J. Aquat. Plant Manage. 48: 1-5

Cost and Effectiveness of Hand Harvesting to Control the Eurasian Watermilfoil Population in Upper Saranac Lake, New York

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ABSTRACT

An intensive hand harvesting project was undertaken to achieve whole-lake control of Eurasian watermilfoil in Upper Saranac Lake, New York. Beginning in 2004, six crews of divers hand harvested the entire littoral zone of Upper Saranac Lake twice per summer for three years, after which the harvesting effort was scaled down to a maintenance configuration. Eurasian watermilfoil cover and removal data were collected by the crews, and the process was also monitored using permanent underwater transects to track the Eurasian watermilfoil response to management. Eurasian watermilfoil cover was reduced to rare (<5% cover) for more than 90% of the littoral area, and plant removal decreased from about 16,640 kg in 2004 to 460 kg in 2006, the final year of intensive management. Eurasian watermilfoil density in the transects dropped from 1650 stems/ha (±343 S.E.) in August 2004 to 63 stems/ha (±9.26 S.E.) in August 2006, with similarly low density during the maintenance period. Labor cost averaged $351,748/yr during intensive management and $146,475/yr during the maintenance period. Results indicate that hand harvesting is a viable management technique for achieving whole-lake control of Eurasian watermilfoil; however, successful use of hand harvesting requires a large financial investment.

Key words: Adirondack Park, milfoil, *Myriophyllum spicatum.*

INTRODUCTION

There are approximately 3000 lakes and ponds in New York's Adirondack Park, the largest publicly protected area in the contiguous United States. Eurasian watermilfoil (*Myriophyllum spicatum* L.) has been in the Adirondack Park since at least 1979, when it was first documented in the Chateaugay Lakes by Dr. John Peverly from Cornell University. According to the Adirondack Park Invasive Plant Program (APIPP), Eurasian watermilfoil is the most commonly observed aquatic invasive plant, growing in 48 of 53 lakes and ponds infected with aquatic invasive plants out of 216 surveyed. Management is occurring in approximately 19 of the 48 infested lakes and ponds (H. Smith, personal communication, 12 September 2009).

In the Adirondack Park, hand harvesting and benthic barriers are the most common methods used to manage Eurasian watermilfoil; however, water level draw down is also used for a small number of lakes. Chemical and biological control methods are being considered for use; however, to date, no applicant has successfully obtained a permit for chemical control. According to the Adirondack Park Agency, there is currently one active permit for biological control of Eurasian watermilfoil using grass carp (*Ctenopharyngodon idella*), and a permit for the milfoil moth (*Acentria ephemerella*) was issued several years ago, but the project yielded mixed results (E. Snizek, personal communication, 7 May 2009).

Hand harvesting has been used successfully in Lake George in the southeastern region of the Adirondack Park since 1989 to reduce Eurasian watermilfoil densities at a limited number of sites (Boylen et al. 1996, Eichler et al. 1993, 1995). However, no large-scale hand removal for moderate- to high-density areas has been used to date[2]. The Lake George Association currently reports Eurasian watermilfoil to exist in 157 locations, 24 of which contain dense beds[2], indicating that this aquatic invasive species has continued to expand throughout the lake despite significant effort to control it.

Eurasian watermilfoil was first reported in Upper Saranac Lake in 1996 (Martin 1998). A limited control effort using mainly hand harvesting and some benthic matting was conducted from 1999 through 2003, with about $55,000 expended annually. While localized reductions were achieved, aquatic plant surveys showed Eurasian watermilfoil expansion through the unmanaged areas of the lake.

Recognizing the partial success of the control effort and the documented expansion of Eurasian watermilfoil in other parts of Upper Saranac Lake, members of the lake community developed a new management approach. The new approach was implemented in 2004 and is referenced to herein as the "intensive management effort." This approach called for the selective removal of Eurasian watermilfoil using diver hand harvesting of the entire littoral zone of the lake at least twice each summer for three years. The objective was to achieve an annual maintenance level after three years, defined by expending approximately $150,000/yr in perpetuity to maintain the Eurasian watermilfoil population at a sustained low level.

The intensive management effort in Upper Saranac Lake represents the first attempt in the region at controlling Eurasian watermilfoil in an entire lake using primarily hand har-

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vesting. Our objective was to describe the intensive management approach used to achieve whole-lake control and to provide an evaluation of its efficacy.

MATERIALS AND METHODS

Study Site

Upper Saranac Lake is located in southern Franklin County, New York, and lies entirely within the six million acre Adirondack Park (Figure 1). It has an overall length of 12.1 km, 59.5 km of shoreline, maximum depth of 28.8 m, and a total surface area of 1912 ha. The lake is composed of approximately 483 ha of littoral zone (estimated based on depths <4 m). Three distinct basins (north, middle, and south) occur as a result of depth characteristics and an irregular shoreline, with numerous bays and coves. The lake forms the headwaters of the Saranac River, a major tributary of Lake Champlain, and is a popular recreational resource in the Adirondack region. Upper Saranac Lake is classified as a mesotrophic, soft-water (average alkalinity 8 mg/L as $CaCO_3$), low pH (average pH 6.8) waterbody. Secchi disk values range from 2.9 to 4.9 m with slightly higher transparency in the south basin (Martin 1998). In May 2004, prior to the initiation of this study, 140 benthic barrier mats were installed in the lake and removed the following year. The total area of mat coverage was 0.4 ha and represents 0.08% of the littoral zone of the lake.

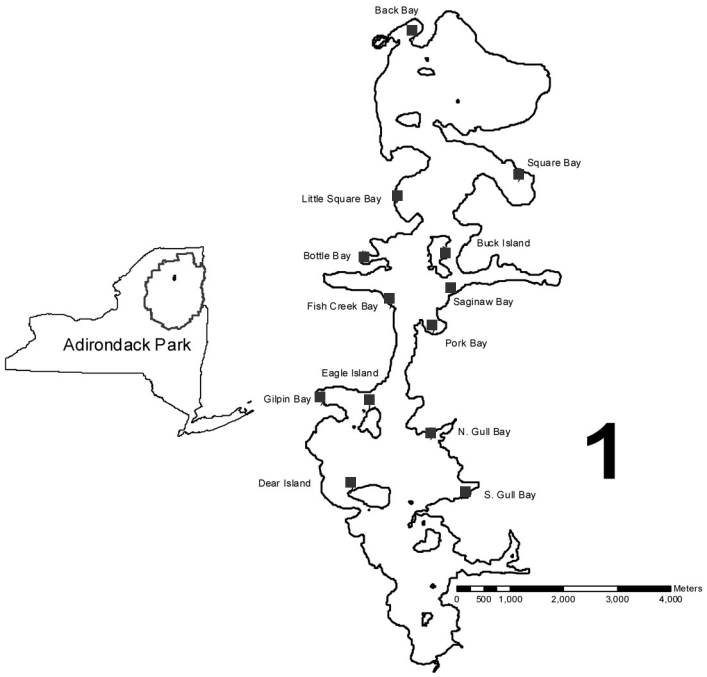

Figure 1. Geographical location of Upper Saranac Lake in the Adirondack Park of New York State. Hand removal of Eurasian watermilfoil was conducted in the lake from 2004 to 2008. The 13 sites with historically high milfoil abundance are indicated as squares along the shoreline; these sites were selected for intensive underwater monitoring.

Harvesting Method

Crew configuration. Two distinct types of harvesting crews were used on the lake. The first were hookah crews, utilized in areas of dense Eurasian watermilfoil growth and typically employing four divers and a top-water person. One of the divers served as supervisor; not only harvesting plants, but also managing the crew, estimating percent cover of Eurasian watermilfoil and recording data. A hookah rig consists of an air compressor with four 45-m long air hoses. A crew can harvest a circular area of approximately 6300 m^2 before moving the hookah rig. At each location, a waypoint was taken with a GPS unit (Etrex Vista, Garmin International Inc., Olathe, KS, USA) prior to harvesting. The supervisor estimated the percent cover of Eurasian watermilfoil following the rating system of Eichler et al. (1995) in Lake George: abundant (>50% bottom cover), common (25-50%), present (15-25%), occasional (5-15%), rare (<5%). Data on percent cover by location were analyzed spatially with GIS software (ArcMap, ESRI, Redlands, CA, USA). Divers then removed all Eurasian watermilfoil from the area, each diver working his/her own quadrate. Divers took special care to remove all of the plant material including roots, thus substantially limiting the rate of regrowth (Nicholson 1981). Divers stuffed all plant material into mesh dive bags, which were brought to the surface when full. The mesh bags have a diameter of 28 cm and a depth of 80 cm. Full bags averaged 9.2 kg (±2.5 SD, n = 50). Average bag weight was used to convert total number of bags harvested to kg wet weight removed from the lake. Plant fragments produced by the harvesting operation were collected by the top-water personnel. Time spent harvesting and number of bags removed was recorded for each location.

The second crew type employed SCUBA in areas of low density growth and typically included three people, two divers and a top-water person. The tank crews systematically swam the littoral zone from shallow to deep water, harvesting occasional plants and keeping data on location, time, percent cover, and total number of bags removed in the same manner as the hookah crews.

Harvesting Effort. Eurasian watermilfoil harvesting occurred from 1 June through mid-August 2004-2008. The objective was to circumnavigate the entire littoral zone of the lake at least twice during each year, with more frequent visits to sites with high Eurasian watermilfoil densities. The intensive management period was from 2004 to 2006. During these three years there were typically four hookah crews (roughly 20 workers) and two tank crews (roughly six workers) harvesting in the lake. The approach was to reduce the effort (man*days) needed to survey, harvest, and collect data by 50% in 2007, and again in 2006 as the lake entered into the maintenance period. In 2007 there were two hookah crews and in 2008 there was only one crew. Due to the subsequent reduction in Eurasian watermilfoil densities, hookah crews shifted to an approach where divers swam together in a line along the littoral zone removing isolated pockets of Eurasian watermilfoil.

Assessment Method

To assess large scale hand harvesting as a viable tool for Eurasian watermilfoil management, 13 sites with historically

high Eurasian watermilfoil densities were selected for intensive evaluation (Figure 1). At each site a combination of transect and fixed-plot methods were used to monitor the presence and abundance of Eurasian watermilfoil, similar to methods described by Madsen et al. (1988, 1991) and Eichler et al. (1995).

2004 Assessment. Four transect lines were established at each of the 13 sites in 2004 with the exception of the Gull Bay and Deer Island sites, which had two and three transects, respectively. Each transect was laid out perpendicular to the shoreline in water depths of 1 to 5 m, a range known to bracket the extent of Eurasian watermilfoil growth, and consistent with work done on other regional lakes such as Lake George (Madsen et al. 1988, Eichler et al. 1995). At some locations the lake bottom had very little slope, in which case 45-m long transects were established, and the corresponding depths at the endpoints were recorded. The endpoints of each transect line were marked permanently with rebar and PVC pipe and geo-referenced with a sub-meter GPS unit (ProXR, Trimble, Sunnyvale, CA, USA). In August and September 2004 a diver recorded the number of Eurasian watermilfoil stems in a 1-m^2 plot at 1, 3, and 5 m depth along each transect line. Each set of measurements were collected in a one-week period.

2005-2008 Assessment. To increase the sampling area, transect lines were installed permanently in May 2005. Nylon rope with flagging every 3 m was fixed to the bottom at each site. Approximately 3700 m of nylon line was fixed to the lake bottom. Instead of only enumerating stems/m^2 at 1, 3, and 5 m depth intervals, as was done in 2004, Eurasian watermilfoil stems were counted in 2-m wide bands in each 3 m transect segment. This change increased the bottom surface area sampled for Eurasian watermilfoil and allowed more accurate scaling of Eurasian watermilfoil stem counts. In addition, the frequency of transect measurements was increased from August and September to May through September in 2005 and May through October in 2006-2008.

All study sites received the same Eurasian watermilfoil removal effort as the rest of the lake; the dive crews harvested all Eurasian watermilfoil twice during each year, once at the end of June and again in early August. Data from each transect were compiled at the site level. Eurasian watermilfoil density was estimated by averaging the number of Eurasian watermilfoil stems per hectare across all 13 sites.

RESULTS AND DISCUSSION

Harvesting effort remained relatively constant during the intensive management period, averaging 1463 man*days per year at an average cost of US$728/ha of littoral zone (Table 1). Eurasian watermilfoil harvest was greatest in 2004, with more than 16,643 kg removed. In 2005 there was a 67% reduction in the amount of Eurasian watermilfoil removed, followed by a further reduction of 97% in 2006. These results indicate that the intensive hand harvesting effort resulted in a rapid decrease of Eurasian watermilfoil and was over 97% effective in the removal of Eurasian watermilfoil from the lake. In 2007, the first year of the maintenance period, total removal was similar to that of 2006 (386 vs. 460 kg); however, this removal was achieved with a 50% reduction in man*days, indicating a 50% reduction in the number of hours needed to harvest the entire littoral zone of the lake. In 2008 the effort was again reduced by 50% and 239 kg of Eurasian watermilfoil were removed. Similar results were reported for hand harvesting in Lake George, New York. Boylen et al. (1996) reported hand harvesting to be 80% effective in removing Eurasian watermilfoil from 14 infested sites during 1989-1990, despite a 56% reduction in effort between years.

The cost/kg of Eurasian watermilfoil removed increased with each year of management, starting at $23/kg during the first year of intensive management and reaching $485/kg in 2008 (Table 1). This is to be expected due to a minimum set up and survey time required to inspect the entire littoral zone, no matter what abundance of Eurasian watermilfoil is encountered; thus, harvest per unit effort will continue to increase as abundance of Eurasian watermilfoil goes down. Prioritizing areas to be inspected annually could further reduce survey times and thus costs. Compared to the other years, the cost/kg removed in 2006 was considerably higher because the management crews were over prepared for relatively low milfoil density. This suggests that objectives for the intensive management period were achieved during the first two years and that a third year of intensive management may not have been warranted.

A comparison of lake wide Eurasian watermilfoil cover between years further illustrates the reduction achieved during the harvesting effort (Table 2). In 2004, Eurasian watermilfoil was found to be either common or abundant in 16% of the lakes littoral area. At the end of the intensive harvesting period, Eurasian watermilfoil was common in only 3% of the

TABLE 1. SUMMARY OF HAND HARVESTING EFFORT, LABOR COST (US$), AND WET WEIGHT OF EURASIAN WATERMILFOIL REMOVAL IN UPPER SARANAC LAKE, NY, FROM 2004 THROUGH 2008.

Year	Start Date	Man*days	Payroll $	$/ ha	kg removed	$/kg
			Intensive management period			
2004	May 23	1618	384,389	796	16,643	23
2005	May 22	1334	324,890	672	5,419	60
2006	May 21	1436	345,965	716	460	752
			Maintenance period			
2007	June 1	723	176,951	366	386	458
2008	June 9	420	116,000	240	239	485

TABLE 2. PERCENT OF LITTORAL AREA OCCUPIED BY EURASIAN WATERMILFOIL BY COVER CLASS IN UPPER SARANAC LAKE, NY, FROM 2004 THROUGH 2008. COVER CLASSES ARE BASED ON PERCENT OF BOTTOM COVERED.

Year	Abundant (>50%)	Common (25-50%)	Occasional (5-15%)	Rare or Absent (<5%)
		intensive mgt period		
2004	3	13	47	37
2005	0	7	31	63
2006	0	3	5	92
		maintenance period		
2007	0	0	6	94
2008	0	0	8	92

littoral area, and nowhere was percent cover recorded as abundant. At the end of this study, Eurasian watermilfoil was rare in 92% of the littoral area, and did not achieve common or abundant cover anywhere in the lake.

Finally, results from the 13 monitoring sites corroborate the validity of hand harvesting as a tool for Eurasian watermilfoil management (Figure 2). Density was greatest in August of 2004 with an average of 1650 (±343 S.E.) stems/ha. A steep decline in stem density occurred during the intensive management period with a reduction of 93% by October 2006. Eurasian watermilfoil densities remained consistently low during the maintenance period, ranging from 23 to 75 stems/ha in 2007 and from 8 to 113 stems/ha in 2008. Initially in 2004, 10 of the 13 sites had established Eurasian watermilfoil populations. In 2005 this number increased to 12 sites, but was reduced to four sites by the end of the intensive period. The number of sites with Eurasian watermilfoil has trended up during the maintenance period, with the species occurring in eight sites in 2008 (Figure 3). These results indicate that Eurasian watermilfoil is continuing to expand its range in the lake, despite substantial reductions in density, and that recolonization of controlled areas may occur.

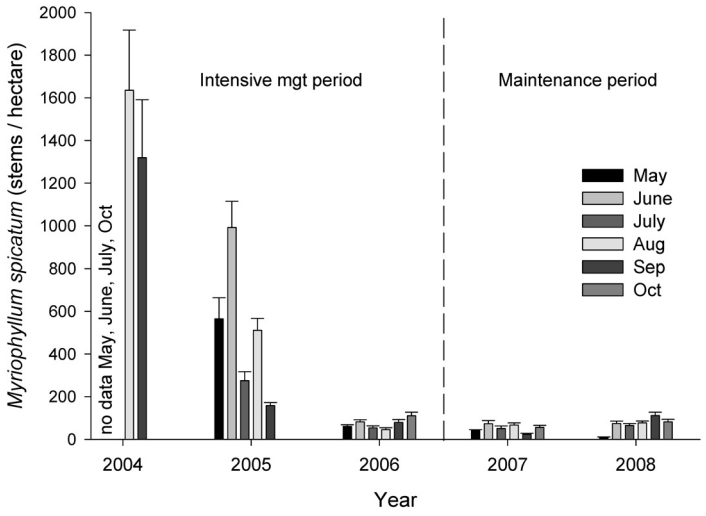

Figure 2. The average density of Eurasian watermilfoil at the 13 underwater monitoring sites in Upper Saranac Lake 2004-2008. Vertical bars represent one standard error (SE) of the mean, n = 13.

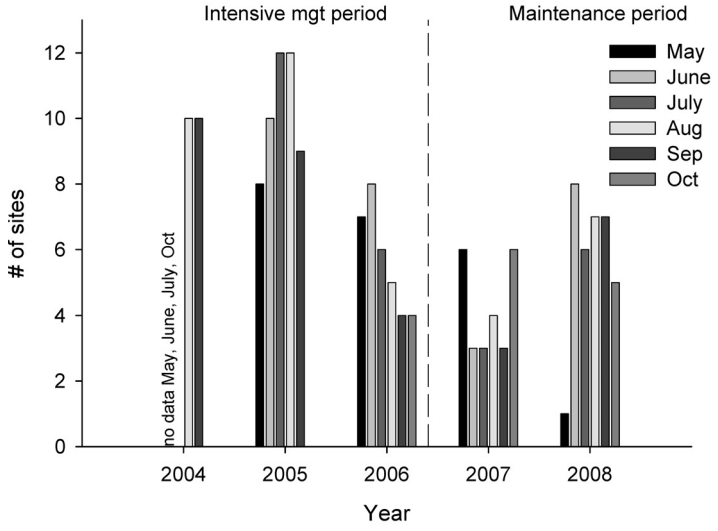

Figure 3. Frequency of occurrence of Eurasian watermilfoil at the 13 underwater monitoring sites in Upper Saranac Lake by month, 2004-2008.

It is highly unlikely that the management approach will eradicate Eurasian watermilfoil from Upper Saranac Lake, but it has reduced the infestation to a level that can be managed within the financial limits defined by the stakeholders. In fact, the greatly reduced density of Eurasian watermilfoil reported in 2008 (Table 2) is comparable to the density reported in 1998 (Martin 1998). Thus, it seems that the management effort has in effect "knocked back" the Eurasian watermilfoil population to the level reported when its presence was first detected in the lake 10 years earlier.

The maintenance cost in 2008 was approximately 33% of the annual average cost of intensive management. If holding the Eurasian watermilfoil population at 1998 levels remains the management goal, then there is no reason to believe that the maintenance cost will decline over time. In fact, given that Eurasian watermilfoil seems to be expanding its range again during the maintenance period, the crew size may be too small to effectively keep the population in check. To limit reinvasion and to control costs, the maintenance plan going forward will integrate intensive monitoring by volunteers and paid staff. New plants detected by the monitors will then be removed by the harvesting crew in a within-lake rapid response mode. If this approach is successful then the maintenance costs will be approximately $120,000/yr in perpetuity.

Regardless of the approach chosen to control Eurasian watermilfoil (or other aquatic invasive plants), management of aquatic invasive plants is an expensive proposition. More than $1.5 million was invested in control in Upper Saranac Lake from 1999 through 2008, and though results show that the management effort has succeeded thus far, the high level of investment needed may exceed the ability of stakeholders at other infested lakes. With 29 of the 48 lakes known to support Eurasian watermilfoil in the Adirondack Park currently not being managed, and considering that raising the funds needed for control will be a great challenge for most lake groups, far more emphasis should be placed on spread prevention. Though not conventionally thought of as a management technique, spread prevention is widely believed to be

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inance of monocotyledon species among the native vegetation, which are generally tolerant to these herbicides.

the most cost effective method for controlling invasive species. Well-coordinated volunteer or paid boat inspector programs at launch sites provide protection for as yet uninfected lakes.

The results from this study demonstrate that hand harvesting can be used to achieve whole-lake Eurasian watermilfoil control in large lakes. The financial investment required to support intensive hand harvesting is significant and will vary greatly depending on the extent of infestation. For longer term budgeting purposes, stakeholders need to also consider the annual costs of maintenance control. Until other more efficacious methods of control are proven and permitted for use in the Adirondack Park, hand harvesting should be considered a viable management tool for whole-lake control of Eurasian watermilfoil in Adirondack lakes and ponds.

ACKNOWLEDGMENTS

Curt Stiles, Tom Chipperfield, and Tim LaDue were instrumental in helping to design and implement this project. This work would not have been possible without the enthusiastic and conscientious field assistance provided by Paul Smith's College graduates, Kathy Bozony and Chris Audette. Financial support for this project was provided by the Upper Saranac Lake Foundation.

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