Aquatic vegetation of Long and Spring Lakes

Meeker County, Minnesota

May 2004, June 2009, 2010 and 2011

Lake ID#'s 47-0026-00 (Long) and 47-0032-00 (Spring)

White waterlilies in Long Lake, 2010.

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Summary

Long and Spring lakes (Meeker County) represent two south-central Minnesota lakes in which different in-lake conditions result in different aquatic plant communities. The lakes were surveyed in 2004, 2009, 2010, and 2011 and within lake variations in plant community composition and distribution were seen between years.

Higher water clarity in Long Lake allowed for plant growth to depths of 10-14 feet and within the 0-15 feet depth zone, plants occurred in at least 76% of the sites in each year. Lower water clarity in downstream Spring Lake restricted most aquatic plant growth to water depths less than 10 feet; within the 0-15 feet depth zone only 30-60% of the sites contained plants in any year.

A total of 22 native aquatic plant species were found in these lakes but each lake contained a different group of species. Long Lake contained a mix of emergent, floating-leaved and submerged species, including submerged species that are intolerant of turbidity. The species found in Spring Lake were primarily submerged species that are tolerant of turbidity.

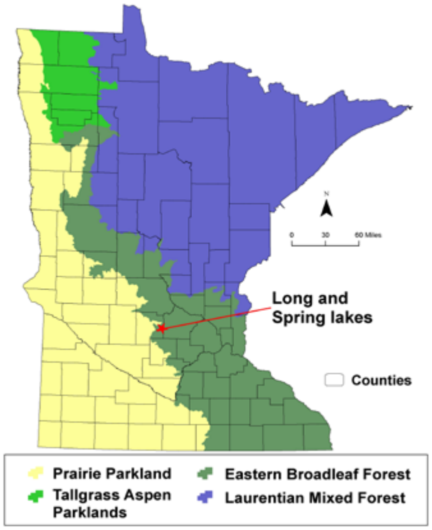
The non-native submerged plant, curly-leaf pondweed, was present in both lakes in all survey years and was more frequent in the clearer lake, Long Lake. In 2004, curly-leaf pondweed was the most frequent plant in both lakes and was the only commonly occurring plant in Spring Lake. In 2009, 2010 and 2011, curly-leaf pondweed was still present in both lakes but native submerged plants occurred more frequently than the non-native plant. In all survey years, at least 70% of the Long Lake sites contained at least one native submerged plant species. In Spring Lake, native plant frequency was only 18% in 2004 but increased to at least 35% in 2009, 2010 and 2011 as several native species increased in shallow water.

Multiple factors can influence the composition and abundance of aquatic plant communities and it can be difficult to determine why some changes occur or predict what may occur in future years. Annual changes in plant communities may be linked to changes in water clarity, snow cover and life histories of individual plant species.

Introduction

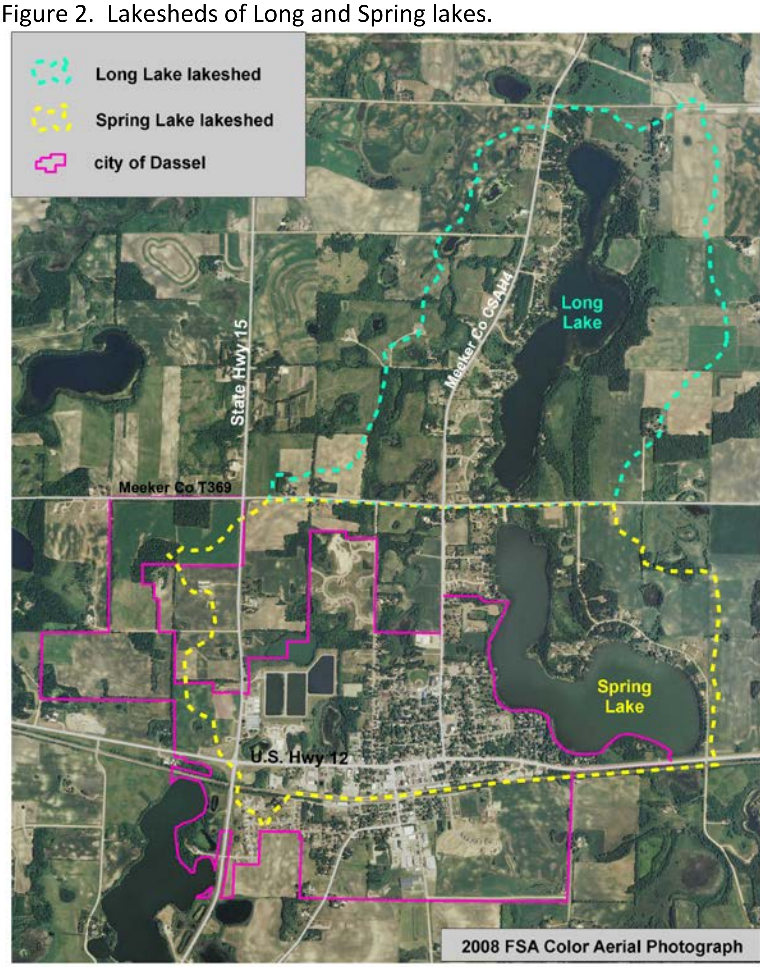
Long Lake and Spring Lake are connected lakes that are located by the city of Dassel in Meeker County, Minnesota. The lakes occur at the western edge of the ecological region known as the Eastern Broadleaf Forest Province (Figure 1). These lakes are positioned in the east-central portion of the North Fork Crow River Watershed within the Big Woods ecological subsection.

Figure 1. Long and Spring lakes (Meeker Co) in Eastern Broadleaf Forest Province.



Both lakes have small lakesheds[1] relative to lake surface area (Vavricka and Heiskary 1992) and adjacent land use activities can greatly impact the lakes. The Big Woods subsection was once dominated by oak woodland and maple-basswood forest but today most of the land is agricultural or urban. The lakeshed of Long Lake is primarily agricultural land with small forested tracts along the eastern lakeshore (Figure 2). The lakeshed of Spring Lake includes most of the city of Dassel and agricultural land.

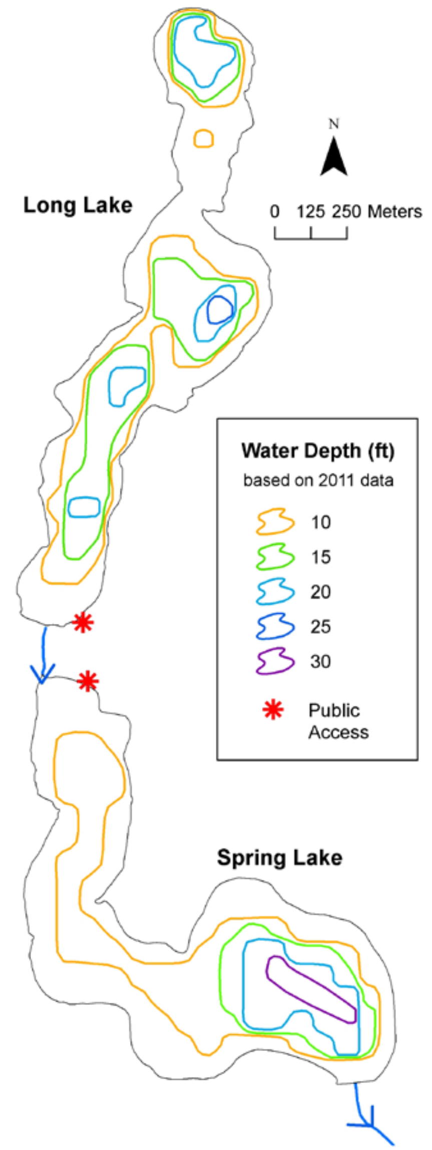
Figure 2. Lakesheds of Long and Spring lakes.



Due to landform characteristics, the drainage network in the Big Woods subsection is undeveloped and many lakes are groundwater controlled with no inlets or outlets. Long and Spring lakes are primarily closed basins and water levels are influenced by precipitation and shoreline runoff. There are no direct inlets to Long Lake and intermittent flow from Long into Spring occurs through a road ditch (Figure 2). Water levels fluctuations on Long Lake are usually less than 0.10 feet above or below the ordinary high water mark and on Spring Lake water levels may change by about 0.25 feet (Appendix 1).

[1] land that drains directly to the lake

Figure 3. Long and Spring lakes depth contours and flow direction.



Long Lake is an elongated basin with a surface area of 162 acres. It has a maximum depth of 28 feet and about 66% of the lake is shallow (less than 15 feet deep) (Figure 3). Spring Lake is 202 acres in surface area. It has a maximum depth of 30 feet and about 76% of the lake is less than 15 feet deep (Figure 3).

The eastern shore of Long Lake includes undeveloped forested tracts (Figure 4) but the western shore and most of Spring Lake shores are mostly developed with residential homes. Shoreline management ranges from lots where some shoreline trees, shrubs and/or understory plants have been retained (Figure 5) to lots that have been completely converted to turf grass. Both lakes have a public boat access.

Long and Spring lakes differ in water quality parameters including nutrient levels and clarity. Long Lake is characterized as eutrophic, based on phosphorus (nutrients), chlorophyll a (algae concentration) and summer water clarity as measured by Secchi[2] depth. Spring Lake is described as hyper-eutrophic with a higher mean total phosphorus concentration, higher mean chlorophyll a, and lower summer water clarity (MPCA 2012). Water quality problems have been reported in Spring Lake since the late 1940's and were attributed to the city of Dassel's discharge of primary treated sewage into Spring Lake. Sewage treatment ponds were constructed in 1985, diverting the discharge into the new ponds instead of the lake. Since the discharge has been removed from the lake, water quality (in terms of phosphorus and clarity) has improved, but the highly enriched sediments may continue to supply substantial amounts of nutrients to the lake (Vavricka and Heiskary 1992).

Water transparency data for these lakes are limited, but in the past two decades, clarity was generally higher in Long Lake where the mean summer[3] water clarity was 8.5 feet compared to 4.2 feet in Spring Lake (Appendix 2) (MPCA 2012). In both lakes, water clarity was highest in

[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] Summertime = June 16-Sept 15

Figure 4. Undeveloped shoreline of Long Lake, 2010.

Figure 5. Developed Spring Lake shoreline with understory vegetation removed 2010.

May and early June and decreased during summer months as algal populations increased. In Spring Lake, although clarity varied annually, there appears to be an increasing trend in both May - June clarity and late summer clarity.

As a general rule, sunlight can penetrate to a depth of 1.7 times the Secchi depth (Scheffer 1998) and rooted aquatic plant growth is generally limited to that depth range. Based on recent (2004-2011) summer Secchi disk measurements alone, rooted aquatic plants in Spring Lake may be limited to depths less than seven feet[4] while they may grow as deep as 14 feet[5] in Long Lake. However, other factors influence how deep plants may grow, including the types of plants present in a lake. Some plant species can compensate for low clarity by forming long stems with leaves concentrated at the water surface where more light is available (Middelboe and Markager 1997).

Historic aquatic plant communities of Long and Spring lakes

Previous lakewide, aquatic plant surveys of Long Lake were conducted in 1973, 1984, 1994 and 2003 and surveys of Spring Lake were conducted in 1947, 1974, 1989, 1994 and 2003 (MnDNR Lake files) (Appendices 3 and 4). These surveys provide a general description of the Summer plant communities of these lakes.

A total of nine emergent and floating-leaf plants have been previously recorded in these lakes. Cattails (*Typha* spp.) and bulrush (*Schoenoplectus* spp.) were historically reported as common in both lakes and white waterlily (*Nymphaea odorata*), and yellow waterlily (*Nuphar variegata*) were described as common only in the shallow bays of Long Lake. Bulrush was found at various locations of Long Lake, while it was only found in the inlet and outlet of Spring Lake. Horsetail (*Equisetum* sp.) was found on the west and south shores of Long Lake.

Ten native submerged species have been previously found in Long Lake compared to only six species in Spring Lake. Long Lake's historic native submerged plants included a mix of turbidity tolerant species (Nichols 1999) such as coontail (*Ceratophyllum demersum*) and sago pondweed

[4] For Spring Lake, 2004-2011, mean Summertime Secchi disc reading was 4.2 feet; 4.2 *1.7 = 7.1 feet.
[5] For Long Lake, 2004-2011, mean Summertime Secchi disc reading was 8.5 feet; 8.5 * 1.7 = 14.5 feet.

(*Stuckenia pectinata*) as well as plants that require higher light levels (Nichols 1999) such as native pondweeds (*Potamogeton* spp.) and northern watermilfoil (*Myriophyllum sibiricum*). Spring Lake's historic native submerged species were mostly limited to turbidity-tolerant species, with coontail and sago pondweed dominating. The non-native submerged plant, curly-leaf pondweed (*Potamogeton crispus*) was first recorded in Long Lake in 1973 and was documented in Spring Lake by 1989.

Objectives

The purpose of these vegetation surveys was to provide a quantitative description of the plant populations of Long and Spring lakes and compare annual differences between the lakes. Specific tasks included:

1. Record the aquatic plant species that occur in each lake
2. Estimate the maximum rooting depth and percent of lake occupied by vegetation
3. Estimate the frequency of occurrence for commonly occurring species
4. Create distribution maps for the commonly occurring species

Methods

Emergent and floating-leaf Plant Bed Delineation

The boundaries of major plant beds were delineated from review of 2003 FSA Color Aerial photographs with in-field verification. This provides a general estimation of plant bed location and size but detailed mapping of plant beds using global positioning system (GPS) was not conducted.

Lakewide (Point-intercept) vegetation survey

Lakewide vegetation surveys were conducted on Long Lake and Spring Lake in 2004, 2009, 2010 and 2011 using a point-intercept survey method (Madsen 1999, MnDNR 2012). Survey waypoints were created using a geographic information system (GIS) computer program and downloaded into a handheld GPS unit. At a minimum, we wanted to sample about 75 points within the vegetated zone of each lake and place sample points at a minimum distance of 100 meters for mapping purposes. Survey points were placed in a grid pattern across each lake. In 2004, 2010 and 2011, points were spaced 75 meters (246 feet) and surveyors sampled sites where the water depth was 20 feet or less (Figure 6). In 2009 survey points were spaced 80 meters (262 feet) apart and all sites were sampled (Figure 6).

Sampling was conducted in late May to early June (Appendix 5) to sample both the curly-leaf pondweed population and native plants. Surveys were conducted by boat and a GPS unit was used to navigate the boat to each sample point. One side of the boat was designated as the sampling area. At each site, water depth was recorded to the nearest foot using a measured stick in water depths less than seven feet and an electronic depth finder in deeper water.

Plant sampling

Surveyors recorded all plant species found within a one square meter sample site at the pre-designated side of the boat. A double-headed, weighted rake (Figure 7), attached to a rope was used to survey vegetation not visible from the water surface. 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 (2012).

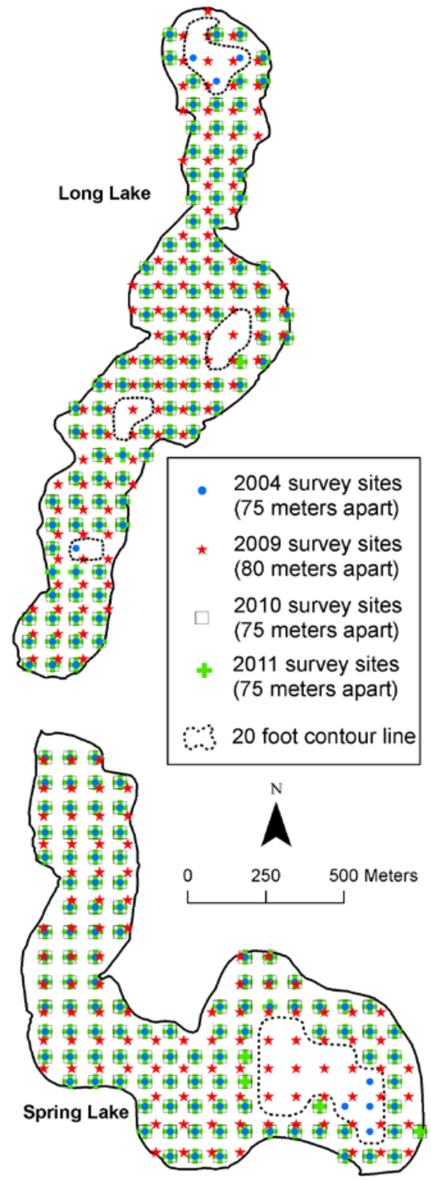
Frequency estimates for individual species were calculated for the depth zone that contained vegetation (0-15 feet)[6] and sampling points were also grouped by water depth (five feet increments) for analyses (Appendix 5).

Figure 7. Survey rake.

Substrate sampling

In 2011, in water depths of seven feet and less, surveyors evaluated lake bottom substrate at the sample station by tapping a pole into the lake bottom. Soft substrates were brought to the surface on the pole for evaluation. Standard lake substrate classes were recorded (Table 1).

Figure 6. Vegetation survey sites.



Results and Discussion

Shoal Substrates

The shoal substrates of Long and Spring lakes were primarily soft substrates of silt and muck (Figure 8). Scattered areas of sand occurred on some shores.

Table 1. Substrate classes

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

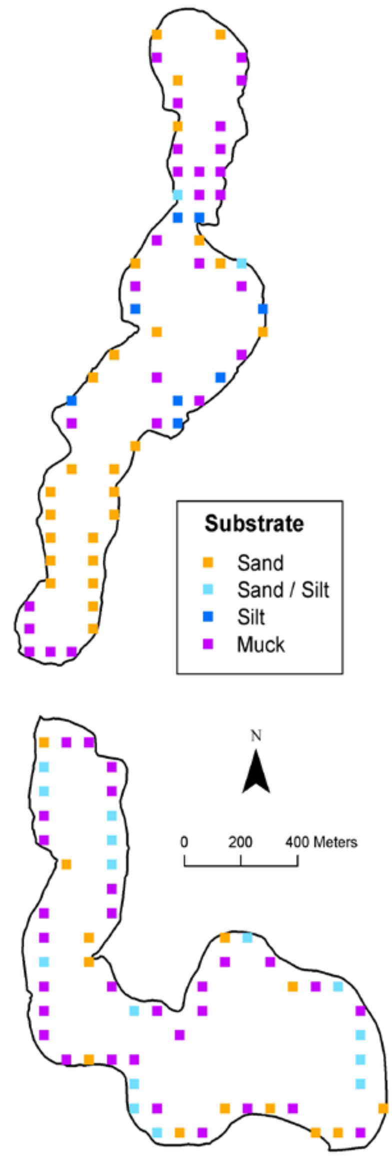
Types of plants recorded

A total of 23 aquatic plant species (types) were recorded in these lakes. The plants found included four emergent, two floating-leaved,

[6] In 2009 and 2010, one or two sites in the 16-20 feet depth zone contained plants.

three free-floating, and 14 submerged plants. Six of these species were recorded for the first time during the 2004-2011 surveys (Appendices 1-2). Twenty-one aquatic plant species were found in Long Lake (Appendix 1) compared to 13 species in Spring Lake (Appendix 2). Long Lake's plant community included emergent, floating-leaved, submerged and free-floating species while only submerged and emergent plants were found in Spring Lake. All but one of the in-lake plant species found were native to Minnesota. The non-native submerged plant, curly-leaf pondweed, was found in both lakes in every survey year.

Figure 8. Shoal substrates, 2011.



Plant distribution and abundance

In all survey years, plants were distributed around the shorelines of both lakes and plants were more frequently found in shallow areas including the north half of Long Lake and the southwest shorelines of Spring Lake (Figure 9). In each survey year, at least 76% of the Long Lake sample sites, or about half of the surface area, contained vegetation compared to Spring Lake where only 35-60% of the sample sites[7], or about one-third of lake's surface area, contained plants.

Spring Lake lacked beds of emergent and floating-leaf plants; waterlilies have been observed in the lake[8] but were not found within sample sites. In Long Lake, mixed beds of white and yellow waterlilies occurred to a depth of four feet and covered about 11 acres; bulrush stands occurred to a depth of six feet and occupied about three acres.

Submerged plants dominated in both lakes. Maximum rooting depth[9] varied annually in both lakes ranging from 10 feet to 14 feet in Long Lake and from six to 13 feet in Spring Lake.

In Long Lake, plant occurrence was similar in all survey years: nearly all sites from shore to a depth of 10 feet contained vegetation and then plant growth declined with increasing water depth (Figure 10). In Spring Lake, plants were frequently found in the shore to five feet depth zone in each year; in the six to 10 feet depth zone plant occurrence gradually increased from 2004 through 2011 but never approached the abundance levels found in Long Lake (Figure 10).

[7] Unless otherwise noted, the percent of sites containing plants is calculated from only the sites within the vegetated zone from shore to a depth of 15 feet.
[8] Personal observation by Craig Soupir (DNR Fisheries Habitat Specialist) during 2010 and 2011.
[9] Maximum rooting depth was calculated as the depth to which 95% of vegetated sample sites occurred.

Figure 9. Aquatic plant distribution in Long and Spring Lakes 2004-2011.

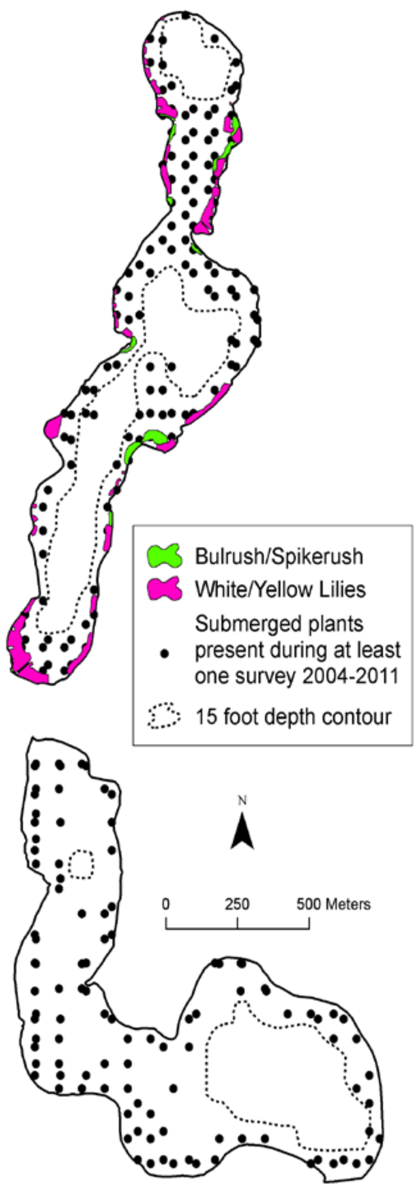
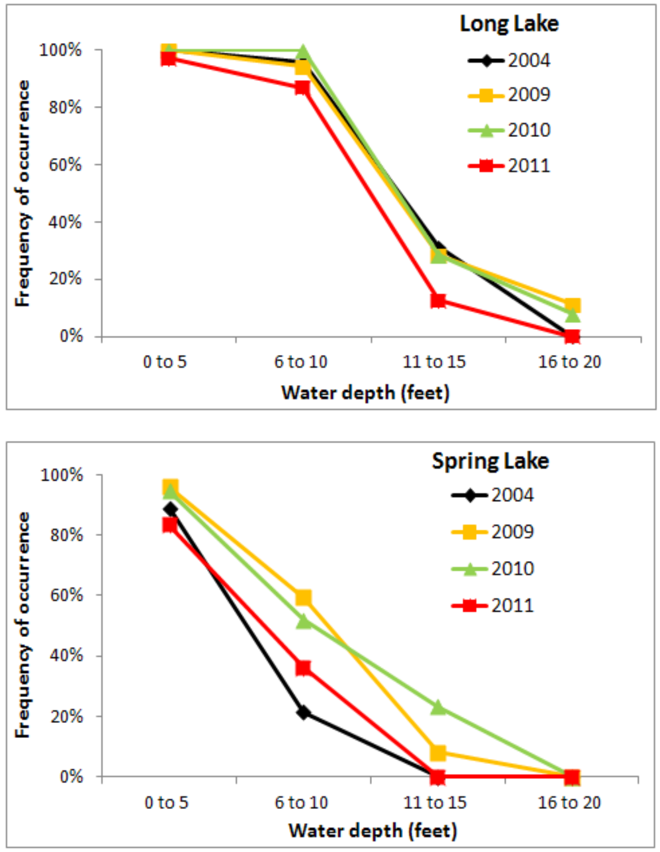


Figure 10. Aquatic plant frequency vs. water depth.



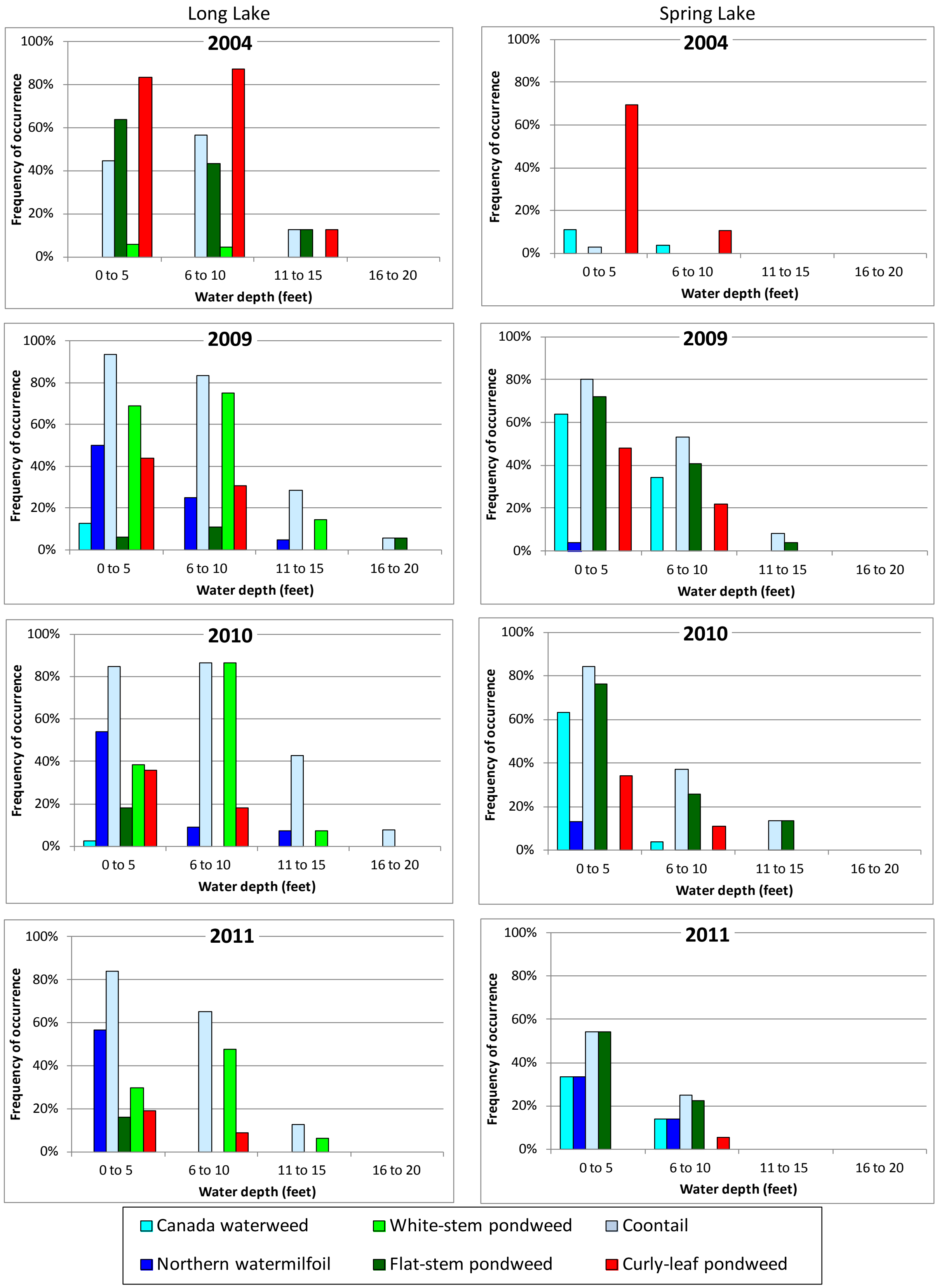
Commonly occurring plant species

The non-native plant, curly-leaf pondweed, dominated both lakes during the 2004 survey. In Long Lake it occurred in 69% of the sample sites and was common to depths of 10 feet; in Spring Lake it was mostly restricted to depths less than six feet and occurred in 29% of the sample sites (Figure 11).

Native plant species that were common[10] in Long Lake included species that are tolerant of turbidity: coontail (*Ceratophyllum demersum*); species that require moderately clear water: flat-stem pondweed (*Potamogeton zosteriformis*) and northern watermilfoil (*Myriophyllum sibiricum)*; and a species that requires high clarity: white-stem pondweed (*Potamogeton praelongus*) (Nichols 1999). Flat-stem pondweed and coontail were the most common native plants during the 2004 survey but from 2009 through 2011, flat-stem pondweed declined in abundance as white-stem pondweed and northern watermilfoil increased.

[10] For this report, commonly occurring species are defined as those that occurred in at least 10% of the sample sites in at least one year.

Figure 11. Common submerged plants by water depth interval, Long Lake (left) and Spring Lake (right).



In Spring Lake, no native plants were common in 2004 but from 2009 to 2011, species of low to moderate clarity [coontail, flat-stem pondweed, Canada waterweed (*Elodea canadensis*) and northern watermilfoil] increased in frequency (Figure 11).

In 2004, most of the Long Lake vegetated sites contained a mix of native plants and curly-leaf pondweed while most of the Spring Lake vegetated sites contained only curly-leaf pondweed (Figure 12). From 2009 to 2011, curly-leaf pondweed decreased in frequency in both lakes. By 2011, curly-leaf was found in only 12% of the Long Lake sample sites and 2% of the Spring Lake sites and did not dominate at any depth. Native plants replaced it as the dominant species at all vegetated depths. In Long Lake, the percent of sites containing only native submerged plants increased from 15% in 2004 to more than 50% in 2009 to 2011; in Spring Lake native only sites increased from 11% in 2004 to more than 30% in 2009 to 2011.

Aquatic plant community dynamics

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. Within any given year, the composition and/or abundance of the plant community can vary in response to water clarity, water depth, and other environmental factors. Individual growth patterns of species also vary. Determining why plant communities change can be complicated because multiple factors may be involved. Year to year changes in plant communities may be more pronounced in turbid, productive lakes than in less disturbed systems (Valley and Drake 2007).

No large-scale permitted aquatic plant management activities have been conducted on Spring and Long lakes and plant community dynamics are largely influenced by environmental changes and species growth patterns. However, understanding these changes is further complicated because data on monthly water clarity, snowfall and ice-out dates are limited. It is also important to note that the 2004 through 2011 surveys were conducted in May and June and native plant communities in particular may have increased in abundance through the course of the summer.

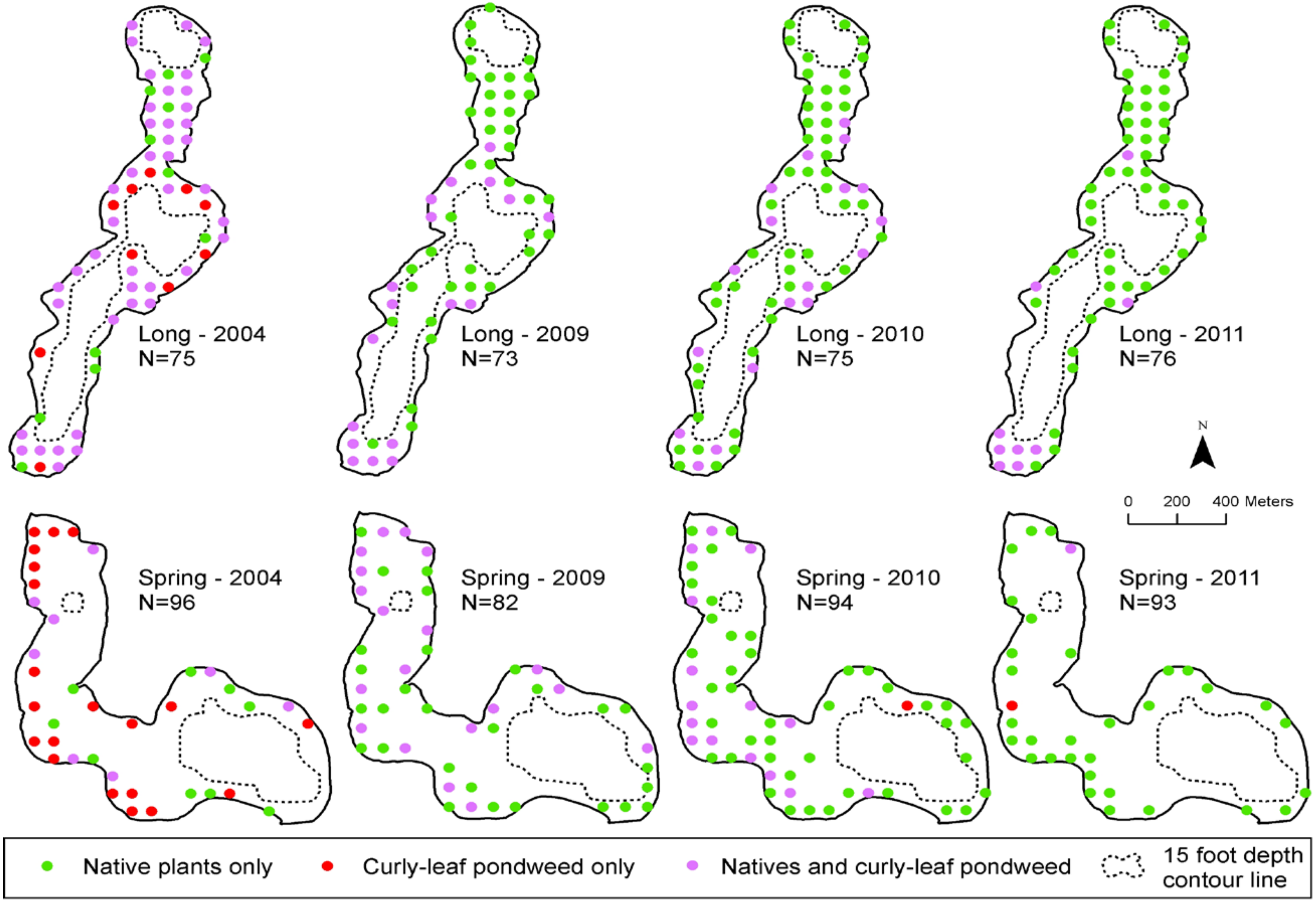
Species responses to water clarity changes

Water clarity is one of the primary factors contributing to differences in the plant communities in Spring and Long lakes. Higher clarity in Long Lake allows submerged plants to grow to deeper depths and enables “turbidity intolerant” species, such as white-stem pondweed, to grow more frequently than in Spring Lake. Water clarity, specifically spring-time water clarity, appears to be increasing in Spring Lake and if this trend continues plant growth may expand into deeper water and turbidity intolerant species may increase in abundance.

Species responses to snow and ice cover

The amount of snow and ice cover on lakes impacts the amount of sunlight reaching the lake in winter months and in turn, can affect plant growth beneath the ice. Aquatic plant species differ in their strategies for surviving winter and therefore respond differently to changes in snow and ice cover.

Figure 12. Distribution of aquatic plants in Long and Spring lakes, 2004, 2009, 2010, 2011. (Plant frequency is calculated for the 0-15 feet depth zone, N= number of sample sites).



In strongly dormant species like flat-stem pondweed, the main plant typically dies back at the end of summer and only small dormant buds remain in the substrate under the ice. Winter survival is independent of winter light regime and plants resume growth when water temperatures increase through the summer.

Other species, like white-stem pondweed, are moderately dormant. The plant has hardy rhizomes that survive the winter but main plant leaves and stems may also remain "evergreen" under the ice. In the spring, these plants already have upright leaves and stems that occupy the water column and may have a competitive advantage as they produce new shoots.

Northern watermilfoil has a conservative strategy of weak dormancy, overwintering by a hardy rootstalk and winter buds. In Spring, growth is delayed until water temperatures increase, thus reducing the probability that new shoots will be killed by cold temperatures or heavy snow cover.

Uncharacteristic of its name, Canada waterweed is most common in regions with low or no snow and ice cover, lacks a true dormant mechanism, and growth is dependent on the winter light irradiance (Haag 1979). This plant is capable of growth at any time of year and can start growing quickly in low Spring water temperatures. However, the evergreen shoots can die under heavy snow and a population can be drastically reduced by winter ice cover.

Curly-leaf pondweed is similar to Canada waterweed in that it can be actively growing at low temperatures under the ice and can be negatively impacted by reduced winter light. It does form a dormant "turion" but the structure is formed in late Spring and acts as a Summer dispersal mechanism for the plant.

In plant survey years 1973, 1984, 2003 and 2004, snow fall at Spring and Long lakes was less than 30 inches compared to other plant survey years when snow fall ranged from ranged from 35 o 71 inches (Appendix 1). Quantitative Spring-time data are not available from all of these years, but the highest recorded occurrence of curly-leaf in both lakes is from 2004 (a low snow year). A summer 1984 survey described curly-leaf as "abundant" in Long Lake, suggesting that it was also abundant in the Spring of that low snow year.

Patterns of change in native species are less clear; for example, after 2004, flat-stem pondweed declined in Long Lake yet increased in Spring Lake. In general native species are increasing as curly-leaf declines and native species competition may partly influence the abundance of both native plants and curly-leaf pondweed.

Because no large-scale control work is planned for these lakes, they provide an opportunity to continue to monitor annual changes in both native and curly-leaf pondweed populations. Patterns observed in these lakes may help predict changes in plant populations of similar lakes within this Ecoregion.

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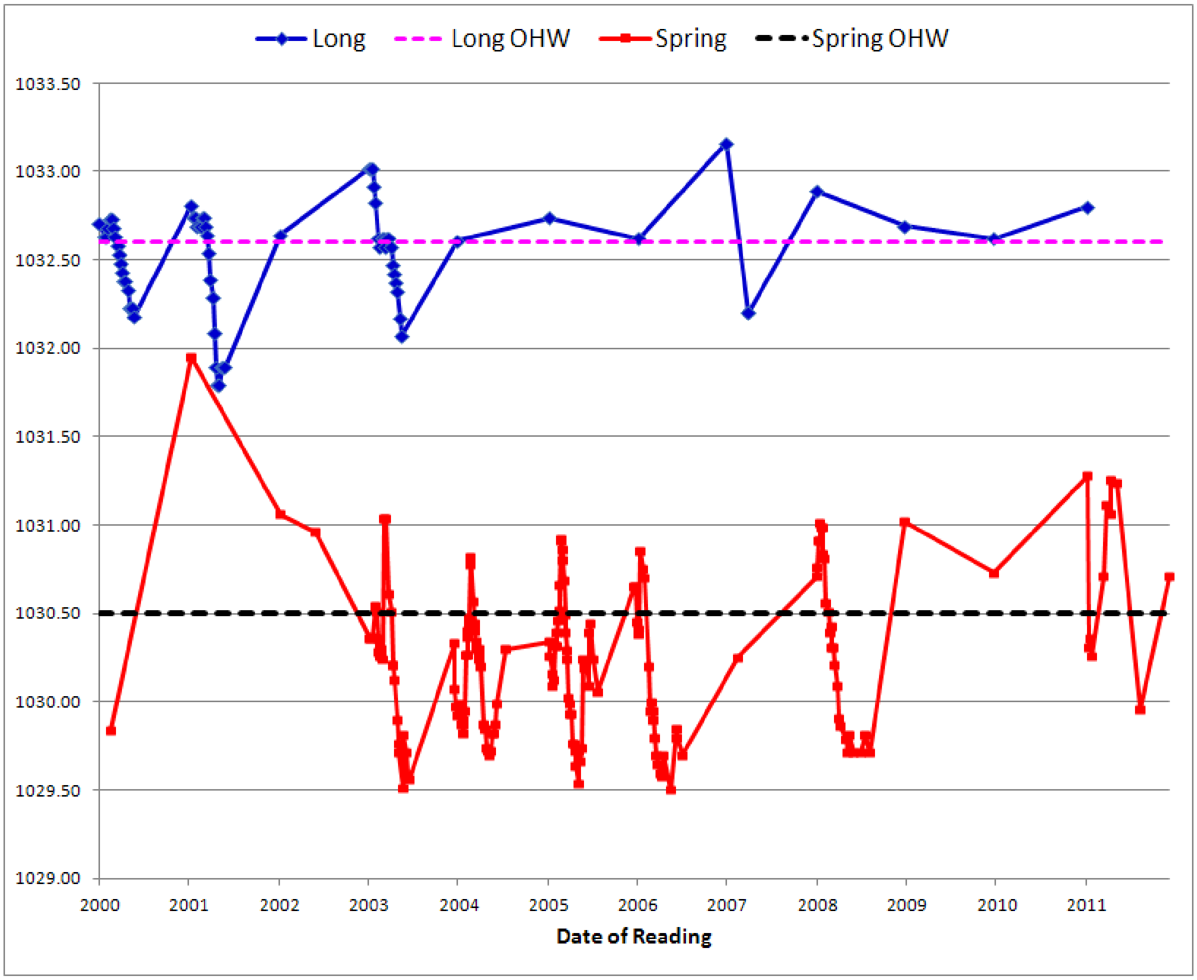
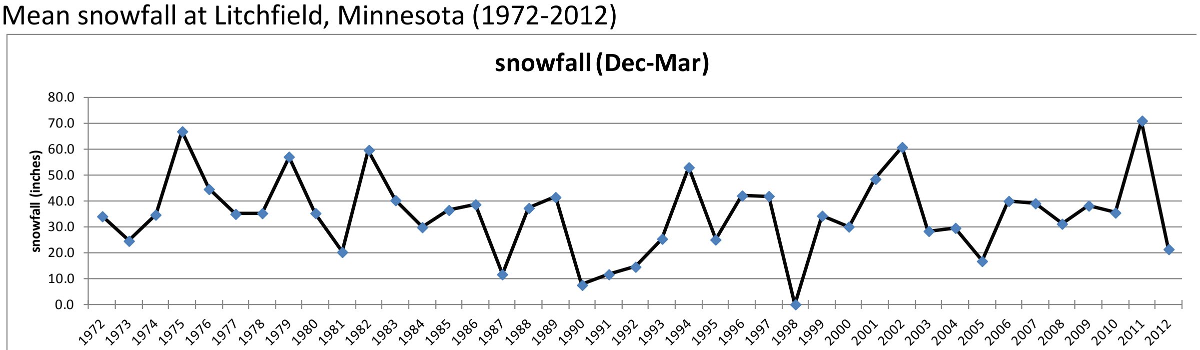
Appendix 1. Annual water levels and snowfall for Long and Spring Lakes.

Long and Spring lakes water levels (2000-2011).

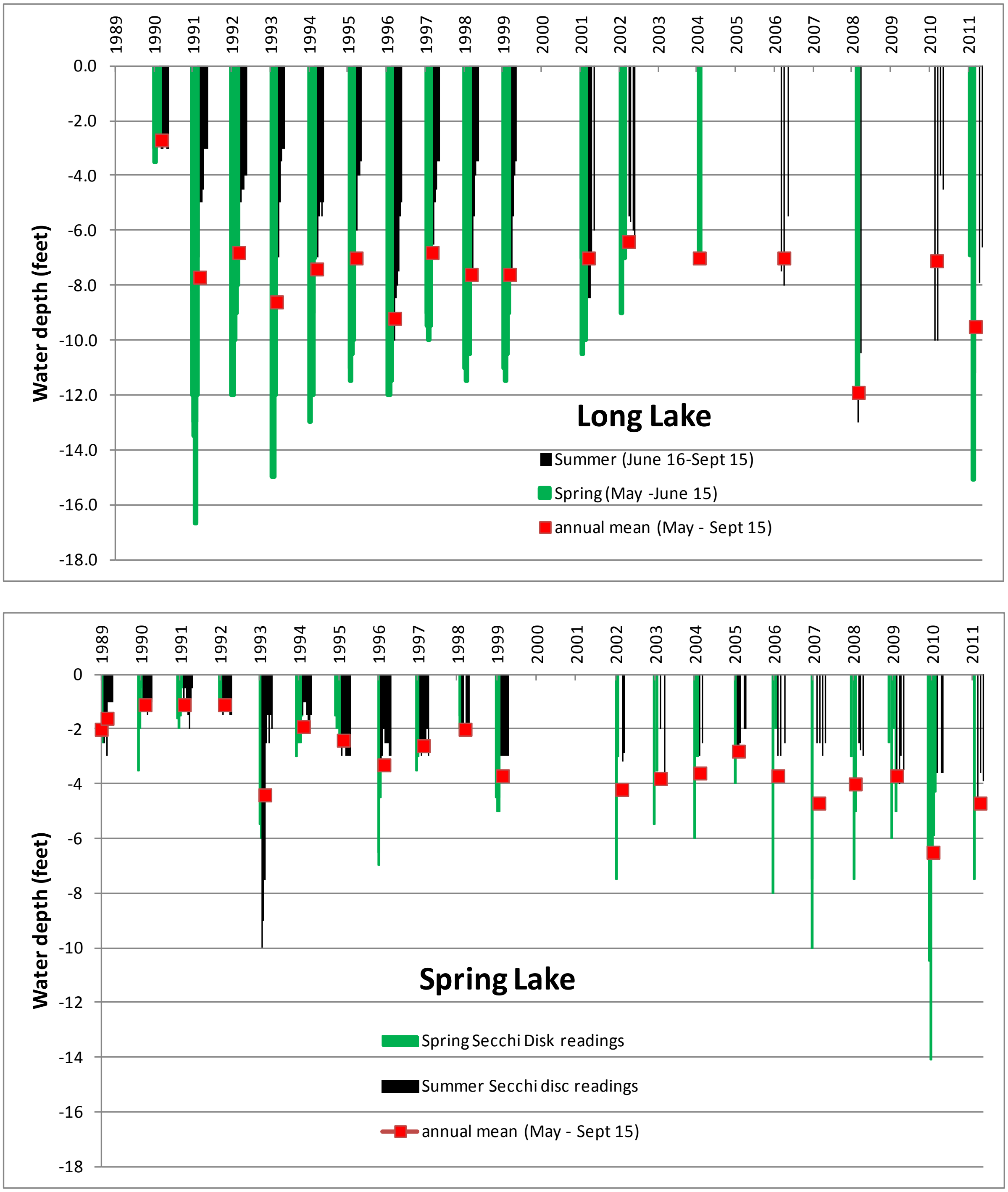


Mean snowfall at Litchfield, Minnesota (1972-2012)



Appendix 2. Water clarity for Long and Spring Lakes.

Long and Spring lakes water clarity.



Appendix 3. Aquatic and wetland plants of Long Lake, Meeker County, Minnesota (1973-2011)

Submerged plants of Long Lake			**Survey Year**							
	Common Name	Scientific Name	1973	1984	1994	2003	2004	2009	2010	2011
Macroalgae	Muskgrass	*Chara* sp.			C	O	1			1
Monocots	Canada waterweed	*Elodea canadensis*			C	P		3	1	
	Water star-grass	*Heteranthera dubia*				O	7			3
	Bushy pondweed	*Najas flexilis*				O			1	
	Southern naiad	*Najas guadalupensis*								3
	Curly-leaf pondweed (I)	*Potamogeton crispus*	R	A	P	O	69	25	24	12
	White-stem pondweed	*Potamogeton praelongus*			**A?**	P	4	56	45	30
	Narrow-leaved pondweed	*Potamogeton* sp.	R	O		X				3
	Flat-stem pondweed	*Potamogeton zosteriformis*	R	C	C	A	47	7	9	8
	Sago pondweed	*Stuckenia pectinata*	A	O	O	C	3		5	1
Dicots	Coontail	*Ceratophyllum demersum*		O	O	C	41	70	73	63
	Northern watermilfoil	*Myriophyllum sibiricum*		O	C	O	P	25	32	28
		Total	4	6	8	11	8	6	8	10

Floating-leaf and emergent plants of Long Lake			**Survey Year**							
	Common Name	Scientific Name	1973	1984	1994	2003	2004	2009	2010	2011
Floating-leaf	Yellow waterlily	*Nuphar variegata*	C	C		X	1	5	3	
	White waterlily	*Nymphaea odorata*	O	C	X	X	15		19	7
Emergent	Needlegrass	*Eleocharis acicularis*		R	X					
	Spikerush	*Eleocharis* sp.					P			
	Hard-stem bulrush	*Schoenoplectus acutus*	C	C	X	X	1		5	3
	Arrowhead	*Sagittaria* sp.				X				
	Giant Burreed	*Sparganium eurycarpum*				*X	P		P	
	Broad-leaf cattail	*Typha latifolia*	C	C	X	X				
	Narrow-leaf cattail	*Typha* sp.		R			P		P	
		Total	4	6	4	6	6	1	5	2

Appendix 3. (continued) Aquatic and wetland plants of Long Lake, Meeker County, Minnesota (1973-2011)

Free-floating plants of Long Lake		**Survey Year**							
Common Name	Scientific Name	1973	1984	1994	2003	2004	2009	2010	2011
Lesser duckweed	*Lemna* sp.		R		X			1	12
Star duckweed	*Lemna trisulca*				X			4	
Greater duckweed	*Spirodela polyhriza*			X	X			1	1
	Total	0	1	1	3	0	0	3	2

Wetland emergent plants of Long Lake		**Survey Year**							
Common Name	Scientific Name	1973	1984	1994	2003	2004	2009	2010	2011
Swamp milkweed	*Asclepias incarnata*				X				
Sedge	*Carex* sp.		O	X	X				
Swamp horsetail	*Equisetum fluviatilis*	P	R						
Yellow Iris (I)	*Iris psuedacorus*								P
Blue flag iris	*Iris versicolor*		O	X	X	P		P	
Reed canary grass (I)	*Phalaris arundinaceae*			X	X			P	
Leafy bulrush	*Schoenoplectus atrovirens*		O						
	Total	1	4	3	4	1	0	2	1

For 2004 to 2011 surveys, frequency values were calculated for 0-15 feet depth zone. 2004, N= 75, 2009, N=73, 2010, N=75, 2011 N= 76)

I = introduced, *indicates plant was only identified to the genus level, X = present
P = Present; O = Occasional; R = Rare; A = Abundant; C = Common

Historical Survey Sources:
1973 (July 11): John Hangeveld, MnDNR Fisheries Survey
1984 (June 25): Phil Meier, MnDNR Fisheries Survey
1994 (August 9): MnDNR Fisheries transect survey (1994 – pondweed is not identified to species, presumed to be Potamogeton praelongus)
2003 (July 24): MnDNR Fisheries transect survey

Appendix 4. Aquatic and wetland plants of Spring Lake, Meeker County, Minnesota (1947-2011)

Submerged plants of Spring Lake			**Survey Year**								
	Common Name	Scientific Name	1947	1974	1989	1994	2003	2004	2009	2010	2011
Macro algae	Muskgrass	*Chara* sp.								1	1
Monocots	Canada waterweed	*Elodea canadensis*				X	X	5	33	27	14
	Water star-grass	*Heteranthera dubia*							2	4	3
	Curly-leaf pondweed (I)	*Potamogeton crispus*			O		X	29	23	17	2
	Narrow-leaved pondweed	*Potamogeton* sp.				X	X	3		5	3
	Flat-stem pondweed	*Potamogeton zosteriformis*					X		39	43	23
	Sago pondweed	*Stuckenia pectinata*	C	C	O	X	X	8		3	
	Horned pondweed	*Zannichellia palustris*						2		9	
Dicots	Coontail	*Ceratophyllum demersum*	R	C			X	1	48	49	24
	Northern watermilfoil	*Myriophyllum sibiricum*							1	5	14
	White water buttercup	*Ranunculus aquatilis*						1			
		Total	2	2	2	3	6	7	6	10	8

Floating-leaf and emergent plants of Spring Lake			**Survey Year**								
	Common Name	Scientific Name	1947	1974	1989	1994	2003	2004	2009	2010	2011
Floating-leaf	Yellow waterlily	*Nuphar variegata*	R	P							
	White waterlily	*Nymphaea odorata*					X				
Emergent	Needlegrass	*Eleocharis acicularis*			O						
	Arrowhead	*Sagittaria* sp.			R						
	Hard-stem bulrush	*Schoenoplectus acutus*	C		C	X	X	*P		*P	
	Soft-stem bulrush	*Schoenoplectus tabernaemontani*			C						
	Broad-leaf cattail	*Typha latifolia*	C	P	C	X	X				
	Narrow-leaf cattail	*Typha* sp.			O			P		P	P
		Total	3	2	6	2	3	2	0	2	0

Appendix 4. (continued) Aquatic and wetland plants of Spring Lake, Meeker County, Minnesota (1947-2011)

Wetland emergent plants of Spring Lake		**Survey Year**								
Common Name	Scientific Name	1947	1974	1989	1994	2003	2004	2009	2010	2011
Swamp milkweed	*Asclepias incarnata*					X				
Water plantain	*Alisma trivale*			P						
Sedges	*Carex* spp.	C		O	X					
Reed meadow grass	*Glyceria grandis*			R						
Rush	*Juncus* sp.			O						
Yellow Iris (I)	*Iris psuedacorus*								P	
Reed canary grass (I)	*Phalaris arundinaceae*			C	X	X	P		P	
Giant cane	*Phragmites australis*	R	P		X					
Leafy bulrush	*Schoenoplectus atrovirens*			O						
	Total	2	1	6	3	2	1	0	2	0

For 2004 to 2011 surveys, frequency values were calculated for 0-15 feet depth zone. (2004, N= 96; 2009, N=82; 2010, N=94; 2011 N= 93)

(I) = introduced
P = Present; O = Occasional; R = Rare; A = Abundant; C = Common
X = present
*indicates plant was only identified to the genus level

Historical Survey Sources:
1947 (August 12-14): Soulen, MnDNR Department of Conservation, Division of Game and Fish
1974(August 18-20): Richard Schuh, MnDNR Fisheries Survey
1989 (June 19-23): Bob Hogg, MnDNR Fisheries Survey
1994 (August 4): MnDNR Fisheries Transect Survey
2003 (July 22): MnDNR Fisheries Transect Survey

Appendix 5: Survey Details

Survey Dates

Year	Long	Spring
2004	May 27, June 2	May 27
2009	June 15, 17	June 12
2010	June 9	June 9
2011	June 1, 6	June 6

Survey effort by depth interval.

Water depth (feet)	Number of sample sites							
	Long				Spring			
	2004	2009	2010	2011	2004	2009	2010	2011
0 to 5	36	16	39	37	36	25	37	24
6 to 10	23	36	22	23	28	32	27	36
11 to 15	16	21	14	16	32	25	30	33
Total (0-15)	75	73	75	76	96	82	94	93
16 to 20	25	18	25	29	9	6	11	14
21 to 25	0	12	0	0	1	12	0	0
Total	100	103	100	105	106	100	105	107

Appendix 6: Frequency of Occurrence

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 0-15 feet depth zone.

Example:
In Spring Lake there were 94 sample sites in the 0-15 feet depth zone in 2010.
Coontail occurred in 40 sites.
Frequency of coontail in 0-15 feet zone = (40/94)*100 = 43%

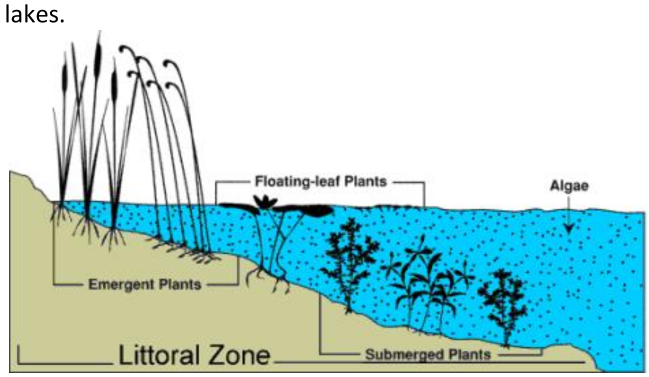
Appendix 7. Amounts and types of aquatic plants in Minnesota lakes

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.

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[11]. 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. 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 1), 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.

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

Figure 1. Forms of aquatic plants found in Minnesota lakes.



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

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.

Aquatic plant communities provide critical fish and wildlife habitat and other lake benefits. (Click here for more information on: value of aquatic plants).

For information on the laws pertaining to aquatic plant management: MnDNR APM Program.

Appendix 8: Description of Plants found in Long and Spring Lakes

Coontail (Figure 1) grows entirely submerged and may float freely or be loosely anchored to the lake bottom. It is adapted to a broad range of lake conditions and is tolerant of higher turbidity and can grow in muck substrates. Coontail is perennial and can over winter as a green plant and as dormant plant tips 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 1. Coontail

Northern watermilfoil (Figure 2) is a native, submerged plant. It is a rooted perennial with finely dissected leaves. 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 and grows best in clear water lakes. For information on how to distinguish the native northern watermilfoil from the non-native, Eurasian watermilfoil, click here: identification.

Figure 2. Northern watermilfoil

Canada waterweed (Figure 3) 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. Canada waterweed does not have a dormant phase and can overwinter as an evergreen plant (Haag 1979). It spreads primarily by fragments.

Figure 3. Canada waterweed

Pondweeds (*Potamogeton* spp.) are a group of aquatic plants that are primarily submerged but some will also form floating leaves. There are about 28 different native species of pondweeds in Minnesota and they can be described by their leaf shapes and sizes. These are perennial plants that are anchored to the lake bottom by rhizomes. Pondweeds can overwinter as dormant vegetative shoots. They form cigar-shaped flowers that extend above the water surface. Flat-stem pondweed (*Potamogeton zosteriformis;* Figure 4) is named for its flattened, grass-like leaves. White-stem pondweed (*Potamogeton praelongus*; Figure 5) is a broadleaf plant that is sometimes called "cabbage" by anglers. This species is not tolerant of turbidity (Nichols 1999) and is often one of the first species to decline if water clarity declines.

Figure 4. Flat-stem pondweed

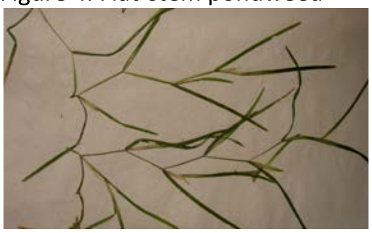
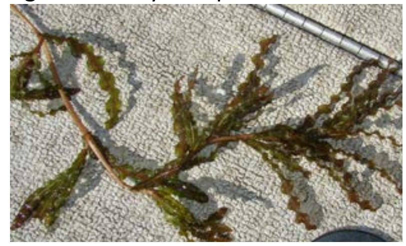


Figure 5. White-stem pondweed

Figure 6. Curly-leaf pondweed



Curly-leaf pondweed (*Potamogeton crispus*; Figure 6) is closely related to native pondweeds a non-native, submerged plant that has been present in Minnesota since at least 1910 (Moyle and Hotchkiss 1945) and is now found in more than 750 Minnesota lakes (Invasive Species Program 2011). It was first documented in Long Lake in 1973 and was reported in Spring Lake in 1989.

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

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

Figure 7. Bulrush

Bulrushes (*Schoenoplectus* sp.) are emergent, perennial plants that are rooted in the lake bottom with narrow stems that may extend several feet above the water (Figure 7). 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 8. White waterlily

White and yellow waterlilies can be found in lakes in both northern and southern Minnesota. White waterlily (*Nymphaea odorata*; Figure 8) has showy white flowers and round leaves with radiating veins. Yellow waterlily (*Nuphar variegata*; Figure 9) has smaller yellow flowers and oblong leaves with parallel veins. These species often co-occur in mixed beds but yellow waterlily is generally restricted to depths less than seven feet and white waterlily may occur to depths of 10 feet (Nichols 1999).

Figure 9. Yellow waterlily