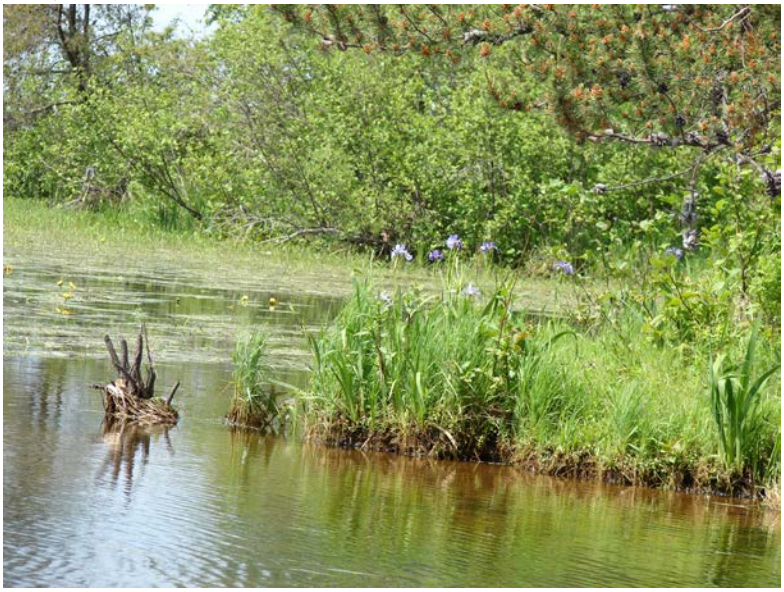
Aquatic vegetation of Arrowhead Lake

June, August, 2011

Arrowhead Lake, ID# 18-0366-00

Crow Wing County, Minnesota

Blue Flag Iris in channel between Arrowhead and Whitefish lakes, June, 2011.



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Survey Context

This lake vegetation survey of Arrowhead 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, Bertha, 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

Arrowhead 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 mapping emergent and floating-leaf plant beds and sampling plant occurrence and diversity at 245 sites.

The lake contains a high diversity of native plants. Since 1938, a total of 39 aquatic plant species (types) have been recorded and in 2011, 32 species were found including 6 emergent, 4 floating-leaved, 2 free-floating, and 20 submerged plants. No non-native aquatic plants were found in the lake.

Arrowhead Lake is shallow with a maximum depth of 12-13 feet and plant growth occurred across the entire lake with 95% of all survey sites containing plants.

Wild rice (*Zizania palustris*) dominated the plant community and covered 124 acres, or about 1/3 of the lake surface. Waterlilies (*Nymphaea odorata* and *Nuphar variegata*) and other emergent plants occurred adjacent to and scattered within these wild rice beds.

Many of the submerged species located during historical surveys are still relatively common in the lake. Coontail (*Ceratophyllum demersum*) occurred in 77% of the sites, followed by star duckweed (*Lemna trisulca*) (42%), southern naiad (*Najas guadalupensis*) (40%), flat-stem pondweed (*Potamogeton zosteriformis*) (38%), and Canada waterweed (*Elodea canadensis*) (35%).

The greatest diversity of plants occurred in the near-shore zone where water depths were 10 feet and less. Fifty-six percent of the plant species were restricted to this shallow 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

Arrowhead 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. Arrowhead Lake, Crow Wing County, Minnesota.

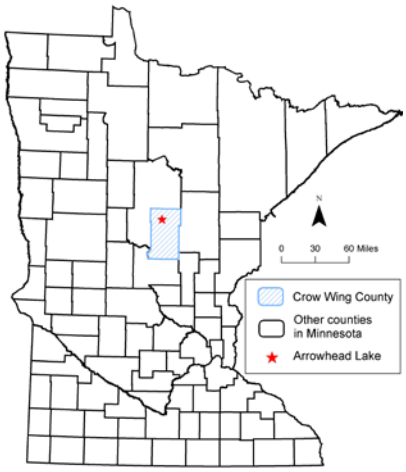
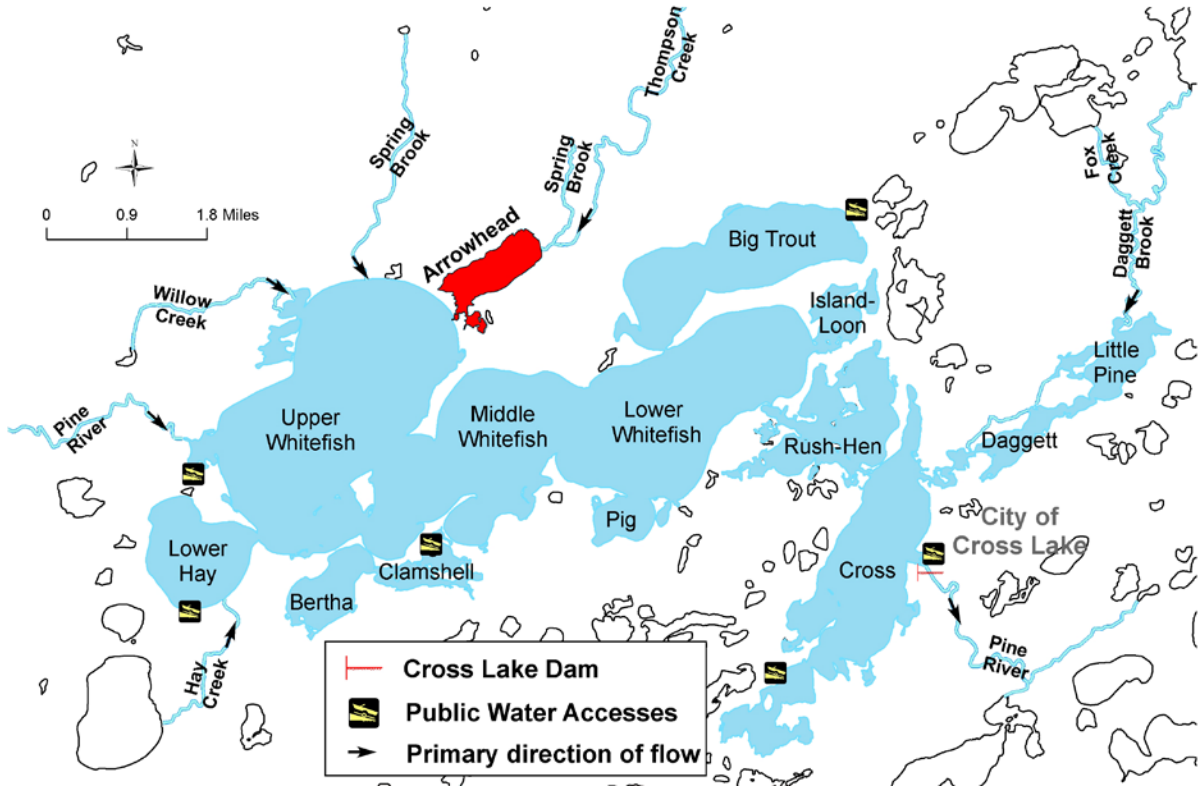


Figure 2. Location of Arrowhead Lake within the Whitefish Chain of Lakes.



[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.

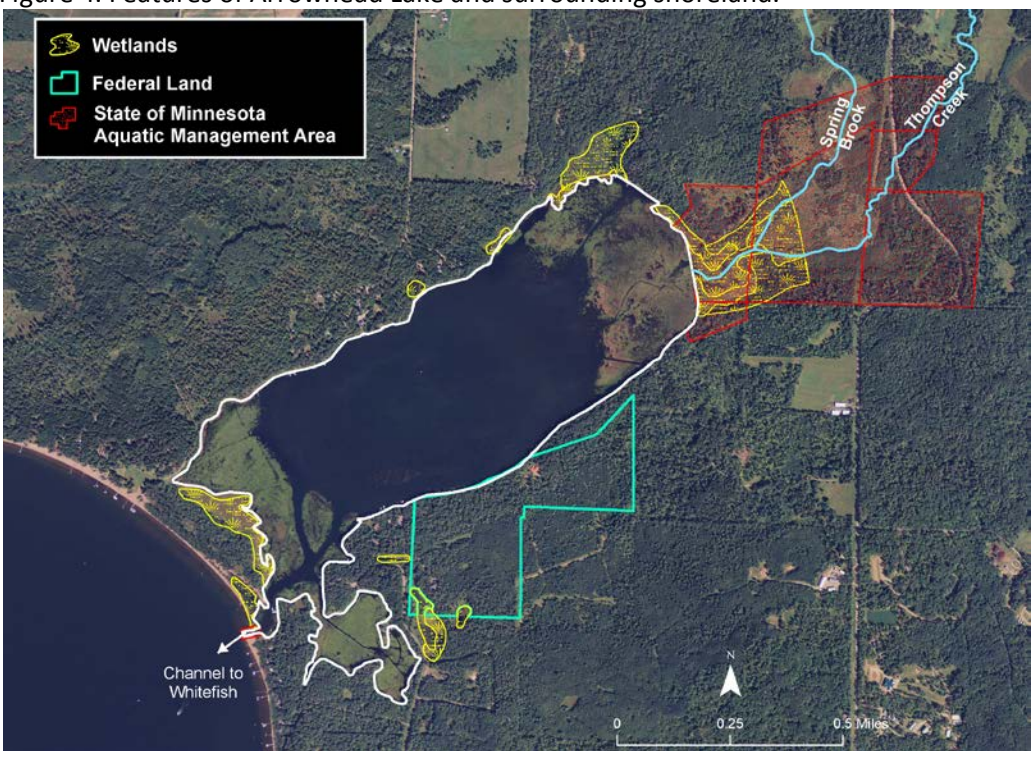
Lake Characteristics

Arrowhead Lake occurs on the north end of the Whitefish Chain and receives flow from Thompson Creek and Spring Brook. A permanent connection between Arrowhead Lake and the Whitefish Chain did not occur until 1961 when an intermittent stream between Arrowhead and Upper Whitefish was dredged (Figure 3). The channel was intended to allow spawning fish passage into Arrowhead and to prevent winter fish kill in Arrowhead (MNDNR Lake Files). Boaters use this channel to navigate between the lakes.

Figure 3. Channel between Arrowhead and Whitefish lakes.

The lake receives its name because its main basin roughly resembles an arrow pointed to the northeast (Figure 4). A 19 acre bay on the southeast shore is connected to the main basin by a narrow channel. Arrowhead is one of the smaller lakes in the chain, with a surface area of 308 acres and a total shoreline length of about 4 miles. The entire lake is shallow with a maximum depth of 13 feet.

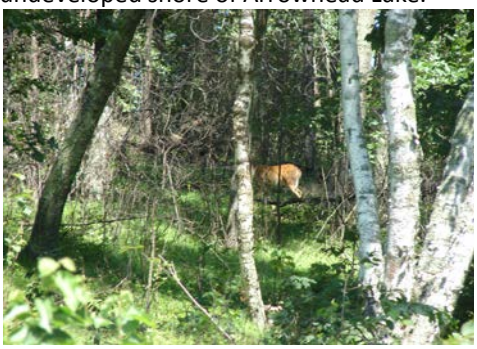
Figure 4. Features of Arrowhead Lake and surrounding shoreland.



Arrowhead Lake's shoreland is mostly forested (Figure 5) with wetlands bordering the northeast and southwest ends (Figure 4). Shoreland ownership is a mix of private, federal, and

state and development is low with about 30 residential homes. State land on the northeast shore has been designated as an Aquatic Management Area (AMA[2]).

Figure 5. Whitetail deer on forested undeveloped shore of Arrowhead Lake.

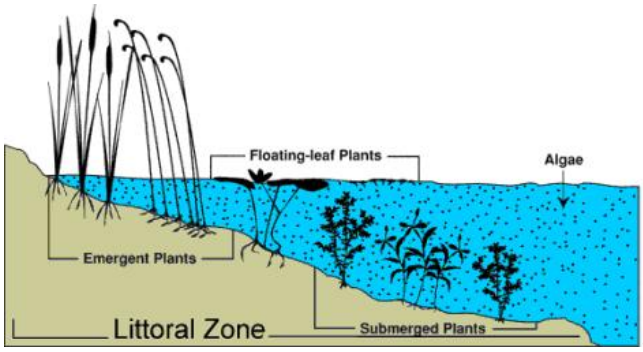


Arrowhead Lake is characterized as eutrophic, based on phosphorus (nutrients), chlorophyll a (algae concentration) and Secchi[3] depth (transparency). Transparency in the lake stays relatively consistent throughout the summer and in 2010, mean summer[4] water clarity was 9 feet (MPCA 2011). Based on Secchi disk measurements alone, aquatic plants in Arrowhead Lake have the potential to reach depths of at least 13 feet[5], meaning they could grow across the entire basin.

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 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.

Figure 6. Forms of aquatic plants found in Minnesota lakes.



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 6), often favor certain water depth zones around the lake but overlap occurs with one life form grading

[2] In 1992, the Minnesota Legislature created a new public land classification called Aquatic Management Areas (AMAs). Modeled after Wildlife Management Areas, AMAs are purchased from willing sellers to protect the environmentally vital shoreline and shallow water edge of lakes, streams, and rivers. Because these areas are critical shoreline habitat for fish spawning and nurseries, they are protected from development.

[3] 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.

[4] June through September

[5] 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.

into another. Each life form group has unique functions and values.

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[6]. 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

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

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 Arrowhead Lake were conducted in 1942, 1950, 1960, 1990, and 1995 (MnDNR Lake files). These surveys focused on the commonly occurring in-lake plants and recorded a total of 26 aquatic plant species: 7 emergent, 2 floating-leaf, 2 free-floating, and 15 submerged species (Appendix 1). Plants that were reported in previous surveys included native plants that are commonly found in many Crow Wing County lakes: wild rice (*Zizania palustris*), bulrush (*Schoenoplectus* spp.), waterlilies (*Nymphaea odorata* and *Nuphar variegata*), coontail (*Ceratophyllum demersum*), northern watermilfoil (*Myriophyllum sibiricum*), Canada waterweed (*Elodea canadensis*), star duckweed (*Lemna trisulca*), and flat-stem pondweed (*Potamogeton zosteriformis*). Non-native aquatic plants have not been documented in the lake.

Objectives

The purpose of this vegetation survey was to provide a quantitative description of the 2011 plant population of Arrowhead 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

Methods

Mapping floating-leaf and emergent vegetation beds

Mapping focused on plant beds 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). Draft maps of floating-leaf and emergent plant beds were created prior to field surveys using 2010 Farm Service Administrative (FSA) true color aerial photographs. Field surveys were conducted July 21, 2011 to map plants like bulrush (*Schoenoplectus* spp.), which are difficult to identify from aerial photos, and to verify photo-interpretation of other plant beds. Surveyors mapped emergent and floating-leaf plant beds in the field by motoring or wading around the perimeter of each bed 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 beds were classified by the dominant species or species-group.

Lakewide vegetation survey

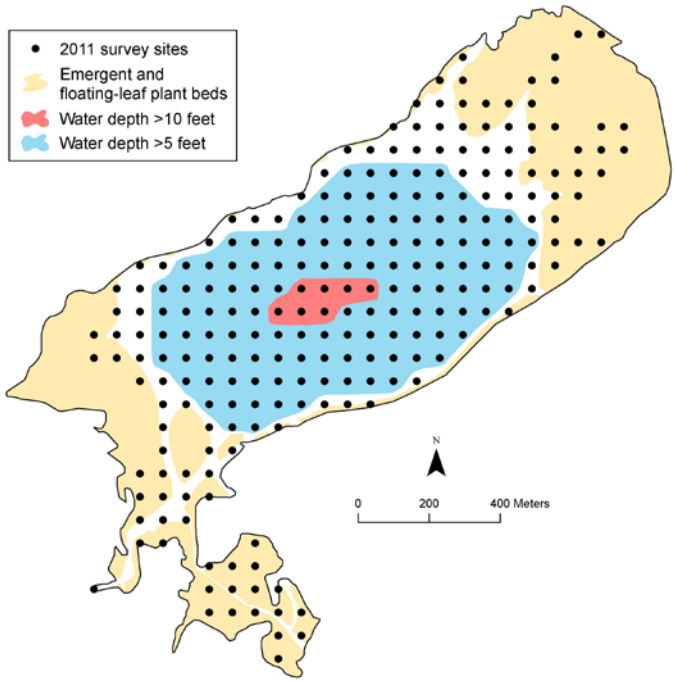
A lakewide vegetation survey was conducted on June 14, August 10, 25, 2011 using a point-intercept survey method (Madsen 1999, MnDNR 2009). Survey waypoints were created using a GIS computer program and downloaded into a handheld GPS unit. Survey points were placed across the entire lake and spaced 65 meters (213 feet) apart.

Table 1. Survey effort by depth interval.

Water depth (feet)	Number of sample sites
0 to 5	119
6 to 10	119
11 to 12	7
Total	245

A total of 245 sites were surveyed (Table 1, Figure 7). Sample sites in the southeast bay were sampled on June 14, 2011; these sites were surveyed in early summer because by late summer wild rice growth limits boat navigation into the bay. The main lake was surveyed on August 10 and 25, 2011. Some sites in shallow areas of the northeast and southeast shores were not surveyed due to abundant wild rice growth.

Figure 7. 2011 vegetation survey sites on Arrowhead Lake.



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.

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 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 8). 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 8. Survey rake.

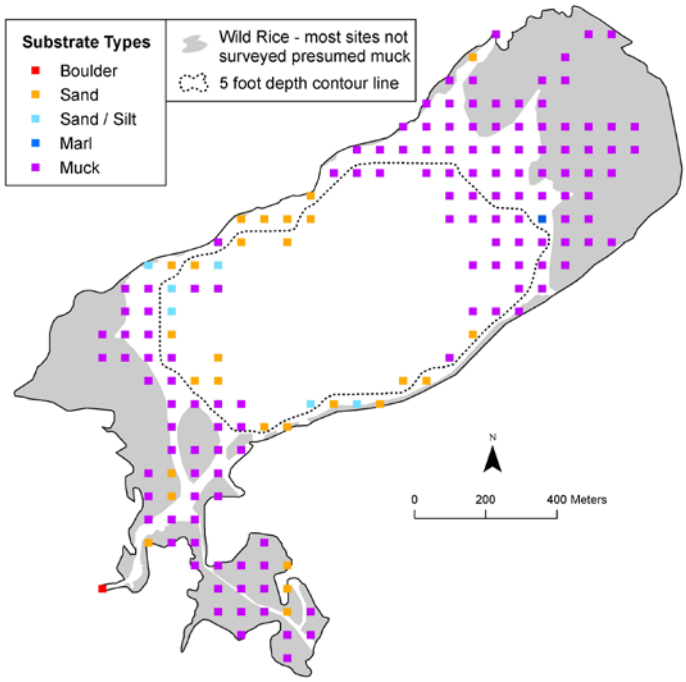
Frequency was calculated for the area from shore to 12 feet (the depth zone where plants were detected) and data were also separated into 5 feet increment depth zones for analysis (Table 1). Frequency estimates were also calculated for individual species and selected groups of species (example calculations shown in Appendix 2).

Results and Discussion

Shoal Substrates

The shoal substrates of Arrowhead Lake were primarily softer substrates of muck and silt. Substrate was not sampled within the extensive wild rice beds but these areas are presumed to be mucky. Hard substrates of sand or gravel occurred on portions of some shores (Figure 9).

Figure 9. 2011 shoal substrates on Arrowhead Lake.



Types of plants recorded

A total of 32 native aquatic plant species (types) were recorded in Arrowhead Lake in 2011. The plants found included 6 emergent, 4 floating-leaved, 2 free-floating, and 20 submerged plants (Table 3). Twelve of these species were recorded for the first time during the 2011 survey (Appendix 1). No non-native aquatic plants were found in the lake. Six species that were previously recorded in the lake were not detected in 2011 and may still occur in the lake but at low numbers.

Table 3. Frequency of submerged aquatic plants in Arrowhead Lake, June, August, 2011.

Life Form		Common Name	Scientific Name	Frequency (% occurrence) 245 sites
EMERGENT[1]		Wild rice	*Zizania palustris*	16
		Stiff wapato	*Sagittaria rigida*[a]	P
		Bulrush	*Schoenoplectus* sp.[b]	P
		Eastern burreed	*Sparganium americanum*	P
		Giant burreed	*Sparganium eurycarpum*	P
		Narrow-leaved cattail	*Typha* sp.[c]	P
FLOATING-LEAVED		White waterlily	*Nymphaea odorata*	9
		Yellow waterlily	*Nuphar variegata*	6
		Watershield	*Brasenia schreberi*	1
		Floating-leaf pondweed	*Potamogeton natans*	1
SUBMERGED	Macroalgae	Muskgrass	*Chara* sp.	5
	Moss	Watermoss	*Not identified to genus*	<1
	Dissected-leaf rooted plants	Coontail	*Ceratophyllum demersum*	77
		Northern watermilfoil	*Myriophyllum sibiricum*	4
		Water marigold	*Bidens beckii*	1
		White-water buttercup	*Ranunculus aquatilis*	1
		Greater bladderwort	*Utricularia vulgaris*	4
		Lesser bladderwort	*Utricularia minor*	P
		Flat-leaved bladderwort	*Utricularia intermedia*	<1
	Small-leaf rooted plants	Southern naiad	*Najas guadalupensis*[d]	40
		Canada waterweed	*Elodea canadensis*	35
	Narrow-leaf pondweeds	Narrow-leaf pondweed group[e]	*Potamogeton* sp.	1
		Sago pondweed	*Stuckenia pectinata*	P
	Broad-leaf pondweeds	Clasping-leaf pondweed	*Potamogeton richardsonii*	4
		White-stem pondweed	*Potamogeton praelongus*	2
		Large-leaf pondweed	*Potamogeton amplifolius*	<1
	Grass-leaf rooted plants	Flat-stem pondweed	*Potamogeton zosteriformis*	38
		Wild celery	*Vallisneria americana*	1
		Water star-grass	*Heteranthera dubia*	<1
		Ribbon-leaf pondweed	*Potamogeton epihydrus*	P
FREE-FLOATING		Star duckweed	*Lemna trisulca*	42
		Greater duckweed	*Spirodela polyrhiza*	1

Frequency is the percent of sample sites in which a plant species occurred within the 0 to 12 ft water depth.

P=Present in lake but did not occur in any sample sites

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

Table 3 (continued). Frequency of submerged aquatic plants in Arrowhead Lake, June, August, 2011.

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 rigida*, but it is not known if that was the only species of arrowhead present.

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

[c]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*).

[d]Southern naiad (*Najas guadalupensis*) was positively identified in the lake. It is possible that a similar, native species, Bushy pondweed (*Najas flexilis*) was also present in the lake. Both species were identified in other lakes in the Whitefish Chain but it can be difficult to distinguish these species.

[e]Several species of narrow-leaf pondweeds were identified in other lakes in the Whitefish Chain. Species in this group can be difficult to identify if flowers or fruits are not present. At least on narrow-leaf pondweed species was present in Arrowhead Lake but it could not be identified to the species level.

Distribution of aquatic plants

Plants were found to a depth of 11 feet and 95% of all survey sites (95% of the lake basin) contained vegetation. Plant occurrence was highest in depths of 10 feet and less and in deeper water about 50% of the sites contained plants (Figure 10). The greatest number of plant species was found in shallow water, from 0-5 feet (Figure 11). Only 3 species were found in the 11-12 feet depth zone.

Figure 10. Aquatic plant frequency vs. water depth.

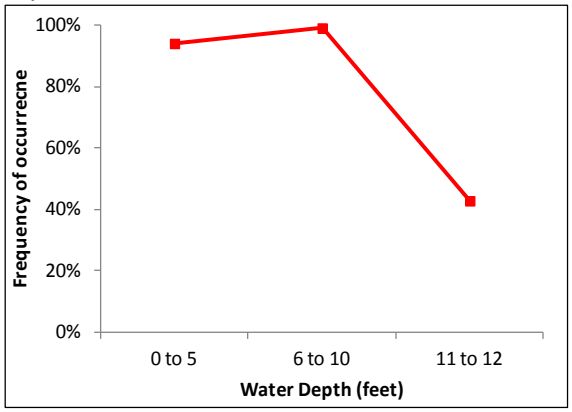
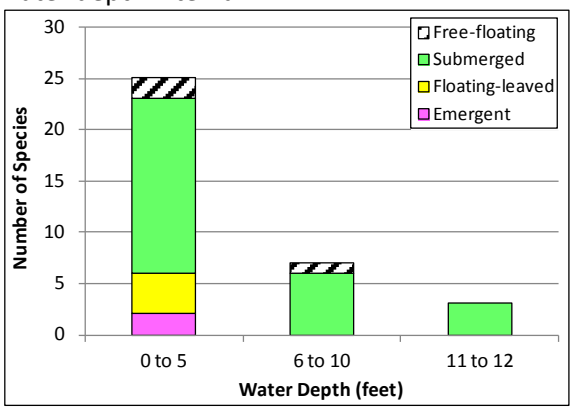
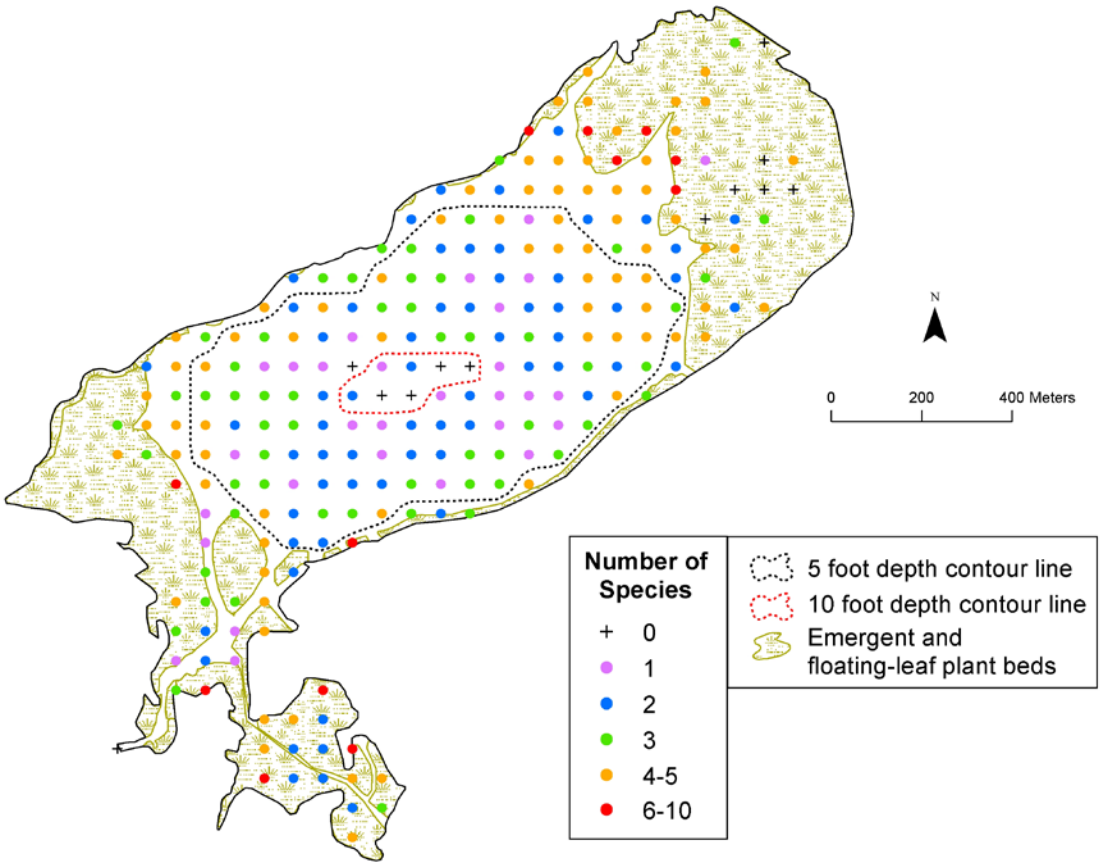


Figure 11. Number of plant types found at each water depth interval.



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 6 feet and included sites where emergent, floating-leaf, and submerged plants co-occurred (Figure 12).

Figure 12. Number of plant species per site, Arrowhead Lake 2011.



Emergent and Floating-leaf Plant Beds

Approximately 131 acres of emergent and floating-leaf plant beds were mapped in Arrowhead Lake and most of these plant beds occurred on the northeast and southwest shores (Figure 13).

Wild rice (*Zizania palustris*) was the most frequently occurring emergent plant and coved 124 acres, or about 1/3 of the lake's surface. The largest beds occurred on the northeast and southwest ends of the lake (Figure 13, 14). Wild rice dominated these stands but co-occurred with waterlilies. Wild rice 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 (Figure 15) before becoming fully emergent (Figure 16). 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).

Figure 13. Emergent and floating-leaf plant beds, Arrowhead Lake 2011.

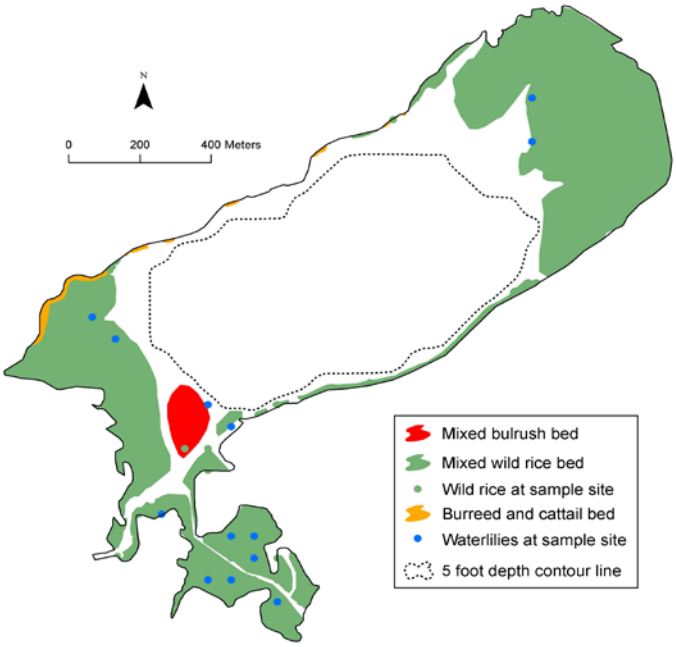
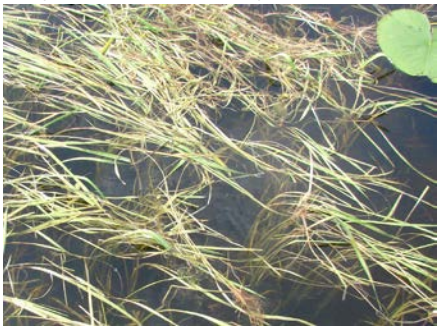


Figure 14. Wild rice bed on southwest shore of Arrowhead Lake

Figure 15. Floating-leaf stage of wild rice, Arrowhead Lake , June 2011



A 4-acre bed of mixed bulrush occurred on the southwest end of the lake (Figure 13). This stand was dominated by Bulrush (*Schoenoplectus* spp.) with waterlilies and wild rice scattered within the bed. Bulrushes are emergent, perennial plants that are 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 humans, motorboat activity and excess herbivory. Restoration of these plant beds can be very difficult, making established beds particularly unique and valuable.

Figure 16. Emergent form of wild rice

Narrow bands of other emergent plants occurred along the northwest shore (Figure 13) and included mixtures of cattails (*Typha* sp.), burreed (*Sparganium* spp.), and arrowhead (*Sagittaria* spp.). Floating-leaf plants such as white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*), watershield (*Brasenia schreberi*), and floating-

leaf pondweed (*Potamogeton natans*) were found primarily mixed in with wild rice in the southeast bay (Figure 17) and intermixed within other wild rice and bulrush beds.

Figure 17. Waterlilies in the southeast bay of Arrowhead Lake, 2011

Emergent and floating-leaf plants provide shade and shelter for fish, frogs, and invertebrates. The flowers produce seeds that are eaten by waterfowl and the rhizomes are a food source for muskrats and deer (Borman et al. 2001). The extensive root network of these plants helps to stabilize shorelines. These plants are particularly susceptible to destruction by direct cutting by humans, motorboat activity and excess herbivory. In shallow water, they may spread by underground rhizomes but restoration of emergent and floating-leaf plant beds can be very difficult, making established beds particularly unique and valuable.

Submerged aquatic plants

Submerged plants occurred at 90% of all sample sites and were found to a maximum depth of 11 feet. Five species were common (occurring in more than 30% of the sample sites): coontail (*Ceratophyllum demersum*), star duckweed (*Lemna trisulca*), southern naiad (*Najas guadalupensis*), flat-stem pondweed (*Potamogeton zosteriformis*), and Canada waterweed (*Elodea canadensis*). These species were also recorded in most previous surveys of the lake, indicating that they have historically been common in the lake. In 2011, each of these plants occurred around the entire perimeter of the lake but differed in their depth distribution (Figure 18, 19).

Figure 18. Common submerged plants at each water depth interval, Arrowhead Lake, 2011.

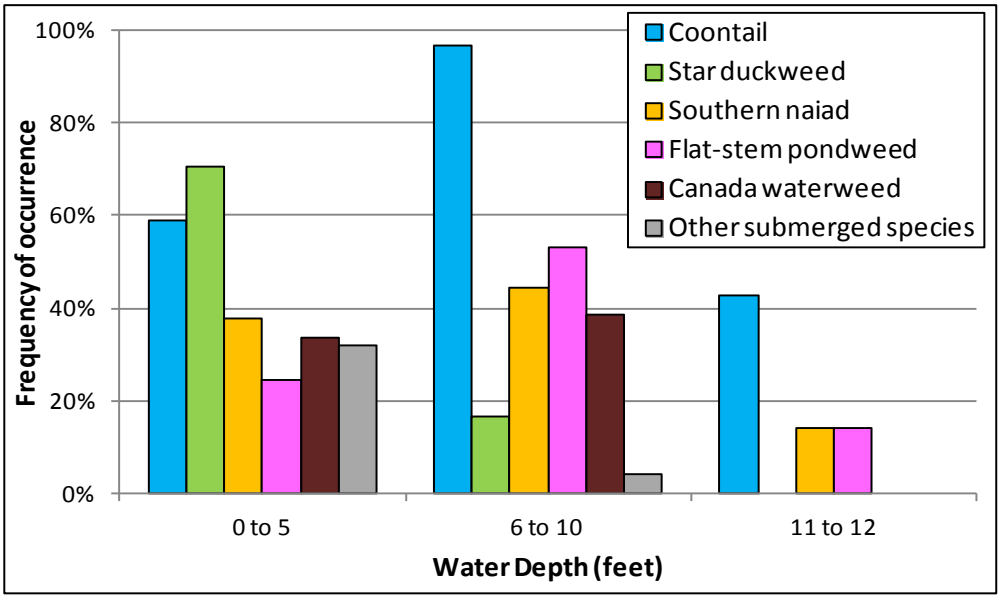
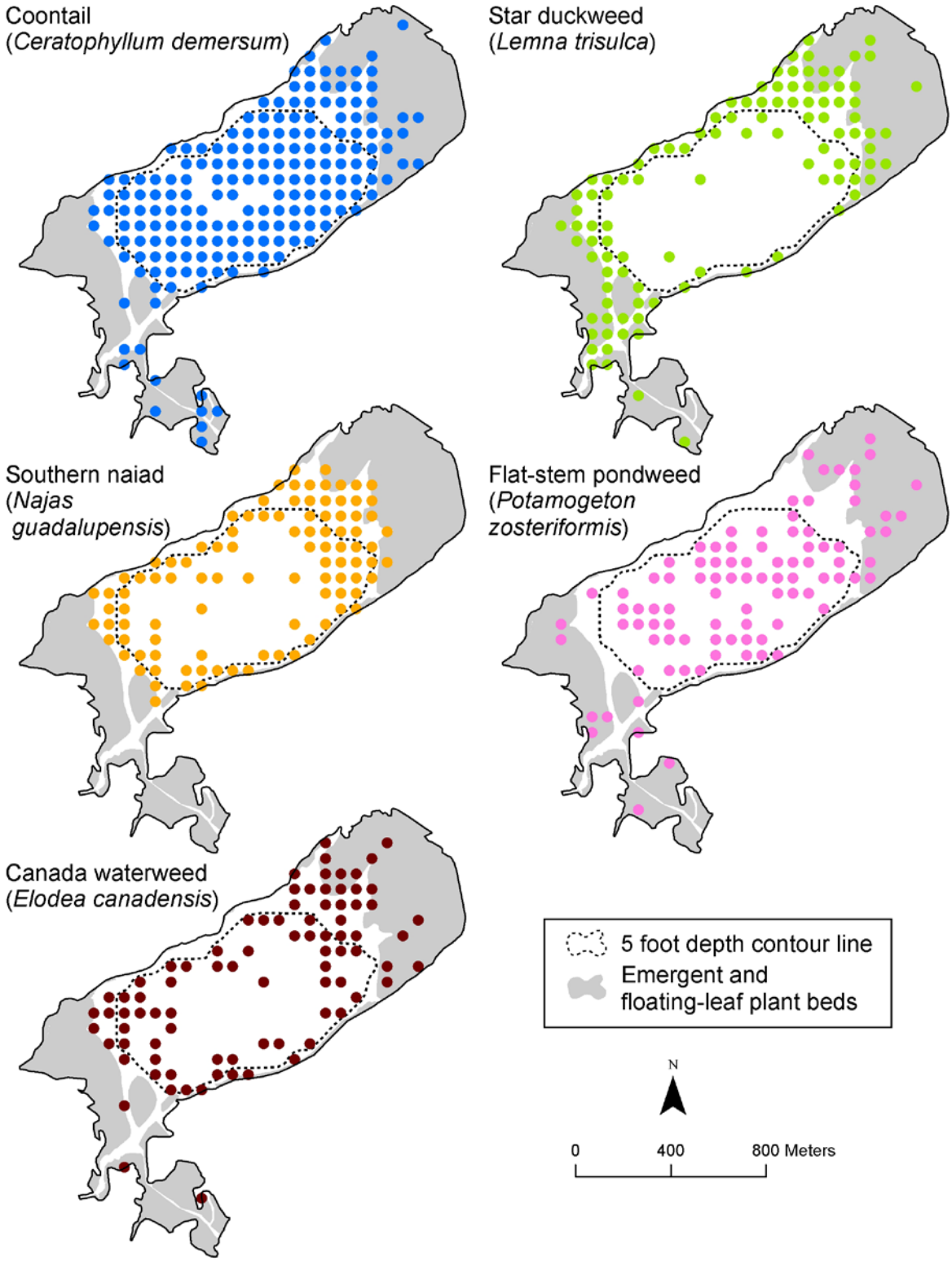


Figure 19. Distribution of commonly occurring submerged plants in Arrowhead Lake, 2011.



Coontail (*Ceratophyllum demersum*) was the most common submerged plant in Arrowhead Lake and was found in 77% of the sample sites (Table 3). It was common at all depth zones and dominated the 6-10 feet zone where it occurred in 97% of the sites (Figure 18). It was widespread throughout the main lake and was also present in the southeast bay (Figure 19).

Figure 20. Coontail

Coontail (Figure 20) 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.

Star duckweed (*Lemna trisulca*) was present in 42% of the Arrowhead Lake survey sites (Table 3). It was most frequent in water depths less than 6 feet (Figure 18) and was commonly found except on the south shore where water depths increase (Figure 19). Star duckweed (Figure 21) 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 is named for its star-shaped leaves.

Figure 21. Star duckweed (photo by Robert Freckman- UW - Stevens Point)

Naiads (*Najas* spp.) occurred in 40% of the sample sites (Table 3). Two species of naiads were found in the Whitefish Chain and since they can be difficult to distinguish, they were grouped together for analyses. Southern naiad (*Najas guadalupensis*; Figure 22) can sprout from seed or overwinter as a perennial plant. Bushy pondweed (*Najas flexilis*) 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 22. Southern naiad.
Photo: Kerry Dressler ©1996 Univ. of Florida Center for Aquatic Plants

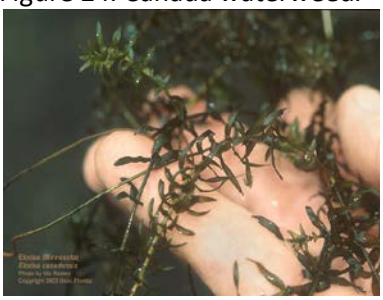
Flat-stem pondweed (*Potamogeton zosteriformis*) is one of 7 native pondweeds found in Arrowhead Lake and it was the most common pondweed, occurring with a frequency of 38% (Table 3). It was most frequent in the 6-10 feet depth zone, where it was found in 53% of the sites (Figure 18).

Figure 23. 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. Flat-stem pondweed (Figure 23) is named for its flattened, grass-like leaves. Other pondweeds found in Arrowhead Lake include broad-leaf "cabbage" type plants and plants with finer leaves. Seeds and tubers of all pondweeds 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).

Canada waterweed (*Elodea canadensis)* was found in 35% of the Arrowhead Lake survey sites (Table 3). It was found to a depth of 10 feet (Figures 17, 18). Canada waterweed (Figure 24) is a perennial submerged species that is widespread throughout Minnesota. It is adapted to a variety of conditions and is tolerant of low light and prefers soft substrates (Nichols 1999). Canada waterweed can overwinter as an evergreen plant and spreads primarily by fragments.

Figure 24. Canada waterweed.



Other submerged species found in Arrowhead Lake were uncommon, occurring in less than 5% of the survey sites. 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 Arrowhead Lake increases, submerged vegetation may be more common at depths greater than 10 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 abundance and assortment of aquatic plants found in Arrowhead 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. 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).

Arrowhead Lake, August 2011

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Appendix 1. Historical aquatic and wetland plants of Arrowhead Lake

Blue highlight indicates species that were common (occurring in at least 30% of sites) in 2011.

Submerged plants

Common Name	Scientific Name	1942	1950	1960	1990	1995	2011
Water marigold	*Bidens beckii*						X
Coontail	*Ceratophyllum demersum*	X	X	X	X	X	X
Muskgrass	*Chara* sp.						X
Canada waterweed	*Elodea canadensis*				X	X	X
Water star-grass	*Heteranthera dubia*						X
Leaf-less watermilfoil	*Myriophyllum tenellum*					X	
Northern watermilfoil	*Myriophyllum sibiricum*	X		X			X
Bushy pondweed	*Najas flexilis*					X	X
Southern naiad	*Najas guadalupensis*						
Large-leaf pondweed	*Potamogeton amplifolius*				X		X
Ribbon-leaf pondweed	*Potamogeton epihydrus*						X
White-stem pondweed	*Potamogeton praelongus*				X	X	X
Clasping leaf pondweed	*Potamogeton richardsonii*				X	X	X
Robbins pondweed	*Potamogeton robbinsii*					X	
Narrow-leaved pondweed[1]	*Potamogeton* sp.					[a]X	[a]X
	Potamogeton strictifolius				X		
Flat-stem pondweed	*Potamogeton zosteriformis*		X	X	X	X	X
White water buttercup	*Ranunculus aquatilis*					X	X
Sago pondweed	*Stuckenia pectinata*	X		X		X	X
Greater bladderwort	*Utricularia vulgaris*					X	X
Lesser bladderwort	*Utricularia minor*						X
Flat-leaved bladderwort	*Utricularia intermedia*						X
Wild celery	*Vallisneria americana*				X	X	X
Watermoss	*Not identified to genus*						X
	Total	3	2	4	8	13	21

Floating-leaved plants

Common Name	Scientific Name	1942	1950	1960	1990	1995	2011
Watershield	*Brasenia schreberi*						X
Yellow waterlily	*Nuphar variegata*				X	X	X
White waterlily	*Nymphaea odorata*				X	X	X
Floating-leaf pondweed	*Potamogeton natans*						X
	Total	0	0	0	2	2	4

Free-floating plants

Common Name	Scientific Name	1942	1950	1960	1990	1995	2011
Star duckweed	*Lemna trisulca*				X	X	X
Duckweed	*Lemna* spp.					X	
Greater duckweed	*Spirodela polyrhiza*						X
	Total	0	0	0	1	2	2

Emergent plants

Common Name	Scientific Name	1942	1950	1960	1990	1995	2011
Horsetail	*Equisetum fluviatile*				X		
Stiff wapato	*Sagittaria rigida*					[a]X	X
Bulrush[2]	*Schoenoplectus acutus*	[a]X	[a]X	[a]X	[a]X	[a]X	[a]X
	Schoenoplectus validus						
Three-square bulrush	*Schoenoplectus pungens*				X		
Eastern burreed	*Sparganium americanum*						X
Giant burreed	*Sparganium eurycarpum*				X		X
Wild rice	*Zizania palustris*				X	X	X
Broad-leaved cattail	*Typha latifolia*	X	[a]X	X	X		
Narrow-leaved cattail	*Typha angustifolia*						[3]X
	Total	2	2	2	6	3	6

Wetland emergent plants

Common Name	Scientific Name	1942	1950	1960	1990	1995	2011
Sweet flag	*Acorus americanus*	X		X			
Alder	*Alnus* sp.						X
Water arum	*Calla palustris*						X
Wide-leaf sedge	*Carex* spp.						X
Joe-pye weed	*Eupatorium dubium*						X
Bedstraw	*Galium* spp.						X
Touch-me-nots	*Impatiens* spp.						X
Blue flag iris	*Iris versicolor*				X		X
Reed canary grass (I)	*Phalaris arundinaceae*						X
Skullcap	*Scutellaria* sp.						X
	Total	1	0	1	1	0	9

I = introduced

[a]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.

[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 the 2011 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:

1942 (September 23): Robert Sharp; Division of Game and Fish
1950 (July 13-19): Division of Game and Fish
1960 (June 22): Thomas Bonde (Crew leader), Howard Knight, Howard Trick; DNR Fisheries Survey
1990 (June 11-13): Wayne Mueller (Crew Leader); DNR Fisheries Survey
1995 (June 12): MnDNR Fisheries Survey
2011 (June, August): Simon, Perleberg, Eininger, Dickson, MnDNR Division of Ecological & 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 0-12 feet depth zone.

Example:

In Arrowhead Lake there were 245 sample sites in the 0-12 feet depth zone.
Coontail occurred in 189 sites.
Frequency of Coontail in 0-12 feet zone = (189/245)*100 = 77%