SŌLITUDE
LAKE MANAGEMENT

# Summer Lake

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# Fisheries Management

Fisheries Management Plan (FMP) is a comprehensive approach for managing fish populations by using a variety of tools and techniques. The appropriate management method(s) are dictated by the goals for the water body, site-specific environmental conditions and budget. A Fisheries Management Plan should be the basis for any fishery under management.

Prior to deciding on an FMP, long term goals for the fishery need to be determined. The goals will directly impact all management decisions. Once the goals are understood, the following limiting factors need to be addressed: Habitat, predator to prey ratios and proper fish species. When properly balancing these variables, you can create a well balanced aquatic community. Throw in good genetics, and you have the fundamentals to produce a trophy fishery.

## Fish Habitat Management

Habitat is the most important aspect of fisheries management. With the proper habitat the fishery will have the needed foundation to thrive. Habitat is a general term used to describe the environment surrounding the fish community. Habitat includes all aspects of the water in the pond or lake along with all cover and structure.

**Cover:**

Cover provides needed refuge to small fish and the desired hunting grounds for larger fish. Cover includes things such as vegetation, rocks, rubble, brush, logs, old farm equipment, and more modern man made cover. It is best to find a balance amongst several types of cover depending on the needs of the fish species within the water body. It is important to have designated areas of dense cover which server a nurseries for juvenile fish. It is also important to have larger forms of cover to serve as focal points for the predator fish. It is critical to find a balance between both types of cover.

It is important to note that too much cover will spread fish out, making it difficult for predator fish to feed and fisherman to catch. Too few will make it easy for predators to "gang up" on smaller fish. Although vegetation is often considered a nuisance, it can play an important role in the health of your pond's eco-system.

**Aquatic Algae & Vegetation:**
Algae are non-vascular plants with simple reproductive systems that do not have true roots, stems, leaves, or vascular tissue, although some macroscopic algae may resemble plants in appearance. Algae occur in both freshwater and marine habitats, and are an important aquatic food source for many animals. However, excessive algae blooms can be damaging to aquatic ecosystems, and some species produce harmful toxins.

Vascular aquatic plants may be submersed, floating, or emergent, and native species are essential to a healthy aquatic habitat. Vascular aquatic plants are classified as "weeds" when they are growing in areas where they are not wanted, and many species are prolific enough to occupy the entire water column or surface of a water body.

Aquatic vegetation is an extremely important component of most freshwater systems, providing habitat, refuge, and food for a wide variety of organisms including fish, invertebrates, and waterfowl. However, overabundant native algae and aquatic vegetation, as well as exotic species can throw the fishery out of balance by disrupting interaction between the fish community while also negatively impacting water quality

Aquatic vegetation and algae often become problematic and will eventually threaten the productivity of your fishery. Four common methods used to proactively manage your ponds vegetation and algae are: 1) Stocking herbaceous and omnivorous fish such as Triploid Grass Carp and Tilapia, 2) Decreasing the sunlight's ability to penetrate deep into the water using plankton or dyes. (If your pond is relying on supplemental feeding, then dye may meet your goals, but in most cases dye should be avoided and plankton should be encouraged using fertilizer.), 3) Managing nutrients using aeration. and 4) Tolerating certain species of beneficial vegetation and allowing it to grow in shallow areas. When combining these four approaches, vegetation management becomes much easier. Staying ahead of the plants and not letting them become a problem is important. If you have undesired species, make sure to control them before they take over the pond. Herbicides and algaecides will often be needed, but with proper management they will be utilized less frequently and in smaller quantities. When putting your pond or lake on a fertilizing program, it is imperative that undesired algae and plants species are eradicated prior to fertilizing.

Managing for 15 percent vegetation coverage is an ideal goal for most fisheries. This vegetation is often ideal if it is an emergent species that is not able to grow in waters that are greater than 2 feet deep. Beneficial emergent plant species mesh very well with the long-term Fisheries Management Plan, since they do not require expensive herbicides to control. It is important to avoid vegetation species that are capable of taking over greater than 15 % of the waterbody since it can become difficult and expensive to contain on an annual basis. Emergent vegetation such as Pickerel Weed, Duck Potato, Irises, Rushes and Sedges are all examples of the desired beneficial species.

In the process of managing submerged vegetation species it is a very good idea to incorporate Triploid Grass Carp into the management plan. Triploid Grass Carp are fish native to Asia and eat certain species of vegetation. Because the fish are non-native and could be invasive, only fish that have been certified as triploid

and cannot reproduce are allowed to be stocked in water bodies in the United States. A permit is required in many states from the State regulatory agency. Several states do not allow the stocking of grass carp. The carp can be useful in eradicating dense stands of submersed vegetation, but they are non-selective and may also eat beneficial native plants. They prefer delicate, leafy species of submersed plants, and are not effective on algae or many coarse, brittle submersed species or emergent plants.

When Grass Carp are used as a management tool, it is important that the right quantity of fish be selected for the particular size and characteristics of the lake or pond, as well as the type and magnitude of the target aquatic weeds present or likely to be present following the stocking. Under-stocking and overstocking are equally problematic, as too few fish will not be able to produce the desired control results, and too many fish can be excessively damaging to the overall ecosystem. Additionally, once the correct stocking rate is determined by a qualified fisheries professional, planning must be in place for stocking maintenance rates of these fish in future years. The loss of these fish through predation or natural mortality over the years must be offset by a long term stocking program that is designed to account for these losses while also considering the amount of nuisance aquatic weeds present and in need of control.

**Herbicides:**
Aquatic herbicides are chemicals specifically formulated for use in water to kill or control aquatic plants. Herbicides approved for aquatic use by the United States Environmental Protection Agency (EPA) have been reviewed and are considered compatible with the aquatic environment when used according to label directions. However, some individual states also impose additional constraints on their use. These products must be registered and approved by the Federal government (EPA) as well as each individual state in which they are being applied.

Aquatic herbicides are sprayed directly onto floating or emergent aquatic plants or are applied to the water in either a liquid or pellet form. Systemic herbicides are capable of killing the entire plant. Contact herbicides cause the parts of the plant in contact with the herbicide to die back, leaving the roots alive and able to regrow. Non-selective, broad spectrum herbicides will generally affect all plants that they come in contact with. Selective herbicides will affect only some plants (often dicots which are broad leaf plants will be affected by selective herbicides whereas monocots may not be affected.)
***(See Appendix 1A for additional herbicide and algaecide information)***

**Advantages of Herbicide Use**

- Properly performed herbicide treatments will typically provide good long term control of target species, and are much more effective, safe, and less expensive than many other available options.

**Disadvantages of Herbicide Use**

- Some herbicides have swimming, drinking, fishing, irrigation, and water use restrictions (check the label and general permit). However, this is easily overcome through proper application techniques, the proper identification of the target pest, and utilizing a licensed and experienced applicator who understands how to best select the correct herbicide that considers all site conditions in addition to the overall lake and pond management goals.

- Non-targeted plants as well as nuisance plants may be controlled or killed by some herbicides. This risk is mitigated when using a licensed and experienced applicator who understands how to best gain good selective control of target species.
- Depending on the herbicide used, it may take several days to weeks or several treatments during a growing season before the herbicide controls or kills treated plants.
- Improperly performed treatments utilizing herbicides could lead to low oxygen conditions in the lake or pond as a result of too many plants dying and decomposing simultaneously, which utilizes available oxygen in the water, especially in very warm weather. If this occurs, there is a risk of a fish kill. A licensed and experienced applicator will consider all factors including temperature, treatment timing, herbicidal mode of action, utilizing protocols and treatment methodology to greatly minimize any such risk.
- To be most effective, generally herbicides must be applied to rapidly-growing plants, although sometimes fall applications of perennial plants can also be effective. This limits herbicides as a control option to only the growing seasons each year.
- Some expertise in using herbicides is necessary in order to be successful and to avoid unwanted impacts. Never treat unless you have been properly trained and gained the experience necessary to understand all site conditions that might impact treatment, have properly identified the target pest species, and have chosen the correct product that considers all of these factors.
- Many people have strong feelings against using chemicals in water.

**Beneficial Bacteria**
Beneficial bacteria occur naturally in ponds and lakes, and are the microbes responsible for processing dead organic material. There are many different types of bacteria, which work in different ways to break down organic compounds. Aerobic bacteria use oxygen and rapidly break down organic compounds. Anaerobic bacteria are able to work without oxygen, but work much more slowly. The bacteria produce enzymes that allow them to break down organic compounds and take them into their cells as nutrients. Many bacteria also perform denitrification, transforming nitrate into nitrogen gas and removing it from the pond system. They can also convert soluble phosphorus from the water column into calcium phosphate and calcium iron phosphate, which are insoluble minerals that are not available to most types of algae.

Since the bacteria convert nutrients into unavailable forms, they can be beneficial in reducing nuisance algae blooms in ponds and lakes. In fresh water, phosphorus is generally the limiting nutrient for algal growth. The ratio of nitrogen to phosphorus determines the types of algae that will grow and thrive in a pond. In situations where there is excess phosphorus, there is a potential for nuisance species of filamentous and blue-green algae (cyanobacteria) to dominate the pond instead of the beneficial planktonic green algae that form the base of the food web. The bacteria themselves can also contribute to the food web, becoming a food source for zooplankton and benthos, which then become food for fish and other organisms.

Biochemists have found ways to culture beneficial bacteria so that they can be added to ponds and lakes to accelerate the decomposition process and to remove nutrients from the aquatic system. This process is often referred to as biological water quality augmentation. Initially, a large inoculation dose is added to get the bacterial population established, and then maintenance doses are applied to ensure that the bacteria continue to thrive. As the bacteria grow and replicate, they tie up phosphorus and nitrogen in their cells so that it is not available to nuisance algae. The majority of the bacteria will go to the bottom and sides of the lake (the benthic

and littoral zones) where they break down excess organic matter. Some of the bacteria remain in the water column, where they process dead phytoplankton and soluble nutrients.

There are many different types and formulations of beneficial bacteria. Most product formulations are based on aerobic bacteria and target compounds that are slow to degrade. We use bacteria products in our Management Programs for organic waste degradation and general water quality improvement. We can also supplement these products with a formulation of bacteria and enzymes that is specifically geared towards digesting the organic matter that builds up on the pond bottom – this process is known as biological dredging. Some of the enzymes are even targeted to break down specific compounds, such as the cellulose found in leaves and sticks that accumulate in the pond. While this process does not address the build-up of inorganic soil particles, it can greatly increase pond depths and decrease the amount of organic bottom sludge.

It is important to note that because most beneficial bacteria formulations include aerobic bacteria, they work much better when used in conjunction with aeration. Bacterial metabolism is optimized when dissolved oxygen levels are maximized, so a fountain or aerator will greatly improve the overall results of any water quality augmentation program. Teaming beneficial bacteria into your management strategy will allow the water body to support a greater biomass of fish. Inoculating a water body with bacteria is expensive and is often utilized only on sites looking to push the limitations surrounding Trophy Fish Management.

**Water Quality**

Water quality plays a large role in keeping both the fish and the surrounding eco-system healthy and prosperous. With a fit environment you will set the foundation for a balanced fishery. Monitoring the water column for Dissolved Oxygen (DO), pH, temperature and visibility will provide information essential to determining the best approach to manage the fishery. It is also important to monitor other key nutrients and minerals that influence productivity. Testing water from the surface and from the bottom for Ammonia, Nitrite, Nitrate, Alkalinity, Hardness, Phosphorous and the Nitrogen/Phosphrous Ratio will also provide valuable insight on how the lake should be managed. Knowing the highs and lows of these parameters throughout the course of the year will give a good indication of any improvements needed. Poor water quality stresses fish. Even with plenty of food available fish won't grow well in unhealthy water. Water quality data is very useful in gauging how aggressive of a management approach you can take to get the fish to grow. Testing the water quarterly will provide a good baseline of data that can be used to understand trends and make decisions in the future. If you are expecting fish to grow, it is always good to understand if the fish are stressed out from poor water or if they are happy with their environment. Reducing assumptions with water quality can improve the success at which a pond is managed.

***(See Appendix 1B for additional water quality parameter information)***

**Stratification**

As spring temperatures warm up, water temperatures within ponds become layered with warmer water at the surface and cooler, more dense water at the bottom. This difference in density between the warm and cool water creates a temperature barrier that actually prevents the upper and lower water from mixing. As a result, cooler water is cut off from its primary oxygen source (atmospheric air) and left with a limited oxygen supply until the fall season. Over the course of the growing season (spring, summer and fall), organics settle to the bottom of the pond creating a demand for oxygen that exceeds the limited supply. As this occurs, a "dead zone" of anoxic water forms at the bottom of the pond. During the growing season this dead zone will continue to enlarge, often taking up 25% to 50% of the pond's livable space. These anoxic conditions often force fish to live in warmer than desired water temperatures, putting stress on them and as result slowing their growth. Once fall temperatures drop, ponds and lakes turn over and the toxic parameters built up over the summer mix throughout the entire water column, putting additional stress on fish during a time when they should be focused on growing. Most bodies of water experience issues with algae and vegetation growth as a result of all of the organics that accumulated during the anoxic conditions. The best way to prevent ponds from stratifying is using bottom diffused aeration. Properly sized aeration units can greatly improve a pond's ability to sustain a healthy environment that promotes fish growth.

Aeration is a great tool used to keep most water parameters within the acceptable range. Aeration improves circulation of the water column and improves dissolved oxygen levels throughout the water body, thus increasing productivity while serving as an insurance policy for the health of your fish if low oxygen levels become a threat. Surface aerators produce spray patterns with water droplets that add oxygen to the water and create wave action to enhance circulation. Submersed diffused air systems produce air bubbles that lift and circulate the water from the bottom of the lake, thus increasing the interaction of the entire water column with atmospheric oxygen. An important benefit of aeration is that it encourages the growth of beneficial bacteria, which compete with algae for excess nutrients, and also break down decaying organic matter. Aeration also discourages thermal stratification and helps ensure adequate oxygen levels throughout the water column.

There are many options for powerful, reliable aeration systems. For those who want to go green or don't have access to power, windmill and solar powered aeration systems are available and will meet the needs of most ponds. Just like powered aeration, the proper sized system needs to be installed. Installing an aeration system that is inadequately sized for your pond will greatly hinder the unit's capability to provide proper aeration. Windmill and Solar aeration have limitations because they do not run 24 hours a day. It is a good rule of thumb to install electric powered aeration when power is available. Aeration powered by electricity has many benefits, one primary advantage outside of the sheer volume of air flow is the ability to run the aerator on a timer. Using a timer you can manipulate the water temperature by pumping warmer or cooler air into the water. It is beneficial to run the aeration during the day in the spring and fall to help warm the water and increase the number of growing days that the fish have available. The opposite is true for the summer. In the summer it is often best to run the aerator at night to help cool the water rather than pumping 90-100 degree daytime air into the water. This year round aeration process will help manipulate the water temperature to increase the number of growing days each year. This process of extending the growing season can significantly influence fish growth over the course of a fish's life.

**Liming**

One very important water quality parameter that greatly influences the productivity in ponds is alkalinity. Alkalinity levels directly affect the availability of nutrients to aquatic organisms. Low alkalinity levels reduce productivity in ponds and are also responsible for broad swings in pH which are very stressful to many aquatic organisms. When creating or maintaining a productive fishery it is important to know your alkalinity level. If alkalinity levels are below 20 parts per million (ppm) agricultural limestone should be applied throughout the pond. The purpose of liming is not to just improve the alkalinity in the water, but to improve the alkalinity throughout the bottom of the pond as well, making the soil suitable for all types of aquatic life. Applying the limestone is best done by loading the limestone on a barge or work boat using a front end loader. The lime is then washed into the pond using a pump. It is often best to place extra lime in the areas where water enters the lake. Good alkalinity is critical to the success of a fertilizing program, so when possible it is beneficial to get your alkalinity levels above 20 parts per million (ppm), preferably a minimum of 50 ppm. Liming should be done in the fall or winter. Liming during the growing season can have adverse effects on fish growth, since the lime will actually bind with plankton and pull it out of suspension. In some instances liming a pond will free up nutrients that are bound within the water body. This results in the potential for algae or vegetation to become a nuisance soon after liming due to a surge in available nutrients. It is important to understand this and have an action plan in place if undesired species of algae or vegetation develop following the lime application.


**Fertilizing**

Fertilizing is a great way to increase the biomass of fish a pond can support. Properly fertilized ponds can sustain 3-4 times the biomass of fish than that of unfertilized ponds. Clear water may be appealing to the eye, but it lacks the backbone to the aquatic food chain: Phytoplankton and Zooplankton. Creating a plankton bloom is most important in the beginning part of the growing season when newborn fish must feed and avoid predation. Adding the proper amount of fertilizer to the pond when water temperatures reach a consistent 60 degrees in the spring will encourage plankton to establish. Ponds with alkalinity levels under 20 ppm should have agricultural limestone

added prior to taking part in a fertilizing program. If you do not know your pond's alkalinity have it tested prior to beginning a fertilizing program.

Fertilizing improperly can have devastating results. Major algae or vegetation growth can occur and fish kills are always a possibility. Be sure you understand the risks and take the precautions needed to keep your pond safe. If putting a waterbody on a fertilizing program, it is often ideal to eradicate all species of vegetation that are capable of growing in water greater than 2 feet deep. It is also ideal to team fertilization with an aeration system rated to handle the volume of water within the water body. Fertilizing poses great risks if not done properly and should be done only in moderation when not teamed with proper aeration. If you are uncomfortable fertilizing your pond, but would like a productive fishing pond, consult with a fisheries biologist on the fertilizing process. Hiring a fisheries biologist to fertilize your pond will greatly reduce the risks while also improving the results. If your water quality is correct and the unacceptable vegetation and algae have been eliminated, you will have a much easier time creating the desired plankton bloom.

The Nitrogen Phosphorous Ratio is another component to the fertilizing process that is important. It is ideal to have a Nitrogen/Phosphorous ratio that is 100:1. Less than 16:1 is considered not ideal and will promote undesired species of algae.

When creating a plankton bloom in the spring you can improve your odds of obtaining the desired bloom by having plankton rich water transplanted into the pond. This process is very common and helps direct the fertilizer towards the correct plankton species.

Measuring the plankton bloom is done using a secchi disk. A secchi disk is a tool used to measure the visibility of the water. A visibility of 18-24" is ideal in ponds with aeration. In ponds without aeration a visibility of 30-36" is a safe approach.

**Oxygen:**
Environmental conditions in ponds are far less stable than the terrestrial environment we know. We take oxygen for granted, but life within ponds can face the depletion of this vital parameter many times throughout life. Sufficient oxygen levels are required by the majority of aquatic life including fish, invertebrates, plants, algae and bacteria. Unfortunately oxygen's high demand can cripple entire ecosystems.

Although plants and algae are a primary producer of oxygen, they are also to blame for oxygen depletion in many ponds. Plants and algae require proper temperature, nutrients and sunlight to grow. Often these parameters are readily available during warm months, resulting in an abundance of algae, phytoplankton and/or vegetation. As favorable weather conditions allow plant matter to thrive, ponds increasingly become more and more unstable.

DO (dissolved oxygen) is measured in milligrams per liter (mg/l) or parts per million (ppm). Most fish species prefer a DO of 4-5mg/l or higher. As oxygen levels drop below 4 mg/l, most fish begin to focus on survival as opposed to growth. Gradual fluctuations in available oxygen levels can allow fish to sustain DO levels lower than 4 mg/l, but quick drops can cause immediate death.

Biological Oxygen Demand (BOD) is the leading cause of fish kills in fresh water. Biological Oxygen Demand is the demand for oxygen used during the process of decomposing organic matter. The most common organics involved with BOD are dying vegetation, leaf litter and dead plankton. In this process bacteria use oxygen as they break down the organics.

Chemical Oxygen Demand (COD) is another process in ponds that requires oxygen. COD is the measure of oxygen needed to oxidize all compounds in water, both organic and inorganic. In this process oxygen is required as different bonds are made between compounds. An example of COD is the process of Nitrification. Nitrification is when toxic Ammonia (waste) is broken down by bacteria into Nitrite, then into less toxic Nitrate. The more productive a pond is, the higher the COD. As productivity in ponds increase, both BOD and COD increase. These processes can lead to DO levels dropping into lethal conditions for fish and other aquatic life.

**Oxygen Cycle:**
Routine ups and downs in DO levels are customary in the daily life of ponds. DO is at its lowest just before and during sunrise and at its highest in the afternoon/evening prior to sunset. As photosynthesis occurs oxygen levels increase throughout the day. Once night falls, Photosynthesis stops and plant matter respires (using oxygen). At this point all aquatic life in the pond is using oxygen, causing DO levels to drop until the next morning when daylight induces the process of photosynthesis. Many fish kills occur in ponds that have a dense phytoplankton bloom in the summer when water temperatures are in the 80's. This is because at these warm temperatures, water holds the least amount of oxygen while simultaneously the oxygen demand is very high. Team a dense phytoplankton bloom with several cloudy days where plants are using oxygen rather than producing it, and the result is often an oxygen crash, unless the pond has sufficient aeration. It is important to note that in these situations where oxygen crashes are a concern, implementing surface aeration is the best method to increase oxygen levels quickly. Water bodies that are pushing an aggressive fertilizing program should highly consider a combination of both bottom diffused aeration and surface aeration.

When oxygen levels are actually crashing it is often best not to mix the deeper water with the surface water. During an oxygen crash aeration should be focused on the surface water. Bottom diffused aeration should be focused on water <3 feet. It is critical to avoid mixing the deep water with the surface water as the result is often a total fish kill. In these dire situations peroxide based products that serve as oxygenators can be applied to improve oxygen levels. It is also beneficial to add aerobic bacteria to help reduce the nutrient load on the water body. Several steps can be taken during an oxygen crash to avoid catastrophe, but the best method is prevention. Don't over fertilize and understand the limitation of the water. If you want to push the limits on productivity, bottom diffused and surface aeration are important.

**Fish Kill**
As water temperatures increase, pond life becomes more active and requires more oxygen, but unfortunately warm water holds less DO than cold water. Ponds are at the highest risk of fish kills when water temperatures reach into the 80's. In the 80's, oxygen demand is at its highest, but the waters ability to hold oxygen is at its lowest.

When dealing with ponds at high risk of an oxygen crash, the crash is often the result of two common BOD scenarios. The first scenario is when an abrupt environmental change occurs, resulting in the death of most of

the algae and plant matter. This creates a large BOD that may not last long, but long enough to remove all of the available DO from the water and kill the fish. The second scenario is when the pond has a dense amount of Phytoplankton, algae or vegetation. Since plant matter needs sunlight to produce oxygen, cloudy weather causes plants to respire (using oxygen). Several cloudy days back to back in ponds with dense plant matter can result in DO levels dropping lower and lower each day. With plants respiring and not photosynthesizing, oxygen production can not keep up with the demand and the pond slowly slips into lethal DO levels. The oxygen may only dip into lethal levels for 20 minutes in the early morning, but this short period will result in a fish kill. When oxygen levels are crashing, larger fish are often the first to die due their higher demand for oxygen.

When ponds are experiencing fish kills, often times the fish die in phases over the course of several days. To prevent fish kills in ponds under these conditions, replace water within the pond if at all possible and use surface aeration. Pumping water from a nearby pond is the best solution teamed with surface aeration. It is most important to pump water during the later parts of the night and early morning when DO levels are likely lethal. Many fish will find the fresh water and ride out the deadly hours of the DO cycle.

Properly managed ponds limit and prevent the BOD and COD from building up to the point where they become lethal. Managing ponds throughout the entire year allows the ecosystem to process organics efficiently. Ecosystems with a healthy balance will not have wide swings in the oxygen levels but will have a stable DO level with little fluctuation. When it comes to fish production, fish will not grow when they are trying to survive poor oxygen levels. Keeping water conditions healthy will pay off in many ways for you and the environment, especially if you're trying to produce larger fish.

**Water Level Draw Down**

Water level draw down is a technique used to consolidate fish within a water body. This is often done in the late summer and fall to improve growth rates of predator fish. It is a useful management strategy for water bodies that have the proper water supply to restore the system back to full pool following the draw down period. Draw downs can provide several advantages, especially when trying to reduce over populated forage species such as Gizzard Shad. Properly timed draw downs can give predators the needed edge to knock back the over abundant forage fish while also improving growth rates.

**Food Chain & Food Web**

Plankton is the base of the food chain in ponds and lakes. Plankton is broken down into two categories: phytoplankton which are microscopic plants (green) and zooplankton which are microscopic animals (brown). Phytoplankton relies on three primary things to grow: sunlight, available nutrients and water temperature above the mid 50's. The primary predator to phytoplankton is zooplankton. Large phytoplankton populations will give the water a green color, whereas large zooplankton populations will give the water a brown color. Phytoplankton and zooplankton populations will fluctuate back and forth, resulting in the water color changing between bright green, olive green, olive brown, brown and clear. In ponds with aeration, the plankton populations will be more stable due to good nutrient management and the additional oxygen source. In ponds where an abundant population of fish is desired, increasing plankton populations should be considered.

Next up the food chain are invertebrates. Invertebrates feed on plankton, plants, small fish and detritus (decaying organics). Invertebrates play an important role as food for larger invertebrates and fish, while they also further the decomposition of organics. A healthy, high quality invertebrate population hinges greatly on good healthy water. With a good population of invertebrates, small fish will prosper.

Small fish are very important to the food chain, as large fish depend on them for survival. Small fish feed heavily on both phytoplankton and zooplankton, while also consuming available invertebrates and other small fish when possible. It is important that small fish have abundant food available to give them the needed energy to face life's challenges. Survival for small fish is difficult, so having abundant plankton is ideal.

Larger fish begin playing a role at this point, primarily feeding on invertebrates and smaller fish. Fish diets vary between the species, but most fish tend to feed on what is readily available.

Predator fish are much more vulnerable to going hungry than those lower in the food chain since they are relying both on the smaller fish's success and competing with their own tendencies to over populate. Too many top end predators will put a large strain on the smaller fish, bringing instability to the food chain. It is very important to actively remove top end predators from ponds before they overpopulate.

The food chain is relatively straight forward and ties directly into the much larger picture of the "Food Web". The Food Web includes the "Food Chain" along with all the Aquatic and Environmental variables that influence the aquatic life such as vegetation, water quality, runoff, sunlight, etc. To maintain a prosperous aquatic environment the food chain needs to be in check, and the Food Web needs to be understood. Many ponds often require the assistance of aeration, vegetation treatment, Grass Carp, additional forage fish, harvesting predators, along with many other management practices. There are dozens of variables that can be modified to bring stability to the ecosystem.

**Parasites:**
A few species of fish have a unique diet. One of these fish is the Redear Sunfish, also know as Shellcracker. Shellcracker play a unique role in the balance of an ecosystem, targeting mollusks as their primary food source. The Shellcraker's unique diet will help break the life cycle of parasites within the pond that are hindering the health of the fish. The life cycle of many aquatic parasites have three stages within three hosts. Their first host are mollusks, then fish, and then finally birds. To break this parasitic life cycle, Shellcracker consume the mollusks, leaving a void in the parasites host requirement, keeping the parasite from being able to infect fish. Reducing the number of parasites on fish will result in better fish growth rates.

# Predator to Prey Ratio

Having a balance of predator to prey species will be a continuous goal, so be sure to stock forage fish that meet the needs of your predators. An off balance predator to prey ratio is one of the most common issues with ponds. Predators have the tendency to overpopulate and overwhelm the baitfish. Once most of the forage base is consumed, predator growth rates slow and health begins to diminish. A balanced fishery needs to have a management plan that takes predator harvest into consideration. A proactive predator harvest program is a management strategy that allows you to stay one step ahead of the potential problems your pond will face. Using an electro-fishing boat, seine, trap nets or through angling, excess predators can be removed annually. Looking at the long- term picture and the costs associated with pond management, it should be a primary goal to proactively manage the fishery through predator removal.

In particular, Largemouth Bass and Black Crappie have a tendency to overpopulate. Most well managed ponds and lakes annually harvest between 15 and 25 pounds of predator fish per acre of water. If the bass and crappie are not able to be removed through angling due to a lack of fishing pressure or if the fisherman does not desire to deal with this management requirement, it is critical to have the fish removed through electro-fishing. This step of harvesting fish is often the single most over looked management strategy. Without proper harvest predator fish growth rates will suffer.

It is ideal to harvest Largemouth Bass in the spring when you can tell the difference between the female and males by simply looking at the body structure. Female bass have the greatest potential to reach trophy size, so it is best to actively harvest the male bass and keep the female bass when possible. It is also important to note that not all bass are the same. Some bass are cannibals and grow much more quickly than the surrounding bass. It is important to identify when a fish looks like it should be released, even if it falls within the determined slot range. It is also important to note that releasing all fish that are healthy looking may result in not harvesting enough predators which in turn will slow down the growth rate of the bass population. Be sure to actively harvest the slot limit and only release the very best looking fish from each size class within the slot limit.

# Species Management

Depending on your goals, different predator species will play into your management strategy. Based on annual water temperature highs and lows you can determine which predator species will best suit the pond, and incorporate them into the overall vision. Whether they are warm water fish, cool water fish, cold water fish or a combination, having the proper species is fundamental. Once you have established which predator species are desired, focus on the forage base. Choosing the right forage species depends on water temperature, cover, water movement, predator species, the base of the food chain along with other management techniques. With proper species selection, you can minimize upcoming efforts needed to keep the fishery balanced. When it comes time to implement the desired species, let the forage base establish prior to introducing the predators whenever possible. Your patience will be rewarded with faster growth rates on the predator fish.

# Supplemental Feeding

Establishing a forage base that is self-sustaining should be a primary goal of pond and lake owners. A good way to achieve this is through supplemental feeding. Using automatic feeders filled with pellet feed is an ideal

method to feed many species of forage fish. The additional food source will give your bait the needed edge to improve survival and reproduction success, while also providing your pond with the needed food to support a much greater biomass of forage.

Feeding is beneficial for predator fish as well. Bass, Catfish and Trout species thrive on artificial feed and the option of feeding should be considered when managing for these species. A large advantage to feeding artificial feed is the front row seat you will have when managing your fishery. The ability to observe fish growth and health up close is a great benefit. Also, feeders provide a great fishing hole for kids and a quick place to catch a meal if desired. Pellet feed is less expensive than stocking forage fish, which reduces costs associated with creating and maintaining a healthy fish community. In times of reduced budgets, feeding rates can be cut back, but a reasonable amount of pellet fish food can still be affordable, allowing you to keep feeding and maintaining a healthy fish community.

Directional Feeders are very reliable systems that have proven their quality over the years. Feeders are an investment and will save a great deal of money in the 5-10 year picture. Fisheries management programs are often crippled because of reduced cash flow when it is time for the fishery to shock forage fish. The biggest benefit of artificial feeders is they allow you to maintain a productive fishery through economic lows. Artificial feed has a 2:1 conversion ratio, so for every 2 pounds of feed you grow 1 pound of fish. Stocking forage fish may have its benefits, but the conversion ratios are only 10:1 To set up a management plan that will have low annual costs to keep your fishery going, fish feeders should most likely be incorporated.

# Fish Stocking

Stocking forage fish to keep the forage base healthy and abundant is an important step in the long-term management of a healthy fishery. The species of fish and the quantity are dependent on the goals and current needs of the fishery. If desired, stocking forage fish once or twice per year can greatly improve fish growth rates. Golden Shiners are usually stocked if looking to maintain a balanced fishery. Those looking for to manage for Trophy Fishing should consider stocking Threadfin Shad.

# Electro-fishing

Electro-fishing is a fish sampling tool used to gather fish population data which allows pond managers to make accurate decisions and improve management techniques. Using an electro-shocking boat, electricity produced from a generator is converted from Alternating Current to Direct Current. It then travels through wires to the bow of the boat where it passes from the cathode through the water to the anode. The electric field produced affects a relatively small area of the water in front of the vessel where fish are momentarily stunned and safely collected with dip nets. The fish are placed in a live well on the boat where length and weight data is recorded, observations are made, and then the fish are released, without harm, back into their environment. The data provides insight to current and future issues, giving pond managers the needed facts to make a pond productive and keep it productive. In addition to collecting data, undesired species of fish or over populated size classes of predators can be removed from the water body.

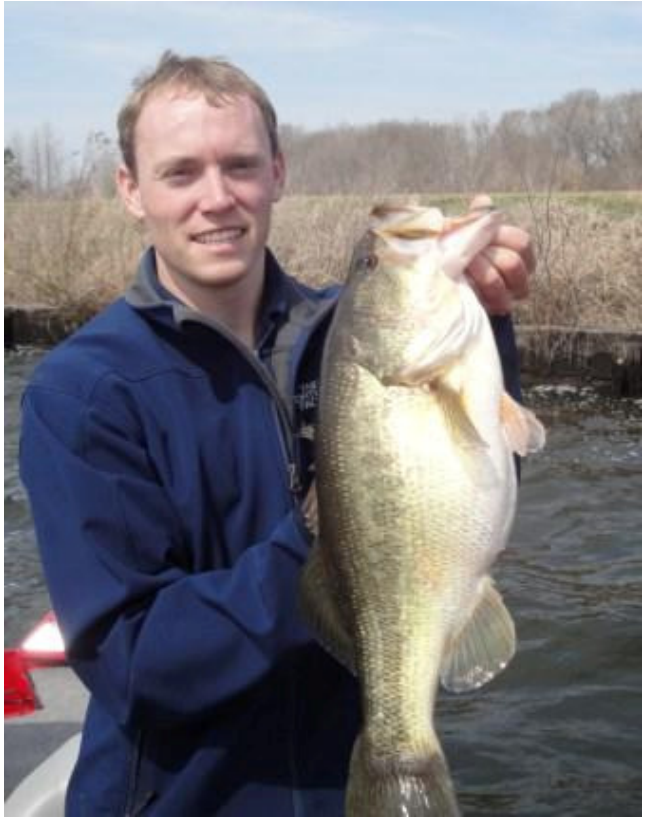
For owners looking to restore a fishery to a balanced state, an initial survey will provide the needed information to make improvements. The frequency in which a water body has an electro-fishing study completed is directly related to the goals of the water body and the available budget. Those who want a balanced, healthy fishery should consider a 3-5 year rotation between studies where as those who want a trophy fishery or want to make big improvements in a relatively short period of time will require electro-fishing once or twice per year.

When developing a fishery, it is important to stay ahead of potential issues. As more is learned about the fish community, management decisions can be tailored to meet the pond's needs. Electro-fishing is a very important tool used in the process of managing a fishery.

Depending on the goals of the study the fish can be aged as well. Aging fish is nearly identical to aging a tree. Like a tree, fish are always producing layers of growth. The two primary ways to age fish is to either to examine scales from the fish or to examine one of the otolith's (inner ear bone). During times of slow growth such as winter the layers of growth are closer together forming a dark line. In the summer when fish are growing more quickly these layers of growth are spread out resulting in a lighter area. Knowing how old fish are can play an important role in the management strategies. Another important part of this aging process is the ability to do back calculations and determine how large the fish was each year of its life. This information can help illustrate how the fishery reached its current state. This data can play an important role in the process of creating a management strategy to improve fish growth rates.

# Trophy Management

The key to creating and maintaining a trophy fishery revolves around all possible limiting factors that could restrict productivity. These limiting factors include habitat, predator to prey ratios, fish species, available food and genetics. Working to create the ideal environment for fish and invertebrates will allow you to reach and exceed your goals. Innovative steps to keep your pond productive should be incorporated into to the plan. Each region of the country has a limited number of growing days each year. Be sure that fish have good water quality and available food every time the fish are hungry. With a complete understanding of the body of water and its limiting factors, management practices can be teamed together to create the ideal management program.



# Genetics

Genetics play an important role in trophy fish management. It is important to diversify the gene pool and reduce the potential of inbreeding. Keep records of where fish were purchased and make a point to stock fish of different blood lines when possible.

| Current Status of Summer Lake Fishery | | | |
|---|---|---|---|
| **Habitat** | **Parameter** | **Rating** | **Notes** |
| | Large Cover | Fair | Multiple trees that have fallen into the water and are serving a good cover for the fish |
| | Dense Cover | Good | Lake has dense emergent vegetation around the parameter |
| | Beneficial Vegetation | Fair | Lake has emergent vegetation around the parameter which are utilizing excess nutrients |
| | Nuisance Vegetation & Algae | Fair | Lake is relatively clean of negative plant species |
| | Spawning Substrate | Good | Lake has suitable spawning substrate |
| | Spawning Locations | Good | Lake has suitable spawning locations |
| | Water Quality | Poor | Zero oxygen below 4 ½ feet. |
| | Productivity (food source) | Good | Pond has a great deal of phytoplankton and zooplankton |
| ***Please note that certain parameters vary over the course of the year and this assessment is based on the fisheries current status on the day the assessment took place*** | | | |

# Management Recommendations:

**Cover-** The lake has good cover for fish. Unfortunately the cover is in the form of both emergent vegetation that is growing in undesired areas and fallen trees which are restricting access to areas of the lake. The emergent vegetation is serving as a good nursery for smaller fish and provides plenty of dense cover. Eradicating the emergent vegetation from the lake is not recommended unless there is a plan in place to install beneficial emergent vegetation.

**Herbicides and Algaecides** - The emergent vegetation species can likely be controlled relatively easily using contact herbicides. Treating the vegetation to the point where it is on obstructing the lakes channel is likely the best management approach. This may only need to be done every few years depending on the growth rate of the plant species. The costs associated with treating this emergent plant species is relatively low since basic contact herbicides should provide good control.

**Water Quality -** The Water quality in the lake is in poor shape. A profile of the water column was tested to better understand the lakes dissolved oxygen level. The lake has very poor water quality, below 4 ½ feet the oxygen reading was 0.0 mg/l. This water quality data illustrates that the lake is in desperate need of an aeration system. Currently the lake is nutrient rich and has a large oxygen demand. The current state of the

water quality is putting a stain on the environment. As the summer progresses the water quality will continue to deteriorate. It is very likely that during the summer only a couple feet of the lakes water column will maintain enough oxygen to support aquatic life. Further testing this summer would help illustrate the severity of the issue, but the best use of resources would be to install an aeration system and get the lake on track to correcting this issue. Testing water quality in the summer on an annual basis would provide baseline water quality data and help illustrate the health of the lake.

**Liming –** based on goals this does not need to be incorporated into the management plan

**Fertilizing–** based on goals this does not need to be incorporated into the management plan

**Beneficial Bacteria–** based on size of the lake and the goals, adding beneficial bacteria is not recommended since the required dose's would be very expensive.

**Water Level Draw Down –** based on goals this does not need to be incorporated into the management plan

**Automatic Feeders –** based on goals automated feeders have an opportunity to play a role in the management of the fishery. Feeders provide fish with a needed food source and if the feeders were desired by the residence they would play a significant roll in improving the fishery

**Harvest Predators –** Harvesting predators may be needed, but without conducting an electro-fishing survey it is difficult to know what fish to harvest, if any.

**Harvest Pan Fish –** Harvesting bluegill is not recommended as they serve as the backbone to the food chain

**Stock Forage Fish –** Stocking forage fish annually is recommended if looking to improve the fishery. Stocking every 2 years would provide benefit, but annual stocking is a more consistent and better approach to improving growth rates on the bass and crappie.

**Stock Predator Fish –** An electro-fishing survey would be required to make this decision. Based on information provided by the residences it is not necessary to stock predator fish at this time.

**Electro-shocking –** Sampling the fishery on a 3-5 year cycle depending on budget would provide beneficial information to help support management decisions.

**Genetics: -** Stocking a small number of Largemouth Bass and Bluegill every 5-10 years would help diversify the genetics within the lake an help reduce inbreeding.

# Fisheries Management Plan

| Property: Summer Lake HOA | Water Body: Summer Lake |
|---|---|

**Goals: To have a healthy, balanced fishery with a range of catchable size fish within the lake**

| | | 2012 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| Habitat | Fertilize | | | | | | | | | | | | |
| | Monitor Plankton Bloom | | | | | | | | | | | | |
| | Test H20 | | | | | | | | | | | | |
| | Add Dense Cover | | | | | | | | | | | | |
| | Add Structural Cover | | | | | | | | | | | | |
| | Add Beneficial Vegetation | | | | | | | | | | | | |
| | Treat Algae & Vegetation | | | | | | X | X | X | X | | | |
| | Stock Grass Carp | | | | | | | | | | | | |
| | Lime | | | | | | | | | | | | |
| | Run Aeration | X | X | X | X | X | X | X | X | X | X | X | X |
| | Add Beneficial Bacteria | | | | | | | | | | | | |
| Predator to Prey Ratio | Electro-shock | | | | | | | | | | | | |
| | Stock Forage Fish | | | | | X | | | | | | | |
| | Stock Predator Fish | | | | | | | | | | | | |
| | Feed (floating pellets) | | | | | | | | | | | | |
| | Harvest Predator Fish | | | | | | | | | | | | |
| | Harvest Pan Fish | | | | | | | | | | | | |
| | Water Level Draw Down | | | | | | | | | | | | |

# Fisheries Management Plan

| Property: Summer Lake HOA | Water Body: Summer Lake |
|---|---|

**Goals: To have a healthy, balanced fishery with a range of catchable size fish within the lake**

| | 2013 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| Habitat | Fertilize | | | | | | | | | | | | |
| | Monitor Plankton Bloom | | | | | | | | | | | | |
| | Test H20 | | | | | | | X | | | | | |
| | Add Dense Cover | | | | | | | | | | | | |
| | Add Structural Cover | | | | | | | | | | | | |
| | Add Beneficial Vegetation | | | | | | | | | | | | |
| | Treat Algae & Vegetation | | | X | X | X | X | X | X | X | X | | |
| | Stock Grass Carp | | | | | | | | | | | | |
| | Lime | | | | | | | | | | | | |
| | Run Aeration | X | X | X | X | X | X | X | X | X | X | X | X |
| | Add Beneficial Bacteria | | | | | | | | | | | | |
| Predator to Prey Ratio | Electro-shock | | | | | | | | | | | | |
| | Stock Forage Fish | | | | X | | | | | | | | |
| | Stock Predator Fish | | | | | | | | | | | | |
| | Feed (floating pellets) | | | | | | | | | | | | |
| | Harvest Predator Fish | | | | | | | | | | | | |
| | Harvest Pan Fish | | | | | | | | | | | | |
| | Water Level Draw Down | | | | | | | | | | | | |

# Appendix's

1A – Herbicides and Algaecides
1B – Water Quality Parameter Information

# Appendix 1A: Herbicides and Algaecides:

There are numerous aquatic herbicides and algaecides that are approved by the EPA for aquatic plant treatment in lakes, ponds, rivers, and streams. Below is information about some of the most commonly used herbicides and algaecides:

## Herbicides:

**Glyphosate**:
Trade names for aquatic products with glyphosate as the active ingredient include Rodeo®, AquaNeat, Touchdown Pro, AquaMaster®, and AquaPro®. This systemic broad spectrum herbicide is used to control floating-leaved plants like water lilies and shoreline plants like purple loosestrife, cattails, phragmites, and many others. It is generally applied as a liquid to the leaves. Glyphosate does not work on submersed plants since it becomes inactive in the water. Although glyphosate is a broad spectrum, non-selective herbicide, a good applicator can somewhat selectively remove targeted plants by focusing the spray only on the plants to be removed. Plants can take several weeks to die and a repeat application is often necessary to remove plants that were missed during the first application.

**Fluridone**:
Trade names for fluridone products include Sonar® and Whitecap®. Fluridone is a slow-acting systemic herbicide used to control floating (e.g., duckweed, watermeal, and azolla) and submersed vegetation (e.g. hydrilla, elodea, Egeria, Eurasian watermilfoil, naiads, and many more). It may be applied as a pellet or as a liquid. Fluridone can show good control of submersed plants where there is little water movement and an extended time for the treatment. Its use is most applicable to whole-lake or isolated bay treatments where dilution can be minimized. It is generally not effective for spot treatments. It is slow-acting and may take six to twelve weeks before the dying plants fall to the sediment and decompose. In water bodies with significant flow, fluridone is applied several times during the spring/summer to maintain a low, but consistent concentration in the water. Granular formulations of fluridone are proven to be effective when treating areas of higher water exchange or when applicators need to maintain low levels over long time periods. Although fluridone is considered to be a broad spectrum herbicide, it can be used to selectively remove certain species of susceptible plants since some native aquatic plants, especially pondweeds, are minimally affected by low concentrations of fluridone.

**2,4-D**:
There are two formulations of 2,4-D approved for aquatic use. The granular formulation contains the low-volatile butoxy-ethyl-ester formulation of 2,4-D (Trade names include Sculpin®, AquaKleen® and Navigate®). The liquid formulation contains the dimethylamine salt of 2,4-D (Trade names include Sculpin G®, Navigate®, Weedar® and DMA*4IVM). 2,4-D is a relatively fast-acting, systemic, selective herbicide used for the control of broad-leaved species. It may be applied as a pellet or as a liquid. Because it is fast acting, 2,4-D can be used to treat smaller areas effectively.

**Endothall**:
A trade name for the dipotassium salt of endothall is Aquathol®. Endothall is a fast-acting non-selective contact herbicide which destroys the vegetative part of the plant but generally does not kill the roots. Endothall may be applied in a granular or liquid form. Typically endothall compounds are used primarily for short term (one season) control of a variety of aquatic plants. However, there has been some recent research that indicates that when used in low concentrations, endothall can be used to selectively remove exotic weeds, leaving some native species unaffected. Because it is fast acting, endothall can be used to treat smaller areas effectively.

**Diquat**:
Two trade names for diquat are Reward® and Knock-Out®. When diquat is taken in by plants, it causes the release of oxidizers in the plant tissues during photosynthesis that damage cell membranes and cytoplasm, which destroys the vegetative parts of the plant but does not kill the roots. It is applied as a liquid. Typically diquat is used primarily for short term (one season) control of a variety of submersed aquatic plants. It is very fast-acting and is suitable for spot treatment. However, turbid water or dense algal blooms can interfere with its effectiveness.

**Triclopyr**:
Triclopyr can be applied as a liquid (trade name Renovate3®) or as a granule (trade name Renovate OTF®). Triclopyr is a systemic, selective herbicide used for the control of broad-leaved species. Many native aquatic species are unaffected by triclopyr. Because it is fast acting, Triclopyr can be used to treat smaller areas effectively.

**Imazapyr**:
A trade name for imazapyr is Habitat®. This systemic broad spectrum, slow-acting herbicide, applied as a liquid, is used to control emergent plants like spartina, reed canarygrass, and phragmites and floating-leaved plants like water lilies. Imazapyr does not work on underwater plants such as Eurasian watermilfoil. Although imazapyr is a broad spectrum, non-selective herbicide, a good applicator can somewhat selectively remove targeted plants by focusing the spray only on the plants to be removed.

**Imazamox**:
A trade name for imazamox is Clearcast®. Imazamox is a broad spectrum slow-acting systemic herbicide that can be applied directly to the water as a granular formulation, or as a foliar spray with the liquid formulation. It is effective on numerous emergent, floating-leaved and submersed plants, and is particularly effective on the difficult to control species of yellow floating heart and late season water chestnut. Imazamox binds with a plant-specific enzyme which causes the plants to stop growing slowly die as their food reserves are exhausted. It has a very favorable environmental profile and also has minimal irrigation restrictions.

**Flumioxazin**:
A trade name for flumioxazin is Clipper®. This broad spectrum, fast-acting contact herbicide is formulated as a water dispersible granule that is diluted with water prior to application. It is effective for treatment of floating plants like watermeal and duckweed, and submersed plants like Eurasian watermilfoil, hydrilla, and curly leaf pondweed. It is a whole-lake treatment and is not suitable for spot treatments. It is most effective in

waters with a pH of less than 8.5. Flumioxazin dissipates quickly from the water column and does not accumulate in the sediment, which provides a favorable environmental safety profile.

**Bispyribac**:
A trade name for bispyribac is Tradewind®. This slow-acting systemic herbicide is available in a soluble powder that is mixed with water prior to application. It is applied either directly to the water or as a foliar spray. It is an acetolactase systhase (ALS) inhibitor with a favorable environmental profile. It can be applied directly to the water as a whole-lake treatment or as a foliar spray.

**Chelated copper herbicides**:
Trade names for chelated copper herbicides are Nautique® and Komeen®. Chelated copper herbicides are fast-acting contact herbicides that are very economical and widely used. The plants take in the copper ions, which inhibit photosynthesis and cell growth. The products are available in a liquid formulation and are applied directly into the water. There are no irrigation restrictions with chelated copper herbicides.

**Penoxsulam**:
A trade name for penoxsulam is Galleon®. This slow-acting systemic herbicide is available in a liquid formulation that is either applied directly to the water or as a foliar spray. It is an acetolactase synthase (ALS) inhibitor that has been classified by the EPA as a Reduced-Risk herbicide. The key target species are watermeal, duckweed, and hydrilla. It is a whole-lake treatment except when applied as a foliar spray.

## Algaecides – Certain herbicides have been specially formulated for efficacy on algae.

**Copper Sulfate**:
Trade names for copper sulfate are Cutrine® (granular), Crystal Blue® (granular), and SeClear® (liquid). Copper sulfate is a naturally occurring inorganic salt that is labeled for use as an algaecide. It is available in both granular and liquid formulations. It is a fast-acting algaecide that inhibits photosynthesis and cell growth. It is widely used municipal water treatment facilities because of its short residence time in the water bodies.

**Chelated Copper**:
Trade names for chelated copper products are Captain® (liquid) and Cutrine-Plus® (granular). The copper in these products is chelated with a mixture of ethanolamines. The pH of the formulated product is approximately 10.5, which allows the copper to stay in solution even under conditions of high hardness and alkalinity. It is this soluble copper which is algaecidal. The increased contact time provides for more complete copper uptake by individual algae cells. No loss of copper occurs due to chemical precipitation or binding to particulate matter.

**Endothall (Amine Salt)**:
A trade name for the amine formulation of endothall is Hydrothol 191®. Hydrothol 191® is a rapidly acting non-selective contact herbicide or algaecide. Hydrothol 191® may be used for filamentous algae control or cyanobacteria control (blue-green algae) in selected water bodies. Several treatments each season may be needed to control algae/cyanobacteria. Hydrothol 191® has a high acute toxicity to fish and must be used

with extreme care. Unlike copper compounds that are also used for algae control, Hydrothol 191® does not accumulate in sediments and breaks down rapidly.

**Peroxygen-based Granular Algaecide:**
Trade names include GreenClean® and Pak27®. These are peroxygen-based granular algaecides used for the prevention and control of algae in ponds, streams, irrigation systems, ornamental pools, and fountains. Areas being treated with these products must be closed to recreational activities during and for two-hours after treatment.

**Diquat dibromide:**
Two trade names for diquat are Reward® and Knock-Out®. Diquat is a fast-acting non-selective contact herbicide that is also labeled for algae control. When diquat is taken in by algae, it causes the release of oxidizers during photosynthesis that damage cell membranes and cytoplasm, which destroys the algal tissue. It is applied as a liquid. It is very fast-acting and is suitable for spot treatment, and is frequently tank-mixed with copper products. However, turbid water can interfere with its effectiveness.

**Adjuvants**:
There are a number of adjuvants (surfactants, stickers, sinking agents) allowed for use under the NPDES permits. These products are designed to be tank mixed with the herbicides and algaecides to improve the overall performance and efficacy of the herbicides will minimizing the amount of herbicide required and reducing the likelihood of treatment failure.

# Appendix 1B Water Quality Parameters:

**Dissolved Oxygen (DO):**

Dissolved Oxygen in surface water is used by all forms of aquatic life; therefore, it is typically is measured to assess the "health" of a water body. Dissolved Oxygen analysis measures the amount of gaseous oxygen (O2) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. Adequate dissolved oxygen is necessary for good water quality. If dissolved oxygen levels in water drop below 5.0 mg/l (or parts per million, ppm), aquatic life is put under stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills in your freshwater system.

Do dissolved oxygen concentrations remain the same throughout the year?

Seasonal temperature fluctuations, organic matter input, and several biological processes can strongly influence the dissolved oxygen concentrations in your lake or pond. In fact, dissolved oxygen concentrations are often fluctuating through a daily cycle as well as a seasonal cycle. Photosynthesis is the primary process affecting the dissolved-oxygen/temperature relation; water clarity and strength and duration of sunlight, in turn, affect the rate of photosynthesis. Colder water holds more dissolved oxygen than warmer waters, therefore dissolved oxygen concentrations often drop to low levels in the summer and early fall.

**pH:**

The balance of positive hydrogen ions ($H^+$) and negative hydroxide ions ($OH^-$) in water determines how acidic or basic the water is. Notice the ' + ' and ' - ' in the chemical symbols above. They indicate that these chemical forms are 'ions', meaning they have a positive or negative electrical charge. When analysts measure pH, they are determining the balance between these ions. The pH scale ranges from 0 (high concentration of positive hydrogen ions, strongly acidic) to 14 (high concentration of negative hydroxide ions, strongly basic). In pure water, the concentration of positive hydrogen ions is in equilibrium with the concentration of negative hydroxide ions, and the pH measures exactly 7.

As a generalization, most lakes are basic (alkaline) when they are first formed and become more acidic with time due to the build-up of organic materials. As organic substances decay, carbon dioxide ($CO_2$) forms and combines with water to produce a weak acid, called "carbonic" acid. Large amounts of carbonic acid lower water's pH. In water bodies with low Alkalinity pH levels can fluctuate greatly over the course of the day. These fluctuations are directly related to the process of photosynthesis. When the sun is shining plants and algae use carbon dioxide, resulting in the pH going down. At night plants and algae respire, in this process they actually use oxygen and produce carbon dioxide as a byproduct. This cycle results in pH fluctuating throughout the day and night going from an lower pH in the morning to a higher pH in the afternoon.

**Alkalinity:**

The alkalinity of water is a measurement of its buffering capacity or ability to react to strong acids. Alkalinity is not a pollutant. It is a total measure of the substances in water that have "acid-neutralizing" ability. Some may confuse alkalinity with pH. However, pH measures the strength of an acid or base, while alkalinity indicates a solution's power to react with acid and "buffer" its pH — that is, the power to keep its pH from changing. Alkalinity of natural waters is typically a combination of bicarbonate, carbonate, and hydroxide ions.

How does alkalinity affect my freshwater system?
In natural waters, excessive alkalinity can render water unsuitable for irrigation purposes and may indicate the presence of industrial effluents. Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to stressful pH fluctuations.

**Hardness:**
Hard water is water that has high mineral content. Hardness is a measure of calcium and magnesium ions. Hardness concentrations are usually similar to alkalinity (if derived from limestone) but can be different especially in coastal areas.

One of the key functions of having the proper hardness levels is the regulation of heavy metal absorption. Just like hard water leaves a film on your glassware it also coats the gills of a fish and prevents the fish from absorbing lead, cadmium, arsenic and other materials that are harmful to both the fish and the end consumer. A lack of hardness can also reduce plankton production, cause muddiness, inhibit fish growth, and undermine your whole lake management program. By maintaining the proper hardness levels you can reduce the rate at which your fish absorb these detrimental materials and have a healthier freshwater system.

**Ammonia:**
Ammonia, NH3, measured in parts per million (ppm), is the first measurement to determine the "health" of the biologic converter. Ammonia should not be detectable in a pond with a "healthy" bio-converter. The ideal and normal measurement of Ammonia is zero. When ammonia is dissolved in water, it is partially ionized depending upon the pH and temperature. The ionized ammonia is called Ammonium and is not toxic to the fish. As the pH drops and the temperature decreases, the ionization and Ammonium increases which decreases the toxicity. As a general guideline for a water temperature of 70°F., most fish would be expected to tolerate an Ammonia level of 1 ppm if the pH was 7.0, or even as high as 10.0 if the pH was 6.0. At a pH of 8.0, just 0.1 ppm could be dangerous. Ammonia tends to block oxygen transfer from the gills to the blood and can cause both immediate and long term gill damage. The mucous producing membranes can be destroyed, reducing both the external slime coat and damaging the internal intestinal surfaces. Fish suffering from Ammonia poisoning usually appear sluggish, often at the surface as if gasping for air. Deionized ammonia (NH3) present in pond water is extremely toxic to fish. Even low levels of ammonia can affect the fish's central nervous system, reduce its ability to obtain oxygen from the water and lower resistance to disease. Presence of this form of ammonia in a pond is rare but can be a sign of an excessively overcrowded fish population, chemical pollution and/or excessive organic material rotting in water.

Ammonia is a gas primarily released from the fish gills as a metabolic waste from protein breakdown, with some lesser secondary sources such as bacterial action on solid wastes and urea.

Ammonia is removed by bacterial action in the bio-converter and some is directly assimilated by the algae in the pond. Nitrosonomas bacteria consume the Ammonia and produce Nitrites as a waste product. A significant portion of this bacterial action can occur on the walls of the pond as well as in the bio-converter. Ammonia readings may increase with a sudden increase in bio-converter load

until the bacterial colony grows to accept the added material. This can happen following the addition of a large number of new fish to a pond or during the spring as the water temperature increases. Fish activity can often increase faster following a temperature increase than the bacterial action does.

**Nitrite:**
Nitrite, NO2-N, measured in parts per million (ppm), is the second chemical measurement made to determine the "health" of the biologic converter. Nitrite should not be detectable in a pond with a properly functioning bio-converter. Thus the ideal and normal measurement of Nitrite is zero. A low Nitrite reading combined with a significant Ammonia reading indicates the Ammonia- Nitrite biologic converter action is not established, while a low Ammonia reading with a detectable Nitrite reading indicates that the Nitrite-Nitrate bacterial conversion activity is not yet working.

Nitrite is produced by the autotrophic Nitrosomonas bacteria combining Oxygen and Ammonia in the bio-converter and to a lesser degree on the walls of the pond. Just as with Ammonia, Nitrite readings may increase with a sudden increase in bio-converter load until the bacterial colony grows to accept the added material. This can happen following the addition of a large number of new fish to a pond or during the spring as the water temperature increases. Fish activity can often increase faster following a temperature increase than the bacterial action does.

Nitrite has been termed the invisible killer. The pond water may look great but Nitrite cannot be seen. It can be deadly, particularly to the smaller fish, in concentrations as low as 0.25 ppm. Nitrite damages the nervous system, liver, spleen, and kidneys of the fish. Even lower concentrations over extended periods can cause long term damage. Short term, high intensity, "spikes" which often occur during bio-converter startup may go undetected yet cause problems to develop within the fish months later. A common indication of a fish that has endured a Nitrite spike in the past is that the gill covers may be slightly rolled outward at the edges. They do not close flat against fish's body.

About the only control of Nitrite is through the maintenance of a "healthy" bio-converter. Within the media, Nitrobacter bacteria combine Oxygen with the Nitrite to convert it to the relatively benign Nitrate. The Nitrobacter bacteria receive considerably less energy from this conversion process than do the Nitrosomonas bacteria in the Ammonia to Nitrite process. For this reason, they are not as hardy and tend to be the last to come and the first to go when a problem occurs within the bio-converter. The addition of salt helps reduce the toxic effects significantly but should only be used as a interim measure, not as an ongoing treatment.

**Nitrate:**
Nitrate, NO3-N, measured in ppm, is the third and last measurement used to determine the "health" of the bio-converter. Nitrate is produced by the autotrophic Nitrobacter bacteria combining Oxygen and Nitrite in the bio-converter. A zero Nitrate reading, combined with a non-zero Nitrite reading, indicates the Nitrite-Nitrate bacterial converter action is not established.

Where Ammonia and Nitrite were toxic to the fish, Nitrate is essentially harmless. There have been reports that high nitrate levels may weaken the colors in fish but there have also been reports that high nitrate levels can enhance the colors. Similarly, reports suggest that high nitrate levels will both stimulate and suppress spawning activity. If the Nitrate concentration gets too high, the Nitrite-Nitrate converting bacteria (Nitrobacter) may not be able to do their job effectively resulting in a raised Nitrite level. Nitrate is the end result of the nitrification cycle and is very important to plants in their life cycle. This is why the plants in your garden can flourish from being watered with the waste water from your pond. The nitrate concentration is controlled naturally through routine water change outs and to a lesser degree through plant/algae consumption.

**Total Phosphorus:**
Total phosphorus, in relation to a water sample, means the total concentration of all forms of phosphorus found in the water sample and is an essential nutrient for plants and animals. It is naturally limited in most fresh water systems because it is not as abundant as carbon and nitrogen; introducing a small amount of additional phosphorus into a waterway can have adverse effects. Sources of phosphorus include soil and rocks, fertilizers, animal waste, development or paved surfaces, industrial discharge, phosphate mining, drinking water treatment, forest fires and synthetic materials.

In freshwater lakes, phosphorus is often found to be the growth-limiting nutrient, because it occurs in the least amount relative to the needs of plants.

The loss of oxygen in the deeper areas of a water body can free phosphorus previously trapped in the sediments, further increasing the available phosphorus and adding to a nutrient load.

**Orthophosphate:**
Inorganic phosphate is phosphate that is not associated with organic material. Types of inorganic phosphate include orthophosphate and polyphosphates. Orthophosphate is sometimes referred to as "reactive phosphorus." Orthophosphate is the most stable kind of phosphate, and is the form used by plants. Orthophosphate is produced by natural processes and is found in sewage. Phosphates are not toxic to people or animals unless they are present in very high levels.

**Conductivity:**
Conductivity is defined as a measure of the ability of water to allow an electrical current to pass through it. It measures how much dissolved particles are in the water. Water bodies which are polluted usually have more dissolved particles in them than those that are clean. The measurement unit is "mho" or "siemens".
Conductivity is measured in "mho's" per centimeter of "microsiemens per centimeter". By way of comparison, distilled water has a conductivity of 0.5 to 2.1 umhos/cm. Typical rivers have conductivity ranging from 40 to 1500 umhos/cm. In the case of water and as an example of "typical" conductivity limits, a pond that has a range of 140 to 550 uhos.cm will support good fish life.
Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium,

calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity.

**ORP (Oxidation Reduction Potential):**
ORP is a measure of the tendency of a chemical species (atoms, molecules, ions) to acquire electrons and thereby be reduced. Reduction potential is measured in volts(V), or millivolts (mV). Each species has its own intrinsic reduction potential; the more positive the potential, the greater the species' affinity for electrons and tendency to be reduced.
In aqueous solutions, the reduction potential is a measure of the tendency of the solution to either gain or lose electrons when it is subject to change by introduction of a new species. A solution with a higher (more positive) reduction potential than the new species will have a tendency to gain electrons from the new species (i.e. to be reduced by oxidizing the new species) and a solution with a lower (more negative) reduction potential will have a tendency to lose electrons to the new species (i.e. to be oxidized by reducing the new species). Just as the transfer of hydrogen ions between chemical species determines the pH of an aqueous solution, the transfer of electrons between chemical species determines the reduction potential of an aqueous solution. Like pH, the reduction potential represents an intensity factor. It does not characterize the capacity of the system for oxidation or reduction, in much the same way that pH does not characterize the acidity.

**Sodium/Chloride:**
Sodium chloride applications are made to increase chloride concentrations and counteract nitrite toxicity. Fish in waters containing 10 to 20 times more chloride than nitrite will not be harmed by high nitrite concentration, for chloride interferes with nitrite absorption across the gill. Sodium chloride applications usually are between 50 and 100 ppm, and such small doses will not increase chloride concentration or salinity enough to harm freshwater aquatic organisms. Effluents from salt-treated ponds do not represent an ecological threat.

**Turbidity:**
What is turbidity? Turbidity is a very general term that describes the “cloudiness” or “muddiness” of water. Turbidity can be caused by many substances, including microscopic algae (phytoplankton), bacteria, dissolved organic substances that stain water, suspended clay particles, and colloidal solids. Although turbidity can be a problem in many different types of water, turbidity caused by suspended clay tends to occur most often in soft, poorly-buffered (low alkalinity) waters. Some of the substances that cause turbidity are more desirable in fish culture or recreational farm ponds than others. In moderate amounts, phytoplankton is a desirable form of turbidity because it provides food for microscopic animals (zooplankton) and filter-feeding fish, and improves water quality by producing dissolved oxygen and removing potentially toxic compounds such as ammonia. On the other hand, turbidity caused by clay particles is generally undesirable because it keeps light from penetrating the water, and light is required for algal growth. At very high concentrations, clay particles can also clog

fish gills or smother fish eggs. Turbidity also may be objectionable to pond owners from an aesthetic standpoint.
Some sources of clay turbidity are runoff from clear-cut or overgrazed watersheds, road or building construction, the activities of cattle watering in farm ponds, pond bank erosion from wave action, excessive aeration, or the feeding activities of certain bottom- dwelling fish such as common carp.

The dissolved oxygen in sport fish or farm ponds normally fluctuates widely during the summer. During the day, plant photosynthesis increases the oxygen concentration; during the night, plant and fish respiration reduces the oxygen concentration in the water. Clay turbidity reduces the magnitude of daily fluctuations in dissolved oxygen concentration, so that it gets neither very high nor very low. However, muddy water tends to have a lower average concentration of dissolved oxygen than water with a green phytoplankton bloom. Clay turbidity can sometimes develop quite suddenly, as when heavy storm runoff enters the pond or high winds churn the water and cause bottom soils to be re-suspended. In such cases, oxygen may decline to critically low levels and make it necessary to aerate the pond.

**Total Dissolved Solids (TDS):**
Total Dissolved Solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in: molecular, ionized or micro-granular suspended form. Generally the operational definition is that the solids must be small enough to survive filtration through a sieve the size of two micrometer. Total dissolved solids are normally discussed only for freshwater systems, as salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects) it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants.
Primary sources for TDS in receiving waters are agricultural and residential runoff, leaching of soil contamination and point source water pollution discharge from industrial or sewage treatment plants. The most common chemical constituents are calcium, phosphates, nitrates, sodium, potassium and chloride, which are found in nutrient runoff, general stormwater runoff and runoff from snowy climates where road de-icing salts are applied. More exotic and harmful elements of TDS are pesticides arising from surface runoff. Certain naturally occurring total dissolved solids arise from the weathering and dissolution of rocks and soils.

**Secchi Disk (visibility):**
A Secchi disk is a circular disk used to measure water transparency in oceans and lakes. The Secchi disk is used to measure how deep a person can see into the water. It is lowered into the lake by lowering it until the observer loses sight of it. The disk is then raised until it reappears. The depth of the water where the disk vanishes and reappears is the Secchi disk reading and is related to water turbidity.