UNIVERSITY OF FLORIDA
EXTENSION
Institute of Food and Agricultural Sciences

Circular 707

Weed Control in Florida Ponds[1]

D.D. Thayer, K.A. Langeland, W.T. Haller, and J.C. Joyce[2]

Ponds are often built to supplement farm income via fish production, for personal enjoyment, or for stormwater management. Soon after the pond is constructed, unforeseen problems often arise. One major problem that occurs is that the pond becomes clogged with aquatic plants. The level at which an aquatic plant becomes a weed problem depends on the pond's intended use. A farm pond used primarily for weekend fishing can tolerate considerably more vegetation than a pond constructed specifically for fish production and/or irrigation. Shoreline grasses can help stabilize and prevent bank erosion, but out of control grasses may encroach into the water, where they restrict access and usability. This circular provides information on aquatic weed identification and control for farm and aquaculture ponds and surface water retention ponds.

Prevention is the best technique for reducing takeover by aquatic weeds. It's easier and more economical to prevent weed problems than it is to cure them. Preventive measures include proper pond location and construction and protecting the pond from introduction of weeds.

Site Selection

Where you dig a pond can be an important decision when it comes to preventive control. Proper location can help minimize erosion and nutrient enrichment from the runoff of silt and inorganic and organic fertilizers that decrease the lifespan of the pond and limit its usefulness.

Whether you fertilize your pond for fish production or avoid intentional nutrient enrichment, sites near fertilized fields, feedlots, barnyards, septic tanks, gardens, roadways, or other sources of runoff should be avoided. Agricultural and domestic runoff such as from parking lots and roadways may also contribute heavy metals, oils, and pesticide contaminants. If an “ideal” pond location cannot be found, a berm to divert runoff away from the pond can be constructed (Figure 1).

Avoid building a pond with a flowing stream unless excessive water can be diverted. When a fertilization program is being used for algae production, the continual flushing action of a flowing stream would be counterproductive, resulting in the use of much more fertilizer to maintain an algae bloom. Herbicide effectiveness may also be diminished when a long contact period is required for

1. This document is Circular 707, one of a series of the Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date October 1986. Revised April 2001. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.
2. D.D. Thayer, director, South Florida Water Management District, Aquatic Plant Management Division; K.A. Langeland, professor, Agronomy Department, Center for Aquatic and Invasive Plants; W.T. Haller, professor, Agronomy Department, Center for Aquatic and Invasive Plants; J.C. Joyce, professor, Executive Associate Vice President, Office of Vice President for Agriculture and Natural Resources; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

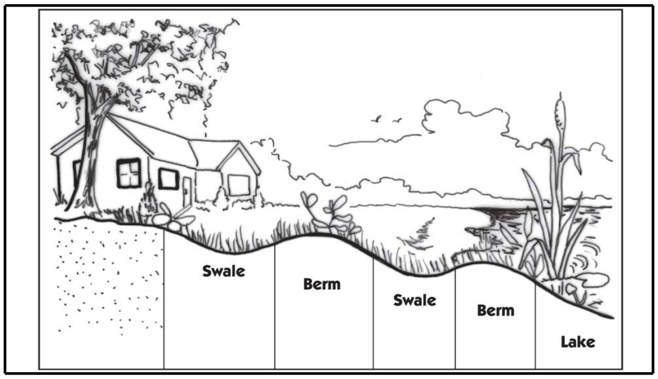

Figure 1. A swale and berm system slows down stormwater runoff and traps pollutants before they reach the pond.

underwater plants. Aquatic plants growing in the stream itself are much more difficult to control, even with the faster acting contact-type herbicides. Without control of water input, water quality in general will suffer and become difficult to manage.

After considering the factors mentioned above, select locations that have recommended watershed-to-pond ratios if you don't have a well or other water source. The USDA Natural Resources Conservation Service (NRCS) recommends that, based on Florida's annual rainfall, an excavated pond should be no less than 6 to 8 feet deep (Figure 2), and that a drainage area of 2 to 3 acres is necessary to maintain one foot of water in a one-acre pond (Figure 3). Experience with farm ponds in North Florida indicates that deeper ponds (10 to 20 feet deep) have fewer aquatic weed problems than shallower ponds. If a properly balanced fish population is to be maintained, then at least one surface acre of water is required. So, to build a one-acre pond with an average depth of 8 feet, an average 16 to 24 acres of watershed would be required. The surrounding vegetation cover, soil type, land slope, and other land use characteristics will have an effect on the degree of drainage. If the surrounding vegetation is primarily woodlands, then more watershed is required than if the surrounding land is primarily in pasture.

If possible, choose a location that maximizes use of prevailing winds. Good water circulation is essential for increasing dissolved oxygen in the water column, cycling nutrients, increasing bacterial populations in the hydrosoil, and restraining floating plants from covering the pond.

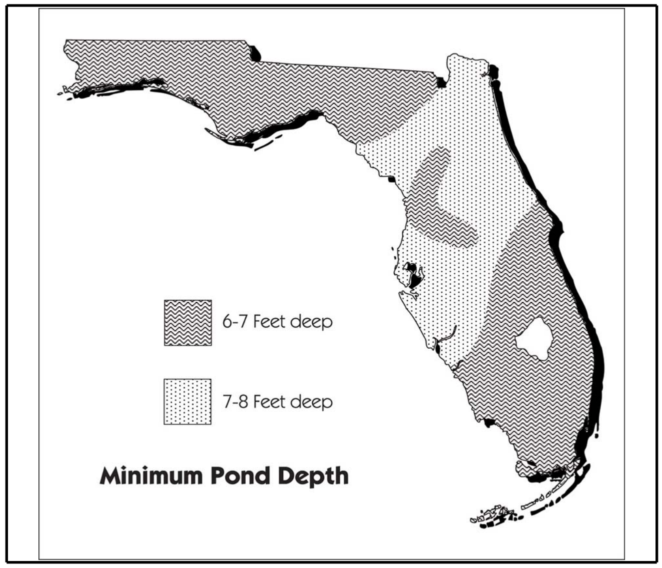

Figure 2. Based on probable seepage and evaporation losses, Florida ponds should have a minimum depth of 6 to 8 feet.

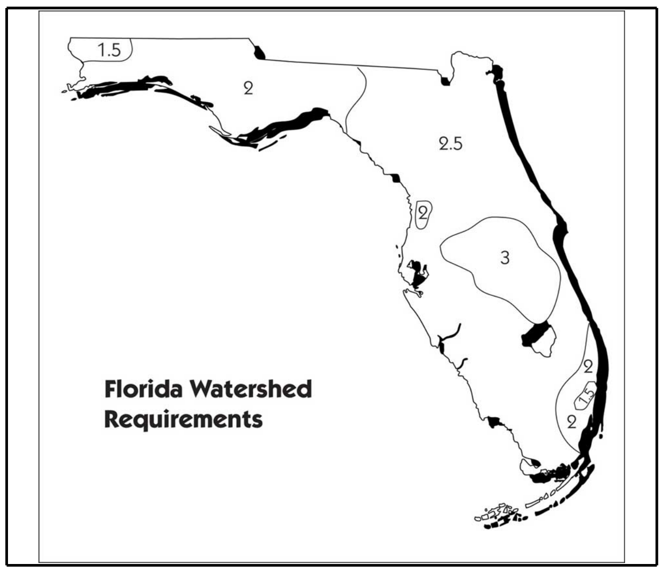

Figure 3. The watershed required for most of Florida would be 2 to 3 acres of watershed to 1 acre-ft of water.

If at all possible, avoid a location that will have heavy livestock usage. If the pond is going to be used primarily for watering livestock, divert water to a watering trough or section off a portion of the pond in order to prevent the livestock from wading in at will (Figure 4). Livestock increase erosion, levee destruction, organic pollution, and turbidity, as well as disturb fish spawning areas. Restricting livestock provides cleaner drinking water and will increase the life of the pond. The cost of fencing will be more than offset by the lowered cost of pond maintenance.

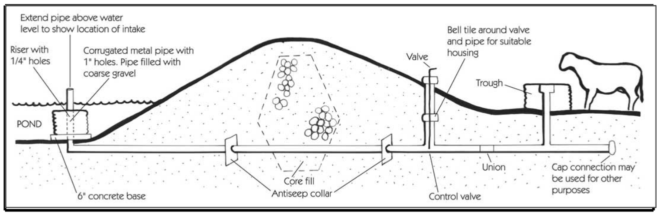

Figure 4. Water is piped through the dam's drainpipe to a stockwater trough.

Pond Construction

Pond banks should be as steep as possible along the edges to a depth of several feet to avoid shoreline vegetation from becoming established. They should then gradually slope to a depth of 6 to 8 feet to the pond center. Removal of brush and trees along the edge will increase berm stability and reduce leaf and branch litter. Grass species should be encouraged to grow along the banks to prevent erosion and washouts.

The construction of a small berm (Figure 1) around the entire pond can be helpful in trapping rainwater runoff that may be rich in nutrients and suspended solids (leaf litter, trash, etc.). The water that percolates through the berm into the pond will be filtered rather than flowing directly into the pond itself. Terracing adjacent fields can also be a valuable method of decreasing both field erosion and sedimentation. If your future plans include water drawdown for pond reconstruction, now is the time to plan for drainpipes, risers, valves, etc.[3]

Stormwater Ponds

Urban storm water ponds, technically called wet detntion areas, have the primary purpose of flood control. Secondarily, surface water detntion ponds are hoped to protect receiving waters from pollutants and may also be used in part or in total to mitigate destruction of wetlands. Wet detention ponds are often constructed with shallow sloping areas, called littoral shelves. The purpose of the littoral shelf is to provide habitat for rooted plant life. Storm water ponds often have permits associated with them that require management of aquatic plants in the pond, including maintaining a certain amount and type of plants. Before attempting any weed control measures in storm water ponds, the Water Management District in which you are located should be contacted. It is advisable to contract a professional pond management company to manage weed problems in storm water ponds. For additional information on storm water pond management see "Storm Water Ponds--A Citizen's Guide to Their Purpose and Management", available from Southwest Florida Water Management District: 352/796-7211 or 800/423-1476.

Methods of Aquatic Weed Control

Fertilization

The principle behind a pond fertilization program is that phytoplankton (microscopic algae) populations increase as a result of the controlled addition of fertilizer nutrients until light penetration is reduced below the level required for growth of submersed weeds.

Before you decide on fertilization for weed control, consider the following. 1) Once a fertilization program has begun, you must always continue the program or face possible severe weed problems. 2) Particular weeds, such as hydrilla (see “Submersed Plants” in Appendix 1), have been shown in Florida to outcompete phytoplankton communities for nutrients, thereby making the weed problem worse. It is therefore imperative that fertilization should not be initiated until current weed infestations have been totally controlled. 3) If the fertilization of a pond is intended to be used to stimulate food production in an aquaculture pond, then additional weed control with herbicides or with weed-eating carp *Ctenopharyngodon idella* (see page 6, “Herbivorous Fish”) may be beneficial (Figure 5).

Phytoplankton is the base of the food chain. Increases in phytoplankton will increase the production of zooplankton, which ultimately increases fish production. Most fertilization recommendations suggest adding inorganic fertilizer every 2 weeks until a shiny object placed 18 inches below the surface is no longer visible (Figure 6). Once this level of phytoplankton is obtained, maintain that level with periodic fertilization. The optimum pH should be at least 6.5 or higher, and liming may be required prior to fertilization. The best time of year to begin a fertilization program is in the

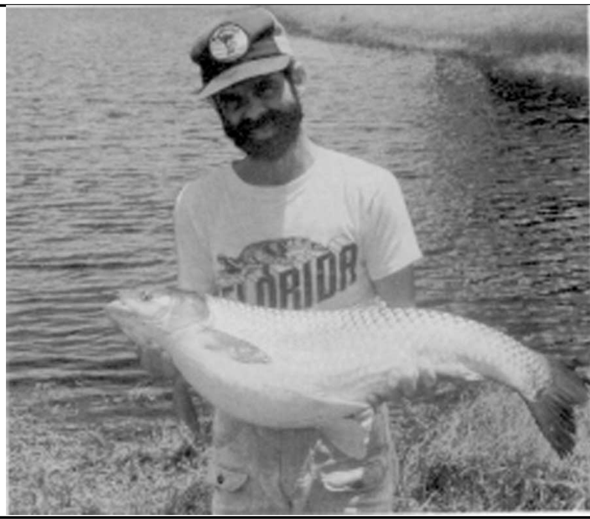

Figure 5. The grass carp provides effective weed control for most submersed and many floating weeds.

spring before aquatic weeds have begun growth. Once established, submersed vegetation must be controlled either with chemicals or grass carp or must be physically removed in order to ensure good algae production. Fertilization shortly after an herbicide application may speed decomposition resulting in oxygen depletion and should be avoided. Remember, if you desire clear water for swimming or other recreational purposes, do not fertilize your pond. NEVER add fertilizer to a permitted stormwater retention pond.

Figure 6. Fertilization encourages production of phytoplankton that reduces light penetration into the water.

Nutrient Reduction

The converse of fertilization is reduction of fertilizer nutrients into your pond. While most Florida ponds will have sufficient natrurally occuring nutrients to support problem levels of plant growth, decreasing the amount of nutrients going into a pond can minimize some problems, especially the growth of algae and floating plants, which derive their nutrients from the water, not the pond bottom. Sources of nutrients that can be decreased include: the amount of food provided to the fish, fertilizer (especially those that contain high nitrogen) applied to landscapes in the watershed, livestock and domestic ducks.

Drawdown

Water level fluctuation or pond draining can be used very effectively if the conditions are favorable. Exposing the bottom of your pond to the atmosphere will solidify suspended mud and consolidate bottom sediments to a watertight condition. Excessive nutrients suspended in the water column will be diluted as a result of the water exchange. In order to have a successful drawdown, you must leave the water level down long enough to desiccate and kill submersed plants. An incomplete drawdown may have little to no effect, and some plant species that are not susceptible to drawdown may spread into the de-watered lake bottom more easily. Cattails are often opportunistic and may establish during extended drawdowns (Figure 7). The consolidation of bottom muck by drying should also improve fish spawning and nursery areas. Drawdowns also increase options for chemical weed control. Some herbicides are only labeled for use on drained pond bottoms, and treatments at this time often provide several years of weed control because the herbicides are bound in the bottom sediments.[4]

Figure 7. Cattails flourish in a pond that has been drawn down to kill weeds.

Mechanical Control

Mechanical control involves the physical harvesting of vegetation by hand or with specifically engineered equipment. For the owner of a small pond, mechanical control can be helpful for removing small populations of nuisance plants. For example, a small population of duckweed (see “Floating Plants” in Appendix 1) can be netted when plants form windrows against the shoreline. Brush species, cattails, and other shoreline vegetation can be cut with a sickle or pulled by hand while still immature. Booms or barriers extended across an incoming creek or stream can often keep plants such as waterhyacinths (see “Floating Plants” in Appendix 1) from entering the pond. When confined, these plants can easily be hand removed or sprayed with herbicide. While the simplest mechanical harvesting devices for weed control are often the cheapest, and often highly effective, commercially made mechanical harvesters (Figure 8) designed specifically for aquatic weed management are available. These harvesters vary in size from simple hydraulic sickle-bar cutters powered by a 5-H.P. engine and mounted on the front of a pontoon boat to 10,000-pound capacity harvesters which convey cut vegetation on board for transport to shoreline dumping sites. In general, large mechanical harvesting equipment can be difficult to maneuver in a smaller pond, and weed control cost would be exorbitant for the private pond owner.

Figure 8. Aquatic plant harvester clears weeds from a lake surface.

Biological Control

Ideally, the best weed control agent is one that keeps weed pests restrained naturally. Many native plants have biological restraints that keep them from growing prolifically. The major aquatic weed problems in Florida are caused by nonnative plants that were introduced from foreign lands without their natural pests and controlling organisms. In the absence of natural enemies, these nonnative plants grow uncontrolled and rapidly invade new areas. To provide some insight into biological control for these nuisance plants, research scientists travel to their foreign habitat searching for insects, disease, or other organisms that may aid in controlling their growth. In theory, this concept sounds ideal; however, years of research are required to insure that the introduced organism does not become another dangerous pest. Once it has been determined that the biocontrol agent will not be a pest, and the control agent will exist under the environmental conditions of the pest host, the organism is released. Most biological organisms will not eradicate the host plant, but will instead reduce the plant s potential to become a serious pest.

Several biocontrol agents have been released in Florida or occur naturally; however, others must be added to the pond and are presently available for release in Florida.

Insects and Plant Pathogens

Over the years, insects have proven to be the most popular biological control agents due to their high degree of host specificity. The insect is generally effective at destroying only the host plant because of its parallel evolutionary development with the plant's taxonomic characteristics. Plant pathogens such as viruses, bacteria, fungi, or nematodes are already present in the aquatic environment and may limit the growth of aquatic weeds by invading weak or wounded plant tissue.

The alligatorweed flea beetle (*Agasicles hygrophila*), discovered in South America and introduced into the United States in 1964, is the best example of an extremely successful biocontrol program using insects for aquatic weed control. In regions of the country where the flea beetle can overwinter, as it does in Florida, alligatorweed is no longer considered a major weed problem.

The waterhyacinth has had several biocontrol agents introduced to it over the years that help in reducing the prolific growth that it is capable of; however, unlike alligatorweed, these biocontrol agent don't appear capable of quickly controlling the plant. Two waterhyacinth weevils (*Neochetina eichhorniae* and *N. bruchi*), the waterhyacinth mite (*Orthagalumna terebrantis*), and fungus (

Cercospora rodmanii) have been imported to Florida and can often be found associated with the plant. Because one requirement of a successful biological control program utilizing insects is self-dissemination, locating sources of insects for introduction should not be necessary.

Herbivorous Fish

Numerous nonnative fishes around the world are reported to consume aquatic vegetation. However, because of the concern for potential damage in Florida's diverse lakes and rivers, only a few of these fish have been investigated and even fewer show promise for weed control. Many of these species may not be suitable for weed control because the individual has insufficient consumption (high stocking rates needed), they are prolific spawners (often cause overcrowding), or they are restricted to warm climates (must be overwintered in controlled environments).

Of the fishes examined to date, the grass carp (Figure 5) is the best candidate for aquatic plant control in a variety of situations and climates and may provide the only practical control method for water bodies where herbicides cannot be used. This fish has provided excellent control of submersed plants, filamentous algae, and small floating plants such as duckweeds. The grass carp is used by Arkansas and other states for this purpose in natural lakes and has been researched by a number of other states. Florida has conducted research and has approved the use of the triploid grass carp, which has three sets of chromosomes compared to the normal two sets and is thus sterile.

As stated previously, the grass carp does consume vegetation and if stocked in sufficient numbers is likely to remove all submersed plants from pond systems. Before stocking ponds that have heavy vegetation cover, it is often advantageous to treat with herbicides. In order to determine proper stocking rates for a given pond, a competent fish biologist should be consulted and a permit obtained from a Florida Game and Fresh Water Fish Commission office.

There are three possible management strategies utilizing grass carp: 1) complete vegetation removal within one to two years with a heavy stocking rate; 2) winter stocking, before the spring growth of weeds begins, using fewer fish to maintain a lesser amount of vegetation in the system and increasing the grass carp population as needed; and 3) integrated control using herbicide treatments to obtain desired levels quickly and stocking grass carp to maintain this level. Again, the grass carp population should be adjusted as needed. A word of caution is in order: it is much easier to stock additional grass carp than to remove unwanted fish from the system.

Herbicides

Controlling aquatic plants with herbicides is the most commonly used method of weed control. Chemical weed control has several advantages.

- Herbicides may be directly applied to undesirable vegetation, offering a high degree of selectivity and leaving desirable levels of vegetation.
- Pre-emergence application of appropriate herbicides can provide early weed control. This may be used to promote desirable vegetation without competition during critical early growth stages.
- Herbicides reduce the need for mechanical control which can increase turbidity and affect fish populations.
- Erosion may be reduced by promoting the lower growing grass species for cover.
- Many weeds, especially perennials, that cannot be effectively controlled by other methods are generally susceptible to herbicides.
- Routine use of herbicides under a maintenance program usually reduces the cost of weed control.

Herbicide Selectivity

Herbicides may be placed into two general categories: selective and nonselective. Selective herbicides are used to control weeds without damaging nearby plants, crops, lawns, and ornamentals. Nonselective herbicides are chemicals that kill all plants that are sprayed at an adequate rate.

Herbicides in this latter category are used where no plant growth is wanted such as fencerows, ditchbanks, driveways, etc. Factors that influence selectivity include application rate, time and method of application, environmental conditions, stage of plant growth, and the biological characteristics of the plant.

Mode of Action

Herbicide activity can be divided into contact and systemic types. Contact herbicides only kill the parts of the plant that they physically contact; therefore, the entire plant must be sprayed. They usually cause rapid die-back of the vegetation they come in contact with and are generally more effective on annuals. Systemic herbicides are absorbed by both roots and foliage and translocated within the plant's vascular system. Systemics are particularly effective against deep rooted perennial weeds, providing long term control, and do not need uniform coverage of the entire plant.

Herbicide Formulation

The active ingredient of a herbicide is rarely 100 percent of the formulation. Instead, the herbicide is mixed with water or an oil blend and often includes inert adjuvants that facilitate the spreading, sticking, wetting, and other modifying characteristics of the spray solution. These special ingredients usually improve the safe handling, measuring, and application of the active ingredient.

The majority of liquid herbicide formulations are liquid (L). Each gallon of formulation usually contains 2 to 8 pounds of active ingredient. The high concentration generally means easier handling, transport, and storage. liquids require little agitation and are considered to be nonabrasive. liquids are usually mixed with water at a ratio of 1:50 or 1:100 prior to use.

Many of the aquatic herbicides have not only liquid but dry formulations as well. The vast majority of these dry formulations are sold as granules (G) or pellets (P). The active ingredient is generally adsorbed onto clay particles with the amount of active ingredient ranging from 1 to 15 percent. Granules are convenient for spot treatments, are ready to use and require no mixing, reduce drift hazards, and can be applied easily. The disadvantages of granules are their high expense per pound of active ingredient and their ineffectiveness as a treatment on the foliage of emergent plants.

Another common dry formulation is the wettable powder (WP). WP formulations resemble a fine dust and generally contain greater than 50 percent active ingredient. When mixed with water, agitation is required to keep the insoluble particles in suspension. The advantages of a WP are the lower cost, ease of handling, and ease of measuring. Some disadvantages of WP are the abrasion of suspended particles on spray equipment and the requirement for constant tank agitation.

Adjuvants

An adjuvant is an inert ingredient added to the spray solution in order to facilitate or modify the action of the herbicide. Spray tank additives may include surfactants, thickening agents, spreaders, stickers, wetting agents, penetrants, anti-foaming agents or many other modifiers. Many herbicides contain adjuvants in their formulation and may not need any additional material added to the spray tank; however, many of these same herbicide labels may suggest that additional surfactant be added. Most of the adjuvants are strictly optional and may be added to help modify the spray solution. For instance, a spreader-sticker may be added to the herbicide mix for spraying a contact type of herbicide, because covering as much of the leaf surface as possible would increase the percentage of weed control. Additional surfactant for wetting may be necessary when target weeds have dense leaf hairs. The best source of information for deciding on adjuvant addition is the herbicide label or the chemical manufacturer's representative.

The Label

All herbicide containers must have attached to them a label that provides instructions for storage and disposal, use of the product, and precautions for the user and the environment. The label is the law. It is unlawful to alter, detach, or destroy the label. It is also unlawful to use a pesticide in a manner that is inconsistent with or not specified on the label. For example, herbicides that are sold for use in the garden should never be used in ponds unless the label specifies this use. Misuse of a herbicide is not only a violation of federal and state law; herbicides used contrary to label directions may seriously contaminate water, rendering it unfit for fish, irrigation, and swimming, and as a source of potable water. Herbicides sold for use in water have been state and EPA approved and have undergone years of costly and extensive research to ensure their environmental safety.

The herbicide label contains a great deal of information about the product and should be read thoroughly and carefully before each use. Before purchasing a herbicide, read the label to determine:

- whether the weed species can be controlled with the product
- whether the herbicide can be used safely under particular application conditions
- what herbicide formulation best suits your needs and application equipment
- how much herbicide is needed
- where the herbicide can be used and what restrictions apply if you are also watering livestock, fishing, swimming, consuming as potable water, watering crops, etc.
- what the toxicity is to various fish species
- when to apply the pesticide (time of year, stage of plant growth, etc.)
- whether there are any restrictions for use of the pesticide (certified applications only, ditchbanks only, ponds only, etc.)
- what safety equipment is needed
- signal word that indicates the acute toxicity to humans, i.e., danger, warning or caution.

Precautions with Herbicides

When a large percentage of a water body is infested with weeds, care is needed when fish safety is a concern. Several herbicides act on contact, killing the weeds in a matter of hours. When aquatic plants die and begin to decay, they remove oxygen from the water, creating what is known as a biological oxygen demand. If too large an area in a pond volume is controlled, dissolved oxygen levels in the pond may drop below the concentration necessary to sustain fish. Here are several general rules to keep in mind when treating aquatic plants.

- Avoid treating on cloudy days when dissolved oxygen levels will naturally be lower.
- If a large portion of the pond is covered with plants, treat no more than one-third to one-half of the plants at once, leaving time between applications for oxygen recovery.
- Treat early in the spring before plants get out of control.
- In order to get maximum performance from your herbicide, treat when the water temperature is above 60°F and plants are actively growing.

The majority of EPA and state approved aquatic herbicides have a wide range of safety with nontarget organisms. The level at which some herbicides become toxic to fish is several hundred times higher than field application rates. However, herbicides like copper sulfate ($CuSO_4$) may be toxic to several fish species at label use rates and require extra precaution when large treatments are to be made, especially in soft water. Appendix 3 lists the 96-hour LC_{50} (lethal concentration to 50 percent of any particular population) in ppm and also the pounds of various aquatic herbicides needed per acre-foot of water to be toxic to bluegill, channel catfish, rainbow trout, crawfish, and freshwater shrimp.

How to Use Herbicides

When using herbicides, as with any toxic material, it is important that personal exposure be kept to an absolute minimum. Most accidents result from careless handling and a general lack of label knowledge. Herbicides are categorized into four groups based on their oral, dermal, and inhalation toxicity. Every label contains a signal word (Danger, Warning, or Caution) that indicates level of toxicity.

While mixing and spraying herbicides, protective clothing and equipment such as long-sleeved shirts and long-legged pants, gloves, rubber boots, and goggles or a face shield should be used. Most labels will suggest you wear protective clothing and will tell you the precautions to be taken when using the herbicide.

While mixing, loading, handling, and cleaning up, observe all safety recommendations on the label. When minor spills occur, use absorbent materials such as soil or sawdust to soak up the chemical. Place contaminated materials into a sealed container for disposal. Cleanup of a major spill may be too difficult for an untrained person to handle. Should there be a bad spill, call Chemtrec toll-free at 1-800-424-9300 for emergency assistance. For first aid information about herbicide poisoning, refer to the label for instructions and contact your physician.

If you choose herbicides as a means of control, refer to Appendix 2 and locate the herbicide listed as effective for your particular weed problem. Product tradenames, water systems labeled for use, mode of action, duration of herbicidal activity, and precautions are listed for herbicides.

Once you review the herbicides and decide which best suits your problem, review Appendix 3 to ensure that there will be no toxicity problems.

Appendix 1: Aquatic Weed Identification

Aquatic plants are commonly classified into several categories depending on the location in the water column they inhabit. Aquatic plants may be free floating, emersed, submersed, or shoreline plants. Free floating plants are rarely if ever rooted into the soil and their leaves are located above the water. Emersed aquatic plants are rooted in the soil under water with their leaves on or above the water surface. Submersed aquatic plants are usually rooted in the soil with all or most of their leaves growing under water. Ditchbank plants are not true aquatic plants, but are often associated with the moist soils located around ponds and lakes and are therefore included here, as are common types of algae.

FLOATING PLANTS

Common Duckweed

(*Lemna minor*) Figure 9

Description: Small, footprint-shaped leaves, no more than 1/8 inch long having one root. Leaves are pale green and float flat on the water surface. Reproduction occurs by seeds and rapidly through budding.

Control: Nutrient Reduction. Biological: grass carp. Herbicides: diquat, fluridone.

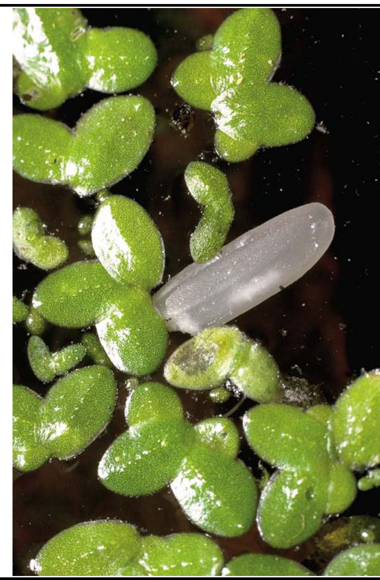

Figure 9. Common duckweed Credits: Kerry Dressler

Common salvinia

(*Salvinia minima*) Figure 10

Description: Circular leaves 1/4—1/2 inch in diameter with dense leaf hairs on the upper leaf surface. Leaves are brownish green and float flat on the surface. Salvinia is a fern and reproduces by spores and fragmentation.

Control: Nutrient reduction. Biological: partial control with grass carp. Herbicides: diquat.

Common watermeal

(*Wolffia* species) Figure 11

Description: These are tiny, floating, rootless plants that are less than 1/32 inch long. The plant body is rounded and feels grainy when rolled

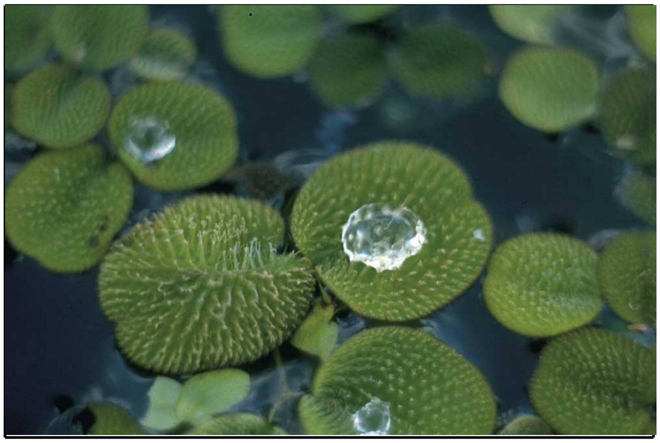

Figure 10. Common salvinia Credits: David Sutton

between the fingertips. The plants are so small they appear to be merely green specks or dots. Often two to three are attached.

Control: Nutrient Reduction. Biological: none.

Herbicides: fluridone (repeat applications).

Figure 11. Common watermeal (smallest) and duckweed Credits: Kerry Dressler

Mosquito fern

(*Azolla caroliniana*) Figure 12

Description: Free-floating fern less than 1/2 inch across, with branching stems. Leaves tiny, bilobed, in two ranks, usually reddish (especially in full sun), or green. Propagates vegetatively, rapidly forming large thick mats.

Control: Nutrient reduction. Biological: attacked by native insects, which are suppressed by predation from fire ants.

Herbicides: diquat, fluridone.

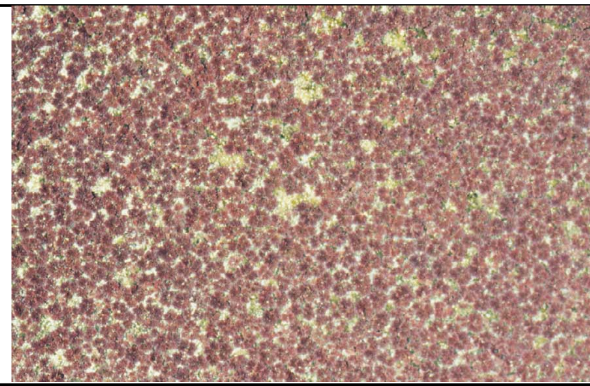

Figure 12. Mosquito fern Credits: Kerry Dressler

Waterhyacinth

(*Eichhornia crassipes*) Figure 13

Description: Plants several inches to two feet in height. Smooth leaves attached to spongy bulb-shaped stalks. Reproduction is primarily through the production of daughter plants.

Control: Biological: hyacinth weevil, partial control with fungus. Herbicides: 2,4-D, diquat, glyphosate.

Figure 13. Waterhyacinth Credits: Alison Fox

Waterlettuce

(*Pistia stratiotes*) Figure 14

Description: Resembles a head of lettuce. Grows in a rosette with spongy, dense hairy leaves 6—8 inches in diameter. Daughter plants are the major means of reproduction.

Control: Biological: waterlettuce weevil. Herbicides: diquat, endothall liquid.

Figure 14. Waterlettuce and salvinia Credits: Vernon V. Vandiver, Jr.

EMERSED PLANTS

Pickerelweed

(*Pontederia lanceolata*) Figure 15

Figure 15. Pickerelweed Credits: Vernon V. Vandiver, Jr.

Description: An erect plant with lance-shaped leaves up to 10 inches long. Each stem has violet-blue flowers at the top. Reproduction occurs by seed and creeping rootstalks.

Control: Herbicides: triclopyr,* partial control with 2,4-D and glyphosate.

Alligatorweed

(*Alternanthera philoxeroides*) Figure 16

Figure 16. Alligatorweed Credits: Ken Langeland

Description: Hollow-stemmed perennial capable of forming dense mats. Leaves are opposite between 2 and 4 inches long, and football-shaped. Stems have a solitary white flower head at the tip. Reproduction by fragmentation.

Control: Biological: alligatorweed flea beetles and thrips. Herbicides: triclopyr,* partial control with 2,4-D and glyphosate.

Cattail

(*Typha* species) Figure 17

Description: Erect perennials (up to 9 feet) that can reproduce by seed or creeping rootstalk. Grass-like leaves are flat and smooth to the touch. Flowers look like a "cat's tail" and can be found in a tightly packed spike usually 6-8 inches long.

Control: Herbicides: diquat, glyphosate, fluridone.

Pennywort

(*Hydrocotyle umbellata*) Figure 18

Description: Dark green, shiny rounded leaves which are centrally attached to a long stalk. Leaves may lie flat on the water surface or be erect. Pennywort reproduces by seed and creeping stems.

Figure 17. Cattail Credits: Vernon V. Vandiver, Jr.

Control: Herbicides: diquat, 2,4-D, glyphosate.

Figure 18. Pennywort Credits: Kerry Dressler

Smartweed

(*Polygonum* species) Figure 19

Description: Leaves are alternate, lance-shaped, and attached to swollen joints on the stem. The flower stalk consists of many small pinkish white flowers in a single spike. Smartweed spreads by seed, and may form large floating mats.

Control: Herbicides: triclopyr,* partial control with glyphosate (species dependent) and 2,4-D.

*Do not apply directly to water.

Figure 19. Smartweed Credits: Kerry Dressler

White water-lily

(*Nymphaea odorata*) Figure 20

Description: Leaves are flat, rounded, and attached at the center to the stalk. Leaves are often 10 inches in diameter and split to the center on one side. The flower is sweet-scented, white and showy. Reproduction is by seed and branching stems.

Control: Herbicides: fluridone, 2,4-D liquid and granular, glyphosate.

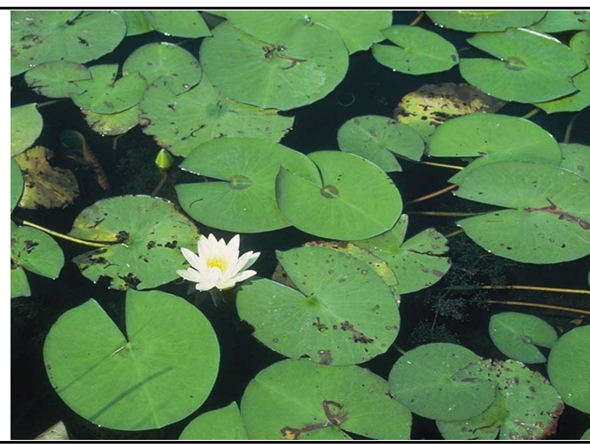

Figure 20. White water-lily Credits: Vernon V. Vandiver, Jr.

Spatterdock

(*Nuphar luteum*) Figure 21

Description: Large heart-shaped leaves arising from a stalk attached to a thick creeping root system. The flower is yellow and about one inch in diameter. Reproduction is by seed and new sprouts.

Control: Herbicides: glyphosate, fluridone.

Figure 21. Spatterdock Credits: Kerry Dressler

SUBMERSED PLANTS

Coontail

(*Ceratophyllum demersum*) Figure 22

Description: Leaves grow in a whorl, are finely dissected, and have teeth on one side of the leaf margin. Leaves are 1/2—1 inch in length and crowded towards the stem tip giving the appearance of a raccoon's tail. Coontail is rootless and floats near the surface in the warmer months. Reproduction is by seed and fragmentation.

Control: Biological: grass carp. Herbicides: diquat, endothall liquid and granular, fluridone,

2,4-D granular.

Hydrilla

(*Hydrilla verticillata*) Figure 23

Description: Long stemmed, branching plant that is rooted to the bottom and often forms large surface mats. Leaves grow in a whorl with toothed margins that feel rough. Hydrilla can spread by plant fragments, underground stems, seed, leaf buds, or buds located on the underground stems.

Control: Biological: grass carp (insect biocontrol under investigation). Herbicides: copper, diquat, endothall (liquid and granular), fluridone.

Figure 22. Coontail Credits: Kerry Dressler

Figure 23. Hydrilla Credits: Kerry Dressler

Bladderwort

(*Utricularia* species) Figure 24

Description: A submersed, free floating plant, having a variety of growth forms. Although leaf shapes and flowers differ, all species bear small urnlike bladders which are used to trap small aquatic animals. Reproduction is by seed and fragmentation.

Control: Biological: grass carp. Herbicides: diquat, fluridone, 2,4-D granular.

Southern naiad

(*Najas guadalupensis*) Figure 25

Description: Bottom-rooted, slender-leaved, dark green to greenish purple plant with branching

Figure 24. Bladderwort Credits: Kerry Dressler

stems. Leaves are less than 1 inch in length and narrow. Reproduction is by seed and fragmentation.

Control: Biological: grass carp. Herbicides: diquat, endothall liquid and granular, fluridone, 2,4-D granular.

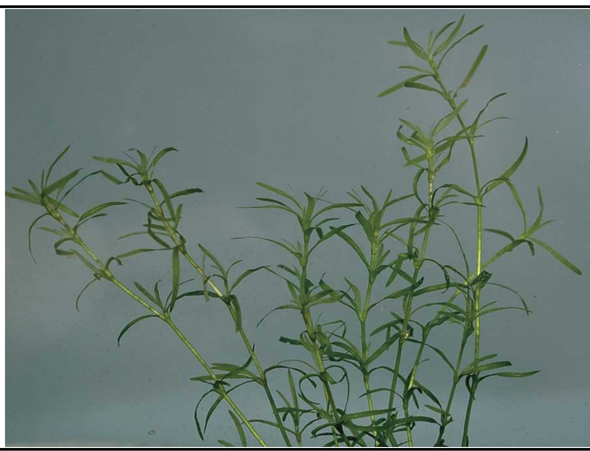

Figure 25. Southern naiad Credits: Kerry Dressler

Fanwort

(*Cabomba caroliniana*) Figure 26

Description: Leaves of fanwort are finely dissected and fan-shaped. Leaves are opposite and generally no more than 1—1 1/2 inches wide. The flower is white or cream colored, about 1/2 inch in diameter and blooms above the water surface. Reproduction is by seed and fragmentation.

Control: Biological: grass carp. Herbicides: diquat, fluridone, 2,4-D granular.

Figure 26. Fanwort Credits: Kerry Dressler

Pondweed

(*Potamogeton* species) Figure 27

Description: Several species of pondweed are found in Florida; Illinois pondweed (*P. illinoensis*) is most frequently encountered. It has both floating and submersed leaf forms. The football-shaped floating leaves are not always present, but are easily distinguishable from the lance-shaped submersed leaves. The flowers are clustered together on a spike 1-2 inches long located just above the water surface at the stem tip. Reproduction is by seed and from underground stems.

Control: Biological: grass carp. Herbicides: diquat, endothall (Hydrothol) liquid and granular, fluridone, 2,4-D granular.

Figure 27. Pondweed Credits: Alison Fox

GRASSES AND SEDGES

Torpedograss

(*Panicum repens*) Figure 28

Description: Narrow leaved (less than 1/4-inch wide), with stems often several feet in length. Torpedograss creeps horizontally by underground stems and forms large floating mats. Reproduction is by seed and creeping stems.

Control: Biological: partial control with grass carp. Herbicides: partial control with glyphosate, fluridone.

Figure 28. Torpedograss Credits: Kerry Dressler

Maidencane

(*Panicum hemitomon*) Figure 29

Description: Maidencane leaves usually grow at 90° angles from the stem and generally 1/2-inch in width. An extensive creeping root system allows maidencane to form dense floating mats with stems often several feet in length. Reproduction is by seed and creeping root stalk.

Control: Biological: partial control with grass carp. Herbicides: partial control with glyphosate.

Paragrass

(*Brachiaria purpurascens*) Figure 30

Figure 29. Maidencane Credits: Kerry Dressler

Description: Paragrass often forms stems several yards in length which often fall on the ground. Paragrass can be easily identified by the dense hairs located at the stem joints. Dense floating mats often form. Reproduction is by seed and stem joints forming roots.

Control: Biological: partial control with grass carp. Herbicides: glyphosate, fluridone.

Figure 30. Paragrass Credits: Mark V. Hoyer

Proliferating spikerush (roadgrass, hairgrass)

(*Eleocharis baldwinii*) Figure 31

Description: Proliferating spikerush has two growth forms. When it occurs on moist soils at the edge of ponds or lakes it is erect and the leafless stems are 1-4 inches tall. When submersed, the stems become long and proliferate throughout the water column. Leaves occur only as bladeless sheaths at stem bases.

Control: Biological: grass carp. Herbicides: fluridone (repeat applications).

Figure 31. Proliferating spikerush Credits: Ken Langeland

Sedge

(*Cyperus* species) Figure 32

Description: Many sedges are found in Florida and are generally difficult to identify by species. In general, sedges can be identified by the triangular stem and leaf blades, which are generally rough to the touch. Flower stalks arise from the center forming a compact group or headlike cluster of flower spikes. Reproduction is by seed.

Control: Herbicides: partial control with glyphosate.

Figure 32. Sedge Credits: Kerry Dressler

DITCHBANK BRUSH

Wax Myrtle

(*Myrica cerifera*) Figure 33

Description: Shrub or small tree usually 10 feet tall. Leaves are alternate, pale green, and lance-shaped. When crushed, leaves emit a pleasant aroma. Close inspection of the leaves will reveal numerous small dark scales on top and bright orange scales below. Reproduction is by seed.

Control: Herbicides: imazapyr,* triclopyr.*

* Do not apply directly to water.

Figure 33. Wax Myrtle Credits: Mark V. Hoyer

Willow

(*Salix* species) Figure 34

Description: Fast growing shrub which can become a tree in a short period of time. Leaves are alternate and lance-shaped with finely toothed margins. The fruit capsule contains many small hairy seeds which drift in air currents.

Control: Herbicides: partial control with 2,4-D, glyphosate, imazapyr,* triclopyr.*

*Do not apply directly to water.

Brazilian pepper

(*Schinus terebinthifolius*) Figure 35

Description: An extremely fast growing shrub found predominantly in disturbed areas of south Florida. This aggressive nonnative species produces large quantities of seeds contained in a red fruit

Figure 34. Willow Credits: Brian Nelson

usually about 1/4-inch in diameter. Reproduction is by seed.

Control: Herbicides: glyphosate, 2,4-D, imazapyr,* triclopyr.*

* Do not apply directly to water.

Figure 35. Brazilian pepper Credits: Amy Ferriter

Water primrose

(*Ludwigia* species) Figure 36

Description: Small shrub attaining height of up to 6 feet with multiple branching stems. Leaves are lance-shaped with small soft hairs on both sides. Flowers are yellow with four symmetrical petals. Reproduction is by seed and underground stems.

Control: Herbicides: 2,4-D

Figure 36. Water primrose Credits: Kerry Dressler

ALGAE

Macrophytic algae

Figure 37

Description: Macro, meaning large, describes a type of algae that looks more like a submersed plant. Capable of attaining several feet in length, muskgrass (Chara species), is the most common of these algae found in Florida. The algae appear to have a whorl of spined leaves, grey-green in color, resembling the submersed plant coontail. However, algae have no true leaves. When crushed, Chara emits a musky odor.

Control: Biological: grass carp. Herbicides: copper, diquat, endothall (Hydrothrol) liquid and granular. Nutrient Reduction.

Figure 37. Macrophytic algae Credits: Kerry Dressler

Filamentous algae

Figure 38

Description: Many species of filamentous algae are frequently a problem in Florida ponds. These threadlike filaments are often called “pond scum” or “pond moss” when they are seen floating on the pond surface. Although many species of filamentous algae can frequently become a problem to pond owners, most species can be controlled in a similar manner. A few species, especially some of the blue-green algae (e.g., *Pithophora* and *Lyngbya*), are difficult to control and would require special recommendations from a qualified biologist.

Control: Biological: partial control with grass carp. Herbicides: copper, endothall (Hydrothol).

Figure 38. Filamentous algae Credits: Alison Fox

Planktonic algae

Figure 39

Description: Microscopic (planktonic) algae are small plants that cannot be identified without magnification. They occur in all ponds and, after fertilization, give the pond its green color. Most of the microscopic algae are beneficial to ponds, converting nutrients into a source of food in the food chain. There is rarely a need to control microscopic algae; however, when large blooms occur, oxygen depletion, foul odors, off-flavor fish, and even fish kills may occur.

Control: Herbicides: copper. Nutrient Reduction.

Figure 39. Planktonic algae Credits: Alison Fox

Figure 40. Pond before plant management Credits: Chuck Cichra

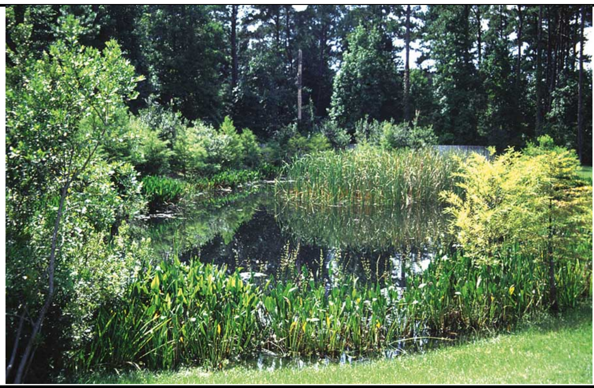

Figure 41. Pond after plant management Credits: Chuck Cichra

Appendix 2: Herbicides

Copper Products

Copper sulfate (cupric sulfate pentahydrate)

Tradenames: Tennessee, Chem One Copper Sulfate, Noranda, Old Bridge, and others.

Copper chelate (alkanolamine complex)

Tradenames: CUTRINE-PLUS, Captain.

Copper chelate (triethanolamine complex)

Tradenames: K-TEA.

Copper chelate (ethylenediamine complex)

Tradenames: Komeen, Nautique, Clearigate.

Water systems labeled for use: **Copper sulfate**: impounded waters, lakes, ponds, reservoirs, and irrigation systems. **Copper chelates**: ornamental, fish, and fire ponds; potable water reservoirs; freshwater lakes and fish hatcheries.

Mode of action: Contact herbicide, often used in combination with other contact herbicides.

Duration of herbicidal activity: Copper sulfate may persist up to 7 days before the free copper is precipitated to insoluble forms and remains an inactive precipitate in bottom sediments. As the hardness of the water increases, the persistence of the free copper decreases. The chelated coppers can be used where hard water may precipitate uncomplexed forms of copper too rapidly.

Precautions: Copper sulfate can be very corrosive to steel and galvanized pipe. Chelated coppers are virtually noncorrosive. Contact with skin and eyes may be irritating. As water hardness decreases, toxicity to fish increases. Copper sulfate may be toxic to fish species at recommended dosages. Generally, the chelated coppers are nontoxic to trout, tropical fish, ornamental fish, and other sensitive fish at recommended dosages.

2,4-D Products

2,4-D Granular

Tradenames: Aqua-Kleen, AQUACIDE, Navigate.

2,4-D Amine

Tradenames: 2,4-D Amine No. 4; Riverside 2,4-D Amine (Pro Source); WEEDAR 64; A-4D.

Diquat

Tradenames: Reward.

Water systems labeled for use: May be used in slowly moving bodies of water, ponds, lakes, rivers, drainage and flood control canals, ditches, and reservoirs.

Mode of action: Contact herbicide.

Duration of herbicidal activity: Diquat is rapidly and completely inactivated by soil.

Precautions: Do not apply to muddy water because the diquat will be inactivated. Never treat more than 1/3 1/2 of a densely vegetated pond at any one time because rapidly decaying vegetation will deplete oxygen, thereby suffocating fish. Skin contact may cause irritation. Avoid drift.

Diuron

Tradenames: Direx 4L, DIURON 80, KARMEX, Nautilus.

Water systems labeled for use: Irrigation and drainage ditches that have been drained of water for a period of 72 hours. After 72 hours diuron is fixed to the soil and the ditch may then be used.

Nautilus is registered for the control of macroalgae in commercially operated, freshwater ponds, used only for ornamental fish production; discharge from ponds within 30 days of application is not allowed.

Mode of action: Diuron is readily absorbed through the root system, less so through foliage, and translocated upward toward plant foliage.

Duration of herbicidal activity: Control duration will vary with amount of chemical applied, soil type, rainfall and other conditions. Usually control will last for a period of 10 12 months.

Precautions: May irritate eyes, nose, throat, and skin. Avoid breathing dust. Apply before expected seasonal rainfall. Do not treat any ditch with desirable tree roots extended into them or injury may result. Prevent drift of dry powder to desirable plants. Do not contaminate any body of water.

Endothall

Tradenames: Granular: AQUATHOL, HYDROTHOL 191. Liquid: AQUATHOL K, HYDROTHOL 191.

Water systems labeled for use: Irrigation and drainage canals, ponds and lakes.

Mode of action: Contact herbicide.

Duration of herbicidal activity: Microbiological break down is fairly rapid in water and soil with a short herbicidal duration.

Precautions: Hydrothol 191 liquid + granular should not be used where fish are an important resource. Fish may be killed by dosages necessary to kill weeds. Skin contact may cause irritation. May be corrosive to application equipment.

Fluridone

Tradenames: Sonar AS, Sonar SRP, Avast!, Avast! SRP.

Water systems labeled for use: Lakes, ponds, ditches, canals, and reservoirs.

Mode of action: Fluridone is foliage absorbed and translocated into the actively growing shoots where destruction of the chlorophyll pigments occurs, resulting in white growing points.

Duration of herbicidal activity: Depending upon application and vegetation being controlled, control may last 1 year.

Precautions: Do not use treated water for irrigation of agronomic crops or turf for 7 to 30 days following treatment. Trees or shrubs growing in treated water may be injured. Higher treatment rates will be required if there is a large turnover in water volume in treated water.

Glyphosate

Tradenames: Rodeo, Aquamaster, Aquaneat, Eagre, Aquapro, GlyPro.

Water systems labeled for use: Lakes, ponds, streams, rivers, ditches, canals, reservoirs, and any other freshwater bodies.

Mode of action: Glyphosate is foliage absorbed and translocated throughout the plant and root system, killing the entire plant.

Duration of herbicidal activity: Only effective at the time of treatment.

Precautions: Not to be used for submersed or pre- emergence vegetation. Floating mats of vegetation will require treatment. A rain-free period of 6 hours after application is required. May be corrosive to galvanized steel. Avoid drift to desirable vegetation as glyphosate is nonselective and will affect contacted vegetation.

Imazapyr

Tradename: ARSENAL.

Water systems labeled for use: Nonirrigation ditchbanks and similar areas.

Mode of action: Both foliage and root absorbed and translocated throughout the entire plant.

Duration of herbicidal activity: Provides control of existing and germinating seedlings throughout the growing season.

Precautions: Do not contaminate any water supply. Do not apply on ditches used for irrigation. Do not treat in areas where desirable tree roots are visible. Prevent drift to desirable plants. Should not be mixed or stored in unlined steel containers or spray tanks.

Triclopyr

Tradenames: Garlon 3A, Garlon 4.

Water systems labeled for use: Nonirrigation ditchbanks. Not labeled for use in water (Experimental Use Permit only).

Mode of action: Triclopyr induces characteristic auxin-type responses in growing plants. It is absorbed by both leaves and roots, and it is readily translocated throughout the plant. Foliage applications have achieved maximum plant response to treatment when the treatment has been applied soon after full leaf development and soil moisture is adequate for normal plant growth.

Duration of herbicidal activity: Time required for 50 percent breakdown in soil is between 10 and 46 days depending on environmental conditions and soil type. At label rates, phytotoxic residues in soils should cause no problems. Triclopyr has a 2- to 6-hour half-life in water.

Precautions: Keep out of lakes, streams or ponds. Do not contaminate water by cleaning of equipment or disposal of wastes.

Additional Notes:

3. Contact your local NRCS office for specifications.

4. Consult an aquatic plant biologist before attempting a drawdown for aquatic weed control to ensure that weed problems can be controlled in this manner.

Appendix 3. Toxicity of Aquatic and Ditchbank Herbicides to Selected Aquatic Organisms.

	Treatment[1] Rate ppm	Toxicity[2] 96-HR LC_{50}, ppm		
		Bluegill Sunfish	**Rainbow Trout**	**Invertebrates**
Copper Sulfate	0.1-1.0			17.0[3]
Soft Water		0.9	0.01	
Hard water		7.3	-	
Copper Chelate	0.1-1.0			19.0[4]
Soft water		1.2	<0.2	
Hard water		7.5	4.0	
2, 4-D Amine	negligible [5]	524	377	184[6]
2, 4-D BEE	1.25-2.5[7]	0.61	2.0	7.2[3]
Diquat	0.12-0.72	>115	21	>100[8]
Diuron	negligible (0.25-1.0)[10]	8.2	16	0.16[4]
Imazapyr	negligible	>100	>100	>100[3]
Endothol (Aquathol)	1.0-5.0	501	529	320[9]
Endothol (Hydrothol)	0.1-3.0	1.2	1.3	0.36[5]
Fluridone	0.01-0.15	14.3	11.7	6.3[5]
Glyphosate (Rodeo)	negligible	>1000	>1000	930[5]

[1] Estimated concentration in water after application according to label instructions.
[2] Toxicity varies according to experimental conditions. Values are typical from various sources.
[3] Freshwater shrimp
[4] Blue Shrimp
[5] Labeled only for foliar or ditchbank application, therefore concentrations in water are negligible.
[6] Daphnia
[7] Calculated for label rates of 26.7% G.
[8] *Gammarus fasciatus*
[9] Daphnia, 48 hr
[10] Nautilus

Appendix 4. Formulas for Herbicide Calculations

Formulas for Active Ingredient

(1) Gallons of liquid formulation required = lb ai* required ÷ lb ai per gal of concentrate

(2) Pounds of dry formulation required = lb ai required ÷ % ai in formulation expressed as decimal

Formulas for Herbicide Application to Ponds or Lakes

(3) Volume of pond in cu ft = surface area in sq ft x average depth in ft

(4) Volume of pond in ac ft = surface area in ac x average depth in ft

(5) Volume of pond in ac ft = volume of pond in cu ft ÷ 43,560 ft^2 per ac

(6) Total gal of chem required = ac ft x ppmv** x 0.33

Appendix 4. Formulas for Herbicide Calculations

(7) ppmw = (lb ai of chem applied ÷ volume in ac ft) x 2.72

(8)Total lb ai required = ac ft x 2.72 x ppmw desired

(9) Total gal of liquid formulation required = ac ft x 2.72 x ppmw desired ÷ lb ai per gal of concentrate

Acre-feet Calculation

(10) Acre-feet = acres x average depth in feet

Acreage Calculations

(11a) Rectangular shape: Acres = width in ft x length in ft ÷ 43,560 ft^2 per ac

(11b) Circular shape: Acres = 3.14 x $(\text{radius in ft})^2$ ÷ 43,560 ft^2 per ac

Herbicide Application Coverage

(12) Acres/min = (swath width in ft x speed in mph) ÷ 495

Volume of Herbicide Concentrate Required

(13)Gallons of herbicide concentrate required = weight of active ingredient required in spray mixture ÷ weight of active ingredient per gallon of herbicide

*ai= active ingredient; ac=acre; ppmv=parts per million by volume; ppmw=parts per million by weight

Appendix 5. Convenient Conversion Factors

Multiply...	**By...**	**To get...**
Acres	0.405	Hectares
Acres	4,047	Square meters
Acres	4,840	Square yards
Acres	43,560	Square feet
Acre-feet	1,233	Cubic meters
Acre-feet	43,560	Cubic feet
Acre-feet	325,900	Gallons
Centimeters	0.394	Inches
Centimeters	0.01	Meters
Centimeters	10.0	Millimeters
Cubic feet	0.0283	Cubic meters
Cubic feet	0.0370	Cubic yards
Cubic feet	0.804	Bushels
Cubic feet	7.48	Gallons(fluid)
Cubic feet	25.7	Quarts (dry)
Cubic feet	28.3	Liters
Cubic feet	29.9	Quarts (fluid)
Cubic feet	51.4	Pints (dry)
Cubic feet	59.8	Pints (fluid)
Cubic feet	62.4	Pounds of water

Appendix 5. Convenient Conversion Factors

Multiply...	By...	To get...
Cubic feet	1,728	Cubic inches
Cubic feet	28,320	Cubic centimeters
Cubic inches	0.000016	Cubic meters
Cubic inches	0.0006	Cubic feet
Cubic inches	0.0037	Gallons (dry)
Cubic inches	0.0043	Gallons (fluid)
Cubic inches	0.0149	Quarts (dry)
Cubic inches	0.0164	Liters
Cubic inches	0.0173	Quarts (fluid)
Cubic inches	0.0298	Pints (dry)
Cubic inches	0.0346	Pints (fluid)
Cubic inches	0.0361	Pounds of water
Cubic inches	0.5540	Ounces (fluid)
Cubic inches	16.39	Cubic centimeters
Cubic yards	0.765	Cubic meters
Cubic yards	21.7	Bushels
Cubic yards	27.0	Cubic feet
Cubic yards	202.0	Gallons (fluid)
Cubic yards	807.9	Quarts (fluid)
Cubic yards	1,620	Pints (fluid)
Cubic yards	7,646	Liters
Cubic yards	46,656	Cubic inches
Cups	0.25	Quarts (fluid)
Cups	0.5	Pints (fluid)
Cups	8.0	Ounces (fluid)
Cups	16.0	Tablespoons
Cups	48.0	Teaspoons
Cups	236.5	Milliliters
Feet	0.3048	Meters
Feet	0.3333	Yards
Feet	12.0	Inches
Feet	30.48	Centimeters
Feet per minute	0.01136	Miles per hour
Feet per minute	0.01667	Feet per second
Feet per minute	0.01829	Kilometers per hour
Feet per minute	0.3048	Meters per minute
Feet per minute	0.3333	Yards per minute
Feet per minute	60.0	Feet per hour

Appendix 5. Convenient Conversion Factors

Multiply...	**By...**	**To get...**
Gallons (dry)	269.0	Cubic inches (dry)
Gallons (fluid)	0.00378	Cubic meters
Gallons (fluid)	0.1337	Cubic feet
Gallons (fluid)	3.785	Liters
Gallons (fluid)	4.0	Quarts (fluid)
Gallons (fluid)	8.0	Pints (fluid)
Gallons (fluid)	8.337	Pounds
Gallons (fluid)	128.0	Ounces (fluid)
Gallons (fluid)	3,785	Cubic centimeters
Gallons of water	3.785	Kilograms
Gallons of water	8.345	Pounds of water
Gallons of water	3,785	Grams
Grains	0.0648	Grams
Grams	0.001	Kilograms
Grams	0.0022	Pounds
Grams	0.0353	Ounces
Grams	15.53	Grains
Grams	1,000.	Milligrams
Grams per liter	10.0	Percent
Grams per liter	1,000.	Parts per million
Hectares	2.47	Acres
Hectares	10,000.	Square meters
Hectares	11,950	Square yards
Hectares	107,600	Square feet
Inches	0.0254	Meters
Inches	0.0278	Yards
Inches	0.0833	Feet
Inches	2.54	Centimeters
Kilograms	0.0011	Tons
Kilograms	2.205	Pounds
Kilograms	35.28	Ounces
Kilograms	1,000.	Grams
Kilometers	0.6214	Miles
Kilometers	1,000.0	Meters
Kilometers	1,093.	Yards
Kilometers	3,281.	Feet
Kilometers per hour	0.6214	Miles per hour
Kilometers per hour	16.67	Meters per minute

Appendix 5. Convenient Conversion Factors

Multiply...	**By...**	**To get...**
Kilometers per hour	18.23	Yards per minute
Kilometers per hour	54.68	Feet per minute
Liters	0.001	Cubic meters
Liters	0.0353	Cubic feet
Liters	0.2642	Gallons (fluid)
Liters	1.0	Kilograms of water
Liters	1.057	Quarts (fluid)
Liters	2.113	Pints (fluid)
Liters	33.81	Ounces (fluid)
Liters	61.02	Cubic inches
Liters	1,000.	Cubic centimeters
Liters	1,000.	Grams of water
Meters	0.001	Kilometers
Meters	1.094	Yards
Meters	3.281	Feet
Meters	39.37	Inches
Meters	100.0	Centimeters
Meters	1,000.	Millimeters
Metric tons	1.1	Tons (U.S.)
Metric tons	1,000.	Kilograms
Metric tons	2,205.	Pounds
Metric tons	1,000,000.	Grams
Miles	1.609	Kilometers
Miles	1,609.	Meters
Miles	1,760.	Yards
Miles	5,280.	Feet
Miles per hour	1.467	Feet per second
Miles per hour	1.609	Kilometers per hour
Miles per hour	26.82	Meters per minute
Miles per hour	29.33	Yards per minute
Miles per hour	88.0	Feet per minute
Miles per minute	26.82	Meters per second
Miles per minute	29.33	Yards per second
Miles per minute	88.0	Feet per second
Milliliters	0.00105	Quarts (fluid)
Milliliters	0.0021	Pints (fluid)
Milliliters	0.0042	Cups (fluid)
Milliliters	0.0338	Ounces (fluid)

Appendix 5. Convenient Conversion Factors

Multiply...	**By...**	**To get...**
Milliliters	0.0676	Tablespoons
Mililiters	0.2029	Teaspoons
Milliliters	1.0	Cubic centimeters of water
Milliliters	1.0	Grams of water
Ounces (dry)	0.0625	Pounds
Ounces (dry)	28.35	Grams
Ounces (dry)	437.5	Grains
Ounces (fluid)	0.00781	Gallons (fluid)
Ounces (fluid)	0.03125	Quarts (fluid)
Ounces (fluid)	0.0625	Pints (fluid)
Ounces (fluid)	0.125	Cups (fluid)
Ounces (fluid)	1.805	Cubic inches
Ounces (fluid)	2.0	Tablespoons
Ounces (fluid)	6.0	Teaspoons
Ounces (fluid)	29.57	Milliliters
Parts per million (ppm)	0.0001	Percent
Parts per million	0.001	Liters per cubic meter
Parts per million	0.001	Grams per liter
Parts per million	0.001	Milliliters per liter
Parts per million	0.013	Ounces per 100 gallons of water
Parts per million	0.0584	Grains per US gallon
Parts per million	0.330	Gallons per acre-foot of water
Parts per million	1.0	Milligrams per liter
Parts per million	1.0	Milligrams per kilogram
Parts per million	1.0	Milliliters per cubic meter
Parts per million	2.72	Pounds per acre-foot of water
Parts per million	8.35	Pounds per million gallons
Percent (%)	1.33	Ounces (dry) per gallon of water
Percent	8.34	Pounds per 100 gallons of water
Percent	10.00	Grams per kilogram
Percent	10.00	Grams per liter
Percent	10,000.	Parts per million
Pints (dry)	0.0156	Bushels
Pints (dry)	0.0625	Pecks
Pints (dry)	0.5	Quarts (dry)
Pints (dry)	33.6	Cubic inches
Pints (fluid)	0.125	Gallons (fluid)
Pints (fluid)	0.474	Liters

Appendix 5. Convenient Conversion Factors

Multiply...	**By...**	**To get...**
Pints (fluid)	0.5	Quarts (fluid)
Pints (fluid)	2.0	Cups
Pints (fluid)	16.0	Ounces (fluid)
Pints (fluid)	28.88	Cubic inches
Pounds	0.0005	Tons
Pounds	0.454	Kilograms
Pounds	16.0	Ounces
Pounds	453.6	Grams
Pounds	7,000.	Grains
Quarts (dry)	0.03125	Bushels
Quarts (dry)	0.0389	Cubic feet
Quarts (dry)	0.125	Pecks
Quarts (dry)	2.0	Pints (dry)
Quarts (dry)	67.20	Cubic inches
Quarts (fluid)	0.00094	Cubic meters
Quarts (fluid)	0.0012	Cubic yards
Quarts (fluid)	0.0334	Cubic feet (fluid)
Quarts (fluid)	0.25	Gallons (fluid)
Quarts (fluid)	0.946	Liters
Quarts (fluid)	2.0	Pints (fluid)
Quarts (fluid)	2.087	Pounds of water
Quarts (fluid)	4.0	Cups
Quarts (fluid)	32.0	Ounces (liquid)
Quarts (fluid)	57.75	Cubic inches
Square feet	0.000009	Hectares
Square feet	0.000023	Acres
Square feet	0.0929	Square meters
Square feet	0.111	Square yards
Square feet	144.0	Square inches
Square miles	2.590	Square kilometers
Square miles	259.	Hectares
Square miles	640.	Acres
Square miles	2,590,000	Square meters
Square miles	3,098,000	Square yards
Square miles	27,880,000	Square feet
Square yards	0.00008	Hectares
Square yards	0.00021	Acres
Square yards	0.8361	Square meters

Appendix 5. Convenient Conversion Factors

Multiply...	By...	To get...
Square yards	9.0	Square feet
Square yards	1,296.	Square inches
Tablespoons	0.0625	Cups
Tablespoons	0.5	Ounces (fluid)
Tablespoons	3.	Teaspoons
Tablespoons	15.0	Milliliters
Teaspoons	0.0208	Cups
Teaspoons	0.167	Ounces (fluid)
Teaspoons	0.333	Tablespoons (fluid)
Teaspoons	5.0	Milliliters
Tons	0.907	Metric ton
Tons	907.	Kilograms
Tons	2,000.	Pounds
Tons	32,000.	Ounces (dry)
Yards	0.000568	Miles
Yards	0.914	Meters
Yards	3.	Feet
Yards	36.	Inches