A guide to

Invasive Aquatic Plants of Connecticut

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Cover photo: Eurasian water-milfoil, *Myriophyllum spicatum,* by Alison Fox, University of Florida

Introduction to aquatic plants

Aquatic plants are essential components of healthy ecosystems in freshwater lakes and ponds, producing oxygen, reducing erosion and regulating nutrient cycling (Hutchinson, 1975). They provide food for many birds as well as habitat that supports rich communities of aquatic invertebrates and vertebrates (Sculthorpe, 1967).

Invasive plants, however, are not native species, and they are often destructive (Vitousek et al., 1996). Non-native plants and animals are responsible for economic losses and control costs estimated in one analysis at $137 billion per year in the United States alone (Pimentel et al. 2000). Invasive aquatic plants are noted for their explosive growth potential (Barrett, 1989) and their ability to grow from a few plants to cover hundreds of acres in a few years (Groth et al., 1996). Invasive aquatic plants have caused declines in native plant populations throughout New England (Sheldon, 1994). In some water bodies, invasive plants have become so abundant that they have displaced native species (Langeland, 1996). Many biologists feel invasive species are second only to habitat destruction as the most serious threat to endangered species globally (Wilcove et al., 1998).

Because of their great growth potential, invasive aquatic plants can block navigation channels, irrigation ditches and water intake pipes, and they can reduce aesthetic and recreational value of water bodies, affecting tourism and real estate values (Catling and Dobson, 1985). In some cases, the plants have been found to increase breeding habitat for mosquitoes (Eiswerth et al., 2000). An estimated 76% of the invasive aquatic plants in southern New England were introduced as cultivated plants and later escaped (Les and Mehrhoff, 1999). It is thought that much of the subsequent spread of invasive plants from one lake to another is from recreational boating (Couch and Nelson, 1985).

Attempts to eradicate invasive aquatic plants once they become established often have failed (Anonymous, 1993; Groth et al., 1996; Simberloff, 1997), and management is expensive (Langeland, 1997; Center et al., 1997). Early identification of invasive plant populations, thus, is critically important (Simberloff, 1997; Wittenberg & Cook, 2001).

The Connecticut Agricultural Experiment Station (CAES) has begun a surveillance and monitoring program to establish the geographical distribution of invasive aquatic plants in state lakes and ponds. The program will establish where invasive plants occur and track their spread in the future. In many cases, quantitative vegetation surveys have not previously been done, and the absence of historic information makes it difficult to determine what changes resulted from plant invasions and what resulted from management activities (Sheldon, 1994). The CAES surveillance program will provide baseline information so the extent and nature of ecological change resulting from any future plant invasions can be determined. The surveys build on aquatic plant and bathymetric work done through the state Department of Environmental Protection's Geologic and Natural History Surveys as well as many decades of collecting by professional and amateur botanists in the state.

This guide contains information on the history, ecology and identification of nine invasive aquatic plants. Distribution maps for each species, based on herbarium records and surveys done by many biologists, are also shown. However, all of the state's lakes have not been surveyed, so the maps likely represent incompete distributions of the plants. The nine plants discussed here are not all of the species that threaten Connecticut lakes and ponds, but they are among those with the greatest potential to cause environmental and economic damage. This guide is intended to help non-scientists identify the plants in the interest of retarding their spread in the state and, where possible, preventing their introduction.

EURASIAN WATER-MILFOIL

Myriophyllum spicatum

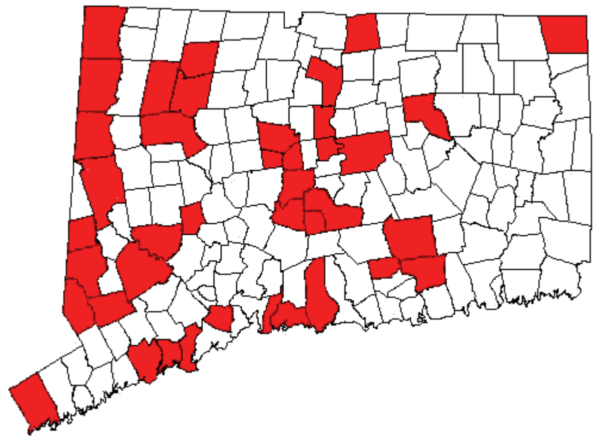

Figure 1. Distribution of *Myriophyllum spicatum* in Connecticut.

Eurasian water-milfoil is one of the most serious threats among invasive aquatic plants in the United States (Bartodziej and Ludlow, 1998). A native of Europe and Asia, the first reliable collections of Eurasian water-milfoil in the United States date from the 1940s, when it was reported from Washington, D.C., Arizona, California and other states, apparently as the result of independent escapes from cultivation (Les and Mehrhoff, 1999). The species was first collected in Connecticut in 1979, and it has spread quickly since then, occurring primarily in the alkaline waters of the western part of the state. Herbarium records and surveys indicate that it occurs in more than 40 ponds and lakes in Connecticut as well as in many areas on the Connecticut River (Figure 1).

Figure 2. Eurasian water-milfoil, *Myriophyllum spicatum*

Eurasian water-milfoil is one of several milfoils that occur in Connecticut ponds and lakes, including several native species, so identification can be difficult. Leaves occur in whorls around the stem, usually four leaves together (Aiken et al., 1979), as shown in Figures 2 and 3. Eurasian water-milfoil leaves have a very fine, feathery appearance. Each leaf is com-

Photo by Vic Ramey
University of Florida

Figure 3. Eurasian water-milfoil, *Myriophyllum spicatum*

posed of threadlike leaflets, and Eurasian water-milfoil leaves usually have more than 14 pairs of leaflets on each leaf (Moody and Les, 2002). Other milfoil species usually have fewer than 14 pairs of leaflets. Eurasian water-milfoil can be distinguished from variable-leaf milfoil, another invasive species, by the distance between the leaves on the stem. On Eurasian water-milfoil, leaves are more spread out on the stem and are generally more than an inch apart except at the very top of the stem, whereas variable-leaf milfoil has whorls of leaves less than an inch apart all up and down the stem (Hellquist and Straub, 2002).

Plants germinate early in the year, producing long stems that can reach the surface in 12 feet of water or more (Reed, 1997). When it reaches the surface (Figure 4), the stems spread out and can form a thick mat of vegetation (Aiken et al., 1979). The species can produce very thick stands of large plants (Reed, 1977), interfering with boating, swimming and other recreational activities (Reed, 1977; Bates et al., 1985), displacing native plants (Madsen et al., 1991), altering the abundance of fish populations (Keast, 1984) and depressing real estate values (Bates et al., 1985).

Stems of Eurasian water-milfoil break easily, producing fragments that then can grow into new plants. In fact, the plants reproduce primarily in this way, although they also produce seed and spread over short distances with horizontal stems in the sediment (Madsen et al., 1988; Madsen et al., 1991). Propellers on boat motors are effective at producing fragments that then act as propagules, dispersing the plant to new locations (Liddle and Scorgie, 1980).

Once established, Eurasian water-milfoil spreads aggressively, and managing it is difficult and expensive (Pimentel et al., 2000; Eiswerth et. al. 2000). As a result, preventing the species from arriving is important. Once it is introduced into a region, the species can spread by boaters who carry fragments of plants on their propellers or trailers (Johnstone et al., 1985; Howard-Williams, 1993), although the species likely spreads in other ways as well (Les and Mehrhoff, 1999). Any fragment can act as a propagule that could establish a new population of the species in a lake where it does not already occur.

Figure 4. Eurasian water-milfoil, *Myriophyllum spicatum*

VARIABLE-LEAF WATER-MILFOIL

Myriophyllum heterophyllum

This species is native to the southern United States and has become a nuisance in many Connecticut lakes since arriving in 1936, especially in the southeast part of the state (Les and Mehrhoff, 1999). It is known to occur in at least 30 ponds and lakes in Connecticut (Figure 5) and appears to prefer water with lower pH and alkalinity than Eurasian water-milfoil.

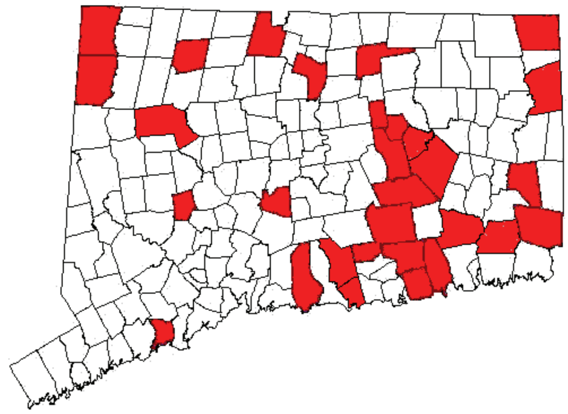

Figure 5. Distribution of *Myriophyllum heterophyllum* in Connecticut.

Variable-leaf milfoil produces long stems that rise to the surface of the water, where they spread out, producing mats of vegetation (Figure 6) that can interfere with boating and

Figure 6. Variable-leave water-milfoil, *Myriophyllum heterophyllum*

other recreational uses. Stems of the plant are thickly covered by fine, feathery leaves that are close together (Hellquist and Straub 2002) and collapse onto the stems when they are removed from the water. The stems have a coarse, ropy appearance in the water.

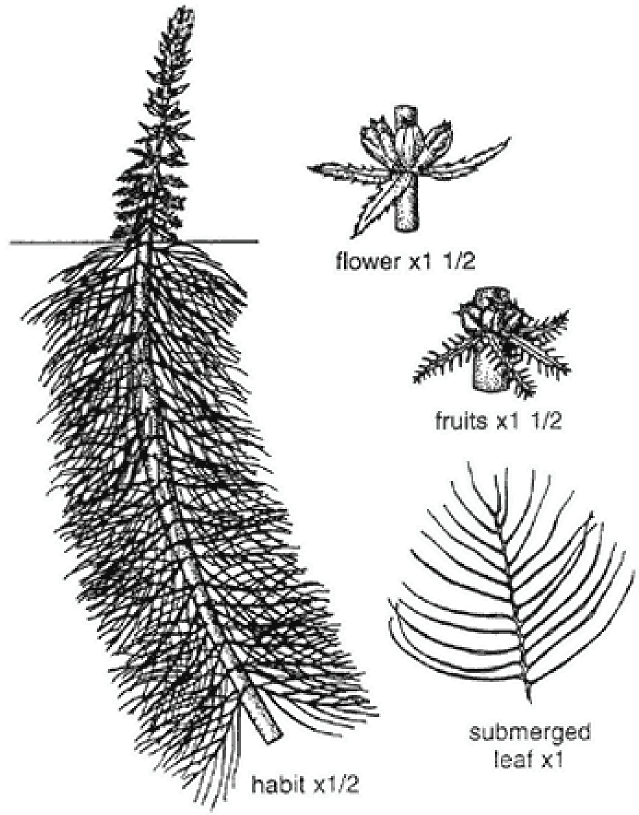

Figure 7. Variable-leaf water-milfoil, *Myriophyllum heterophyllum.*

Leaves are arranged in whorls on the thick often-red stems (Godfrey and Wooten, 1981), usually 4 to 6 leaves in each whorl. Like other milfoils, each leaf has paired, thread-like elements arranged along a central axis. On variable-leaf milfoil, there usually are 10 or fewer pairs of threadlike pinnae on each leaf (Figure 7), which distinguishes them from Eurasian water-milfoil, which has 14 or more pairs of pinnae on each leaf (Aiken et al., 1979). Variable-leaf milfoil plants produce flowering spikes that can be several inches long and emerge above the surface of the water. Identification of the species can be difficult because it closely resembles a hybrid of *M. heterophyllum* and a Southern milfoil species, and the two can be reliably distinguished from each other only with molecular analysis (Moody and Les, 2002).

Variable-leaf milfoil can reproduce by fragmentation, by spreading along horizontal shoots in the sediment and possibly by seed (Les and Mehrhoff, 1999). Control of the species can be difficult, and CAES scientists are continuing research on the effectiveness of spot herbicide treatments at Bashan Lake (Bugbee et al. 2003).

PARROT-FEATHER

Myriophyllum aquaticum

(Photo by Kerry Dressler)

Figure 8. Parrot-feather, *Myriophyllum aquaticum.*

Parrot-feather is an ornamental milfoil species that is native to the Amazon (Sytsma and Anderson, 1993). It is commonly sold for use in aquariums and water gardens (Aiken, 1981; Les and Mehrhoff, 1999) because of its distinctive, blue-green leaves, which, unlike other milfoil species, rise above the surface of the water (Crow and Hellquist 2000a), making this species relatively easy to recognize (Figure 8). The emergent leaves, which occur in whorls of 4–6 leaves, are twice as long as they are wide (Aiken, 1981).

Figure 9. Parrot-feather, *Myriophyllum aquaticum.*

Parrot-feather has been collected in few Connecticut locations (Fig. 10), but the species overwinters in the Northeast (Hellquist and Straub, 2002) and may represent a serious threat to the state's water bodies (Les and Mehrhoff , 1999). It reproduces in the United States only by fragmentation (Aiken, 1981) and can be dispersed on boat trailers (Les and Mehrhoff, 1999).

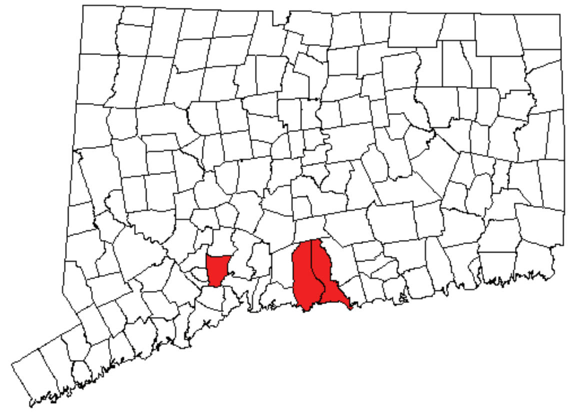

Figure 10. Distribution of *Myriophyllum aquaticum* in Connecticut.

EGERIA, BRAZILIAN ELODEA

Egeria densa

Egeria densia is originally from South America and until recently was sold as "Brazilian elodea" or "South American waterweed" in aquarium supply stores. *Egeria* is related to *Elodea* species native to Connecticut, and it looks much like them (Figures 11, 12) but has leaves in whorls of four around the stem, whereas leaves occur in whorls of three on *Elodea* plants. Leaves on *Egeria* also are longer and wider than those on *Elodea*, generally 1–3 cm long and up to 5 mm wide (Crow and Hellquist, 2000b).

(Photo courtesy of Washington Department of Ecology)

Figure 11. *Egeria densa* on the right, shown with the much smaller native species, *Elodea canadensis*, on the left.

The species was introduced in the United States in 1893, and the first Connecticut specimen dates from 1992 (Les and Mehrhoff, 1999). The plant is popular with aquarium hobbyists and water gardeners, and it has spread through the United States as a result of introductions and escapes from cultivation (Crow and Hellquist, 2000b).

(LiveAquaria.com photo)

Figure 12. *Egeria densa*.

Like many aquatic plants, *Egeria* spreads via fragments. Any piece of a stem with leaves on it can establish a new plant or population in a new lake. Once established, the species can produce thick mats of plants, growing from the bottom to to the surface in shallow water, then spreading out, shading out native plants (Hofstra et al., 1999). *Egeria densa* has been reported in at least five ponds in Connecticut, although it may have been eradicated in two of them (Figure 13). It remains a threat because of its popularity, its aggressive growth, its ability to tolerate northern winters, and the difficulty with which it is controlled (Les and Mehrhoff, 1999). It often is misidentified as *Elodea* and commonly is shipped as an unordered contaminant with other aquarium plants (Maki and Galatowitsch, 2004).

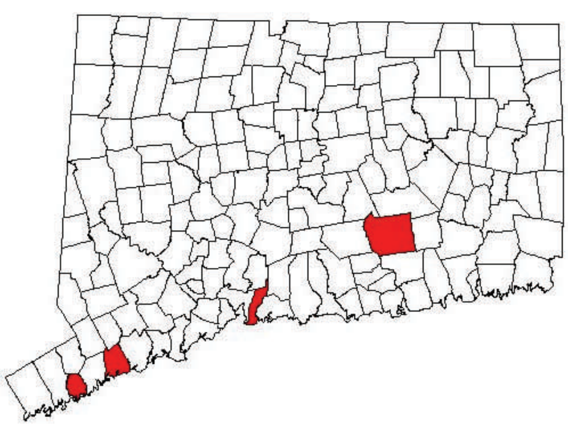

Figure 13. Distribution of *Egeria densa* in Connecticut.

HYDRILLA

Hydrilla verticillata

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Figure 14. *Hydrilla verticillata*

A native of Asia, *Hydrilla* (Figure 14) was first recorded in the United States in 1960, when it appeared in Florida (Les and Mehrhoff, 1999). Populations had spread through the southeast states by 1967, primarily by escaping from cultivation (Les and Mehrhoff, 1999), and the species became established in California after plants were shipped there in a shipment of water lilies (Maki and Galatowitsch 2004). The ability of the plant to survive Northern winters had been questioned, but its range in Asia extends to within 9 degrees of the Arctic circle (Les et al., 1997), and it has survived in Connecticut at least since 1989. The first verifiable specimen of *Hydrilla* in Connecticut was collected in 1989 but not identified until several years later (Les et al., 1997), and the species was found in a second town in 1997 (Figure 15).

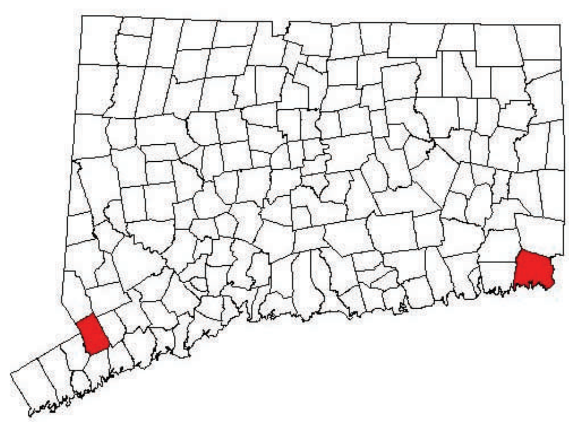

Figure 15. Distribution of *Hydrilla verticillata* in Connecticut.

Among all the invasive aquatic plants, *Hydrilla* may represent the most serious threat to Connecticut ponds and lakes (Les and Mehrhoff, 1999). The species is extremely aggressive and can outcompete native species and even other invasive species (Hofstra et al., 1999). It is also difficult to control (Center et al., 1997). *Hydrilla* grows very quickly in shallow and deep water (Godfrey and Wooten, 1979) and occurs in lakes, ponds, streams and marshes. A few plants can grow to cover hundreds of acres in a few years, crowding out other plants (De Kozlowski, 1991). The plant reproduces by fragmentation and produces tubers that overwinter in the sediment (Les et al., 1997). Plants can disperse between lakes either as tubers or as fragments (Les and Mehrhoff, 1999).

Hydrilla is in the same plant family as *Egeria* and native *Elodea*, and these species can be hard to differentiate. *Hydrilla* leaves generally occur in whorls of five (Figure 16; whorls of 4 – 8 leaves can be found, Crow and Hellquist 2000b), whereas leaves on *Egeria* occur in whorls of four leaves, and those on *Elodea* are in whorls of three (Figure 17). In addition,

Figure 16. A whorl of five leaves on the stem of a *Hydrilla* plant.

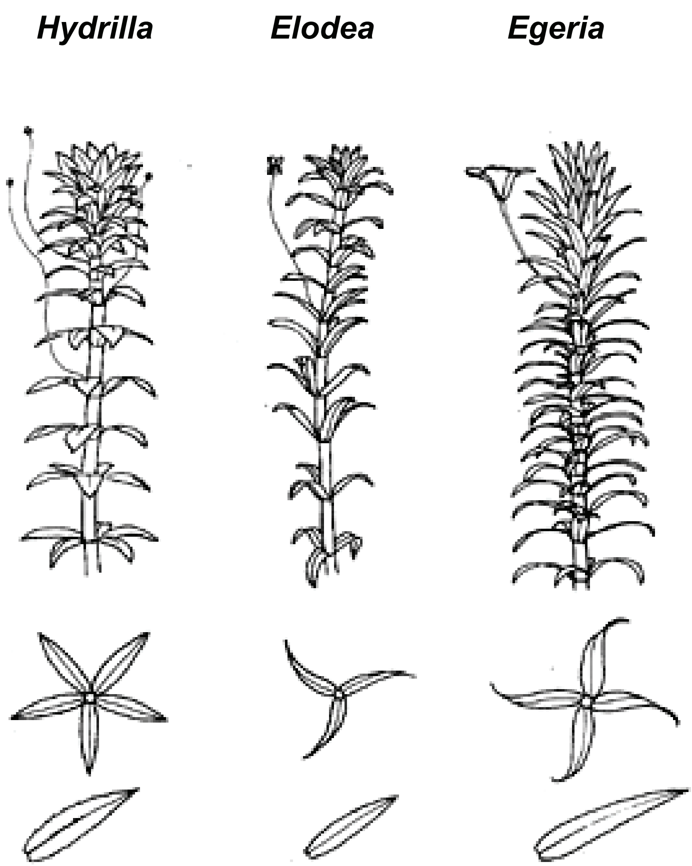

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Figure 17. *Hydrilla* is related to native *Elodea* species and to the invasive *Egeria densa*, and the species in these three genera can be hard to tell apart. *Hydrilla* leaves usually occur in whorls of five, whereas *Elodea* leaves are in whorls of three and those on *Egeria* in whorls of four.

Hydrilla leaves are about 1.5 cm long, whereas leaves on *Egeria* are usually about 2.5 cm long and those on *Elodea* average about 1.0 cm in length. The edges of *Hydrilla* leaves also have clearly visible teeth; on *Elodea* and *Egeria* leaves, teeth either are lacking or are so small that they can be seen only under magnification. The tubers that *Hydrilla* plants produce on stems in the sediment are small (14–18 mm long) and whitish, and these are found on neither *Elodea* nor *Egeria* plants.

CURLY LEAF PONDWEED

Potamogeton crispus

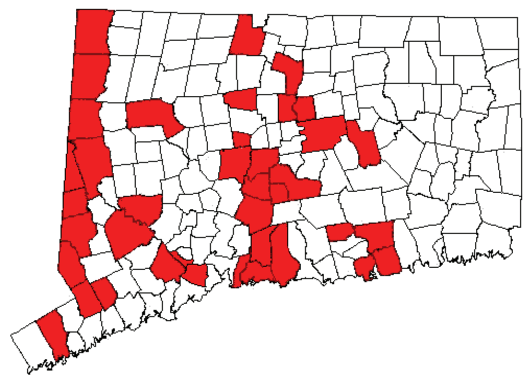

Figure 18. Distribution of *Potamogeton crispus* in Connecticut.

Curly-leaf pondweed is one of the most common invasive plants in Connecticut. A native of Asia, Europe and Africa, the species arrived in the United States before 1860 and had spread across the continent by the early 20th century (Stuckey, 1979), reaching Connecticut by 1932 (Les and Mehrhoff, 1999).

The species occurs in more than 40 Connecticut ponds and lakes as well as in the Connecticut and Housatonic rivers (Figure 18). Although its original introduction and early spread through the United States was likely related to distribution of fisheries stocks, it also has been spread by deliberate plantings (Les and Mehrhoff, 1999) and may have been distributed by birds (Tehon, 1929). Curly leaf pondweed is sometimes transported on boat trailers (Johnstone et al., 1985), is sold through aquarium and horticultural suppliers and sometimes is shipped as a contaminant in orders of other aquatic plants (Maki and Galatowitsch, 2004).

Curly-leaf pondweed is broadly tolerant of ecological conditions, occurring in oligotrophic and eutrophic waters of ponds, lakes, marshes, ditches, canals, streams and rivers (Stuckey, 1979). It appears to have an affinity for water with high alkalinity. It can occur in water more than 5m deep and forms dense stands, inhibiting growth of native plants and interfering with recreational activities (Nichols and Shaw, 1986).

(Photo by Vic Ramey, Copyright 2001 University of Florida)

Figure 19. Curly leaf pondweed, *Potamogeton crispus.*

Curly leaf pondweed is unusual in that it dies back my mid-summer (Nichols and Shaw, 1986). The species reproduces mostly by vegetative turions, which are hard, highly compact shoot tips, and this makes managing the species difficult. Production of turions is triggered by warming water in the early spring (Bartley and Spence, 1986). The turions, which are about 2.5 cm long, remain dormant until the water begins to cool in the fall, when they sprout, producing plants that grow slowly through the winter and flower in the spring, although studies have shown that few seeds germinate (Nichols and Shaw, 1986).

Potamogeton crispus is easy to recognize. It has flattened stems and distinctive leaves with wavy edges (Figure 19). Leaves are 3–8 cm long and about 50 mm wide, with rounded ends and tiny teeth (Catling and Dobson, 1985).

FANWORT

Cabomba caroliniana

(Photo by Amy Smagula)

Figure 20. Fanwort, *Cabomba caroliniana*.

Fanwort is native to the southeast United States and South America and has occurred in Connecticut since 1937 (Les and Mehrhoff, 1999), becoming a serious problem in a number of lakes since then. Until recently, the plant was sold in aquarium stores because of its attractive, bright green, fan-shaped leaves.

Submerged leaves of fanwort are opposite and have petioles (short "stems") and have finely divided blades about 3 cm long and up to 5 cm wide (Figure 20). Plants also produce floating leaves on flower shoots, but they are small and inconspicuous (Godfrey and Wooten, 1981). White or pinkish flowers, about 1.5 cm across, are raised above the surface of the water.

Like many other invasive plant species, fanwort can form dense stands that shade out native plants and interfere with recreation (Riemer and Ilnicki, 1986). It is believed to reproduce primarily by vegetative fragments (Riemer and Ilnicki, 1986). Fanwort is a popular species in water gardening and for aquariums and has escaped from cultivation many times (Les and Mehrhoff, 1999). Fanwort plants are readily cut by boat motors, and production of these vegetative fragments is known to have accelerated its dispersal within lakes, while plants carried on boat trailers have likely resulted in the species' dispersal to new lakes (Les and Mehrhoff, 1999). *Cabomba* has been collected from wetlands along the Connecticut River and from more than 30 lakes and ponds, primarily in the southern and eastern parts of the state (Les and

Mehrhoff, 1999), but it probably is much more widespread (Fig. 21). Lake Quonnipaug in Guilford has been the site of recent CAES research on control of *Cabomba* for several years, primarily using various herbicide treatments.

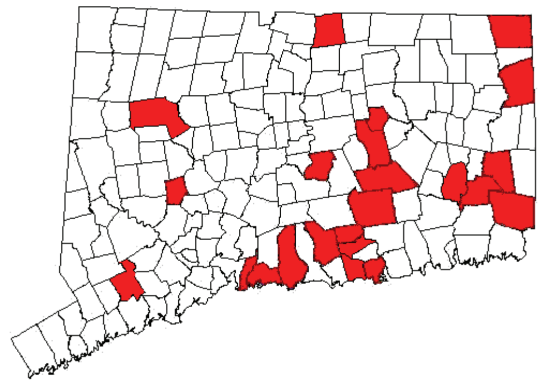

Figure 21. Distribution of *Cabomba caroliniana* in Connecticut.

WATER CHESTNUT

Trapa natans

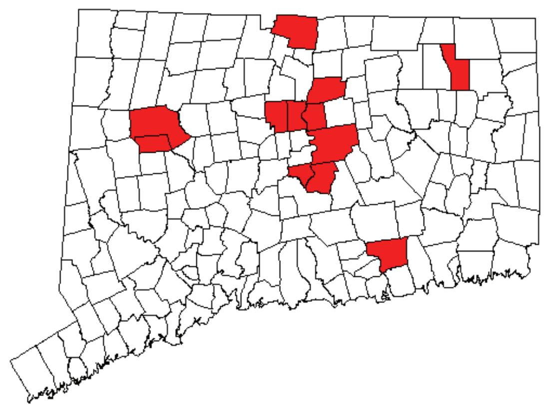

Figure 22. Distribution of *Trapa natans* in Connecticut.

Like many other invasive aquatic plants, water chestnut has escaped from cultivation (Les and Mehrhoff, 1999). A native of Asia, the species has been widely distributed for horticultural use in the United States since the 19th century (Les and Mehrhoff, 1999). Individual rosettes can be moved by water currents and wind, and the species is thought to have been introduced to some lakes on boat trailers (Les and Mehrhoff, 1999). The species arrived in Connecticut in 1999 (Nancy Murray, personal communication)and represents a serious threat to the state's lakes, ponds and rivers (Les and Mehrhoff, 1999). *Trapa* produces floating rosettes of leaves and spreads clonally, producing secondary and tertiary rosettes during the growing season (Groth et al., 1996).

Like other invasive aquatic plants, the growth of *Trapa* often is described as explosive (Groth et al., 1996). Plants spread quickly and can cover the surface of a lake within a few

(Photo copyright 2002 by Ann Bove; inset photo by Vic Ramey, University of Florida)

Figure 23. Water chestnut, *Trapa natans.* Inset: Fruits of water chestnut are hard and spiny.

years. Biomass can increase tenfold from one year to the next. Plants form dense mats on the surface of the water, shading out submerged plants (Figure 23).

Trapa is an annual plant and each year produces large quantities of large seeds with sharp spines that can injure swimmers (Les and Mehrhoff, 1999). A single seed can produce more than 10 plants, each of which then can produce as many as 20 seeds of its own. Seeds can remain viable in the sediment for as long as 12 years. Unlike other annual species, however, *Trapa* is able to outcompete perennial aquatic plants (Groth et al., 1996). Control in Connecticut has been through hand removal.

Water chestnut is easy to recognize. The leaves on floating rosettes are roughly triangular and have teeth on their front edges (Figure 24). Plants produce small incon-spicuous white flowers. Fruits are hard and have sharp spines (Figure 23, inset).

(Photo by Leslie J. Mehrhoff, University of Connecticut)

Figure 24. Water chestnut, *Trapa natans.*

NAJAS MINOR

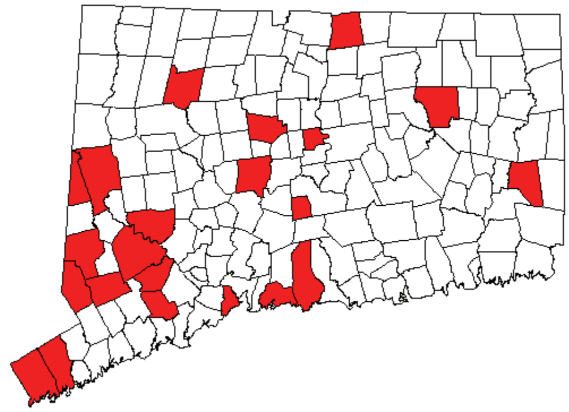

Figure 25. Distribution of *Najas minor* in Connecticut.

A native of Europe, *Najas minor* was introduced to the United States in 1934 and spread quickly, reaching the Midwest and Florida within 30 years (Meriläinen, 1968). The species arrived in Connecticut during the 1980s, and it is spreading quickly (Les and Mehrhoff, 1999). It has been collected from more than 20 Connecticut ponds and lakes (Figure 25) and was found in 31% of 32 lakes surveyed by the CAES in 2004. It is likely that the species occurs in many more lakes but has been mistaken for one of the native *Najas* species.

Unlike some invasive species, this plant does not produce long stems that grow to and spread on the surface of the water. However, it can grow very densely on the bottom and can produce shoots up to 1 m long (Meriläinen, 1968), shading out native plants and becoming dense enough to interfere with recreational activities (Hellquist and Straub 2002).

Najas minor can be confused with native *Najas* species, including the common *Najas flexilis*. Both have leaves that appear opposite each other on the stem, and small teeth occur on the leaves of both species. However, the teeth on *N. flexilis* are much smaller than those on *N. minor*. Generally, if the teeth on the leaves of a plant can be seen without a magnifying glass, it is the invasive *N. minor* (Figure 26).

Najas minor is an annual species and reproduces through production of abundant seeds (Meriläinen, 1968). Although introduced to the United States by escaping from cultivation, the species likely has been spread since then primarily by waterfowl, which eat the abundant seeds

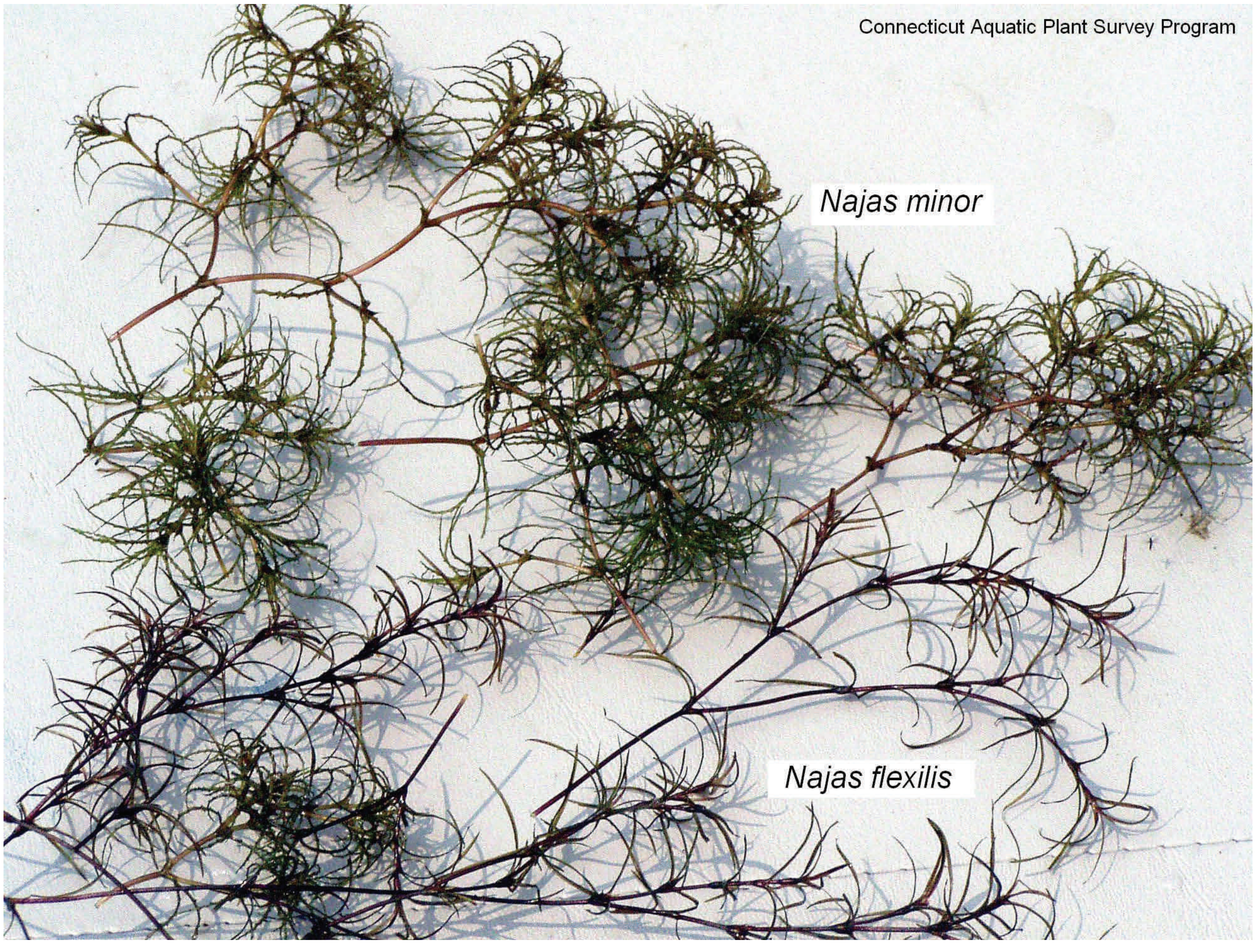

Figure 26. *Najas minor*, above, and the native *N. flexilis*, below.

of *Najas* species (Meriläinen, 1968; Les and Mehrhoff, 1999). Controlling the spread of this species by boat trailers and boats will be particularly challenging, because the seeds are inconspicuous and can be carried in bilges, trailer wheel wells and other out-of-the-way places.

Methods for controlling invasive aquatic plants

Preventing invasive aquatic plants from reaching Connecticut lakes and ponds is the preferred method of control. People can move plants from one body of water to another on boats and trailers. Through the Sea Grant program and the boating safety office of the state Department of Environmental Protection, signs have been posted at state boat ramps, detailing what the aquatic invasive plants look like and explaining the importance of checking boats and trailers to make sure they are not carrying pieces of the plants. Recent legislation (Connecticut Public Act No. 03-136) imposes fines on individuals found transporting invasive, non-native plants in this way. Plants liberated from aquariums or water gardens are another way non-native aquatic plants are introduced into freshwater ecosystems. Properly disposing of aquarium plants and isolating water gardens will help reduce these risks. Public Act No. 04-203 restricts the sale of most invasive aquatic plants in Connecticut.

Unfortunately, the spread of invasive, non-native aquatic plants in Connecticut is likely to continue because large numbers of lakes and ponds already contain the plants, and natural movement by flowing water and aquatic wildlife is largely uncontrollable. Eradication of new infestations is more likely to be successful than elimination of large areas of established plants. Volunteer monitoring programs can be initiated to routinely check water bodies for new plants. The Connecticut Agricultural Experiment Station can offer assistance to volunteers on how to survey and identify aquatic vegetation.

Many techniques are available for controlling unwanted aquatic vegetation. Regardless of the method, knowing the potential harmful effects on non-target organisms is important. Mechanical control includes hand-pulling, machine harvesting, hydroraking, benthic barriers and dredging. Typically, these methods are used in localized areas. Machine harvesting, hydroraking and dredging require permits from local, state and federal agencies. Water drawdown, particularly during the winter when freezing temperatures can damage plants, is a low-cost weed-control option. The Connecticut Department of Environmental Protection must be notified before any drawdown. Chemical aquatic weed control involves applying an herbicide to decrease the population of a plant. Invasive plants are rarely eliminated, but the recreational value of a lake or pond can be improved, and the spread of the invasive plant can be slowed. Selecting the proper herbicide and the time of application requires accurate information on the life cycle of the nuisance plant. A permit from the state DEP is required before an aquatic herbicide can be used. Experts at the experiment station and the DEP can answer questions on the use of aquatic herbicides. Biological control agents, including beneficial insects and microbes, may someday be viable aquatic weed control alternatives. To date, the only biological control used successfully in Connecticut is a plant-eating fish, the grass carp *(Ctenopharyngodon idella)*. This fish is not native and must be certified as sterile (triploid) to assure it will not reproduce in the environment. The DEP monitors the release of this fish, and a permit is required before they can be purchased. Typically, grass carp are used in small ponds. Containment of grass carp to the body of water where they are introduced is required, and special screens are needed at inflows and outflows.

Because plants need nutrients to proliferate, reducing the nutrients reaching a water body may inhibit the growth of invasive aquatic plants. Proper design and maintenance of septic systems, establishment of unfertilized shoreline buffer zones and minimizing the misapplication of fertilizer to paved areas can reduce the amount of nutrients that reaches lakes and ponds.

Anyone with aquatic plant specimens to identify or with questions about aquatic plants may call the Aquatic Plant Survey Program at (203) 974-8500 or, toll-free, 877-855-3327. Specimens may be sent to the Connecticut Agricultural Experiment Station, Aquatic Plant Survey Program, P.O. Box 1106, New Haven CT 06504.

Additional information on aquatic plants and the survey program is available at our web site, www.caes.state.ct.us/aquaticplants

Information on aquatic plant ecology and management is available at from the Army Corps of Engineers Aquatic Plant Information System: http://el.erdc.usace.army.mil/aqua/apis/

Information on management also is available at: http://plants.ifas.ufl.edu/guide/ and from the Connecticut Department of Environmental Protection: http://www.dep.state.ct.us/wst/pesticides/aweeds.pdf

Advice on how to protect a lake is available from the Vermont Department of Environmental Conservation site: http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp_lakesonlyyou.htm

Information on monitoring of invasive aquatic plants is available from the Massachusetts Department of Conservation and Recreation site: http://www.mass.gov/dcr/waterSupply/lakepond/lakepond.htm

Other sources of information on invasive aquatic plants are:

Center for Aquatic and Invasive Plants http://plants.ifas.ufl.edu/

State of Washington Department of Ecology Non-Native Freshwater Plants http://www.ecy.wa.gov/programs/wq/plants/weeds/exotic.html

The Invasive Plant Atlas of New England http://invasives.eeb.uconn.edu/ipane/

The National Invasive Species Council http://www.invasivespecies.gov

USGS Center for Aquatic Resource Studies http://nas.er.usgs.gov/plants/index.html

Connecticut Federation of Lakes http://ctlakes.org/ct_lakes_version_1_001.htm

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References

Aiken, S.G., P.R. Newroth and I. Wile. 1979. The biology of Canadian weeds. 34. *Myriophyllum spicatum* L. Canadian Journal of Plant Science 59:201-215.

Aiken, S.G. 1981. A conspectus of *Myriophyllum* (Haloragaceae) in North America. Brittonia 33:57-69.

Anonymous, 1993. Harmful Non-Indigenous Species in the United States. Office of Technology Assessment, U.S. Congress, Washington, D.C.

Barrett, S.C.H. 1989. Waterweed invasions. Scientific American 261:90-97.

Bartley, M.R., and D.H.N. Spence. 1986. Dormancy and propagation in helophytes and hydrophytes. Archiv für Hydrobiologie 27

Bartodziej, W., and J. Ludlow. 1998. Aquatic vegetation monitoring by natural resource agencies in the United States. Aquatics 20:15-18.

Bates, A.L., E.R. Burns and D.H. Webb. 1985. Eurasian watermilfoil (*Myriophyllum spicatum* L.) in the Tennessee valley: An update on biology and control. Pp 104-115 in Anderson, L.W.J., ed., Proceedings of the First International Symposium on Watermilfoil (*Myriophyllum spicatum*) and Related Haloragaceae Species. Aquatic Plant Management Society, Vicksburg, Mississippi.

Bugbee, G.J., J.C. White and W.J. Krol. 2003. Control of variable watermilfoil in Bashan Lake, CT with 2,4-D: Monitoring of lake and well water. Journal of Aquatic Plant Management 41:18-25.

Catling, P.M., and I. Dobson. 1985. The biology of Canadian weeds. 69. *Potamogeton crispus* L. Canadian Journal of Plant Science 65:655-668

Center, T.D., J.H. Frank and F.A. Dray. 1997. Biological control. Pp. 245-266 in: Simberloff, D., D.C. Schmitz and T.C. Brown, eds., Strangers in Paradise. Island Press, Washington, D.C.

Couch,, R., and E. Nelson. 1985. *Myriophyllum spicatum* in North America. Pp 8-18 in: Anderson, L.W.J., ed., Proceedings of the First International Symposium on Water Milfoil (*Myriophyllum spicatum*) and related Haloragaceae Species. Aquatic Plant Management Society, Vicksburg, Mississippi.

Crow, G.E., and Hellquist, C.B. 2000a. Aquatic and Wetland Plants of Northeastern North America. Vol. 1. Pteridophytes, Gymnosperms and Angiosperms: Dicotyledons. University of Wisconsin Press, Madison.

Crow, G.E., and Hellquist, C.B. 2000b. Aquatic and Wetland Plants of Northeastern North America. Vol. 2. Angiosperms: Monocotyledons. University of Wisconsin Press, Madison.

De Kozlowski, S. J. 1991. Lake Marion sterile grass carp stocking project. Aquatics 13:13-16.

Eiswerth, M.E., S.G. Donaldson and W.S. Johnson. 2000. Potential environmental impacts and economic damages of Eurasian watermilfoil (*Myriophyllum spicatum*) in western Nevada and northeastern California. Weed Technology 14:511-518.

Godfrey, R.K., and J.W. Wooten. 1981. Aquatic and Wetland Plants of Southeastern United States. Dicotyledons. University of Georgia Press, Athens.

Groth, A.T., L. Lovett-Doust and J. Lovett-Doust. 1996. Population density and module demography in *Trapa natans* (Trapaceae), an annual, clonal aquatic macrophyte. American Journal of Botany 83:1406-1415.

Hellquist, C.B., and J. Straub. 2002. A guide to selected invasive non-native aquatic species in Massachusetts. Massachusetts Department of Environmental Management, Boston.

Hofstra, D.E., J. Clayton, J.D. Green and M. Auger. 1999. Competitive performance of *Hydrilla verticillata* in New Zealand. Aquatic Botany 63:305-324.

Howard-Williams, C. 1993. Processes of aquatic weed invasions: A New Zealand example. Journal of Aquatic Plant Management. 31:17-23.

Hutchinson, G.E. 1975. A Treatise on Limnology. Vol. 3. J. Wiley, New York.

Johnstone, I.M., B.T. Coffey and C. Howard-Williams. 1985. The role of recreational boat traffic interlake dispersal of macrophytes: A New Zealand case study. Journal of Ecological Management 20:263-279.

Keast, A. 1984. The introduced aquatic macrophyte, *Myriophyllum spicatum*, as habitat for fish and their invertebrate prey. Canadian Journal of Zoology 62:1289-1303.

Langeland, K.A. 1996. *Hydrilla verticilla* (L.F.) Royle (Hydrocharitaceae), “The perfect aquatic weed.” Castanea 61:293-304.

Les, D.H., L.J. Mehrhoff, M.A. Cleland and J.D. Gabel. 1997. *Hydrilla verticilla* (Hydrocharitaceae) in Connecticut. Journal of Aquatic Plant Management 35:10-14.

Les, D.H., and L.J. Mehrhoff. 1999. Introduction of nonindigenous aquatic vascular plants in southern New England: A historical perspective. Biological Invasions 1:281-300.

Liddle, M.J., and H.R.A. Scorgie. 1980. The effects of recreation on freshwater plants and animals: A review. Biological Conservation 17:183-206.

Madsen, J.D., L.W. Eichler and C.W. Boylen. 1988. Vegetative spread of Eurasian watermilfoil in Lake George, New York. Journal of Aquatic Plant Management 26:47-50.

Madsen, J.D., J.W. Sutherland, J.A. Bloomfield, L. W. Eichler and C.W. Boylen. 1991. The decline of native vegetation under dense Eurasian watermilfoil canopies. Journal of Aquatic Plant Management 29:94-99.

Maki, K., and S. Galatowitsch. 2004. Movement of invasive aquatic plants into Minnesota (USA) through horticultural trade. Biological Conservation 118:389-396.

Meriläinen, J. 1968. *Najas minor* All. in North America. Rhodora 70:161-175.

Moody, M.L., and D.H. Les. 2002. Evidence of hybridity in invasive watermilfoil (*Myriophyllum*) populations. Proceedings of the National Academy of Science 99:14867-14871.

Nichols, S.A., and B.H. Shaw. 1986. Ecological life histories of the three aquatic nuisance plants, *Myriophyllum spicatum*, *Potamogeton crispus* and *Elodea canadensis*. Hydrobiologia 131:3-21.

Pimentel, D., L. Lach, R. Zuniga and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. Bioscience 53:53-65.

Reed, C.F. 1977. History and distribution of Eurasian watermilfoil in United States and Canada. Phytologia 36:436.

Riemer, D.N., and R.D. Ilnicki. 1968. Reproduction and overwintering of *Cabomba* in New Jersey. Weed Science 16:101-102.

Sculthorpe, C.D. 1967. The Biology of Aquatic Vascular Plants. Edward Arnold Publishers Ltd., London.

Sheldon, S.P. 1994. Invasians and declines of submerged macrophytes in New England, with particular reference to Vermont lakes and herbivorous invertebrates in New England. Lake and Reservoir Management 10:13-17.

Simberloff, D. 1997. Eradication, Pp. 221-228 *in*: Simberloff, D., D.C. Schmitz and T.C. Brown, eds., *Strangers in Paradise*, Island Press, Washington, D.C.

Stuckey, R.L. 1979. Distributional history of *Potamogeton crispus* (curly pondweed) in North America. Bartonia 46:22-42.

Sytsma, M.D., and L.W.J. Anderson. 1993. Nutrient limitation in *Myriophyllum aquaticum*. Journal of Freshwater Ecology 8:165-176.

Tehon, L.R. 1929. The present range of *Potamogeton crispus* L. in North America. Torreya 29:42-46.

Vitousek, P.M., C.M. D'Antonio, L.I. Loope and R. Westerbrooks. 1996. Biological invasions as global environmental change. American Scientist 84:468-478.

Whittenberg, R., and M.J.W. Cook, eds. 2001. *Invasive Alien Species: A Toolkit of Best Prevention and Management Practices*. CAB International, Wallingford UK

Wilcove, D.S., D. Rothstein, J. Dubow, A. Phillips and E. Losos. 1998. Quantifying threats to imperilled species in the United States. BioScience 48:607-615.

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