Aquatic vegetation of Lower Hay Lake

August, 2011

Lower Hay Lake, ID# 18-0378-00

Crow Wing County, Minnesota

MnDNR surveyor collecting southern naiad (*Najas guadalupensis*), a native submerged plant that was commonly found in Lower Hay Lake in 2011.

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Survey Context

This lake vegetation survey of Lower Hay Lake was part of the larger Sensitive Lakeshore Identification project conducted by MNDNR on the Whitefish Chain of Lakes. During 2010 and 2011, MNDNR biologists conducted field surveys of aquatic vegetation, near-shore fish and frogs, and shoreland birds in these lakes: Lower Hay, Lower Hay, Clamshell, Arrowhead, Whitefish (Upper, Middle and Lower), Pig, Big Trout, Island, Loon, Rush-Hen, Cross, Daggett and Little Pine. Field data will be used to identify areas along lakeshores that provide unique or critical ecological habitat. Once those areas are identified, local and state resource managers can use the information to help ensure that sensitive habitats are receiving sufficient protection.

More information on the MNDNR's Sensitive Lakeshore Identification, including Sensitive Lakeshore reports for individual lakes, can be found online at:
http://www.dnr.state.mn.us/eco/sli/index.html

Summary

Lower Hay Lake is one of 13 connected waterbodies that comprise the Whitefish Chain of Lakes in Crow Wing County. In 2011, as part of the DNR's larger Sensitive Lakeshore Identification project, surveyors assessed the aquatic vegetation of the lake. Surveys included searches for emergent and floating-leaf plant beds and sampling plant occurrence and diversity at 203 sites.

Since 1938, a total of 30 aquatic plant species (types) have been recorded in Lower Hay Lake. In 2011, 22 species were found and the plant community was primarily comprised of submerged plants with no beds of emergent or floating-leaf plants observed. Waterlilies that were recorded as present (not abundant) in previous surveys may still occur as isolated patches in the lake.

Plant growth occurred around the entire shore and extended lakeward about 150 meters. Plants were found to a maximum depth of 25 feet and within the 0-25 feet depth zone, 81% of the sites contained plants. Vegetation was sparse in depths greater than 20 feet.

Many of the submerged species located during historical surveys are still relatively common in the lake. Coontail (*Ceratophyllum demersum*) and naiads (*Najas flexilis and Najas guadalupensis*) were the most common species in 2011, occurring in 46% and 43% of the sites, respectively. They co-dominated the 6-20 feet depth zone and were among the few species found in depths greater than 15 feet. Northern watermilfoil (*Myriophyllum sibiricum*) and flat-stem pondweed (*Potamogeton zosteriformis)* each occurred in at least 30% of the sites and were most frequent in the 6-10 feet depth zone. The macroalgae, muskgrass (Chara sp.) was present in 28% of the sites and was the dominant species in the 0-5 feet depth zone.

The greatest diversity of plants occurred in near-shore zone where water depths were 10 feet and less. Forty-five percent of the plant species were restricted to this narrow zone. This shallow water is also where much recreational activity occurs, some of which may threaten this critical habitat if aquatic plants are damaged or removed. Protecting existing native aquatic plant beds will help maintain critical fish and wildlife habitat and the general water quality of the lake.

Introduction

Lower Hay Lake is located in the forested, lake-rich region of north central Minnesota (Figure 1). It is one of 13 waterbodies in the 14,000 acre Whitefish Chain of Lakes[1]. The Pine River flows east through the chain and in 1886 the Pine River Dam was completed at Cross Lake (Upham 1920) and raised water levels making channels between the lakes (Figure 2). The U.S. Army Corps of Engineers attempts to maintain fairly stable water levels on the entire chain by regulating outflow at the Cross Lake Dam but heavy rain or drought conditions can also influence the water level. Although lakes in the Whitefish Chain are connected, differences such as lake size, depth, flow, and shoreland management create differences in nutrient levels and water clarity between the lakes. These physical differences influence the types and amounts of plants that occur in each lake.

Figure 1. Lower Hay Lake, Crow Wing County, Minnesota.

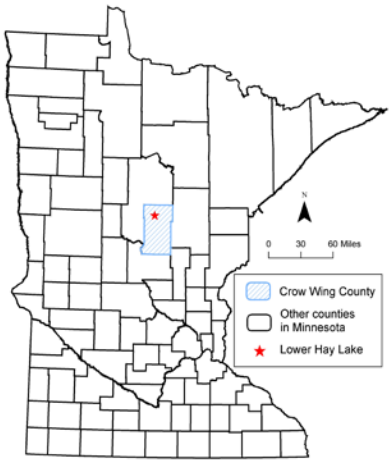
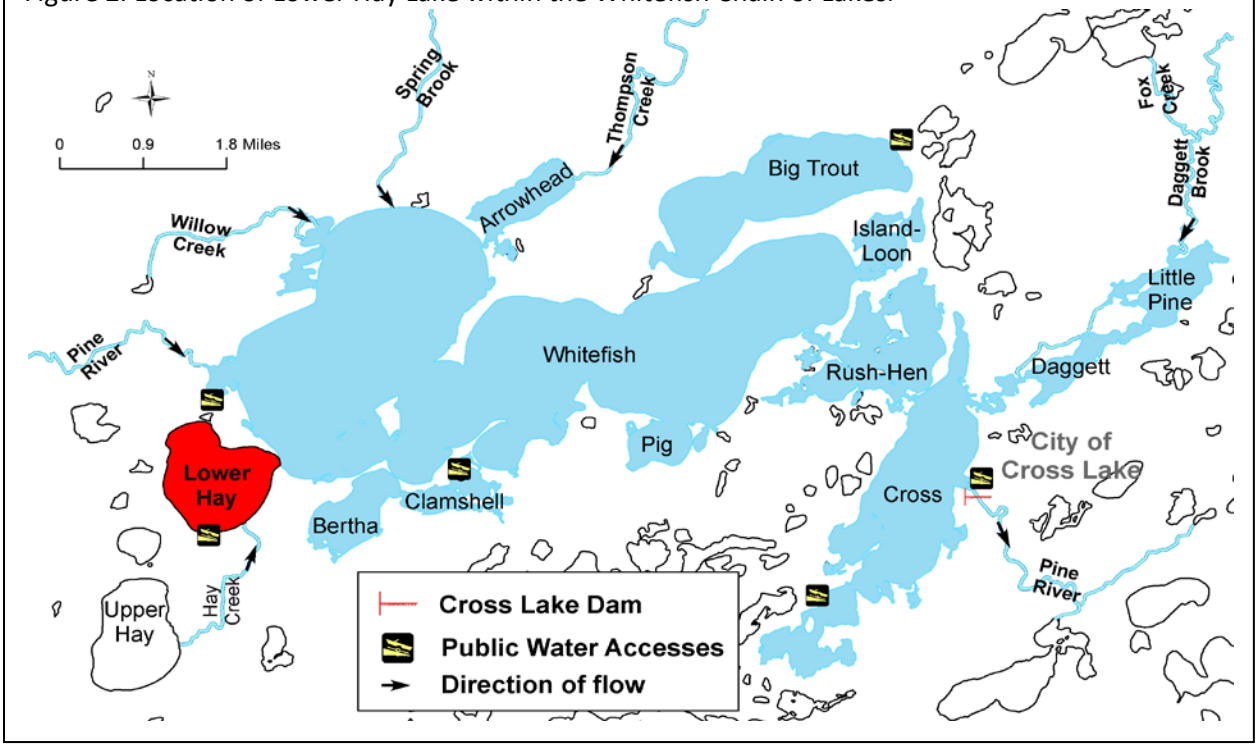


Figure 2. Location of Lower Hay Lake within the Whitefish Chain of Lakes.



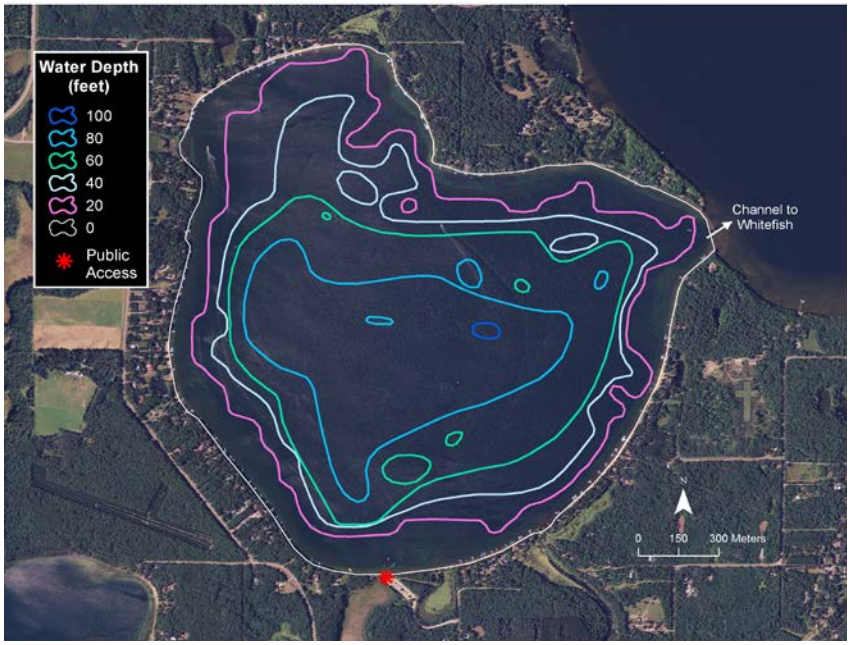
[1] The total number of waterbodies considered to be part of the Whitefish Chain of Lakes varies. We included the lakes that are directly connected within the main portion of the chain.

Lake Characteristics

Lower Hay Lake occurs on the southwest end of the chain and was not originally connected to the other lakes. Hay Creek flows from Upper Hay Lake into Lower Hay Lake (Figure 2). A navigable channel now connects the east side of Lower Hay Lake to Whitefish Lake.

The lake is roughly circular in outline and has a surface area of 685 acres. The maximum water depth is 100 feet and 31% of the lake is shallow (15 feet or less in depth) (Figure 3).

Figure 3. Depth contours of Lower Hay Lake.



There are about 4 miles of shoreline, most of which are privately owned and heavily developed with residential homes. While trees remain on many lake lots, much of the understory vegetation has been removed at developed lots. The Minnesota Department of Natural Resources maintains a public access on the south end of the lake.

Lower Hay Lake is characterized as mesotrophic, based on phosphorus (nutrients), chlorophyll a (algae concentration) and Secchi[2] depth (transparency). Transparency in the lake stays relatively consistent throughout the summer and in 2010, mean summer[3] water clarity was 14 feet (MPCA 2011). Based on Secchi disk measurements alone, aquatic plants have the potential to reach depths of at least 21 feet in Lower Hay Lake[4].

Amounts and types of aquatic plants in Minnesota lakes

Within a lake, types and amounts of aquatic plants are influenced by a variety of factors including water clarity, water chemistry, water depth, substrate, and wave activity. Deep or wind-swept areas may lack aquatic plant growth, whereas sheltered shallow areas may support an abundant and diverse native aquatic plant community. The annual abundance, distribution

[2] 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 is influenced by the amount of particles in the water column and can fluctuate seasonally and annually.

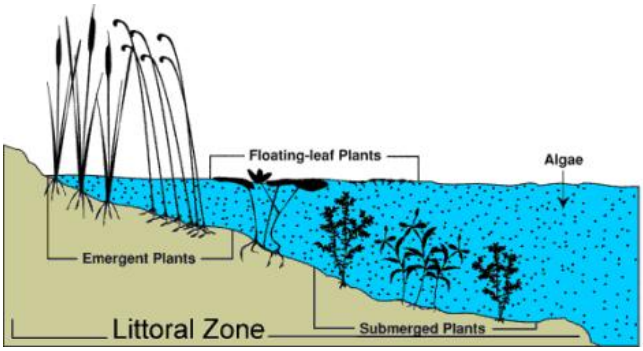
[3] June through September

[4] 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.

and composition of aquatic plant communities may change due to environmental factors, predation, the specific phenology of each plant species, introductions of non-native plant or animal species and human activities in and around the lake.

Aquatic plants can be divided into four groups or "life forms" based on whether the main portion of the plant occurs above, on, or below the water surface. These life forms: emergent, floating-leaved, free-floating and submerged plants (Figure 4), often favor certain water depth zones around the lake but overlap occurs with one life form grading into another. Each life form group has unique functions and values.

Figure 4. Forms of aquatic plants found in Minnesota lakes.



Emergent plants, like cattails and bulrush, are rooted in the lake bottom with most of their leaves and stems extending above the water surface. Floating-leaf plants, such as waterlilies, are also 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 and emergent plants also help buffer the shoreline from wave action, offer shelter for insects and young fish, and provide shade for fish and frogs. These beds also provide food, cover and nesting material for waterfowl, marsh birds and muskrat. Floating-leaf and emergent plants are most often found in shallow water to depths of about 6 feet and may extend lake-ward onto mudflats and into adjacent wetlands.

Submerged plants have stems and leaves that primarily grow underwater but they may also form flowers, fruits and some leaves that emerge above or float on the water surface. Submerged plants are typically anchored to the lake bottom but some species do drift freely with the currents. This group includes non-flowering plants such as large algae, mosses, and fern-like plants, and flowering plants that may produce flowers above or below the water surface. Submerged plants may form low-growing mats or may grow several feet in the water column with leaf shapes that include broad ovals, long and grass-like, or finely dissected. Submerged plants 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.

Plant species richness is a term used to describe the total number of plant species present in a lake and it can be used to help describe the general health of the waterbody. In Minnesota, plant species richness can range from zero (un-vegetated lakes) to more than 40 species in a lake[5]. Species richness is generally higher in high clarity lakes than in turbid lakes and more species 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 species. Water quality changes that result in lower clarity may also result in the loss of some plant species, or a lower species 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 an historical "one-day" survey, it may be due to the more extensive sampling that occurs during current surveys. If fewer species are located during current surveys, it may indicate a true decline in the plant species richness of the lake.

Historic aquatic plant community

Previous lakewide, aquatic plant surveys of Lower Hay Lake were conducted in 1950, 1990, and 1995 (MnDNR Lake files). These surveys focused on the commonly occurring in-lake plants and recorded a total of 29 native aquatic plant species: 6 emergent, 2 floating-leaf, 2 free-floating, and 19 submerged species (Appendix 1). Submerged plants were the most commonly reported types and included species that are commonly found in many Crow Wing County lakes: coontail (*Ceratophyllum demersum*), northern watermilfoil (*Myriophyllum sibiricum*), flat-stem pondweed (*Potamogeton zosteriformis*), and muskgrass (*Chara* sp.). Waterlilies and several emergent plants were reported in some surveys but no major beds were documented.

Objectives

The purpose of this vegetation survey was to provide a quantitative description of the 2011 plant population of Lower Hay 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 species that occur in the lake
3. Estimate the abundance of each species
4. Develop distribution maps for the commonly occurring species

[5] These values are from a review of MNDNR lake vegetation surveys.

Methods

Lakewide vegetation survey

A lakewide vegetation survey was conducted on August 11, 18, 2011 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 65 meters (213 feet) apart. In the field, surveyors sampled sites where water depth was less than 31 feet. A total of 203 sites were surveyed including 183 sites within the 0-25 feet zone (Figure 5, Table 1).

Figure 5. 2011 vegetation survey sites on Lower Hay Lake.

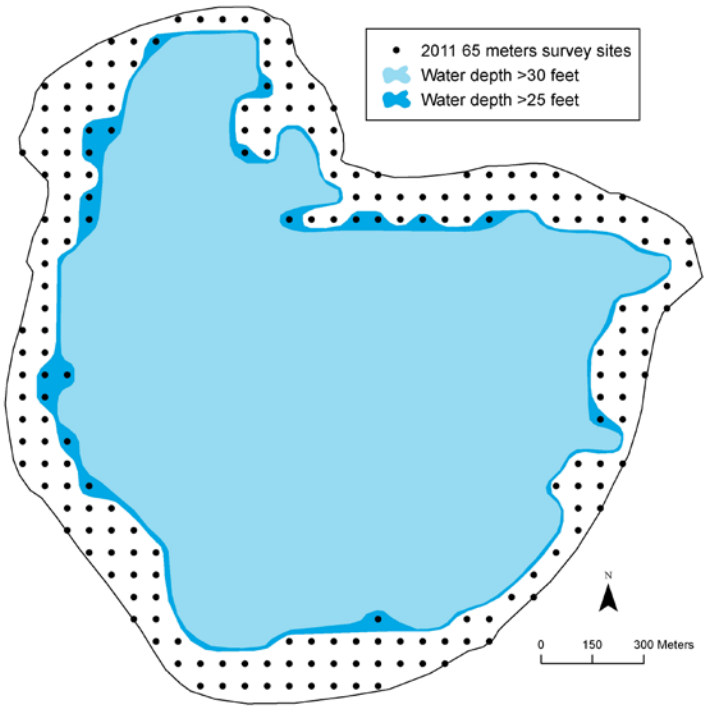


Table 1. Survey effort by depth interval.

Water depth (feet)	Number of sample sites
0 to 5	36
6 to 10	88
11 to 15	15
16 to 20	21
21 to 25	23
Total (0-25)	183
26 to 30	20
Total	203

Table 2. Substrate classes

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

The survey was conducted by boat and a GPS unit was used to navigate 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; this information was used for mapping purposes.

Plant sampling

Surveyors recorded all plant species 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 (Figure 6). 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 (2011).

Figure 6. Survey rake.

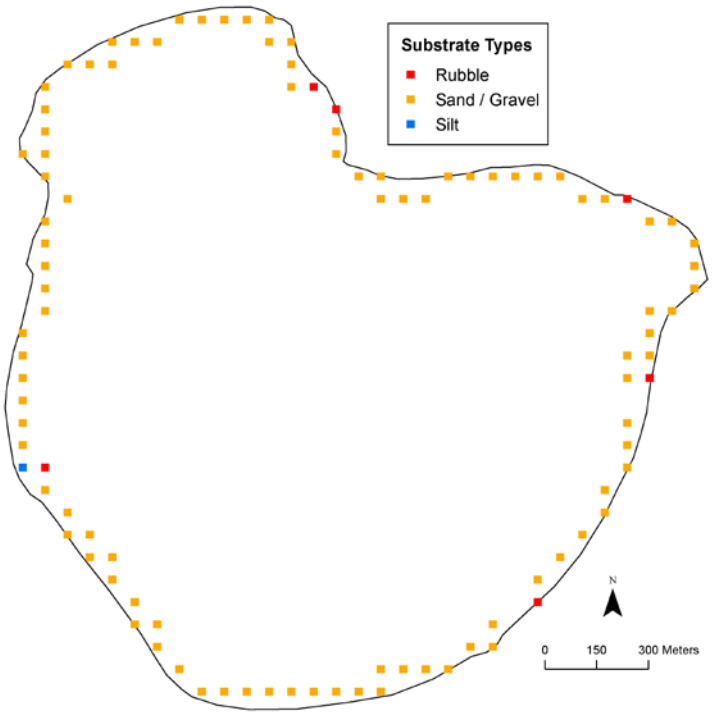
Frequency was calculated for the area from shore to 25 feet (the depth zone where plants were detected) and data were also separated into 5 feet increment depth zones for analysis (Table 1). Frequency estimates were also calculated for individual species and selected groups of species (example calculations shown in Appendix 2).

Results and Discussion

Shoal Substrates

The shoal substrates of Lower Hay Lake were primarily hard substrates of sand and gravel (Figure 7).

Figure 7. 2011 substrate on Lower Hay Lake.



Types of plants recorded

A total of 22 aquatic plant species (types) were recorded in Lower Hay Lake. No non-native aquatic plants were found in the lake. The plants found included 2 emergent, 1 free-floating, and 19 submerged plants (Table 3). Four of these species were recorded for the first time during the 2011 survey (Appendix 1). Ten species that were recorded in previous surveys were not found in 2011.

These included 2 submerged and one free-floating plant that were not historically common in the lake and may still be present in low numbers. Several emergent and floating-leaf plants (waterlilies) that were found in earlier surveys were not detected in 2011.

Table 3. Frequency of submerged aquatic plants in Lower Hay Lake, August, 2011.

Life Form		Common Name	Scientific Name	Frequency (% occurrence) 183 sites
Emergents[1]		Arum-leaved arrowhead	*Sagittaria cuneata*[a]	1
		Wild rice	*Zizania palustris*	1
SUBMERGED	Macroalgae	Muskgrass	*Chara* sp.	28
	Dissected-leaf rooted plants	Coontail	*Ceratophyllum demersum*	46
		Northern watermilfoil	*Myriophyllum sibiricum*	32
		Water marigold	*Bidens beckii*	10
		White-water buttercup	*Ranunculus aquatilis*	3
		Greater bladderwort	*Utricularia vulgaris*	1
	Small-leaf rooted plants	Bushy pondweed	*Najas flexilis*[b]	43
		Southern naiad	*Najas guadalupensis*[b]	
		Canada waterweed	*Elodea canadensis*	19
	Narrow-leaf pondweeds	Narrow-leaf pondweed group[c]	*Potamogeton friesii*	13
		Sago pondweed	*Stuckenia pectinata*	5
	Broad-leaf pondweeds	Clasping-leaf pondweed	*Potamogeton richardsonii*	10
		White-stem pondweed	*Potamogeton praelongus*	10
		Illinois pondweed	*Potamogeton illinoensis*	6
		Variable pondweed	*Potamogeton gramineus*	5
		Large-leaf pondweed	*Potamogeton amplifolius*	2
	Grass-leaf rooted plants	Flat-stem pondweed	*Potamogeton zosteriformis*	30
		Wild celery	*Vallisneria americana*	7
		Water star-grass	*Heteranthera dubia*	5
FREE-FLOATING		Star duckweed	*Lemna trisulca*	1

Frequency is the percent of sample sites in which a plant species occurred within the 0 to 25 ft water depth.

[1] includes only in-lake emergents and not wetland plants

The following taxonomic groupings were made because field identification to the species level was difficult or not possible:

[a] Most arrowhead plants that were found in the lake were not in flower or fruit and could not be identified to the species level. A few plants were positively identified as *Sagittaria cuneata*, but it is not known if that was the only species of arrowhead present.

[b] Bushy pondweed (*Najas flexilis*) and Southern naiad (*Najas guadalupensis*) were grouped together for analysis because field identification to the species level was difficult.

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

Distribution and richness of aquatic plants

Plants were found to a depth of 25 feet and in the 0-25 feet depth zone, 81% of the survey sites contained vegetation. Vegetation was most common in the 0-15 feet depth zone, where 96% of sites contained plants (Figure 8). Plant abundance declined with increasing water depth and in depths of 21-25 feet, only 4% of the sites were vegetated. No plants were found in the 26 to 30 feet depth zone.

The greatest number of plant species were found in shallow water, from 0 to 10 feet. Of the 22 species found in the lake, all were present in the 0 to 10 feet depth zone. Only 12 submerged species occurred in deeper water and only 4 of these occurred in depths greater than 15 feet (Figure 9).

Figure 8. Aquatic plant frequency vs. water depth.

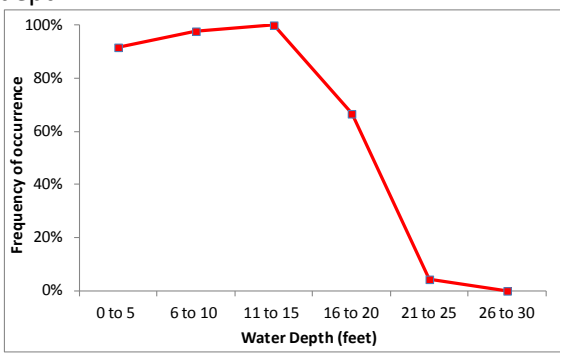
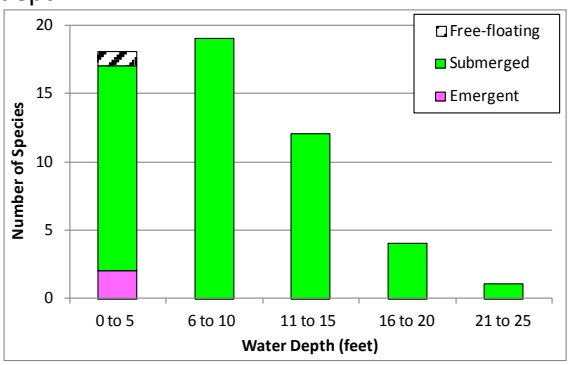


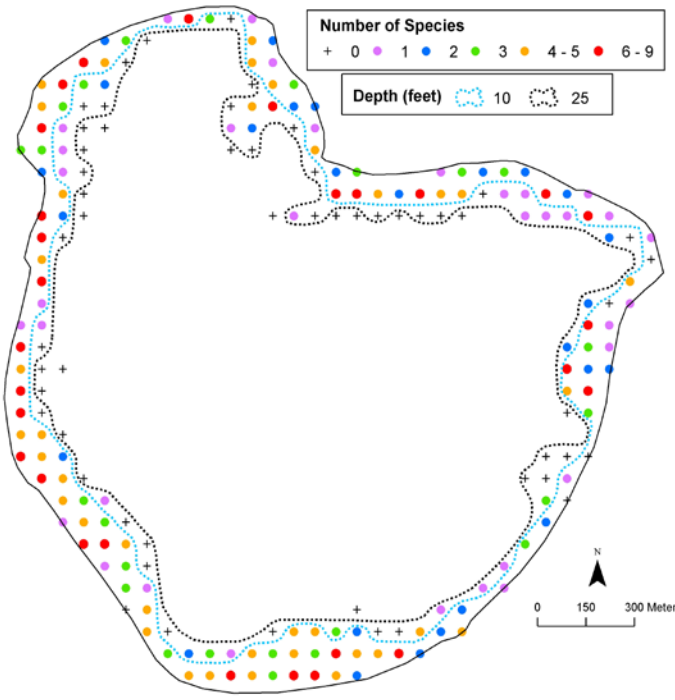
Figure 9. Number of plant species vs. water depth.



Plants were distributed around the entire shoreline but plant growth was restricted to the shallow zone (<25 feet) which extended about 150 meters lakeward (Figure 10).

The number of plant species found at each sample site ranged from 0 to 10 with a mean of 3 species per site. Sites of high species richness (6 or more species per site) often occurred in depths less than 10 feet, within the first 100 meters of shore (Figure 10).

Figure 10. Number of species per site, Lower Hay Lake 2011.



Emergent and floating-leaf plants

No beds of floating-leaf or emergent plants were found in the lake. Arum-leaved arrowhead (*Sagittaria cuneata*) and wild rice (*Zizania palustris*) were recorded during the survey but only scattered plants were found. Waterlilies, which were listed as present in the 1950 and 1995 surveys, were not documented during the 2011 survey and if they occur in the lake, they are present in low numbers.

Submerged aquatic plants

Of the 19 submerged species found in the lake, 5 were common (occurring in more than 20%[6] of the sample sites). The most frequently occurring species were coontail (46% occurrence), naiads (43%), northern watermilfoil (32%), flat-stem pondweed (30%), and muskgrass (28%). These species were also recorded in most previous surveys of the lake, indicating that they have historically been common in the lake.

All of these species were distributed throughout the vegetated zone of the lake (Figure 11) but they varied in their depth distributions (Figure 12). The species with the highest lakewide occurrence (coontail and naiads), were frequent in both shallow and deep water, while the other species were most frequent in depths of 10 feet and less (Figure 12).

Figure 11. Distribution of commonly occurring submerged plants in Lower Hay Lake, 2011.

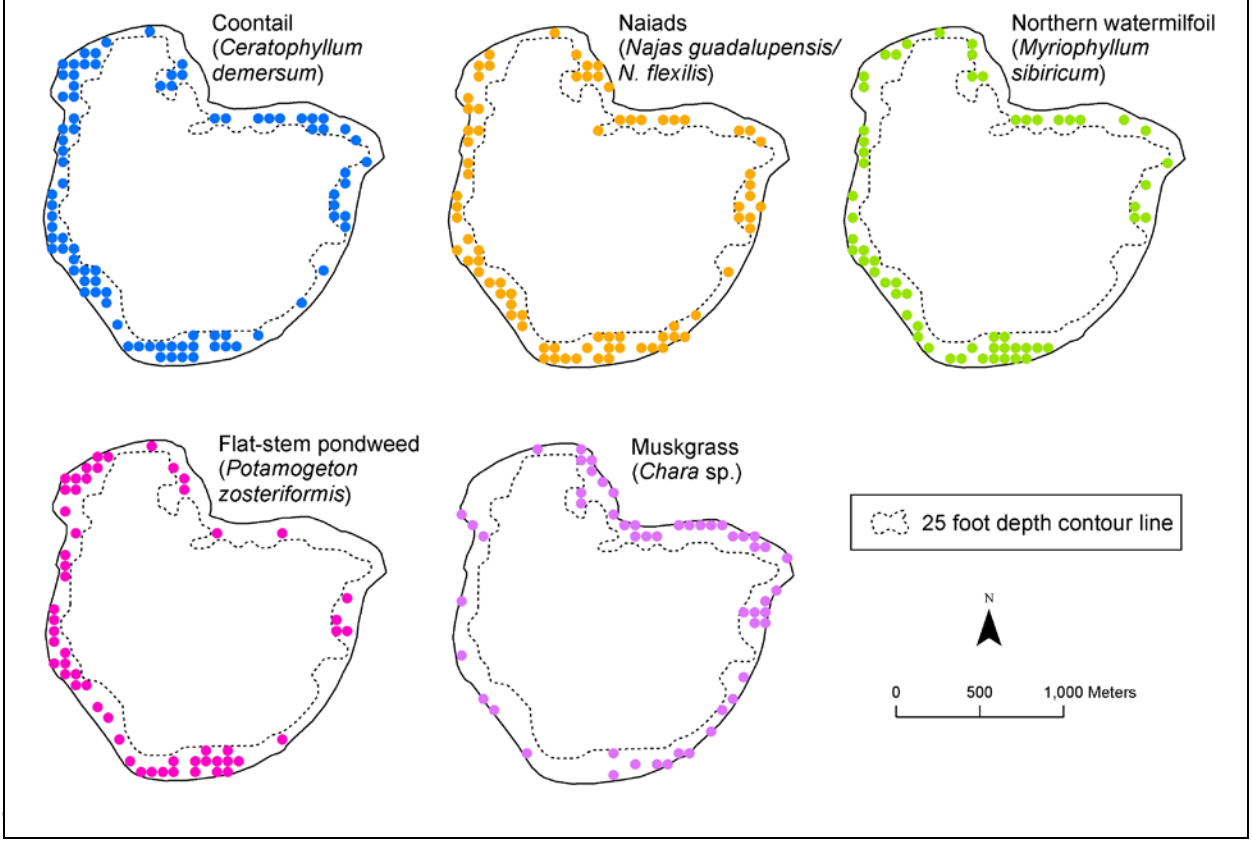
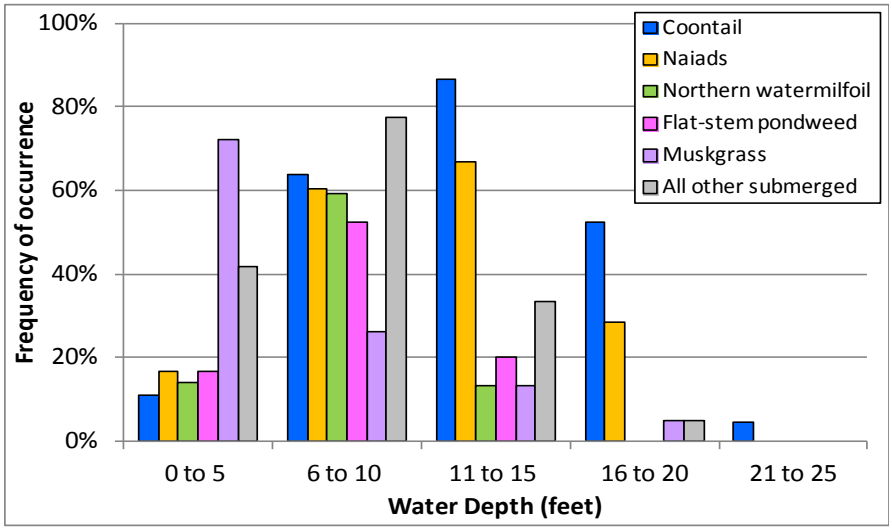


Figure 12. Common submerged plants at each water depth interval, Lower Hay Lake, 2011.



Coontail (*Ceratophyllum demersum*) was the most frequently occurring plant in Lower Hay Lake and occurred in 46% of the sites (Table 3). It was most often found in the 6-20 feet zone and was the only plant found in the 21-25 feet zone (Figure 12). Coontail (Figure 13) grows entirely submerged and its roots are only 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 (Nichols 1999). 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.

Figure 13. Coontail

Naiads (*Najas guadalupensis* and *N. flexilis*) were the second-most commonly found submerged plant group in Lower Hay Lake and were found in 43% of the sites (Table 3). Like coontail, this plant was most frequent in the 6-20 feet zone (Figure 12). Two species of naiads were found in Lower Hay Lake and since they can be difficult to distinguish, they were grouped together for analyses. Southern naiad (*Najas guadalupensis*; Figure 14) can sprout from seed or overwinter as a perennial plant. Bushy pondweed is an annual plant that grows each year from seed. Both species grow entirely submerged and produce seeds and foliage that provide important duck food and good fish cover.

Figure 14. Southern naiad.
Photo: Kerry Dressler ©1996 Univ. of Florida Center for Aquatic Plants

Northern watermilfoil (*Myriophyllum sibiricum*) was found in 32% of all sites (Table 3). It occurred to a depth of 13 feet and was most common in the 6-10 feet depth zone (Figure 12). This native[7], submerged plant is a rooted perennial with finely dissected leaves (Figure 15). Particularly in depths less than 10 feet, this plant may reach the water surface and its flower stalk will extend above the water surface. It spreads primarily by stem fragments and over-winters by hardy rootstalks and winter buds. Northern watermilfoil is not tolerant of turbidity (Nichols 1999) and grows best in clear water lakes.

Figure 15. Northern watermilfoil

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

Flat-stem pondweed (*Potamogeton zosteriformis*) is one of 8 native pondweeds found in Lower Hay Lake and was the most common pondweed, occurring with a frequency of 30% (Table 3). Similar to northern watermilfoil, it was most frequent in the 6-10 feet depth zone (Figure 12). 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 is named for its flattened, grass-like leaves (Figure 16).

Figure 16. Flat-stem pondweed.

Muskgrass (*Chara* sp.) occurred in 28% of the Lower Hay Lake survey sites (Table 3) and was the most frequent plant in the 0-5 feet depth zone where it occurred in 72% of the sites (Figure 12). Muskgrass is a freshwater macroalgae[8] 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 (Figure 17). Muskgrass is adapted to variety of substrates and is often the first species to colonize open

Figure 17. Muskgrass

[7] For information on how to distinguish the native northern watermilfoil from the non-native, Eurasian watermilfoil, click here: identification.

[8] Algae are primitive forms of plants that do not form true roots, flowers or vascular tissue. They range in size from single cell to giant seaweed. Freshwater algae that live in Minnesota lakes include tiny, free-floating planktonic algae, filamentous algae and macroalgae. Macroalgae often resemble rooted plants and provide similar habitat and water quality benefits and were therefore included in this survey.

areas of lake bottom where it can act as a sediment stabilizer. Beds of muskgrass can provide important fish spawning and nesting habitat.

Other submerged species found in the lake were mostly restricted to depths of 15 feet and less and most species reached their maximum occurrence in depths of 10 feet and less. The plant community included a diversity of growth forms including broad-leaf "cabbage" plants, grass-leaved plants and finely-divided leaf plants.

Factors influencing 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 2011 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. In general, factors that may lead to change in aquatic plant communities include:

- Change in water clarity

  If water clarity in Lower Hay 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.

- Snow and ice 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, submerged plants may increase in abundance or there may be a shift in species dominance.

- 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 assortment of underwater plant types found in Lower Hay Lake provides a habitat complexity that can be utilized by a variety of fish and wildlife and also provides a variety of other lake benefits. The lake has very limited growth of emergent and floating-leaf plants which would provide another habitat structural layer. Protecting existing native aquatic plant beds will help maintain critical fish and wildlife habitat and the general water quality of the lake.

(Click here for more information on: value of aquatic plants).

Northern pike in submerged aquatic plant bed.

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Appendix 1. Historical aquatic and wetland plants of Lower Hay Lake

Blue highlight indicates species that were common (occurring in at least 20% of sites) in 2011.

Submerged plants

Common Name	Scientific Name	1950	1990	1995	2011
Water marigold	*Bidens beckii*				X
Coontail	*Ceratophyllum demersum*	X	X	[a,b]X	X
Muskgrass	*Chara* sp.	X	X	[a]X	X
Needlegrass	*Eleocharis acicularis*			[b]X	
Canada waterweed	*Elodea canadensis*		X	[a,b]X	X
Water star-grass	*Heteranthera dubia*				X
Northern watermilfoil	*Myriophyllum sibiricum*	X	X	[a]X	X
Bushy pondweed	*Najas flexilis*			[a]X	X
Southern naiad	*Najas guadalupensis*				
Large-leaf pondweed	*Potamogeton amplifolius*		X	[a]X	X
Narrow-leaf pondweed group[1]	*Potamogeton* sp.			[a]X	
	Potamogeton friesii				X
	Potamogeton strictifolius			[b]X	
Variable pondweed	*Potamogeton gramineus*	x		[a,b]X	X
Illinois pondweed	*Potamogeton illinoensis*			[b]X	X
White-stem pondweed	*Potamogeton praelongus*		X	[a]X	X
Clasping leaf pondweed	*Potamogeton richardsonii*		X	[a,b]X	X
Robbin's pondweed	*Potamogeton robbinsii*		X		
Flat-stem pondweed	*Potamogeton zosteriformis*	X	X	[a,b]X	X
White water buttercup	*Ranunculus aquatilis*			[b]X	X
Sago pondweed	*Stuckenia pectinata*	X		[a,b]X	X
Greater bladderwort	*Utricularia vulgaris*			[a,b]X	X
Wild celery	*Vallisneria americana*		X	[a]X	X
	Total	6	10	18	18

Floating-leaved plants

Common Name	Scientific Name	1950	1990	1995	2011
White waterlily	*Nymphaea odorata*	X		[b]X	
Yellow waterlily	*Nuphar variegata*	X			
	Total	2	0	1	0

Free-floating plants

Common Name	Scientific Name	1950	1990	1995	2011
Lesser duckweed	*Lemna* sp.			[a]X	
Star duckweed	*Lemna trisulca*			[a,b]X	X
	Total	0	0	2	1

Appendix 1 (continued)

Emergent plants

Common Name	Scientific Name	1950	1990	1995	2011
Spikerush	*Eleocharis* sp.			[a]X	
Horsetail	*Equisetum fluviatile*			[b]X	
Arrowhead	*Sagittaria cuneata*			*[a]X	*X
Bulrush[2]	*Schoenoplectus* spp.			[a]X	
Wild rice	*Zizania palustris*				X
Broad-leaved cattail	*Typha latifolia*	X	X		
Narrow-leaved cattail[3]	*Typha angustifolia*	X			
	Total	2	1	4	2

*X = Plant was identified only to genus level.

[1] narrow-leaf pondweed (*Potamogeton* sp.). This may have been one of several different *Potamogeton* species that have narrow, submerged leaves. In 2011, one narrow-leaved pondweed, *Potamogeton friesii*, was positively identified but it is not known whether all narrow-leaved pondweeds found in that survey were *P. friesii*. Plants identified as *P. friesii,* or *Potamogeton* sp. was grouped together for analysis.

[2] a species of bulrush (*Schoenoplectus* sp.) was used to record bulrush plants that were hard-stem bulrush (*Schoenoplectus acutus*), soft-stem bulrush (*S. tabernaemontani*) or the hybrid.

[3] Narrow-leaf cattail was identified in survey but it is not known whether this included narrow-leaf cattail (*Typha angustifolia*) and/or the hybrid of narrow-leaf and broad-leaf cattail (*Typha x glauca*).

Sources:
1950 (July 10-12): Maloney, Division of Game and Fish
1990 (June 18-21): Wayne Mueller (Crew Leader); DNR Fisheries Survey
1995[a] (June 19): MnDNR Fisheries Survey
1995[b] (July 1): Karen Myhre, MnDNR Division of Ecological and Water Resources, MN County Biological Survey Program, survey of site along southern shore near public access.
2011 (August): Simon, Perleberg, Eininger, Dickson, MnDNR Division of Ecological and Water Resources

Appendix 2: Calculation of plant abundance

Frequency of occurrence was calculated as the percent of sites, within a specific depth zone, where a plant species was detected. Unless otherwise noted, frequency values were calculated for the 0-25 feet depth zone.

Example:

In Lower Hay Lake there were 183 sample sites in the 0-25 feet depth zone.
Coontail occurred in 84 sites.
Frequency of Coontail in 0-25 feet zone = (84/183)*100 = 46%