Aquatic vegetation of Grand Lake

July and August, 2010

ID# 73-0055-00

Stearns County, Minnesota

Wild rice bed, south shore of Grand Lake 2010.

Report by:
Stephanie Simon, Aquatic Biologist
Donna Perleberg, Aquatic Plant Ecologist

Minnesota Department of Natural Resources
Division of Ecological and Water Resources
1601 Minnesota Drive, Brainerd, MN 56401

Surveyors:
Nick Whichello, Intern, MnDNR Ecological and Water Resources, Brainerd
Zach Van Dyne, Intern, MnDNR Ecological and Water Resources, Brainerd
Audrey Kuchinski, Aquatic Plant Management Specialist, MnDNR Fisheries Section, Little Falls
Larry Zimmerman, Aquatic Plant Management Specialist, MnDNR Fisheries Section, Little Falls

Emergent mapping (2008):
Jason Neuman, Fisheries Specialist, MnDNR Fisheries Section, Montrose

Report Review:
We would like to thank Mark Pelham, MnDNR Fisheries Specialist (Montrose) and Audrey Kuchinski, MnDNR Fisheries Specialist (Little Falls) for their review of this report.

A note to readers:
Text that appears in blue underline is a hypertext link to a web page where additional information is provided. If you are connected to the Internet, you can click on the blue underlined text to link to those web pages.

This report is also available online at:
http://www.dnr.state.mn.us/eco/pubs_aquatics/veg_reports.html

This report should be cited as:
Simon, S. and D. Perleberg. 2011. Aquatic vegetation of Grand Lake (ID# 73-0055-00) Stearns County, Minnesota, 2010. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, 1601 Minnesota Drive, Brainerd, MN 56401. 24 pp.

Summary

Grand Lake is a 650 acre lake in Stearns County, central Minnesota. In July and August 2010, surveyors conducted a lakewide assessment of Grand Lake's vegetation and sampled aquatic plants and water depth at 201 sites (172 sites within the 0-15 feet depth zone). This information was combined with emergent plant bed delineation conducted in September 2008 by MnDNR Fisheries.

The aquatic plant communities of Grand Lake have historically contained a diversity of native plants and in 2010, 21 species were observed including 4 emergent, 3 floating-leaved and 23 submerged and/or free-floating species.

Plants occurred around the entire perimeter of the lake to a depth of 15 feet. Within the 0-15 feet depth zone, 78% of sites contained plants. The broadest zones of plants were found on the northwest and south shores of the lake.

Emergent and floating-leaf plants occupied 11 acres, but were restricted to water depths less than 6 feet. Within the shallow water (0-5 feet) zone, emergent and floating-leaf plants occurred in 18% of the sample sites and included bulrush (*Schoenoplectus* sp.), wild rice (*Zizania palustris*), cattails (*Typha* sp.) and yellow waterlily (*Nuphar variegata*).

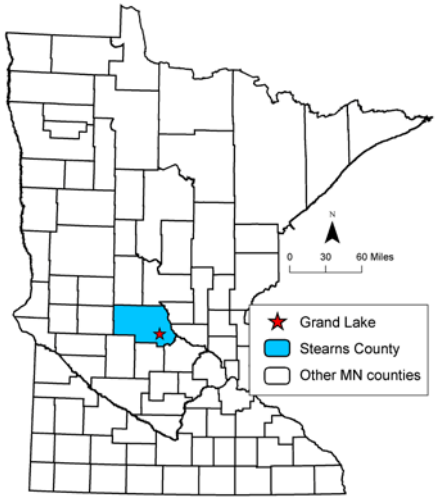
Submerged plants were found to a maximum depth of 15 feet. Muskgrass (*Chara* sp.) was the most common submerged species and occurred in 47% of the survey sites. It dominated the 0 to 5 feet depth zones where it was found in 79% of the sites. Other submerged plants that occurred in at least 10% of the sites were coontail (*Ceratophyllum demersum*), bushy pondweed (*Najas flexilis*) and star duckweed (*Lemna trisulca*).

The non-native submerged plant, curly-leaf pondweed (*Potamogeton crispus*), was present in the lake but was a minor component of the plant community and was found in 7% of the sample sites.

Introduction

Grand Lake is located 2 miles south of Rockville in Stearns County, central Minnesota (Figure 1). With a surface area of 650 acres, Grand Lake is the 5th largest lake in Stearns County. A state owned public boat ramp is located on the south shore of the lake off Grand Lake road (Figure 2).

Figure 1. Grand Lake, Stearns County, Minnesota.



The land area that drains directly to Grand Lake can be referred to as the lakeshed. The Lakeshed of Grand Lake covers about 7000-acres (including the lake) (Figure 2) and is a mix of agricultural, forested tracts and small wetlands. Grand Lake receives inflow from the northwest (Johannes Creek) and southwest (Ploof Creek) which flows south out of Grand Lake into an unnamed creek (Feiler, 2005).

Grand Lake is oval in outline with about 4 miles of shoreline. The immediate shoreline of Grand Lake is heavily developed with residential homes. Shoreline management ranges from heavily cleared lots to sites where at least a marginal border of trees and some understory vegetation have been retained (Figure 3).

Figure 2. Lakeshed of Grand Lake (photo source: 2008 FSA Color Aerial Photograph)

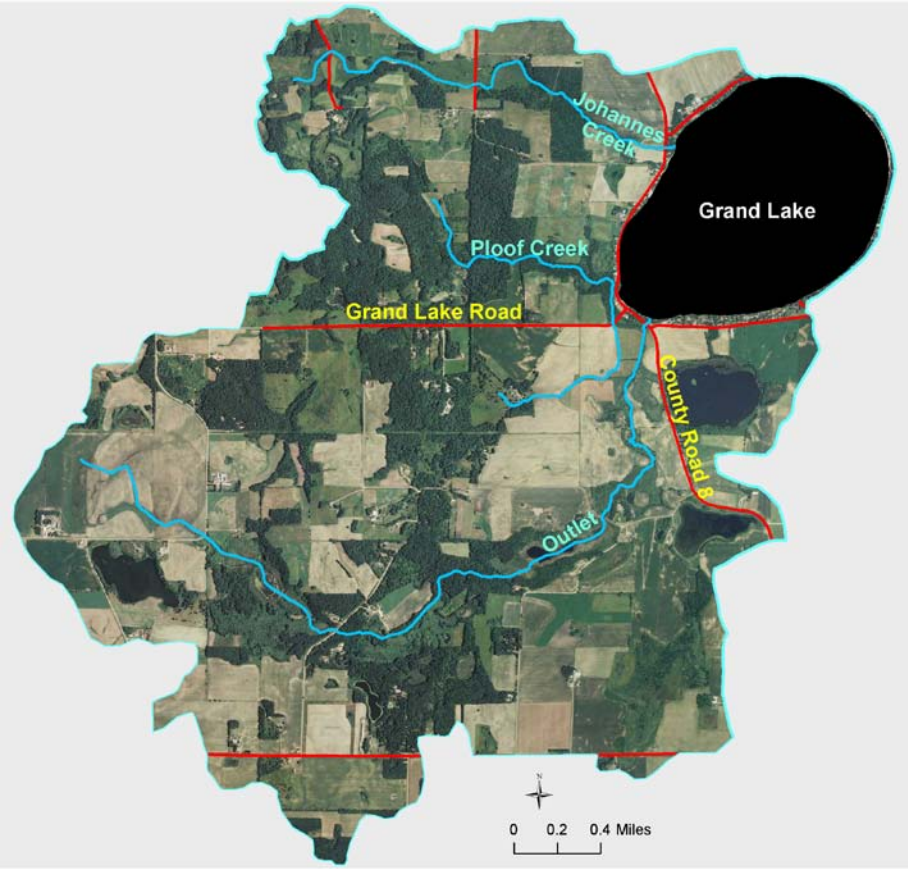
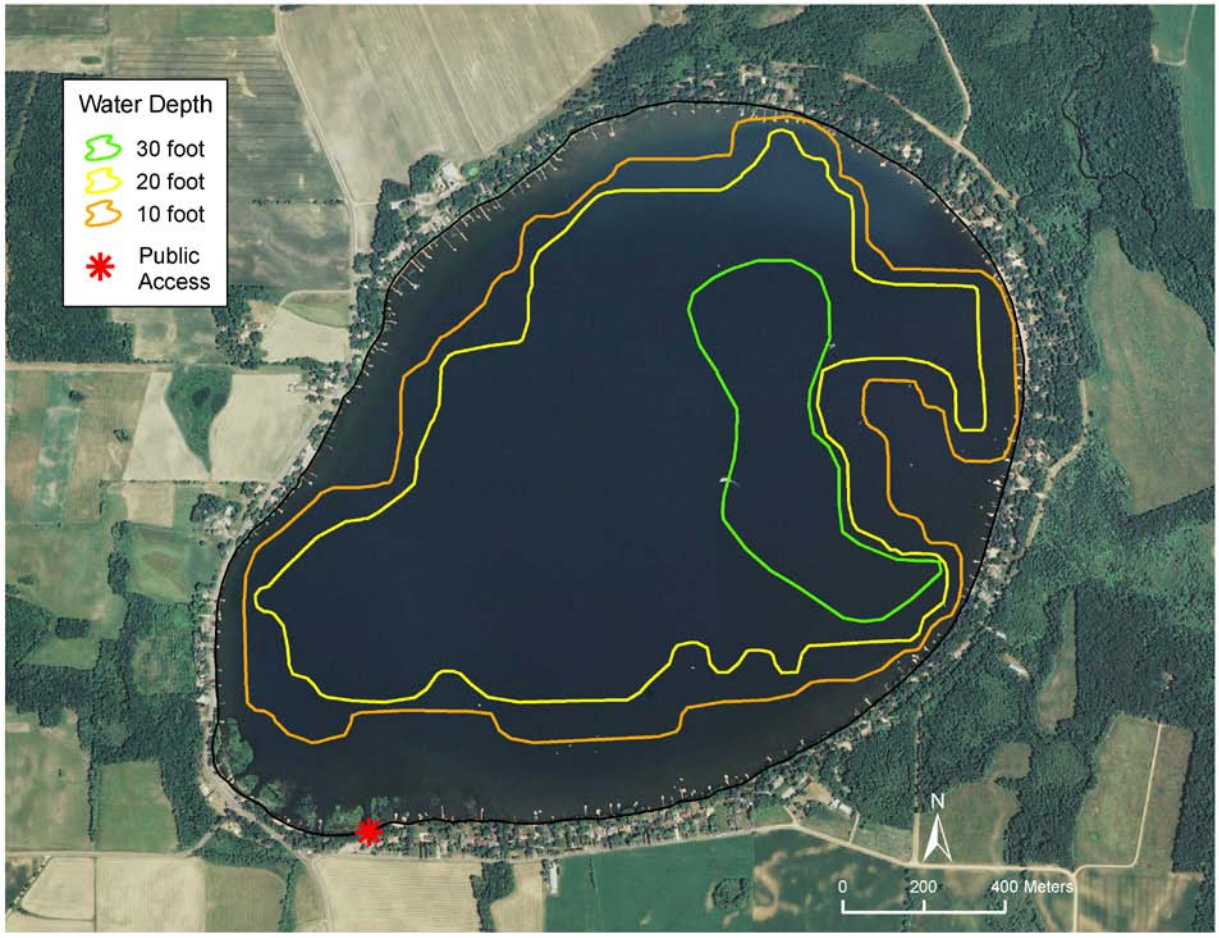


Figure 3. Grand Lake depth contours (10 and 20 foot contours based on 2010 data). (photo source: 2008 FSA Color Aerial Photograph)



Grand Lake is characterized as a eutrophic (high nutrients), hard water lake, with relatively clear water. The Secchi disc transparency measures the depth to which a person can see into the lake and provides a rough estimate of the light penetration into the water column. Water clarity can fluctuate annually and depends on the amount of particles in the water. In 2009, mean summer (June through September) water clarity, as measured by Secchi disc readings, was 7 feet in Grand Lake (MPCA 2010). As a general rule, sunlight can penetrate to a depth of two times the Secchi depth and aquatic plants can grow to a depth of one and a half times the Secchi depth. Based on Secchi disk measurements alone, aquatic plants have the potential to reach depths of at least 12 feet in this lake.

Historic aquatic plant community

Previous lakewide, aquatic plant surveys of Grand Lake were conducted in 1949, 1975, 1998 and 2008 (MnDNR Lake files). These surveys recorded a total of 38 aquatic plant species: 12 emergent, 4 floating-leaf, 4 free-floating and 18 submerged species (Appendix 1). Submerged plants have been found to a depth of 18 feet and included muskgrass (*Chara* sp.), 8 different native pondweeds (*Potamogeton* spp.), northern watermilfoil (*Myriophyllum sibiricum*), coontail (*Ceratophyllum demersum*), bushy pondweed (*Najas flexilis*) and Canada waterweed

(*Elodea canadensis*). An additional 6 wetland emergent species were recorded during the 1998 and 2008 surveys (Appendix 1).

The non-native submerged plant, curly-leaf pondweed (*Potamogeton crispus*), was first documented in the lake in 1998. In early summer 2008, curly-leaf pondweed covered about 44 acres, or about 7% of the lake surface.

Objectives

The purpose of this vegetation survey was to provide a quantitative description of the 2010 plant population of Grand Lake. Specific objectives included:

1. Describe the shoal sediments of the lake
2. Estimate the maximum depth of rooted vegetation
3. Estimate the percent of the lake occupied by rooted vegetation
4. Record the aquatic plant species that occur in the lake
5. Estimate the abundance of common species
6. Develop distribution maps for the common species

Methods

Mapping floating-leaf and emergent vegetation beds (2008)

Emergent and floating-leaf plant beds were delineated in September 2008 by Montrose Fisheries biologists. Surveyors mapped beds in the field by motoring around the perimeter of each bed and recording their track with a handheld Global Positioning System (GPS) unit. Field data were uploaded to a computer and a Geographic Information System (GIS) software program was used to estimate acreage.

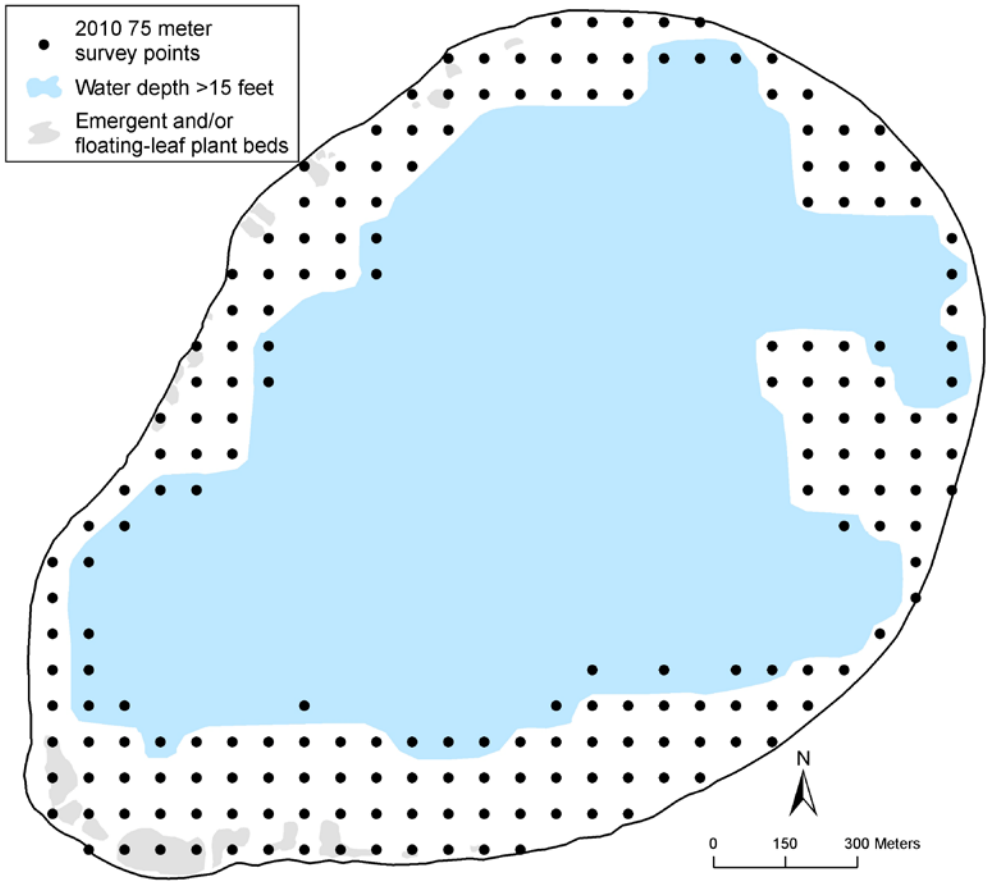
Lakewide vegetation survey (2010)

A lakewide vegetation survey was conducted on July 16 and August 17, 2010 using a point-intercept survey method (Madsen 1999, MnDNR 2009). Survey waypoints were created using a GIS computer program and downloaded into a handheld GPS unit. Survey points were placed across the entire lake and spaced 75 meters (246 feet) apart. In the field, surveyors sampled sites where water depth was less than 16 feet. To minimize damage to vegetation, surveyors did not survey sites if they occurred in dense beds of emergent or floating-leaf plants. A total of 172 sites were surveyed within the 0-15 feet zone of Grand Lake (Figure 4, Table 1). An additional 29 points were surveyed beyond 15 feet but no vegetation was found.

Table 1. Survey effort by depth interval.

Water depth (feet)	Number of sample sites
0 to 5	85
6 to 10	63
11 to 15	24
Total (0to15)	172
16 to 20	29
Total	201

Figure 4. 2010 vegetation survey sites on Grand Lake.



The survey was conducted by boat and a GPS unit was used to navigate the boat to each sample point. One side of the boat was designated as the sampling area. At each site, water depth was recorded in one-foot increments using a measured stick in water depths less than 7 feet and an electronic depth finder in deeper water.

Substrate sampling

At each sample site where water depths were 7 feet and less, surveyors described the bottom substrate using standard substrate classes (Table 2). If more than one substrate type was found, surveyors recorded the most common type. Surveyors attempted to record a substrate description at the shore side of each row of points. If a sample site occurred near shore but in water depths greater than 7 feet, surveyors collected depth and vegetation data and then motored into shallower water and recorded the substrate type adjacent to the actual survey point.

Table 2. Substrate classes

muck	decomposed organic material
marl	calcareous material
silt	fine material with little grittiness
sand	diameter less than 1/8 inch
gravel	diameter 1/8 to 3 inches
rubble	diameter 3 to 10 inches
boulder	diameter over 10 inches

Plant sampling

Surveyors recorded all plant species found within a one square meter sample site at the pre-designated side of the boat. A double-headed, weighted garden rake, attached to a rope was used to survey vegetation not visible from the water surface (Figure 5). Any additional plant species found outside of sample sites were recorded as "present" in the lake but these data were not used in frequency calculations. Plant identification followed Crow and Hellquist (2000) and Flora of North America (1993+) and nomenclature followed MnTaxa (2010).

Figure 5. Survey rake.

Data were entered into a Microsoft Access database and frequency of occurrence was calculated for each species as the number of sites in which the species occurred divided by the total number of sample sites. Frequency was calculated for the entire area from shore to 15 feet and sampling points were also grouped by water depth and separated into 3 depth zones for analysis (Table 1).

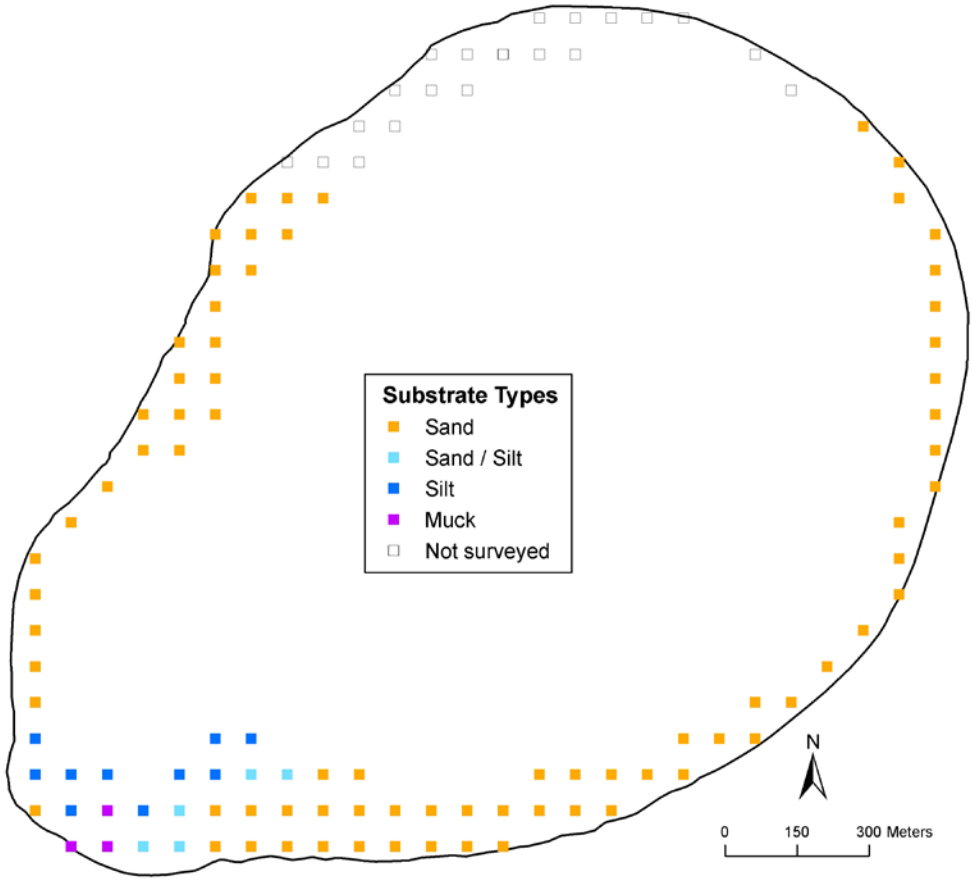
Example:
In Grand Lake there were 172 samples sites in the 0-15 feet depth zone.
Muskgrass occurred in 80 sites.
Frequency of muskgrass in 0 to 15 feet zone = (80/ 172)*100 = 47%

Results and Discussion

Shoal Substrates

The shoal substrates of Grand Lake included hard substrates of sand along the north, east and west shores (Figure 6). Softer substrates of silt and muck were found on the south shore where wild rice and bulrush were found (Figure 6). On the north end of the lake substrate was not sampled.

Figure 6. Shoal substrates of Grand Lake, 2010.



Types of plants recorded

In 2010, 21 native plant species (types) were recorded in Grand Lake including 4 emergent, 1 floating-leaved, and 16 submerged and/or free-floating plants (Table 3). During the 2010 survey, surveyors only recorded species present in the actual sample sites. Therefore, species that were present only outside of the sample sites were not recorded. Several species (small pondweed, water star-grass, straight-leaved pondweed, ribbon-leaved pondweed, floating-leaf pondweed, white waterlily, floating-leaf burreed, lesser and greater duckweed, water meal, arrowhead, three-way sedge, burreed) (See Appendix 1 for Scientific names) that were reported in previous surveys but not recorded in 2010 may still occur with a limited distribution in the lake.

Submerged plants included macroalgae and a diversity of rooted, flowering plants that can be grouped by leaf shape and size: dissected, small, narrow, broad and grass-leaved plants. One submerged species, greater bladderwort, was documented for the first time in the lake during the 2010 survey (Appendix 1).

One non-native submerged plant, curly-leaf pondweed (*Potamogeton crispus*) was documented.

Table 3. Frequency of aquatic plants in Grand Lake, July and August, 2010.

[Frequency is the percent of sample sites in which a plant species occurred within the 0 to 15 ft water depth).

Life Form		Common Name	Scientific Name	Frequency (%)
				172
SUBMERGED	Macroalgae	Muskgrass	*Chara* sp.	47
	Dissected-leaf rooted plants	Coontail	*Ceratophyllum demersum*	28
		Northern watermilfoil	*Myriophyllum sibiricum*	8
		White-water buttercup	*Ranunculus aquatilis*	2
		Greater bladderwort	*Utricularia vulgaris*	1
	Small-leaf rooted plants	Bushy pondweed	*Najas flexilis*	14
		Canada waterweed	*Elodea canadensis*	1
	Narrow-leaf pondweeds	Narrow-leaf pondweed group[A]	*Potamogeton friesii*	7
		Sago pondweed	*Stuckenia pectinata*	3
	Broad-leaf pondweeds	White-stem pondweed	*Potamogeton praelongus*	4
		Clasping-leaf pondweed	*Potamogeton richardsonii*	4
		Illinois pondweed	*Potamogeton illinoensis*	1
		Variable pondweed	*Potamogeton gramineus*	1
		Curly-leaf pondweed (I)	*Potamogeton crispus*	7
	Grass-leaf rooted plants	Flat-stem pondweed	*Potamogeton zosteriformis*	9
		Wild celery	*Vallisneria americana*	2
Free-floating	Duckweeds	Star duckweed	*Lemna trisulca*	10
Floating-leaved		Yellow waterlily	*Nuphar variegata*	4
EMERGENT (includes only in-lake emergents and not wetland plants)		Wild rice	*Zizania palustris*	4
		Bulrush	*Schoenoplectus* sp.	3
		Narrow-leaved cattail[B]	*Typha* sp.	1
		Three-square bulrush	*Schoenoplectus pungens*	1

I = introduced species

[A] Species in this genus were grouped together for analysis because field identification to the species level was difficult. At least two species of narrow-leaf pondweeds were identified in the lake: Fries' pondweed (*Potamogeton friesii*) and small pondweed (*Potamogeton pusillus*). Additional narrow-leaf pondweed species (*Potamogeton* spp.) may have also been present.

[B] narrow leaf cattail was identified in survey but it is not known whether this included *Typha angustifolia* and/or *Typha* x *glauca*.

Distribution of aquatic plants

Plants were found to a depth of 15 feet in Grand Lake and within the 0-15 feet depth zone, 78% of the survey sites contained vegetation. Vegetation was most common in the 0 to 5 feet depth zone, where 99% of sites contained plants (Figure 7). Plant abundance declined with increasing water depth and in depths greater than 15 feet no plants were found.

Plants were distributed throughout the littoral zone and the broadest zone of vegetation occurred along the northwest and southern shorelines (Figure 8). Along the northeast shoreline plant beds were restricted to the first 50 meters from shore because the depth contours were close together.

Figure 7. Aquatic plant frequency vs. water depth.

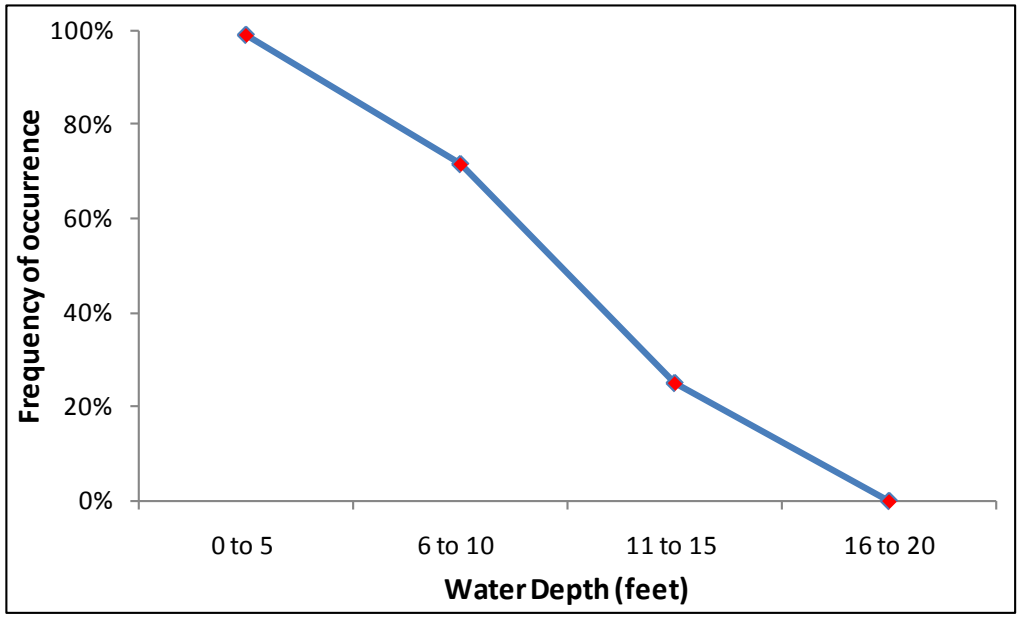
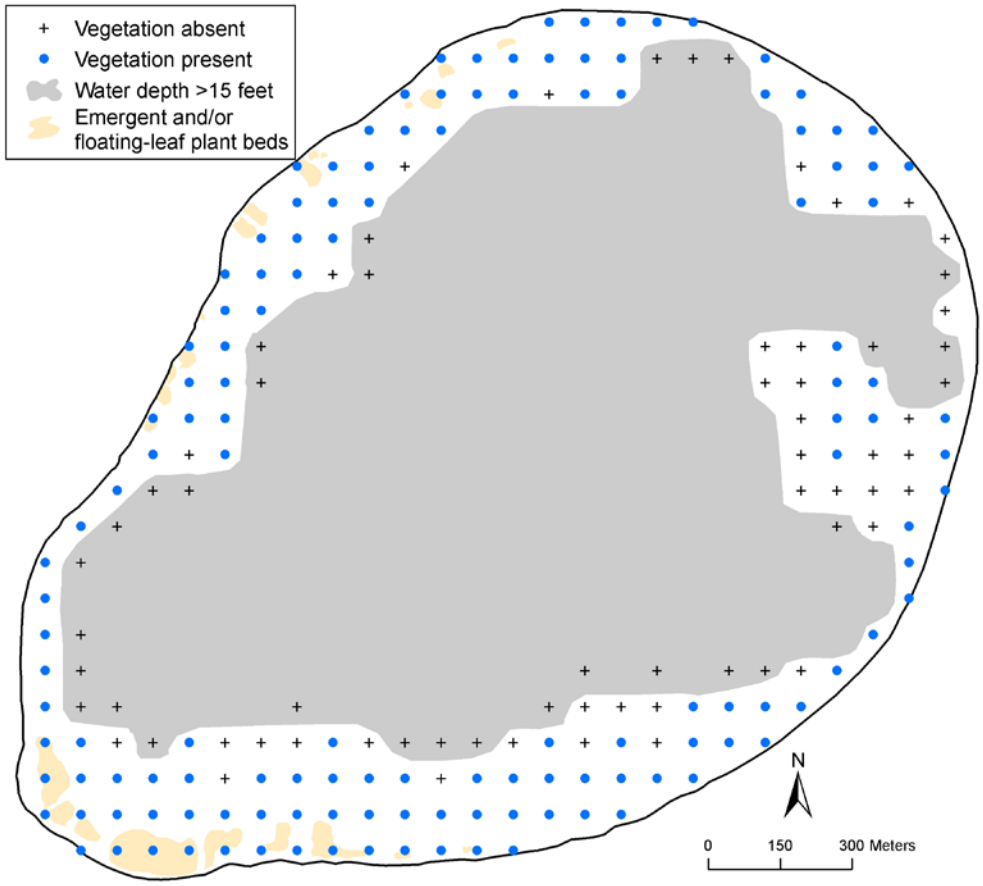


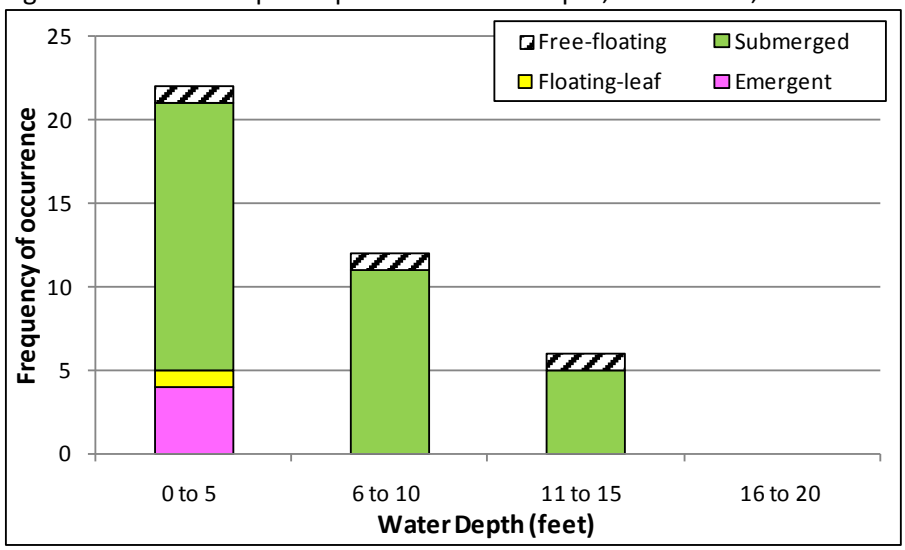
Figure 8. Distribution of aquatic plants, Grand Lake 2010.



Plant communities richness

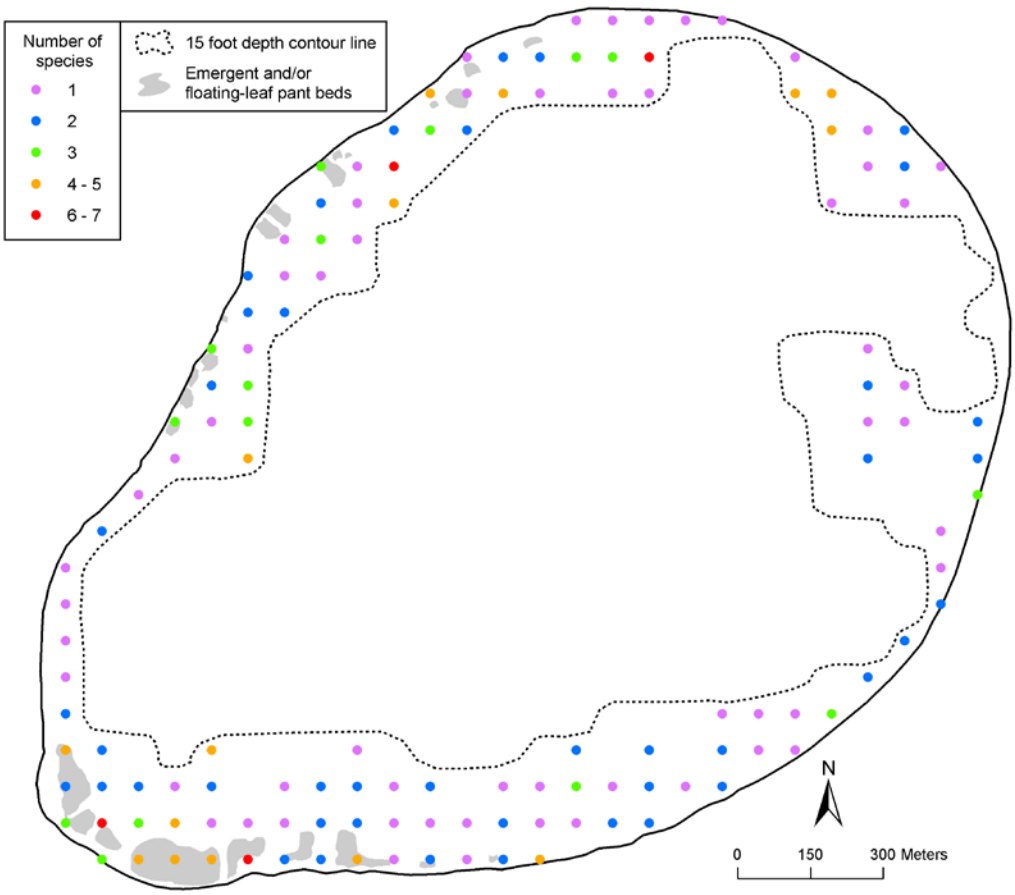
The highest number of plant species was found in shallow water, from shore to a depth of 5 feet (Figure 9). Most emergent and floating-leaf plants were restricted to shallow water (less than 6 feet). Most submerged species were found in depths of 10 feet and less and only 5 species (coontail, curly-leaf pondweed, narrow-leaf pondweed, flat-stem pondweed, and star duckweed) occurred in depths greater than 10 feet.

Figure 9. Number of plant species vs. water depth, Grand Lake, 2010.



The number of plant species found at each one square meter sample site ranged from 0 to 7 with a mean of 2 species per site (Figure 10).

Figure 10. Number of species per site, Grand Lake 2010.

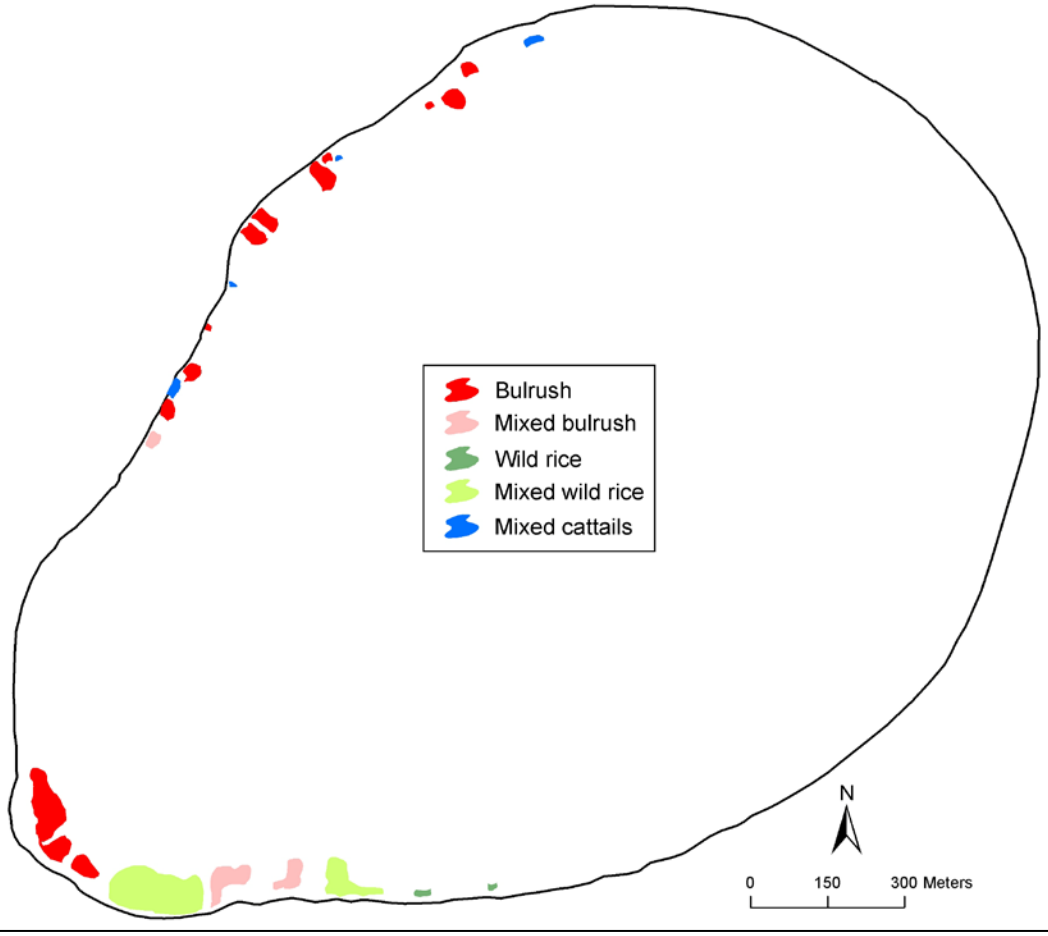


Emergent and Floating-leaf Plant Beds

Emergent and floating-leaf aquatic plants offer food, cover and nesting material for waterfowl, marsh birds and muskrats, and provide shelter and shade for insects, young fish, and amphibians. The root systems of emergent and floating-leaf plants protect shorelines against erosion by buffering the wave action and by holding soil in place.

Approximately 11 acres of bulrush, wild rice and cattail plant beds were mapped in Grand Lake using 2008 Fisheries emergent mapping data. Emergent and floating-leaf plants were restricted to 5 feet and less, and were common in the shallow water zone (0 to 5 feet) where 18% of the Grand Lake sites contained at least one emergent or floating-leaf plant. Plant beds were classified by the dominant species (Figure 11).

Figure 11. Emergent and floating-leaf plant beds of Grand Lake, 2008. (Based on 2008 Fisheries Data)



Bulrush (*Schoenoplectus* sp.; Figure 12) is an emergent, perennial plant that is rooted in the lake bottom with narrow stems that may extend several feet above the water. In addition to providing valuable fish and wildlife habitat, the extensive root network of this plant help to stabilize sandy shorelines. In shallow water, bulrush may spread by underground rhizomes but is particularly susceptible to destruction by direct cutting by humans, motorboat activity and excess herbivory. Restoration of these plant beds can be very difficult, making established beds particularly unique and valuable. In Grand Lake, bulrush was most often found on sandy or rocky shores of the west and south shores (Figure 11). A total of 6 acres of bulrush or mixed bulrush beds were mapped.

Figure 12. Bulrush in shallow water in Grand Lake.

Wild rice (*Zizania palustris*; Figure 13) prefers soft substrates (Lee 1986, Nichols 1999) and generally requires moving water for growth (MnDNR 2008). Wild rice is an annual plant that germinates each year from seed that fell to the lake bottom in the previous fall. The plant begins growth underwater and then forms a floating-leaf stage before becoming fully emergent. Wild rice is susceptible to disturbance because it is weakly rooted to the lake bottom. In addition to its ecological value as habitat and food for wildlife, wild rice has important cultural and economic values in Minnesota (MnDNR 2008). This valuable plant is increasingly threatened by factors such as lakeshore development and increased water recreational use (MnDNR 2008). Wild rice was found in 4% of the Grand Lake sites (Table 3) and a total of 5 acres were mapped (Figure 11).

Figure 13. Wild rice in Grand Lake.

Cattails (*Typha* spp.; Figure 14) are emergent plants that are found in lakes and marshes throughout Minnesota. They are perennial plants that emerge from a spreading rhizome and they have long and narrow leaves. Cattails provide shelter and food for many different kinds of fish and bird species. Less than 1 acre of cattails was mapped in Grand Lake along the western shoreline (Figure 11).

Figure 14. Cattails

Submerged aquatic plants

Submerged plants occurred in 78% of the Grand Lake sample sites and were found throughout the littoral zone (Figure 15). The most frequently occurring species were muskgrass (*Chara* sp.), coontail (*Ceratophyllum demersum*), bushy pondweed (*Najas flexilis*), and star duckweed (*Lemna trisulca*). These species were all common in the 0-10 feet zone, where they each occurred with a frequency of at least 10%. In deeper water, the non-native curly-leaf pondweed was the most common species (Figure 16).

Figure 15. Distribution of common submerged plants in Grand Lake, 2010.

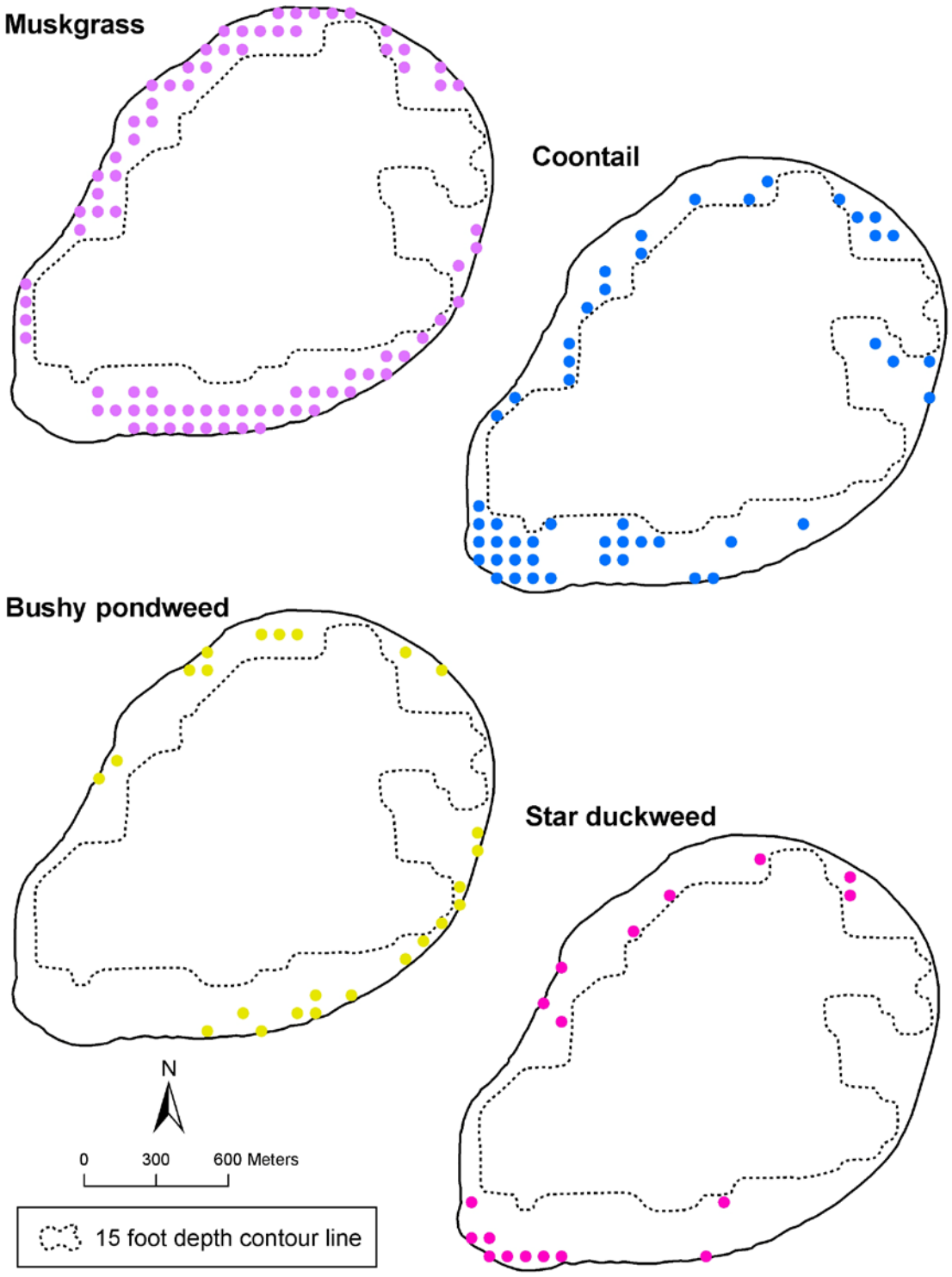
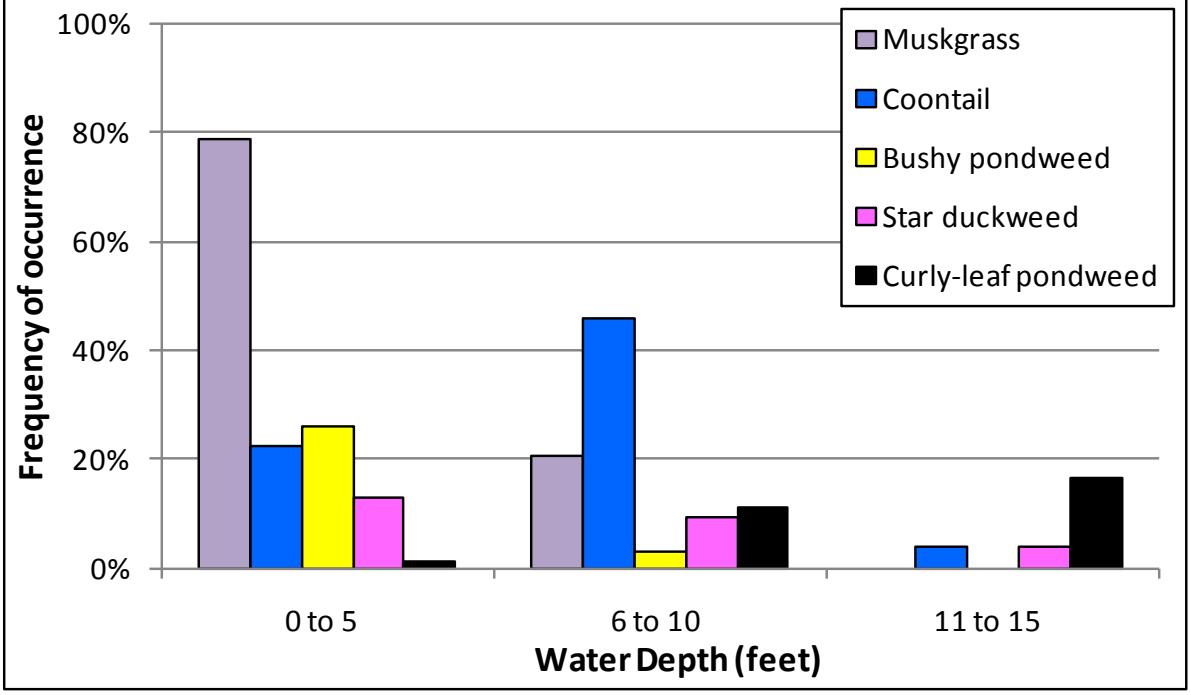


Figure 16. Common submerged plants at each water depth interval, Grand Lake 2010.



Submerged native plants

Figure 17. Muskgrass

Muskgrass (Figure 17) is a freshwater macroalgae, a primitive plant that does not form true roots, flowers or vascular tissue. Macroalgae often resemble rooted plants and provide similar habitat and water quality benefits and were therefore included in this survey. Muskgrass is common in many hard water Minnesota lakes. It has a brittle texture and a characteristic "musky" odor. Because muskgrass does not form true stems, it is a low-growing plant, often found entirely beneath the water surface where it may form low "carpets" on the lake bottom. Muskgrass is adapted to variety of substrates and is often the first species to colonize open areas of lake bottom where it can act as a sediment stabilizer. Beds of muskgrass can provide important fish spawning and nesting habitat. In Grand Lake, muskgrass occurred with a frequency of 47% (Table 3). It occurred along the sandy shorelines of Grand Lake (Figure 15) and was common in the 0 to 5 feet depth zone where it was found in 79% of the sites (Figure 16).

Figure 18. Coontail

Coontail (Figure 18) grows entirely submerged and may float freely or be loosely anchored to the lake bottom. It is adapted to a broad range of lake conditions and is tolerant of higher turbidity and can grow in muck substrates. Coontail is perennial and can over winter as a green plant under the ice and then

begins new growth early in the spring, spreading primarily by stem fragmentation. The finely divided leaves of this plant provide a home for insects valuable as fish food. Coontail was found in 28% of the sample sites in Grand Lake (Table 3) and was most common in the 6 to 10 feet depth zone where it occurred in 46% of the sites (Figure 16).

Bushy pondweed (Figure 19) is an annual aquatic plant and re-grows each year from seed set in the previous summer. For that reason, its annual distribution and abundance can be quite variable. In Grand Lake, bushy pondweed was most frequent in water depths less than 5 feet (Figure 16). It was most common in the sand sediments of the north, west and east shorelines (Figure 15). It occurred in 14% of the sample sites in the 0 to 15 feet depth zone (Table 3).

Figure 19. Bushy pondweed (photo by Robert Freckman- UW - Stevens Point)

Star duckweed (Figure 20) is a free-floating species that often occurs submerged near the lake bottom but it does not anchor to the substrate and can float freely with the current. This plant was present in 10% of the Grand Lake survey sites (Table 3). It was common on the south shoreline within the wild rice beds (Figure 15) and was most frequent in water depths from 0 to 5 feet (Figure 16).

Figure 20. Star duckweed (photo by Robert Freckman- UW - Stevens Point)

Non-native submerged plant

Curly-leaf pondweed (*Potamogeton crispus*; Figure 21) is a non-native, submerged plant that has been present in Minnesota since at least 1910 (Moyle and Hotchkiss 1945) and is now found in more than 750 Minnesota lakes (Invasive Species Program 2010).

Figure 21. Curly-leaf pondweed

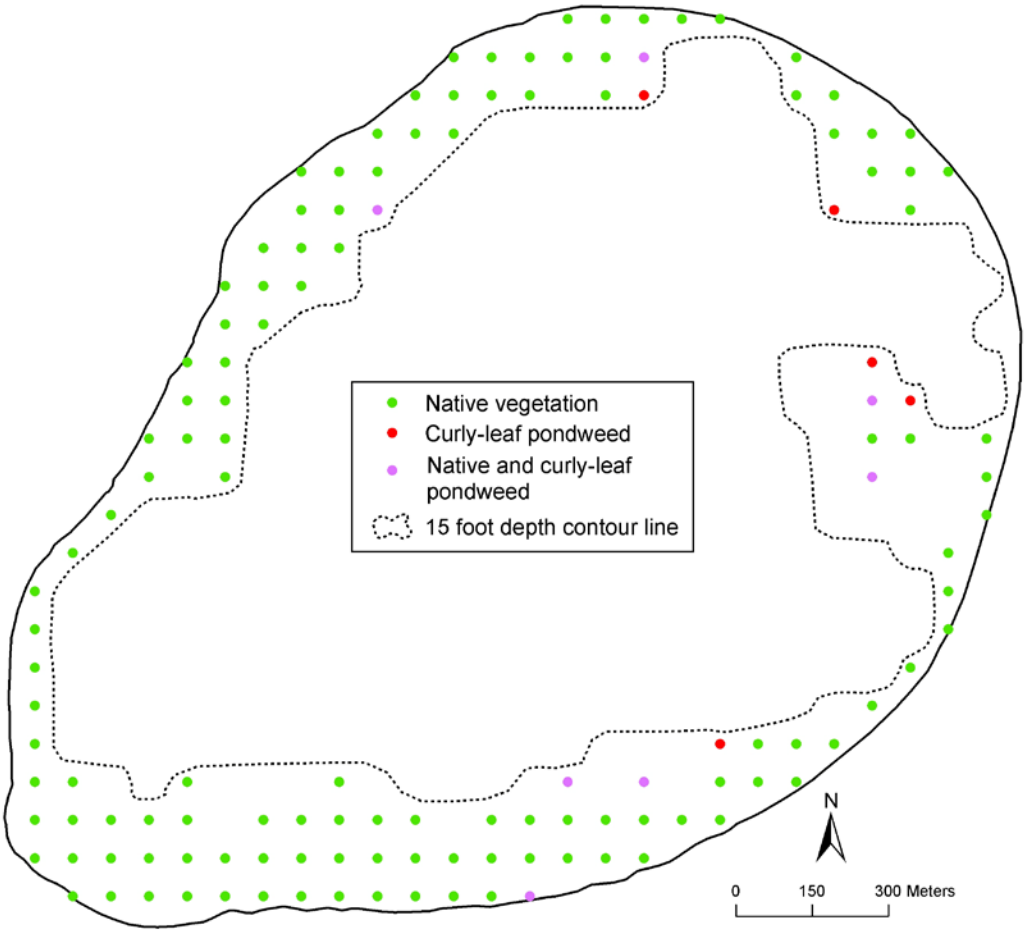
Like many submerged plants, it is perennial but it has a unique life cycle that may provide a competitive advantage over native species. Curly-leaf pondweed is actually dormant during late summer and begins new growth in early fall. Winter foliage is produced and continues to grow under ice (Wehrmeister and Stuckey 1978). Curly-leaf reaches its maximum growth in May and June, when water temperatures are still too low for most native plant growth. In late spring and early summer, curly-leaf plants form structures called “turions” which are hardened stem tips that break off and fall to the substrate. Turions remain dormant through the summer and germinate into new plants in early fall (Catling and Dobson 1985).

The foliage of curly-leaf pondweed does provide some fish and wildlife habitat, but it may also create problems in some lakes, or in areas of some lakes. During its peak growth in spring, curly-leaf may reach the water surface at certain depths and create dense mats. These dense growths may compete with native vegetation and can also cause problems for recreational lake users.

It is difficult to know when curly-leaf pondweed first appeared in Grand Lake because most surveys are conducted in mid to late summer, after the plant has naturally died back. It was first documented in the lake in 1998. In early summer 2008, DNR Fisheries staff mapped beds of curly-leaf pondweed during its peak growth and estimated that it covered about 44 acres, or about 7% of the lake surface and about 19% of the shallow water area (0-15 ft).

During the July-August 2010 survey, curly-leaf pondweed was found in 7% of the shallow water area (0-15 ft), but this may underestimate the actual abundance of the plant because the survey was conducted after most of the plant population had naturally died back. Curly-leaf pondweed was most common in the 11 to 15 feet depth zone where it occurred in 17% of the sites (Table 3, Figure 16). It often co-occurred with native species such as coontail, muskgrass, and bushy pondweed.

Figure 22. Curly-leaf pondweed versus native submerged plants, Grand Lake 2010.



Change in aquatic plant communities

The types and amounts of aquatic vegetation that occur within a lake are influenced by a variety of factors including water clarity, water chemistry, depth, substrate type and wave activity. Monitoring change in the aquatic plant community can be helpful in determining whether changes in the lake water quality are occurring and for estimating the quality of vegetation habitat available for fish and wildlife communities. Data collected in 2010 can be used to monitor finer-scale changes that may occur, such as an increase in a particular species or a change in the depths at which individual species occur. In general, factors that may lead to change in native and non-native aquatic plant communities include:

- Change in water clarity
  If water clarity in Grand Lake increases, submerged vegetation may be more common at depths greater than 15 feet.

- Snow and ice cover
  Curly-leaf pondweed, in particular, may fluctuate in abundance in response to snow cover. Many native submerged plants also have the ability to grow under the ice, especially if there is little snow cover and sunlight reaches the lake bottom. In years following low snow cover, and/or a reduced ice-over period, curly-leaf and some native submerged plants may increase in abundance.

- Water temperatures / length of growing season
  In years with cool spring temperatures, submerged plants may be less abundant than in years with early springs and prolonged warm summer days.

- Aquatic plant management activities
  Humans can impact aquatic plant communities directly by destroying vegetation with herbicide or by mechanical means. The results of these control activities can be difficult to predict and should be conducted with caution to reduce potential negative impacts to non-target species. Motorboat activity in vegetated areas can be particularly harmful for species such as wild rice. Shoreline and watershed development can also indirectly influence aquatic plant growth if it results in changes to the overall water quality and clarity. For information on the laws pertaining to aquatic plant management: MnDNR APM Program.

The abundant and diverse aquatic plant communities found in Grand Lake provide critical fish and wildlife habitat and other lake benefits. (Click here for more information on: value of aquatic plants).

Literature Cited

Catling, P. M. and I. Dobson. 1985. The biology of Canadian weeds. 69. *Potamogeton crispus* L. Canadian Journal of Plant Science 65:655-668.

Crow, G.E. and C.B. Hellquist. 2000. Aquatic and wetland plants of Northeastern North America. 2 volumes. The University of Wisconsin Press.

Feiler, E. 2005. Grand Lake Vegetation Management Plan. Minnesota Department of Natural Resources – Division of Fish and Wildlife. Appendix 1-4. 37 pp. http://grandlakeassociation.org/images/Lake%20Management%20Plan/Aquatic%20Vegetation%20Plan.3.pdf

Flora of North America Editorial Committee, eds. 1993+. Flora of North America north of Mexico. 12+ vols. New York and Oxford. www.efloras.org

Invasive Species Program. 2010. Invasive Species of Aquatic Plants and Wild Animals in Minnesota: Annual Report for 2009. Minnesota Department of Natural Resources, St. Paul, MN. http://www.dnr.state.mn.us/eco/pubs_invasives.html

Madsen, J. D. 1999. Point intercept and line intercept methods for aquatic plant management. *APCRP Technical Notes Collection* (TN APCRP-M1-02). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/aqua

MnDNR Fisheries Lake Files. Minnesota Department of Natural Resources. Division of Fish and Wildlife, Section of Fisheries, Lake Survey Program. 500 Lafayette Rd., St. Paul, MN 55155.

MnDNR. 2008. Natural wild rice in Minnesota. A wild rice study document submitted to the Minnesota Legislature by the Minnesota Department of Natural Resources, February 15, 2008. 117 pp.http://files.dnr.state.mn.us/fish_wildlife/legislativereports/20080215_wildricestudy.pdf

MnDNR. 2009. Minnesota's Sensitive Lakeshore Identification Manual: a conservation strategy for Minnesota lakeshores (version 2). Division of Ecological and Water Resources, Minnesota Department of Natural Resources.

MnTaxa. 2010. Minnesota State checklist of vascular plants. Minnesota Department of Natural Resources, Division of Ecological Resources, St. Paul.

Moyle, J. B. and N. Hotchkiss. 1945. The aquatic and marsh vegetation of Minnesota and its value to waterfowl. Minnesota Department of Conservation. Technical Bulletin 3. 122 pp.

MPCA. 2010. Minnesota Pollution Control Agency. St. Paul, MN. Lake Water Quality Assessment Program. Lake Water Quality Data Search website: http://www.pca.state.mn.us/water/lkwqSearch.cfm (accessed January 2011)

Nichols, S.A. 1999. Distribution and habitat descriptions of Wisconsin lake plants. Wisconsin Geological and Natural History Survey. Bulletin 96. Madison. 266 pp.

Wehrmeister and Stuckey. 1978. The life history of *Potamogeton crispus* with emphasis on its reproductive biology. Ohio Journal of Science. 78 (April program and abstract) supplement: 16.

Appendix 1. Historical aquatic and wetland plants of Grand Lake

Submerged plants

Common Name	Scientific Name	1949	1975	1998	2008	2010
Coontail	*Ceratophyllum demersum*	X	X	X	X	X
Muskgrass	*Chara* sp.	X	X	X	X	X
Canada waterweed	*Elodea canadensis*	X		X	X	X
Water star-grass	*Heteranthera dubia*		X	X	X	
Northern watermilfoil	*Myriophyllum sibiricum*	X	X	X	X	X
Bushy pondweed	*Najas flexilis*			X	X	X
Curly-leaf pondweed (I)	*Potamogeton crispus*			X	X	X
Fries pondweed	*Potamogeton friesii*			X	X	X
Variable pondweed	*Potamogeton gramineus*			X	X	X
Illinois pondweed	*Potamogeton illinoensis*			X	X	X
White-stem pondweed	*Potamogeton praelongus*			X	X	X
Clasping leaf pondweed	*Potamogeton richardsonii*	X	X	X	X	X
Straight-leaved pondweed	*Potamogeton strictifolius*			X	X	
Ribbon-leaved pondweed	*Potamogeton epihydrus*		X			
Flat-stem pondweed	*Potamogeton zosteriformis*	X		X	X	X
White water buttercup	*Ranunculus aquatilis*			X	X	X
Sago pondweed	*Stuckenia pectinata*	X	X	X	X	X
Greater bladderwort	*Utricularia vulgaris*					X
Wild celery	*Vallisneria americana*			X	X	X
Total		7	6	16	17	16
Max depth where plants were recorded (feet)		8	18-20	18	17	15

Floating-leaved plants

Common Name	Scientific Name	1949	1975	1998	2008	2010
Floating leaf pondweed	*Potamogeton natans*	X			X	
Yellow waterlily	*Nuphar variegata*	X	X	X	X	X
White waterlily	*Nymphaea odorata*				X	
Floating-leaf burreed	*Sparganium* sp.		X			
Total		2	2	1	3	1

Free-floating plants

Common Name	Scientific Name	1949	1975	1998	2008	2010
Lesser duckweed	*Lemna* sp.	X		X	X	
Star duckweed	*Lemna trisulca*	X		X	X	X
Greater duckweed	*Spirodela polyhriza*			X	X	
Water Meal	*Wolffia columbiana*				X	
Total		2	0	3	4	1

Emergent plants

Common Name	Scientific Name	1949	1975	1998	2008	2010
Three-way sedge	*Dulichium arundinaceum*		X			
Broad-leaf arrowhead	*Sagittaria latifolia*			X	X	
Stiff wapato	*Sagittaria rigida*		X	X		
Arrowhead	*Sagittaria* sp.		X		X	
Bulrush	*Schoenoplectus acutus*	X	X	X	X[a]	X[a]
	Schoenoplectus validus			X		
Three-square bulrush	*Schoenoplectus pungens*		X			X
Giant burreed	*Sparganium eurycarpum*				X	
Burreed	*Sparganium* sp.	X				
Wild rice	*Zizania palustris*		X	X	X	X
Broad-leaved cattail	*Typha latifolia*		X		X[a]	
Narrow-leaved cattail	*Typha* sp.[b]			X		X
	Total	2	7	6	6	4

Wetland emergent plants

Common Name	Scientific Name	1949	1975	1998	2008	2010
Swamp milkweed	*Asclepias incarnata*				X	
Chufa nut grass	*Cyperus esculentus*				X	
Touch-me-nots	*Impatiens capensis*				X	
Water horehound	*Lycopus americanus*				X	
Leafy bulrush	*Schoenoplectus atrovirens*			X		
Blue vervain	*Verbena* sp.				X	
	Total	0	0	1	5	0

I = introduced

X[a] = Species identified only to genus level

[b] narrow leaf cattail was identified in survey but it is not known whether this included *Typha angustifolia* and/or *Typha* x *glauca*.

Sources:

1949 (June, 23-28): DNR Fisheries Survey
1975 (August 18-20): Tim Musick, DNR Fisheries Survey
1998 (July 30 – August 3): Montrose Area Fisheries, DNR Fisheries Survey
2008 (August 18-25): Montrose Area Fisheries, DNR Fisheries Survey
2010 (July and August): Whichello, Van Dyne, MnDNR Division of Ecological and Water Resources and Kuchinski, Zimmerman, MnDNR Fisheries, Point Intercept Survey