Water Quality in Sportfish ponds

Water quality measurements tell the pond owner what is happening chemically in the pond. Any thing that affects water quality including pollution, wind, weather and rain runoff can affect fish health. Understanding the basics of water quality can help pond managers predict and prevent situations that reduce pond productivity or kill fish and other organisms.

This fact sheet describes the water quality measurements most important to sportfish pond owners, temperature, dissolved oxygen, alkalinity, pH, hardness and salinity.

Temperature

Temperature is the easiest water quality measurement to perform. A thermometer is all that is needed, although more sophisticated devices are needed to measure temperature at various depths in rivers and lakes. A common instrument used to measure water temperature at various depths of a body of water is a temperature probe. A sensor is attached to the end of a long cable, often wound on reel for convenient storage. The cable and sensor are lowered into the water and the temperature at any specific depth is read from a meter connected to the cable and sensor.

Analyzing water with a water quality test kit.

Temperature Tolerances

Fish are **exothermic**, their body temperature is about that of the surrounding environment; and affects all metabolic processes. Cold water slows metabolism and warm water increases metabolic rate. Fish have adapted to a wide range of temperatures. Some cold water species can tolerate temperatures below 32^0 F.; while desert killifish can live in pools in Death Valley at temperatures in excess of 110^0 F. Native warm-water fish have a temperature tolerance range of about 34- 104^0 F. although many species will become stressed near either of these extremes. There

optimum temperature is about 75-85^{0}F.
Below 55^0 F. activity and feeding slow. Above 95^0 F. many warm-water fish begin to reach upper lethal

temperature tolerance limits. Tropical fish such as the tilapia, can not tolerate cold water. They become stressed when water reaches 60^0 F. and die at water temperatures below 50^0 F.

Trout and other coldwater fish will die when water temperature exceeds 70^0 F. Their optimum temperature is about 55-65^0 F. and they are active down to 40^0 F.

Fish must adjust to temperature changes gradually. A warm-water fish may survive in 100^0 F. water if slowly acclimated to it, however, a sudden change from a water temperature of 65^0 F. to 75^0 F. May shock and kill the fish.

Temperature and Dissolved Gases

Temperature is important because it, along with barometric pressure, determine the amount of a particular gas that can be dissolved in water (Boyle's Law). The higher the water temperature the less gas can dissolve in a given volume of water. Also, as barometric pressure decreases, less gas can dissolve in a given volume of water, although this effect is usually negligible.

Oxygen is an important example. In winter when water temperature may be near 40^0 F., water can hold 12.5 mg/l dissolved oxygen. In summer at a water temperature of 80^0, the water can hold only 7.9 mg/l dissolved oxygen. This is the **saturation level** at sea level, or the maximum amount of a gas that can be dissolved in water under a given temperature and pressure. Under certain circumstances, water may become super saturated with gases. This can occur where water is released from a dam or in the photic zone (fraction of water column illuminated by sunlight) on a sunny day.

Thermal Stratification

Most ponds and lakes in temperate North America are **dimictic**. Temperatures in dimictic lakes follow an annual cycle that results in stratification during most of the year, punctuated by mixing of the water column in spring and fall. (Fig. 1.).

During **summer**, strong heating from the sun and warm air temperatures heat the surface of the body of water. Heated water is less dense than colder bottom water and remains near the surface. A **thermocline** gradually develops. This is a sharp line of temperature change, usually 4-8 feet below the water surface, although it may vary through out the year. Warm water above the thermocline, the **epilimnion**, does not mix with the cooler water, the **hypolimnion**, below this level.

Many times, swimmers can feel the thermocline and often mistake the cold water underneath for a spring flowing into the lake from the bottom.

Because the upper and lower layers of water do not mix, oxygen entering the surface water can not reach lower levels.

Below the thermocline oxygen levels may be near 0 mg/l.; and can not sustain fish or many other aquatic organisms except for brief periods of time. Decaying plant life and dead organisms fall to the anoxic (no oxygen) depths of the hypolimnion and accumulate. Organic matter requires oxygen to decompose or oxidize. Oxidation can not happen until oxygen from the surface water mixes with water at lower depths. The thermocline strengthens during the relatively calm stable months of summer. However, with the approach of **autumn**, weather begins to change. Cold fronts begin to affect local conditions. Cool air and cloudy days lower surface water temperatures until they are near the temperature of bottom water. The thermocline weakens. Strong winds associated with the passage of a cold front begin to circulate the lake water. Surface water breaks through the weakened thermocline and mixes with bottom water.

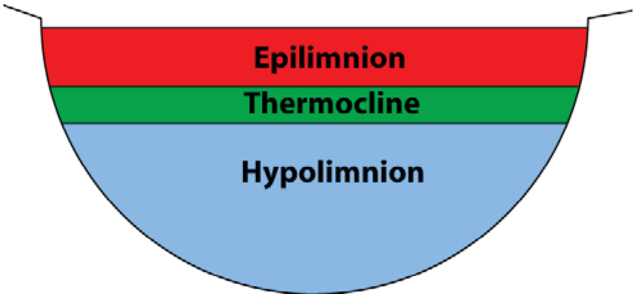

Fig. 1 Thermal stratification in typical North American lakes and ponds.

The entire lake can mix or **“turn over”** in a short time. Sometimes less than an hour is needed to mix the lake or pond.

As oxygen from the surface water reaches the bottom of the lake, much of it can be used up in the chemical process of oxidation as decaying organic matter, dead plants and other organisms begin the decomposition process.

Lake “turn over “can kill fish if oxygen removal due to decomposition reaches lethal levels, usually below 1-2 mg/l, for a sufficient period of time. This is most likely to happen in polluted lakes or ponds that receive large amounts of animal waste, leaves or fertilizer. Fish kills due to fall turnover frequently happen to small ponds that are heavily stocked with food fish and are given fish feed on a regular basis.

During **winter**, cold air and winds cool the surface water and increase its density. The water of greatest density sinks to the bottom of the lake. Water has a very important and interesting physical property. Its density increases as its temperature drops, until it reaches a temperature of 39.2^0 F. (4^0 C.). Below this temperature, density begins to decrease.

Water changes form to ice at 32^0 F. The ice is less dense than the surrounding, unfrozen water and therefore floats to the surface. The coating of ice at the water’s surface prevents wind mixing and reduces lake cooling. If this phenomenon did not occur, water would freeze on the bottom of the lake, killing many plants and aquatic organisms. Eventually, ice would fill up the entire water column, killing all fish and other aquatic life.

During **spring** the water again begins to warm and mix as the water column nears the same temperature. The thermocline redevelops and strengthens as the season progresses into summer.

Oxygen

Oxygen is used in respiration by most aquatic organisms. Fish require at minimum, 0.25 -5 mg/l dissolved oxygen for survival. Most warmwater fish in ponds and streams can survive with lower dissolved oxygen levels than coldwater fish such as trout. Oxygen is not easily extracted from the water and concentrations are relatively low compared to atmospheric levels. Normal levels of dissolved oxygen in natural bodies of water range from about 3-12 mg/l depending on temperature and time of day.

Table 1. Oxygen solubility (mg/l) in fresh water at various temperatures.

Temperature		Oxygen conc.
^{0}F	^{0}C	mg/l
32	0	14.6
41	5	12.8
50	10	11.3
59	15	10.2
68	20	9.2
77	25	8.4
86	30	7.6
95	35	7.1

The total amount of a gas that can dissolve in a given amount of water at a given temperature and pressure is called the saturation level. Table 1. shows the saturation level for oxygen at various temperatures at average sea level atmospheric pressure. Bodies of water are often under saturated with oxygen. In special circumstances water may become supersaturated with oxygen. This can happen when water is intensely agitated in the presence of air. Oxygen enters the water primarily in two ways. Wind and wave action agitate the surface of lakes and ponds; circulating water and incorporating oxygen from the atmosphere. Turbulence produced by flowing water also is a significant source of atmospheric oxygen in streams and rivers.

The major source of oxygen comes from the sun driven, photosynthetic processes of phytoplankton, the microscopic floating plants that often give water a green tinge of color and to a lesser extent, the rooted aquatic plants.

Oxygen, Carbon Dioxide and the Photosynthetic Cycle

Because most dissolved oxygen is produced by photosynthesis in plants, oxygen concentrations vary diurnally (See fig. 2.). As the sun rises in the morning, phytoplankton begin to use up carbon dioxide and produce oxygen as the by product of photosynthesis.

Dissolved oxygen levels increase throughout the day, reaching a peak in mid-afternoon. The more sunlight available, the more oxygen will be produced.

Respiration also occurs during the day. This metabolic process uses oxygen and releases carbon dioxide. Photosynthesis usually produces more oxygen during the day than is consumed in respiration.

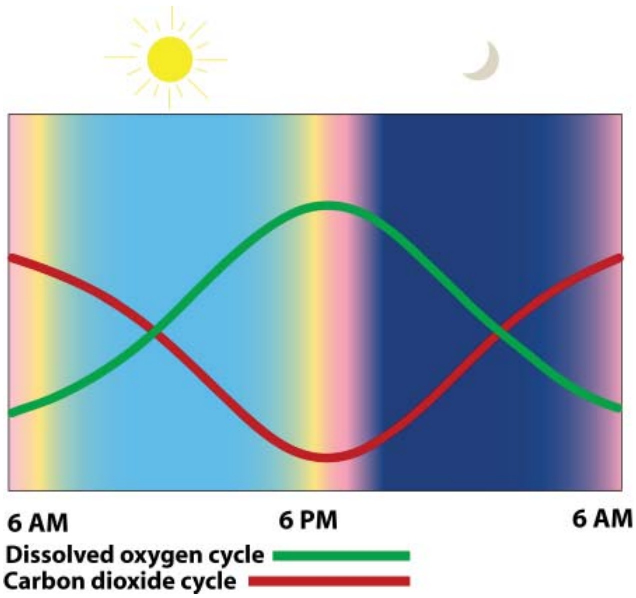

Fig. 2. Daily oxygen and carbon dioxide cycles.

After sunset, photosynthetic activity stops, however, respiration continues throughout the night, using up oxygen produced during the day. Dissolved oxygen levels decline throughout the night and reach their lowest level just before sun rise.

Carbon dioxide levels reach maximum values at this time, usually not higher than 20-30 mg/l. Dissolved oxygen levels and dissolved carbon dioxide levels are conversely related to each other because of photosynthesis and respiration.

In a natural situation, this daily cycle can be disrupted by overcast skies which reduce the rate of photosynthesis. On cloudy days, less oxygen may be produced by photosynthesis than is used in respiration during a 24 hour period.

Oxygen levels in a body of water will be a little lower each morning until cloud cover lifts. If clouds persist long enough, the oxygen level in the water may drop below the tolerance range of the fish long enough to cause suffocation and death. This process, combined with water's inability to hold as much dissolved oxygen at higher temperatures, explains why most oxygen related fish kills occur when prolonged cloudy conditions persist during the summer

Decline of dissolved oxygen is intensified under **eutrophic conditions**. In water polluted from organic waste or fertilizers, soluble levels of nitrogen and phosphorous are high. These elements are plant fertilizers and they cause excessive growth of algae and phytoplankton. These plants can form dense mats that shade out sun and prevent photosynthesis below a few feet of water. They often become dense enough to cause a sudden "crash" or die off; leaving little plant life to produce more oxygen.

At the same time dead algae and phytoplankton decompose and consume the available oxygen in the process, which increases the probability of a fish kill caused by low oxygen conditions.

Alkalinity and pH

The pH is a measurement of acidity or alkalinity. The pH scale ranges from 0 - 14. A pH of 7 is neutral. Values below ph 7 are acidic while values above pH 7 are basic. The desirable pH range for fish is between 6.5- 9. Long term exposure to pH values beyond these limits slows fish growth and reduces health. Alkalinity is a measure of the total negative ions available to neutralize hydrogen ions when an acid is added to water. In practical terms it is usually a measure of the amount of carbonate (CO_3^{2-}) and bicarbonate ($HCO_3^{!}$) in the water.

Carbonates are most often derived from the mineral carbonates, calcium carbonate and magnesium carbonate that are found in rocks and soil of the watershed.

Alkalinity is expressed as milligrams per liter (mg/l) of calcium carbonate.

Alkalinity and pH are interrelated and connected with photosynthesis and respiration. Daily changes in alkalinity caused by photosynthesis results in a daily rise in pH. The pH declines to a nearly neutral value over night as respiration releases carbon dioxide. (See fig. 3.)

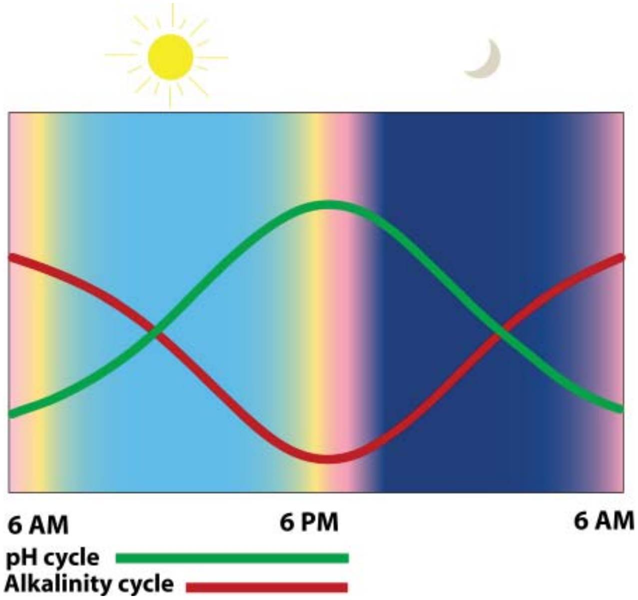

Fig. 3. Daily, cyclical changes in pH and alkalinity.

Alkalinity acts to stabilize pH changes in aquatic environments. Carbonates **buffer** changes in pH that result from plant photosynthesis and respiration. During photosynthesis, CO_2 is removed from the water. Removal of acidic carbon dioxide results in a rise in pH of the water throughout the day.

On a bright sunny day, in ponds with low alkalinity (less than 50 mg/l calcium carbonate) and intense phytoplankton blooms; pH may rise from a morning value of 7.0 to an afternoon peak of 9 or10 due to photosynthetic removal of carbon dioxide from the water.

Carbonates and bicarbonates in the water buffer the rise by supplying more carbon dioxide to the system.

Two bicarbonate ions dissociate to form 1 molecule of water, 1 carbon dioxide ion that is acidic, but is removed from the water during photosynthesis; and 1 carbonate ion that is basic, and remains in the water.

To maintain the chemical equilibrium between carbonate and bicarbonate when a carbon dioxide ion is removed, a carbonate ion hydrolyzes with water to produce only 1 bicarbonate ion for each pair of bicarbonate ions that dissociate to form carbon dioxide.

Because the carbonate ions that are produced in these reactions are basic, the pH must rise. Some bicarbonate is also directly absorbed by the plants further increasing pH.

In water that has an alkalinity of at least 40 mg/l, there is enough carbonate and bicarbonate in the system to continually react and replace carbon dioxide used in photosynthesis. The pH rises but less rapidly due to the buffering action of the carbonates and bicarbonates. At lower alkalinity levels, carbon dioxide and bicarbonate removal during photosynthesis exceeds the buffering capacity of the carbonates and bicarbonates and pH can rise to higher levels faster.

At night, respiration releases carbon dioxide and pH falls continually until day break. During warm months in eutrophic systems, carbon dioxide can be incorporated as organic carbon into the plant and removed from water, at a faster rate during photosynthesis than it can be released through respiration. This process causes morning pH values to gradually rise over the summer.

Organic carbon produced from carbon dioxide, is stored in the aquatic plant tissue. Some plants may be consumed by fish and other organisms in the food web. Dead plants are consumed by decomposing bacteria. Ultimately the carbon is released back into the atmosphere as Carbon dioxide.

Carbonate and bicarbonate in the water is continually replenished from rainfall that dissolves minerals from the rocks and soil of the watershed and washes them into streams and lakes.

Alkalinity and Acid Lakes

Some lakes have very low alkalinity levels. These lakes are located in watersheds that do not contain carbonate bearing rocks. Granites are usually the dominant rock types in these areas, many of which are found in the Northeastern United States.

Normal rainfall is slightly acidic due to carbonic acid formation from water and carbon dioxide in the atmosphere. Acidity increases and pH values may be as low as 2 when sulfur compounds released into the atmosphere from coal generated power plants react with rain water to form acid rain.

Acidic conditions develop quickly in low alkalinity lakes when acid rains fall and accumulate in the lake basin; because there is no carbonate buffering system to react and neutralize the acids present in the rainfall. Fish growth is slowed when pH levels are chronically below 6.5 - 5. Below pH 5 - 4, reproduction does not occur. Below pH 4 fish will die.

Hardness

Hardness is a measure of the total concentration of alkaline earth minerals in the water and is related to alkalinity. These minerals are almost always calcium carbonate and magnesium carbonate. Hardness measures positively charged ions (cations). Calcium and magnesium are usually the only cations of importance in freshwater. Other cations such as iron, copper and zinc are usually in trace amounts except in unusual situations.

Soft water has less than 75 mg/l hardness while hard water contains 150 mg/l or greater hardness. Aquatic organisms do best in water with hardness values between 100 and 400 mg/l although they may survive at hardness values above and below these levels. Hardness below 50 mg/l can affect maturation and development of fish eggs, resulting in poor or absent fish populations. Minerals that make up hardness are also important for production of shells, exoskeletons, bones and plant tissues.
Hardness and alkalinity usually occur in the same proportions in water because the calcium and magnesium ions are bonded with carbonate ions.
In some polluted situations, hardness may be high and alkalinity very low because the usual calcium and magnesium carbonate ions are absent. Iron and iron sulfate may be responsible for all the hardness measured.

Hard water has economic importance. High levels of calcium and magnesium can coat water pipes and hot water heaters causing blockage and damage to plumbing. Hardness or softness of water is often associated with the ability to produce soap suds. Soft water is desirable because of its ability to generate a lather of suds. Many homes use water filters that remove hardness from the water to protect pipes and improve performance of laundry and dish washing detergents.

Salinity

Salinity is a measure of the total salts dissolved in a given weight of water. In most fresh water, salinity is of little importance. Test kits made for fresh water actually test for chlorinity which is the amount of halides or chloride ions in the water.

Salinity is expressed in mg/l at low concentrations. When measuring brackish water or sea water, salinity is usually expressed as parts per thousand (ppt or 0/00).

Specific gravity is also a measure of salinity often used. Specific gravity is the ratio between the weight of a given volume of sea water and the weight of an equal volume of distilled water. Specific gravity is measured with a hydrometer. The specific gravity of sea water and sea water aquarium mixes is 1.025.

Ponds sited near abandon oil wells may have measurable salinity levels. During periods of prolonged rains the water table can rise and force salt water released by past drilling activity to the surface. Salt water forced to the surface can flow overland and accumulate in down stream ponds. Salinity can reach levels lethal to fish and other aquatic organisms.