LAKE ECOLOGY AND FISH BIOLOGY
U.S. Army Corps of Engineers, J. Strom Thurmond Project
2017 Middle School Eco-Meet Study Packet

The Corps of Engineers' station will focus on lake ecology and fish biology. In particular, students will be expected to understand how lakes are formed, basic physical and biological aspects of lake ecosystems, and basic features of fish biology.

Students should be prepared to answer questions on the following topics:

- How lakes are formed
- Types of lakes
- Basic concept of lake stratification
- Lake zones
- Lake food chains and basic food chain/web components
- Basic types of fish
- Basic fish biology and how to measure and age fish

Pay attention to all **bold** words. You should know the definitions and/or be able to answer questions about those words. All test questions will come directly from information in this packet.

So now, let's explore lakes!

Lakes are water bodies which are deep enough (greater than 2 m) to contain water for long periods of time and to sustain fish during the winter by not freezing to the bottom. **Lentic** is a term applied to bodies of water, such as lakes, where the waters are standing or still. Bodies of water that move or flow, such as rivers and streams, are referred to as **lotic**.

Formation of Lakes

Lakes may be formed by geological, climatological, or biological mechanisms. They may form after sudden, catastrophic events (such as meteorites), or may form more gradually (such as salt lakes). They may even form from man's activities, such as building dams.

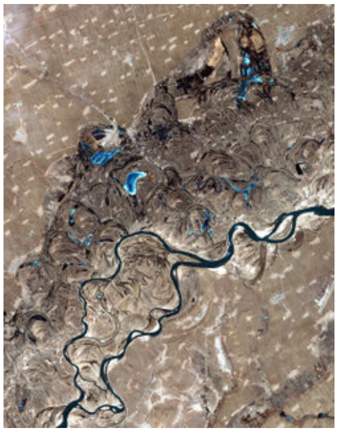
Many present-day lakes, called **Glacial Lakes,** were formed by glaciers. Between one million and ten thousand years ago, Earth experienced four ice ages. At times, as much as 31% of the earth's surface was covered by glaciers. The last glacial period, or ice age, was responsible for creating the vast majority of lakes now present in the northern U.S. and Canada, including the Great Lakes. As glaciers began to recede toward the end of the ice ages, they scoured the ground beneath, leaving large pockets or basins filled with rain water or melted glacial water. Today, glaciers cover only about 10% of the earth's surface. Lake Michigan, pictured above, is an example of a glacial lake.

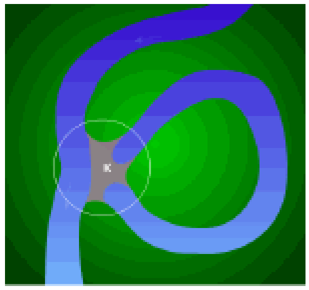
Tectonic Lakes are formed by earthquakes, movements of the earth's crust that create a basin that can fill with water. Movement of the tectonic plates also causes uplifting of the earth in places. During the end of the ice ages, some of the uplifted areas were modified by glacial scouring, creating lakes that show characteristics of both tectonic and glacial lakes. Lake Superior is an example of a lake with both glacial and tectonic origins.

Lakes Created by Landslides form in stream valleys behind the debris dam created by a landslide.

Lakes Created by an Impact or Volcanic Eruption typically have a high rim or edge and are circular in shape. Crater Lake in Oregon (pictured left) is an example of a lake formed in the caldera of a volcano.

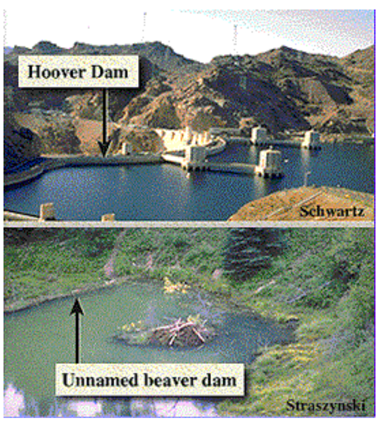
Saline Lakes are found in areas with closed watersheds (no flow leaves the lake to reach the ocean). Saline lakes have a higher salinity, or salt content, than most other lakes. Their salt content comes from the underlying and surrounding rocks. One of best known saline lakes in the U.S. is the Great Salt Lake in Utah (pictured below). This lake does not have any streams that drain it, making it a **terminal lake**. Water is lost from the lake mostly through evaporation. Four rivers and numerous streams flow into the lake. When inflow from the streams equals water lost to evaporation, the level of the lake remains constant. If inflow is greater or less than evaporation, the level of the lake will rise or fall, respectively and the salinity, or saltiness, of the lake will change as well.





Lake Basins Formed by River Activity. Rivers are constantly changing water bodies, moving across the landscape. When they move and change course, rivers can deposit sediments, which build up and may cut off or isolate areas of water from the main channel of the river. This creates lakes known as **oxbow lakes**. The Savannah River has formed many oxbow lakes in its history. Although they are cut off from the main river channel, they are located in the floodplains of rivers and are replenished with water when the nearby rivers flood. The aerial pictures above show how oxbow lakes form.

Coastal Lakes often form along irregularities in the shoreline of the sea or large lakes. Longshore currents, ocean currents that flow parallel to the shore, deposit sediments in bars or spits that eventually isolate a fresh or brackish-water lake. The picture to the right shows an example of coastal lakes isolated from the ocean over time.



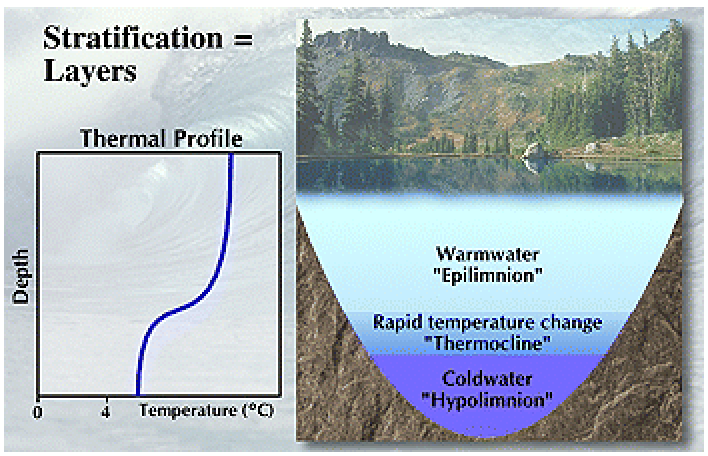
Lakes Created by Plants and Animals can be formed in different ways. Dams of tree debris, plants and moss have been reported to impound streams and rivers, creating some lakes like Caddo Lake in Texas. The damming activity of beavers results in the impoundment of streams with subsequent flooding of the landscape, making beavers the largest lake builder in America after humans. **Reservoirs** are lakes created by humans through the damming of river valleys. The photos at left show lakes created by man-made dams and beaver dams.

Once a lake is formed, however, it is doomed. A lake's basin naturally accumulates sediments over time, leading eventually to its "death." In time, lakes will fill in and marshes, meadows and forests will grow on what was once a lake. The process of lakes, and all ecosystems, aging and changing into other types of ecosystems is called **succession**.

DISTRIBUTION OF HEAT AND STRATIFICATION

Thermal stratification is a direct result of heating by the sun. **Thermal stratification** is the phenomenon in which lakes develop two distinct layers of water, each with different temperatures: warm water on top, called the **epilimnion**, and cold water below, called the **hypolimnion**. These layers are separated by a region of rapid temperature change, the **metalimnion** or **thermocline**.

The stratification of water based on temperature is a result of the density of water at different temperatures. For the most part, as water increases in temperature it becomes less dense. Conversely, water becomes denser as it decreases in temperature. Colder, denser water is found on the bottom of a lake (**hypolimnion**); warmer, less dense water at the surface of the lake (**epilimnion**), and a zone where the temperature changes from warm to cold rapidly is located in the middle (**thermocline**). The picture below shows the location of the three temperature layers or zones within a lake that is stratified.



Thermal stratification occurs most commonly in deep temperate region lakes. Deep lakes, however, do not stay stratified all year. Water temperatures in a lake change with the seasons. Let's start with spring when the lake water is generally the same temperature from the surface to the bottom. Wind allows circulation and mixing of the lake water. Surface water can be pushed to the lake bottom and bottom water can rise to the surface (Figure 1). This mixing is very important because it allows relatively large amounts of oxygen to reach the bottom of the lake. Mixing of the lake water at this time of year is called spring turn-over.

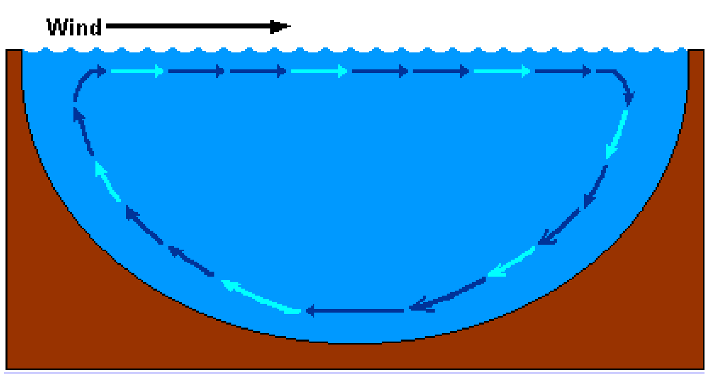


Figure 1 Complete mixing of water can occur when all water within the lake is generally the same temperature. Wind helps to drive this process.

As air temperatures rise in late spring, heat from the sun begins to warm the lake surface. The lake heats from the surface down, and the amount of sunlight and heat that penetrates the water decreases with depth. The warm water is less dense than the colder water below resulting in a layer of warm water that floats over the cold water. The two layers are separated by the thermocline. The three distinct layers of water, each with a different temperature, is an excellent example of thermal stratification within a lake system. Figure 2 below shows how the depth of the epilimnion increases through the spring and into the early summer.

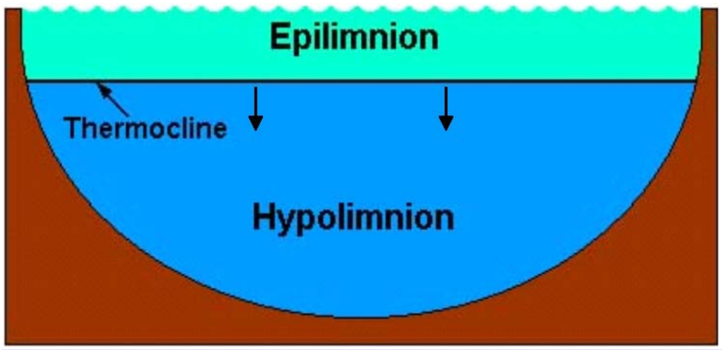


Figure 2 As summer approaches, the surface of the lake begins to get warmer. This creates a relatively warm surface layer over a relatively cool bottom layer. They are separated by a zone that changes temperature very rapidly with depth.

During the summer, the epilimnion will reach a maximum depth and stratification will be maintained for the rest of the summer. The warm water, abundant sunlight, and nutrients brought up from the lake bottom during spring turn-over provide an ideal environment for algae to grow within the epilimnion. Stratification during the summer prevents the lake from completely mixing. Wind circulates the surface water, but the warm water of the epilimnion is unable to drive through the cold, dense water of the hypolimnion. As a result, the water is only mixed in the epilimnion (Figure 3).

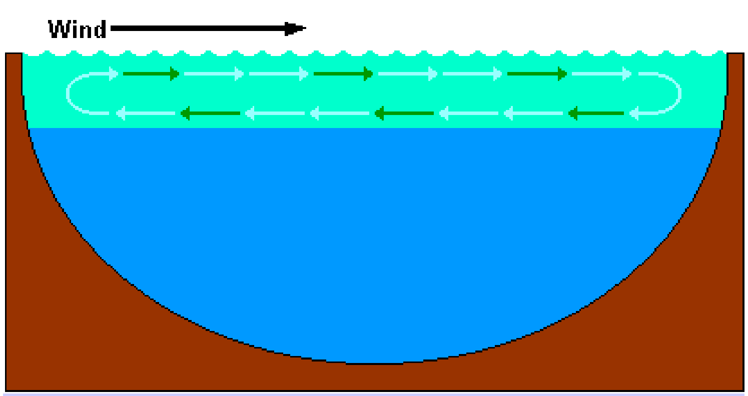


Figure 3 During summer density differences act as a barrier to complete mixing of the lake. This deprives the lake bottom of oxygen.

Without mixing to provide dissolved oxygen, the lake bottom, lacking enough light for photosynthesis to occur, tends to have a very limited supply of oxygen during the summer. Animals and bacteria can deplete the dissolved oxygen at the bottom of the lake. Dead algae sink to the lake bottom and are decomposed by bacteria. This accelerates the depletion of dissolved oxygen in the hypolimnion as bacteria use oxygen to decompose the organic material. During summer the lake bottom can become **anoxic** (i.e., without oxygen).

As autumn approaches and temperatures decrease at the lake surface, the epilimnion begins to decrease in depth (Figure 4). Eventually the epilimnion gets so shallow that it is no longer a separate layer and the lake loses its stratification. As in the spring, the lake water in the autumn has generally uniform temperature, and wind can once again thoroughly mix the lake. This process is called autumn turn-over (Figure 5).

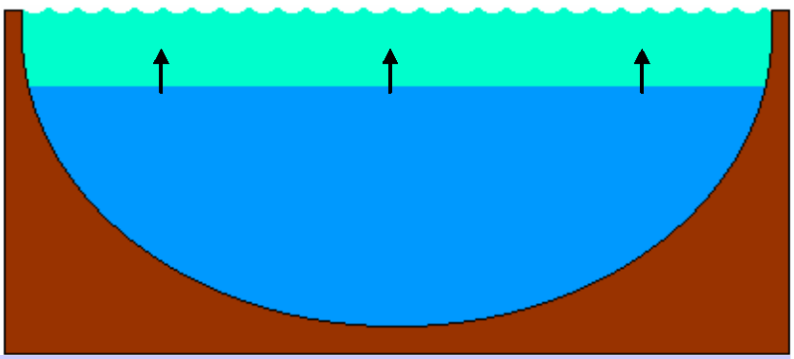


Figure 4 As seasonal temperatures decrease, so does the depth of the warm water layer known as the epilimnion. Conversely, the cold layer known as the hypolimnion increases in thickness.

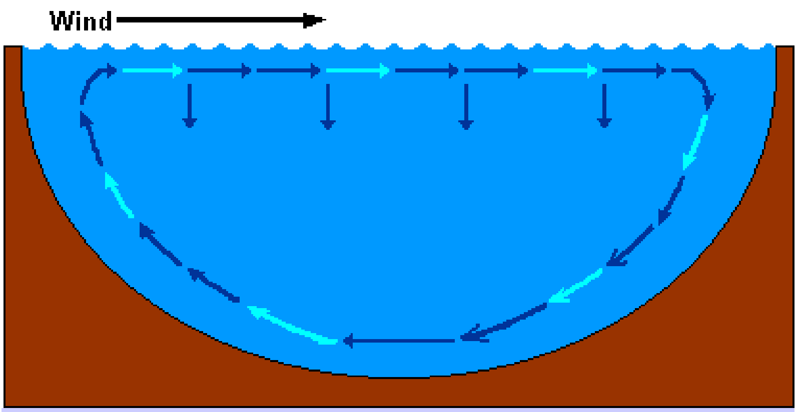
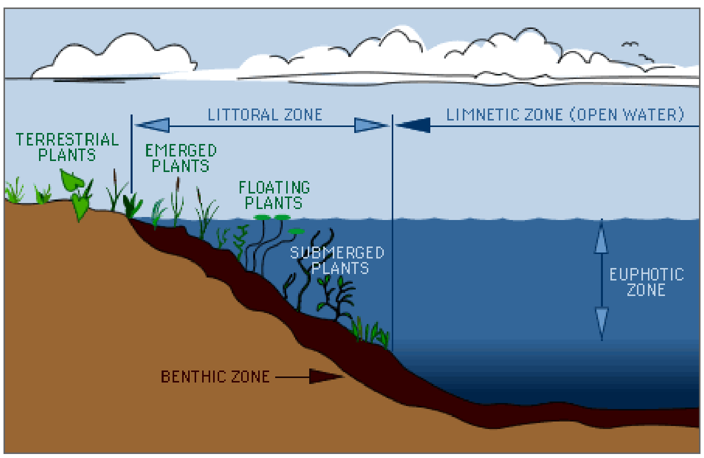


Figure 5 Complete mixing of water can occur when all water within the lake is generally the same temperature. In addition, the atmosphere cools the water at the lake's surface. This dense water sinks to the bottom and further contributes to lake mixing.

In northern temperate climates, lakes undergo a second seasonal stratification as ice forms on the lake surface. In these situations, the water immediately below the ice is slightly warmer (4^{o}C) but denser than the ice. Think about a glass of ice water. The ice floats at the top of the glass, just as it does in a lake. Most lakes in southern temperate climates, such as those in Georgia and South Carolina, do not stratify during winter, but remain mixed throughout the entire lake.

DISTRIBUTION OF LIGHT AND LAKE ZONES

In addition to influencing the temperature of lakes, sunlight also influences where plants can grow in lakes. This depends upon how deep light can penetrate through water to allow plants to photosynthesize. Lakes can be divided into three primary zones of biological communities, the **littoral, limnetic and benthic zones**.



The diagram at left shows the three primary zones, as well as the types of plants able to photosynthesize and live in those zones. The **littoral zone** is along and near the shore where sunlight penetrates all the way to the sediment and allows aquatic plants to grow. The plants in the littoral zone, in addition to being a food source for algae and invertebrates, provide a habitat for fish and other organisms that is very different from the open water environment. The dynamic littoral zone is subject to dramatic annual changes as lake levels change with flood and drought, from shoreline vegetation changing sunlight levels and nutrients.

The **limnetic zone** is the open water area where light does not penetrate all the way to the bottom. Plants typically do not occur in this area due to lack of sediments to root in and low light. Free-floating plants and algae may be found on or near the lake surface in the open water of the limnetic zone.

The bottom sediment is known as the **benthic zone.** The benthic zone includes the sediment layer under both the littoral and limnetic zones. The upper portion of these sediments is abundant with organisms. Most of the organisms in the benthic zone are invertebrates (organisms that don't have a backbone), such as insect larvae (midges, mosquitoes, black flies, etc.) or small crustaceans.

Lake Organisms

Organisms in a lake can be classified by the areas or zones in a lake where they live and how they move among those zones. These classifications include:

THOSE THAT GO WHERE THEY CHOOSE (move on their own)		
FISH	**AMPHIBIANS TURTLES**	**LARGER ZOOPLANKTON AND INSECTS**

THOSE THAT GO WHERE THE WATER TAKES THEM (float with the current – these are usually very small, microscopic organisms, difficult to see with the naked eye)	
SMALL, MICROSCOPIC, FREE-FLOATING LIVING THINGS = PLANKTON animals - zooplankton free-floating algae - phytoplankton bacteria - bacterioplankton	**DEAD STUFF = DETRITUS** internal - produced within lake external - washed in from watershed

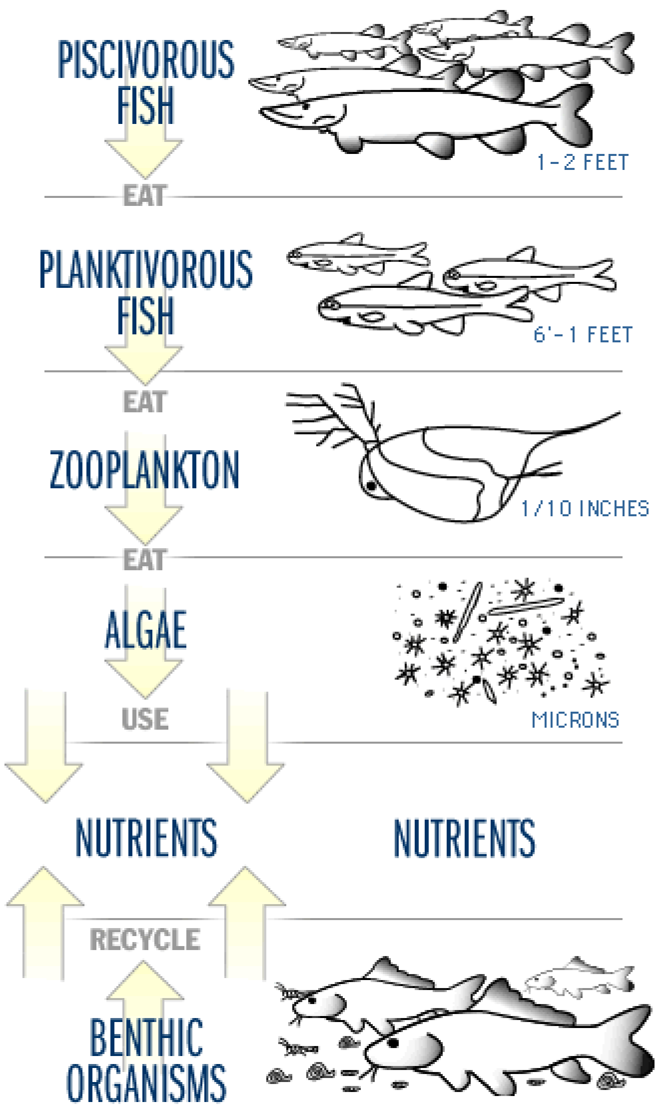
THOSE THAT LIVE ON THE LAKE BOTTOM		
BENTHOS = ANIMALS aquatic insects molluscs - clams, snails other invertebrates - worms, crayfish	**PLANTS** higher plants attached algae	**BACTERIA & FUNGI** sewage sludge mixture of algae, fungi and bacteria

Many organisms depend on lakes for part of their lives, though they do not live exclusively in lakes. **Dragonflies** are an example of one insect group that lays its eggs by water bodies, has aquatic larvae that feed in the water, but then pupates and emerge as adults that no longer need to remain by water bodies.

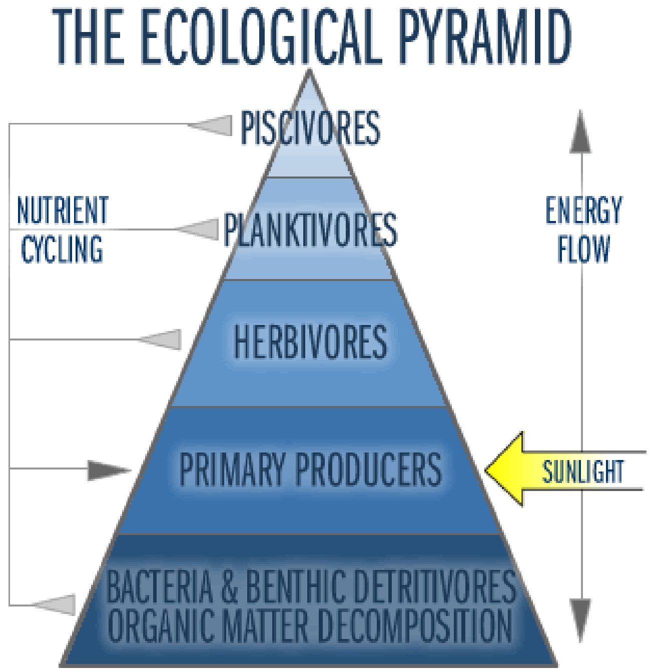
LAKE FOOD WEBS/FOOD CHAINS

Organisms within lakes can also be classified by the role they play in their food chain or food web. Learning about the lake food chain helps us understand how the ecosystem functions. The diagram below shows a basic lake food chain. In the food chain, there are 3 basic levels of organisms: **primary producers, consumers** and **decomposers.** The **primary producers** consist of the algae (**phytoplankton**) and plants that use sunlight and nutrients. The **consumers** include the **zooplankton** that feed on phytoplankton**,** and fish. Fish are classified in the food chain by what they eat. For instance, **planktivorous fish** feed on the phytoplankton and zooplankton, and **piscivorous fish** feed on other fish. The **decomposers** include **benthic organisms and bacteria** that break down and decompose waste matter. It is important to remember that the lake food chain is also a part of a larger food web in which predators such as birds and mammals, including humans, feed on fish.

TYPICAL FOOD CHAIN



The diagram below shows the flow of energy and nutrients through the various levels of a lake ecosystem. The broad base of primary producers supports the levels above: **herbivores** (zooplankton), **planktivores** and much smaller numbers of **carnivores** (predators). It is important to remember, however, that many organisms are **omnivorous** and may fit into more that one level. Furthermore, consumers in often shift levels throughout their life cycle. For example, a larval fish may initially eat fine material that includes algae, bacteria and detritus. Then it may switch and graze on larger zooplankton and ultimately end up feeding on smaller fish or even young game fish (i.e., top predators) when it reaches maturity.



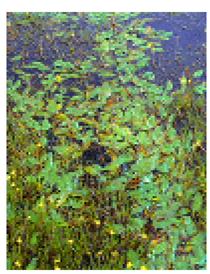
In order to better understand lake food chains, we need to look at the three primary levels - the primary producers, consumers and decomposers.

Primary Producers

Primary producers make up the food basis for all other levels of the food chain. Primary producers are typically plants and algae, and use nutrients in the water, light, oxygen and carbon dioxide to grow and provide food for all other organisms that live in lakes. Many of the plants found in this level of the food chain can be found in the littoral zone of a lake where enough sunlight is available to photosynthesize.

Some common primary producers in lakes in the U.S. are:

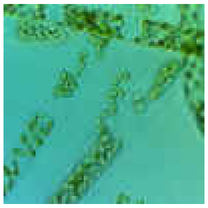
Water Lily



Pondweed

Cattails

Algae, or phytoplankton, are the other main group of primary producers. They come in countless forms and live in nearly all kinds of environments. Most are microscopic, growing as single cells, small colonies, or filaments of cells. If algae populations grow large, the water will become noticeably green or brown rather than clear. Below are some photos of algae found in lakes.


Spirogyra


Fragillaria


Cryptomonas

Consumers

Consumers include the organisms in an ecosystem that eat, or consume, other organisms, including herbivores, carnivores, and omnivores. This group, however, does not include those that feed on the remains of other organisms, the decomposers.

The smallest consumers in a lake ecosystem are **zooplankton**, small animals that swim about in open water. They graze on algae, bacteria, and detritus (partially decayed organic material). Some species can be seen with the naked eye, although they are more easily observed with a hand lens or microscopes. If you wish to see them, stare into the water of a pond or lake on a calm night with a flashlight beam shining from above. Zooplankton often found in lakes include:


Daphnia


Chaoborus


Rotifers

The next level of consumers, called secondary consumers, feed on zooplankton. These include fish (planktivores) and some invertebrates.

Another type of consumer is the benthic organisms that live and feed primarily in the sediments on the lake bottom. These include invertebrates, such as clams and mussels, as well as bottom-feeding fish like catfish. They feed on detritus and organic matter in the lake, and are important recyclers of nutrients trapped in the sediments.

The best known group of aquatic consumers is fish. Many small fish, such as sunfish and perch, primarily eat zooplankton. Larger fish, such as bass, gar and lake trout, prey on the smaller fish.

Decomposers

Decomposers, which include bacteria, fungi, and other microorganisms, are the other major group in the food chain. They feed on the remains of all aquatic organisms and in so doing break down or decay organic matter. Some of the decayed material is recycled as nutrients, such as phosphorus and nitrogen, which are then available for new plant growth.

The decomposers are found in all zones of a lake, although they are found in largest numbers in the lower hypolimnion, where there is plenty of dead organic matter. Decomposition of organic matter in the hypolimnion is responsible for the depletion of oxygen over the course of the summer while the lake is stratified. This can lead to anoxic water in the deepest portions of a lake.

THE BASICS OF FISH BIOLOGY

Although all organisms in the lake ecosystem are critical, the fish are the most well known and easiest to study. Let's take a closer look at fish and their biology.

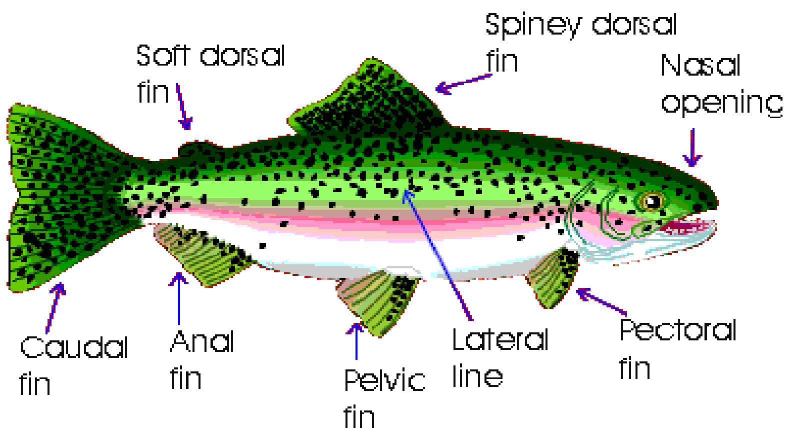
Fish are limbless aquatic animals with fins and internal gills. There are **three classes of fish: the primitive jawless fishes** like lampreys**, the cartilaginous fishes** likes sharks and rays**, and the bony fishes**. There are over 28,000 living species of fish. They range in size from < ½ in. to >45-ft in length. Many are brightly colored, and many have shapes and patterns that serve as camouflage. They are found in all marine, fresh, and brackish waters throughout the world and at all depths. Members of different species of fish tolerate water temperatures ranging from freezing to over 100°F. Freshwater fish live in a variety of habitats, from rivers and streams to ponds, lakes and wetlands. As we learned before, fish may be carnivorous, herbivorous, or omnivorous. Some are scavengers on lake or ocean bottoms.

Over 95% of all fish species alive today are classified as bony fish, and they make up the majority of all vertebrates on Earth. Bony fish have a bone skeleton and swim bladder. Most bony fish have gills adapted to breathing under water. Some fish, such as mudskippers, however, have lungs and can breathe air if they are out of the water. Fish use **swim bladders** to control their depth, moving easily from shallow to deep water and back again. The idea behind the swim bladder is relatively simple. Air is less dense than water, therefore, air floats on top of water. The swim bladder of the fish holds air, which allows the fish to be lighter in the water and makes it more buoyant. If the fish lets air out of the swim bladder, it will get more dense and begin sinking.

How Fish Swim

The density of water makes it very difficult to move in, but fish can move very smoothly and quickly. A swimming fish is relying on its skeleton for framework, its muscles for power, and its fins for thrust and direction.

The skeleton of a fish is among the most complex of all vertebrates. The skull acts as a fulcrum, the relatively stable part of the fish. The vertebral column acts as levers that operate for the movement of the fish. The muscles provide the power for swimming and make up 80% of the fish's body. The muscles are arranged in multiple directions that allow the fish to move in any direction. The fins transform the movement of the muscles into the movement of water passing the body. Fins give a fish control over its movements by directing thrust, supplying lift and even acting as brakes.



The basic fins on a fish are the **dorsal, pectoral, anal, pelvic and caudal fins.**

Fish generally are either cruisers or burst swimmers. Cruisers are the fish that swim almost continuously in search for food, such as the tuna. They may travel long distances and swim in a manner that can be sustained for long periods of time. Burst swimmers, such as coral reef fish, usually stay in the same place most of their life and swim in short, quick bursts to catch food, then return quickly to cover for safety.

How Fish Breathe

The water surrounding a fish contains a small percentage of oxygen. This is much less than the oxygen per liter of air that we breathe, so the fish must use a special system for concentrating the oxygen in the water to meet their physiological needs. The circulation of blood in fish is simple. The heart only has two chambers, in contrast to our heart which has four. This is because the fish heart only pumps blood in one direction. The blood enters the heart through a vein and exits through a vein on its way to the **gills**. In the gills, the blood picks up oxygen from the surrounding water and leaves the gills in arteries, which go to the body. The oxygen is used in the body and goes back to the heart. Fish must allow new water to pass over their gills continuously to keep a supply of oxygenated water available.

STUDYING FISH IN THEIR NATURAL ENVIRONMENT

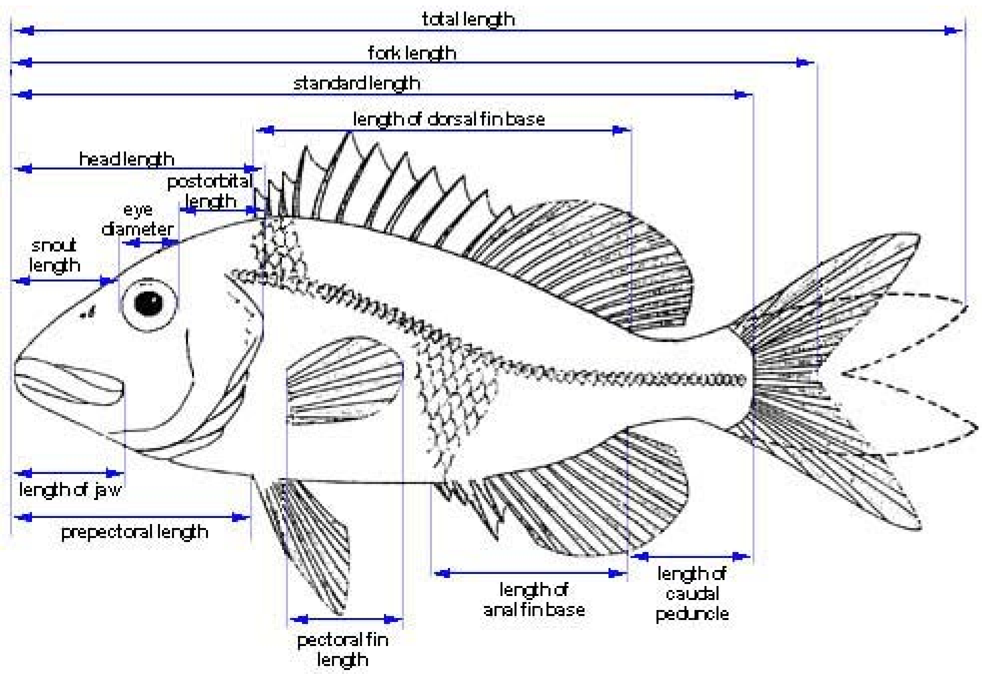
Studying fish in their natural environment can provide a lot of information about the population of a species, as well as the health of the particular body of water. Biologists use many techniques to study fish and may collect a great deal of information. They may simply collect samples of fish at various places in a lake and count the number of each species. They can then use these numbers to estimate the total population size for each species in a lake. They can also determine which habitats and zones in a lake are inhabited by which species. Fish and game managers may use this information to set catch limits for fishing in particular lakes.

Some of the most basic data collected during almost all fish studies is their size (length and weight) and their age.

Measuring Fish

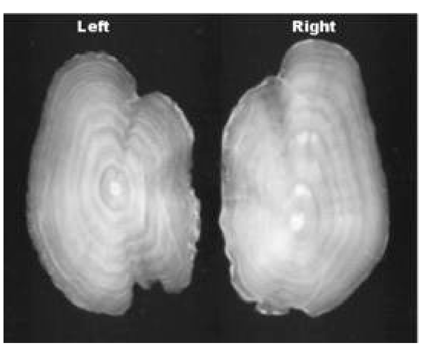
When biologists study fish, whether in lakes, rivers, streams or the ocean, they collect certain basic data. Some of that data is the length and weight of the fish. This helps biologists determine how healthy fish are, which helps them determine how well they are eating and then determine the health of the ecosystem the fish live in. Fish can be measured in a variety of ways. The most commonly used measurements are the **total length, fork length, and standard length**. The **total length** is the length of the fish from the end of the snout or mouth to the tip of the caudal fin or tail, with the tail extended. The **fork length** is measured from the end of the snout to the fork or V in the caudal fin or tail. Finally, the **standard length** is a measurement of the body of the fish, minus the caudal fin. It spans from the end of the snout to the end of the body at the base of the tail. The diagram below shows examples of the various lengths and measurements that biologists record in the field.

Standard Measurements of Bony Fish



Aging Fish

Another piece of data biologists often collect is the age of fish in a population. Biologists can determine how well a population is reproducing based on the ratio of old to young fish. Fish are commonly aged by examining a scale or the **otolith**, a calcareous structure in the inner ear of fish. These are sometimes called **earstones**. Age can be determined by counting bands, much in the same way we age trees by counting rings. In warm temperate waters, fish grow fast during the summer months when water temperatures are warm, and slow during the cold winter months. A year of growth is defined as one summer zone plus one winter zone. These zones are identified on scales as areas of wide (summer) and narrow (winter) bands. On otoliths, these zones are identified as alternating opaque and translucent bands when viewed under a microscope. The space between the rings can also indicate how well a fish is growing. Fish that are eating well and growing quickly will have wider spaces between rings.



Otoliths (bands very visible)

Fish scale

In addition to collecting physical data about fish, biologists also collect data about fish environments to determine what they are eating, the effects of chemicals or pollutants on the aquatic environment, impacts of changes to the nearby terrestrial environment on the aquatic environment, and the impacts of an exotic species (one not naturally occurring in the habitat, but introduced from another location) on a native fish population. All of this information, and much more, can be used to determine how we, humans, are having an impact on the environment around us, steps we can take to improve degraded environments, and steps to protect those healthy aquatic environments all around us.

Below are some web sites to explore for more information about fish biology and lake ecology:

http://www.ecy.wa.gov/programs/wq/plants/management/joysmanual/nutrients.html
http://www.enviroliteracy.org/category.php/3.html
http://www.nps.gov/crla
http://dnr.wi.gov/org/caer/ce/eek/nature/habitat/lakes.htm

Curriculum Standards Addressed:

Georgia	**South Carolina**
S6CS1, S6CS5, S6E3	6-1, 6-3
S7CS1, S7CS5, S7L2, S7L4	7-1, 7-4
S8CS1	8-2, 8-3