Understanding Water Quality Parameters to Better Manage Your Pond

Guide W-104

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INTRODUCTION

Successful pond management requires an understanding of the role of nutrients and other water quality parameters, as well as regular monitoring of environmental conditions within the pond's ecosystem. Water quality is often overlooked in pond management, and poor water quality can lead to common problems, such as excessive algal blooms, overgrowth of plants, noxious smells, or dead and dying fish. In order to prevent these problems, an understanding of basic water chemistry and other physical parameters is necessary. This publication describes the most important water quality factors that influence the health of ponds. Some factors that are particularly important in recreational fish ponds to ensure fish health and pond productivity are also discussed. A basic understanding of how these factors interact with one another will help pond owners maintain good water quality and a healthy pond ecosystem. Many companies produce kits and other materials to monitor water quality on your own, or you can send water samples to commercial laboratories for analysis.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is probably the single most important water quality factor for pond owners. Oxygen is needed by fish and other aquatic organisms, and levels of DO will determine the ability of ponds and other water bodies to support aquatic life. Oxygen dissolves in water at very low concentrations measured in parts per million (ppm, which can be used interchangeably with milligrams per liter [mg/L]). Ponds will rarely have more than 10 ppm DO. Most oxygen in water is produced by algae and green plants through photosynthesis, the process whereby green plants use solar energy to convert water and carbon dioxide (CO_2) to oxygen and carbohydrates. Oxygen is also naturally incorporated into water from the atmosphere through surface diffusion and turbulence caused by wind.

Daily fluctuations and seasonal changes in DO

Dissolved oxygen levels can vary dramatically in a 24-hour period. During the day, DO concentrations generated by photosynthesis will increase. During the night, DO levels will decline as oxygen is removed from water through respiration, the process whereby plants and animals consume oxygen and release carbon dioxide as they convert organic material to energy. For this reason, DO levels are typically highest at dusk and lowest just before dawn. There is also a strong relationship between temperature and DO: the warmer the water, the less oxygen it can hold. For example, water at 52°F (11°C) can hold 40% more oxygen than water at 80°F (27°C). Warm water increases the metabolism of fish and therefore increases their consumption of oxygen. Bacteria also consume oxygen as they decompose organic matter. Therefore, during the summer months, DO levels will be lower because of increased oxygen demands of fish, warmer water that holds less oxygen, and increased bacterial decomposition of dead plant and algal material toward the end of the growing season.

Effects of low DO

Oxygen depletion occurs when the demands for oxygen are greater than what is being produced. Oxygen deple-

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tion can occur for different reasons. Situations typically associated with oxygen depletion are

- Hot, cloudy, and still (windless) days;
- Pond stratification followed by turnovers (the mixing of stratified layers, which develop during the summer in ponds 8 ft deep or greater);
- After a sudden algal bloom die-off (from natural causes or after a chemical application); and
- Organic waste decomposition (oxygen depletion will occur in the presence of excessive organic matter from waste products, such as uneaten feed).

Whenever DO levels fall below 3 to 4 ppm, oxygen stress will occur. Lack of adequate dissolved oxygen is the leading cause of fish kills. Normal oxygen content in a healthy pond will range from 5 to 10 ppm. Warmwater fish (e.g., bass, bluegill, catfish) require about 5 ppm and coldwater fish (e.g., trout, salmon) require about 6.5 ppm to maintain good health. Dissolved oxygen levels of less than 3 ppm will kill warmwater fish and levels less than 5 ppm will kill coldwater fish. Fish exposed to low, nonlethal levels of DO over prolonged periods will be chronically stressed, stop eating, and be more susceptible to disease. Low oxygen concentrations also increase the activity of anaerobic bacteria, which create methane and hydrogen sulfide gases during anaerobic decomposition. Ponds with oxygen-poor bottoms and accumulated organic matter can release these gases when the bottom sediment is disturbed. Hydrogen sulfide has a rotten egg smell and is very toxic to fish.

Preventing low DO conditions

To help maintain safe DO levels in ponds, particularly in deeper ponds in which fish are intensively cultured, mechanical aeration is often needed. Aerators help keep pond water mixed so that layering is minimized and the surface water is well-oxygenated. However, aeration should only be thought of as one of many management tools to help maintain healthy oxygen levels. External nutrient loading is still the critical issue that must be addressed because excessive nutrients can lead to an overabundance of aquatic weeds and algae, which can result in oxygen depletions when they die and decompose.

NUTRIENTS (PHOSPHORUS AND NITROGEN)

It is important to understand the sources and basic pathways of nutrients because there is a direct correlation between available nutrients and populations of algae and aquatic weeds. The most important nutrients in aquatic systems are phosphorus (P) and nitrogen (N) in the forms of phosphates (PO_3) and nitrates (NO_3). These nutrients are critical to the growth of plants and animals in aquatic systems. Phosphorus has been identified as the limiting factor for algal growth in most lakes and, as such, is the largest contributor to aquatic plant growth. One gram of phosphorus will produce 100 grams of algal biomass. Excessive amounts of nutrients will lead to over-fertilization, or eutrophic conditions, which can result in an over-abundance of aquatic plants and algal blooms. When the excess plants and/or algae die, they decompose, which leads to a depletion of oxygen that can affect water clarity and smell and can lead to fish kills.

Sources of nutrients

The main sources of nutrients in ponds are bottom silt, dead vegetation, landscape debris, runoff from the surrounding area, poorly functioning septic systems, and wastes from livestock and waterfowl. As aquatic plants and algae grow and die, they sink to the bottom of the pond and provide a source of nutrients for future aquatic growth, a phenomenon known as nutrient cycling. This, along with landscape debris such as grass clippings, leaves, and pine needles, contributes nutrients to ponds, and these nutrients must be managed to prevent eutrophic conditions from developing. Runoff from fertilized fields and lawns in immediate surrounding areas as well as roads, farms, and outlying areas can also be major sources of nutrient enrichment.

Dissolved and particulate phosphorus

Phosphorus in water comes in two forms: dissolved and particulate. Dissolved phosphorus enters the aquatic environment from fertilizers, crop residues, or human or animal wastes, and is the form that is readily available to aquatic plants and algae. Particulate phosphorus is bound to soil particles and minerals that contain aluminum, iron, or calcium, as well as to organic matter, and enters aquatic systems primarily through soil erosion and surface runoff. While it may not be as readily available to aquatic plants, particulate phosphorus can accumulate in sediments and can be a source of slow release of phosphorus into the water for years.

NITROGENOUS WASTE (AMMONIA)

Ammonia is another compound that can affect the health and performance of your pond.

Sources of ammonia

Ammonia is a form of nitrogen found in organic materials and many fertilizers. It is the first form of nitrogen released when organic matter decays and is the main nitrogenous waste excreted by most fish and freshwater invertebrates. It is very unlikely that ammonia levels in your pond will reach levels that are lethal to fish. However, under conditions where fish are cultured intensively and fed protein-rich diets, they can produce high concentrations of ammonia, and fish may be exposed to sub-lethal levels (greater than 0.02 ppm) for extended periods of time. This can lead to reduced growth and increased susceptibility to disease.

Forms of ammonia

Ammonia can exist in two forms: un-ionized ammonia (NH_3) and ionized ammonia, also known as ammonium ion (NH_4^+). The ratio of un-ionized to ionized ammonia depends on pH and water temperature. Un-ionized ammonia (NH_3) is extremely toxic to fish and is the predominant form of ammonia when pH is high. Ionized ammonia (NH_4^+) is nontoxic except at extremely high levels and is the predominant form in water when pH is low. As a general rule, less than 10% of the ammonia will be the toxic un-ionized form when water pH values are lower than 8; however, this proportion increases greatly as pH increases. Water temperature will also affect the equilibrium between NH_3 and NH_4^+. At any given pH, more toxic NH_3 will be present in warmer water than in cooler water.

Ammonia removal and transformation processes

There are two processes that remove or transform ammonia released into the water. The first is uptake of ammonia by plants and algae, which readily use the nitrogen in ammonia as a nutrient for growth. For this reason, ammonia levels are usually low in ponds during summer months when algae are most productive, but can increase rapidly after the crash of an algal bloom. This is also one of the reasons why ammonia levels will tend to be higher in ponds during the winter months when algal production is low.

The second process, which transforms ammonia, is a step in the nitrogen cycle known as nitrification, the biological conversion of ammonia and ammonium to nitrate nitrogen. Nitrification is a two-step process. First, *Nitrosomonas* bacteria convert ammonia and ammonium to nitrite (NO_2). Nitrite, which is also highly toxic to fish, is then converted to nitrate (NO_3) by *Nitrobacter* bacteria. These reactions are usually coupled, and nitrite is rapidly converted to nitrate, so nitrite levels are usually low. The rate of nitrification is affected by water temperature. Maximum rates of nitrification occur at water temperatures between 86 and 95°F (30–35°C). At temperatures of 104°F (40°C) and higher, nitrification rates fall to near zero. At temperatures below 68°F (20°C), nitrification proceeds at a slower rate, but will continue at temperatures of 50°F (10°C) or less. For this reason, ammonia levels tend to be higher in fall and early spring before nitrification rates have increased as a result of increasing temperatures.

pH

The term pH refers to the concentration of hydrogen ions, and is a measure of whether a substance is an acid, a base, or neutral. The "p" in pH stands for "power" and the "H" for hydrogen ions. The scale of pH values ranges from 0 to 14; 7 represents neutral conditions, values less than 7 indicate more acidic conditions, and values above 7 indicate more alkaline or basic conditions.

Daily fluctuations in pH

The pH of freshwater ponds can fluctuate considerably both daily and seasonally; the magnitude of this fluctuation will depend on how well-buffered the freshwater system is. These fluctuations are due to photosynthesis and respiration by plants and animals, which results in the highest pH typically occurring at dusk and the lowest at dawn. This is because during the night respiration increases concentrations of carbon, which interacts with water to produce carbonic acid (H_2CO_3), lowering the pH. During the day, carbon dioxide concentrations decrease because of photosynthesis, driving pH values up.

How pH affects animals and other water quality variables

Optimum pH for fish growth and health is between 6 and 9. If pH is outside this range, fish growth will be reduced. Mortalities will occur when pH values are less than 4.5 or greater than 10. In addition to the direct effects pH can have on fish and other aquatic animals, pH interacts with other water quality variables such as ammonia, hydrogen sulfide, and dissolved metals, affecting their aqueous equilibria and toxicity as well. For example, as previously mentioned, high pH increases the toxicity of ammonia to fish, whereas low pH increases toxicity of aluminum and copper. Hydrogen sulfide (H_2S) is a toxic, colorless gas that can form in pond sediments when bacteria feed on organic debris in areas that are low or depleted of oxygen, giving off a rotten egg smell when the sediments are stirred up. When dissolved in water, H_2S can undergo two chemical steps, which go back and forth depending on the pH. At pH less than 6, most of the hydrogen sulfide will be in the toxic H_2S form, whereas at higher pH (8-12), most of the hydrogen sulfide will be in the less toxic HS^- form.

ALKALINITY

Alkalinity refers to the water's buffering capacity, or its ability to withstand changes in pH. It is a measure of the total concentration of bases in pond water, including carbonates, bicarbonates, hydroxides, phosphates, and borates, and is expressed in ppm calcium carbonate. All these bases react with and neutralize acids, which in turn buffers changes in pH. The pH of well-buffered water will normally fluctuate between 6.5 and 9. Carbonates and bicarbonates are the most common and important components of alkalinity. In an established pond, the ideal alkalinity measurement should be around 100 ppm, but readings from 50 to 200 ppm are acceptable. If the alkalinity is low, even a small amount of acid can cause a large change in pH. Alkalinity values greater than 300 ppm will not adversely affect fish, but such high values will render some commonly used chemicals, such as copper sulfate, ineffective. Alkalinity can be increased by adding agricultural limestone [$CaCO_3$ and $CaMg(CO_3)_2$] to ponds.

HARDNESS

Hardness is a measure of divalent salts, or positively charged ions, particularly calcium (Ca^{2+}) and magnesium (Mg^{2+}), in water. Total hardness is the sum of the concentrations of Ca^{2+} and Mg^{2+}, expressed in ppm calcium carbonate. Calcium carbonate hardness is a general term that indicates the total amount of divalent salts present, but it does not specify which salts are causing water hardness. Hardness and alkalinity are often confused because both are expressed using the same term (ppm calcium carbonate), and sometimes both parameters have similar values in a given water body. However, alkalinity measures negative ions (carbonate and bicarbonate) and hardness measures positive ions (calcium and magnesium), and sometimes these values can differ greatly. If limestone (calcium carbonate) is the cause of hardness and alkalinity, these values will be similar or identical. However, if sodium bicarbonate ($NaHCO_3$) is responsible for high alkalinity, it is possible for water to have high alkalinity and low hardness and calcium. Calcium and magnesium are essential to fish for biological processes such as bone and scale formation. If your pond is used to culture fish, water hardness should be above 50 ppm and can be adjusted by adding agricultural limestone.

SUMMARY

A basic understanding of the chemical components of aquatic ecosystems is important to successfully manage any pond or lake. The interaction between temperature, nutrients, and oxygen plays a critical role in many common problems encountered by pond owners, such as excessive algal growth, oxygen depletion, and fish kills. A healthy pond ecosystem is easier to achieve by understanding this interaction and managing excessive nutrient loading to the pond system. Other parameters, such as pH, alkalinity, and hardness, can also affect fish growth and survival and can influence toxicity of other compounds, such as ammonia and metals. Water quality testing should be considered if your pond is to be used for intensive fish culture. A variety of methods are available to monitor water quality. Several companies produce kits and materials to monitor water quality, or water samples can be sent off to commercial laboratories for testing.

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