

**BFS Technical Report # 22
AQUATIC MACROPHYTE
MANAGEMENT PLAN FACILITATION
LAKE MORaine, MADISON COUNTY, NY
2004**

- 1. MACROPHYTE BIOMASS MONITORING**
- 2. MONITORING EFFECTS OF SELECTIVE HERBICIDE
SONAR[®]**
- 3. WATER QUALITY ANALYSIS**

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INTRODUCTION

Aquatic macrophyte communities in Lake Moraine have undergone monitoring by the Biological Field Station of SUNY Oneonta since the summer of 1997 to evaluate the success of efforts to control Eurasian watermilfoil (*Myriophyllum spicatum*), an invasive species of aquatic plant. Mechanical harvesting and non-selective herbicides such as copper sulfate were long applied as control measures (Hohenstein et al. 1997) before the Lake Moraine Association decided to investigate more environmentally-friendly options. A selective herbicide known as Sonar A.S.[®] (SePRO Corporation) (Slater 2004) was chosen and first applied in the spring of 1996. Problems discovered in the sampling methodology used in 1996-97 prevented an empirical demonstration by BFS personnel of the success level of the herbicide application. Nonetheless, anecdotal observations suggested a reduction in the amounts of *M. spicatum*. Two years were allowed to pass in order to exhaust any effects of the herbicide prior to the 1998 stocking of the upper basin of Lake Moraine with *Euhrychiopsis lecontei*, an aquatic weevil found to have value as a biocontrol agent in several laboratory and field studies (Sheldon 1997). It was proposed that this introduction, as well as a repeated stocking in 2000, would lead to successful biological control of *M. spicatum* in Lake Moraine. Data collected to date have failed to show either a sustained increase in the population of *E. lecontei* in Lake Moraine or an increase in the evident damage to surviving milfoil by the weevils (Harman et al. 2002). Bennett et al. (1998) and Harman et al. (1998; 2000; 2001; 2002) provide a complete overview of limnological monitoring relating to management efforts of Eurasian watermilfoil.

In May of 2001 Sonar[®] was applied throughout the entire littoral zone of Lake Moraine's lower basin. Monitoring in the summer of 2001 showed that milfoil had nearly been eradicated in the lower basin. The population of curlyleaf pondweed (*Potamogeton crispus*), another exotic macrophyte, was also drastically reduced. Sonar[®] also had an impact on native plants, but most showed recovery over the course of the summer (Harman et al. 2002). Monitoring in the summer of 2003 showed that *M. spicatum*, as well as the native macrophyte *Elodea canadensis*, had failed to recover throughout much of the lower basin whereas curlyleaf pondweed had rebounded. The general trend among native plant species exposed to Sonar[®] was a continued increase in biomass (Harman et al. 2004b). Management efforts of 2004 in Lake Moraine have focused on herbicidal control of *M. spicatum* in the upper basin after the apparent failure of *E. lecontei* in controlling the plants.

BACKGROUND

Lake Moraine (42° 50' 47" N, 75° 31' 39" W; Figure 1) was originally formed through the damming of a valley by glacial moraine. Artificial impounding of water at the western end of the lower basin has increased the lake's surface area to approximately 261 acres (106 ha). A causeway divides Lake Moraine into two distinct basins to the northeast and southwest (Figure 1). A submerged culvert beneath the causeway

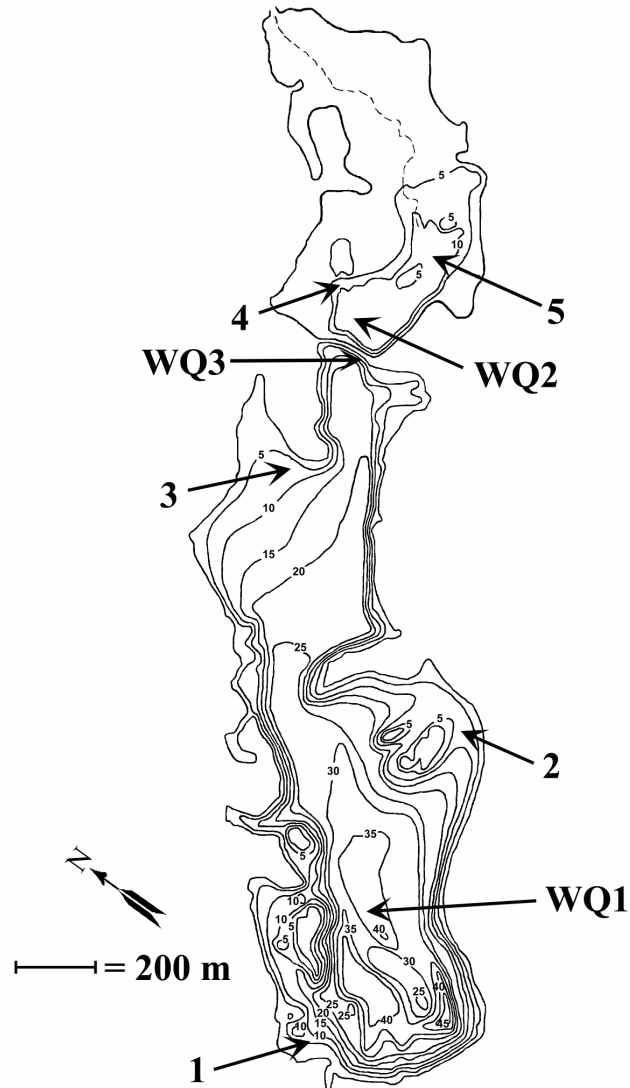


Figure 1. Bathymetric map of Lake Moraine, Madison County, NY. Contours in feet. WQ1, WQ2 and WQ3 indicate sites of water quality testing. Sites 1-5 indicate where plant biomass was sampled.

traversed by Madison County Highway 87 connects the two basins. With a mean depth of 1.1 m and a maximum depth of 3.7 m, the upper (northeast) basin occupies 79 acres (32 ha). The larger lower basin has a mean depth of 5.4 m, a maximum depth of 13.7 m, and a surface area of 182 acres (74 ha). Lake Moraine provides recreational opportunities such as boating, fishing and swimming, all of which are potentially inhibited by excessive growth of Eurasian watermilfoil (Bennett et al. 1998).

Lake Moraine is considered meso-eutrophic due to its high levels of algal and macrophytic productivity as well as depleted levels of dissolved oxygen in the hypolimnion following summer stratification (Hohenstein et al. 1997). According to Bennett et al. (1998), the bulk of nutrient loading in both basins is primarily attributed to agricultural activities and residential development in the watershed. Another major source of nutrient pollution is likely to be septic leachate. Local geological factors such as poor percolation rates, steep slopes and shallow, fractured bedrock intensify the problem of septic pollution in Lake Moraine. Approximately 200 dwellings in the watershed are located on parcels of land adjacent to the lake. A 1988 survey showed a variety of shortcomings in septic systems such as excessive age, insufficient capacity, and close proximity to the lake. Also, nutrients found in sewage are already in a form that can be taken up by plants. These factors combined make it unlikely that improvements in the water clarity and dissolved oxygen levels of Lake Moraine will be achieved without a reduction in nutrient loading by septic systems (Bennett et al. 1998).

The excessive growth of submergent macrophytes is considered the greatest threat to the recreational use of Lake Moraine (Welch 1997). It has been observed that plants have occupied up to 45% of the lake's surface at one time. Eurasian watermilfoil became particularly abundant by 1990. It has proven pestiferous through its tendency to grow in dense beds that reach the surface even in depths of 5 meters. Such aggregates exclude native species by completely shading the area beneath the canopy in addition to creating an unnaturally high water temperature in the shallow layer above the canopy. Native macrophytes such as *E. canadensis*, *Vallisneria americana*, and the macroalga *Chara vulgaris* exhibit growth patterns that allow better penetration of light and circulation of water. A community of native macrophytes bearing a collective heterogeneity of leaf structures and growth patterns provide a wider range of microhabitats for the lake's faunal community than do the monotypic milfoil beds (Harman et al. 2004a).

One strategy that has been employed to control Eurasian watermilfoil in Lake Moraine is mechanical harvesting. There are three serious drawbacks to this method. One is that the plants tend to repopulate zones from which they have been removed fairly rapidly. Another is the possibility of further spreading the invasive macrophyte into uninfested areas of the same body of water as well as new bodies of water through propagation of incidentally created plant fragments. Finally, physical removal tends to reduce the populations of herbivorous insects due to their tendency to inhabit the upper regions of the plants targeted in the harvest (Harman et al. 2002).

A few examples of herbivorous insects known to feed on Eurasian watermilfoil in Lake Moraine are the milfoil weevil (*E. lecontei*), aquatic macrophyte moth (*Acentria ephemerella*), and milfoil midge (*Cricotopus myriophylli*) (Harman et al. 2004b). These species were noted in Lake Moraine in the autumn of 1997. The milfoil weevil is of particular interest to those involved in the macrophyte management plan as milfoil is its preferred food source (Sheldon 1997). It was initially postulated that *E. lecontei* would prove to be an effective biological control agent. A total of 13,000 specimens of *E. lecontei*, provided by EnviroScience, Inc., were released in the upper basin between 30 June 1998 and 18 July 2000. In none of the four years of research was a reduction in

milfoil biomass or evident weevil herbivory on the milfoil observed (Harman et al. 1998; 2000; 2001; 2002). It was postulated that the high bluegill (*Lepomis macrochirus*) densities in Lake Moraine reduced the weevil numbers to a level at which they proved ineffective as a biological control agent (Lord 2004). Another concern regarding the ecological interaction of *M. spicatum* and *E. lecontei* is the annual *ca.* 1.5 m (5 ft.) winter drawdown of Lake Moraine. Although this has been shown to inhibit the growth of *M. spicatum* to a degree (Harman et al. 2004b), it is feared that the beneficial weevil populations might be unintentionally kept in check as well. *Euhrychiopsis lecontei* hibernates at the water's edge where populations can be lost as a result of winter drawdown (Harman et al. 2002).

A variety of herbicidal compounds have been applied to Lake Moraine since the 1940s. Copper sulfate (CuSO₄) was initially used as a non-selective herbicide to target phytoplankton as well as macrophytes. 1972-73 brought an application of Diquat (1,1'-ethylene-2,2'-bipyridylium dibromide [C₁₂H₁₂N₂Br₂]) as a means of targeting planktonic algae. Simazine (6-chloro-N₂,N₄-diethyl-1,3,5-triazine-2,4-diamine [C₇H₁₂ClN₅]) was used in 1974-75 with the intention of controlling both algae and macrophytes. The use of other herbicides in Lake Moraine during the 1980s has been suggested anecdotally.

After several decades of herbicide applications, an alternative more agent specific to the invasive plants was sought and ultimately found in the aforementioned Sonar[®] herbicide, the active ingredient being fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H) pyridinone [C₁₉H₁₄F₃NO]) (Harman et al. 2004a). May of 1996 marked the first application of fluridone in Lake Moraine. The littoral zone of both basins was treated. A second application performed on 13 May 2001 treated the littoral zone of the lower basin. Most recently, Sonar[®] was applied throughout the upper basin in May 2004. Sonar[®] is advertised as non-toxic and bears a "caution" warning, the lowest the EPA can assign. SePRO claims that the herbicidal efficacy may last for over a year following an appropriate application. This has been substantiated by BFS research in the lower basin of Lake Moraine following the treatment in 2001 (Harman et al. 2004a). Fluridone is a systemic herbicide and is relatively tolerable to most aquatic plants native to North America according to the manufacturer. Eurasian watermilfoil, as well as fellow exotics hydrilla (*Hydrilla verticillata*) and curlyleaf pondweed, exhibit greater biochemical susceptibility. Fluridone kills by interfering with carotenoid production. This in turn leaves chlorophyll unprotected from decomposition by sunlight and ultimately inhibits photosynthesis (Lord 1999). Finally, the senescence of macrophytes following an uptake of fluridone progresses slowly. This benefits the aquatic community by preventing the rapid and extreme oxygen depletion that would follow a spike in the biological oxygen demand of aerobic bacteria thriving as a result of a sudden increase in dead plant biomass.

Another issue of possible relevance to researchers of Lake Moraine's plant community are the recent applications of copper sulfate pentahydrate (CuSO₄•5H₂O) performed amidst the fluridone treatments. Algaecidal treatments occurred in July of 1999 and August of 2000-02. One hundred acres of the lake were treated each time with 142 kg of Phelps Dodge Copper Sulfate at an application rate not to exceed 0.3 µg/l. As

the goal of these treatments was control of planktonic algae (NYSDEC 1999; 2000; 2001; 2002), there was a theoretical possibility that preexisting hypoxic conditions following summer stratification would become more severe as a result of the premature death and decomposition of unnaturally large quantities of algae.

A sampling protocol designed to evaluate the effectiveness of Sonar[®] in Lake Moraine was initiated in June 1996 (Fuller 1997). Three sampling sites were initially selected in the lower basin where Sonar[®] had been applied a month prior, and one site in an untreated area of the upper basin was sampled as a control (Figure 1). Following their collection, macrophytes were separated by species, thoroughly desiccated, and weighed to determine their biomass. Similar methodologies have been used by the BFS in continued monitoring efforts since 1997, with some modifications to site locations. Later expansion of monitoring work on Lake Moraine focused on evaluating the efficacy of *E. lecontei* as a biocontrol agent in the upper basin as well as monitoring the entire littoral zone of the lower basin in regards to the Sonar[®] application of May 2001 (Harman et al. 2002). This report focuses on the Sonar[®] applications of 2004 in the upper basin as well as providing a complete summary of biomass data collected to date.

METHODS

An application of Sonar[®] in Lake Moraine occurred on 16 May 2004 (Harman 2004a). A “FasTEST” (SePRO 2004a) was run on water samples collected on 1 June. Sonar[®] concentrations were determined to be below the necessary target range and so were consequently raised by an additional application on 5 June. Subsequent testing and anecdotal observations of plant response to the treatment failed to warrant a third application (Slater 2004).

Sampling occurred on 2 June, 7 and 29 July, 20 August and 5 October. In preparation for each collection excursion, 25 plastic bags were labeled with a paired letter and number corresponding to each of five replicate samples per site. Upon arriving and anchoring at each of the five sampling sites, a weighted line marked at one meter intervals was tossed from the side of the boat to promote randomness in the sampling. A diver outfitted with a snorkel, mask and fins progressed along the line while carrying a mesh net attached to a metal ring 0.32 meters in diameter (surface area inside ring = 0.08 m²). At five separate marks, the diver maneuvered the net from surface to bottom while collecting all plant biomass within the area of the ring. Senescent or decomposing plant material was not intentionally collected. In the event of plant specimens originating within the surface area of the net and spreading outside it upon reaching the surface, the diver would start at the bottom and pull the plants within the appropriate area down from the surface prior to loading them into the net. The diver would be provided with an empty net in exchange for a full net upon returning to the boat. The contents of the returned net were then transferred into an appropriately labeled bag (the number of the site followed by a letter from A-E) and stored on ice.

After returning from the field, biomass samples were sorted by species, site, and replicate sample prior to being organized into heat resistant open containers and thoroughly desiccated overnight in a convection oven at 105°C. Immediately following removal from the oven, samples were weighed on an electronic balance. Values were ultimately transferred into Microsoft Excel where they were converted to and reported as species dry weight/ m².

A Hydrolab Scout 2[®] multiprobe digital multiprocessor was used at the deepest point in each basin. Temperature, pH, conductivity, and dissolved oxygen concentrations were measured in profile at 1 m intervals. Secchi transparency readings were also taken. Water samples were collected at the three sites shown in Figure 1 and were analyzed for total phosphorus concentrations using the ascorbic acid method following digestion by potassium persulfate and nitrate + nitrite using cadmium reduction (APHA 1992). WQ3 (see Figure 1) was added this year to evaluate potential nutrient migration from the upper to lower basins, which might be attributable to plant decomposition, and/or destabilized organic substrate, following the Sonar[®] treatment.

RESULTS AND DISCUSSION

All water quality parameters (nitrate + nitrite, phosphorus, conductivity, dissolved oxygen, pH, temperature, and Secchi transparency) fell within the range spanning the lowest and highest values observed in previous years of CSLAP data (NYSFOLA and NYSDEC, 2004).

Tables 1-25 provide a complete outline of the macrophyte biomass data collected in 2004. Species present at < 0.02 g per sampled are denoted with “*”. These data, along with those collected during the summers of 1996-2003, are graphically presented in Figures 2-6 for sites 1-5, respectively. Because the primary goal of the Lake Moraine aquatic management strategy has been to control of *M. spicatum*, these graphs have been simplified in order to compare the biomass of *M. spicatum* to that of all other plants between years as well as sampling dates within a single growing season. Figures 7 and 8 generalize these data even more broadly in providing a simple year-by-year comparison of the approximate ratio between Eurasian watermilfoil biomass and that of all other plants in the upper basin versus the lower basin. Yearly biomass data from upper basin sites 4 and 5 are presented in Figure 7 whereas data from lower basin sites 1-3 are presented in Figure 8. In Figures 2-8, the time at which Sonar[®] was applied at the corresponding area is denoted by an arrow.

Although data collected from 1996-98 show a general increase in total plant biomass following the first Sonar[®] application, this cannot be confidently attributed to management efforts due to the methodological change initiated in 1998. It became evident in 1997 that winter drawdown of Lake Moraine had an affect on plant growth in the sampling areas. As a result, the sampling stations were relocated to deeper water where data collected would better reflect lake-wide conditions (Harman et al. 2004a).

	A	B	C	D	E	
SITE 1: 6/2/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>						
<i>Chara vulgaris</i>		1221.88	980.25	293.00	388.88	576.80
<i>Vallisneria americana</i>	3.88			*		0.78
<i>Elodea canadensis</i>			*			
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>	*					
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>				4.88	6.88	2.35
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
TOTAL						579.93

Table 1. Synopsis of macrophyte biomass, site #1, 2 June 2004.

	A	B	C	D	E	
SITE 2: 6/2/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>				3.63		0.73
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	63.88	30.13	99.50	602.88	287.25	216.73
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>			*		1.50	0.30
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>		*				
<i>Potamogeton crispus</i>	1.75	134.25	3.00	15.13	12.50	33.33
<i>Potamogeton zosteriformis</i>	10.75	35.00		3.13	13.13	12.40
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
TOTAL						263.48

Table 2. Synopsis of macrophyte biomass, site #2, 2 June 2004.

	A	B	C	D	E	
SITE 3: 6/2/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>			6.25			1.25
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	192.63	283.88	207.13	283.75	134.25	220.33
<i>Chara vulgaris</i>		3.13				0.63
<i>Vallisneria americana</i>						
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>	62.50	589.00	56.25		209.88	183.53
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
TOTAL						405.73

Table 3. Synopsis of macrophyte biomass, site #3, 2 June 2004.

	A	B	C	D	E	
SITE 2: 7/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>					68.13	13.63
<i>Najas flexilis</i>	18.63	*			4.88	4.70
<i>Ceratophyllum demersum</i>	101.00	126.50		3.88	8.63	48.00
<i>Chara vulgaris</i>					2.25	0.45
<i>Vallisneria americana</i>		28.88	*	8.63	29.50	13.40
<i>Elodea canadensis</i>	21.75	122.38		76.88	151.25	74.45
<i>Ranunculus aquatilis</i>				7.50	8.25	3.15
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>		*				
<i>Potamogeton crispus</i>	2.50	16.88			4.50	4.78
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>	1.25				10.88	2.43
<i>Nitella flexilis</i>						
					TOTAL	164.98

Table 7. Synopsis of macrophyte biomass, site #2, 7 July 2004.

	A	B	C	D	E	
SITE 3: 7/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>	10.63	358.50				73.83
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	714.25	859.50	499.50	186.63		451.98
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>	241.38			641.88		176.65
<i>Elodea canadensis</i>				42.50		8.50
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>	3.38					0.68
<i>Potamogeton zosteriformis</i>	*					
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	711.63

Table 8. Synopsis of macrophyte biomass, site #3, 7 July 2004.

	A	B	C	D	E	
SITE 4: 7/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	233.13	25.38	65.25		227.75	110.30
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>						
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>			*			
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	110.30

Table 9. Synopsis of macrophyte biomass, site #4, 7 July 2004.

	A	B	C	D	E	
SITE 5: 7/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>	*					
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>			38.50			7.70
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	954.13	446.13	402.25	377.25	168.38	469.63
<i>Chara vulgaris</i>			117.00			23.40
<i>Vallisneria americana</i>			8.25			1.65
<i>Elodea canadensis</i>			70.63			14.13
<i>Ranunculus aquatilis</i>			*			
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>			2.38			0.48
<i>Potamogeton crispus</i>			8.63			1.73
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	518.70

Table 10. Synopsis of macrophyte biomass, site #5, 7 July 2004.

	A	B	C	D	E	
SITE 1: 7/29/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>	369.00					73.80
<i>Ceratophyllum demersum</i>			26.63	36.63		12.65
<i>Chara vulgaris</i>		1643.25	428.88	689.00	324.25	617.08
<i>Vallisneria americana</i>	129.00		202.88	383.75	263.00	195.73
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>	9.00	86.00		86.13	29.00	42.03
<i>Nitella flexilis</i>						
					TOTAL	941.28

Table 11. Synopsis of macrophyte biomass, site #1, 29 July 2004.

	A	B	C	D	E	
SITE 2: 7/29/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>			10.25		8.00	3.65
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>		4.00		18.63	24.88	9.50
<i>Ceratophyllum demersum</i>	10.63	61.50	40.38	22.38	10.00	28.98
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>	5.38	147.75	296.75	19.63	140.88	122.08
<i>Elodea canadensis</i>	201.25	162.88	453.63	410.38	122.00	270.03
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>				*		
<i>Nitella flexilis</i>						
					TOTAL	434.23

Table 12. Synopsis of macrophyte biomass, site #2, 29 July 2004.

	A	B	C	D	E	
SITE 3: 7/29/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>	10.13			107.50		23.53
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	122.63	187.25	831.38	340.88	102.88	317.00
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>	21.25				312.13	66.68
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	407.20

Table 13. Synopsis of macrophyte biomass, site #3, 29 July 2004.

	A	B	C	D	E	
SITE 4: 7/29/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	22.88	72.88	72.63	25.50	92.88	57.35
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>						
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>		*				
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	57.35

Table 14. Synopsis of macrophyte biomass, site #4, 29 July 2004.

	A	B	C	D	E	
SITE 5: 7/29/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	24.38	3.75	30.50	4.00	*	12.53
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>						
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	12.53

Table 15. Synopsis of macrophyte biomass, site #5, 29 July 2004.

	A	B	C	D	E	
SITE 1: 9/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>			2.75			0.55
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>						
<i>Chara vulgaris</i>	817.13	471.63	827.63	568.88	387.38	614.53
<i>Vallisneria americana</i>	436.75	47.88		383.75	244.13	222.50
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>	24.63	4.63		5.50	45.00	15.95
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	853.53

Table 16. Synopsis of macrophyte biomass, site #1, 7 September 2004.

	A	B	C	D	E	
SITE 2: 9/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>				5.00		1.00
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	7.50	2.75	1.63	0.75	6.38	3.80
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>	1.25	97.88	963.50	130.63	378.00	314.25
<i>Elodea canadensis</i>	900.00	220.75	3.38	187.13	329.25	328.10
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	647.15

Table 17. Synopsis of macrophyte biomass, site #2, 7 September 2004.

	A	B	C	D	E	
SITE 3: 9/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>		391.88			88.88	96.15
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>	1.50			1.00	211.88	42.88
<i>Najas flexilis</i>		4.38	0.25		155.13	31.95
<i>Ceratophyllum demersum</i>	1154.13	1431.25	478.88	678.88	440.38	836.70
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>	1.63	54.63			361.25	83.50
<i>Elodea canadensis</i>	0.38	1.38	1.38			0.63
<i>Ranunculus aquatilis</i>					2.13	0.43
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>		8.00				1.60
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	1093.83

Table 18. Synopsis of macrophyte biomass, site #3, 7 September 2004.

	A	B	C	D	E	
SITE 4: 9/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	34.25	107.88	77.50	32.25	43.88	59.15
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>						
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>					6.25	1.25
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
TOTAL						60.40

Table 19. Synopsis of macrophyte biomass, site #4, 7 September 2004.

	A	B	C	D	E	
SITE 5: 9/7/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	22.63	4.00		2.63		5.85
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>						
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>	1.00	0.75		0.40		0.43
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
TOTAL						6.28

Table 20. Synopsis of macrophyte biomass, site #5, 7 September 2004.

	A	B	C	D	E	
SITE 1: 10/5/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>						
<i>Chara vulgaris</i>	599.13	822.00	25.25	278.25	616.50	468.23
<i>Vallisneria americana</i>		5.45	1021.00	383.75	134.63	308.97
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>				17.13	28.28	9.08
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
TOTAL						786.27

Table 21. Synopsis of macrophyte biomass, site #1, 5 October 2004.

	A	B	C	D	E	
SITE 2: 10/5/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>		1.36		1.95		0.66
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>	0.28	0.36				0.13
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	54.00	2.93	32.63	8.18	4.85	20.52
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>	92.13	291.25	5.45	859.88	29.58	255.66
<i>Elodea canadensis</i>	2085.50	1742.13	1682.00	662.13	2323.13	1698.98
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>				1.65		0.33
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	1976.27

Table 22. Synopsis of macrophyte biomass, site #2, 5 October 2004.

	A	B	C	D	E	
SITE 3:10/5/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>	40.58		13.16		4.24	11.60
<i>Megalodonta beckii</i>						0.00
<i>Zosterella dubia</i>	434.13		0.71			86.97
<i>Najas flexilis</i>	4.44		1.65			1.22
<i>Ceratophyllum demersum</i>	698.25	1044.00	646.13	1081.00	942.38	882.35
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>		5.24				1.05
<i>Elodea canadensis</i>	68.86					13.77
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>	3.63		1.20			0.97
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	997.92

Table 23. Synopsis of macrophyte biomass, site #3, 5 October 2004.

	A	B	C	D	E	
SITE 4: 10/5/04	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>		2.63		3.13	4.71	2.09
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>						
<i>Najas flexilis</i>	5.41					1.08
<i>Ceratophyllum demersum</i>	27.26					5.45
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>						
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>					0.95	0.19
<i>Potamogeton zosteriformis</i>	4.56	1.49	0.49			1.31
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	10.13

Table 24. Synopsis of macrophyte biomass, site #4, 5 October 2004.

SITE 5:10/5/04	A	B	C	D	E	
	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)	Dry Wt. (g/m ²)
<i>Myriophyllum spicatum</i>						
<i>Megalodonta beckii</i>						
<i>Zosterella dubia</i>				0.99		0.20
<i>Najas flexilis</i>						
<i>Ceratophyllum demersum</i>	6.51	1.75	7.09	11.06	2.41	5.77
<i>Chara vulgaris</i>						
<i>Vallisneria americana</i>						
<i>Elodea canadensis</i>						
<i>Ranunculus aquatilis</i>						
<i>Ranunculus trichophyllus</i>						
<i>Stuckenia pectinata</i>						
<i>Potamogeton crispus</i>						
<i>Potamogeton zosteriformis</i>						
<i>Potamogeton pusillus</i>						
<i>Nitella flexilis</i>						
					TOTAL	5.96

Table 25. Synopsis of macrophyte biomass, site #5, 5 October 2004.

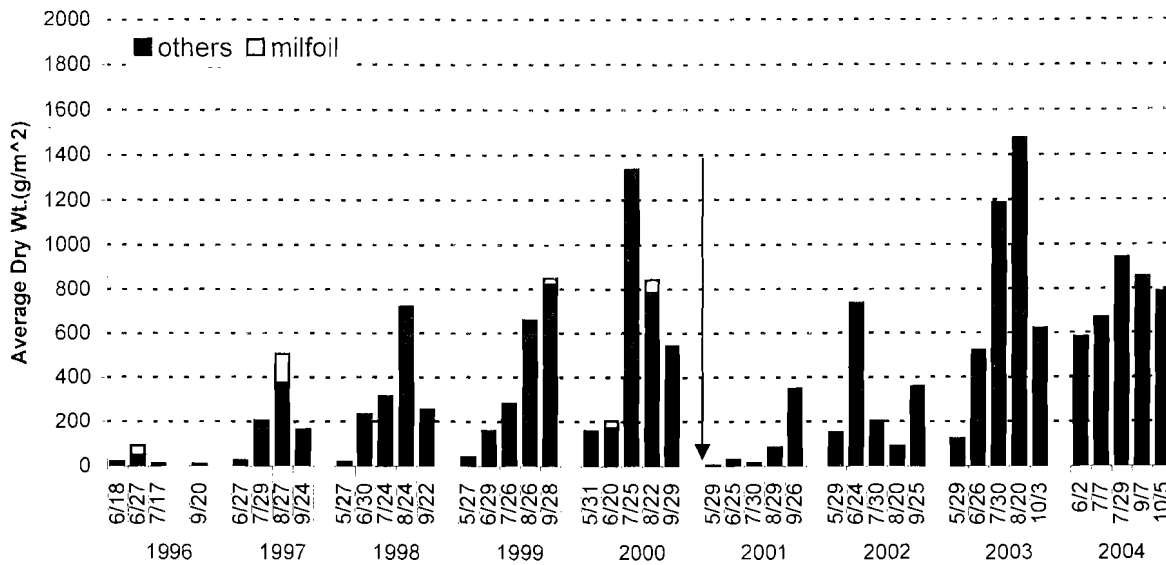


Figure 2. Comparison of dry weight (g/m²) of EWM and other plants combined, site #1, 1996-2004. Each bar represents the mean of five replicate samples. Arrow represents Sonar application.

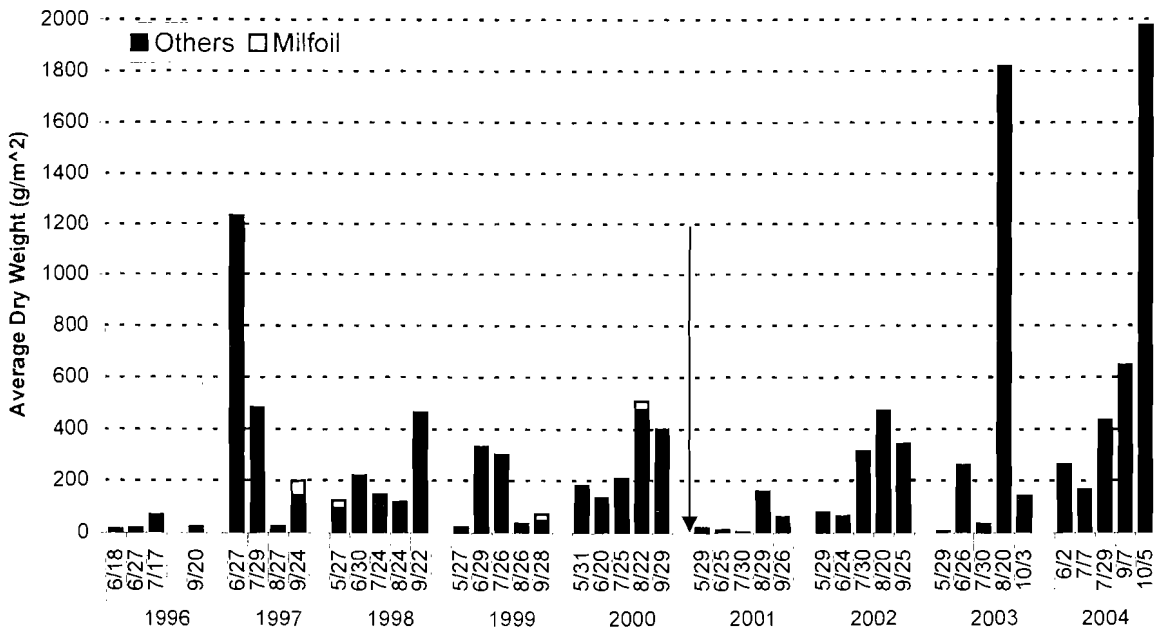


Figure 3. Comparison of dry weight (g/m²) of EWM and other plants combined, site #2, 1996-2004. Each bar represents the mean of five replicate samples. Arrow represents Sonar application.

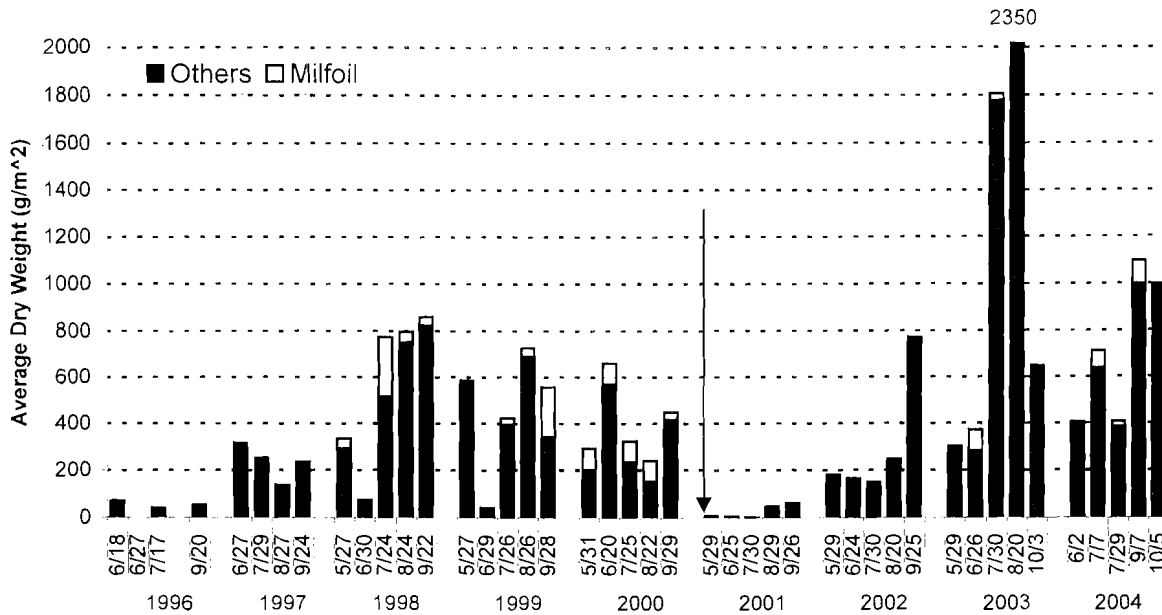


Figure 4. Comparison of dry weight (g/m^2) of EWM and other plants combined, site #3, 1996-2004. Each bar represents the mean of five replicate samples. Arrow represents Sonar application.

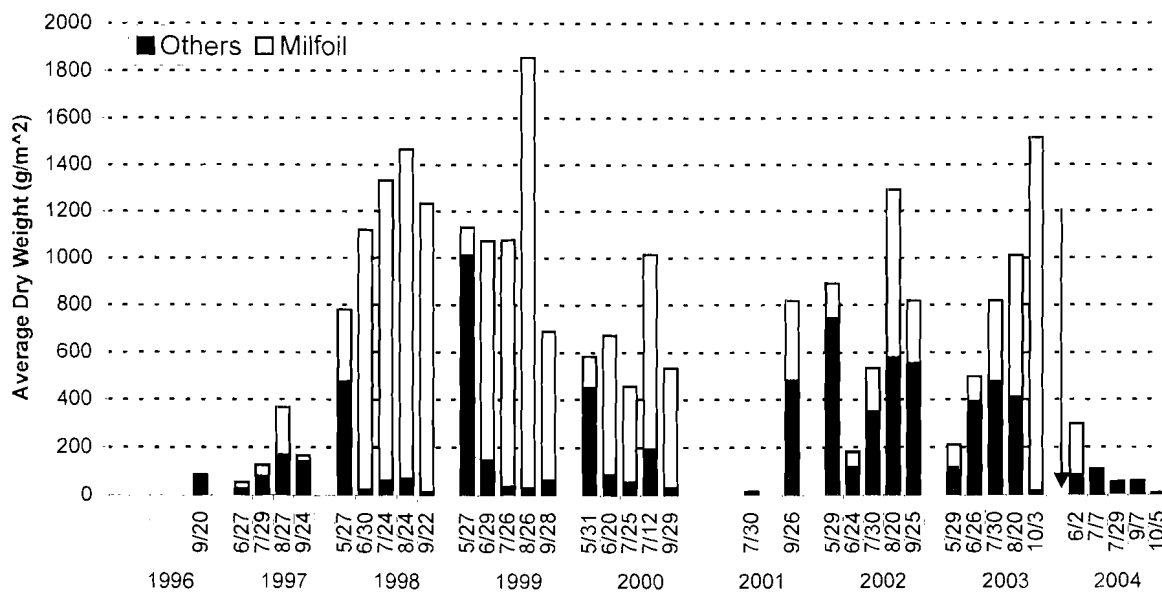


Figure 5. Comparison of dry weight (g/m^2) of EWM and other plants combined, site #4, 1996-2004. Each bar represents the mean of five replicate samples. Arrow represents Sonar application.

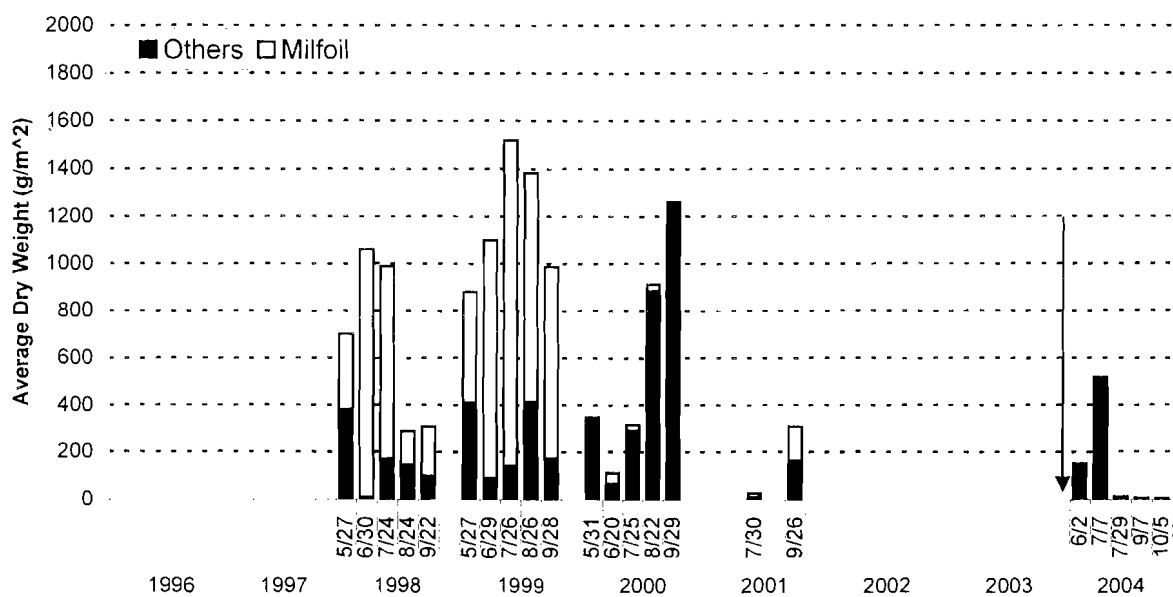


Figure 6. Comparison of dry weight (g/m^2) of EWM and other plants combined, site #5, 1996-2004. Each bar represents the mean of five replicate samples. Arrow represents Sonar application.

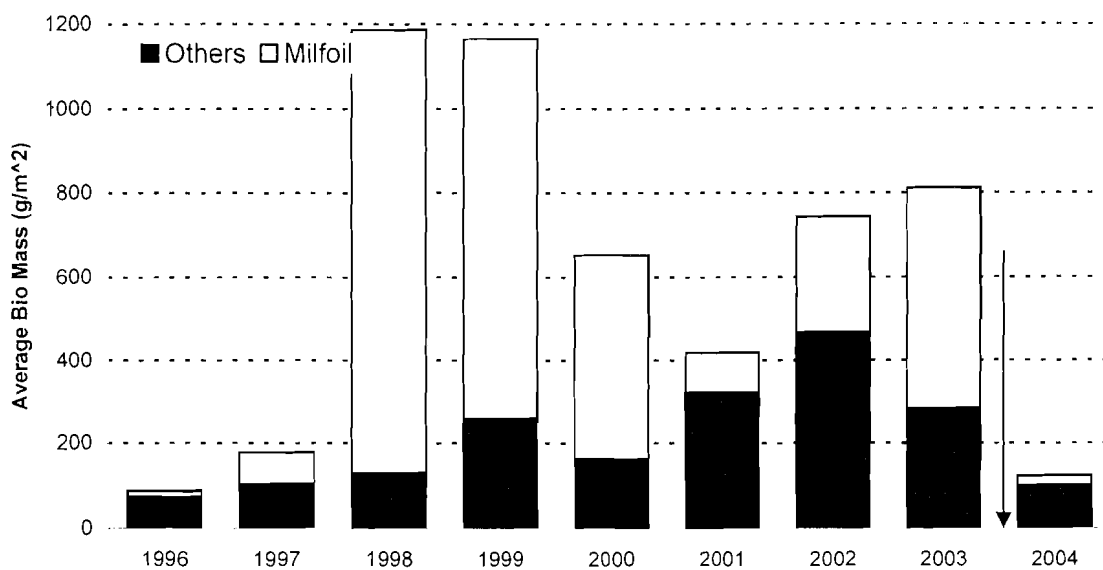


Figure 7. Comparison of the annual mean biomass of EWM and other aquatic plants 1996-2004 in upper basin. Arrow represents Sonar application.

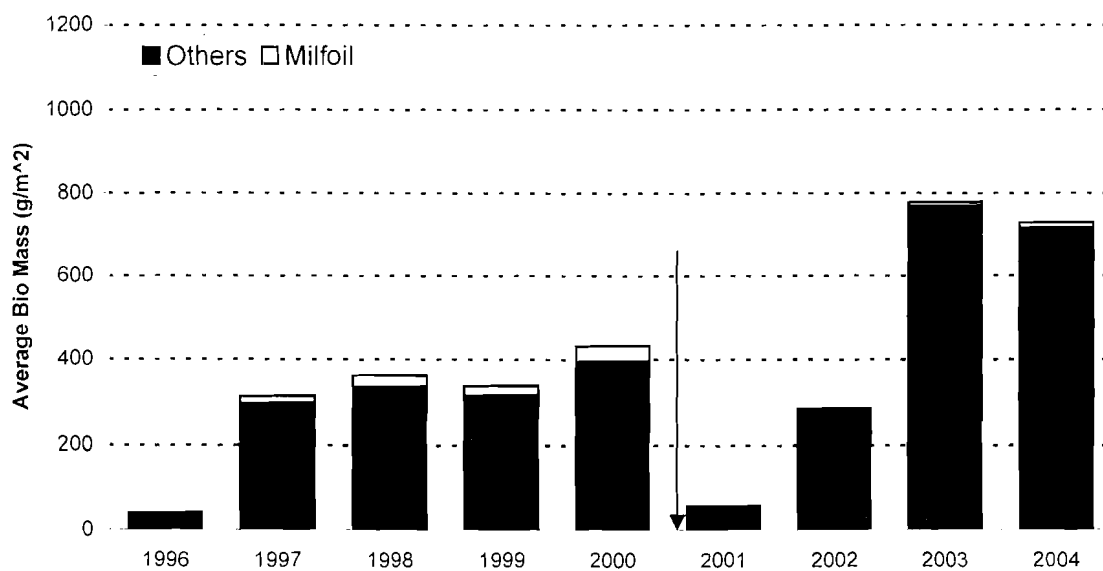


Figure 8. Comparison of the annual mean biomass of EWM and other aquatic plants 1996-2004 in lower basin. Arrow represents Sonar application.

Eurasian watermilfoil was virtually absent in the lower basin from the spring 2001 Sonar[®] application through most of the growing season in 2002. In August of 2002, however, several rooted specimens of milfoil were observed in the lower basin adjacent to the causeway. These plants likely originated as fragments that flowed through the culvert from the upper basin where milfoil was the dominant species. These plants were sufficiently few in number to warrant the Lake Moraine Association's decision to employ a SCUBA diver to manually remove them (Harman et al. 2004a).

Eurasian watermilfoil occurred in 2003, but was a minor component of the community. It was present at biomass site 3 on each sampling date. The native *E. canadensis* had been impacted by the Sonar[®] application of 2001 to a level comparable to that of Eurasian watermilfoil. It was likewise collected only at site 3 during the 2003 growing season (Harman et al. 2004a). These factors combined provided further evidence to the untreated upper basin serving as the source of the plants. The observed sensitivity of *E. canadensis* to Sonar[®] is consistent with claims made by its manufacturer (SePRO 1999).

During the summer of 2004, milfoil was found regularly at sites 2 and 3, though it was a minor component of the community. Observations throughout the lower basin indicated an increase in that plant as the summer progressed. That was particularly the case at the southwest portion of the lake, west of the islands and in the embayments. By fall it was becoming dominant in those areas, and by summer 2005 it will likely pose a recreational hindrance there. The rebound of *Elodea* mirrored that of milfoil.

Milfoil was common in the upper basin only at the first (2 June) sampling, and that observed was unhealthy and regressing, presumably due to the Sonar[®] application of two weeks prior. At that time coontail (*Ceratophyllum demersum*), generally common there, appeared to have been impacted by the application as the apical regions were bleached. Later in the summer, the apparent health of coontail improved, though in general it was not abundant. This situation was similar to that observed in the lower basin following the spring 2001 Sonar[®] application, when it initially seemed depressed. It had rebounded by early 2002.

MANAGEMENT CONCERNS

Research operations conducted since 1998 suggest that the aquatic macrophyte community of Lake Moraine has comprised 14 native species (Tables 1-25) plus the macroalgae *C. vulgaris*. The lake's diverse native plant community provides a littoral environment analogous to typical forest ecosystems, the main difference being that the former undergoes successional changes over the course of each growing season rather than over the course of decades. The seasonal heterogeneity and combination of species found in Lake Moraine is considered nearly ideal for its shape and size. Exotic species are therefore an undesirable addition to the ecosystem (Harman et al. 2004a).

Myriophyllum spicatum and *P. crispus* are the current exotic plants threatening the ecological balance of Lake Moraine. In the absence of proper management, both species have been shown to flourish and become pestiferous in the upper basin by June. Prior to 2001, large beds of *P. crispus* were observed near biomass site 3 in the lower basin while *M. spicatum* had formed dense beds covering much the upper basin over the course of an entire growing season. *Myriophyllum spicatum* began to recolonize the lower basin several years after its eradication in 1996. Isolated colonies were observed near the causeway and in the vicinity of biomass site 3 in 1999. A large milfoil bed was observed near biomass site 3 extending south along the western shore by the end of the growing season in 2000. Smaller beds occurred in other areas of the lower basin that year as well. The 2001 Sonar[®] application resulted in the reduction of *M. spicatum* to vestigial quantities in the lower basin. Furthermore, research in 2002-2004 verified the claim that Sonar[®] can control Eurasian watermilfoil for multiple growing seasons following an application. *Potamogeton crispus* also suffered substantially from the Sonar[®] applications. Most native species were initially affected but fared far better overall (Harman et al. 2004a). Since 1996 the biomass of native species has increased by more than 100%.

Depths less than 2 meters in the littoral zone of the lower basin tend to be dominated by eelgrass (*V. americana*) for most of the summer and yellow star flower (*Zosterella dubia*) from late summer into autumn. Grassy pondweed (*S. pectinata*) occurred in great density near biomass site 2 in the early summer of 1997 (Harman et al. 1998) just as it did in the summer of 2004. In spite of their status as native plants, the aforesaid three species are pestiferous to varying degrees in their abundance from year to year as well as within a single growing season. All have been regarded as problematic in the past due to their occasional interference with shallow-water recreation. One recommended means of controlling the densities of these native plants is physical removal by hand in small critical areas of impaired recreational uses such as swimming. The use of synthetic fiber barriers to inhibit the spread of the plants has also been suggested provided that substrate disturbance is minimized. Attempts to bury the plants through artificial deposition of sediment in beach areas have not been deemed advisable. Non-selective herbicides have been judged as posing an excessive threat to the ecological balance of the littoral community (Harman et al. 2004a).

Monitoring following the experimental augmentation of *E. lecontei* populations in the upper basin did not suggest that long-term benefits would follow. It has been suggested that the actual effectiveness of biocontrol through herbivorous insects can only be determined in the absence of mechanical and chemical control methods and may even require population management of predatory fish such as *L. macrochirus* (Lord 2004).

Educational programs are a recommended component in the management of Lake Moraine for several reasons. Ensuring that stakeholder expectations do not exceed feasible results of macrophyte management efforts is one advantage. Another benefit is the reduced likelihood of introducing additional pestiferous exotics to Lake Moraine (Harman et al. 2004a). Examples of invasive plants occurring in New York State but yet to be found in Lake Moraine include Eurasian water chestnut (*Trapa natans*) and fanwort

(*Cabomba caroliniana*) (NYSFOLA and NYSDEC 2004). The arrival of invasive zooplankton such as spiny water fleas (*Bythotrephes cederstroemi*), zoobenthos such as zebra mussels (*Dreissena polymorpha*), and nekton such as alewives (*Alosa pseudoharengus*) may also be delayed or prevented by public education. All of these species occur in nearby lakes such as Oneida and could lead to additional imbalance in the ecology of Lake Moraine following a successful introduction. Means through which the chances of such introductions can be reduced range from signage at launch sites to boat inspections and washing facilities (Harman et al. 2004a).

Increasing deposition of fine sediment as well as changes in the distribution of emergent macrophytes along shorelines is indicative of eutrophication in a lake ecosystem. This can be prevented or reduced through long term planning that involves land use regulations intended to minimize nutrient loading from runoff in the watershed. Problems with sewage have also cited as a nutrient source to Lake Moraine. The nature of watershed soils severely limits the ability of conventional systems to assimilate nutrient pollution associated with septic leachate. It should be noted that recent advances have provided technologies that effectively remove phosphorus from leachate (see Green 2002). As of 1988, the average septic system in the watershed was undersized, outdated, and in close proximity to the lake. Lakefront homes can thus be expected to continue making substantial contributions to nutrient loading, thereby sustaining the eutrophic status of Lake Moraine and the subsequent level of difficulty in suppressing the biomass of its invasive macrophytes (Harman et al. 2004a).

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