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Ponds are ideal habitats for aquatic plants, and some will always be present. Plants are a necessary component of pond ecosystems because they perform valuable functions. Photosynthesizing plants produce oxygen that is needed to sustain fish life. Also, plants assimilate ammonia that is excreted by fish thereby helping to prevent accumulation of potentially toxic concentrations of ammonia. Nevertheless, plants can cause problems in ponds and control measures often must be used to eliminate or reduce their abundance.

Types of weeds

The plants that grow in ponds can be categorized into two groups. The algae are primitive plants that have no true roots, stems, or leaves, and do not produce flowers or seeds. Algae can be categorized as phytoplankton or filamentous algae.

The higher aquatic plants are more advanced, and usually have roots, stems, and leaves, and produce flowers and seeds. Higher aquatic plants can either be submersed, emergent, or floating.

Algae

Phytoplankton. These algae are microscopic simple plants suspended in water or forming floating scums of near-microscopic colonies on pond surfaces. Communities of phytoplankton are called the “bloom.” There are hundreds of species of phytoplankton, and identification of the different species is difficult, requiring a microscope.

Phytoplankton are the most common type of plant found in ponds. Moderate densities of phytoplankton are desirable in ponds because they shade the pond bottom preventing establishment of more troublesome types of plants. Phytoplankton become a weed problem when they become excessively abundant or when certain undesirable species become dominant in the community. Excessive phytoplankton abundance causes serious water quality problems such as frequent periods of dangerously low concentrations of dissolved oxygen. This problem is often associated with dense blooms of blue-green algae (Figures 1 & 2). The blue-green bloom floats to the top of the pond forming a scum that can block sunlight and prevent proper photosynthesis. These blooms can also cause an off-flavor problem in fish raised in aquaculture ponds.

Figure 1. Blue-green algae (cyanobacteria) forming a surface scum.

Figure 2. Blue-green algae floating on a pond surface.

Filamentous algae. Most filamentous algae begin growing on the bottom of the pond and rise to the surface when gas bubbles become entrapped in the plant mass. They form mats of cottony or slimy plant material. These filamentous algae are also known as "pond scum" or more commonly "moss." However, one type of filamentous algae, *Chara* spp., resembles submersed higher plants in growth habit. It is weakly anchored in the mud and grows up through the water. Positive identification of the different types of filamentous algae usually requires a microscope. Control methods are similar for all filamentous algae except *Pithophora* spp., which is very resistant to most copper-based algicides and requires special treatment. It is thus important to identify the species of filamentous algae present in the pond to ensure the proper treatment is selected. The most common filamentous algae in ponds are:

Hydrodictyon spp. (waternet) – each cell is attached repeatedly to two others forming a repeating network of 5 or 6-sided mesh that looks like a "fish net" stocking (Figure 3).

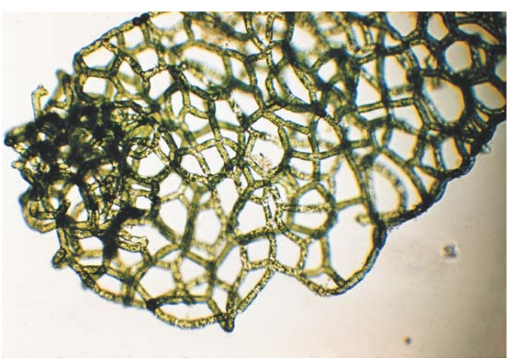

Figure 3. Microscopic view of water net (*Hydrodictyon* sp.). Photo from the Internet.

Spirogyra spp. – usually a dark green slimy mass that can be pulled apart and drawn out into fine filaments (Figure 4). This algae usually is easy to identify microscopically because the chloroplast is spiraled in a characteristic "corkscrew" along the inside of the cell wall (Figure 5).

Figure 4. The filamentous algae, *Spirogyra* sp. is slick and slimy and persists in ponds throughout the winter. It often goes away in hot summer temperatures.

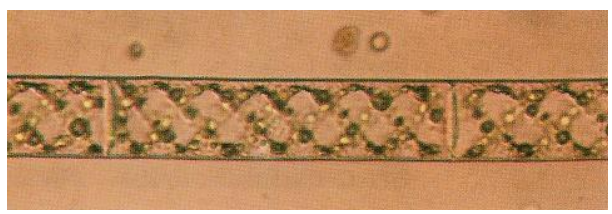

Figure 5. Spiraled chloroplast in microscopic photograph of *Spirogyra* sp.

Pithophora spp. – probably the most noxious and difficult filamentous algae to control. *Pithophora* spp. is irregularly branched, not slimy, and somewhat coarser than masses of *Spirogyra* spp. A mass of *Pithophora* spp. feels like wet wool to the touch (Figure 6). The distinguishing microscopic characteristic is the presence of barrel-shaped spores along the filament (Figure 7).

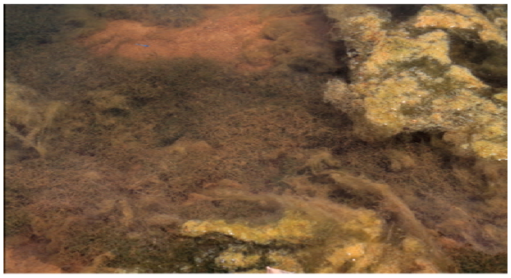

Figure 6. The filamentous algae, *Pithophora* sp. is more coarse (like wet wool) compared to *Spirogyra* sp. It is very difficult to control chemically.

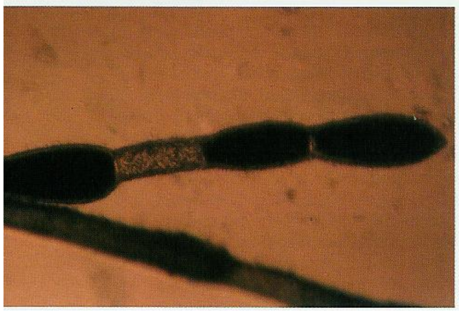

Figure 7. Microscopic photograph of the terminal of a filament of *Pithophora* sp. showing the dark, swollen spores that are characteristic of the genus.

Chara spp. – a more advanced group of algae which resembles submersed higher plants in growth habit. This plant is commonly called "muskgrass" because of the garlic or skunk-like odor released when it is crushed. Masses of *Chara* spp. are serrated and feel rough or crusty when crushed in the hand (Figure 8).

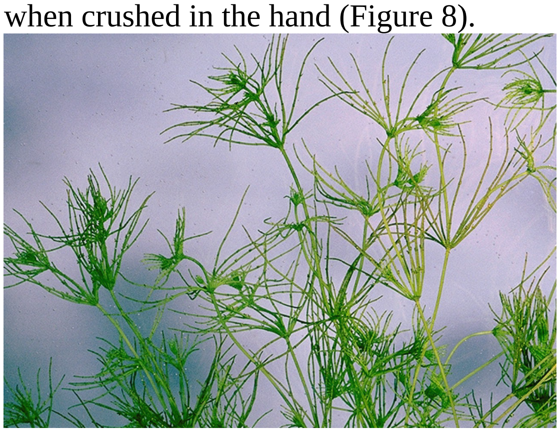

Figure 8. Muskgrass (*Chara* sp.) Photo from University of Arizona.

Filamentous algae are aesthetically undesirable, giving the pond a "clogged-up" overgrown appearance, and they interfere with fishing by snagging the fisherman's hook. In aquaculture, filamentous algae can prevent fish or shrimp from being harvested by seine nets. Seines may ride up over the mass of weeds, allowing fish to escape, and the weight of plant material caught in the seine may strain equipment or completely stop the harvesting process. Even if seining is possible, fish or shrimp may become entangled in the mass of weeds in the seine and will be stressed as workers pick through the weeds to recover them. This is particularly a problem with fingerlings and shrimp.

Higher aquatic plants

Submersed plants. Submersed plants spend their entire lifetime beneath the surface of the water, although the flower may extend above the surface. Usually the plants are rooted in the mud, but masses of plants may tear loose and float free in the water. These plants are objectionable because they interfere with fishing and fish harvest. The most common submersed higher aquatic plants in ponds are:

Najas guadalupensis (bushy pondweed) – rooted, submersed plants with slender branching stems and narrow ribbon-like leaves arranged opposite or in whorls of three. Bushy pondweed is a common submersed weed problem in ponds (Figure 9).

Figure 9. Bushy pondweed (*Najas* sp.) is a submersed aquatic plant.

Potamogeton pectinatus (sago pondweed) – rooted, wholly submersed plants with long, narrow leaves tapering to a point. The stems are irregularly (and often highly) branched (Figure 10).

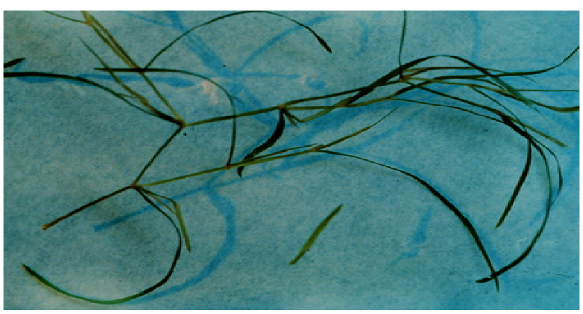

Figure 10. Sago pondweed (*Potamogeton pectinatus*) is a submersed plant with long ribbony leaves.

Ceratophyllum demersum (coontail) – these plants have long thin stems which are not rooted. The leaves are in whorls and are forked (Figure 11).

Figure 11. Coontail (*Ceratophyllum demersum)* is a submersed aquatic plant. Photo from U. of Florida on the Internet.

Emergent plants. Emergent aquatic plants are rooted in the bottom mud and grow above the water. Many can also grow under strictly terrestrial conditions. The plants are rigid and not dependent on the water for support. Emergent plants usually infest only the pond margins and other shallow areas resulting from inadequate pond construction, water-shortage conditions, or excessive bank erosion. If stands of emergent plants become too dense or widespread, they may interfere with fishing, seining or feeding of fish. They can also create a habitat that harbors snakes. Fast-growing emergent plants such as smartweed (*Polygonum pennsylvanicum*) inhabit shallow areas quickly and can often outpace the rising water level when ponds fill slowly (e.g. during dry seasons or if only a slow-flowing well is available to fill the pond).

The most common emergent weeds in ponds are:

Polygonum spp. (smartweed) – leaves are alternate and elliptical on this plant. The stem is erect and jointed, with each swollen node covered by a thin sheath. Flowers are usually white or pink (Figure 12).

Figure 12. Smartweed (*Polygonum* sp.) inhabits shallow areas of ponds.

Typha spp. (cattails) – cattails are familiar plants with stout, erect stems up to 8 feet tall. Leaves are stout, long, flat and ribbon-like. The flowers are brown and cigar-shaped (Figure 13).

Figure 13. Cattails (*Typha* sp.) grow along a pond's edge in shallow water.

Salix spp. (willows) – shrubs or trees with simple, elliptical leaves in alternate arrangement (Figure 14).

Figure 14. Willows (*Salix* sp.) grow on the pond's edge and get in the way of seining and other pond operations.

Floating plants. This category includes free-floating plants such as duckweeds (Figure 15) and watermeal (Figure 16), and floating-leaf plants, such as water lilies. Many floating plants are present only when pond waters are relatively stagnant and sheltered from winds. Small recreational ponds often have problems with duckweed (*Lemna* spp.) and watermeal (*Wolffia* spp.). In aquaculture ponds, on the other hand, periodic draining and refilling, and frequent fish harvest activity make conditions unfavorable for these plants; these larger ponds are often unsheltered from the wind, and duckweeds are continually washed ashore where they dry up and die.

Figure 15. Duckweed (*Lemna* sp.) has small leaves and roots.

Figure 16. Watermeal (*Wolffia* sp.) feels grainy like corn meal. Photo from Texas A&M University on the Internet.

Occurrence of weed problems

Some plant life will always be present in ponds, but the type of aquatic plant community that becomes established in a pond depends on the relative abilities of particular plants to compete for resources. The growth of phytoplankton is favored in waters with high concentrations of nitrogen, phosphorus, and other plant nutrients dissolved in the water. Phytoplankton are efficient at using dissolved nutrients and reproduce rapidly. Once established, the phytoplankton community competes effectively for nutrients and also restricts the penetration of light so that plants that germinate on the bottom do not receive enough light to continue growing.

Rooted submersed plants tend to establish in ponds with low supplies of nutrients in the water. These ponds often are clear with light penetrating to the bottom, and rooted plants can use the nutrients in the bottom mud for growth. Established stands of submersed weeds compete for nutrients and light and prevent phytoplankton from becoming established. Some submersed plants also produce chemicals that inhibit the growth of phytoplankton.

Emergent plants usually colonize only the margins of ponds where the water is less than 2 to 3 feet deep. If levees or banks of the pond are eroded and have large areas of shallow water, expansive growths of emergent plants may be present. Emergent plants are rooted and can use nutrients in the mud. Thus, their establishment is also favored by low nutrient levels in the water.

Aquaculture ponds containing **food-sized fish** receive high levels of nutrients from daily feeding of formulated fish food. These ponds, therefore, rarely have submersed or emergent aquatic weed problems; the nutrients in the water promote an actively growing phytoplankton bloom which, in turn, shades the pond bottom and prevents weed growth. Aquaculture **fingerling** production ponds, on the other hand, receive fairly low levels of nutrients because of the smaller biomass of fish; these ponds are much more likely to have a scant phytoplankton bloom and a problem with macrophytic plant growth such as submersed and emergent weeds. Likewise, **recreational** ponds, especially ones that are not fertilized, also have a tendency to have an inadequate bloom and a macrophytic weed problem such as *Najas* spp. (bushy pondweed).

Environmentally-sound and costeffective aquatic weed management depends on the type of plant, the extent of plant coverage, the species and life-stage of fish or crustaceans in the pond, water quality, time of year, and weather. Understanding these interactions, which differ for each weed problem, is largely a matter of experience. Until that experience is gained, seek advice from private consultants or experts at universities.

Prevention of aquatic weeds

Almost any plant can be tolerated as long as it does not become so abundant that it interferes with the intended use of the pond. It is, however, difficult to predict whether a small infestation of weeds will spread and become a problem, so most control measures are implemented when fairly large stands of weeds have already become established. At that time, using herbicides is usually the fastest way to eradicate weeds and re-establish a phytoplankton bloom, which is usually the most desirable plant form in ponds. Chemical weed control is, however, risky in fish ponds because water quality deteriorates when dense stands of weeds are killed. Prevention of weeds is a preferred approach to aquatic plant management.

Certain management procedures can be used to minimize the chances of infestations of submersed and emergent plants and filamentous algae. Such procedures should become part of common pond management and may help avoid the use of chemical control measures.

Pond construction. Most noxious weed growth starts in the shallow (less than 2 ½ feet deep) areas of ponds. If the area of the pond where light can penetrate to the bottom is reduced, rooted plants have less chance to become established. Pond levees and/or dams should have a fairly abrupt slope of about 3:1 (3 feet out toward the center of the pond for every 1 foot drop toward the pond bottom) or 4:1. A slope of greater that 4:1 would be too gradual and would create excessive shallow area, while a slope of less than 3:1 would be too steep making the levee prone to erosion and sloughing-off. Plans should be made during construction for the shallowest part of the pond to be no shallower than 2 ½ feet when the pond is close to full (near the top of the drain pipe).

Refilling an empty pond. In many cases a newly constructed pond will be completed by the end of summer (by the time the dry period of the year ends). The rainiest part of the year typically will occur during fall and winter, and the new pond will fill from rain run-off from the watershed during a time when weeds are less likely to grow. Ponds with a well water source are ideally filled during winter for this same reason. If they are filled during other times, it is best to fill the pond as quickly as possible from the well to attain an adequate water depth that will prevent aquatic weed growth. (If one well serves four ponds, for example, one pond should be filled at a time to minimize the time needed to get the proper depth for weed control). Also, grass carp may be stocked to prevent growth of nuisance weeds. About seven triploid grass carp per acre is a good preventive stocking rate. In addition, ponds can be left empty until the farmer plans to actually stock and begin feeding his fish unless the pond is made of highly structured clay (stereotypically red clay); in this case, allowing the pond to dry out would promote deep cracking of the pond's clay lining which could cause leaks when the farmer attempts to refill the pond at a later date. If water needs to be maintained in a pond, a fertilization program can help to prevent the water from being clear. Fertilization promotes a healthy phytoplankton bloom that will shade out sunlight from reaching potential weeds attempting to germinate at the bottom of the pond.

Fertilization. The implementation and continued use of the proper fertilization program is perhaps the best method of preventing the growth of troublesome weeds in recreation ponds as well as fry nursery ponds. To avoid weed problems, establish a phytoplankton bloom as quickly as possible after filling the ponds. The best way to do this is to add inorganic fertilizers to the pond. The key ingredient in fish pond fertilizers is phosphorus. The most common phosphorus source in bagged, granular fertilizers is triple superphosphate (0-46-0). It should be noted, however, that when triple superphosphate is broadcast over ponds, it settles to the bottom because the granules are very insoluble. Most of the phosphorus reacts with the bottom mud and never reaches the water. Any phosphorus that dissolves while the granules settle through the water quickly reacts with calcium in the water and is changed into unavailable calcium phosphate. Granular fertilizers should be put on an underwater platform or in a porous container so they can dissolve slowly into the water before they contact the mud bottom.

Liquid fertilizers are more effective than granular fertilizers at stimulating a phytoplankton bloom, especially in hard, alkaline waters. The phosphorus in liquid fertilizers is already in solution and immediately available for uptake by the phytoplankton. Although the phosphorus from liquid fertilizers also will eventually become unavailable due to reactions with calcium in the pond water, it remains in solution long enough to be taken up in adequate quantities by the phytoplankton.

The most common, and best, analysis for liquid fertilizers runs from about 10-34-0 to 13-38-0. This general analysis of about three times as much phosphorus (expressed as P_2O_5) as nitrogen (expressed as N) has been found to have an excellent balance. The rate used successfully by many commercial fish producers is about 1 quart per acre applied every other day for 3 to 14 days or until a noticeable phytoplankton bloom develops. Liquid fertilizer is heavier than water, so it should first be diluted in water before it is applied to the pond, preventing it from sinking into the bottom mud. It can be sprayed from the bank or applied from a boat outfitted for chemical applications.

It should be noted that excessive water flow through ponds flushes plant nutrients from the water, favoring rooted weeds that can obtain nutrients from bottom soils. Ponds should not have watershed areas larger than necessary to maintain water level; excess runoff from large watersheds should be diverted away from ponds. Springs running into ponds can also dilute nutrients, and they too can be diverted away from the pond and can be allowed to enter the pond only when water is needed.

Manual harvesting. Removing potentially noxious emergent weeds by hand is another management practice that may reduce the possibility of having to use chemicals. As small areas of the pond margin become infested, plants are removed manually. Manual harvesting of weeds is only suited for controlling emergent vegetation in relatively small ponds. Care should be taken to remove as much of the rootstock or rhizome as possible to minimize re-growth. Mechanical removal of filamentous algae or submersed plants almost always proves to be futile.

Routine mowing of pond banks will help prevent the establishment of dense growths of shoreline plants such as willows and will also reduce habitat for snakes.

Water draw-downs. Periodic water draw-downs are sometimes effective in killing or preventing aquatic weeds. The vegetation along the pond margin (the most common location for weed problems) is stranded and dies from drying up.

Biological control of aquatic plants

Biological weed control in ponds involves the use of fish to consume unwanted aquatic vegetation. Grass carp are normally used in warmwater ponds. They are most often used to control submersed plants or filamentous algae. Koi (colorful common carp, *Cyprinus carpio koi*) are presently being evaluated at Kentucky State University for their weed prevention potential.

Grass carp. The grass carp or "white amur" (*Ctenopharyngodon idella*, Figure 17) was introduced into the United States from Southeast Asia in 1963 and is now widespread especially in the southeastern states. The fish is banned in many states and some states allow only sterile, triploid grass carp. Where legal and available, this fish is a valuable tool to control nuisance aquatic weeds.

Figure 17. Triploid grass carp fingerling (*Ctenopharyngodon idella*).

The controversy over the distribution and use of grass carp is based on the potential effect of this fish on native fish and wildlife.

Considerable discretion should be used when planning to stock these fish into ponds and every effort should be made to prevent their escape into natural waters. To further diminish the likelihood that that grass carp will reproduce and thrive in natural waters, it is recommended that only sterile, triploid carp be used.

The grass carp has several traits that make it a good species for recreational ponds and for polyculturing with channel catfish. Small grass carp (less than 1-2 pounds) are almost completely herbivorous and will not compete to a significant degree with catfish for feed. Grass carp tolerate a wide range of environmental conditions: they can survive at water temperatures of 32º to 105º F and are nearly as tolerant as catfish to low dissolved oxygen concentrations. The fish grows rapidly, as much as 5 to 10 pounds a year. It must consume large quantities of plant material to grow and may consume 2 to 3 times its weight in plant material per day.

Grass carp prefer to eat succulent submersed plants such as *Najas* spp. and *Chara* spp. Fibrous plants such as grasses and smartweed are less preferred and grass carp will not eat these plants if more preferred plants are available. Food consumption by grass carp is greatest at water temperatures of 80º to 85º F, and the fish stops eating when the temperature falls below about 55º F.

In catfish nursery ponds, grass carp should be stocked prior to stocking the catfish fry in order to prevent weed growth. Likewise, in recreational ponds, grass carp should be stocked before weeds become a problem.

Grass carp also are used by some pond owners to control existing weeds. However, considerable time is required for grass carp to reduce weed infestations, particularly if coverage is extensive. Results may take a year to be realized. Food-fish ponds are usually not drained each year and grass carp become a permanent inhabitant of the pond. Larger grass carp learn to feed on pelleted feeds and often do little to control weeds in the second or third year they are present. Usually weed problems have been controlled by this time and a phytoplankton community has developed which prevents further weed growth.

The stocking rate for grass carp depends on the severity of the weed problem. When used to prevent the establishment of submersed weeds, 5-10 small (3-6 inch) carp per acre should be stocked. The same stocking rate is also adequate if the pond is lightly infested with weeds. For more severe weed problems, 10-15 fish per acre should be stocked. For heavily weed infested ponds, stocking rates can be increased to 15-25 per acre or greater. Grass carp must be stocked at a size large enough to prevent them from being eaten by predator fish such as bass and large catfish.

Koi. Koi have been shown to reduce the occurrence of submersed aquatic weeds and filamentous algae by keeping pond water turbid. The turbidity may be caused by their activity in the pond bottom which keeps the mud suspended in the water column and releases nutrients, supplying a food source for the phytoplankton bloom. The "rooting-around" on the pond bottom also prevents weeds from establishing there. Koi have been chosen for university demonstration projects over non-colorful common carp because of the side benefits of having an attractive addition to the pond and a fish that can be marketed for its ornamental value (Figure 18). Cover photographs illustrate ponds without koi (front cover) and ponds with koi (back cover) at Kentucky State University Aquaculture Center.

Figure 18. Koi keep pond water turbid which reduces the occurrence of nuisance aquatic weeds.

Control of aquatic plants with herbicides

Control of aquatic weeds with herbicides is the most common means of eradicating weeds in ponds. Correct identification of weeds is critical because potential impacts and management differ for each plant.

Strategies effective on one species may be ineffective even on similar species. In particular, herbicides are selective (some much more than others), and effective control depends on matching the weed with the most appropriate herbicide. Private consultants or experts at local universities can help identify the weed problem.

In the United States, registration of chemicals for fishery use is granted by the Environmental Protection Agency or the Food and Drug Administration under the Federal Environment Pesticide Control Act (FEPCA) of 1972. The lack of registration does not necessarily mean that the chemical is harmful to the environment or that it is extremely toxic. Aquaculture is considered a minor use by most chemical companies, and they are simply not willing to spend the large amount of money needed to compile the data necessary for registration review. However, some unregistered herbicides are toxic to fish or their use may result in chemical residues in the edible portion of the fish. For these reasons, only herbicides labeled for use in food-fish ponds should be used by pond owners, and label instructions should be carefully followed. Proper chemical usage can also minimize the effects on non-target organisms inside and outside the pond. Skin and eye protection should be worn when working with all chemicals to prevent absorption into the body.

The following herbicides or herbicide groups are labeled for use in food-fish ponds. The tables on pages 22 and 23 summarize herbicide use for common weeds in fish ponds.

Copper sulfate (various trade names). Copper sulfate ($CuSO_4 \bullet 5H_2O$; copper sulfate pentahydrate) is available in various particle sizes from fine powder to large crystals. The fine powder is more effective because it dissolves faster. Copper sulfate should only be used to control algae, because rates necessary to kill other plants may also be toxic to fish. The filamentous algae, *Pithophora* spp., is resistant to copper sulfate. Most algae are controlled more effectively if treatment with copper sulfate is made soon after plant growth has started.

In soft waters of low alkalinity, copper is extremely toxic to fish and it is recommended that copper sulfate not be used in waters with a total alkalinity of less than 50 parts per million (ppm) as $CaCO_3$. Copper sulfate is less effective as an algicide in hard, alkaline waters because the copper rapidly precipitates out of solution. The treatment rate increases with total alkalinity, and the formula used to calculate the treatment rate is:

ppm copper sulfate = (ppm total alkalinity) ÷ 100.

In waters with a total alkalinity greater than about 300 ppm as $CaCO_3$, copper from copper sulfate precipitates out of solution so rapidly that it is difficult to achieve an effective treatment.

Use of copper sulfate can lead to dangerously low oxygen concentrations, especially in the summer. When treating filamentous algae, the danger of low dissolved oxygen concentrations following treatment can be minimized by treating $^1/_3$ to $^1/_2$ of the water area at a time and waiting 10 to 14 days between treatments.

Dissolve the number of pounds of copper sulfate to be used in at least the same number of gallons of water before applying to the pond (for instance, dissolve 10 pounds of copper sulfate in 10 gallons of water). It is best to apply copper sulfate in clear water above 60º F and on a sunny day. It should also be noted that putting copper sulfate solution in galvanized containers causes the copper to chemically displace the galvanized lining. This removes copper from the treatment solution.

Chelated copper (Cutrine-Plus, Clearigate, Cutrine-Ultra, K-Tea, Algimycin, Komeen, Pondmaster, Nautique, Captain). These herbicides are available in both liquid and granular form, but the liquid is most commonly used. The copper in these herbicides is bound in organic complexes so that the copper will not precipitate out of solution as rapidly as uncomplexed copper in hard, alkaline waters. Cutrine-Plus, for example, has a prolonged effectiveness because its chelating agent, ethanolamine, decomposes slowly in sunlight. Although chelated copper herbicides usually are more effective than copper sulfate, they are considerably more expensive to use. The table on page 21 of this booklet lists the aquatic weeds controlled by each of the chelated copper compounds. Copper herbicides have a reputation for effectively killing algae including phytoplankton, some filamentous algae and *Chara* (musk grass) which is also an algae. However, Cutrine-Ultra is specially designed to kill *Pithophora* with a penetrating surfactant. And Komeen, Pondmaster, Nautique, and Captain, unlike many other chelated coppers, are able to control higher aquatic plants like *Najas*, coontail, *Elodea* and sago pondweed.

Additionally, chelated coppers are often combined with other herbicides such as Reward, Aquathol, or Sonar to enhance their effectiveness, and in some cases, reduce the amount needed of both herbicides.

Diquat (Reward, Weedtrine D). Diquat is sold as a liquid containing 2 pounds active ingredient per gallon. It is a wide-spectrum herbicide and will control most filamentous algae including *Pithophora* spp. and *Chara* spp., submersed weeds such as *Najas* spp. and coontail, and can be mixed with a surfactant and sprayed to control emergent weeds such as cattail. Diquat should not be used in muddy water and mud should not be stirred up during application because diquat will bind tightly with clay particles suspended in the water rendering the herbicide ineffective at controlling plants growing beneath the surface. Diquat should be applied on a sunny day to actively growing weeds. Only $^{1}/_{3}$ to $^{1}/_{2}$ of the pond water area should be treated at one time with a 14-day interval between treatments. A 14-day withdrawal period is required by law after diquat use before treated water can be used for animal consumption, swimming, spraying, irrigation or drinking.

Endothall, dipotassium salt (Aquathol, Aquathol K, Aquathol Super K). The dipotassium salt of endothall is available in liquid (Aquathol K) or granular (Aquathol) form. It will not kill algae but will control a wide variety of submersed higher plants, including *Najas* spp., coontail, and fanwort. The granular formulation is relatively expensive, but is particularly effective on *Najas* spp. Dipotassium salt of endothall is a contact killer. It is sprayed onto or injected below the water surface and can be sprayed at high concentrations directly on exposed weeds. For best results, water temperatures should be 65º F or above. When water temperatures are high and an increased danger of dissolved oxygen depletion exists, this herbicide should be applied to $^{1}/_{3}$ to $^{1}/_{2}$ of the pond per treatment with a 5 to 7 day interval between treatment applications.

Water treated with granular Aquathol must not be used for irrigation or for agricultural sprays on food crops or for domestic purposes within 7 days of treatment. More detailed restrictions exist for Aquathol K. It may not be used for the above mentioned purposes as well as for watering livestock for 7 days after applying it up to 0.5 ppm; for 14 days after application up to 4.25 ppm; and for 25 days after application up to 5.0 ppm. In addition, water treated with Aquathol K may not be used for swimming until 24 hours after treatment.

Endothall, alkylamine salt (Hydrothol 191). The alkylamine salt of endothall (Hydrothol 191) is most commonly used in the liquid formulation. It is a more potent herbicide than the potassium salt (Aquathol K) and will control most filamentous algae including *Pithophora* spp. and *Chara* spp. Repeat treatments are recommended if algae growth reappears. Hydrothol 191 is a relatively toxic herbicide to fish and treatment rates required to treat submersed higher plants are generally too risky in commercial catfish ponds to justify its use. When the herbicide is used to treat filamentous algae, only a portion of the pond should be treated at one time. Fish avoid the treated area and are usually not killed. Hydrothol 191 treatments as high as 0.3 ppm (often needed to kill *Pithophora* spp.) can be used, but higher rates will kill fish.

Fish in treated waters may not be consumed within 3 days after treatment with Hydrothol 191. Likewise, treated water should not be used for watering livestock, preparing agricultural sprays for food crops, irrigation, or domestic purposes within 7 days after application when up to 3.0 ppm Hydrothol 191 is used.

Fluridone (Sonar, Avast). Fluridone is available as an aqueous suspension or as pellets. Fluridone will not kill phytoplankton or filamentous algae, but controls a broad spectrum of submersed higher plants. This herbicide is slow acting, and results may take 30 to 90 days to be noticeable. Usually within 7 to 10 days of treatment the growing points of treated plants become white or pink as a result of chlorophyll photo degradation. Sonar should be applied to actively growing weeds, and the entire pond surface should be treated at once. Partial or spot treatments result in dilution of the herbicide with the untreated water. Do not use treated water for crop irrigation for 30 days after application.

2,4-D (Aquacide, Aqua-Kleen, Weed-Rhap, Weedtrine II, etc.). This herbicide is formulated for aquatic use as the dimethylamine salt or isooctyl ester. It is available in liquid or granular form. The granular form is effective at controlling submersed higher plants such as *Najas* spp. and coontail. The liquid formulations of 2,4-D are most effective in spring when weeds start to grow. Acid pH (6 and below) enhances its herbicidal activity while a pH of 8 or above tends to make it less effective. Treating early in the morning when pH is usually lowest will increase the effectiveness of 2,4-D.

Glyphosate (Rodeo, Aquamaster, AquaPRO, etc.). Glyphosate is sold as a liquid and is for use mostly on emergent and shoreline plants. The herbicide is mixed with a surfactant and sprayed on the vegetation. Glyphosate is a broad spectrum herbicide and is useful for the control of cattails, grasses, smartweed, and willows around pond margins. Application when weeds are in the flowering or fruiting stage is more effective than earlier application. Visible results (wilting and yellowing) are usually not seen for 2 to 7 days after application. Rainfall occurring within 6 hours of application reduces the effectiveness of Rodeo.

Imazapyr (Habitat). Imazapyr is a liquid herbicide that is mixed with water and a surfactant or vegetable oil and sprayed on emergent or floating aquatic weeds. When sprayed directly onto emergent leaves, the herbicide is translocated throughout the weed, concentrating in the roots where it causes the weed to die (which sometimes takes more than two weeks) and prevents future re-growth. Imazapyr is most effective if applied when the weed is actively growing. The effectiveness of imazapyr is reduced if it rains within an hour of application. The label notes that "Habitat does not control plants which are completely submerged or have a majority of their foliage under water."

Due to the risk of oxygen depletion from decomposing weeds, no more than half the pond's surface area should be treated at one time, and at least 10 to 14 days should separate treatments. An applicator's license is required to purchase and apply imazapyr. The most current herbicide directions (found in the leaflet label attached to the container) should override any other treatment advice, including that found in this booklet.

Imazapyr is relatively environmentally safe. Treated waters have no restrictions for recreation including swimming and fishing or for livestock consumption. However, imazapyr may not be applied to water within one-half mile upstream of an active potable water intake.

Triclopyr (Renovate 3, Garlon 3A). Triclopyr is a liquid herbicide used to control certain emergent, submersed and floating aquatic plants (including alligatorweed, milfoil, waterhyacinth, waterlily, and waterprimrose) in bodies of water that have little or no continuous outflow. Mixing triclopyr with a non-ionic surfactant is recommended to improve its effectiveness.

Triclopyr treated water should not be used for irrigation for 120 days unless the triclopyr is not detectable by laboratory analysis. The most current herbicide directions (found in the leaflet label attached to the container) should override any other treatment advice, including that found in this booklet.

Sodium Carbonate Peroxyhydrate (GreenCleanPRO, Phycomycin, Pak 27). Sodium Carbonate Peroxyhydrate (percarbonate) is a granular algaecide/fungicide used to treat, control and prevent a broad spectrum of algae and fungi. For the most effective treatment, use percarbonate when algae growth first appears, and treat early in the day when sunny with little or no wind. Floating algae mats should be broken up before or during treatment; and after treatment, dead algae can be removed from the water surface to prevent excessive nutrients from entering back into the water (during decomposition) and stimulating subsequent heavy phytoplankton blooms. The BioSafe Systems' technical bulletin points out that GreenCleanPRO has no restrictions for use after treatment and it is labeled for use in aquaculture. Planktonic blue-green algae blooms are treated with 9 to 30 lb per acre-foot of water; the exact amount needed depends on the quantity of algae growth, light intensity, and water quality. The most current directions (found on the container) should override any other treatment advice, including that found in this booklet.

The following web site has labels for the aquatic herbicides mentioned above: http://aquat1.ifas.ufl.edu/guide/labmsds.html

Another helpful web site is http://www.appliedbiochemists.com/products.htm

Carefully follow herbicide labels

Herbicides sold in the United States must be registered with federal and state regulatory agencies. The printed information accompanying the herbicide container is called the "label" and constitutes a legal document. Failure to use herbicides according to label instructions can lead to severe penalties. From a practical standpoint, misuse of herbicides can result in poor weed control; risks to people, fish, or wildlife; or herbicide residue problems in fish.

The label provides information on the active ingredient, directions for correct use on target plant species, warnings and use restrictions, and safety and antidote information. Remember, state and local regulations may be more restrictive than federal regulations. Certain products are registered as "Restricted Use" herbicides and can be legally applied only by trained and certified applicators or by people under their direct supervision. Be sure to check federal, state, and local regulations prior to using herbicides.

Herbicide treatment rates are based on pond area or pond volume. Miscalculation will result in either over-treatment or under-treatment (which may require additional treatments to eradicate the weed). In either case, more chemical than needed will be applied to the pond. Carefully measure pond dimensions and keep up-to-date records of pond size and depth. Pond depth tends to decrease over time because of erosion of embankments and sedimentation of pond bottoms. The only way to be certain of average pond depth is to measure water depth before treatment at several dozen random locations.

Handle herbicides safely

Although aquatic herbicides are relatively safe to handle, it is nevertheless important for applicators to keep chemical exposure to an absolute minimum. Herbicide labels and material safety data sheets advise what protective clothing and equipment should be worn, any precautions the handler should follow, a statement of practical treatment in case of poisoning, statements concerning hazards to the environment, any physical or chemical hazards, and directions on proper storage and disposal. By law, copies of labels and any supplementary labels must be in the possession of the applicator at the application site for each herbicide used. Anyone who handles a pesticide must read and understand all label statements prior to using the product. Herbicide safety is reviewed in SRAC publication 3601 which can be found at www.msstate.edu/dept/srac .

Dispose of herbicide containers properly

Improper disposal of herbicide containers can cause contamination of soil and water, and may result in fines or loss of an applicator's license. Empty herbicide containers must be triple rinsed, with each rinsing drained into the herbicide mix tank. If no mix tank is used, the rinse water from the container should be applied to the pond in the same manner as the herbicide in the container. Containers must then be punctured or crushed so that they can not be reused. Empty bags must be rinsed or shaken clean and cut so that they can not be used for other purposes. Laws regarding disposal of rinsed containers vary among states, so be sure to follow all state and local regulations regarding pesticide container disposal.

Two aquatic herbicides, 2,4-D and endothall, are regulated as hazardous materials under federal law, and any waste generated during their use must be disposed of as hazardous waste. Triple-rinsed containers can be disposed of as with any other pesticide container. Any rinse water from cleaning of containers or application equipment must be applied as if it were the herbicide or disposed of at a hazardous waste disposal facility.

Consequences of herbicide use

When used according to the manufacturer's specifications, herbicides are seldom directly toxic to fish. However, the addition of any herbicide to a plant-infested body of water will alter water quality. Oxygen production by photosynthesis will be decreased and decomposition of the dead plant material will increase oxygen consumption. The result will be a noticeable decrease in dissolved oxygen concentrations compared to pretreatment levels. The extent to which dissolved oxygen levels are reduced depends on the amount of plant material killed, the amount of plant material unaffected by the herbicide, the rate that death occurs, water temperature and other factors. Decomposition of the dead plants will also raise carbon dioxide and total ammonia concentrations. The increase in total ammonia concentrations tends to decrease the pH, causing much of the ammonia to be in the non-toxic, ionized form. Phosphorus, potassium, and other minerals are also released upon plant decomposition, and concentrations of all essential plant nutrients will usually be higher after herbicide treatment. At some time after treatment, the concentration of herbicide will decrease to a non-toxic level and these nutrients will be available for new plant growth.

The deterioration in water quality following herbicide use can have serious consequences in catfish ponds. Obviously, if dissolved oxygen concentrations fall to very low levels, fish will be killed. This is particularly a problem in catfish fry ponds because fry often cannot find the area of aerated water behind emergency aerators. Even if dissolved oxygen concentrations are maintained above lethal levels, the fish may be severely stressed and more susceptible to fish diseases.

Stressed fish also feed poorly and decreased fish growth can be expected, particularly if water quality is affected for an extended length of time.

Control of phytoplankton abundance

Low concentrations of dissolved oxygen and development of off-flavor are the most important water quality problems in channel catfish pond culture. Both problems are the result of uncontrolled phytoplankton growth in heavily fed ponds. Numerous efforts have been made to manage phytoplankton communities in fish ponds, but most methods are ineffective and many actually further degrade water quality.

A variety of algaecides have been used to reduce phytoplankton density, but the ultimate results are always undesirable. When sufficient algaecide is added to a pond with a dense bloom, the sudden die-off usually causes severe oxygen depletion and high levels of carbon dioxide and ammonia. Phytoplankton repopulate the pond as soon as algaecide levels decrease because nutrient levels remain high. Episodes of poor water quality resulting from this cycle of death and regrowth will stress fish and cause reduced growth or increased susceptibility to infectious diseases. Similar problems occur when algaecides are used in attempts to eliminate specific noxious phytoplankton species. All of the effective algaecides registered for use in food fish ponds are broad spectrum in activity and cannot be used to selectively eliminate one species or one type of phytoplankton.

Biological control of phytoplankton growth is an alternative to the use of herbicides. Most efforts have involved the use of plankton-feeding fish such as silver carp, bighead carp, or tilapia. In theory, the plankton-feeding fish continually harvests the bloom, improves water quality, and provides additional fish production. However, most attempts at biological control of phytoplankton growth have failed. Quite often phytoplankton abundance increases when plankton-feeding fish are present because these fish effectively remove large phytoplankton and zooplankton which compete with or consume small phytoplankton. The presence of plankton-feeding fish may thus change the structure of the plankton community, but usually will not decrease overall phytoplankton density.

Decreasing nutrient levels by limiting daily feed allotments is the only reliable method available for reducing, on average, the incidence of phytoplankton-related water quality problems. Such problems are rare if maximum daily feeding rates are less than about 50 pounds per acre, but this feeding rate is uneconomical in most commercial enterprises.

Copper-based Herbicides	**Trade Name**	**Effective Against**
Copper sulfate pentahydrate	Various names	Planktonic algae Filamentous algae except for *Pithophora* sp. *Chara* sp. (musk grass)
Mixed copper-ethanolamine complexes	Cutrine®-Plus Clearigate®	Planktonic algae Filamentous algae *Chara*/*Nitella* *Hydrilla*
Mixed copper-ethanolamine complexes in an emulsified formulation . Contains an emulsified surfactant/penetrant for highly effective control of coarse (thick cell-walled) filamentous algae – *Pithophora* sp.	Cutrine®-Ultra	Planktonic algae Filamentous algae including *Pithophora* *Chara*/*Nitella* *Hydrilla* *Egeria*
Copper-triethanolamine complex and copper hydroxide	K-Tea®	Green algae Blue-green algae Diatoms Flagellated protozoa
Copper citrate and copper gluconate	Algimycin®	Planktonic algae Filamentous algae except for *Pithophora* sp.
Copper-ethylenediamine complex and copper sulfate pentahydrate	Komeen® Pondmaster®	*Hydrilla* Waterhyacinth *Egeria* *Elodea* *Najas* Coontail Watermilfoil Sago Pondweed American Pondweed Water Lettuce
Copper carbonate	Nautique® Captain®	Controls all of the above plants controlled by Komeen® and also controls Curlyleaf pondweed Horned pondweed Thin Leaf pondweed Vallisneria Widgeon grass

Aquatic group & vegetation	**Copper sulfate and some chelated copper complexes**	**Cutrine -Ultra**	**Komeen Pondmaster Nautique Captain**	**2, 4-D**	**Diquat**	**Aquathol**	**Hydrothol**	**Glyphosate**	**Fluridone**	**Triclopyr**	**Imazapyr**	**Sodium carbonate peroxyhydrate**
Algae												
phytoplankton	E	E		P	P		G	P	P			G
filamentous algae	E	E		P	G	P	G	P	P			G
Pithophora spp.		G					G					
muskgrass (*Chara* spp.)	E	E		P	P	P	G	P	P			
Floating plants												
duckweeds	P			F	G	P	P	P	E		F	
water hyacinth	P		G	E	E			G	E	E	E	
watermeal	P			F	F				G			
Submersed plants												
coontail	P		G	G	E	E			E			
milfoils	P		G	E	E	E			G	E		
naiads	P		G	F	E	E			E			
pondweeds	P		G	P	G	E			E		G[1]	
Emergent plants												
alligatorweed				F	P			G	F	E	E	
arrowhead	P			E	G	G		E	E		E	
cattails	P			F	G	P		E	F		E	
sedges & rushes	P			F	F			G	P		E[2] F[3]	
slender spikerush	P				G			P	G		F	
smartweed	P		F	E	F			E	F	E	E	
waterlilies	P			E	P			G	E	G	G	
water primrose	P			E	F	P		E	F	E	E	
watershield	P			E	P			G	G		E	
willows	P			E	F	P		E	P	E	E	

E = excellent control, G = good control, F = fair control, P = poor control, blank = unknown or no response [1]Spray only emergent portion, [2]E for sedge, [3]F for rush Table from SRAC 361

Product	Common Trade Names
Copper	Copper sulfate, Cutrine-Plus, Aquatrine, Clearigate, Cutrine-Ultra, K-Tea, Algimycin, Komeen, Pondmaster, Captain, Nautique
Endothall	Aquathol, Aquathol K, Aquathol Super K, Hydrothol 191
Hydrothol	Hydrothol 191
2, 4-D	Navigate, WeedRhap, Weedar 64, Aqua-Kleen
Fluridone	Sonar, Sonar AS, Sonar PR, Sonar SRP, Sonar Q, Avast, Avast SRP
Diquat	Reward, Weedtrine D
Glyphosate	Rodeo, Aquamaster, AquaPRO, AquaNeat, Eraser AQ, Eagre, Glypro, Aquastar
Triclopyr	Renovate 3, Garlon 3A
Imazapyr	Habitat
Sodium carbonate peroxyhydrate	GreenClean, GreenCleanPRO, Pak 27, Phycomycin
Surfactant	Cide Kick
Dyes	Aquashade, Aquashadow, Admiral Liquid, Admiral WSP

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