Aquatic plants among most destructive invasives

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In the past 150 years, aquatic plants have provided some of the most potent demonstrations of the power of invasive species to alter natural ecosystems and to interfere with human activities, both economic and recreational. From *Elodea canadensis* (waterweed) in Europe to *Eichornea crassipes* (water-hyacinth) in Florida, aquatic invasive species have frustrated natural resource managers and amazed botanists with their ability to grow rapidly, producing enormous numbers of plants, often vegetatively, crowding out native plants, covering the surface of lakes and rivers, and clogging navigation channels, flood-control canals, water intake pipes and drainage ditches.

As one example, Lake Kariba was created in 1958 by damming the Zambezi River on the Zimbabwe-Zambia border to generate hydroelectric power. One year later, *Salvinia molesta*, an aquatic fern native to Brazil, was first observed in the lake. After three years, the plant covered 1,000 square kilometers, more than 20% of the lake's surface area, threatening the hydroelectric dam's operation as well as commercial fisheries and recreational use of the lake. Calculations showed that what came to be known as Kariba weed had a doubling time of 4.6 days and that dry weight of the species was increasing at a rate of 4% per day. Herbicide treatments and mechanical removal were unable to control the plant, but biological control efforts with invertebrates (a grasshopper and a weevil) now have greatly reduced the species' abundance.

Kariba weed is probably not a threat to Connecticut, but *Hydrilla verticillata* (hydrilla) is. *Hydrilla* was intentionally introduced to drainage canals in Florida by the aquarium trade around 1950, and it had spread to all drainage basins in Florida by the early 1970s. It reached 13,340-acre Orange Lake in 1972 and covered 90% of the lake's surface four years later. An economic impact study determined that the economy of the Orange Lake region incurred losses of about $10 million a year through lost tourism, reduced real estate values and declines in recreational activities due to the effect of *Hydrilla*. Meanwhile, *Hydrilla* continued to spread through Florida and was found in 41% of the state's water bodies by 1991. The state spent $14.5 million on *Hydrilla* control in 2003-04.

Other states' experience with *Hydrilla* has been similar. Connecticut, so far, has been lucky. *Hydrilla* arrived in 1995 and has been confined since then to a few small ponds. Biologists take little comfort in this. Even when invasive aquatic plants do not grow explosively, they represent a threat for the future.

Invasive aquatic plants are not new to Connecticut, but they are receiving increased attention, in part because the public is becoming more aware of their serious effects, economic and ecological. Annual losses and control costs related to invasive aquatic plants total $110 million in the United States, and among the causes of species' extinctions globally, invasive species rank second only to habitat destruction.

The Connecticut Agricultural Experiment Station has engaged in research on invasive aquatic plants for a number of years, focusing primarily on management. In the past year, support from U.S. Department of Agriculture has permitted expansion of the program to include aquatic plant surveys of state lakes and ponds.

The surveys have several goals. First, Experiment Station scientists hope to find invasive plants more quickly, which may make it possible to eradicate them. Second, the surveys will allow scientists to track the spread of invasive species already present in the state, and this will lead to testable hypotheses about the species' environmental affinities and about what factors place lakes at risk of invasion. Third, surveys over time will reveal how aquatic plants communities are changing. Finally, the surveys provide baseline information on lakes that have no invasive species, and this, too, is valuable in quantifying the effects of invasions on native communities. This kind of basic information is currently lacking for most Connecticut lakes and ponds.

The surveys are conducted in a boat by two people, one to sample vegetation and one to record observations and sampling locations (Fig. 1), using Global Positioning System equipment that records satellite-generated signals. Vegetative beds are mapped in each lake (Fig. 2), and specimens of all submerged and floating-leaved species are collected, dried and archived. The mapping is done by surface observation of plants and sampling in deep water with a long-handled rake. Water is tested in the lake for clarity, and temperature and dissolved oxygen profiles are recorded. Water samples are collected and returned to the laboratory for pH, alkalinity, conductivity and phosphorus analysis. Correlations are being sought between water chemistry and aquatic vegetation.

Experiment Station investigators also obtain quantitative information on species abundance in permanent, 80 m georeferenced transects established perpendicular to the shoreline in each lake, recording the abundance of all aquatic plants at 5–10 m intervals.

In addition to conducting the surveys, Experiment Station scientists are working with the Connecticut Department of Environmental Protection, the Invasive Plant Atlas of New England and other agencies to coordinate activities and consolidate information on invasive aquatic plants in the northeast United States.

A database is being developed in which information on aquatic plant occurrence and abundance will be compiled and made available for research. In addition, a web site is being developed that will provide access to the database and other information, including information on management of aquatic plants.

Experiment station scientists and the Connecticut Federation of Lakes will launch a program in the spring to recruit volunteers to monitor state lakes, perform surveys of aquatic plants, analyze water for chemical changes or distribute literature on aquatic plants at boat ramps. This program will put more people to work, looking for new invasive species and tracking those already here, and thus, will generate more information than would be available otherwise.

During the first summer of surveillance in 2004, 32 lakes were surveyed, ranging in size from 18 to 445 acres. A total of 59 species were recorded, including five floating-leaved species. Of the total, seven were invasive taxa (Table 1). The most frequently found invasive species was curly leaf pondweed (*Potamogeton crispus*), found in 41% of surveyed lakes, followed by Eurasian water-milfoil (*Myriophyllum spicatum*) found in 34%.

One of the survey program's first substantive contributions was the discovery that an annual species native to Europe, *Najas minor*, is more common and is spreading more quickly than had been appreciated (Figs. 3, 4). The species, which probably arrived in Connecticut during the 1980s, was found in 10 of the 32 lakes surveyed in 2004 (31%).

Of the 32 lakes examined, 24 had at least one invasive species, and not surprisingly, the number of invasive species in the surveyed lakes increased with lake area. The lakes with the fewest aquatic species also were the smallest – Maltby Lake No. 1 in West Haven, which had four aquatic plant species, and Dooley Pond in Middletown, with five. Three bodies of water had high plant diversity: Lake Quonnipaug in Guilford, 25 species, Manitook Lake in Granby, 24, and Holbrook Pond in Hebron, 23. Lake Quonnipaug also had more invasive plant species than any other surveyed lake, a total of four, while Manitook Lake and Holbrook Pond had two and three invasive plant species, respectively. Several of the plant species recorded in 2004 represented first-time reports in the surveyed towns, and the collection of European water-clover (*Marsilea quadrifolia*, Fig 5) in Batterson Park Pond was the first record of the species in Hartford County.

Compared with all Connecticut lakes and ponds, those surveyed in 2004 were disproportionately large, in part because large lakes tend to have boat ramps, so access is easier. Station scientists plan to survey more small ponds and lakes in 2005 to obtain a more representative sample of the state's water bodies.

Table 1. The frequency of aquatic plants recorded during surveys of 32 Connecticut lakes and ponds is reported. Shown are the names of aquatic plants and the percentage of the surveyed lakes in which each was observed in 2004. Invasive species are in boldface.

SUBMERGED SPECIES			
Potamogeton pusillus	59.4	*Potamogeton spirillus*	12.5
Ceratophyllum demersum	46.9	*Elodea canadensis*	12.5
Elodea nuttallii	46.9	*Najas gracillima*	12.5
Najas flexilis	43.8	*Gratiola aurea*	12.5
Potamogeton bicupulatus	40.6	*Potamogeton illinoensis*	9.4
Potamogeton epihydrus	40.6	***Myriophyllum heterophyllum* X *laxum***	**9.4**
Potamogeton crispus	**40.6**	*Utricularia intermedia*	9.4
Utricularia gibba	37.5	*Isoëtes* sp.	9.4
Myriophyllum spicatum	**34.4**	*Potamogeton vaseyi*	6.3
Vallisneria americana	34.4	*Potamogeton oakesianus*	6.3
Najas minor	**31.3**	*Myriophyllum tenellum*	6.3
Potamogeton amplifolius	28.1	*Myriophyllum humile*	6.3
Potamogeton gramineus	28.1	*Zosterella dubia*	6.3
Potamogeton natans	25.0	*Zannichellia palustris*	6.3
Potamogeton robbinsii	25.0	*Isoëtes tuckermanii*	6.3
Utricularia purpurea	25.0	*Isoëtes echinospora*	6.3
Myriophyllum heterophyllum	**21.9**	*Elatine triandra*	6.3
Najas guadalupensis	21.9	*Callitriche* sp.	6.3
Potamogeton perfoliatus	18.8	*Potamogeton friesii*	3.1
Potamogeton pulcher	18.8	*Myriophyllum sibiricum*	3.1
Utricularia geminiscapa	18.8	*Utricularia minor*	3.1
Potamogeton zosteriformis	18.8	*Utricularia subulata*	3.1
Utricularia vulgaris	15.6	*Ranunculus longirostris*	3.1
Utricularia radiata	15.6	*Isoëtes lacustris*	3.1
Ceratophyllum echinatum	15.6	*Elatine minima*	3.1
Polygonum amphibium	15.6	*Elatine americana*	3.1
Cabomba caroliniana	**15.6**	*Callitriche heterophylla*	3.1
FLOATING LEAVED SPECIES		EMERGENTS	
Nymphaea odorata	56.3	*Eleocharis acicularis*	40.6
Nuphar variegata	53.1	*Eriocaulon aquaticum*	21.9
Brasenia schreberi	43.8	*Sparganium* sp.	6.25
Nymphoides cordata	15.6	*Eleocharis parvula*	3.1
Nymphaea odorata ssp. *tuberosa*	3.1	Unidentified sedges	21.9
Marsilea quadrifolia	**3.1**	*Sagittaria* sp.	*
Lemnaceae	*		

* Several species in the family Lemnaceae and the genus *Sagittaria* also were observed, but their presence was not recorded.

Fig. 1. Roslyn Selsky, a researcher working on the Aquatic Plants Survey Program, inspects plants collected during a survey done in July 2004 on Lake Saltonstall.

Fig. 2. A map of Holbrook Pond in Hebron shows the location of aquatic plants observed during a survey done in 2004. Data on abundance of the plants were obtained in nine transects, T1–T9.

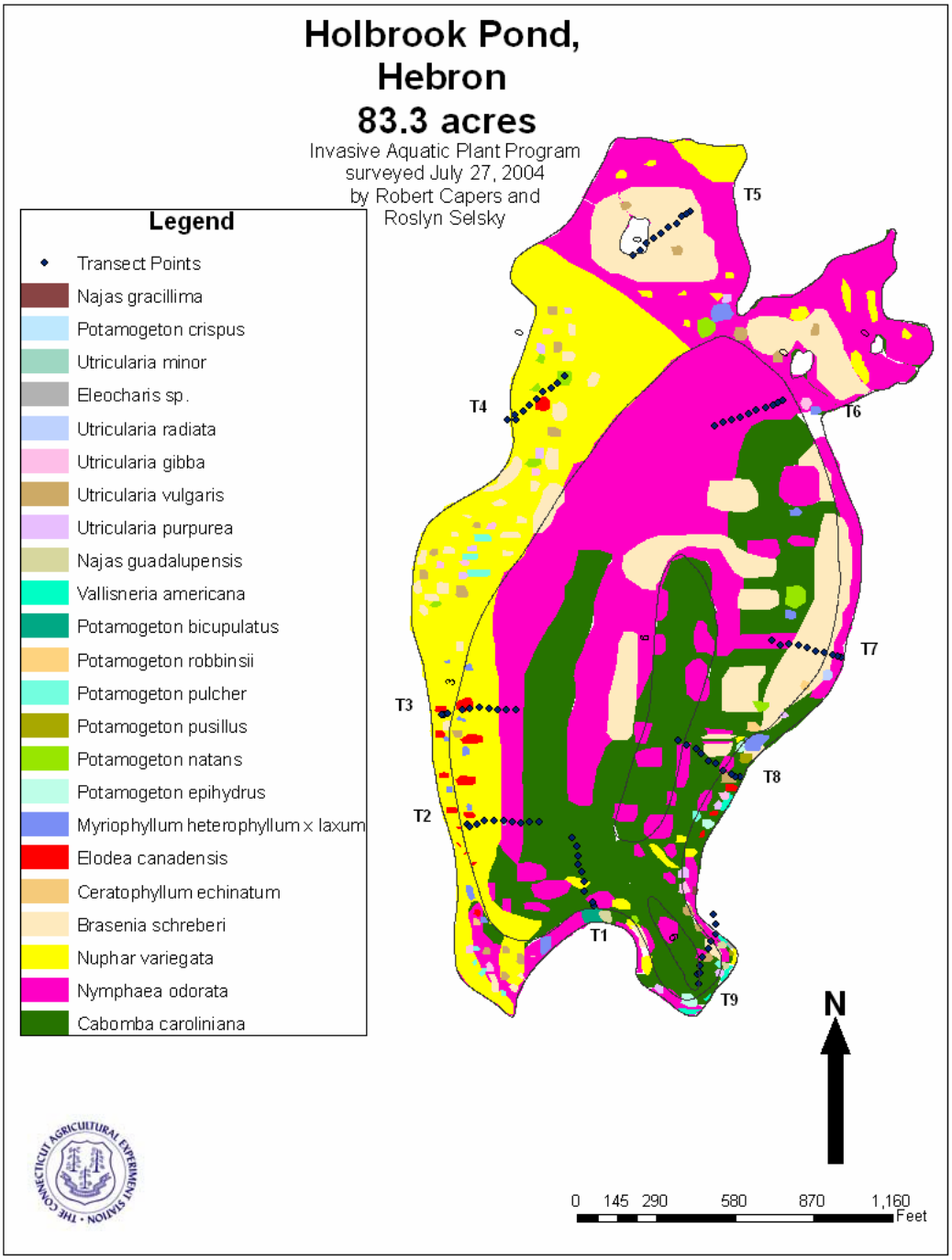

Fig. 3. The invasive *Najas minor* (top) and the native *Najas flexilis* (below). Specimens of both species were collected during an August 2004 survey of Canoe Brook Lake in Trumbull.

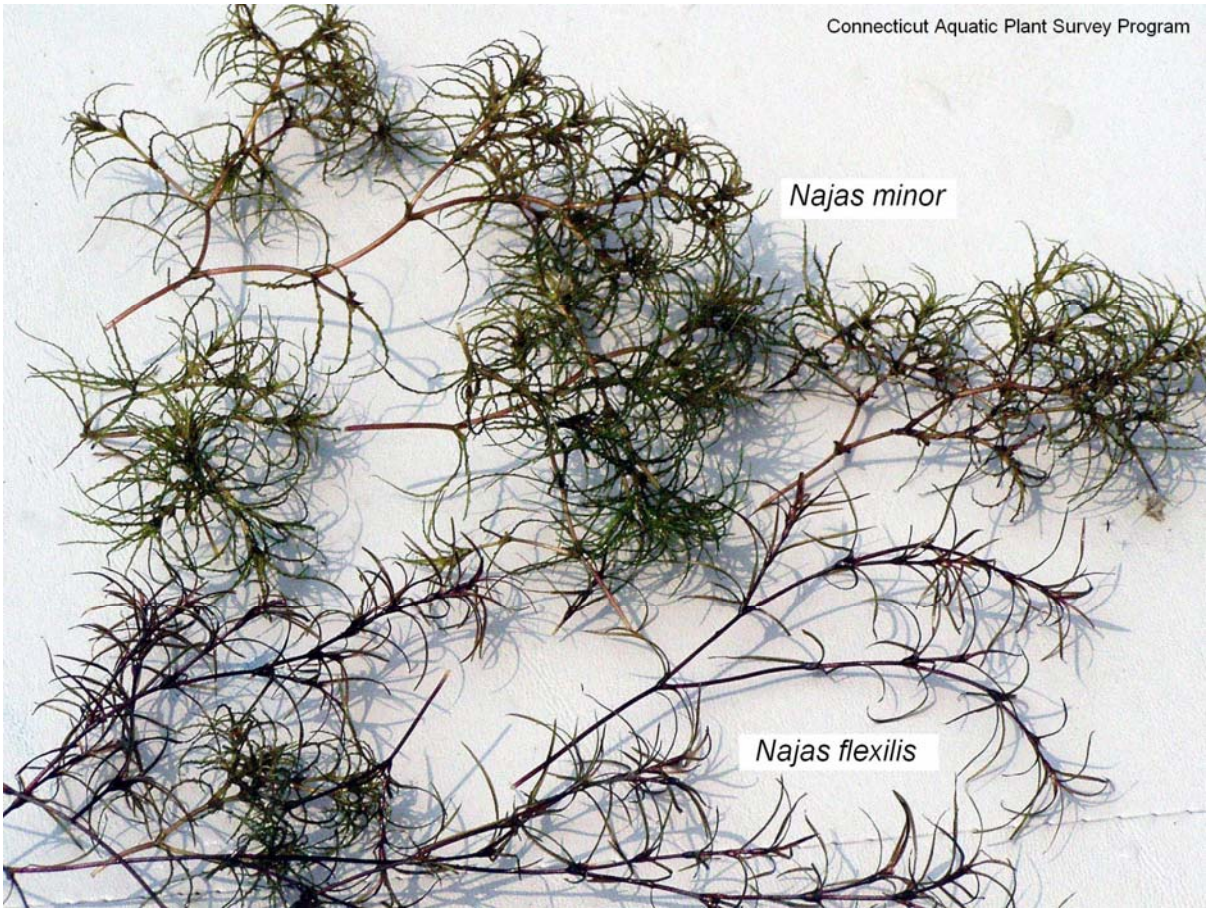

Fig. 4. The distribution of *Najas minor* in Connecticut, in 2004. The species, a native of Europe and Asia, has been found in each of the towns shown in red.

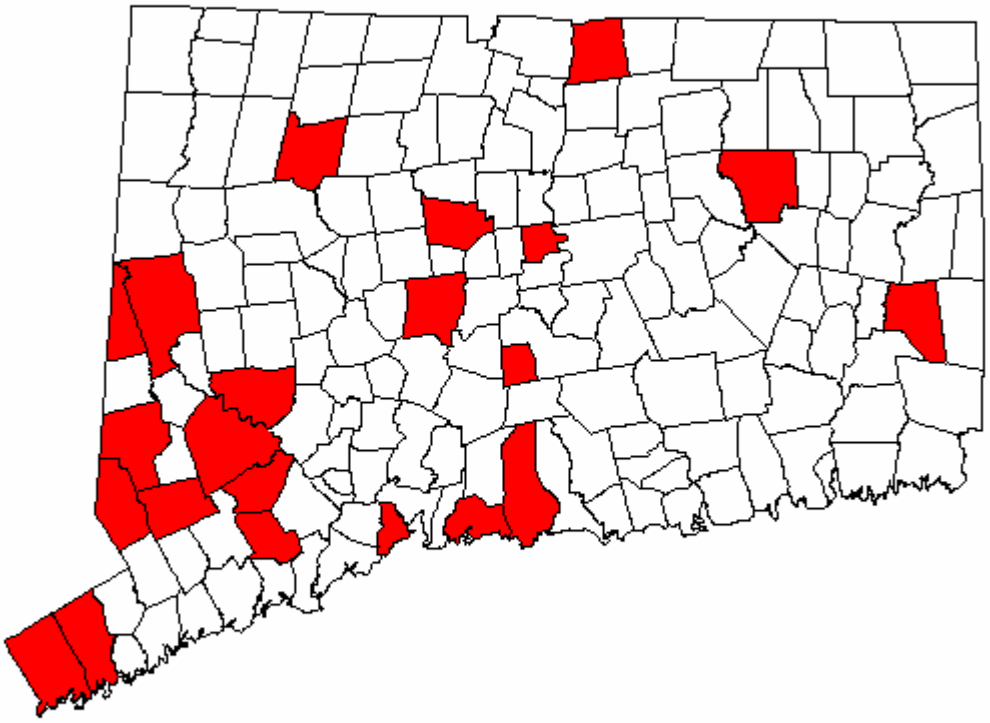

Fig. 5. *Marsilea quadrifolia*, a fern that is native to Europe, was photographed at Batterson Park Pond in Farmington.