Aquatic Vegetation Surveys of

Ossawinnamakee Lake (DOW #18-0352-00)

Crow Wing County, Minnesota

2005 and 2009

Ossawinnamakee Lake. August 2009

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

Throughout the report there will be a tag called Map 1  that shows the common species of 2005 and 2009.

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

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Summary

Ossawinnamakee is a mesotrophic, hard-water lake in north central Minnesota. The lake has good water clarity and has historically supported an abundant and diverse native aquatic plant community. In 2002, the non-native plant, Eurasian watermilfoil (*Myriophyllum spicatum*) was reported in the lake. Non-native zebra mussels (*Dreisenna polymorpha*) were confirmed in the lake in 2003.

Aquatic vegetation surveys were conducted in 2005 and 2009 to assess the aquatic plant communities and included 490 sample sites within the shore to 25 feet depth zone. At each survey site, surveyors recorded information on water depth and plant species occurrence. Surveyors also recorded presence or absence of zebra mussels at each vegetated site.

In 2005, submerged plants were found to a depth of 25 feet (the maximum depth sampled that year). Sampling was extended to 28 feet in 2009 and one 26 feet deep site contained vegetation. Within the 0-25 feet depth zone, plants were found in 67% of the sites in 2005 and in 81% of the sites in 2009. In both years, vegetation was most frequent in the 0-15 feet depth zone where more than 85% of the sites were vegetated. In deeper water (16-25 feet), plant frequency increased from 28% in 2005 to 53% in 2009.

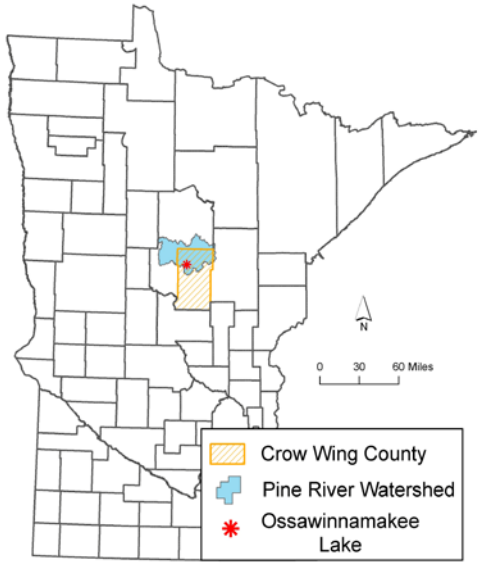
A total of 35 native aquatic plant taxa were recorded including nine emergent, three floating-leaved and 23 submerged plants. The most frequently occurring submerged taxa were flat-stem pondweed (*Potamogeton zosteriformis*), coontail (*Ceratophyllum demersum*), muskgrass (*Chara* sp.), northern watermilfoil (*Myriophyllum sibiricum*), Canada waterweed (*Elodea canadensis*), sago pondweed (*Stuckenia pectinata*), narrow-leaf pondweed (*Potamogeton* spp.) and broadleaf pondweeds (*Potamogeton* spp.). The frequencies and distributions of most plant taxa were similar in 2005 and 2009 but the mean number of plant taxa per site increased from 2.0 in 2005 to 2.5 in 2009.

The non-native plant, Eurasian watermilfoil (*Myriophyllum spicatum*), was found at only one sample site in 2005 and at six sites in 2009. It occurred within mixed beds of native vegetation in water depths of 9 to 16 feet.

In 2005, the non-native zebra mussel (*Dreisenna polymorpha*) was found only in the west half of the lake and occurred in 21% of all sample sites and 31% of vegetated sites. By 2009, it was found around the entire shoreline and was present 58% of all sites and 71% of vegetated sites. In 2009, zebra mussels were also found at three un-vegetated sites.

Introduction

Figure 1. Lake Ossawinnamakee in Crow Wing Co, MN.

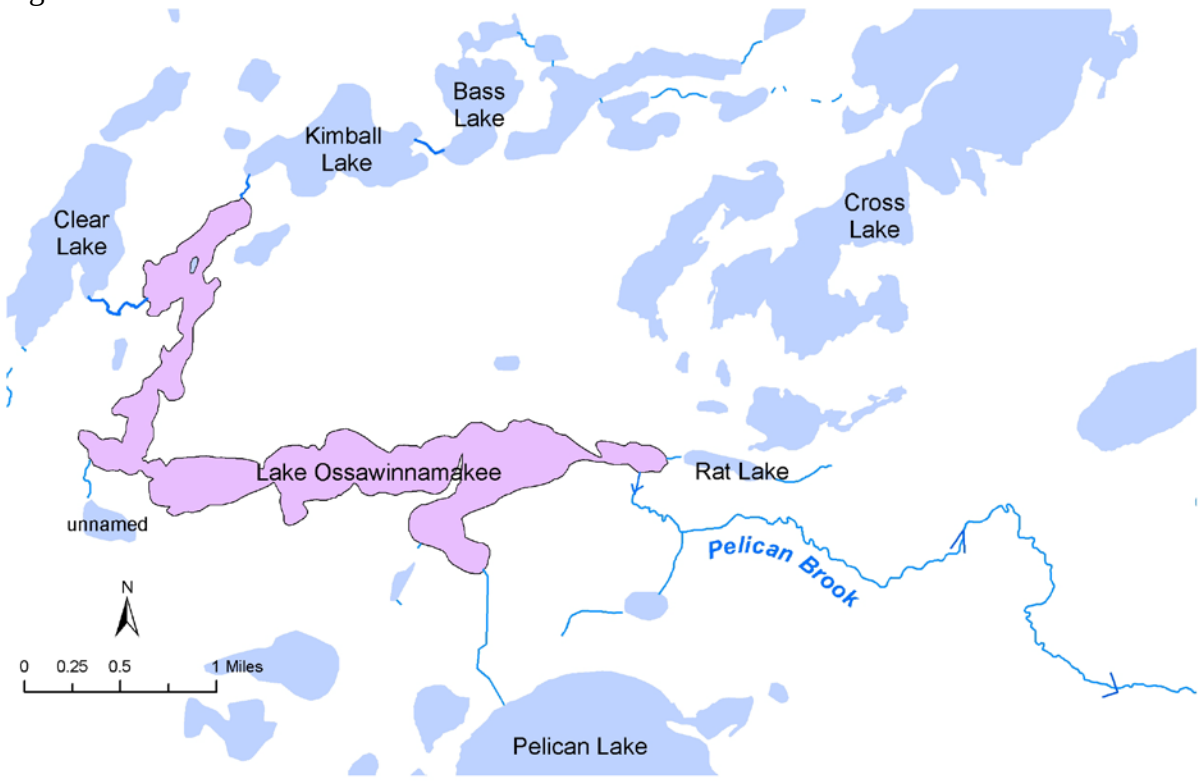


Lake Ossawinnamakee is located in Crow Wing County, north-central Minnesota in the southwest corner of the Pine River Watershed (Figure 1). There are about 150 lakes in the Pine River Watershed and about 245 lakes in Crow Wing County that are at least 50 acres in size. Ossawinnamakee Lake, with a surface area of 644 acres, is the 14th largest lake in the watershed and the 30th largest lake in the county.

Ossawinnamakee is a flow-through lake with water entering at the north from Kimball Lake and Clear Lake (Figure 2). There is a connection from Pelican Lake at the south, but no water flow occurs due to differences in elevation. Water leaves the eastern-most bay of Ossawinnamakee and flows southeast through Pelican Brook. Flow continues east to the Pine River and eventually to the Mississippi River.

Ossawinnamakee is "L"-shaped in outline, with a north-south facing basin and an east-west facing basin that meet to form a right angle (Figure 2). The north arm is about 1.5 miles in length and the east-west arm is about 2.5 miles long. Several smaller bays are located along

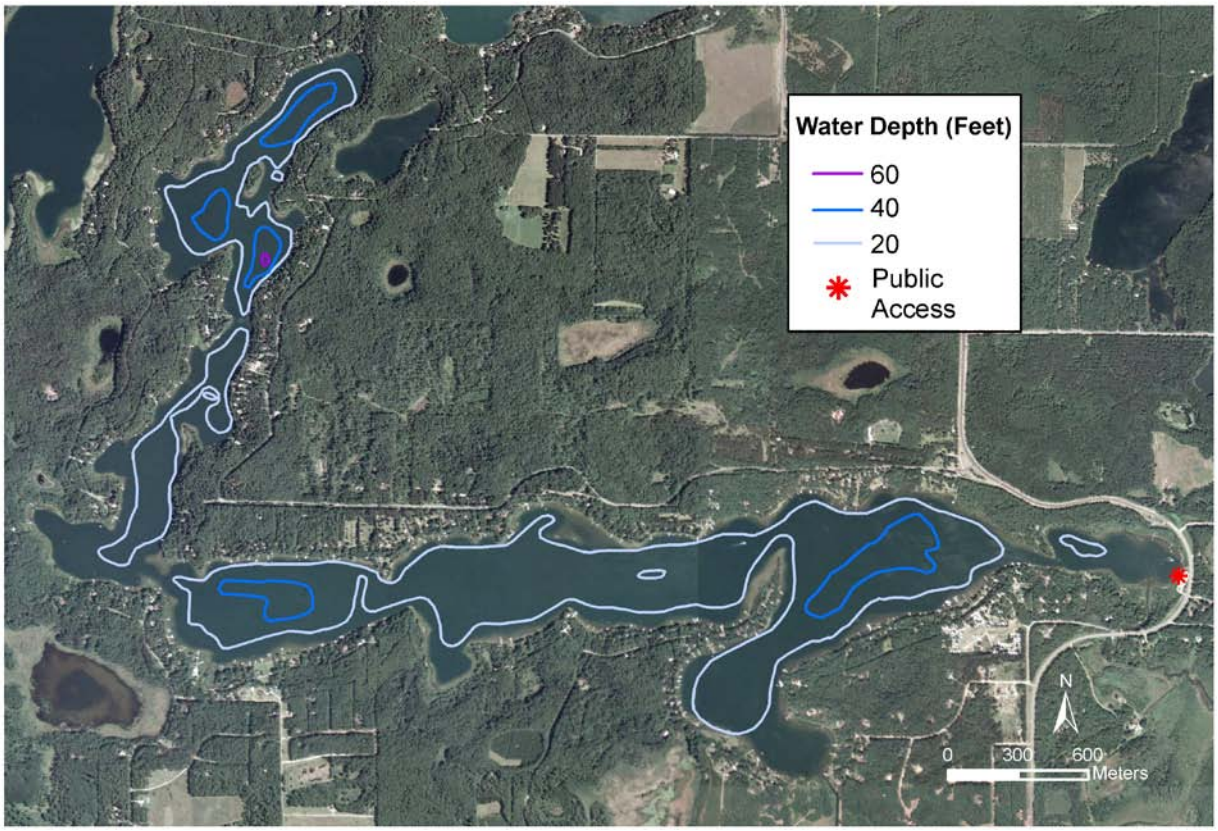
Figure 2. Waterbodies connected to Lake Ossawinnamakee.



these elongated basins. A small, half-acre, island occurs at the north end of the lake.

Forested uplands surround Lake Ossawinnamakee. The lake's 13 miles of shoreline are privately owned and developed with residential homes and several resorts. A public access is located on the east side of the lake from Crow Wing County Highway 39 (Figure 3). The lake has a maximum depth of 63 feet and about 40% of the lake basin is less than 15 feet in depth (Figure 3). This shallow area that rings the lake shoreline is referred to as the littoral zone. Rooted submerged plants are often common in the littoral zone if adequate sunlight reaches the lake bottom.

Figure 3. Lake Ossawinnamakee depth contours.



Lake Ossawinnamakee is a mesotrophic, or moderately nutrient enriched lake with relatively high water clarity. 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. Between 1990 and 2005, the average summer water clarity, as measured by Secchi disc readings, was about 17 feet in Lake Ossawinnamakee (MPCA, 2009). Beginning in 2006, summer water clarity has increased to about 20 feet (MPCA, 2009). 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 half times the Secchi depth. Based on Secchi disk measurements alone, aquatic plants are expected to grow to at least 25 feet in Ossawinnamakee Lake. Other factors that may influence the depth of plant growth include substrate type, wind fetch, and plant species composition.

Previous vegetation surveys of Lake Ossawinnamakee found abundant plant growth (Lindon 1993). More than 40 different plant species have previously been recorded in the lake including bulrush (*Schoenoplectus* spp.), wild rice (*Zizania palustris*), waterlilies (*Nymphaea odorata* and *Nuphar variegata*), and a variety of submerged plants such as coontail (*Ceratophyllum demersum*), northern watermilfoil (*Myriophyllum sibiricum*), clasping-leaf pondweed (*Potamogeton richardsonii*), and flat-stem pondweed (*Potamogeton zosteriformis*) (MnDNR Fisheries Lake Files). Submerged plants have been recorded to a depth of 25 feet (MnDNR Fisheries Lake Files). Beds of emergent and floating-leaf vegetation were delineated in 2006 by MnDNR Brainerd Area Fisheries biologists.

In 2002, the non-native plant, Eurasian watermilfoil (*Myriophyllum spicatum*) was reported in the lake. In 2003, non-native zebra mussels (*Dreisenna polymorpha*) were located in Lake Ossawinnamakee. The Minnesota DNR took actions to try to prevent the spread of zebra mussels to connecting waters. Large boulders were placed in the channel between Ossawinnamakee and Kimball Lake to stop motorized boat movement between the two lakes. During the summer of 2004 and 2005, chelated copper sulfate (CuSO4) was applied to the entire 26 acres of the eastern-most bay of Lake Ossawinnamakee to kill zebra mussel veligers (planktonic larvae) within that bay and reduce potential spread downstream. In fall 2005, zebra mussels were found in Rice Lake, downstream of the connection from Ossawinnamakee Lake to the Mississippi River. As this invasive had already spread to waters downstream along the Mississippi River, further treatments were stopped.

Objectives

The report provides a quantitative description Lake Ossawinnamakee plant communities in 2005 and 2009. Specific objectives included:

1. Estimate the maximum depth of vegetation
2. Estimate the percent of the lake occupied by vegetation
3. Record the aquatic plant taxa that occur in the lake
4. Estimate the abundance of common plant species
5. Develop distribution maps for the common plant species
6. Estimate the abundance and distribution of Eurasian watermilfoil.
7. Estimate the abundance and distribution of zebra mussels attached to sampled vegetation.

Methods

Vegetation Sampling

A point-intercept vegetation survey method was conducted and followed the methods described by Madsen (1999). Survey sites were established in a grid pattern across the lake. Because the lake has a narrow littoral zone, survey sites were spaced 50 meters apart to ensure adequate sampling within the shallow zone. Survey site waypoints were created using a Geographic Information System (GIS) computer program and downloaded into a handheld Global Positioning System (GPS) receiver.

Lake Ossawinnamakee was surveyed on August 22-24, 2005 and August 18, 19, 24, 2009. Surveys were conducted by boat and surveyors used GPS units 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 seven feet and an electronic depth finder in depths greater than seven feet. Surveyors did not sample sites if the waypoint location occurred on shore, within a dense stand of emergent vegetation, or at a location occupied by an angler or other recreational lake user.

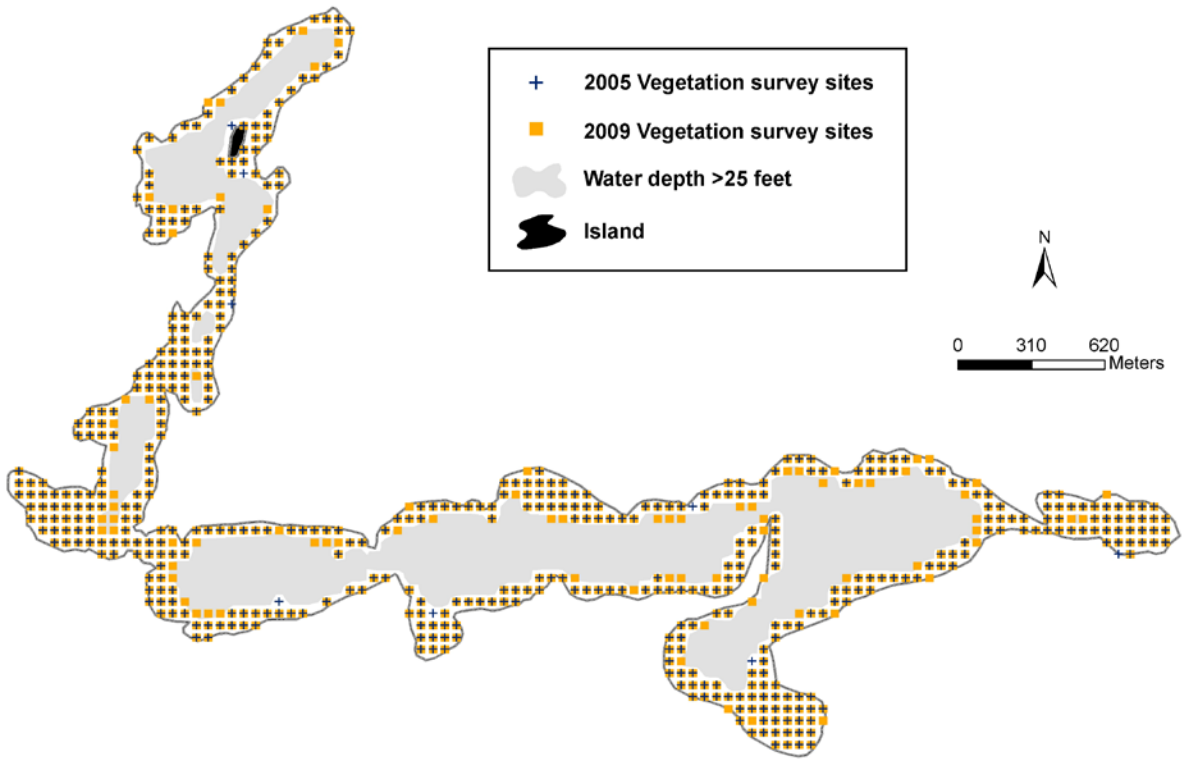
In 2005, surveyors sampled to a depth of 25 feet, for a total of 496 sample sites (Table 1). In 2009, surveyors extended sampling to a depth of 28 feet, for a total of 534 sample sites (Table 1). There were 490 sites that were sampled in both years (Figure 4) and only data from these sites were used to calculate frequency data.

Table 1. Sample effort by water depth.

Water depth interval	Sample sites	
	2005	2009
0 to 5	147	155
6 to 10	78	86
11 to 15	91	102
16 to 20	110	97
21 to 25	70	94
26 to 28	0	36
Total	496	534

Surveyors recorded all plant taxa found within a one square meter sample site at the pre-designated side of the boat. A double-headed, weighted garden rake, attached to a rope was used to survey vegetation not visible from the surface (Figure 5). Plant identification and nomenclature follows MnTaxa (2009). Voucher specimens were collected for most plant species and were submitted to The Herbarium of the University of

Figure 4. Vegetation survey sites on Lake Ossawinnamakee, 2005 and 2009.



Minnesota Bell Museum of Natural History, St. Paul, MN or are stored at the Minnesota Department of Natural Resources in Brainerd.

Figure 5. Sampling rake.

As surveyors navigated between survey sites, they searched for additional plant species. If surveyors located additional plant species not found in any sample sites, they recorded these species as "present" in the lake.

Frequency Calculations

Data were entered into a Microsoft Access database and frequency of occurrence was calculated for each plant species as the number of sites in which a species occurred divided by the total number of sample sites. Frequency was calculated for the entire area from shore to 25 feet and sampling points were also grouped by water depth and separated into five depth zones for analysis (Table 1).

Example:

In Ossawinnamakee there were 490 samples sites within the shore to 25 feet depth zone that were sampled in both 2005 and 2009.

In 2005, muskgrass (*Chara* sp.) occurred in 102 of those sites.

Frequency of muskgrass in Lake Ossawinnamakee in 2005 = 102/490 (*100) = 21 %

Zebra Mussel Sampling

At each site, surveyors sampled for zebra mussel presence by examining the rake, and rocks present and any collected vegetation. If zebra mussels were found, they were recorded as present at the site. Zebra mussel frequency of occurrence was calculated for all sites and for sites containing vegetation.

Substrate Sampling

In 2009, surveyors described bottom substrate at each sample site where water depth was seven feet and less. Standard substrate classes were used (Table 2) and if several substrate types occurred at a site, surveyors recorded the most common type.

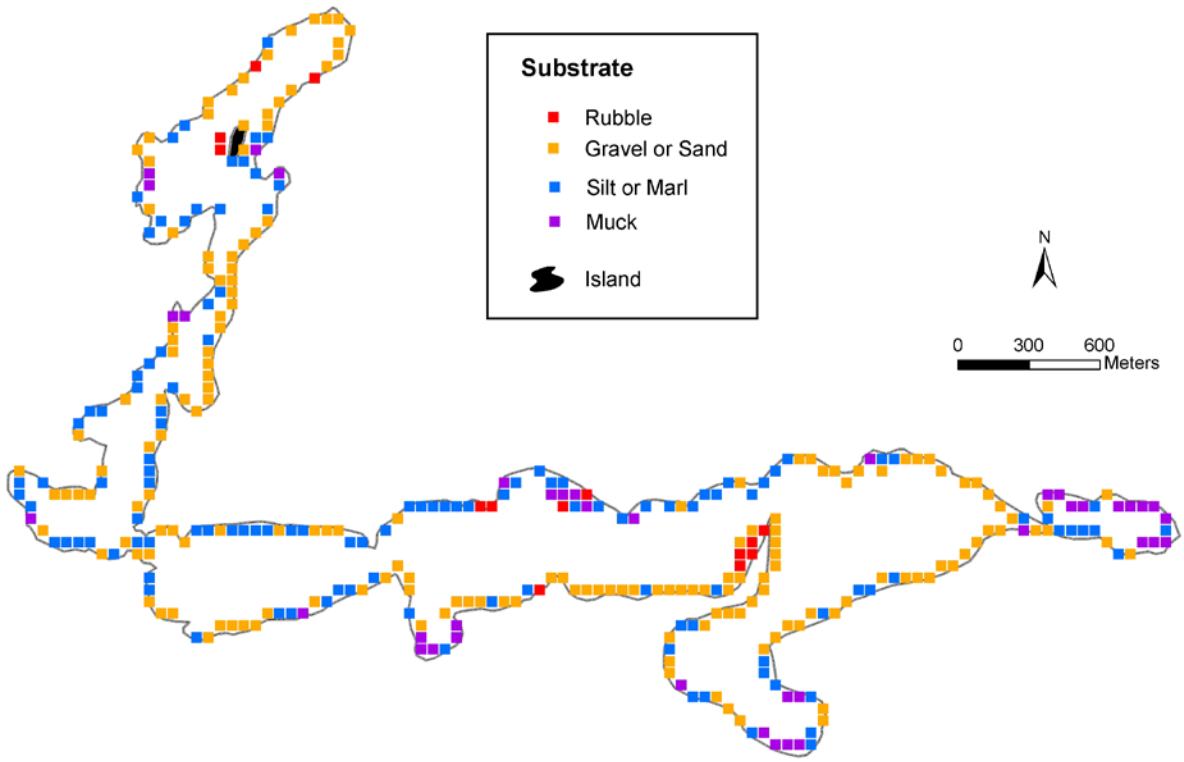
Table 2. Substrate classes

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

Results

Shoal substrates
Most shorelines contained hard substrates of sand, gravel and rubble. Softer substrates of silt, marl and muck were found in protected bays as well as along open shorelines (Figure 6).

Figure 6. Shoal substrates of Lake Ossawinnamakee, 2009.



Distribution of aquatic plants
Aquatic plant occurrence was similar in both years with vegetation occurring within a relatively narrow band around the entire perimeter of the lake (Figure 7). Along many shorelines, plant beds extended lakeward less than 75 meters due to steep increases in water depth. The broadest zones of plants occurred in shallow bays where submerged plant beds extended lakeward as far as 150 to 300 meters.

In 2005, submerged plants were found to a depth of 25 feet (the maximum depth sampled that year) and in 2009, one 26 feet deep site contained vegetation. The 0-25 feet depth zone of Lake Ossawinnamakee covers about 300 acres, which means that about 45% of the lake supports some aquatic plant growth. In both years, plant frequency was greatest in the 0-10 feet depth where at least 90% of the sites were vegetated (Figure 8). Plant frequency decreased with increasing water depth and in 21 to 25 feet depths, less than 30% of the sites were vegetated in either year.

Between 2005 and 2009, increases in vegetation were seen at several locations around the lake, including the eastern-most bay. Within the vegetated zone (0-25 feet), plants occurred in 67% of

the 2005 sites and in 81% of the 2009 sites (Figure 7). By 2009, plant frequency had increased at each water depth interval (Figure 8). In both years, vegetation was most frequent in the 0-15 feet depth zone where more than 85% of the sites were vegetated. In deeper water (16-25 feet), plant frequency increased from 28% in 2005 to 53% in 2009.

Figure 7. Distribution of aquatic plants in Lake Ossawinnamakee, 2005 and 2009.

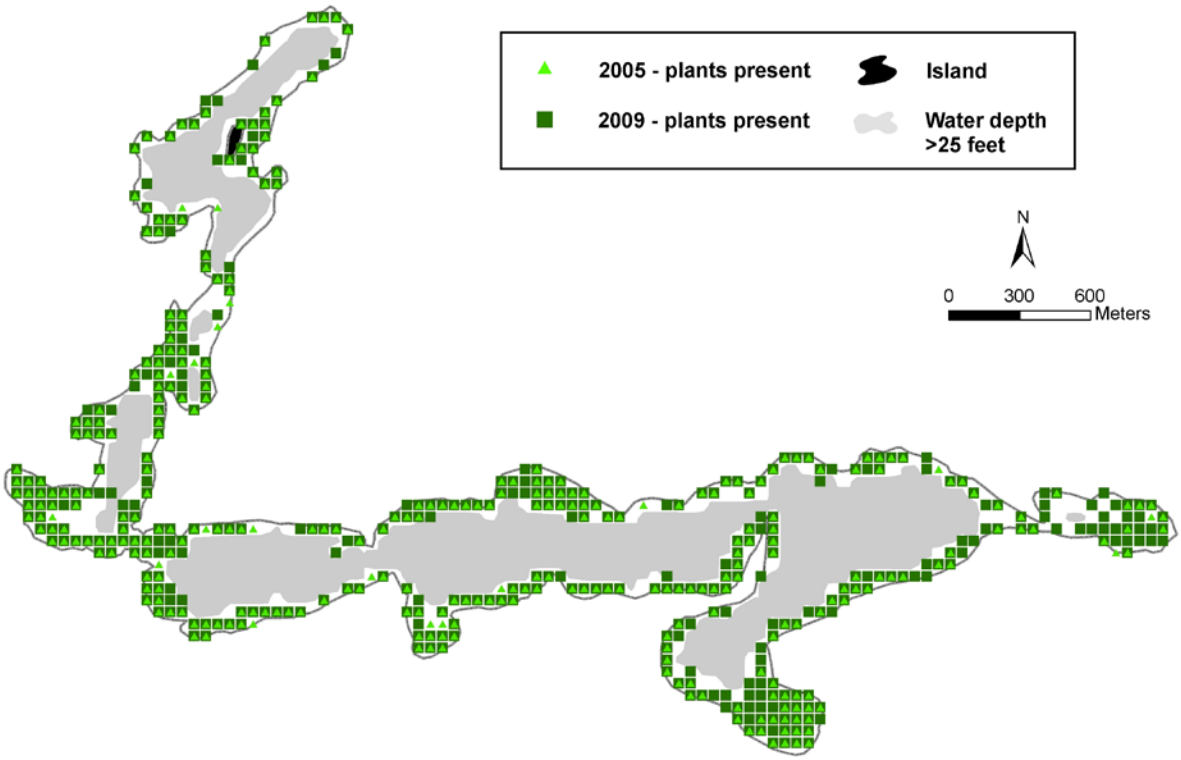
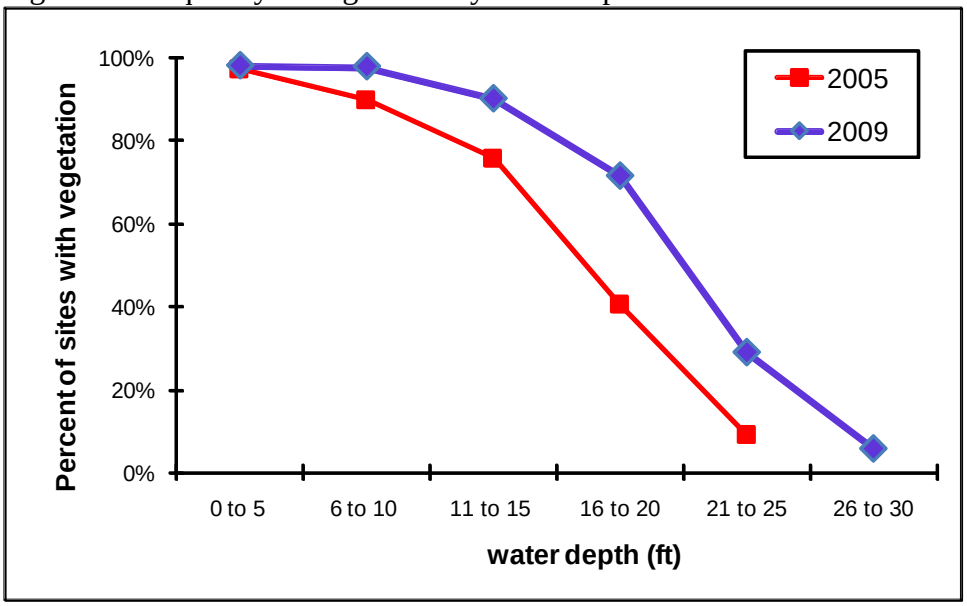


Figure 8. Frequency of vegetation by water depth.



Number and types of plants recorded

A total of 35 native aquatic plant taxa were recorded in Ossawinnamakee Lake including nine emergent, three floating-leaved, 23 submerged plants (Table 3). The non-native, submerged plant, Eurasian watermilfoil (*Myriophyllum spicatum*) was found in both survey years.

Table 3. Frequency of aquatic plants in Lake Ossawinnamakee, 2005 and 2009.

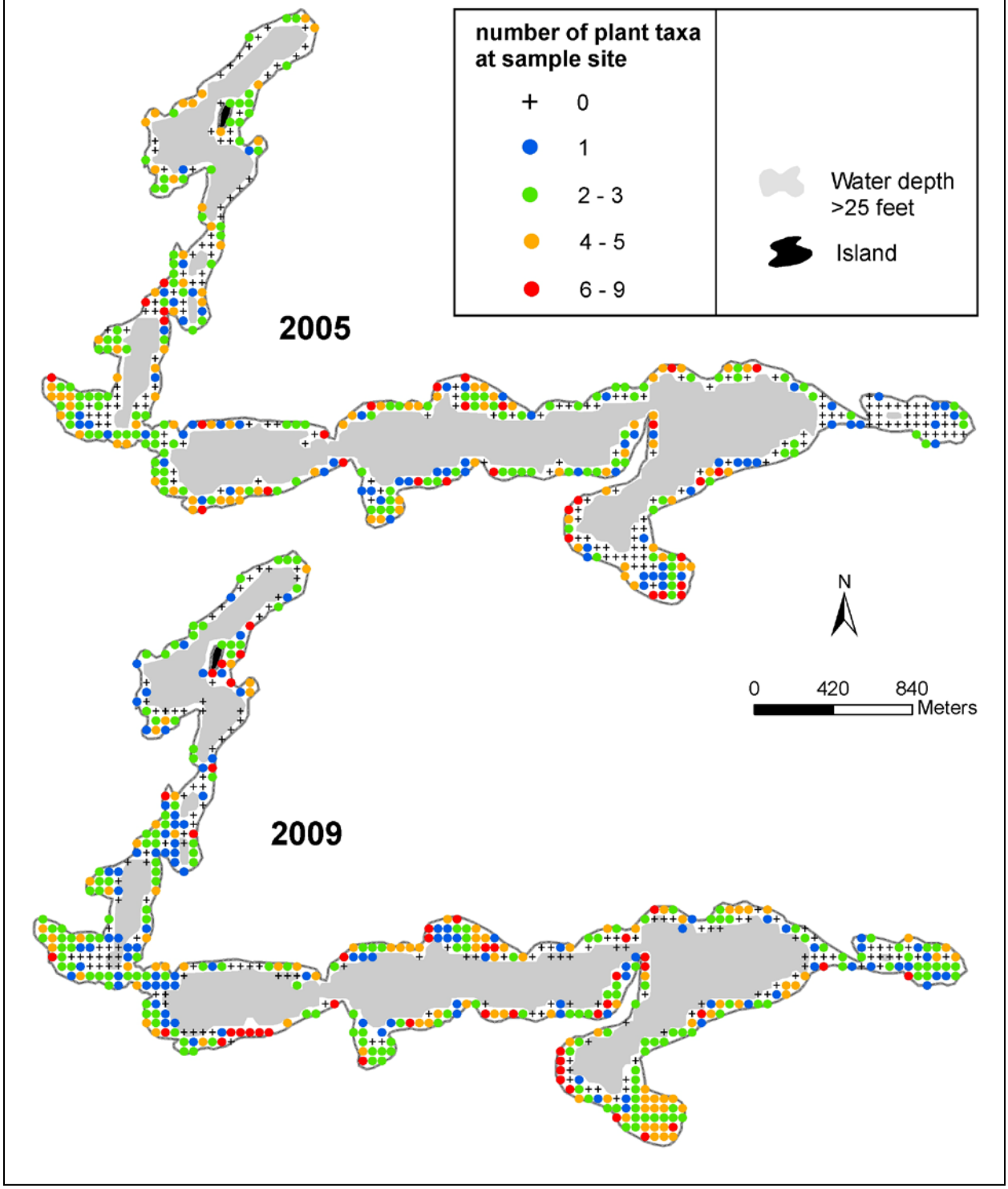
Life Form		Common Name	Scientific Name	Frequency 2005	Frequency 2009
ANCHORED SUBMERGED		Flat-stem pondweed	*Potamogeton zosteriformis*	35	39
		Coontail	*Ceratophyllum demersum*	26	30
		Muskgrass	*Chara* sp.	21	18
		Northern water milfoil	*Myriophyllum sibiricum*	18	26
		Canada waterweed	*Elodea canadensis*	6	21
	Narrow-leaf pondweeds	Sago pondweed	*Stuckenia pectinata*	14	8
		Fries' pondweed	*Potamogeton friesii*	13	14
		Small pondweed	*Potamogeton pusillus*		
		Leafy pondweed	*Potamogeton foliosus*		
	Broad-leaf pondweeds	Clasping-leaf pondweed	*Potamogeton richardsonii*	13	6
		Illinois pondweed	*Potamogeton illinoensis*	7	7
		Large-leaf pondweed	*Potamogeton amplifolius*	3	5
		Variable pondweed	*Potamogeton gramineus*	2	1
		White-stem pondweed	*Potamogeton praelongus*	<1	3
		Bushy pondweed	*Najas flexilis*	10	10
		Wild celery	*Vallisneria americana*	8	10
		White water buttercup	*Ranunculus aquatilis*	4	13
		Water stargrass	*Heteranthera dubia*	4	12
		Water marigold	*Megalodonata beckii*	4	3
	Non-native	Eurasian water milfoil	*Myriophyllum spicatum*	<1	1
FREE-DRIFTING SUBMERGED		Stonewort	*Nitella* sp.	3	5
		Greater bladderwort	*Utricularia vulgaris*	2	2
		Water moss	*Not identified to genus*	<1	<1
		Star duckweed	*Lemna trisulca*	<1	--
FLOATING		White waterlily	*Nymphaea odorata*	4	5
		Yellow waterlily	*Nuphar variegata*	1	3
		Floating leaf pondweed	*Potamogeton natans*	<1	<1
EMERGENT		Hardstem bulrush	*Schoenoplectus acutus*	1	2
		Three-square bulrush	*Schoenoplectus pungens*	<1	<1
		Wild rice	*Zizania palustris*	<1	<1
		Spikerush	*Eleocharis sp.*	<1	---
		Needlerush	*Eleocharis acicularis*	<1	<1
		Broadleaf arrowhead	*Sagittaria latifolia*	<1	---
		Narrow-leaved arrowhead	*Sagittaria* sp.	<1	1
		Narrow-leaf cattail	*Typha sp.*	present	<1
		Broad-leaf cattail	*Typha latifolia*	present	<1

Frequency is % of sample sites in which a plant species occurred within the shore to 25 ft water depth (N=490).

**Potamogeton friesii, P. pusillus* and *P. foliosus* were both present in the lake but were grouped as "narrow-leaved pondweeds" because they were not always distinguishable in the field.

In 2005 and 2009, the number of plant taxa found at each site ranged from zero to nine. The mean number of taxa per site increased from 2.0 in 2005 to 2.5 in 2009. Sites with the highest number of plant taxa occurred near shore, within mixed beds of emergent, floating-leaved and submerged plants (Figure 9).

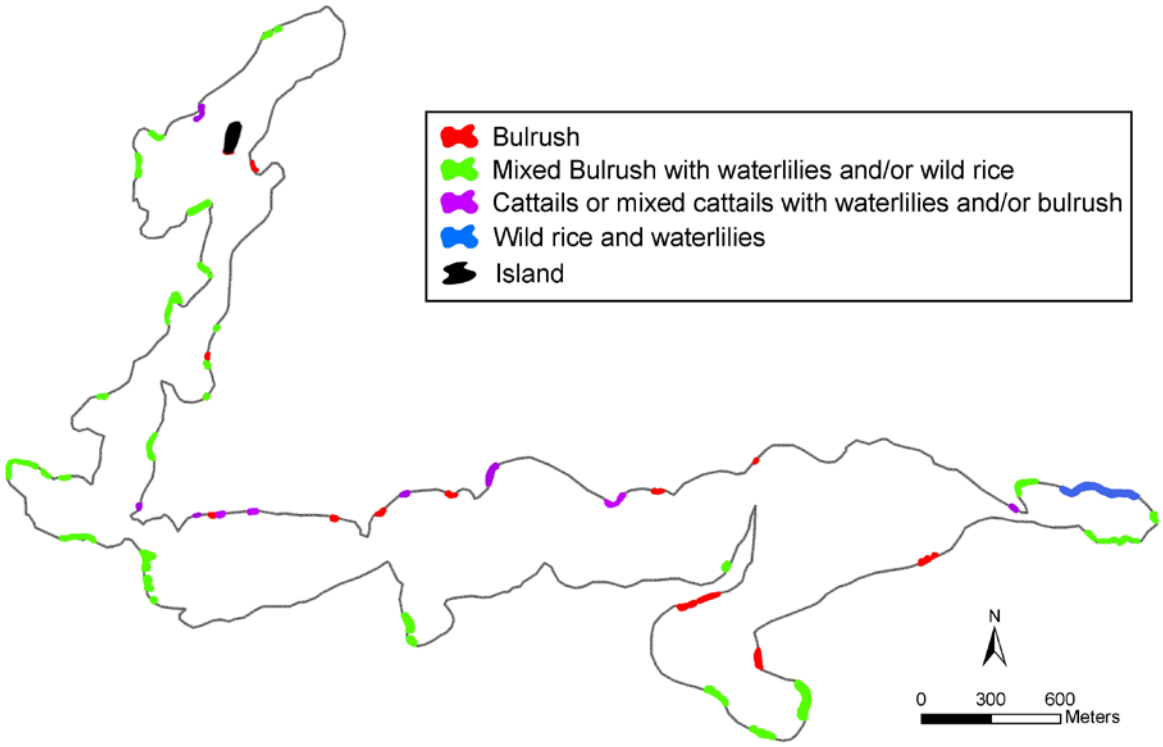
Figure 9. Number of plant taxa at each sample site, Ossawinnamakee Lake, 2005 and 2009.



Emergent and floating-leaf plants

Emergent plants occurred to a depth of five feet and floating-leaf plants were found to seven feet. Approximately 9 acres of emergent and floating-leaf plant beds were mapped in 2006 by DNR Fisheries. Some plant beds extended as much as 300 meters along shore, but most beds did not extend more than 45 meters into the lake (Figure 10). Plant bed types included cattail, bulrush, wild rice, waterlilies and mixed beds.

Figure 10. Emergent and floating-leaf plant beds of Lake Ossawinnamakee (DNR Fisheries 2006).



Hardstem bulrush (*Schoenoplectus acutus*) is a perennial emergent that may occur from shore to water depths of about six feet and its stems may extend several feet above the water surface. It may grow in pure stands or with other emergents and waterlilies. Bulrush spreads by rhizomes and regeneration is most successful on very shallow sites. Restoration of bulrush beds can be very difficult, making established beds particularly unique and valuable. Approximately seven acres of mixed beds of bulrush and other species were delineated in Lake Ossawinnamakee (Figure 11).

Figure 11. Bulrush bed on Lake Ossawinnamakee

Wild rice (*Zizania palustris*) is an annual plant that germinates each year from seed that fell to the lake bottom in the previous fall. It prefers soft substrates (Lee 1986, Nichols 1999) and

generally requires moving water for growth (MnDNR 2008). The plant begins growth underwater and then forms a floating-leaf stage before becoming fully emergent. Wild rice is susceptible to disturbance from storms and motorboats 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). About two acres of wild rice (Figure 12), or wild rice mixed with other species, were mapped.

Figure 12. Wild rice bed on Lake Ossawinnamakee

Figure 13. Waterlilies and burreed in Lake Ossawinnamakee.

Other emergent and floating-leaved plants occurred in less than 1% of the sample sites but some of these species, such as cattails (*Typha* spp.) and burreed (*Sparganium* spp.) were common within the shallow, non-accessible areas of emergent plant beds. Waterlilies often co-occurred within the emergent beds (Figure 13) and included yellow waterlily (*Nuphar variegata*), floating-leaf pondweed (*Potamogeton natans*) and white waterlily (*Nymphaea odorata*).

Submerged native plants

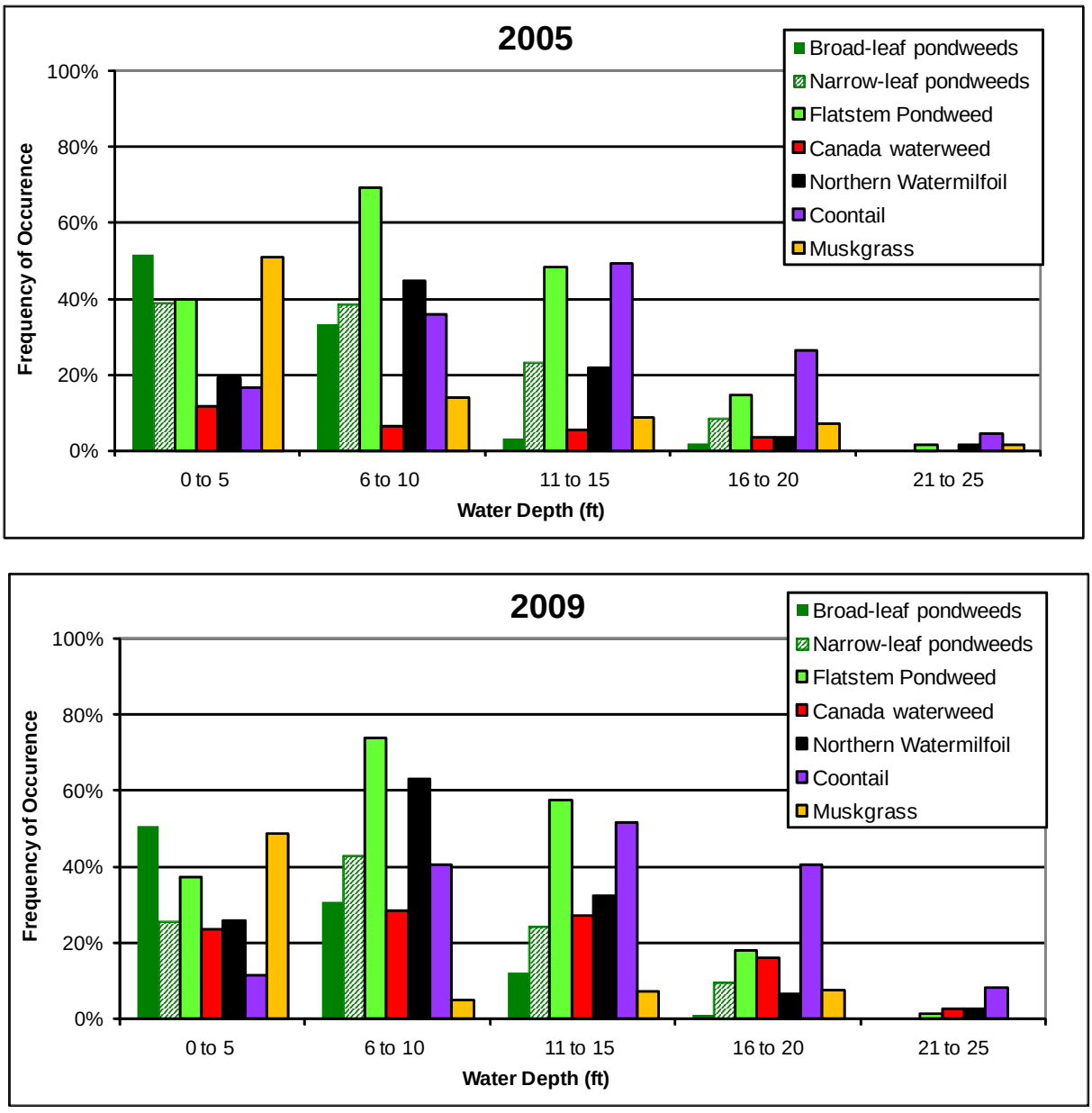
Submerged plants occurred in 66% of the 2005 survey sites and in 80% of the 2009 sites. Most submerged plant species were restricted to depths of 20 feet and less and only six plant taxa occurred in depths greater than 20 feet. The most commonly occurring taxa were flat-stem pondweed, coontail, muskgrass, northern watermilfoil and Canada waterweed. Each of these species occurred in at least 15% of all sample sites in one or both survey years (Table 3).

Flat-stem pondweed (*Potamogeton zosteriformis*) (Figure 14) is a perennial plant that is anchored to the lake bottom by underground rhizomes. It is named for its flattened, grass-like leaves. This species prefers soft substrates but is not tolerant of turbidity (Nichols 1999). Depending on water clarity and depth, these plants may reach the water surface and may produce flowers that extend above the water. These pondweeds are anchored to the lake bottom by rhizomes and over winter-by-winter buds.

Figure 14. Flat-stem pondweed.

In Lake Ossawinnamakee, flat-stem pondweed was the most frequently found submerged species (Map 1) and occurred in at least 35% of the survey sites in both years (Table 3). Flat-stem pondweed grew to a maximum depth of 25 feet and was one of only six plant taxa found in depths greater than 20 feet (Figure 15). In both years it was the dominant or co-dominant species in depths less than 16 feet.

Figure 15. Distribution of common submerged plants in Lake Ossawinnamakee, 2005 and 2009.



Coontail (*Ceratophyllum demersum*) (Figure 16) 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 16. Coontail

In Lake Ossawinnamakee, coontail occurred with a frequency of 26% in 2005 and 30% in 2009 (Table 3) and had a distribution similar to flat-stem pondweed (Map 1). It was most common in depths of 6 to 20 feet and was the most frequent species in depths greater than 15 feet (Figure 15).

Muskgrass (*Chara* sp.) (Figure 17) is a macroscopic, or large, algae that is common in many hard water Minnesota lakes. It has a brittle texture and a characteristic "musky" odor. Because muskgrass does not form true stems, it is a low-growing plant, often found entirely beneath the water surface where it may form low "carpets" on the lake bottom. Muskgrass is adapted to variety of substrates and is often the first species to colonize open areas of lake bottom where it can act as a sediment stabilizer. Muskgrass beds provide important fish spawning and nesting habitat.

Figure 17. Muskgrass Photo:Vic Ramey ©2001 Univ of Florida

Muskgrass was widespread in Lake Ossawinnamakee in 2005 and 2009 (Map 1), and occurred in about 20% of the sample sites (Table 3). It was the dominant plant in depths less than six feet where it occurred in about 50% of the sites (Figure 15).

Northern watermilfoil (*Myriophyllum sibiricum)* (Figure 18*)* is a rooted, perennial submerged plant with finely dissected leaves. It may reach the water surface, particularly in depths less than ten feet and its flower stalk extends above the water surface. It spreads primarily by stem fragments and overwinters by hardy rootstalks and winter buds. Northern watermilfoil is not tolerant of turbidity (Nichols 1999) and grows best in clear water lakes.

Figure 18. Northern watermilfoil

Northern watermilfoil occurred in 18% of the 2005 sites and 26% of the 2009 sites. It often co-occurred in mixed beds of pondweeds (*Potamogeton* spp.) and coontail (Map 1). It occurred at all depth intervals sampled and was most common in water depths of six to ten feet (Figure 15).

Canada waterweed (Elodea canadensis) (Figure 19) is perennial submerged species that is widespread throughout Minnesota because it is adapted to a variety of conditions. It is tolerant of low light and prefers soft substrates. This species can over winter as an evergreen plant and

spreads primarily by fragments. In both years it was distributed around the entire lake (Map 1), and increased in frequency from 6% in 2005 to 21% in 2009 (Table 3).

Figure 19. Canada waterweed
(photo by Vic Ramey, Univ of Florida)

Narrow-leaf pondweeds (Figure 20) are rooted, perennial submerged plant with small, thin leaves. Leaves grow entirely below the water surface but flowers extend above the water. This plant also over winters as rhizomes and winter buds. There are several different types of pondweeds that are included in this general group and without fruit or flowers they are difficult to distinguish. In Lake Ossawinnamakee, four different species were identified: and sago pondweed (*Stuckenia pectinata*), Fries' pondweed (*Potamogeton friesii*), small pondweed (*P. pusillus*), and leafy pondweed (*P. foliosus*).

Figure 20. Sago pondweed, a narrow-leaf pondweed

At least 20% of the sample sites contained at least one narrow-leaf pondweed in each survey year (Table 3). Narrow-leaf pondweeds were most often found in depths of 15 feet and less (Figure 15 and Map 1).

Broad-leaf pondweeds, (Figure 21) often called "cabbage" plants by anglers, are rooted, submerged perennial plants with wide leaves. The fruits of pondweeds are a favorite duck food and the broad leaves provide food and shelter for fish. In Lake Ossawinnamakee, this group includes clasping-leaf pondweed (*Potamogeton richardsonii*), Illinois pondweed (*P. illinoensis*), large-leaf pondweed (*P. amplifolius*), variable pondweed (*P. gramineus*), and white-stem pondweed (*P. praelongus*).

Figure 21. White-stem pondweed, a broad-leaf pondweed.

At least 20% of the sample sites contained at least one broad-leaf pondweed in each survey year (Table 3). Broad-leaf pondweeds were well distributed around the lake and were most often found in depths of ten feet and less (Figure 15 and Map 1).

Other native submerged species occurred in 10% or less of the sample sites.

Non-native Eurasian watermilfoil

The non-native species, Eurasian watermilfoil (*Myriophyllum spicatum*) (Figure 22) was located in only one survey site in 2005 and in six sites in 2009. It was found in depths of 9 to 16 feet and did not reach the water surface. In some areas of some lakes, Eurasian watermilfoil can form thick beds and crowd out native plants. During the survey years in Lake Ossawinnamakee, it

did not form dense mats but co-occurred with northern watermilfoil and in mixed beds of pondweeds (*Potamogeton* spp.), coontail (*Ceratophyllum demersum*), Canada waterweed (*Elodea canadensis*) and water celery (*Vallisneria americana*). For information on how to distinguish the non-native, Eurasian watermilfoil from the native northern watermilfoil, click here: identification.

Figure 22. Eurasian watermilfoil

Non-native zebra mussels

Zebra mussels (*Dreisenna polymorpha*) (Figure 23) are small striped exotic mussels that were introduced to the United States around the late 1980's in ballast water from trans-Atlantic ships. They were first documented in Minnesota waters of the Mississippi River in the early 1990's. The first inland lake with confirmed zebra mussels was reported in 2000 in southern Minnesota and as of 2008, this invasive has since been confirmed in less than a dozen inland lakes, including Lake Ossawinnamakee.

Figure 23. Zebra Mussels

Zebra mussels have two distinct life stages: the attached, sessile adult, and a planktonic, free-living larval stage (veliger). The planktonic veliger stage is an effective dispersal form, moved about by wind and currents. Any lake with a reproducing zebra mussel population can be expected to have veligers dispersed throughout the system, unless physical barriers prevent their movement. However, once the veligers mature and develop a sufficient shell, they settle and attach themselves to any solid object (rocks, wood, vegetation, etc) in suitable habitats. Movement of the shelled adult stage is extremely limited or non-existent. High zebra mussel densities can cause ecological problems in lakes, such as killing native mussels, changing food webs and altering nutrient pathways. These adults can also clog pipes and intakes. The filter-feeding by zebra mussels can increase water clarity by removing large amounts of phytoplankton as well as inorganic material.

In 2005, zebra mussels were located only in the west half of the lake and none were found within a mile of the public water access (Figure 24). Surveyors observed zebra mussels in 21% of all sample sites and in 31% of vegetated sites. Zebra mussels were found at all depths sampled (to 25 feet) and were most frequently found in the 6 to 20 feet depth zone where they occurred on about 40% of the vegetated sites (Figure 25). By 2009, zebra mussels were found around the entire shoreline and were present at 58% of all sites and 71% of vegetated sites. In 2009, zebra mussel occurrence on plants increased at all water depths sampled and was highest in the 0 to 15 feet zone (Figure 25).

Figure 24. Distribution of zebra mussels in Lake Ossawinnamakee, 2005 and 2009.

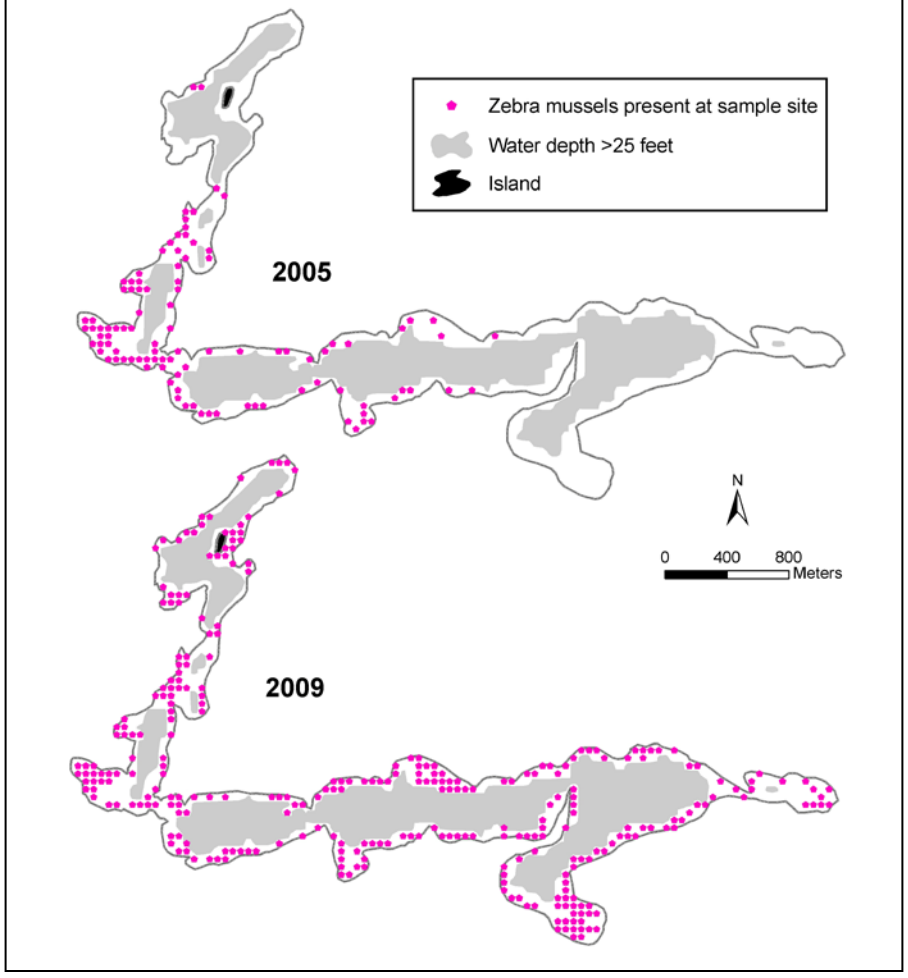
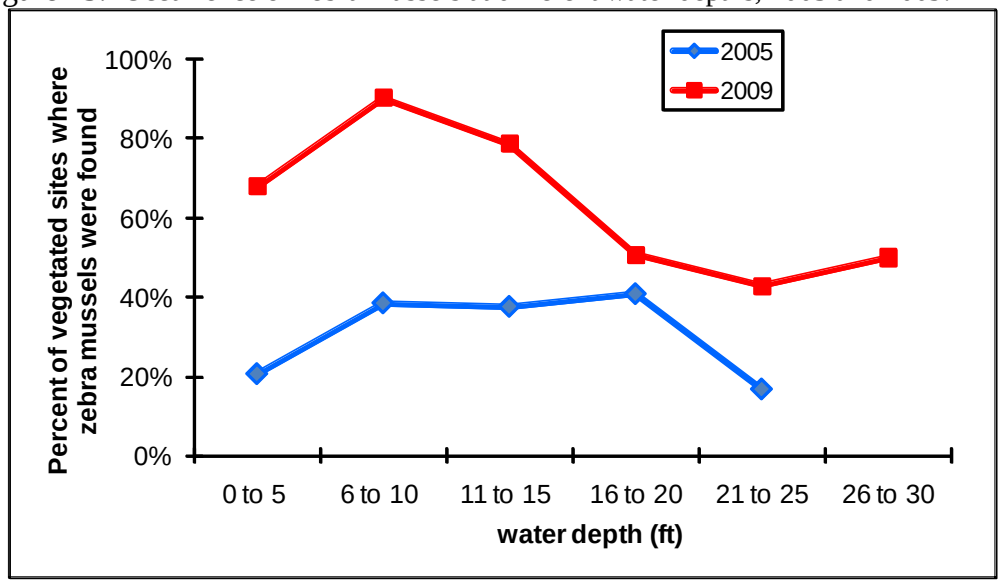


Figure 25. Occurrence of zebra mussels at different water depths, 2005 and 2009.



Zebra mussels were present on all plant types including leafy, rooted plants (Figure 26) and finely branched, large algae (Figure 27).

In 2009, surveyors also located zebra mussels on rocks at three un-vegetated sites but actual presence of zebra mussels in non-vegetated sites is unknown because surveyors did not visually search the lake bottom for presence of zebra mussels.

Figure 26. Zebra Mussels on rooted vegetation in Lake Ossawinnamakee, 2009

Figure 27. Zebra Mussels on large algae (*Nitella* sp.) in Lake Ossawinnamakee, 2009

Discussion

The types and amounts of aquatic vegetation that occur within a lake are influenced by a variety of environmental factors including water clarity, water chemistry, depth, substrate type and wave activity. Plant communities also change in abundance and diversity due to life cycle changes of individual plant species. Invasions of non-native plant and/or animal species can also lead to changes in the native plant population.

The water clarity of Lake Ossawinnamakee is sufficiently high to allow aquatic plant growth to a depth of about 25 feet but available light beyond that depth is not sufficient for most rooted plants. Filter-feeding activity of zebra mussels can lead to increased water clarity (Leach 1993, Effler et al. 1997). From 2006 through 2008, mean summer Secchi depth readings in Lake Ossawinnamakee averaged about 20 feet, compared to about 17 feet in previous years (MPCA 2008). It is not known whether this apparent increase in water clarity was due to zebra mussels but it does coincide with the increase in plant occurrence from 2005 to 2009. If water clarity continues to increase in the lake, aquatic plant occurrence may increase in the 20-25 feet zone and the maximum depth of plant growth may increase.

Relatively high water clarity, shallow water zones, and a diversity of substrate types provide for a diversity of plant types in Lake Ossawinnamakee. The abundant and diverse native aquatic plant communities found in the lake provides critical fish and wildlife habitat and other lake

benefits. (Click here for more information on: value of aquatic plants). Even though Eurasian watermilfoil occurs in the lake, the non-native plant remains quite low in abundance and distribution. Continued protection of the native plant beds may help mitigate the potentially harmful impacts of non-native plants.

Humans can impact aquatic plant communities directly by destroying vegetation with herbicide or by mechanical means. For information on the laws pertaining to aquatic plant management, click here: MnDNR APM Program or contact your local DNR office. Motorboat activity in vegetated areas can be particularly harmful for species such as bulrush and 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. Herbicide and mechanical control of aquatic plants can directly impact the aquatic plant community. Limiting these types of activities can help protect native aquatic plant species.

Undeveloped shoreline in east bay of Lake Ossawinnamakee, August 2005.

Literature Cited

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

Effler, S.W., S.R. Boone, C.A. Seigfried, L. Walrath and S.L. Ashby. 1997. Mobilization of ammonia and phosphorus by zebra mussels (*Dreisenna polymorpha*) in the Seneca River, New York. 187-207 In Zebra Mussels and Aquatic Nuisance Species, F. M. D'Itri, editor

Engel, S. and S.A. Nichols. 1994. Aquatic macrophyte growth in a turbid windswept lake. Journal of Freshwater Ecology. Vol. 9., pp 97-109.

Leach, J. H. 1993. Impacts of the Zebra Mussel (Dreissena polymorpha) on water quality and fish spawning reefs in western Lake Erie. 381-413 In "Zebra Mussels: Biology, Impacts and Control, T. F. Nalepa and D. W. Schloesser, eds.

Lee, P. F. 1986. Ecological relationships of wild rice, *Zizania aquatica*. 4. Environmental regions within a wild rice lake. Canadian Journal Botany 64:2037-2044.

Lindon, M., S. Heiskary, and Ossawinnamakee Lake Association. 1993. Ossawinnamakee Lake MnDNR ID #18-0352, Crow Wing County. Minnesota Pollution Control Agency, Environmental Analysis and Outcomes Division. St. Paul, MN.
Lake Water Quality Assessment Reports - Minnesota Pollution Control Agency

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

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

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

MPCA. 2008. Minnesota Pollution Control Agency. St. Paul, MN. Lake Water Quality Assessment Program. Lake Water Quality Data Search website: http://www.pca.state.mn.us/water/lkwqSearch.cfm (accessed November 2008).

MnTaxa. 2009. Minnesota State Checklist of Vascular Plants. Minnesota Department of Natural Resources, Division of Ecological Resources, St. Paul.

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

