# EXECUTIVE SUMMARY

Based on water clarity and concentration of algae and nutrients, Long Lake is a mesotrophic lake with good water clarity and quality.

*Potamogeton robbinsii* was the dominant species in 2005, with *Potamogeton epihydrus* as the sub-dominant. One species of Special Concern occurs in Long Lake: *Potamogeton vaseyii.* Although the 0-1.5ft depth zone supported the most abundant plant growth, plant growth in Long Lake is sparse (27% of the sites supported vegetation, 16% of the lake was vegetated). All plant species occur at low density or coverage in Long Lake.

The Long Lake aquatic plant community is characterized by excellent species diversity, above average quality, a higher than average sensitivity to disturbance and a closeness to undisturbed condition.

The aquatic plant community has changed in Long Lake, the 1986 and 2005 plant communities only 24% similar. Several measures of the aquatic plant community have shown a cyclic, up and down pattern in Long Lake. In 1986 and 1989, the aquatic plant community appeared to be at its lowest in quality and amount of vegetation. In 2005, every measure of the aquatic plant community increased the highest level recorded in Long Lake. There are several pieces of evidence that rusty crayfish are at least one factor in the cyclic aquatic plant growth in Long Lake.

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

**Recommendations for Lake District Management**

1) Cooperate with efforts to protect the natural landscape in the watershed.
2) Residents use best management practices on shoreline property. Relatively small watershed that is largely protected with natural cover means that shoreline properties play a larger role in protecting the water quality.
3) Residents to preserve the natural vegetation along the lakeshore and replace natural shoreline in areas that have been converted to cultivated lawn. The disturbed shoreline littoral zone is impacted by disturbance, is less diverse and provides less habitat.
4) Lake District initiate and conduct annual monitoring of crayfish populations to correlate with changes in the aquatic plant community.
5) Residents and agencies follow recommendations for the sensitive areas on Long Lake.
6) Continue volunteer water quality monitoring

**Changes in the Aquatic Plant Community of Long Lake,**
**Chippewa County**
**1986-2005**

## I. INTRODUCTION

Studies of the aquatic macrophytes (plants) in Long Lake were conducted August 1986, July 1989, August 1992, July 1995, July 1998, July 2001 and August 2005 by Water Resources staff of the Western Central Region - Department of Natural Resources (DNR). In 1977, Environmental Resource Assessments conducted an aquatic plant survey in Long Lake (Cairns and Sorge 1978), using different methods than those used by the DNR.

The surveys were conducted as part of a Long Term Trend Monitoring Program involving 50 lakes throughout the state. The program was initiated in 1986 to provide long-term chemical and biological data on a variety of Wisconsin lakes. The lakes were selected to represent a wide range in water quality, size and amount of development. Long Lake was included in the program because it exhibited a high potential for change and because of its importance as a regional recreation resource. Aquatic plant data is collected every three years and water quality data is collected every year on the trend lakes.

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

### Background

Long Lake is a 1052-acre groundwater drainage lake located in Chippewa County, Wisconsin. It has a maximum depth of 101 feet and a two foot concrete control structure that is owned by Chippewa County. Cedar Creek flows into the lake along the northwest shore, out of the lake along the northeast shore and eventually into Chain Lake.

The majority of Long Lake's 3930-acre watershed is largely undeveloped forest and wetland. There are 260 acres of wetlands and tamarack bogs adjacent to the lake. (Bernhardt 1984). Because the watershed is relatively small (4:1 watershed to lake ratio) it would not have a major impact on water quality, especially since it is mostly protected by forest and wetland.

### History

Diminishing aquatic plant populations became a concern of local residents during the early- to mid-1960's. While aquatic plants were decreasing, residents noted increasing

populations of rusty crayfish (*Orconectes rusticus*).
The rusty crayfish, a native to Illinois, Indiana, Ohio, Kentucky and Tennessee, is an exotic species in Wisconsin. This species of crayfish was likely introduced through its use as fishing bait (Lorman 1980). Plant material makes up a major portion of the rusty crayfish diet (Magnuson, et. al. 1975). Since, *Orconectes rusticus* has a higher metabolic rate than other species of crayfish, it can eat twice as much plant biomass as some of the native crayfish (Gunderson 1995). Crayfish biomass greater than $9g/m^2$ can reduce plant biomass by 64% and greater than $140g/m^2$ can eliminate all aquatic plants (Miller et. al).

In 1974, a study was sponsored by the National Science Foundation and the Wisconsin Department of Natural Resources to assess the role of crayfish in the decline of aquatic plants. The crayfish study in Long Lake (Magnuson et. al. 1975) indicated:

1) Rusty crayfish density in Long Lake was high, compared to other lakes with rusty crayfish populations.
2) The mean density of rusty crayfish in Long Lake was 51 crayfish per $meter^2$ on rock substrate and 4 crayfish per $meter^2$ on sand substrate. (Rusty crayfish in Long Lake would need to be in the size range of only 2.7-35 grams each to completely eliminate all vegetation in the area in which they occurred.)
3) There was an inverse relationship between crayfish abundance and aquatic plant density. Sites in Long Lake with high crayfish densities lacked plants. Areas of the lake in which crayfish were less abundant supported more vegetation (Magnuson et. al. 1975).

The rusty crayfish dominated the crayfish community in Long Lake, almost to the total exclusion of native crayfish. The 1974-78 crayfish population in Long Lake was estimated at 5.2 million crayfish, with a yearly production of 6700 kg of crayfish tissue per year (dry weight) (Magnuson et. al. 1975).

A Lake District was formed in 1977: Long Lake Inland Lake Management District. It was renamed the Lower Long Lake Protection and Rehabilitation District.

In 2001, a Sensitive Areas Study was conducted on Long Lake by staff of the DNR. Sites that are most important to the habitat and water quality values of Long Lake were identified and mapped. Recommendations for protecting each of the sensitive areas was outlined (Konkel 2001).

## II. METHODS

### Field Methods

The same study design and transects were used for the 1986-2005 aquatic plant studies. The design was based on the rake-sampling method developed by Jessen and Lound (1962). Twenty-seven equal-distance transects were placed perpendicular to the shoreline with the first transect being randomly placed (Appendix XXII).

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

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

The sediment type at each sampling site was recorded. Visual inspection and periodic samples were taken between transect lines in order to record the presence of any species that did not occur at the sampling sites. Specimens of all plants 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 estimated percentage of cover types within this 100' x 30' rectangle was recorded.

### Data Analysis

Data for each year was analyzed separately and compared.
The percent frequency of occurrence of each species was calculated (number of sampling sites at which it occurred / total number of sampling sites) (Appendices I-VII). Relative frequency was calculated (the number of occurrences of a species / sum of all species occurrences) (Appendices I-VII). The mean density was calculated for each species (sum of a species' density ratings / number of sampling sites) (Appendices VIII-XIV). Relative density was calculated (the sum of the density ratings of a species / sum of all plant densities) (Appendices VIII-XIV). "Mean density where present" was calculated for each species (sum of a species' density ratings / number of sampling sites at which that species occurred) (Appendices VIII-XIV). The relative frequency and relative density were summed to obtain a dominance value (Appendices XV-XXI). Simpson's Diversity Indices were calculated for each sampling year $1-(\sum(\text{Relative Frequency}^2))$ (Appendices I-VII).

Each sampling year was compared by a Coefficient of Community Similarity.
The Aquatic Macrophyte Community Index (AMCI), developed for Wisconsin lakes by Nichols (2000), was applied to Long Lake. Seven parameters that characterize the aquatic plant community (Table 8) are measured and the data for each is converted to a value 0 – 10 and summed.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated for each sampling year to measure disturbance in the plant community (Nichols 1998). A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in a relatively undisturbed habitat; the Average Coefficient of Conservatism is the mean of the coefficients for each species found in a lake; Floristic Quality Index is calculated from the Average Coefficient of Conservatism.

## III. RESULTS

### PHYSICAL DATA

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

**WATER QUALITY** - The trophic state of a lake is an indication of its water quality. Phosphorus concentration, chlorophyll concentration, and water clarity data are collected and combined to determine the trophic state.
**Oligotrophic lakes** have low nutrients and biomass, supporting smaller populations of fish.
**Eutrophic lakes** have high nutrients and biomass and often experience algal blooms.
**Mesotrophic lakes** are intermediate in nutrient and biomass.

The DNR has collected water quality data on Long Lake as part of the Long-Term Trend Monitoring Program.

Water chemistry data was collected by volunteer lake monitors in the Self Help Volunteer Lake Monitoring Program. Pete Scolaro collected water clarity data from 1994-1999. Lou Frase, collected water clarity data 1999-present and started collecting water chemistry data in 2001. The volunteer data is valuable in that it is collected more frequently, augments the data points collected by the DNR and is collected for continuous years.

#### Nutrients

Phosphorus is the limiting nutrient in many Wisconsin lakes. This means that the addition or reduction of phosphorus is the nutrient that will have the most impact on water quality. Therefore, phosphorus concentrations are measured as an indication of the nutrient status of a lake. The phosphorus concentrations in Long Lake, 2004-2005, volunteer and DNR data indicates that Long Lake is a mesotrophic range (Table 1).

**Table 1. Trophic Status, 2005**

| | Quality Index | Phosphorus ug/l | Chlorophyll ug/l | Secchi Disc ft. |
|---|---|---|---|---|
| Oligotrophic | Excellent | <1 | <1 | > 19 |
| | Very Good | 1-10 | **1-5** | **8-19** |
| Mesotrophic | Good | **10-30** | **5-10** | 6-8 |
| | Fair | 30-50 | 10-15 | **5-6** |
| Eutrophic | Poor | 50-150 | 15-30 | 3-4 |
| Hypereutrophic | Very Poor | >150 | >30 | >3 |
| Long Lake – DNR data, 2004 | Good | 18 | 2.6 | 5.7 |
| Long Lake – Volunteer data 2005 | Good | 18.7 | 6.4 | 12 |

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

### Algae

Algae cells contain chlorophyll, so chlorophyll concentrations are measured to indicate algae concentrations. Chlorophyll in Long Lake during 2004-05 was in the oligotrophic/mesotrophic range (Table 1).

Both phosphorus and chlorophyll have varied between oligotrophic/mesotrophic status during the trend studies (Figure 1). In 1992, there was unusually high chlorophyll (Figure 1). Chlorophyll decreased to the lowest concentrations recorded in 2002. Both chlorophyll and phosphorus have declined since 1986, phosphorus has declined very slightly.

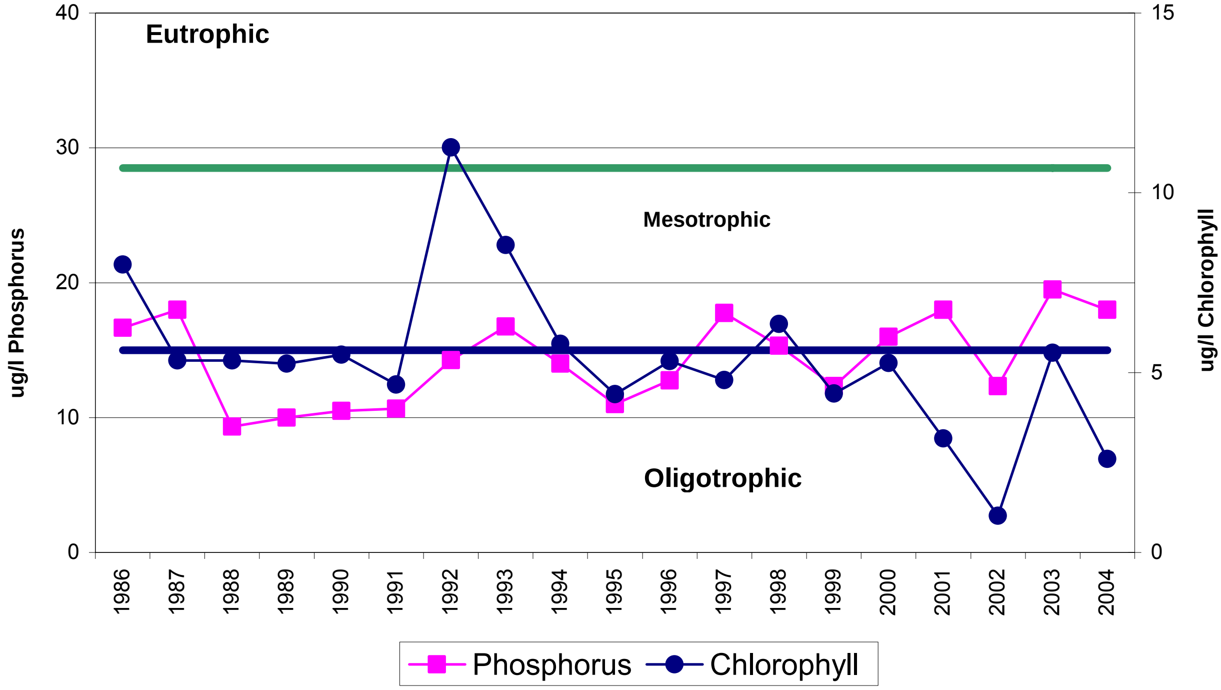



**Figure 1. Mean summer phosphorus and chlorophyll in Long Lake, 1986-2004.**

### Water Clarity

The light availability is a critical factor for plant growth (Chambers and Kalff 1985, Duarte et. al. 1986, Kampa 1994). Aquatic plants cannot survive when they receive less than 1-2% of the available surface light. Water clarity is impacted by a combination of color (dissolved materials) and turbidity (suspended materials). A Secchi Disc measures the combined effects of color and turbidity.

Water clarity in Long Lake was in the oligotrophic range in 2005 according to volunteer data and in the mesotrophic range in 2004 according to DNR data. The differences could be due to differences in the conditions for two different years or differences in the breadth of the data. The DNR data was collected only twice, in July and August and the volunteer data was collected over the entire growing season.

Since 1985, water clarity has had good clarity several years and has been in the oligotrophic range most years. Water clarity has increased slightly since 1985 (Figure 2).

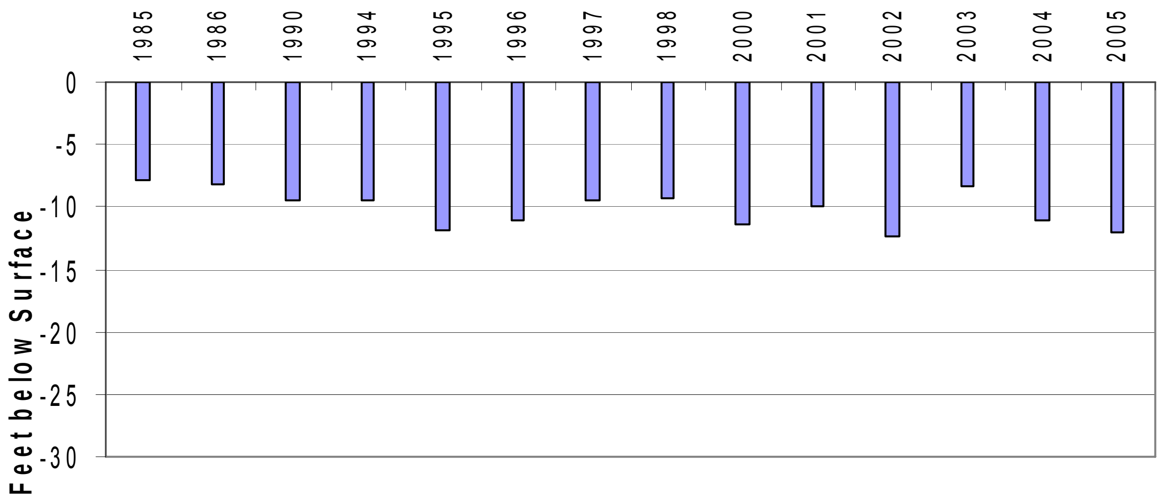



**Figure 2. Water clarity (Secchi Disc) in Long Lake, 1986-2005.**

The combination of 2004-2005 phosphorus (nutrient), chlorophyll (algae) and water clarity data places Long Lake in the mesotrophic range with good water quality.

Data collected at the same time of the year was averaged to show the change in water clarity during the year in Long Lake (Figure 3). Water clarity increases from good to very good clarity in the spring. During the summer, as the water warms and creates ideal conditions for algae reproduction, water clarity decreases to poor clarity and as the water cools again in the fall, increases again to good clarity.

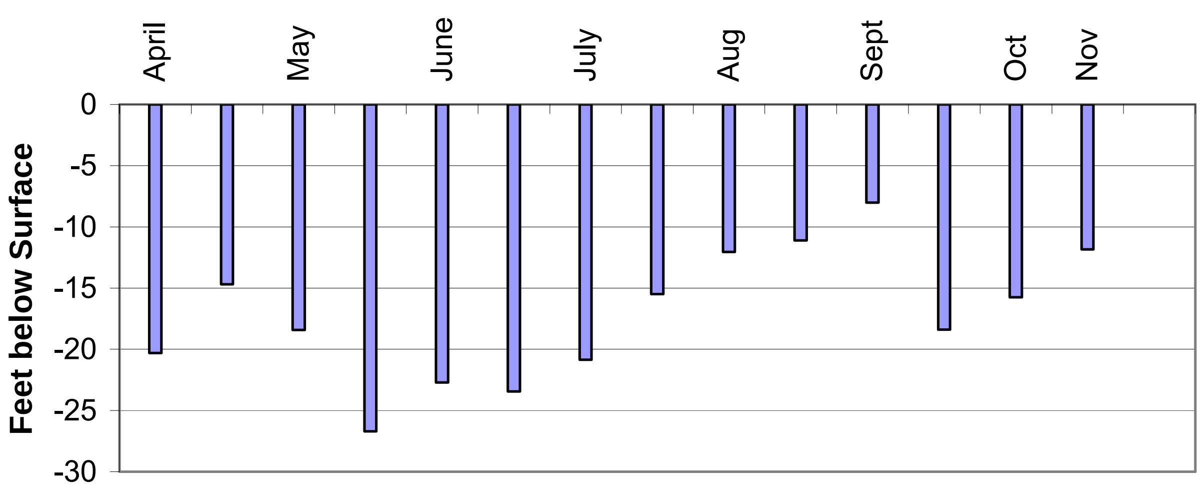



**Figure 3. Change in mean water clarity during the season, Long Lake.**

### Hardness

Hardness is affected by the type of minerals in the soil and bedrock and how often the water comes in contact with the soil/bedrock. The water hardness in Long Lake, as measured by the amount of calcium carbonate in a volume of water, during the 17-year study has varied from 46 to 62 mg/l CaCo3. Water with hardness values of 0-60mg CaCO3/l is considered soft (Shaw et. al. 1993). Soft water lakes such as Long Lake have a high sensitivity to the effects of acid rain and tend to have less plant growth.

### Lake Morphometry

The morphometry of a lake impacts the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone accounted for 72% of the observed variability in the growth of submergent vegetation. Steep slopes often inhibit the rooting success of plants; gentle slopes support a broad zone of potential plant growth (Engel 1985).

About 40% of the littoral zone in Long Lake is steeply-sloped, the southwest end of Long Lake is the steepest (Appendix XXII). This limits the area suitable for colonization by aquatic plants. More gradually sloped lake bottoms in the rest of the lake could be more conducive to plant growth.

### SEDIMENT COMPOSITION

Sand was the dominant sediment at the sample sites (Table 2) and occurred throughout the lake, most abundant in the 1.5-5ft depth zones. In the 0-1.5 ft depth zone, sand mixed with rock was more abundant and sand mixed with gravel was common.

Rock and gravel mixtures were also common or dominant in the 0-1.5ft depth zone; sand and rock mixtures were common in the 1.5-5ft depth zone (Table 2) (Figure 4).

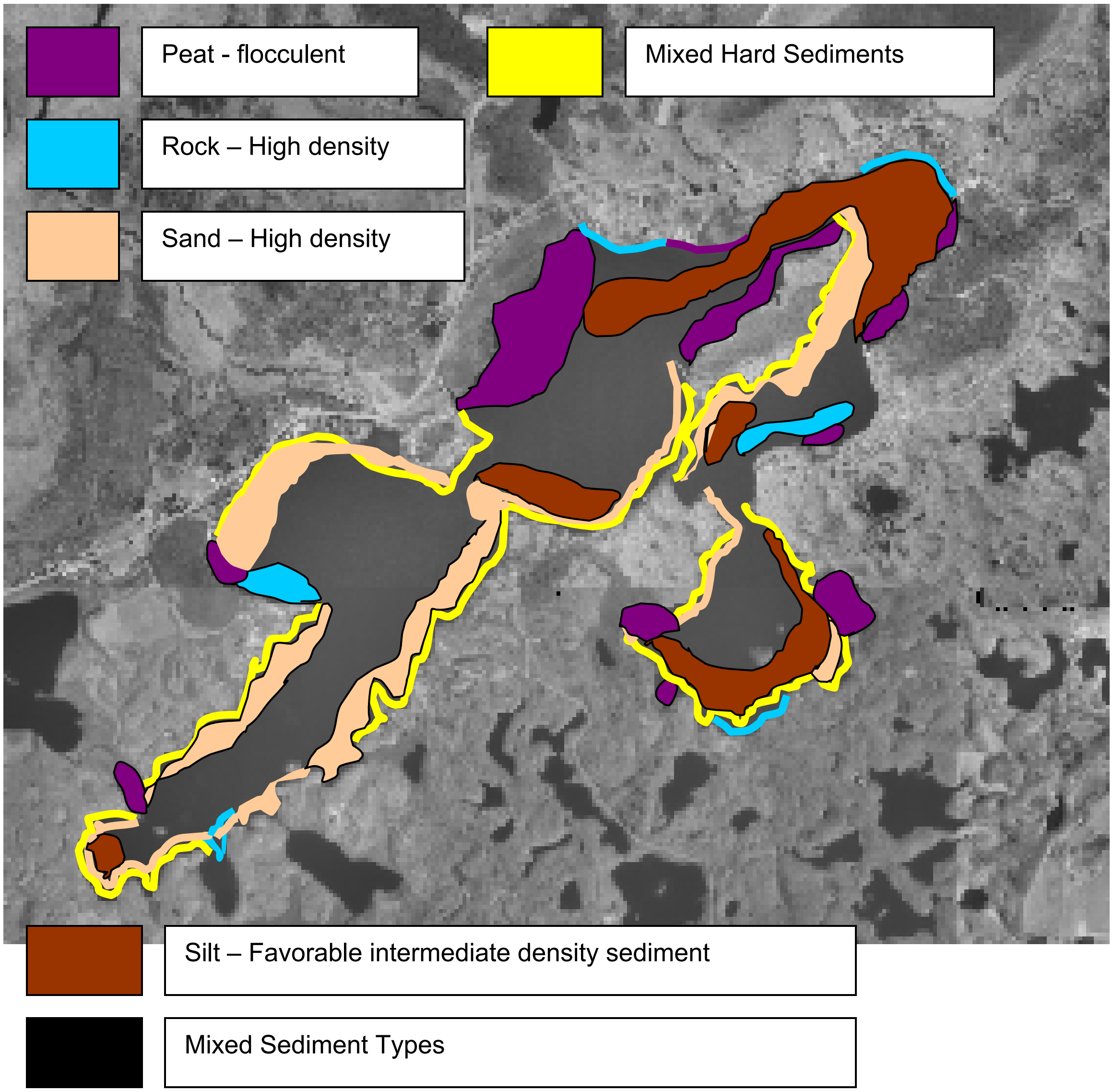



**Figure 4. Distribution of sediment types in Long Lake, Chippewa County 2005.**

**Table 2. Sediment Composition 2005**

| Sediment | | 0.1.5ft | 1.5-5ft | 5-10ft | 10-20ft | Overall |
|---|---|---|---|---|---|---|
| **Hard Sediments** | **Sand** | 4% | 44% | 26% | 29% | 26% |
| | **Sand/rock** | 33% | 11% | 22% | 4% | 18% |
| | **Rock** | 18% | 7% | 11% | 4% | 10% |
| | **Sand/gravel** | 22% | 4% | | | 7% |
| **Mixed Sediments** | **Sand/silt** | 4% | 4% | 7% | 12% | 7% |
| | **Sand/peat** | | | | 12% | 3% |
| **Soft Sediments** | **Peat** | 11% | 11% | 11% | 8% | 10% |
| | **Silt** | | 11% | 22% | 29% | 15% |
| | **Silt/peat** | | 7% | | | 2% |
| | **Muck** | 7% | | | | 2% |

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

The availability of mineral nutrients for plant growth is highest in sediments of intermediate density such, as silt (Barko and Smart 1986), but silt occurred infrequently in Long Lake and only in the deeper zones (Table 3).

Rock, sand and gravel sediments can be nutrient limiting due to their high density (Barko and Smart 1986). Sand sediments, which were the dominant sediments in Long Lake, supported some vegetation (8% of the sand sites were vegetated) (Table 3). Rock, sand and gravel mixtures were also commonly encountered and infrequently supported vegetation.

Peat sediments can be too flocculent for effective rooting of vegetation but supported vegetation at half the sites on which peat occurred (Table 3). Silt and peat mixtures and organic muck sediment supported the highest percentage of vegetation (100% vegetated). The silt mixed with the peat may add enough firmness to provide a more favorable rooting substrate. However, peat and sand mixtures were not commonly occurring (Table 2).

**Table 3. Aquatic Plant Occurrence at Sediment Types, 2005.**

| Sediment Category | | Frequency of Occurrence of Sediment | % Vegetated |
|---|---|---|---|
| Hard Sediments | Sand/gravel | 7% | 28% |
| | Sand/rock | 18% | 10% |
| | Sand | 26% | 8% |
| | Rock | 10% | 0% |
| Mixed Sediments | Sand/silt | 3% | 43% |
| | Sand/peat | 1% | 33% |
| Soft Sediments | Muck | 2% | 100% |
| | Silt/Peat | 2% | 100% |
| | Peat | 10% | 54% |
| | Silt | 15% | 25% |

## SHORELINE LAND USE

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

Native herbaceous plant cover was the most frequently encountered shoreland use in 2005 and wooded cover had the highest mean coverage at the transects in Long Lake (Table 4). Native herbaceous cover has increased since 1995, but shrub and wooded cover has decreased.

Disturbed shoreline commonly occurred; cultivated lawn, hard structure and eroded areas (Table 4).

**Table 4. Shoreline Land Use, 1995-2005**

| Cover Type | | Mean Coverage | | | Frequency of Occurrence |
|---|---|---|---|---|---|
| | | 1995 | 2001 | 2005 | 2005 |
| Natural Shoreline | Wooded | 53% | 56% | 43% | 82% |
| | Shrub | 21% | 12% | 11% | 66% |
| | Native Herbaceous | 13% | 12% | 20% | 92% |
| Total | | 87% | 80% | 74% | |
| Disturbed Shoreline | Cultivated Lawn | 9% | 13% | 14% | 30% |
| | Hard Structure | 2% | 2% | 4% | 26% |
| | Bare Soil | 1% | 1% | 4% | 22% |
| | Rip-rap | | 1% | 1% | 15% |
| | Road | 1% | 3% | 2% | 7% |
| Total | | 13% | 20% | 25% | |

Some type of natural shoreline was found at all transects n 2005; the coverage of natural shoreline decreased from 87% coverage in 1995; to 80% in 2001; to 74% in 2005.

Some type of disturbed shoreline was encountered at 59% of the sites in 2005 and mean coverage increased from 13% coverage in 1995; to 20% in 2001; to 25% in 2005 (Table 4).

## <u>MACROPHYTE DATA</u>

### SPECIES PRESENT

A total of 40 different species of aquatic plants have been found during the 1986-2005 studies: 19 emergent species, 6 floating leaf species, and 15 submergent species (Table 5).

No endangered, threatened or non-native species were found. One special concern species was found: *Potamogeton vaseyi.* Special Concern Species are species with which there is concern about their lack of abundance or distribution. The main purpose of this designation is to focus attention on these species before they become threatened or endangered.

**Table 5. Long Lake Aquatic Plant Species, 1986-2005**

| Scientific Name | Common Name | I. D. Code |
|---|---|---|
| **Emergent Species** | | |
| 1) *Alnus incana* (L.) Moench. | tag alder | alnin |
| 2) *Asclepias incarnata* L. | swamp milkweed | ascin |
| 3) *Bidens discoidea* (T. & G.) Britton | bur marigold | biddi |
| 4) *Carex* sp. | sedge | carsp |
| 5) *Chamaedaphne calyculata* (L.) Moench. | leatherleaf | chaca |
| 6) *Decodon verticillatus* (L.) Elliott. | swamp loosestrife | decve |
| 7) *Dulichium arundinaceum* (L.) Britton | three-way sedge | dular |
| 8) *Eleocharis palustris* L. | creeping spikerush | elepa |
| 9) *Equisetum fluviatile* L. | water horsetail | equfl |
| 10) *Iris versicolor* L. | northern blue flag | irive |
| 11) *Pontederia cordata* L. | pickerelweed | ponco |
| 12) *Potentilla palustris* (L.) Scop. | marsh cinquefoil | potpa |
| 13) *Sagittaria latifolia* Willd. | common arrowhead | sagla |
| 14) *Sagittaria* sp. | arrowhead | sagsp |
| 15) *Scirpus americanus* Pers. | Olney's threesquare | sciam |
| 16) *Scirpus validus* Vahl. | softstem bulrush | sciva |
| 17) *Thelypteris palustris* Schott. | marsh fern | thepa |
| 18) *Typha angustifolia* L. | narrow-leaf cattail | typan |
| 19) *Typha latifolia* L. | broadleaf cattail | typla |
| **Floating leaf Species** | | |
| 20) *Brasenia schreberi* J. F. Gmelin. | watershield | brasc |
| 21) *Lemna minor* L. | mall duckweed | lemmi |
| 22) *Lemna trisulca* L. | forked duckweed | lemtr |
| 23) *Nuphar variegata* Durand. | bull-head pond lily | nupva |
| 24) *Nymphaea odorata* Aiton. | white water lily | nymod |
| 25) *Spirodela polyrhiza* (L.) Schleiden. | great duckweed | spipo |
| **Submergent Species** | | |
| 26) *Ceratophyllum demersum* L. | coontail | cerde |
| 27) *Elodea canadensis* Michx. | common waterweed | eloca |
| 28) *Myriophyllum tenellum* Bigelow. | dwarf water milfoil | myrte |
| 29) *Najas flexilis* (Willd.) Rostkov & Schmidt. | slender naiad | najfl |
| 30) *Potamogeton amplifolius* Tuckerman. | large-leaf pondweed | potam |
| 31) *Potamogeton epihydrus* Raf. | ribbon-leaf pondweed | potep |
| 32) *Potamogeton foliosus* Raf. | leafy pondweed | potfo |
| 33) *Potamogeton gramineus* L. | variable-leaf pondweed | potgr |
| 34) *Potamogeton illinoensis* Morong. | Illinois pondweed | potil |
| 35) *Potamogeton pusillus* L. | small pondweed | potpu |
| 36) *Potamogeton robbinsii* Oakes. | fern pondweed | potro |
| 37) *Potamogeton spirillus* Tuckerman. | n. snail-seed pondweed | potsp |
| 38) *Potamogeton vaseyi* Robbins. | Vasey's pondweed | potva |
| 39) *Potamogeton zosteriformis* Fern. | flatstem pondweed | potzo |
| 40) *Vallisneria americana* L. | water celery | valam |

## FREQUENCY OF OCCURRENCE

The frequency of aquatic plant species in Long Lake varied among the survey years. The most frequent species during one sample year sometimes did not occur at any sample sites in another year. The overall low occurrence and sparse growth of aquatic plants is probably the reason for this variability. Even small increases in frequency of these sparse species could result in the species having the highest frequency in the lake.

In 1986, *Nuphar variegata* was the most frequent species and has remained at stable frequencies (Table 6).

In 1989, *Ceratophyllum demersum, Eleocharis palustris* and *Potamogeton amplifolius* became the most frequent species.

In 1992 and 1998, *Pontederia cordata* was the most frequent species but occurred at lower frequencies other years.

In 1995, *Elodea canadensis* and *Potamogeton epihydrus* were the most frequent species (Table 6).

In 2001, *Scirpus validus* was the most frequent species: this species had occurred at lower frequencies in previous studies and declined again in 2005.

In 2005, *Potamogeton robbinsii* and *P. zosteriformis* increased and became the most frequently occurring species (Table 6).

**Table 6. Frequencies of Prevalent Aquatic Plants in Long Lake 1986-2005.**

| Species | 1986 | 1989 | 1992 | 1995 | 1998 | 2001 | 2005 |
|---|---|---|---|---|---|---|---|
| *Ceratophyllum demersum* | 0.9% | **1.8**% | 2.8% | 1.8% | 0.9% | 1.9% | 4.8% |
| *Eleocharis palustris* | | **1.8%** | | | 0.9% | 0.9% | |
| *Elodea canadensis* | | | 2.8% | **3.7%** | 0.9% | | 4.8% |
| *Nuphar variegata* | **1.8%** | | 1.8% | 0.9% | 1.8% | 1.9% | 1.0% |
| *Pontederia cordata* | 0.9% | 0.9% | **5.6%** | 0.9% | **2.8%** | 1.9% | 1.0% |
| *Potamogeton amplifolius* | | **1.8%** | 3.7% | 1.8% | 1.8% | | 2.9% |
| *Potamogeton epihydrus* | | 0.9% | 3.7% | **3.7%** | 1.8% | 1.9% | 4.8% |
| *Potamogeton robbinsii* | | | | | 1.8% | 1.9% | **5.7**% |
| *Potamogeton zosteriformis* | | | 2.8% | 1.8% | 0.9% | 2.8% | **5.7%** |
| *Scirpus validus* | 0.9% | 0.9% | 1.8% | | | **4.7%** | 1.9% |

The occurrence of filamentous algae has also been cyclic (Figure 5). The lowest occurrence of filamentous algae was in 1989 (4%) and the highest occurrence of filamentous algae was in 1995 (17%) (Figure 5).

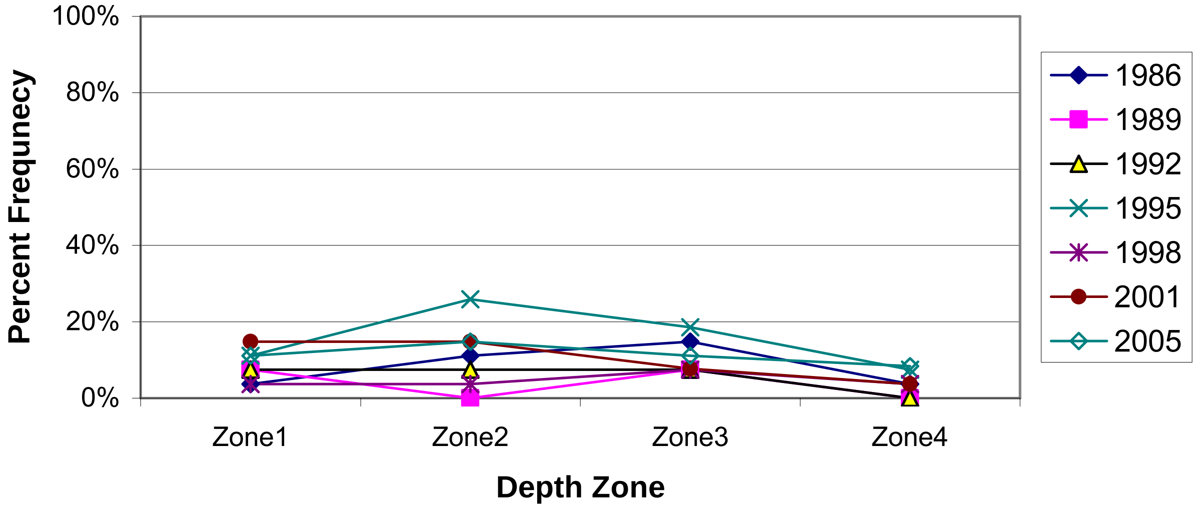



**Figure 5. Occurrence of filamentous algae in Long Lake by depth zone, 1986-2005.**

### DENSITY

The mean density of aquatic plants in Long Lake has varied, but all plant densities have been low (Appendix VIII-XIV). The highest mean density of any species was *Pontederia cordata* (0.15 on a scale of 0-5) in 1992.

"Density where present" measures how dense of a growth form a species exhibits. The species in Long Lake have a low frequency and low mean density over the lake, but where some species occur, they may exhibit a dense form of growth in some years. Different species have exhibited dense growth forms ("density where present" > 2.5) in different year. Many species have cycled between dense and sparse growth forms from year to year. This could indicate that there is a real change in a species growth, or that the transects are shifting slightly and recording different plant beds in different years.

### DOMINANCE

The dominance value illustrates the dominance a species within the community. Any discussion of the dominance of aquatic plant species in Long Lake must be with the understanding that overall frequency and density of aquatic plants in Long Lake is low and small changes in the frequency or density of species can change the dominance of individual species.

The dominant species have varied over the study years (Figure 6). *Nuphar variegata* and *Pontederia cordata* were the dominant species in 1986. *Potamogeton amplifolius* was the dominant species in 1989; *Pontederia cordata* was again dominant in 1992;

*Elodea canadensis* was the dominant species in 1995; *P. cordata* was the dominant species again in 1998; *Scirpus validus* was the dominant species in 2001 and *Potamogeton robbinsii* was the dominant species in 2005 with *P. epihydrus* as sub-dominant (Figure 6).

## DISTRIBUTION

Aquatic plant growth in Long Lake has occurred at depths up to 15 feet, in scattered beds. The littoral zone has had sparse aquatic plant growth, but in 2005, the plant growth appeared to be noticeably increased, although still sparse. In 2005, aquatic plants occurred at only 27% of the sampling sites, approximately 170 acres (16%) of the lake was colonized by aquatic plant growth (Figure 7). Of this, 38 acres (4%) was emergent plant growth, 48 acres (5%) was floating-leaf plant growth and 64 acres (6%) was submergent plant growth. Most plant growth is in the north end of the lake and in the southeast section, referred to as Herde Lake (Figure 7).

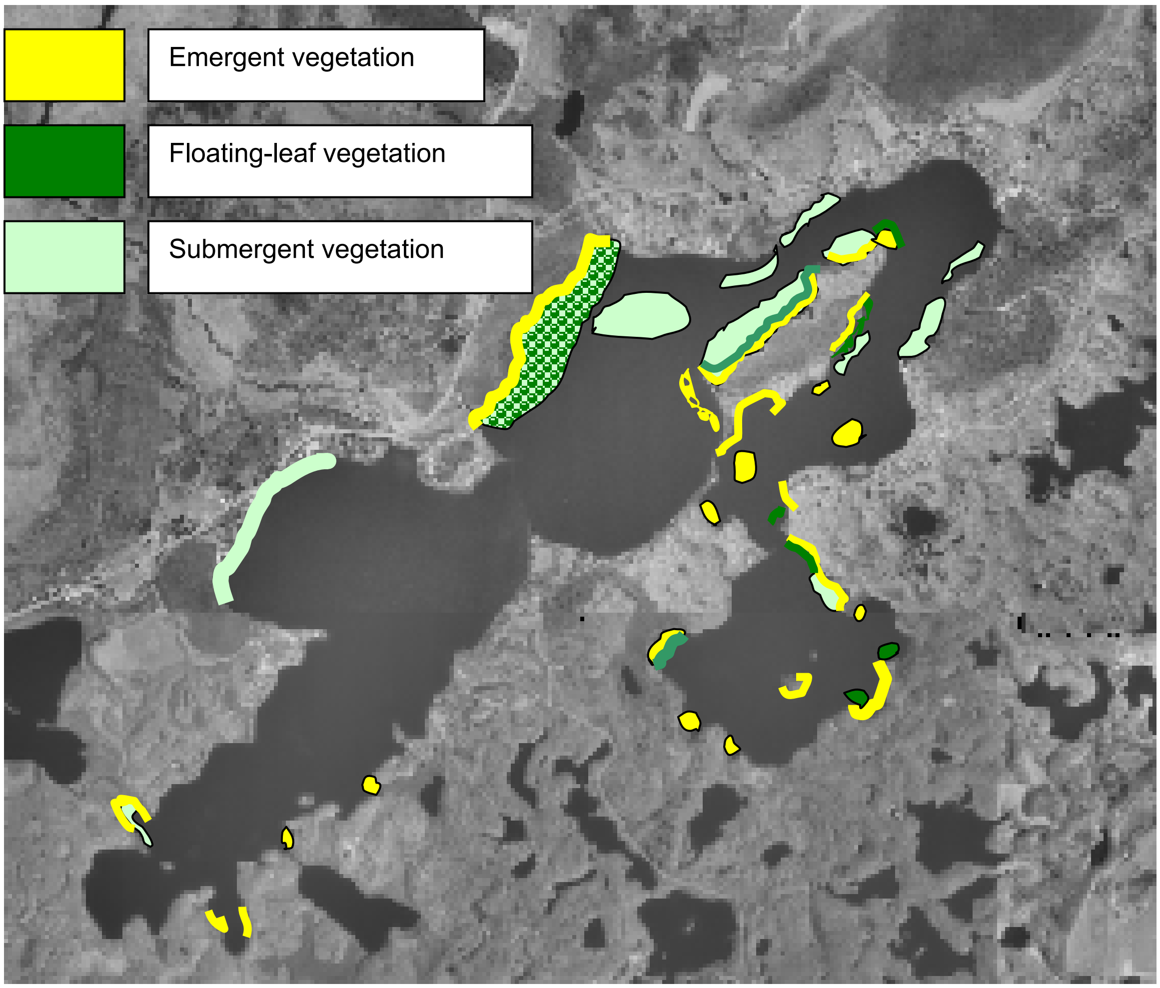



**Figure 7. Distribution of aquatic vegetation in Long Lake, August 2005.**

The highest percent of vegetated sites has varied between the 0-1.5ft and the 1.5-5ft depth zones in different study years (Figure 8). In 2005, the percent of vegetated sites increase in all depth zones.

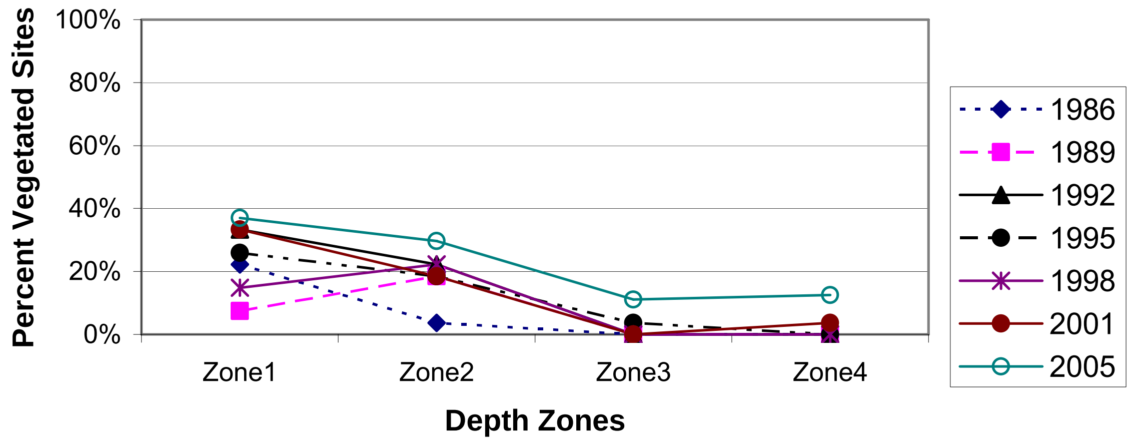



**Figure 8. Percentage of littoral zone that is vegetated in Long Lake, by depth zone, 1986-2005.**

The zone with the highest total occurrence (Figure 9) and total density (Figure 10) of aquatic plant growth varied between the first two depth zones during the study years. The highest total occurrence and density of plant growth was in 2005 and the lowest in 1986.

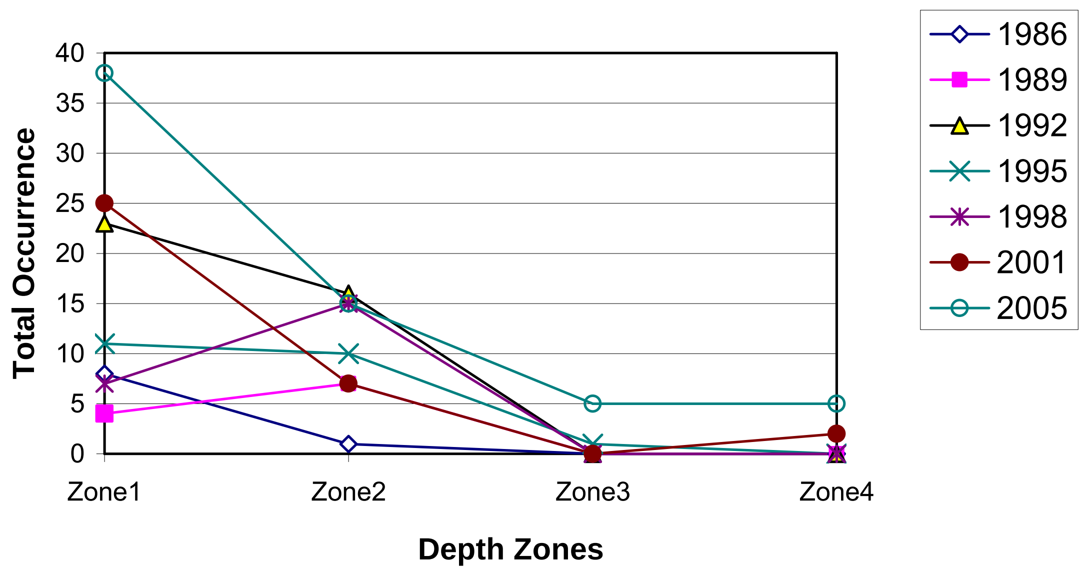



**Figure 9. Total occurrence of aquatic plants by depth zone, 1986-2005.**

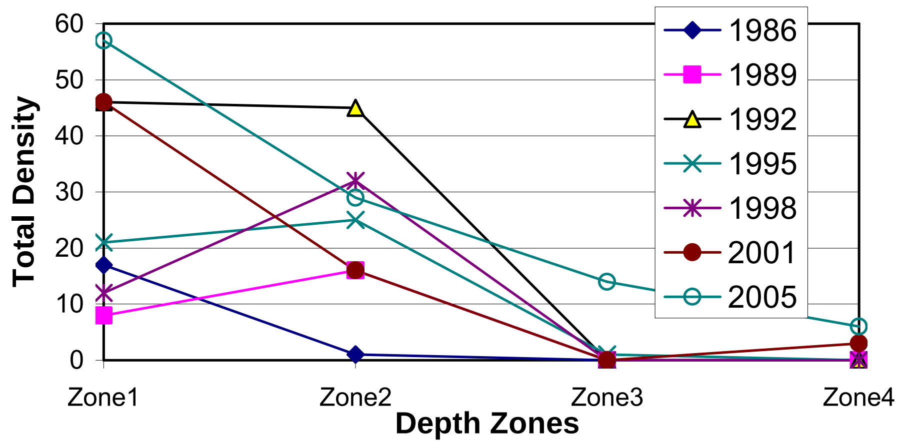



**Figure 10. Total density of aquatic plants by depth zone, 1986-2005.**

The depth zone with the greatest species richness in Long Lake has generally been in the 0-1.5ft depth zone. The lowest species richness was in 1986 and 1989. The greatest species richness was in 2005 (Figure 11).

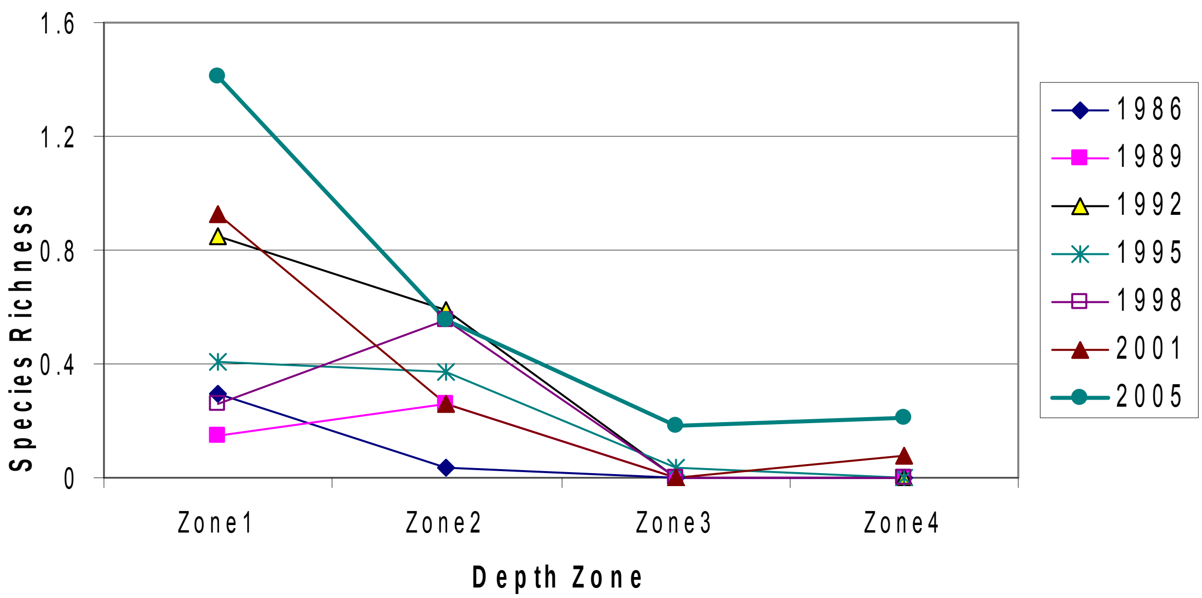



**Figure 11. Species Richness (mean number of species per sample site) by depth zone in Long Lake, 1986-2005.**

Aquatic plant distribution patterns have varied in Long Lake over the years. Maps drawn in conjunction with aquatic plant surveys provide an approximation of plant colonization (Konkel 1999). The 2001 map (Figure 12) indicates more plant beds of smaller sizes than the earlier maps (1939 – 1998) (Konkel 1999). Plant beds appeared to be cycling between periods of sparse growth and periods of even sparser growth. This cycling may be due to natural phenomena or human-induced disturbances (Konkel 1999). The aquatic plant distribution in Long Lake in 2005 appears to be at the highest colonization in the history of recorded plant distribution (Figure 7).

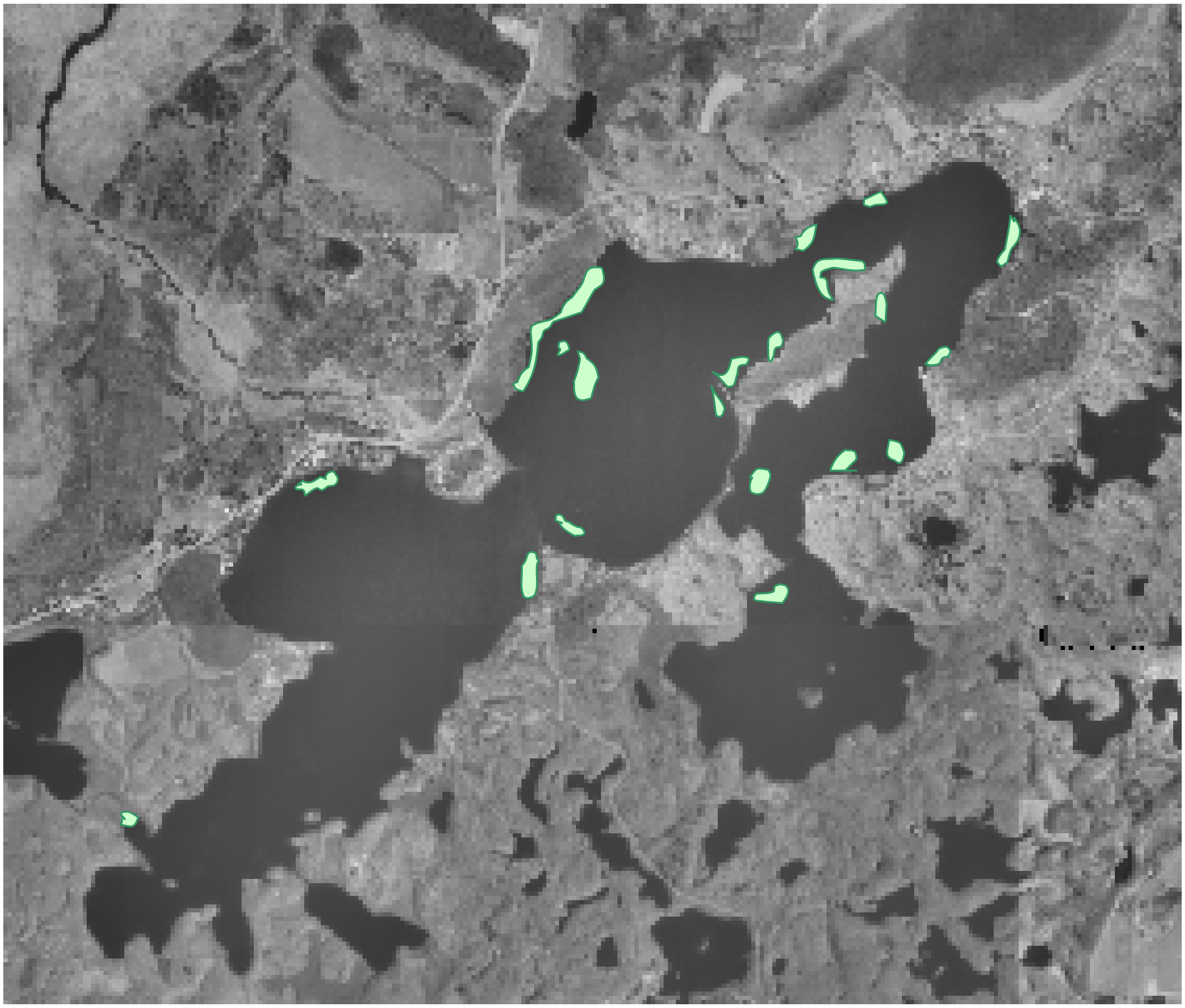


**Figure 12. Distribution of plant beds in Long Lake, 2001.**

The predicted maximum rooting depth can be calculated from water clarity data (Dunst 1982).

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

During 1986-1998, the actual maximum rooting depth had remained constant, 3-3.5 feet, and much less than the predicted maximum rooting depth (Figure 13). In 2001, the maximum rooting depth of plant growth increased substantially to 15 feet; when *Myriophyllum tenellum* and *Sagittaria* sp., small rosette species, were recorded at 15 feet. The maximum rooting depth in 2001 was in the predicted range of 11.7 to 17.7 feet, based on water clarity (Figure 13). In 2005, the maximum rooting depth was 13.5 feet with *Elodea canadensis* and *Potamogeton zosteriformis* at the maximum depth.

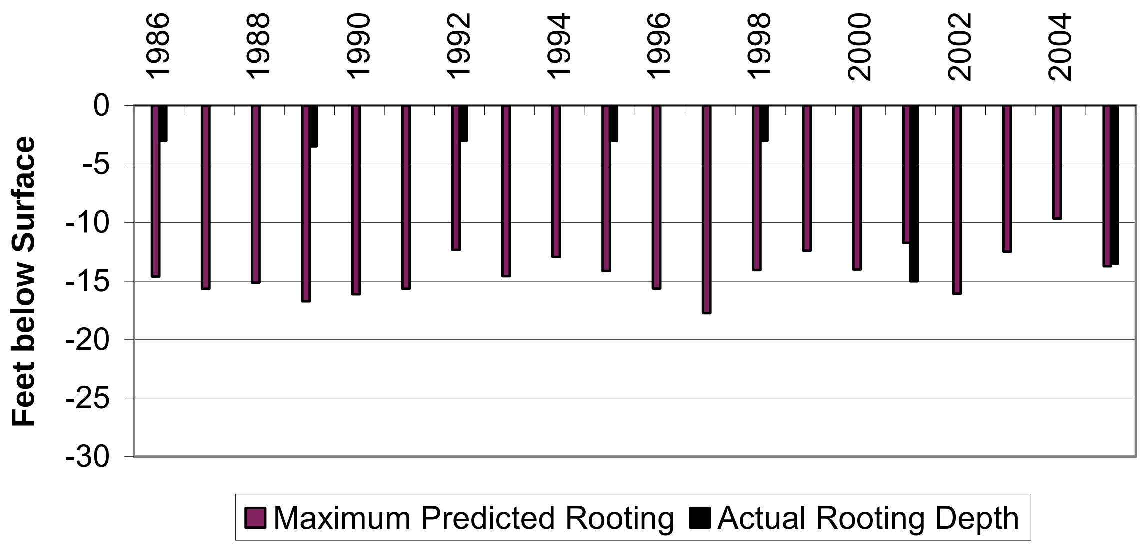



**Figure 13. Maximum rooting depth of aquatic plants in Long Lake, 1986-2005.**

**MACROPHYTE COMMUNITY**

The Coefficients of Community Similarity indicate that the aquatic plant community in Long Lake has changed significantly (Table 7). The aquatic plant community appeared to be undergoing significant change each year during 1986-2005, with no community being more than 64% similar to the previous community and some communities only 38% similar to the previous community.

The accumulated changes during the study years has resulted in the most recent 2005 plant community being only 24% similar to the community of 1986 (Table 7).

**Table 7. Coefficients of Community Similarity, 1986-2005.**

| Years compared | Coefficient | Percent Similarity* |
|---|---|---|
| 1986-89 | 0.384 | 38% |
| 1989-92 | 0.490 | 49% |
| 1992-95 | 0.638 | 64% |
| 1995-98 | 0.455 | 46% |
| 1998-2001 | 0.505 | 50% |
| 2001-2005 | 0.482 | 48% |
| 1986-2005 | 0.238 | 24% |

* - Communities that are less than 75% similar are considered significantly different.

Several parameters and indices can be used to assess the aquatic plant community and determine what changes have occurred within the community.

In Long Lake, several parameter increased from 1986-1992, declined in 1995 and subsequently increased through 1998-2005: number of species recorded, diversity index, percent of the littoral zone vegetated, percent cover of emergent species, quality of the aquatic plant community (AMCI Index) and Floristic Quality (measuring disturbance in the community, discussed later) (Table 8).

The maximum rooting depth in Long Lake had remained fairly stable, until a dramatic increase in 2001-05. Two small rosette/turf species were recorded at depths of 15 feet in 2001 and a pondweed and common waterweed in 2005 (Table 8).

Some parameters increased dramatically in 2005: the percent cover of free-floating species, percent cover of floating-leaf species a nd the percent cover of submergent species (Table 8).

**Table 8. Changes in the Macrophyte Community, 1986-2005.**

| | 1986 | 1989 | 1992 | 1995 | 1998 | 2001 | 2005 | %Change 1986-2005 |
|---|---|---|---|---|---|---|---|---|
| Number of Species | 8 | 8 | 17 | 11 | 16 | 18 | 25 | 212% |
| Maximum Rooting Depth | 3.0 | 3.5 | 3.0 | 3.0 | 3.5 | 15.0 | 13.0 | 333% |
| % of Littoral Zone Vegetated | 6.5 | 6.5 | 13.9 | 12.0 | 9.3 | 15.0 | 26.7 | 310% |
| %Sites/Emergents | 2.8 | 3.7 | 9.3 | 4.6 | 5.6 | 9.3 | 8.6 | 207% |
| %Sites/Free-floating | 1.9 | 1.9 | 2.8 | 1.9 | 0.9 | 0.9 | 4.8 | 152% |
| %Sites/Submergent | 0.9 | 1.9 | 6.5 | 7.4 | 4.6 | 5.6 | 16.2 | 1700% |
| %Sites/Floating-leaf | 1.9 | 0.0 | 1.9 | 0.9 | 1.9 | 0.9 | 2.9 | 53% |
| AMCI | 31 | 33 | 42 | 36 | 42 | 49 | 52 | 68% |
| Simpson's Diversity Index | 0.86 | 0.86 | 0.92 | 0.88 | 0.93 | 0.93 | 0.94 | 9% |
| Ave. Coefficient of Conserv | 6.13 | 5.75 | 6.19 | 6.00 | 6.38 | 6.33 | 6.16 | 0.5% |
| Floristic Quality Index | 17.32 | 16.26 | 24.75 | 18.97 | 25.00 | 26.87 | 30.80 | 78% |

The aquatic plant community in 1986-89 appeared to be at its lowest level. The fewest number of species, the smallest percent of the littoral zone vegetated, the smallest percent coverage of emergent species and submergent species, the lowest diversity and the lowest floristic quality (highest disturbance) occurred during 1986-1989 (Table 8).

The aquatic plant community in 2005 was characterized by the greatest number of species, the highest percentage of the littoral zone vegetated, the highest species diversity, the highest floristic quality, the greatest quality (AMCI discussed later) and the greatest coverage of submergent species (Table 8).

Overall, all parameters had increased between 1986 and 2005. The coverage of submergent species increased the most between 1986 and 2005, a seventeen-fold increase. Simpson's Diversity indices in Long Lake increased from fair diversity in 1986 to excellent diversity in 2005 (Table 8).

According to the Aquatic Macrophyte Community Index (AMCI), the quality of the aquatic community in Long Lake has been improving. In 1986-1998, Long Lake was in the lowest quartile of lakes in Wisconsin and the Northern Lakes and Forest Region, the group of lakes with the lowest quality aquatic plant community. In 2001, the quality increased to below average for the state and region. In 2005, the quality of the plant community continued to increase and is above average quality for Wisconsin lakes (Table 9).

**Table 9. Aquatic Macrophyte Community Index Values for Long Lake, 1986-2005.**

| | 1986 | 1989 | 1992 | 1995 | 1998 | 2001 | 2005 |
|---|---|---|---|---|---|---|---|
| Maximum Rooting Depth | 1 | 1 | 1 | 1 | 1 | 9 | 7 |
| % Littoral Zone Vegetated | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| Relative Frequency of Submersed Species | 1 | 1 | 3 | 1 | 2 | 1 | 3 |
| # of Taxa | 3 | 3 | 8 | 5 | 8 | 8 | 9 |
| Exotic Species | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Simpson's Diversity Index | 7 | 7 | 9 | 8 | 10 | 10 | 10 |
| Relative Frequency of Sensitive Species | 8 | 10 | 10 | 10 | 10 | 10 | 10 |
| Total | 31 | 33 | 42 | 36 | 42 | 49 | 52 |

The maximum AMCI value is 70

The sparse colonization of aquatic vegetation in the littoral zone and low ratio of submergent vegetation are still limiting the quality of the aquatic plant community in Long Lake (Table 9).

The Average Coefficient of Conservatism for the Long Lake aquatic plant community was above the mean for Wisconsin lakes in 1986, decreased to below the mean in 1989, and increased to above the mean in 1992-2005 (Table 10). However, compared to lakes in the Northern Lakes and Forest Region, Long Lake was below the mean in 1986, decreased into the lowest quartile in 1989-1995 and below the mean in 1998-2005. (Table 10).

This indicates that the plant community in Long Lake has been cycling in its disturbance tolerance, likely due to a fluctuating amount of disturbance within Long Lake. The plant community is more tolerant of disturbance than the average lake in the state or region.

**Table 10. Floristic Quality and Coefficients of Conservatism of Long Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.**

| | (C) Average Coefficient of Conservatism † | (I) Floristic Quality ‡ |
|---|---|---|
| Wisconsin Lakes | 5.5, 6.0, 6.9* | 16.9, 22.2, 27.5* |
| NLFL | 6.1, 6.7, 7.7* | 17.8, 24.3, 30.2* |
| Long Lake, 1986-2005 | | |
| 1986 | 6.13 | 17.32 |
| 1989 | 5.75 | 16.26 |
| 1992 | 5.82 | 24.01 |
| 1995 | 6.00 | 18.97 |
| 1998 | 6.38 | 25.50 |
| 2001 | 6.33 | 26.87 |
| 2005 | 6.16 | 30.80 |

- - upper limit of lower quartile, mean and lower limit of upper quartile

(NLFL) The North Lakes and Forest Region is the region in which Long Lake is located.

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

‡ - The lowest Floristic Quality in Wisconsin lakes 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 Long Lake followed the same fluctuating pattern as seen with the Average Coefficients of Conservatism. Compared to lakes in the Northern Lakes and Forest Region, Long Lake was in the lowest quartile in 1986-1989, increased to below the mean in 1992-1995, increased to above the mean in 1998-2001 and increased into the upper quartile again in 2005 (Table 10).

This suggests that the plant community in Long Lake has been cycling in its closeness to an undisturbed condition. This is likely due to cyclic disturbance in Long Lake. More recently, it appears that Long Lake is recovering from disturbance and in 2005 was in the upper quartile of lakes in the state and region, the group of lakes closest to an undisturbed condition.

Disturbances can be of many types:

1) Biological disturbances include the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by the fish population.
2) 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.
3) Indirect disturbances can be the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation

from erosion, increased algae growth due to nutrient inputs.

Major disturbances in Long Lake are likely damage to the plant beds by a population of non-native crayfish and shoreline development.

Plant communities change because the species within the community change. In Long Lake the biggest changes have been in new species appearing. Since the first survey in 1986, 18 additional species have been recorded in Long Lake, 8 of these species were found for the first time in 2005. Besides the new species that have been found, 5 species have increased in frequency and density since 1986, *Ceratophyllum demersum* has increased the most with a 4-fold increase in frequency and a 9-fold increase in mean density. *Potamogeton pusillus* has tripled and *Sagitttaria* rosettes have doubled in frequency and increased 6-fold in coverage.

One species has disappeared since 1986; *Lemna minor.*

Several species have been variously recorded in some years but not others. All of these species were species that occurred at only one site and were not common, so could have been missed in some surveys.

## IV. DISCUSSION

Based on water clarity and concentration of algae and nutrients, Long Lake is a mesotrophic lake with good water clarity and good water quality. Lakes in this trophic range should have moderate amounts of biomass. The relatively small watershed to lake ratio (~4:1) is one factor in preserving the good water quality. In addition, a large portion of the watershed is protected by forest and wetlands.

The soft water, the steeply sloped littoral zone in nearly half the lake, the dominance of high-density sand and rock sediments and herbivory by rusty crayfish would limit aquatic plant growth in Long Lake. The moderate amount of nutrients and good water clarity would favor aquatic plant growth.

### 2005 Aquatic plant community

Plant growth in Long Lake is sparse (only 27% of the sites supported vegetation, only 16% of the lake) to a maximum rooting depth of 13.5 feet. All plant species occur at low density or coverage in Long Lake. *Potamogeton robbinsii* was the dominant species in 2005, with *Potamogeton epihydrus* as the sub-dominant. One species of Special Concern occurs in Long Lake: *Potamogeton vaseyii.* The 0-1.5ft depth zone supported the most abundant plant growth, the greatest total density, total plant occurrence, species richness and percentage of vegetated sites.

Although vegetation is sparse Long Lake, the aquatic plant community has excellent species diversity. The quality of the aquatic plant community in Long Lake is of above average quality for Wisconsin lakes as measured by the AMCI Index. The quality of the aquatic plant community is limited by the sparse growth, especially submergent plant growth. The Average Coefficients of Conservatism and Floristic Quality Indices indicate that the aquatic plant community in Long Lake more sensitive to disturbance than the average lake in Wisconsin and the Region and is the group of lakes in the state (25%) closest to an undisturbed condition.

### Change in the aquatic plant community

The Coefficients of Community Similarity indicate that the composition of the aquatic plant community has been significantly different in each survey. From one study to the next, the communities have been only 38-64% similar. The dominant species, most frequently occurring species and the species recorded at the maximum depth have changed in very study throughout 1986-2005. The 1986 and 2005 plant communities are only 24% similar.

The Average Coefficients of Conservatism and Floristic Quality Indices suggest that the aquatic plant community in Long Lake has cycled in its disturbance tolerance and closeness to an undisturbed condition. This suggests a disturbance that is cyclic.

Other measures of the aquatic plant community have shown a cyclic, up and down

pattern in Long Lake:
Number of species recorded
Simpson's Diversity Index
Floristic Quality (disturbance)
Percent coverage of vegetation
Percent coverage of emergent species
Occurrence of filamentous algae (4-17%)

In 1986 and 1989, the aquatic plant community appeared to be at its lowest:

1) the lowest percentage of vegetated sites (including the lowest coverage of submergent species and emergent species)
2) the lowest total occurrence of aquatic plants
3) the lowest total density of aquatic plants
4) the lowest number of species
5) the lowest species diversity
6) the lowest Floristic Quality Index (highest disturbance).

In 2001, many measures of the aquatic plant community increased their highest:

1) the highest percentage of vegetated sites
2) the greatest coverage of emergent species
3) the greatest number of species
4) the highest species diversity
5) the highest quality plant community (AMCI Index): increased from low quality in 1986 to above average quality in 2005.
6) the maximum rooting depth had increased dramatically
7) the highest Floristic Quality Index (lowest disturbance).

In 2005, all of these increased continued (except for maximum rooting depth) in addition to the increases to highest level of

1) highest total occurrence of aquatic plants
2) highest total density of aquatic plants
3) the greatest cover of submergent species
4) the greatest cover of floating-leaf species
5) the greatest species richness

The cover of submergent species increased the most, a seventeen-fold increase.

Although the plant community and the measurements of the community have cycled up and down, overall, from 1986 to 2005, all parameters measuring the aquatic plant community have increased.

**Reasons for change in the plant community**

There are many factors that do not favor aquatic plant growth in Long Lake, high-density sediments, soft water, steeply-sloped littoral zone. So although aquatic plant growth would never likely be abundant in Long Lake, residents on Long Lake noticed that the decline of the aquatic plant community coincided with an increase in the rusty crayfish population. The 1986 plant survey recorded the lowest abundance and quality of aquatic plant growth during the Long Term Trend Study. The rusty crayfish population started declining after the 1986 plant survey. The 1992 aquatic plant survey recorded greater abundance of plant growth. This cycling of aquatic plants is similar to the cycles Saiki and Tash (1979) recorded in their study of the interaction of rusty crayfish populations with aquatic plant communities.

A 1974 Long Lake crayfish study found that the density of rusty crayfish at sampling sites was inversely proportional to the density of aquatic plant growth at the same sites and, based on food requirements of the rusty crayfish, the population densities of rusty crayfish in Long Lake were sufficient to eliminate the aquatic vegetation (Magnuson et. al. 1975).

The frequency and density of aquatic plants and the quality of the plant community may cycle up and down as the rusty crayfish population goes through cycles of increase and decline (Magnuson et. al. 1975).

**Shoreline Impacts**

Long Lake has some protecting buffer of native plant growth (wooded, shrub and native herbaceous). However, natural shoreline cover has decreased continuously from 87% cover in 1995 to 74% cover in 2005. Conversely, disturbed shoreline has increased since 1995, from 13% coverage to 25% coverage in 2005. Cultivated lawn alone increased from 9% to 14% coverage and occurs at nearly one-third of the sites.
Hard structures and eroding soils are also commonly occurring at the shoreline.

Cultivated lawn can contribute added nutrients and toxic chemicals from run-off of pet waste and lawn chemicals. Eroding soils add nutrients, turbidity and cover lake bed with inappropriate soil. Mowed lawn, eroded soils and hard structure increase the speed of run-off to the lake and do not filter the run-off as effectively as native vegetation.

To measure the impact of shoreline disturbance, the aquatic plant transects at sites with 100% natural shoreline were compared to aquatic plant transect sites at shoreline that contained any amount disturbance (Appendices XXIII-XXIV). The comparison of various parameters indicate that disturbance on the shore has impacted the aquatic plant community at those sites.

There is a difference in the plant communities at natural shoreline sites and disturbed shoreline sites. *Potamogeton epihydrus* and *P. robbinsii* were dominant and sub-dominant at natural shore littoral zone and *Elodea canadensis* and *P. zosteriformis* were dominant and sub-dominant at disturbed shore littoral zones.

The natural shoreline communities supported better diversity in the plant community which will provide a more diverse habitat for more diverse wildlife and fish communities. This is seen in the higher Simpson's Diversity Index which indicates very good diversity for the disturbed shoreline community and excellent diversity for the natural shoreline community. The higher diversity of the plant community was also seen in the greater number of species that occurred at natural sites and the greater Species Richness (mean number of species occurring at a site) both overall and in all depth zones 0-10 feet (Table 11).

The natural shoreline communities provide more habitat. More of the littoral zone is vegetated, the percent cover of submergent plant species is higher and the maximum percent cover of emergent species (an important habitat component) were all greater at natural shoreline littoral zones (Table 11).

Several parameters point to disturbance as the likely factor for the difference in the plant communities. The most sensitive species in Long Lake (Nichols 2000) occurred only at the sites near natural shoreline (Table 11).

The Average Coefficient of Conservatism was higher at the natural shoreline communities (Table 11). The natural shoreline sites are less tolerant to disturbance than the average lake in the state and the disturbed shoreline sites are among the quartile of lake in the Northern Lakes and Forest Region most tolerant of disturbance, this is likely due to selection by past disturbance.

The Floristic Quality Index is also higher at the natural shoreline sites. The natural shoreline sites are closer to an undisturbed condition than the average lake in the Northern Lakes and Forest Region and the disturbed shoreline sites are farther from an undisturbed condition than the average lake in the region (Table 11).

**Table 11. Comparison of the Aquatic Plant Community at Natural Shoreline Sites and Disturbed Shoreline Sites on Long Lake, 2005.**

| Parameter | | Natural Shoreline | Disturbed Shoreline |
|---|---|---|---|
| Simpson's Diversity Index | | 0.932 | 0.918 |
| Number of species | | 20 | 16 |
| Species Richness (mean number of species per site) | Overall | 0.926 | 0.39 |
| | 0-1.5ft Depth Zone | 2.54 | 0.625 |
| | 1.5-5ft Depth Zone | 0.636 | 0.5 |
| | 5-10ft Depth Zone | 0.273 | 0.125 |
| Amount of Habitat | % Littoral Zone Vegetated | 27% | 20% |
| | % Cover of Submergent Species | 20% | 16% |
| | % Cover of Emergent Species | 10% | 6% |
| Most Sensitive Species: *Potamogeton vaseyii* | Frequency | 2.4% | 0 |
| Average Coefficient of Conservatism | | 6.94 | 5.50 |
| Floristic Quality Index | | 29.46 | 22.00 |

## V. CONCLUSIONS

Based on water clarity and concentration of algae and nutrients, Long Lake is a mesotrophic lake with good water clarity and good water quality. The relatively small watershed that is protected by natural cover is one factor in preserving the good water quality.

*Potamogeton robbinsii* was the dominant species in 2005, with *Potamogeton epihydrus* as the sub-dominant. One species of Special Concern occurs in Long Lake: *Potamogeton vaseyii.* Although the 0-1.5ft depth zone supported the most abundant plant growth, plant growth in Long Lake is sparse (27% of the sites supported vegetation, 16% of the lake was vegetated). All plant species occur at low density or coverage in Long Lake.

The Long Lake aquatic plant community is characterized by excellent species diversity, above average quality, a higher than average sensitivity to disturbance and a closeness to undisturbed condition.

The Coefficients of Community Similarity indicate that the composition of the aquatic plant community has changed. The 1986 and 2005 plant communities are only 24% similar. Several measures of the aquatic plant community have shown a cyclic, up and down pattern in Long Lake. In 1986 and 1989, the aquatic plant community appeared to be at its lowest in quality and amount of vegetation.

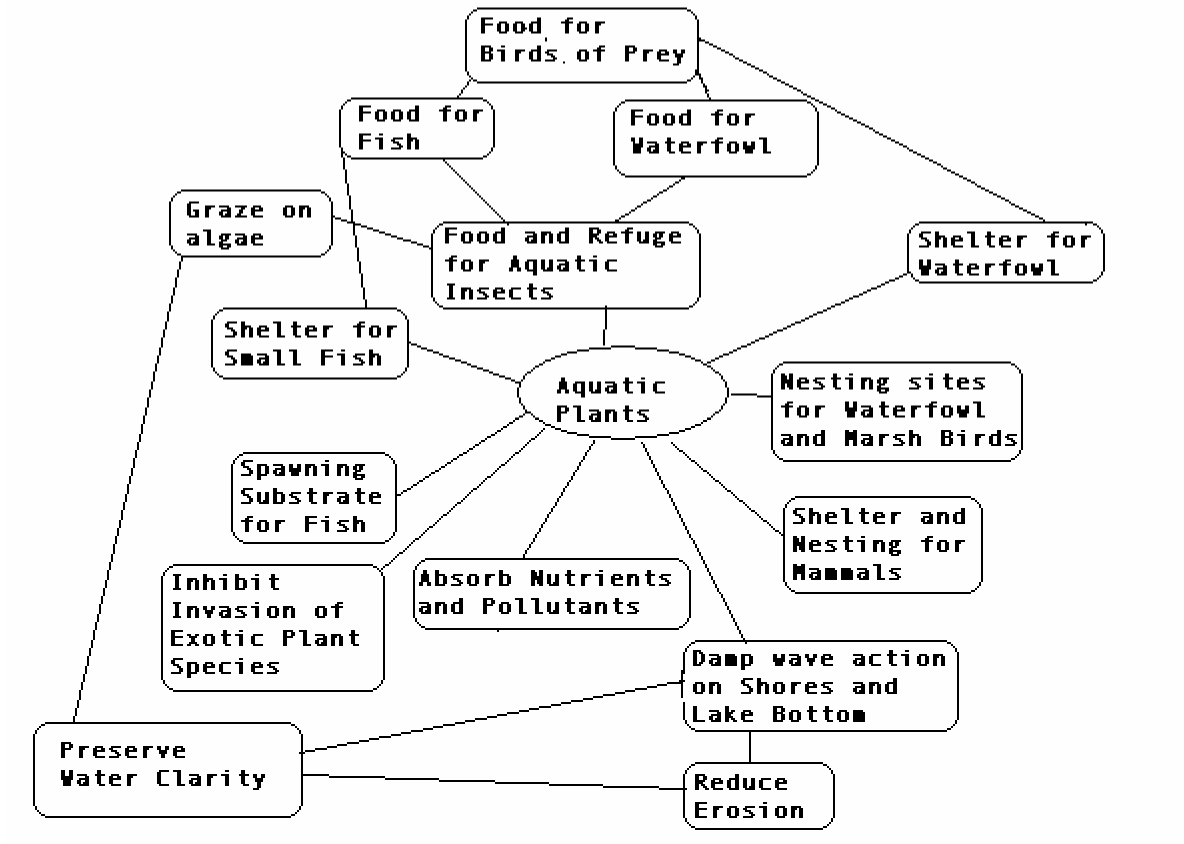
In 2005, every measure of the aquatic plant community increased their highest level. The aquatic plant community in 2005 had the highest percentage of vegetated sites, greatest coverage of emergent, submergent and floating-leaf species, the greatest number of species, the highest species diversity, the highest quality, the lowest disturbance, highest total occurrence and density of aquatic plants and the greatest species richness.

There are several pieces of evidence that rusty crayfish are at least one factor in the cyclic aquatic plant growth in Long Lake.

1) The 1974 study of the crayfish population found that the areas of Long Lake with the lowest coverage of plant growth were also the areas with the densest populations of rusty crayfish (Magnuson et. al. 1975).
2) The estimated size of the rusty crayfish population in Long Lake (Magnuson et. al. 1975) and the estimated food requirement of that population is sufficient to decimate the plant beds in Long Lake (Miller et. al. 1989).

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 resources for
fish and wildlife 3) resisting invasions of non-native plant species and 4) checking excessive growth of more tolerant species that could crowd out other species, reducing

diversity.




1) Aquatic plants improve water quality in many ways: they trap nutrients, debris, and pollutants entering a water body; they may absorb and break down the 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 (Table 12). Aquatic 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. Compared to non-vegetated lake bottoms, aquatic plant beds support larger, more diverse invertebrate populations (Engel 1985; Crowder and Cooper 1979); that in turn will support larger and more diverse fish and wildlife populations (Wiley et. al. 1984). Sparse plant growth supports fewer prey fish, while dense plant growth is overly protective of the prey fish by limiting the success of predatory fish.

**Table 12. Fish and Wildlife Uses of Aquatic Plants in Long Lake**

| Aquatic Plants | Fish | Water Fowl | Song and Shore Birds | Upland Game Birds | Muskrat | Beaver | Deer |
|---|---|---|---|---|---|---|---|
| **<u>Submergent Plants</u>** | | | | | | | |
| *Ceratophyllum demersum* | F,I*, C, S | F(Seeds*), I, C | | | F | | |
| *Elodea canadensis* | C, F, I | F(Foliage) I | | | | | |
| *Myriophyllum tenellum* | 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 foliosus* | F, I, S*,C | F*(All) | | | F* | F | F |
| *Potamogeton gramineus* | F, I, S*,C | F*(Seeds, Tubers) | | | F* | F | F |
| *Potamogeton illinoensis* | F, I, S*,C | F*(Seeds) | F | | F* | F | F |
| *Potamogeton pusillus* | F, I, S*,C | F*(All) | | | F* | F | F |
| *Potamogeton robbinsii* | F, I, S*,C | F* | | | F* | F | F |
| *Potamogeton spirillus* | | F(Seeds) | F | | F | F | F |
| *Potamogeton vaseyi* | | F | | | | | |
| *Potamogeton zosteriformis* | F, I, S*,C | F*(Seeds) | | | F* | F | F |
| *Vallisneria americana* | F*, C, I, S | F*, I | F | | F | | |

| Aquatic Plants | Fish | Water Fowl | Song and Shore Birds | Upland Game Birds | Muskrat | Beaver | Deer |
|---|---|---|---|---|---|---|---|
| **Floating-leaf Plants** | | | | | | | |
| *Brasenia schreberi* | S, I, C | F(Seeds) | | | F | F | F |
| *Lemna minor* | F | F*, I | F | F | F | F | |
| *Lemna trisulca* | F, I | F*, I | | | | | |
| *Nuphar variegata* | F,C, I, S | F, I | F | | F* | F | F* |
| *Nymphaea odorata* | F,I, S, C | F(Seeds) | F | | F | F | F |
| *Spirodela polyrhiza* | F | F | | F | | | |
| | | | | | | | |
| **Emergent Plants** | | | | | | | |
| *Alnus incana* | | | | F, C | | F | F |
| *Asclepias incarnata* | | | | Fibers for nests | Roots | | |
| *Bidens* spp. | | F (Seeds), | F | F | F | | |
| *Carex* spp. | S* | F* (Seeds), C | F* | F* (Seeds) | F (Roots, Sprouts) | F | F |
| *Chamaedaphne calyculata* | | | | F | | | F |
| *Decodon verticillatus* | | F (seeds) | | | F, C | | |
| *Eleocharis smallii (palustris)* | I | F, C | | | | | |
| *Equisetum fluviatile* | | F | | F | F | | |

| Aquatic Plants | Fish | Water Fowl | Song and Shore Birds | Upland Game Birds | Muskrat | Beaver | Deer |
|---|---|---|---|---|---|---|---|
| *Iris versicolor* | | F, C | F | | F | | |
| *Pontederia cordata* | F, I, C | F*(Seeds), C | | | F | | |
| *Sagittaria latifolia* | | F, C | F(Seeds), C | F | F | F | |
| *Scirpus americanus* | F, S, C | F*(Seeds) | F(Seeds, Tubers), C | F | F* | | |
| *Scirpus validus* | F, C, I | F (Seeds)*, C | F(Seeds, Tubers), C | F (Seeds) | F | F | F |
| *Typha angustifolia* | S, C | | | | | 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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An intermediate density of aquatic plants promotes better growth rates in fish than either high of low density (Crowder and Cooper 1979). Some studies have suggested optimal coverage of plants, 36% cover over the entire water body (Wiley et. al. 1984). Aquatic plants in Long Lake provide 16% cover within the littoral zone. This is much less than the suggested optimal coverage of aquatic plants and is even less when calculated over the entire lake surface.

**Recommendations**

1) Cooperate with efforts to protect the natural landscape in the watershed that is protecting the water quality in Long Lake
2) Residents use best management practices on shoreline property. Relatively small watershed that is largely protected with natural cover means that shoreline properties play a larger role in protecting the water quality.
   a) Maintain septic systems along the lakeshore to insure that septic systems are not contributing nutrients.
   b) Implement stormwater management practices
   c) Eliminate fertilizer use on shoreline properties
3) Residents to preserve the natural vegetation along the lakeshore. Much of the shoreline around Long Lake is protected by natural plant cover, but the amount of disturbed shoreline has increased since 1995. The mean coverage of disturbed shoreline (lawns, hard structures, bare soils, and pavement) has increased from 13% in 1995 to 25% in 2005. A comparison of the littoral zone at natural shoreline sites with littoral zone at disturbed shoreline sites indicates that the plant community is different.
   a) Different plant species dominate natural and disturbed shore sites.
   b) The disturbed shoreline littoral zone is less diverse (lower Diversity Index, sell species and lower species richness) which would support less diverse fish and wildlife communities
   c) The disturbed shore littoral zone provides less habitat: less cover of vegetation, less cover of submergent vegetation and less cover of important emergent vegetation.
   d) Floristic Quality Index supports the impact of disturbance at the disturbed shoreline sites.
4) Lake residents to replace natural shoreline in areas that have been converted to cultivated lawn. Replacing shrub cover that has declined would also enhance wildlife habitat.
5) Lake District initiate and conduct annual monitoring of crayfish populations to correlate with changes in the aquatic plant community.
6) Residents and agencies follow recommendations for the sensitive areas designated on Long Lake.
7) Continue volunteer water quality monitoring