Aquatic Vegetation of Borden Lake

July, August, September, 2013

Borden Lake, ID# 18-0020-00

Crow Wing County, Minnesota

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A note to readers:

Text that appears in green underline is a hypertext link to the glossary provided at the end of this report.

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.

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SUMMARY

Aquatic vegetation surveys of Borden Lake (18-0020-00), Crow Wing County, Minnesota, were conducted in July, August and September of 2013. Surveys included characterization of near-shore substrate types, mapping of emergent and floating-leaf plant beds and lakewide assessments of vegetation and water depths at over 600 sample stations.

Fifty-five native aquatic plant taxa were found including 14 emergent, five floating-leaved, four free-floating and 32 submerged taxa. The highest number of taxa was found in shallow water less than 11 feet and 88 percent of the taxa were restricted to this depth.

Emergent and floating-leaved plants occurred in shallow water (0-6 feet deep) and occupied 260 acres within that depth zone (or 68% of the shallows). Approximately 160 acres of bulrush (*Schoenoplectus* sp.) and 65 acres of wild rice (*Zizania palutris*) stands were delineated. Floating-leaf plants covered about 27 acres and included white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*), watershield (*Brasenia schreberi*) and floating-leaf pondweed (*Potamogeton natans*).

Submerged plants were found to a maximum depth of 22 feet but were most frequent in depths from shore to 15 feet, where 89 percent of the sample stations contained at least one submerged species. The most common submerged plant species were muskgrass (*Chara* sp.) (31% occurrence within the shore to 25 feet zone), coontail (*Ceratophyllum demersum*) (19%), greater bladderwort (*Utricularia vulgaris*) (18%), narrow-leaved pondweed (*Potamogeton* spp.) (14%), flat-stem pondweed (*Potamogeton zosteriformis*) (20%), northern watermilfoil (*Myriophyllum sibiricum*) (17%) and naiads (*Najas flexilis* and *N. guadalupensis*) (14%).

One state listed rare emergent plant, twig rush (*Cladium mariscoides*) was found in the lake. Several unique submerged plants included flat-leaved bladderwort (*Utricularia intermedia*), lesser bladderwort (*Utricularia minor*), creeping spearwort (*Ranunculus flammula*), water bulrush (*Schoenoplectus subterminalis*) and small waterwort (*Elatine minima*). These species are not widespread in Minnesota and are usually associated with undisturbed areas in clear water lakes of northern Minnesota.

The abundance and diversity of native plants, including the extensive stands of emergent and floating-leaf plants and mixture of many types of submerged plants, help maintain high water clarity and provide critical habitat for fish and wildlife in this lake.

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INTRODUCTION

Lake location and characteristics

Borden Lake is in the Laurentian Mixed Forest Province of north central Minnesota, about one mile west of Garrison in Crow Wing County (Map 1). This region of the state is characterized by broad areas of conifer forest, mixed hardwood and conifer forests, and conifer bogs and swamps with numerous glacial lakes.

Borden Lake lies within the Rum River watershed. It is a flow-through lake that receives inflow from Borden Creek from the west and two small streams from the north. The lake outflows from the northeast to form Garrison Creek (Map 1). Garrison Creek flows west into the Rum River which continues south to join the Mississippi River.

Borden Lake has a surface area of 1,015 acres, is the 18th largest lake in Crow Wing County and the 3rd largest lake in the watershed. The lake has an irregular outline with several islands and a total of 12 miles of shoreline. The shoreline is developed with residential homes. The State of Minnesota maintains a public access on the northeast side of the lake (Map 2). Borden Lake contains seven islands and four of the islands have Aquatic Management Area's (AMA's) owned by the state of Minnesota.

Borden Lake has a maximum depth of 84 feet but about 30 percent of the lake is 15 feet or less in depth (Map 2). The lake is a **hard water** lake and is characterized as **mesotrophic**, based on phosphorus (nutrients), chlorophyll-a (algae concentration) and Secchi depth (transparency). The 2001 to 2013 mean summer water clarity was 10 feet (MPCA 2014). Based on Secchi disk measurements alone, aquatic plants have the potential to reach depths of about 15 feet in the lake. Other factors that may influence the depth of plant growth include substrate, wind fetch and the types of plants present.

Historical aquatic plant community

Previous lakewide, aquatic plant surveys of Borden Lake were conducted in 1941, 1972, 1982, 1993, 1996, and 2008 (MNDNR Lake files). These surveys varied in methods; the earliest surveys were conducted by non-botanists and focused on the commonly occurring in-lake plants while the 1996 survey included a detailed listing of any plant taxa encountered by an experienced botanist. Collectively, from all of the previous surveys, a total of 56 native aquatic plant **taxa** have been reported in Borden Lake including: 17 emergent, five floating-leaf, six free-floating and 28 submerged taxa (Appendix 1). These include plants that are commonly found in many clear-water northern Minnesota lakes: a variety of pondweeds, northern watermilfoil (*Myriophyllum sibiricum*), greater bladderwort (*Utricularia vulgaris*), white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*), and bulrush (*Schoenoplectus* sp.).

Survey objectives

The purpose of these vegetation surveys was to provide a quantitative description of the 2013 plant population of Borden Lake. Specific objectives included:

1. Describe the general distribution of plants in the lake including the depths at which plants occur.
2. Record the aquatic plant taxa that occur in the lake.
3. Estimate the abundance of plants by estimating the frequency of occurrence of each taxon within the vegetated zone.
4. Develop distribution maps for the commonly occurring taxa.

METHODS

Lakewide vegetation survey

A lakewide vegetation survey was conducted on July 30-31, August 1, 5-8, 12-13, 2013 using a point-intercept survey method (Madsen 1999, MNDNR 2012). Survey waypoints were created using a GIS computer program and downloaded into a handheld GPS unit. Survey sites were placed across the entire lake and spaced 65 meters (213 feet) apart; this resulted in a total of 680 survey sites (Map 3, Table 1). This sample spacing was selected to ensure that at least 50 sites were placed in each depth zone and that a minimum of 100 sites were placed in the shallowest depth zone, where plant diversity is expected to be highest.

Table 1. Survey effort by depth

Water depth zone (feet)	Number of survey sites
0 to 5	356
6 to 10	56
11 to 15	63
16 to 20	114
21 to 25	91
Total	680

The survey was conducted by boat and a GPS unit was used to navigate to each sample site. 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 seven feet and an electronic depth finder in deeper water.

Substrate sampling

At each sample site where water depths were seven feet and less, surveyors described the bottom substrate using standard substrate classes (Table 2). Surveyors evaluated substrate visually and by tapping a pole into the lake bottom; soft substrate could usually be brought to the surface on the pole or sampling rake for evaluation. If more than one substrate type was found, surveyors recorded the most common type.

Table 2. Substrate classes

Soft	muck	decomposed organic material
	marl	calcareous material
	silt	fine material with little grittiness
Hard	sand	diameter <1/8 inch
	gravel	diameter 1/8 – 3 inches
	rubble	diameter 3 – 10 inches
	boulder	diameter > 10 inches

Plant sampling

Surveyors recorded all plant taxa found at each **sample site** (approximately 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 (Photo 1). Any additional plant taxa found outside of sample sites were recorded as "present" in the lake but these data were not used in frequency of occurrence calculations. Plant identification followed Crow and Hellquist (2000) and Flora of North America (1993+) and nomenclature followed MNTaxa (2013).

Photo 1. Survey rake.

Frequency of occurrence was calculated for the entire vegetated zone (0-25 feet) and data were also separated into five feet increment depth zones for analysis (Table 1). Frequency estimates were also calculated for individual taxa and selected groups of plants.

Mapping floating-leaf and emergent vegetation stands

Surveyors mapped emergent and floating-leaf plant stands that were at least 0.01 acres, or about 400 square feet, in size (generally larger than the surface area covered by a pontoon boat). Field surveys were conducted August 26 & 29, and September 5 & 9, 2013. Surveyors motored or waded around the perimeter of each stand and recording a 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. Plant stands were classified into one of nine classes by the dominant species or species-group (Table 3).

Table 3. Plant stands

Class	**Dominant Species**
Wild rice	*Zizania palustris*
Wild rice and other	*Zizania palustris* and other common taxa
Rushes	Bulrush (*Schoenoplectus*) or Spikerush (*Eleocharis*)
Rushes and other	Bulrush (*Schoenoplectus*) or Spikerush (*Eleocharis*) and other common taxa
Waterlilies	White waterlily (*Nymphaea*) or Yellow waterlily (*Nuphar*)
Waterlilies and other	White waterlily (*Nymphaea*) or Yellow waterlily (*Nuphar*) and other common taxa
Cattail	*Typha* spp.
Other emergent	Ex. Pickerelweed (*Pontederia*), arrowhead (*Sagittaria*)
Other floating	Ex. Floating-leaf pondweed (*Potamogeton natans*), Floating-leaf smartweed (*Persicaria amphibia*)

Results and Discussion

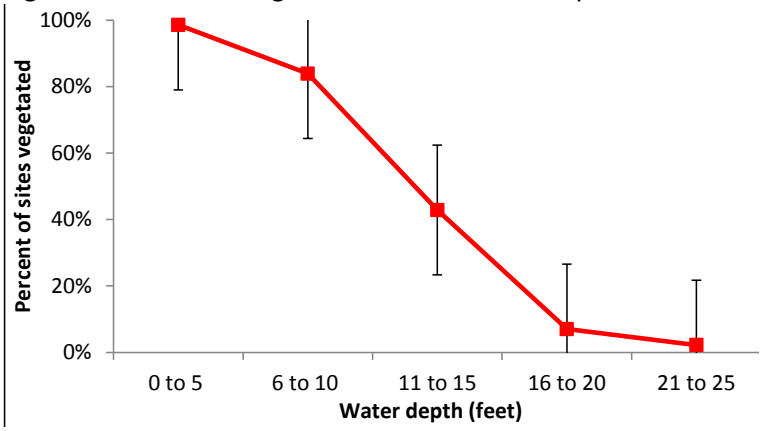
Near-Shore Substrates

The near-shore substrates of Borden Lake included a mix of hard substrates (boulder, rubble, sand and gravel) and soft substrates (silt, marl and muck) (Map 4). Shallow, protected areas had soft substrates and windswept shores and off-shore shallow sites had harder substrates.

Distribution of aquatic plants

Plants were found to a depth of 22 feet in Borden Lake and in the 0-25 feet depth zone, 64 percent of the survey sites contained vegetation. Vegetation was most common in the 0-5 feet depth zone, where 99 percent of sites contained plants (Figure 1). Plant abundance declined with increasing water depth and in depths greater than 15 feet 5% of sites were vegetated. Plants were distributed around Borden Lake with the broadest zones of vegetation occurring in the shallow protected areas (Map 5).

Figure 1. Percent of vegetated sites vs. water depth.



Plant richness and diversity

A total of 55 native aquatic plant taxa (types) were recorded in Borden Lake. The plants included 14 emergent, five floating-leaved, four free-floating and 32 submerged plants (Appendix 1). Seven of these taxa were recorded for the first time during the 2013 survey. One non-native submerged plant, curly-leaf pondweed a submerged aquatic plant was detected. This plant is naturalized in Minnesota, has been present in Crow Wing County since at least 1950 and was found very infrequently in Borden Lake.

The highest number of plant taxa was found in shallow water, in depths less than 11 feet. All of the 55 taxa found in the lake were present within this shallow zone and 44 were only found in this area. Only coontail occurred in depths greater than 20 feet (Figure 2).

The number of plant taxa found at each sample site ranged from 0-15 with a mean of 2.7 species per site. Sites of high species richness (six or more taxa per site) often occurred in depths less than 10 feet and included sites of where emergent, floating-leaf and submerged plants co-occurred (Map 6).

Emergent and Floating-leaf Plant Stands

Emergent and floating-leaf plants were restricted to shallow water of six feet and less and covered 260 acres, or 68 percent of the shallow water zone. Approximately 233 acres of emergent plant stands and 27 acres of floating-leaf plant stands were mapped (Map 7). In addition to providing critical habitat for fish and wildlife, the extensive root network of emergent and floating-leaf plants help to stabilize shorelines and provide a buffer from waves.

Wild rice (*Zizania palustris*) 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 (Photo 2). The plant prefers soft substrates (Lee 1986, Nichols 1999) and generally requires moving water for abundant growth (MNDNR 2008). 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).

Photo 2. Wild rice

Bulrush (*Schoenoplectus* spp.) occupied about 160 acres and was found on sandy sites in water depths from shore to six feet. The largest bulrush beds occurred along shorelines in the southern 2/3rds of the lake including shorelines and around islands. Bulrush (Photo 3) 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 these plants help to stabilize sandy shorelines. In shallow water, they may spread by underground rhizomes but these plants are particularly susceptible to destruction by direct cutting by human, motorboat activity and excess herbivory. Restoration of bulrush beds can be very difficult, making established beds particularly unique and valuable.

Photo 3. Bulrush with Pickerelweed

Most of the other plant beds were classified as "waterlily" beds and were dominated by floating-leaf plants such as white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*), watershield (*Brasenia schreberi*) and floating-leaf pondweed (*Potamogeton natans*). Waterlily beds often contained scattered emergent plants such as wild rice, burreed, bulrush and submerged plants. The floating leaves of waterlilies provide shade and shelter for fish, frogs and invertebrates (Photo 4). The showy flowers produce seeds that are eaten by waterfowl and the rhizome are a food source for muskrats and deer (Borman et al. 2001).

Photo 4. Waterlilies in Borden Lake, 2013.

Pickerelweed (*Pontederia cordata*) has heart-shaped leaves that emerge from a rhizome and can reach a height of 3.5 feet (Photo 5). The leaves have air-filled stocks and firm blades. Pickerelweed has small violet-blue flowers crowded on a single spike that can range from 3-4 inches long (Borman et al. 2001). It is found in freshwater along lakes, streams and wetlands. It can grow in water levels up to six feet. Pickerelweed fruit is eaten by ducks and muskrats and the rest of the plant is eaten by deer, geese, muskrats, snails and carp.

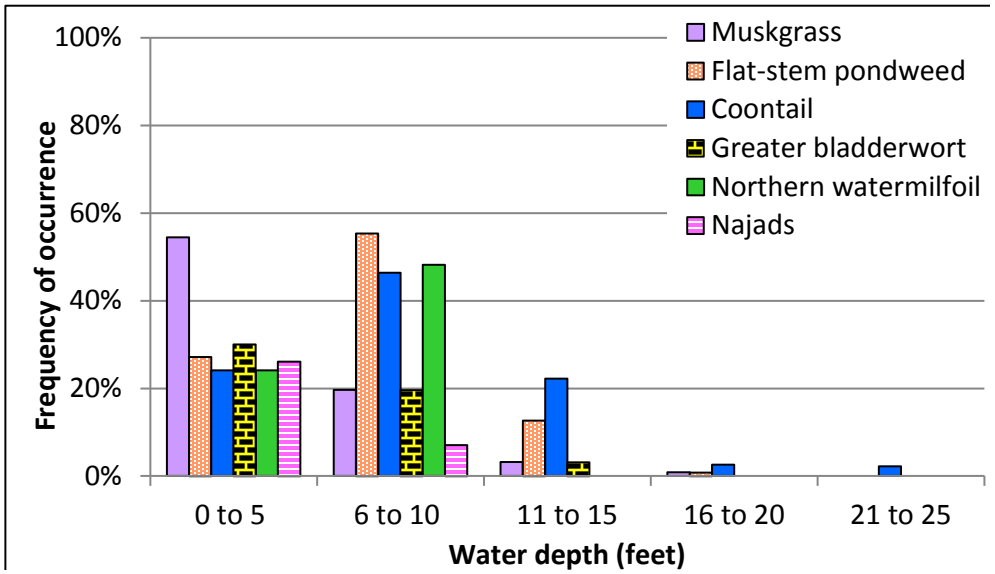
Photo 5. Pickerelweed in Borden Lake, 2013.

Other emergent plants included spikerush (*Eleocharis* sp.), burreed (*Sparganium* sp.), broad-leaf arrowhead (*Sagittaria latifolia*), cattails (*Typha* sp.), and giant cane (*Phragmites australis*).

Submerged aquatic plants

Submerged plants occurred in 64 percent of the sites and included macroalgae and rooted plants. Submerged plants were found to a depth of 22 feet but were most frequent in depths of 15 feet and less. The most common submerged plant species were muskgrass (*Chara* sp.), coontail (*Ceratophyllum demersum*), greater bladderwort (*Utricularia vulgaris*), pondweed (*Potamogeton* spp.), northern watermilfoil (*Myriophyllum sibiricum*) and naiads (*Najas* spp.) (Figure 2).

Figure 2. Common submerged aquatic plants in Borden Lake.



Muskgrass (*Chara* sp.) is a freshwater **macroalgae** and 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 (Photo 6). Muskgrass is adapted to variety of substrates, can withstand heavier wave action

Photo 6. Muskgrass

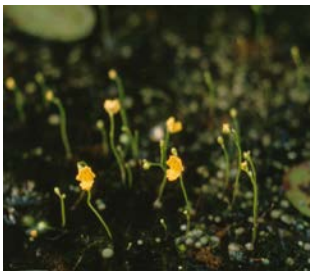
than can rooted plants, and is often the first plant to colonize open areas of lake bottom where it can act as a sediment stabilizer. Beds of muskgrass can provide important fish spawning and nesting habitat.

Muskgrass dominated the submerged plant community in Borden Lake, occurring in 31 percent of the survey sites (Appendix 1). It was the most frequent plant in the 0-5 feet depth zone (Figure 2) and was distributed around the shorelines of the entire lake.

Photo 7. Coontail

Coontail (*Ceratophyllum demersum*; Photo 7) is the most common submerged flowering plant in Minnesota lakes. It grows entirely submerged and is adapted to a broad range of lake conditions, including turbid water. Coontail is a perennial and can over-winter as a green plant under the ice and then begins new growth early in spring. Because it is only loosely rooted to the lake bottom it may drift between depth zones (Borman et al. 2001). Coontail provides important cover for young fish, including bluegills, perch, largemouth bass and northern pike. It also supports aquatic insects beneficial to both fish and waterfowl. Coontail occurred in 19 percent of the Borden Lake sites (Appendix 1) and was common in the 0-15 foot depth zone (Figure 2).

Photo 8. Bladderwort flowers.



BLADDERWORTS (*Utricularia* spp.) are submerged plants with finely divided leaves. They produce roots but do not firmly anchor to the lake bottom. Bladderworts have specialized air bladders that regulate their position in the water column. They also act as "underwater Venus fly-traps" by catching and digesting small insects in the bladders. Bladderworts produce small but showy flowers (Photo 8) that emerge above the water surface. They prefer soft substrates (Nichols 1999) but also float freely in the water column and may be found in protected areas such as waterlily beds. Greater bladderwort (*U. vulgaris*) is found in lakes and ponds throughout Minnesota and occurred in 18 percent of the Borden Lake survey sites (Appendix 1) and occurred in depths of 0-15 feet.

Photo 9. Flat-stem pondweed.

PONDWEEDS (*Potamogeton* spp. and *Stuckenia* spp.) are primarily submerged, perennial plants that are anchored to the lake bottom by underground rhizomes. Depending on water clarity and depth, these plants may reach the water surface and may produce flowers that extend above the water. Pondweed seeds and tubers are an important source of waterfowl food (Fassett 1957) and the foliage of pondweeds is food for a variety of marsh birds, shore birds and wildlife and provides shelter, shade and spawning sites for a range of fish species (Borman et al. 2001).

Flat-stem pondweed (*Potamogeton zosteriformis*) is named for its flattened, grass-like leaves (Photo 9). It was the most common

pondweed in Borden Lake (Figure 2), occurring with a frequency of 20 percent (Appendix 1). It was most frequent in the 6-10 feet depth zone, where it was found in 55 percent of the sites. Flat-stem pondweed is a perennial submerged plant that occurs in many Minnesota lakes but it is not tolerant of turbid lakes (Nichols 1999). It prefers soft substrates and reproduces mainly by cloning but can also produce seeds.

Narrow-leaf pondweeds occurred in 14 percent of the survey sites (Appendix 1). They were found to a depth of 16 feet and within the 6-10 feet depth zone they occurred in about 27 percent of the sites (Figure 2). These include taxa that can be difficult to identify if not found in flower or fruit. Fries' pondweed (*Potamogeton friesii*), and sago pondweed (*Stuckenia pectinata*; Photo 10) were positively identified in the lake, but additional narrow-leaf species may have also been present.

Photo 10. Sago Pondweed

WATERMILFOILS are mostly submerged rooted perennial plants with finely dissected, "feather-shaped" leaves. There are several native species of watermilfoils in Minnesota and these plants are not tolerant of turbidity (Nichols 1999) and grow best in clear water lakes. Particularly in depths less than 10 feet, watermilfoils may reach the water surface and their flower stalk will extend above the water surface (Photo 11). They spread primarily by stem fragments and over-winters by hardy rootstalks and winter buds. Northern watermilfoil (*Myriophyllum sibiricum*) was the only watermilfoil found in Borden Lake. It was found in 17 percent of all sites (Appendix 1), occurred to a depth of 10 feet and was most common in the 6-10 feet depth zone (Figure 2).

Photo 11. Northern watermilfoil

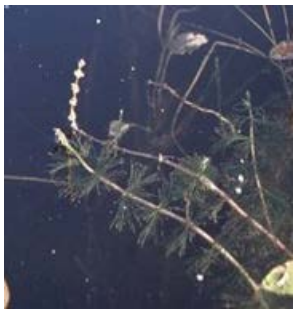


Photo by: Andrew Hipp (UW Madison-Wisc State Herbarium)

NAIADS [Bushy pondweed (*Najas flexilis*; Photo 12) and southern naiad (*Najas guadalupensis*)] are native submerged plants that often grow low in the water column and form inconspicuous flowers. The two species look very similar, but bushy pondweed is unusual because it is one of the few annual submerged species in Minnesota and must re-establish every year from seed. It prefers hard substrates and is not tolerant of turbidity (Nichols 1999). Southern naiad may overwinter as a perennial plant or sprout from seed. The seeds and foliage of both plants are an important duck food and the foliage provides good fish cover. Naiads were found in 14 percent of the surveyed sites (Appendix 1) and were common in the 0-5 feet depth zone where they occurred in 26 percent (Figure 2).

Photo 12. Bushy pondweed

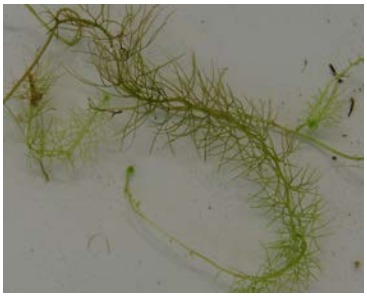
Photo by Gary Fewless (UW Green bay)

Unique plants

In addition to the commonly occurring groups of native submerged plants in Borden Lake, there were several unique plants located during the survey including flat-leaved bladderwort

(*Utricularia intermedia*), humped bladderwort (*Utricularia gibba*), minor bladderwort (*Utricularia minor*), creeping spearwort (*Ranunculus flammula*), small waterwort (*Elatine minima*), water bulrush (*Schoenoplectus subterminalis*), and twig rush (*Cladium mariscoides*). These species are not widespread in Minnesota and are usually associated with undisturbed areas in clear water lakes of northern Minnesota. None of these species were common in Borden Lake but their presence may indicate unique microhabitat conditions in some areas of the lake.

Photo 13. Flat-leaved bladderwort.



In addition to common bladderwort (*Utricularia vulgaris*) there are several other species that are much less common in Minnesota lakes. Unique bladderwort species include flat-leaved bladderwort (Photo 13) and lesser bladderwort. They are found in protected, shallow lake areas and have been documented at scattered locations throughout northern Minnesota (Ownbey and Morley 1991).

Photo 14. Creeping spearwort

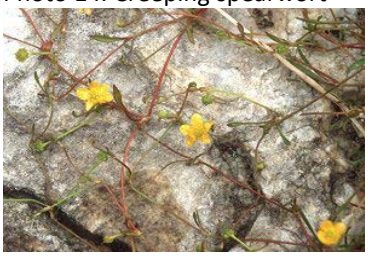


Photo by: Emmit Judziewicz, U of WI-Stevens Point Herbarium

Creeping spearwort is mostly found in the northern half of Minnesota (Flora of North America 1993+). It grows on hard substrates like sand and gravel (Borman et al. 2001). Creeping spearwort often grows as a submerged plant but may grow as a short emergent on mudflats. It has linear leaves that emerge in small clusters from the arched runners or stolons. This plant is in the buttercup family and if stranded on mudflats, it may form characteristic yellow buttercup flowers (Photo 14).

Photo 15. Small waterwort

Copyright 2005 Gary Fewless

Small waterwort has opposite leaves and can grow up to 7 cm. The leaf blades are flat and only 0 .7 to 5 mm long (Photo 15). Small waterwort has short white flowers and occurs in sandy or mucky shallow areas in clear lakes.

Photo 16. Water bulrush

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Water bulrush is closely related to the emergent bulrush plants but grows primarily as a submerged plant. It is a rooted perennial with fine, grass-like leaves and may form mats near the water surface. In mid to late summer its leaf tips and flower stalk may emerge above the water surface (Photo 16). This species once had a patchy distribution throughout North America but may now be extirpated from Illinois (Flora of North America 1993+) and its conservation status is listed as critically impaired in several other states (NatureServe 2008). It is infrequently found in Wisconsin (Nichols 1999) and Minnesota (Ownbey and Morley 1991) lakes.

Photo 17. Twig rush

Twig rush is a special concern species. Twig rush is a coarse perennial sedge that can reach heights up to one meter. The inflorescence can be terminal with stiff ascending branches and numerous spikelets in groups of 3-5. The inflorescence typically has a dark reddish or reddish brown color and can be mistaken with a larger rush (Photo 17).

Aquatic plant community dynamics

Borden Lake supports an abundant and diverse native plant community that provides critical fish and wildlife habitat and other lake benefits. (Click here for more information on: value of aquatic plants). The types and amounts of aquatic plants are influenced by a variety of factors including water clarity, water chemistry, depth, substrate type and wave activity. Within lake differences in these physical features as well as different levels of human activity can result in different types and amounts of vegetation.

The 2013 survey provides a snapshot of the Borden Lake plant communities and there may be a year to year difference in amounts and types of plants present in the lake. The annual abundance, distribution and composition of aquatic plant communities may change annually due to environmental factors and the specific phenology of each plant species. 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 2013 can be used to monitor finer-scale changes that may occur, such as an increase in a particular species, loss of species, or changes in the depths at which individual species occur.

Some taxa, such as muskgrass, perennial pondweeds, and firmly-rooted bulrush plants, usually regrow within the same lake area each year and are not likely to vary naturally on an annual basis. However, other plants have different reproductive and dispersal characteristics that result in changing patterns between years. Wild rice is an annual plant and relies on seeds produced in the previous year to germinate and grow to adults in order to have a successful growth year. Low seed production or storm activities that uproot young plants can result in low annual production for this particular plant. Changes in the abundance of one species may trigger a change in other species as they compete with each other for available space.

The rate of aquatic plant growth varies with temperature in years with cool spring temperatures, submerged plants may be less abundant than in years with early springs and prolonged warm summer days. If water clarity in Borden Lake increases, submerged vegetation may be more common at depths greater than 20 feet. Declines in water clarity may lead to fewer plants and fewer types of plants in the deep end of the current vegetated zone. 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, submerged plants may increase in abundance or there may be a shift in species dominance.

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 taxa 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.

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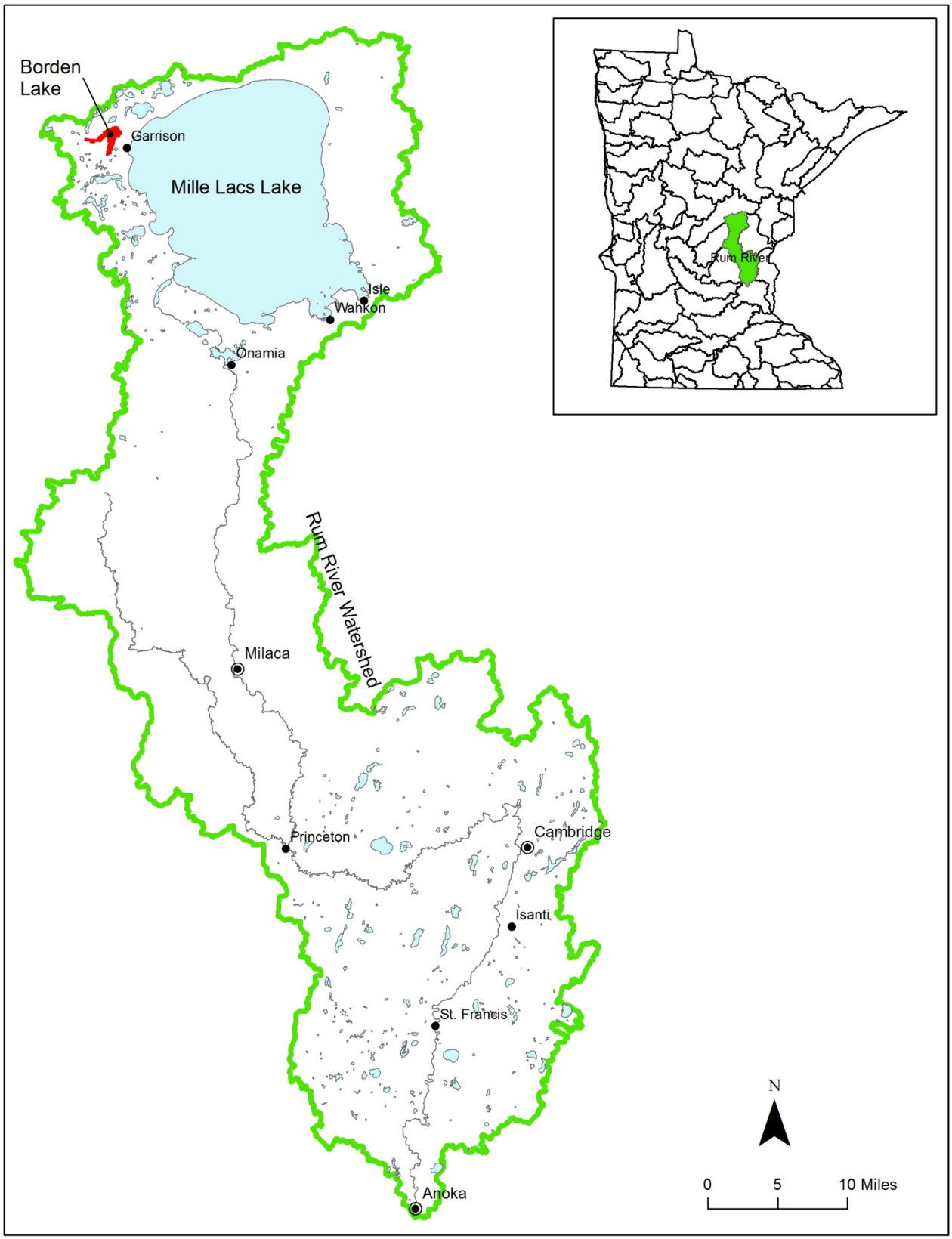
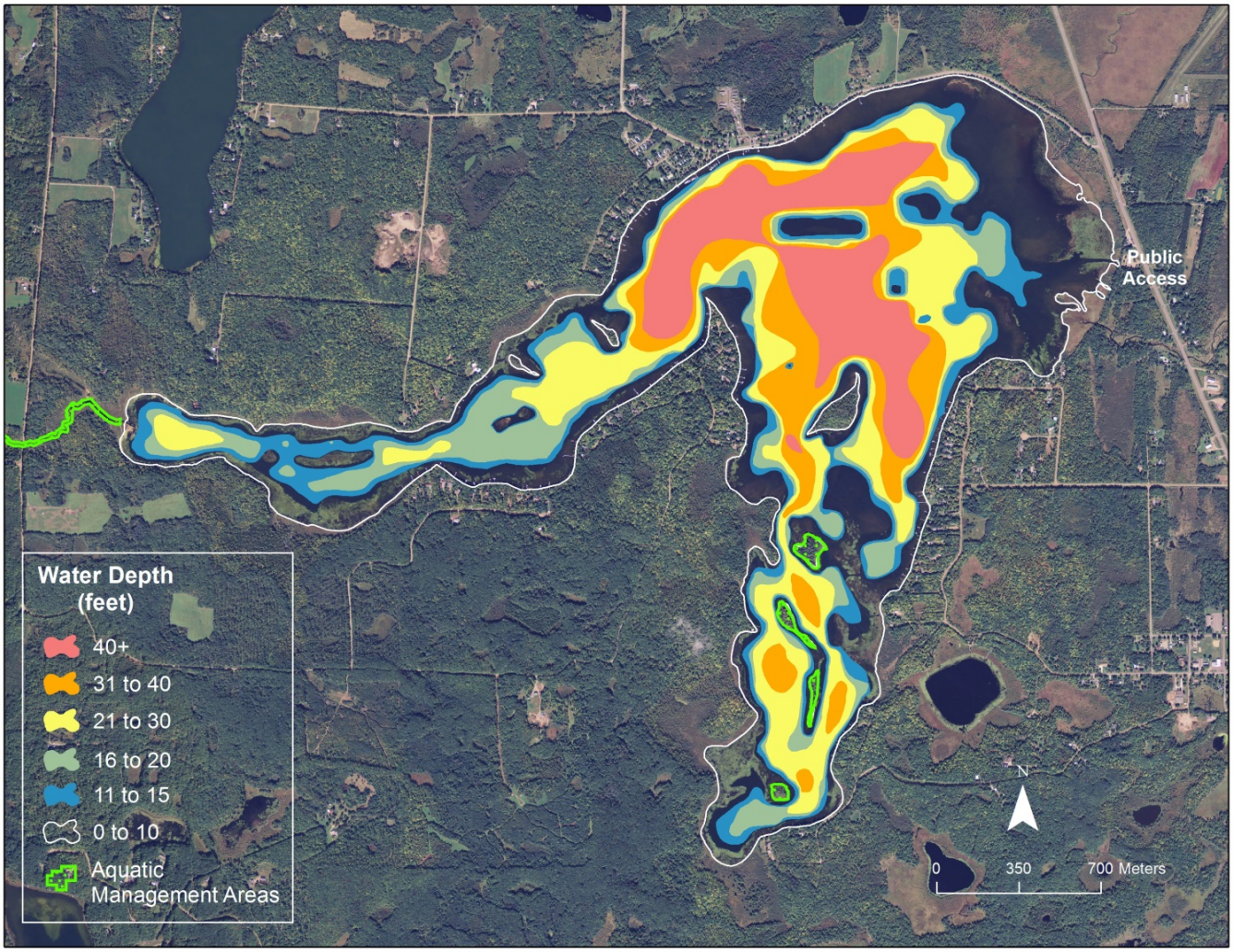
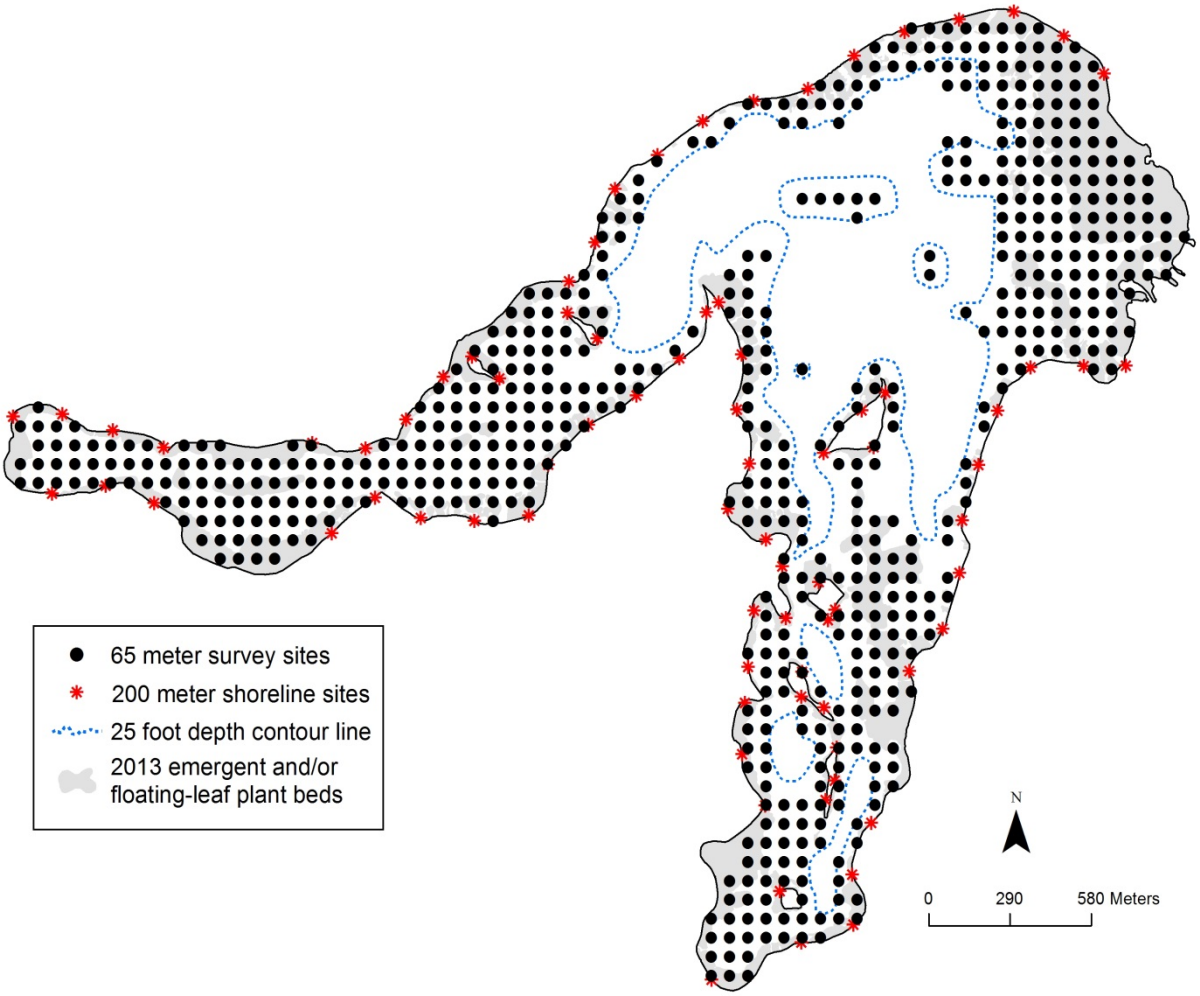
MAP 1. BORDEN LAKE WITHIN THE RUM RIVER WATERSHED



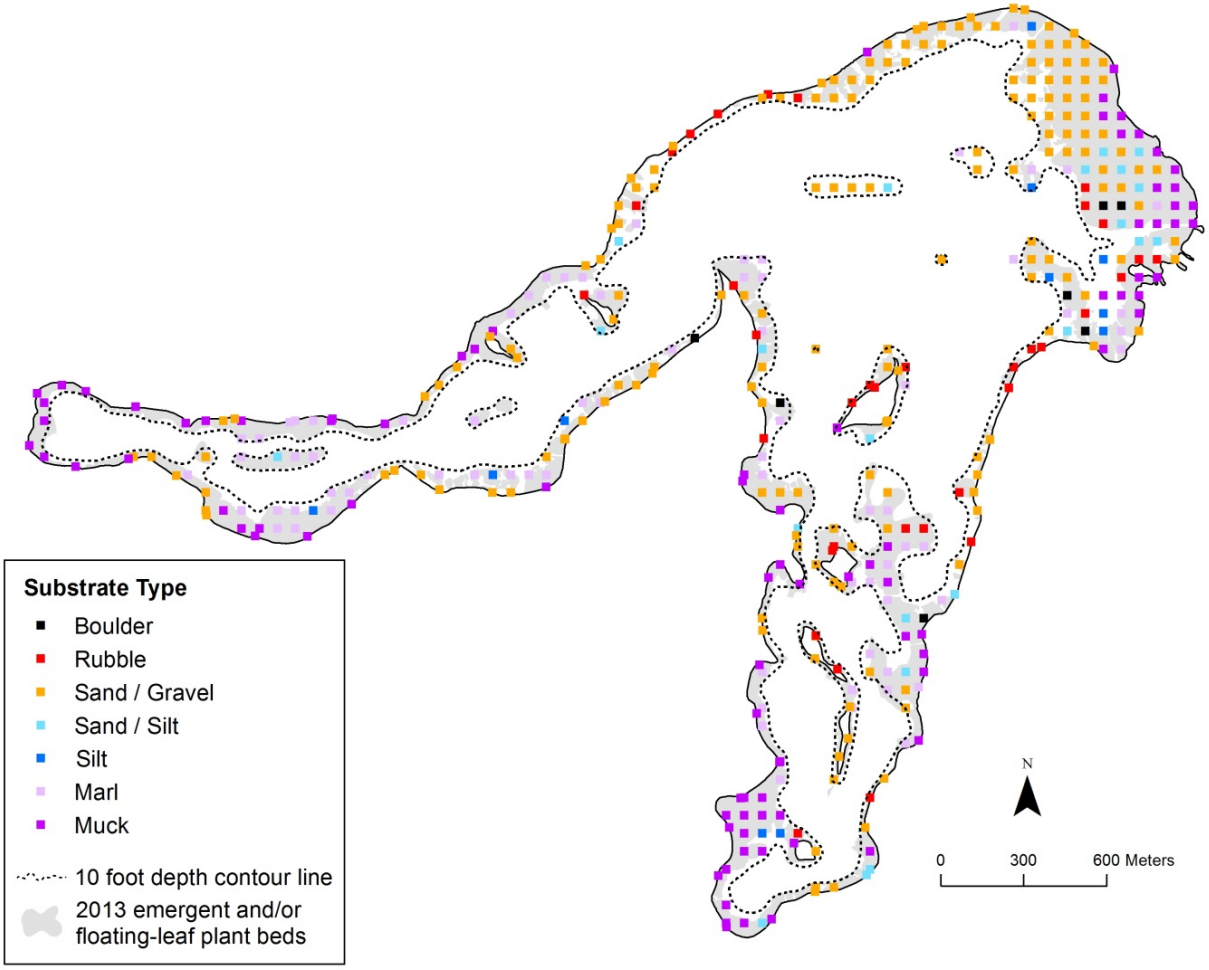
MAP 2. DEPTH CONTOUR MAP (10 AND 20 FOOT CONTOURS ARE BASED ON 2013 PLANT DATA)



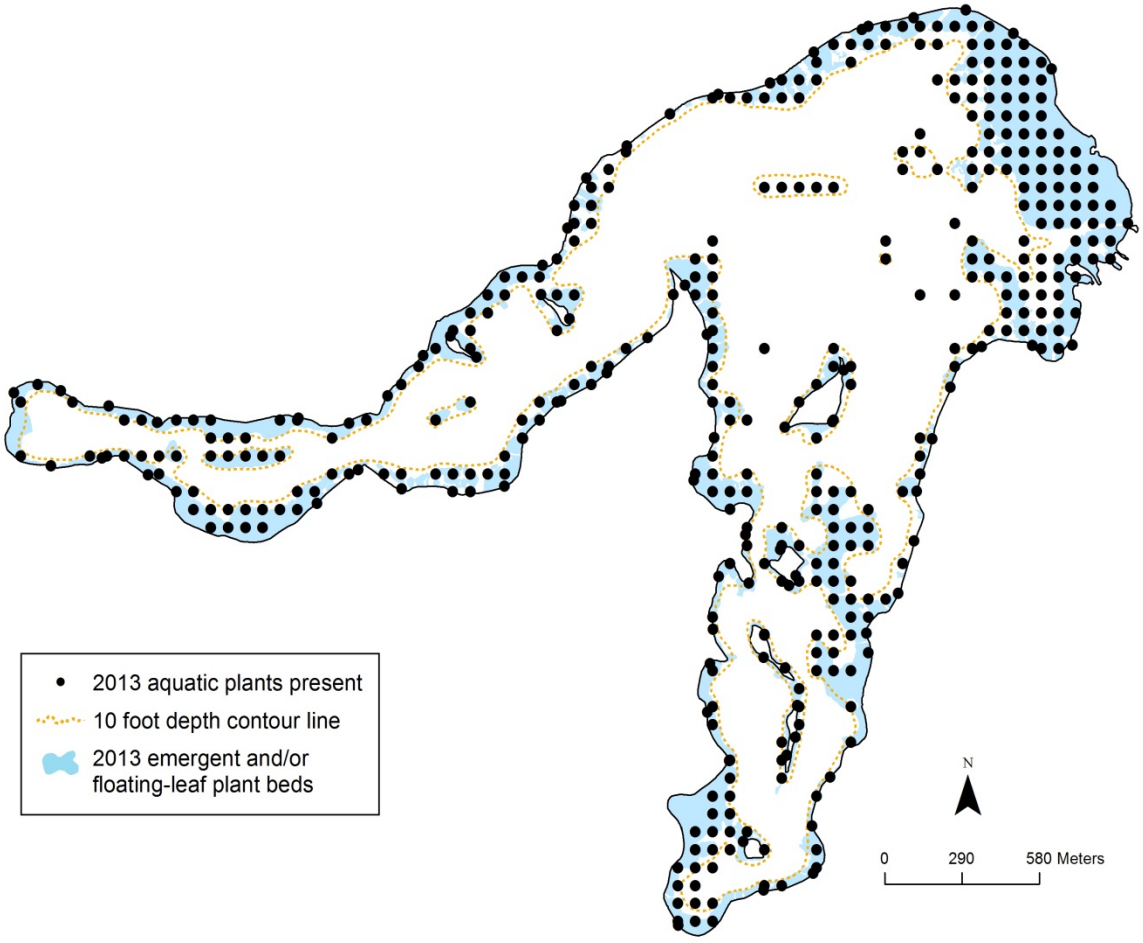
MAP 3. 2013 POINT-INTERCEPT 65 METER SURVEY SITES.



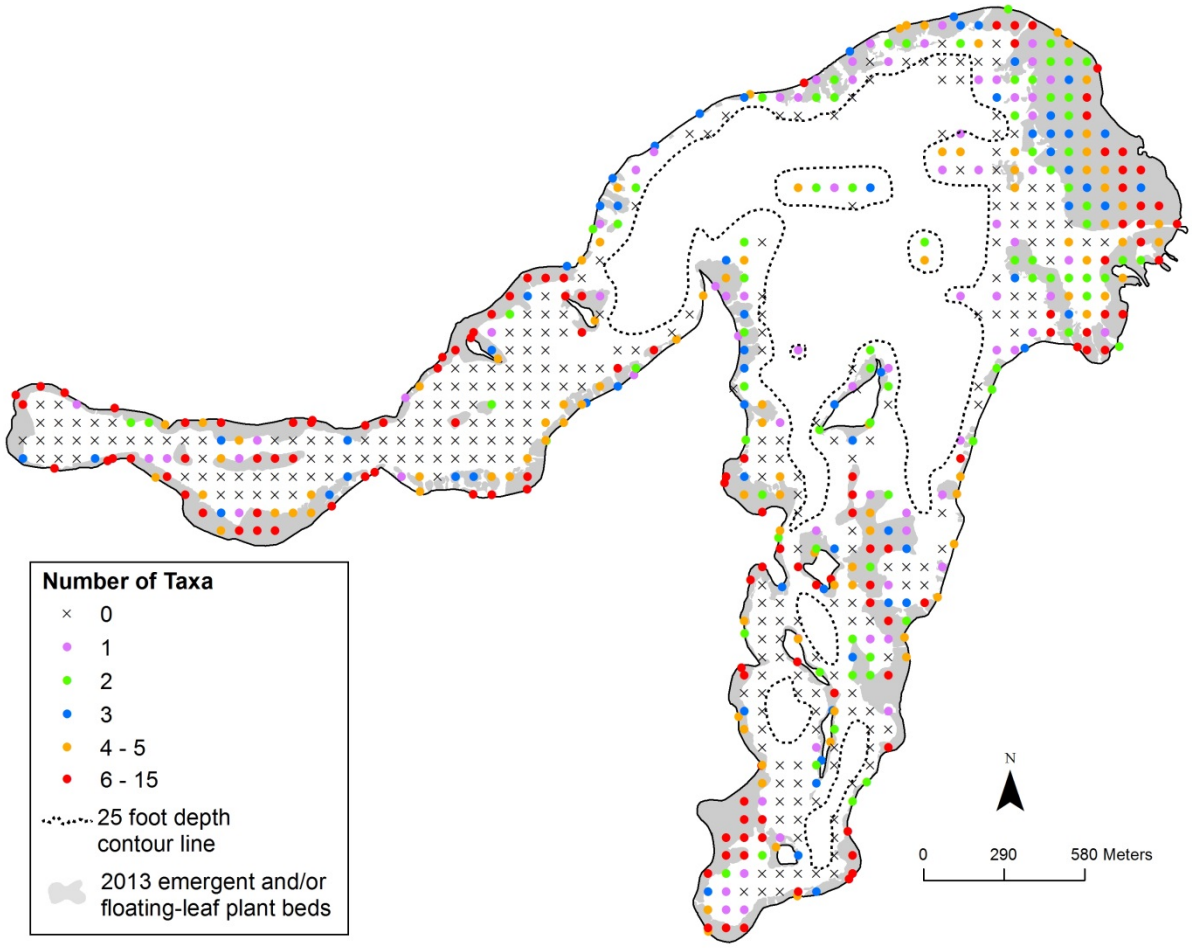
MAP 4. NEAR-SHORE SUBSTRATES OF BORDEN LAKE, 2013.



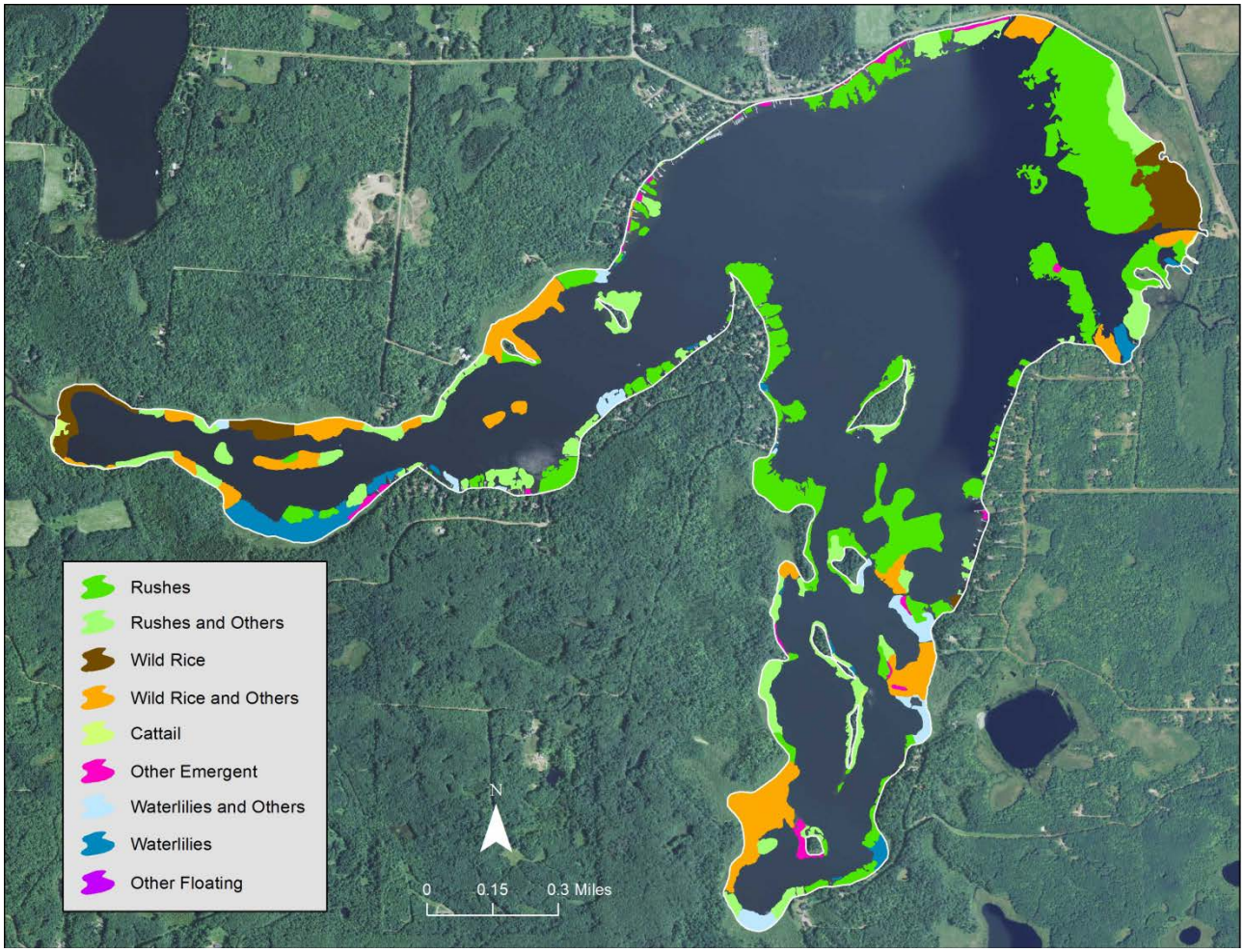
MAP 5. AQUATIC VEGETATION PRESENT AT SAMPLE SITES ON BORDEN LAKE.



MAP 6. NUMBER OF PLANT TAXA PER SAMPLE SITE, BORDEN LAKE, 2013.



MAP 7. EMERGENT AND FLOATING-LEAF PLANT STANDS, BORDEN LAKE, 2013.



APPENDIX 1: HISTORICAL AND CURRENT PLANTS OF BORDEN LAKE

Submerged plants

	Common Name	Scientific Name	1941	1972	1982	1993	1996	2008	2013
Large Algae	Muskgrass	*Chara* sp.	X	X	X	X		X	31
	Stonewort	*Nitella* sp.							1
Moss	Watermoss	*Not identified to genus*						X	1
Monocots	Small waterwort	*Elatine minima*							<1
	Needlegrass	*Eleocharis acicularis*				X			<1
	Canada waterweed	*Elodea canadensis*			X	X	X		6
	Water star-grass	*Heteranthera dubia*				X	X		3
	Bushy pondweed	*Najas flexilis*	X			X	X	X	14
	Southern naiad	*Najas guadalupensis*							
	Large-leaf pondweed	*Potamogeton amplifolius*	X	X	X	X	X	X	5
	Curly-leaf pondweed (N)	*Potamogeton crispus*							<1
	Ribbon-leaf pondweed	*Potamogeton epihydrus*	X						--
	Fries' pondweed	*Potamogeton friesii*		X*	X*	X*		X*	11*
	Small pondweed	*Potamogeton pusillus*					X		--
	Sago pondweed	*Stuckenia pectinata*	X	X	X	X	X	X	4
	Variable pondweed	*Potamogeton gramineus*				X	X	X	4
	Illinois pondweed	*Potamogeton illinoensis*					X	X	6
	River pondweed	*Potamogeton nodosus*				X		X	1
	White-stem pondweed	*Potamogeton praelongus*		X	X	X	X	X	2
	Clasping-leaf pondweed	*Potamogeton richardsonii*		X	X	X	X	X	2
	Robbins' pondweed	*Potamogeton robbinsii*					X	X	1
	Flat-stem pondweed	*Potamogeton zosteriformis*		X		X	X	X	20
	Water bulrush	*Schoenoplectus subterminalis*					X		3
Dicots	Water marigold	*Bidens beckii*					X	X	<1
	Coontail	*Ceratophyllum demersum*	X	X	X	X	X	X	19
	Hornwort	*Ceratophyllum echinatum*							2
	Marestail	*Hippuris vulgaris*				X			--
	Northern watermilfoil	*Myriophyllum sibiricum*	X	X	X	X	X	X	17
	White-water buttercup	*Ranunculus aquatilis*						X	1
	Creeping spearwort	*Ranunculus flammula*						X	P
	Humped bladderwort	*Utricularia gibba*							<1
	Flat-leaved bladderwort	*Utricularia intermedia*			X			X	1
	Minor bladderwort	*Utricularia minor*				X			2
	Greater bladderwort	*Utricularia vulgaris*	X			X	X	X	18
	Wild celery	*Vallisneria americana*	X			X	X	X	7
		Total	9	8	9	18	18	21	32

*some plants were only identified to the genus level in this lake. It is possible that additional species of this genus were present in the lake, but only two species were positively identified.

Free-floating plants

Common Name	Scientific Name	1941	1972	1982	1993	1996	2008	2013
Lesser duckweed	*Lemna* sp.		X	X	X	X[1]	X	1
Star duckweed	*Lemna trisulca*		X	X	X		X	6
Greater duckweed	*Spirodela polyhriza*				X	X	X	2
Watermeal	*Wolffia* spp.				X	X[2]		1
	Total	0	2	2	4	4	3	4

[1] *Species identified as Lemna turionifera in this survey*

[2] *Species identified as Wolffia borealis and Wolffia columbiana in this survey*

Floating-leaved plants

Common Name	Scientific Name	1941	1972	1982	1993	1996	2008	2013
Watershield	*Brasenia schreberi*	X					X	1
White waterlily	*Nymphaea odorata*	X	X	X	X	X	X	9
Yellow waterlily	*Nuphar variegata*	X	X	X	X	X	X	14
Floating-leaf smartweed	*Persicaria amphibian*							<1
Floating-leaf pondweed	*Potamogeton natans*	X	X		X	X	X	2
Floating-leaf burreed	*Sparganium* sp.	X	X			X		--
	Total	5	4	2	3	4	4	5

Emergent plants

Common Name	Scientific Name	1941	1972	1982	1993	1996	2008	2013
Water plantain	*Alisma triviale*					X		
River bulrush	*Bolboschoenus fluviatilis*						X	<1
Water arum	*Calla palustris*		X					--
Sedge	*Carex* sp.					X[3]		<1
Twig rush	*Cladium mariscoides*							<1
Three-way sedge	*Dulichium arundinaceum*	X						--
Spikerush	*Eleocharis* sp.		X	X	X	X[4]	X	3
Horsetail	*Equisetum fluviatile*	X	X	X		X		1
Giant cane	*Phragmites australis*		X		X			<1
Pickerelweed	*Pontederia cordata*		X	X		X		5
Arrowheads	*Sagittaria* spp.		X	X[5]	X	X[6]	X	5[7]
Three-square bulrush	*Schoenoplectus pungens*			X	X		X	2
Bulrush	*Schoenoplectus* sp.	X	X	X	X	X[8]	X	19
Burreed	*Sparganium* sp.		X[10]	X[9]	X	X[9]	X	<1
Narrow-leaf cattail	*Typha glauca*							<1
Broad-leaf cattail	*Typha latifolia*		X	X		X		<1
Wild rice	*Zizania palustris*		X	X	X	X	X	9
	Total	4	9	9	6	13	7	14

X[3] Species identified as Carex utriculata

X[4] Species identified as Eleocharis eryrthropoda

X[5]Species identified as Sagittaria latifolia

X[6] Species identified as Sagittaria latifolia, Sagittaria rigida and Sagittaria sp.

5[7] Species identified as Sagittaria latifolia and Sagittaria sp.

X[8] Species identified as Schoenoplectus acutus

X[9] Species identified as Sparganium eurycarpum

X[10] Species identified as Sparganium americanum and Sparganium eurycarpum

Wetland emergent plants

Common Name	Scientific Name	1941	1972	1982	1993	1996	2008	2013
Sweet flag	*Acorus americanus*		X					--
Swamp milkweed	*Asclepias incarnata*					X		P
	Total	0	2	0	1	1	0	2

N = Naturalized

1941, June 26. MNDNR
1972, July 10-11. MNDNR Fisheries
1982, July 10-14. MNDNR Fisheries
1993, July 26. MNDNR Fisheries
1996, July 10. Karen Myhre, MNDNR Minnesota Biological Survey
2008, July 21. MNDNR Fisheries

GLOSSARY

Within this glossary, 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.

Water quality terms

Alkalinity is a measure of the amount of carbonates, bicarbonates, and hydroxide present in the water. Carbonate and bicarbonate are two alkaline compounds that provide acid buffering to the lake. These compounds are usually found with two hardness ions: calcium and magnesium. Lakes with high quantities of calcium and magnesium in the water are described as "**hard water**" and lakes with low quantities are described as "**soft water**". A lake's hardness and alkalinity are affected by the type of minerals in the soil and watershed bedrock. In Minnesota, there is a general trend of increasing alkalinity from northeast to southwest, with soft-water lakes primarily found in the northeast, hard water lakes in central Minnesota, and very hard-water lakes in the southwest. Regardless of their location in the state, if a lake receives most of its water input from precipitation, hardness and alkalinity may be low.

Level of hardness	total hardness as mg/l of calcium carbonate
Soft	0 - 60
Moderately hard	61 - 120
Hard	121 - 180
Very hard	>180

Hard-water lakes are usually in watersheds with fertile soils that add phosphorus to the lake; they tend to produce more fish and aquatic plants than soft water lakes. Increasing alkalinity is often related to increased algae productivity.

Conductivity measures the water's ability to conduct an electric current and is related to the amount of dissolved minerals in the water. It is related to hardness; soft water lakes typically have lower conductivity than hard water lakes.

Lake trophic status refers to the fertility of the lake and is based on the amount of nutrients (phosphorus and nitrogen) available for organisms. Lakes can be classified based on their fertility:

Oligotrophic lakes have very low nutrients. These lakes are usually found in northern Minnesota, have deep clear water, rock and sandy bottoms and very little algae. Cold water fish like lake trout and whitefish may be found in these lakes. Aquatic plants growth is limited and may be dominated by short, rosette-forming plants.

Mesotrophic lakes have a medium amount of nutrients and are usually found in central Minnesota. These lakes have clear water and algal blooms may occur in late summer. These

lakes often support sportfish populations of walleye, perch, smallmouth bass, muskellunge and/or northern pike. Submerged plant growth may be abundant, particularly in shallow areas.

Eutrophic lakes are very fertile with high levels of nutrients. Algal and fish populations may be high. If sufficient light is available, submerged plant growth may be moderate but is often limited due to competition with algae.

Hypereutrophic lakes have excessive nutrients and are dominated by algal blooms. Rough fish typically dominate the community and few aquatic plants are present due to limited light availability.

Water quality terms	Oligotrophic	Oligotrophic-Mesotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Total Phosphorus (ppb)	<6	6-12	12-24	24-48	48-200+
Secchi depth (feet)	>26	13-26	6.5-13	1.5-6.5	<1.5
Chlorophyll a (ppb)	<0.95	.95-2.6	2.6-7.3	7.3-56	56-155+

Sources: RMB Environmental Laboratories Inc. and Minnesota Pollution Control Agency

Secchi disk 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 is influenced by the amount of particles in the water column as well as by the water's color and can fluctuate seasonally and annually. 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.

Plant identification terms

Species is a term to define a group of plants that are capable of interbreeding and producing fertile offspring in nature. Botanists assign a scientific name to each species that is a combination of the genus and species. As an example, red oak and bur oak are both species within the "Oak" genus. Red oak is assigned the scientific name of *Quercus rubra* and bur oak is named *Quercus macrocarpon*. If a surveyor cannot distinguish between a red oak and a bur oak tree, they give it the generic name of *Quercus* sp.

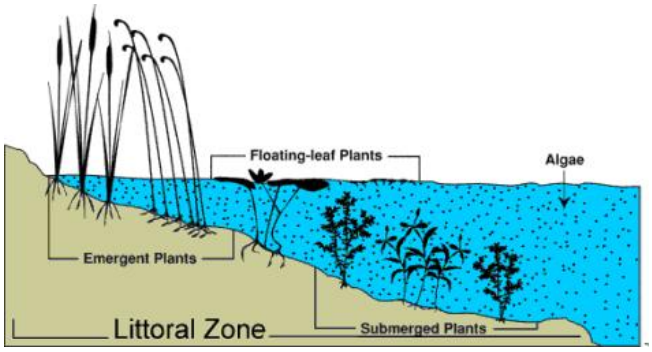
Taxa (singular taxon) is a term that refers to any group of plants, such as species or genus. In this report it is used to identify the number of different types of plants that were identified during a lake survey. In several cases, plants could not be identified to the species level but could be distinguished as unique types of plants. As an example, a surveyor may locate a maple tree and an oak tree during a survey but may not be able to distinguish the exact species of each tree (ex. red maple vs. sugar maple or red oak vs. bur oak). In this case, since the trees were not identified to the species level, it is more accurate to state that two taxa of trees were identified as opposed to two species.

Plant growth form terms

Emergent plants are rooted in the lake bottom with most of their leaves and stems extending above the water surface. Root systems of these plants form extensive networks that take up nutrients and help consolidate and stabilize bottom substrate. Beds emergent plants help buffer the shoreline from wave action, offer shade and shelter for insects, young fish, and frogs and provide food, cover and nesting material for waterfowl, marsh birds and muskrat.

Floating-leaf plants such as waterlilies, are anchored in the lake bottom with leaves and flowers that float on the water surface. Root systems of these plants form extensive networks that take up nutrients and help consolidate and stabilize bottom substrate. Beds of floating-leaf plants help buffer the shoreline from wave action, offer shade and shelter for insects, young fish, and frogs and provide food, cover and nesting material for waterfowl, marsh birds and muskrat.

Forms of aquatic plants found in Minnesota lakes.



Submerged plants have stems and leaves that primarily grow underwater and many may also form flowers, fruits and/or some leaves that emerge above or float on the water surface. Submerged plants are typically anchored to the lake bottom but some types drift freely with the currents. Growth forms of these plants range from low-growing mats to plants that grow several feet in the water column. Some plants obtain nutrients from the lake substrate and the water column, while others rely exclusively on the water column for nutrients. These plants play a key role in the ecosystem of a lake: they release oxygen into the water column, compete for nutrients with microscopic algae, and provide food and shelter for a variety of invertebrates, fish, amphibians and other wildlife.

Free-floating plants are the smallest of Minnesota's lake plants and include small flowering plants that are commonly known as "duckweeds" as well as microscopic algae. Different survey methods are required to assess microscopic algae and they are not included in this report. Duckweeds are present in many Minnesota lakes and if present in sufficient amounts, they can accumulate into mats and create a shade barrier along protected shorelines. As their name implies, they are also an important food source for waterfowl.

Macroalgae are primitive forms of submerged plants that do not form true roots, flowers or vascular tissue. They range in size from single cell plants to larger plants that resemble rooted plants. Macroalgae can provide similar habitat and water quality benefits as rooted plants and were therefore included in this survey.

Pondweeds (*Potamogeton* spp. and *Stuckenia* spp.) are the largest group of submerged aquatic plants in Minnesota lakes with about 25 different species considered native to the state. These perennial plants are anchored to the lake bottom by underground rhizomes. Some species of pondweeds may form specialized floating leaves, while others grow entirely submerged below

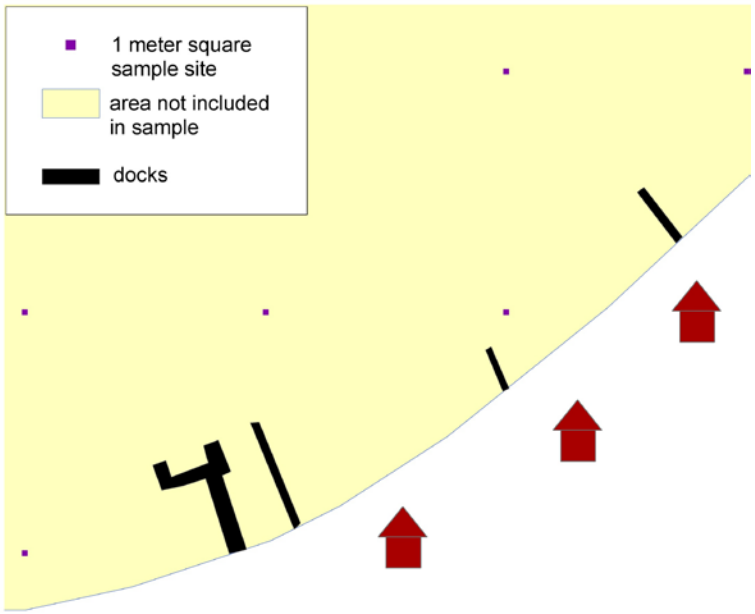
the water surface. Depending on water clarity and depth, any pondweed may produce flowers that extend above the water. Pondweed seeds and tubers are an important source of waterfowl food (Fassett 1957) and the foliage of pondweeds is food for a variety of marsh birds, shore birds and wildlife and provides shelter, shade and spawning sites for a range of fish species (Borman et al. 2001). Pondweeds are often named and described based on their leaf shape and size. Some pondweed species have very specific habitat requirements while others can grow in a wide range of lake conditions. Certain species have the ability to form submerged and floating leaves while others form only submerged leaves. The vegetative portions of pondweeds can be highly variable depending on water levels, water flow and other habitat conditions. If flowers or fruits are not present, pondweeds can be difficult to identify to the species level.

Plant abundance terms

Frequency of occurrence = the percentage of sites where the plant taxon or taxa of interest occurred
Examples:
Lakewide, coontail occurred in 129 of the 680 sites = 19% occurrence lakewide
Within the 0-5 feet depth zone, coontail occurred in 85 of the 356 sites = 24% occurrence in this shallow zone.

Point intercept sample site: For point-intercept surveys, a very small area is actually sampled (see Figure B). Many small sites (represented by purple boxes) are surveyed and used to estimate plant abundance in much larger area of lake (yellow area). This information is useful on a lakewide basis but is not appropriate to describe "site-specific" conditions, such as abundance of plants immediately adjacent to an individual's shoreline home. For that type of information, a specific site visit is required.

Figure B. Actual area of sample site used in point-intercept survey compared to non-sampled areas of lake.



This method is designed to estimate the frequency of occurrence of commonly occurring taxa. To detect infrequently occurring taxa, thousands of samples would be required. Surveyors did conduct some special searches for infrequent taxa; any additional plant taxa found outside of sample sites were recorded as "present" in the lake but these data were not used in frequency of occurrence calculations.

Other measures of “abundance” include:

Cover = the amount of surface area occupied by a plant. For submerged lake plants, this is very difficult to measure from the boat surface. Additionally, it is difficult to consistently measure cover because it is a visual estimate. For emergent and floating-leaf plants, cover is a useful measurement that can be reliably estimated from aerial photographs and/or by delineating plant beds with GPS.

Density = the number of stems within a sample area. For aquatic plants, this requires SCUBA gear and intensive underwater measurements. It is also complicated because many aquatic plants are highly branching and it is difficult to determine where one stem begins and another one ends.

Biomass = the mass or weight of plants within a sample area. For aquatic plants, this requires SCUBA gear or other specialized equipment and plant samples must be separated, cleaned and dried before measuring. Biomass typically increases throughout the growing season.

Richness = is used to describe the total number of plant taxa present in a lake and can help describe the general health of the waterbody. In Minnesota, plant taxa richness can range from zero (un-vegetated lakes) to more than 40 taxa in a lake (Radomski and Perleberg 2012). Plant taxa richness is generally higher in high clarity lakes than in turbid lakes and more plant taxa are usually found in moderately fertile lakes than in nutrient poor lakes. Therefore, lakes of north central Minnesota are often among the “richest” in terms of numbers of plant taxa. Water quality changes that result in lower clarity may also result in the loss of some plant taxa, or lower taxa richness. However, caution must be used when comparing historical and present survey data because of differences in how the surveys were conducted. For example, if a current MNDNR plant survey locates more species than found during a historical “one-day” survey, it may be due to the more extensive sampling that occurs during current surveys. If fewer taxa are located during current surveys, it may indicate a true decline in the plant taxa richness of the lake.