**Changes in the Aquatic Plant Community**

**of**

**Pine Lake,**

# St. Croix County, Wisconsin

# 1993-2006

****

**Wisconsin Department of Natural Resources**

**West-Central Region**

**Eau Claire, WI**

**May 2007**

**EXECUTIVE SUMMARY**

Pine Lake is a mesotrophic lake with fair-to-good water quality and fair water clarity. Filamentous algae was common in Pine Lake, abundant in the shallow zone.

*Potamogeton robbinsii* (fern-leaf pondweed) was the dominant species in 2006, occurring at more than three-quarters of the sites, dominating all depth zones andexhibiting a dense growth form in Pine Lake. *Ceratophylllum demersum* (coontail) was sub-dominant in 2006.

Aquatic plants colonize 89% of littoral zone, 65% of the total lake, up to the maximum rooting depth of 13 feet. The 0-1.5ft depth zone supported the greatest amount of aquatic plant growth. The aquatic plant community in Pine Lake is within the group of lakes in the state and region most tolerant of disturbance and farthest from an undisturbed condition. The community is characterized by very poor species diversity and an above average quality.

**Changes: 1993-2006**

There has been an extreme change in the aquatic plant community in Pine Lake; the 1993 and 2006 aquatic plant communities are only 15% similar. Increased disturbance to the aquatic plant community has been measured. Some changes are likely due to the severe runoff event the lake has experienced during the late 1980’s. The greatest changes have been:

1. There has been a dramatic switch in dominance from *Elodea canadensis* in 1993 to *Potamogeton robbinsii* (a species preferring low alkalinity)*.*
2. The decrease and disappearance of six (6) emergent species.
3. Total occurrence and total density of aquatic plants species has decreased.
4. Diversity of the aquatic plant community decreased.

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

**Recommendations**

* 1. Lake shore residents protect the natural shoreline buffers on Pine Lake. The disturbed shoreline aquatic plant community has been impacted by disturbance, supports a higher frequency of tolerant species, has a slightly lower quality plant community and has a lower diversity plant community.

1. Lake shore residents install stormwater management to prevent run-off to lake.
2. Lake shore residents use no fertilizers on property.
3. DNR consider designating Critical Habitat Areas on Pine Lake.
4. DNR and Lake Residents maintain exotic species signs at boat landing.
5. Lake shore residents become reinvolved in the Citizen Lake Monitoring Program.

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**Changes in the Aquatic Plant Community of**

**Pine Lake** (T31N R19W)**, St. Croix County, Wisconsin**

**1993-2006**

**I. INTRODUCTION**

Surveys of the aquatic plants (macrophytes) in Pine Lake (T31N R19W) were conducted during September 1993 and July 2006 by Water Resources staff from the Western Central Region – Wisconsin Department of Natural Resources (DNR). Only the 33-acre western most basin was surveyed in 1993, likely because low water levels prevented access to the three smaller east basins.

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 critical habitat areas, aquatic plant management and water resource regulations. The 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**

Pine Lake is a 89-acre seepage lake in northwestern St. Croix County, Wisconsin. It consists of 4 basins, defined by peninsulas that nearly cut off the basins, each progressively smaller towards the east. It has a maximum depth of 19 feet. There is one public access boat landing off the county highway on the west end. Fishing is the primary recreational use, with large mouth bass as the dominant game fish.

In the late 1980’s, there was a significant runoff event from surrounding agricultural fields that created sand deltas. After the runoff, the shore was covered with flooded timber out to the 8-foot depth contour. Algal blooms and fish kills followed the run-off. In the 1990’s, submergent vegetation started to return to Pine Lake and water quality improved as the vegetation expanded. Bluegill, bass and northern pike started replacing the walleye, crappie and smallmouth bass fish community.

Currently, the water level on Pine Lake is declining.

**II. METHODS**

Field Methods

The same study design was used for the 1993 and 2006 aquatic plant studies. The design was based on the rake-sampling method developed by Jessen and Lound (1962). Eighteen (18) stratified-random transect lines were placed perpendicular to the shoreline, using a random numbers table (Appendix VII).

One sampling site was randomly located at each depth zone (0-1.5ft., 1.5-5ft., 5-10 ft. 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 corner 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), the number of rake samples at each sampling site on which it was present.

A rating of 1 for each species present on one rake sample at a site;

A rating of 2 for each species present on two rake samples at the site;

A rating of 3 for each species present on three rake samples;

A rating of 4 for each species present on four rake samples;

A rating of 5 indicates that a species was abundant on all rake samples at that sampling site.

The species recorded include aquatic vascular plants and macrophytic algae, such as muskgrass and nitella. The presence of filamentous algae was recorded. The actual depth and sediment type at each sampling site was recorded.

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on 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 ft. X 30 ft. rectangle 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 each species present were collected and saved in a cooler for preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

Data Analysis

The data was analyzed separately for each year and compared. The percent frequency of occurrence of each species was calculated (number of sampling sites at which it occurred/number of sampling sites) (Appendices I-II). Relative frequency was calculated (number of sample sites at which it occurred\the sum of all species occurrences) (Appendices I-II). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendices III-IV). Relative density was calculated (the density rating of a species\the sum of all species densities) (Appendices III-IV). A “density where present” was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendices III-IV). The relative frequency and relative density of each species was summed to obtain a Dominance Values for each species (Appendices V-VI).

Species diversity was measured by calculating Simpson's Diversity Index (1-sum(relative frequencies)2) (Appendices I-II). The sampling years were compared by the Coefficient of Community Similarity.

An Aquatic Macrophyte Community Index (AMCI), developed for Wisconsin lakes, was applied to Pine Lake. Data in seven categories that characterize the aquatic plant community is converted to values 0 - 10 and summed as outlined by Nichols (2000) (Table 6).

The Average Coefficient of Conservatism and Floristic Quality Index were used to evaluate disturbance in the community (Nichols 1998). 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 of conservatism for all species found in a lake and measures the sensitivity of the community to disturbance. The Floristic Quality Index is calculated from the coefficients and measures the plant community’s closeness to an undisturbed condition.

# III. RESULTS

**PHYSICAL DATA**

**Water Chemistry**

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

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

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

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

**Mesotrophic lakes** have intermediate levels of nutrients and biomass.

##### Nutrients

Phosphorus is a limiting nutrient in the majority of 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, occasionally, excess plant growth.

**July 2002 phosphorus concentration in Pine Lake was 17 ug/l**

This concentration of phosphorus in Pine Lake is indicative of 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 |
| Pine Lake 2002 | **Fair-to-Good** | **17** | **12** | **6.2** |

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

**Algae**

Chlorophyll concentrations provide a measure 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.

**July 2002 chlorophyll concentration in Pine Lake was 12.1 ug/l.**

The chlorophyll concentration in Pine Lake indicates that it was a mesotrophic lake (Table 1).

Filamentous algae occurred at 22% of the sample sites in 2006, more frequent in the shallowest zone. No filamentous algae was recorded in 1993. It is not known whether it did not occur or whether the methods of that study omitted recording it.

**Figure 1. Occurrence of filamentous algae in Pine Lake, 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

**July 2002 Secchi Disc clarity in Pine Lake was 6.2 ft.**

Water clarity indicates (Table 1) that Pine Lake was a mesotrophic lake with fair water clarity.

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicates that Pine Lake is a mesotrophic lake with fair-to-good water quality. This trophic state would support moderate plant growth and occasional summer algae blooms.

**Hardness**

The 2002 hardness value was 26 mg/l CaCO3. Lakes with a hardness value of 0-60mg/l CaCO3 are considered soft water lakes. Soft water lakes tend to have less abundant plant growth than hard water lakes.

**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).

Pine Lake has a shallow oval basin with a moderately-sloped littoral zone in most of the lake.

**SEDIMENT COMPOSITION**

The most common sediment in Pine Lake was a sand/silt mixture, especially in the deepest zone (Table 2) (Figure 2). Sand was common in the depth zones greater than 5 feet.

Silt, a sand/silt mixture and a sand/rock or gravel mixture were common in the 0-1.5ft depth zone (Figure 2). Peat/muck mixtures were abundant in the 1.5-5ft depth zone.

# Table 2. Sediment Composition: Pine Lake, 2006

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **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% |  | 28% | 33% | 19% |
| Sand/Gravel or Sand/Rock | 28% | 11% |  |  | 9% |
| **Mixed**  **Sediments** | Sand/Silt | 22% | 11% | 22% | 39% | 24% |
| Sand/Peat |  | 11% |  | 11% | 6% |
| **Soft Sediments** | Peat/Muck |  | 44% | 6% |  | 13% |
| Silt | 22% |  | 11% | 11% | 11% |
| Peat | 6% |  | 17% | 6% | 7% |
| Silt/Peat |  | 11% | 17% |  | 7% |
| Muck | 6% | 6% |  |  | 3% |
| Silt/Muck |  | 6% |  |  | 1% |



Mixed Soft Sediments

Mixed Sediment Types

Muck

Peat

Sand

Silt

Mixed Hard Sediments

**Figure 2. Sediment Type Distribution in Pine Lake, 2006.**

# SEDIMENT INFLUENCE

Many aquatic plants depend on the sediment in which they are rooted for required nutrients. The richness or sterility of the lake sediment and its density will determine which species of plants can survive in a location and how abundantly they will grow.

Sand/silt, the overall dominant sediment in Pine Lake is both limiting and favorable to plant growth. The availability of mineral nutrients essential for plant growth is highest in sediments of intermediate density, such as silt (Barko & Smart 1986), but sand can be limiting to plant growth due to its high density. However, all sediment types supported abundant plant growth in Pine Lake. It appears that a mixture of silt and sand is a favorable substrate for plant growth.

**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 into the lake and increased run-off of nutrients, fertilizers and toxics applied to the land. These impacts occur in both rural and residential settings.

Native herbaceous plant growth was the most frequently encountered shoreline cover at the transects and wooded cover had the highest mean coverage. Bare sand was also abundant as a narrow band around the shore (Table 3). Natural shoreline (wooded, shrub, native herbaceous, sand, rock) was found at all of the sites and had a mean coverage of 84%.

Disturbed shoreline was also encountered: cultivated lawn, pavement for roads, and hard structures (Table 3). Disturbed shoreline was found at 33% of the sites and had a mean coverage of 16%.

**Table 3. Shoreline Land Use - Pine Lake, 2006**

|  |  |  |  |
| --- | --- | --- | --- |
| **Cover Type** |  | **Frequency of Occurrence at Transects** | **Mean % Coverage** |
| Natural  Shoreline | Wooded | 78% | 54% |
| Native Herbaceous | 100% | 21% |
| Bare Sand | 67% | 7% |
| Shrub | 11% | 1% |
| Rock | 6% | 1% |
| **Total Natural Shoreline** | |  | **84%** |
| Disturbed  Shoreline | Pavement | 17% | 8% |
| Cultivated Lawn | 11% | 6% |
| Hard Structures | 17% | 2% |
| **Total Disturbed Shoreline** | |  | **16%** |

**MACROPHYTE DATA**

**SPECIES PRESENT**

Seventeen (17) species of aquatic plant species have been recorded in Pine Lake: 8 were emergent species, 1 was a floating-leaf species and 8 were submergent species (Table 4).

No endangered or threatened species were found.

One exotic species was present in 1993: *Phalaris arundinacea –* reed canary grass

**Table 4. Aquatic Plant Species in Pine Lake, 1993-2006**

**Scientific Name Common Name I. D. Code**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Emergent Species

1) *Carex* spp. sedge carsp

2) *Eleocharis smallii* Britt. creeping spikerush elesm

3) *Juncus effusus* L. soft rush junef

4) *Leersia oryzoides* (L.) Swartz.. rice cut-grass leeor

5) *Phalaris arundinacea* L. reed canary grass phaar

6) *Sagittaria rigida* Pursh. sessile-fruited arrowhead sagri

7) *Scirpus cyperinus* (L.) Kunth. woolgrass scicy

8) *Typha latifolia* L. common cattail typla

Floating-leaf Species

9) *Spirodela polyrhiza* (L.) Schleiden. great duckweed spipo

Submergent Species

10) *Ceratophyllum demersum* L. coontail cerde

11) *Chara* sp. muskgrass chasp

12) *Eleocharis acicularis* (L.) Roemer & Schultes. needle spikerush eleac

13) *Elodea canadensis* Michx. common waterweed eloca

14) *Potamogeton amplifolius* Tuckerman. large-leaf pondweed potam

15) *Potamogeton natans* L. floating-leaf pondweed potna

16) *Potamogeton pusillus* L. small pondweed potpu

17) *Potamogeton robbinsii* Oakes. fern pondweed potro

**FREQUENCY OF OCCURRENCE**

*Potamogeton robbinsii* (fern-leaf pondweed) was the most frequently occurring species in Pine Lake in 2006 (82% of the sample sites) (Figure 3), although the species had not occurred in 1993. *Elodea canadensis* (common waterweed) had been the most frequently occurring species in 1993 (98%), but disappeared in 2006. No other species were commonly occurring in either year (Figure 3).

**Figure 3. Frequency of aquatic plant species in Pine Lake, 1993-2006.**

**DENSITY**

*Potamogeton robbinsii* (fern-leaf pondweed) was also the species with the highest mean density in 2006 (2.96 on a scale of 0-5). *Elodea canadensis* (common waterweed) had been the species in 1993 that had the highest mean density (3.43), but disappeared in 2006 (Figure 4). The mean density of all other plant species in Pine Lake was extremely low.

**Figure 4. Mean density of aquatic plant species in Pine Lake, 1993-2006.**

The “density where present” of *Potamogeton robbinsii* (fern-leaf pondweed) (3.61 on a scale of 0-5) indicates that this species exhibited a dense growth form in Pine Lake in 2006 (Figure 5). *P. robbinsii* was the only species that exhibited a dense growth form in 2006. *Elodea canadensis* (common waterweed) had exhibited a dense growth form in 1993 (3.51). Three emergents (*Carex, Leersia oryzoides, Typha latifolia)* had growth forms of above average density in 1993, but were not commonly occurring in Pine Lake in 1993 or 2006 (Figure 5).

**Figure 5. “Density where present” of plant species in Pine Lake, 1993-2006.**

# DOMINANCE

Combining the relative frequency and relative density of each species into Dominance Values, illustrates how dominant each species is within the plant community (Appendices V-VI).

In 2006, *Potamogeton robbinsii* (fern-leaf pondweed) was the dominant species with *Ceratophyllum demersum* (coontail) as a distant sub-dominant species. This is a change from 1993, when, *Elodea canadensis* (common waterweed) had been the dominant species, with *Leersia oryzoides* (rice cutgrass) as a distant sub-dominant species (Figure 6).





**Figure 6. Dominance of most prevalent aquatic plant species in Pine Lake, 1993-2006.**

*Elodea canadensis* (common waterweed) dominated all depth zones in 1993 and occurred throughout the lake, but seemed to have vanished by 2006. *Potamogeton robbinsii* (fern-leaf pondweed) had not been found in 1993, but by 2006, this species dominated all depth zones and was found throughout the lake (Appendices I-IV).

If the sites in the small east basins are eliminated to compare with the transects in 1993, *Ceratophyllum demersum* (coontail) is not a sub-dominant and did not even occur in the west basin in either year, so would not have been recorded in 1993 (Figure 7). There were not many other differences in the dominance of the entire lake compared with the west basin only in 2006.



**Figure 7. Dominance within the west basin of Pine Lake, 2006.**

**DISTRIBUTION**

Aquatic plants occurred throughout the littoral zone of Pine Lake, 89-97% of the sample sites in 1993 and 2006, to maximum rooting depth of 12-13 feet (Figure 8). In 2006, submergent vegetation colonized approximately 43 acres (82% of the littoral zone, 65% of the total lake area) and emergent vegetation colonized less than 1-acre (23% of the littoral zone, 1% of the lake).



Emergent vegetation

Submergent vegetation

**Figure 8. Distribution of aquatic vegetation in Pine Lake, 2006.**

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

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

**The predicted maximum rooting depth in Pine Lake, based on 2002 water clarity, is 10.25 feet.**

This is less than the actual maximum rooting depth of 12-13 feet recorded in Pine Lake. This may be due to plant growth starting earlier in the year when water clarity is generally greater or using clarity data from a different year than the plant survey was conducted.

The highest total occurrence and total density of plant growth occurred in the shallowest depth zone (0-1.5ft depth zone) in both years (Figure 9). Total occurrence of plants and total density of plant growth decreased between 1993 and 2006 (Figure 9).

**Figure 9. Total occurrence and total density of aquatic plant growth, by depth zone in Pine Lake, 1993-2006.**

The greatest percent of vegetated sites and greatest Species Richness (mean number of species per site) also occurred in the shallowest depth zone (0-1.5ft depth zone) and declined with increasing depth (Figure 10). Percent vegetation and Species Richness both decreased between 1993 and 2006 (Figure 10). Species Richness declined from 1.66 in 1993 to 1.18 in 2006.

**Figure 10. Percent of vegetated sites and Species Richness in Pine Lake, by depth zone, 1993-2006.**

**Changes in Community, 1993-2006**

The Coefficient of Community Similarity measures the percent similarity between two communities. Coefficients less than 0.75 indicate that the communities are less than 75% similar and considered significantly different (Nichols pers. comm.)

**The Coefficient of Community Similarity of the 1993 and 2006 aquatic plant communities in Pine Lake was 0.154. This suggests that the 1993 and 2006 aquatic plant communities are only 15% similar and therefore extremely and significantly different** (Appendix VIII).

Several parameters that measure an aquatic plant community can be compared to show the type of changes that have occurred (Table 5). Parameters of the plant community in 1993 were compared with parameters calculated only on transects in the west basin in 2006. This was because the 1993 study did not go into the smaller east basins.

Between 1993 and 2006, the number of species occurring at the sample sites decreased as did the percent of the littoral zone vegetated, the cover of emergent and submergent vegetation, the diversity index, the plant community’s closeness to an undisturbed condition (Floristic Quality, discussed later) and Species Richness (number of species per site) (Table 5). The number of species decreased the most, 57%.

Parameters that increased were: maximum rooting depth, the Average Coefficient of Conservatism (discussed later) and the quality of the plant community (AMCI discussed later). The quality of the plant community increased the most, 19% (Table 5).

**Table 5. Changes in the Pine Lake Aquatic Plant Community, 1993-2006**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **1993** | **2006** | **Change**  **1993-2006** | **%Change**  **1993-2006** |
| **Number of Species** | 14 | 6 | -8 | -57% |
| **Maximum Rooting Depth** | 12 | 13 | 1 | 8% |
| **% of Littoral Zone Vegetated** | 97 | 89 | -8 | -8% |
| **%Sites/Emergents** | 22 | 17 | -5 | -23% |
| **%Sites/Free-floating** |  |  |  |  |
| **%Sites/Submergents** | 97 | 89 | -8 | -8% |
| **%Sites/Floating-leaf** |  |  |  |  |
| **Simpson's Diversity Index** | 0.62 | 0.40 | -0.42 | -8% |
| **Average Coefficient of Conservatism** | 5.08 | 5.50 | 0.14 | 2% |
| **Floristic Quality Index** | 18.33 | 13.47 | -4.86 | -26% |
| **AMCI** | 42 | 50 | 8 | 19% |
| **Species Richness** | 1.61 | 1.17 | -0.44 | -27% |

The Simpson’s Diversity Index (0.50) indicates that Pine Lake had an extremely poor diversity of aquatic plant species. A Diversity index of 1.0 would mean that each individual in a community was a different species, the most diversity that could be found. The diversity had decreased since 1993, but had been very poor diversity at that time also.

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols, et al (2000) was applied to Pine Lake (Table 6). The AMCI for Pine Lake was 52 and places the quality of the aquatic plant community above average for Lakes in Wisconsin and the North Central Hardwoods Region of the state.

This quality of the Pine Lake aquatic plant community increased from below average quality in 1993 to above average quality in 2006 (Table 6).

**Table 6. Aquatic Macrophyte Community Index, Pine Lake, 1993-2006**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Category | 1993 | | 2006 | |
| Maximum Rooting Depth | 3.66 meters | 6 | 3.96 meters | 7 |
| % Littoral Zone Vegetated | 93% | 10 | 82% | 10 |
| Simpson's Diversity | 0.63 | 2 | 0.50 | 1 |
| # of Species | 14 | 7 | 9 | 4 |
| % Submergent Species | 74% Rel. Freq. | 9 | 78%Rel. Freq. | 10 |
| Exotic Species | 1% Rel. freq. | 6 | 0% Rel. Freq. | 10 |
| % Sensitive Species | 4% Rel. Freq. | 5 | 75% Rel. Freq. | 10 |
| Totals |  | 45 |  | 52 |

The maximum for the value is 70.

The Average Coefficient of Conservatism for Pine Lake was in the lowest quartile for Wisconsin lakes and lakes in the North Central Hardwood Region (Table 7) in 2006. This suggests that the aquatic plant community in Pine Lake is within the group of lakes in the state and region most tolerant of disturbance. The tolerance has decreased slightly since 1993.

**Table 7. Floristic Quality and Coefficient of Conservatism of Pine Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes, 1993-2006.**

|  |  |  |
| --- | --- | --- |
|  | Average Coefficient of Conservatism **†** | Floristic Quality **‡** |
| 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 |
| Pine Lake 1993 | 4.69 | 17.56 |
| Pine Lake 2006 | 5.22 | 15.67 |

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

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

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

The Floristic Quality Index of the plant community in Pine Lake was within the group of lakes in the North Central Hardwood Lakes Region and Wisconsin farthest from an undisturbed condition in 2006 (Table 7). Disturbance has increased since 1993 when Pine Lake was farther from an undisturbed condition than the average lake.

Disturbances can be of many types:

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

Disturbances in Pine Lake likely include toxic run-off from roads and fluctuating water levels.

**Change in Individual Species, 1993-2006**

Communities ultimately change because the species in the community change. Nine species have disappeared from the Pine Lake aquatic plant community. Seven of these species were only found in a few locations in 1993, so that a shift in a transect could have caused them to not be recorded. Four species that disappeared were also emergents and two other emergent species decreased in frequency, density and dominance. If there have been changes in water levels, emergents would have been impacted.

The most dramatic change was the disappearance of the 1993 dominant species that was found at nearly all sites, *Elodea canadensis* (common waterweed)*.* When *E. canadensis* disappeared between 1993 and 2006, a species that did not occur in 1993, *Potamogeton robbinsii* (fern-leaf pondweed)*,* became dominant and colonized more than three-quarters of the sites at a high density.

One other species (*Eleocharis acicularis,* needle spikerush*)* increased in frequency, density and dominance and its preference is for low alkalinity.

**IV. DISCUSSION**

Pine Lake is an 89-acre mesotrophic lake with fair-to-good water quality and fair water clarity. Filamentous algae was common in Pine Lake, abundant in the shallow zone.

The adequate nutrients (trophic state) and abundance of fertile sediments would favor plant growth. The soft water and fluctuating water levels could limit aquatic plant growth.

The aquatic plant community in Pine Lake is within the group of lakes in the state and region most tolerant of disturbance and farthest from an undisturbed condition. The community is characterized by very poor species diversity and an above average quality aquatic plant community. Aquatic plants colonize 89% of littoral zone, 65% of the total lake, up to the maximum rooting depth of 13 feet. The 0-1.5ft depth zone supported the greatest amount of aquatic plant growth in 2006: the greatest total occurrence, total density and Species Richness.

Seventeen (17) species were found during the plant surveys. *Potamogeton robbinsii* (fern-leaf pondweed) was the dominant species in 2006, occurring at more than three-quarters of the sites and dominating all depth zones. *P. robbinsii* exhibited a dense growth form in Pine Lake. *Ceratophylllum demersum* (coontail) was sub-dominant in 2006 but occurred at only about 10% of the sites and only in the smaller east basins.

**Shoreline Impacts**

Pine Lake has some protection from natural shoreline. Some type of natural shoreline covered 84% of the lake shore. Native herbaceous cover had the highest occurrence and wooded shoreline covered more than half of the shore. Disturbed shoreline was commonly occurring and covered 16% of the shore.

Even the small amount of shoreline disturbance appears to have had some impact to the aquatic plant community. To measure these impacts, the transects in Pine Lake was divided into two sets: the transects offshore from natural shoreline and the transects offshore from shoreline with any amount or type of disturbance (Appendices X-XI). These two sets of transects were analyzed as two separate communities and compared.

There were small differences (Table 8) between the developed shoreline and natural shoreline communities.

A couple measures confirm that disturbance is a factor in any differences in the communities. The Floristic Quality Index for the natural shore community was higher then the disturbed shore community, indicating that the natural shore community was closer to an undisturbed condition. The species most tolerant of disturbance in Pine Lake, *Typha latifolia* (common cattail)*,* occurs at a higher frequency at disturbed shore transects (Table 8).

The disturbance may be having a small impact on the quality of the aquatic plant community (as measured by AMCI Index). The quality of community was higher at the natural shoreline sites (below average quality for lakes in the region) than at disturbed shoreline sites (within the group of lakes in the region with the lowest quality) (Nichols 2000) (Table 8, 9).

The natural shoreline aquatic plant community has a higher diversity of species as measured by Simpson’s Diversity Index (Table 8). Greater diversity in the aquatic plant community will support greater diversity in the fish and wildlife community.

**Table 8. Comparison of the Plant Community at Natural and Disturbed Shoreline.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Metric** |  | **Natural Shoreline Community** | **Disturbed Shoreline Community** |
| **Floristic Quality Index** |  | 15.2 | 13.4 |
| **Most Tolerant Species in Pine Lake** | *Typha latifolia* cattail | 6%  5.3% Relative | 8%  7.1% Relative |
| **AMCI Index (Community Quality)** |  | 50.5 | 49 |
| **Simpson’s Diversity Index** | On a scale of 0-1.0 | 0.524 | 0.423 |

**Table 9. AMCI Index of Aquatic Plant Community at Natural and Disturbed Sites.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Category** | **Natural Shoreline** | | **Disturbed Shoreline** | |
| **Maximum Rooting Depth** | 3.8 meters | 7 | 4.0 meters | 7 |
| **% Littoral Zone Vegetated** | 88% | 10 | 79% | 10 |
| **Simpson's Diversity** | 0.524 | 1 | 0.423 | 1 |
| **# of Species** | 6 | 3 | 8 | 2 |
| **% Submergent Species** | 86% Rel. Freq. | 9.5 | 75% Rel. Freq. | 9 |
| **Exotic Species** | 0% | 10 | 0% | 10 |
| **% Sensitive Species** | 72 % Rel. Freq. | 10 | 82% Rel. Freq. | 10 |
| **Totals** |  | 50.5 |  | 49 |

**Changes: 1993-2006**

There has been an extreme and significant change in the aquatic plant community in Pine Lake between 1993 and 2006 as measured by Coefficients of Community Similarity. The 1993 and 2006 aquatic plant communities are only 15% similar.

There has been a dramatic switch in the dominant species in Pine Lake; from *Elodea canadensis* (common waterweed) which grew at a high density, occurred at nearly all sites and dominated all depth zones in 1993 to *Potamogeton robbinsii* (fern-leaf pondweed) which grew at a high density, occurred at more than three-quarters of the sites and dominated all depth zones in 2006*.* This is even more dramatic in that *P. robbinsii* did not even occur in 1993 and *E. canadensis* did not simply decline in 2006, it disappeared. A possible reason for this change is the significant runoff event in the late 1980’s that inundated about 8-feet of shoreline around the lake and resulted in algal blooms. Submergent vegetation was likely nearly eliminated during this period. When water clarity improved and submergent vegetation started recolonizing Pine Lake in the 1990’s, pioneer species such as *Elodea canadensis* would have been the species to colonize at that time. The first plant survey was conducted at that time. During the years between 1993 and 2006, the aquatic plant community would have continued to evolve as other species replaced the *E. canadensis.*

An additional change in the make-up of the aquatic plant community is the loss of four emergent species and decline of two emergent species, which is likely due to fluctuating water levels.

Increases from 1993-2006:

1. *Eleocharis acicularis* (needle spikerush) nearly tripled in frequency and increased in density and dominance 5-fold.
2. The maximum rooting depth increased.
3. The quality of the aquatic plant community has increased from average quality to above average quality. The quality index (AMCI) increased 19%.
4. Disturbance to the plant community increased. Pine Lake has gone from a condition of farther from an undisturbed condition than the average lake in the state and region to the 25% of lakes in the state and region farthest from an undisturbed condition. The disturbances may include:
5. nutrient enrichment from lawns and run-off from the road that results in reduced water clarity
6. toxic substances and salt from the road
7. water level fluctuations

Decreases form 1993-2006:

1. Emergent species decreased. Frequency, density and dominance of two emergent species decreased and four emergent species disappeared from Pine Lake. One of these species had been the sub-dominant species in 1993 and another had exhibited a dense form of growth. If water levels have been fluctuating, these species would have been doubly impacted by inundation (compromising gas exchange) alternating with desiccation when the levels were low.
2. There has been a loss of two pondweed species in the lake (but a gain of one pondweed for a net loss of one pondweed species); the pondweed family provides some of the most valuable habitat.
3. Total occurrence and total density of aquatic plants species has decreased.
4. Diversity of the aquatic plant community decreased; the number of aquatic plant species in the lake decreased, Species Richness (mean number of species per site) and Simpson’s Diversity Index have all decreased.
5. Percent of the littoral zone that is vegetated and percent of the littoral zone with submerged species have decreased.
6. The largest decrease was in number of species, 57% decreased a loss of more than half.

**V. CONCLUSIONS**

Pine Lake is a mesotrophic lake with fair-to-good water quality and fair water clarity. Filamentous algae was common in Pine Lake, abundant in the shallow zone.

Seventeen (17) species were found during the plant surveys. *Potamogeton robbinsii* (fern-leaf pondweed) was the dominant species in 2006, occurring at more than three-quarters of the sites, dominating all depth zones andexhibiting a dense growth form in Pine Lake. *Ceratophylllum demersum* (coontail) was sub-dominant in 2006 but occurred at only about 10% of the sites and only in the smaller east basins.

Aquatic plants colonize 89% of littoral zone, 65% of the total lake, up to the maximum rooting depth of 13 feet. The 0-1.5ft depth zone supported the greatest amount of aquatic plant growth. The aquatic plant community in Pine Lake is within the group of lakes in the state and region most tolerant of disturbance and farthest from an undisturbed condition. The community is characterized by very poor species diversity and an above average quality aquatic plant community.

**Changes: 1993-2006**

There has been an extreme change in the aquatic plant community in Pine Lake; the 1993 and 2006 aquatic plant communities are only 15% similar.

The changes may be due the maturation of the aquatic plant community following the severe runoff event in the late 1980’s which may have wiped out the plant community.

* 1. The dramatic switch in dominance from *Elodea canadensis* (common waterweed) in 1993 to *Potamogeton robbinsii* (fern-leaf pondweed) in 2006*.* *E. canadensis* is a pioneer species and would have been one the first species to recolonize the lake when the water quality improved during the 1990’s.
  2. Greater disturbance in the aquatic plant community was measured in the 1993 community.
  3. Two emergent species have decreased and four emergent species have disappeared from Pine Lake. Fluctuating water levels would impact the community with alternating inundation and desiccation.
  4. The maximum rooting depth increased (as the water quality may have continued to improve).
  5. The quality of the aquatic plant community has increased since 1993.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants have 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.

Aquatic plant communities improve water quality in many ways (Figure 11): filtering nutrients, debris, soil particles and pollutants entering a water body, absorbing and breaking down some pollutants, reducing shoreline erosion by damping wave action and stabilizing shorelines and lake bottoms, taking up nutrients that would otherwise be available for algae blooms (Engel 1985).



**Figure 11. Benefits of aquatic plants in the lake ecosystem.**

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 10).

**Table 10. Wildlife and Fish Uses of Aquatic Plants in Pine Lake**

| **Aquatic Plants** | **Fish** | **Water**  **Fowl** | **Song and Shore**  **Birds** | **Upland Game**  **Birds** | **Muskrat** | **Beaver** | | **Deer** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Submergent Plants** |  |  |  |  |  |  | |  | |
| *Ceratophyllum demersum* | F,I\*, C, S | F(Seeds\*), I, C |  |  | F |  | |  | |
| *Chara*  sp. | F\*, S | F\*, I\* |  |  |  |  | |  | |
| *Eleocharis acicularis* | S | F |  |  | F |  | |  | |
| *Elodea canadensis* | C, F, I | F(Foliage) I |  |  |  |  | |  | |
| *Potamogeton amplifolius* | F, I, S\*,C | F\*(Seeds) |  |  | F\* | F | | F | |
| *Potamogeton natans* | F, I, S\*,C | F\*(Seeds, Tubers) |  |  | F\* | F | | F | |
| *Potamogeton pusillus* | F, I, S\*,C | F\*(All) |  |  | F\* | F | | F | |
| *Potamogeton robbinsii* | F, I, S\*,C | F\* |  |  | F\* | F | | F | |
|  |  |  |  |  |  |  | |  | |
| **Floating-leaf Plants** |  |  |  |  |  |  | |  | |
| *Spirodela polyrhiza* | F | F |  | F |  |  |  | |
|  |  |  |  |  |  |  |  | |
| **Emergent Plants** |  |  |  |  |  |  |  | |
| *Carex sp.* | S\* | F\*(Seeds), C | F\*(Seeds) | F\*(Seeds) | F | F | F | |
| *Eleocharis smallii* | I | F, C |  |  |  |  |  | |
| *Juncus effusus* | S | C | C | C | F |  |  | |
| *Leersia oryzoides* |  | F |  |  | F |  |  | |
| *Sagittaria rigida* |  | F (tubers, seeds) |  |  | F (stems, tubers) | F (stems, tubers) |  | |
| *Scirpus cyperinus* | F, S, C | F, C | F(Seeds, Tubers), C | F | F | F | F | |
| *Typha latifolia* | I, C, S | F(Entire), C | F(Seeds), C, Nest | Nest | F\* (Entire), C\*, Lodge | 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.

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Plant cover within the littoral zone of Pine Lake is 89% of the littoral zone. The cover of vegetation is greater than desirable to support a balanced fishery. Game fish populations have been found to decline when submerged aquatic vegetation cover is less than 10% and greater than 60% (Valley et. al. 2004).

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

**Recommendations**

Lake shore residents on Pine Lake protect the natural shoreline buffers that protect water quality and provide habitat. In 2006, natural native shoreline protected 84% of the shore, but disturbed shoreline was common. 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 fertilizers, pesticides and other toxics to the lake. Nitrogen and phosphorus input was 10-100 times greater at developed lawn than wooded areas (Hunt et. al. 2006). Even the 16% of disturbed shoreline appears to have impacted the aquatic plant community at the disturbed sites. A comparison of sample sites at disturbed shoreline and natural sites indicate:

* 1. The Floristic Quality Index is lower at disturbed shoreline and supports the assertion that disturbance on shore is the likely cause for differences at disturbed and natural shoreline. In addition, the species in Pine Lake most tolerant of disturbance has a higher frequency at disturbed shoreline.
  2. The disturbance on shore has impacted the quality of the aquatic plant community. The quality of the plant community was slightly lower at the disturbed shoreline sites.
  3. The disturbance may be impacting the habitat in the lake. The aquatic plant community at disturbed shorelines had a lower diversity (Simpson’s Diversity Index). Communities with lower diversity are less stable and support less diversity in the fish and wildlife communities.

1. Lakeshore property owners use best management practices on shoreland property to prevent nutrient enrichment and stormwater run-off to the lake. Abundant filamentous algae suggests nutrient enrichment to the lake.
   1. Eliminate fertilization near shoreline
   2. Use no-phosphorus fertilizer on remainder of the property
   3. Minimize use of toxic chemicals and no disposal of chemicals in the lake
   4. Use and maintain erosion barriers during any construction
   5. Inspect and maintain septic systems
   6. Reduce size of areas with hard surface
   7. Design landscaping so that stormwater run-off runs away from the lake, onto porous land cover and/or into rain barrels or rain gardens
2. Lake shore residents use no fertilizers on property.
3. DNR consider designating Critical Habitat Areas on Pine Lake.
4. DNR and Lake residents maintain exotic species signs at boat landing to deter introduction of exotic species into Pine Lake.
5. Lake shore residents become reinvolved in the Citizen Lake Monitoring Program.

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**Appendix VII. Location of Aquatic Plant Study Transects on Pine Lake.**



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