Volume 21 • Number 2 • 2005

EURASIAN WATERMILFOIL INVASIONS AND MANAGEMENT ACROSS THE UNITED STATES

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EURASIAN WATERMILFOIL IS A NON-NATIVE AQUATIC PLANT *from Europe and Asia that is green throughout the entire year. Growing completely underwater, with only the inflorescences above the water's surface, it can often be difficult to notice in early stages. Once mature, its dense canopy can interfere with boating, swimming, fishing, or other aquatic activities. Ecologically, it suppresses native plants and changes the equilibrium between predators, like bass, and their prey. Eurasian watermilfoil nuisance growths cost lake users millions of dollars a year to manage, and even more in other economic losses. While many management techniques are available, all are expensive and result in long-term management programs. The best option is to prevent the spread of this, and other, nuisance aquatic plants.*

Invasive plant species are widely recognized as a major concern to habitats across the country, including agricultural fields, pastures, rangeland, woodlots and forests, streamsides, and wetlands. In recognition of the importance of wetlands as habitats for fish and wildlife, much concern has focused on invasive species like purple loosestrife, melaleuca, salt cedar, and alligatorweed. Even wetland aficionados, however, forget that a wetland does not end at the surface of the water. An often-neglected community is that of the submersed aquatic plants, though this is often the most important community for fish spawning and nursery habitat. The submersed plant zone is being invaded by non-native species like hydrilla, egeria, and Eurasian watermilfoil, the topic of this paper. Eurasian watermilfoil is the most widely distributed invasive submersed plant in the United States.

EURASIAN WATERMILFOIL DESCRIPTION

Eurasian watermilfoil (*Myriophyllum spicatum L.*) grows completely under water (see Figure 1 on page 22), but can form a canopy of leaves and branches very close to the surface (see Figure 2 on page 22). It is a submersed evergreen perennial plant, with green shoots present throughout the year. Eurasian watermilfoil grows in water depths from one to 15 feet, from which it can grow to the surface. It occasionally grows in even deeper water, if water clarity is particularly high. Eurasian watermilfoil forms a dense root crown, from which numerous shoots grow towards the surface. The root crown and associated new shoots are the primary means by which Eurasian watermilfoil overwinters (see Figure 3 on page 22). As it grows to the surface, it branches repeatedly to form a very dense canopy with a profusion of leaves. The leaves are pinnately compound, with 14 to 24 pairs of thin tubular leaflets. These leaves typically occur in groups of four whorled at each node of the stem, though some variation can occur. The plant forms a short inflorescence, or flowering spike, above the surface of the water, composed of pollen-forming flowers on top and seed-producing flowers below (see Figure 4 on page 23). The flowers are wind pollinated. Stems and apical tips of Eurasian watermilfoil tend to be reddish, but variation in this color also occurs. Since Eurasian watermilfoil looks like some of the native Myriophyllum species, confusion in the identification of this nuisance invader frequently occurs. The native watermilfoil species provide valuable habitat for aquatic species, and rarely cause the same nuisance problems produced by Eurasian watermilfoil.

ECOLOGY OF EURASIAN WATERMILFOIL

Eurasian watermilfoil grows in a diverse range of aquatic habitats, including rivers, reservoirs, natural lakes and freshwater, and brackish estuaries. Eurasian watermilfoil can tolerate salinity as high as 13 ppt (approximately 33 percent of seawater), and growth is undiminished below salinities of 6 ppt (approximately 15 percent of seawater; Haller et al., 1974). In freshwater, it tolerates environments ranging from soft water, low alkalinity systems to hard water lakes, and trophic states from oligotrophic to eutrophic (Smith and Barko, 1990 and Madsen, 1998). The growth can vary across its range from being winter dormant in northern lakes to dormant in both winter and mid-summer (from heat stress) in the south (Madsen, 1997).

Eurasian watermilfoil requires light, nutrients, and carbon dioxide to grow. Since it forms a dense surface canopy, light can be collected from near the water surface in even relatively turbid water (Madsen et al., 1991a). Because it is a rooted plant, it derives most of its nutrients from the sediment rather than the water column. In most instances, nitrogen rather than phosphorus is limiting to growth (Smith and Barko, 1990). Carbon dioxide is taken from the water as either dissolved carbon dioxide or as bicarbonate (Grace and Wetzel, 1978).



Figure 1 (left). Underwater view of the canopy of Eurasian watermilfoil in 12 feet water depth, in the clear waters of Lake George, New York. Figure 2 (middle). Eurasian watermilfoil growing close to the surface in the waters of Lake Hortonia, Vermont. Figure 3 (right). The dense root crown of Eurasian watermilfoil is how the plant grows and overwinters.

While seeds are produced, they generally do not appear to be an important source of new colonies (Hartleb et al., 1993). Seeds resist desiccation; so one possible mechanism of reproduction by seed is after drawdown (Standifer and Madsen, 1997). Reproduction is almost entirely by vegetative means, either through spread by stolons or fragments (Madsen et al., 1988 and Madsen and Smith, 1997). The plants produce fragments seasonally that act as dispersal units, and can survive for long periods of time before establishment occurs.

PROBLEMS CAUSED BY EURASIAN WATERMILFOIL

Eurasian watermilfoil invasions are not only problematic to human use of water resources, but also have negative ecological impacts on aquatic systems.

Human uses that are adversely affected by Eurasian watermilfoil infestations include recreational boating, shore and boat fishing, water skiing, and swimming (Newroth, 1985). Eurasian watermilfoil also increases sedimentation in reservoirs, and imparts unwanted taste and odor to drinking water. As with other submersed plants, it can increase the risk of flooding, reduce the flow of floodwater, impede hydroelectric generation, and foul water intakes (OTA, 1993).

Ecological impacts to aquatic habitats are somewhat more difficult to quantify than those to human uses. Dense Eurasian watermilfoil decreases both the diversity and abundance of native aquatic plants, causing localized extinction of species (Madsen et al., 1991b; Boylen et al., 1999). Eurasian watermilfoil reduces dissolved oxygen under the canopy, and may increase nutrient loading from sediments (Unmuth et al., 2000; Smith and Adams, 1986). Widespread growth of Eurasian watermilfoil in a lake may reduce macroinvertebrate density, and abundance (Cheruvelil et al., 2002). Fish communities and predator/prey equilibria may also be altered (Valley and Bremigan, 2001).

HOW EURASIAN WATERMILFOIL IS SPREAD

Eurasian watermilfoil spread throughout the United States is a combination of human intervention and natural processes, depending on the scale of dispersal (see Figure 5 on page 23). The initial transfer from Europe and Asia was completely by human transport. Some possible theories include the use of Eurasian watermilfoil as an aquarium plant, use as solid ballast in ships, or in the aquatic nursery trade. Interstate transfer of Eurasian watermilfoil was also predominantly human-vectored, though in some instances water flow could carry Eurasian watermilfoil across state boundaries. The most likely carrier of Eurasian watermilfoil between states or watersheds is on boats and boat trailers, with some transfer by means mentioned above (Johnstone et al., 1985). Inadvertent transfer with bait is also possible. Within a watershed or in-lake, transfer is likely done solely by water movement carrying fragments (Kimbel, 1982). Eurasian watermilfoil is a prolific former of autofragments, fragments created by an abscission layer in the stem, which are stem segment propagules (Madsen et al., 1988; Madsen and Smith, 1997). Thus, once Eurasian watermilfoil is in a lake or a watershed, it is difficult to prevent its spread by natural means. Wave action, boating, or other mechanical stresses that break the stem may also form stem fragments, which may form new colonies of Eurasian watermilfoil.

CURRENT DISTRIBUTION OF EURASIAN WATERMILFOIL

Eurasian watermilfoil was first found in the United States in the 1940s, with almost simultaneous introductions to California, Arizona, Ohio, and the Chesapeake Bay (Couch

Figure 4. Eurasion watermilfoil stems at the water surface with flower spikes extending into the air.

and Nelson, 1985; see Figure 6). Apparently, all these states acted as loci for spread, with populations found in a number of northeastern, midwestern, southwestern, and southeastern states by 1960. By the 1980s, numerous sites occurred throughout the United States with the apparent exception of the northern plains states. Currently, it is one of the most widespread invasive aquatic plants, occurring in at least 45 states and in three Canadian provinces (Jacono and Richerson, 2003). Given its adaptability to a wide range of environmental conditions, it is the invasive aquatic plant most likely to be found in any state of the U.S., in waters ranging from cool mountain lakes to brackish estuaries. Once established in a new state, it continues to spread to new lakes.

TECHNIQUES TO MANAGE EURASIAN WATERMILFOIL

Before managing a Eurasian watermilfoil infestation, a plan should be developed that includes defining the problem, setting management goals, determining resources and needs, assessing the problem, developing a method of assessing the management success, and informing the public. All management techniques should be considered based on their merits, and all aquatic plant management techniques have positive and negative attributes; there is no perfect and painless solution. All management techniques, including doing nothing, have some negative environmental impact. The techniques should be selected based on economic, environmental, and technical constraints.

A brief overview of management techniques specifically for Eurasian watermilfoil is provided in Table 1 on page 26, with more detail given elsewhere (Madsen, 2000). In addition, the Aquatic Ecosystem Restoration Foundation has recently published a Best Management Practices manual that includes Eurasian watermilfoil (AERF, 2004). Several lakes have management plans or guidance documents that are helpful; one recent effort for Houghton Lake (MI) is particularly thorough in its review of the literature (Getsinger et al., 2002)

Institutional controls should be part of an overall plan, but alone will not protect a lake from invasive species. A combination of regulations that prevent transport of species and public education about invasive species will help reduce the spread of problematic species. Before introduction of invasive species, concerned citizens should start monitoring their lakes for invasive plants, or ensure that the responsible entity is doing so, to serve as an early warning of invasion. Early response is the key to preventing widespread management problems.

A number of biological control organisms have been utilized for Eurasian watermilfoil. Grass carp do not prefer Eurasian watermilfoil, so they are a poor control option at best. Native insects (Madsen et al., 2000) and a native pathogenic fungus (Nelson and Shearer, 2002) have both shown some promise, but are still under development. The bottom line is

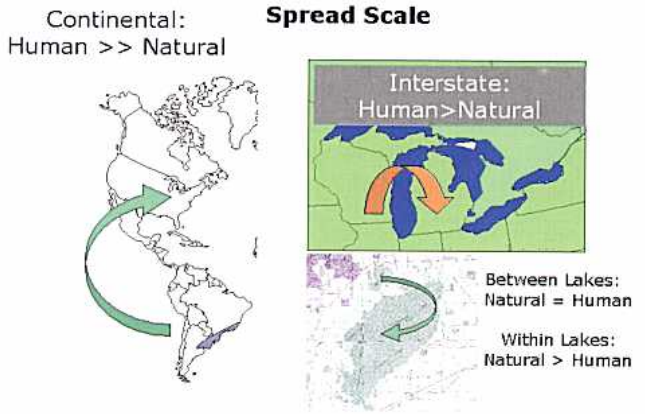

Figure 5. Scale of invasive plant spread determines whether human or natural processes predominate.

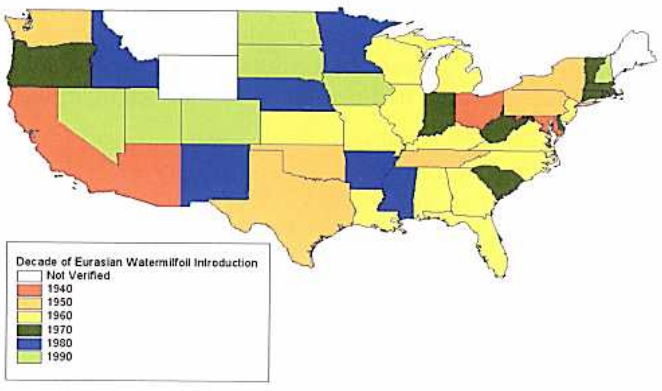

Figure 6. Estimated decade of introduction to each state in the U.S.

that there is not currently an operational biocontrol agent for Eurasian watermilfoil.

Herbicides are the most commonly used control technique for Eurasian watermilfoil. New herbicides have been approved or are in the process of registration by the U.S. E.P.A for use in aquatic environments for control of Eurasian watermilfoil. Currently, approved systemic aquatic herbicides are 2, 4-D, fluridone, and triclopyr. The contact herbicides diquat and endothall are also used on small infestations or along shorelines as a "spot" treatment.

Mechanical controls are also widely used for managing Eurasian watermilfoil. Of these, hand harvesting or hand implements are used on small segments of shoreline. Harvesters are commonly used to relieve the nuisance growth in larger areas offshore, with the plant material removed from the lake. While users get immediate relief from plant growth, this technique will not result in long-term control. Other techniques in use include rotovating, using an underwater tilling apparatus, and diver-operated suction harvesting, where SCUBA divers use a vacuum lift to remove plants by their roots.

Physical control techniques include a number of approaches, such as shading or dredging, to decrease the light available to plants. Of the physical techniques, the most affordable and effective is drawdown, particularly winter drawdown, in which the lake is drained during the winter period to desiccate and freeze the plant. Obviously, this technique is only feasible if the lake has a water control structure.

These are just some of the techniques available to manage Eurasian watermilfoil; more research is continuing on the management of this widespread nuisance plant. Whatever the management techniques selected, the goal is to reduce the abundance of this non-native invader and allow desirable native vegetation to grow and provide habitat for fish and wildlife.

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MORE RESOURCES FROM THE BRIDGE:

Aquatic Ecosystem Restoration Foundation:
http://www.aquatics.org/

Aquatic Plant Management Society:
http://www.apms.org

Biological Control of Eurasian Watermilfoil:
http://www.fw.umn.edu/research/milfoil/milfoilbc.html

Mississippi State University, GeoResources Institute, Invasive Species Page:
http://www.gri.msstate.edu/lwa/invspec.php

Sea Grant Non-Indigenous Species Site:
http://www.sgnis.org/

University of Florida's Center for Aquatic and Invasive Species:
http://aquat1.ifas.ufl.edu/

USACE Aquatic Plant Control Research Program:
http://www.wes.army.mil/el/aqua/

U.S. Geological Survey Non-Indigenous Aquatic Species:
http://nas.er.usgs.gov/

PHOTO CREDITS:

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Page 23 (bottom right) Couresty of Data from Couch and Nelson (1985), and Jacono and Richerson (2003).

Page 26 Table 1 modified from Madsen, 2000

TECHNIQUES TO MANAGE EURASIAN WATERMILFOIL

TECHNIQUE	DESCRIPTION	NOTES
INSTITUTIONAL		
Quarantine	Regulations restricting possession and transport	May reduce the spread of Eurasian watermilfoil
Education	Advertising, signage at boat launches	Alerting public about Eurasian watermilfoil
BIOLOGICAL		
Grass carp	Herbivorous fish	Not recommended for Eurasian watermilfoil
Milfoil weevil, other native insects	Herbivorous native insects	Some success, but mostly in research phase
Mycoleptodiscus terrestris	Pathogenic fungus	Some success in research and demonstration
Native plant community restoration	Planting native plants in infested areas	Restorative rather than a treatment
CHEMICAL		
2,4-D	Selective systemic herbicide	Generally effective for Eurasian watermilfoil
Diquat	Broad spectrum contact herbicide	Effective for small treatments
Endothall	Broad spectrum contact herbicide	Effective for small treatments
Fluridone	Slow-acting systemic herbicide	Requires very long contact time
Triclopyr	Selective systemic herbicide	New aquatic herbicide for Eurasian watermilfoil
MECHANICAL		
Hand-removal	Direct hand pulling or use of hand tools	Effective for individual plants
Cutting	Cut weeds without removal	May spread Eurasian watermilfoil
Harvesting	Cutting and removing weeds	May spread Eurasian watermilfoil
Diver-operated suction harvesting	Diver-operated vacuum lift to remove plants	Effective for small beds or plots
Rotovating	Underwater tiller that disrupts root crowns	May spread Eurasian watermilfoil
PHYSICAL		
Dredging/Sediment Removal	Mechanical sediment removal to deepen water	Extremely expensive for only plant control
Drawdown	"De-water" water body for an extended period of time	Effective for controlling Eurasian watermilfoil
Benthic barrier	Use natural or synthetic sheet or barrier over plants	Effective in small beds, but expensive

Table 1.