

Florida Crop/Pest Management Profile: Aquatic Weeds¹

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Aquatic Weed Facts

- Florida has 1.5 million acres of lakes and rivers. There are approximately 7,700 ponds and lakes and 1,700 rivers and streams. There are about 450 public lakes and rivers that total 1.3 million acres (i.e., 87 percent of water acreage is public) (1).
- It is estimated that \$1.5 billion in annual revenues are generated from freshwater fishing and wildlife observation (1).
- In 2005, invasive, non-native plants infested 96 percent of the 450 public waterways. Floating plants (water hyacinth, water lettuce) covered 14,400 acres in the 271 water bodies in which they were detected. Hydrilla covered 20,409 acres in the state in 288 water bodies. Nine other invasive plants infested about 17,600 acres and 87 percent of public water bodies (1).
- In addition to localized infestations of certain weedy species, Florida must deal with tussocks, which are freely drifting small islands comprised of many plant species. Florida spent nearly as much for tussock management as hydrilla management in 2005 with 7,110 acres of drifting tussocks being destroyed (1).
- Approximately \$22.5 million was spent in 2005 for aquatic plant control in public waters (44 percent hydrilla, 38 percent tussocks, 12 percent floating plants, and 6 percent other plants (primarily torpedograss). This represents about 80 percent of the aquatic treatments that occur in all of Florida (1).
- Although there are five water management districts in Florida, the majority of resources are spent by three, the St. Johns Water Management District, the Southwest Florida Water Management District, and the South Florida Water Management District. They are responsible for more than 95 percent of the funding directed toward aquatic plant management (1).
- The majority of funding for public aquatic plant control is from state sources. Federal agencies (Army Corps of Engineers) contribute to control projects on the St. Johns River and Lake Okeechobee. Local funding is minimal (1).

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Infestation Regions

Aquatic weeds are not distributed uniformly throughout the state. Freezing temperatures are generally found north of Orlando in any given year. Consequently, the majority of floating aquatic plant management resources are spent south of Interstate 4, which extends from Tampa to Daytona Beach. While the freezes enhance floating plant management in the northern part of the state, floating plants are still intensively managed on the St. Johns River system and as far north as Lake Seminole. Water bodies of significant concern include the St. Johns and Kissimmee River systems and Lake Okeechobee (1).

Within any one region there are differences between infestation level, depending largely on water body size and depth. Some of the large lakes are fairly shallow and nutrient rich, and they can support significant hydrilla populations. Some lakes have significant algae blooms that inhibit submersed plant colonization. Finally, some lakes are either quite deep or nutrient poor (mainly northeastern Florida) and they do not tend to support large submersed plant infestations. Floating plants such as water hyacinth or water lettuce can cover entire water surfaces if not managed. These large lakes are usually public use water bodies and management is agency funded. Small private ponds and lakes are usually treated by the owner(s), either directly or through contract applicators. Private aquatic plant treatment is estimated to comprise about 20 percent of the aquatic applications in Florida on an area basis (2).

Management Practices

By Florida statute, aquatic plant management objectives are to keep the invasive plant levels at the lowest feasible level. Florida aquatic plant management takes many forms, largely depending on the species of plant, size of the infestation, and the area of the water body. Methods of weed control include the increase (or reduction) of water fertility, drawdown, mechanical control, biological control, or chemical control (3). For chemical control on small water bodies, pesticides may be dispersed from the shoreline, from a floating device, or from a boat. Manifold booms may also be mounted on trucks driving near the shore edge.

Boats (airboat or conventional) and/or helicopters are often employed when large expanses must be treated chemically. Handgun sprayers, granule spreaders, and weighted trailing hoses are used to apply herbicides from boats, depending on whether the vegetation is floating or submersed. Helicopters either apply through boom (microfoil) sprayers or apply granules (4).

Plots are evaluated both before and after treatment. Initial surveys must be conducted to examine the extent of invasion. If chemicals are used, fathometer tracings can give bottom contour maps which are used to determine the average depth of treatment as well as acreage. These values are used to determine how much material to apply to a site, as well as how much it will cost or how many fish would need to be stocked for biocontrol. Often, chemical treatments to large areas are split up (e.g. one-third treatment) to avoid dissolved oxygen depletion during vegetation decay (4).

There are also different management schemes. Maintenance control describes the process of making scheduled, or as needed, applications at locations known to harbor undesirable aquatic plants. Complaint management refers to control strategies used when the situation becomes untenable. Maintenance control is more proactive and ecologically sound, as heavy loads of decaying vegetation associated with complaint management treatments may lead to oxygen depletion.

Management Activities

Mechanical harvesting of aquatic weeds requires one person to operate the harvester and at least one person to deal with trucking the materials to an approved site. In manatee aggregation areas a spotter is also required on the harvester. On a good day, the mechanical harvester is able to process about 5 acres of aquatic vegetation per day (2).

Although none of the herbicides registered for aquatic use in Florida are restricted, many aquatic applicators maintain licensure for contractual reasons. Many applicators are employed by water management districts and others serve as contractors to these districts. Applicators can cover between 10 and 20 acres a day depending on application type.

Granules are the quickest to apply, followed by boom, handgun, and weighted trailing hose applications (2).

For shoreline applications, one person is sufficient to broadcast granules or floating dispensers.

For trucks, boats, and helicopters, often one person loads and mixes while the other applies. Lake water is often used to make up the treatment solutions. For some herbicides (e.g. diquat, glyphosate), care must be taken not to use turbid or overly-hard water for this process.

Weeds

Almost 100 percent of Florida's public waters inventoried in 2005 contained one or more exotic (non-native) plants. The Florida Exotic Pest Plant Council lists 12 of the 24 non-native aquatic plants found in Florida's public waters among the 65 Category I invasive plants reported in Florida. Category I plants invade or disrupt native plant communities via rapid growth, multiple reproductive methods, wide dispersal/high survival, environmental tolerance, and resistance to management. These Category I invasive plants were reported in 96 percent of the public waters inventoried during 2005 and impacted 110,761 acres (80 percent or 88,861 acres are impacted by hydrilla standing crop and/or tubers) (1).

Hydrilla, water hyacinth, water lettuce, and torpedograss are the four most troublesome exotic aquatic weeds in Florida, roughly in order of importance. Other Category I plants found in Florida public waters include aquatic nightshade, giant salvinia, hygrophila, napiergrass, paragrass, water spinach, West Indian marshgrass, and wild taro. Additionally, plant islands or tussocks, comprised of many types of plants, become mobile during water-level-altering events, and these mobile masses can impact drainage structures, road infrastructure, and boat navigation (1,3,4). In private waters, owners sometimes try to control algae, which can make water bodies unattractive for swimmers or boaters. Several algae (*Cylindrospermopsis* and *Microcystis*) have formed significant blooms in recent years; *Microcystis* has caused health alerts in the St. Johns River. *Lyngbya* is also a concern in

spring-fed rivers. Aquarium fish producers have problems with the macrophytic algae *Chara*, which invades fish ponds. Filamentous forms of algae are common problems in small ponds and some spring-fed canals (2).

HYDRILLA. Introduced into Florida waters in the 1950s, this aquarium trade plant forms submersed and surface mats with plants emerging from as deep as 35 feet. It is distributed statewide, and is currently under maintenance control, with 20,409 acres surveyed in 2005. Plants can grow up to four inches a day in Florida waters, and with 80 percent of its biomass in the upper two feet of water column, the plants block sunlight for native plants and impede air exchange. It disperses by fragments, buds, and runners, and also forms underground tubers (estimated to cover 88,900 acre in 2005) which can lie dormant for several years (1,3).

Hydrilla has been biologically controlled using sterile grass carp, which feed on the plant. There has been little insect biocontrol success. Hydrilla is also machine harvested or hand pulled where chemicals are not effective or desired. In terms of chemical management, fluridone had been used as the general standard in large scale applications, while endothall is more appropriate for treating smaller areas. The cost-effective technique of using low concentrations of fluridone over long periods as a method for selective phytotoxicity is no longer effective in many areas due to the presence of fluridone-tolerant hydrilla in several of the large lake systems (1,5).

WATER HYACINTH. One of the most troublesome floating aquatic plants, water hyacinth has been in Florida waters since the 1880s. The plant reproduces by producing daughter plants but can also produce seeds. Populations double in as little as two weeks. It is currently under maintenance control, with 8,302 acres reported as of 2005 (1,3).

Water hyacinth expansion has been curtailed by several weevils and a moth larvae, but large expanses are still known to cover water bodies if not managed by other means. Diquat and 2,4-D are most commonly used to chemically control hyacinth. Occasionally, glyphosate, triclopyr, and/or copper are used. Mechanical harvesters or shredders may be used around flood control structures when time is

critical, and pioneer plants may be hand-picked in some waterbodies (1).

WATER LETTUCE. Water lettuce is another floating aquatic plant that impacts Florida waters. Growth rate is similar to water hyacinth, with populations doubling in as little as two weeks. Water lettuce is currently under maintenance control, with 6,097 acres reported as of 2005 (1,3).

Several insects have been released to control water lettuce, but are considered ineffective at this point. Diquat is the primary chemical used to control water lettuce, but such heavy reliance on a single compound is contrary to resistance management strategies. Several terrestrial and aquatic weeds are known to be resistant to paraquat/diquat, so this phenomenon has been observed in other plants. Drawdowns are sometimes used to control water lettuce, and it may be mechanically harvested around flood control structures (1,5).

TORPEDOGRASS. This emergent grass can live on dry land as well as in water six feet deep. It spreads over water surfaces in thick mats which can stop navigation and water movement. It has extensive rhizome reserves that allow it to grow back after treatment. It also reproduces by seed. Torpedograss is currently under complaint management, with 14,506 acres reported as of 2005 (1).

Several strategies, including drawdown coupled with burning or discing, have been employed in managing torpedograss. There are no biological controls that have been field-released. Glyphosate or imazapyr are typically used to manage torpedograss (1,3).

GIANT SALVINIA. Giant salvinia is from South America, and was brought to the U.S. by horticulturists. It is found floating on quiescent waters of central and southern Florida. The plant clogs waterways and grows rapidly, depleting oxygen in the water. It is considered one of the world's worst weeds. This plant is under an early detection and rapid response eradication program to avoid establishment in the state. Giant salvinia can be chemically managed with diquat, glyphosate, or fluridone. A South American weevil is also effective

in limiting the growth and reproduction of this plant (1).

HYGROPHILA. Hygrophila is another escaped aquarium plant that has been found in Florida waters since the 1940s. It can grow as both a submersed (from as deep as 15 feet) or emergent plant. Fragile stems root at each leaf node allowing rapid dispersal and establishment. It too blocks sunlight for native plants and impedes air exchange as well as hindering navigation and flood control. It is found more commonly in central and southern Florida in high-flow areas such as flood control canals, and it is extremely expensive and difficult to control. Hygrophila is currently under complaint management, with 144 acres reported as of 2005 (1).

Biological control has been accomplished using extremely high rates of sterile grass carp in canal systems. Chemicals in general provide marginal control. Floating mats are harvested mechanically or by hand pulling or raking (1).

PARAGRASS. Similar to torpedograss, paragrass is an old world grass that grows along shorelines and forms floating mats. A very tall grass (up to 15 feet), it spreads by seed and also by stem joints which root when the plant falls over. Paragrass was originally brought into the state as a forage crop. Paragrass is currently under complaint management, with 235 acres reported as of 2005 (1,3).

Several strategies, including drawdown coupled with burning, have been employed in managing paragrass. There are no biological controls that have been field-released. Glyphosate is typically used to manage paragrass (1).

NAPIERGRASS. Although not technically an aquatic plant, napiergrass is another old world grass that grows along shorelines and forms floating mats. Napiergrass grows up to 12 feet, and it propagates vegetatively from root crown divisions or rhizome and stem fragments, especially after mechanical control such as tilling. Like paragrass and torpedograss, napiergrass was originally brought into the state as a forage crop. Napiergrass is currently under complaint management, with 384 acres reported as of 2005 (1).

Several strategies, including drawdown coupled with burning, have been employed in managing napiergrass. There are no biological controls that have been assessed. Glyphosate is typically used to manage napiergrass (1).

WEST INDIAN MARSH GRASS. West Indian marsh grass has origins in the Americas and the Caribbean and it has been known in the state since the 1970s. The grass forms dense monocultures in marshes and along shorelines and it also displaces native plants because of its broader tolerance to wet and dry periods. West Indian marsh grass is currently under maintenance control, with 359 acres reported as of 2005 (1).

West Indian marsh grass is difficult to control when growing among native grasses because they are susceptible to the same control methods. There are no biological control methods and mechanical control can rarely be practiced due to the low water levels present in marsh settings. Typically, fire and glyphosate are two methods which can be used alone or in conjunction to control this grass (1).

WILD TARO. Taro is an Asian food crop which has been cultivated in Florida, with great expansion over the last 25 years, although it has been present in the state since the early 1900s. The plant displaces native plants along shaded shorelines and in wetlands. It is established statewide, and effort is made to eradicate new colonies when found. There were 597 acres of the plant in half that many water bodies during 2005 (1).

There is no biological control of taro, and hand pulling must be done with caution, as oxalic acid in the plant is irritating to the skin. Chemically, a mixture of 2,4-D and silicone surfactant applied several times is most efficacious, although triclopyr may also be used (1).

ALGAE. Although there are several divisions of algae that are present in either fresh or saltwater habitats in Florida, private control activities are largely directed at blue-green algae such as *Lyngbya*, *Anabaena*, *Microcystis*, and *Aphanizomenon*. These plants can form floating mats that collect at the surface. This occurs most frequently in small bodies of water (6). Algae is not actively controlled by

public funds (2). Private applicators often use copper (sulfate or complexed) for algae control, but endothall and diquat are also available and active against certain algae (15).

Control

Non-chemical

An integrated aquatic vegetation management program involves the consideration of all options over time including cultural, mechanical, and biological methods. Each of these has advantages and sometimes drawbacks that must be considered when utilizing them in aquatic systems.

Cultural control is reflected largely in regulatory programs. Under the Federal Noxious Weed Act of 1974, the U.S. Department of Agriculture is given the responsibility to designate certain foreign weeds as noxious and prevent the entry of these weeds into the states. A permit from the USDA is required to import plants or plant products into the country, and another permit is required to move all designated noxious weeds into and throughout the U.S. Florida has also passed the Florida Aquatic Weed Control Act and the Nonindigenous Aquatic Plant Control Act, which together direct, guide, and fund research as well as establish lists of prohibited aquatic plants (4). Another form of cultural control is drawdown, wherein plants are desiccated when water recedes. Sometimes burning (or discing/herbicide treatment) is combined with drawdown to achieve a higher amount of control (3).

Mechanical control is accomplished primarily by using an aquatic harvester. Harvesters vary in size from simple hydraulic sickle-bar cutters powered by a five horsepower engine mounted on the front of a pontoon boat to 10,000-pound capacity harvesters that convey cut vegetation on board for transport to shoreline dumping sites. Because of their cost and issues associated with launching and using harvesters in small water bodies, weed control via mechanical harvesting would be exorbitant for the private pond owner (3). A second type of mechanical control addresses water movement as a tool for aquatic plant control. These systems generally circulate water laterally to reduce both blue-green algae and floating plants. Aeration may also reduce algal populations.

Since aquatic habitats are less disturbed than agricultural plantings, the potential to manage invasive aquatic plants with biological agents is much higher. The major aquatic weed problems in Florida are caused by non-native plants that were introduced from foreign lands. A substantial amount of funding has gone into programs that try to find specific biocontrol agents for aquatic weeds. The alligatorweed flea beetle, water hyacinth weevil, water hyacinth mite, and fungi have shown to negatively affect the health of aquatic plants. In contrast, non-specific feeding can be achieved by stocking sterile (triploid) grass carp. This fish has provided excellent control of submersed plants, filamentous algae, and small floating plants such as duckweed. There are three possible management strategies utilizing sterile grass carp. The first is complete vegetation removal within one to two years with heavy stocking rate. Once stocked, carp are extremely difficult to remove and control can last for 15 to 20 years. The second strategy is winter stocking, before the spring growth of weed begins, using fewer fish to maintain a lesser amount of vegetation in the system and increasing the carp population as needed. The third scenario is integration using herbicide treatments to obtain desired levels quickly and stocking grass carp to this level (3).

Chemical

Chemical control of aquatic plants is the most common method of weed control. Chemical weed control has certain advantages not found in other methods. Herbicides may be directly applied to undesirable vegetation, offering a high degree of selectivity and leaving desirable levels of vegetation in some cases. 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. Use of herbicides under a maintenance program usually reduces the cost of weed control (3).

Until recently, only herbicide products with the active ingredients 2,4-D, copper, diquat, endothall, fluridone, and glyphosate have been registered for aquatic use. Four herbicides, carfentrazone, imazapyr, hydrogen peroxide, and triclopyr have

been registered in the last five years, while four others (imazamox, penoxsulam, flumioxazin, and bispyribac) are currently under Section 18, Special Local Needs, or experimental use permits for hydrilla or aquatic weeds in general (5). It is important to note that typically, the cost of the herbicide accounts for approximately 30 percent of the cost of treatment for floating plants, while the ratio is just the opposite (70 percent of the cost of the treatment is for herbicide) for submersed plant treatments (2).

2,4-D. The herbicide 2,4-D has been reregistered for use in aquatics, and it is selective for non-grass plants. The liquid formulation of 2,4-D provides excellent control of water hyacinth, but is not recommended for water lettuce (15). Diquat (which is efficacious on water lettuce) is often mixed with 2,4-D to treat mixes of these two floating plants. The granular form of 2,4-D provides control (15) of submersed and emersed plants such as variable leaf milfoil, fragrant waterlily, and spatterdock and good control of others because the granules are able to penetrate into the hydrosol of the waterbody.

In 2004-2005, 28,549 acres of floating plants were treated at a cost of \$2,812,231 (\$98.50/acre)(1). At a cost of \$10.00 per pound of 2,4-D, a maximum labeled treatment for water hyacinth (1.75 lb ae/A) would cost approximately twenty dollars (7). Based on percentage of water publicly treated and formulations (liquid and granular), an estimate for use of 2,4-D in Florida aquatic habitats for the 2004-2005 period is approximately 150,000 pounds of active ingredient (1,2,8,9).

COPPER. Copper has a long history of use in aquatic habitat. However, in Florida, this use has been curtailed in public applications. Specifically, since the early 1990s, the state has decided that no funding will be spent on copper applications in public waterways if a suitable alternative product is available. Copper is not allowed for use in designated manatee aggregation sites. Like 2,4-D, copper has recently gone through the reregistration process and has been approved for use in aquatic sites. Copper has fair to good activity on algal species as well as a few floating and submersed weeds (15). Algal control of private water bodies is the major aquatic use of copper in the state. Copper is also mixed with

diquat to treat difficult-to-control species such as hydrilla.

On a national level, copper use as an algaecide captured 95 percent of the total market in 2004. There are many forms of copper registered for aquatic uses, but sales are evenly split between copper sulfate and copper complexes (EDTA, ethanolamine, triethanolamine, citrate, gluconate, carbonate). The use of complexes extends the life of soluble copper, but also increases the price. Granular formulations (to increase ease of application and reduce exposure) also increases the treatment price. Average costs for copper sulfate, liquid complexes, and granular complexes are approximately \$2, \$15, and \$100 an acre foot (one acre of water, one-foot deep), respectively (9).

On a national basis, approximately 10 million pounds of elemental copper in the form of copper sulfate pentahydrate are applied each year solely for algal and aquatic weed control. Approximately 300,000 pounds of elemental copper in various forms of complexed copper compounds are applied annually for these same pests (10). In the Southeast, target treatment concentrations range between 0.2 to 0.5 PPM elemental copper, and between 10 and 24 applications are made annually (11). It is estimated that copper use in private Florida waters accounts for no more than a million pounds of elemental copper annually.

DIQUAT. Diquat is a non-selective contact herbicide that provides control of a number of floating and submersed aquatic plants (15). Additionally, diquat is often mixed with 2,4-D or copper to increase the efficacy of the treatment. Recently, a diquat-resistant population of duckweed was identified in Florida (12).

In 2004-2005, 28,549 acres of floating plants were treated at a cost of \$2,812,231 (\$98.50/acre)(1). While most of this acreage would be sprayed with 2,4-D, a portion of this acreage would be sprayed with diquat or a mixture of diquat and 2,4-D. Diquat would also be used on a portion of the submersed plants which are treated. At a cost of \$67 per pound, the average cost per surface acre (2 pounds) for diquat is \$134. For submersed plant control, this price can double. Diquat is likely used for about 20

percent of the treated floating and submersed plants. Based on percentage of water publicly treated, an estimate for use of diquat in Florida aquatic habitats for the 2004-2005 period is approximately 30,000 pounds of active ingredient (1,2,9).

ENDOTHALL. Endothall, together with fluridone, comprise the tandem that has been used to treat hydrilla in the state for well over two decades. Endothall has differing activity based on its formulation, with the alkylamine salt providing fair to excellent control on submersed plants as well as some algae, while the potassium salt lacks this efficacy on algae (15). Because endothall kills plants quicker than fluridone, it is often employed in situations (e.g. canals) where water is moving (approximately 40 percent of treatments). Water cannot be moving too quickly or ineffective treatment will result. Contact time with the weeds should be no less than two hours.

In 2004-2005, 16,575 acres of hydrilla were treated at a cost of \$9,937,412 (\$600/acre)(1). Additionally, there were other submerged plants treated with endothall and treated privately. At a cost of \$15.50 per pound of endothall acid, a maximum labeled treatment for an acre of hydrilla in a four foot column of water (15 pounds of endothall acid) would cost approximately \$250 (9,13). Based on percentage of water publicly and privately treated and an average depth of four feet, an estimate for use of endothall in Florida aquatic habitats for the 2004-2005 period is approximately 220,000 pounds of active ingredient (1,2,9).

FLURIDONE. As stated above, fluridone and endothall have been used to treat hydrilla in the state for well over two decades. Years of research with fluridone established a long period/low dose treatment regime that has worked well at selectively removing hydrilla while preserving other native plants. Fluridone works by inhibiting carotenoid formation in the affected plants, but this process takes time (recommended contact time 45 days with maximum effect up to 90 days). Fluridone has excellent efficacy on hydrilla and several other problematic aquatic weeds, and fair to good control of others (15). Hydrilla has developed resistance to fluridone in many of the large central Florida lakes

and the full extent of the resistance is currently unknown.

In 2004-2005, 16,575 acres of hydrilla were treated at a cost of \$9,937,412 (\$600/acre)(1). At a cost of \$340 per pound of fluridone, a maximum labeled treatment for an acre of hydrilla in a four foot column of water (1 pound of fluridone) would cost approximately \$340 (9,14). Based on percentage of water publicly treated and an average depth of four feet, an estimate for use of fluridone in Florida aquatic habitats for the 2004-2005 period is approximately 10,000 pounds of active ingredient (1,2,9). However, publicly-purchased fluridone was not used during the 2003-2005 period due to the natural control and adverse water conditions caused by hurricanes that impacted the state (1).

GLYPHOSATE. Glyphosate is a non-selective herbicide, and it is used to manage such species as cattail and torpedograss (15). In 2004-2005, approximately 5,000 acres of grasses were treated at a cost of approximately \$600,000 (\$120/acre)(1). At a cost of \$12 per pound of glyphosate, a maximum labeled treatment for an acre of torpedograss (3.75 pounds of glyphosate acid) would cost \$45 (9,14). Based on percentage of water publicly and privately treated, an estimate for use of glyphosate in Florida aquatic habitats for the 2004-2005 period is approximately 25,000 pounds of active ingredient (1,2,9).

Key Contacts

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