Houghton Lake, MI
—*Restoring the Aquatic Vegetation*

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Summary

Problems resulting from the proliferation of Eurasian watermilfoil in Houghton Lake led to the development of a plan for managing Eurasian watermilfoil and restoring the native vegetation of the lake. In 2001, conditions in the lake were evaluated and integrated pest management strategy for controlling Eurasian watermilfoil was devised. The strategy uses a whole-lake herbicide application to get Eurasian watermilfoil under control and then the milfoil weevil, *Euhrychiopsis lecontei*, to keep Eurasian watermilfoil under control. The first phase of the restoration was conducted in 2002, when the entire lake was treated with Sonar® aquatic herbicide (active ingredient: fluridone). By August, Eurasian watermilfoil abundance had decreased by 91 percent.

Description of Houghton Lake

Located about two-thirds of the way up the Lower Peninsula, Houghton Lake is the largest inland lake in Michigan. The lake has a surface area of 20,103 acres and an average depth of approximately nine feet. Houghton Lake and its watershed comprise the headwaters of the Muskegon River, which flows west across Michigan to enter Lake Michigan at Muskegon. Much of the Houghton Lake watershed is state-owned land, including state parks and recreation areas, and over 20 percent of the watershed is water. Houghton Lake is generally classified as eutrophic or meso-eutrophic (Pecor et al. 1973; U.S. Environmental Protection Agency 1975), but in general, the lake has not experienced the adverse conditions usually associated with eutrophication.

Houghton Lake is very heavily used for recreation and supports a local economy dependent on tourism. The lake is among the most important fishing resources in Michigan and has been stocked with smallmouth bass, northern pike, walleye, yellow perch, and bluegill. Houghton Lake is also an important resource for waterfowl, particularly migrating ducks and coots.

Houghton Lake has long supported abundant aquatic plant growth and a diverse community of aquatic plants. Recent aquatic plant problems in the lake are associated with the expansion of the exotic plant, Eurasian watermilfoil (*Myriophyllum spicatum*). Prior to 1999, northern watermilfoil and Eurasian watermilfoil were not distinguished, so it is impossible to determine exactly when Eurasian watermilfoil was introduced to the lake, but watermilfoil was not reported as particularly abundant prior to 1996. By 1996, watermilfoil had become the second-most dominant submersed plant in the lake and was dense enough in several locations to be a cause for concern. By 1999, Eurasian watermilfoil occupied over 10,000 acres and had come to dominate the submersed plant community of the lake.

Historically, Houghton Lake also supported large offshore beds of emergent aquatic plants, including wild rice. A decline of wild rice appears to have begun in 1989 (Bonnette 1996), well before the expansion of Eurasian watermilfoil. By 2001, offshore beds of emergent vegetation were gone, and the areas that formerly supported them were occupied by Eurasian watermilfoil.

Pre-Restoration Conditions in the Lake

As part of the process of developing a restoration plan, previous studies of Houghton Lake were reviewed and data were collected to evaluate the water depth, aquatic vegetation, abundance of milfoil weevils, and water quality in the lake. Goals and strategies for managing Eurasian watermilfoil and restoring the native vegetation of the lake were formulated. Water depth and aquatic vegetation were sampled using a grid of 912 sample locations spaced on a 300-meter grid, with additional samples in nearshore locations. Aquatic plant survey methods followed those mandated by the Michigan Department of Environmental Quality, which are described elsewhere (Smith and Pullman 1997). Weevil abundance was sampled in approximately half of the grid locations, by randomly collecting Eurasian watermilfoil stems and examining them for the presence of weevils.

In 2001, Eurasian watermilfoil was the most abundant plant in the lake. It was detected in approximately 10,800 acres of the lake and was common or dense in approximately 5,300 acres.

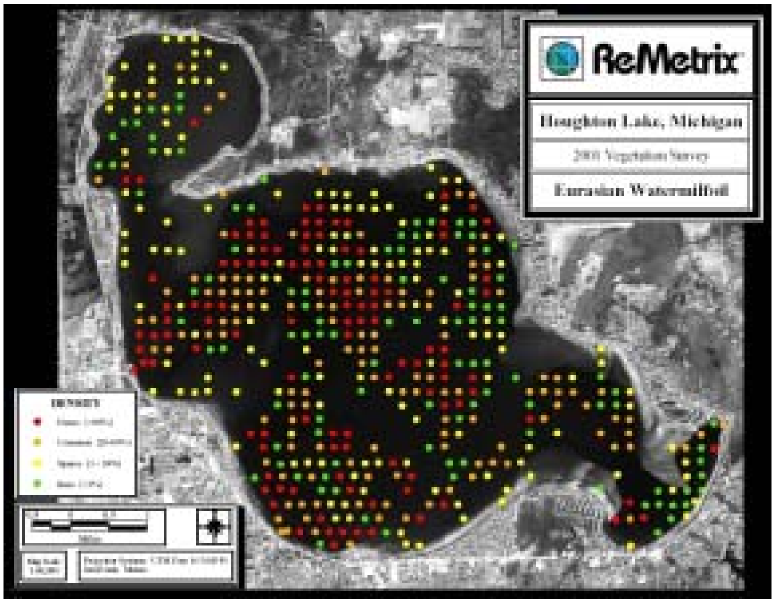


Figure 1. Areas of common or dense Eurasian watermilfoil cover observed in 2001 overlaid on a high-resolution satellite image of the lake taken September 30, 2002.

Figure 1 shows the distribution of Eurasian watermilfoil, overlaid on a high-resolution satellite image of the lake. Approximately 20 native aquatic plant species were encountered during vegetation surveys. The most abundant native species was elodea (*Elodea canadensis*), which had been the most abundant plant in the lake prior to the expansion of Eurasian watermilfoil (Bonnette 1996).

The milfoil weevil, *Euhrychiopsis lecontei*, was found in a number of locations in the lake. Weevil populations exhibited a clumped distribution, with weevils detected in groups of adjacent sampling locations. Weevil populations exceeded the threshold at which control of Eurasian watermilfoil becomes likely in several areas of the lake. However, milfoil control by the weevils was not apparent. Overall, weevil survey results indicate that a number of areas of the lake have some weevils but few areas have weevil densities high enough to significantly impact Eurasian watermilfoil.

Selection of a Restoration Strategy

After considering several alternatives, the Houghton Lake Improvement Board adopted an integrated strategy for managing Eurasian watermilfoil in the lake. The selected strategy used the Integrated Method for Controlling Aquatic Plants (IMCAP), which included a whole-lake application of the aquatic herbicide Sonar® (active ingredient: fluridone) in the first year to get Eurasian watermilfoil under control. As Eurasian watermilfoil populations recover, milfoil weevils will be introduced to maintain control. Native plants, particularly elodea, will be replanted if the initial impact of the whole-lake Sonar® application warrants.

Concerns about whole-lake fluridone treatments focus on the impact of these treatments on non-target aquatic plants. Although low-rate fluridone treatments, such as those allowed in Michigan, are quite selective, they adversely affect some of the native plant species found in Houghton Lake. The non-target plants likely to be most severely affected were elodea (*Elodea canadensis*), naiad (*Najas* spp.), water marigold (*Megalodonta beckii*), and northern watermilfoil (*Myriophyllum sibiricum*). Repeated whole-lake application of Sonar® would make reestablishing these species difficult. Since the milfoil weevils do not control these species, using the weevil to control recovering Eurasian watermilfoil makes it possible to reestablish them.

Phase One:
Controlling Eurasian Watermilfoil

In 2002, the first phase of the restoration, a whole-lake application of the aquatic herbicide Sonar®, was completed. Prior to treatment, the susceptibility of the target Eurasian watermilfoil to Sonar® was determined using PlanTEST™ pre-treatment fluridone susceptibility analysis. Plants were collected from 25 sites within Houghton Lake and the associated canals and each measurement was replicated three to six times. Susceptibility testing indicated that the normal "Michigan" treatment protocol (an initial treatment at a calculated dose rate of 6 ppb, followed in two-three weeks by a second "bump-up" application to return the concentration to 6 ppb) would provide excellent control of the Houghton Lake Eurasian watermilfoil.

Based on soundings taken in 2001, a detailed bathymetric map of the lake was created and the volume of the lake recalculated to ensure an accurate herbicide dose. The new depth information resulted in a calculated volume of 192,257 acre-ft. The volume of the top ten feet of the lake (used to calculate fluridone dose rates in Michigan) was calculated as 161,316 acre-ft. These figures are approximately ten percent higher than those derived from older, less detailed lake maps.

A Variable Rate Application Sonar Injection System (VRASIS*), utilizing VAR technology, developed for and used extensively in precision agriculture, was used to ensure an extremely precise and even application of Sonar®. A GIS-based digital prescription adjusted the application rate for each one-foot change in water depth. As application boats traversed east-west swaths across the lake, VRA software adjusted the application rate based on the prescribed rate and the boat speed. The initial treatment was conducted using swaths 100 meters (328 feet) apart. At this swath width, each pass across the lake treated approximately 180 acres of lake surface area. The bump-up application used swaths 200 meters apart. Navigation along designated swath lines was performed using a second GPS receiver. Each treatment was conducted in slightly more than a day, using six application boats for the initial Sonar® application and five for the bump-up treatment. VRA software recorded the total volume of Sonar® applied as well as real-time georeferenced application rates, which was used to produce an "as-applied" map for the Sonar® treatment. The initial treatment used 660.3 gallons of Sonar® and the bump-up required 307.1 gallons.

The initial treatment yielded an average fluridone concentration of 7.02 ppb 48-hours after treatment (Figure 2). This concentration is slightly above the target of 6 ppb, presumably because vertical mixing of the herbicide was not yet complete at 24 hours. The fluridone concentration declined to 3.2 ppb 14 days post-treatment, and was increased to 6.2 ppb 48 hours after the bump-up. In all, concentrations above the threshold for growth of Houghton Lake Eurasian watermilfoil were maintained for 90 days following the initial treatment, as determined by pretreatment PlanTEST sampling.

After treatment, Eurasian watermilfoil samples were collected from the same sites used for pre-treatment plant sampling, and these samples were analyzed using a suite of biochemical techniques (EffecTest, SePRO Corporation, Carmel, IN) designed to determine whether the Sonar® concentration in the lake exceeded a lethal threshold for these plants. For some sites as the treatment progressed, Eurasian watermilfoil was in extremely poor condition or no longer present. Therefore, samples were analyzed from 3 to 12 sites depending on plant tissue condition. Samples for post-treatment analysis were collected 30, 43, 56, and 86 days after the initial herbicide treatment. Following treatment plants exhibited chlorosis 30 days after treatment. As characteristic with low-dose Sonar® treatments in Michigan the plant canopy did not achieve ultimate collapse until 65 days after initial treatment. This very slow vegetative response is what enables large-scale restoration to occur while minimizing excessive decaying plant matter that can create a dissolved oxygen problem.

By late August, the number of sample sites at which Eurasian watermilfoil was found decreased by 91% from 490 in 2001 to 45 in 2002 (Figure 3). Most of the remaining Eurasian watermilfoil consisted of small green sprouts from blackened stems.

Overall, the number of sample sites with aquatic vegetation decreased from 705 in 2001 to 505 in 2002. Thirteen aquatic plant species decreased following the Sonar® treatment of Houghton Lake while nine species increased (Figure 4). One species, floating-leaved pondweed, did not change. Water marigold and northern watermilfoil were present in 2001, but not detected in 2002.

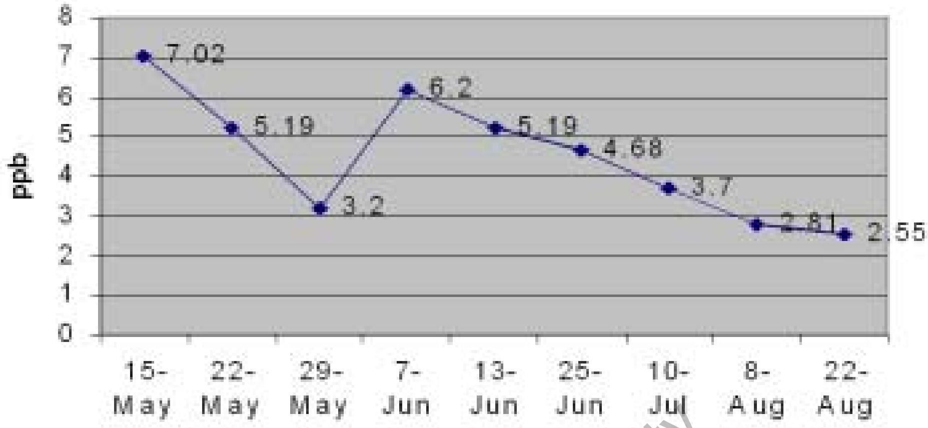


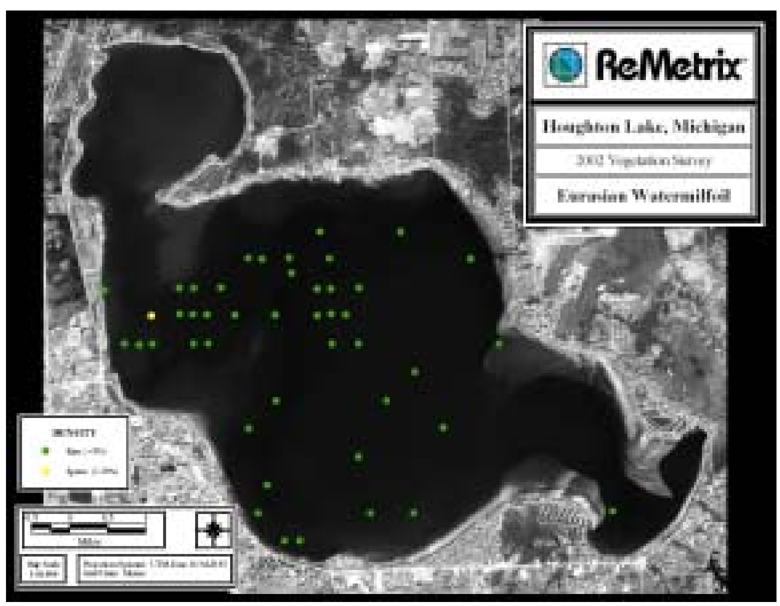
Figure 2. Sonar® concentrations achieved by the 2002 whole-lake treatment.

Completing the Restoration

Annual monitoring of aquatic vegetation will document the reestablishment of Eurasian watermilfoil and the recovery of native plants. Once Eurasian watermilfoil begins to recover in the lake, the milfoil weevil, *Euhrychiopsis lecontei*, will be used to keep the Eurasian watermilfoil population under control. The weevil is a native North American insect that eats virtually nothing but Eurasian watermilfoil and spends most of its life on the Eurasian watermilfoil plant. The only other plant fed on by the milfoil weevil is northern watermilfoil (*Myriophyllum sibiricum*), which is a native, North American watermilfoil that is very closely related to Eurasian watermilfoil. Unlike Eurasian watermilfoil, weevil feeding has little effect on northern watermilfoil; thus, the weevil has almost no impact on non-target aquatic plants.

The Houghton Lake Restoration Plan recommends replanting non-target plant species dramatically reduced or eliminated by the initial fluridone treatment if they do not recover spontaneously. Except for elodea, water marigold, and northern watermilfoil, native plant species are expected to recover rapidly without replanting. Planting of elodea in 2004 would help to quickly restore this formerly dominant species, potentially slowing the reestablishment of Eurasian

Figure 3. Areas of common or dense Eurasian watermilfoil cover observed in 2002.



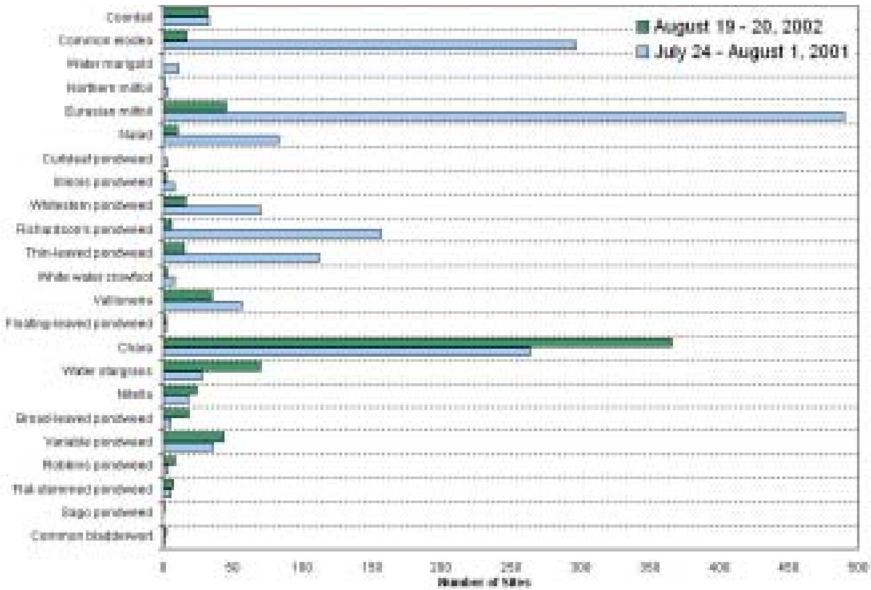


***Figure 4**. Changes in presence of aquatic plant species following treatment.*

watermilfoil. Reintroduction of less abundant, harder to establish species such as water marigold and northern watermilfoil can proceed once it is clear that the weevil is successfully controlling Eurasian watermilfoil.

Plans for Future Work

A one-year post-treatment survey will be conducted in late summer 2003. Sample sites and methodology utilized will be consistent with the previous surveys taken in 2000, 2001, and 2002. The data from the pre- and post-treatment surveys will provide valuable insight for understanding the full extent of plant community changes as a result of the Houghton Lake restoration project.

An evaluation to understand the economic impact of the 2002 restoration effort is being undertaken. Houghton Lake is a major resource for a variety of recreational activities in the state of Michigan, drawing users from the entire state and beyond. The support of the local economy is heavily supported by tourism. The year-round population of approximately 11,000 residents swells to near 30,000 during the summer vacation peak from Memorial Day through Labor Day and then again to over 40,000 during the winter festival held the third and fourth weekends of January. Local commerce was significantly impacted by fluctuations in tourism which occurred as a direct result of water quality changes in the lake. A research project is underway to identify and document the changes in direct use and indirect use values as well as quantify gains and losses experienced by the local economy. Particular focus is being given to those economic activities that changed as a direct result of the restoration project. Various methods of economic impact analysis will be employed to focus on costs and benefits accruing to people living in the Houghton Lake area.

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