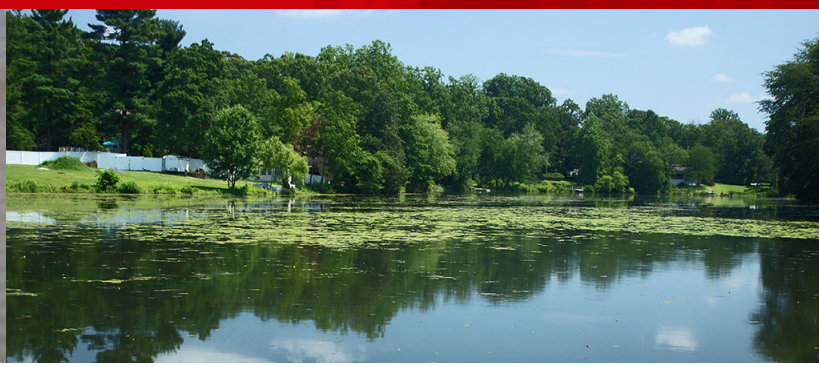
Pond and Lake Management Part VII: Aquatic Invasive Species: Hydrilla

Bulletin E352





Cooperative Extension

Patricia Rector Environmental and Resource Agent, Morris and Somerset Counties

Peter Nitzsche Agricultural Agent, Morris County

Hydrilla [*Hydrilla verticillata* (L.f.) Royle)], is an invasive aquatic plant species that is native to Asia. The U.S. Department of Agriculture has designated hydrilla as a noxious weed, and prohibits the importing, exporting or interstate commerce of this aquatic plant. In the southeastern U.S., hydrilla has had several negative impacts to water bodies and their use. Impacts include water quality changes, fish community alterations, canal flow reductions, clogging of water pumps, impediments to recreational uses and boat navigation, displacement of native aquatic plants, and reduced aesthetics and the associated economic impacts. Hydrilla has recently been identified in several Mid-Atlantic States, including New Jersey, however fortunately to date it has not yet had widespread and large-scale impacts in the state. In order to provide effective management of an aquatic nuisance plant an understanding of the biology, life cycle and ecology of the plant is necessary. If you are uncertain if the plant in your lake or stream is hydrilla you can bring a damp stem with leaves to your local county Rutgers Cooperative Extension office for identification http://njaes.rutgers.edu/county.

Biology

Hydrilla is a perennial submerged plant in the same taxonomic family (Hydrocharitaceae) as water celery (*Vallisneria americana*) (also called tape grass). Hydrilla can grow up to 25-feet long on slender stems with multiple branches. The leaves of hydrilla are translucent green, pointed and saw-toothed and are attached directly to the stem in whorls of four to eight. Leaf whorls of five are most common in the Northeast (Fig. 1). Hydrilla can reproduce by seeds or vegetatively by tubers (Fig. 2), turions (Fig. 3) and fragments, although seeds are the least common method. Hydrilla is unusual in that it occurs in two sexual reproductive forms. One form (also called a biotype) of hydrilla is a self-fertilizing (monoecious) type with both male and female flowers on the same plant. The second form has male and female flowers on separate plants (dioecious), requiring both plant types for seed fertilization (Table 1). In the U.S., only the female dioecious hydrilla has been observed. Hydrilla typically overwinters as tubers and turions in the northeast.

Tubers form on rhizomes (thin white stems similar to runners on strawberry plants) at the end of an underground stem. Tubers are white to yellowish in color (Fig. 2) unless the sediment is highly organic, in which case they will be brownish-black to black. Approximately 2/3 of the tuber is starch. The tuber detaches from the parent plant as the rhizome decays and new plants will sprout from the tubers in the sediment. Optimum sprouting temperatures for tubers are between 15° and 35°C (39° and 95°F). A variety of factors influence tuber sprouting, and not every tuber sprouts each year, thus providing a reproductive tuber bank capable of perpetuating the population through unfavorable years. Hydrilla tubers may last four to five years in the sedi-

RUTGERS
New Jersey Agricultural Experiment Station

Rutgers, The State University of New Jersey
88 Lipman Drive, New Brunswick, NJ 08901-8525
Phone: 732.932.5000

Table 1. Comparison of Monoecious and Dioecious Types of Hydrilla.

	Monoecious	Dioecious
Reproduction strategy	Self-fertilizing; both male and female flower on the same plant. Can produce seeds but this is the least effective form of reproduction.	Cross-fertilization; requires both a male and female plant for fertilization. In the U.S. only the female form has been identified; therefore, propagation occurs asexually through rhizomes, tubers and turions in the U.S.
Flowers	Male and female flower parts appear on the same plant. Flowers have three white petals and three translucent petals.	Male and female flower parts appear on separate plants. Monoecious and dioecious flowers are identical in appearance.
Branching	Begin to branch at sediment level and grow rapidly to surface	Branch profusely at surface
Distribution	Typically north of North Carolina, infestations in California, Washington State	Southeastern states, west to Alabama, Texas and infestations in California.
Leaves	Delicate, 4-10 mm length, translucent.	Leaves, delicate, translucent 6-20mm length.
Midrib spine	No pronounced midrib, usually do not have midrib spine on the underside	Single distinct pronounced midrib that is sometimes reddish, sharp spine along midrib on the underside of leaf.
Appearance	Overall appearance of the monoecious form is more delicate	Dioecious hydrilla appears as a more robust form.
Tubers	Production is greater than dioecious; average of tuber weight is less (179-202 mg).	Production is less than monoecious; average weight is greater (160-376 mg).
Turions	Weigh less than dioecious (up to 77 mg) and can be found at densities of up to 1,700/ m^2. Produced June through November.	Greater weight (up to 380 mg) but density in sediment is less (600/m^2). Produced October through April.

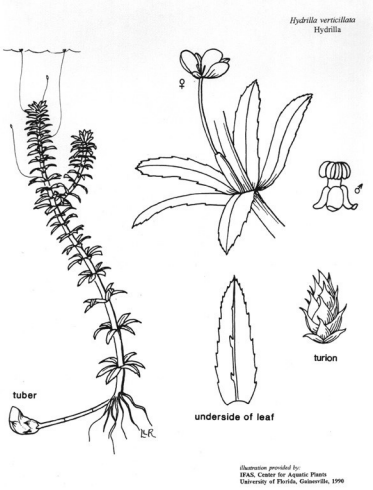


Figure 1



Figure 2

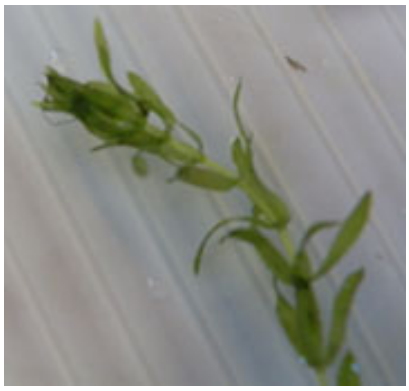


Figure 3

ment and over time can accumulate into high densities. Non-sprouting tubers that lay dormant in the sediment are not typically affected by conventional herbicides. Tubers may also be digested by waterfowl, pass through and remain viable. Unless tubers lose more than 50% of their moisture, they may remain viable. Monoecious hydrilla behaves as an annual plant, the foliage of monoecious hydrilla does not overwinter, and the tubers from monoecious hydrilla plants require a period of cold for germination.

Hydrilla turions are formed in the angle between the leaf and the stem (leaf axil) appearing as scaly, green compressed shoots. As an abscission zone forms, the turion will fall to the water (similar to the process of a leaf falling in autumn), float and eventually sink to the substrate, overwinter and sprout the following spring. Free-floating plants will produce more turions than rooted hydrilla plants. Floating turions may assist colonization of new areas of a water body. Turions in the sediment either germinate or die after one year.

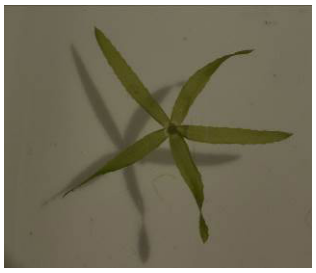
Identification

Hydrilla may be easily confused with three other species in the same family; a native aquatic plant, common waterweed (*Elodea canadensis* Michx), Nuttall's waterweed (*E. nuttallii*), and an invasive species Brazilian waterweed (*Egeria densa* Planchon).

Ecology

Hydrilla can grow in a variety of habitats, including low nutrient (oligotrophic) and high nutrient (eutrophic) basins, a wide variety of bottom substrates from fine muck to sand to larger cobble, and in still or flowing water. The ability of hydrilla to inhabit flowing water systems puts the streams and rivers along with the lakes and ponds of New Jersey at risk of infestation. Hydrilla can proliferate rapidly. Research has shown growth rates for hydrilla under

Table 2. Comparison of characteristics of hydrilla and look alike aquatic plants.

Characteristic	Hydrilla Hydrilla verticillata	Common waterweed Elodea canadensis	Nutall's waterweed Elodea nutallii	Brazilian waterweed Egeria densa
Number of leaves in the whorl	4-8, typically 5 in the northeast	3 (occasionally 4)	3	4-6
Leaf edge	Serrated edge visible with naked eye	Finely serrated, may be visible under microscope		Finely serrated, may be visible under microscope
Leaf geometry	Linear-lanceolate Up to 20 mm long and 2 mm wide	Length usually 8.1 mm; (range 5-13 mm); width usually > 1.75 mm (range 1.1 -5 mm)	Length usually no longer than 10 mm; (range 4-15.5 mm); width usually < 1.75 mm (range 0.4 -2.4 mm)	Length 10-40 mm; width 1.5-4.5 mm
Picture*	 Note: Leaf with five whorls.	 Note: Leaf three whorls.	 Note: The curly leaves.	 Brazilian water weed stem. Note: The short internodal space (space between whorls).

**Photograph credit: Hydrilla verticillata, Mike Haberland, Rutgers Cooperative Extension; Elodea canadensis, Peter Nitzsche, Rutgers Cooperative Extension; Elodea nutallii, Wikipedia https://en.wikipedia.org/wiki/Elodea_nuttallii ; Elodea densa, Wikipedia http://en.wikipedia.org/wiki/Egeria_densa*

optimal conditions far exceeds the growth rate for Eurasian watermilfoil, an invasive species that has been a problem in New Jersey for decades. Growth rate, including lateral branching exceeds 1-4 inches per day. Efficient CO_2 absorption from the water column, necessary for photosynthesis, and the ability to grow under low light or even turbid conditions creates a greater range of photosynthetic opportunities for hydrilla. Often the ability of hydrilla to grow under low light conditions allows it to create a dense canopy able to block light from other plants before they have reached the surface. Growth under low light conditions also allows hydrilla to colonize deep water. Hydrilla has been found in water depths as deep as 20 to 25 feet. The clarity of the water, the available nutrient concentrations, and the depth and the persistence of the other vegetation factors into the ability of hydrilla to form dense canopies in large portions of a waterbody. Hydrilla tolerates a wide range of salinity (up to 7ppt) and may be found in brackish water. In nutrient-rich waters, especially with high nitrogen, hydrilla is a very efficient competitor and it can store nutrients for later use.

Hydrilla can outcompete native aquatic plants such as wild celery (*Valisneria americana* Michx), native pondweed species (*Elodea canadensis*), and native naiads. In lower nutrient systems; however, these native species may be able to compete, maintain a presence or even dominate the aquatic plant community. Some aquatic plants such as species of spikerush plants (*Eleocharis cellulosa* Torr. and Eleocharis interstincta (Vahl) R. & S.) and arrowhead (*Saggittaria subulata*) utilize allelopathy (a process when one plant releases a chemical or toxin that inhibits the growth of others) to reduce hydrilla shoot weight and tuber production and weight.

Distribution

Hydrilla was first noted in Florida in the 1950's, possibly through introduction as an aquarium plant, and became a problem in waterways by the 1970's. In the 1980's hydrilla was found in the Potomac River Basin. Hydrilla is currently found as far west as California, as far north as Washington State, throughout the southeast, and has been identified in northeastern states including New York, Pennsylvania, Connecticut, Maine, and New Jersey.

The first documented occurrence (2003) of hydrilla in New Jersey was from a sample in Lake Mallard, Burlington County. The New Jersey Invasive Species Strike Team has listed hydrilla occurrences at Kingfisher Pond and

Mallard Pond in Tamarack Lakes, Ocean County, Lake Mallard, Burlington County, and Franklin Lakes in West Long Branch, Monmouth County. There are confirmed occurrences in Lake Shenandoah in Lakewood, Ocean County, and Alcyon Lake in Pitman, Camden County. There have also been undocumented reports of hydrilla in other locations.

The monoecious form of hydrilla was first found in the Potomac River, VA and DNA analysis indicates it probably originated in Korea. The dioecious form from Florida and other southern states has been genotyped as originating in Southeast Asia. Except for a dioecious population in Connecticut, the monoecious form is typically found in temperate climates in the U.S. from North Carolina north and west. A documented occurrence in Lake Mallard, Burlington County, New Jersey was genotyped and determined to be monoecious. The distribution of the two forms do not usually overlap, although there have been a few instances, including Lake Gaston, NC where both biotypes have overlapped in the same waterbody.

Impacts

Hydrilla mats are often thick enough to reduce recreational access and use, or reduce water flow for irrigation and intakes of hydroelectric plants. Economic impacts also include the loss of use and real estate value as well as with the cost of control treatments. In Florida, hydrilla costs to manage 9,000 acres in 2013/2014 were estimated at $5.3M.

Some research in Florida suggests that at lower densities hydrilla provided suitable habitat for largemouth bass (*Micropterus salmoides*) populations. With excessive coverage (about 30% or greater) of hydrilla, largemouth bass tend to have decreased weight and loss in growth and fertility. Hydrilla may also provide food for waterfowl including ducks, but hydrilla is detrimental to birds or waterfowl that prefer open water. Hydrilla has recently been linked to a cyanobacteria (blue-green algae) that grows on its stems. The cyanobacteria *Aetakthonos hydrillicola* (eagle killer) is epiphytic (lives on the surface of plants) and produces neurotoxins, causing a disease in birds named Avian Vaculor Myelinopathy (AVM). The effects of the neurotoxin are dose-dependent and biomagnify so that consumers at higher levels of the food chain are most affected. AVM has caused the death of mallards, buffleheads, ring-neck ducks, Canada geese, and killdeer. The disease has also killed thousands of American coots, a great horned owl and at least 100 bald eagles.

Management

Exclusion/Early Detection

Due to the potential for this invasive species to exhibit high invasive potential in waterways, early detection, identification and rapid removal is a key management measure. Movement of hydrilla and its fragments, turions or tubers between water bodies can be by human and wildlife transport. Hydrilla can grow from small fragments, therefore the prevention of movement of the plant, or parts of the plant, between water bodies is critical to prevent new infestations. Simple tactics to prevent the spread of hydrilla and other pest species between waterbodies should be stressed and include removing all visible mud, plants, fish or animals from boats, equipment, trailers, clothing, boots and buckets. Clean all trailers, boats and other equipment that have come in contact with the plant with hot or salt water, and allow the surfaces to completely dry.

The aquarium and water garden trade can be a contributor to the spread of hydrilla. Vendors may unknowingly sell and ship hydrilla. Hydrilla plants, reproductive structures or fragments may be included in plant material for aquaria or mistakenly included in shipments. Although one study found that unintentional introductions occured in approximately 3% of the samples, when considering the amount of aquatic plant purchases nation-wide, this yields a considerable amount of plants. The movement of monoecious hydrilla to California was traced to an unintentional shipment of aquatic plants.

Drawdowns

Reductions/releases of water in lakes and ponds thus exposing shoreline areas to the elements, known as drawdowns, are a recommended management option for addressing hydrilla infestations. Drawdowns are utilized to subject the invasive plant or reproductive structures to a hard, sustained freeze to kill the plant and/or structures. Drawdowns may also affect native species such as wild celery or tape grass (*Vallisneria americana*) or American waterweed (*Elodea canadensis*) reducing the ability of these species to repopulate the lake after a drawdown. Therefore, plans for reintroducing native plants may be necessary after a drawdown. The purpose of a drawdown for hydrilla control differs from a winter drawdown with an expectation of a freeze of the sediment. The drawdown is not necessarily to promote freezing and/or drying of the plant and tubers. Although desiccation will reduce viability, despite drawdown conditions hydrilla tubers may still maintain sufficient moisture (up to 51%) to be viable after a one-year drawdown. The optimal timing for a hydrilla drawdown is spring/summer to promote the sprouting of hydrilla tubers. A drawdown or multiple drawdowns can promote hydrilla

tuber sprouting, thereby reducing the available tubers for future growth. Tubers in the sediment may be dense (400-1,000 tubers per m2) and monoecious tubers may remain in undisturbed sediments for as long as 4 years. After a drawdown has forced sprouting of tubers is an optimal time for a coordinated effort using hand pulling, diver-assisted suction harvesting or an herbicide application on the sprouted tubers. Timing is important because herbicide will not have an effect on dormant tubers. Drawdowns can work well with smaller ponds or other contained waterbodies.

Mechanical Harvesting

Mechanical harvesting can be a short-term solution to open up a water body, but the harvesting may produce fragments that will drift or be carried to other areas of a water body, or even encourage spread throughout the watershed. Since hydrilla can reproduce by fragments, mechanical harvesting can lead to greater distribution of the problem rather than a long-term management solution.

Hand Pulling

Divers or snorkelers manually removing hydrilla plants from the sediment by hand is another management option. Care must be taken to assure that the root crowns, tubers and turions are also removed. A density of approximately 500 hydrilla plants/acre for a few acres would be the maximum for hand pulling. Trained volunteers or professionals should be utilized for this management option. When hand pulling a barrier to capture fragments should be set up to prevent drift into other areas.

Diver Assisted Suction Harvesting

Diver Assisted Suction Harvesting (DASH), similar to hand pulling, utilizes divers pulling hydrilla from the bottom sediments. Rather than simply hand pulling, a suction hose is utilized that pulls volumes of water. The diver will feed the hydrilla into the hose allowing for greater amounts of plant to be removed. This option is best used in localized areas, in soft sediment, and in areas with lower plant density and less water depth, as variations from each of the preceding will lead to increased work and cost. The pumped water will move through a mesh bag that will allow the water to exit while the plants remain. The mesh needs to be large enough to allow sediment to exit or the bag will quickly become clogged.

Based on the experience of Cornell University, due to the fragility of hydrilla there is a potential for breakage and therefore for fragments to exit the bag, creating the potential for drift or re-establishment. Tubers and turions may also pass through the mesh openings. The use of a fragment barrier may assist with utilizing this option.

Biological Control Measures

One of the reasons hydrilla is so competent at taking over a waterbody is a lack of natural pests or predators. Biological control involves the use of introduced predatory species (insect or disease organisms) to target the species of concern, reducing the density of the pest species without causing other environmental impacts. A leaf-mining fly, *Hydrellia pakistanae* Deonier, native to Asia has been introduced and used for control of hydrilla in some states. New Jersey is not one of the release states.

Sterile triploid grass carp (*Ctenopharyngodon idella)*, also known as white amur, may provide some biological control. Hydrilla is listed as a preferred food source for grass carp (Diet for a Small Lake, 2009). Utilization of grass carp for hydrilla control however, has shown mixed results ranging from very good control of hydrilla, to no effect, to the complete elimination of all submerged vegetation. In New Jersey, there are stringent requirements on the use of grass carp and stocking grass carp requires a permit from the New Jersey Department of Environmental Protection's (NJDEP) Division of Fish and Wildlife. Additionally, permits in New Jersey are only issued to waterbodies less than or equal to 10 acres in surface area. Grass carp feeding activity increases turbidity, which can inhibit desirable plant growth. This turbidity may lead to an algae-dominated system and nutrients suspended in the water column. Grass carp may also shift the fish community away from desirable game fish to benthic species.

Research is being conducted on the potential to utilize a native fungal pathogen, *Mycoleptoddiscus terrestris* (Gerd.) Ostazeski as another biological control agent of hydrilla, which may be host-specific. Hydrilla was affected by *M. terrestris* under demonstration programs, but there was not sufficient mortality to provide control, although it may decrease the amount of herbicide needed.

Chemical

The chemical control of hydrilla is a regulated activity in New Jersey and requires a permit from the NJDEP and a certified pesticide applicator. Aquatic pesticide applications for the control of hydrilla are best conducted during the early growth phase of the plants between mid-May and early July.

Chemical treatment for aquatic systems can be with either systemic or contact herbicides.

- Contact herbicides are applied directly to the plant and cause the die-back of the part of the plant that came in contact with the herbicide, while the root and remainder of the plant remains viable and may still sprout new shoots.
- A systemic herbicide is applied to the water, either in a granular or liquid form. Systemic herbicides are taken up by the plant, either through the leaf or

the root and transported throughout the plant and interfere with normal functions including photosynthesis and reproduction. Systemic herbicides are slow-acting but are capable of killing or disrupting vital functions of the entire plant.

- Broad spectrum herbicides kill all plants they come in contact with while selective herbicides will affect only certain plant species and not affect others. Although some other herbicides such as imazamox, penoxsulum, copper, diquat, and bispyribac-sodium can be used to control hydrilla their use is not widespread and they will not be discussed in this fact sheet.

Fluridone

Fluridone (trade name Sonar®) is a systemic herbicide that has been used effectively to manage hydrilla populations in Florida lakes. There are no US EPA restrictions on the use of Fluridone-treated water for swimming or fishing when used according to label directions. Sonar's US EPA- approved labeling states that in lakes and reservoirs that serve as drinking water sources, Sonar applications can be conducted within one-fourth mile (1,320 feet) of a potable water intake. Fluridone is available in liquid and several granular formations for a variety of habitat types.

In Florida, fluridone-resistant hydrilla (FRH) has been documented after frequent, long-term use of the chemical. Thousands of acres of lakes are infested with FRH. The level of fluridone resistance varies among populations of hydrilla. The most resistant strains of FRH may still be vulnerable to fluridone, but successful control requires higher and more frequent dosages, increasing costs and the potential for impacts to other native vegetation. There are strategies to help reduce the chances for hydrilla to develop resistance. These include avoiding using the same product two consecutive years, using alternate products, using integrated methods of control and conducting post-treatment plant monitoring for loss of efficacy.

Endothall

Endothall (trade name Aquathol® K) is a broad-spectrum contact herbicide that can be used to control hydrilla. Native plants vary in their response to endothall dependent upon species, concentration and the length of exposure. Some native plants will tend to die off immediately after treatment, but come back within a few weeks to a higher population perhaps due to less competition from hydrilla. Other native plants do not make a comeback. Endothall is being used more frequently due to FRH.

Flumioxazin

Flumioxazin (trade name Clipper®) is a relatively new contact herbicide registered for use in New Jersey. Flumioxazin has a greater contact time in lower pH water, so it can be suitable in low alkalinity, low pH water bodies such as found in southern New Jersey. Flumioxazin has a five day crop irrigation restriction, but no restrictions for swimming or fishing.

For more information

Gettys, L.A., W.T. Haller and M. Bellaud, eds. 2009. Biology and control of aquatic plants: a best management practices handbook. Aquatic Ecosystem Restoration Foundation, Marietta GA. http://www.aquatics.org/bmp.html 210 pp.

Maine Center for Invasive Aquatic Plants. 2007. Maine Field Guide to Invasive Aquatic Plants and their common native look alikes. Maine Volunteer Lake monitoring Program. http://www.mainevolunteerlakemonitors.org/mciap/FieldGuide.pdf

Trade or Brand Names

The trade or brand names given herein are supplied with the understanding that no discrimination is intended and no endorsement by Rutgers Cooperative Extension is implied. Furthermore, in some instances the same compound may be sold under different trade names, which may vary as to label clearances. For the convenience of our users, both product names and active ingredients are provided and any product name omissions are unintended.

Pesticide-User Responsibility

Always follow the label and use pesticides safely. Remember, the user is always responsible for the proper use of pesticides, residues on crops, storage and disposal, as well as for damage caused by drift. State and federal pesticide regulations are constantly under revision. Be sure to determine if such changes apply to your situation. Using pesticides inconsistent with label directions is illegal.

Acknowledgements: The authors would like to acknowledge Chris Doyle, Allied Biological for providing considerable input for this fact sheet.

© 2015 Rutgers, The State University of New Jersey. All rights reserved.

For a comprehensive list of our publications visit www.njaes.rutgers.edu *December 2015*

Cooperating Agencies: Rutgers, The State University of New Jersey, U.S. Department of Agriculture, and County Boards of Chosen Freeholders. Rutgers Cooperative Extension, a unit of the Rutgers New Jersey Agricultural Experiment Station, is an equal opportunity program provider and employer.

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Rutgers, The State University of New Jersey
88 Lipman Drive, New Brunswick, NJ 08901-8525
Phone: 732.932.5000