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Pond Dynamics and the Health of the Aquatic Residents

The water quality is constantly changing in a pond. The animals, such as fish, living in the pond are able to acclimate to some of these changes without any ill effects. However, if the water quality change is drastic, then serious consequences to the health of the aquatic life in the pond can result. Important water quality parameters that should be monitored in order to maintain the health of the aquatic animals living in a pond include measurement of dissolved oxygen (DO), temperature, pH, Ammonia, Nitrite, and Nitrate.

Oxygen and Environmental Hypoxia

Oxygen enters the pond water by photosynthesis from plant life (such as algae) or diffusion of atmospheric oxygen. The concentration of oxygen dissolved in water is measured as Dissolved Oxygen. Oxygen is poorly soluble in water (for example, the maximum amount of DO in freshwater at 82^{o} F is 7.84 mg/L compared to 150 mg/L in air at sea level).

In ponds with inadequate aeration, photosynthesis becomes the most significant source of oxygen. Ponds that rely primarily of photosynthesis, especially from algae, exhibit diurnal changes in pond water quality. A certain amount of algae in the pond is desirable because it increases the DO. This allows for more fish to be stocked. In return, the fish excrement proves the plants with nutrients. In ponds that rely on plant photosynthesis, there is a marked diurnal variation in the DO. The DO of the pond is highest near sunset because maximum oxygen production occurs during the day. However, at night, the oxygen levels decline because photosynthesis has stopped. Since plant and animal respiration occurs continuously, a net loss of oxygen occurs at night. The DO is at its lowest just before sunrise. Low DO is common in ponds, especially in the summer, with warm temperatures, which decreases the solubility of oxygen in water. In winter, ice can form on a pond, which causes a progressive decrease in dissolved oxygen because the ice blocks photosynthesis and prevents oxygen diffusion into the pond.

Environmental hypoxia is detected by a low DO. It results from overcrowding (excessive use of oxygen), poor water flow (poor aeration), algae crash (sudden lack of photosynthesis and excessive use of oxygen), and prolonged overcast days (decreased photosynthesis). Acute hypoxic effects in the pond is detected by sudden death of all but the air-breathing fish, fish pipping for air, and fish gathering at the water inflow. Fish that have died of hypoxia will have their mouths agape and flared opercula. Usually the larger fish are the first to die. Chronic environmental hypoxia results in a chronic stress response that predisposes fish to secondary infectious diseases to bacteria and fungi.

Temperature and Temperature Stress

Because fish are poikilothermic, temperature has a dramatic affect on their metabolism, including the immune system. Fish kept below their optimal temperature zone have a suppressed immune system. There are large fluctuations in the water temperature of ponds in the spring and fall. This is often a time when fish diseases appear in ponds. As with hypoxia, fish can be subjected to both acute and chronic temperature stress. Temperate species of fish are able to tolerate a wider temperature range than most tropical species or cold water species. Most fish are able to tolerate a rapid drop in water temperature better than an equivalent rise in temperature. The metabolic rate, which includes oxygen consumption, increases with as the temperature rises. Therefore, as the DO decreases and the oxygen consumption increases with the increase in temperature, hypoxia is frequently a serious concern with high temperatures. The temperature of ponds may fluctuate as much as 10^{0} C each day without harm to the fish because fish that are acclimated to temperature fluctuations are not as affected by temperature changes as fish acclimated to a constant temperature.

Hypothermia is associated with water temperatures at or near the lower lethal limit of a particular species of fish. The affected fish demonstrate shimmies, lethargy, water mold infections, and mortality of coldintolerant species. Hyperthermia is associated with water temperatures at or near the upper lethal limit of a particular species of fish. Affected fish often exhibit high mortality and increased susceptibility to opportunistic pathogens. The ability of a fish to withstand hypo- or hyper- thermia depends on how low or high the temperature becomes and how quickly the temperature changes. When the temperature is near a species upper lethal limit, it is advised not to feed the fish because the amount of oxygen needed for homeostasis and digestion may exceed the amount of oxygen that can be extracted from the water.

Temperature stratification occurs when two distinct temperature zones develop in a pond. The surface water of the pond warms up while the bottom of the pond remains cold. This is a problem in large ponds over 5 feet deep. This condition develops during hot, calm summer days when little mixing occurs by wind action. The two layers of water temperature, the upper warm water and the lower cold water are separated by thermocline, which acts like a physical barrier between the two. As a result, considerable energy is needed to overcome this barrier and mix the two water temperature layers ("turn over"). The DO of the bottom layer rapidly declines because oxygen is used up during the degradation of debris that falls to the bottom of the pond. An anaerobic environment is then created. As a result toxic substances are formed of the pond's floor. The danger here is that when the pond does eventually turn over, the water from the bottom with depleted oxygen and toxic compounds mixes with the surface water where the fish are able to live. Turn over usually occurs in the fall when the surface water begins to cool.

Water Hardness, Alkalinity, and pH

As with temperature, fish differ in their optimal pH range, however a pH range between 6.5 and 9.0 is recommended for freshwater fish. A pH value outside of this range is stressful and potentially lethal to fish. Fish acclimated to a relatively low pH can survive a drop in pH better than the same species maintained at a higher pH. Also, fish routinely exposed to wide pH fluctuations, which is typical in ponds, are most likely to tolerate a rapid change in pH than fish kept under stable pH conditions. In a pond, the pH is highly influenced by the soil type. Acid sulfate soils may create a pond pH less than 4, which is not suitable for fish. The metabolic activity of plants and animals living in the pond produces acids, which tend to gradually decrease the pH. If water changes are not regularly performed or the pH is not adjusted, then the pH can reach 5, which is stressful to fish or below that which can be lethal. Pond water pH is influenced by the buffering capacity of the water, such as the amount of bicarbonate present, and photosynthesis. Photosynthesis uses carbon dioxide, which increases the pH. This peaks at sunset. At night, however, photosynthesis stops and the carbon dioxide increase causes the pH to decrease. Thus, it is common for the pH to fluctuate in a pond diurnally from 6.5 to 9.

Increasing the buffering capacity of ponds with pH values that consistently fall below 6 will solve the pH problems. In warm-water fish ponds with an alkalinity less than 50mg/l as $CaCO_3$, buffer should be added. Ponds with chronic diurnal high pH problems are usually associated with an excessive amount of phytoplankton or higher plant photosynthesis, which tends to increase the pH during the day as CO_2 is consumed. Wide pH swings in ponds occurs in low alkalinity water because there is not enough buffering capacity to moderate the plant-associated metabolic alkalosis. Most ponds, however, have the proper amounts and proportions of hardness and alkalinity, therefore high pH stress is an uncommon ailment of pond fish. High pH in ponds is important because it increases the amount of toxic, unionized ammonia in the water.

Water hardness refers to the concentration of mineral ions in water predominated by calcium and magnesium. It is expressed in terms of calcium carbonate ($CaCO_{3)}$. One degree of hardness equals 17ppm $CaCO_{3.}$ Soft water refers to water with 0-75ppm $CaCO_3$ and has the lowest buffering capacity. Moderately hard water has 75-150ppm $CaCO_3$. Hard water has 150-300ppm $CaCO_3$ and very hard water had a concentration of $CaCO_3$ greater than 300ppm, which has the highest buffering capacity.

Alkalinity refers to the concentration of basic substances, i.e. bicarbonate, carbonate and hydroxide ion in solution. It is expressed as ppm equivalents of carbonate; therefore, in general, total hardness measurements will be close to measurements of total alkalinity because Ca and Mg are generally associated with carbonate. Water with a high alkalinity is more strongly buffered than water with a low alkalinity. In a closed aquatic system, the pH decreases because of increase hydrogen ions from respiratory processes and a pH "crash" (pH <4) occurs in soft water when all the buffering capacity is utilized. If a pH crash occurs, then a portion of the water should be changed and a commercially available buffer, such as dolomitic limestone, coral gravel, or oyster shell, should be added.

The Nitrogen Cycle

Ammonia, nitrite, and nitrate production or the nitrogen cycle and nitrification are important metabolic features of a pond or aquatic system. Excess food, feces, plant debris, and expired NH_4 from the gills produce ammonia. Ammonia is converted to nitrite by bacterial (*Nitrosomonas*) decomposition. Nitrite is converted to nitrate by bacterial (*Nitrobacter*) decomposition. Bacteria, algae, and higher plants utilize nitrate as a nutrient. Ammonia and nitrite are toxic to fish.

An example where a problem can occur with the nitrogen cycle is “the new tank syndrome." This term refers to the period of water quality without the initial seeding of a new aquarium with nitrifying bacteria. In a closed aquatic system where fish have been added there is a period where ammonia and nitrites are elevated until nitrifying bacteria become established to remove these toxins. As a result, fish will begin to die of ammonia and nitrite toxicity [nitrites form methemoglobin from hemoglobin resulting in hypoxia] in a few days (i.e. 4-7 days) following the establishment of the new aquarium. This can be avoided by conditioning the tank with nitrifying bacteria (i.e. add 20% or greater gravel from an established aquarium or organic soil) and feeding the system with ammonia salts or urea (10ppm). Frequent 50% or greater water changes (twice weekly) may be required until the ammonia and nitrites are below toxic levels. One should avoid overstocking and feeding. Begin stocking with a few hardy fish for the first two months, and then add fish slowly over time until the capacity of the system has been reached.

Treatment of an aquatic system for ammonia toxicity (>0.05ppm) involves:

1. Water changes and addition of conditioned gravel or foam filter from an established system
2. Decreasing the pH to near 7, if the pH is above 7 to convert ammonia to nontoxic ammonium.
3. Ammonia absorbers (zeolites) can be used, however they do not remove nitrites and do not work in marine systems.

Treatment of an aquatic system for nitrite toxicity (>0.1ppm) involves:

1. Water changes or removal of the fish to a healthier system will provide immediate treatment for nitrite toxicity.
2. Addition of gravel or foam filter from an established aquarium.
3. Increasing the salinity to 100 ppm (7 teaspoons table salt to 10 gallons) will prevent nitrite uptake in freshwater fish because chloride ion competes with nitrites for uptake.
4. Avoid use of methylene blue because it kills nitrifying bacteria and is not absorbed by fish.

Sources of Water for an Aquatic System

The sources of water used in the aquatic system may vary (i.e. tap water, wells, lakes, streams, seawater, artificial seawater) and the physical, chemical, and biological parameters of water added to aquatic systems are variable.

Sources of freshwater:

1. Municipal water supply may be chlorinated and fluorinated. It may be hard and alkaline. Tropical freshwater fish do well in soft, slightly acidic, biologically active water. Sodium bisulfate and sodium dioxide may be added to potable water to remove excess chlorine. Both chemicals are toxic to fish. One can decrease the water hardness by dilution with distilled water or by boiling and decanting the upper portion into the aquarium. This is easily done with smaller aquaria. Copper sulfate (to control algae) and flocculating agents (to clarify the water) may also cause problems with aquarium fish. Metal pipes (i.e. new copper) may result in heavy metal toxicity, therefore run water through pipes before filling tank. New construction of large aquariums may cause the leaching of toxic compounds into the aquarium water; therefore, new aquariums require filling and flushing the aquarium to dilute out some to the toxic compounds associated with new construction.
2. Surface water (lakes and rivers) can be contaminated with toxic compounds or infectious agents. The pH, DO, CO_2 may fluctuate. It is recommended to boil the water when using surface water.
3. Ground water can be contaminated and is typically high in CO_2, low in DO, and contains ferric hydroxide. Ground water requires vigorous aeration.

Filtration is Incorporated in an Aquatic System to Maintain Proper Water Quality

The three basic types of filtration are mechanical, chemical, and biological. Mechanical filtration removes suspended particles from water as it passes through a mesh. Chemical filtration removes molecular contaminants from water. Biological filtration refers to the fixation of nitrogenous wastes into less toxic compounds.

Examples of mechanical filtration are sand filters, foam fractionators, and filter floss.

Examples of chemical filtration are ion exchange (i.e. activated carbon) and oxidative (i.e. ozone) chemical reactions. Ozone is added to aquatic systems as an oxidizing agent to kill pathogenic organisms (as chlorine is used in swimming pools). Enough ozone is added to meet the demand of the system, but excess ozone will kill fish. Ozone generators (U.V. or electrical) produce ozone, which is a radical with high oxidizing potential in water. Ozone creates other oxidizing residuals (i.e. nitric acid, bromic acid) that will destroy gills and kill fish. The air supply for the ozone generator should be chilled and dried (silica is used in home units) for efficient generation of ozone. Treated water passes through the contact chamber before entering the destruction chamber (heat or catalytic process is used to destroy ozone). Water free of ozone is returned back to the system. Ultraviolet (UV) filters are another type of chemical reaction. The use of ultraviolet light for sterilizing water is not efficient for most large aquariums because of the slow exposure process required. They do work well with smaller aquatic systems, such as small aquariums.

Examples of biological filtration are a variety of media and fluidized beds used to grow bacteria for nitrification.