Changes in the Aquatic Plant Community of Bass Lake, Saint Croix County, Wisconsin

1987-2006

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EXECUTIVE SUMMARY

Bass Lake is an oligotrophic/mesotrophic lake with good water clarity and good-to-very good water quality. Nutrients have gradually increased since 1999. Algae has decreased and clarity has increased slightly since 1986. Filamentous algae occurred at 14% of the sites and was common in the 1.5-5ft depth zone.

Aquatic plants are distributed throughout the lake at 92% of the sites (46% of the lake area), up to a maximum depth of 18 feet. The most abundant growth is in the in the 1.5-5ft depth zone. The dominant aquatic plant species was *Najas flexilis* (slender naiad), occurring at half of the sites and dominating the 0-1.5ft depth zone. The sub-dominant species was *Potamogeton illinoensis* (Illinois pondweed), occurring at nearly half of the sites and dominating the 1.5-10ft depth zones. Both species exhibited a growth form of above average density.

The aquatic plant community is characterized by very good species diversity, high quality, a tolerance of disturbance and a condition close to an undisturbed condition.

Changes 1987-2006

The aquatic plant community was stable during 1987-1993. Between 1993 and 1996, the plant community started undergoing significant change that continued up to 2002. During this time of change, water levels in Bass Lake rose, Eurasian watermilfoil was introduced in 1997, water levels dropped again, Eurasian watermilfoil spread through the lake and became the dominant species and then the Eurasian watermilfoil dramatically declined. The milfoil likely declined due to the milfoil weevils in the lake. In 2002-2006, the aquatic plant community in Bass Lake stabilized and reached its highest quality.

Management Recommendations

1) Lake District to continue program of restoring natural vegetation buffer zones to provide critical habitat for wildlife, fish and milfoil weevils and protect water quality.
2) Lake residents protect existing natural shoreline buffers. Disturbed shoreline appears to have impacted the in-lake plant community at the disturbed sites. Disturbed shorelines in Bass Lake have a lower occurrence of sensitive species, a lower quality and less diverse aquatic plant community, a shallower maximum rooting depth, a lower percentage of vegetated sites and less cover of emergent and floating-leaf vegetation (important habitat structure).
3) Residents use native emergent vegetation to stabilize shorelines instead of rip-rap.
4) Lake District and residents cooperate with efforts in the watershed to reduce run-off and nutrient enrichment to protect the water quality in Bass Lake.
5) Lake residents protect the native plant community to help repel the spread of Eurasian watermilfoil.
6) Lake residents use best management practices on shoreline properties.
7) Lake District maintain stable water levels in Bass Lake.
8) Lake District become involved in Citizen Lake Monitoring Program.
9) DNR continue monitoring the aquatic plant community and Eurasian watermilfoil.

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I. INTRODUCTION

Studies of the aquatic plants (macrophytes) in Bass Lake were conducted during July in 1987, 1990, 1993, 1996, 1999 and 2002 and August 2006 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR). The surveys are 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

Bass Lake is a 416-acre groundwater seepage lake in western St. Croix County with a maximum depth of 45 feet.

The 1,398-acre watershed of Bass Lake is relatively small compared to lake size; the watershed-to-lake ratio is approximately 3:1. This is a contributing factor in maintaining good water quality in Bass Lake (Hess et. al. 1997). The watershed has a mixture of land cover, but cropland is decreasing and developed acreage is increasing.

Eurasian watermilfoil

In August 1997, Eurasian watermilfoil was first found in Bass Lake. It was densely colonizing a location near the boat landing that, in July 1996, had been verified to be free of Eurasian watermilfoil. A survey was conducted in September 1997 to map the extent of the Eurasian watermilfoil colonization (Konkel 2003).

In June 1998, native milfoil weevils were found at naturally high numbers in Bass Lake (Jester 1998).

By the summer of 1999, dense stands of Eurasian watermilfoil were beginning to limit the use of some docks. In June 2000 and May 2001, selective chemical treatments for Eurasian watermilfoil were conducted at the docks of individual landowners that requested treatment. A permit for chemical treatment of Eurasian watermilfoil was applied for in 2002, but the exotic milfoil did not appear at the docks in 2002.

The quantitative survey conducted in the summer of 2002 and the present study found Eurasian watermilfoil had declined lake-wide and has since remained at very low levels in scattered locations.

II. METHODS

Field Methods

The same study design and transects were used for the 1987-2006 aquatic plant studies, the design based on the rake-sampling method developed by Jessen and Lound (1962). Twenty equal-distance transects were placed perpendicular to the shoreline with the first transect being randomly placed (Appendix XXII).

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. 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.

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 site.

Aquatic vascular plants and macrophytic algae (algae with morphologies similar to vascular plants), such as muskgrass and nitella were recorded. The presence of filamentous algae was noted. The sediment type at each sampling site was recorded. 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 preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on each side of the transect intercept with the shore and 30 feet deep, was evaluated. The percentage of each cover type (Table 3) within this 100' x 30' rectangle was recorded and verified by a second researcher.

Data Analysis

The aquatic plant 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 sampling sites) (Appendices I-VII). Relative frequency was calculated (number of occurrences of a species / total of all species occurrences) (Appendices I-VII). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendices VIII-XIV). Relative density was calculated (sum of the species density ratings / sum of all plant densities). "Density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendices VIII-XIV). The relative frequency and relative density were summed to obtain a dominance value for each species (Appendices XV-XXI). Simpson's Diversity Indices $1-(\sum(\text{Relative Frequency}^2)$ were calculated for each sampling year (Appendices I-VII). Sampling years were compared by Coefficients of Community Similarity, which measure the percent similarity between two communities.

The Aquatic Macrophyte Community Index (AMCI) (Nichols 2000) was calculated for Bass Lake to quantify the quality of the plant community. Several parameters that characterize the quality of the aquatic macrophyte community are converted to a value 0 – 10 and summed. The Average Coefficients of Conservatism and Floristic Quality Indices (Nichols 1998) were calculated for each sampling year to measure disturbance in the plant community. A Coefficients of Conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for the species found in a lake. The Floristic Quality Index is calculated from the Average Coefficient of Conservatism and measures the community's closeness to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

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

WATER QUALITY - The trophic state of a lake is an indication of its water quality. Nutrient, algae and water clarity data are collected and combined to determine the trophic state.
Oligotrophic lakes are low in nutrients and biomass.
Eutrophic lakes are high in nutrients and biomass and often experience algae blooms.
Mesotrophic lakes are intermediate in nutrients and biomass.

Nutrients

Phosphorus is a limiting nutrient in many Wisconsin lakes and is measured as an indication of the nutrient status.
2006 mean summer phosphorus in Bass Lake was 17ug/l.
This concentration of phosphorus indicates Bass Lake was a mesotrophic lake (Table 1).

Table 1. 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
Bass Lake 2006	Very Good	**17**	**3.07**	**8.6**

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

Phosphorus concentration since 1986 has varied largely within the mesotrophic range, but has been increasing since 1998 (Figure 1).

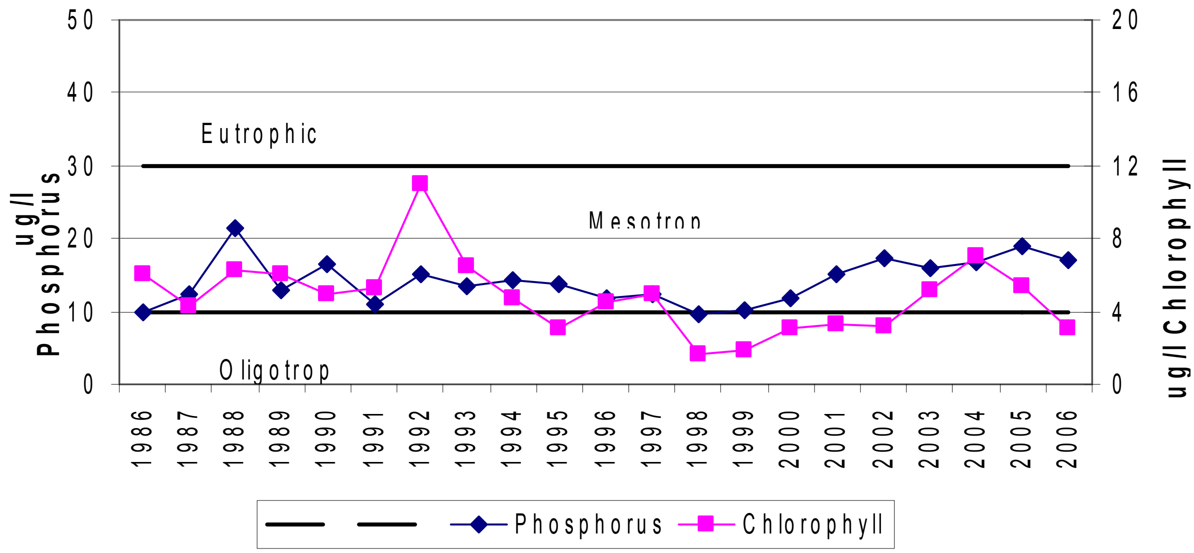


Figure 1. Mean summer phosphorus and chlorophyll in Bass Lake, 1986-2006.

Algae

Algae are natural and essential in a lake ecosystem, but prolonged algae blooms will reduce water clarity, thus reducing light availability. This can inhibit the growth of submersed vegetation. Since algae cells contain chlorophyll, chlorophyll is measured in lake water to determine concentration of algae.

2006 mean summer chlorophyll in Bass Lake was 3.07ug/l.

This concentration of chlorophyll indicates Bass Lake was an oligotrophic lake (Table 1).

Chlorophyll concentration in Bass Lake has also varied within the mesotrophic/oligotrophic range and is showing a slight decreasing trend (Figure 1).

The occurrence of filamentous algae was 14% within the littoral zone of Bass Lake in 2006. This is a decrease from the highest frequency of filamentous algae in 2002 (28%) but increased from lowest frequency of occurrence in 1990 (2.6%) (Figure 2). The depth zone with the highest occurrence of filamentous algae has shifted from the 0-1.5ft depth zone in 1990-1999 to the 5-10ft depth zone in 2002 and to the 1.5-5ft depth zone in 2006 (Figure 2).

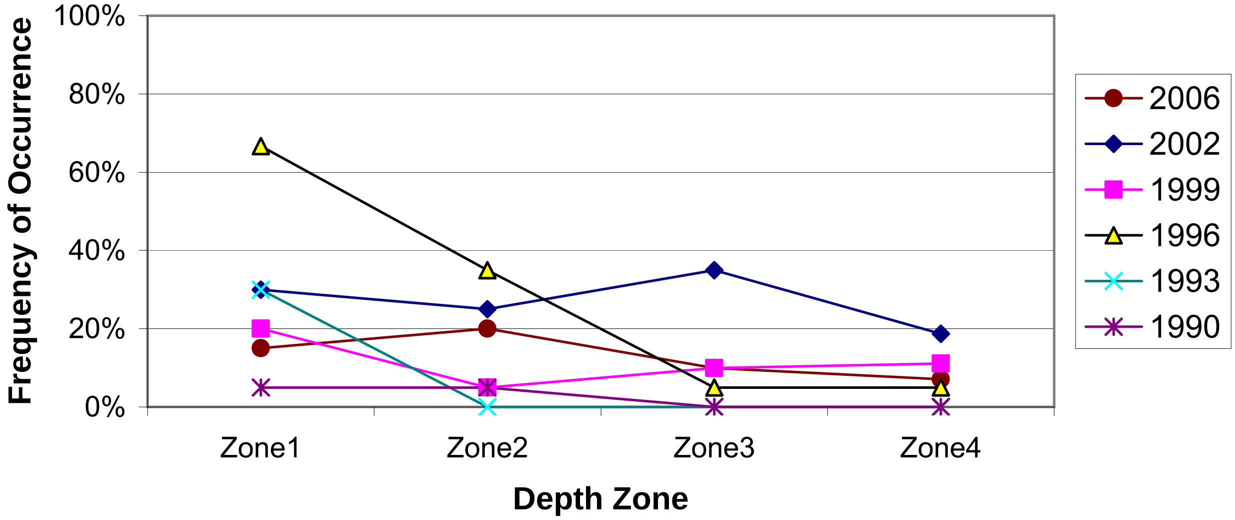


Figure 2. Frequency of filamentous algae in Bass Lake by depth zone, 1990-2006.

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

2006 Mean summer Secchi Disc clarity in Bass Lake was 8.6 ft.

This indicates that Bass Lake is an oligotrophic lake with good water clarity. Mean summer water clarity has increased slightly since 1986 (Figure 3).

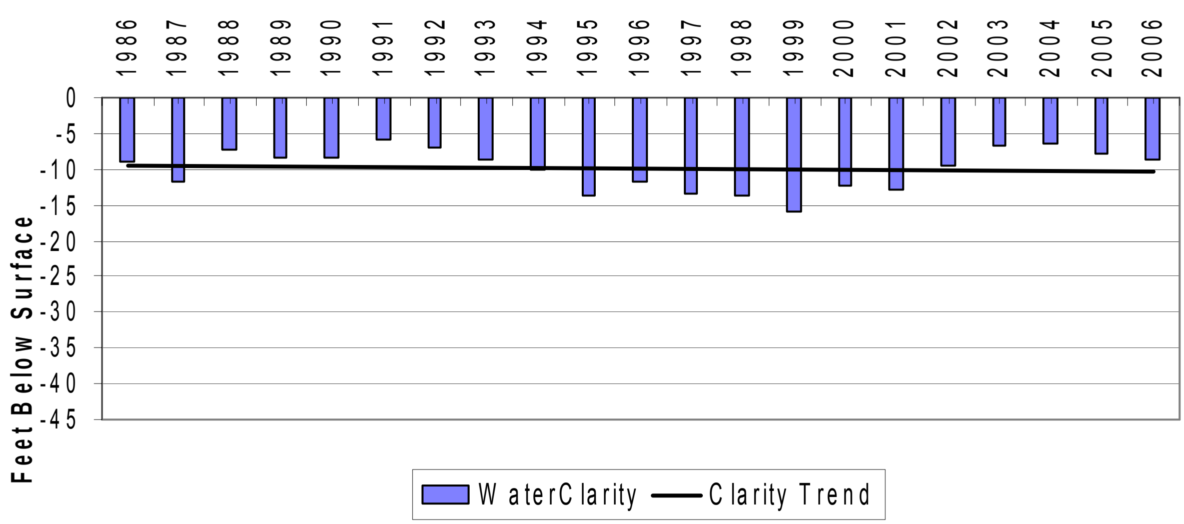


Figure 3. Water Clarity in Bass Lake, 1986-2006.

Based on 2006 water quality data, Bass Lake is an oligotrophic/mesotrophic lake with good to very good water quality. This trophic state would support moderate aquatic plant growth and occasional algae blooms.

Hardness

The hardness values recorded in Bass Lake, as measured by the amount of calcium carbonate, have been between 120 and 152mg/l CaCo3. Water in the range of 121-180mg CaCO3/l is considered hard. Hard water lakes have a low sensitivity to the effects of acid rain and tend to support more plant growth.

Water Level

Bass Lake has experienced fluctuating water levels (Konkel and Borman 1996). The lowest recorded level was 876.37 feet (above sea elevation) in 1963 and the highest recorded level was 888.25 feet (above sea elevation) in 1995. This is a vertical change of 11.91 feet in 32 years.

LAKE MORPHOMETRY - The morphometry of a lake is a factor in determining the distribution of aquatic aquatic plants. 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 more favorable rooting environment and a broader zone of potential plant growth than steep slopes (Engel 1985).

The littoral zone along the east and west shores of Bass Lake is steep, limiting the area suitable for colonization by aquatic plants. Shallow bays and gradually sloped littoral zones favorable for plant growth occur at the north and south ends of the lake (Appendix XXII).

SEDIMENT COMPOSITION - Sand was the dominant sediment in 2006, dominating all depth zones (Table 2, Figure 4). Sand mixed with gravel was abundant in the 0-1.5ft depth zone. Silt, alone, was common only at depths of 5-10 feet (Table 2).

Table 2. Sediment Composition in Bass Lake, 2006

		0-1.5ft	1.5-5ft	5-10ft	10-20ft	All
Hard Sediments	**Sand**	21%	65%	55%	71%	52%
	Sand/Gravel	47%	10%			15%
	Sand/Rock	16%		5%		5%
	Rock			5%		1%
Mixed Sediments	**Sand/Silt**	11%	5%	5%	7%	7%
Soft Sediments	**Silt**		15%	35%	19%	13%

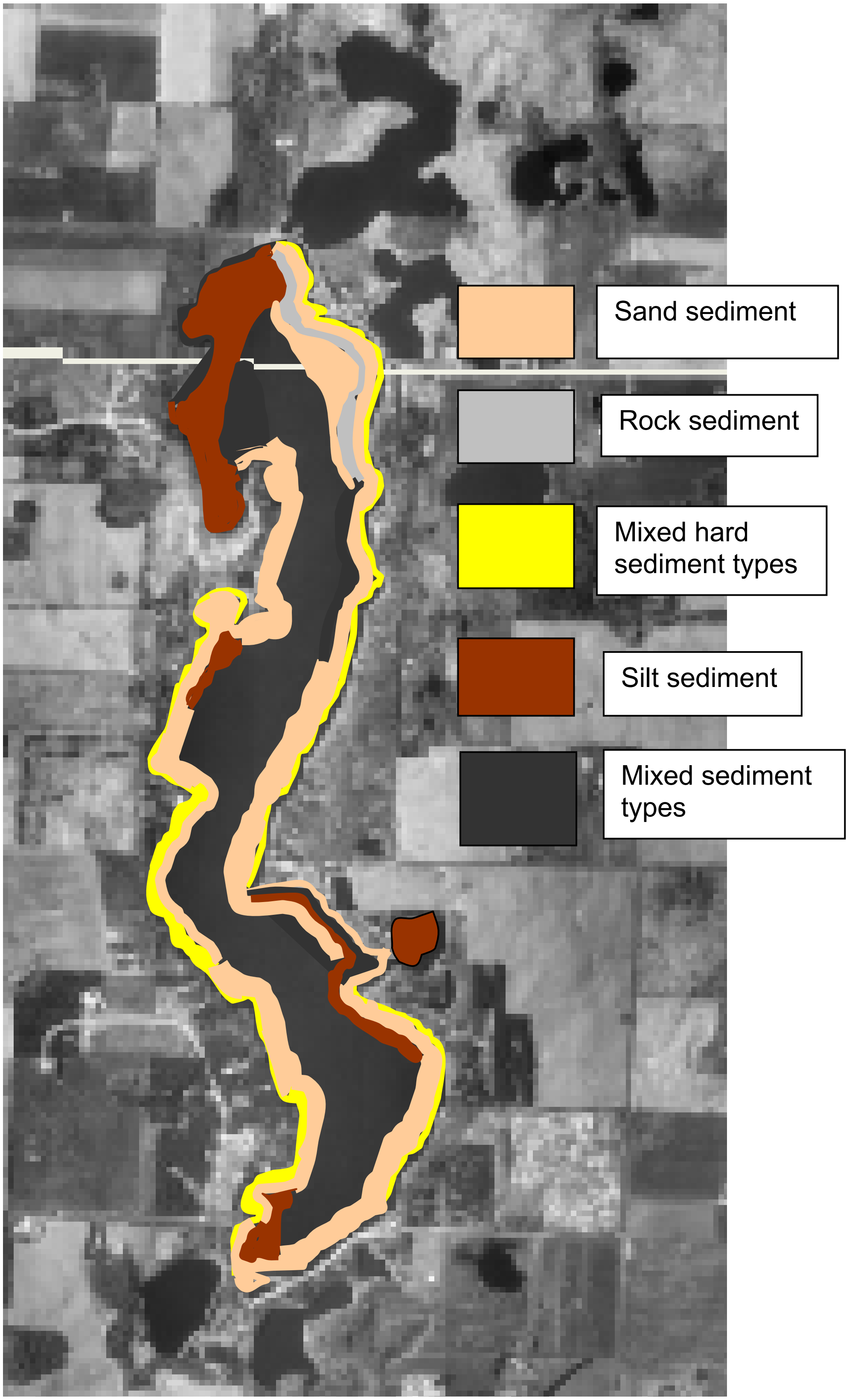


Figure 4. Distribution of sediment types in Bass Lake, 2006.

SEDIMENT INFLUENCE

Some aquatic plants depend on the sediments for required nutrients. The richness or sterility, texture and density of the sediment influence the distribution of plants.

Sand is the dominant sediment in Bass Lake and can be nutrient limiting for some species due to its high density. Gravel and other rock-type sites are also high-density sediments that can be nutrient limiting. The availability of mineral nutrients for plant growth is highest in sediments of intermediate density. Silt is intermediate density sediment that is favorable for plant growth (Barko and Smart 1986), but silt was not commonly occurring in Bass Lake, except in the 5-10ft depth zone (Table 2). However, all sediment types supported abundant vegetation in Bass Lake in 2006.

SHORELINE LAND USE

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

Native herbaceous cover was the most frequently encountered shore cover and had the highest mean coverage in 2006 (Table 3). Shrub growth and wooded cover was commonly encountered also. Bare sand occurred at the shore for the first time and was abundant. This may be the result of declining water levels, leaving a ring of sand, as the lake drops from its high level in 1995.

Cultivated lawn and hard structures (types of disturbed shoreline) were also commonly found at the transects in 2006 (Table 3). Cultivated lawn and hard structures are problematic in that they do not filter run-off entering the lake and speed the run-off. Both also have a high likelihood of carrying increased nutrients and toxics to the lake.

Natural shoreline occurred at 95% of the sites in 2006 and protected 85% of the shoreline. Disturbed shoreline was found at 45% of the sites and impacted 15% of the shore. Natural shoreline has been increasing since 1996, but shifting from wooded shore to herbaceous cover. Cover of disturbed shoreline has been decreasing since 1996 (Table 3).

Table 3. Shoreline Land Use, Bass Lake, 1996-2006.

		Mean Coverage		2006	
Cover Type		1996	2002	Frequency of Occurrence at Transects	**Mean Coverage**
Natural Shoreline	Native Herbaceous	**13%**	**48%**	95%	**46%**
	Wooded	**60%**	**28%**	35%	**11%**
	Shrub	**6%**	**6%**	45%	**8%**
	Bare Sand			70%	**20%**
Total Natural		**79%**	**82%**		**85%**
Disturbed Shoreline	Cultivated Lawn	**4%**	**10%**	20%	**7%**
	Eroded/Bare Soil	**5%**	**3%**	5%	**1%**
	Paved Road	**4%**	**3%**	5%	**2%**
	Rip-rap		**2%**	10%	**1%**
	Hard Structure	**8%**	**1%**	25%	**4%**
Total Disturbed		**21%**	**19%**		**15%**

MACROPHYTE DATA

SPECIES PRESENT

Fifty-one (51) different species of aquatic plants have been found in Bass Lake during the 1987-2006 studies: 19 emergents species, 7 floating leaf species and 25 submergent species (Table 4). However, not all species were found in all years.

No endangered or threatened species were found. Three non-native species have been found: *Myriophyllum spicatum* (Eurasian watermilfoil), *Phalaris arundinacea* (reed-canary grass) and *Potamogeton crispus* (curly-leaf pondweed).

Table 4. Bass Lake Aquatic Plant Species, 1987-2006

Scientific Name	Common Name	I. D. Code
1) *Acorus calamus* L.	sweet flag	acoca
2) *Calamagrostis canadensis* (Michx.) P. Beauv.	blue joint	calca
3) *Carex comosa* F. Boott.	bristly sedge	carco
4) *Carex pseudocyperus* L.	sedge	carps
5) *Carex vulpinoidea* Michx.	fox sedge	carvu
6) *Cicuta bulbifera* L.	bulb-bearing water hemlock	cicbu
7) *Eleocharis palustris* L.	creeping spikerush	elepa
8) *Eupatroium perfoliatum* L.	boneset	euppe
9) *Iris versicolor* L.	northern blue flag	irive
10) *Juncus effusus* L.	soft rush	junef
11) *Lycopus americanus* Muhl.	American waterhorehound	lycam
12) *Phalaris arundinacea* L.	reed canary grass	phaar
13) *Sagittaria latifolia* Willd.	common arrowhead	sagla
14) *Sagittaria rigida* Pursh.	stiff arrowhead	sagri
15) *Salix* sp.	willow	salsp
16) *Scirpus cyperinus* (L.) Kunth.	wool-grass	scicy
17) *Scirpus validus* Vahl.	softstem bulrush	sciva
18) *Spartina pectinata* Link.	cordgrass	spape
19) *Typha angustifolia* L.	narrowleaf cattail	typan
Floating leaf Species		
20) *Lemna minor* L.	small duckweed	lemmi
21) *Lemna trisulca* L.	forked duckweed	lemtr
22) *Nuphar variegata* Durand.	bull-head pond lily	nupva
23) *Nymphaea odorata* Aiton.	white water lily	nymod
24) *Polygonum amphibium* L.	water smartweed	polam
25) *Spirodela polyrhiza* (L.) Schleiden.	great duckweed	spipo
26) *Wolffia columbiana* Karsten.	common watermeal	wolco
Submergent Species		
27) *Bidens beckii* Torr.	bur-marigold	bidbe
28) *Ceratophyllum demersum* L.	coontail	cerde
29) *Chara* sp.	muskgrass	chasp
30) *Eleocharis acicularis* (L.) Roemer & Schultes.	needle spikerush	eleac
31) *Elodea canadensis* Michx.	common waterweed	eloca
32) *Myriophyllum sibiricum* Komarov.	common water milfoil	myrsi
33) *Myriophyllum spicatum* L.	Eurasian watermilfoil	myrsp
34) *Najas flexilis* (Willd.) Rostkov & Schmidt.	slender naiad	najfl
35) *Nitella* sp.	nitella	nitsp
36) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
37) *Potamogeton crispus* L.	curly-leaf pondweed	potcr
38) *Potamogeton foliosus* Raf.	leafy pondweed	potfo
39) *Potamogeton gramineus* L.	variable-leaf pondweed	potgr
40) *Potamogeton illinoensis* Morong.	Illinois pondweed	potil
41) *Potamogeton natans* L.	floating-leaf pondweed	potna
42) *Potamogeton nodosus* Poiret.	long-leaf pondweed	potno
43) *Potamogeton pectinatus* L.	sago pondweed	potpe
44) *Potamogeton pusillus* L.	small pondweed	potpu
45) *Potamogeton richardsonii* (Ar. Bennett) Rydb.	clasping-leaf pondweed	potri
46) *Potamogeton robbinsii* Oakes.	fern pondweed	potro
47) *Potamogeton zosteriformis* Fern.	flatstem pondweed	potzo
48) *Ranunculus longirostris* Godron.	stiff water crowfoot	ranlo
49) *Utricularia vulgaris* L.	common bladderwort	utrvu
50) *Vallisneria americana* L.	water celery	valam
51) *Zosterella dubia* (Jacq.) Small.	water stargrass	zosdu

FREQUENCY OF OCCURRENCE

Myriophyllum sibiricum (northern watermilfoil) was the most frequent species in 1987 (56%) and decreased in subsequent years (Table 5). *Najas flexilis* (slender naiad) increased from 1987 to become the most frequent species in 1990 - 1993 and again in 2002 and 2006. *Ceratophyllum demersum* (coontail) became the most frequent species in 1996, but declined in 1999 - 2006. *Myriophyllum spicatum* (Eurasian watermilfoil) invaded Bass Lake in 1997 and by 1999 had already become the most frequent species. Its frequency dropped substantially in 2002-2006.

Table 5. Frequency of Prevalent Aquatic Plant Species in Bass Lake 1987-2006.

Species	1987	1990	1993	1996	1999	2002	2006
Ceratophyllum demersum	46%	47%	23%	**47%**	22%	32%	20%
Chara sp.	40%	47%	42%	13%	38%	32%	24%
Elodea canadensis	31%	4%	8%	6%	22%	1%	
Myriophyllum sibiricum	**56%**	38%	31%	9%	35%	9%	28%
Myriophyllum spicatum					**50%**	8%	7%
Najas flexilis	39%	**51%**	**53%**	38%	40%	**54%**	**58%**
Potamogeton crispus	26%	16%	17%	17%	1%	5%	
Potamogeton illinoensis	18%	22%	12%	9%	20%	30%	47%
Potamogeton pectinatus	29%	17%	13%	8%	14%	24%	24%
Potamogeton zosteriformis	29%	19%	12%	17%	22%	42%	45%
Zosterella dubia	32%	21%	17%	12%	9%	22%	18%

DENSITY

In each survey, the species with the highest frequency of occurrence also had the highest mean density (Table 6).

Table 6. Mean Densities of Prevalent Macrophyte in Bass Lake 1987-2006.

Species	1987	1990	1993	1996	1999	2002	2006
Ceratophyllum demersum	1.18	1.39	0.55	**1.12**	0.53	0.72	0.43
Chara sp.	1.00	1.22	1.06	0.19	1.0	0.64	0.53
Elodea canadensis	0.75	0.05	0.12	0.09	0.46	0.01	
Myriophyllum sibiricum	**1.21**	0.74	0.63	0.09	0.56	0.09	0.54
Myriophyllum spicatum					**1.36**	0.14	0.11
Najas flexilis	0.91	**1.44**	**1.23**	0.99	0.91	**1.21**	**1.46**
Potamogeton crispus	0.58	0.21	0.31	0.23	0.03	0.11	
Potamogeton illinoensis	0.39	0.64	0.19	0.14	0.35	0.78	1.24
Potamogeton pectinatus	0.53	0.48	0.17	0.12	0.26	0.41	0.36
Potamogeton zosteriformis	0.70	0.44	0.22	0.31	0.5	1.14	1.04
Zosterella dubia	0.45	0.32	0.32	0.15	0.13	0.33	0.35

Density on a scale or 0-4.

"Density where present" indicates whether a species exhibits a dense form of growth in a lake. Even though a species may occur only in a few locations and not have a high mean density over the entire lake, it could exhibit a dense growth form where it does occur. Different species and different number of species exhibited a growth form of above average density in Bass Lake in different years (Appendices VIII-XIV). Two species exhibited a growth form of above average density in 1987; 7 species in 1990, 4 species in 1993, 2 species in 1996, 4 species in 1999, 5 species in 2002 and 4 species in 2006. In 2006, *Najas flexilis* (slender naiad) and *Potamogeton illinoensis* (Illinois pondweed) exhibited growth forms of slightly above average density in Bass Lake. *P. praelongus* (white-stem pondweed) and *Ranunculus longirostris* (stiff water crowfoot) exhibited dense growth forms in 2006, but occurred only in limited locations in the lake.

DOMINANCE

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

During 1987-1993, the same species were either dominant or sub-dominant in Bass Lake. *Myriophyllum sibiricum* (northern watermilfoil), *Ceratophyllum demersum* (coontail), *Chara* (muskgrass) and *Najas flexilis* (slender naiad) (Figure 5). In 1996, *Chara* spp. and *Myriophyllum sibiricum* dropped from dominant or sub-dominant status, leaving *Ceratophyllum demersum* and *Najas flexilis* as the only dominant species. In 1999, two years after *Myriophyllum spicatum* (Eurasian watermilfoil) had first been found in Bass Lake, *M. spicatum* was the dominant species; *Chara* sp. and *N. flexilis* were sub-dominant. In 2002 and 2006, *N. flexilis* was the dominant species again, with *Potamogeton zosteriformis* (flat-stem pondweed) as the sub-dominant in 2002 and *P. illinoensis* (Illinois pondweed) as the sub-dominant in 2006.

Figure 5. Dominance of the most preavalent species in the Bass Lake aquatic plant community, based on Dominance Value, 1987-2006.

DISTRIBUTION

Aquatic plants occurred throughout the littoral zone of Bass Lake at 81%-92% of the sampling sites in 1987-2006 and were found in all depth zones. In 2006, vegetation colonized approximately 190 acres (92% of the littoral zone, 46% of the total lake area) to a maximum rooting depth of 18 feet (Figure 6). Submergent vegetation colonized 185 acres (88% of the littoral zone, 44% of the total lake); rooted floating-leaf vegetation colonized 43 acres, (26% of the littoral zone, 10% of the total lake) emergent vegetation colonized 2 acres, (10% of the littoral zone, less than 1% of the total lake).

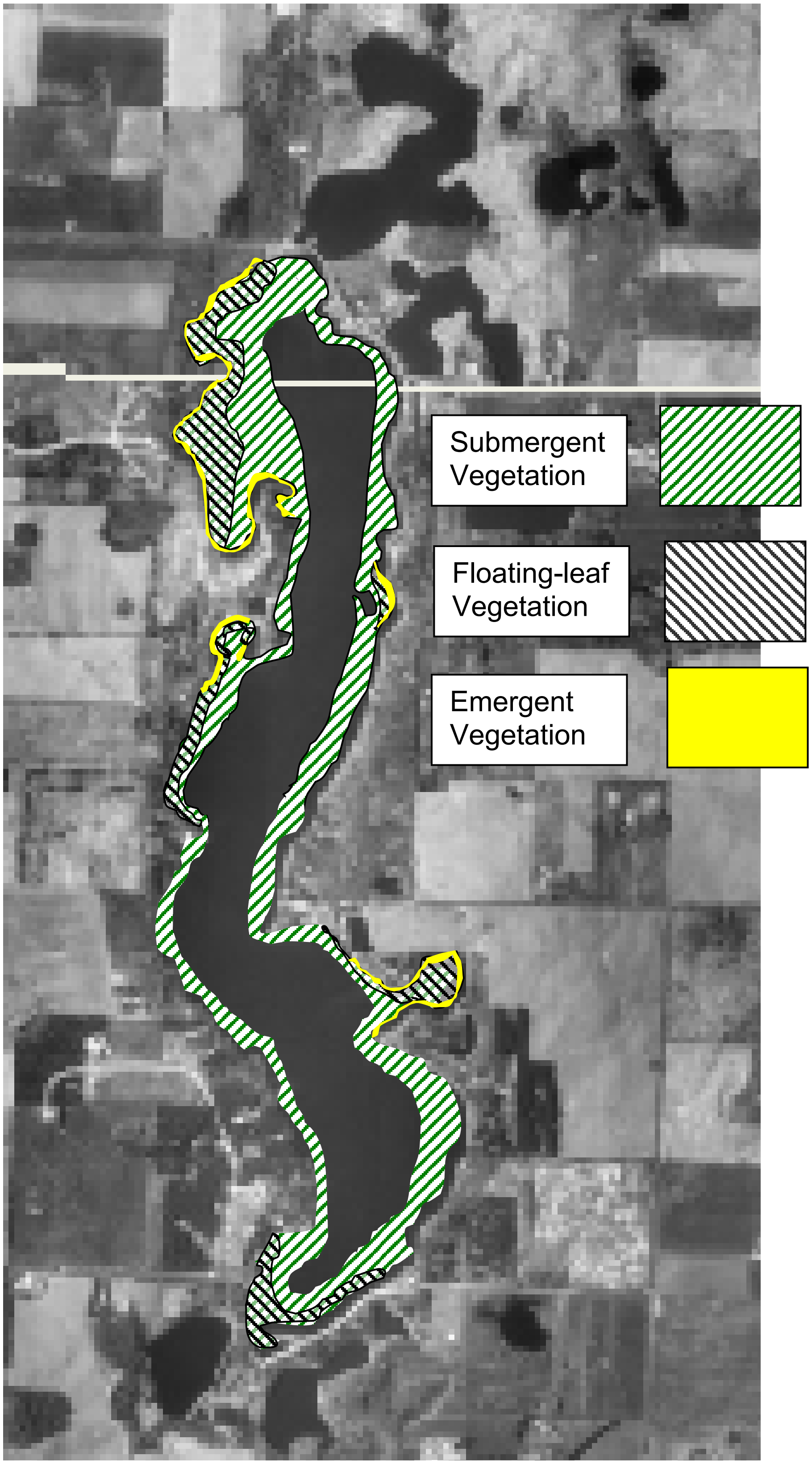


Figure 6. Distribution of vegetation in Bass Lake, 2006.

The highest percent of sites with vegetation has been in the 0-10ft depth zones (Figure 7).

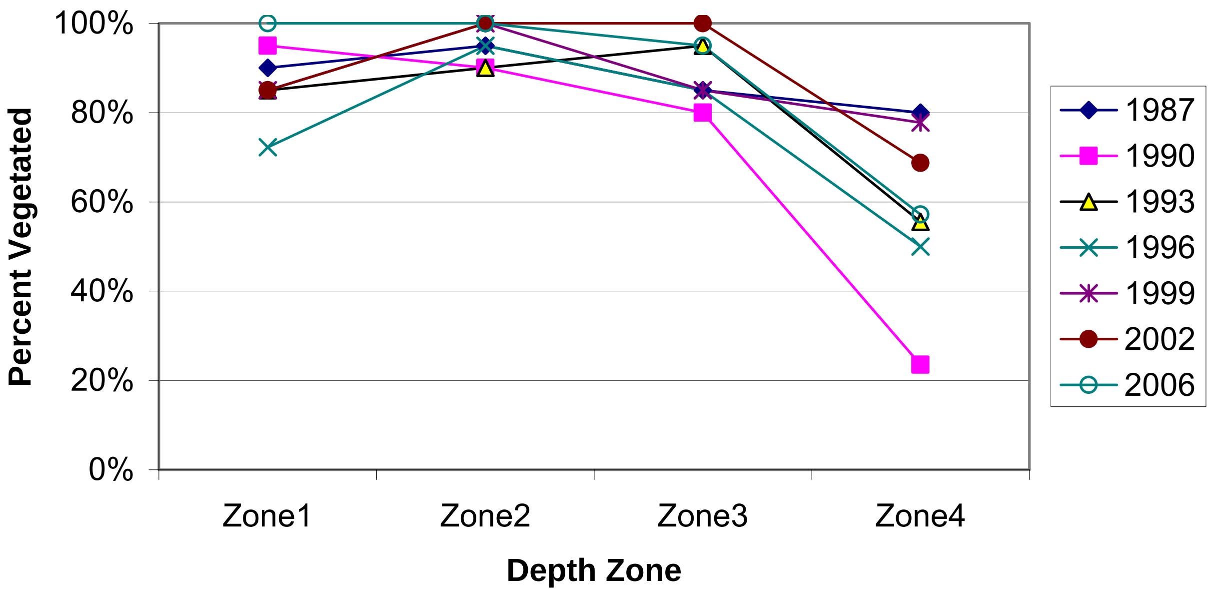


Figure 7. Percentage of sites vegetated in Bass Lake by depth zone, 1987-2006.

The depth zone with the highest total occurrence (Figure 8) and total density (Figure 9) of plant growth was in the 1.5-5ft depth zone in 1987, shifted into the 0-1.5ft depth zone in 1990 and returned to the 1.5-5ft depth zone in 1993-2006. The total occurrence and density of plant growth was highest in 1987 and lowest in 1996 (Figure 8, 9).

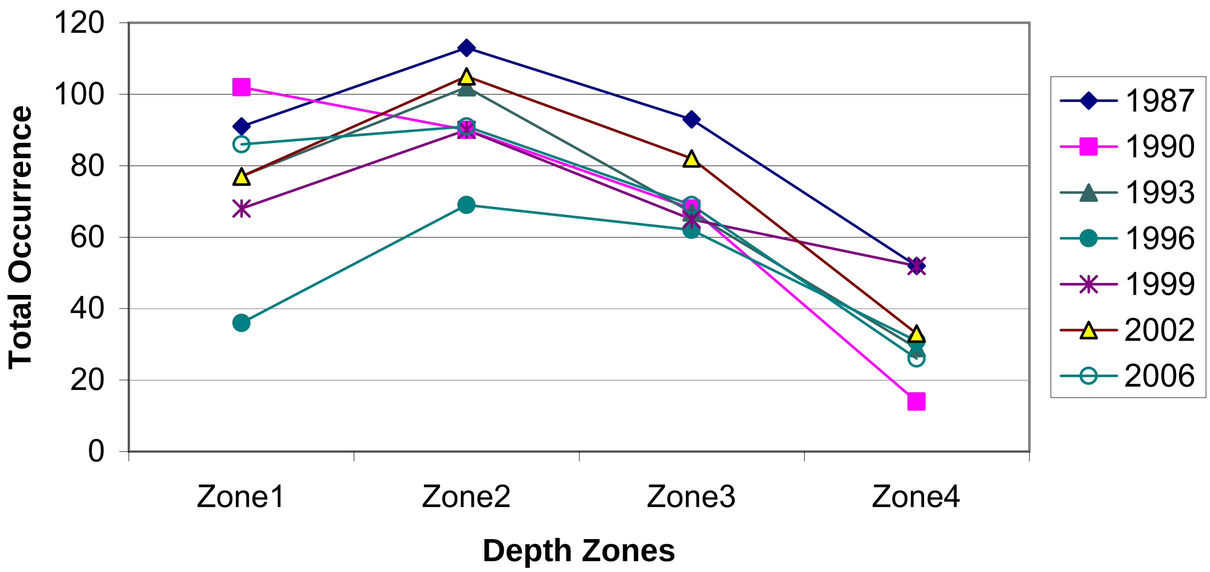


Figure 8. Total occurrence of aquatic plants by depth, Bass Lake, 1987-2006.

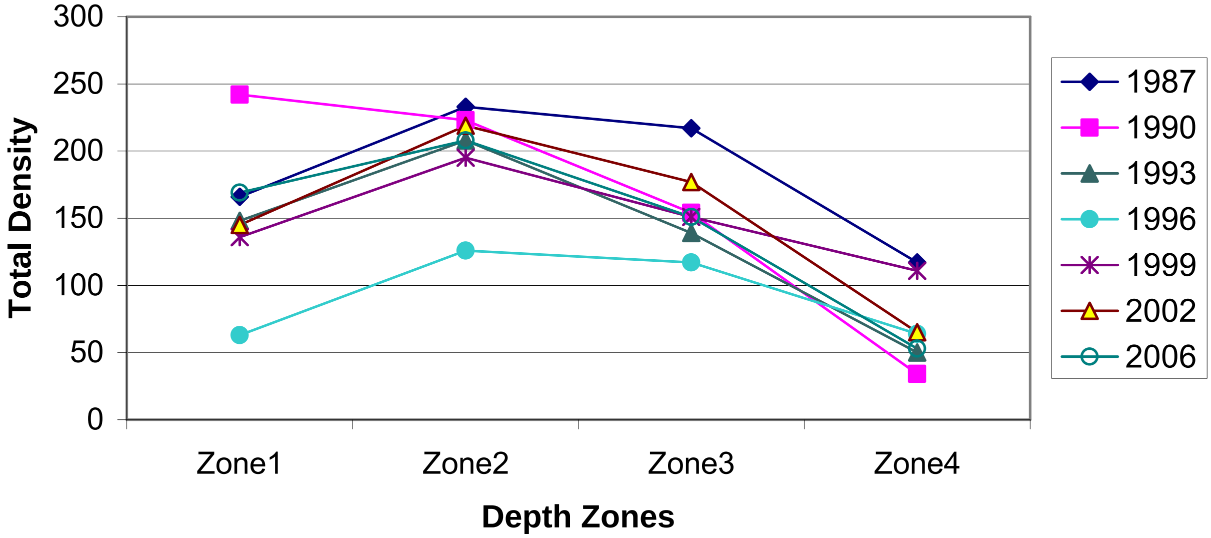


Figure 9. Total density of aquatic plants in Bass Lake by depth zone, 1987-2006.

The greatest Species Richness (number of species per site) was in the 1.5-5ft depth zone in 2006 (Figure 10). The greatest species richness was in 1987 and the poorest species richness was in 1996 (Figure 10).

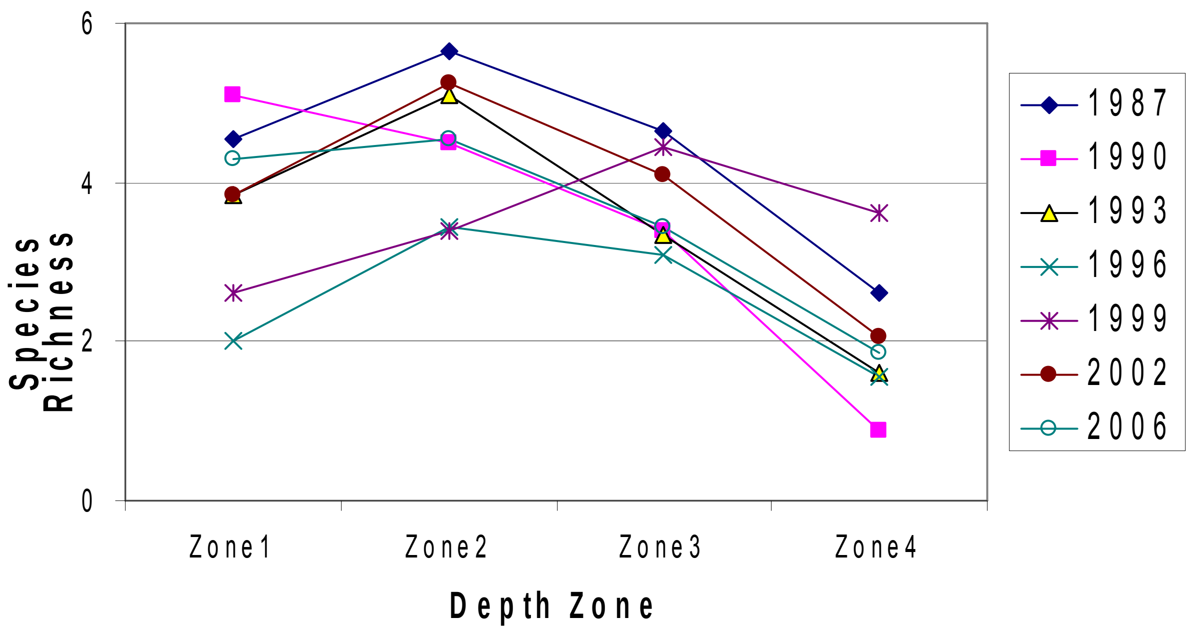


Figure 10. Species Richness in Bass Lake by depth zone, 1987-2006.

Secchi Disc water clarity data can be used to calculate a predicted maximum rooting depth (Dunst 1979).

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

The actual maximum rooting depth remained less then the predicted depth until 2002-2006 (Figure 11).

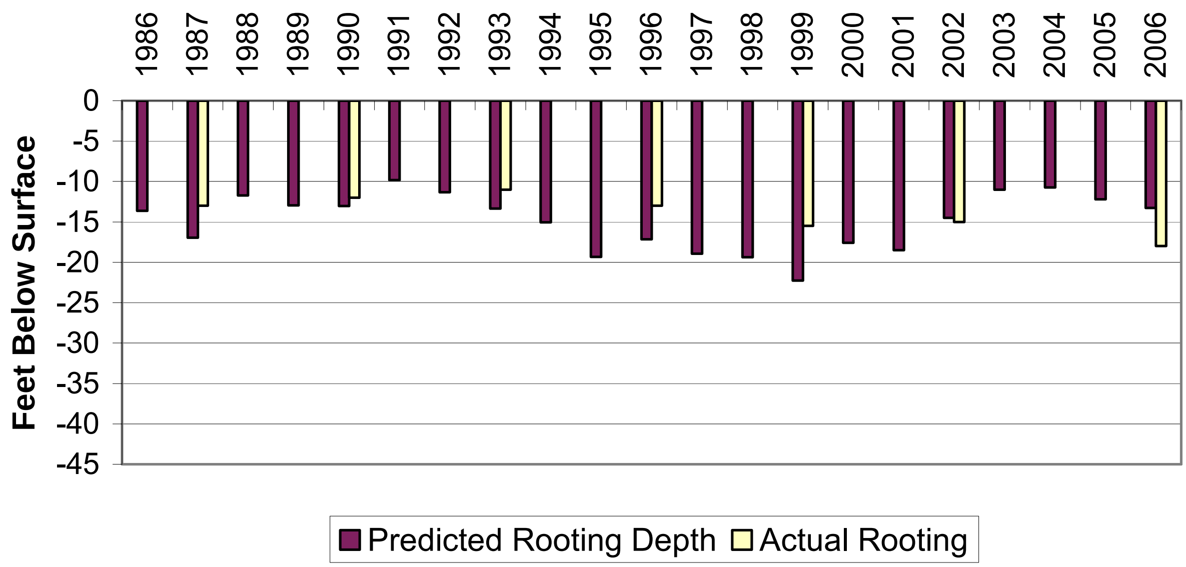


Figure 11. Predicted and actual maximum rooting depth in Bass Lake, 1986-2006.

Many aquatic plant species have been found at the maximum rooting depth in Bass Lake in different years: *Ceratophyllum demersum, Chara* sp., *Elodea canadensis, Myriophyllum sibiricum, M. spicatum, Najas flexilis, Potamogeton amplifolius, P. crispus, P. pusillus, P. foliosus, P. robbinsii*, *P. zosteriformis* and *Zosterella dubia.*

MACROPHYTE COMMUNITY

The Coefficients of Community Similarity indicate that the aquatic plant community in Bass Lake has changed significantly in some years. The 1987-1993 aquatic plant communities were not significantly different (Table 7), therefore, the aquatic plant community appeared to be stable during that time period.

Significant change started in 1993 and the aquatic plant community changed significantly with each survey during 1993-2002 (Table 7). Between 2002 and 2006, the plant community appeared to stabilize again since the two communities had a relatively higher similarity coefficient, 79%. The continual change in the plant community over nineteen years has resulted in the 2006 aquatic plant community being only 62% similar to the community of 1987 (Table 7).

Table 7. Coefficients of Community Similarity, Bass Lake, 1987-2006.

Year Compared	Coefficient	Percent Similarity
1987-90	0.7836	78%
1990-93	0.7877	79%
1993-96	0.6745*	68%
1996-99	0.5548*	55%
1999-02	0.6535*	65%
2002-2006	0.7927	79%
1987-2002	0.6170*	62%

***** - A coefficient less than 0.75 indicates a significant difference, less than 75% similar.

Several measures of the plant community can be used to assess the type of changes that have occurred within the aquatic plant community, resulting in the significant difference (Table 8). Although most parameters of the plant community have fluctuated up and down during the study years, the net change between 1987 and 2006 are:

1) The maximum rooting depth, percent cover of vegetation, percent cover of submergent and rooted floating-leaf species, Average Coefficient of Conservatism (discussed later in this document), Floristic Quality Index (discussed later in this document) and quality of the plant community (AMCI Index (discussed later in this document) have all increased from 1987 to 2006 (Table 8).
2) The number of species, Species Richness, Simpson's Diversity Index, coverage of free-floating species and cover of emergent species have all declined since 1987 (Table 8).
3) The maximum rooting depth has increased the most, 38%; the cover of free-floating species has decreased the most, 57%.

Most measures of the aquatic plant community have cycled up and down over the 19 years of the study. No measure has continually declined or continually increased (Table 8). This is likely due to the many changes (fluctuating water levels and introduction and decline of Eurasian watermilfoil) that occurred in Bass Lake during that time period.

Simpson's Diversity Index has varied up and down, between 0.91 and 0.93, during 1987-2006, indicating very good to excellent species diversity. A rating of 1.0 would mean that each plant in the lake would be a different species (the most diversity achievable). In 2006, the diversity index was 0.91, very good diversity of species.

Table 8. Changes in the Aquatic Plant Community of Bass Lake, 1987-2006.

	1987	1990	1993	1996	1999	2002	2006	Change 1987-06	Maximum Change	%Change 1987-2006
Number of Species	26	23	33	27	23	38.0	24	-2	15	-7.7%
Maximum Rooting Depth	13.0	12.0	11.0	13.0	15.5	15	18.0	5	7	38.5%
% of Littoral Zone Vegetated	86	82	82	81	87	86.0	92	6.0	11.0	7.0%
%Sites/Emergents	11.3	7.8	15.4	3.8	6.4	14.5	9.5	-1.8	11.6	-15.9%
%Sites/Free-floating	47.5	48.1	23.1	48.7	20.5	31.6	20.3	-27.2	28.4	-57.3%
%Sites/Submergent	85.0	74.0	76.9	66.7	87.2	86.8	87.8	2.8	21.1	3.3%
%Sites/Floating-leaf	20.0	10.4	15.4	17.9	16.7	40.80	25.7	5.7	30.4	28.5%
Species Richness	4.36	3.56	3.52	2.54	3.52	3.90	3.7	-1	2	-15.6%
Simpson's Diversity Index	0.93	0.91	0.93	0.92	0.91	0.93	0.91	-0.02	0.02	-2.2%
Average Coefficient of Conservatism	4.66	5.35	5.39	5.44	5.17	5.06	5.46	0.80	0.80	17.2%
Floristic Quality Index	25.07	25.65	30.98	28.29	24.81	30.33	26.74	1.67	6.17	6.7%
AMCI Index	62	59	58	57	58	64	63.0	1.00	7.00	1.6%

According to the Aquatic Macrophyte Community Index (AMCI), the quality of the aquatic plant community in Bass Lake has been in the upper quartile of lakes in the state and the North Central Hardwood Region in all years (Table 9). This means that Bass Lake is within the group of lakes in the state and region with the highest quality aquatic plant community. Though the quality has remained high, the index value was lowest in 1996, just before Eurasian watermilfoil was found and may have been the result of the abnormally high water levels at that time. The quality index was highest in 2002, just after the dramatic decline of the Eurasian watermilfoil.

Table 9. Aquatic Macrophyte Community Index for Bass Lake, 1987-2006.

	1987	1990	1993	1996	1999	2002	2006
Maximum Rooting Depth	7	6	6	7	9	9	10
% Littoral Zone Vegetated	10	10	10	10	10	10	10
Simpson's Diversity Index	10	9	10	10	9	10	9
Relative Frequency of Submersed Species	10	10	10	7	9	9	10
Taxa Number	10	9	10	10	9	10	9
Relative Frequency of Exotic Species	5	6	5	5	4	6	6
Relative Frequency of Sensitive Species	10	9	7	8	8	10	9
Total	62	59	58	57	58	64	63

The maximum AMCI value is 70.

The Average Coefficients of Conservatism for the Bass Lake aquatic plant community has been in the lowest quartile for all Wisconsin lakes in all years, indicating it is within the group of lakes in the state most tolerant of disturbance (Table 10). When compared to lakes in the North Central Hardwoods Region Bass Lake was in the lowest quartile of most tolerant lakes in 1987, below the average (more tolerant of disturbance than average) in 1990-1996, in the lowest quartile again in 1999-2002 and below average again in 2006 (Table 10). This suggests that the plant community in Bass Lake is tolerant of disturbance, likely due to past disturbance.

Table 10. Floristic Quality Index and Average Coefficient of Conservatism of Bass Lake, Compared to Wisconsin and North Central Hardwood Region Lakes, 1987-2006.

	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*
Bass Lake, 1987-2006		
1987	4.66	25.07
1990	5.35	25.65
1993	5.39	30.98
1996	5.44	28.29
1999	5.17	24.81
2002	5.06	30.33
2006	5.46	26.74

***** - upper limit of lower quartile, mean, lower limit of upper quartile. (NCHR) North Central Hardwoods Region, the region in which Bass Lake is located

† - The 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).

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

The Floristic Quality Indices were above average for lakes in Wisconsin during 1987-1990 (closer to an undisturbed condition than the average lake), was within the upper quartile in 1993-96 (within the group of lakes closest to an undisturbed condition), decreased to above average again in 1999 when Eurasian watermilfoil was found, increased to the upper quartile again in 2002 and decreased to above average again in 2006 (closer to an undisturbed condition than the average lake). When compared to lakes in the North Central Hardwoods Region, Bass Lake was within the upper quartile in all years (Table 10). This indicates that Bass Lake was within the 25% of lakes in the region closest to an undisturbed condition.

Disturbances can be of many types:

1) 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.
2) 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.
3) 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, increased algae growth due to nutrient inputs.

Fluctuating water levels, shoreline development and the introduction of a non-native plant species are likely the major disturbance factors in Bass Lake.

Ultimately the aquatic plant community changes because the species in the community change in their abundance. Over the course of the nineteen-year study, the frequency, density and dominance of several species have changed:

1) Five species have appeared and disappeared at the sample site, four of these only occurred at one or two sites in any year. Shifting of a transect could have missed them in some years (Appendix XXIII).
2) Eleven species have appeared at the sample sites since the first study in 1986, four of these occurred at only one or two sites. *Myriophyllum spicatum* (Eurasian watermilfoil) has gone through the greatest maximum change, appearing in 1997, dramatically increasing in 1999 and decreasing nearly as dramatically in 2002.
3) Six species have disappeared from the sample sites, four of these occurred at only one or two sites.
4) Thirteen species have
5) declined: *Ceratophyllum demersum* (coontail)*, Chara* sp. (msukgrass), *Elodea canadensis* (common waterweed)*, Myriophyllum sibiricum* (northern watermilfoil)*, Polygonum amphibium* (water smartweed)*, Potamogeton amplifolius, P. crispus, P. foliosus, P. natans, P. pectinatus* (large-leaf, curly-leaf, leafy, floating-leaf and sago pondweeds)*, Ranunculus longirostris* (white water crowfoot)*, Sagittaria laifolia* (common arrowhead) and *Zosterella dubia* (water stargrass) (Appendix XXIII). *Elodea canadensis* has decreased the most since 1987, 93-98%.
6) Seven species have increased: *Najas flexilis* (slender naiad)*, Nymphaea odorata* (white water lily)*, Potamogeton illinoensis, P richardsonii, P. robbinsii, P. zosteriformis* (Illinois, clasping-leaf, fern-leaf and flatstem pondweeds) and *Sagittaria rigida* (stiff arrowhead)*. P richardsonii* has increased the most, 426-700% (Appendix XXIII).

There is no clear pattern as to the sensitivities or environmental preferences of the species that have increased or decreased in Bass Lake during 1987-2006.

IV. DISCUSSION

In 2006, Bass Lake was a mesotrophic/oligotrophic lake with good-to-very good water quality and good water clarity. Bass Lake has fluctuated on the borderline of a mesotrophic/oligotrophic lake during the study period (1987-2006). Trend analysis indicates that there has been a trend of decreasing algae and slight increasing clarity since 1986. The mean summer phosphorus (nutrients) and chlorophyll (algae) in 1998 were the lowest recorded since 1986, phosphorus has been increasing gradually since 1999.

Filamentous algae occurred at 14% of the sites in 2006 and was commonly occurring in the 1.5-5ft depth zone. Occurrence of filamentous algae has fluctuated in different years, likely due to differing weather conditions, fluctuating water levels that may bring new nutrient sources to the lake and the die-back of Eurasian watermilfoil.

The small watershed to lake surface ratio is one factor that helps preserve water quality in Bass Lake, limiting the impact that run-off from the watershed has on the lake. However, there can be impacts as changes in the watershed accumulate. Since 1992, cropland has decreased. Reduction in cropland in the watershed can result in less agricultural run-off but, the increase in developed land will increase impermeable surface and the increase of lawn chemical use will cause increased run-off of contaminated water.

The 2006 Aquatic Plant Community

The hard water, adequate nutrients and good water clarity would favor plant growth in Bass Lake. The steeply-sloped littoral zone along the east and west shores and the dominance of high-density sand and rock sediments could limit plant growth.

Plant growth in Bass Lake colonized 92% of the littoral zone (46% of the lake) to a maximum depth of 18 feet in 2006. The dominant aquatic plant species was *Najas flexilis* (slender naiad), occurring at half of the sites and dominating the 0-1.5ft depth zone. The sub-dominant species was *Potamogeton illinoensis* (Illinois pondweed) occurring at nearly half of the sites and dominating the 1.5-10ft depth zones. Both species exhibited a growth form of slightly above average density. *Potamogeton zosteriformis* (flat-stem pondweed) dominated the 10-20ft depth zone and occurred at less than half of the sites.

The most abundant plant growth in Bass Lake was in the 1.5-5ft depth zone. This depth supported the highest total occurrence, highest total density and greatest species richness. The Aquatic Macrophyte Community Index suggests that the quality of the plant community in Bass Lake is high, in the top 25% of the lakes in Wisconsin and the North Central Hardwood Region with the highest quality plant community. Bass Lake has very good diversity of aquatic plant species. The aquatic plant community in Bass Lake is tolerant of disturbance, but still close to an undisturbed condition.

Shoreline Impacts

Much of the shoreline on Bass lake is protected by native plant buffers (wooded, shrub and herbaceous). Natural shoreline occurred at 95% of the sites and covered 85% of the shore. Cover of natural shoreline has increased slightly from 74% in 1996. Wooded shoreline was dominant in 1996, but was surpassed by herbaceous plant growth in 1999-2006. Some of the increase in natural shoreline and especially herbaceous cover is due in part to the shoreline restoration projects on Bass Lake. Some increase in herbaceous cover is due to lower water levels that have recently exposed bare soil on which herbaceous pioneer species have colonized. Preserving this natural shoreline is critical to maintaining water quality and wildlife habitat. Conversion of the natural shoreline to lawn, rip-rap or hard structures would result in significant loss of shoreline habitat loss for wildlife. The loss of natural shoreline would also destroy the buffer that infiltrates 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).

Disturbed shoreline has decreased slightly overall, but was still found at nearly half of the sample sites. Cultivated lawn alone is abundantly occurring around the shore and covers 15% of the shore. Hard structure is commonly occurring. Cultivated lawn and hard structure promote increased run-off and can supply added nutrients and toxics to the lake from lawn chemicals.

Disturbance on shore appears to be impacting the aquatic plant community at those locations. To measure the impacts, the 2006 data for Bass Lake was divided into two sets: the transects at natural shoreline were separated from the transects that had any amount or type of disturbed shoreline (Appendices XXIV-XXV). These two sets of transects were analyzed as two separate communities and compared.

A clue that disturbance is the factor is that the most sensitive species in Bass Lake had a higher occurrence at the natural shoreline sites (Table 11) (Nichols 1998).

The disturbance may be impacting the quality of the aquatic plant community. The quality of the plant community (as measured by AMCI Index) was higher at the natural shoreline sites than the disturbed shoreline sites (Nichols 2000) (Table 11, 12).

Disturbed shoreline may be impacting the in-lake habitat at those sites. Diversity of the aquatic plant community was greater at the natural shoreline sites. The diversity index was higher; there were slightly more species; and Species Richness (the mean number of species found at a site) both over all depths and in each depth zone was greater at natural shore sites. More diversity results in a more stable community and better habitat potential for more diverse of fish and wildlife communities (Table 11).

Natural shore communities support more habitat: more total habitat because of greater rooting depth, greater percent of vegetated sites and greater coverage of submergent vegetation. The cover of two structural types of vegetation that are especially valuable for habitat, floating-leaf and emergent, have a higher cover at natural shore communities.

Table 11. Comparison of the Plant Community at Natural and Disturbed Shores.

Metric		**Natural Shoreline Community**	**Disturbed Shoreline Community**
Most Sensitive Species	*Sagittaria rigida*	4.1%	2%
AMCI Index (Community Quality)	Scale of 7-70	63	58
Simpson's Diversity Index	Scale of 0.5-1.0	0.919	0.899
Number of Species		21	20
Species Richness	overall	4.1	3.39
	0-1.5ft Depth Zone	4.56	4.09
	1.5-5ft Depth Zone	4.67	1.09
	5-10ft Depth Zone	3.78	3.18
	10-17ft Depth Zone	2.0	1.82
Maximum rooting Depth		18 feet	12 feet
% of Littoral Zone Vegetated		97%	89%
Cover of submergent vegetation		90%	86%
Cover of emergent vegetation		17%	4%
Cover of rooted floating-leaf vegetation		37%	18%

Table 12. AMCI Index of Aquatic Plant Community at Natural and Disturbed Sites.

Category	Natural Shoreline		Disturbed Shoreline	
Maximum Rooting Depth	5.8 meters	10	3.6 meters	6
% Littoral Zone Vegetated	97%	10	89%	10
Simpson's Diversity	0.919	9	0.899	8
# of Species	21	9	20	9
% Submergent Species	77% Rel. Freq.	10	89% Rel. Freq.	9
Exotic Species	1.6% Rel. Freq.	6	2.0% Rel. Freq.	6
% Sensitive Species	28 %Re. Freq,	9	32% Rel. Freq.	10
Totals		63		58

Changes in the Aquatic Plant Community

The Coefficients of Community Similarity indicate there has been a significant change in the aquatic plant community since 1987. The 2006 plant community is only 62% similar to the 1987 plant community. The aquatic plant community appeared stable during 1987-1993. Significant change started to occur between 1993 and 1996 when water levels were rising. During 1996 - 2002, the aquatic plant community changed significantly in every study as the plant community was impacted, first, by high water levels, then the invasion of Eurasian watermilfoil, then a decline in water levels and finally a decline of Eurasian watermilfoil. The plant community appeared to stabilize again after 2002 with no significant change between 2002 and 2006.

The dominant species also appeared stable during the 1987-1993 time period and dominance of species started shifting when the community changed significantly. The community has changed from a *Myriophyllum sibiricum/Ceratophyllum demersum* community in 1987 to a *Najas flexilis/Potamogeton illinoensis* community in 2006. *Myiophyllum spicatum* was dominant in 1999, two years after its introduction.

When the water levels were high and the community and dominant species first changed in 1996, the aquatic plant community was at its lowest abundance. The aquatic plant survey in 1996 recorded the lowest percent of vegetated sites, the lowest total occurrence and total density of plant growth, the lowest cover of emergent and submergent species, the lowest quality (measured by the AMCI Index) and the lowest species richness (mean number of species per site).

Eurasian watermilfoil was introduced in 1997 and spread dramatically during 1997-2001, but in 2002 it nearly disappeared.

The 2002 and 2006 studies recorded a community that has rebounded with the highest quality in the plant community, the most species, the highest coverage of rooted floating-leaf and submerged species, the greatest maximum rooting depth and highest percent of vegetated sites in the littoral zone.

Fluctuating water levels have likely contributed to the disturbance and changes in Bass Lake and set up a condition that allowed a newly introduced exotic species to spread rapidly in the lake. Fluctuating water levels appeared to be the most likely factor because:

1) The depth zone that supported the greatest amount of plant growth shifted from mid-depths into shallow water, out to deeper water and back again.
2) Many parameters that measure the aquatic plant community fluctuated through increases and decreases: the number of species, the percent of the littoral zone that was vegetated, the cover of emergent, submergent and floating-leaf species, the diversity index, the quality index and the disturbance index.
3) The dramatic decrease in all plant growth in 1996 was likely due to rising water levels. When water levels rise, light availability for plant growth is reduced (Nichols 1975).
4) The percent occurrence at the sample sites of different sediment types changed each year. As the water levels fluctuated, the depth changed at which sediments occurred.
5) The emergent community was sparse in 1996 when the water levels were high because of the flooding impact on new shoots trying to become established. As the water levels decreased, the new exposed sediments made ideal germination areas for the increased emergent growth seen in 2002.
6) The maximum rooting depth may have been less than the predicted depth based on water clarity during 1987-1999 because plants can not colonize sites that have favorable light availability as fast as the water levels rise and fall.
7) Free-floating species: *Ceratophyllum demersum* (cootail), *Lemna minor* (small duckweed), *Spirodela polyrhiza* (great duckweed) and *Wolffia columbiana* (common watermeal), had increased in frequency and dominance until 1996. Because they are not rooted, increased water levels and decreased water clarity would not suppress the growth of these species.
8) The increasing dominance of *Najas flexilis* (slender naiad) and increase of *Chara* spp. (muskgrass) in some years indicate disturbance. These are annual species that can quickly colonize recently disturbed areas.
9) When water levels in Bass Lake were high, there could have been localized nutrient input from failing septic systems. A number of failing or seasonally failing septic systems around the lake had been identified. This nutrient source may be the reason for the increased frequency of filamentous algae in Bass Lake from 1987-2002.

Net changes in the aquatic plant community from 1987-2006 in Bass Lake.

1) The total number of species, diversity of species and species richness (mean

number of species per sample sites) have decreased.
2) The decreased total occurrence and total density of aquatic plants.
3) The cover of emergent species has decreased.
4) The decreased cover of free-floating species (the duckweeds and *Ceratophyllum demersum*) that are tolerant of poor water clarity. The cover of these species have decreased the most, by more than half
5) The cover of floating-leaf vegetation has increased.
6) The cover of submergent vegetation increased.
7) The percent cover of vegetation overall has increased.
8) The quality of the aquatic plant community measured by the AMCI Index increased, although the Bass Lake aquatic plant community has had consistently high quality.
9) The Floristic Quality Index and Average Coefficient of Conservatism have increased suggesting a decline in disturbance to the plant community.
10) The maximum rooting depth of aquatic plants has increased, the parameter with the largest increase (38%).

Eurasian watermilfoil
Myriophyllum spicatum, Eurasian watermilfoil, first appeared in Bass Lake in 1997. By 1999, it had become the dominant species in Bass Lake. *M. spicatum* grew at above densities, colonized 50% of the littoral zone and dominated the 1.5-20ft depth zone up to the maximum rooting depth. *Najas flexilis* (slender naiad) and *Chara* spp. (muskgrass), two species that indicate disturbance, were subdominant species in 1999.

Eurasian watermilfoil, declined dramatically three years later in 2002. During 2002-2006, Eurasian watermilfoil lost dominance overall and in all depth zones. Its frequency decreased to 7-8% and density decreased to below average (Figures 12, 13). Its dominance ranking in the community dropped from first to 12th and 14th (Figure 14).

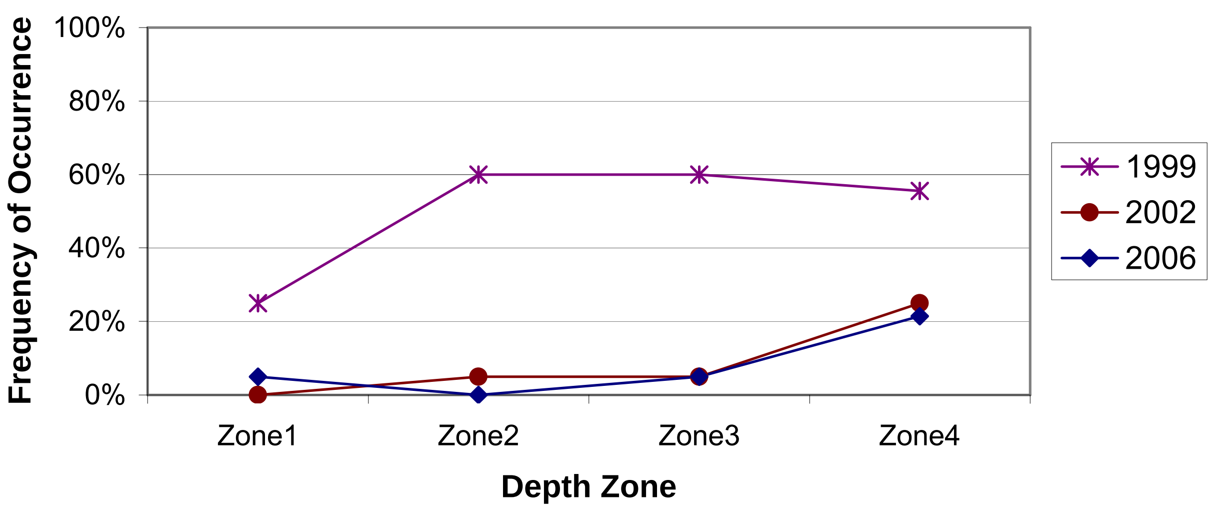


Figure 12. Frequency of Eurasian watermilfoil, by depth, 1999-2006.

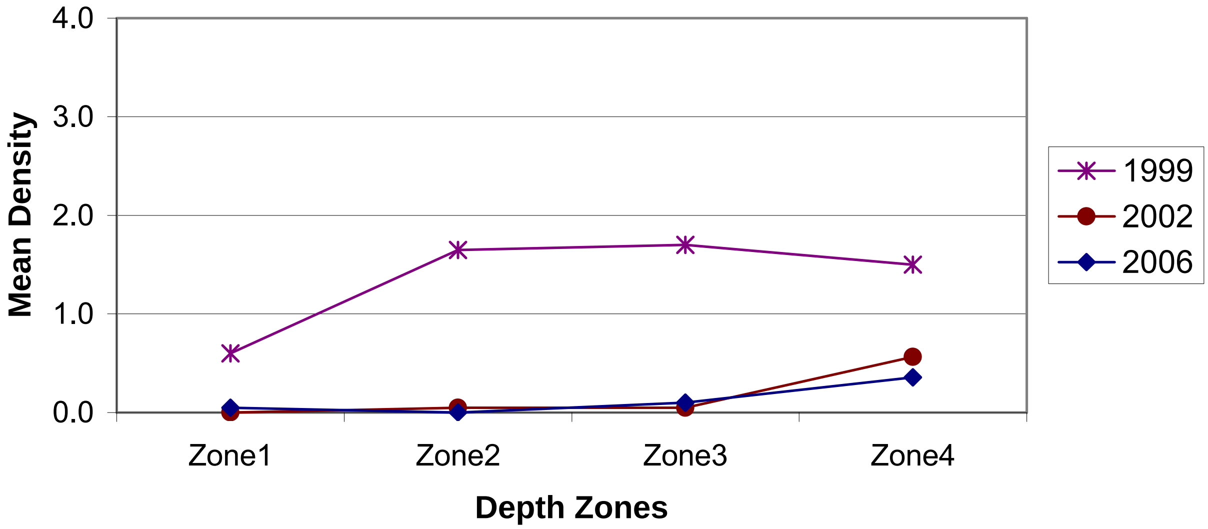
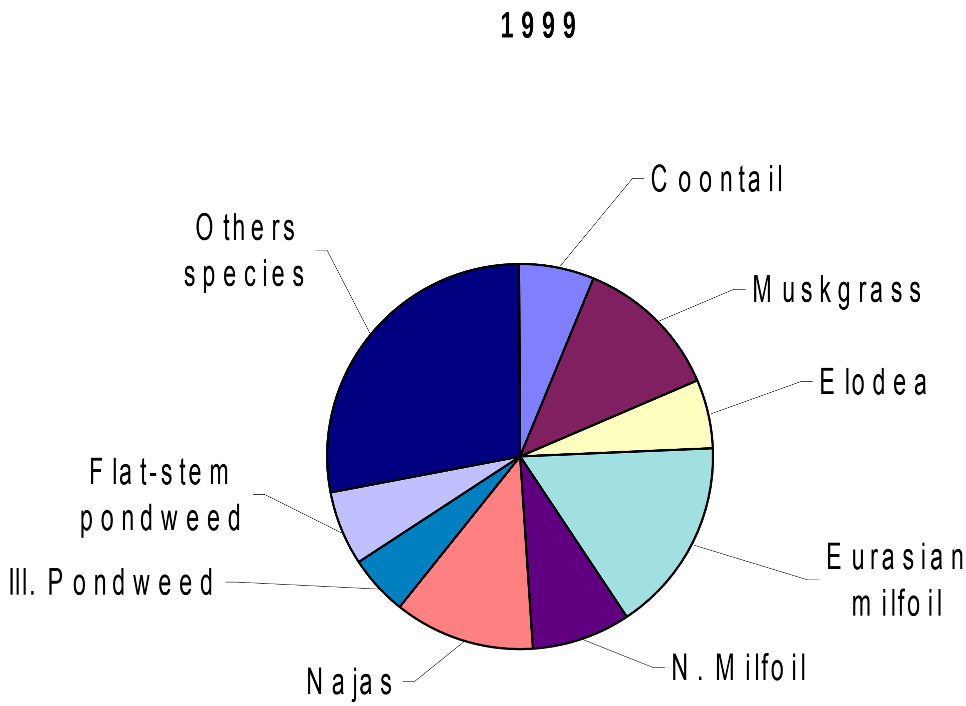


Figure 13. Mean Density of Eurasian watermilfoil, by depth, 1999-2006



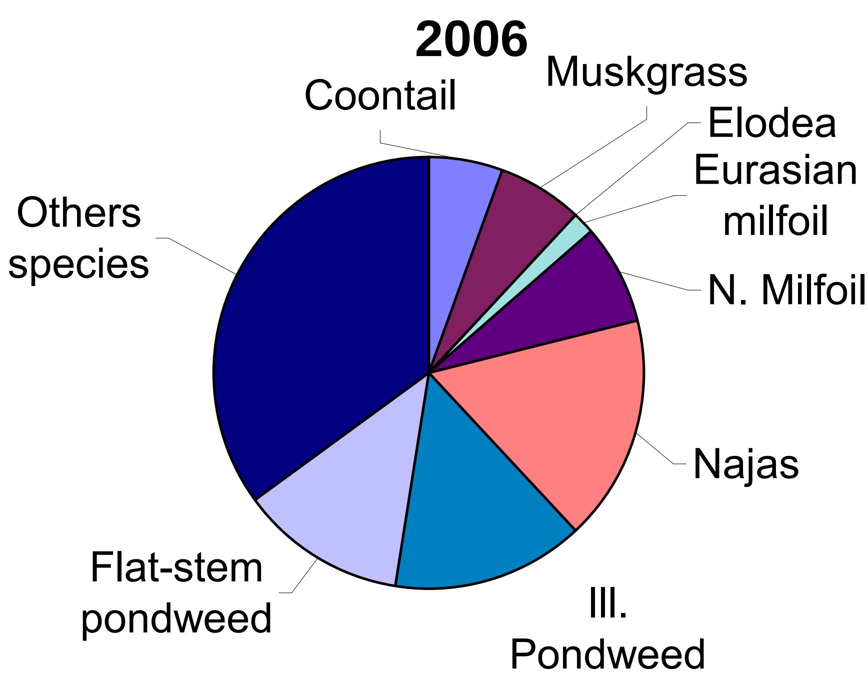


Figure 14. Change in dominance of Eurasian watermilfoil 1999-2006 within the Bass Lake aquatic plant community.

The decline of Eurasian watermilfoil was lakewide, in areas that were treated with herbicide and areas that were never treated, in areas where it first colonized and areas to which it had recently spread. This unexplained lakewide decline and location where Eurasian watermilfoil is currently found (Figure 12, 13, 15), in the deeper water, may indicate that the milfoil weevils (which had a high population in Bass Lake) were responsible for this decline and the control of the milfoil. The weevils would be coming out of hibernation from the shore each spring so that beds farther from shore may not receive as many weevils, in addition, beds in deeper water would be subject to more disturbance from boat traffic.

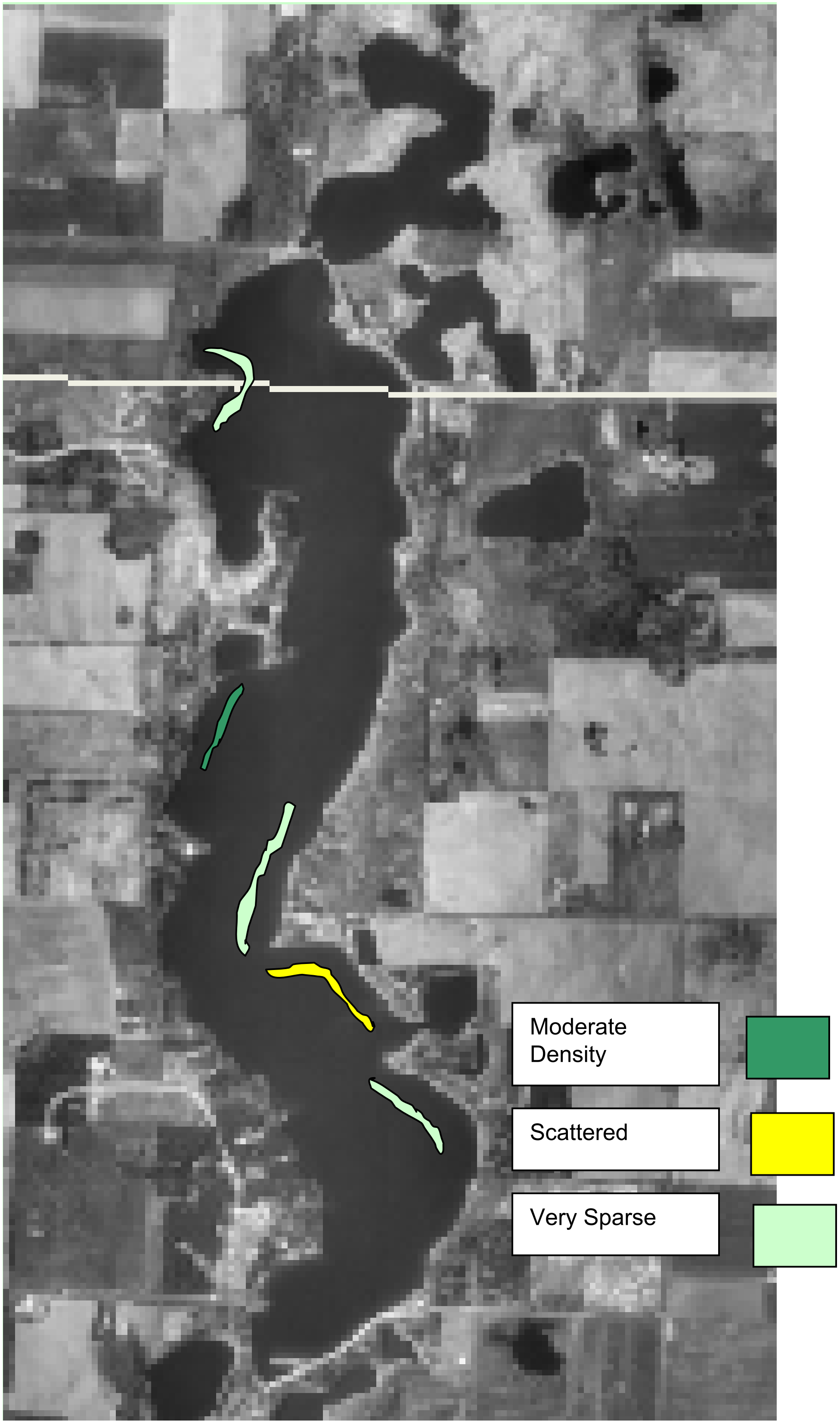


Figure 15. Location of Eurasian watermilfoil in Bass Lake, August 2006.

V. CONCLUSION

Bass Lake is an oligotrophic/mesotrophic lake with good water clarity and good-to-very good water quality. The 1999 chlorophyll (algae) and phosphorus (nutrients) were the lowest recorded and the water clarity was the highest since monitoring started on Bass Lake in 1986. Phosphorus has gradually increased since 1999. Algae has decreased and clarity has increased slightly since 1986. Filamentous algae occurred at 14% of the sites and was common in the 1.5-5ft depth zone.

Aquatic plants are distributed throughout the lake, at 92% of the sites (46% of the lake area), up to a maximum depth of 18 feet. The most abundant growth is in the in the 1.5-5ft depth zone.

The dominant aquatic plant species was *Najas flexilis* (slender naiad), occurring at half of the sites and dominating the 0-1.5ft depth zone. The sub-dominant species was *Potamogeton illinoensis* (Illinois pondweed), occurring at nearly half of the sites and dominating the 1.5-10ft depth zones. Both species exhibited a growth form, slightly above average density.

The aquatic plant community is characterized by very good species diversity, high quality, a tolerance of disturbance and a condition close to an undisturbed condition.

Changes 1987-2006

The aquatic plant community was stable during 1987-1993. The same four species had the highest dominance during those years.

Between 1993 and 1996, the plant community started undergoing significant change that continued up to 2002. As water levels in Bass Lake were rising and reaching their maximum level, the plant community in 1996 was at its lowest abundance, diversity and quality. In this condition in 1997, Eurasian watermilfoil was introduced, water levels started dropping again, the introduced Eurasian milfoilf spread through the lake to become the dominant species and then a few years later, the Eurasian watermilfoil dramatically declined. During this period there was a shift in species dominance to indicators of disturbance and poor water clarity.

In 2002-2006, the aquatic plant community in Bass Lake stabilized and reached its highest quality.

A healthy aquatic plant community plays a vital role within the lake community. Plants provide improved water quality and valuable resources for fish and wildlife. Lakes with a healthy and diverse community of native aquatic plants are more resistant to invasions of non-native species and excessive growth of more tolerant species (Figure 16). Healthy aquatic plant communities improve water quality by:

1) trapping nutrients, debris, and pollutants entering a lake;
2) absorbing and breaking down some pollutants;
3) stabilizing banks and shorelines, stabilizing bottoms, and reducing wave action

which reduces erosion, sedimentation and resususpension of sediments
4) removing nutrients that would otherwise be available for algae blooms (Engel 1985).

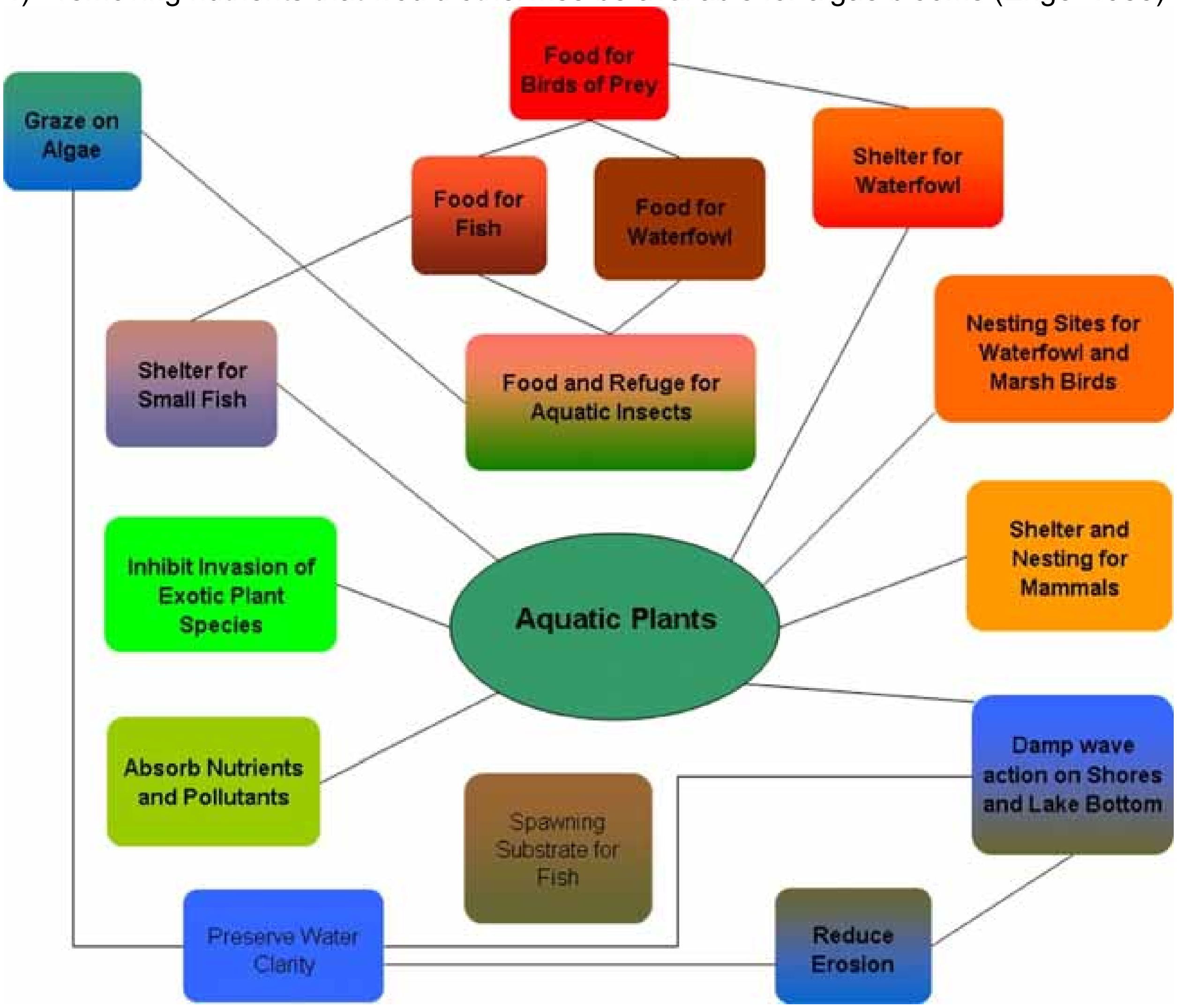


Figure 16. Benefits of aquatic plants in the lake ecosystem.

Healthy aquatic plant community provides important fishery and wildlife resources. Plants (including algae) start the food chain that supports many levels of aquatic life and, at the same time, produce dissolved oxygen needed by animal life. Plants are used as food and cover by a variety of wildlife and as food, cover, and spawning sites by fish (Engel 1985) (Table 13).

Compared to non-vegetated lake bottoms, aquatic plant beds supported larger, more diverse invertebrate populations (Engel 1985). These larger and more diverse invertebrate populations will in turn support larger and more diverse fish populations. Mixed stands of aquatic plants support 3-8 times as many invertebrates and fish as monocultural stands. Diversity creates more microhabitats for the preferences of more species (Engel 1990).

Table 13. **Wildlife and Fish Uses of Aquatic Plants in Bass Lake**

Aquatic Plants	**Fish**	**Water Fowl**	**Song and Shore Birds**	**Upland Game Birds**	**Muskrat**	**Beaver**	**Deer**
<u>Submergent Plants</u>							
Bidens beckii		F (seeds)					
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		
Myriophyllum spicatum	F, C						
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 gramineus	F, I, S*,C	F*(Seeds, Tubers)			F*	F	F
Potamogeton illinoensis	F, I, S*,C	F*(Seeds)	F		F*	F	F
Potamogeton natans	F, I, S*,C	F*(Seeds, Tubers)			F*	F	F
Potamogeton nodosus	F, I, S*,C	F*(Seeds)			F*	F	F
Potamogeton pectinatus	F, I, S*,C	F*			F*	F	F

Aquatic Plants	**Fish**	**Water Fowl**	**Song and Shore Birds**	**Upland Game Birds**	**Muskrat**	**Beaver**	**Deer**
Potamogeton pusillus	F, I, S*,C	F*(All)			F*	F	F
Potamogeton richardsonii	F, I, S*,C	F*(All)			F*	F	F
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			
Vallisneria americana	F*, C, I, S	F*, I	F		F		
Zosterella dubia	F, C, S	F(Seeds)					
<u>Floating-leaf Plants</u>							
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
Polygonum amphibium	I, S	F*(Seeds)		F(Seeds)	F(Seeds)		F
Spirodela polyrhiza	F	F		F			
Wolffia columbiana		F			F		
<u>Emergent Plants</u>							
Acorus calamus		F, C, Nests			F, S		
Calamagrostis spp.					F*		F*
Carex comosa	S*	F*(Seeds), C	F*(Seeds)	F*(Seeds)	F	F	F

Aquatic Plants	**Fish**	**Water Fowl**	**Song and Shore Birds**	**Upland Game Birds**	**Muskrat**	**Beaver**	**Deer**
Eleocharis palustris	I	F, C					
Iris versicolor		F, C	F		F		
Juncus effusus	S	C	C	C	F		
Sagittaria latifolia		F, C	F(Seeds), C	F	F	F	
Sagittaria rigida		F (tubers, seeds)			F (stems, tubers)	F (stems, tubers)	
Scirpus validus	F, C, I	F (Seeds)*, C	F(Seeds, Tubers), C	F (Seeds)	F	F	F
Typha angustifolia	S, C					F	

F=Food, I= Shelters Invertebrates, a valuable 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.

After Fassett, N. C. 1957. A Manual of Aquatic Plants. University of Wisconsin Press. Madison, WI

Nichols, S. A. 1991. Attributes of Wisconsin Lake Plants. Wisconsin Geological and Natural History Survey. Info. Circ. #73

Aquatic plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990). 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 coverage of aquatic plants in Bass Lake (92% of the littoral zone, 46% of the lake) is appropriate to support a balanced fishery.

Management Recommendations

1) Lake District continue creation of natural vegetation buffer zones that include emergent plant beds around the lake. This will filter run off to the lake and provide critical habitat for wildlife, fish and milfoil weevils. The weevil is the most likely cause of the decline of Eurasian watermilfoil. In order to maintain Eurasian watermilfoil at a low frequency and density, the weevils must be protected.
2) Lake residents protect existing natural shoreline buffers. This item is also very important for preserving the over-wintering habitat of the milfoil weevil. Even though disturbed shoreline has decreased slightly since 1996, cultivated lawn and hard structure are still common around the lake and will not provide the winter habitat needed by the milfoil weevil. Disturbed shorleline appears to have impacted the in-lake plant community at those disturbed sites.
    a) The most sensitive species in Bass Lake has a lower occurrence at disturbed shore sites.
    b) Disturbed shore has likely impacted the quality of the aquatic plant community. Disturbed shore sites had a lower quality aquatic plant community as measured by AMCI Index.
    c) The diversity is lower at disturbed shore sites which results in less diverse habitat and a less stable community.
    d) Disturbed shore community provides less habitat; disturbed shore sites had a shallower maximum rooting depth, a lower percentage of vegetated sites and lower cover of submerged species.
    e) The quality of the habitat is less at disturbed shore sites; there is less cover of emergent and floating-leaf vegetation, which are premier cover types for habitat.
3) Lake residents use native emergent vegetation to stabilize shorelines as opposed to placing rip-rap. Increased use of rip-rap will make it difficult for milfoil weevils to reach the shore for hibernation and emergent vegetation provides important fish and wildlife benefits.
4) Lake district, residents and users protect the quality of the water entering Bass Lake and prevent nutrient enrichment. Mesotrophic lakes may be the most vulnerable class of lake to developing nuisance levels of Eurasian watermilfoil. This increases the importance of keeping nutrient levels down and maintaining the trophic status of Bass Lake close to the oligotrophic side.
5) Lake residents protect the native plant community. A healthy, diverse stand of native vegetation can repel the spread of Eurasian watermilfoil.
6) Lake District maintain stable water levels in Bass Lake. Fluctuating water levels were likely the main cause of significant change in the plant community. The disturbance

that the fluctuating water levels caused opened areas that were vulnerable to the first invasion of Eurasian watermilfoil.

7) DNR continue monitoring the aquatic plant community as it attempts to stabilize at the lowered water level and recolonize areas recently vacated by Eurasian watermilfoil and monitor Eurasian watermilfoil future declines or recoveries.
8) Lake District cooperate with efforts in the watershed to reduce run-off to the lake.

LITERATURE CITED

Barko, J. and R. Smart. 1986. Sediment-related mechanisms of growth limitation in submersed macrophytes. Ecology 61:1328-1340.

Duarte, Carlos M. and Jacob Kalff. 1986. Littoral slope as a predictor of the maximum biomass of submerged macrophyte communities. Limnol. Oceanogr. 31(5):1072-1080.

Dunst, R.C. 1982. Sediment problems and lake restoration in Wisconsin. Environmental International 7:87-92.

Engel, Sandy. 1990. Ecosystem Response to Growth and Control of Submerged Macrophytes: A Literature Review. Technical Bulletin #170. Wisconsin Department of Natural Resources. Madison, WI.

Engel, Sandy. 1985. Aquatic Community Interactions of Submerged Macrophytes. Wisconsin Department of Natural Resources. Technical Bulletin No. 156. Madison, WI

Fassett, Norman C. 1957. A Manual of Aquatic Plants. University of Wisconsin Press. Madison, WI.

Gleason, H. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada (Second Edition). New York Botanical Gardens, NY.

Graczyk, David, R. Hunt, S. Greb, C. Buchwald and J. Krohelski. 2003. Hydrology, Nutrient Concentrations and Nutrient Yields in Nearshore Areas of Four Lakes in Northern Wisconsin, 1999-2001. USGS Water Resources Investigations Report 03-4144.

Hess, Lynne, Peter Kling and Karen Voss. 1997. Nonpoint Source Control Plan for the St. Croix County Lakes Cluster Priority Watershed Project. Wisconsin Department of Natural Resources. Madison, WI.

Hunt, Randall, S. Greb and D. Gracyzk. 2006. Evaluating the Effects of Nearshore Development on Wisconsin Lakes. USGS Fact Sheet 2006-3033.

Jessen, Robert and Richard Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Minnesota Department of Conservation. Game Investigational Report No. 6.

Jester, Laura. 1998. The Geographic Distribution of the Aquatic Milfoil Weevil (*Euhrychiopsis lecontei*) and Factors Influencing its Density in Wisconsin Lakes. University of Wisconsin – Stevens Point. Stevens Point, WI.

Konkel, Deborah. 2003. Changes in the Aquatic Plant Community of Bass Lake, St. Croix County, 1987-2002. Wisconsin Department of Natural Resources, Eau Claire, Wisconsin.

Konkel, Deborah and Susan Borman. 1996. Changes in the Aquatic Plant Community of Bass Lake, St. Croix County, 1987-1996. Wisconsin Department of Natural Resources, Eau Claire, Wisconsin.

Lillie, R. and J. Mason. 1983. Limnological Characteristics of Wisconsin Lakes. Wisconsin Department of Natural Resources Tech. Bull. #138. Madison, WI.

Nichols, Stanley, S. Weber, B. Shaw. 2000. A proposed aquatic plant community biotic index for Wisconsin lakes. Environmental Management 26:491-502.

Nichols, Stanley. 1998. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2):133-141.

Nichols, Stanley A. and James G. Vennie. 1991. Attributes of Wisconsin Lake Plants. Wisconsin Geological and Natural History Survey. Information Circular 73.

Shaw, B, C. Mechenich and L. Klessig. 1993. Understanding Lake Data. University of Wisconsin – Extension. Madison, WI

Valley, Ray, T. Cross and P. Radomski. 2004. The Role of Submersed Aquatic Vegetation as Habitat for Fish in Minnesota Lakes, Including the Implications of Non-Native Plant Invasions and Their Management. Minnesota Department of Natural Resources Special Publication 160.

Appendix XXII. Location of Study Transects on Bass Lake, 1987-2006.