Executive Summary

Tree Lake is a mesotrophic lake with good water quality and fair water clarity. Filamentous algae is common, especially in the shallow depth zone. Nutrients in the lake increased from 1994 to 1997.

The aquatic plant community colonized 90% of the littoral zone to a maximum depth of 11.5 feet with the most abundant plant growth in the 1.5-10ft depth zone. The community is also characterized by above average quality, good species diversity, a below average tolerance to disturbance and a lack of sensitive plant species.

Vallisneria americana is the dominant species within the plant community, especially in the 0-10ft depth zone and exhibited a dense growth form in Tree Lake. *Ceratophyllum demersum* and *Najas flexilis* were sub-dominant.

A healthy aquatic plant community is important because it can improve water quality, provide valuable habitat resources for fish and wildlife, resist the inroduction of non-native species and check excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.

Management Recommendations

1) Protect the quality of the aquatic plant community in Tree Lake.
2) Become involved in the Self-Help Volunteer Lake Monitoring Program again, monitoring water clarity.
3) Chemical treatments for plant growth are not recommended in Tree Lake due to the undesirable side effects of chemical treatments.
4) Restore natural shoreline. Protect emergent plant beds for habitat and to stabilize the shore and prevent erosion.
5) Reduce nutrient input to the lake.
    a) Restoring natural shoreline and protecting emergent plant beds will also help reduce nutrient input to the lake.
    b) Eliminate all lawn fertilizer use, organic or inorganic.
    c) Check and maintain septic systems.
    d) Devise a harvesting plan that will among other things, remove nutrients contained in the plant biomass.
6) Harvesting can remove significant plant biomass and its nutrients and can be used to control species that are invasive or that have become overabundant. The harvesting plan should focus on removing nutrients, providing navigation, targeting nuisance species, preventing the spread of species that are encouraged by harvesting and improving habitat.

The Aquatic Plant Community in Tree Lake, Portage County 2004

I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Tree Lake was conducted during August 2004 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and Cary Farah, member of the Tree Lake Association. This was the first quantitative vegetation study of Tree Lake by the DNR. A qualitative assessment was conducted in August 1997 by the author and in 1978 by other DNR personnel.

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

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

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

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

Background and History: Tree Lake is a 74-acre drainage lake in northeast Portage County, Wisconsin. Tree Lake has a maximum depth of 33 feet and an average depth is 13 feet. Water inflow to Tree Lake is from Klondike Creek on the south shore and Mud Lake via wetlands on the northwest shore. Water flows out of Tree Lake to the Little Wolf River on the northeast shore.

The assessment conducted by DNR personnel in 1978 only recorded the dominant aquatic plant species and other species present. The dominant species in Tree Lake was *Najas flexilis,* ~90%, with lesser amounts of *Myriophyllum sibiricum, Potamogeton amplifolius, P. pectinatus* and *Vallisneria* *americana,* approximately 10% each. Aquatic plants were found in three large beds (Figure 13).

Chemical control of aquatic plants and algae has been attempted in Tree Lake (Table 1). The treatments took pace in the near-shore areas, in discontinuous bands around the entire lake. Broad-spectrum herbicides have been used as well as two types of copper-based algaecides.

Table 1. Herbicide Applied to Tree Lake

	Diquat (gal.)	AV-70 (gal. algaecide)	Copper Sulfate (lbs. Algaecide)	2,4-D (gal.)	Acres Treated
1976	6	6			5.2
1981	7	5			6.9
1982	6.5	6.5	12		5.5
1983	3.5	3.5	50	1	5.27
Total	23	21	62	1	

Tree Lake District applied for a permit for mechanical harvesting of aquatic plants in 2004. Channels were harvested from shoreline properties to improve access to open areas of the lake (Table 2).

Table 2. Mechanical Harvesting of Aquatic Vegetation in Tree Lake, 2004

	Date	Acres Harvested	Loads removed	Weight of loads (pounds)	Total Weight (pounds)
2004	July 12-17	~10	7	9000	63000

Groundwater studies conducted by University of Wisconsin – Stevens Point (Turyk 2004) indicate that groundwater entering on the west side of the lake contains elevated phosphorus and nitrogen. The nutrient sources are likely lawn fertilizers and septic systems.

II.METHODS

Field Methods

The study design was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines. The shoreline was divided into 13 equal segments and a transect, perpendicular to the shoreline, was randomly placed within each segment (Appendix IV), using a random numbers table.

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 from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5), 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 it was present on three rake samples
a rating of 4 indicates that it was present on all four rake samples
a rating of 5 indicates that a species was abundantly present on all rake samples.

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

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 percent cover of land use within this 100' x 30' rectangle was visually estimated.

Data Analysis

The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites) (Appendix I). Relative frequency was calculated (number of occurrences of a species/total occurrence of all species (Appendix I). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendix II). Relative density was calculated (sum of a species density/total plant density). A "mean density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendix II). The relative frequency and relative density of each species were summed to obtain a dominance value for each species (Appendix III). Species diversity was measured by Simpson's Diversity Index (Appendix I).

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols, et. al (2000) was applied to Tree Lake. Measures for each of seven categories that characterize a plant community are converted to values between 0 and 10 and summed.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant community. A coefficient 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 all species found in the lake. The Floristic Quality Index is calculated from the Coefficient of Conservatism (Nichols 1998) and is a measure of a plant community's closeness to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

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

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

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

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

Mesotrophic lakes have intermediate levels of nutrients and biomass.

Volunteer lake monitors in the Self-help Volunteer Lake Monitoring Program, Bob and Jan Underly, collected water quality data on Tree Lake during 1990-1997. Bob and Jan collected water clarity data 1990-1997 and nutrient and chlorophyll data 1994-1997.

Nutrients

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

1994-1997 summer mean phosphorus concentration in Tree Lake was 27.1 ug/l

This concentration of phosphorus in Tree Lake 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**
Eutrophic	Fair	30-50	**10-15**	5-6
	Poor	50-150	15-30	3-4
Tree Lake 1994-1997 Mean	Fair	27.1	10.4	6.1

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

Phosphorus concentrations in Tree Lake varied during the years that data was collected. Phosphorus concentrations have varied between eutrophic and mesotrophic (Figure 1), lowest (mesotrophic) in 1994 and highest (eutrophic) in 1995.

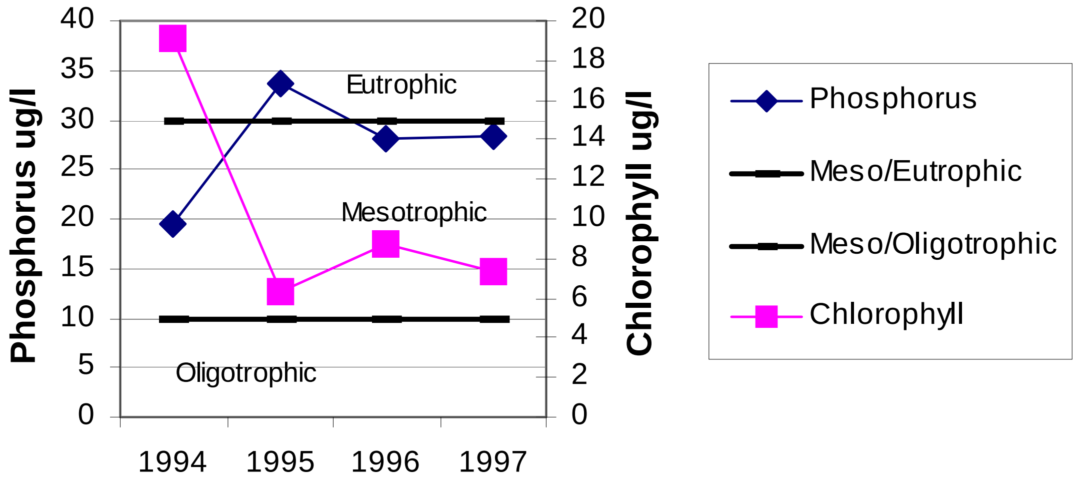


Figure 1. Variation in mean summer phosphorus and chlorophyll concentrations in Tree Lake, 1994-1997.

Algae

Chlorophyll concentrations provide a measurement of 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.

1994-1997 summer mean chlorophyll concentration in Tree Lake was 10.4 ug/l.

The chlorophyll concentration in Tree Lake indicates that it was a eutrophic lake (Table 3).

During 1994-1997, chlorophyll (algae) concentrations did not appear to vary with nutrient levels. The concentration of chlorophyll has ranged from eutrophic in 1994 to mesotrophic during 1995-1997 (Figure 1). Other factors besides nutrient availability can impact algae growth, such as variations in summer temperatures and rain events.

Phosphorus and chlorophyll also vary during the growing season. Phosphorus is high, eutrophic, during spring turnover and drops in June. Phosphorus gradually increases again during the summer and drops slightly in the autumn (Figure 2).

Chlorophyll concentrations start near the oligotrophic range in early summer when the water is cooler. Algae again increase through August to the eutrophic range as the water warms. In fall the chlorophyll concentrations decrease to the mesotrophic range as the water cools (Figure 2).

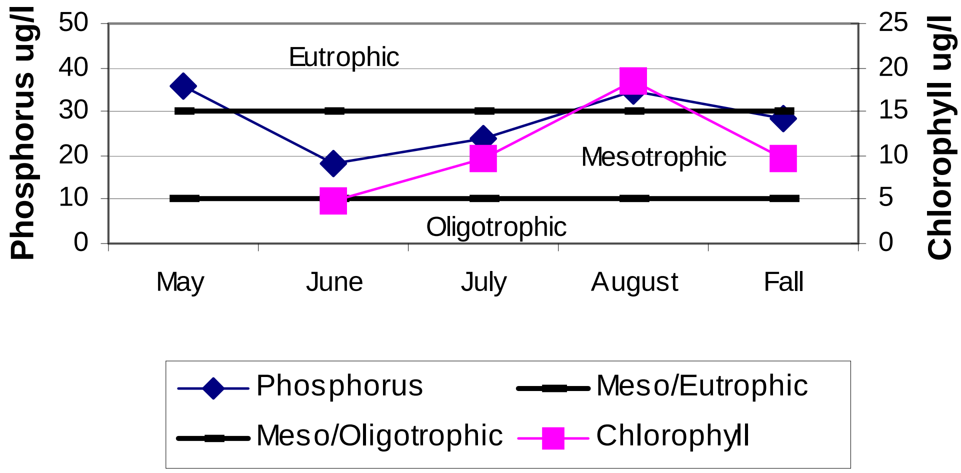


Figure 2. Variation in phosphorus and chlorophyll concentrations in Tree Lake during the growing season, 1994-1997.

Filamentous algae occurred at 29% of the sample sites. Filamentous algae occurred at:

46% of the sites in the 0-1.5ft depth zone
31% of the sites in the 1.5-5ft depth zone
8% of the sites in the 5-10ft depth zone
33% of the sites in the 10-20ft depth zone

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

Mean summer Secchi disc clarity in Tree Lake, 1990-1997, was 6.1 ft.

Water clarity indicates (Table 3) that Tree Lake was a mesotrophic lake with fair water clarity.

The water clarity in Tree Lake varied during 1990-1997, with the best clarity recorded in 1997 and the lowest clarity in 1993 (Figure 3). From 1990 to 1997, there was a trend toward increasing water clarity. Variations in clarity can be the result of variations in algae growth in different years and turbidity after storm events.

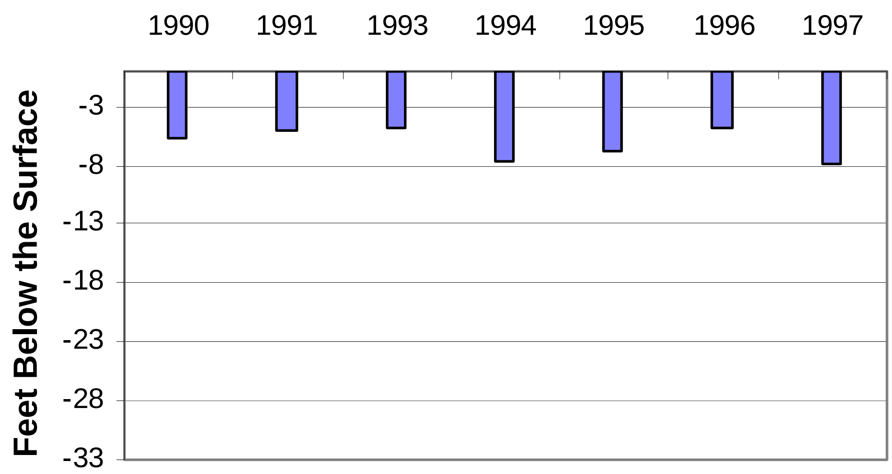


Figure 3. Variation in mean summer water clarity in Tree Lake, 1990-1997.

Water clarity varies during the growing season also, but only slightly (Figure 4).

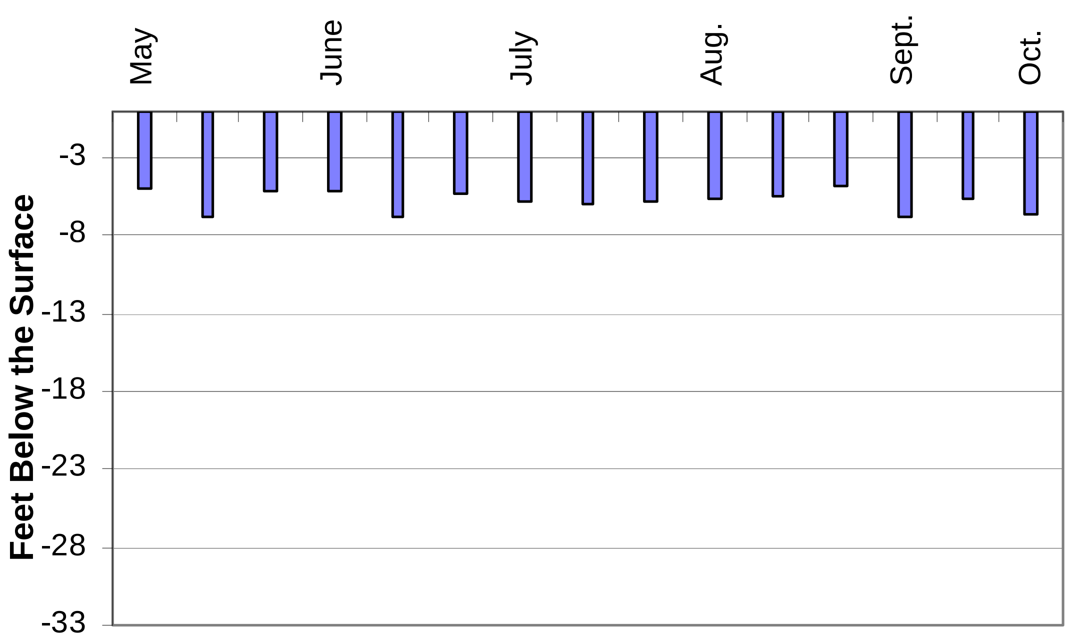


Figure 4. Variation in water clarity during the growing season in Tree Lake, 1990-1997.

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicates that Tree Lake is a mesotrophic lake with good water quality. This trophic state would favor moderate levels of plant growth and occasional algae blooms.

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

Tree Lake has a round basin with a gradually sloped littoral zone over most of the lake. There are small areas of more steeply sloped littoral zones along the southeast shore. Areas of the lake with shallow depths and gradual slopes would favor plant growth.

SEDIMENT COMPOSITION – The dominant sediment in Tree Lake was a marl/silt mixture, especially in the 5 -10ft depth zone and in the northeast third of the lake (Table 4). Silt alone was common in the 5-10ft zone and dominant at depths greater than 10 feet, especially in the west half of the lake.

Sand and marl mixtures were common at depths of 1.5-5 feet, found in the north half of the lake. Sand gravel mixtures were dominant throughout the shallowest zone (0-1.5ft) (Table 4).

Table 4. Sediment Composition in Tree Lake, 2004

Sediment Type		0-1.5' Depth	1.5-5' Depth	5-10' Depth	10-20' Depth	Percent of all Sample Sites
Hard Sediments	Sand	17%	8%	23%	33%	19%
	Sand/Gravel	58%				15%
	Sand/Rock		8%			2%
Mixed Sediments	Sand/Marl		23%			6%
	Sand/Silt	8%	8%			4%
	Sand/Marl/ Gravel		8%			2%
Soft Sediments	Marl/Silt		15%	54%	11%	21%
	Silt		8%	23%	56%	19%
	Muck	17%	8%			6%
	Marl		15%			4%

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

Silt/marl was the dominant sediment found in Tree Lake and would be favorable to plant growth due to its intermediate-density (Barko and Smart 1986) and did support vegetation at 100% of the silt/marl sites (Table 5). However, all sediment types supported abundant vegetation. The only sediment types that did not support 100% vegetation were sand and sand/marl sediments (Table 5). These are high-density, hard sediments that are less favorable for plant growth.

Table 5. Influence of Sediment in Tree Lake, 2004

Sediment Type		Percent of all Sample Sites	Percent Vegetated
Hard Sediments	Sand	19%	78%
	Sand/Gravel	15%	100%
	Sand/Rock	2%	100%
Mixed Sediments	Sand/Marl	6%	67%
	Sand/Silt	4%	100%
	Sand/Marl/ Gravel	2%	100%
Soft Sediments	Marl/Silt	21%	100%
	Silt	19%	100%
	Muck	6%	100%
	Marl	4%	100%

SHORELINE LAND USE – Land use can strongly impact the aquatic plant community and therefore the entire aquatic community. Land use can directly impact the plant community by increased erosion and sedimentation and increased run-off of nutrients, fertilizers and toxics applied to the land. These impacts occur in both rural and residential settings.

Cultivated lawn and wooded shorelines were the most frequently encountered shoreline covers at the transects. Native herbaceous growth, shrubs, rock, hard structures and rip-rap, were also commonly encountered (Table 6).

Wooded cover had the highest mean coverage, based on the transect sites, but still covered only slightly more than one-third of the shoreline. Other natural shoreline cover types had low mean coverage (Table 6).

Table 6. Shoreline Land Use - Tree Lake, 2004

Cover Type		**Frequency of Occurrences at Transects**	**Mean % Coverage**
Natural Shoreline	Wooded	77%	35%
	Native Herbaceous	69%	6%
	Shrub	46%	8%
	Rock	23%	2%
Total Natural Coverage			**52%**
Disturbed Shoreline	Cultivated Lawn	77%	29%
	Hard Structures	69%	10%
	Rip-rap	38%	3%
	Bare Sand	15%	4%
	Eroded	15%	2%
Total Disturbed Cover			**48%**

Some type of natural shoreline (wooded, shrub, native herbaceous) was found at 92% of the sites and had a mean coverage of 52% (Table 6).

Some type of disturbed shoreline (cultivated lawn, hard structures, eroded and rip-rap) was found at 92% of the sites and had a mean coverage of 48% (Table 6).

MACROPHYTE DATA

SPECIES PRESENT

Of the 24 species found in Tree Lake, 5 were emergent species, 4 were floating-leaf species and 15 were submergent species (Table 7).
No threatened or endangered species were found.
No exotic species were found:

Table 7. Tree Lake Aquatic Plant Species, 2004

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Calla palustris* L.	water arum	calpa
2) *Sagittaria latifolia* Willd.	common arrowhead	sagla
3) *Scirpus validus* Vahl.	softstem bulrush	sciva
4) *Typha latifolia* L.	common cattail	typla
5) *Zizania palustris* L.	northern wild-rice	zizpa
Floating-leaf Species		
6) *Lemna minor* L.	small duckweed	lemmi
7) *Nuphar variegata* Durand.	bull-head pond lily	nupva
8) *Nymphaea odorata* Aiton.	white water lily	nymod
9) *Spirodela polyrhiza* (L.) Schleiden.	great duckweed	spipo
Submergent Species		
10) *Bidens beckii* Torr.	water marigold	bidbe
11) *Ceratophyllum demersum* L.	coontail	cerde
12) *Chara* sp.	muskgrass	chasp
13) *Elodea canadensis* Michx.	common waterweed	eloca
14) *Myriophyllum sibiricum* Komarov.	common water milfoil	myrsi
15) *Najas flexilis* (Willd.) Rostkov and Schmidt.	slender naiad	najfl
16) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
17) *Potamogeton epihydrus* Raf.	ribbon-leaf pondweed	potep
18) *Potamogeton illinoensis* Morong.	Illinois pondweed	potil
19) *Potamogeton natans* L.	floating pondweed	potna
20) *Potamogeton pectinatus* L.	sago pondweed	potpe
21) *Potamogeton zosteriformis* Fern.	flatstem pondweed	potzo
22) *Ranunculus longirostris* Godron.	white watercrowfoot	ranlo
23) *Utricularia vulgaris* L.	great bladderwort	utrvu
24) *Vallisneria americana* L.	water celery	valam

FREQUENCY OF OCCURRENCE

Vallisneria americana was the most frequently occurring species in Tree Lake in 2004, (60% of sample sites) (Figure 5). *Ceratophyllum demersum, Chara* spp., *Myriophyllum sibiricum, Najas flexilis, Nymphaea odorata* and *Potamogeton zosteriformis* were also commonly occurring species, (52%, 40%, 31%, 52%, 22% 27%).

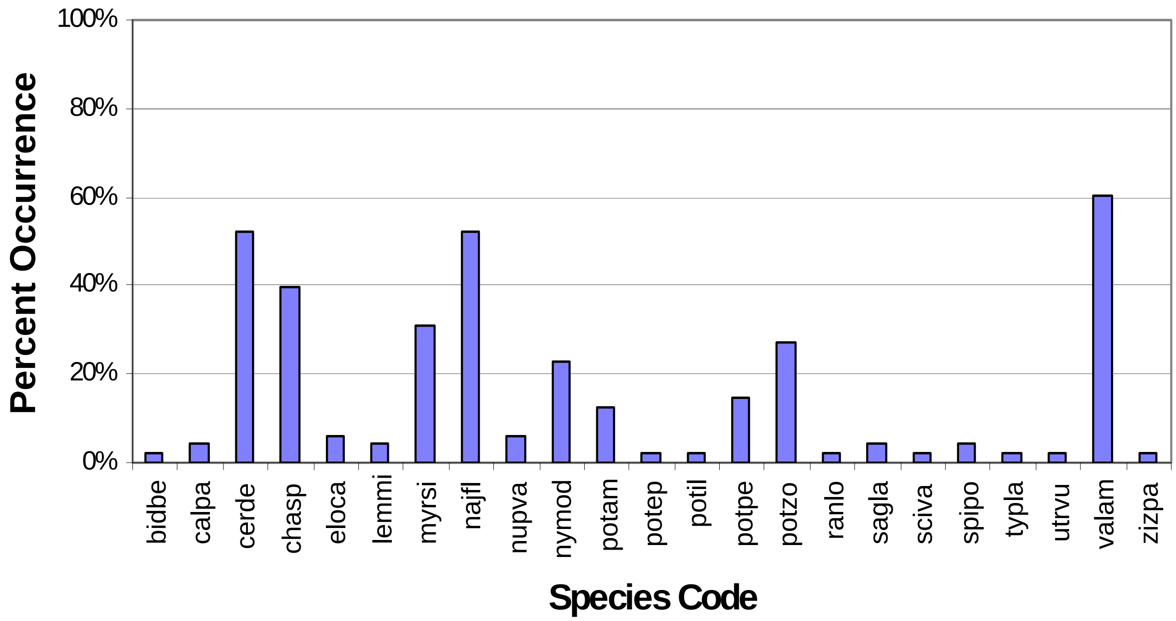


Figure 5. Frequencies of aquatic plant species in Tree Lake, 2004

DENSITY

Vallisneria americana was also the species with the highest mean density in Tree Lake (1.96 on a density scale of 1-4) (Figure 6).

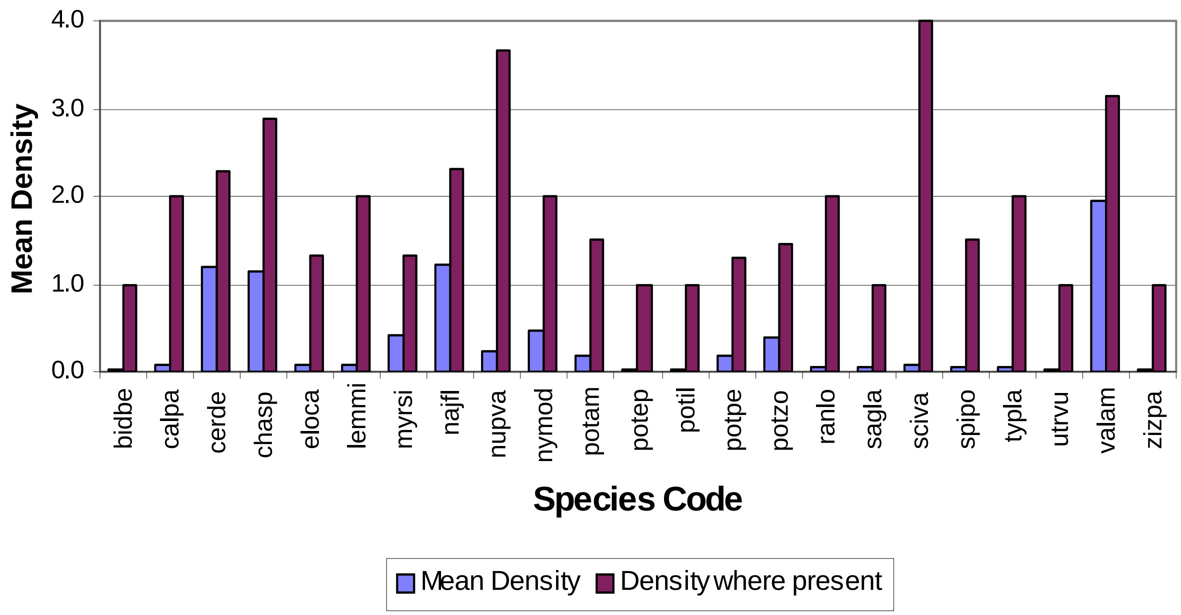


Figure 6. Densities of aquatic plant species in Tree Lake, 2004

Vallisneria americana had a "mean density where present" of 3.1. Its "mean density where present" indicates that, where *V. americana* occurred, it exhibited a growth form of above average density in Tree Lake (Figure 6). *Chara* sp., *Nuphar variegata* and *Scirpus validus* also had "densities where present" of 2.5 or more, indicating that they also exhibited a dense growth form in Tree Lake (Appendix II).

DOMINANCE

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community (Appendix III). Based on the Dominance Value, *Vallisneria americana* was the dominant aquatic plant species in Tree Lake (Figure 7). *Ceratophyllum demersum* and *Naja flexilis* were sub-dominant.

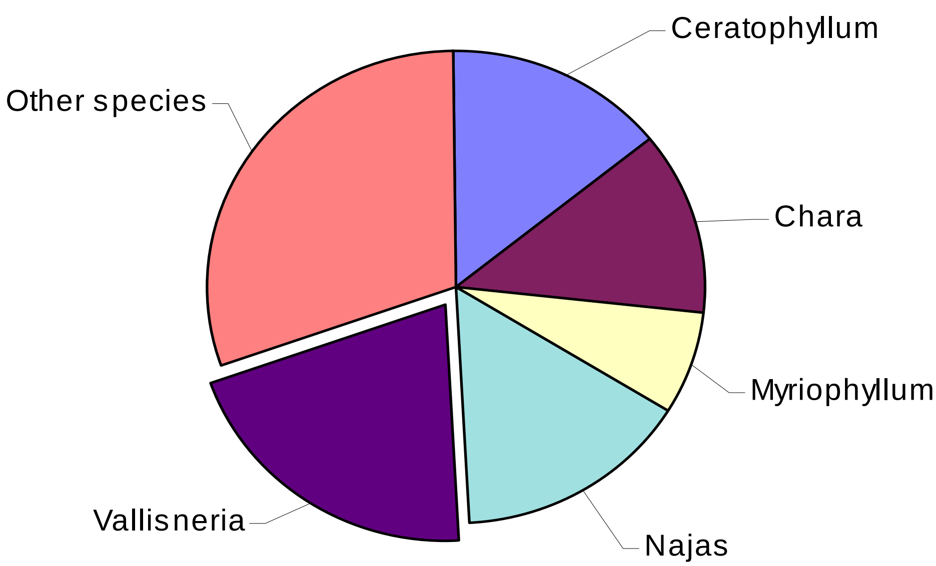


Figure 7. Dominance within the macrophyte community, of the most prevalent macrophyte species in Tree Lake, 2004.

DISTRIBUTION

The sub-dominant species, *Najas flexilis,* and the dominant species, *Vallisneria americana,* were the species with the highest frequencies and densities in the 0-1.5ft depth zone (Figure 8, 9). *N. flexilis* occurred at its highest frequency in the 0-1.5ft depth zone and at its highest density in the 5-10ft depth zone (Figure 8, 9).

Chara spp. and the dominant *V. americana* were the species with the highest frequencies and densities in the 1.5-5ft depth zone (Figure 8, 9). *Chara* spp. occurred at its highest frequency and density in this depth.

Another sub-dominant species, *Ceratophyllum demersum,* and the dominant *V. americana* were the species with the highest frequencies and densities in the 5-10ft depth zone with both species occurring at their highest frequency and density at this depth zone (Figure 8, 9).

C. demersum and *N. flexilis* were the only species recorded in the 10-20 ft depth zone.

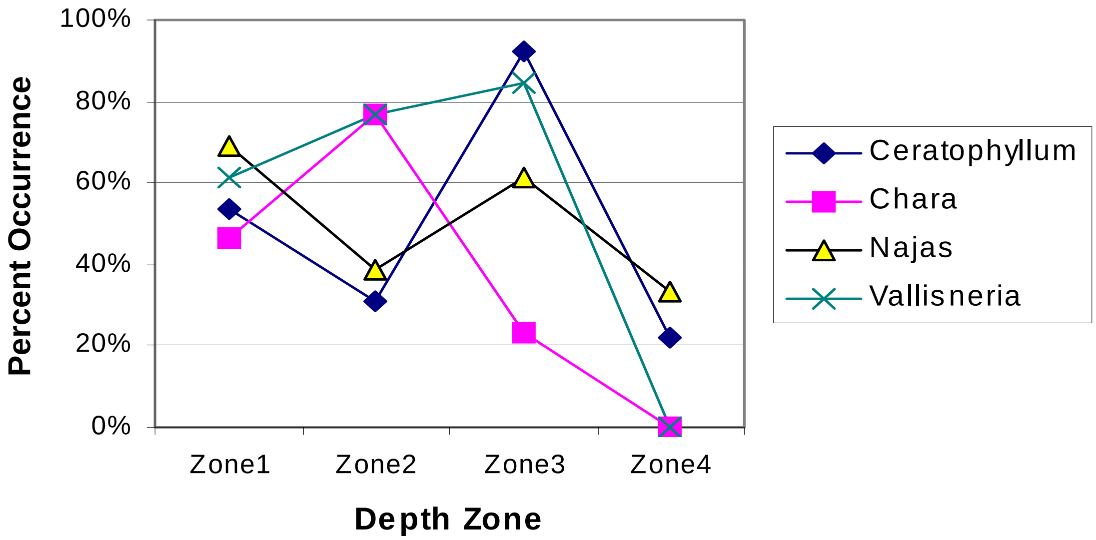


Figure 8. Frequency of occurrence of prevalent macrophyte species in Tree Lake, by depth zone, 2004.

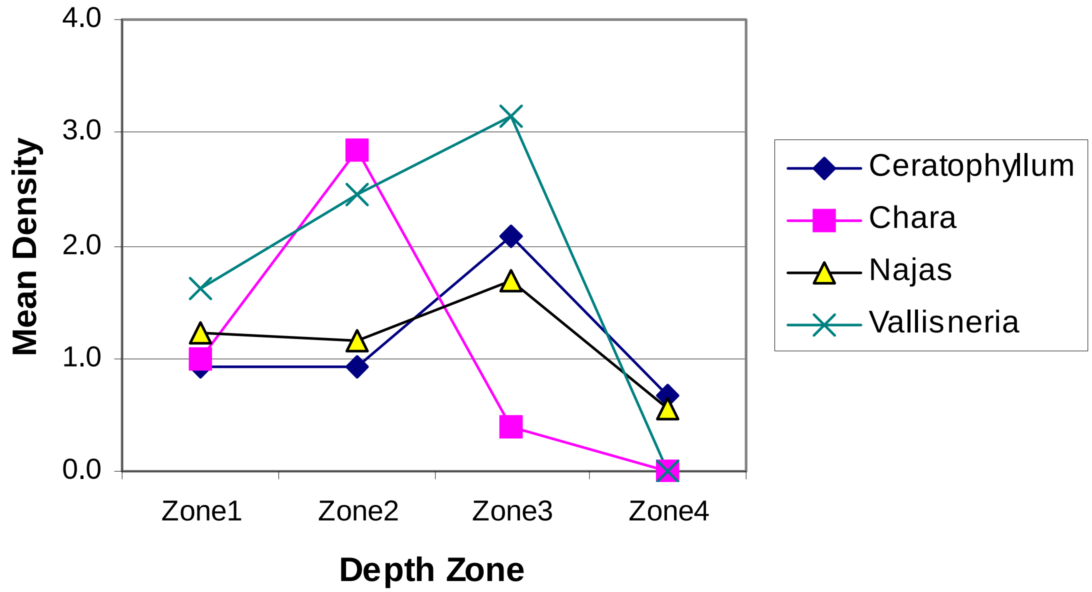


Figure 9. Density of prevalent macrophyte species in Tree Lake by depth zone, 2004.

Aquatic plants occurred throughout Tree Lake, at 90% of the sampling sites, to a maximum depth of 11.5 feet. *Najas flexilis* occurred at the maximum rooting depth. 85% of the sample sites were vegetated with rooted plants. The most prevalent species were found throughout the lake.

Secchi disc readings can be used to calculate a predicted maximum rooting depth for plants in a lake (Dunst 1982).
Based on the 1990-1997 mean summer Secchi disc clarity, the predicted maximum rooting depth in Tree Lake would be between 8.7 and 12.4 ft (Figure 10).

The actual maximum rooting depth is within the range of predicted maximum rooting depths based on water clarity (Figure 10).

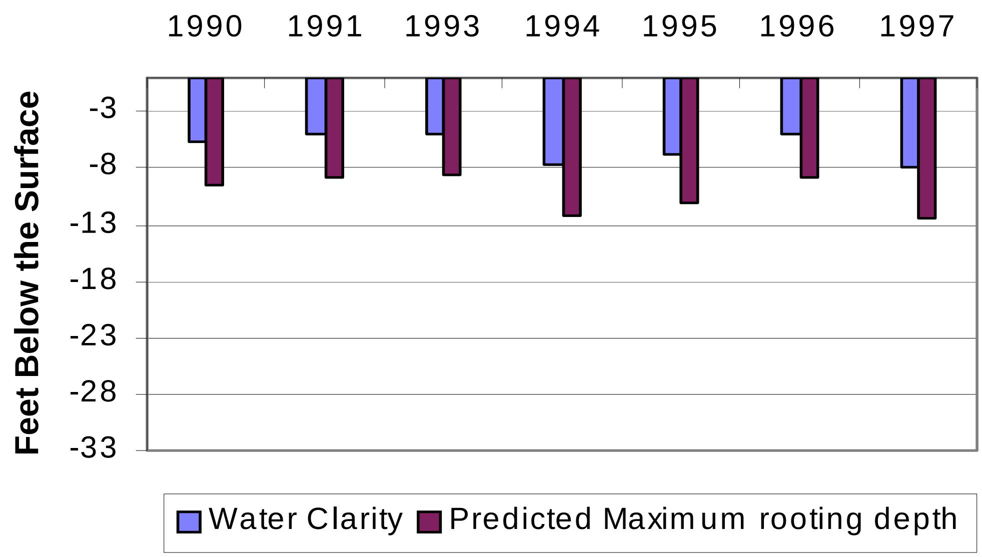


Figure 10. Predicted maximum rooting depth in Tree Lake, based on water clarity, 1990-97.

The 5-10 ft depth zone supported the highest total occurrence of plants and the 1.5-5ft depth zone supported the highest total density of plant growth (Figure 11).

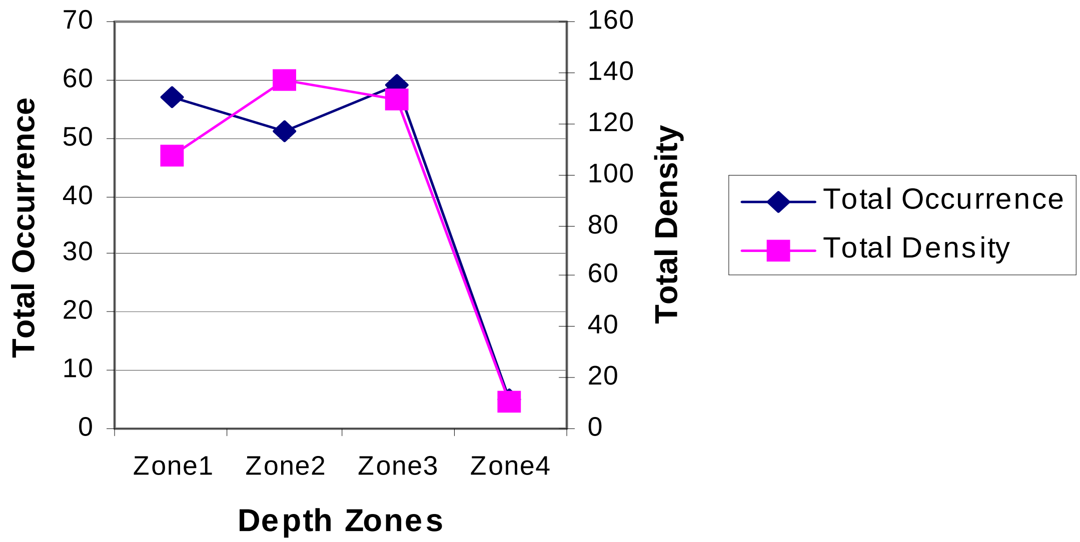


Figure 11. Total occurrence and total density of plants in Tree Lake by depth zone.

The highest percentage of vegetated sites and the greatest species richness (mean number of species per site) was recorded in the 5-10ft ft. depth zone (Figure 12).

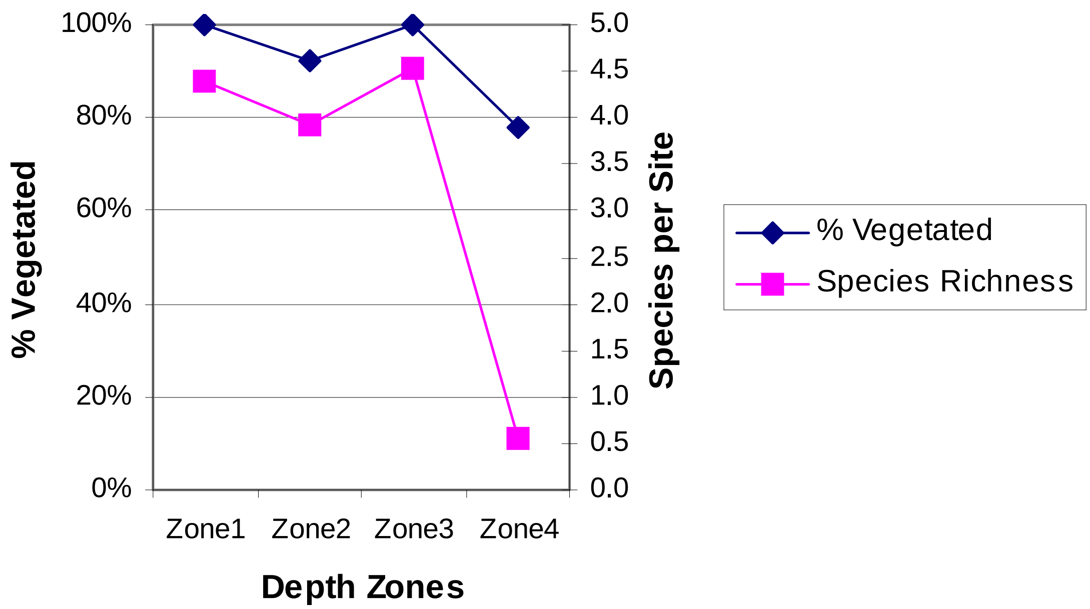


Figure 12. Percentage of vegetated site and species richness in Tree Lake, by depth zone, 2004.

Overall species richness (mean number of species found at sampling sites) was 3.58

THE COMMUNITY

Simpson's Diversity Index was 0.90, indicating good species diversity, above average for lakes in the North Central Hardwood Region of Wisconsin. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable).

The Aquatic Macrophyte Community Index (AMCI) for Tree Lake (Table 8) is 57. This is above average quality for lakes in the North Central Region of Wisconsin. The highest value for this index is 70 (Nichols, et. al 2000).

Table 8. Aquatic Macrophyte Community Index, Tree Lake, 2004

Category	Parameter	Value
Maximum Rooting Depth	3.5 meters	6
% Littoral Zone Vegetated	89.6%	10
Simpson's Diversity	0.90	8
# of Species	23	9
% Exotic species	0	10
% Submergent Species	74% Relative Freq.	9
% Sensitive Species	6% Relative Freq.	5
Totals		57

The low occurrence of sensitive species is a limiting factor in the quality of the Tree Lake aquatic plant community.

The Average Coefficient of Conservatism for Tree Lake was below average for all Wisconsin lakes and above average for lakes in the North Central Hardwood Region of the state (Table 9). This suggests that the aquatic plant community in Tree Lake is more tolerant of disturbance than the average lake in Wisconsin and less tolerant of disturbance than the average lake in the North Central Hardwoods Region. This is likely due to selection by past disturbance.

The Floristic Quality Index of the plant community in Tree Lake was in the upper quartile of all Wisconsin lakes and North Central Hardwood Region lakes (Table 9). This indicates that the plant community in Tree Lake is among the group of lakes in the state and region closest to an undisturbed condition.

Table 9. Floristic Quality and Coefficient of Conservatism of Tree Lake, Compared to Wisconsin Lakes and North Central Wisconsin Lakes.

	Average Coefficient of Conservatism †	Floristic Quality ‡	Based on Relative Frequency	Based on Dominance Value
Wisconsin Lakes	5.5, 6.0, 6.9 *	16.9, 22.2, 27.5		
NCH Region	5.2, 5.6, 5.8 *	17.0, 20.9, 24.4		
Tree Lake 2004	5.74	27.52	27.19	27.23

* - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.

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

‡ - Lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

These values were based only on the presence or absence of tolerant and intolerant species; the frequency or dominance of tolerant and intolerant species within the plant community was not taken into consideration. The Floristic Quality Index was recalculated by weighting each species' coefficient with its relative frequency and dominance value. The resulting values indicate that Tree Lake was in the upper quartile for lakes in the region, in the group of lakes closest to an undisturbed condition, but above average for all lakes in the state, closer to an undisturbed condition than the average lake.

Disturbances can be of many types:

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

Comparison with the 1978 and 1997 Aquatic Plant Assessments

The 1978 and 1997 assessments were not quantitative survey using the same methods as the 2004 plant study. In the 1978 and 1997 assessments, the researcher boated around Tree Lake and noted species present in the plant beds. Because of the different methods, direct comparisons can not be made, but some observations can be compared.

The number of species in Tree Lake appears to have increased (Table 10). However, more species may have been found simply because each subsequent study was more rigorous. Plant growth and diversity appear to have increased. Within the 13 areas into which the lake was divided during the 1997 assessment, diversity of species has increased in 11 of the areas two of the areas without plant growth have filled in since 1997 (Figure 13, 14, 15).

Table 10. Tree Lake Aquatic Plant Species, 1978-2004

1978	1997	2004
Emergent Species	Emergent Species	Emergent Species
		Calla palustris
		Sagittaria latifolia
	Scirpus validus	*Scirpus validus*
	Typha latifolia	*Typha latifolia*
		Zizania palustris
Floating-leaf Species	Floating-leaf Species	Floating-leaf Species
	Lemna minor	*Lemna minor*
	Nuphar variegata	*Nuphar variegata*
	Nymphaea odorata	*Nymphaea odorata*
		Spirodela polyrhiza
Submergent Species	Submergent Species	Submergent Species
		Bidens beckii
	Ceratophyllum demersum	*Ceratophyllum demersum*
	***Chara* spp.**	*Chara* spp.
	Elodea canadensis	*Elodea canadensis*
Myriophyllum sibiricum	*Myriophyllum sibiricum*.	*Myriophyllum sibiricum*
***Najas flexilis*	*Najas flexilis*	*Najas flexilis*
Potamogeton amplifolius	*Potamogeton amplifolius*	*Potamogeton amplifolius*
		Potamogeton epihydrus
	Potamogeton illinoensis	*Potamogeton illinoensis*
		Potamogeton natans
Potamogeton pectinatus	*Potamogeton pectinatus*	*Potamogeton pectinatus*
	Potamogeton zosteriformis	*Potamogeton zosteriformis*
		Rannunculus longirostris
		Utricularia vulgaris
Vallisneria americana	*Vallisneria americana*	***Vallisneria americana*
	Filamentous algae	Filamentous algae

*** -** Dominant species

The dominant species have shifted from *Najas flexilis* in 1978, to *Chara* sp. in 1997, to *Vallisneria americana* in 2004. Overall coverage of plant growth appears to have increased from 1978 to 2004 (Figure 13, 14, 15).

In the 13 areas delineated in 1997:

Ceratophyllum demersum has increased in 10 areas,
Elodea canadensis has increased in 3,
Lemna minor in 1,
Myriophyllum sibiricum in 8,
Najas flexilis in 6,
Nymphaea odorata in 4,
Potamogeton amplifolius in 3,
P. pectinatus in 1,
P. zosteriformis in 5,
Spirodela polyrhiza in 1 and
Vallisneria americana in 4 (becoming the dominant species in 3).

C. demersum appears to have undergone the greatest lake-wide increase.

Figure 13. Map of Aquatic Plant Beds in 1978.

Figure 14. Map of Aquatic Plant Beds in 1997.

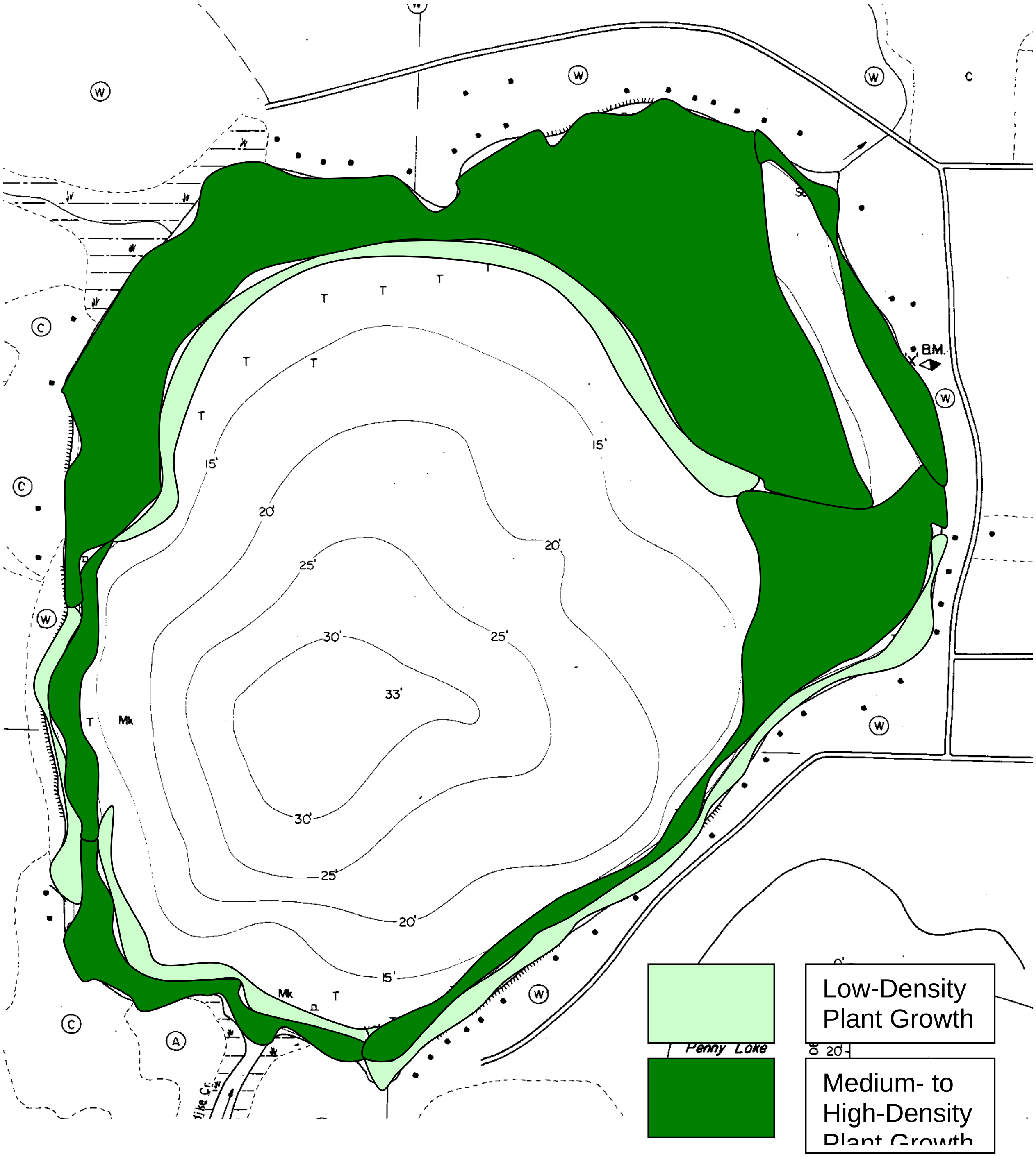


Figure 15. Map of Aquatic Plant Beds in 2004.

V. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Tree Lake is a mesotrophic lake with fair water clarity and good water quality. This trophic state should support moderate plant growth and occasional algae blooms. However, nutrients in Tree Lake increased from 1994-1997 and is very close to the eutrophic range; further increase in nutrients could push the lake into the eutrophic category. This would result in more abundant plant growth and more frequent algae blooms. A University of Wisconsin-Stevens Point study found that nutrients are entering Tree Lake through groundwater on the west side of the lake and that the most likely source was lawn fertilizers and septic systems.

Filamentous algae occurred at 29% of sites, most frequent in the 0-1.5ft depth zone (46%), but was not recorded along the east shore.

Adequate nutrients (mesotrophic trophic state), the large zone of shallow water depths and the gradually sloped littoral zone in most of Tree Lake favor plant growth. The dominance of intermediate-density silt and silt/marl sediments in Tree Lake also favor plant growth. Intermediate-density sediments were more dominant at depths greater than 5 feet.

Aquatic herbicide treatments were conducted 1976-1983, using broad-spectrum chemicals and copper based algaecides. Copper does not break down and builds up in the sediments, resulting in sediments that are toxic to some aquatic life. Plant growth appears to have increased during this time period of herbicide treatments. In 2004, mechanical harvesting of aquatic plants was conducted in Tree Lake and removed approximately 63,000 pounds of plant material. This removal of vegetation would help with nutrient reduction.

2004 Plant Community

Aquatic plants occurred at 90% of the sites (85% with rooted vegetation), to a maximum depth of 11.5 feet. This maximum rooting depth is in agreement with the predicted maximum rooting depth based on water clarity. The greatest amount of plant growth occurred in the 1.5-10ft depth zone. The highest total density of plant growth was found in the 1.5-5ft depth zone and the highest total occurrence of plant growth, the greatest percentage of vegetated sites and the greatest species richness occurred in the 5-10ft depth zone.

Twenty-four species were recorded in Tree Lake in 2004. The dominant most abundant aquatic plant species were distributed throughout the lake. *Vallisneria americana* was the dominant plant species in Tree Lake, especially in the 0-10ft depth zone, occurring at more than half of the sample sites. *Vallisneria americana* exhibited a growth form of above average density in Tree Lake.

Ceratophyllum demersum and *Najas flexilis* were sub-dominant. *N. flexilis* frequently occurred in the 0-1.5ft depth zone. As an annual, *N. flexilis* indicates disturbance and is commonly frequent in this shallow, wave-wash zone.

Ceratophyllum demersum was abundant in the 5-10ft depth zone.

Chara spp. was also abundant in Tree Lake, especially in the 1.5-5ft depth zone. *Chara* spp. exhibited a dense growth form in Tree Lake. Two other species exhibited dense growth forms in Tree Lake, but only occurred in limited locations.

The Aquatic Macrophyte Community Index (AMCI) for Tree Lake was 57, indicating that the quality of the plant community in Tree Lake is of above average quality for North Central Wisconsin Lakes, but Tree Lake lacks sensitive species. The lake of sensitive species may be due to past disturbances, such as chemical treatments, boat traffic and shoreline development, that have eliminated species sensitive to disturbance. Simpson's Diversity Index (0.90) indicates that the plant community had a good diversity of species. Species richness was 3.58 species per sample site.

The Average Coefficient of Conservatism and the Floristic Quality Index suggests that Tree Lake has an average tolerance to disturbance and within the 25% of the lakes in the state and region closest to an undisturbed.

Tree Lake has some protection by natural shoreline cover (wooded, shrub, native herbaceous growth), but disturbed shoreline covered 48% of the shore. One type of disturbed cover, cultivated lawn, occurred at 77% of the sample sites and covered 29% of the shoreline. Areas with cultivated lawn could impact the lake by increased run-off of lawn fertilizers, pesticides and pet wastes into the lake. The shorter blade length and root depth of cultivated lawn does not effectively slow run-off or absorb excess nutrients and water. Nutrients from lawn fertilizers and septics appear to be entering the lake on the west side via groundwater (UWSP 2004).

Changes 1978-2004

1) The dominant species have shifted from *Najas flexilis* in 1978, to *Chara* spp. in 1997, to *Vallisneria americana* in 2004. The 1978 and 1997 dominant species are indicative of disturbance and the 2004 dominant is indicative of good water clarity.
2) The lake-wide coverage of plant growth appears to have increased from 1978 to 1997 and from 1997 to 2004 (Figures 13-15).
3) Eleven (11) individual species appear to have increased since the 1997 assessment. T
4) The occurrence of *Ceratophyllum demersum* has increased the most of all species. This species is indicative of high turbidity.

VI. CONCLUSIONS

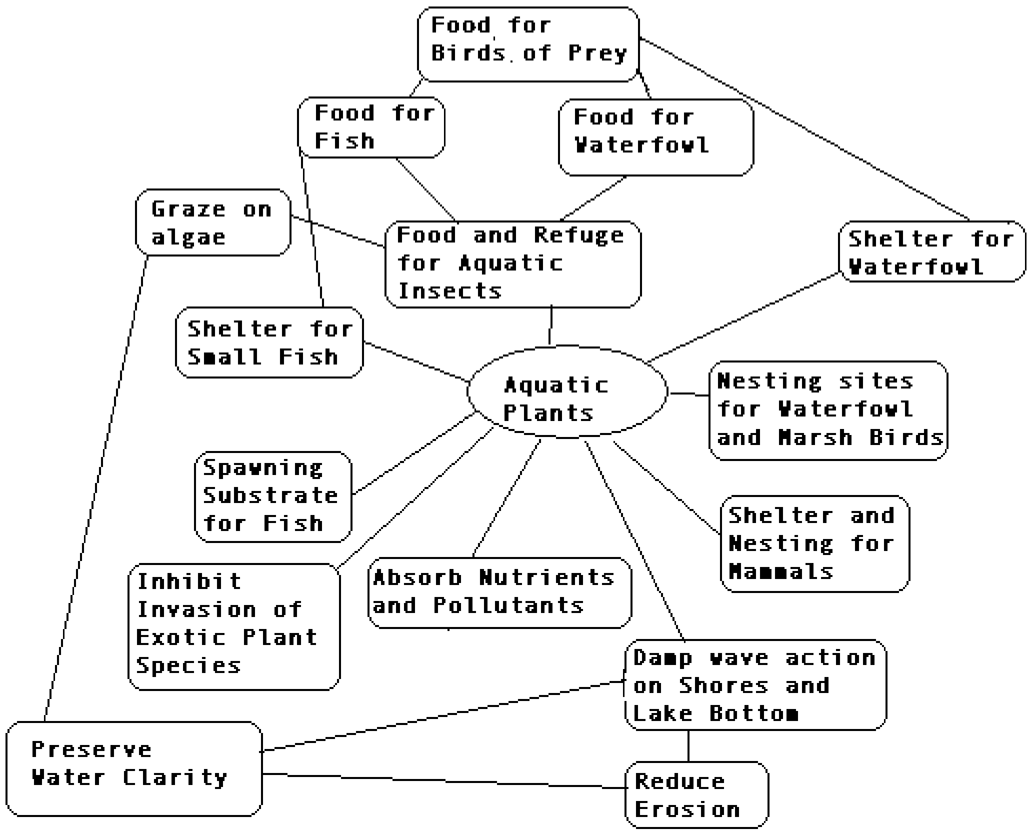
Tree Lake is a mesotrophic lake with good water quality and fair water clarity. Nutrients increased from 1994 to 1997, placing the lake very close to an eutrophic condition. Filamentous algae is common, especially abundant in the 0-1.5ft depth zone. The east side of the lake has less algae growth.

The aquatic plant community is characterized by average quality for Wisconsin lakes, good species diversity, a below average amount of disturbance and an average tolerance to disturbance. Tree Lake lacks sensitive species.

The aquatic plant community colonized 90% of the littoral zone to a maximum depth of 11.5 feet. The 1.5-10ft depth zone supported the most abundant aquatic plant growth. Plant growth is favored by the intermediate-density sediments, adequate nutrients and gently-sloped lake bed.

Vallisneria americana is the dominant species within the plant community, especially in the 0-10ft depth zone. *V. americana* was found at more than half of the sites and exhibited a dense growth form. *Ceratophyllum demersum* and *Najas flexilis* were sub-dominant. *Chara* spp. also exhibited a dense growth form, especially in the 1.5-5ft depth zone.

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



1) Aquatic plant communities improve water quality in many ways:
    they trap nutrients, debris, and pollutants entering a water body;
    they absorb and break down some pollutants;
    they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
    they remove nutrients that would otherwise be available for algae blooms (Engel 1985).
2) Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table 11). Plant cover within the littoral zone of Tree Lake is 90% and is greater than the ideal 25-85% to support a balanced fishery.

Table 11. Wildlife Uses of Aquatic Plants in Tree Lake

Aquatic Plants	Fish	Water Fowl	Song and Shore Birds	Upland Game Birds	Muskrat	Beaver	Deer
Submergent Plants							
Bidens beckii		F (seeds)					
Ceratophyllum demersum	F,I*, C, S	F(Seeds*), I, C			F		
Chara sp.	F*, S	F*, I*					
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)				
Potamogeton amplifolius	F, I, S*,C	F*(Seeds)			F*	F	F
Potamogeton epihydrus	F, I, S*,C	F*(All)			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 pectinatus	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 spp.	F, C, I	I			F		

Aquatic Plants	Fish	Water Fowl	Song and Shore Birds	Upland Game Birds	Muskrat	Beaver	Deer
Vallisneria americana	F*, C, I, S	F*, I	F		F		
Floating-leaf Plants							
Lemna minor	F	F*, I	F	F	F	F	
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			
Emergent Plants							
Sagittaria latifolia		F, C	F(Seeds), C	F	F	F	
Scirpus validus	F, C, I	F (Seeds)*, C	F(Seeds, Tubers), C	F (Seeds)	F	F	F
Typha latifolia	I, C, S	F(Entire), C	F(Seeds), C, Nest	Nest	F* (Entire), C*, Lodge	F	
Zizania palustris	F, C	F*, C	F, C	F, C	F*		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.

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

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

Management Recommendations

1) Become involved in the Self-Help Volunteer Lake Monitoring Program again, monitoring water clarity.
2) Chemical treatments for plant growth are not recommended in Tree Lake due to the undesirable side effects of chemical treatments.
    a) The decaying plant material dies in place, enriching the sediments, encouraging more plant growth.
    b) The decay releases nutrients that feed algae growth that reduce water clarity.
    c) Broad-spectrum treatments would open up areas that would be vulnerable to the introduction of the exotic species.
    d) Copper compounds used to treat algae will build up in the sediment, resulting in toxic sediments.

    Plant growth appears to have actually increased during the time period that chemical treatments occurred. The shift from dominant plant species in 1978 and 1997 that are disturbance tolerant to a dominant species dependent of clear water may signal a recovery from past herbicide treatments.
3) Restore natural shoreline. Disturbed shoreline covers nearly half of the shore; mowed lawn alone covers more than one-quarter of the shore. Unmowed native vegetation reduces shoreline erosion and run-off into the lake and filters the run-off that does enter the lake. Shoreline restoration could be a as simple as leaving a band of natural vegetation around the shore by discontinuing mowing or as ambitious as planting native grasses, flowers, shrubs and trees on the shore and native wetland vegetation in the shallow water zone off shore.
4) Protect emergent plant beds for habitat and to stabilize the shore and prevent erosion.
5) Reduce nutrient input to the lake. Tree Lake is near the eutrophic range and small increases in nutrients could result in much greater plant and algae growth. A University of Wisconsin-Stevens Point (Turyk 2004) study suggested that nutrients from lawn fertilizers and septic systems were entering the lake through the groundwater.
    e) Restoring natural shoreline and protecting emergent plant beds will also help reduce nutrient input to the lake by reducing erosion and sediment that carry nutrients and by slowing and absorbing nutrients in run-off.

f) Eliminate all lawn fertilizer use, organic or inorganic.
g) Check and maintain septic systems.
h) Devise a harvesting plan that will among other things, remove nutrients contained in the plant biomass.

7) Harvesting can remove significant plant biomass and its nutrients and can be used to control species that are invasive or that have become overabundant. The harvesting plan should focus on removing nutrients, providing navigation, targeting nuisance species, preventing the spread of species that are encouraged by harvesting and improving habitat (Figure 16).
   a) Removing nutrients. The 1.5-5ft depth zone has the greatest density of plant growth. Harvesting in the 3-5ft zone would more effectively remove nutrients. This is also the zone with the highest density of *Chara* spp., which has been dominant in some years and is currently exhibiting a habit of dense growth. *Chara* can be scooped out as the harvester cuts in this zone and filamentous algae can be skimmed and removed before it decays and releases nutrients.
   b) Providing navigation. Cutting vegetation in the 3-5ft zone will provide a ring around the lake for navigation. In addition, where the ends of docks are shallower than 3 feet or deeper than 5 feet, additional channels can be added at the end of the docks that join with the 3-5ft zone. Channels cut into the docks can be added where needed.
   c) Controlling invasive species. No exotic species exist currently in Tree Lake. Harvest minimally at the boat ramp, one channel the width of an average boat. The public access is the site at which new invasions generally start. By not disturbing the plant bed at this site, harvesting will not open up an area for exotic species to colonize.
   d) Nuisance species. *Ceratophyllum demersum* is not yet a nuisance condition, but has increased lake-wide more than the other species. This species is not rooted and can be skimmed as the cutter cuts channels and harvests the 3-5ft zone. The 10-20ft depth zone can be cut as necessary. This is the most appropriate zone for higher speed boat traffic and is colonized only by *C. demersum* and *Najas flexilis* (a low-growing plant). Cleaning the *C. demersum* from this zone will reduce obstructions to recreation and help reduce *C. demersum* in Tree Lake.
   e) Prevent spread of abundant species. Avoid harvesting in the 5-10ft depth zone, only cutting where a channel from a boat dock needs to be extended to the >10ft zone. This is the zone with the greatest species diversity and should be left undisturbed. *Vallisneria americana* is dominant in this zone and harvesting this species encourages its growth.
   f) Improve habitat. The colonization of plants in Tree Lake is currently higher than ideal for quality fish habitat. But cutting the channels and areas indicated above, areas would be opened for wildlife use and as cruising lanes to facilitate hunting by predator fish. This will encourage a more balanced fishery.

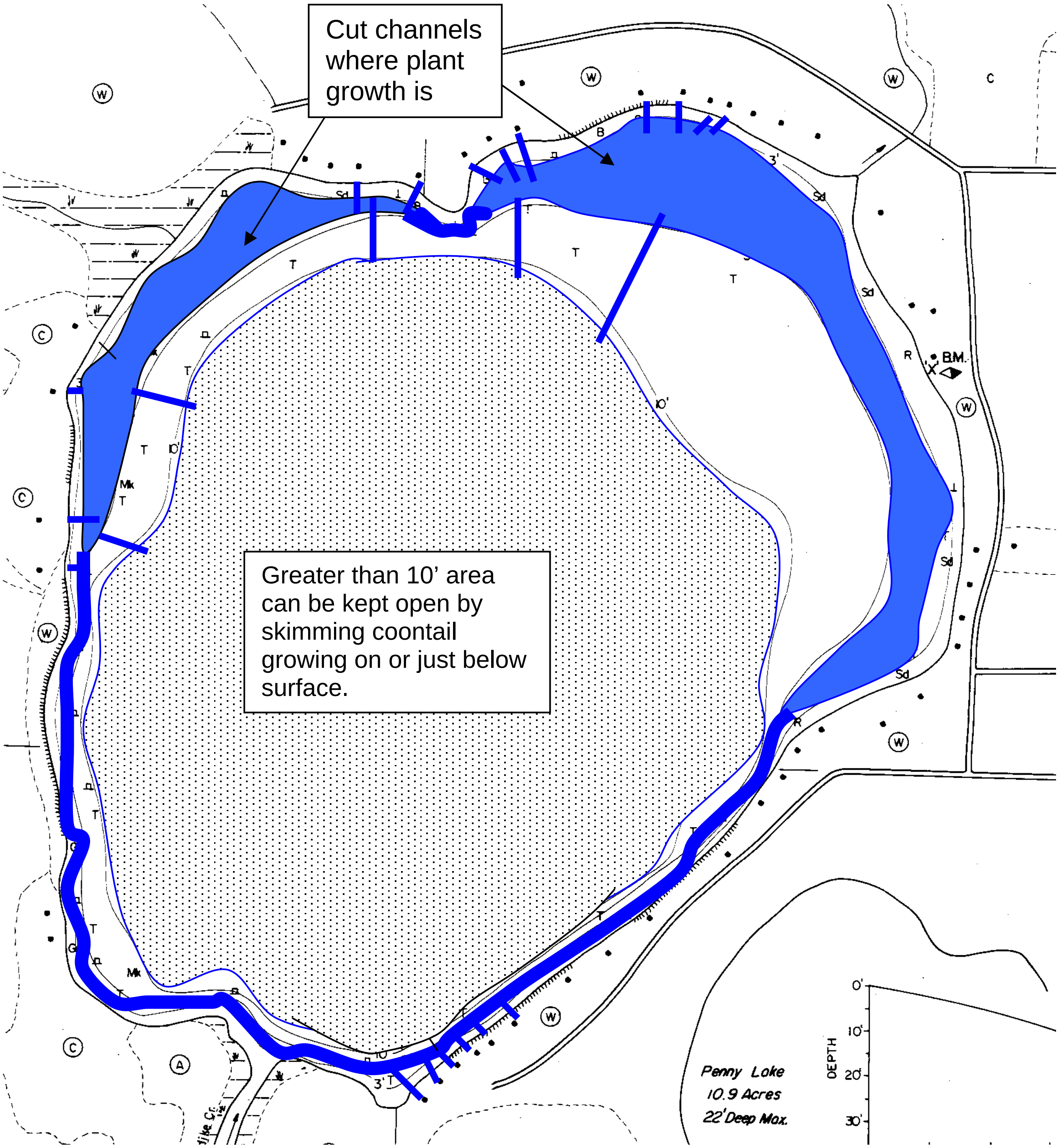


Figure 16. Map of suggested mechanical harvesting.

LITERATURE CITED

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

Dennison, W., R. Orth, K. Moore, J. Stevenson, V. Carter, S.Kollar, P. Bergstrom, and R. Batuik. 1993. Assessing water quality with submersed vegetation. BioScience 43(2):86-94.

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.

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.

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

Turyk, Nancy. 2004. Memo on file at WI-DNR, West-Central Region Aquatic Plant Management Files for Tree Lake, Portage County.