

Effects of Harvesting on Plant Communities Dominated by Eurasian Watermilfoil in Lake Minnetonka, MN

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ABSTRACT

Extensive mechanical harvesting has been used in 5,746 hectare Lake Minnetonka, Minnesota since 1989 to control populations of Eurasian watermilfoil (*Myriophyllum spicatum*). Approximately 47% of the 544 infested hectares were harvested during the summer of 1990. We measured effects of one series of harvests in five separate locations in Lake Minnetonka. Plant relative growth rates were greater ($p = 0.001$) in 54 m² harvested plots than in adjacent reference plots. The increased growth rate did not result in harvested areas having greater canopy density or higher total shoot biomass than adjacent reference areas. Harvesting reduced total shoot biomass and plant abundance at the water surface for up to 6 weeks following harvest. Eurasian watermilfoil was the dominant plant in all areas, although its presence in an area was not correlated with high total shoot biomass in that area. Total shoot biomass was positively correlated with both water clarity and percentage of sediment organic matter and negatively correlated with the percentage of clay in the sediments.

Key words: macrophytes, *Myriophyllum spicatum*, management, growth rate.

INTRODUCTION

Eurasian watermilfoil (*Myriophyllum spicatum* L.), hereafter called milfoil, impairs use of water resources in many parts of the United States and Canada (Aiken et al. 1979). Problems associated with milfoil include degradation of beaches (Verhalen et al. 1985), interference with boat launching (personal observation) and decreased recreational opportunities (Schloesser and Manny 1984). The negative effects of milfoil infestation are most evident when high biomass and matting on the surface occur (*e.g.* shading of other plant species [Aiken et al. 1979], limited boat access [Painter 1988] and reduced recreational activities such as fishing, swimming, and water skiing [Rawls 1975]).

Researchers in Ohio reported that milfoil grows back to reference levels within 1 month of harvesting (Cooke et al. 1990). This suggests that harvesting causes an increase in

growth rate of the plant. The aim of our study was to test the following hypotheses: i) Harvesting stimulates milfoil growth rate; and ii) An increased growth rate after harvesting eventually results in a greater amount of milfoil in the harvested areas than in the unharvested areas (*i.e.*, more biomass or plant stems at the surface). We also wished to determine how long the effects of harvesting lasted (*i.e.* how long after harvesting does milfoil biomass or canopy density become equal in harvested and reference areas).

We also studied the correlation between physical characteristics of the lake basin and water column, plant biomass and percentage of milfoil. As of August 1993, there were 63 waterbodies in Minnesota with confirmed milfoil infestations (Minnesota Department of Natural Resources, unpublished data). Because most of the 12,000 lakes in Minnesota (Baker and Swain 1989) have yet to be infested with milfoil, these correlations can be used to help design milfoil management programs by identifying some conditions conducive to high plant biomass (a nuisance state).

MATERIALS AND METHODS

Study Site

Milfoil was first found in Minnesota in 1987 in Excelsior Bay of Lake Minnetonka³ (Figure 1). Since that time it has spread both within Lake Minnetonka and to other lakes in Minnesota. The Lake Minnetonka Conservation District (LMCD) is responsible for most milfoil management activities in Lake Minnetonka. The LMCD has been using custom designed mechanical harvesters which cut a path 4.9 meters wide when fully extended to manage milfoil since the summer of 1989.

Paired harvested and unharvested plots were located in 5 of the bays of Lake Minnetonka (Figure 1). Unharvested plots provided reference conditions for biomass accumulation and canopy density at the surface. Plots were established near Shady Island in Phelps Bay (145 hectares), near Hard-scrabble Point in West Upper Lake (360 hectares), in Crystal Bay (336 hectares), in North Arm (132 hectares), and in Maxwell Bay (120 hectares) (Figure 1) (Smith et al. 1991, Crowell unpublished data). The sampling locations showed distinct differences in water clarity and sediment organic matter among the bays (Table 1).

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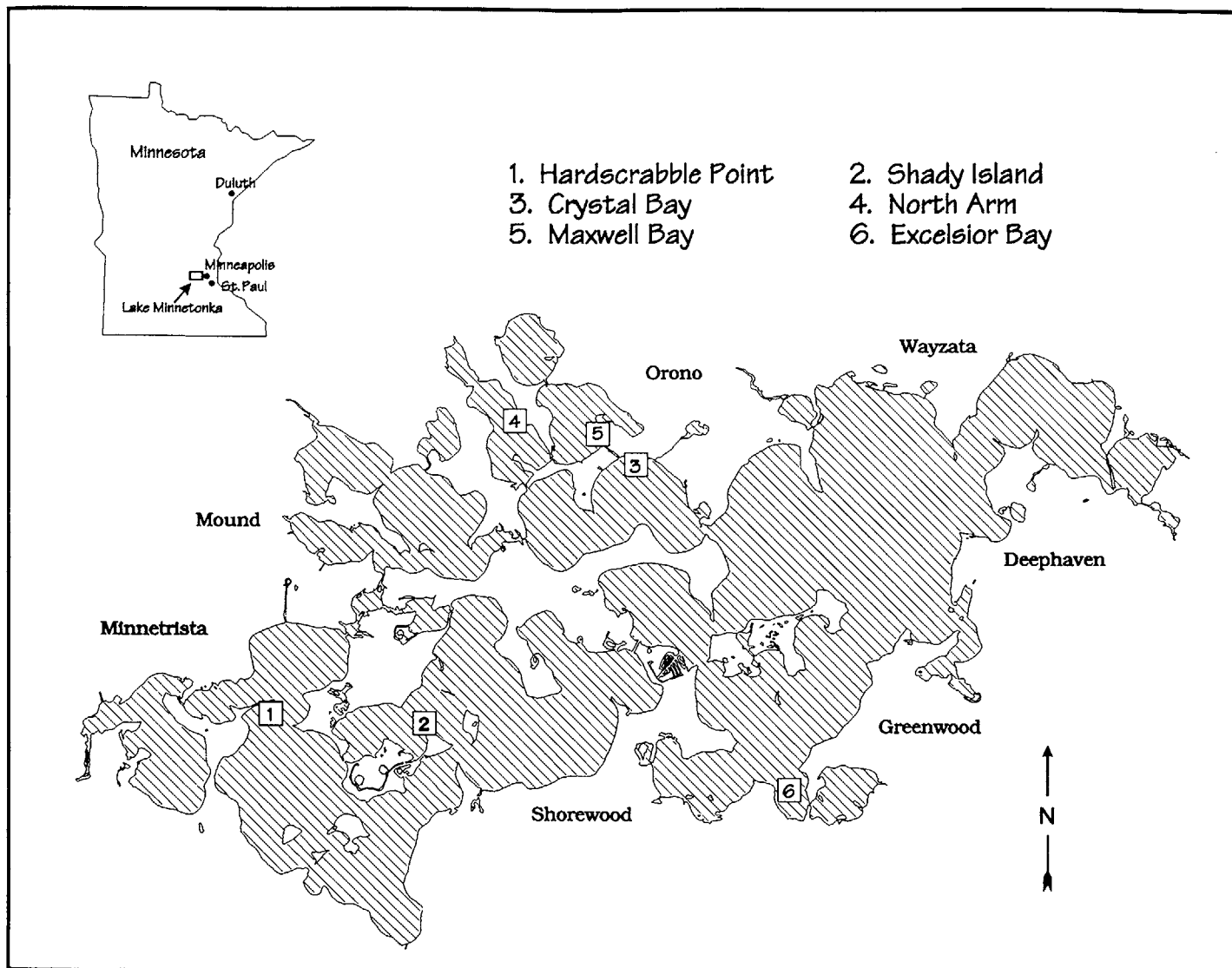


Figure 1. Lake Minnetonka, Minnesota. Locations one through five were experimental plot sites. Location six is the first area milfoil was found in Lake Minnetonka.

Harvesting took place on July 3, 1990, in the middle of the growing season, after milfoil had reached peak biomass. At each site a mechanical harvester cut a path 4.9 meters wide from the off shore weed line to the inshore weed line along a predetermined path. Following harvest an 18 meter by 3 meter plot was delineated with buoys. Reference plots of

equal area were marked adjacent to each treatment plot on a random side. Each plot was subdivided into three equal areas; "near shore", "mid-area", and "furthest from shore". Three biomass samples were taken in each subdivision each week for 9 weeks following harvest (except for the 1st week when only 2 samples were taken).

TABLE 1. WATER CLARITY AND PERCENT ORGANIC MATTER IN THE SEDIMENTS. SITES SHARING THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT (P.0.05).

Location	Secchi depth ¹ (m)	Percent organic matter in sediments ¹
Shady Island	2.0a	6.0 a
Crystal Bay	1.6 b	3.1 b
Hardscrabble Point	1.35 c	1.6 c
North Arm	1.3 c	1.5 c
Maxwell Bay	1.2 s	1.3 c

¹ Each value is a mean of 27 samples or measurements.

SAMPLING METHODS

Density of the vegetation precluded SCUBA sampling for biomass. Thus we sampled with a rake, with a 3 meter extending to 5 meter handle, which was lowered to the sediment surface and rotated 360 degrees. The 0.15 m wide rake sampled 0.02 m² area. To test accuracy and precision of this method, samples were taken at two sites in Lake Minnetonka during the summer of 1991 using both 0.0625 m² SCUBA quadrats and the rake and compared using analysis of variance and coefficients of variation. Results show that while the rake method gave larger estimates of biomass than the quad-

rat method (1669 ± 748 versus 799 ± 379 g/m² DW ($x \pm SE$, $n = 12$, $p < 0.01$)), variability of the two methods was comparable (116 versus 110% coefficient of variation). Thus, caution is needed in comparing our results to other researcher's data but our values indicate that the rake sampling method provides accurate comparisons among our sites.

After collection, plants were washed, roots were removed and above ground shoots were dried to a constant weight at 60 C (after Engel 1990). Milfoil was separated from other plants on the 3rd, 6th and 9th sampling date using the taxonomic key of Fassett (1957). Dry weights were determined for milfoil, and for all other plants combined, and percentage milfoil by weight was determined.

Dissolved oxygen, specific conductivity, and temperature were measured on each sampling date at 0, 1, and 2 meters depth and then averaged. Dissolved oxygen, specific conductivity and temperature were measured with Yellow Springs Instruments (YSI) meters. Water clarity was measured on each sampling date with a 20.3 cm Secchi disk in open water at random locations within 5 meters of each experimental plot.

To assess canopy density at the surface, we developed a method using a Secchi disk (called a plant disk when used in a weed bed). This disk was lowered into the weeds and the depth at which the plant canopy obscured the disk was measured. This was done in both harvested and unharvested areas from the 3rd to the 9th week. The disk was gently lowered through the plant stems by moving the disk side to side so that it did not push down surface mats, but rather slipped underneath them. Plant surface cover was measured as the ratio of Secchi disk to plant disk depth. When plant stems do not obscure the plant disk at all the ratio of plant disk depth to Secchi depth outside the weed bed (the plant canopy

ratio) will be near 1.0 [this ratio may be slightly different from 1.0 due to the effects macrophytes can have on phytoplankton production (Wetzel 1983)].

Sediment cores were collected in the 3 sub-divisions of each plot 3, 6, and 9 weeks after harvest. Cores represented a composite of the upper 15 cm of sediment. Forty grams were sub-sampled from the cores for textural analysis using a hydrometer (Klute 1986). An additional 20 grams of dried material from each core were ashed at 545 C to determine organic content (following Lillie and Barko 1990).

DATA ANALYSIS

Differences in plant biomass between harvested and unharvested plots were analyzed with an ANOVA for each sampling date ($n = 30$ for each date). Biomass data was averaged within each depth range (near shore, mid, and furthest from shore) and \log_{10} transformed, to compensate for unequal sample variance because plants grow in a geometric progression. ANOVAs were also used to compare differences in plant canopy ratios for each week ($n = 30$ for each week). Standard errors for both biomass and plant canopy ratios are determined for weekly data and reflect the variability within treatment plots, sub divisions, and between bays.

The rate of biomass accumulation was determined using linear regression of the weekly \log_{10} transformed biomass average over all sites and depth ranges (Figure 2) ($n = 9$). The slopes were determined as:

$$\frac{\log W_2 - \log W_1}{T_2 - T_1} = \text{Relative growth rate}$$

with units of week⁻¹. W_2 and W_1 are biomass at time 2 (T_2) and time 1 (T_1) respectively.

We tested the statistical difference in rates of biomass accumulation with the following model H_0 : the slopes of the regression lines were parallel and the intercepts are different; H_a : the slopes and intercepts are different. The models were compared using an F-test (Weisberg, 1985). Bay to bay differences in lake physical/chemical characteristics were determined using Tukey's pairwise comparison of means for each bay. Pearson correlation and multiple regression techniques were used to look at the relationships between lake characteristics and plant biomass and percentages of milfoil.

RESULTS AND DISCUSSION

Regrowth after harvest

Harvested plots had significantly higher relative growth rates over the remaining field season than did reference areas ($p = 0.001$). Relative growth rates, determined from the slopes of the regression lines shown in Figure 2, were -0.03 week⁻¹ ($p = 0.001$ for regression) in reference areas and 0.02 week⁻¹ (regression not significant) in harvested areas.

Without the data from the 2nd week the relative growth rate in the harvested areas is 0.03 week⁻¹ ($p = 0.08$ for regression). The anomalous increase in harvested biomass shown the 2nd week after harvest (Figure 2) may be due to an increase in fragments, which are also sampled by our method. Before this sampling date there was a storm which

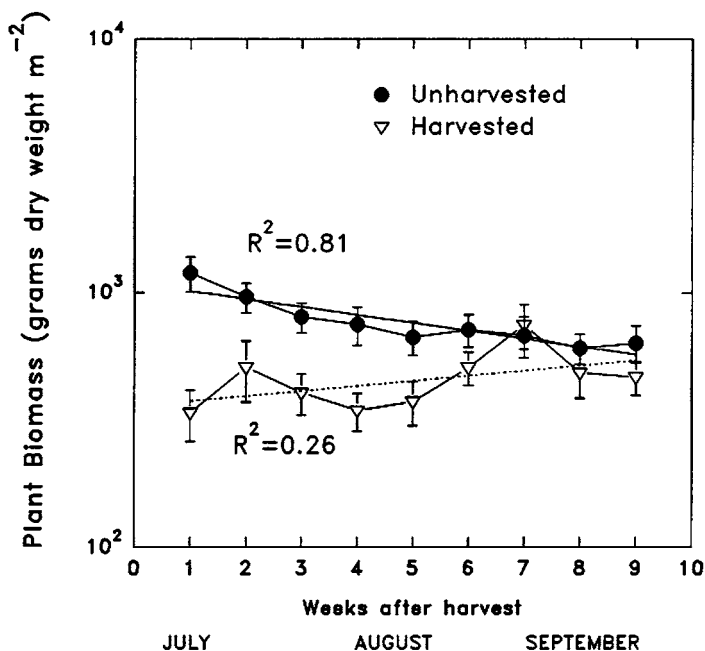


Figure 2. Plant biomass changes over time in harvested and unharvested plots. Harvest done on July 3, 1990. Results presented as mean \pm standard error.

left many broken pieces of milfoil floating in the water column. The fact that there was a rapid decline in the biomass in the 3rd week of sampling supports this interpretation.

Harvested areas had lower average biomass than reference areas for 6 weeks after harvest. Biomass increased in harvested areas and decreased in reference areas such that the two were no longer different 6 weeks after harvest based on weekly comparisons of harvested and reference biomass (Figure 2) [week 3 $p = 0.0019$, week 6 $p = 0.0919$, week 9 $p = 0.3132$].

Plant canopy cover was inversely related to plant biomass (Figure 3), with plant biomass explaining 46% of the variability in the plant canopy ratios. As plants regrew after harvesting, plant canopy ratios showed a similar pattern to biomass readings, with harvested and reference canopy ratios converging to a single point at week 9 (Figure 4). Harvested areas had significantly higher plant canopy ratios than reference areas until the 6th week after harvesting [$p = 0.0022$ week 3, $p = 0.0820$ week 6, $p = 0.912$ week 9].

Other researchers have found that harvesting reduced biomass for only 3 to 4 weeks. Thus, milfoil populations harvested in mid-July attained pre-harvest and reference levels within 23 days after harvesting in LaRue Reservoir, Ohio (Cooke et al. 1990) and sites in Dundee and Herring Creek, Maryland had to be harvested once per month throughout the summer in order to attain effective management (Rawls 1975). However, harvesting is sometimes more effective. Milfoil in lake Wingra, Wisconsin never returned to reference levels when harvested during July (Kimbel and Carpenter 1981). Similarly, in Lake Minnetonka, both plant canopy ratio and biomass data indicated that harvesting was an effective control method for up to 6 weeks after harvesting, when harvested in early July.

While harvested areas in Lake Minnetonka achieved reference area biomass and canopy density 6 weeks after harvest they did not achieve a significantly higher biomass or canopy density in the following weeks. Despite a higher relative growth rate in harvested areas than in reference areas following harvest, harvested areas at no time attained higher biomass or canopy density than reference areas (Figures 2 and 4). The growth of milfoil is often limited by water depth (Aiken et al., 1979) which could account for harvested areas' biomass leveling out after regrowth.

Plant biomass in relation to environmental factors

The percentage of milfoil by weight in the reference areas for each site was not correlated with any lake characteristic, nor did the percentage of milfoil correlate with biomass in the control areas ($r^2 = 0.005$). This indicates that in Lake Minnetonka a high percentage of milfoil does not always coincide with high total plant biomass nor does having high total plant biomass imply that there is greater abundance of milfoil in that area than in areas with lower plant biomass. While milfoil relative abundance was not correlated with abiotic conditions, total plant biomass was correlated ($p < 0.01$) with water clarity and percent sediment organic matter (Table 2).

There were significant differences in sediment organic matter among sites ($p < 0.05$) (Table 1). Within the range of

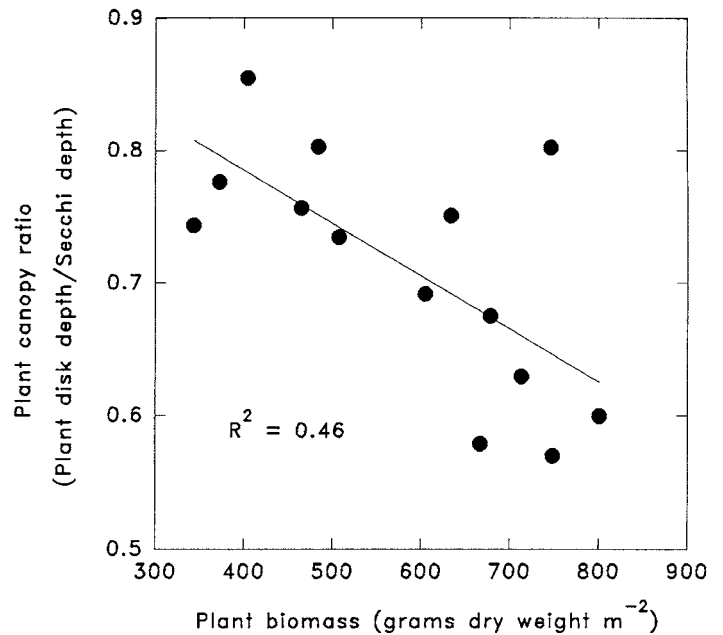


Figure 3. Plant canopy ratio in relation to plant biomass.

physical variability in our plots, higher total plant biomass occurred in sediment with more organic matter. This correlation could be due to a preference of aquatic plants for sediments which are enriched with organic matter or could be caused, as Lillie and Barko (1990) suggest, by the enrichment of the sediments by the aquatic vegetation itself.

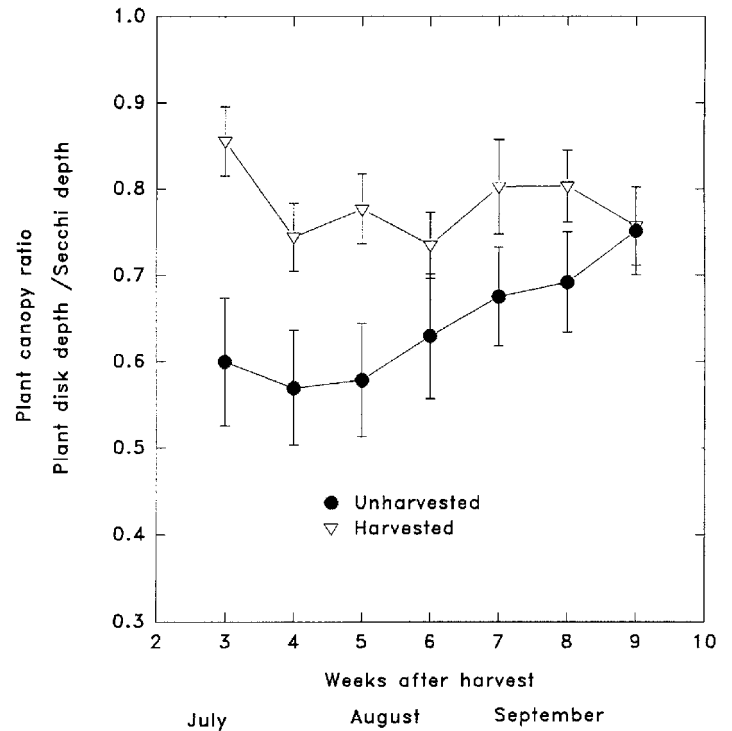


Figure 4. Plant canopy ratio changes over time in harvested and unharvested plots. Harvest done on July 3, 1990. Results presented as mean \pm standard error.

TABLE 2. PEARSON CORRELATIONS OF ENVIRONMENTAL CHARACTERISTICS AND ABOVE GROUND PLANT BIOMASS.

	COND	Gravel	Sand	Silt	Clay	PCOM	SECCHI
COND	1						
Gravel	-0.90***	1					
Sand	0.85***	-0.81***	1				
Silt	ns	ns	-0.61*	1			
Clay	-0.74**	0.64*	-0.90***	0.57*	1		
PCOM	ns	ns	ns	0.69**	ns	1	
SECCHI	ns	ns	ns	0.64**	ns	0.84***	1
Biomass	ns	ns	ns	ns	ns	0.84***	0.74**

COND is specific conductivity (micro mhos/cm).

Gravel, Sand, Silt, Clay and PCOM (percent organic matter) are their respective percentages in the sediments.

SECCHI is Secchi depth (meters).

Biomass is biomass in reference plots.

Significant correlations are marked: (***) p<0.001, (**) p<0.01, (*)P<0.05, and (ns)non significant.

There was also wide range of water clarity among the 5 sites studied. Three of the 5 bays showed differences in Secchi depth readings (p < 0.05) (Table 1). The positive relationship between Secchi depth transparency and biomass suggests that plants in Lake Minnetonka are light limited. Smith et al. (1991) report that clear deep water can reduce milfoil matting on the surface, which could account for greater success by other plant species, and therefore a higher total plant biomass. However, this did not appear to be the case in Lake Minnetonka. Although milfoil grows to the surface and forms mats which can inhibit the growth of other aquatic plants (Aiken et al. 1979), the area which showed the highest biomass was also the area which had the most surface matting. In Lake Minnetonka, it is possible that higher water clarity leads to higher biomass because the native species we found, such as *Potamogeton spp.*, and *Ceratophyllum demersum* are able to grow well, despite the presence of milfoil.

In addition to individual correlations, multiple regression techniques were used to determine the best predictors of plant biomass. The models in table 3 were the best predictors of total biomass with r² > 0.81, and t-values < 0.05 for the regression coefficients and intercepts. However, because percent organic matter and percent silt, and conductivity and percent sand are autocorrelated (Weisberg 1985) (Table 2), model 2 represents the best predictor of biomass. Percent clay and percent organic matter together explain 81% of the variability in biomass in Lake Minnetonka aquatic plants (Table 3). Percentage of clay varied from 1.7% to 10.1%; and was negatively correlated with biomass.

These findings may be useful in identifying areas likely to produce high total plant biomass. Information on sediment

TABLE 3. BEST SUBSET REGRESSIONS FOR CONTROL AREA BIOMASS.

Model	R ²	Model
1	0.84	300 - 27(Silt) +278(PCOM)
2	0.81	431 - 68(Clay) +229(PCOM)
3	0.89	3507 + 43(Sand) - 22(COND) +1127(Secchi)

Silt is percent silt in sediments, PCOM is percent organic matter in sediments, Clay is percent clay in sediments, Sand is percent sand in sediments, COND is specific conductivity in the water column (micro mhos/cm), Secchi is Secchi depth (m) outside the weed beds.

texture and water clarity for many Minnesota lakes is available from the Minnesota Department of Natural Resources. Along with other factors, such as proximity to lakes already infested with milfoil, those lakes which are likely to produce high total plant biomass could be prioritized for monitoring for new milfoil infestations. Milfoil infestations can then be stopped first in areas where they are likely to result in high biomass plant beds.

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