The Aquatic Plant Community of Otter Lake,

Chippewa County, Wisconsin

1995-2004

Wisconsin Department of Natural Resources
Eau Claire, WI

May 2006

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Submitted by:

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EXECUTIVE SUMMARY

Otter Lake is a hypereutrophic lake with very poor water clarity and quality. Nutrients and algae have increased since 1991. Water clarity has decreased since 1993.

Aquatic plant growth is scattered throughout the Otter Lake, at approximately half of the sites, to a maximum rooting depth of 8.5 feet. The 0-5ft depth zone supports the greatest amount plant growth. The plant community is characterized by good diversity of plant species, a below average quality of the community for Wisconsin, a high tolerance to disturbance and a highly disturbed condition. Much of the diversity is in the emergent plant community.

Elodea canadensis was the dominant species, found at one-third of the sites up to the maximum rooting depth. *E. canadensis* was especially dominant in the 1.5-10ft depth zone and grew at an above average density. *Ceratophyllum demersum* was sub-dominant. *Potamogeton crispus*, a non-native aquatic plant species, occurred at a low frequency and density in Otter Lake.

A healthy aquatic plant community plays a vital role within the lake community. Aquatic plants help improve water quality, provide valuable habitat resources for fish and wildlife, help resist invasions of non-native species and check the excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.

Management Recommendations

1) Lake residents work with efforts in the watershed to reduce nutrient input (both phosphorus and nitrogen) to Otter Lake.
2) All lake residents and visitors practice best management on their lake properties.
    a) Keep septic systems cleaned and in proper condition.
    b) Use no lawn fertilizers; both nitrogen and phosphorus can feed algae blooms in Otter Lake.
    c) Clean up pet wastes.
    d) Do not compost near the water or allow yard wastes and clippings to enter the lake.
3) Residents become involved in the Self-Help Volunteer Lake Monitoring Program, monitoring water quality to track seasonal and year-to-year changes.
4) DNR to designate sensitive areas within Otter Lake. These are areas within the lake that are most important for habitat and maintaining water quality.
5) Protect the natural shoreline around Otter Lake.
6) Protect the aquatic plant community as a whole in Otter Lake. The standing-water emergent community, floating-leaf community and submergent plant community are all important for fish and wildlife habitat and water quality protection. This diverse aquatic plant community will support a diverse fish and wildlife community for fish and wildlife habitat and water quality protection.

Changes in the Aquatic Plant Community of Otter Lake, Chippewa County 1995-2004

I. INTRODUCTION

Studies of the aquatic macrophytes (plants) in Otter Lake were conducted during August 1995 and June 2004 by Water Resources staff of the Western Central Region - Department of Natural Resources (DNR).

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake due to the important ecological role of aquatic vegetation and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

Ecological Role: All other life in the lake depends on the plant life (including algae) - the beginning of the food chain. Aquatic plants provide food and shelter for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake, impact recreation, and serve as indicators of water quality.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

The present study will provide information that is important for effective management of the lake: including fish habitat improvement, protection of sensitive areas, aquatic plant management, and water resource regulations. The data will be compared to past and future plant studies and offer insight into changes occurring in the lake.

Background:

Otter Lake is a 661-acre impoundment on Otter Creek in eastern Chippewa County, Wisconsin. The 14-foot dam was built in 1969, inundating a 50-acre natural seepage lake. Two other small tributaries provide additional inflow to Otter Lake. The maximum depth of Otter Lake is 43 feet and its mean depth is 11 feet. Otter Lake is considered to be the largest, most productive lake in the "east Chippewa County, west Taylor and Clark Counties, and northeast Eau Claire County area" and is a popular year-round fishing resource (Kurz 1989).

Aquatic Plant Control with herbicides was attempted twice in Otter Lake.

1) A one-acre section in the east bay of Otter Lake was treated in 1988 with Aquacide (2,4-D) to control *Ceratophyllum demersum*.
2) On the east shore, near the town boat landing, one shoreline landowner treated a 50x50 foot area in 2000 with a broad-spectrum chemical (diquat) to control *Elodea canadensis*.

II.METHODS

Field Methods

The study design was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines. The shoreline was divided into 29 equal segments and within each segment, a transect was randomly placed, using a random numbers table (Appendix VII).

One sampling site was randomly located in each depth zone (0-1.5ft., 1.5-5ft., 5-10ft. and 10-20ft.) along each transect. Using a long-handled steel thatching rake, four rake samples were taken at each sampling site, one rake sample from each quarter of a 6-foot square quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5) based on the number of rake samples on which it was present at that sampling site.

A rating of 1 indicates that a species was present on one rake sample at that site
A rating of 2 indicates that a species was present on two rake samples
A rating of 3 indicates that a species was present on three rake samples
A rating of 4 indicates that it was present on all four rake samples
A rating of 5 indicates that it was abundantly present on all rake samples at that sampling site.

The actual depth and sediment type at each sampling site was recorded. The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet back from the shore, was evaluated. The percentage of each cover type within this 100' x 30' rectangle was estimated.

Visual inspection and periodic samples were taken between transect lines in order to record the presence of any species that did not occur at the sampling sites. Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

Data Analysis

Its sampling year was analyzed separately and compared. The frequency of occurrence of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites) (Appendix I, II). Relative frequency was calculated (number of occurrences of a species relative/sum of all species occurrences) (Appendix I, II). The mean density was calculated for each species (sum of a species' density ratings / number of sampling sites) (Appendix III, IV). Relative density was calculated (sum of a species' density ratings / sum of all plant densities) (Appendix III, IV). A "mean density where present" was calculated for each species (sum of a species' density ratings / number of sampling sites at which the species occurred) (Appendix III, IV). The relative frequency and relative density of each species was summed to obtain a dominance value for each species (Appendix V, VI).

Simpson's Diversity Index was calculated (Appendix I, II). Each sampling year was compared by a Coefficient of Community Similarity (Appendix VIII).

An Aquatic Macrophyte Community Index (AMCI), developed for Wisconsin lakes, was applied to Otter Lake. Data in seven categories that characterize the aquatic plant community is converted to values 0 - 10 and summed as outlined by Nichols (2000).

Coefficients of Conservatism and Floristic Quality Indices were used to evaluate the closeness of the aquatic plant community to an undisturbed condition (Nichols 1998). A Coefficient of Conservatism is an assigned value, 0-10, the probability that a species will occur in a relatively undisturbed habitat. The Average Coefficient of Conservatism is the mean of the Coefficients of Conservatism for all species found in the lake and measures tolerance to disturbance. The Floristic Quality Index is calculated from the Average Coefficient of Conservatism and measures the closeness of the community to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

Many physical parameters impact the aquatic plant community. Water quality (nutrients, algae, water clarity and water hardness) influence the plant community as the plant community can in turn modify these parameters. Lake morphology, sediment composition and shoreline use also impact the aquatic plant community.

WATER QUALITY - The trophic state of a lake is a classification of its water quality. Phosphorus concentration, chlorophyll concentration and water clarity data are collected and combined to determine the trophic state.

Eutrophic lakes are high in nutrients and therefore support a large biomass.

Oligotrophic lakes are low in nutrients and support limited plant growth and smaller populations of fish.

Mesotrophic lakes have intermediate levels of nutrients and biomass.

Phosphorus is a limiting nutrient in many Wisconsin lakes. Increases in phosphorus in a lake can feed algal blooms and excess plant growth.

July 2004 total phosphorus in Otter Lake was 138-164 ug/l.

The phosphorus concentration in Otter Lake places it in the hypereutrophic range (Table 1).

Table 1. Trophic Status

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Discft.
Oligotrophic	Excellent	<1	<1	> 19
	Very Good	1-10	1-5	8-19
Mesotrophic	Good	10-30	5-10	6-8
	Fair	30-50	10-15	5-6
Eutrophic	Poor	50-150	15-30	3-4
Hypereutrophic	Very Poor	**>150**	**>30**	**>3**
Otter Lake 2004 Site 1	Very Poor	164	63.4	2.6
Otter Lake 2004 Site 2	Very Poor	138	39	2.8

After Lillie & Mason (1983) & Shaw et. al. (1993)

Although the majority of lakes in Wisconsin are phosphorus limited, about 10% of lakes are nitrogen limited. The nitrogen:phosphorus ratio in Otter Lake varies between 9.5:1 and 10.5-1. Lakes with a N:P ratio less than 10:1 are considered nitrogen limited and those with a ratio between 10:1 and 15:1 are considered transitional. This means that additions of nitrogen can also impact algae growth. Lakes with low N:P ratios are also associated with nuisance blue-green algae (cyanobacteria) blooms.

Measuring the concentration of chlorophyll measures the amount of algae in the lake. Algae are natural and essential in lakes, but high algal levels can cause problems, contributing to turbidity and reducing the light available for plant growth.
July 2004 chlorophyll in Otter Lake was 39-63.4 ug/l.
Lakes with chlorophyll in this range are considered hypereutrophic (Table 1).

Filamentous algae was found at 22.4% of the sampling sites in 1995 and 14% of the sample sites in 2004. In 2004, filamentous algae occurred at:

24% of the sample sites in the 0-1.5ft depth zone
24% of the sample sites in the 1.5-5ft depth zone
4% of the sample sites in the 5-10ft depth zone
0% of the sample sites in the 10-20ft depth zone

Water clarity is a critical factor for aquatic plants. When aquatic plants receive less than 1 - 2% of the surface illumination, they can not survive. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Water clarity can be measured with a Secchi disc that shows the combined effect of turbidity and color.
July 2004 Secchi disc depth clarity was 2.6-2.8 feet.
The water clarity data indicates that Otter Lake has very poor water clarity and is in the hypereutrophic range (Table 1).

The combination of the phosphorus, chlorophyll, and clarity values indicates that Otter Lake is a hypereutrophic lake (Table 1). This trophic state favors abundant plant growth and frequent algae blooms that result in high turbidity.

Ed Molter, a volunteer lake monitor in the Self-Help Program, monitored Otter Lake for water clarity, phosphorus and chlorophyll during 1989-1993. Combining Ed Molter's 1990-1993 data with the data collected by the WI-DNR in 1995 and 2004, suggests that both phosphorus and chlorophyll have increased in Otter Lake (Figure 1).

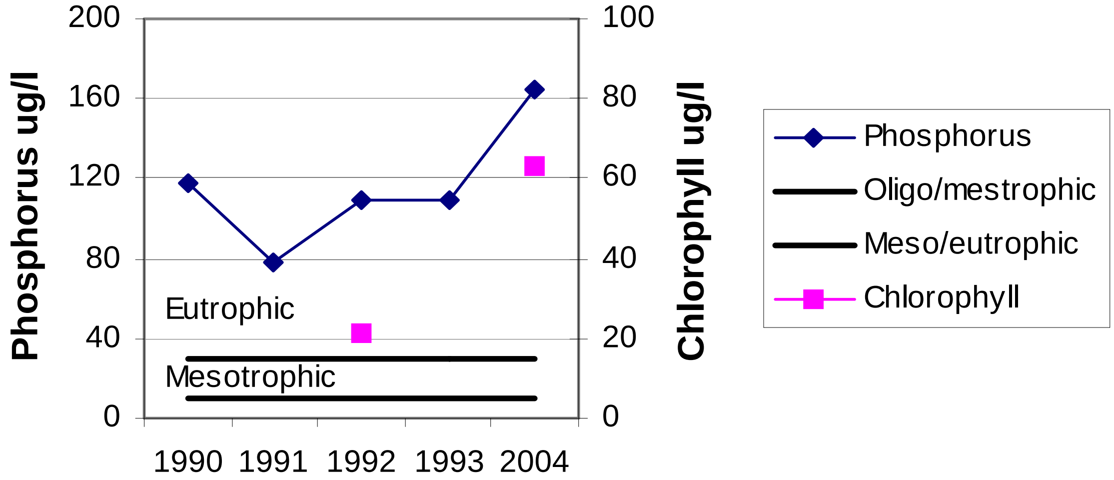


Figure 1. Increase of phosphorus and chlorophyll in Otter Lake, 1990-2004.

The combination of water clarity data from Ed Molter and the WI-DNR shows that there was no discernable trend in water clarity during 1989-2004, but there has been a decline during 1993 - 2004 (Figure 2). Yearly variations in rainfall, temperature, etc. can impact water clarity.

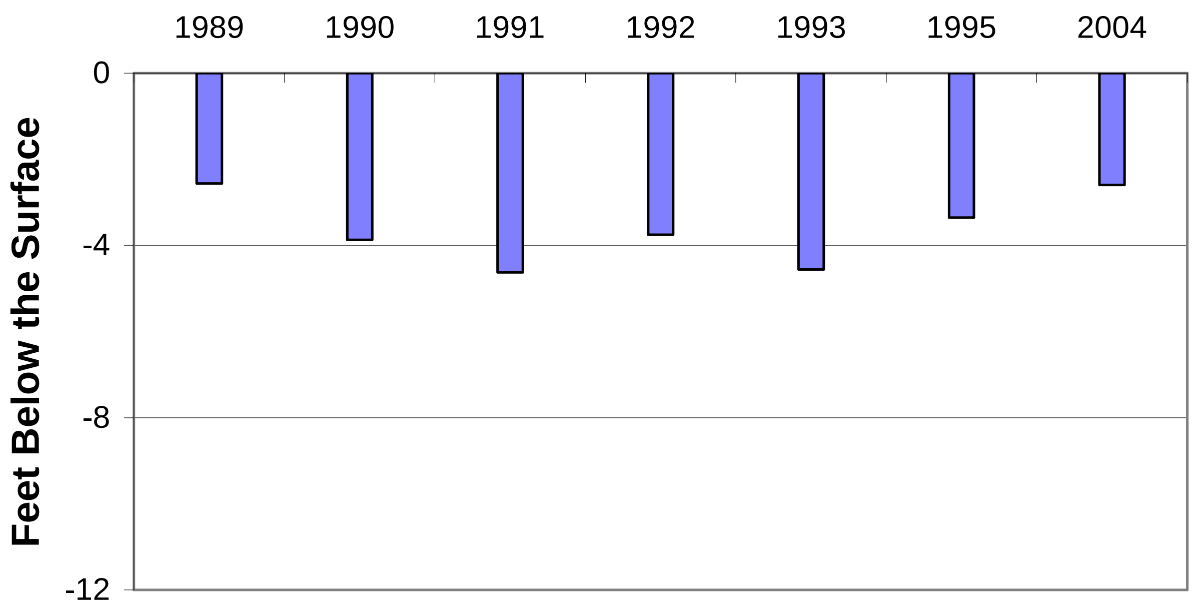


Figure 2. Summer mean water clarity in Otter Lake, 1989-2004.

Averaging clarity data collected during the same time period each year shows that water clarity also varies during the growing season. Water clarity is usually fair during the spring before algal growth occurs (Figure 3). Clarity then decreases during the summer as the water warms and then increases slightly in the fall after the algae die back (Figure 3).

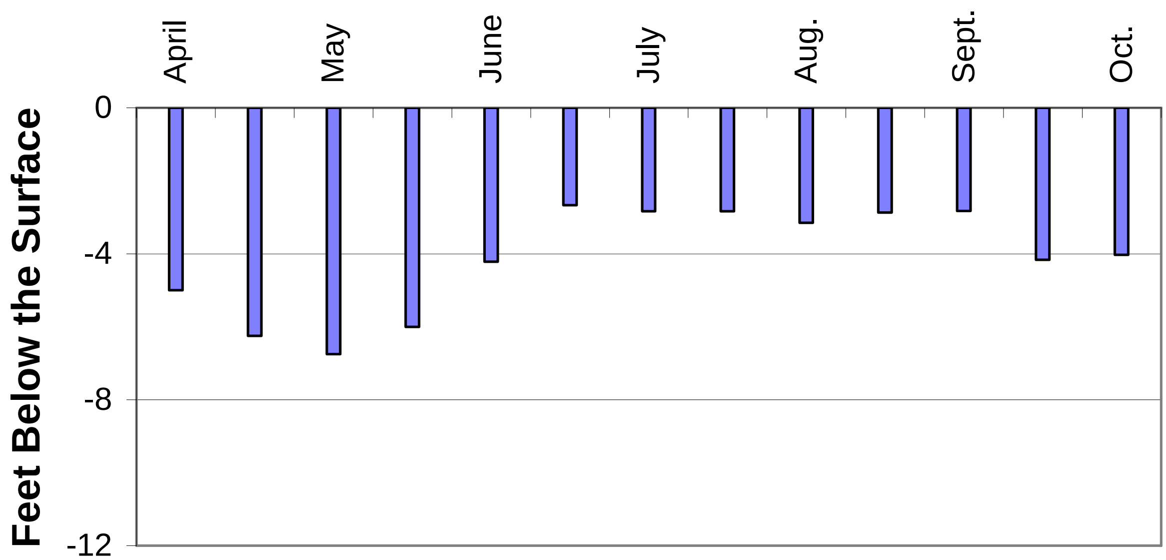


Figure 3. Variation in water clarity during the growing season in Otter Lake, 1989-2004.

ALKALINITY

1995-2004 Alkalinity in Otter Lake was between 32 and 45mg CaCO3/l.
Alkalinity values less than 60mg CaCO3/l indicate soft water. Soft water lakes tend to have less plant growth.

LAKE MORPHOMETRY - The morphometry of a lake is an important factor determining the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel 1985).

Otter Lake is a narrow, long lake with a moderately sloped littoral zone in about half of the lake. There are large areas of shallow depths and several shallow bays. The north quarter and south quarter of the lake have a steeply sloped littoral zone. The areas with shallow depths and a gradually-sloped littoral zone are favorable for plant growth.

SEDIMENT COMPOSITION -
Silt was the dominant sediment in the lake (Figure 4). Silt was found throughout the lake, especially dominant at depths greater than 1.5-feet (Table 2). Silt mixed with sand was common in the 5-10ft depth zone.

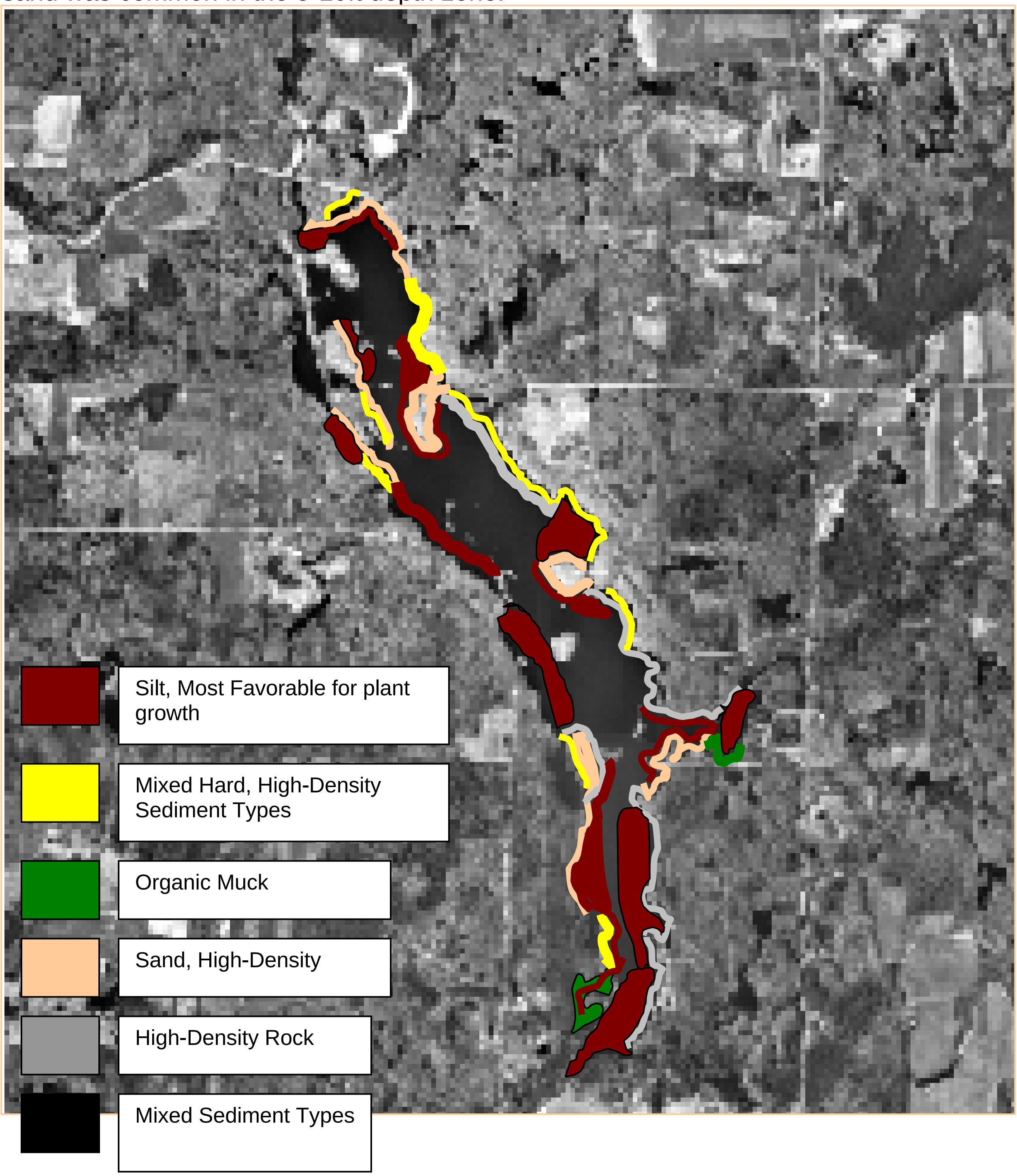


Figure 4. Distribution of sediment types in Otter Lake, 2004.

Rock and gravel sediments were more abundant in the main body of the lake in the shallowest zone. Sand was common in the shallow zone. Organic muck and peat sediments were found in the bays, organic muck at depths less than 5 feet (Table 2).

Table 2. Sediment Composition: Otter Lake, 2004

Sediment Type		**0-1.5' Depth**	**1.5-5' Depth**	**5-10' Depth**	**10-20' Depth**	**Percent of all Sample Sites**
Soft Sediments	Silt	7%	39%	36%	61%	33%
	Silt/ Peat			7%	6%	3%
	Muck	7%				2%
Mixed Sediments	Sand/Silt	11%	18%	25%	6%	16%
	Silt/Gravel		4%	11%		4%
	Silt/Wood			7%	11%	4%
Hard Sediments	Sand	25%	18%		6%	13%
	Sand/Gravel	36%	7%	11%		15%
	Rock/Boulder	14%	7%		6%	9%
	Wood		7%	4%	6%	3%

SEDIMENT INFLUENCE – Many species of plants depend on the sediment in which they are rooted for their nutrients. The richness or sterility and texture of the sediment will determine the type and abundance of aquatic plant species that can survive in a location.

Silt, an intermediate-density sediment considered most favorable for plant growth, was the dominant sediment in the lake. The availability of mineral nutrients for growth is highest in sediments of intermediate density (Barko and Smart 1986). However, silt sediment supported aquatic plant growth at less than half of the sites with silt (Table 3). This may be due to silt occurring more often in deeper water where light availability could be a limiting factor (Table 2).

Rock and gravel sediments were more prevalent in the shallow zone and sand was also common in the shallow zone. Sand, gravel and rock sediment are high-density sediments and may limit plant growth due their high-density (Barko and Smart 1986). Sand supported plant growth at more than half the sites; sand/gravel mixtures supported plant growth at slightly less than half the sites and other high-density sediments supported low levels of plant growth. The greater light availability at the shallower sites may outweigh the lower nutrient availability in high-density sediments at the shallower zones. Light appears to be more of a limiting factor for plant growth than sediment.

Organic muck and sand/silt mixtures supported plant growth at all sites at which they occurred.

Table 3. Aquatic Plant Growth at Sediment Types, 1995-2004

		1995		2004	
Sediment Type		**Percent of all Sample Sites**	**Percent Vegetated**	**Percent of all Sample Sites**	**Percent Vegetated**
Soft Sediments	Silt	30%	53%	33%	44%
	Silt/ Peat	4%	75%	3%	0%
	Muck	7%	100%	2%	100%
Mixed Sediments	Sand/Silt	6%	33%	16%	75%
	Silt/Gravel	7%	38%	4%	100%
	Silt/Wood			4%	0%
Hard Sediments	Sand	14%	53%	13%	69%
	Sand/Gravel	14%	67%	15%	47%
	Rock/Boulder	15%	31%	9%	28%
	Wood Debris			3%	25%

SHORELINE LAND USE - Land use practices strongly impact the aquatic plant community and therefore the entire aquatic community. Practices on shore can directly impact the plant community through increased sedimentation from erosion, increased nutrient input from fertilizer run-off and soil erosion and increased toxics from farmland and urban run-off.

Wooded cover was found at nearly all of the shoreline transects and had the greatest mean coverage (Table 4). Shrub and herbaceous growth were commonly occurring, but had low coverage (Table 4).

Table 4. Shoreline Land Use on Otter Lake, 1995-2004

Cover Type		**Frequency of Occurrences at Transects**		**% Mean coverage at sample sites**	
		1995	**2004**	**1995**	**2004**
Natural Cover	Wooded	100%	96%	79%	80%
	Shrub	69%	36%	9%	5%
	Herbaceous	41%	50%	7%	6%
Totals				**95%**	**91%**
Disturbed Shoreline	Cultivated Lawn	7%	4%	3%	3%
	Hard Surface	14%	14%	2%	2%
	Bare Soil	3%	14%	1%	3%
	Rip-rap		3%		1%
Totals				**5%**	**9%**

Some type of natural shoreline occurred at all of the sites in 1995 and 2004 and covered approximately 95% of the shore in 1995 and 91% of the shore in 2004.

Some type of disturbed shoreline occurred at 17% of the site in 1995 and 28% of the sites in 2004. Disturbed shoreline covered approximately 5% of the shore in 1995 and 9% of the shore in 2004. Bare soil and rip-rap were the disturbed cover types that appeared to have increased between 1995 and 2004.

MACROPHYTE DATA

SPECIES PRESENT

A total of 40 species was found in Otter Lake. Of the 40 species, 20 were emergent species, 6 were floating-leaf species, and 14 were submergent species (Table 5). No endangered or threatened species were found.
One non-native species, *Potamogeton crispus* was found.

Table 5. Otter Lake Aquatic Plant Species, 1995-2004

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Asclepias incarnata* L.	swamp milkweed	ascin
2) *Bidens discoidea* (T. & G.) Britton.	bur marigold	biddi
3) *Calla palustris* L.	water arum	calpa
4) *Carex comosa* F. Boott.	bristly sedge	carco
5) *Carex crinita* Lam.	sedge	carcr
6) *Cicuta bulbifera* L.	water hemlock	cicbu
7) *Decodon verticillatus* (L.) Ell.	swamp loosestrife	decve
8) *Dulichium arundinaceum* (L.) Britton.	three-way sedge	dular
9) *Eleocharis smallii* Britt.	creeping spikerush	elepa
10) *Impatiens capensis* Meerb.	spotted jewelweed	impca
11) *Leersia oryzoides* (L.) Swartz.	rice cut-grass	leeor
12) *Lycopus virginicus* L.	bugleweed	lycvi
13) *Phalaris arundinacea* L.	reed canary grass	phaar
14) *Sagittaria* sp.	arrowhead	sagsp
15) *Sagittaria latifolia* Willd.	common arrowhead	sagla
16) *Salix* sp.	willow	salsp
17) *Scirpus cyperinus* (L.) Kunth	wool grass	scicy
18) *Scirpus validus* Vahl.	softstem bulrush	sciva
19) *Sparganium eurycarpum* Engelm.	common burreed	spaeu
20) *Typha latifolia* L.	broad-leaf cattail	typla
Floating-leaf Species		
21) *Lemna minor* L.	small duckweed	lemmi
22) *Lemna trisulca* L.	forked duckweed	lemtr
23) *Nuphar variegata* Durand.	bull-head pond lily	nupva
24) *Nymphaea odorata* Aiton.	white water lily	nymod
25) *Spirodela polyrhiza* (L.) Schleiden.	great duckweed	spipo
26) *Wolffia columbiana* Karst.	common watermeal	wolco
Submergent Species		
27) *Ceratophyllum demersum* L.	coontail	cerde
28) *Eleocharis acicularis* (L.) Roemer & Schultes.	needle spikerush	eleac
29) *Elodea canadensis* Michx.	common waterweed	eloca
30) *Najas flexilis* (Willd.) Rostkov. & Schmidt.	slender naiad	najfl
31) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
32) *Potamogeton crispus* L.	curly-leaf pondweed	potcr
33) *Potamogeton foliosus* Raf.	leafy pondweed	potfo
34) *Potamogeton gramineus* L.	variable-leaf pondweed	potgr
35) *Potamogeton praelongus* Wulf.	white-stem pondweed	potpr
36) *Potamogeton pusillus* L.	small pondweed	potpu
37) *Potamogeton richardsonii* (ar. Bennett.) Rydb.	clasping-leaf pondweed	potri
38) *Potamogeton zosteriformis* Fernald.	flat-stem pondweed	potzo
39) *Vallisneria americana* L.	water celery	valam
40) *Zosterella dubia* (Jacq.) Small.	water star grass	zosdu

FREQUENCY OF OCCURRENCE

The species with the highest frequency of occurrence in both 1995 and 2004 was *Elodea canadensis* (42%, 34%) (Figure 2). Other frequently occurring species have been *Ceratophyllum demersum* (24%, 17%), *Lemna minor* (26%, 3.8%), *Nymphaea odorata* (23%, 14%) and *Wolffia columbiana* (22%, 1%) (Appendices I-II).

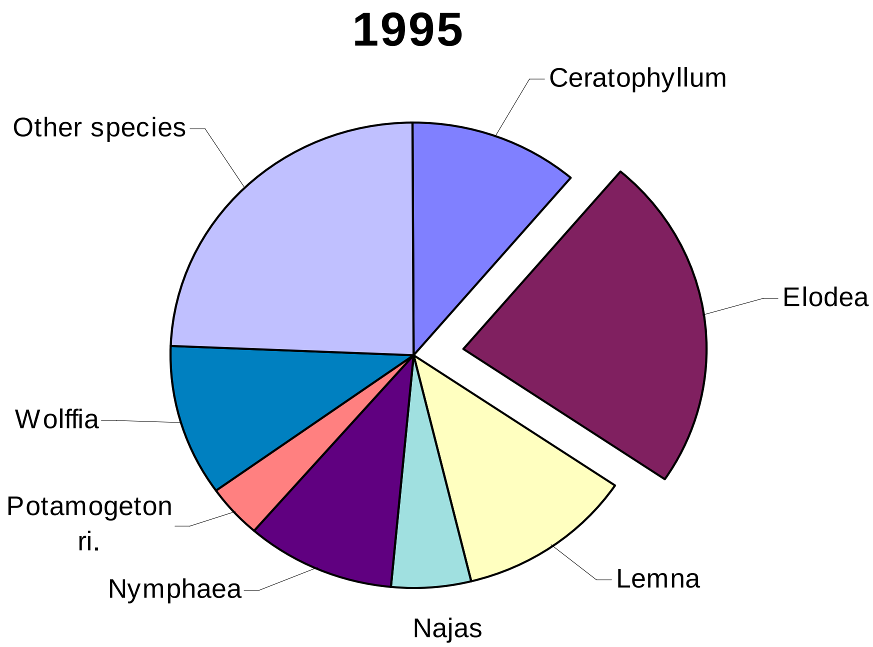
DENSITY

Elodea canadensis was also the species with the highest mean density (1.19 and 0.90 on a density scale of 1-4) in both 1995 and 2004. Other species occurred at low mean densities in Otter Lake (Appendices III-IV).

Elodea canadensis had a "density where present" of greater than 2.5 both years, (2.76, 2.61) indicating that it exhibited an aggregated or dense growth form in Otter Lake (Appendices III, IV). *Typha latifolia, Carex crinita* and *Decodon verticillatus* also had a "density where present" greater than 2.5 in 1995 and *Sparganium eurycarpum* and *Wolffia columbiana* in 2004, indicating that these species exhibited an aggregated or dense growth form in Otter Lake (Appendices III, IV). Although these species did not frequently occur throughout Otter Lake, where they did occur, they grew at higher than average densities.

DOMINANCE

Combining the relative frequency and relative density of species into a dominance value illustrates the dominance of a species in the plant community (Appendix V, VI). Based on the dominance value, *Elodea canadensis* was the dominant species in Otter Lake in 1995 and 2004 (Figure 5). *Ceratophyllum demersum* and *Lemna minor* were sub-dominant in 1995; *Ceratophyllum demersum* was sub-dominant in 2004.



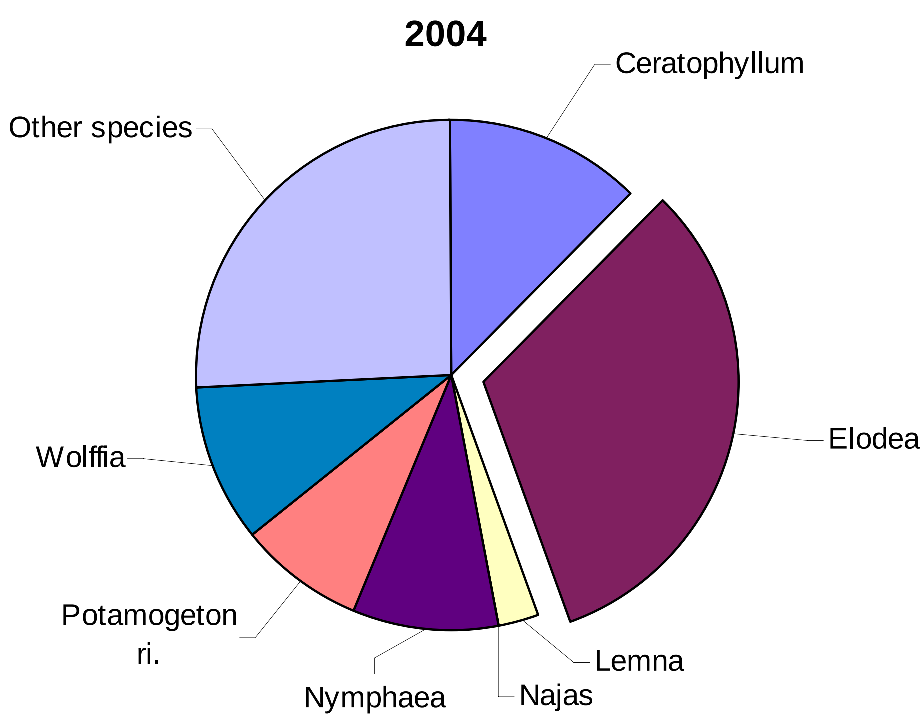


Figure 5. Dominance of the most prevalent aquatic plant species within the plant community, based on Dominance Value.

DISTRIBUTION

Aquatic plants were found growing at 65% of all sampling sites in 1995 (44% with rooted vegetation) and 54% of all sampling sites in 2004 (47% with rooted vegetation). In 2004, plants colonized 228 acres, 34% of the total lake area. In both years, aquatic plants were found, scattered throughout the lake, up to a maximum depth of 11 feet in 1995 and 8.5 feet in 2004 (Figure 6).

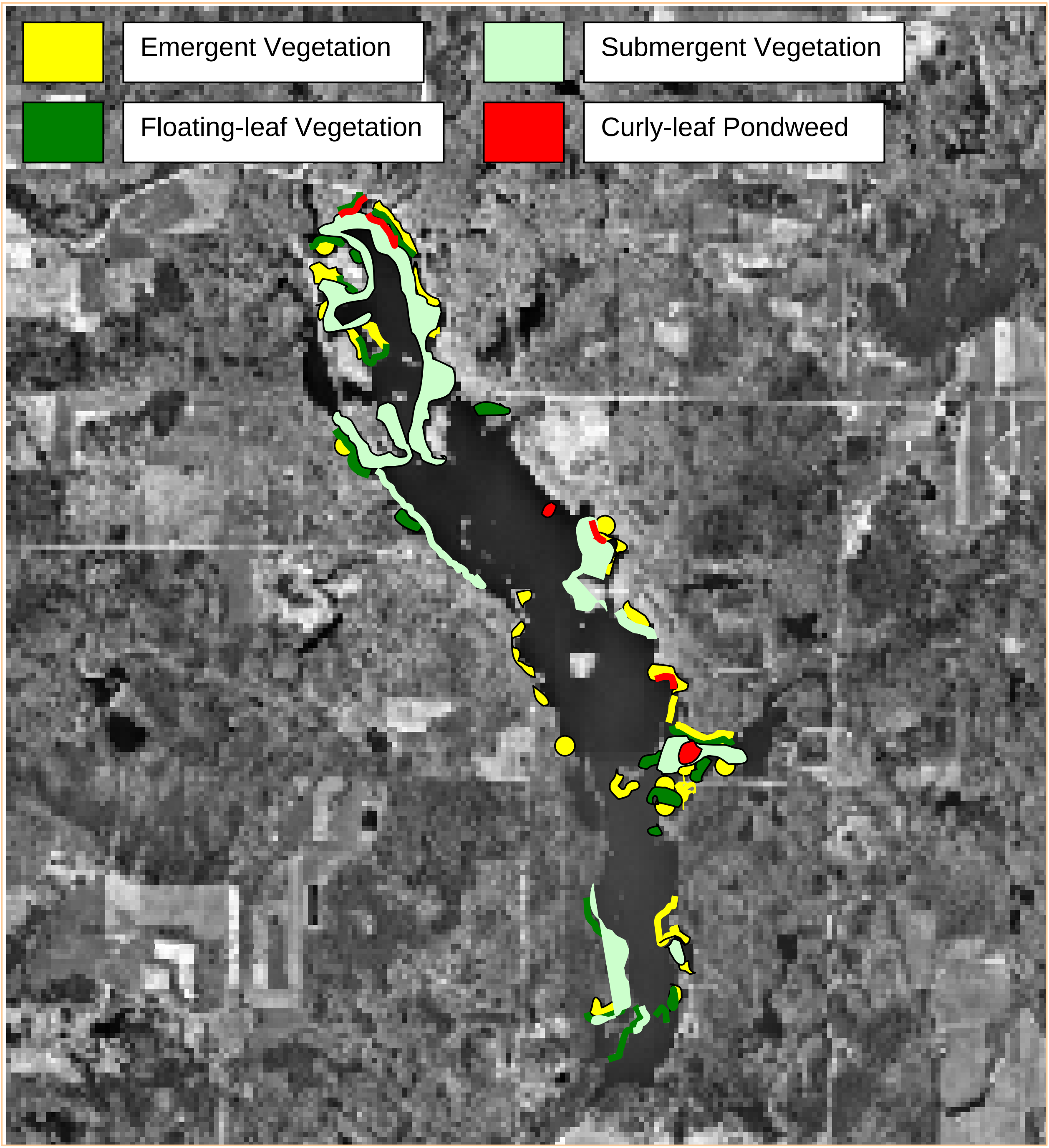


Figure 6. Distribution of aquatic vegetation in Otter Lake, June 2004.

The dominant species, *Elodea canadensis* was found throughout the lake except in the south quarter. The other common species were found scattered throughout the lake.

Secchi disc water clarity data are used to calculate a predicted maximum rooting depth for plants in a lake (Dunst 1982).
Based on the water clarity data, the predicted maximum rooting depth in Otter Lake was 6.8 feet in 1995 and 5.9 feet in 2004.

Elodea canadensis was found at the greatest depth maximum rooting depth both years. This actual maximum rooting is greater than the predicted rooting depth based on water clarity (Figure 7). This is may be due to better clarity early in season when the plants were beginning their growth or the tolerance of *E. canadensis* to low light levels.

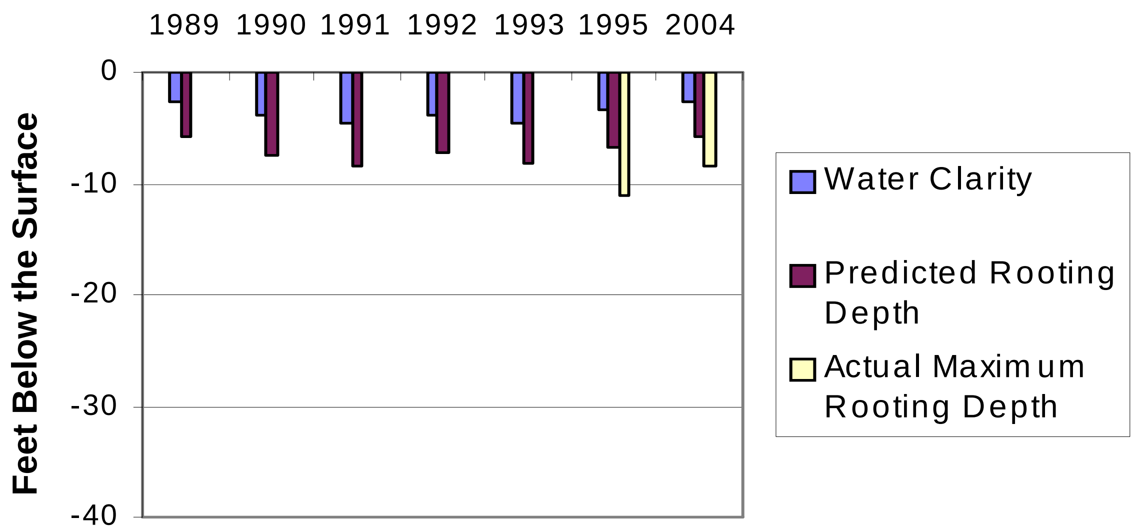


Figure 7. Predicted and actual maximum rooting depth in Otter Lake, 1995-2004.

Elodea canadensis, the dominant species, dominated the 1.5-10ft depth zone (Figure 8, 9), and occurred at its highest frequency and density in the 1.5-5ft depth zone. The frequency and density of *E. canadensis* declined in the 1.5-10ft depth zone between 1995 and 2004.

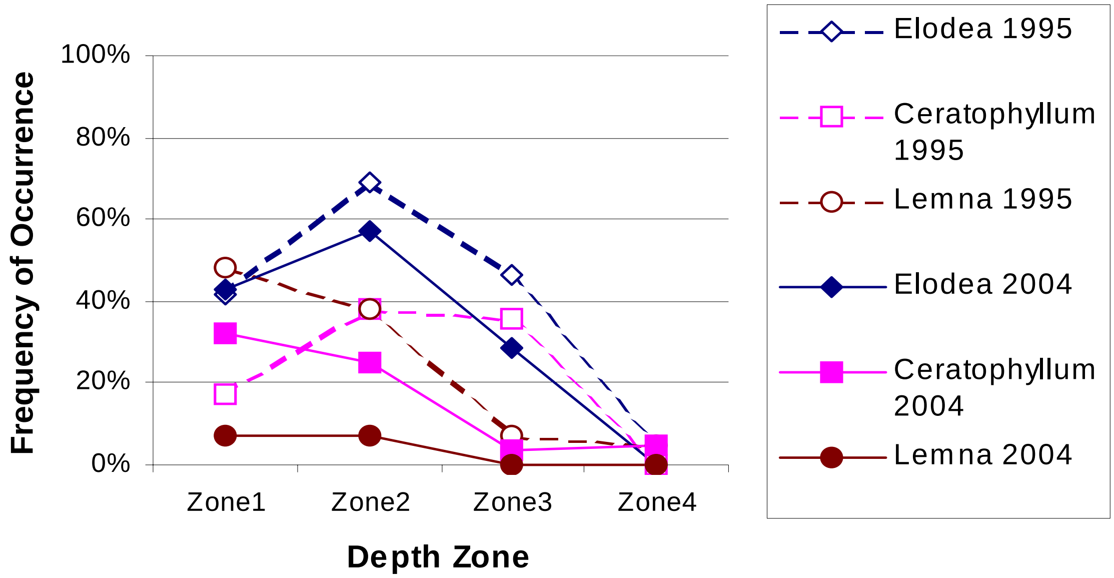


Figure 8. Change in frequency of the dominant aquatic plant species, by depth zone, 1995-2004.

Ceratophyllum demersum was the sub-dominant species both years. Between 1995 and 2004, the frequency and density of *C. demersum* declined in the 1.5-10ft depth zone and increased in the 0-1.5ft and 10-20ft depth zones (Figure 8, 9).

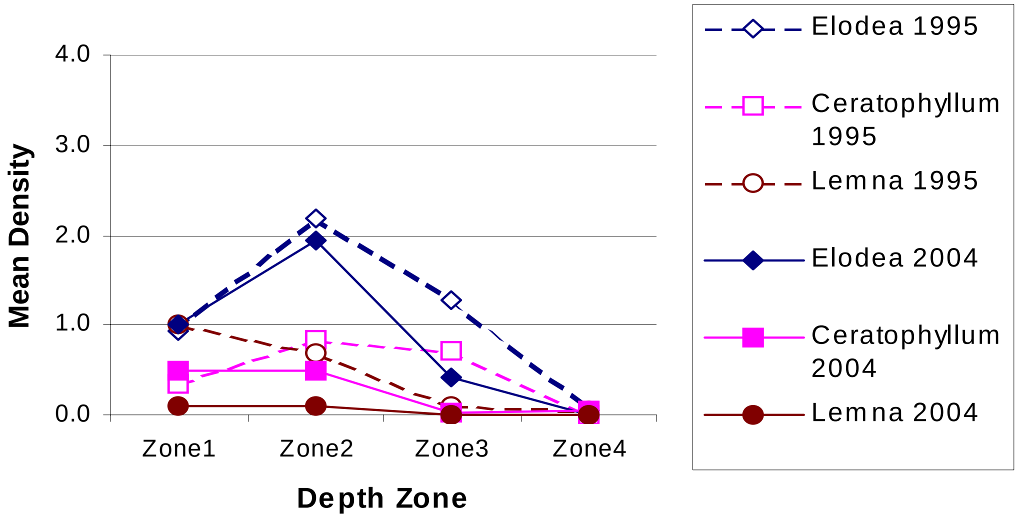


Figure 9. Mean density of the dominant aquatic plant species, by depth zone.

Lemna minor was a sub-dominant species in 1995 and dominated the 0-1.5ft depth zone, but declined to a very low frequency and density in 2004 (Figure 8, 9).

The highest total occurrence and total density of aquatic plants occurred in the 1.5-5ft depth zone in 1995 (Figure 10). In 2004, the highest total density of plant growth was still in the 1.5-5ft depth zone, but the highest total occurrence of plants had shifted to the 0-1.5ft depth zone. Overall, total occurrence and density of plant growth decreased between 1995 and 2004 (Figure 10).

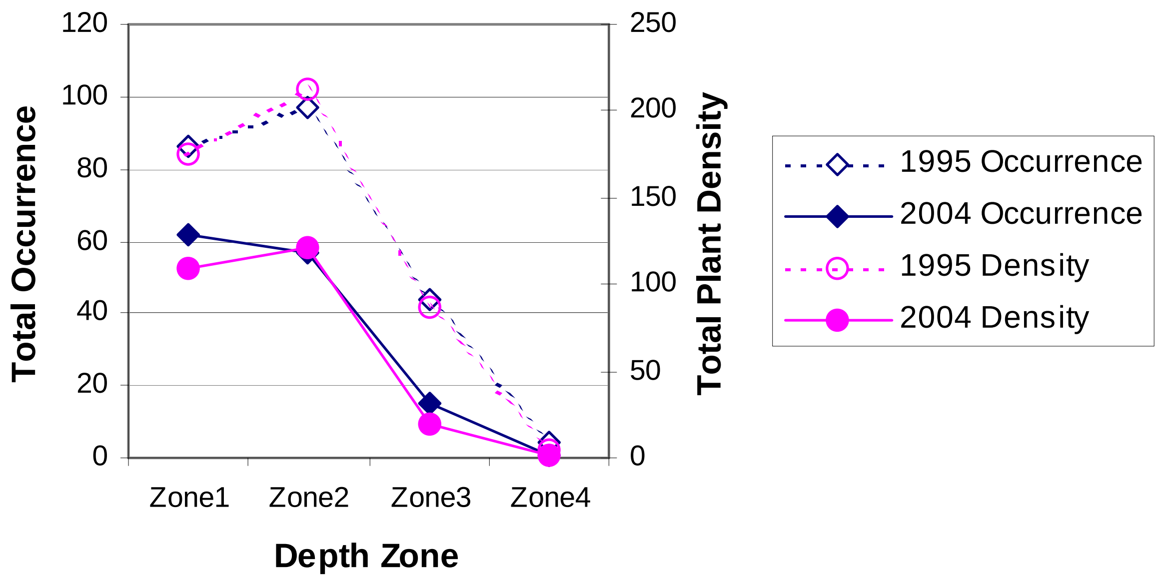


Figure 10. Total occurrence and density of aquatic plants by depth zone.

The highest percentage of vegetated sites and greatest species richness (number of species per site) occurred in the 1.5-5ft depth zone in 1995 (Figure 11). In 2004, the highest percentage of vegetated sites was still in the 1.5-5ft depth zone, but the greatest species richness had shifted to the 0-1.5ft depth zone. Overall, species richness decreased between 1995 and 2004 (Figure 11).

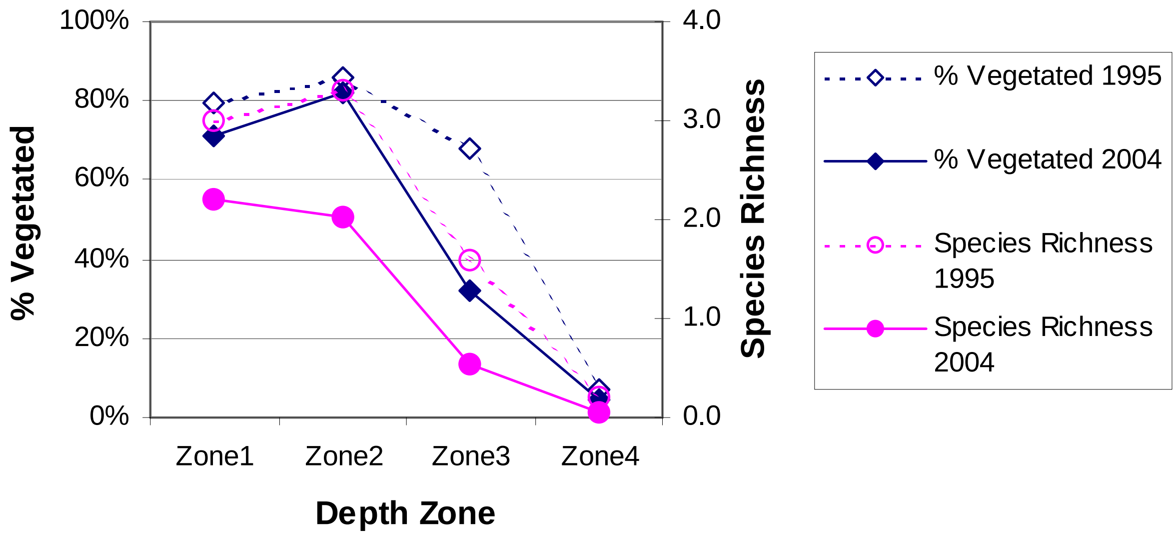


Figure 11. Percent of sites vegetated and Species Richness, by depth zone, 1995-2004.

Lake wide species richness (mean number of species per sampling site) decreased between 1995 and 2004. Lake wide species richness was 2.1 in 1995 and 1.28 in 2004.

THE AQUATIC PLANT COMMUNITY

The Coefficient of Community Similarity is a measure of the percent similarity between two communities. Coefficients less than 0.75 suggest that the two communities are only 75% similar and considered to be significantly different. The Coefficient of Community Similarity for Otter Lake (0.63559) indicates that the 1995 and 2004 aquatic plant communities were different (Appendix viii), only 64% similar.

Several measures of aquatic plant communities can show what details of the community changed.

Changes in the plant community from 1995 to 2004 (Table 6) are:

1) A decrease in the number of species found at the transects
2) A decrease in the maximum rooting depth of aquatic plants
3) A decrease in the percentage of the littoral zone that is vegetated
4) Decreases in the percentage of sites supporting submergent, free-floating and floating-leaf vegetation
5) A slight decrease in the quality of the community as measured by the Aquatic Macrophyte Community Index (AMCI)
6) A decrease in the Diversity Index and Species Richness

7) A decrease in the Floristic Quality Index.

The greatest decrease was in the occurrence of free-floating vegetation (duckweeds, coontail, etc.) (Table 6). These species expand colonization during July and August and would have likely had a greater occurrence and density with a survey later in the summer.

Table 6. Changes in the Otter Lake Aquatic Plant Community, 1995-2004

	1995	2004	Change 1995-2004	%Change 1995-2004
Number of Species	31	28	-3	-9.7%
Maximum Rooting Depth	11.0	8.5	-3	-22.7%
% of Littoral Zone Vegetated	65	54	-10.5	-16.2%
%Sites/Emergents	11	12	1.3	11.7%
%Sites/Free-floating	40	18	-21.7	-54.5%
%Sites/Submergents	51	45	-6.1	-12.0%
%Sites/Floating-leaf	23	15	-7.9	-34.2%
Species Richness	2.1	1.28	-0.82	-39.0%
AMCI (Table 6)	46	45	-1.0	-2.2%
Simpson's Diversity Index	0.90	0.88	-0.02	-2.2%
Floristic Quality (Table 7)	27.75	24.95	-2.80	-10.1%

The only increased measure was an increase in the sites supporting emergent vegetation.

Simpson's Diversity Index was 0.90 in 1995 and 0.88 in 2004, indicating a decline in species diversity from very good to good. A rating of 1.0 would mean that each species in the lake was a different species (the most diversity achievable).

The Aquatic Macrophyte Community Index (AMCI) (Nichols 2000) was applied to Otter Lake. The highest value for this index is 70. The AMCI for Otter Lake was 46 in 1995 and 45 in 2004 (Table 7). This indicates that the quality of the plant community is below average for lakes in Wisconsin and in the lowest quartile for lakes in the North Central Hardwoods Region.

Table 7. Aquatic Macrophyte Community Index: Otter Lake 1995-2004

Category	1995		2004	
Maximum Rooting Depth	3.35 meters	6	2.59 meters	5
% Littoral Zone Vegetated	65%	10	54%	10
Simpson's Diversity	90	9	88	8
# of Species	31	10	28	10
% Submergent Species	40.4% Rel. Freq.	2	49% Rel. Freq.	4
Exotic Species	1% Rel. Freq	6	6% Rel. Freq.	5
% Sensitive Species	2 % Rel. Freq.	3	1% Rel. Freq.	3
Totals		46		45

The lack of sensitive species and low ratio of submergent species in the community are limiting the quality of the plant community in Otter Lake.

The Average Coefficient of Conservatism for Otter Lake was in the lowest quartile both years for all Wisconsin lakes and lakes in the North Central Hardwood Region of Wisconsin (Table 8). This suggests that the aquatic plant community in Otter Lake is among the group of lakes in Wisconsin and the North Central Hardwoods Region most tolerant of disturbance.

Table 8. Floristic Quality and Average Coefficient of Conservatism of Otter Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	Average Coefficient of Conservatism †	Floristic Quality ‡	Based on Dominance Value
Wisconsin Lakes	5.5, 6.0, 6.9 *****	16.9, 22.2, 27.5	
NCHR	5.2, 5.6, 5.8 *****	17.0, 20.9, 24.4	
Otter Lake - 1995	4.91	27.75	20.46
Otter Lake 2004	4.71	24.95	16.69

*** -** Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.
† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).
‡ - lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

The Floristic Quality Index (FQI) of the plant community in Otter Lake was in the upper quartile of lakes in the state and North Central Hardwood Region in 1995. In 2004, the FQI was above the mean for lakes in the state and in the upper quartile for lakes in the region (Table 8). This indicates that the plant community in Otter Lake was within the group of lakes in the state and region closest to an undisturbed condition in 1995, but declined somewhat in 2004 to a condition closer to average in its closeness to an undisturbed condition.

These values were based only on the presence or absence of tolerant and intolerant species; the frequency or dominance of these tolerant and intolerant species within the plant community was not taken into consideration. The Floristic Quality Index was recalculated by weighting each species coefficient with its dominance value. The resulting values indicate that Otter Lake was below average for lakes in the state and the region in 1995 and, in 2004, in the lowest quartile of lakes. This suggests that Otter Lake was farther from an undisturbed condition than the average lake in 1995, but disturbance increased in 2004 to place it within the group of lakes farthest from an undisturbed condition.

Disturbances can be of many types:

1) Physical disturbances to the plant beds result from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
2) Indirect disturbances are the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion and increased algae growth due to nutrient inputs.
3) Biological disturbances include competition from the introduction of a non-native or invasive plant species, grazing from an increased population of

aquatic herbivores and destruction of plant beds by a fish or wildlife population.

The major disturbances in Otter Lake are likely nutrient inputs that result in very poor water clarity and boat traffic through the shallow areas.

Plant communities change when the occurrence and density of individual species within the community change. There were several changes between 1995 and 2004 (Appendix IX). The species that increased the most in frequency, mean density and dominance from 1995 to 2005 was *Potamogeton crispus* (Appendix VII). This is likely due to conducting the survey earlier in the season in 2004 when *P. crispus* typically dominates the aquatic plant community, before its early-summer dieback. Other species that increased by at least doubling were *Phalaris arundinacea* and *Decodon verticillatus*, two emergent species. Two other emergent species increased slightly.

New species appeared. Six (6) species were recorded in 2005 which were not found in 1995. All of those species except *Nuphar variegata* occurred in very limited locations in 2004 and could easily have been missed in 1995 if the sample sites were shifted slightly.

There were decreases in 19 species, either decreased frequency and density or disappearance from the community during 1995-2004.

Nine (9) species were recorded in 1995, but not found in 2004. All of those species, except *Najas flexilis* occurred in very limited locations in 1995 and could easily have been missed in 2004 if the sample sites were shifted slightly. *N. flexilis* was decreased because it was likely that the full extent of seed germination had not taken place yet. Besides the species that disappeared, the species that decreased the most were two duckweed species. *Lemna minor* was decreased 78-88% and *Wolffia columbiana* was decreased 90-96%, most likely because in June, these species had not reached their full colonization.

IV. DISCUSSION

Based on the water clarity and chlorophyll and phosphorus concentration, Otter Lake is a hypereutrophic lake with very poor water clarity and quality. The phosphorus (nutrients) and chlorophyll (algae) concentrations increased in Otter Lake between 1995 and 2004. However, Otter Lake appears to be nitrogen-limited which means that additions of nitrogen can also result in worsening algae blooms and may make the lake more prone to blue-green algae (cyanobacteria) blooms. Filamentous algae was common in 1995, but decreased to 14% occurrence in 2004 and was common only in the 0-5ft depth zone. The measured decrease in filamentous algae may be due mostly to the earlier time period of the 2004 study, before the algae had reached its full growth.

The trophic status (abundant nutrients), dominance of favorable silt sediment, large areas of shallow depth and gradually sloped littoral zone in parts of the lake would favor aquatic plant growth. The soft water, very poor water clarity and moderately-to-steeply sloped littoral zone in other parts of the lake could limit aquatic plant growth.

Aquatic plant growth was found scattered throughout the littoral zone of Otter Lake, at about half the sites (65% in 1995 and 54% in 2004), up to the maximum rooting depth of 11 feet in 1995 and 8.5 feet in 2004. The maximum rooting depth was deeper than the maximum predicted rooting depth. Species that occurred deeper than the maximum rooting depth are *Ceratophyllum demersum, Elodea canadensis, Potamogeton crispus,.* These species are turbidity tolerant (Nichols and Vennie 1991) and can survive low light levels.

The most abundant plant growth (highest total occurrence of plants, highest total density of plant growth, greatest percentage of vegetated sites, the greatest species richness) was found in the 0-5ft depth zone.

40 species of aquatic plants have been found in Otter Lake, half of the species are emergent species. *Elodea canadensis* was the dominant species in Otter Lake, especially in the 1.5-10ft depth zone, occurring at less than half the sites in 1995 and one-third of the sites in 2004. *E. canadensis* exhibited a growth form of above average density and was found throughout the north three-quarters of the lake to the maximum rooting depth. Its frequency and density declined from 1995 to 2004. *Ceratophyllum demersum* was the sub-dominant species. Other common species were found scattered throughout the lake. One non-native species occurred in Otter Lake, *Potamogeton crispus*. However, it occurred at low frequency and density, making up only 5% of the Otter Lake Plant community.

Simpson's Diversity Index indicated good diversity in 2004 (0.88). Emergent species contribute much of the diversity in Otter Lake. The quality of the aquatic plant community, as measured by the AMCI Index, places the quality of the Otter Lake aquatic plant community in the lowest quartile of lakes in the region and below average for lakes in the state. The Average Coefficients of Conservatism and Floristic Quality Index in 2004 indicate that Otter Lake is among the 25% of lake in the state and region most tolerant of disturbance and farthest from a disturbed condition. Poor water clarity and boat traffic through the shallow areas are likely the major disturbances in Otter Lake.

Otter Lake has good protection by native shoreline buffers, woods, shrub and herbaceous growth. This natural shoreline must be protected. The occurrence of disturbed shoreline has increased slightly, specifically bare soil and rip-rap. Bare soil can result in sedimentation and nutrient input from erosion. Rip-rap does not protect the shoreline as well as natural buffers and does not filter pollutants from the run-off.

Changes 1995-2004

The Coefficient of Community Similarity for Otter Lake 1995 – 2004 indicates that the two communities are significantly different. The 1995 and 2004 communities are only 64% similar. Much of the change may be attributed to the change in the timing of the aquatic plant survey. It was foreseen that a plant study earlier in the season could result in changes in the plant community resulting from less maturity of plant growth. However, the timing was changed in a desire to determine the dominance of *Potamogeton crispus* in the early summer plant community and if its mid-summer die-off could be impacting water quality.

Changes in the aquatic plant community between 1995 and 2004 that can be attributed the earlier survey date and therefore may artificially indicate change:

1) Increased frequency and density of *Potamogeton crispus.*
2) Decreased frequency and density of *Najas flexilis, Ceratophyllum demersum* and *Lemna minor.*
3) Decreased density of *Elodea canadensis*
4) Decreased occurrence of filamentous algae.
5) Decrease in the number of species recorded, Simpson's Diversity Index and Species Richness. Diversity Index indicated very good diversity in 1995 and good diversity in 2004.
6) Decreased total occurrence and density of plant growth
7) Decrease in the percent occurrence of floating-leaf and free-floating species

Changes that are likely attributed to other factor:

1) Increased occurrence of emergent plant species
2) Decreased maximum rooting depth
3) Decreased occurrence of *Elodea canadensis*
4) Decrease in the percentage of sites with emergent vegetation
5) Decrease in the Floristic Quality Index and Average Coefficient of Conservatism which suggests increased disturbance in the community.

The decrease in water clarity between 1995 and 2004 could be one factor for these changes. Whether attributable to the early date of the survey or other factors, the changes led to a decrease in the quality of the community as measured by the Aquatic Macrophyte Community Index.

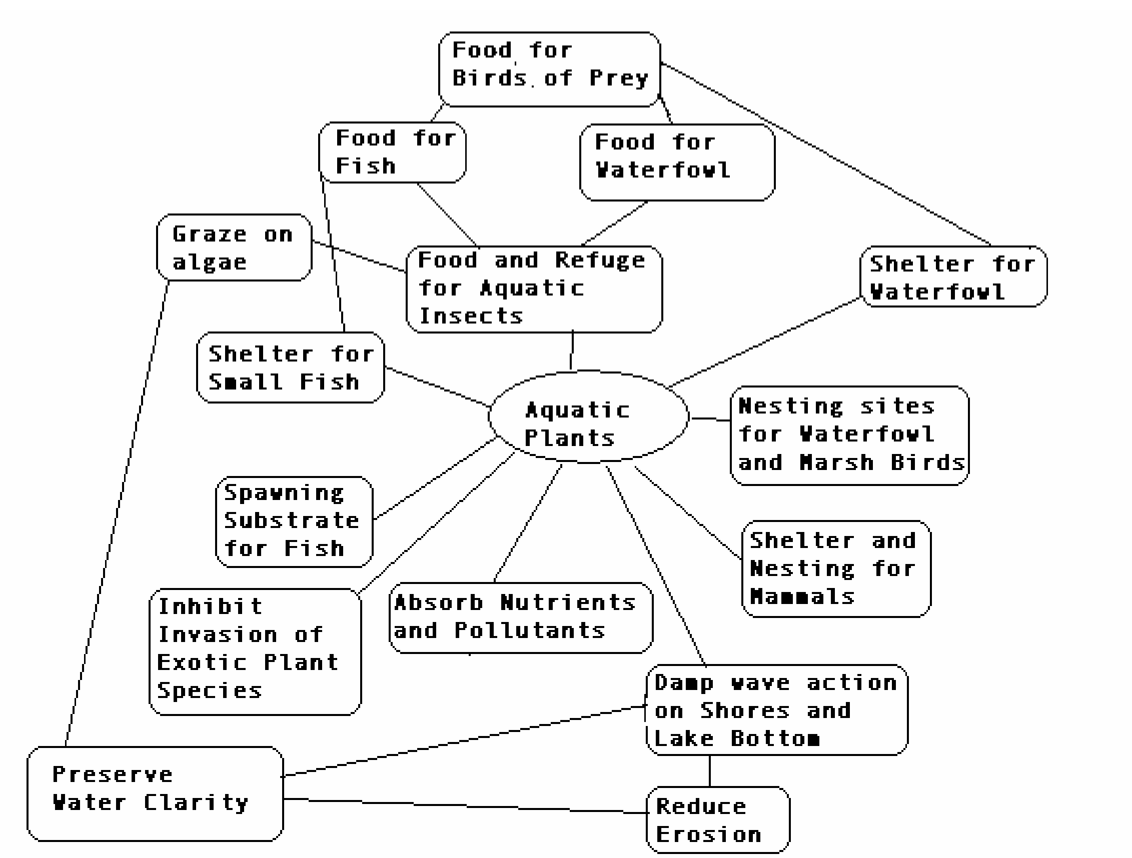
V. CONCLUSIONS

Otter Lake is a hypereutrophic lake with very poor water clarity and quality. Nutrients and algae have increased since 1991. Water clarity has decreased since 1993.

Aquatic plant growth is scattered throughout the Otter Lake, at approximately half of the sites, to a maximum rooting depth of 8.5 feet. The 0-5ft depth zone supports the greatest amount plant growth. The plant community is characterized by good diversity of plant species, a below average quality of the community for Wisconsin, a high tolerance to disturbance and a highly disturbed condition. Much of the diversity is in the emergent plant community.

Elodea canadensis was the dominant species, found at one-third of the sites up to the maximum rooting depth. *E. canadensis* was especially dominant in the 1.5-10ft depth zone and grew at an above average density. *Ceratophyllum demersum* was sub-dominant. *Potamogeton crispus*, a non-native aquatic plant species, occurred at a low frequency and density in Otter Lake.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in
1) improving water quality 2) providing valuable habitat resources for fish and wildlife 3) resisting invasions of non-native species and 4) checking excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.



1) Aquatic plant communities improve water quality in many ways:
    - Plants trap nutrients, debris, and pollutants entering a water body;
    - Plants absorb and break down some pollutants;
    - Plants reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
    - Aquatic plants remove nutrients that would otherwise be available for algae growth (Engel 1985).

2) Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table 9). Plant cover within the littoral zone of Otter Lake is 54% and over the entire lake is 34% which is appropriate (25-85%) to support a balanced fishery.

Compared to non-vegetated lake bottoms, plant beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of aquatic plants support 3-8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Aquatic plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).

Management Recommendations

1) Lake residents work with efforts in the watershed to reduce nutrient input (both phosphorus and nitrogen) to Otter Lake. Water clarity has decreased since 1993 and nutrients have increased since 1991. Some changes in the aquatic plant community may be due to nutrient enrichment and decreased water clarity.
    a) decreased maximum rooting depth
    b) increased disturbance measured by decreased Floristic Quality Index and Average Coefficient of Conservatism
    c) decreased occurrence and density of plants
    d) decreased colonization of submergent plant species

2) All lake residents and visitors practice best management on their lake properties.
    a) Keep septic systems cleaned and in proper condition.
    b) Use no lawn fertilizers; both nitrogen and phosphorus can feed algae blooms in Otter Lake.
    c) Clean up pet wastes.
    d) Do not compost near the water or allow yard wastes and clippings to enter the lake.

3) Residents become involved in the Self-Help Volunteer Lake Monitoring Program, monitoring water quality to track seasonal and year-to-year changes.

4) DNR to designate sensitive areas within Otter Lake. These are areas within the lake that are most important for habitat and maintaining water quality.

5) Protect the natural shoreline around Otter Lake. Most of the shoreline of Otter Lake

Table 9. **Wildlife and Fish Uses of Aquatic Plants in Otter Lake**

Aquatic Plants	Fish	Water Fowl	Song and Shore Birds	Upland Game Birds	Muskrat	Beaver	Deer
Submergent Plants							
Ceratophyllum demersum	F,I*, C, S	F(Seeds*), I, C			F		
Eleocharis acicularis	S	F			F		
Elodea canadensis	C, F, I	F(Foliage) I					
Najas flexilis	F, C	F*(Seeds, Foliage)	F(Seeds)				
Potamogeton amplifolius	F, I, S*,C	F*(Seeds)			F*	F	F
Potamogeton crispus	F, C, S	F(Seeds, Tubers)					
Potamogeton foliosus	F, I, S*,C	F*(All)			F*	F	F
Potamogeton gramineus	F, I, S*,C	F*(Seeds, Tubers)			F*	F	F
Potamogeton praelongus	F, I, S*,C	F*(All)			F*	F	F
Potamogeton pusillus	F, I, S*,C	F*(All)			F*	F	F
Potamogeton richardsonii	F, I, S*,C	F*(All)			F*	F	F
Potamogeton zosteriformis	F, I, S*,C	F*(Seeds)			F*	F	F
Vallisneria americana	F*, C, I, S	F*, I	F		F		
Zosterella dubia	F, C, S	F(Seeds)					
Floating-leaf Plants							
Lemna minor	F	F*, I	F	F	F	F	
Lemna trisulca	F, I	F*, I					
Nuphar variegata	F,C, I, S	F, I	F		F*	F	F*
Nymphaea odorata	F,I, S, C	F(Seeds)	F		F	F	F

Aquatic Plants	Fish	Water Fowl	Song and Shore Birds	Upland Game Birds	Muskrat	Beaver	Deer
Spirodela polyrhiza	F	F		F			
Wolffia columbiana		F			F		
Emergent Plants							
Asclepias incarnata				Nest mat.	Roots		
Bidens spp.		F (Seeds),	F	F	F		
Carex comosa	S*	F*(Seeds), C	F*(Seeds)	F*(Seeds)	F	F	F
Decodon verticillatus		F (seeds)			F, C		
Eleocharis smallii	I	F, C					
Leersia oryzoides		F			F		
Sagittaria sp.		F*, C	F(Seeds), C	F, C	F	F	
Sagittaria latifolia		F, C	F(Seeds), C	F	F	F	
Scirpus cyperinus	F, S, C	F, C	F(Seeds, Tubers), C	F	F	F	F
Scirpus validus	F, C, I	F (Seeds)*, C	F(Seeds, Tubers), C	F (Seeds)	F	F	F
Sparganium eurycarpum	I	F(Seeds), C	F, C		F		F*
Typha latifolia	I, C, S	F(Entire), C	F(Seeds), C, Nest	Nest	F*, C*, Lodge	F	

F=Food, I= Shelters Invertbrates, a valuble food source C=Cover, S=Spawning
***=Valuable Resource in this category**

*Current knowledge as to plant use. Other plants may have uses that have not been determined.

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Nichols, S. A. 1991. Attributes of Wisconsin Lake Plants. Wisconsin Geological and Natural History Survey. Info. Circ. #73 was protected by native plant growth, woods, shrub and herbaceous growth. The occurrence and coverage of disturbed shoreline has increased slightly, specifically bare soil and rip-rap. These result in increased sedimentation, increased run-off and increased nutrient input.

6) Protect the aquatic plant community in Otter Lake. The standing-water emergent community, floating-leaf community and submergent plant community are all important for fish and wildlife habitat and water quality protection. This diverse aquatic plant community will support a diverse fish and wildlife community.

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