# Executive Summary

Crystal Lake is a eutrophic lake with poor water quality and very poor water clarity. Filamentous algae is abundant, especially at depths greater than 5 feet.

The aquatic plant community in Crystal Lake is characterized by below average quality for Wisconsin lakes, fair species diversity, abundant plant growth and within the group of lakes farthest from an undisturbed condition. *Lemna minor* is the dominant species within the plant community, especially in the 0-5ft depth zone. *Elodea canadensis* and *Wolffia columbiana* were sub-dominant species. All three species exhibited a dense or aggregated growth form in Crystal Lake.

Since 1980, disturbance in the aquatic plant community, colonization of aquatic plants and coverage of filamentous algae have all increased.

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

**Management Recommendations**

1) Conduct water quality monitoring.
2) Restore natural vegetation along the shore.
3) Cooperate with efforts in the watershed to reduce nutrient run off and erosion that add sediments and nutrients to the lake.
4) Investigate the use of a mechanical harvester to open up channels to improve the fish population and lake use.
5) If dredging is considered, shape the lake bottom to include some deep-water habitat and some shallow water islands. Place a sediment trap upstream to be maintained regularly.

# The Aquatic Plant Community in Crystal Lake, Trempealeau County 2003 MWBC 1825100

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## I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Crystal Lake was conducted during August 2003 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and Village of Strum personnel. This was the first quantitative vegetation study of Crystal Lake by the DNR. An aquatic plant assessment was conducted in July 1980.

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. Aquatic plants provide habitat for fish and wildlife, improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation.

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

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

**Background and History:** Crystal Lake is a 54-acre, impoundment on the Buffalo River in northern Trempealeau County, Wisconsin. With a maximum depth of 8 feet and an average depth is 3 feet, Crystal Lake is a shallow water resource.

The watershed that drains into Crystal Lake is approximately 75,000 acres, 52,000 acres below the Lake Martha dam. This is a drainage area/lake ratio of approximately 962:1. Lakes with drainage area/lake size ratios greater than 10:1 tend to have water quality problems (Field 1994).

Crystal Lake was formed in 1937 with the construction of the dam as a WPA project.

Chemicals were applied for control for aquatic plants in Crystal Lake during the 1960's (Table 1).

**Table 1. Herbicides Applied to Crystal Lake**

| | **Aquathol** |
|---|---|
| **1966** | 500 lbs |
| **1967** | 1200 lbs |
| **Total** | 1700 lbs |

During the winter of 1974-75, the lake was drawn down to reduce the rough fish population and may have impacted some species of plants in the drawdown zone.

Crystal Lake was dredged in 1992 to remove sediment imported by the river that was causing the lake to become shallower.

## II.METHODS

### Field Methods

The study design was based primarily on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines.

The shoreline was divided into 12 equal segments and a transect, perpendicular to the shoreline, was randomly placed within each segment (Appendix IV), using a random numbers table.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft and 5-10ft) along each transect. Using a long-handled, steel, thatching rake, four rake samples were taken at each sampling site. The four samples were taken from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5); the number of rake samples on which it was present at each sampling site.

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

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

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet back from the shore was evaluated. The percentage of each cover type within this 100' x 30' rectangle was estimated.

### Data Analysis

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

The Aquatic Macrophyte Community Index (AMCI) developed by Weber et. al. (1995) was applied to Crystal Lake (Table 4). Measures of each of six parameters that characterize a plant community are converted to values between 0 and 10 and summed.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the Coefficients for all species found in the lake. The FQI is calculated from the Coefficient of Conservatism (Nichols 1998) and is a measure of a plant community's closeness to an undisturbed condition.

## III. RESULTS

### PHYSICAL DATA

Many physical parameters impact the macrophyte community. Water quality influences the macrophyte community as the macrophyte community can in turn modify these parameters. Lake morphology, sediment composition and shoreline use also impact the macrophyte community.

**WATER QUALITY** - The trophic state of a lake is a classification of its water quality.

**Eutrophic lakes** are high in nutrients and therefore support a large biomass.
**Oligotrophic lakes** are low in nutrients and support limited plant growth and smaller fish populations.
**Mesotrophic lakes** have intermediate levels of nutrients and biomass.

**Nutrients**

Phosphorus is a limiting nutrient in many Wisconsin lakes and is measured as an indication of the nutrient status of a lake. Increases in phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth. Phosphorus was measured in 1980. This data is old and should be repeated, however, the data can still give an idea of the trophic state of the lake.

**1980 mean summer phosphorus concentration in Crystal Lake was 257.5ug/l**

This amount of phosphorus in Crystal Lake was indicative of a hypereutrophic lake (Table 2).

**Table 2. Trophic Status**

| | Quality Index | Phosphorus ug/l | Secchi Disc ft. |
|---|---|---|---|
| Oligotrophic | Excellent | <1 | > 19 |
| | Very Good | 1-10 | 8-19 |
| Mesotrophic | Good | 10-30 | 6-8 |
| | Fair | 30-50 | 5-6 |
| Eutrophic | Poor | 50-150 | **3-4** |
| Hypereutrophic | Very Poor | **>150** | < 3 |
| Crystal Lake | Good | 257.5 (1980 data) | 3.125 (2003 data) |

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

While phosphorus is the limiting nutrient in most Wisconsin lakes, nitrogen can be the limiting nutrient in some lakes. The nitrogen:phosphorus ratio in Crystal Lake is approximately 4:1. Lakes with N:P ratios less than 10:1 are considered nitrogen limited and are associated with blue-green algae blooms (Shaw et. al. (1993)). This means that nitrogen is the limiting nutrient, so that addition of nitrogen can increase plant and algae growth.

### 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.

Water clarity data has been collected by volunteers in the Self-Help Volunteer Lake Monitoring Program. LaVerne Anderson collected clarity data in 1986. George Breien has been collecting clarity data since 1995.

**Mean summer Secchi disc clarity in Crystal Lake in 2003 was 3.12 ft.**
Water clarity in this range indicates (Table 2) that Crystal Lake was a eutrophic lake with very poor water clarity.
The most frequent collection of water clarity data was during 1995-2003 by George Breien. The data shows yearly variation in water clarity, likely due to variations in weather conditions and rain. The best average water clarity was in 1998; the poorest water clarity was in 1995 and 2003 (Figure 1). The clarity appeared to increase gradually from 1995 to 1998 and decreased since 1998 (Figure 1).

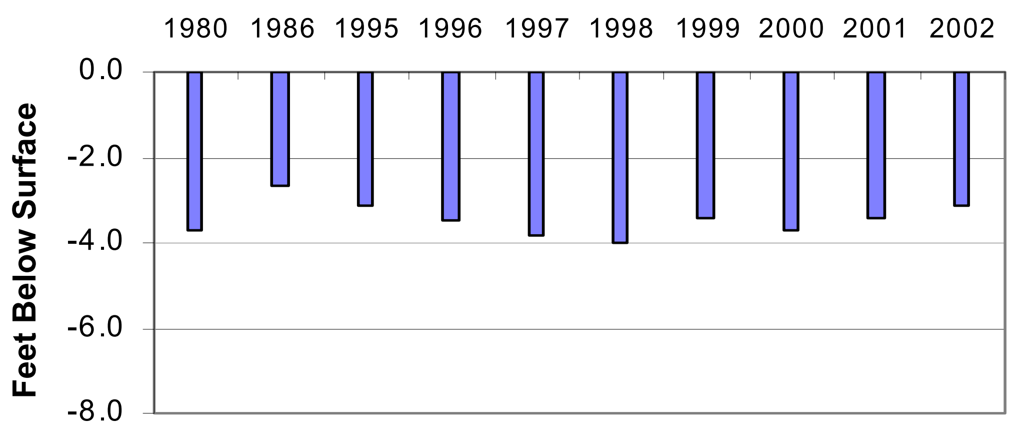



**Figure 1. Mean summer water clarity in Crystal Lake 1980, 1986 and 1995-2003.**

Water clarity also varies during the growing season. Mean water clarity for the same time of year is best in the spring and decreases during the growing season to a low in mid-June, it increases slightly before a sharp decrease in late autumn (Figure 2).

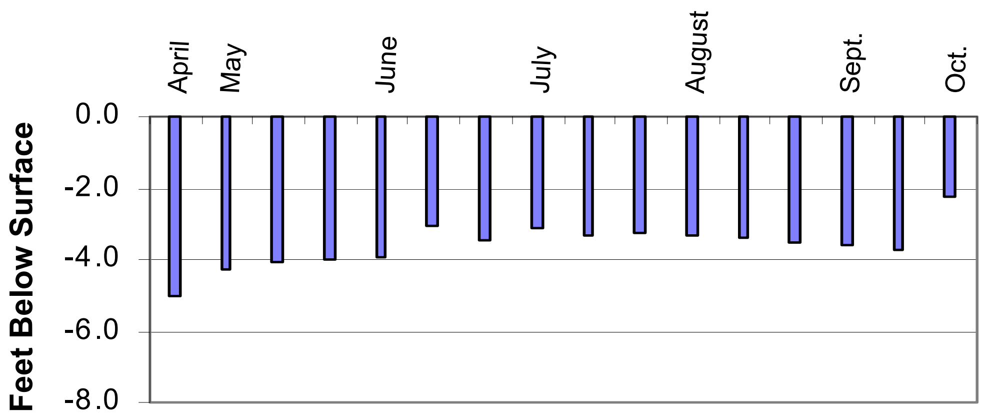



**Figure 2. Change in mean water clarity during the growing season, Crystal Lake 1995-2003.**

The combination of nutrient concentration and water clarity indicates that Crystal Lake is a eutrophic lake with poor water quality. This trophic state would favor abundant plant growth and frequent algae blooms.

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

Crystal Lake has a shallow basin with a very gradually sloped littoral zone. The shallow depths and gradual slopes would favor plant growth.

**SEDIMENT COMPOSITION** – The dominant sediment in Crystal Lake was a mixture of sand and silt, especially at depths greater than 1.5ft (Table 3). Mixtures of sand, gravel and rock were also common in the lake and dominant in the 0-1.5ft depth zone (Table 3).

**Table 3. Sediment Composition - Crystal Lake, 2003**

| **Sediment Type** | | **0-1.5' Depth** | **1.5-5' Depth** | **5-10' Depth** | **Percent of all Sample Sites** |
|---|---|---|---|---|---|
| **Hard Sediments** | Sand/Gravel/Rock | 30% | | 25% | 20% |
| | Sand | 23% | | | 12% |
| | Rock | 8% | | | 4% |
| **Mixed Sediments** | Sand/Silt | 23% | 88% | 75% | 52% |
| | Sand/Muck | 8% | 12% | | 8% |
| **Soft Sediments** | Silt/Muck | 8% | | | 4% |

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

Sand/silt mixtures were the dominant sediment found in Crystal Lake. Sand is a high-density sediment that could be limiting to plant growth (Barko and Smart 1986). Silt is an intermediate density sediment. The availability of mineral nutrients for growth is highest in sediments of intermediate density (Barko and Smart 1986). The combination of these two sediments are likely a good medium for plant growth and supported plant growth at 92% of the sites (Table 4).
All sediment types supported a high percentage of vegetation (Table 4).

**Table 4. Influence of Sediment in Crystal Lake, 2003.**

| Sediment Type | | Percent of all Sample Sites | Percent of Vegetated |
|---|---|---|---|
| **Hard Sediments** | Sand/Gravel/Rock | 20% | 100% |
| | Sand | 12% | 75% |
| | Rock | 4% | 100% |
| **Mixed Sediments** | Sand/Silt | 52% | 92% |
| | Sand/Muck | 8% | 100% |
| **Soft Sediments** | Silt/Muck | 4% | 50% |

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

Cultivated lawn was the most frequently encountered shoreline cover at the transects and had the highest mean coverage. It covered more than three-quarters of the shoreline. Paved areas and native herbaceous cover were also commonly occurring (Table 5). Disturbed shoreline (cultivated lawn and pavement) covered 88% of the shoreline.

**Table 5. Shoreline Land Use - Crystal Lake, 2003**

| Cover Type | | Frequency of Occurrences at Transects | Mean % Coverage |
|---|---|---|---|
| Disturbed Shoreline | Cultivated Lawn | 100% | 75% |
| | Pavement | 36% | 13% |
| Natural Shoreline | Wooded | | |
| | Native Herbaceous | 78% | 10% |
| | Shrub | 14% | 1% |

## MACROPHYTE DATA

### SPECIES PRESENT

Of the 10 species found in Crystal Lake, 3 were emergent species, 2 were free-floating species and 5 were submergent species (Table 6).
No threatened or endangered species were found.
One non-native species was found: *Potamogeton crispus*

**Table 6. Crystal Lake Aquatic Plant Species, 2003**

| Scientific Name | Common Name | I. D. Code |
|---|---|---|
| Emergent Species | | |
| 1) *Bidens frondosus* L. | beggar-tick | bidfr |
| 2) *Phalaris arundinacea* L. | reed canary grass | phaar |
| 3) *Sparaganium* spp. | burreed | spasp |
| Floating-leaf Species | | |
| 4) *Lemna minor* L. | small duckweed | lemmi |
| 5) *Wolffia columbiana* Karsten. | common watermeal | wolco |
| Submergent Species | | |
| 6) *Ceratophyllum demersum* L. | coontail | cerde |
| 7) *Elodea canadensis* Michx. | common waterweed | eloca |
| 8) *Nitella* sp. | nitella | nitsp |
| 9) *Potamogeton crispus* L. | curly-leaf pondweed | potcr |
| 10) *Potamogeton zosteriformis* Fern. | flatstem pondweed | potzo |

### FREQUENCY OF OCCURRENCE

*Lemna minor* was the most frequently occurring species in Crystal Lake in 2003, (86% of sample sites) (Figure 3). Several other species were abundant (*Ceratophyllum demersum, Elodea canadensis, Wolffia columbiana)* or commonly occurring *(Phalaris arundinacea, Potamogeton zosteriformis).*

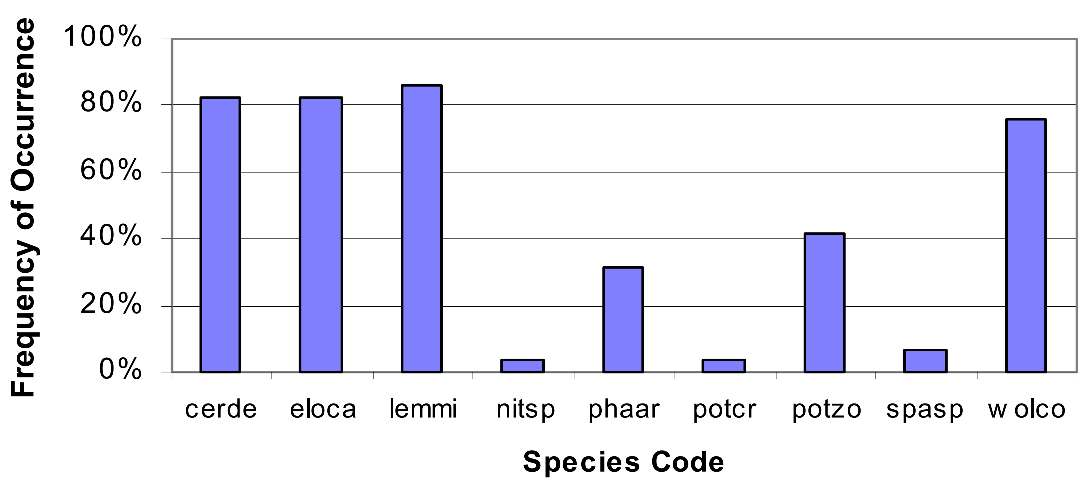



**Figure 3. Frequencies of macrophyte species in Crystal Lake, 2003**

Filamentous algae occurred at 65% of the sample sites, occurring at:

57% of the sites in the 0-1.5ft depth zone
60% of the sites in the 1.5-5ft depth zone
100% of the sites in the 5-10ft depth zone

**DENSITY**

*Lemna minor* also had the highest mean density (3.62; on a density scale of 1-4) of all plant species in Crystal Lake (Figure 4). *Elodea canadensis* and *Wolffia columbiana* occurred at high densities also.

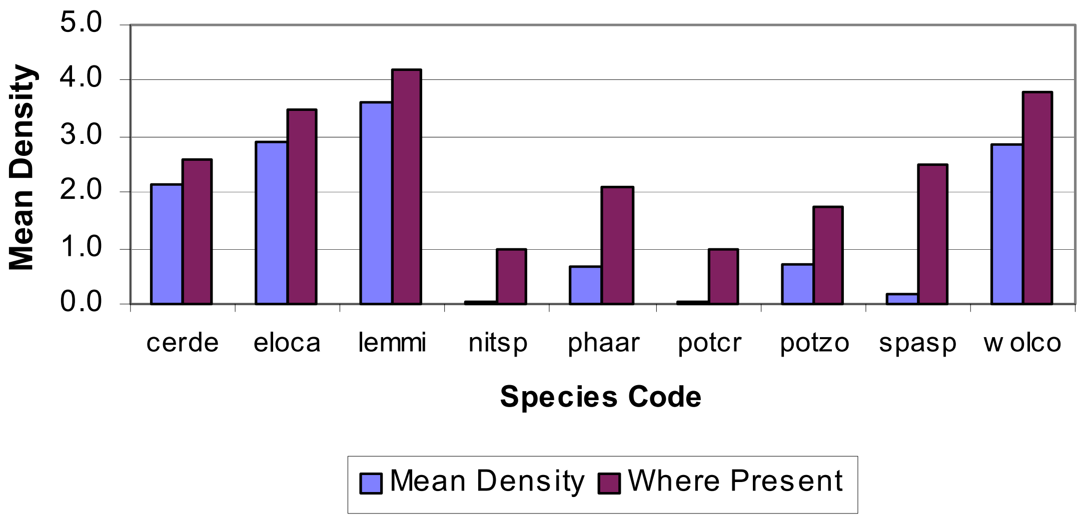



**Figure 4. Densities of macrophyte species in Crystal Lake, 2003**

"Mean density where present" indicates the growth form of a species. *Lemna minor* had the highest "mean density where present" (4.2); *Elodea canadensis* and *Wolffia columbiana* also had high “mean densities where present” (4.0) (Figure 4). This means that, where these species occurred, these species exhibited a dense or aggregated growth form in Crystal Lake, irregardless of the number of sites at which they occurred.

**DOMINANCE**

Combining relative frequency and relative density into a Dominance Value illustrates how dominant a species is within the aquatic plant community (Appendix III). Based on the Dominance Value, *Lemna minor* was the dominant aquatic plant species in Crystal Lake (Figure 5). *Elodea canadensis* and *Wolffia columbiana* were sub-dominant.

The aquatic plant community of Crystal Lake was dominated by relatively few plant species.

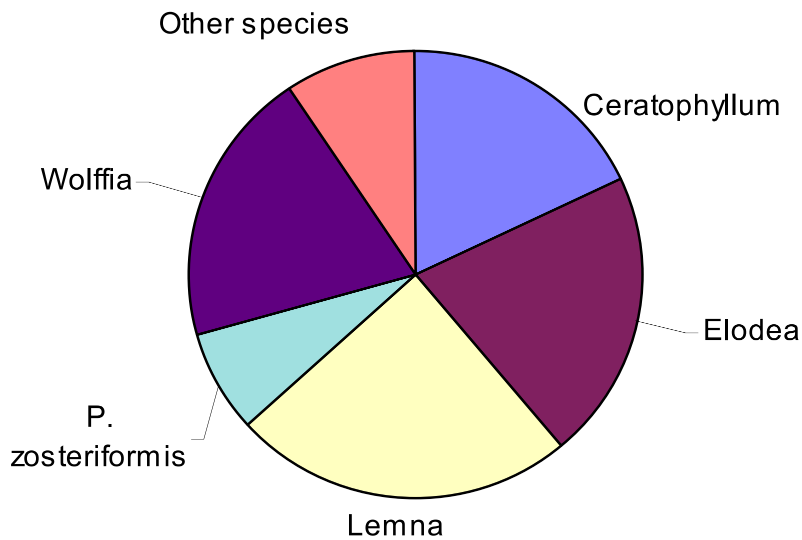



**Figure 5. Dominance within the macrophyte community, of the most prevalent aquatic macrophytes in Crystal Lake, 2003.**

*Lemna minor,* the dominant species, dominated the 0-5ft depth zone (Appendices I, II) and was found at its highest frequency and density in the 0-1.5ft depth zone (Figure 6, 7). *L. minor* gradually declined with increasing depth.

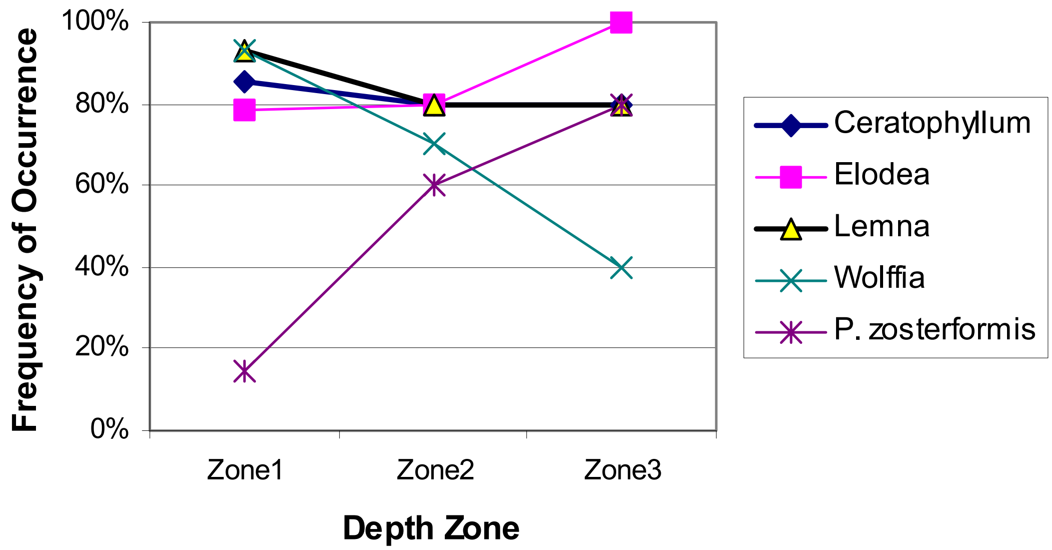



**Figure 6. Frequency of occurrence of prevalent macrophytes in Crystal Lake, by depth zone, 2003.**

*Wolffia columbiana* also occurred at a high frequency in the 0-1.5ft depth zone (Figure 6). *Ceratophyllum demersum* and *Elodea canadensis* also occurred at high frequencies in the 1.5-5ft depth zone (Figure 6).

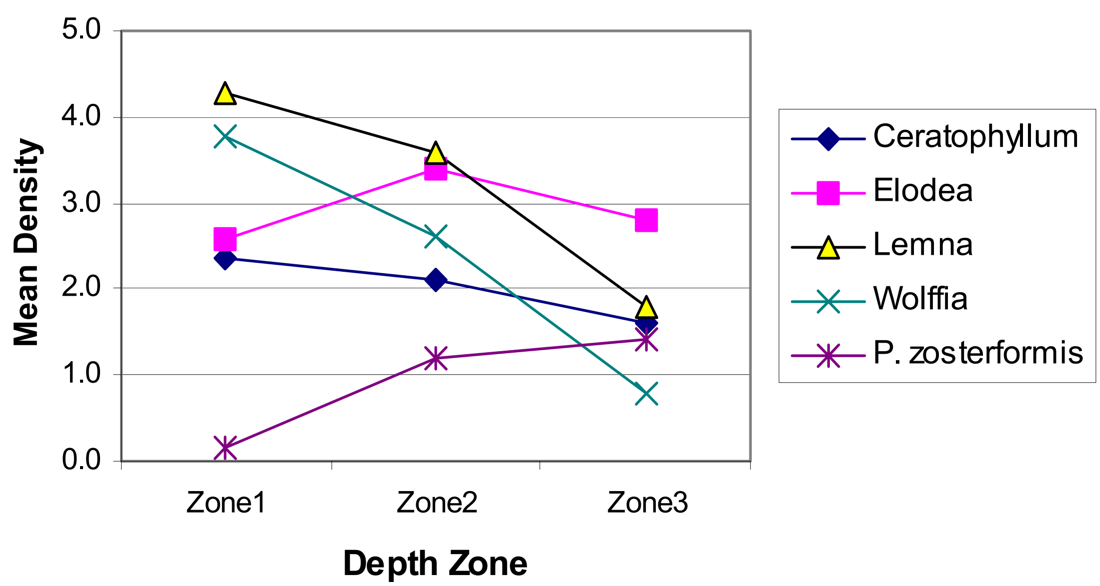



**Figure 7. Density of prevalent macrophytes by depth zone.**

*Elodea canadensis*, a sub-dominant species, dominated the 5-8ft depth zone (Appendices I, II) and was found at its highest frequency in this depth zone (Figure 6, 7).

**DISTRIBUTION**

Aquatic plants occurred throughout Crystal Lake. The dominant and prevalent species were found throughout Crystal Lake.

Over the whole lake, 93% of the sampling sites were vegetated, 86% of the sites with rooted plants. Aquatic plants were found up to the maximum depth of the lake, 8 feet, with *Ceratophyllum demersum, Elodea canadensis, Lemna minor, Potamogeton zosteriformis* and *Wolffia columbiana* occurring at the maximum rooting depth. This rooting depth is deeper than the predicted maximum rooting depth of 6.5, based on the 2003 water clarity (Figure 8).

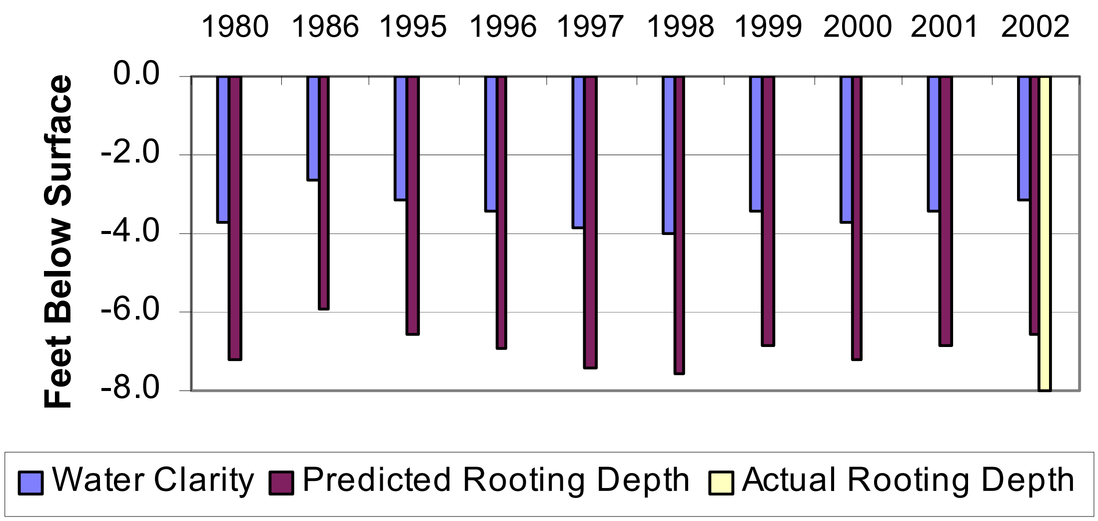



**Figure 8. Actual maximum rooting depth and predicted maximum rooting depth in Crystal Lake, based on water clarity, 2003.**

The 0-1.5ft depth zone supported the greatest amount of plant growth. The highest total occurrence and total density of plant growth was recorded in the 0-1.5ft depth zone (Figure 9). The greatest mean number of species per site (species richness) was also found in the 0-1.5 ft. depth zone (Figure 10).

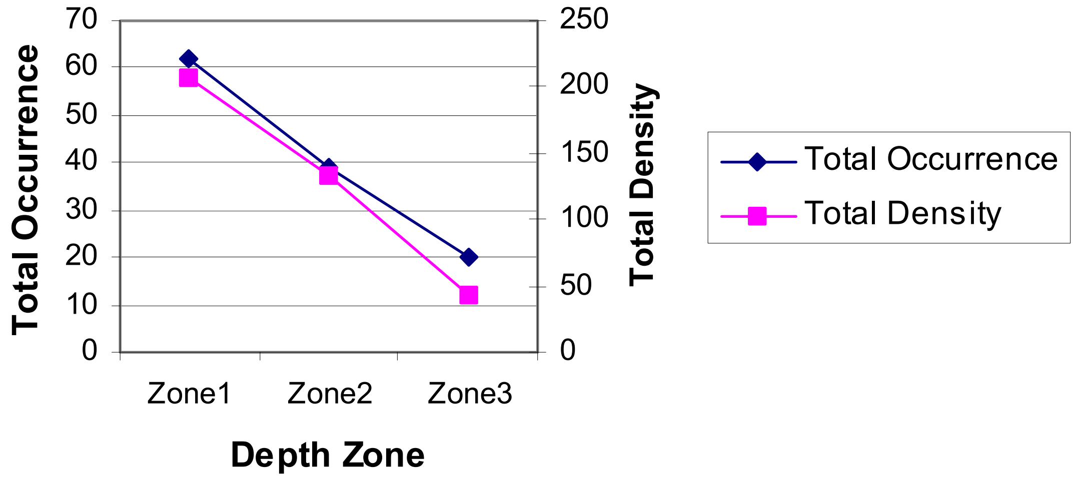



**Figure 9. Total occurrence and density of plants by depth zone.**

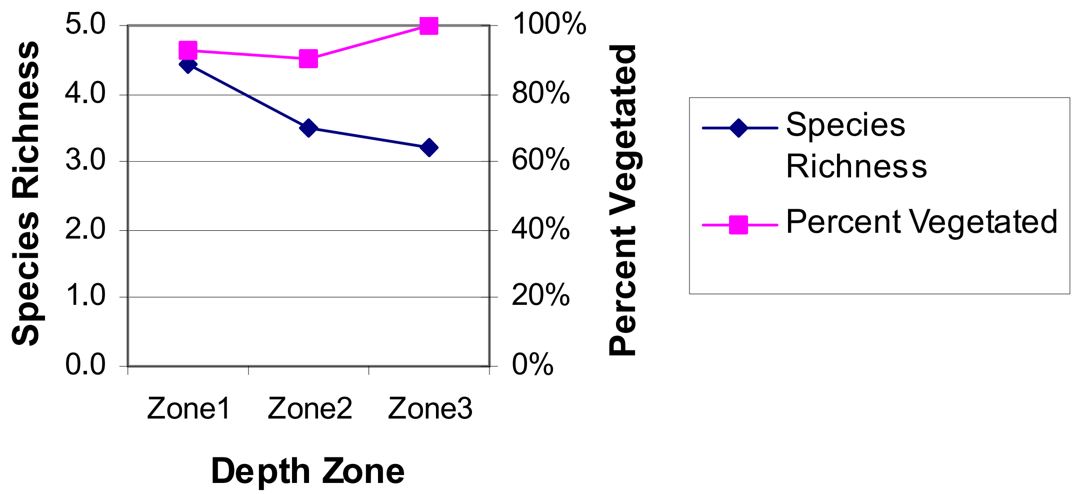



**Figure 10. Species richness and percent of vegetated sites in Crystal Lake, by depth zone.**

The species richness over the whole lake was 1.76 species per site.
The highest percentage of vegetated sites was found in the 5-8ft depth zone (Figure 10).

**THE COMMUNITY**

Simpson's Diversity Index was 0.83, indicating fair species diversity. A rating of 1.0 would mean that each plant in the lake would be a different species (the most diversity achievable).

The Aquatic Macrophyte Community Index (AMCI) for Crystal Lake (Table 7) is 29. This is well below average quality (40) for lakes in Wisconsin. The highest value for this index is 60.

**Table 7. Aquatic Macrophyte Community Index**

| Category | | Value |
|---|---|---|
| Maximum Rooting Depth | 2.4 meters | 4 |
| % Littoral Zone Vegetated | 93% | 10 |
| Simpson's Diversity | 0.83 | 8 |
| # of Species | 10 (1 exotics) | 3 |
| % Submergent Species | 32% Rel. Freq. | 4 |
| % Sensitive Species | 0% Relative Freq. | 0 |
| Totals | | 29 |

The quality of the plant community is limited by the shallow depth, low number of species, lack of sensitive species and the dominance of free-floating species over submergent species.

The Average Coefficient of Conservatism for Crystal Lake was in the lowest quartile for all Wisconsin lakes analyzed and below the mean for lakes in the Driftless Area/Mississippi River (DMR) (Table 8). This suggests that the aquatic plant community in Crystal Lake are among the group of lakes most tolerant of disturbance in Wisconsin andmore tolerant than the average lake in the Driftless Area/Mississippi River Region, likely by being impacted by disturbance.

**Table 8. Floristic Quality and Coefficient of Conservatism of Crystal Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes, 2003.**

| | Average Coefficient of Conservatism † | Floristic Quality ‡ |
|---|---|---|
| Wisconsin Lakes | 5.5, 6.0, 6.9* | 16.9, 22.2, 27.5 |
| DMR | 4.6, 5.0, 5.5* | 10.2, 14.3, 18.1 |
| Crystal Lake 2003 | 3.5 | 11.07 |

* - 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 of the plant community in Crystal Lake was in the lowest quartile for Wisconsin lakes and below the mean for Driftless Area/Mississippi River Region Lakes (Table 8). This suggests that the plant community in Crystal Lake is in the group of lakes in the state farthest from an undisturbed condition and farther from an undisturbed condition than the average lake in the region.

Disturbances can be of many types:

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

Disturbances in Crystal may include the poor water quality and shoreline development.

**Comparison with 1980 aquatic plant survey**

The plant community has changed somewhat since 1980.

Both the 1980 and 2003 plant community were composed of 10 species, but four species disappeared and four new species were added, one an exotic (Table 9).

**Table 9. Change in Crystal Lake Aquatic Plant Species, 1980-2003**

| 1980 | 2003 |
|---|---|
| Emergent Species | Emergent Species |
| | *Bidens frondosus* |
| *Equisetum litorale* | |
| *Phalaris arundinacea* | *Phalaris arundinacea* |
| *Sagittaria latifolia* | |
| *Sparaganium* spp. | *Sparaganium* spp. |
| | |
| Floating-leaf Species | Floating-leaf Species |
| *Lemna minor* | *Lemna minor* |
| | *Wolffia columbiana* |
| | |
| Submergent Species | Submergent Species |
| *Ceratophyllum demersum* | *Ceratophyllum demersum* |
| *Elodea canadensis* | *Elodea canadensis* |
| | *Nitella* sp. |
| | *Potamogeton crispus* |
| *Potamogeton nodosus* | |
| *Potamogeton pectinatus* | |
| *Potamogeton zosteriformis* | *Potamogeton zosteriformis* |

Maps produced during the 1980 and 2003 surveys show that plant growth has expanded (Figure 11, 12, 13, 14, 15, 16). The maps also suggest that shallow water habitat has expanded and former shallow water habitat has been converted to terrestrial communities. This has likely been caused by a build up of sediments carried in by the river.

Since 1980, colonization of emergent vegetation has increased (Figure 11, 12) as has the colonization of submergent vegetation (Figure 13, 14) likely due to input of sediment from the river. The coverage of free-floating vegetation and filamentous algae has increased since 1980 (Figure 15, 16), due to increased nutrients.

The Average Coefficient of Conservatism and Floristic Quality Index indicate that disturbance in the plant community increased from 1980-2003. In 1980, The average Coefficient of Conservatism was higher but still in the lowest quartile in the state and region, in the group of lakes most tolerant of disturbance (Table 10).

**Table 10. Change in Floristic Quality and Coefficient of Conservatism of Crystal Lake, 1980-2003.**

| | Average Coefficient of Conservatism † | Floristic Quality ‡ |
|---|---|---|
| Wisconsin Lakes | 5.5, 6.0, 6.9* | 16.9, 22.2, 27.5 |
| DMR | 4.6, 5.0, 5.5* | 10.2, 14.3, 18.1 |
| Crystal Lake 1980 | 4.2 | 13.28 |
| Crystal Lake 2003 | 3.5 | 11.07 |

* - 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 was also greater in 1980. Although Crystal Lake was still in the lowest quartile of lakes in the state, the Floristic Quality was below the mean for lakes in the region (Table 9).

The condition in Crystal Lake shifted from a lake farther from an undisturbed condition than the average lake in the region in 1980 to the group of lakes in the region farthest from an undisturbed condition in 2003.

Disturbances since 1980 could include dredging, decreased water clarity and increased development on the lake.

## V. DISCUSSION

Based on water clarity and phosphorus data, Crystal Lake is a eutrophic lake with very poor water clarity and poor water quality. This trophic state will support abundant plant growth and frequent algae blooms. The watershed to lake ratio is large (962:1). This large watershed could be the source of abundant nutrients. Crystal Lake appears to be nitrogen limited, so that inputs of nitrogen will cause increases in algae and plant growth.

Filamentous algae was abundant, occurring at 65% of the sites. Filamentous algae increases with increasing depth to 100% coverage at sites greater than 5 feet deep.

Adequate nutrients, shallow depth, gradually sloped littoral zone and dominance of favorable silt mixture sediments favor plant growth.

Aquatic plant growth occurred throughout Crystal Lake. Aquatic plants occurred at 93% of the sites (86% with rooted vegetation), to the maximum depth of the lake. This maximum rooting depth is greater than the predicted maximum rooting depth of 6.5 feet based on water clarity. This is likely due to better water clarity early in the season when plant growth is beginning.

The highest total occurrence of plants, highest total density of plants and the greatest species richness (mean number of species per sample site) was recorded in the shallowest depth zone (0-1.5ft).

*Lemna minor* was the dominant plant species in Crystal Lake, especially in the 0-5ft depth zone, occurring at 86% of the sample sites. *Elodea canadensis* and *Wolffia columbiana* were sub-dominant plant species in Crystal Lake. All three of these species exhibited a dense growth form in Crystal Lake.

The Aquatic Macrophyte Community Index (AMCI) for Crystal Lake was 29, indicating that the quality of the aquatic plant community in Crystal Lake is below average (40) for Wisconsin lakes. Simpson's Diversity Index (0.83) indicates that the plant community had a fair diversity of plant species. There were only 10 species recorded in Crystal Lake and only a handful of species dominant nearly the entire plant community. The mean number of species per sample site was 1.76.

The Average Coefficient of Conservatism and the Floristic Quality Index places Crystal Lake in the group of lakes in the state that are most tolerant of disturbance and farthest from an undisturbed condition and more disturbance tolerant and closer to a disturbed condition than the average lake in the Driftless Area/Mississippi Backwater Region.

The major disturbances in Crystal Lake are likely the poor water quality, sedimentation on the plant beds, the developed shoreline and localized impacts by past winter drawdowns, dredging and broad-spectrum chemical treatments.

Changes between 1980 and 2003:

1) species diversity (measured by number of species) has remained the same, but four species have been lost and four new species have been added.
2) One of the new species is an exotic, curly-leaf pondweed.
3) Disturbance has increased in the plant community since 1980 as measured by the Floristic Quality Index.
4) The coverage of all classes of aquatic vegetation (submergent, emergent, free-floating and filamentous algae) has increased also.
5) It appears that sedimentation has occurred in the upper end of the lake, converting shallow-water habitat to terrestrial communities and creating new shallow water habitat form deeper water.

Crystal Lake has little protection by natural shoreline cover (wooded, shrub and native herbaceous growth). As found by Meyer et. al. (1997) on other developed lakes in the state, the shrub cover at the shoreline has nearly been eliminated. This has removed an entire class of habitat and the species that depend on that habitat. Disturbed shoreline covered approximately 88% of the shore. Mowed lawn alone covered 75% of the shoreline. Mowed lawn results in increased run-off of lawn fertilizers, pesticides and pet wastes into the lake.

Restoring a buffer of natural vegetation along the shore will replace habitat, help prevent shoreline erosion and reduce additional nutrient/chemical run-off that can add to algae growth and sedimentation of the lake bottom.

## VI. CONCLUSIONS

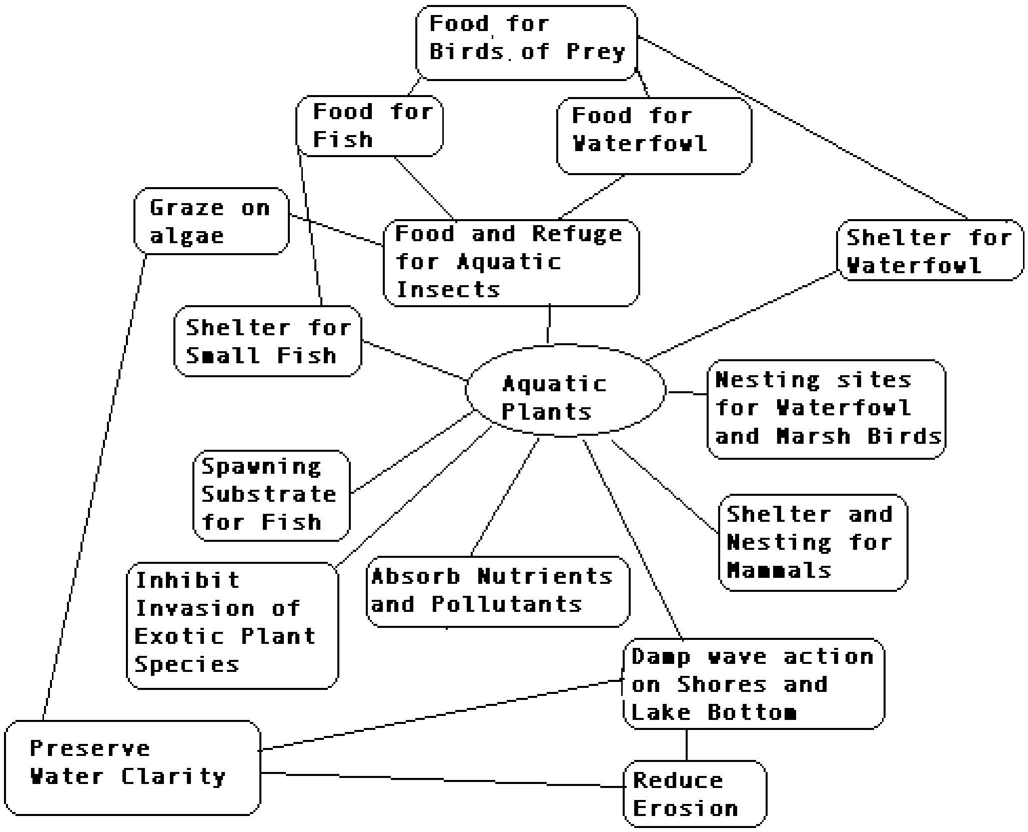
Crystal Lake is a eutrophic lake with poor water quality and very poor water clarity. Filamentous algae is abundant, especially at depths greater than 5 feet. The large watershed to lake size is likely a major source of nutrients.

The quality of the aquatic plant community in Crystal Lake is below average for Wisconsin lakes and is characterized by fair species diversity and within the group of lakes in the state most tolerant of disturbance and farthest from an undisturbed condition. Since 1980, disturbance in the plant community has increased and the colonization of aquatic plants and filamentous algae has increased. Disturbances are likely the poor water quality, sedimentation of the plant beds, developed shoreline, the introduction of the exotic species (curly-leaf pondweed) and localized impacts from past dredging, drawdowns and broad-spectrum chemical treatments.

The aquatic plant community colonized nearly the entire lake to its maximum depth. The 0-1.5 ft. depth zone supported the most abundant aquatic plant growth. Adequate nutrients and a gradually-sloped littoral zone, favorable sediments and the shallow depth of the lake favor plant growth. The dominance of high-density sediments can limit aquatic plant growth.

Only ten aquatic plant species colonize Crystal Lake. *Lemna minor* is the dominant species within the plant community, especially in the 0-5ft depth zone. *Elodea canadensis* and *Wolffia columbiana* were sub-dominant species.
All three species exhibited a dense or aggregated growth form in Crystal 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 habitat resources for fish and wildlife 3) resisting invasions of non-native species and 4) checking excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.




1) Macrophyte communities improve water quality in many ways:
they trap nutrients, debris, and pollutants entering a water body;
they absorb and break down some pollutants;
they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
they remove nutrients that would otherwise be available for algae blooms (Engel 1985).

2) Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table 11). Plant cover within the littoral zone of Crystal Lake is 93% and is likely too dense to support a balanced fishery (25-85%).

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

**Management Recommendations**

1) Repeat chemical analysis of the lake water. The last data collected was in 1980.
2) Restore natural vegetation along the shore. Unmowed native vegetation reduces shoreline erosion and run-off into the lake and filters the run-off that does enter the lake. Nearly 90% of the lakeshore is impacted by disturbed shoreline. Three-quarters of the shore is impacted by disturbance from cultivated lawn. Leaving a band of natural vegetation around the shore by discontinuing mowing and cutting at the shoreline would be the simplest method. Planting native grasses, flowers, trees and shrubs would be the ideal method.
3) Cooperate with efforts in the watershed to reduce nutrient run off and erosion that add sediments and nutrients to the lake. Programs should target reductions in phosphorus and nitrogen.
4) Investigate the use of a mechanical harvester to open up channels to improve the fish population and lake use.
5) If dredging is considered, shape the lake bottom to include some deep water habitat and some shallow water islands. Place a sediment trap upstream to be maintained regularly.