SOUTHERN REGIONAL AQUACULTURE CENTER

SRAC Publication No. 360
April 2014
Revision

Aquatic Weed Management: Control Methods

Lyn A. Gettys[1]

Water is a valuable resource that we rely on for drinking, irrigation, recreation, and aquaculture. Mixed populations of native aquatic plants are a necessary part of natural aquatic environments. They provide structure, habitat, and food for fish, waterfowl, and other wildlife. Plants also remove phosphorus, nitrogen, and other elements from the water column. The southeastern United States has a mild climate that provides an ideal habitat for many organisms, including aquatic plants. Because our waters are typically warm and nutrient-rich, aquatic plants flourish and grow quickly, which can result in excessive growth. For example, a single plant of water hyacinth *(Eichhornia crassipes)* (Fig. 1) can grow to cover an entire surface acre of water if conditions are optimal. Pond management can be difficult if plant growth is excessive because plants may limit fish access to feed, cause problems with seining, and introduce or harbor snails, parasites, and other aquatic fauna. Non-native aquatic plants can be introduced to aquatic systems in a number of ways, including transport by animals, water currents, or wind. But most problematic plants are introduced—intentionally or accidentally—as a result of human activities.

Many aquatic weed problems in the U.S. are the result of intentional introduction. For example, the floating weed water hyacinth was reportedly introduced in the U.S. at the Southern States Cotton Expo in New Orleans in the 1880s, where visitors were given water hyacinth plants as souvenirs. Local legend states that a Florida resident brought plants back to his water garden near the

Figure 1. Water hyacinth was introduced to the U.S. in the 1880s and is one of the world's worst weeds.

St. Johns River and tossed his extra plants into the river as his water garden became overgrown. It took less than a decade for the St. Johns to become so clogged with water hyacinth that navigation was impossible. This floating weed causes other problems as well. Dense populations reduce the penetration of light and oxygen through the water column, and mosquitoes find breeding grounds in the stagnant water held by the crown or rosette of the plant. Water hyacinth is arguably the nation's worst floating weed, and managers throughout the southeastern U.S. continue to battle this noxious species.

The submersed weed hydrilla *(Hydrilla verticillata)* (Fig. 2), which has been called the "world's worst weed," was also introduced intentionally as an aquarium plant in the 1950s. Historical accounts suggest that some aquar-

[1]University of Florida IFAS

Figure 2. Hydrilla was introduced to the U.S. via the aquarium industry and is one of the world's worst weeds.

ium plant dealers cultivated hydrilla in canals and waters near their nurseries to have easy access to plant material for their customers. Hydrilla is constantly being re-introduced as contaminated boat trailers are moved from one body of water to another and as hobbyists dispose of extra aquarium plants by dumping them in the nearest body of water. Hydrilla can produce roots and new plants from extremely small fragments, so other vectors for introduction include birds and other wildlife and recreational equipment such as boats, jetskis, and trailers. This noxious weed causes a number of problems in aquatic ecosystems; it crowds out native plants to form monocultures, which are poor habitat for aquatic wildlife and fish. Dense plant growth also traps heat, which increases the temperature of surface water and depletes dissolved oxygen, resulting in conditions that can harm fish. Hydrilla also obstructs water flow, which can clog irrigation systems and cause flooding during tropical storms, hurricanes, and other severe weather. Hydrilla hinders the recreational uses of water as well. Outboard boat motors quickly become clogged and strangled with weeds; fishing lines are snagged within moments of being cast; and swimmers have reportedly drowned after becoming entangled in hydrilla.

Water hyacinth and hydrilla quickly become invasive almost everywhere they are introduced, but they are not the only aquatic plants that cause problems in natural systems, reservoirs, aquaculture ponds, and canals in the southeastern U.S. Crested floatingheart *(Nymphoides cristata)* (Fig. 3), which was introduced as an ornamental water garden plant, is invading lakes and reservoirs in the region. Populations of giant salvinia *(Salvinia molesta)* (Fig. 4), which was also introduced through the aquarium and water garden industries, now forms dense floating mats with consequences similar to those described for water hyacinth. Crested floatingheart and giant salvinia likely escaped cultivation rather than being introduced

Figure 3. Floating-leaved emergent plants. Upper left: crested floating-heart (invasive). Lower left: fragrant white waterlily (native). Upper right: spatterdock (native). Lower right: American lotus (native).

Figure 4. Floating plants. Left: giant salvinia (invasive). Upper right: duckweed (native). Lower right: frog's-bit (native).

intentionally to aquatic systems. The accidental introduction of invasive plants happens quite often. In addition to escaping cultivation, weeds can "hitchhike" as contaminants when desirable native plants are transported and sold. Misidentification is rampant, particularly among hobbyists. Before planting native aquatic species, it is critically important to inspect plant material to verify the identity of the plants being received and to avoid planting exotic hitchhikers.

Because invasive aquatic weeds can have such harmful effects, it is imperative that they be controlled.

Weed identification

Aquatic plants can be grouped into two major classes: algae and macrophytes.

Algae

Algae are the base of the food chain and the primary food source for small aquatic organisms. It is estimated that algae also provide as much as half of the planet's oxygen through the process of photosynthesis, or the conversion of sunlight and carbon dioxide to energy and oxygen. There are many forms and species of algae, ranging from microscopic planktonic algae to filamentous algae to "branched" or stonewort algae *(Chara* and *Nitella)* that look like macrophytes. *Planktonic algae,* also called phytoplankton, are single-celled organisms or groups of microscopic organisms that are suspended in the water column and give water a pea-green color. Some species of planktonic algae may also cause an "off flavor" in fish or drinking water. *Filamentous algae* form long strings that clump together to form mats, which often develop on the bottom of a pond and float to the water surface when the population becomes dense. *"Branched" algae* are most commonly called macrophytic, stonewort, or "Chara-Nitella" algae because these are the genera that make up this group; they are anchored in the sediment and appear to be branched, but they lack roots and true branches (Fig. 5).

Figure 5. Algae. Upper: planktonic algae. Center: filamentous algae. Lower: Macrophytic algae.

Aquatic macrophytes

Aquatic macrophytes can be divided into four main groups based on their growth habits—floating, shoreline emergent, floating-leaved emergent, and submersed. *Floating plants* (Fig. 4) have roots that dangle in the water column, with most or all of the plant's growth floating on the surface of the water. Floating plants come in many shapes and sizes, ranging from tiny native duckweeds *(Lemna* sp.) and larger invasive giant salvinia to the medium-sized native frog's-bit *(Limnobium spongia)* and the much larger and invasive water hyacinth.

Emergent plants are rooted in the sediment, but some or most of the plant's growth is above the waterline. *Shoreline* or *littoral zone emergent plants* are usually found in the transitional zone between deeper water (more than 3 feet [1 m] deep) and the moist shoreline. Emergent shoreline plants help to stabilize the shoreline and prevent erosion while providing food, cover, and nesting grounds for animals that live near water. Native emergent shoreline species include pickerelweed *(Pontederia cordata),* duck potato *(Sagittaria latifolia),* and rushes *(Eleocharis, Scirpus,* and *Schoenoplectus* sp.) (Fig. 6). Emer-

Figure 6. Native shoreline emergent plants. Left: pickerelweed. Center: duck potato. Right: Gulf Coast spikerush.

Figure 7. Invasive shoreline emergent plants. Upper: flowering rush. Center: primrosewillow. Lower: wild taro.

gent shoreline invaders include flowering rush *(Butomus umbellatus),* primrose-willow *(Ludwigia peruviana),* and wild taro *(Colocasia esculenta)* (Fig. 7).

Like emergent shoreline plants, *floating-leaved emergent plants* are rooted in the sediment and some of the plant's leaves and flowers float on the surface of the water. However, floating-leaved emergent plants are often found in deeper water (more than 3 feet [1 m] deep), and most of the plant's growth remains below the waterline. The petioles or leaf stalks of floating-leaved emergent plants provide structure to the underwater environment and the floating leaves create a shady spot for fish to rest and hide. Native floating-leaved emergent plants include fragrant white waterlily *(Nymphaea odorata),* spatterdock *(Nuphar lutea),* and American lotus *(Nelumbo lutea),* while floating-leaved emergent invaders include crested floatingheart and snowflakelily *(Nymphoides indica)* (Fig. 3).

Submersed plants are usually rooted in the sediment and all or most of the plant's growth occurs below the surface of the water. Submersed plants provide structure to the underwater habitat and also serve as a food source and spawning grounds for fish and other aquatic organisms. Native submersed species include eelgrass *(Vallisneria americana),* southern naiad *(Najas guadalupensis),* and Illinois pondweed *(Potamogeton illinoensis)* (Fig. 8), while submersed invaders include hydrilla, Eurasian watermilfoil *(Myriophyllum spicatum),* and curlyleaf pondweed *(Potamogeton crispus)* (Fig. 9).

Professional help with identification

In order to select the most effective weed control method, the invader must first be positively identified. The most common way to do this is to send high-resolu-

Figure 8. Native submersed plants. Upper: eelgrass. Center: southern naiad. Lower: Illinois pondweed.

Figure 9. Invasive submersed plants. Upper: Eurasian watermilfoil. Lower: curlyleaf pondweed.

tion digital photographs of the plant to your aquaculture or fisheries specialist or other trained individual (do not send live or pressed specimens unless the identifier requests them). Be sure to provide good, clear, in-focus images that will be useful for identification. Your photo collection should include a shot of the habitat where the plant occurs (from a distance to show scale and close up to show detail) and a portrait of the entire plant, both submersed and emergent plant parts. More detailed images are useful as well. Use a solid background (white, black, or gray) as a backdrop for detailed images. Place a ruler, pencil, or other object of known size in the frame to show size or scale. Detailed images should include:

Vegetative growth (Fig. 10)

- Leaves showing veins, arrangement/attachment to the stem, petiole (leaf stalk) attachment to the leaf and the stem, stipules (small appendages where the petiole attaches to the stem), and ligules (clasping

Figure 10. Vegetative plant parts. Clockwise from left: cut stem showing interior structure; runners and roots; tubers; leaf attachment and arrangement; rhizome.

region where the leaf attaches to the stem—common in grasses) if present.
- Stems (intact and cut to show whether the interior is solid or hollow). Also, make a note of anything unusual that may not show up well in photographs, including color, hairs, thorns, texture, glossiness, waxiness, smell, etc.
- Roots, rhizomes, runners, tubers or corms (wash off debris and sediment before photographing).

Reproductive structures (Fig. 11)

- Flowers, showing the entire flower, the interior of the flower, the peduncle (flower stalk), and the arrangement of flowers in a compound inflorescence.
- Fruits and seeds.

If possible, collect and press a specimen for reference. If the species has not been found in your area before, your local herbarium may ask you to submit a dried sample so they can voucher the plant and have a record of its presence.

Figure 11. Reproductive structures. Clockwise from upper left: flower and unripe seed pod; inflorescence; ripe seeds; capsule with seeds; flower size and position.

Weed control methods in aquatic systems

Exclusion

The most effective way to avoid invasion by exotic plants is through exclusion, or preventing them from entering uninfested aquatic systems. Make sure you plant only native plants that are free of exotic hitchhikers. Ensure that nobody dumps aquariums or water garden plants in your pond. Accidental transfer of aquatic weeds can be avoided if you thoroughly inspect and clean boats, trailers, seines, nets, and other equipment before using them in your pond. Prevent fertilizer runoff from entering your pond to reduce the nutrients that encourage the excessive growth of aquatic plants.

If your pond has been invaded and your weed has been positively identified, there are a number of techniques you can use to control it.

Cultural and physical control

Cultural and physical control methods (Fig. 12) can sometimes be used if they are appropriate for your situation. For example, some populations of algae can be reduced by aerating the pond (introducing oxygen to the bottom of the water column), adding alum to inactivate phosphorus in the water column, or using dyes or pond covers to reduce light penetration. However, these methods are most effective *before* serious algae blooms occur and have limited use once algae has taken over a pond. Submersed weeds can be managed by installing benthic barriers, which smother the weeds; these can be made from durable materials such as vinyl or plastic or from biodegradable materials such as burlap. Submersed weeds also can be controlled by lowering the water level (drawdown) and allowing the bottom sediments to dry out for several months. Although useful, benthic barriers and drawdowns have drawbacks and limitations. Neither method is selective, so desirable native plants will be killed along with the weeds. Also, neither method can be used in fish production ponds unless the fish can be removed to another pond first.

Figure 12. Cultural control methods. Upper left: aerator. Lower left: drawdown. Right: benthic barrier being deployed.

Manual or mechanical removal

Manual removal or mechanical control can be an option, particularly if the invasion is small and localized. Target weeds can be pulled by hand or with a rake if the water is shallow enough. The success of this method will depend on whether it is possible to remove entire plants. Many aquatic invaders will regrow from root crowns, tubers, rhizomes, or plant fragments, so all plant material must be completely removed for this method to be successful.

Figure 13. Mechanical harvester gathering hydrilla.

If the water is deep and the infestation is large, specialized equipment such as mechanical harvesters (Fig. 13) can be used to remove as much plant material as possible. However, harvesters remove only the plant growth they can reach; shallow-water and deep-water harvesters capture plant material in the upper 5 and 10 feet (1.5 and 3 m), respectively, of the water column. Mechanical harvesting typically produces many fragments from which the invasive species can easily root, so this technique may actually spread the weed if the fragments are not collected. Mechanical harvesting is also non-selective, so desirable plants, fish, and other aquatic organisms that share the habitat with the invader will be harvested too.

Another factor to consider is the disposal of the harvested plant material. Ideally, it could simply be deposited on a “high-and-dry” area near the pond where it can be left to dry and then composted. However, if the freshly harvested material must be transported to a landfill it could be quite expensive. As much as 95 percent of the fresh weight of aquatic weeds is water (for example, a single acre of hydrilla can weigh as much as 24,000 pounds [10,900 kg], but only 1,200 pounds [545 kg] of that weight is plant material and the remaining 22,800 pounds [10,365 kg] is water). This could make hauling costs and disposal site tipping fees prohibitive.

Another mechanical method is dredging, or removing the upper layer of bottom sediment from the pond, which may require permits from local, state, or federal agencies. This can be done on a small scale (for example, using divers with suction rigs to spot-dredge new infestations) or on a larger scale, with specialized equipment that can manage large areas in a relatively short time. Dredging reduces the amount of seeds, rhizomes, tubers, and other plant material in the sediment, which can lessen the likelihood of weed regrowth after dredging is complete. However, dredging is non-selective and can cause long-term turbidity, since sediments can remain suspended in the water column for a long time. Dredging also increases overall water depth, which may not be desirable.

Biological control

Biological control is the use of living organisms to reduce weed populations. This technique, also referred to as biocontrol, is based on the concept that most species become invasive after introduction to a new region because the predators that keep them in check in their native range aren't present in their new habitat. Finding and testing potential biocontrol agents is time-consuming and expensive. Researchers travel to the invader's native region and collect insects, pathogens, or other organisms that are found in association with the target weed species. These biological agents are brought back to the U.S. and maintained under quarantine conditions while they are tested to determine whether they fit the criteria and requirements of successful biocontrol agents. Biocontrol agents must be host-specific and cause damage only to the target weed species while leaving other plants unharmed; in addition, they must be able to survive, grow, and reproduce in the new range of the weed.

There are several biocontrol organisms that can be useful for aquatic weed control. For example, the alligatorweed flea beetle *(Agasicles hygrophila)* can reduce populations of noxious alligatorweed *(Alternanthera philoxeroides)* to the point that other weed control strategies can be reduced or even eliminated, as long as winter temperatures are mild enough to allow the beetles to survive through the winter. The salvinia weevil *(Cyrtobagous salviniae)* causes significant damage to the weedy floating fern giant salvinia, and two water hyacinth weevils—*Neochetina eichhorniae* and *N. bruchi*—are used to slow the growth of water hyacinth.

In contrast to true biocontrol agents, generalist organisms consume aquatic plants less discriminately. For example, the Asian or Chinese grass carp *(Ctenopharyngodon idella)* is well-known as a voracious consumer of hydrilla, one of the world's worst aquatic weeds. But grass carp are not host-specific and will consume and eliminate virtually all submersed vegetation in a pond. The success of grass carp in controlling hydrilla depends on stocking density; with too few carp the hydrilla infestation will grow virtually unchecked, while too many fish may result in the loss of all pond vegetation. Because the grass carp is a non-native introduced species, special precautions must be taken to reduce the likelihood of these biocontrol agents becoming invasive themselves. In most states, a permit must be issued by state resource managers before grass carp can be introduced to an aquatic system (although some states prohibit the use of grass carp altogether), so check with your state agency before considering this option. In most cases, permit holders must take measures to prevent the fish from escaping into other waters, and all grass carp must be sterile triploids that are unable to reproduce. For more information about grass carp, see SRAC Publication No. 3600, *Using Grass Carp in Aquaculture and Private Impoundments.*

Biocontrol agents such as alligatorweed flea beetles, salvinia weevils, and water hyacinth weevils, along with generalist herbivores such as grass carp, can be useful for aquatic weed control but will not eradicate invasive weeds completely. When more complete and targeted control of aquatic weeds is desired, resource managers rely on chemical control, or the use of herbicides.

Chemical control

Herbicide applications to ponds share some of the challenges associated with treating croplands, including drift and damage to desirable non-target plants. But aquatic herbicide applications are more challenging because of factors unique to aquatic systems. For example, herbicides for controlling weeds in crops usually reach the target weed at the concentration in which they are applied. In contrast, products used to control submersed aquatic weeds must travel through the water column to reach their target and are substantially diluted before they reach the weed. In addition, currents move the herbicide out of the treated area, which reduces the amount of time the product actually contacts the target weed and can make the treatment less effective. Another factor that complicates the use of aquatic herbicides is pond stratification (Fig. 14), especially in temperate regions.

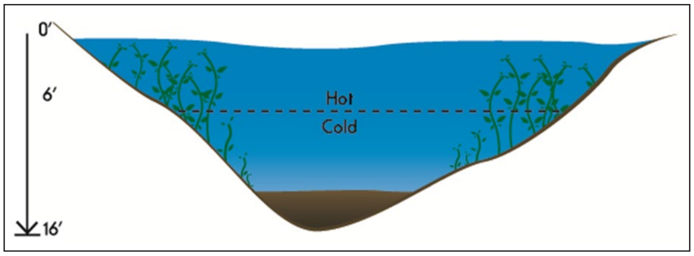

Figure 14. Pond stratification.

Most ponds deeper than 10 feet (3 m) have three distinct zones or layers, with little mixing among the layers. The upper and lower portions of a pond are the epilimnion and hypolimnion, respectively. Water in the epilimnion is exposed to ambient air temperatures, so it is usually very warm in the summer and cold or frozen in the winter. Water in the hypolimnion maintains a more or less constant temperature all year. The epilimnion and hypolimnion are separated by the thermocline, a layer where drastic temperature changes occur. Stratification may not affect the management of emergent or floating aquatic weeds, but can have a substantial effect on the treatment of submersed plants because herbicides applied to the epilimnion are unlikely to penetrate through the thermocline to reach target weeds growing in the hypolimnion.

There is no "one size fits all" chemical control method; besides the challenges listed above, a number of factors must be considered when choosing a herbicide. First and foremost, **the product must be labeled for use in your aquatic system in your state.** The U.S. Environmental Protection Agency regulates herbicide labeling on a national scale, but each state has the authority to enact more restrictive regulations or to prohibit the use of a product altogether. The label is the law; failure to comply with **any and all** of the conditions outlined on a herbicide label is a violation of federal law, and people have been heavily fined and sent to federal prison for the improper use of pesticides.

Once you have determined what herbicides are labeled for your system in your state, you should carefully read the labels or consult with your Extension office to determine which products are best suited to your situation. Important factors to consider include:

- **Efficacy:** Will the product control your target weed?
- **Selectivity:** If there are desirable native plants in your pond, how will the herbicide affect them?
- **Non-target effects:** Will the herbicide harm fish or other aquatic animals in your pond?
- **Water usage:** What are the water use restrictions after treatment? How long after the treatment do you have to wait before you can irrigate crops, water livestock, swim, fish, or drink the treated water?
- **Restrictions and setbacks:** How far away must the herbicide remain from intakes, outflows, or connections to other waters? Are there other specifications outlined on the label, such as minimum droplet size or maximum wind speed during application?
- **Other considerations:** What personal protective equipment is required, and do you have the equipment needed to apply the product? Does your state require you to be a licensed pesticide applicator to purchase and use the product? If you have a small pond, can you purchase just what you need or do you have to buy a large container? Is it affordable?

Clearly, using aquatic herbicides can be a challenging prospect, and many people opt to hire it out rather than trying to do it themselves. Many private companies offer aquatic weed control services, which can be an affordable alternative, particularly if you have a small pond, need very little herbicide, and don't already own the proper equipment described on the label. However, aquatic weed control is certainly something you can manage on your property if you so choose, provided you properly identify the weed, select a product that fits your needs and situation, and follow the label instructions. For more information about aquatic herbicides, see SRAC Publication No. 361, *Aquatic Weed Management: Herbicides,* and SRAC Publication 3601, A*quatic Weed Management: Herbicide Safety, Technology, and Application Techniques.*

A note about fish kills

When you use herbicides to control aquatic weeds in your pond, special precautions must be taken to ensure that fish and other aquatic organisms are not harmed as a result. Only a few aquatic herbicides are directly dangerous to fish, but fish kills are always a major concern when treating ponds. The main reason fish kills occur after aquatic herbicide application is a reduction in dissolved oxygen (DO).

- Living plants add DO to the water through photosynthesis; when plants are killed by herbicides, the DO in the water is reduced.
- Plants killed by herbicides decompose and are broken down by oxygen-using organisms, which further depletes DO.

To reduce the possibility of a fish kill, treat only a portion (no more than one-third) of the pond at one time. This allows fish to escape from treated areas and also prevents the extreme drop in DO that comes with killing all of the plants in an aquatic system.

Conclusions

Native aquatic plants are an important part of the ecosystem, but invasive aquatic weeds degrade the pond habitat and limit the use of affected waters. Most aquatic weeds have been intentionally introduced, so exclusion or prevention is the first line of defense against them. Once a pond has been invaded, a number of strategies can be used to manage aquatic weeds, including cultural, mechanical, biological, and chemical control. Pond owners should first identify the invasive species, then select a product labeled for that weed and for the particular situation, making sure to apply the product according to label instructions to avoid damage to native plants and fish.

Additional resources

Biology and Control of Aquatic Plants: a best management practices handbook. Aquatic Ecosystem Restoration Foundation. Online at *http://aquatics.org/aerf_handbook.pdf*.

Plant Management in Florida Waters: an integrated approach. University of Florida Center for Aquatic and Invasive Plants. Online at *http://plants.ifas.ufl.edu/manage/*.

Southern Region Aquaculture Center publications. Online at *https://srac.tamu.edu/*.

SRAC fact sheets are reviewed annually by the Publications, Videos and Computer Software Steering Committee. Fact sheets are revised as new knowledge becomes available. Fact sheets that have not been revised are considered to reflect the current state of knowledge.

USDA United States Department of Agriculture | National Institute of Food and Agriculture

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 2010-38500-21142 from the United States Department of Agriculture, National Institute of Food and Agriculture.