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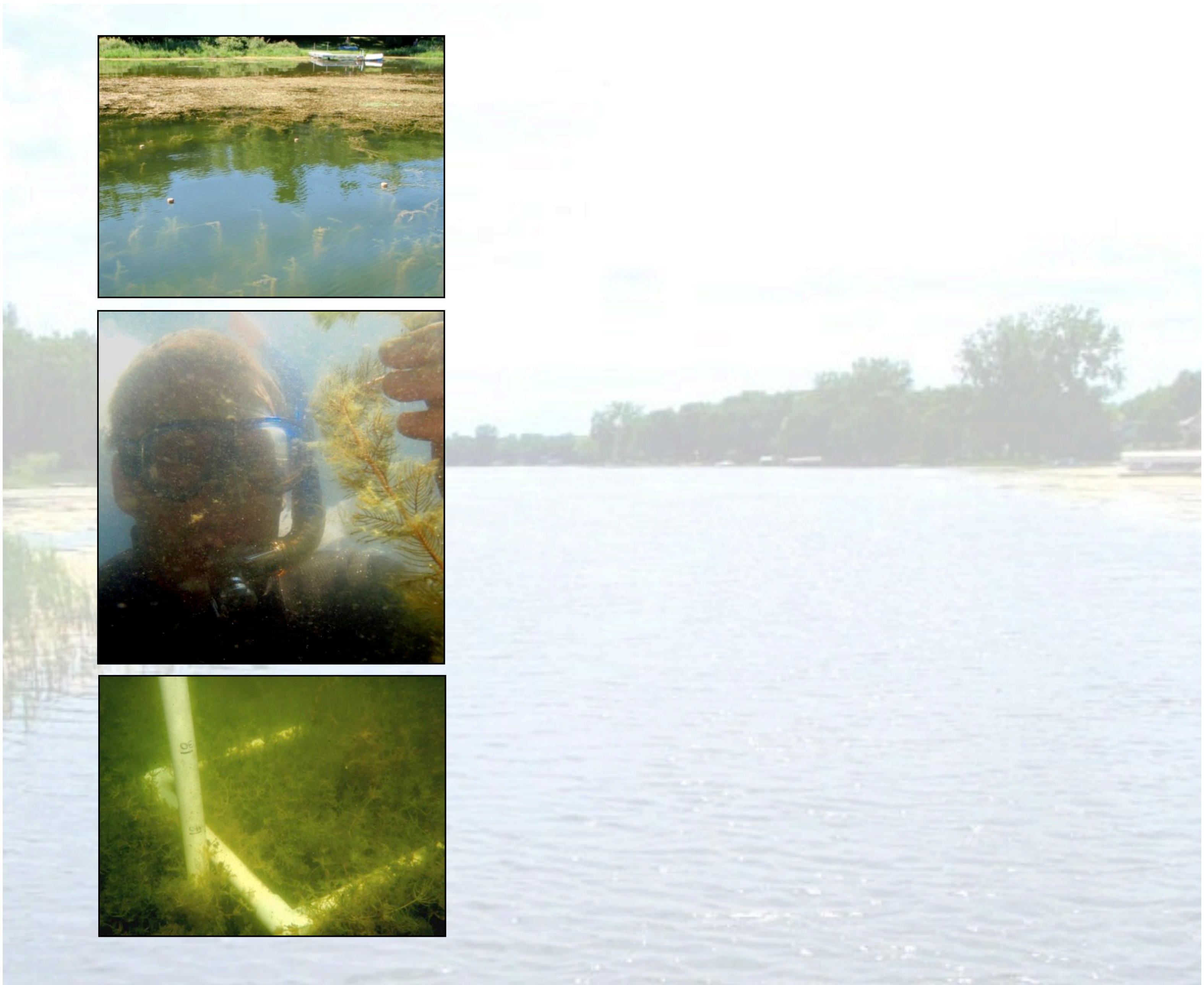
Potential for Native Aquatic Plant Growth after Control of Eurasian Watermilfoil in Crooked Lake, MN *(# 02-0084-00)*

2011 – 2012



Prepared for Crooked Lake Area Association and Coon Creek Watershed District – November 2012

Native Aquatic Plant Growth after Control of EWM (2011-2012); Crooked Lake, MN

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2010 Aquatic Plant Survey – PLM Lake & Land Management Corp. (Pequot Lakes, MN)

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Introduction

Value of Aquatic Plants

Aquatic plants play an important role in freshwater lakes. They anchor sediments, buffer wave action, oxygenate water, and provide valuable habitat for aquatic animals. As a result, the abundance and types of plants in a lake can greatly affect nutrient cycling, water clarity, and food-web interactions (Jeppeson et al. 1998, Scheffer 2004). Furthermore, a diverse plant community is very important for fish reproduction, survival, and growth, and can dramatically impact the type and size of fish in a lake.

Healthy aquatic plant communities in many lakes have been degraded by poor water clarity, excessive plant control activities, and the invasion on non-native nuisance plants. These disruptive forces alter the diversity and abundance of aquatic plant communities and can lead to changes in many other aspects of a lake's ecology. Consequently, it is very important that lake managers find a balance between controlling nuisance plant growth and maintaining a healthy, diverse plant community.

Purpose of Study

Large areas of Crooked Lake are currently infested with invasive, non-native Eurasian watermilfoil (*Myriophyllum spicatum*, henceforth called "milfoil"). The Coon Creek Watershed District (CCWD) and Crooked Lake Area Association (CLAA) have been actively managing milfoil in the lake for more than 20 years using herbicides. However, the invasive milfoil continues to form expansive areas of surface-matted growth. Consequently, lake users still identify milfoil control as a top priority for management (CCWD 2009).

As a part of their long-range management plan for Crooked Lake, the CCWD identified the need for an evaluation of the potential for native plant recruitment in the lake. Such an evaluation was needed to assess whether native plants could naturally reestablish from propagules in the lake after milfoil was controlled. If natives are not able to naturally reestablish, then transplanting or seeding would be needed to promote a healthy native plant community. Accordingly, this study has been designed to determine natural plant recruitment in study plots where milfoil was effectively controlled. Results from this study will help to guide future vegetation management in Crooked Lake.

Objectives

1) Manually remove milfoil from study plots to simulate maximized control
2) Identify native plant taxa that sprout from existing propagules in lake sediments
3) Evaluate the abundance (coverage, height, biovolume) of each native plant taxon in plots
4) Evaluate characteristics of the native plant taxa (ecological value, nuisance potential)
5) Evaluate whether transplanted native taxa can survive and grow in selected plots

Description of Study Lake

Crooked Lake (#02-0084-00) is a small and relatively shallow lake (Table 1) that straddles the border between Coon Rapids, MN and Andover, MN (Figs. 1 and 2). The lake has a public boat access at the far northern end of the lake, and is predominantly used for fishing, waterskiing, and swimming.

The small watershed (~240 acres) that drains to the lake is only about twice as large as the lake itself, and is nearly entirely developed (CCWD 2009); land use consists of residential (~75%), public facilities (~10%), and parkland or open space (~10%). In recent years, average summer water clarity in Crooked Lake has typically ranged between 4 and 7 ft, with total phosphorus between 30 and 40 µg/L, and chlorophyll-a consistently averaging ~10 µg/L (CCWD 2009).

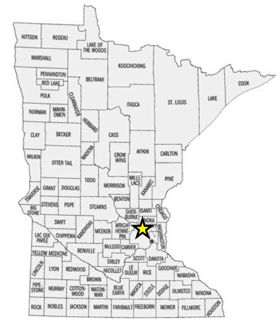


Figure 1. Location of Crooked Lake

Table 1. Lake and watershed characteristics (CCWD 2009)

Surface Area	114 acres
Maximum Depth	26 ft
Mean Depth	9 ft
Lake Volume	1020 acre-ft
% Littoral (<15 ft)	73%
Watershed Area	236 acres
Water Residence Time	7.4 years

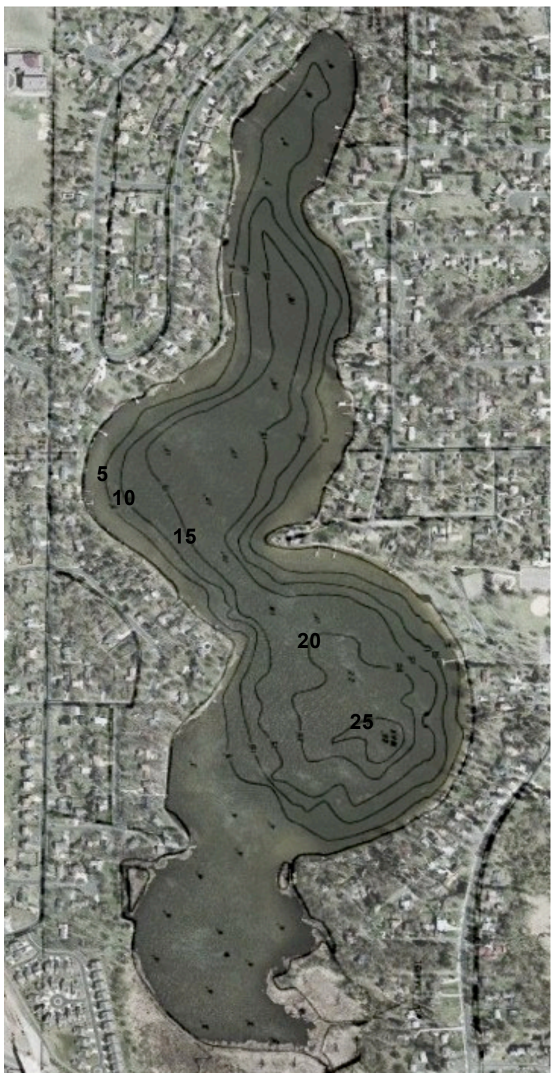


Figure 2. Map of Crooked Lake showing depth contours (MDNR bathymetric map superimposed on aerial image)

History of Aquatic Plants in Crooked Lake

Surveys conducted in the past 10 years showed that Crooked Lake has supported a fairly diverse aquatic plant community for an urban lake. In the early 2000's, plant surveys conducted by the Minnesota Department of Natural Resources (MDNR) found a total of 33 plant taxa in the lake; 15 native submersed taxa, 2 non-native submersed taxa (curlyleaf pondweed and Eurasian watermilfoil), 6 floating taxa, and 10 emergent taxa (Table 2). More recently, a point-intercept vegetation survey conducted in August 2010 by PLM Lake & Land Management Corp. (Pequot Lakes, MN) found a total of 13 plant taxa in the lake; 8 submersed native taxa, 1 non-native submersed taxon (Eurasian watermilfoil), 2 floating taxa, and 2 emergent taxa.

The first verified account of milfoil in Crooked Lake occurred in 1990. Despite aggressive measures to control this invasive plant, the infestation expanded in the lake. In the most recent plant survey (August 2010), it was found growing at roughly 60% of the sampled locations.

Table 2. Frequency (% occurrence) of submersed and floating aquatic plant taxa in Crooked Lake (most identified to species). Plant taxa are listed from most common to least common; values rounded to nearest 10%. Frequencies from surveys in the early 2000's not available; indicated if present (P). Free-floating and emergent taxa are not listed here, but are available in the Crooked Lake 2008 Comprehensive Plan (CCWD 2009). 2000-2006 surveys conducted by MNDNR, 2010 survey conducted by PLM Lake & Land Management Corp. (Pequot Lakes, MN).

		% OCCURRENCE	
COMMON NAME	SCIENTIFIC NAME	2000's	2010
SUBMERSED PLANTS			
Eurasian watermilfoil	*Myriophyllum spicatum*	P	60
Muskgrass	*Chara* spp.	P	20
Bushy pondweed	*Najas* spp.	P	10
Largeleaf pondweed	*Potamogeton amplifolius*	P	10
Sago pondweed	*Stuckenia pectinata*	P	10
Coontail	*Ceratophyllum demersum*	P	<5
Northern watermilfoil	*Myriophyllum sibiricum*	P	<5
Claspingleaf pondweed	*Potamogeton richardsonii*	-	<5
Wild celery	*Vallisneria americana*	P	<5
Curlyleaf pondweed	*Potamogeton crispus*	P	
Leafy pondweed	*Potamogeton foliosus*	P	-
Illinois pondweed	*Potamogeton illinoensis*	P	-
Floating-leaf pondweed	*Potamogeton natans*	P	-
Small pondweed	*Potamogeton pusillus*	P	-
Flat-stem pondweed	*Potamogeton zosteriformis*	P	-
Bladderwort	*Utricularia vulgaris*	P	-
Horned pondweed	*Zanichellia palustris*	P	-
Water stargrass	*Zosterella dubia*	P	-
FLOATING PLANTS			
White lily	*Nymphaea odorata*	P	10
Bullhead lily/Spatterdock	*Nuphar* spp.	P	<5

History of Aquatic Plant Management in Crooked Lake

Lake-Wide Herbicide Treatments

In 1992, Crooked Lake received a whole-lake fluridone treatment to control milfoil (15 µg active ingredient (ai)/L). This experimental whole-lake treatment was supervised and monitored by the MDNR. Although the fluridone treatment successfully controlled milfoil for 4 years, it also resulted in a severe reduction of native aquatic plants in the lake (CCWD 2009). By 1998, six years after the treatment, milfoil had reemerged as a nuisance in Crooked Lake. Subsequent research in other midwestern lakes suggested that at a lower concentration (5 µg ai/L), fluridone could effectively control milfoil without severely reducing native plants (Madsen et al. 2002).

Based upon this new research, Crooked Lake received a second experimental whole-lake fluridone treatment using a lower concentration (5 µg ai/L) to control the reestablished milfoil. However, this treatment produced similar results as the first treatment; resulting in a dramatic reduction of milfoil, but also a reduction in the number of native aquatic plants in the lake. Fortunately, the native plant community largely recovered in the subsequent year.

Spot Herbicide Treatments

Since 2002, milfoil in Crooked Lake has been managed using localized "spot" herbicide treatments that limited herbicide applications (2,4-D or triclopyr) to areas that supported milfoil growth (Fig. 3). In most years, this approach provided short-term control of milfoil growth in the treated areas, and did not appear to dramatically reduce native plants. However, these treatments did not appear to provide long-term control of the milfoil, as it generally reestablished in many of the treated areas in the subsequent years if left untreated. Consequently, many areas have receive treatments in multiple years over the past decade.

Promoting Native Aquatic Plants

In addition to controlling milfoil in the lake, the CLAA and CCWD have expressed interest in promoting desirable native aquatic plant growth in areas where milfoil currently dominates. If milfoil was successfully controlled in these areas, establishing native plants in the place of milfoil would help to minimize nutrient release from shallow sediments, increase quality fish habitat, and possibly slow reestablishment of milfoil in areas where it had been controlled (CCWD 2009).

Figure 3. Map of Crooked Lake showing areas that received herbicide spot treatments between 2005 and 2010 (provided by CCWD).

Methods

Study Plots

We selected 6 nearshore locations for our study plots. All of these selected locations were in areas that had been infested with milfoil in recent years, and that had received some herbicide treatment in the past 5 years. Three of the study plots were located in areas that were treated with triclopyr in 2011 and 2012, with the remaining 3 plots located in areas that were not treated (Fig. 4). These plot locations covered a range of water depths from 2.5 to 6.0 feet and were generally distributed throughout the lake (Figs. 4 and 5). The lake sediment in all six plots was soft, marl, muck, with the southwestern plots appearing to have more marl than the northern and eastern plots.

Figure 4. Map showing location and identification of the 6 study plots used in the 2011-2012 study, and the areas treated with triclopyr (dashed lines). Plots are numbered according to water depth from deepest (plot 1) to shallowest (plot 6). Plot symbols on the map do not reflect the actual size of the plots.

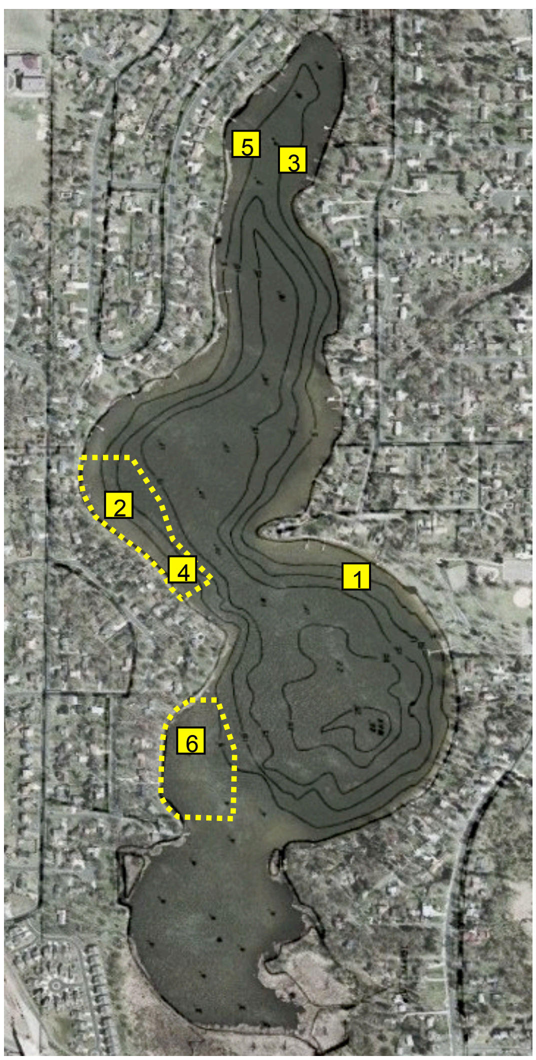


Figure 5. Average water depth within each study plot (n=9 in each plot) as measured on August 29, 2011. Standard deviation of mean depth was <4 inches in each plot. (Water depths were slightly different in 2012 due to changes in lake level and inherent error in GPS unit used to place plots)

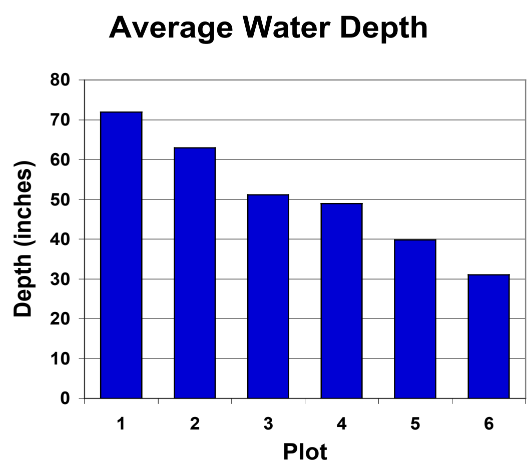
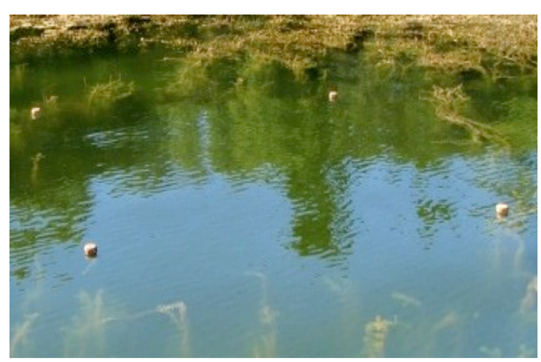


Figure 6. Study plot (plot 2) showing delineated area (12 x 12 ft) and installed plot markers.



Installation of Study Plots

In the spring of 2011 and 2012 (early June), we installed plot markers to delineate all 6 study plots (same locations were used in both years). These plot markers were constructed of PVC pipe with a small fish-net float tethered by 2 ft of nylon rope (Fig. 6). For each plot, we placed these markers to delineate the corners of a 12 x 12-ft square area. These low-profile markers were selected to (1) minimize damage to boats that accidentally ran over them, (2) maintain views of the lake from shore, and (3) reduce the likelihood of vandalism. In 2011, two plot markers were removed by lake users (one at plot 1 and one at plot 4), but on both occasions we were easily able to replace these markers; in 2012, no plot markers were removed.

Manual Removal of Eurasian Watermilfoil from Plots

After marking the study plots, we inspected each plot while snorkeling and manually removed all of the milfoil we found growing within each plot (June 14-15; Figs. 7 and 8). When removing milfoil, we were very careful to avoid disturbing native plants (no flippers; maneuvered with hands only), and removed entire milfoil plants (shoots and roots) to minimize regrowth. All of the collected milfoil plants were placed into a plastic garbage bag, removed from the lake, and disposed of according to MDNR rules. We conducted several additional snorkel inspections of the plots in June, July, and August of each year. All milfoil plants found growing in the plots during these subsequent inspections were removed using the same procedure as described above. The repeated removal of milfoil dramatically reduced its the abundance in the study plots relative to the areas immediately outside of the plots (Figs. 6 and 8), and successfully prevented formation of dense milfoil canopy growth within the plot areas.

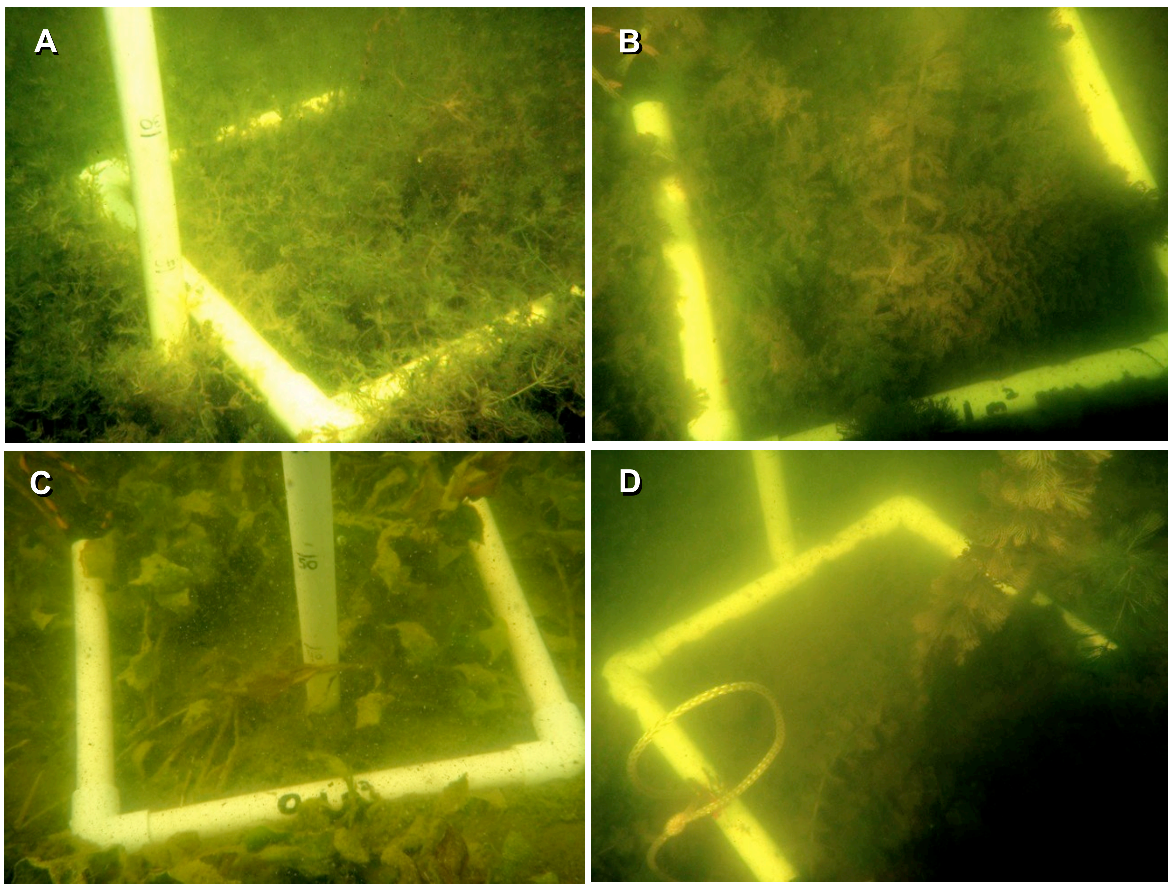
Figure 7. James Johnson (Freshwater Scientific Services, LLC) removing Eurasian watermilfoil from study plot in 2011.

Figure 8. Study plot 1 (August 2012) showing dramatically reduced Eurasian watermilfoil inside the plot relative to the area immediately outside the plot after periodic removal of milfoil. (Also evident in Fig. 6)

Assessment of Plants in Study Plots

We assessed aquatic plants growing in the study plots in late August of each year (August 29, 2011; August 30, 2012). For these assessments, we first divided each plot into 9 cells (each 4 x 4 ft). In each of these cells, we then randomly placed a square, 0.1-m^2 quadrat frame (32 x 32 cm, ≈1 x 1 ft) to delineate the area to be assessed (Fig. 9). For each quadrat assessment, we recorded (1) water depth, (2) plant taxa present, (3) plant height for each taxon, and (4) the percentage of the quadrat area covered by each taxon (% cover). These measurements were recorded while underwater using a grease pencil on a laminated data sheet. Upon returning to the boat, these recorded measurements were transferred to a paper data sheet before assessing the next plot.

Figure 9. Assessment of aquatic plants using a 3-sided, square, 0.1m^2 quadrat frame (32 x 32 cm); examples shown for (A) dense muskgrass in plot 6 (2011), (B) coontail and a rooted Eurasian watermilfoil fragment in plot 5 (2011), (C) Illinois pondweed in plot 6 (2012), (D) sparse coontail and Eurasian watermilfoil in plot 1 (2011).



Results & Discussion

Summary of Aquatic Plants in Study Plots

Although recent lake-wide vegetation surveys conducted by PLM and MDNR documented between 10 and 20 aquatic plant taxa growing in Crooked Lake (Table 2), we documented only 7 submersed plant taxa growing in the study plots (Table 3). This is not surprising given the much smaller area surveyed within the study plots relative to the lake-wide survey. However, the submersed taxa that we found in the plots were generally the most common plants found during the lake-wide surveys. Consequently, our findings likely provide a very good indication of the potential response of the aquatic plant community in Crooked Lake if milfoil is effectively controlled. Table 3 summarizes plant measurements averaged across all 6 study plots. Based upon this analysis, only two plants were consistently found growing densely in the plots (indicated by greater biovolume), namely coontail (*C. demersum*) and muskgrass (*Chara* sp.). Although these lake-wide averages are useful for predicting the overall pattern of plant growth in the lake, they do not tell the whole story. Plant growth differed greatly among the 6 plots (as indicated by the relatively high standard error associated with some of the values reported in Table 3). Furthermore, we did not randomly select the locations of the plots, so these lake-wide statistics are a bit dubious. Consequently, it is important that we also look at how these measures differed across the 6 plots for each of the plant taxa to see if we can find any additional patterns to the plant growth.

Table 3. Statistical summary of assessments for aquatic plant taxa found growing within the Crooked Lake study plots (Aug 2011). Reported values for *% Occ, % Cover, Height*, and *BioVol* are averages of plots means ±1 standard

Common Name	Scientific Name	Year	Plots	% Occ	% Cover	Height *inches*	BioVol *%*
Eurasian watermilfoil	*M. spicatum*	2011	1,3,4,5,6	40±18	6±3	6±2	1±1
		2012	1,2,3,4,5,6	60±16	5±8	13±5	2±2
Coontail	*C. demersum*	2011	1,2,3,4,5	70±20	60±15	7±2	12±5
		2012	1,2,3,4,5	80±17	80±38	14±3	25±6
Muskgrass	*Chara* sp.	2011	1,4,5,6	40±21	30±17	5±2	13±8
		2012	4,6	20±13	3±11	1±1	1±1
Sago pondweed	*S. pectinata*	2011	1,4,6	20±12	3±1	4±3	<1
		2012	1,2,3,4	10±5	1±10	2±3	1±2
Illinois pondweed	*P. illinoensis*	2011	1,4,6	20±16	6±4	1±1	<1
		2012	4,6	30±17	10±29	4±3	9±8
Elodea (waterweed)	*E. canadensis*	2011	–	–	–	–	–
		2012	5	<1	<1	<1	<1
Bushy pondweed	*N. flexilis*	2011	6	2±2	<1	<1	<1
		2012	–	–	–	–	–

Plots = List of the plots where each taxon was found (see Figure 4 for location of plots)
% Occ (% occurrence) = percentage of quadrat samples where each taxon was found (measure of plant frequency)
% Cover = mean percentage of the quadrat area occupied by each taxon (measure of plant density)
Height = mean plant height for each taxon in inches (includes all quadrats; even those with "0" for plant height)
BioVol = percentage of the water column volume occupied by plants (biovolume); [(% Cover x Height) ÷ Water Depth]; indicator of fish habitat availability and plant abundance

% Occurrence

% occurrence (frequency) indicates how frequently we found each type of plant in our study plots. Comparison of the frequency of each plant taxon across our study plots clearly shows that the frequency of plants differed both between taxa (Fig. 10) and between plots (Fig. 11). Although milfoil was found in many of the measured quadrats, it was generally sparse in the plots. Most of the milfoil we encountered consisted of individual stems that were qweakly-rooted and easily removed. This suggests that these plants either sprouted from fragments that settled in the plots, or came from seeds deposited in previous years. Looking at native plants, coontail dominated most of the study plots, but was absent from the shallowest site (plots 6) in both 2011 and 2012. This shallow site was dominated by dense muskgrass (*Chara* sp.) and Illinois pondweed (P. illinoensis) in both 2011 and 2012. Overall, muskgrass seemed to be confined to shallower depths (<3 ft), while coontail dominated areas deeper than 3 ft. Illinois pondweed and sago pondweed were the most common native plant taxa with vertical growth forms (good habitat structure for larger fish).

Figure 10. Mean % occurrence of plant taxa across all study plots (= N of quadrats where present ÷ 54). *All* denotes % occurrence for all taxa collectively; *EWM* denotes Eurasian watermilfoil.

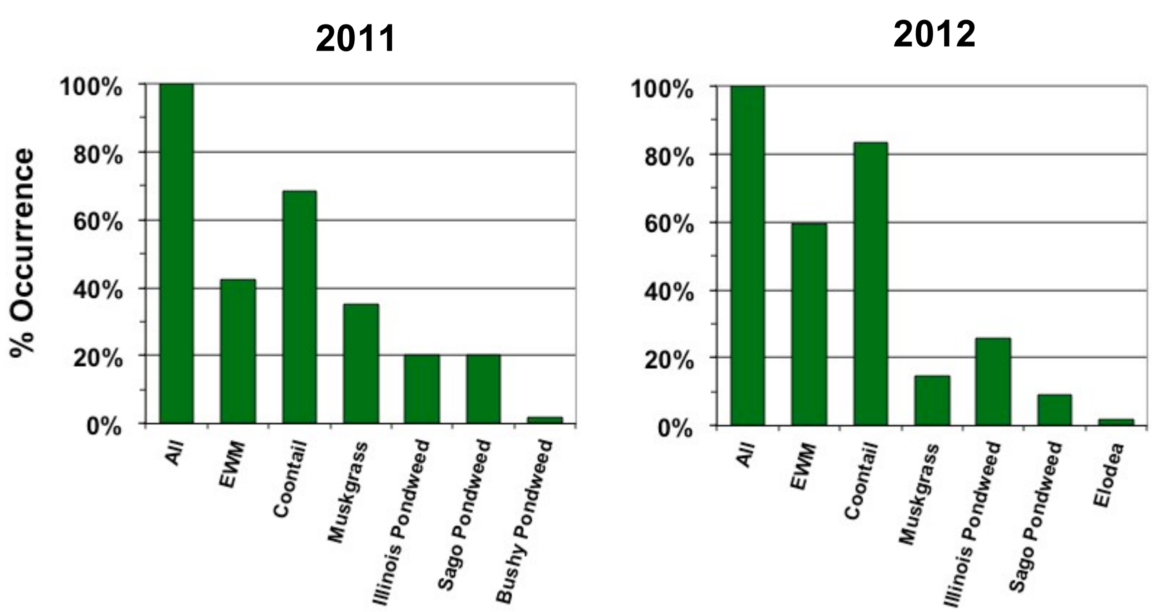
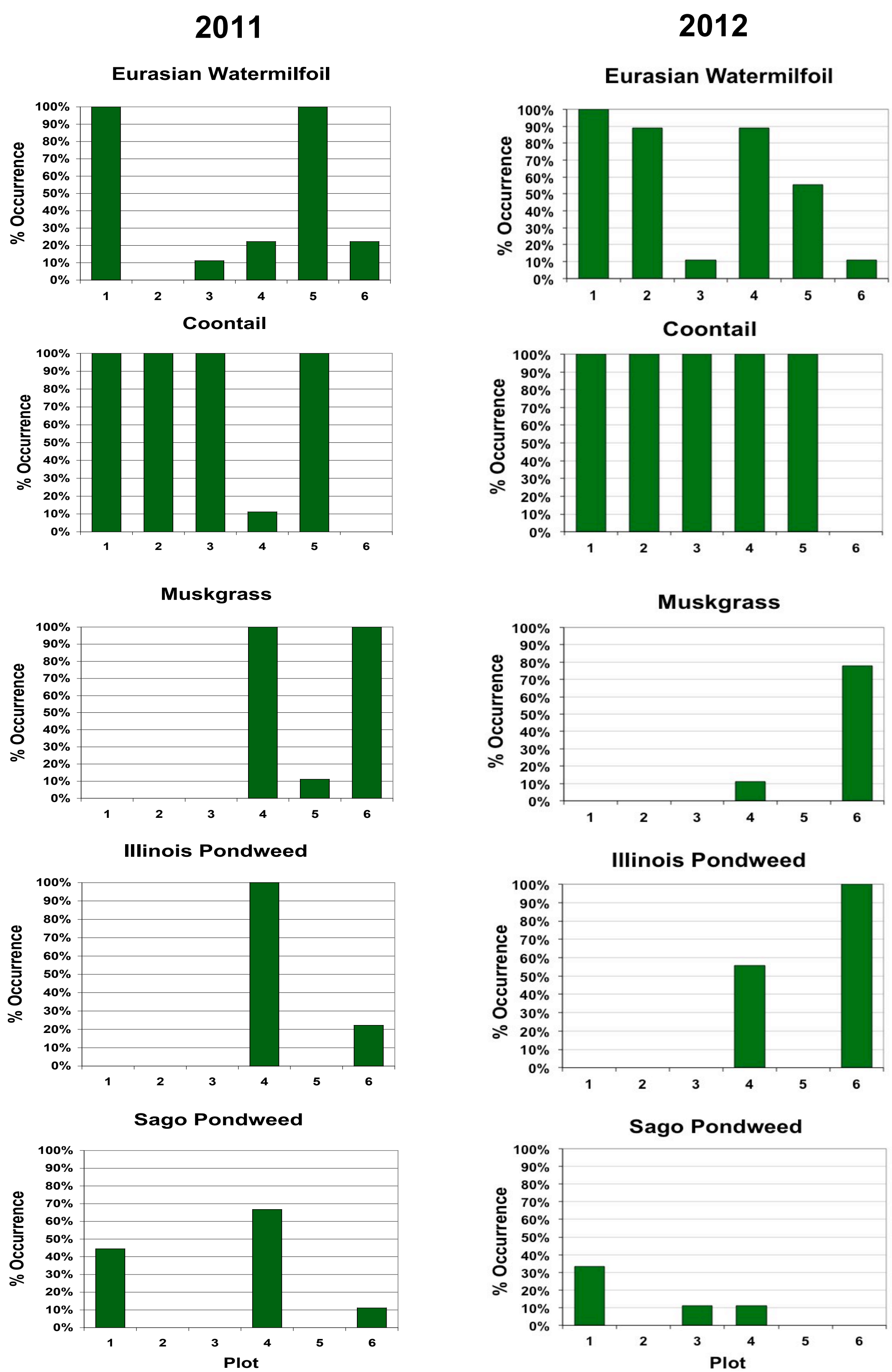


Figure 11. % Occurrence of most common plant taxa in each study plot (= N of quadrats where present ÷ 9).



% Cover

Percent cover indicates how much of the sediment in each plot was covered by plants. Comparison of the % cover for each plant taxon across our study plots clearly shows that % cover differed both between plant taxa (Fig. 12) and between plots (Fig. 13). Although we found milfoil growing in all but one of the plots in 2011 and in all plots in 2012, it covered less than 5% of the area surveyed in plots 2, 3, 4, and 6, and less than 10% in plot 5. However, in plot 1 (deep and not treated) milfoil covered 26% of the surveyed area in 2011 and 14% in 2012. Most of the milfoil plants found in plot 1 appeared to be rooted fragments (most plants were rooted from horizontal stem section) rather than new growth from seeds or roots, suggesting that this area may have experienced frequent motorboat traffic and settling of milfoil fragments. The very low % cover of milfoil in most of the plots indicated that the manual removal effectively minimized its competition with native plants. Furthermore, we did not see dense canopy formation in plot 1, despite the higher frequency of milfoil in that plot (Fig. 8).

Overall, native plant taxa with carpet-like growth forms (coontail and muskgrass) provided the vast majority of coverage (50 to 100%). Again, coontail dominated in the northern and eastern plots (generally the deeper sites) while muskgrass dominated in the shallower southwestern portion of the lake. Illinois pondweed (*P. illinoensis*) and sago pondweed (*S. pectinata*) provided the most substantial amount of vertical structure (most noticeably in plots 4 and 6), but did not contribute greatly to overall plant coverage in plots 1, 2, 3, and 5. In plot 6 (the shallowest plot), Illinois pondweed increased dramatically and muskgrass decreased dramatically in 2012 compared to 2011.

Figure 12. Mean % cover for plant taxa across all study plots (= sum of % cover in all quadrats ÷ 54). *All* denotes % cover for all taxa collectively; *EWM* denotes Eurasian watermilfoil.

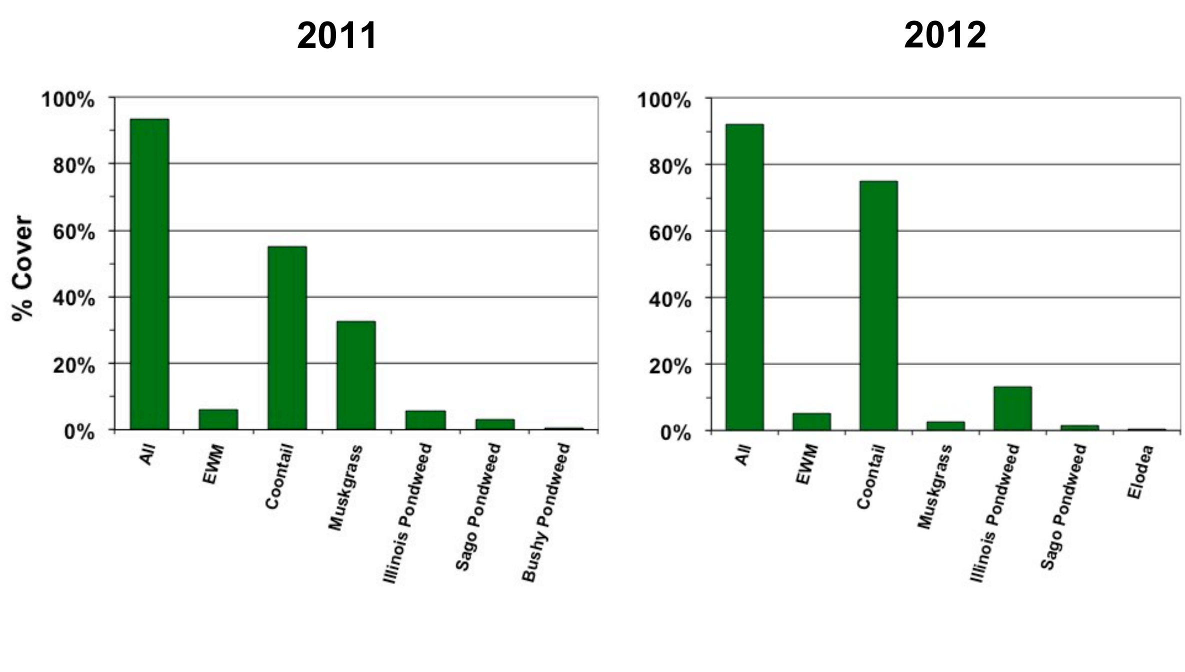
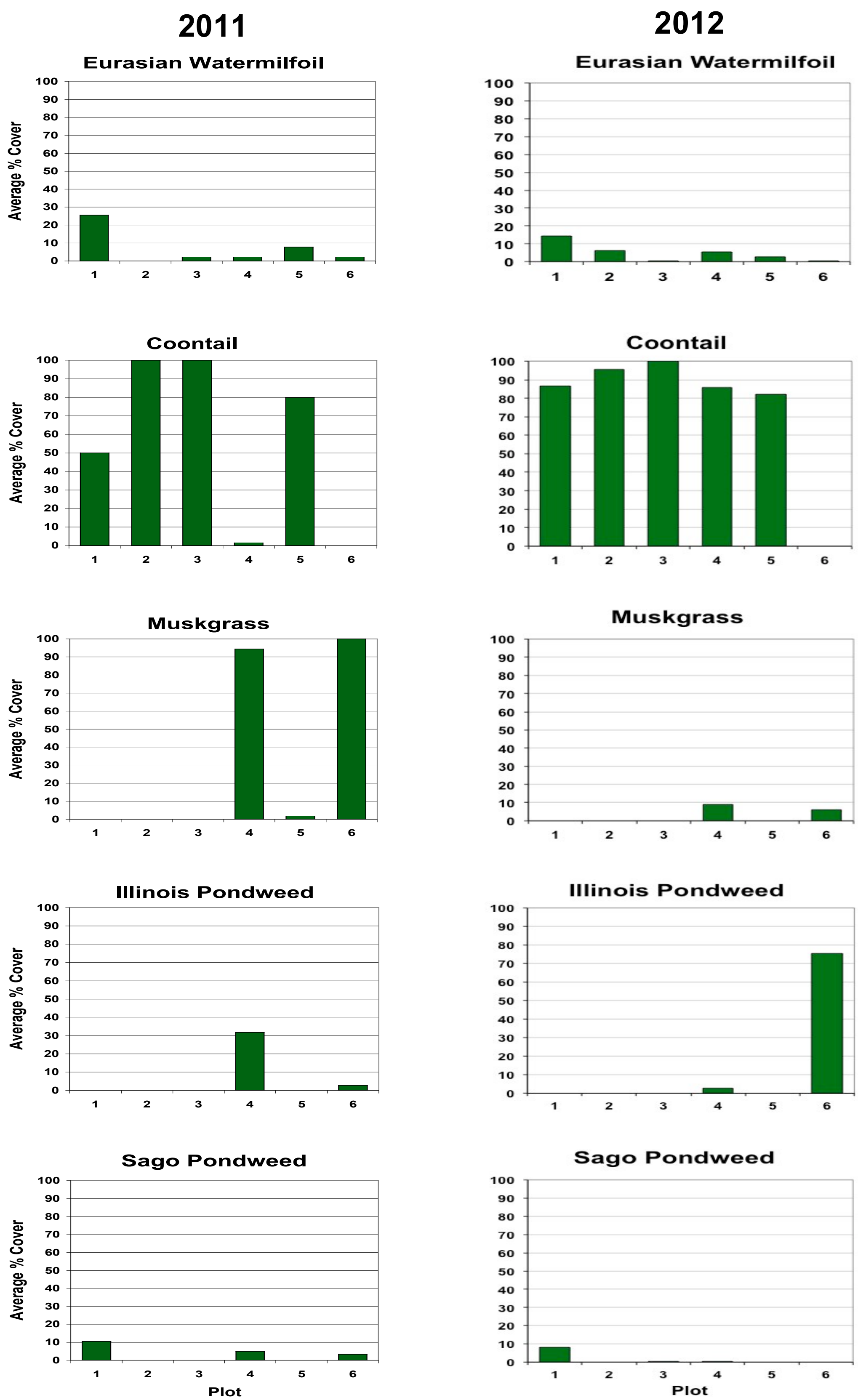


Figure 13. % Cover of most common plant taxa in each study plot (= mean of 9 quadrats in each study plot)



Plant Height

This simple measurement allowed us to (1) evaluate whether plants would be expected to grow tall enough to create a nuisance to lake recreation, (2) assess the structural diversity of plant growth provided by the plants in the lake (different layers of dense carpet, or vertical forest-like habitat), and (3) calculate biovolume – a good indicator of plant abundance and fish habitat. Comparison of the average height of each plant taxon across our study plots clearly shows that plant height differed both between taxa (Fig. 14) and between plots (Fig. 15). Overall, plant growth in most of the study plots consisted of a dense, carpet-like "under-story" (coontail or muskgrass) with a few taller plants (sago pondweed, Illinois pondweed, milfoil) forming sparse to moderate canopy growth in the water above this under-story. We did not find coontail or muskgrass growing to the surface in any of the study plots, however, sago pondweed and Illinois pondweed did grow to the surface in some plots, and Illinois pondweed formed areas of dense surface growth near the far southwestern shore in the vicinity of plots 4 and 6. Overall, plant height appeared to be slightly higher in 2012 than in 2011 across many of the taxa. This was likely due to differences in weather or water clarity between the two years.

Figure 14. Mean plant height of plant taxa across all study plots (= sum of height in all quadrats ÷ 54). *All* denotes mean plant height for all taxa collectively; *EWM* denotes Eurasian watermilfoil.

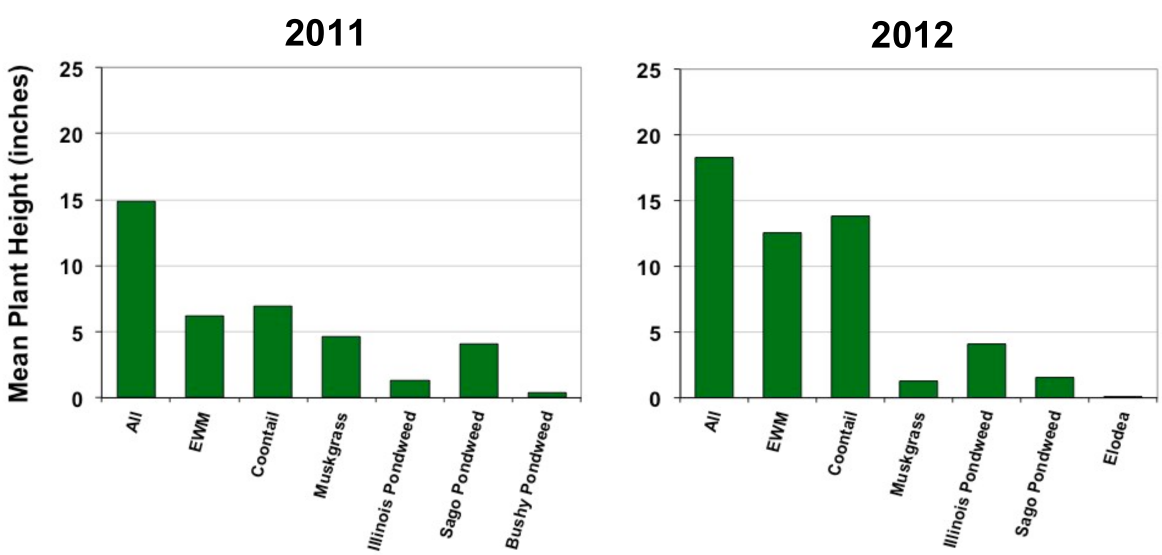
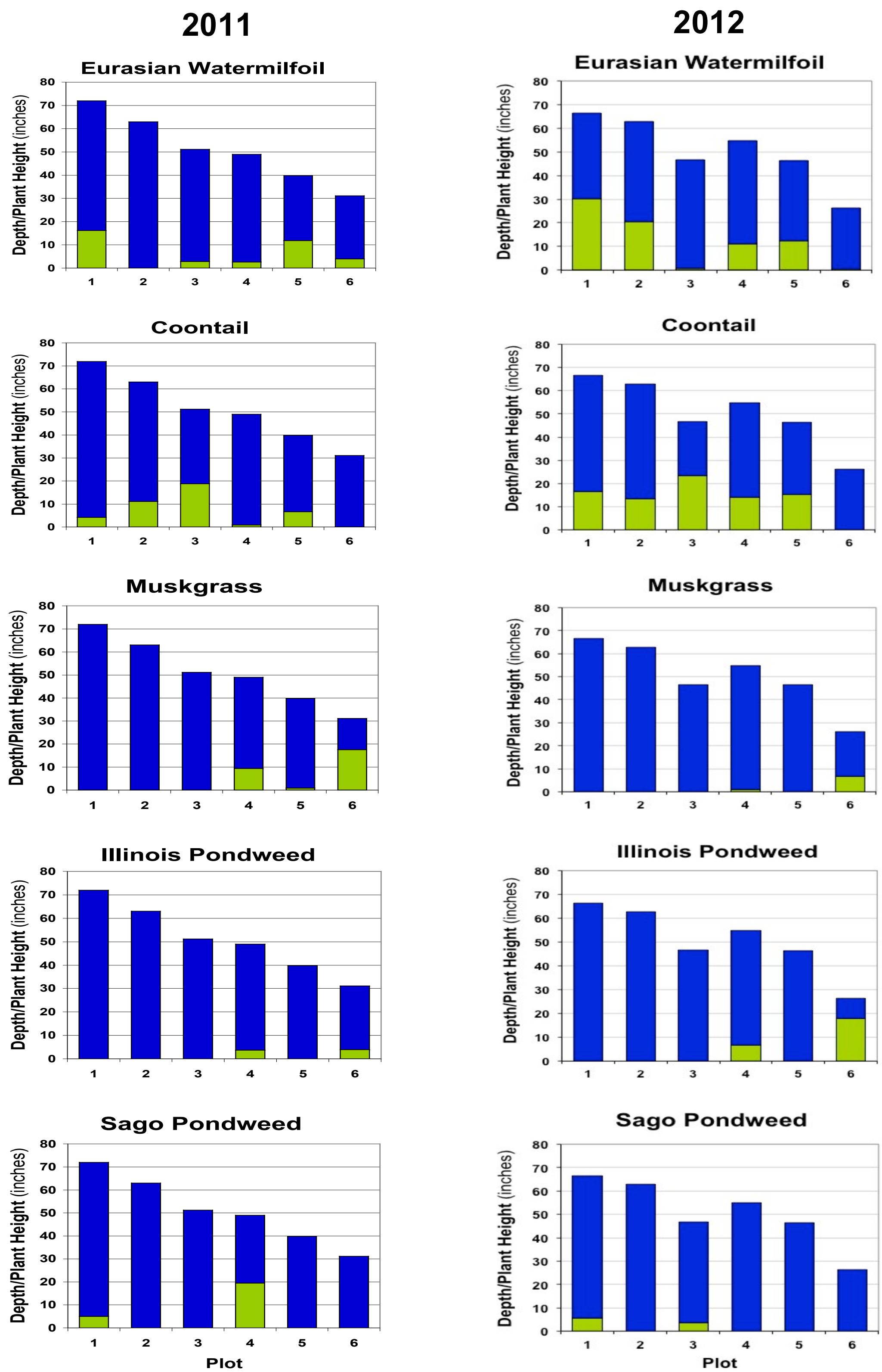


Figure 15. Mean plant height of common taxa (light green bars) relative to the water depth (blue bars) within each study plot (= mean of 9 quadrats in each study plot). Note that water depth in plots differed slightly between 2011 and 2012 due to differences in lake level at the times of sampling (lower in 2012) and slight differences in the placement of plots between years (inherent error in GPS coordinates used when placin plots).



Plant Biovolume (%)
Biovolume is defined as the percentage of the water volume within a given area that is occupied by plants. In general, greater biovolume means there is more habitat for fish and greater protection of sediments from being stirred up by wind and waves. In our study, calculating biovolume allowed us to combine our measurements of plant height and % cover to give us a better understanding of the overall amount of plant growth in the study plots. In addition, biovolume gives us an idea of which plant taxa would likely be most abundant if milfoil was greatly reduced. Comparison of the biovolume for each plant taxon across our study plots clearly shows that there were large differences both between taxa (Fig. 16) and between plots (Fig. 17). However, coontail and muskgrass consistently accounted for the majority of the native plant biovolume in the study plots. The dense, carpet-like growth of these two plant taxa (1) provides high-quality habitat for small fish and the things they like to eat, (2) protects sediments against disturbance from wind and waves, (3) oxygenates the lake, and (4) absorbs nutrients that are released from the sediment. Furthermore, the dense carpet may slow the reestablishment of milfoil, allowing control measures to maintain low milfoil abundance.

Figure 16. Mean plant biovolume (%) of plant taxa across all study plots (= sum of % biovolume in all quadrats ÷ 54). *All* denotes mean % biovolume for all taxa collectively; *EWM* denotes Eurasian watermilfoil.

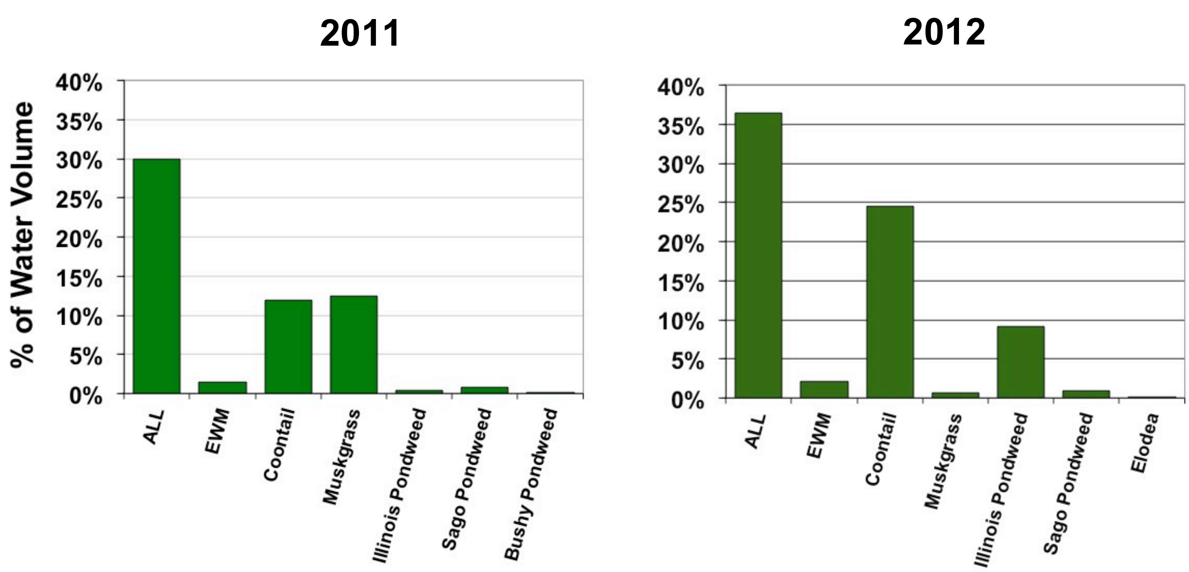
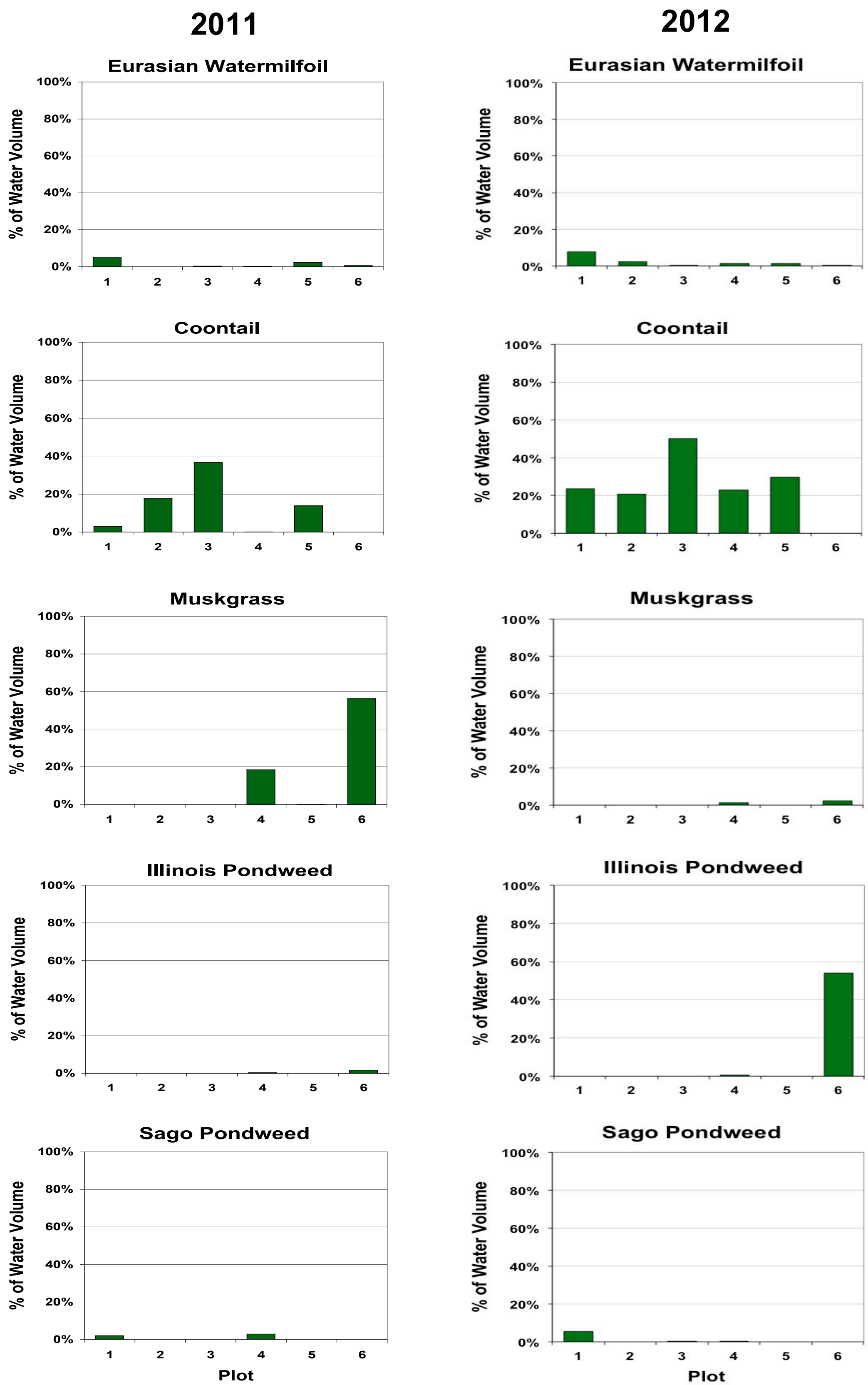


Figure 17. % Biovolume of aquatic plant taxa within each study plot (= mean of 9 quadrats in each study plot)



Native Plant Transplantings in 2012

In June of 2012, we harvested native plants (muskgrass, Illinois pondweed, and sago pondweed) from the southwestern portion of the lake (in the vicinity of plots 4 and 6) and transplanted 3 specimens of each species into a corner of the plots that generally did not support these species in 2011 (1, 2, 3, and 5). We gently rinsed sediment from the harvested specimens (only bare-root specimens planted) to help evaluate whether the native sediments in the transplanted plots could support these plants. Transplanted specimens were anchored to the lake sediment (using small sod staples) within a 1 x 1-ft square immediately adjacent to the northwest corner marker in each plot.

In late August, we inspected these transplanted specimens to see if they were able to survive and grow in the transplanted plots. These inspections showed that sago pondweed successfully established at all of the transplanted locations, suggesting that sago may colonize more areas of the lake if milfoil is controlled. Furthermore, this suggests that sago pondweed may be a strong candidate for transplanting on a larger scale if the CLAA and CCWD wish to enhance the diversity of the native plant community in northern areas of the lake. The other two transplanted species (muskgrass and Illinois pondweed) did not show the same level of survival and growth as sago pondweed. Two of the transplanted specimens of Illinois pondweed survived the summer; one in plot 5 and one in plot 1. However, both of these specimens did not appear to grow actively and generally did not look very healthy in August. This suggests that either conditions for their growth were not favorable (light or sediment) or that the method of transplanting affected this species' ability to survive and grow at the transplanted sites. Transplanted speciments of muskgrass also fared very poorly in the transplanted locations, with only one specimen surviving until August (plot 5) without much apparent growth over the summer.

Overview of Plant Taxa

Eurasian Watermilfoil

Myriophyllum spicatum

Invasive / Non-Native
Ecological Value: Low

Description

Eurasian watermilfoil typically forms expansive areas of dense, surface-matted growth that can dramatically reduce the recreational and ecological quality of lakes. This tendency to form thick, light-blocking surface mats allows it to easily out-compete and displace most native aquatic plants. This can greatly reduce habitat quality and lead to undesirable changes to a lake's fish community.

One of the main reasons why milfoil is such a successful invader lies in its ability to sprout from plant fragments. Milfoil naturally releases plant fragments in the late summer and fall (called "autofragmentation"). However, mechanical harvesting and boat propellers can create many fragments that then drift to new areas, settle and root, thus spreading the milfoil infestation. In addition, small fragments can easily be transported to new lakes on boats and trailers.

Milfoil generally begins actively growing in the early spring from rootstock, and stem fragments. By early summer, it can form expansive, dense surface mats. If left unmanaged, these areas of dense milfoil growth tend to persist for the rest of the summer.

Management

Harvesting: removes surface mats but may spread fragments
Herbicides: sensitive to 2,4-D, triclopyr, imazamox, and fluridone
Hand-Pulling: labor intensive, but effective for controlling milfoil in small areas

Coontail

Ceratophyllum demersum

Native

Ecological Value: Moderate to High

Description

Coontail is a very common native aquatic plant that can thrive in many lakes. Unlike most aquatic plants, it does not produce roots. Consequently, it gets nearly all of its nutrients from the water. Coontail tends to grow as a dense carpet on the bottom of lakes, but can also form dense masses of intertwining stems that look like underwater bushes. Dense coontail can form areas of nuisance, surface-matted growth in some lakes, but typically only reaches the water surface in nearshore areas (<5 ft). High nitrogen levels have been shown to trigger dense coontail growth that can reach nuisance levels.

Coontail's dense growth makes it a good oxygen producer and provides a great habitat for aquatic insects and other similar sources of food fish. At moderate densities, it can also provide a great place for young and small fish to hide from predators. However, very dense coontail beds can be too thick for many fish to swim through, making it less valuable as habitat.

Coontail can survive in areas with very low light, and is often one of the deepest growing plants found during plant surveys. In addition, its tolerance of low light allows it to over-winter in many lakes, even when ice and snow block most of the sun's rays.

Management

Harvesting: removes biomass (temporary)
Herbicides: sensitive to endothall (>4 mg/L) and fluridone
Hand-Pulling: labor intensive, but effective for controlling coontail in small areas

Muskgrass (stonewort)

Chara spp.

Native

Ecological Value: High

Description

Muskgrass is found in many lakes. It grows from spores and can rapidly colonize areas of bare sediment. Technically, it is a large form of algae ("macroalgae") that lacks roots, leaves, and other features of the true "vascular" aquatic plants. However, it acts very much like some of it's "true plant" neighbors in lakes. Muskgrass tends to grow as a dense carpet on the bottom of lakes, but can grow to within a foot of the surface in shallow, nearshore areas. Although muskgrass does not typically form areas of nuisance, surface-matted growth, it may be perceived as undesirable by some lake users on account of its dense growth. Its dense growth and high photosynthetic rate makes it a great oxygen producer. Because it does not produce roots, it gets much of the nutrients it needs directly from the water. Furthermore, it tends to become encrusted with calcium carbonate deposits that can lock up additional phosphorus (via co-precipitation) that would have otherwise fueled planktonic algae growth.

Dense beds of muskgrass have been shown to greatly increase water clarity, reduce nutrient release from sediments, and provide a great habitat for aquatic insects and other invertebrates that are an excellent source of food for fish and waterfowl (Kufel 2002).

Management

Harvesting: removes biomass (temporary)

Herbicides: sensitive to copper compounds (copper sulfate, chelated copper, etc.)
tolerant of endothall – may be promoted in areas treated with endothall

Hand-Pulling: labor intensive, but effective for controlling chara in small areas

Illinois Pondweed

Potamogeton illinoensis

Native

Ecological Value: Moderate to High

Description

Illinois pondweed is a common native aquatic plant that can thrive in many lakes. It produces long, vertical stems that can reach the water surface, even in areas over 10 feet deep. It has long, broad underwater leaves that create a vertical, forest-like habitat for larger fish, and can also form oval floating leaves that lay on the water surface like tiny lily pads. In addition to providing habitat for insects and other invertebrates, this plant produces seeds and tubers that are eaten by waterfowl. Illinois pondweed does not typically form nuisance growth, but may occasionally grow densely enough to clog boat motors in nearshore areas.

Management

Harvesting: removes biomass (temporary)
Herbicides: sensitive to endothall, imazamox, diquat, and fluridone
Hand-Pulling: labor intensive, but effective for controlling coontail in small areas

Sago Pondweed

Stuckenia pectinata

Native

Ecological Value: Moderate to High

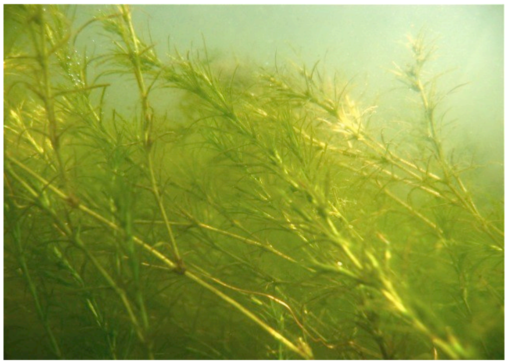
Description

Sago pondweed is a common, native aquatic plant that can thrive in many lakes, but is generally limited to areas shallower than 6 ft. It is adapted for life in murky water and is one of the few plant species that can thrive in hypereutrophic shallow lakes with severe algae blooms. In addition, it is a rapid colonizer, and is often one of the first plants to colonize areas of bare sediment after intensive plant management (such as large-scale herbicide treatment). Sago pondweed produces long, thin, vertical stems with many narrow, thread-like leaves. These stems often reach the water surface, where they form broom-like tufts of thin leaves. Although sago pondweed does not typically form large areas of nuisance growth in lakes, it can form dense beds that can clog boat motors in nearshore areas. In addition to providing habitat for insects and other invertebrates, this plant produces tubers that are a major source of food for waterfowl.

Management

Harvesting: removes biomass (can target surface "tufts" leaving only thin stems
Herbicides: sensitive to endothall, imazamox, and some copper compounds
Hand-Pulling: labor intensive, but somewhat effective for controlling in small areas

Bushy Pondweed *(also called Slender Naiad)*
Najas flexilis



Native

Ecological Value: Moderate to High

Description
Bushy pondweed is a common, native aquatic plant that can thrive in many lakes, but is generally most common in shallow, nearshore areas. It is a prolific seed producer, and a rapid colonizer that is often one of the first plants to colonize areas of bare sediment near shore after intensive plant management. In shallow areas, bushy pondweed creates a carpet-like growth of small, thick stems and small pointed leaves. However, in deeper areas (up to 12 ft) it can form shrub-like patches of dense growth. This plant rarely grows to the water surface and does not produce floating leaves. Consequently, it is not typically the target of plant control activities. Even at its densest growth, this plant provides great habitat for small fish and insects. In addition, it is a very important source of food for waterfowl.

Management
Harvesting: removes biomass (temporary)
Herbicides: sensitive to Hydrothol 191 and some copper compounds, may be promoted in areas treated with endothall to control curlyleaf pondweed
Hand-Pulling: labor intensive, but somewhat effective for controlling in small areas

Canadian waterweed *(or "Elodea")*
Elodea canadensis

Native
Ecological Value: Moderate to High

Description
Elodea is a very common native aquatic plant that can thrive in many lakes. It tends to grow as a dense carpet on the bottom of lakes, but can form areas of nuisance, surface-matted growth in some lakes (typically only in nearshore areas <5 ft deep).

Elodea's dense growth makes it a good oxygen producer and provides a great habitat for aquatic insects and other similar sources of food fish. At moderate densities, it can also provide a great place for young and small fish to hide from predators. However, very dense beds of Elodea can be too thick for many fish to swim through, making it less valuable as fish habitat than some other plants.

Elodea can persist to some degree over the winter, and thus may quickly form areas of dense growth in the spring in some lakes. However, it tends to die back in mid to late summer.

Management
Harvesting: removes biomass (temporary)
Herbicides: sensitive to diquat and fluridone; tolerant of endothall and may increase dramatically in endothall-treated lakes

Final Remarks

This study was designed to answer a few simple questions:

(1) Will native plant species naturally colonize areas where Eurasian watermilfoil is controlled?

(2) Will the growth of native plants be sufficient to maintain current water clarity and provide fish habitat if Eurasian watermilfoil is removed?

(3) Will the native plants that colonize treated areas slow the reestablishment of Eurasian watermilfoil in these areas?

Question 1: Native Plant Colonization
The 2011 and 2012 plot studies clearly showed that native plants will naturally colonize areas of Crooked Lake where Eurasian watermilfoil has been controlled. Manual removal effectively reduced milfoil abundance in our study plots. This dramatically increased the amount of light reaching the sediments, and allowed native plants to colonize and spread in the plots. In general, coontail and muskgrass were the most dominant native colonizers, together accounting for the vast majority of coverage and biovolume. However, the southwestern portion of the lake appeared to support a richer assemblage of native aquatic plants.

Question 2: Native Plants for Water Clarity and Habitat
Given the dense, carpet-like growth of coontail and muskgrass in most of our study plots, it appears that if milfoil is controlled, native plants will be able to help maintain current water clarity by mitigating nutrient release from lake sediment (Madsen et al. 2001, Scheffer 2004). Coontail and muskgrass tend to form a biological barrier over the sediment that provides excellent protection against sediment resuspension by wind and waves, and can reduce the release of nutrients from sediment to the water column. In addition, coontail and muskgrass provide excellent habitat for insects and other invertebrates, as well as for small fish. Although the other plant taxa that colonized our study plots did not grow as densely as coontail or muskgrass, they did increase habitat diversity by providing vertical structure for larger fish. Despite the relatively low abundance of these vertical plant taxa in most of our our plots, we observed that these taxa grew more densely in some areas of the lake. In particular, Illinois pondweed covered a large area along the southwestern shoreline in an area treated with triclopyr in 2011. This suggests that the lake is capable of supporting higher densities of these vertical plants that provide needed habitat for larger fish.

Question 3: Native Plants and Competition with Milfoil
If milfoil is not controlled, it will almost surely out-compete and displace native plants in Crooked Lake; much like it did after it first invaded the lake. However, actively controlling milfoil while also maintaining a healthy, diverse, and abundant native plant community may slow the reestablishment of milfoil. Although no native plants can prevent the establishment of milfoil, dense, carpet-forming native plants like coontail and muskgrass may provide the greatest protection against a rapid resurgence of milfoil infestations. Both of these native plants can rapidly colonize and form dense growth that can beat milfoil at its own game – blocking out light and preventing the growth of other plants. In addition, coontail is very tolerant of low light. This allows it to persist throughout the year (even under the ice in winter) and may allow it to survive in areas shaded by milfoil. Given the dominance of coontail and muskgrass in our study plots, these plants should be expected to rapidly colonize areas where milfoil is controlled; coontail in northern and deeper portions of the lake, muskgrass in southern and shallower areas of Crooked Lake. Although this is generally desirable for the reasons detailed above, these plants can also grow very densely and create areas of nuisance near shore, particularly in nutrient-rich lakes.

Future plant management goals for the lake should include the following:

(1) Maintain Low Abundance of Milfoil
Milfoil currently dominates much of the littoral area of Crooked Lake. This dense milfoil clearly interferes with the dominant recreational uses of the lake (waterskiing, fishing, swimming). Future management should strive to minimize the level of impairment from milfoil while protecting native aquatic plants in the lake. Although I did see evidence of milfoil weevil damage and one adult weevil in 2012 (Fig. 18; formal weevil survey not conducted), these "biocontrol agents" did not effectively control milfoil in the lake. Recent herbicide treatments appear to provide good seasonal control of milfoil in the treated areas. However, given the MDNR 15% littoral limit for maximum treatment area, the CLAA will likely find it difficult to maintain low milfoil abundance unless it seeks a variance to treat more of the littoral area. I recommend that the CLAA submit a short-form lake vegetation management plan (LVMP) and apply for a variance permit in early in 2013. The variance request should propose a maximum treatment area equal to the area that has supported dense milfoil growth in recent years (~30 to 40% of the littoral area). The CLAA should also commit to annual monitoring of milfoil and native plants in the lake. Based upon the findings from this monitoring, the treatment areas should be adjusted accordingly each year to minimize treatment costs and reduce impacts to non-target plant species.

Figure 18. Blackened milfoil stem collected near plot 5 in 2012– likely damage from milfoil weevil larvae (left); adult milfoil weevil found on milfoil removed from plot 5 in 2012.

(2) Promote increased diversity of native plants in the lake (see Smart et al. 1998)
Based upon the results of this plot study and the recovery of the plant community after decimation after fluridone treatment in the 1990's, native plants will likely reestablish in areas currently dominated by milfoil if future treatments are successful. If the CLAA wishes to enhance this recovery, our study suggests that sago pondweed and muskgrass may be good candidates for transplanting (muskgrass transplantings may not survive, but would likely spread propagules in transplanted areas). Large-scale transplantings would require a substantial amount of work and are not likely feasible. Instead, the CLAA should consider establishing a few small patches ("nursery islands") of native plants that can then naturally expand. Such transplanting would require a permit from the DNR, and there are restrictions on the amount of plant material that can be harvested.

(3) Control Nutrients from Runoff
Although most of the recreational impairment is currently due to dense milfoil beds, native coontail currently forms dense mats in some near-shore areas. These areas of dense coontail may expand if milfoil is controlled. Dense coontail growth in near-shore areas can be promoted by excessive nitrogen inputs from lawn fertilizers. The CLAA should consider additional education for watershed and lakeshore homeowners regarding responsible fertilizing practices (lakeshore homeowners and watershed residents alike). In addition, the CLAA should consider promoting shore plantings and vegetated buffer strips along shore to reduce runoff from fertilized lawn areas; particularly in those areas where coontail currently forms nuisance growth.

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