Changes in the Aquatic Plant Community
of
Pike Lake
Marathon County, Wisconsin
1989-2006

submitted by:

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EXECUTIVE SUMMARY

Pike Lake is a mesotrophic, hardwater lake with fair-to-good water quality and poor clarity. Filamentous algae is common. Both filamentous and planktonic algae have decreased since 1986, but water clarity has decreased also.

The aquatic plant community in Pike Lake is characterized by very good species diversity, high quality, impacted by above average amount of disturbance and low density of plant growth. Aquatic plants are distributed throughout the lake, up to a maximum rooting depth of 10.5 feet. The depth zone of most abundant plant growth in 2006 was the 0-1.5ft depth zone.

In 2006, the dominant species was muskgrass (*Chara* spp), exhibiting a growth from of above average density in Pike Lake. Muskgrass occurred at more than half of the sites and dominated the 1.5-10ft depth zones. Illinois pondweed *(Potamogeton illinoensis)* was sub-dominant, occurring at half of the sites.

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

Management Recommendations

1) Lake shore residents should restore shoreline buffers of natural vegetation. Too much shoreline is covered by lawn and other disturbed shoreline and has increased.
2) Lake shore residents should only fertilize shoreline properties if soil tests indicate it a need and use only phosphorus-free fertilizers. Increases in free-floating species suggest increased nutrients and declining water clarity.
3) Riparian property owners should plant emergent aquatic plants to replace rip-rap around the lake.
4) Sportsmen Club should cooperate with efforts in the watershed to reduce non-point pollution to Pike Lake.
5) Lake residents should continue participation in the volunteer, Citizen Lake Monitoring Program.
6) Sportsmen Club and DNR need to maintain signage at the boat landing to educate lake visitors about exotic species and their spread.
7) Sportsmen Club should educate lakes residents about invasive species and preventing their introduction and spread.
8) Sportsmen Club members should learn to identify and monitor aquatic invasive species.
9) Sportsmen Club should monitor and map curly-leaf pondweed in the spring.
10) DNR to designate Critical Habitat Areas in Pike Lake.
11) Sportsman Club will follow recommendations in the Management Plan; evaluate the plan annually and update when necessary.
12) Sportsmen Club will follow mechanical harvesting plan in the Management Plan.

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I. INTRODUCTION

Studies of the aquatic plants (macrophytes) in Pike Lake were conducted July 1989, August 1993 and July 1996 by Water Resources staff of the North Central District - Department of Natural Resources (DNR) and in June of 1999 and 2002 and August 2006 by Water Resource staff of the West-Central Region of the DNR. The surveys were conducted as part of a Long Term Trend Study involving lakes throughout the state. Aquatic plant data is collected every three years and water quality data is collected every year on these trend lakes.

Long term studies of the diversity, density, and distribution of aquatic plants are ongoing and will provide information that will be valuable for decisions about fish habitat improvements, designation of sensitive wildlife areas, water quality improvement and aquatic plant management. Trend data can reveal changes occurring in the lake ecosystem.

Background

Pike Lake is a 205-acre natural drainage lake in eastern Marathon County with a maximum depth of 34 feet and a mean depth of 13-feet. Water enters the lake from Rice Lake Creek on the north shore and flows out to Pike Creek on the south shore.

The watershed to lake ratio is approximately 19:1. Lakes with watershed area:lake size ratios greater than 10:1 tend to have water quality problems (Field 1994). Additionally, 20% of the land use in the watershed is of the type that has the potential to increase run-off and nutrients inputs to the lake (Konkel 2003).

History

Pike Lake has a long history of chemical treatments to reduce aquatic plant and algae growth. Treatments for algae growth have been carried out since 1940, but records of actual chemical usage have been regularly recorded only since 1949. There were likely unrecorded treatments carried out during the 1940's, so the total amount of chemicals used is likely higher than recorded.

During the years 1942-2004, 14,815 pounds of copper sulfate and 319 gallons of Cutrine have been applied to Pike Lake for algae control (Table 1). This means that 3762 pounds of pure elemental copper has gone into Pike Lake. Copper does not degrade any further and remains in the lake sediments, toxic to some forms of aquatic life.

During 1949-64, 3560 pounds of arsenic compounds were added to Pike Lake in an attempt to control aquatic plant growth, 17 pounds of arsenic per acre in Pike Lake (Table 1). Arsenic is highly toxic and does not degrade. The arsenic contaminated sediments must be analyzed to determine if they need to be handled as hazardous waste if sediment work is ever planned.

Silvex (2,4,5-TP) was applied to Pike Lake during 1968-1969 in the amount of 140 pounds (Table 1). Silvex is no longer approved for aquatic use due to its toxicity.

Endothall Acid a broad-spectrum chemical had been applied to Pike Lake in several forms: as granular Aquathol (6345 pounds), liquid Aquathol (742 gallons) and as Hydrothol (4560 pounds). Hydrothol is the monoamine salt formulation and is more detrimental to young fish (Table 1).

Table 1. Aquatic Herbicides Applied to Pike Lake, 1942-2004.

	Copper Sulfate pounds	Cutrine gallons	Arsenic pounds	Silvex 2,4,5-TP pounds	Aquathol pounds	Aquathol gallons	Hydrothol pounds	2, 4-D pounds	Rodeo ounces	Diquat gallons
1942	1150									
1944	440									
1949	1000		110							
1950	1000		150							
1951	850									
1952	1000									
1960			600							
1963	850		1260							
1964	1600		1440							
1965	800									
1966	800									
1967	1900							440		
1968	750			67.5	1350					
1969	1125			72		51				
1970	750				1125					
1971					150					
1973					1010					
1974	300				1060					
1975					350					
1976							870			
1977							415			
1978							300	30		
1979							750	30		
1980					500		1500	10		
1981								10		
1982					550		650	20		
1983	500					24		5		8
1984								10		
1990		50				102	40		15	19
1991		38.75				68.5			3	11.5
1992		14.5				88.5			6	5
1993		39.75				38.5				14.75
1994		20.5			250	36.5	35		3	17
1995		36.5				52.5				12.75
1996		11.5				8.75				4.5
1997		21				42.25				10
1998		18.75				45.5			1	9.5
1999		17.5				37			3	11.25
2000		12.5				30.75			5	17
2001		10				33.5				11.5
2002		13.25				37.5			6	11.75
2003		9.5				29.25				9.75
2004		4.75				16				5.25
Total	14815	319	3560	140	6345	742	4560	555	42	179

The Pike Lake Sportsmen Club started a mechanical harvesting program in 2004 to control aquatic plant growth instead of conducting chemical treatments. Like the chemical control, mechanical harvesting tends not to be selective, but has other advantages over chemical control.

1) The result is immediate, opening areas for navigation and fishing
2) The plant material is removed from the lake so that plant material is not decaying in the lake, removing nutrients from the lake water and the sediments
3) Mechanical harvesting has no risk associated with the unknown toxic impacts to the aquatic community by chemicals.

In three seasons, with two cuttings each, more than one million pounds of aquatic plant material has been removed from Pike Lake (Table 2). In a natural lake without a large input of nutrients each year, this has the potential to reduce the nutrient concentration in the water over time. The phosphorus content of aquatic vegetation in Pike Lake has not been analyzed, but based on the ranges of phosphorus found in plant tissue by other researchers (Bouldan et al. 1994); the amount of phosphorus that has been removed from Pike Lake so far is likely between 1350 pounds and 9400 pounds.

Table 2. Aquatic Plant Material Removed from Pike Lake, 2004-2006.

	Pounds Cut	**Number of Cuts**	**Acres**	**Hours**	**Pounds of Phosphorus Removed ***
2004	246,000	2	15	85	280-1960
2005	314,500	2	21-23	90	360-2510
2006	625,000	2	40-45	124	720-
Total	1,185,500	6		299	1360-9480

* Based on phosphorus concentrations recorded in other research

The Sportsmen Club has completed a detailed process of developing an Aquatic Plant Management Plan with research staff from the University of Wisconsin-Stevens Point. The new management plan will be presented for approval at their 2007 annual meeting. If approved, the lake organization will follow the plan guidelines and recommendations. The plan will be updated it yearly with input from the WI-DNR.

II. METHODS

Field Methods

The same study design was used for the 1989, 1993 and 1996 plant studies and was based on the rake-sampling method developed by Jessen and Lound (1962). Twenty-one (21) equal-distance transect lines were placed perpendicular to the shoreline with the first transect being randomly placed (Appendix X). The 1999, 2002 and 2006 studies were slightly different in that, although the same transects were used for all surveys, the transects included sample sites in the 10-20ft depth zone in the more recent years.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, and 5-10ft). A site in the 10-20ft was added to each transect in 1999, 2002 and 2006. Using a long-handled steel thatching rake, four rake samples were taken at each sampling site. The four samples were taken at each quarter of a 6-foot square quadrat. The aquatic plant species that were present on each rake sample were recorded. The species recorded includes aquatic vascular plants and several types of algae that have morphologies similar to vascular plants, such as muskgrass and nitella. Each species was given a density rating (0-5) based on the number of rake samples on which it was present, at each sampling site.

A rating of 1 indicates that a species was present on one rake sample
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 a species 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 presence of filamentous algae was also noted in 1999, 2002 and 2006. The sediment type was recorded at each sample site. 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 deep, was evaluated. The percentage of each cover type within this 100' x 30' rectangle was recorded and verified by a second researcher.

Specimens of all plants present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

Data Analysis

The data for each year was analyzed separately and compared. The percent frequency of occurrence of each species was calculated (number of sampling sites at which it occurred/total number of sites) (Appendices I-III). Relative frequency was calculated (number of occurrences of a species / sum of all species occurrences) (Appendices I-III). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendices IV-VI). Relative density was calculated (sum of a species' density ratings / sum of all plant densities). A "mean density where present" was calculated (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendices IV-VI). The relative frequency and relative density of each species were summed to obtain a dominance value for each species (Appendices VII-IX). Simpson's Diversity Indices (1-sum(relative frequencies)^2) were calculated for each sampling year (Appendices I-III). Each sampling year was compared by a Coefficient of Community Similarity, measuring the percent similarity between the communities.

The Aquatic Macrophyte Community Index (AMCI) (Nichols et. al. 2000) was applied to Pike Lake to quantify the quality of the aquatic plant community. Seven parameters that characterize the aquatic plant community (Table 11) are converted to a value 0 – 10 as outlined by Nichols (2000).

The Average Coefficient of Conservatisms and Floristic Quality Indices were calculated for each year to measure disturbance in the plant community (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 the species found in a lake. The Floristic

Quality Index is calculated from the Average Coefficient of Conservatism.

III. RESULTS

PHYSICAL DATA

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

WATER QUALITY

Algae, nutrients and water clarity are measured and combined to determine the trophic status of a lake (Table 3). Wisconsin Department of Natural Resources has collected water quality data monthly during June – August, 1986-2006. Summer mean values are the mean of these three samples.

Eutrophic lakes are high in nutrients and 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.

Nutrients

Phosphorus is a limiting nutrient in many Wisconsin lakes and is measured as an indication of the nutrients in a lake. Increases in phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth.

2006 Mean summer phosphorus in Pike Lake was 25.3ug/l

This concentration of phosphorus is indicative of a mesotrophic lake (Table 3).

Table 3. Trophic Status

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc ft.
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
Pike Lake, 2006 Summer Mean	**Good**	**25.3ug/l**	**9.62ug/l**	**4.5 feet**

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

The mean summer phosphorus in Pike Lake has varied within the mesotrophic range (Figure 1). The lowest phosphorus levels were in 1995; the highest phosphorus levels were in 1997. Phosphorus concentrations have not changed significantly during the sampling years (Figure 1). The mean of all years was also in the mesotrophic range.
1986-2006 Mean summer phosphorus in Pike Lake was 27.6ug/l

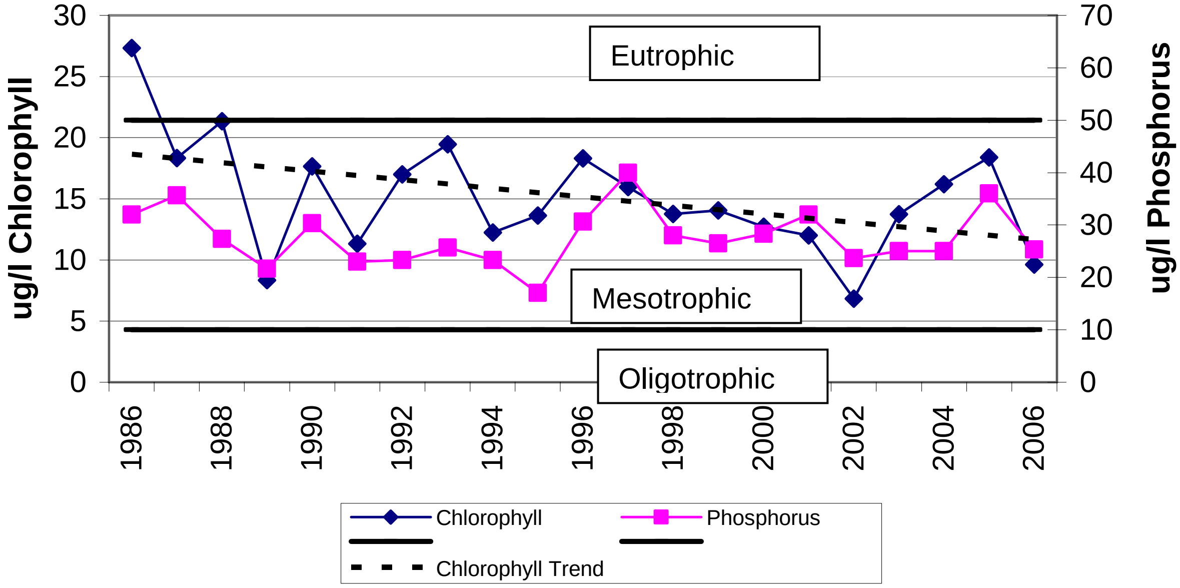

Figure 1. Change in mean summer phosphorus and chlorophyll in Pike Lake, 1986-2006.

Algae

Chlorophyll a concentrations measure the amount of algae in lake water. Algae are natural and essential in lakes, but high algae populations can increase turbidity and reduce the light available for plant growth.
2006 Mean summer chlorophyll in Pike Lake was 9.62ug/l.
This concentration of chlorophyll is indicative of a mesotrophic lake (Table 3).

Chlorophyll concentrations (which measure algae) have also varied within the mesotrophic range in Pike Lake, except for a few high, eutrophic years in the late 1980's. The highest chlorophyll was recorded in 1986, the lowest was in 2002 (Figure 1). **1996- 2006 Mean summer chlorophyll in Pike Lake was 15.2ug/l.**
This mean for all years is also in the mesotrophic range. Trend analysis indicates chlorophyll has been decreasing in Pike Lake since 1986 (r^2=2.144).

Filamentous algae has declined slightly in Pike Lake since 1999; 20% of the sites in 1999; 19% of the sites in 2002; 17% of the sites in 2006. Filamentous algae occurred at its highest frequency in the 0-5ft depth zones (Figure 2).

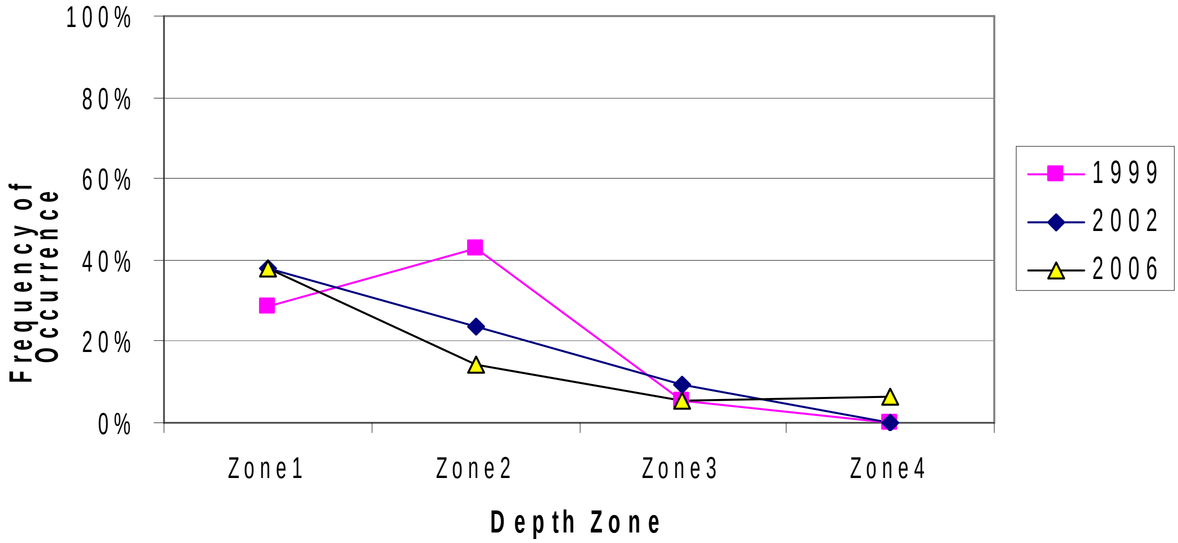

Figure 2. Occurrence of filamentous algae in Pike Lake, 1999-2006.

Water Clarity

Water clarity is a critical factor for plants. When 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 is measured with a Secchi disc that shows the combined effect of turbidity and color.

2005 Mean summer water clarity was 4.5 feet.

This is indicative of a borderline mesotrophic/eutrophic lake with poor water clarity (Table 3).

Water clarity has varied during the study period and trend analysis shows a slight trend of decreasing water clarity since 1986 (Figure 3).

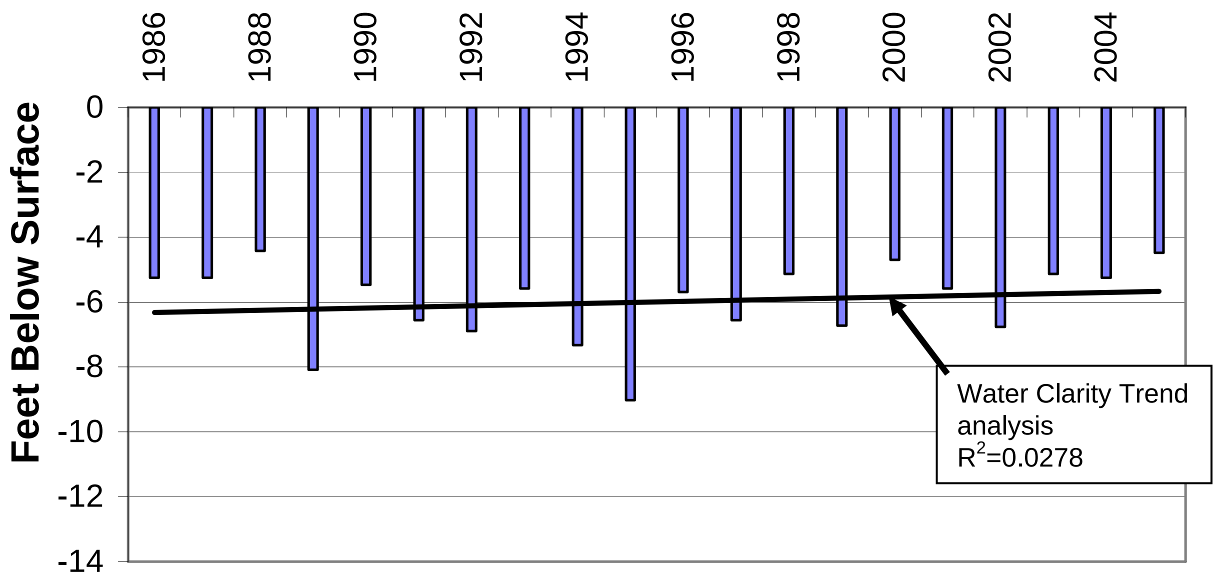

Figure 3. Summer mean water Clarity in Pike Lake, 1986-2005.

Combination of phosphorus, chlorophyll and water clarity data indicate that Pike Lake is a mesotrophic lake with fair to good water quality. This trophic state would support moderate plant growth and occasional algae blooms.

Volunteers in the Self-Help Volunteer Lake Monitoring Program have monitored water clarity off and on during various years. Volunteer lake monitors have monitored water clarity sporadically during 1988-1997. Satellite data has been used to estimate water clarity during 1999-2001. Volunteer and satellite data also indicate that water clarity varies with in the mesotrophic range with an overall trend of declining water clarity (Figure 4).

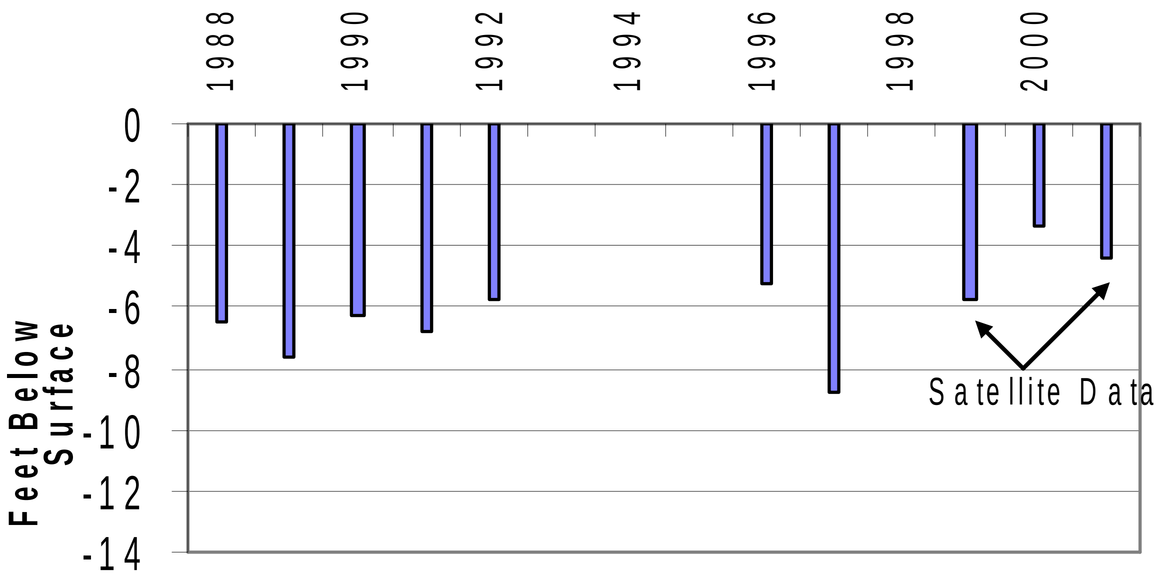

Figure 4. Water clarity data collected by volunteer lake monitors and satellite images, 1988-2001.

The volunteer lake monitoring data collected during the growing season can show how clarity changes during the year. Water clarity collected at the same time of the year was averaged to show the change in water clarity during the year. Water clarity starts out lower in April (spring turnover) and increases to its maximum clarity in May through June. Clarity then decreases during July and August, likely as the warming water promotes algae growth. As the water cools and algae decline in the fall, the clarity increases until dropping to its lowest clarity in October (fall turnover) (Figure 5).

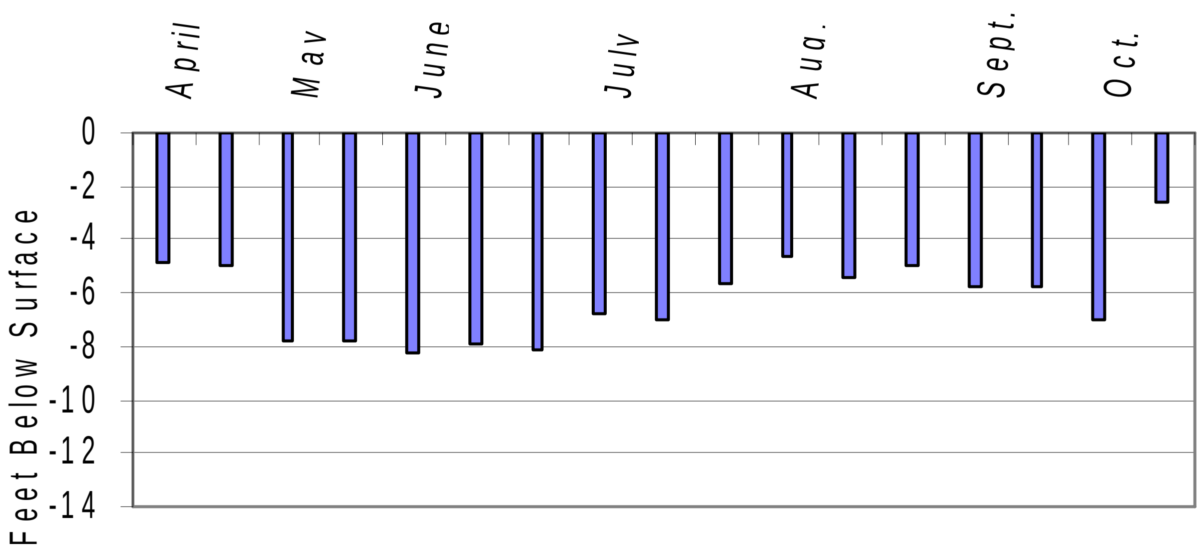

Figure 5. Change in water clarity during the growing season, data from 1988-1997.

Lake Morphometry

Duarte and Kalff (1986) found that the slope of the littoral zone accounted for 72% of the observed variability in the growth of submergent vegetation. Gentle slopes support a broader zone of potential plant growth than steep slopes (Engel 1985).

The majority of the littoral zone in Pike Lake is gradually sloped, except for a section of the northeast shore that is steeply sloped (Appendix X). The deepest point of the lake lies near this shore. The gentle slopes provide a more stable substrate for aquatic plant growth and a broader band of shallow waters favorable for plant growth.

Sediment Composition

Sand was the dominant sediment in Pike Lake, especially in the 0-5ft depth zone (Table 4, Figure 6). Organic muck sediments were common in Pike Lake and dominant in the 5-10ft depth zone. Silt sediments did not occur in the shallowest zone, but increased with increasing depth to become dominant in the 10-20ft depth zone (Table 4).

Table 4. Pike Lake Sediment Composition by Depth Zone, 2006

		0-1.5'	1.5-5'	5-10'	10-20'	Overall
Hard Sediments	**Sand**	61%	43%	16%	38%	40%
	Sand/Gravel	14%	5%			5%
	Sand/Rock	5%	10%			4%
	Cobble	5%				1%
Mixed Sediments	**Sand/Silt**	10%	14%	16%		10%
Soft Sediments	**Muck**	5%	19%	53%	12%	22%
	Silt		10%	16%	50%	17%

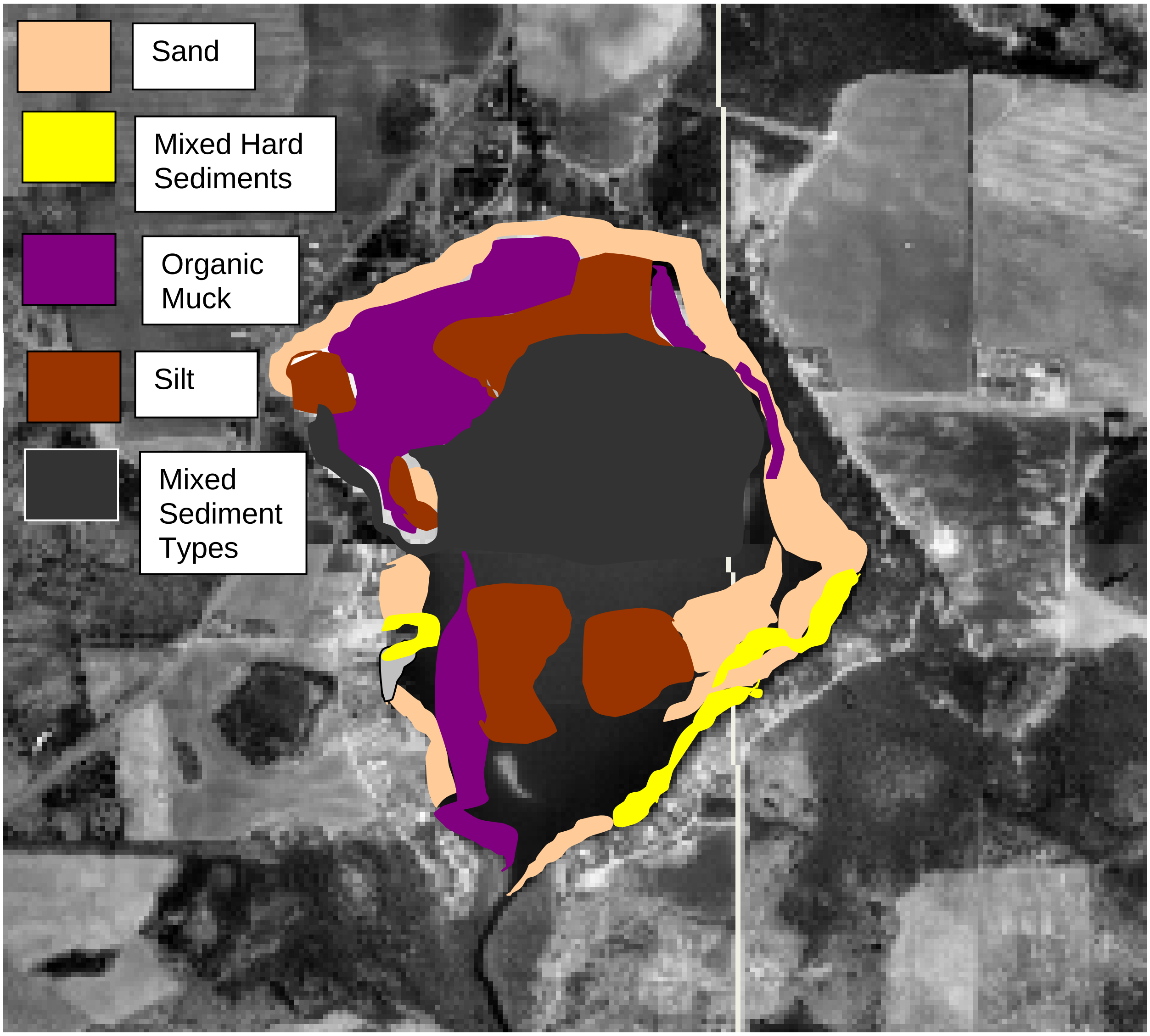

Figure 6. Sediment distribution in Pike Lake, 2006.

Sediment Influence

Some aquatic plants depend on the sediments for required nutrients. The texture and richness or sterility of the sediment will determine the type and abundance of species that can survive in a location. The availability of mineral nutrients for plant growth is highest in sediments of intermediate density. Silt is an intermediate density sediment that is favorable for plant growth (Barko and Smart 1986). Silt sediments were dominant in the deepest depth zone of Pike Lake (Figure 6) and supported high levels of vegetation.

Sand sediment was the dominant sediment in Pike Lake. Sand sediments can be nutrient limiting due to their high density. Although supporting the lowest percent of vegetation cover, sand still supported high levels of vegetative growth in Pike Lake. Sediment did not appear to be the major factor determining plant growth in Pike Lake.

Shoreline Use

Land use activities strongly impact the aquatic plant community. Practices on shore can directly impact the plant community through increased sedimentation from erosion, increased nutrients from fertilizer run-off and soil erosion and increased toxics from farm and residential run-off.

Cultivated lawn had a very high occurrence and the highest mean coverage on Pike Lake (Table 5). Hard structures were abundant, found at nearly three-quarters of the sites. Another disturbed shore type, rip-rap, was also abundant around the lake shore. Cultivated lawn, hard structures and rip-rap all allow more rapid run-off to the lake without filtering the run-off and do not provide habitat benefits. Cultivated lawn can result in increased input of nutrients (fertilizers and pet waste) and pesticides and other toxics to the lake.

Natural herbaceous plant growth had the highest frequency of occurrence but a low coverage. This indicates that very small areas of natural herbaceous cover was scattered in many locations around the lake shore. Wooded cover was also commonly encountered at the aquatic plant sampling transects but did not have a high mean coverage either (Table 5), indicating that wooded cover was also found as small areas scattered around the lake. Some type and amount (very small amounts in some locations) of natural shoreline was found at 90% of the sites, but only had a mean cover of 38% at the shore. Averaging the percent of natural cover found at each site suggests that slightly more than one-third of the shore had natural plant cover.

Disturbed shoreline was encountered at 90% of the sampling sites and covered 61% of the shoreline sites based on shoreline cover at the aquatic plant transects (Table 5). This indicates that shoreline development has degraded the nearshore habitat of Pike Lake. Shoreline restoration would be effective at improving shoreline habitat.

Table 5. Shoreline Land Use, 2006

	Cover Type	Frequency of Occurrence at Transects	Mean % Coverage
Natural Shoreline	**Native Herbaceous**	81%	13%
	Wooded	52%	18%
	Shrub	19%	7%
Total Natural			38%
Disturbed Shoreline	**Cultivated Lawn**	76%	41%
	Hard Structures	71%	12%
	Rip-rap	48%	6%
	Bare sand	5%	1%
	Pavement	5%	1%
Total Disturbed			61%

Between 2002 and 2006, natural shoreline cover decreased on Pike Lake and disturbed shoreline cover increased (Table 6). Native herbaceous cover decreased the most and hard structures increased the most.

Table 6. Change in Mean Cover of Shoreline Land Use, 2002-2006

	Cover Type	2002	2006
Natural Shoreline	**Native Herbaceous**	20%	13%
	Wooded	19%	18%
	Shrub	8%	7%
Total Natural		47%	38%
Disturbed Shoreline	**Cultivated Lawn**	46%	41%
	Hard Structures	5%	12%
	Rip-rap	2%	6%
	Bare sand	1%	1%
	Pavement	1%	1%
Total Disturbed		55%	61%

MACROPHYTE DATA

Forty-one (41) different species of aquatic plants were found during the 1989-2006 studies: 11 emergents species, 6 floating leaf species, and 24 submergent species (Table 7). Not all species were found in the same year (Appendix XI).

No endangered of threatened species were found.

One non-native species was found: *Potamogeton crispus,* curly-leaf pondweed*.*

Table 7. Pike Lake Aquatic Plant Species, 1989-2006

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Calla palustris* L.	water arm	calpa
2) *Carex rostrata* Stokes.	sedge	carro
3) *Dulichium arundinaceum* (L) Britton.	three-way sedge	dular
4) *Eleocharis palustris* (L.) R.& S.	creeping spikerush	elepa
5) *Equisetum fluviatie* L.	scouring rush	equfl
6) *Juncus* sp.	rush	junsp
7) *Pontederia cordata* L.	pickerelweed	ponco
8) *Sagittaria* sp.	arrowhead	sagsp
9) *Scirpus validus* Vahl.	softstem bulrush	sciva
10) *Sparganium* spp.	bur-reed	spasp
11) *Typha latifolia* L.	broad leaf cattail	typla
Floating leaf Species		
12) *Brasenia schreberi* Gmel.	watershield	brasc
13) *Lemna minor* L.	small duckweed	lemmi
14) *Lemna trisulca* L.	forked duckweed	lemtr
15) *Nuphar variegata* Durand.	bull-head pond lily	nupva
16) *Nymphaea odorata* Aiton.	white water lily	nymod
17) *Spirodela polyrhiza* (L.) Schleiden.	great duckweed	spipo
Submergent Species		
18) *Ceratophyllum demersum* L.	coontail	cerde
19) *Chara* sp.	muskgrass	chasp
20) *Eleocharis acicularis* (L.) R.& S.	needle spikerush	eleac
21) *Elodea canadensis* Michx.	common waterweed	eloca
22) *Juncus pelocarpus* Mey.	rush	junpe
23) *Myriophyllum sibiricum* Komarov.	common water milfoil	myrsi
24) *Najas flexilis* (Willd.) Rostkov & Schmidt.	slender naiad	najfl
25) *Nitella* sp.	nitella	nitsp
26) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
27) *Potamogeton crispus* L.	curly-leaf pondweed	potcr
28) *Potamogeton foliosus* Raf.	leafy pondweed	potfo
29) *Potamogeton friesii* Rupr.	pondweed	potfr
30) *Potamogeton illinoensis* Morong.	Illinois pondweed	potil
31) *Potamogeton pectinatus* L.	sago pondweed	potpe
32) *Potamogeton praelongus* Wulf.	whitestem pondweed	potpr
33) *Potamogeton pusillus* L.	small pondweed	potpu
34) *Potamogeton richardsonii* (Ar. Bennett) Rydb.	clasping-leaf pondweed	potri
35) *Potamogeton robbinsii* Oakes.	fern pondweed	potro
36) *Potamogeton zosteriformis* Fern.	flatstem pondweed	potzo
37) *Ranunculus longirostris* Godron.	stiff water crowfoot	ranlo
38) *Utricularia gibba* L.	small bladderwort	utrgi
39) *Utricularia intermedia* Hayne	bladderwort	utrin
40) *Vallisneria americana* L.	water celery	valam
41) *Zosterella dubia* (Jacq.) Small.	water stargrass	zosdu

FREQUENCY OF OCCURRENCE

Chara spp. (muskgrass, a macrophytic algae) was the most frequent species in 1999-2006 (44%, 49%, 60%) (Table 8) with its frequency steadily increasing during 1999-2006. *Potamogeton illinoensis* (Illinois pondweed), the second most frequent species in 2006 has also steadily increased in frequency since 1999. The frequency of *Potamogeton crispus* (curly-leaf pondweed) appears to have declined in 2006, but the decline is likely due to the survey being conducted late in the summer, after *P. crispus* has died back for the year. The 1999 and 2003 surveys were conducted in June when *P. crispus* is at its peak biomass.

Table 8. Frequencies of Prevalent Aquatic Plants in Pike Lake 1999 - 2006.

Species	1999	2002	2006
Chara spp.	44%	49%	60%
Potamogeton illinoensis	10%	32%	54%
Myriophyllum sibiricum	38%	33%	48%
Ceratophyllum demersum	23%	46%	45%
Potamogeton crispus	25%	25%	3%

DENSITY

Chara spp., the macrophytic algae, also had the highest mean density; however mean densities of all plant species were low in Pike Lake during 1999-2006 (Appendices IV-VI). The mean density of *Chara* spp. has increased slightly from 1999-2006 (1.24 - 1.42 - 1.71 on a scale of 0-4).

"Density where present" measures how dense of a growth form a species exhibits in a lake. A species may occur in only a few sites and have a low mean density over the entire lake, but at the sites at which it occurs, it may exhibit a dense form of growth. *Nitella* spp (a macrophytic algae) and *Nymphaea odorata* (white water lily) had an above average “mean density where present” in 1999 (2.75, 2.64 on a scale of 0-4) (Appendices IV-VI). In 2002 and 2006, *Chara* (the dominant species) and *Nymphaea odorata* had above average “mean densities where present”.

Scirpus validus (softstem bulrush) exhibited a dense form of growth in Pike Lake in 1999-2006 (3.0). *Sagittaria* (arrowhead) exhibited a dense form of growth in Pike Lake in 2006 (3.0). However, the bulrush and arrowhead were found only in shallow water in scattered locations around the lake and provide a valuable habitat resource.

DOMINANCE

Combining relative frequency and relative density of a species into a dominance value illustrates how dominant a species is in its community.

Chara spp. was the dominant species in 1999 – 2006. Sub-dominance switched from *Myriophyllum sibiricum* (northern watermilfoil) in 1999 to *Ceratophyllum demersum* (coontail) in 2002 and to *Potamogeton illinoensis* (Illinois pondweed) in 2006 (Figure 7).

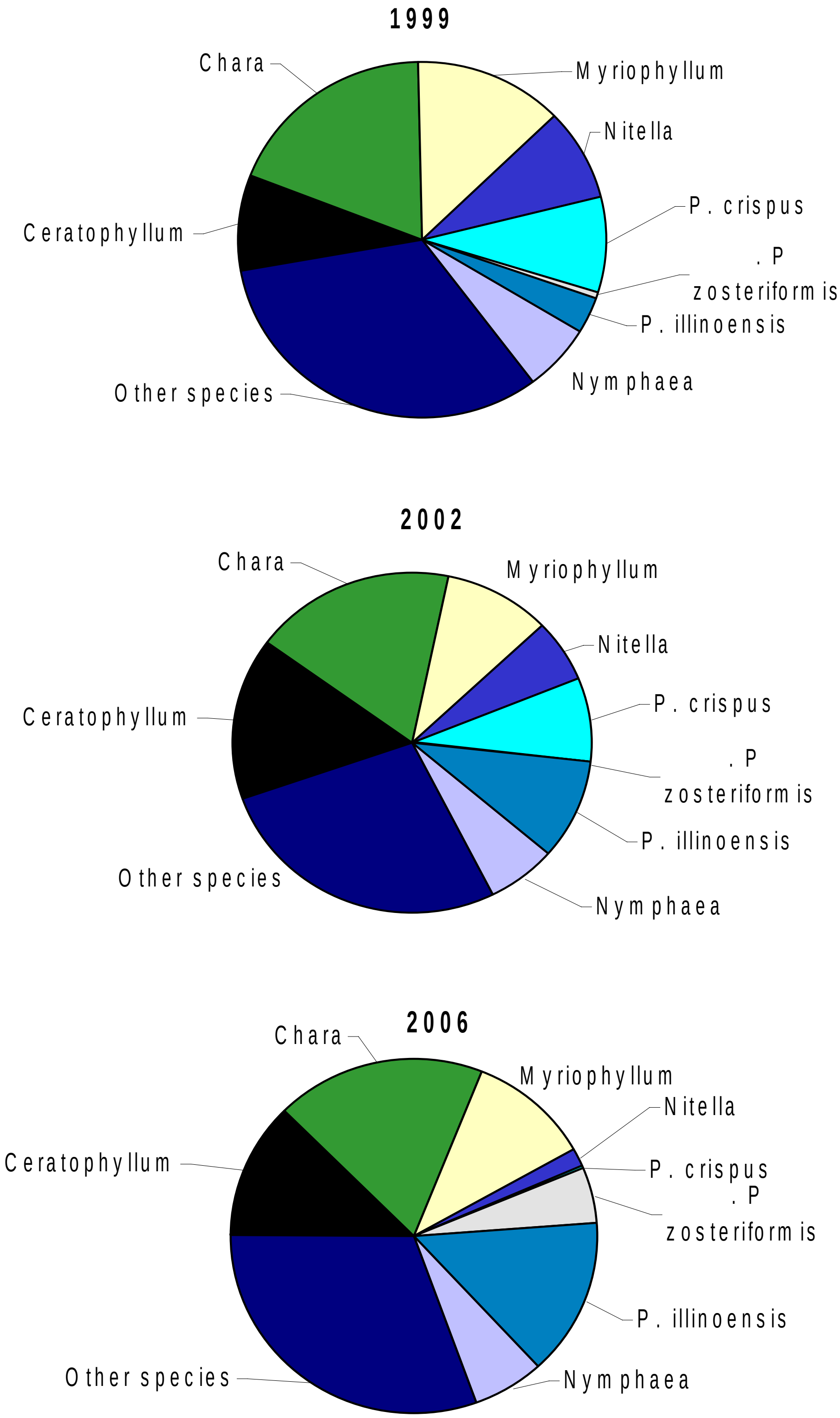

Figure 7. Dominance of prevalent species in Pike Lake, 1999-2006.

DISTRIBUTION

Aquatic plants occurred throughout the littoral zone during 1989-2006 to a maximum rooting depth of 10.5 feet (Figure 8). In 2006, aquatic plants colonized 98 acres of the lake, 48% of the lake and 90% of the littoral zone. Submergent vegetation colonized all vegetated areas, rooted floating-leaf vegetation colonized 23 acres (11% of the lake surface, 23% of the littoral zone) and emergent vegetation colonized 4 acres (2% of the lake surface, 10% of the littoral zone). Free-floating vegetation covered 46% of the littoral zone in August 2006.

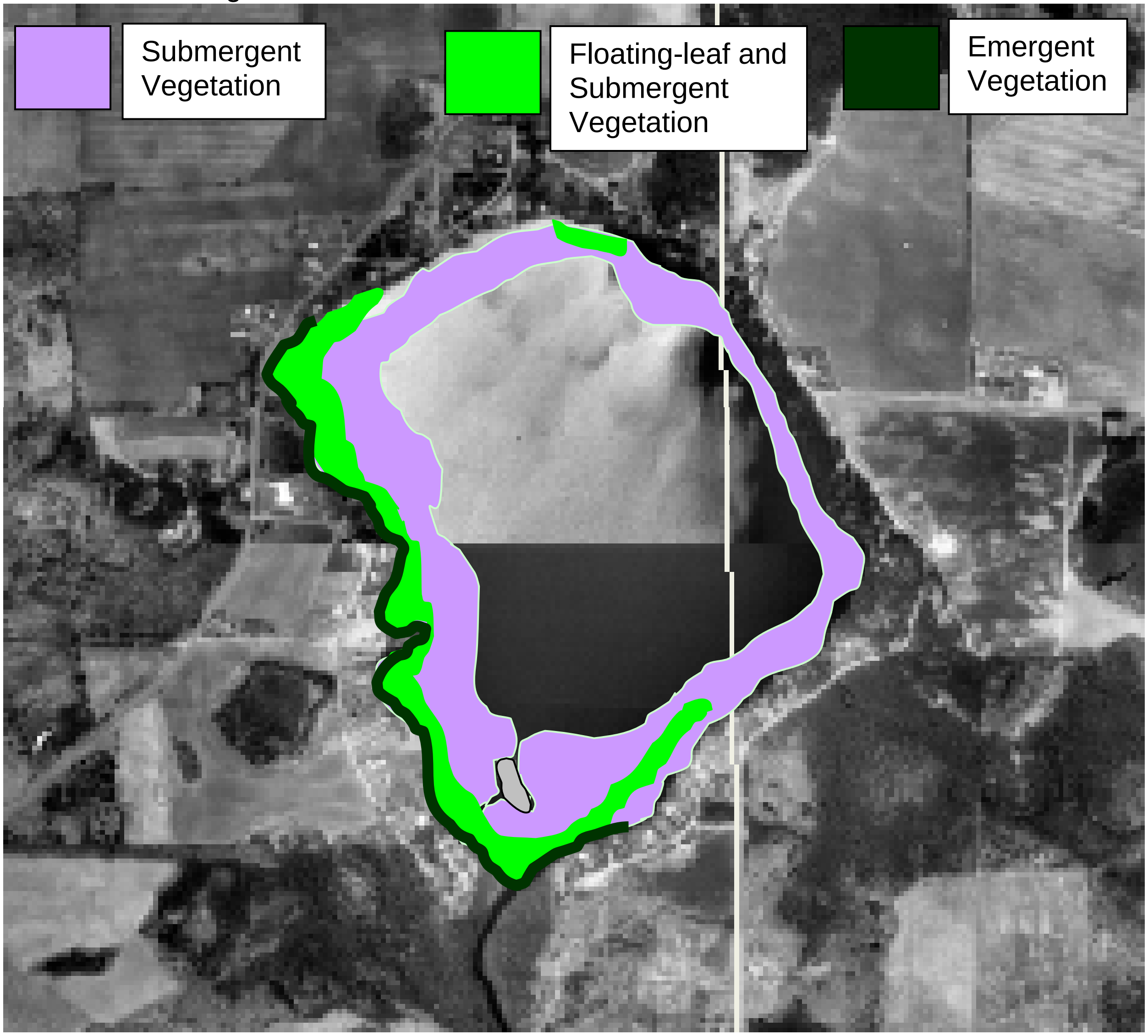

Figure 8. Distribution of aquatic vegetation in Pike Lake, August 2006.

Secchi disc readings are used to calculate a predicted maximum rooting depth for plants in a lake (Dunst 1982).

Predicted Rooting Depth (ft.) = (Secchi Disc (ft.) * 1.22) + 2.73

Based on the 2005 mean summer water clarity (4.5ft), the predicted maximum rooting depth in Pike Lake would be 8.2 ft.

The maximum rooting depth of 10.5 feet is greater than the predicted maximum rooting depth based on water clarity. This may be due to better water clarity early in the spring when aquatic plant growth if first starting.

The actual maximum rooting depth has been slightly greater than the predicted maximum rooting depth based on summer mean water clarity during most study years (Figure 9). This may be due to better clarity in the spring when aquatic plant growth is starting to grow. Summer water clarity data may not be the best predictor, however, DNR data is gathered during the summer season.

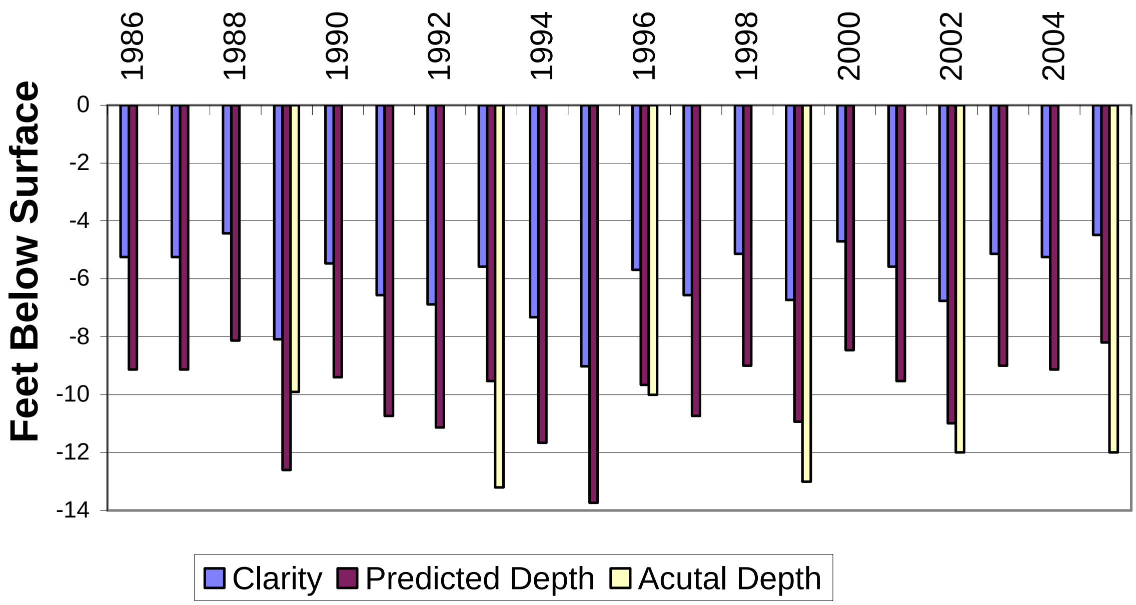

Figure 9. Predicted and actual maximum rooting depth in Pike Lake, 1986-2006.

The depth zone with the highest total occurrence and total density of aquatic plant growth shifted from the 5-10ft depth zone during 1999-2002 to the 0-1.5ft depth zone in 2006 (Figure 10, 11).

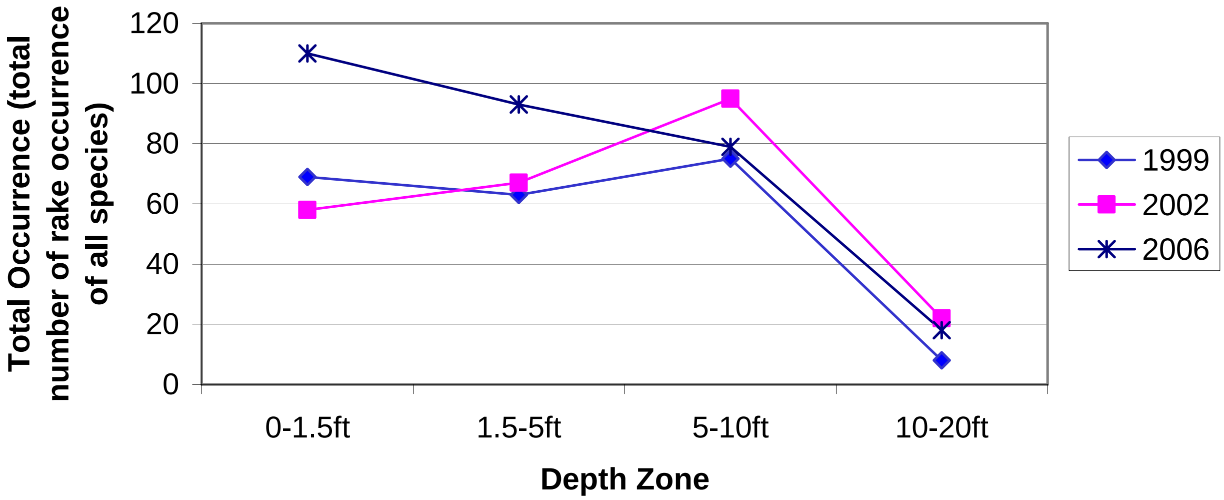

Figure 10. Total occurrence of aquatic plants by depth zone, Pike Lake, 1999-2006.

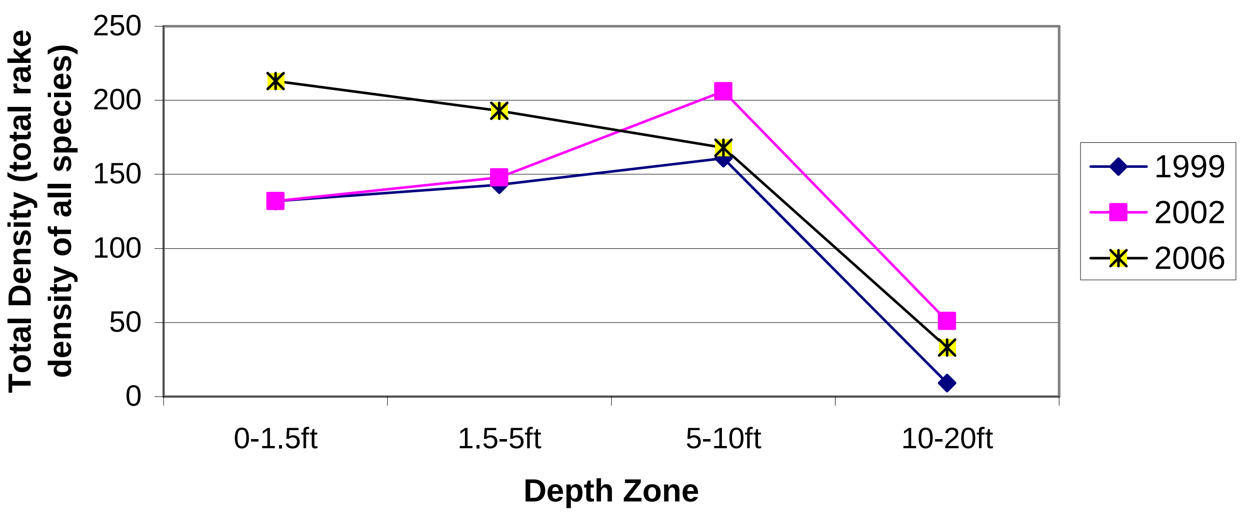

Figure 11. Total density of aquatic plants by depth zone, Pike Lake, 1999-2006.

The zone with the greatest species richness (mean number of species per sample site) also shifted from the 5-10ft depth zone during 1999-2002 to the 0-1.5ft depth zone in 2006 (Figure 12). Overall species richness has increased from 2.72 in 1999 to 3.06 in 2002, to 3.89 in 2006.

The highest percent of vegetated sites has been recorded in the 5-10ft depth zone 1999-2006 (Figure 12).

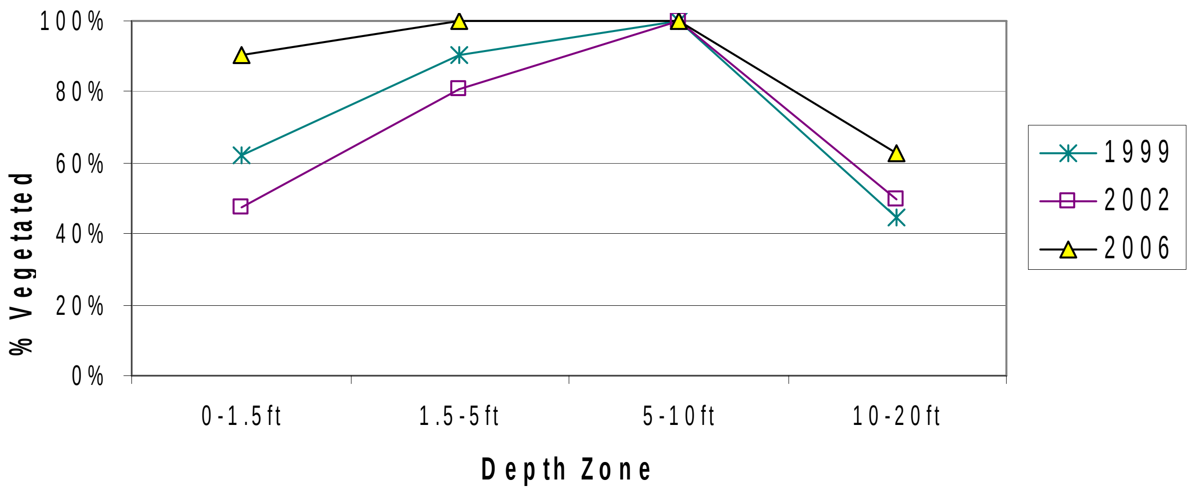

Figure 12a. Percentage of littoral zone vegetated by depth zone, 1999-2006.

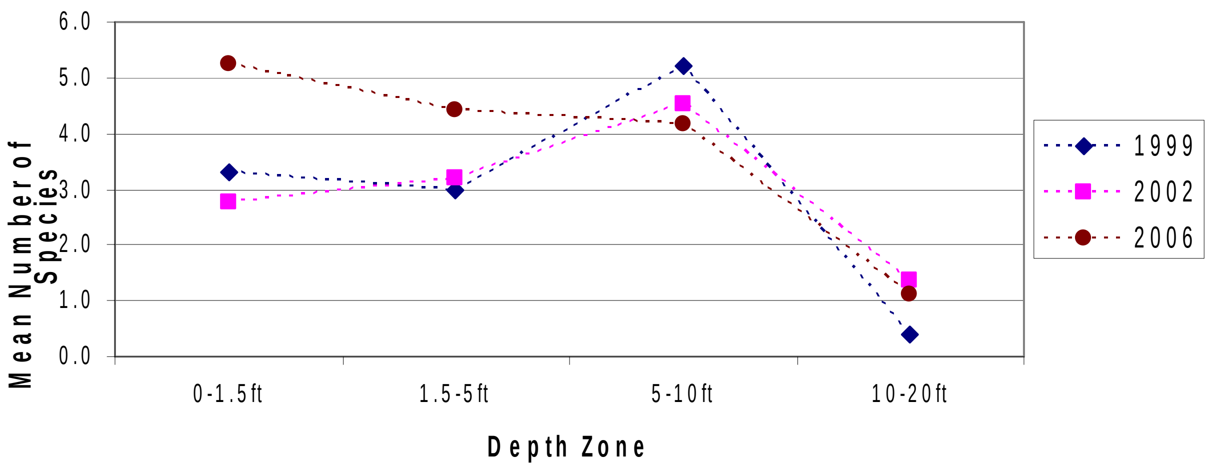

Figure 12b. Mean number of species per site (Species Richness) by depth zone, 1999-2006.

Chara spp., the dominant species in 1999-2006, dominated the 1.5-10ft depth zone all years and occurred at its highest frequency and density in this depth zone (Figure 13).

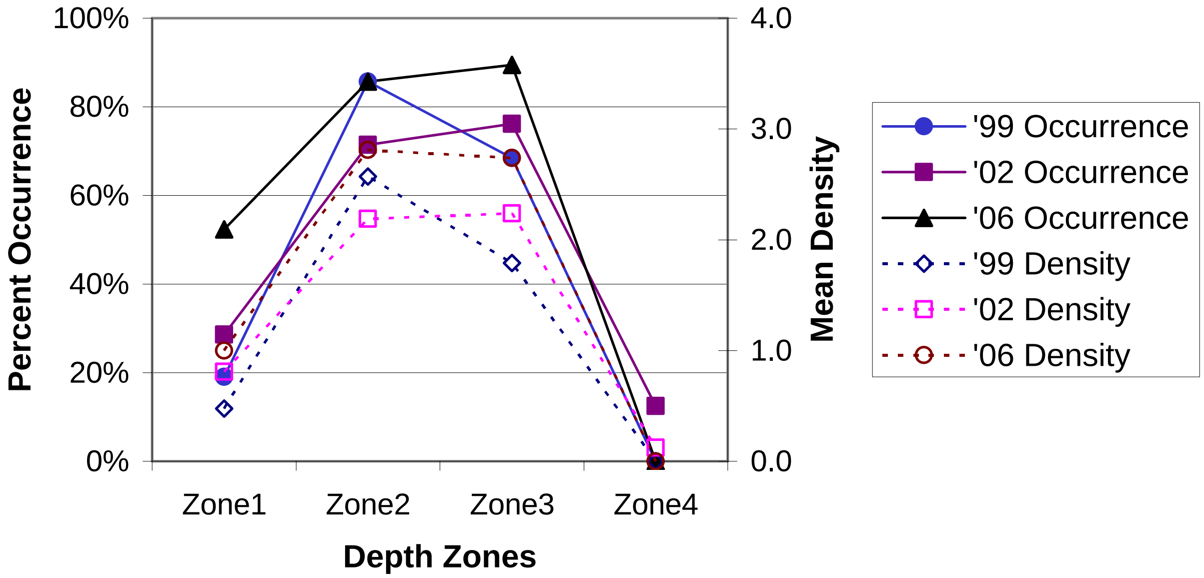

Figure 13. Frequency and density of *Chara* by depth zone, Pike Lake, 1999-2006.

Ceratophyllum demersum, the sub-dominant species in 2002, dominated the 10-20ft depth zone in 2002-2006, but has occurred at its highest frequency and density in the 5-10ft depth zone (Figure 14). The frequency and density *C. demersum* increased from 1999 to 2002 (Figure 14).

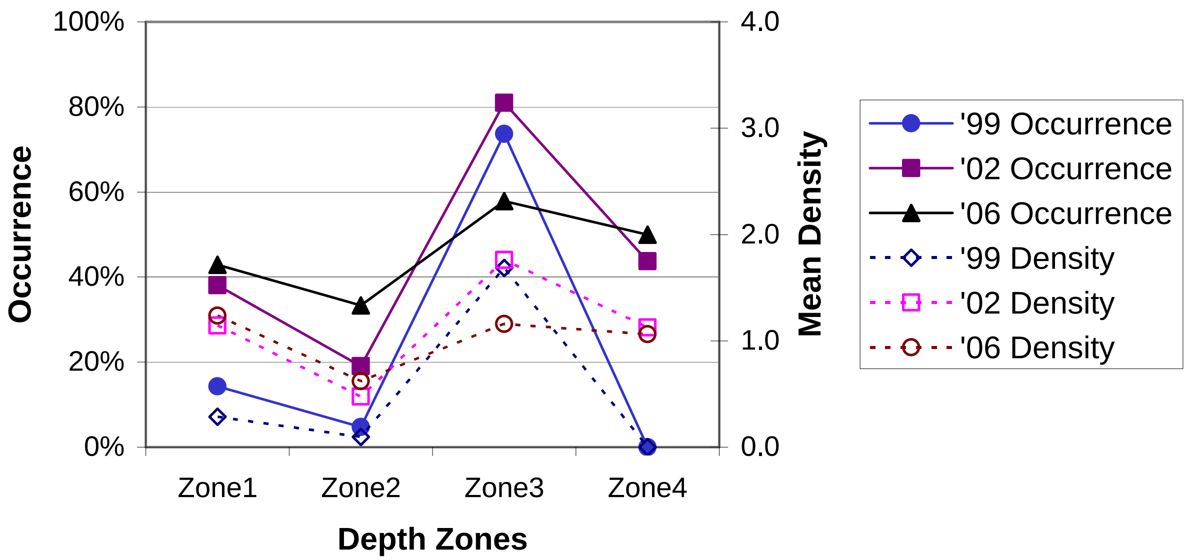

Figure 14. Frequency and density of *Ceratophyllum demersum* by depth zone, 1999-2006.

MACROPHYTE COMMUNITY

The Coefficients of Community Similarity indicate that the aquatic plant community in Pike Lake has changed significantly. The 1999 and 2002 aquatic plant communities were most similar (75%), not significantly different (Table 9). However, the 2002 and 2006 communities were significantly different; they were only 72% similar (Table 9). The additive effect of continual change in the plant community during the ten years has resulted in the 2006 plant community being only 69% similar to the plant community of 1999 (Table 9).

Table 9. Coefficients of Community Similarity Pike Lake 1999-2006.

	Coefficient *	**% Similar**
1999-2002	0.75229	75%
2002-2006	0.72438	72%
1999-2006	0.69288	69%

* - Coefficients less than 0.75 indicate a significant difference.

Several indices and parameters can be used to assess what types of changes that have occurred within the aquatic plant community to have resulted in the significant change (Table 10).

The maximum rooting depth has decreased since 1999. The cover of emergent vegetation and Simpson's Diversity Index has also decreased slightly (Table 10).

The number of species, percent of the littoral zone vegetated, species richness (mean number of species per site), Average Coefficient of Conservatism, Floristic Quality Index, AMCI Index and cover of submergent, free-floating and floating-leaf species have all increased (Table 10). The Average Coefficient of Conservatism, Floristic Quality Index and AMCI Index are discussed later in this document.

The number of species, percent of the littoral zone vegetated, Average Coefficient of Conservatism, Floristic Quality Index and AMCI Index were declining from 1999-2002, but increased in 2006 to values greater than in 1999 (Table 10).

Table 10. Changes in the Pike Lake Aquatic Plant Community, 1999-2006.

	1999	2002	2006	Change 1999-2006	%Change 1999-2006
Number of Species	26	21	34	8.0	30.8%
Maximum Rooting Depth	13.0	12.0	10.5	-2.5	-19.2%
% of Littoral Zone Vegetated	74.7	70.9	89.6	14.9	19.9%
%Sites/Emergents	11.4	12.7	10.4	-1.0	-8.8%
%Sites/Free-floating	30.4	45.6	45.5	15.1	49.7%
%Sites/Submergents	69.6	69.6	83.1	13.5	19.4%
%Sites/Floating-leaf	16.5	20.3	23.4	6.9	41.8%
Simpson's Diversity Index	0.92	0.91	0.91	0.01	-1.1%
Species Richness	2.72	3.06	3.89	1.2	43.0%
AMCI Index	54	51	58	4.0	7.4%
Average Coefficient of Conservatism	5.52	5.05	5.73	0.2	3.8%
Floristic Quality	27.60	22.58	32.90	5.3	19.2%

The maximum rooting depth has decreased the most (19%), decreasing each year since 1999. The cover of free-floating species has increased the most (Table 10).

The Simpson’s Diversity Indices (0.91-0.92) indicate that Pike Lake has very good plant diversity. A Diversity index of 1.0 would mean that each individual in a community was a different species, the most diversity that could be found.

The Aquatic Macrophyte Community Index (AMCI) indicates that the quality of the aquatic plant community was above average quality in 1999, decreased to below average quality in 2002 and increased to the upper quartile of lakes in Wisconsin and the North Central Hardwoods Region of Wisconsin in 2006 (Table 11). **This means that Pike Lake was in the group of lakes in the state and region with the highest quality aquatic plant community.**

Table 11. Aquatic Macrophyte Community Index Values for Pike Lake, 1999-2006.

	1999	2002	2006
Maximum Rooting Depth	7	6	5
% Littoral Zone Vegetated	10	10	10
Simpson's Diversity Index	9	9	9
Relative Frequency of Submersed Species	8	6	9
# of Species	10	9	10
Relative Frequency of Sensitive Species	5	6	9
Exotic Species	5	5	6
Total	54	51	58

The maximum AMCI value is 70

The Average Coefficient of Conservatism for Pike Lake was below average for all Wisconsin lakes and lakes in the North Central Hardwoods Region in 1999. The coefficient decreased to the lowest quartile of lakes in the state and region 2002 (Table 12). **In 2006, Pike Lake was above average for lakes in the region and below average for Wisconsin lakes.** This suggests that the plant community in Pike Lake has an average tolerance to disturbance, but the disturbance was increasing during 1999-2002 and decreasing since 2002.

Table 12. Floristic Quality and Coefficient of Conservatism of Pike Lake, Compared to Wisconsin Lakes and Northern Central Wisconsin Lakes, 1999-2006.

	Average Coefficient of Conservatism †	**Floristic Quality ‡**
Wisconsin Lakes	5.5, 6.0, 6.9*****	16.9, 22.2, 27.5*****
NCHR Lakes	5.2, 5.6, 5.8*****	17, 20.9, 24.4*****
Pike Lake, 1999-2006		
1999	5.52	27.60
2002	5.05	22.58
2006	5.73	32.90

***** - upper limit of lowest quartile, mean, lower limit of upper quartile

***** - North Central Hardwoods Region (NCHR), region within Pike Lake is located

† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (most disturbance tolerant) to a high of 9.5 (least disturbance tolerant)

‡ - The lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) to a high of 44.6 (closest to undisturbed condition)

The Floristic Quality Index in Pike Lake was in the upper quartile of lakes in the state and the North Central Hardwoods Region in 1999, decreased to above average in 2002 and increased to the upper quartile of region and state lakes in 2006 (Table 12). This suggests that Pike Lake is in the group of lakes closest to an undisturbed condition in 2006 and that disturbance had been increasing 1999-2002 and has decreased since 2002.

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 the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by the fish population.

Major disturbance in Pike Lake are likely the development around the lake, nutrient input, the proximity to a major road, boat traffic, past chemical treatments and mechanical harvesting.

Aquatic plant communities change, because the plant species in the community change in frequency and density (Appendix XII). Between 1999 and 2006, three species disappeared, but these species were found in limited locations in the lake and shifting a transect may have missed recording them. Four other species declined. Two of these species declined approximately 30% so the decline was not significant. The species with the greatest decline in frequency, density and dominance was *Lemna trisulca* (forked duckweed). *Potamogeton crispus,* an exotic species, also declined substantially. Since *P. crispus* has a growth form of early spring growth followed by late June die-offs, the timing of the surveys are likely the reason for the *Potamogeton crispus* decrease. The 1999 and 2002 surveys were conducted in June to accommodate the chemical treatments and the 2006 survey was conducted in August since July and August are optimal months to conduct aquatic plant surveys.

Ceratophyllum demersum (coontail), *Nuphar variegata* (yellow pond lily), *Potamogeton illinoensis* (Illinois pondweed), *P. richardsonii*) clasping-leaf pondweed), *P. zosteriformis* (flat-stem pondweed) and *Typha latifolia* (cattail) are species that nearly doubled or more than doubled. These are native species which provide valuable habitat. Thirteen (13) other species increased during 1999-2006, but seven of these species were not likely real increases, species found in only limited locations that could have been missed by shifting transects. Six species increased, but not substantially. The majority of the species that increased were species that prefer soft sediments (83%) and are not tolerant of turbid water (78%) (Nichols 1999). *Potamogeton zosteriformis* (flatstem pondweed), a species that shows this preference, had the greatest increase, increasing more than 9 to 30 fold.

IV. DISCUSSION

Water quality impacts

Pike Lake is a mesotrophic lake with fair-to-good water quality and poor water clarity. Since 1986, algae in the lake has decreased but so has water clarity. Filamentous algae is common in the shallow zone and has declined slightly since 1999. The watershed of Pike Lake is large enough in ratio to lake volume to have an impact on water quality. Commonly occurring agriculture in the watershed, stormwater runoff from lake shore development and the past chemical treatments are likely sources of nutrients to Pike Lake

The adequate nutrients (trophic status), shallow depths and gradually-sloped littoral zone favor aquatic plant growth. The poor water clarity and dominance of high-density sediments could limit plant growth.

Regular herbicide treatments had been conducted on Pike Lake from 1940-2004, with 10 different chemicals having been applied during those years. Aquatic invertebrates provide important forage for fish and are also sensitive to herbicides, even at approved rates for application. Regular treatments with herbicides and algaecides result in ongoing reductions in this food source of fish. The last chemical treatment conducted on Pike Lake was in 2004.

In an attempt to control algae, more than 3700 pounds of pure copper has been added to the sediments of the lake. Copper does not degrade any further and builds up in the sediment; Pike Lake now contains at least 18 pounds of copper per acre, likely more concentrated in the shallow areas of the lake. In addition to the aquatic insects, mollusks, such as clams, are sensitive to copper. Mollusks live on the sediments and therefore are continually impacted by the copper that has built up. Mollusks filter lake water, removing algae cells as food; therefore copper treatments may compromise these water filters. Over time, new sediment may eventually cover the copper rich sediments.

The Arsenic and Silvex (related to the carcinogen, agent orange) applied for aquatic plant control would still be present in the sediments in Pike Lake. Sediment sampling and analysis for these compounds would be required if any sediment work would be planned in Pike Lake.

In 2004 the Pike Lake Sportsman Club changed their method of aquatic plant management to a program of mechanical harvesting. This change was supported by the majority of landowners around the lake during the development of the Pike Lake Aquatic Plant Management Plan. Since 2004 more than 1 million pounds of plant material has been removed from the lake. Because harvesting removes the plant material from the lake, it removes nutrients that plants have taken into their tissues and removes organic matter that would have enriched the sediments. Natural lakes, depending on the size of the watershed, have the potential for significant nutrient reduction in the lake through aquatic plant removal. Based on phosphorus content of aquatic vegetation found in literature reviews (Bouldan et al. 1994), the amount of phosphorus that has been removed from Pike Lake since 2004 is likely between 1350 and 9400 pounds.

Little of the shoreline on Pike Lake is protected by buffers of natural vegetation (wooded, shrub and native grasses and wildflowers). Disturbed shoreline occurred at 90% of the sampling sites and covered 61% of the shoreline; cultivated lawn, hard structures and rip-rap were all abundant. Disturbed shoreline has increased since 2002, especially hard structure. Cultivated lawn was the most abundant disturbed shoreline, occurring at more than three-quarters of the sites and covering nearly half of the shore.

Lawns, rip-rap and hard surfaces increase run-off to a lake and supply added nutrients to a lake from soil erosion, lawn chemicals and pet waste without filtering the run-off. Toxic substances also run into the lake from lawn pesticides and paved surfaces. Conversion of more than half of the natural shoreline to lawn, rip-rap and hard structure results in significant shoreline habitat loss for water dependent wildlife. This loss of natural shoreline also destroys the buffer that would infiltrate stormwater run-off to the lake. Run-off volume from developed lawn is approximately 10 times greater than run-off from natural wooded cover and more run-off events occurred at sites with lawn (Graczyk et. al. 2003). This increased run-off carries more nutrients to the lake. Nitrogen and phosphorus input was 10-100 times greater at developed lawn than wooded areas (Hunt et. al. 2006)

Aquatic Plant Community 2006

Aquatic plant growth is distributed throughout the littoral zone of Pike Lake to a maximum rooting depth of 10.5 feet. Vegetation colonizes 90% of the littoral zone, approximately 48% of the lake area, providing oxygen to the lake, water quality protection and the necessary habitat for aquatic life. Game fish populations have been found to decline when submerged aquatic vegetation is less than 10% and greater than 60% (Valley et. al. 2004).

The depth zone with the greatest amount of plant growth (highest total occurrence and density of plant growth and greatest number of species per site) was the 0-1.5ft depth zone.

A total of 41 aquatic plant species have been found during the plant surveys and the dominant species were distributed throughout the lake. The dominant species in Pike Lake is muskgrass (*Chara* spp), exhibiting a growth from of above average density in Pike Lake. Muskgrass occurred at more than half of the sites and dominated the 1.5-10ft depth zones. Illinois pondweed *(Potamogeton illionensis)* was sub-dominant, occurring at half of the sites. One non-native species, curly-leaf pondweed (*Potamogeton crispus),* occurred but was not common during the summer survey. This species had been commonly occurring during the 1999-2002 surveys which were conducted earlier in the summer. This is likely due to the early maturity and die-back growth habit of curly-leaf pondweed.

The plant community in Pike Lake is of high quality for Wisconsin lakes with very good species diversity. Species Richness is 3.89 species per site. Pike Lake has an average tolerance to disturbance and a condition closer to an undisturbed condition than the average lake in Wisconsin or the North Central Hardwoods Region. Disturbance to the plant community is likely due to the abundant development around the lake that contributes increased run-off and nutrients from septics and lawn chemicals. Past chemical treatments, boat traffic and run-off from the road are other disturbances.

Changes in the aquatic plant community

Significant changes have occurred in the aquatic plant community in Pike Lake. The Coefficient of Community Similarity indicates that the 2006 aquatic plant community was only 72% similar to the 2002 community and only 69% similar to the 1999 community.
The changes that have occurred within the aquatic plant community in Pike Lake since 1999:

Changes that are positive

1) Species Richness has increased and the number of species recorded at the study sites has increased. This increased diversity in the plant community can support more diverse fish and wildlife communities.
2) The quality of the plant community has increased (measured by AMCI) from above average quality to high quality.
3) The percent of the littoral zone that is vegetated and provides habitat has increased.
4) The coverage of rooted floating-leaf vegetation, which is valuable habitat structure, has increased.
5) The coverage of submergent vegetation has increased.
6) Disturbance in the plant community has decreased as measured by the Floristic Quality Index and the Average Coefficient of Conservatism.
7) The sub-dominance has shifted from a species that provides valuable habitat in 1999, *Myriophyllum sibiricum* (northern watermilfoil), to a species that is more limiting in its habitat potential and more likely to cause navigational issues in 2002, *Ceratophyllum demersum* (coontail), to a species that is again a valuable species for habitat in 2006, *Potamogeton illinoensis* (Illinois pondweed).

The number of species, percent of the littoral zone vegetated and quality of the plant community (AMCI Index) were declining and the community was moving farther from an undisturbed condition (Average Coefficient of Conservatism, Floristic Quality Index) from 1999-2002. These parameters increased in 2006 to values greater than in 1999 (Table 10). The only major change during this time period was a switch from chemical treatments to mechanical harvesting. With continued harvesting and no chemical treatments, future plant surveys may be able to determine if this trend continues.

Neutral Changes

1) The depth zone with the greatest amount of plant growth (highest total

occurrence and density of plant growth and greatest number of species per site) has shifted from the 5-10 ft depth zone in 1999-2002 to the 0-1.5ft depth zone in 2006.

This shift is neutral, but also suggests that mechanical harvesting may be a factor in some of these changes. Since mechanical harvesting can only occur in water greater than 3 feet deep, it would result in more vegetative decline in the deeper zones as opposed to the shallow zone.

<u>Changes of Concern</u>

1) The maximum rooting depth has decreased, a nearly 20% decrease. This results in a narrower littoral zone and less total habitat.
2) The coverage of free-floating vegetation has increased substantially (nearly a 50% increase), *Ceratophyllum demersum* (coontail) has doubled in frequency and more than doubled in density. These species are favored by increased nutrients and decreased water clarity. In addition, the habitat they provide is less valuable than rooted vegetation which can be shaded out by these free-floating species.
2) *Chara* spp. which is a macrophytic algae and the dominant species in Pike Lake and *Potamogeton illinoensis* (Illinois pondweed), the sub-dominant species, have increased in frequency and density each year. Continued increases in the dominant species can eventually lead to a simpler community, closer to a monoculture. This results in less diverse habitat.

Decreased water clarity may the cause of decreased maximum rooting depth and increased free-floating vegetation. Increased nutrients may be an additional cause for increased free-floating species. Increased dominance of *Chara* spp. may be the result of past chemical treatments.

The majority of the species that have increased are species that prefer soft sediments and are not tolerant of poor water clarity. Year of chemical treatments released nutrients into the water column to feed algae blooms and provided decaying plant material that composted into soft fertile sediments.

V. CONCLUSION

Pike Lake is a mesotrophic, hardwater lake with fair-to-good water quality and poor clarity. Filamentous algae is common. Both filamentous and planktonic algae have decreased since 1986, but water clarity has also decreased.

The aquatic plant community in Pike Lake is characterized by very good species diversity, high quality and a condition that has been impacted by an above average amount of disturbance.

Aquatic plants are distributed throughout the lake (48% of the lake, 90% of the littoral zone), up to a maximum rooting depth of 10.5 feet. The depth zone of most abundant plant growth in 2006 was the 0-1.5ft depth zone.

In 2006, the dominant species was muskgrass (*Chara* spp), exhibiting a growth from of above average density in Pike Lake. Muskgrass occurred at more than half of the sites and dominated the 1.5-10ft depth zones. Illinois pondweed *(Potamogeton illinoensis)* was sub-dominant, occurring at half of the sites. Muskgrass is favored by disturbance.

Healthy aquatic plant communities provide many invaluable benefits to the lake ecosystem (Figure 15). The native plant community improves water quality, provides the fish and wildlife habitat in a lake, resist the invasion of non-native plant species and check excessive growth of more aggressive species.

The plant community can improve water quality in many ways:

1) trapping nutrients, debris, and pollutants entering a water body;
2) absorbing and breaking down some pollutants;
3) stabilizing banks and shorelines that prevents erosion
4) stabilizing the lake bottom that prevents sediment resuspenion from wave action;
5) using and removing nutrients that would otherwise be available for algae blooms (Engel 1985).

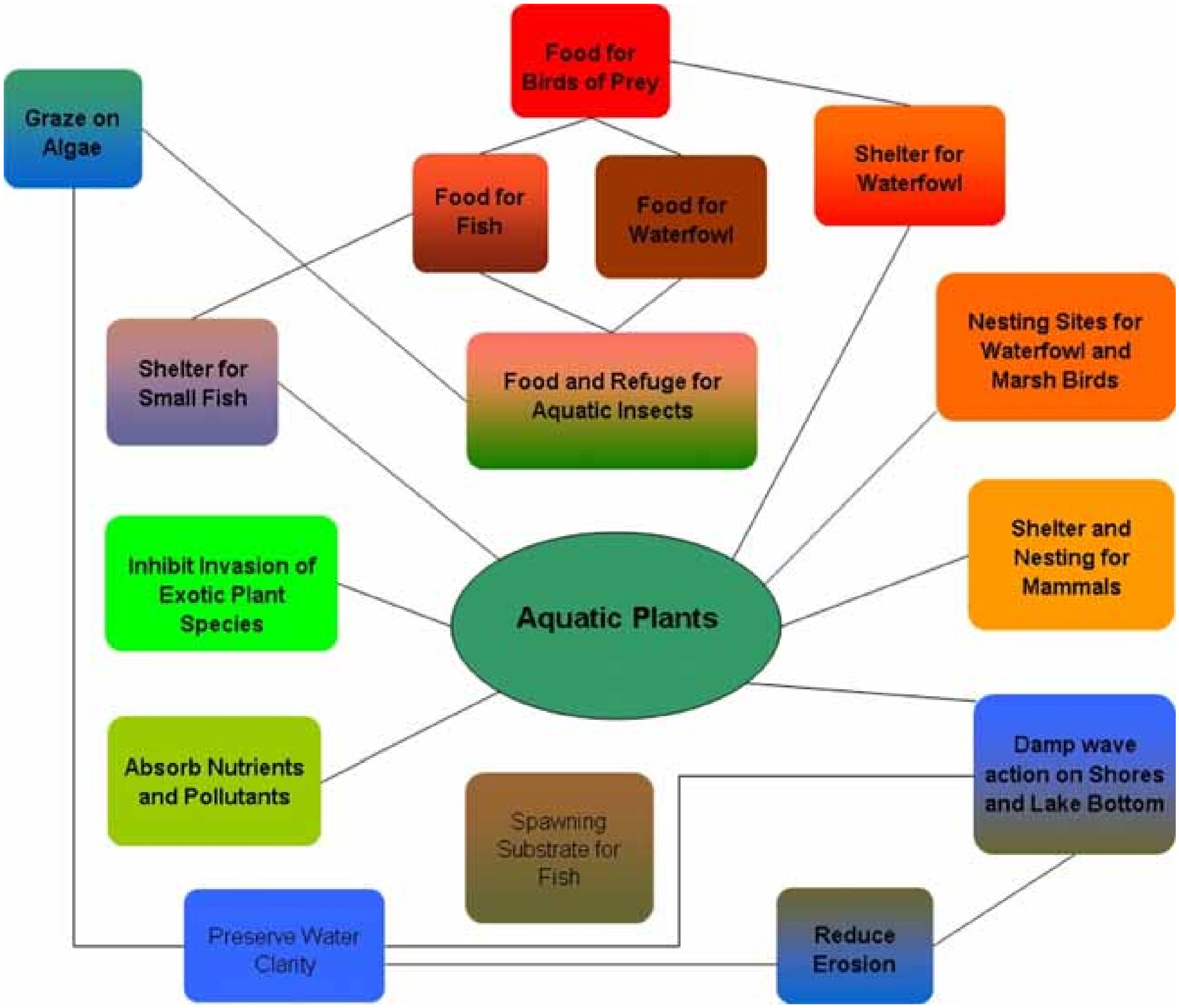

Figure 15. Benefits of Aquatic Plants in the Lake Ecosytem.

Aquatic plant beds offers valuable fish and wildlife habitat (Table 13). Plants start the food chain in a lake while producing oxygen that is needed by all other life in the lake. Invertebrates living on and beneath the plants are prime food sources for wildlife and fish. Plant beds provide shelter for young and adult fish and spawning sites for many species. They are used as nesting sites and cover by wildlife species.

The structure and density of the plants determine the foraging success of the predatory fish, which impacts balance in the fish community. Sparse plant growth results in fewer prey fish, while dense plant growth is overly protective of the prey fish. The aquatic plants colonize 90% of the littoral zone and 48% of the total lake bed in the Pike Lake, which is appropriate (between 25-85% cover) for a balanced fishery.

Table 13. **Wildlife and Fish Uses of Aquatic Plants in Pike 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		
Chara sp.	F*, S	F*, I*					
Eleocharis acicularis	S	F			F		
Elodea canadensis	C, F, I	F(Foliage) I					
Myriophyllum sibiricum	F*, I*, S	F(Seeds, Foliage)	F(Seeds)		F		
Najas flexilis	F, C	F*(Seeds, Foliage)	F(Seeds)				
Nitella sp.		F, I*					
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 friesii	F, C	F*(Seeds, foilage)					
Potamogeton illinoensis	F, I, S*,C	F*(Seeds)	F		F*	F	F
Potamogeton pectinatus	F, I, S*,C	F*			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

Aquatic Plants	Fish	Water Fowl	Song and Shore Birds	Upland Game Birds	Muskrat	Beaver	Deer
Potamogeton robbinsii	F, I, S*,C	F*			F*	F	F
Potamogeton zosteriformis	F, I, S*,C	F*(Seeds)			F*	F	F
Ranunculus longirostris	F	F(Seeds, Foliage)		F			
Utricularia gibba	F, C, I*	I*			F		
Vallisneria americana	F*, C, I, S	F*, I	F		F		
Zosterella dubia	F, C, S	F(Seeds)					
<u>Floating-leaf Plants</u>							
Brasenia schreberi	S, I, C	F(Seeds)			F	F	F
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
Spirodela polyrhiza	F	F		F			
<u>Emergent Plants</u>							
Carex rostrata	S*	F*	F* (Roots, Sprouts, Seeds)	F* (Roots, Sprouts, Seeds)	F* (Roots, Sprouts)	F	F
Eleocharis smallii (palustris)	I	F, C					

Aquatic Plants	Fish	Water Fowl	Song and Shore Birds	Upland Game Birds	Muskrat	Beaver	Deer
Equisetum fluviatile		F		F	F		
Juncus sp.	S				F		
Pontederia cordata	F, I, C	F*(Seeds), C			F		
Sagittaria sp.		F*, C	F(Seeds), C	F, C	F	F	
Sparganium spp.	I	F(Seeds), C	F, C		F		F*
Typha latifolia	I, C, S	F(Entire), C	F(Seeds), C, Nest	Nest	F* (Entire), 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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Management Recommendations

1) Lake shore residents should restore buffers of natural shoreline on Pike Lake to meet state standards. A buffer zone of native grasses, flowers, shrubs and trees are needed to replace the cultivated lawn. Much of the shoreline around Pike Lake is covered by lawn and other disturbed shoreline has increased. Currently, more than half of the shoreline is disturbed; cultivated lawn alone occurs at three-quarters of the shore and covers nearly half of the shoreline. Natural shoreline buffers filter run-off (that may include nutrients and toxics) to the lake and provides important habitat for birds, frogs, turtles and other water-dependent wildlife.
2) Shoreline restorations should include restoration of emergent aquatic plants in shallow water to replace rip-rap commonly found around the lake. Living plants are more effective at protecting the shoreline from erosion than rip-rap and rock walls and have the added value of providing habitat.
3) Lake shore residents should eliminate fertilization of shoreline properties. The disturbed shoreline and high cover of lawn may be contributing to the lower water clarity which may be causing the decrease in maximum rooting depth and increase in free-floating vegetation.
4) Sportsman Club should cooperate with Watershed Management Programs to reduce stormwater run off into Pike Lake.
5) Lake residents continue participation in the volunteer, Citizen Lake Monitoring Program.
6) Sportsman Club and DNR maintain signage at the boat landing to educate lake visitors about exotic species and their spread, especially since Eurasian watermilfoil occurs in some Marathon County lakes.
7) Sportsman Club follow recommendations in the Management Plan that address education of lakes residents about invasive species and preventing their introduction and spread.
8) Sportsman Club members should learn to identify aquatic invasive species and regularly monitor the lake for these species.
9) Sportsmans Club monitor and map curly-leaf pondweed in late-May or early-June. Provide maps to the WI-DNR for possible revision of plan for curly-leaf control.
10) Any project in Pike Lake involving the sediments would require prior analysis of the sediments to determine the extent of the arsenic contamination.
11) DNR to designate Critical Habitat Areas in Pike Lake. These are the areas most important to wildlife and fish habitat and water quality and shoreline protection.
12) Follow guidance and recommendations in the 2006 Aquatic Plant Management Plan. Evaluate the plan annually with DNR and update if necessary. The first plan update should address recommendations in this report and any Critical Habitat Report.
13) Follow mechanical harvesting plan developed in the 2006 Management for controlling plant growth. The harvesting program so far has removed more than one million pounds of aquatic plants, which also removes nutrients from the lake. Unlike chemical control, mechanical harvesting:
    a) Removes plant growth, preventing decay of plant material in the water that releases nutrients that feed algae growth, enrich the sediments and continue the cycle of more plant growth.

b) Harvesting only removes the top of the vegetation and does not clear open areas for the colonization of more opportunistic, non-native plant species as chemical treatments do.
c) Provides cruising lanes for predator fish. This promotes a balance in the fish population of the lake.
d) Harvesting channels where needed to increase edge for habitat and allow for navigation access.
e) Harvest narrow fish channels in dense plant beds to promote a balanced fishery.
f) Minimize channel width and number in designated Critical Habitat Areas to reduce disturbance to habitat.
g) If biomass removal is conducted, concentrate on areas identified as nuisance vegetation areas not in designated Critical Habitat Areas.
h) Mechanical harvester can skim *Chara* and coontail, *Ceratophyllum demersum,* where they have mounded or formed floating rafts near the surface and are shading rooted vegetation.

There have been some improvements in the aquatic plant community during the time period that aquatic plant management in Pike Lake has shifted from broad-spectrum chemical treatments to mechanical harvesting.

a) Pondweeds, which are one of the premier species for habitat, were lost and have started to return with discontinuation of chemical treatments.
b) Coontail, which was becoming very abundant, has been reduced in the 5-10ft depth zones.
c) Disturbance in the plant community as measured by Average Coefficient of Conservatism and Floristic Quality is less than during the years of chemical treatment.
d) The quality of the plant community has increased since 2002.
e) Species numbers and species richness have increased since 2002, suggesting increased diversity.
f) The cover of valuable floating-leaf vegetation has been increasing since 2002.
g) Sub-dominance in the plant community has shifted back to a species more valuable for habitat.

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Appendix X. Location of Aquatic Plant Study Transects, 1999-2006.