moved on to introduce the water cycle and the food chain, and then discussed the concept of watersheds. Later, we described how a lake, or an entire watershed, might be polluted as a result of human activities, followed by a chapter about non-native species. Lastly, we learned how scientists test lakes, and how they use that information to classify lakes into three categories. Do you remember the names of the three classes of lakes?

Many states have laws and regulations to protect lakes from toxins and nonpoint sources of pollution. The following are examples of the types of laws that are existing in some states:

1. No trash can be dumped in or on the banks of a lake.

2. No new point sources of pollution to the lakes are allowed, and no new discharges of phosphorus or nitrogen to surface streams are allowed that would encourage weed or algae growth.

3. Marine toilets cannot be discharged into a lake.

4. Graywater (sink and shower wastes) from boats cannot be discharged into lakes.

5. No automobiles may be washed in or driven into any lake.

6. Automobiles and other petroleum-powered vehicles lost through the ice of a lake must be removed.

7. No dredge and fill activities are allowed in or around a lake without a permit.

8. No construction or transportation of forest products (skidding, etc.) can occur in the shoreland area of a lake without a permit.

9. No non-native species can be introduced to a lake.

10. No pesticides can be applied in or around lakes without a permit.

11. Cottages near lakes or streams cannot be converted from seasonal to year-round use unless an application for approval of the sewage disposal system is submitted.

12. Permits are typically required

for the following:

a. Underground storage tanks
b. Solid waste landfills
c. Sludge pits
d. Creating a beach where none presently exists
e. Hazardous waste site

13. Reductions in phosphates in laundry detergents.

These activities are regulated by most state environmental agencies.

After looking closely at the sample of state regulations protecting lakes, break into small groups and try to list several good reasons why each of these laws have been enacted. What aspects of lake ecology that we have discussed do each of these activities impact? After reviewing all of the activities, choose a speaker and inform the other groups of your reasoning. Is there general agreement on the reasons why these activities are outlawed? Why do you think we need laws such as these? What laws would you recommend that weren't on this list? Are there any on the list with which you don't agree? Discuss your reasoning with the other groups.

In addition to providing the information and activities outlined in this workbook, we hope that this program will motivate you into acting on the information you now have.

You have learned much in the last few weeks and at this point you already know more about lakes than most of the people that you know. You need to share this knowledge with those who are unaware of the problems that lakes face today.

YOU CAN MAKE A DIFFERENCE!

Some of the activities that you can do to inform others are listed below. Try to think of any other activities that might raise the awareness of the public regarding one of the most important natural resources we have: fresh water lakes and ponds.

1. Invite the local representatives to the state legislature into your classroom and ask them what they are doing to help improve the quality of water in the area lakes.

2. Write your state and federal representatives and senators and tell them about the issues that you are now discussing. Ask them if they have plans for legislation that will ensure water quality

for generations to come.

3. Write a letter to the editor of your local newspaper and list some of the do's and don'ts of lake ecology. You might be surprised at the response.

4. Put together a "lake day" when everyone researches a particular lake in your area and discusses the elements of lake ecology as it relates to that lake. Contacting state and local conservation and environmental agencies can be a big help. Put together a "big book" of this information and donate it to your school library so that all students in the school can benefit from your increased knowledge.

5. In language arts class, write a letter to your parents describing the information you have learned about lake ecology and ask them if they have any ideas on how to improve the water quality of lakes in the region.

6. On parent night, be sure to have the materials generated from this unit displayed for all to see.

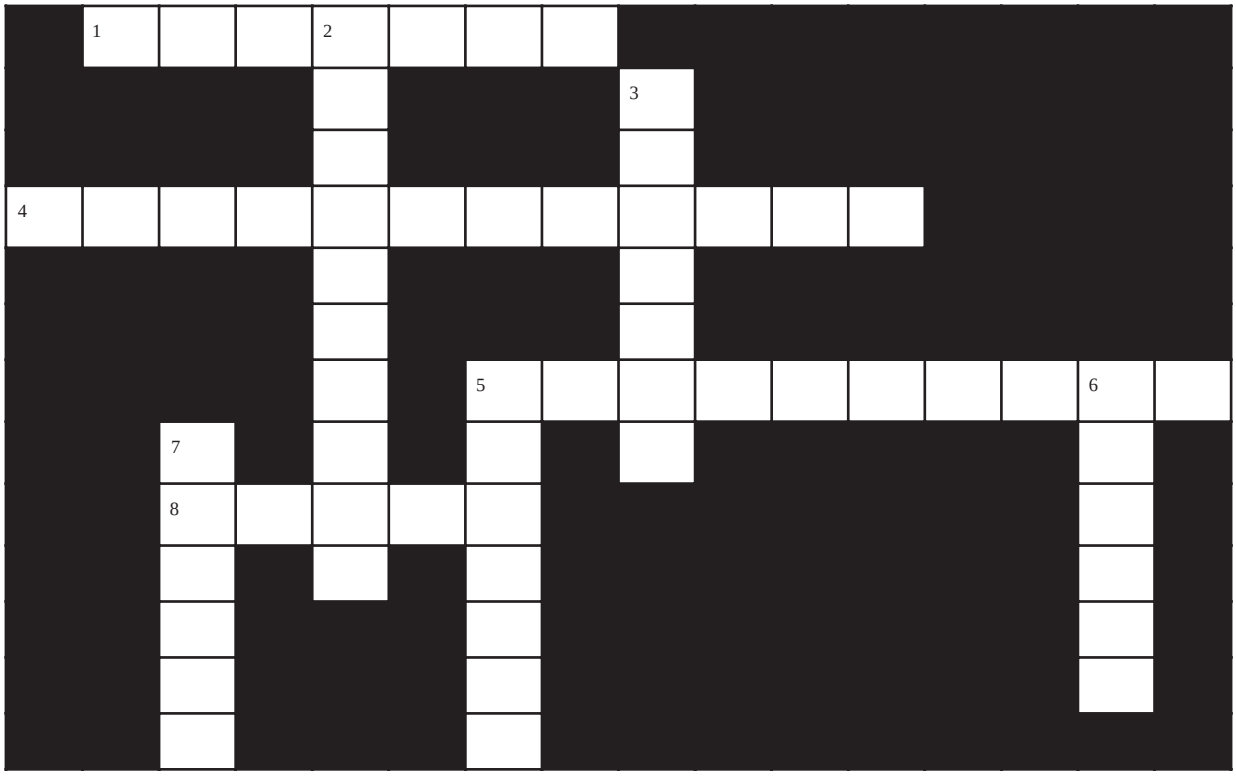
7. Create a bulletin board in a centrally located area of your school. Many students who would not otherwise be aware of the project you are working on might be interested by a graphic display.

8. Have a clean-lake poster contest at your school and allow everyone to participate. Place the top ten winners around the school for others to see.

9. If you want to really get involved, ask your parents to call the state environmental or natural resources department or state university and ask about the volunteer monitoring program. You and your parents could be part of a large network of citizens who help provide information to state agencies on the health of lakes. You may be trained to operate some of the instruments and equipment you learned about during the course of this unit. Your testing results would be forwarded to the state labs for analysis.

So, as you can see, there is a lot you can do to help protect the water quality of the lakes and ponds in your area.

caldera
crater lake
esker
glacier
graben
kettle
moraine
morphology
solution lake



Across
1. A large block of ice, some of which produced many of North America's lakes.
4. A lake created when rock formations are dissolved by water.
5. The structure and form of a lake.
8. A river that cuts through a glacier.

Down
2. A lake created by a volcanic explosion, usually at the top of a mountain.
3. A lake formed when the roof of a partially empty magmatic chamber caves in.
5. A build-up of sediments from a glacier.
6. A depressed segment of the earth's crust surrounded on two sides by faults.
7. A lake or depression created by chunks of ice from a glacier.

condensation
evaporation
freezing
lake turnover
melting
molecule
specific heat
surface tension
thermal layers
thermocline

1. Water striders and water lilies are able to float on the surface of the water due to _____ _____.
2. Lakes in some parts of the world go through a process called _____ _____, when the waters mix.
3. _____ occurs when liquids change to form a gas, like water changing to fog.
4. During the winter in the northern United States lakes go through a process of _____, when ice is formed. In the spring, _____ occurs and the waters are free of ice.
5. _____ _____ in a lake are determined by measuring the temperatures throughout the water column. The _____ is where the temperature change is the greatest.
6. A _____ of water is made up of two Hydrogen atoms and one Oxygen atom, making the well-known formula H_2O.
7. When water vapor cools to form a liquid, _____ has occurred.
8. The amount of heat required to raise the temperature of a unit of a substance one degree Celsius is known as _____ _____.

atmosphere
circulation
domestic use
groundwater
groundwater recharge
industrial use
infiltration
input
output
precipitation
runoff
surface discharge
surface streams
transpiration
water cycle

Find the vocabulary words in the word find, either up-down, left-right, or diagonal.

c	d	o	m	e	s	t	i	c	u	s	e	g	d	s	e	l	s	t	n
f	i	e	f	g	h	j	k	l	h	g	y	r	c	g	s	d	u	e	s
e	p	r	e	c	i	p	i	t	a	t	i	o	n	r	o	i	r	c	e
a	g	c	c	r	d	c	g	y	j	k	o	u	d	o	t	n	f	v	j
h	j	e	r	u	n	o	f	f	v	h	t	n	s	u	e	d	a	a	t
s	v	h	f	i	l	t	d	f	g	j	e	d	a	n	b	u	c	s	r
t	y	u	g	d	r	a	s	e	v	h	j	w	r	d	d	s	e	r	a
t	y	o	u	t	p	u	t	t	h	k	o	a	b	w	j	t	d	k	n
b	j	g	r	f	s	e	a	i	j	b	j	t	l	a	u	r	i	p	s
f	g	t	e	b	m	h	r	n	o	r	d	e	r	t	x	i	s	g	p
p	y	t	u	i	l	g	t	p	e	n	v	r	t	e	r	a	c	y	i
p	r	d	t	g	j	y	i	u	e	y	r	r	x	r	e	l	h	c	r
i	n	f	i	l	t	r	a	t	i	o	n	e	r	f	h	u	a	z	a
g	h	j	x	e	w	a	t	e	r	c	y	c	l	e	f	s	r	r	t
a	i	r	r	r	h	k	i	d	f	v	s	h	r	o	d	e	g	d	i
c	u	g	u	g	r	f	r	d	j	l	p	a	f	k	s	r	e	e	o
g	j	f	g	a	t	m	o	s	p	h	e	r	e	j	v	f	h	a	n
t	y	d	t	j	t	g	j	r	t	y	t	g	c	y	b	c	g	b	t
i	r	s	t	r	u	i	i	h	k	j	h	e	d	e	j	b	d	h	o
y	t	s	u	r	f	a	c	e	s	t	r	e	a	m	s	j	s	j	o

bacteria
carnivores
decomposers
food chain
herbivores
interdependent
nitrogen
nutrients
omnivores
phosphorus
photosynthesis
phytoplankton
primary consumers
primary producers
secondary consumers
tertiary consumers
zooplankton

1. The _____ _____ describes how plants, animals and other organisms depend on each other. In other words, they are _____.
2. _____ use oxygen to break down dead organisms. The tiny microorganisms that perform the process of decomposition are the _____.
3. At the "bottom" of the food chain are the _____ _____, like plants and _____. They make food for themselves by the process called _____.
4. The _____ _____ eat the phytoplankton and plants, and are therefore referred to as _____, or "plant-eaters". The small, animal-like organisms, called _____, are in this category of the food chain.
5. The _____ _____and _____ _____ eat other consumers and some producers. Organisms that are solely meat eaters are called _____, while those that eat a mixture of plants and meat are _____.
6. _____ and _____ are the "food", or _____, for the plants and phytoplankton.

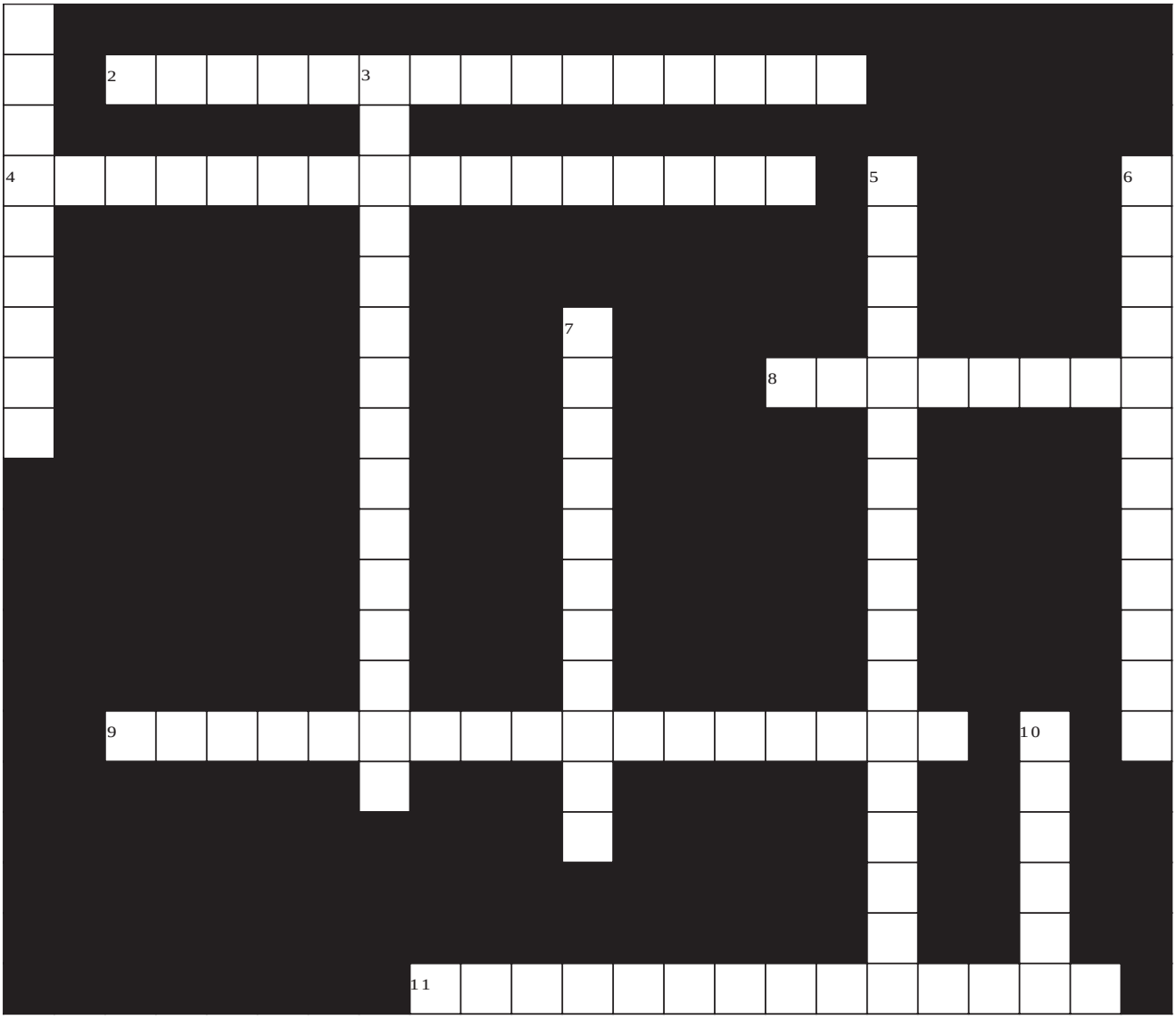
algal bloom
blue-green algae
clear-cutting
topographic map
watershed

1. A _____ is the area of land surrounding a body of water (stream, lake, or river) in which all water flows to the lowest point. A _____ _____ is used to determine the boundaries of a watershed by finding the highest points.
2. Tree and plant roots help to hold soil in place. Therefore, if _____ _____ occurs in a watershed increased erosion may occur.
3. _____ _____ _____ grow excessively when too many nutrients are available to them. This excess growth may cause an _____ _____.

acid rain
non-point sources
point sources
pollution

1. The introduction of harmful substances into the environment is better known as _____.
2. There are two sources of pollution. _____ _____ are those such as a pipe entering a stream from a wastewater treatment facility. _____ _____ are less easy to determine, but can include farms, septic systems and roads.
3. _____ _____ occurs in some areas of the world, typically downwind of an industrial area, and can be detrimental to plants, water and animals.

competitive feeder
Eurasian milfoil
invasive species
invertebrate
native
non-native species
predator
purple loosestrife
round goby
spiny water flea
zebra mussel



Across

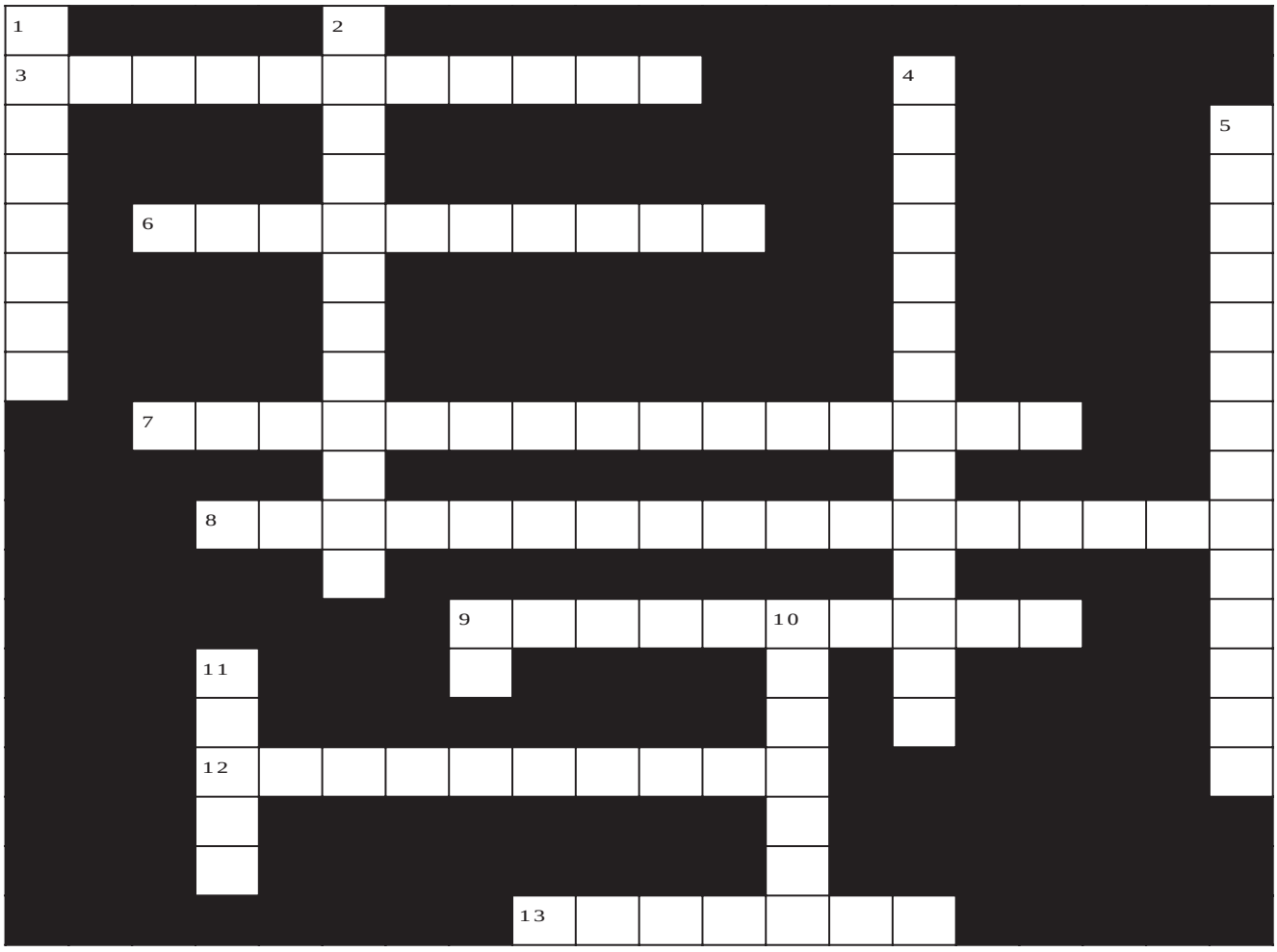
2. A non-native plant species that can grow quickly in lakes with favorable conditions.
4. A plant or animal that is introduced to a region from outside.
8. An animal that consumes another species
9. An invasive plant with dark pink flowers that was brought to the United States for gardening purposes.

11. A nuisance zooplankton species.

Down

1. A fish native to Europe that is a nuisance in the United States.
3. A plant or animal that takes over a lake leaving less room for native species.
5. A non-native organism that eats available food more quickly than native species.
6. An animal without a backbone.
7.A nuisance species that sticks to buoys, boat hulls and intake pipes in the water.
10. A species that has been in a region since the region was created.

analyze
bathymetric map
clarity
classify
color
eutrophication
fathometer
flushing rate
integrated sampler
lay monitor
limnologist
nutrient loading
pH
productive



Across
3. A scientist who studies fresh water lakes and ponds.
6. A piece of equipment used to determine lake depth.
7. When nutrients enter a water body, either from the watershed or the lake itself.
8. A piece of equipment used to collect samples for chlorophyll-a analysis.
9. A lake that produces large quantities of plants and algae.
12. A volunteer who collects water samples.
13. To examine in detail.

Down

1. To categorize lakes based on the results of a series of tests.
2. The time it takes all the water in a lake to be replaced with new water.
4. The process by which a lake “ages”.
5. A contour map that shows depths in a lake.
9. The scale used to measure the acidity or alkalinity of water.
10. The clearness of water.
11. A test performed on lake samples that may determine the presence of substances.

Look at the pictures below and read each description in order to identify the three classifications of lake systems.

eutrophic
mesotrophic
oligotrophic

1. The type of lake illustrated here typically has low dissolved oxygen levels, abundant vascular aquatic plants, as well as high levels of chlorophyll-a . A shallow transparency reading is common in this type of lake.

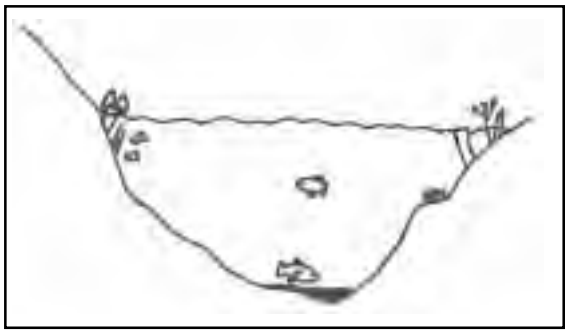
What classification would you give this lake?

_____

2. The type of lake in the drawing to the right has moderate levels of nutrients, some plant and algae growth, and a Secchi disk reading generally between 2 and 3 meters.

What classification would you give this lake?

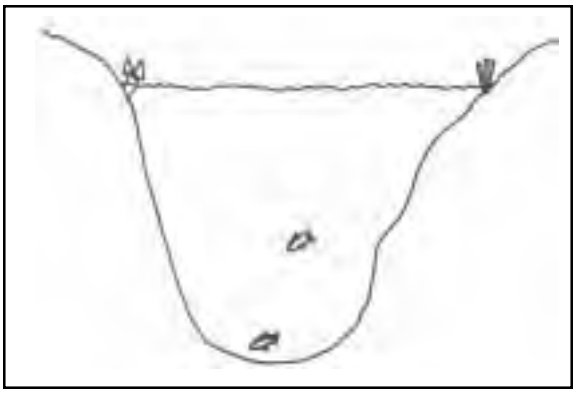
_____



3. This lake has few aquatic plants, high dissolved oxygen levels, low levels of chlorophyll-a, and the transparency is often more than 4 meters.

How would you classify this lake?

_____



Experiments

1. Create Lake Ecology Folders

Materials:

Construction paper, oak tag or manila folder
Pencils
Crayons
Markers

Procedure:

A. Using a piece of construction paper, oak tag or manila folder for the cover, illustrate a certain aspect of lake ecology that interests you. Brainstorm ideas with your teacher and members of your group. Some covers have included a drawing of a food chain, others a picture of some of the plants and animals that live in and around a lake or pond.

B. When it is finished use it to organize all of your notes, experiment records, vocabulary lists and answers to the questions at the end of each chapter.

Chapter 1

2. Demonstrate Lake Types

Find pictures of each type of lake formation and keep them in your lake ecology folder.

Chapter 2

3. Surface Tension

Materials: One of the following for each group:

Needle
Tweezers
Bowl
Water

Procedure:

A. Fill the bowl with water.

B. Using the tweezers, carefully pick up the needle and place it on top of the water. You may have to try it several times before you succeed. You will know you have done it correctly when the needle "floats" on top of the water.

C. Observe the needle carefully. How would you describe the way the needle sits on the water? Write down your observations in your folder. When it is time, share your thoughts with other students in your group.

4. Water Expands as it Freezes

Materials:

Plastic container with tight-fitting lid
Water
Refrigerator with freezer

Procedure:

A. Fill the plastic container with so much water that some floats over the top when you put the lid on.
B. Place the container in the freezer and after the water has frozen, note its condition.
C. What happened? How would you explain this?

5. Specific Heat of Water and Soil

Materials:

2 thermometers
small bucket of soil
32 oz. of tap water
heat source (oven, spot light, flood lamp, etc.)
2 rectangular, shallow pans

Procedure:

A. Fill the two pans to the same level, one with soil and the other with water.
B. Place both pans in the oven (set to warm) or under the light and leave for two hours. Form a hypothesis. Will the water cool faster than the soil when removed from the oven or other heat source? Will the soil cool faster than the water? Or will they cool at the same rate? Write your hypothesis down and be sure to include some reasons for your answer.
C. Remove the pans from the oven (remove the light) and place them on a table.
D. Take an initial temperature of each using the thermometers. Fill in the chart. After thirty minutes, take the temperature for both the soil and the water. What does this tell you? Compare what you now know with your hypothesis. Did you correctly predict the final outcome?

6. Water Density

Materials:

2 clear containers
24 oz. of water
Red food coloring
Heat source
Ice cubes

Procedure:

A. Heat 12 ounces of water to a boil.
B. Chill 12 ounces of water using ice cubes.
C. Transfer the hot water to one clear container and add enough red food coloring to turn it dark red (four or five drops).
D. Transfer the cold water to the other clear container.
E. Tilt the container holding the cold water and very slowly pour the hot, red water into the cold water container.
F. Observe and record what you see.

Chapter 3

7. Create a Water Cycle

Materials:

Large, clear bowl
Plastic wrap
Weight
Smaller container
Rubber band
Water

Procedures:

A. Fill the large, clear bowl with a little water. Place the small container (without water) in the middle of the bowl.
B. Cover the bowl with plastic wrap, then place the rubber band around the plastic wrap. Put the weight in the center of the plastic wrap.
C. Put the bowl on a window sill or under a heat lamp.
D. Check back every few minutes to see if anything is happening. Make note of how long it takes for the water to begin evaporating. How will you know if the water has evaporated?
E. Keep observing the bowl. What happens after the water

has evaporated? Where does it end up?

F. Record all of your observations and compare them with the rest of the class.

G. Try to modify the experiment. Here are some examples:

1. Determine whether water temperature has any effect on the outcome of the experiment. This time, use two bowls. Place warm water in one bowl and cool water in the other. Make a guess about what will occur. Observe as before and record your findings.
2. Determine whether air temperature affects the outcome. Place the same temperature water in both bowls, but place one in a warm room and the other in a cool room. What do you think will happen? Observe and record results.
3. What else do you think would affect the rate of evaporation and condensation? Come up with your own experiments.

Chapter 4

8. Microscopic Plants and Animals

Materials:

Microscopes
Microscope slides of algae, zooplankton, *Euglena*
Logbook for recording illustrations
Reference book to identify plankton

Procedure:

A. Using the prepared slides or any "live" materials that you may have, look carefully at each of the organisms.

B. Draw each microscopic plant or animal that you observe. Be sure to look for as many details as possible. Make each drawing about a half page in size in order to record detail. Identify each organism using the reference book.

C. Compare and contrast each organism. Make a list of the similarities and the differences.

9. Chart with Organisms by Food Chain Category

Materials:

Large poster paper or oak tag
Pencils, pens or markers
Meter stick or other ruler

Procedure:

A. Begin by deciding which animals and plants you want to include. Then make a chart with five columns and six rows.

B. List the food chain categories across the top of the chart. There will be a column for each category (primary producers, primary consumers, secondary consumers, decomposers, etc.).

C. Under each category write in the name of a plant or animal that belongs in that category.

D. Display your work on the class or school bulletin board.

10. Collage of Lake and Pond Flora and Fauna (Class project)

Materials:

Old newspapers
Magazines (*National Geographic* or other periodical with a focus on natural science)
Scissors
Paste, glue or transparent tape

Procedure:

A. Clip or cut out all of the pond-related pictures or photographs that you can find. Decide ahead of time how you would like to arrange the collage. What will your theme be? Some have chosen to work around the idea of a food chain with concentric circles of organisms from each category. Begin with primary producers in the center and work out to the secondary consumers and decomposers on the outside. Others have used pollution as their theme and showed the various types of pollution that can contaminate a lake. Try something new and have fun.

Chapter 5

11. Watershed Model

Materials:

Cardboard box with plastic liner
Sand
Clay
Soil
Rocks

Water
Food coloring

Procedures:

A. Using the above materials, create uneven terrain to represent mountain ridges within the cardboard box (put down the plastic liner first). It can be as simple as a bowl shape. It can be more complex with several ridges and valleys (high and low areas).
B. After you have created a watershed, add some water to different areas to show rain or snow. Observe the water flow pattern. Does the water remain in puddles or quickly seep into the earth?
C. Contaminate your watershed with a few drops of food coloring. Then create a rainstorm by adding water. What is the pattern of contamination? Describes what happens as accurately as possible. What if someone were to dump kerosene that they had used to clean auto parts into a ditch in the backyard? Where would the kerosene end up?

12. Advanced Exercise: Map a Watershed

Materials:

Topographic map
Pencil and eraser

Procedures:

A. Using a topographic map, pick a body of water in your region.
B. Find the high points of land around the lake and mark them with an "X."
C. Connect the "Xs" with lines to form the watershed boundaries, as instructed by your teacher.
D. List potential sources of pollution or nutrients within these boundaries that could affect the lake.

Chapter 6

13. pH of Rain or Lake Water

Materials:

pH paper with color coded chart to read results
Rain or lake water
Plastic container for water

Procedure:

A. Collect rain or lake water. If you collect snow, allow it to melt.
B. Take a small strip of indicator paper and touch its end to the water.
C. After 30 seconds, take the paper strip and place it down on the color chart. The color closest to the strip's color is an approximate pH reading for the sample. Record the pH.
D. If you have more than one sample, repeat the procedure for each sample collected and record the pH for each.
E. Discuss your findings with the other groups. Compare the results to the scale in the student workbook. Do you have acid rain?

14. Phosphorus in Detergents

Procedure:

A. In your home, carefully read the labels on each of the soaps, detergents and cleaners that your family uses.
B. Make a list of all those products with phosphates (and their amounts, if known) and all those without.
C. Post the list in class and try to encourage others to use phosphate-free detergent.
D. Discuss this list with your family and find alternatives for the phosphate-containing items.

15. Vegetation vs. Bare Soil: Create a Planted Buffer Zone

Materials:

Baking pan (13" x 9" may work best)
Modeling clay
Sponge wide enough to cover the width of the pan
Watering can
Jar of muddy water

Procedure:

A. Spread the modeling clay over half of the baking pan to represent the land.
B. Shape the clay so there is a slight slope towards the empty half of the pan, which will act as a lake or pond.
C. Cut the sponge so that it fills the space at the edge of

the clay. The sponge will act as plants along a lake's shoreline.

D. Try the following experiments:
   a. Pour clean water over the clay with the watering can (with sponge in place).
   b. Pour the same amount of water over the clay, but remove the sponge.
   c. Pour the muddy water over the clay, once with the sponge in place and once without.

E. Make observations and explain the differences between each scenario.

Chapter 7

16. Make Posters

Materials:

Poster board
Markers or crayons
Pictures of aquatic plants from magazines
Glue

Procedure:

A. Make a poster depicting ways to keep non-native and invasive species out of lakes and ponds.

B. Make a poster with different aquatic non-native and invasive species in your region. Ask to place the poster at a local boat launch area.

C. Find pictures of native plants and their non-native and invasive look-alikes. Create a poster or pamphlet to distribute to local lake associations.

17. Research Project

Materials:

Magazines
Books
Encyclopedia
Internet

Procedure:

A. Research a non-native species of plant or animal in the U.S. Use your school library or the internet to find information.

B. Try to find where the species originated and how it was introduced to the United States. Explain any effects its presence may have on native species.

C. Give a presentation to the class. Act as if you are a limnologist and give any ideas you have to manage the species.

Chapter 8

18. Rate of Flow

Materials:

Orange
Tape measure
Stop watch
Waders or hip boots

Procedure:

A. Visit a local stream (choose one that's not too deep or fast-running, for safety). Extend the tape measure to a pre-determined length. (If the class is broken up into several groups, each group should use the same distance.)

B. Have one person stand upstream (at the beginning of the tape measure) with the orange. Have another person stand downstream (at the end of the tape measure) with the stop watch.

C. When ready, place the orange in the water slightly upstream from the tape measure. When the orange reaches the tape measure, that person should indicate to the other person to begin timing.

D. Wait until the orange gets to the other end of the tape measure and stop timing.

E. Calculate the flow in feet per second by dividing the distance the orange traveled by the amount of time it took. For instance, if the length was 40 feet and the time to travel that distance was 10 seconds, divide 40 by 10, for a flow rate of 4 feet per second.

F. Repeat the entire procedure 3 or 4 times. Take the average of all flow rate results for your final answer.

G. Discuss factors that might affect flow rate in a stream.

Chapter 9

19. Case Studies of Three Lakes

Procedure:

A. In each case, imagine yourself to be the limnologist. You have been asked by your boss to test and classify these lakes. In addition, she has asked you to develop some ideas on how you might improve the water quality of each lake. You load your car with equipment and head off into the mountains, flush with the excitement of the aquatic adventure that awaits you!

B. For each case study, use a format similar to the one on this page to record important information. Make sure to leave enough space between each observation. These observations will help you focus on the many issues. Read each case study carefully, being certain to write down any details that might help you classify the lake and identify problem areas.

C. These case studies were intended to help you make more sense of all the new information you've learned in this booklet. Remember, you need to look at the watershed for sources of pollution in addition to sampling the lake itself. Use *Table 9-1* to help you make your decision about the classification of each lake.

Field Observations

Maximum Depth

Secchi Disk Reading

Vascular Plants

Chlorophyll-a

Dissolved Oxygen

Classification

Recommendations for improving water quality

Case Study #1

As limnologist, you pack all of your equipment into your vehicle, check your trailer hitch and head off to the day's fieldwork at the crack of dawn.

You drive for a while until you arrive at a scenic lookout. From here you are able to see almost the entire watershed of the lake you are about to test. You observe several large farms with many acres of cultivated fields. At the northern end of the lake, scores of condominiums in a large development dot the shoreline. In addition, small, white cottages that are very close to the high water line surround the entire lake. Much of the waterfront is treeless and green lawns abound.

As you make your way down the valley, you can clearly see abundant collections of vascular plants at the northern tip of the lake. As you pull up to the boat ramp, you notice an abundance of water lilies, cattails, pondweeds and other vascular plants. As you load the boat, a logging truck roars by, filled to the top with huge, freshly cut pine trees.

Once on the water, you begin testing by doing a series of soundings with the fathometer. The readings range from less than one meter to eight meters, which you determine to be the deepest spot. Next, a dissolved oxygen meter records very low levels of oxygen (0.5 parts per million, or ppm) at the bottom. Then you pull the Secchi disk out of its box and begin feeding it over the side of the boat with a brass chain. In a matter of seconds, you lose sight of the disk and pull it back until you see it once again. The markings indicate less than one meter. Lastly, you prepare to use the integrated sampler. Carefully, you lower the sampler into the water and allow it to sink to the proper depth. Then you pull it back into the boat and empty it into a bucket. You empty some of that water into a labeled bottle and store it for chlorophyll-a analysis in the lab.

As you motor around the lake, you observe vascular plants all along the shoreline. In some places, the weeds are so thick you wouldn't want to drive near for fear of choking the propellers. You see ducks, a great blue heron, a kingfisher, turtles, frogs and a great number of flying insects. Finally, you reach shore and head back to the laboratory with your samples. You have a strong feeling about this lake, but you wait until the test results are back before you reach any conclusions.

Two or three days later, as you are looking over your logbook notes,

your boss hands you the results of your testing. Remember, she says, classify this lake according to our scale and recommend some actions that would improve the quality of the water in the lake.

You now have the data to help you make the right decisions. The most important result is the chlorophyll-a test. You review the chart and find that the result was 35 mg/m^3 — a very high reading. It is just what you suspected. Now you sit down to write your report to the boss. What are you going to tell her? Be sure to justify your classification with as many facts as possible. Also be certain to include many recommendations for improving the water quality of the lake.

****

Case Study #2

As a result of your outstanding report on Case #1, the boss wrote you a note of appreciation. Several of the volunteer monitors that live on the lake were impressed with your recommendations and are organizing ways to implement your plan of action.

Once again you load up the vehicle, double check the trailer hitch and you're off to test the second of three lakes.

This lake is located in a remote area that attracts many summer tourists. Many people love to use these waters for boating; fishing for bass, trout and salmon; and for swimming. The clear water is cool all summer long, as it is fed by many surface streams, originating in the surrounding mountains, and underground springs bubbling up through the lake bottom.

Out of the car and into the boat you hop. Scanning the shoreline you observe a large wastewater pumping station on the southwest side of the lake. You've heard that this pumping station moves all the sewage from cottages, condominiums, homes and businesses around the lake to a large treatment system ten miles away.

Using the fathometer as a guide, you steer your boat out to the deepest sections of the lake. You immediately notice the large number of mature trees along most of the waterfront. However, the number of boat docks and marinas that are located all along the shoreline amazes you. You watch as three or four boats are washed down before going into the showroom. The soapsuds run down the launching ramp and into the water. You can clearly see the swirls of color that are the telltale

signs of petroleum products that are regularly used in marinas and most boat docks.

As you cut your engine and throw in the anchor, a small craft approaches. It is the president of the lake association. Maybe he can help provide information that you can use in your report. He says that everything is going fairly well but that he does have several concerns. He informs you that the association has learned that there may be a source of pollution entering at the southern end of the lake. No one is sure of the exact location, but fish have been dying more than usual in that end of the lake. (You are furiously taking notes, aren't you?). He continues and tells you that the town has just decided to start dumping snow from the downtown area off a bridge and into the lake. Lastly, he tells you that in certain bays around the lake, an aquatic weed has begun to increase in population... particularly around boat launches. After exchanging pleasantries he departs and you begin your testing.

There are few if any vascular aquatic plants visible around the shoreline. The water is extremely deep, in some places exceeding sixty meters. When taking a Secchi disk reading, you are prepared to offer the lake plenty of line and it doesn't disappoint you: a transparency reading of twelve meters! The dissolved oxygen meter follows and the readings are extremely high all along the water column, 10 ppm. There is plenty of oxygen for even the most demanding fish present, the salmon.

You then lower the integrated sampler and slowly pull it back up, pouring the contents into your sample bottle and recording among other things the date, time, depth of the collection and the name of the lake. All these records will serve you well later.

In making your way to the shore, you pass a portion of the lake where a large town landfill sits across the main road that services the lake. You notice that a small stream flows into the lake at a point just below the site of the landfill. Just prior to pulling your boat in you notice that the beach is loaded with cans, bottles and other litter overflowing from the trash cans that have been provided by the town. You make note of these observations, and prepare for the trip back to the lab. As you pull the trailer out of the water, you notice a suspicious looking plant hanging from the boat's propellors. You carefully pull it off, place some in a bag to identify later and throw the rest in a nearby trash can.

On your way in, your boss meets you in the hall and asks if you remember that your reports must provide sound reasons for your decision on classification and must include some recommendations to improve

the water quality of the lake. You agree with her thoughts and ask her to follow you to the lab with your sample of the plant. She looks it over and tells you it is a non-native milfoil plant.

It turns out that the chlorophyll-a test indicated only 2.5 mg/m^3. With this information and the extensive notes that you have from the field you go back to your desk, convinced that your hypothesis was correct. Hopefully, the boss will be equally convinced when she sees the report.

What will your report say?

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Case Study #3

Now you are confident. The report was, once again, a success. Several of the suggestions you made for improving the water quality of the lake are on the ciry council's agenda for next month. They even want you to testify before them. Maybe they'll reconsider the snow dumping, but you're hoping for a commitment to closing the landfill and opening a solid waste transfer station.

You've got yet another report to complete and you only have a few days before the deadline. One of those evenings is the council meeting and another is a lake association meeting you have to attend. Better get moving!

You're late and by the time you arrive at work, the last integrated sampler is already checked out. Oh, no! You pass your boss and she reminds you that a local volunteer monitor has one that you might use. You load up the vehicle, double check the hitch and drive to the monitor's home hoping to borrow the integrated sampler.

Fortunately, you also find the volunteer monitor's father, who has lived on the lake for fifty years and has seen a lot of change. There was a time, he tells you, that people could clearly see objects that were twenty-five feet below the surface. No more, he says. You are lucky to see six or seven feet now. The rocks are slippery and green. Used to be trout and salmon here. But, he tells you, bass and pickerel are the common game fish now.

He adds that after the war, many people started building little cottages along the shorefront. They put in small sized septic tanks. As the families grew, additions were made to the cottages and more and

more people spent their summers there.

Later, people turned their cottages into year-round vacation homes, but the septic systems didn't change. The farms began using phosphorus- and nitrogen-rich fertilizer to help their corn grown. "Used to be", he tells you, "cow manure did the trick. Now, look at all the pretty green lawns as you drive around our lake. They look great; but look at the aquatic plants along the shoreline as well. They're common now. Didn't used to be any."

Your hand was cramping from all the notes you'd been taking. You thank him kindly, load the integrated sampler into the car and drive to the nearest boat ramp.

On the way out you notice that what the man said was true. Vascular aquatic plants are common all along the shoreline. As you cut through the water, you notice on your fathometer that the depth ranges from two meters to twenty-five meters. The dissolved oxygen meter yields a reading of 3 ppm at 25-meters, indicating to you a fair amount of bacterial decomposition going on down there.

After gathering a sample for chlorophyll-a analysis, you slowly bring the integrated sampler back into the boat; you are already making a hypothesis on this lake's classification. Then you do your Secchi disk transparency test and you have even greater confidence in your original estimation. You start to see the disk clearly at about three meters.

Satisfied, you check all of your notes and see if you've recorded the information you need on your sample bottles.

The next day you are finalizing your report. The chlorophyll-a test results indicated 6 mg/m^3. You write your report and in addition to your assignment, you write a letter to the boss asking her to do a mailing of the department's brochures on lake eutrophication.

In addition to classifying this lake and recommending action to improve water quality, why do you think lake eutrophication is an issue with this particular lake? Specifically, what did the man say contributed to the lake's problems?

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20. Graph Interpretation Activity

Materials:

Graphs on following pages
Table 9-1
Your brains!

Procedure:

Using the graphs on the following pages, give a brief discussion of Pickerel Lake's water quality. Be sure to take all factors into account. Assign a classification to Pickerel Lake and state the reasons for your choice. What would you expect the characteristics of the lake to be? In other words, is this a deep lake that is free of floating debris? Are there many plants around the shoreline? What types of activities may be occurring in the lake's watershed to affect the Secchi disk readings? Finally, regarding the total phosphorus contributors graph, how do you think the percentages may affect the water quality of Pickerel Lake? Can you give some recommendations to the watershed residents to help reduce the phosphorus loading? Also, compare the Secchi disk graphs for Pickerel Lake and Lake Clear.

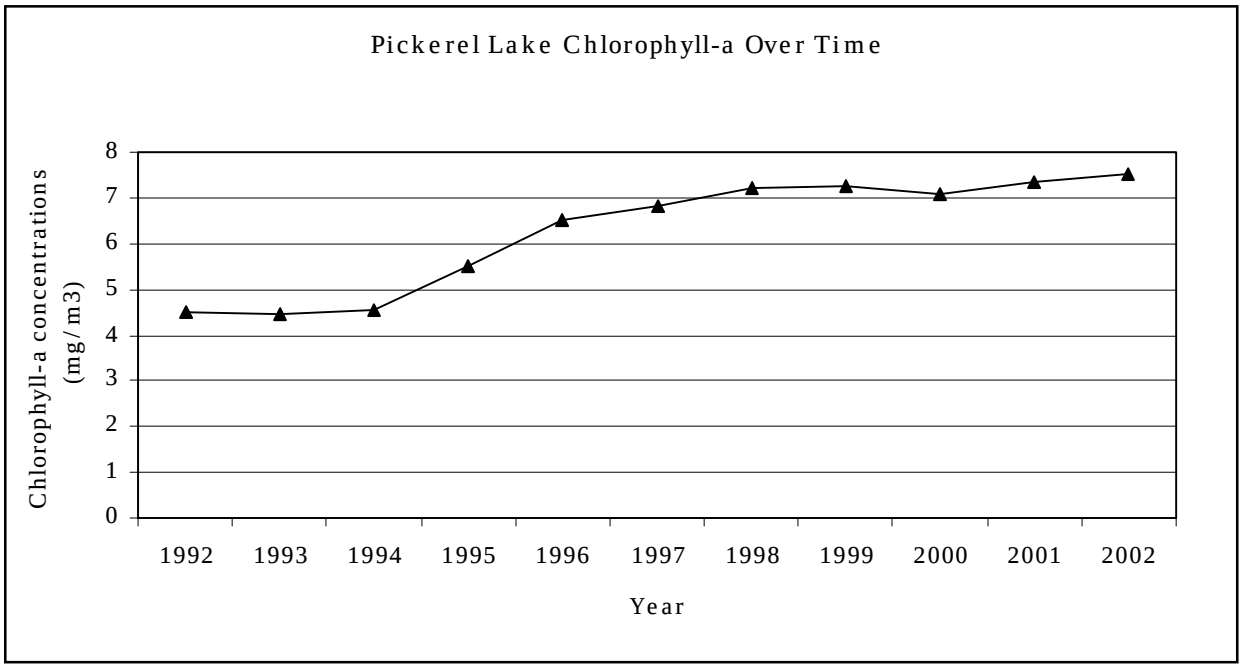

Figure 1.

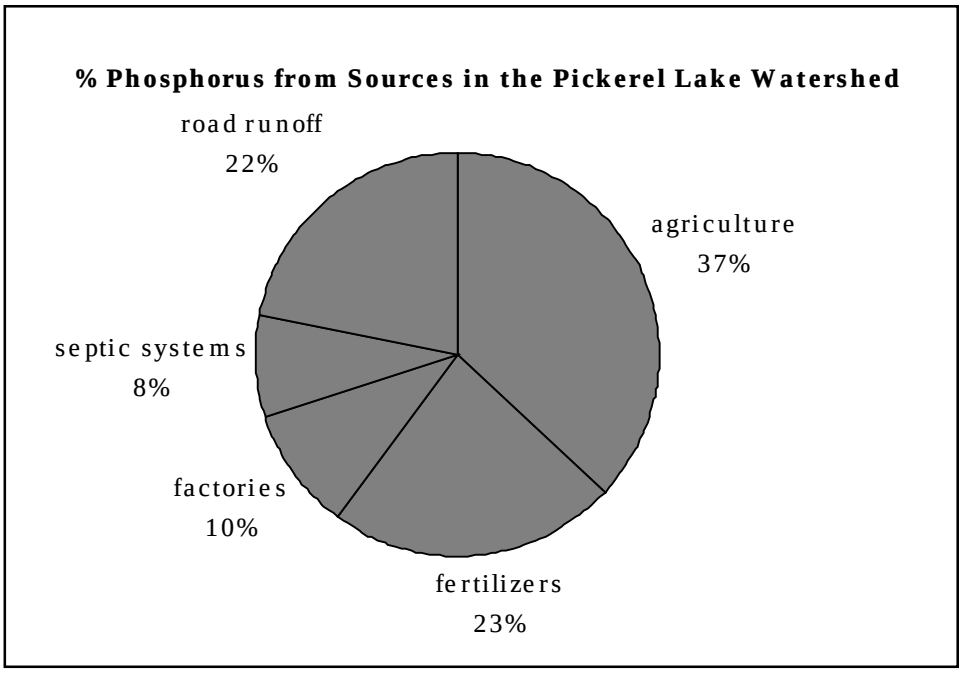

Figure 2.

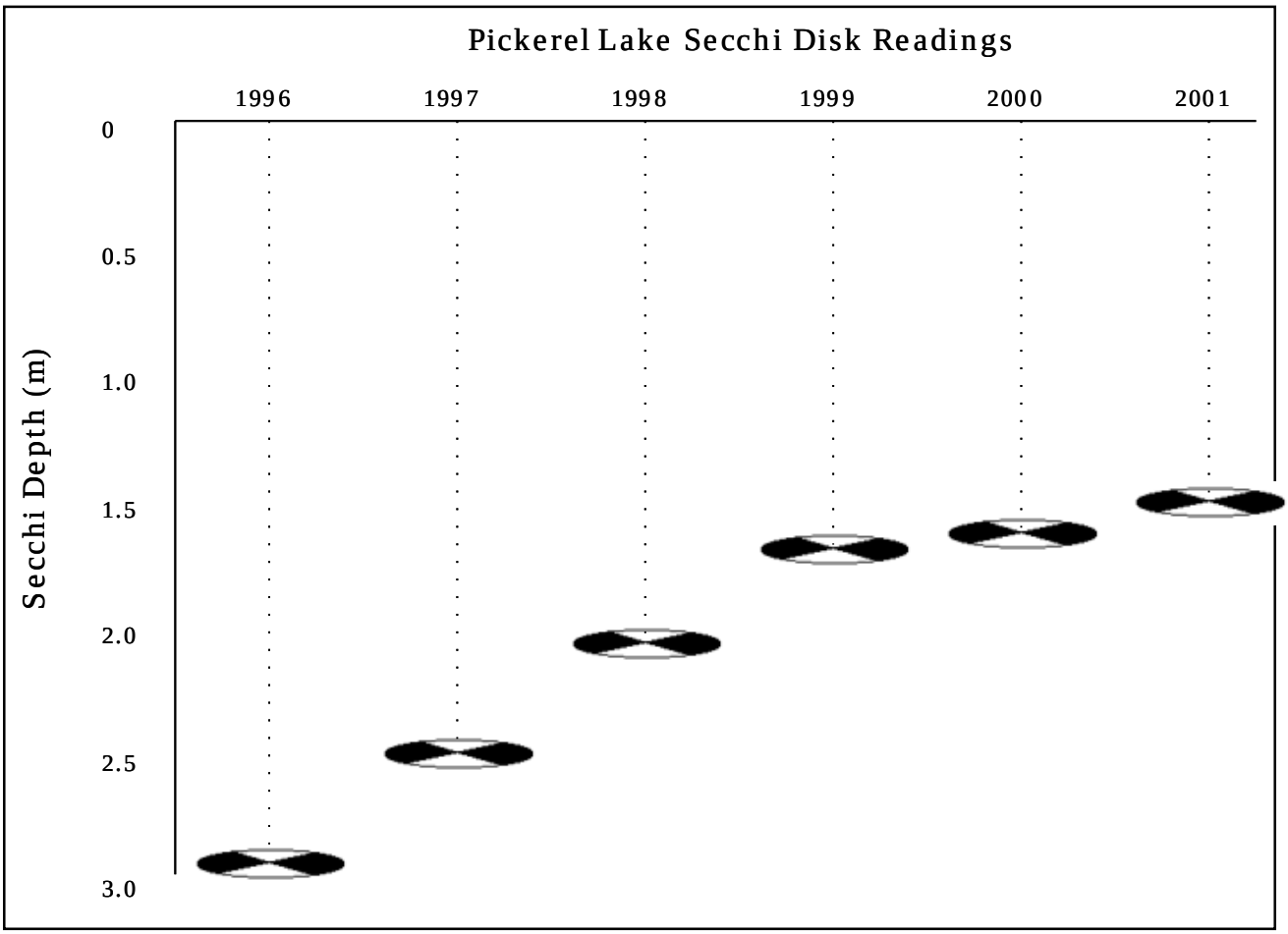

Figure 3.

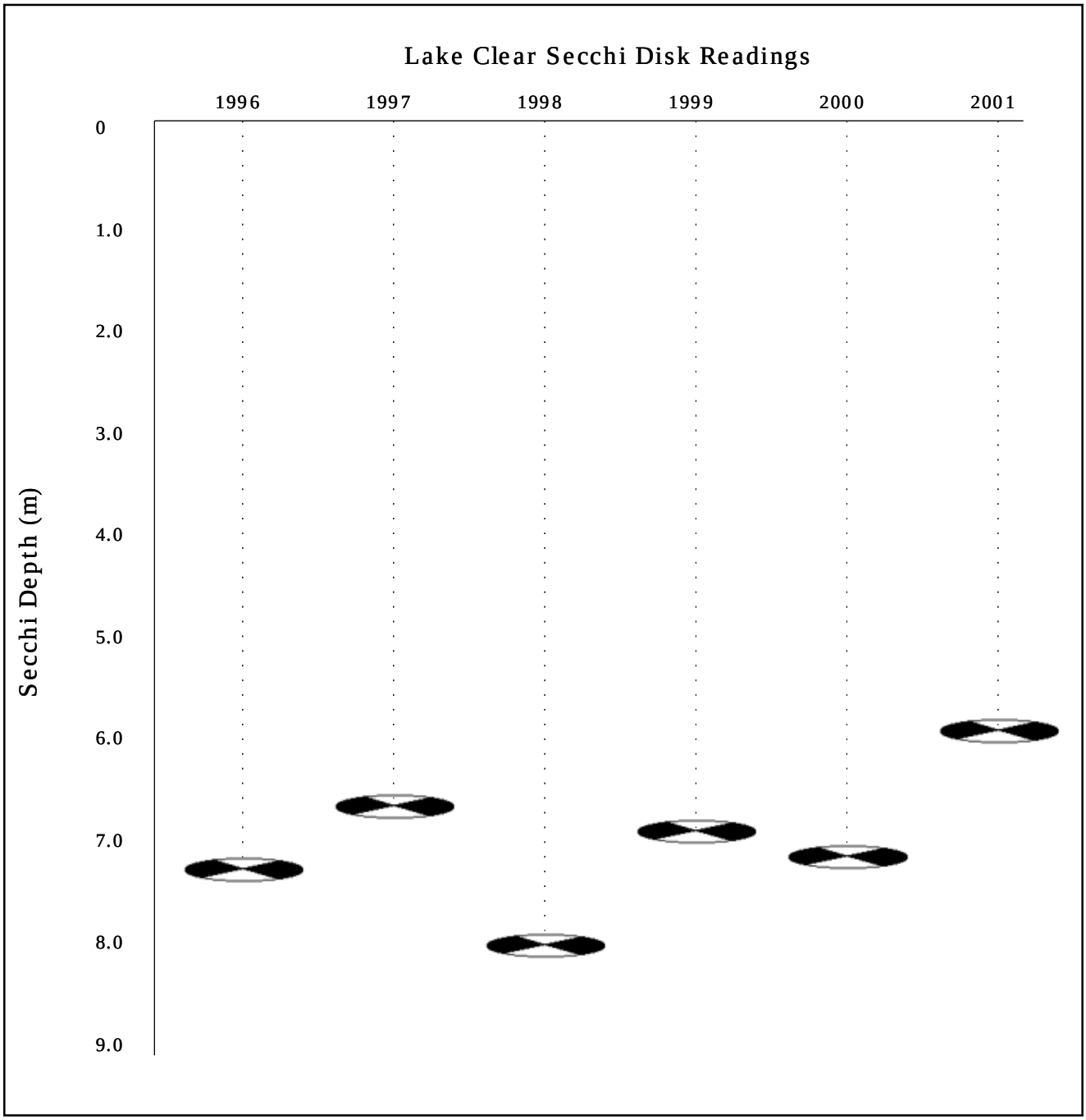
Lake Clear Secchi Disk Readings
1996
1997
1998
1999
2000
2001
Secchi Depth (m)
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

Figure 4.

Glossary

-A-

acid rain: precipitation that falls to earth with a pH reading below 5.6; low pH is caused primarily by sulfuric and nitric acid derived from emissions of sulfur dioxide and nitrogen oxides

algal bloom: a large increase in the population of algae in a lake or pond

analyze: to examine in detail

atmosphere: all of the gases surrounding the earth

-B-

bacteria: tiny microorganisms that are important decomposers in lakes

ballast water: water taken in by large ships to provide stability during ocean crossings

bathymetric map: map that records the various depths of a lake in contour form

blue-green algae: a type of algae that may become a problem in a lake with too many nutrients

-C-

caldera: lakes formed by the caving in of a roof of a partially empty magmatic chamber

carnivore: an organism that eats animals

circulation: movement of a substance through a cycle

clarity: clearness of the water, or how deep the sun penetrates into the lake

classify: in the context of this workbook, to categorize lakes on the basis of the results of a series of tests

clear-cutting: the cutting down of all trees in a particular area

color: one of the tests performed on a lake to determine water quality; color can be an indication of the presence of metals or organic substances

competitive feeder: an organism that competes with another organism for the same food

condensation: the process of water vapor cooling and forming a liquid

crater lake: a lake formed in the crater of a volcano

-D-

decomposers: agents such as bacteria that break down dead and decaying organisms into the essential elements of life, such as nitrogen, phosphorus

dissolved oxygen meter: instrument that records the concentration of dissolved oxygen per liter of water at any desired depth

domestic use: uses of water for the home, like a public drinking water supply or reservoir

-E-

esker: a long narrow ridge or mound of sand, gravel, and boulders deposited by a stream flowing on, within, or beneath a stagnant glacier

Eurasian milfoil: a type of non-native and invasive aquatic plant in the U.S.

eutrophic: lake classification characterized by high nutrient levels leading to high populations of algae and aquatic weeds

eutrophication: the aging of a lake or pond

evaporation: the process of a liquid changing to form a gas (vapor)

-F-

fathometer: an electronic instrument that is used to measure the depth of a lake

flow meter: instrument that measures the rate of water flow in a stream

flushing rate: the time it takes for all the water in a lake to be replaced by new water

food chain: an arrangement of the organisms of an ecological community according to the order in which each uses the lower members as a food source

freezing: the process by which a liquid becomes cold enough to change its form to a solid (e.g. water changing to ice)

-G-

glacier: a large body of ice moving slowly down a slope or valley or spreading outward on a land surface

graben: a depressed segment of the crust of the earth bounded on at least two sides by faults

graywater: sink and shower waste water

groundwater: water that is absorbed by the soil and is still flowing downhill

groundwater recharge: the process by which lake water enters groundwater through percolation

-H-

herbivore: an organism that eats plants

hydrogen: an element that, along with oxygen, makes up water

-I-

industrial use: use of water by large factories or businesses for equipment cooling, production or cleaning

infiltration: water being absorbed by the soil

input: the ways in which water enters a waterbody

integrated sampler: a piece of equipment used by limnologists to collect water samples for chlorophyll-a analysis

interdependence: the idea that all elements within an ecosystem are of equal importance to each other as well as to the ecosystem as a whole

invasive species: a plant or animal that becomes a nuisance in a lake or pond due to its rapid growth

invertebrates: animals without backbones, such as zooplankton and mussels

-K-

Kemmerer bottle: a specially designed bottle used to collect water samples at various depths in a lake

kettle: a steep-sided basin without surface drainage especially in a deposit of glacial drift

-L-

lake turnover: the mixing of nutrients and oxygen throughout the water column of deep water lakes and ponds; caused by seasonal temperature changes in the spring and fall in northern areas; may occur constantly in shallow ponds when temperatures remain constant

lay monitors: non-scientists that assist in tracking the water quality of a waterbody

limnologist: a scientist who studies fresh water lakes and ponds

-M-

melting: the process by which a solid form changes to a liquid

mesotrophic: the stage of lake development that can be best described as “middle-aged,” showing characteristics of both oligotrophic and eutrophic lakes

molecule: the smallest particle of a substance that retains all the properties of the substance and is composed of one or more atoms

moraine: an accumulation of earth and stones carried and finally deposited by a glacier

morphology: the structure and form of a lake

-N-

native species: species of plants or animals that have been a part of a lake since the lake was formed and evolved

nitrogen: a nutrient that is essential for growth of plants

non-native species: a species of plant or animal that was introduced to a lake from a different lake or region

nonpoint pollution: pollutants that flow in surface run-off or percolate into the ground and eventually end up at the bottom of a watershed in a lake, pond or river

nutrients: essential elements of life, used as food; nitrogen, phosphorus, etc.

nutrient loading: when nutrients enter a waterbody, either from the watershed or the lake itself

-O-

oligotrophic: relatively young lake with high bottom dissolved oxygen, few plants and algae, and very clear water

omnivore: an organism that eats all components of the food web, including producers and consumers

output: the ways in which water leaves a body of water

oxygen: element that along with hydrogen makes up the water molecule

-P-

pH: the scale used to measure the acidity or alkalinity of a substance

phosphorus: nutrient element primarily responsible for eutrophication; an important plant nutrient

phytoplankton: the microscopic algae that live in lakes or ponds

plankton net: a piece of equipment used to collect phytoplankton and zooplankton samples

point source pollution: flow of a contaminant directly into a body of water, generally through a pipe

pollution: any material that is introduced to the environment that is harmful or potentially harmful

precipitation: moisture that falls to the earth in the form of rain, snow, hail, sleet, etc.

predator: an organism that feeds on another organism

primary consumers: herbivores who consume primary producers

primary producers: plankton and aquatic plants that manufacture their own food in the form of sugar

productive: a lake that produces large quantities of plants, including both algae and vascular plants

purple loosestrife: a type of non-native and invasive wetland plant

-R-

round goby: a non-native and invasive fish species in the U.S.

runoff: water that has fallen from the sky as precipitation and flows across the earth's surface

-S-

Secchi disk: a twenty-centimeter diameter disk with alternate black and white quadrants that is used to determine the transparency of a lake

secondary consumers: animals and plants that consume primary consumers

solution lake: formed when rock formations are dissolved by water

running through the area

specific heat: the amount of heat required to raise the temperature of one unit of a substance one degree Celsius

spiny water flea: a non-native and invasive zooplankton species in the U.S.

surface discharge: output from a lake that travels on the earth's surface

surface streams: any water running on the earth's surface (i.e., rivers, streams, brooks, creeks, etc.)

surface tension: a measure of the strength of water's surface film; the attraction between the water molecules creates a strong film

-T-

tertiary consumers: larger fish and animals that feed on smaller consumers

thermal layers: distinct layers of water in a lake due to temperature differences

thermocline: middle layer of a deep water lake or pond; barrier between the warm surface layer and the cold deep layer where temperature changes quickly with increasing depth

topographic map: a map that uses lines to show the high and low elevations of the land

total phosphorus: the total amount of phosphorus found in a lake from both living and non-living sources

transpiration: water brought from the roots of plants up to and out of the leaves and evaporated into the atmosphere

-W-

water cycle: the circulation of water in the atmosphere and on the earth in its various forms, powered by the sun

watershed: an area within which all water flows to the lowest spot and collects in a lake, river or the ocean

-Z-

zebra mussel: a non-native and invasive animal in the U.S.

zooplankton: microscopic animals that float in the water and consume phytoplankton and other microscopic materials

Illustration Acknowledgements

Figure 4-1: http://www.stetson.edu/~kwork/favorite.htm

Figure 4-2:
http://vis-pc.plantbio.ohiou.edu/algaeimage/pages/Asterionella.html
http://daphnia.com/daphnia.html
http://www.sarep.cornell.edu/Sarep/fish/Percidae/yellowperch.html
http://www.fishingafrica.co.za/fishpictures10.html

Figure 5-2:
http://vis-pc.plantbio.ohiou.edu/algaeimage/pages/anabaena.html

Figures 6-1, 6-3, 7-3, 7-4: Microsoft Clip art

Figure 6-4: Brandy Penna

Figure 7-1: Brenda Pervanas: goby, spiny water flea and zebra mussels; Patty Warren: Eurasian milfoil; University of Florida: Hydrilla; Stephanie Bowser: purple loosestrife

Figure 7-2: Sheila Murray

All others: created by Alicia Carlson