**Changes in the Aquatic Plant Community**

**of**

**Glen Loch,**

# 1991 - 2006

# Chippewa County, Wisconsin

****

**Submitted by:**

**Deborah Konkel**

**Wisconsin Department of Natural Resources**

**West-Central Region**

**Eau Claire, WI**

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**EXECUTIVE SUMMARY**

Glen Loch is a eutrophic impoundment with poor water quality and very poor clarity. Filamentous algae was abundant and has increased since 1991, occurring at more than three-quarters of the sites.

The aquatic plant community colonizes the entire littoral zone (54% of the lake surface) to a maximum rooting depth of 12 feet. The greatest amount of plant growth occurred in the 0-1.5ft depth zone. *Lemna minor* (small duckweed) was the dominant species in 2006, especially in the 0-1.5ft depth zone and *Wolffia columbiana* (common watermeal) was the sub-dominant species. Both occurred at nearly all sites and exhibited a growth form of above average density.

The aquatic plant community in Glen Loch Lake is characterized by poor species diversity, low quality, a higher than average tolerance of disturbance and a condition closer to an undisturbed condition than the average lake in the state and the region.

**Changes in the community 1991-2006**

The aquatic plant community changed significantly between 1991 and 2006.

1. Sub-dominance in the community shifted from a rooted submerged species to a free-floating duckweed.
2. The zone of most abundant plant growth has shifted into shallower water.
3. Every measure of the aquatic plant community has increased.

These changes may signify increased nutrients since 1991.

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

**Recommendations**

1. Lake shore residents protect natural shoreline buffers that protect water quality and provide habitat. Disturbed shore was commonly encountered and appears to be impacting the aquatic plant community in those areas. Disturbance on shore may be eliminating sensitive species, facilitating the spread of the exotic-invasive reed-canary grass, lowering the quality of the aquatic plant community and lowering the quality of the habitat in the lake.
2. Lake shore residents use best management practices on shoreland property to prevent nutrient enrichment and stormwater run-off to the lake.
3. Residents and agencies initiate and cooperate with programs that protect land in the watershed and reduce nutrient input from the watershed.
4. Lakeshore residents become involved in the Citizen Lake Monitoring Program.
5. Lake residents and DNR maintain exotic species signs at boat landing.

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**Changes in the Aquatic Plant Community of**

**Glen Loch Lake, Chippewa County, Wisconsin**

**1991-2006**

**I. INTRODUCTION**

Surveys of the aquatic plants (macrophytes) in Glen Loch Lake were conducted during July 1991 and 2006 by Water Resources staff from the Western Central Region – Wisconsin Department of Natural Resources (DNR).

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. 1991).

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

**Characterize Water Quality:** Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1991).

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

**Background and History**

Glen Loch Lake is a 39-acre impoundment of Duncan Creek in southern Chippewa County, Wisconsin. It has a maximum depth of 17 feet.

The Duncan Creek Watershed encompasses 123,520 acres, of which Glen Loch is one of a series of small impoundments in this watershed. The Glen Loch subwatershed is 5184 acres, a watershed (drainage area) to lake size ratio of 133:1. Lakes with drainage area/lake size ratios greater than 10:1 tend to have water quality problems (Field 1994).

**II. METHODS**

Field Methods

The same study design and transects were used for the 1991 and 2006 aquatic plant studies. The design was based on the rake-sampling method developed by Jessen and Lound (1962). Thirteen equal-distance transect lines were placed perpendicular to the shoreline with the first transect being randomly placed (Appendix VII).

One sampling site was randomly located at each depth zone (0-1.5ft., 1.5-5ft., 5-10 ft., and 10-17ft.) along each transect. Using a long-handled, steel, thatching rake, four rake samples were taken at each sampling site. The four samples were taken at each corner of a 6-foot square quadrat. The aquatic plant species that were present on each rake sample were recorded. The species recorded include aquatic vascular plants and macrophytic algae, such as muskgrass and nitella. Each species was given a density rating (0-5), the number of rake samples at each sampling site on which it was present.

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

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

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

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

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

The presence of filamentous algae was recorded. The actual depth and 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 each species present were collected and saved in a cooler for preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on each side of the transect intercept with the shore and 30 feet deep was evaluated. The percentage of each cover type within this 100 ft. X 30 ft. rectangle was recorded (Table 3).

Data Analysis

The data was analyzed separately for each year and compared. The percent frequency of occurrence of each species was calculated (number of sampling sites at which it occurred/number of sampling sites) (Appendices I-II). Relative frequency was calculated (number of sample sites at which it occurred\the sum of all species occurrences) (Appendices I-II). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendices III-IV). Relative density was calculated (the density rating of a species\the sum of all species densities) (Appendices III-IV). A “density where present” was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendices III-IV). The relative frequency and relative density of each species was summed to obtain a Dominance Value for each species (Appendices V-VI). Simpson's Diversity Index 1-(∑(Relative Frequency2)) was calculated for each sampling year (Appendices I-II). The sampling years were compared by a Coefficient of Community Similarity.

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

Coefficients of Conservatism and Floristic Quality Indices were used to evaluate the closeness of the aquatic plant community to an undisturbed condition (Nichols 1998). A Coefficient of Conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients of conservatism for all species found in a lake and measures the sensitivity of the community to disturbance. The Floristic Quality Index is calculated from the coefficients and measures the plant community’s closeness to an undisturbed condition.

# III. RESULTS

**PHYSICAL DATA**

**Water Chemistry**

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

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

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

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

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

##### Nutrients

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

**1991 summer mean phosphorus concentration in Glen Loch Lake was 413 ug/l**

This concentration of phosphorus in Glen Loch Lake is indicative of a hypereutrophic lake (Table 1).

# Table 1. Trophic Status

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Quality Index | Phosphorus ug/l | Chlorophyll ug/l | Secchi Disc ft. |
| Oligotrophic | Excellent | <1 | <1 | > 19 |
|  | Very Good | 1-10 | 1-5 | 8-19 |
| Mesotrophic | Good | 10-30 | 5-10 | 6-8 |
|  | Fair | 30-50 | 10-15 | 5-6 |
| Eutrophic | Poor | 50-150 | **15-30** | **3-4** |
| Hypereutrophic | Very Poor | **>150** | >30 | >3 |
| Glen Loch Lake 1991 | **Poor-to-Very Poor** | **413 ug/l** | **22 ug/l** | **3.6 ft.** |

After Lillie & Mason (1983) & Shaw et. al. (1991)

Although the majority of Wisconsin Lakes are phosphorus limited, about 10% are nitrogen limited and nitrogen inputs fuel algae growth (Shaw et. al 1993). The Nitrogen:Phosphorus Ratio in Glen Loch varied between 5:1 and 10:1 in 1991. Since the ratio is 10:1 and less, Glen Loch would be considered a nitrogen limited lake.

**Algae**

Chlorophyll concentrations provide a measure of the amount of algae in lake water. Algae are natural and essential in lakes, but high algae populations can increase turbidity and reduce the light available for plant growth.

**1991 summer mean chlorophyll concentration in Glen Loch Lake was 22 ug/l.**

The chlorophyll concentration in Glen Loch Lake indicates that it was a eutrophic lake (Table 1).

The occurrence of filamentous algae in Glen Loch has increased from 71% in 1991 to 80% in 2006. Filamentous algae has been most abundant in the shallowest depth zones in both years (Figure 1).



**Figure 1. Occurrence, by depth zone of filamentous algae in Glen Loch, 1991-2006.**

**Water Clarity**

Water clarity is a critical factor for plants. When plants receive less than 1 - 2% of the surface illumination, they can not survive. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Water clarity is measured with a Secchi disc that shows the combined effect of turbidity and color

**1991 summer mean Secchi Disc clarity in Glen Loch Lake was 3.6 ft.**

Water clarity indicates (Table 1) that Glen Loch Lake was a eutrophic lake with very poor water clarity.

Satellite images have been used to estimate water clarity in Wisconsin Lakes. Satellite data from 2000 and 2001 suggests that water clarity has increased in Glen Loch since 1991 (Figure 2).

**Figure 2. Change in water clarity in Glen Loch Lake, 1991-2006.**

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicates that Glen Loch Lake is a eutrophic lake with poor water quality. This trophic state would support plant growth and frequent algae blooms.

**Hardness**

The 1991 hardness value was 32 mg/l CaCO3. Lakes with a hardness value of 0-60mg/l CaCO3 are considered soft water lakes. Soft water lakes tend to have less abundant plant growth than hard water lakes.

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

Glen Loch Lake has a narrow, shallow basin with gradually-sloped littoral zone in the north end. The littoral zone is more steeply sloped in the south end.

**SEDIMENT COMPOSITION**

The dominant sediment in Glen Loch Lake was silt, dominating all depths zones (Table 2) (Figure 3). Sand was abundant at the deepest zone. Sand/silt mixture was common in the shallowest zone (0-1.5ft).

**Table 2. Sediment Composition: Glen Loch Lake, 2006**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sediment Type** | | **0-1.5' Depth** | **1.5-5' Depth** | **5-10' Depth** | **10-20’ Depth** | **Percent of all Sample Sites** |
| **Soft**  **Sediments** | Silt | 31% | 62% | 75% | 50% | 53% |
| Muck | 8% | 8% |  |  | 6% |
| Silt/Muck |  | 8% |  |  | 3% |
| **Mixed**  **Sediments** | Sand/Silt | 23% | 8% | 12% |  | 14% |
| Silt/Rock | 8% |  |  |  | 3% |
| **Hard Sediments** | Sand | 15% | 15% | 12% | 50% | 17% |
| Sand/Gravel | 8% |  |  |  | 3% |
| Sand/Rock | 8% |  |  |  | 3% |



Organic Muck

Mixed Sediments types

Mixed Soft Sediments

Mixed Hard Sediments

Silt

Sand

**Figure 3. Distribution of sediment types in Glen Loch, 2006.**

# SEDIMENT INFLUENCE

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

Silt, the dominant sediment in Glen Loch Lake, is most favorable for plant growth due its intermediate density. The availability of mineral nutrients essential for plant growth is highest in sediments of intermediate density, such as silt (Barko & Smart 1986). All sediment types supported vegetation in Glen Loch.

**SHORELINE LAND USE**

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

Wooded cover was the most frequently encountered shoreline cover at the transects and had the highest mean coverage. Shrubs growth and natural herbaceous growth were also commonly encountered and shrubs had a high cover (Table 3). Disturbed shoreline occurred also; hard structures were commonly encountered (Table 3).

Natural shoreline (wooded, shrub, native herbaceous) was found at all of the sites and had a mean coverage of 88%. Disturbed shoreline (cultivated lawn, hard structures, eroded) was found at 31% of the sites and had a mean coverage of 12%.

**Table 3. Shoreline Land Use - Glen Loch Lake, 2006**

|  |  |  |  |
| --- | --- | --- | --- |
| **Cover Type** |  | **Frequency of Occurrence at Transects** | **Mean % Coverage** |
| Natural  Shoreline | Wooded | 77% | 60% |
| Shrub | 46% | 22% |
| Native Herbaceous | 31% | 6% |
|  | **Total Natural** |  | **88%** |
| Disturbed  Shoreline | Hard Structures | 23% | 2% |
| Cultivated Lawn | 15% | 7% |
| Eroded | 8% | 3% |
|  | **Total Disturbed** |  | **12%** |

**MACROPHYTE DATA**

**SPECIES PRESENT**

Twenty (20) species of aquatic plant species were found in Glen Loch Lake, 11 were emergent species, 3 were floating-leaf species and 6 were submergent species (Table 4).

No endangered or threatened species were found. One exotic species was present in 2006: *Phalaris arundinacea,* reed-canary grass; this species had not occurred in the 1991 survey.

**Table 4. Aquatic Plant Species in Glen Loch Lake, 1991-2006**

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

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

Emergent Species

1) *Alnus incana* (L) Moench speckled alder alnvi

2) *Bidens connata* Muhl. purple-stem beggar’s-tick bidco

3) *Calamagrostis canadensis* (Michx.) P.Beauv. bluejoint grass calca

4) *Carex crinita* Lam. sedge carcr

5) *Cicuta bulbifera* L. bulb-bearing water hemlock cicbu

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

7) *Sagittaria latifolia* Willd. common arrowhead sagla

8) *Scirpus validus* Vahl. softstem bulrush sciva

9) *Sparganium eurycarpum* Engelm. giant bur-reed spaeu

10) *Typha latifolia* L. common cattail typla

11) *Zizania aquatica* L. wild-rice zizaq

Floating-leaf Species

12) *Lemna minor* L. small duckweed lemmi

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

14) *Wolffia columbiana* Karst. water-meal wolco

Submergent Species

15) *Ceratophyllum demersum* L. coontail cerde

16) *Elatine minima* (Nutt.) Fischer & Meyer waterwort elami

17) *Elodea canadensis* Michx. common waterweed eloca

18) *Nitella* sp. stonewort nitsp

19) *Potamogeton nodosus* Poiret. long-leaf pondweed potno

20) *Potamogeton pusillus* L. small pondweed potpu

**FREQUENCY OF OCCURRENCE**

*Lemna minor* (small duckweed) was the most frequently occurring species in Glen Loch Lake both years (80%, 97% of the sample sites) (Figure 4). Other species that were commonly occurring both years were *Ceratophyllum demersum* (coontail), *Elodea canadensis* (common waterweed) and *Potamogeton pusillus* (small pondweed)*. Nitella* spp (stonewort, a macrophytic algae) was also commonly occurring in 1991, but declined in 2006. *Wolffia columbiana* (common watermeal) increased dramatically from 1991 and was abundant in 2006 (Figure 4).

**Figure 4. Frequency of aquatic plant species in Glen Loch Lake, 1991-2006.**

**(does not include 5 emergent species that only occurred in limited**

**locations in one of the years)**

**DENSITY**

*Lemna minor* (small duckweed) was also the species with the highest mean density in both years (2.37, 2.75 on a scale of 0-5) (Figure 5).

**Figure 5. Mean density of aquatic plant species in Glen Loch, 1991-2006.**

The “density where present” of *Lemna minor* (2.96, 2.83) indicates that this species exhibited a growth form of above average density both years in Glen Loch Lake (Figure 6). *Typha latifolia* (common cattail) had the highest “density where present“ both years, but was not commonly occurring, indicating it exhibited an aggregated growth form. *Elodea canadensis* (common waterweed) exhibited a growth form of above average density both years and *Wolffia columbiana* (common watermeal) exhibited above average density in 2006 (Figure 6).

**Figure 6. “Density where present” of aquatic plant species in Glen Loch, 1991-2006.**

# DOMINANCE

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

*Lemna minor* (small duckweed) was the dominant species both years with *Elodea canadensis* sub-dominant in 1991and *Wolffia columbiana* (common watermeal) sub-dominant in 2006 (Figure 7).

# 



**Figure 7. Dominance of the most prevalent aquatic plant species within the Glen Loch Lake aquatic plant community, 1991-2006.**

**DISTRIBUTION**

Rooted aquatic plants occurred throughout the littoral zone of Glen Loch Lake, 100% of the littoral zone (54% of the lake surface), to maximum depth of 12 feet (Figure 8). *Elodea canadensis* (common waterweed) occurred at the maximum depth.

In 2006, submergent vegetation colonized 20 acres (51% of the lake surface, 78% of the littoral zone.

Emergent vegetation colonized 1 acre (2% of the lake surface, 17% of the littoral zone.

Because free-floating species can move across a water body with shifts in wind and the mats can expand or contract with changes in growing conditions, is not appropriate to map them as permanent cover. In July 2006, they colonized the entire littoral zone. The dominant, abundant and common species were distributed throughout the lake.



**Figure 8. Distribution of aquatic vegetation in Glen Loch, 2006.**

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

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

**The predicted maximum rooting depth in Glen Loch Lake, based on 2001 Satellite estimated water clarity, is 13 feet.**

This is slightly more than the actual maximum rooting depth of 12 feet recorded in Glen Loch Lake (Figure 9). This may be due to less reliable estimates based on satellite data or using clarity data (2001) from a different year than the plant survey was conducted (2006).

**Figure 9. Predicted and actual maximum rooting depth in Glen Loch, based on water clarity, 1991-2006.**

2006 Rooting Depth

Total occurrence and total density of plant growth increased between 1991 and 2006 (Figure 10). The highest total occurrence and total density of plant growth shifted from the 1.5-5ft depth zone in 1991, to the 0-1.5ft depth zone in 2006 (Figure 10).

**Figure 10. Total occurrence and total density of aquatic plant growth, by depth zone in Glen Loch, 1991-2006.**

The percent of the littoral zone vegetated increased between 1991 and 2006 so that all sites were vegetated in 2006. The depth zone with the highest percent vegetation was the 0-5ft depth zone in 1991 (Figure 11). The greatest Species Richness (number of species per sample site) occurred in the 1.5-5ft depth zone in 1991. Species Richness increased in 2006 and the zone with the greatest richness shifted to the 5-10ft depth zone in 2006 (Figure 11).

**Figure 11. Percent of littoral zone vegetated and Species Richness in Glen Loch Lake, by depth zone, 1991-2006.**

**Changes in Aquatic Plant Community, 1991-2006**

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

**The Coefficient of Community Similarity of the 1991 and 2006 aquatic plant communities in Glen Loch was 0.708. This suggests that the 1991 and 2006 aquatic plant communities are only 71% similar and therefore significantly different** (Appendix VIII).

Several parameters that measure an aquatic plant community can be compared to show the type of changes that have occurred. Between 1991 and 2006, there was increases in the number of species occurring at the sample sites, maximum rooting depth, the percent of the littoral zone colonized by vegetation, the percentage cover of all structural types of vegetation (emergent, submergent and free-floating species), the diversity index, species richness (mean number of species per sample site), the plant community’s closeness to an undisturbed condition (Floristic Quality Index, discussed later), the plant community’s sensitivity to disturbance (Average Coefficient of Conservatism, discussed later) and the quality of the plant community (AMCI, discussed later) (Table 5).

The greatest increase was in the coverage of emergent vegetation, which more than doubled (Table 5).

**Table 5. Changes in the Glen Loch Lake Aquatic Plant Community, 1991-2006**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **1991** | **2006** | **Change**  **1991-2006** | **%Change**  **1991-2006** |
| **Number of Species** | 9 | 14 | 5 | 55.6% |
| **Maximum Rooting Depth** | 9.0 | 12.0 | 3 | 33.3% |
| **% of Littoral Zone Vegetated** | 89 | 100 | 11 | 12.4% |
| **%Sites/Emergents** | 6 | 17 | 11.0 | 183.3% |
| **%Sites/Free-floating** | 86 | 100 | 14.0 | 16.3% |
| **%Sites/Submergents** | 69 | 78 | 9.0 | 13.0% |
| **%Sites/Rooted Floating-leaf** |  |  | 0.0 |  |
| **Simpson's Diversity Index** | 0.78 | 0.84 | 0.06 | 7.7% |
| **Average Coefficient of Conservatism** | 4.8 | 5.21 | 0.41 | 8.5% |
| **Floristic Quality** | 15.18 | 22.71 | 7.53 | 49.6% |
| **AMCI** | 37 | 39 | 2.00 | 5.4% |
| **Species Richness** | 2.54 | 4.19 | 1.65 | 65.0% |

Simpson's Diversity Index was 0.84, indicating poor species diversity (Appendix I). A rating of 1.0 would mean that each plant in the lake would be a different species (the most diversity achievable). Since 1991, the diversity of the aquatic plant community has increased from very poor diversity to poor diversity (Table 5).

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols, et al (2000) was applied to Glen Loch Lake (Table 6). The AMCI Indices for Glen Loch Lake have been in the lowest quartile of lakes in the state and region both years, indicating that Glen Loch Lake is within group of the lakes in the state and region with the lowest quality aquatic plant community. The AMCI for Glen Loch Lake increased slightly from 37 in 1991 to 39 in 2006 (Table 6), indicating a slight increase in the quality of the aquatic plant community.

The paucity of submergent species (compared with other vegetative structure) and lack of sensitive species are limiting the quality of the plant community in Glen Loch (Table 6).

**Table 6. Aquatic Macrophyte Community Index, Glen Loch Lake, 1991-2006**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Category | 1991 | | 2006 | |
| Maximum Rooting Depth | 2.74 meters | 4 | 3.66 meters | 6 |
| % Littoral Zone Vegetated | 89% | 10 | 100% | 10 |
| Simpson's Diversity | 0.78 | 4 | 0.84 | 6 |
| # of Species | 9 | 4 | 14 | 7 |
| % Submergent Species | 52% Rel. Freq. | 4 | 31% Rel. Freq. | 1 |
| Exotic Species | 0 | 10 | 2% Rel. Freq. | 6 |
| % Sensitive Species | 0 % Rel. Freq. | 1 | 1% Rel. Freq. | 3 |
| Totals |  | 37 |  | 39 |

The maximum for the value is 70.

The Average Coefficient of Conservatism for Glen Loch Lake was below average for Wisconsin lakes and lakes in the North Central Hardwood Region in 2006. It has increased from the lowest quartile for Wisconsin lakes and lakes in the North Central Hardwood Region (Table 7) since 1991. This suggests that the aquatic plant community in Glen Loch Lake is more tolerant of disturbance than the average lake in the state or region and its tolerance decreased from being within the group of lakes in the state and region most tolerant of disturbance. Its tolerance of disturbance is likely due to selection from past disturbance.

**Table 7. Floristic Quality Index and Average Coefficient of Conservatism of Glen Loch Lake, Compared to Wisconsin Lakes and North Central Hardwood Region Lakes, 1991-2006.**

|  |  |  |
| --- | --- | --- |
|  | Average Coefficient of Conservatism **†** | Floristic Quality **‡** |
| Wisconsin Lakes | 5.5, 6.0, 6.9**\*** | 16.9, 22.2, 27.5**\*** |
| NCH Region | 5.2, 5.6, 5.8**\*** | 17.0, 20.9, 24.4**\*** |
| Glen Loch 1991 | 4.80 | 15.18 |
| Glen Loch 2006 | 5.21 | 22.71 |

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

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

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

The Floristic Quality Index of the plant community in Glen Loch Lake was in the lowest quartile of lakes in Wisconsin and the North Central Hardwood Region in 1991 (Table 7). In 2006, the Floristic Quality Index increased and was above the mean for lakes in the state and region. This suggests that the plant community in Glen Loch Lake improved from within the group of lakes in the state and region farthest from an undisturbed condition to a condition closer to an undisturbed condition than the average lake in the state and region in 2006.

Disturbances can be of many types:

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

The major disturbances in Glen Loch is likely run-off from the watershed. This run-off would carry toxics and nutrients from farm fields and urban lawns and pavement. The nutrients can feed algae and duckweed growth that decrease water clarity.

**Change in Individual Species, 1991-2006**

Between 1991 and 2006, nine new emergent species and one new submerged species appeared at the transects and one free-floating species disappeared from the transects at Glen Loch Lake. These species however were found in only a few locations, so that a shifting of a transect could have missed these species in one year or another.

Four species increased in frequency and density in Glen Loch Lake between 1991 and 2006: *Ceratophyllum demersum* (coontail)*, Potamogeton nodosus* (long-leaf pondweed)*, Sparganium eurycarpum* (great bur-reed)*, Wolffia columbiana* (common watermeal) (Appendix IX).The increase of *W. columbina* was the most dramatic; not occurring in 1991, but found at nearly all sites in 2006 and ranking as the sub-dominant species. *P. nodosus* nearly tripled in frequency and increased more than 5-fold in density. *C. demersum* nearly doubled in frequency and increased more than 6-fold in density. *S. eurycarpum* nearly doubled in frequency and density, but was found in only a few locations each year.

The remainder of the species decreased slightly, increased slightly or had mixed results of increases in either frequency or density and decreases in the other.

**IV. DISCUSSION**

Glen Loch Lake is a 39-acre eutrophic impoundment with poor water quality and very poor water clarity. Between 1991 and 2001, there appears to have been an increase in water clarity, but this increase in clarity was measured by different methods. Filamentous algae is very abundant and has increased since 1991 from 71% occurrence to 80% occurrence in 2006. Filamentous algae is found only in the 0-10ft depth zones. The ratio of nitrogen to phosphorus in Glen Loch suggests that it is a nitrogen-limited lake, which means increases in nitrogen can feed increased algae growth. Glen Loch’s relatively large watershed (drainage area) as compared to lake size means the lake would experience water quality problems from nutrient inputs from the watershed.

The high concentration of nutrients, dominance of favorable silt sediments in the lake, shallow depths and gradually sloped littoral zone in the north end would favor plant growth in Glen Loch. The soft water, steeply-sloped littoral zone in the south end and very poor water clarity could limit aquatic plant growth.

The aquatic plant community in Glen Loch Lake is closer to an undisturbed condition than the average lake and characterized by poor species diversity, a higher than average tolerance to disturbance and a low quality aquatic plant community. Aquatic plants colonize the entire littoral zone, 54% of the lake surface, up to the maximum rooting depth of 12 feet. Game fish populations have been found to decline when submerged aquatic vegetation cover is less than 10% and greater than 60% (Valley et. al. 2004). The 0-1.5ft depth zone supported the greatest total occurrence and total density of aquatic plant growth in 2006.

Twenty (20) species were found during the plant survey, more than half were emergent species. *Lemna minor* (small duckweed) was the dominant species both years, especially in the shallowest zone, occurring at nearly all the sites and exhibiting a growth form of above average density in Glen Loch. *Wolffia columbiana* (common watermeal) was sub-dominant in 2006, also occurring at nearly all sites and exhibiting a growth form of above average density. Other species that exhibited a dense growth form were *Elodea canadensis* (common waterweed) which was abundant in the lake, especially in the deeper zones and *Typha latifolia* (common cattail) which occurred in only limited locations along the shore. One exotic species, *Phalaris arundinacea* (reed canary grass)*,* occurred in 2006, but was not commonly occurring or at above average density in the lake. The dominant, abundant and common species were distributed throughout the lake.

**Shoreline Impacts**

Glen Loch has some protection from natural shoreline. Some type of natural shoreline covered 88% of the lake shore. Wooded cover had the highest occurrence and covered 60% of the shore. Disturbed shoreline was common and covered approximately 12% of the shore. Hard structure was the most common disturbed shoreline cover. Conversion of the natural shoreline to lawn, rip-rap or hard structures results in significant loss of shoreline habitat for wildlife. The loss of natural shoreline also destroys the buffer that infiltrates stormwater run-off to the lake. Run-off volume from developed lawn is approximately 10 times greater than run-off from natural wooded cover and more run-off events occurred at sites with lawn (Graczyk et. al. 2003). This increased run-off carries more nutrients to the lake. Nitrogen and phosphorus input was 10-100 times greater at developed lawn than wooded areas (Hunt et. al. 2006).

Even the small amount of disturbance on shore may be impacting the aquatic plant community in those areas disturbed. To measure the impacts, the plant data for Glen Loch Lake was divided into two sets: the transects at natural shoreline were separated from the transects at shorelines with any amount of disturbance (Appendices X-XI). These two sets of transects were analyzed as two separate communities compared.

The Average Coefficients of Conservatism and Floristic Quality Indices confirm that disturbance on shore has impacted the in-lake plant community. Both the Average Coefficient of Conservatism and Floristic Quality Index of natural shoreline communities were higher than at disturbed (Table 8). This means the natural shoreline communities are more sensitive to disturbance and closer to an undisturbed condition. The natural shoreline community is farther from an undisturbed condition than the average lake in the state and region, but the disturbed shoreline community is within the 25% of lakes in the state and region farthest from an undisturbed condition.

Another clue that disturbance is the factor is that the most sensitive species in Glen Loch Lake had a higher combined occurrence at the natural shoreline sites (Table 8). The most sensitive species (Nichols 1998), *Alnus incana* (speckled alder)*,* did not occur at the disturbed shoreline sites.

The disturbance may have impacted the quality of the aquatic plant community. The quality of the plant community (as measured by AMCI Index) was slightly higher at the natural shoreline sites than the disturbed shoreline sites (Nichols 2000) (Table 8, 9).

Disturbed shoreline may be impacting the in-lake habitat at those sites. Species Richness (the mean number of species found at a site) was greater at the natural shoreline sites. The richness was higher in all depth zones. Greater Species Richness suggests greater diversity for a more stable community and better habitat potential (Table 8). Sumergent vegetation had a higher coverage at the natural shoreline sites, providing more quality habitat.

Disturbance may also be facilitating the colonization and spread of non-native species The exotic, invasive species, reed-canary grass had a lower occurrence at the natural shoreline sites (Table 8).

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Metric** |  | **Natural Shoreline Community** | **Disturbed Shoreline Community** |
| **Average Coefficient of Conservatism** |  | 5.08 | 4.54 |
| **Floristic Quality Index** |  | 18.30 | 16.36 |
| **Most Sensitive Species** | Combined Relative Frequency | 18% | 13% |
| **AMCI Index (Community Quality)** | Scale of 7-70 | 40 | 38 |
| **Species Richness** | Combined depths | 4.4 | 3.8 |
|  | 0-1.5ft Depth Zone | 4.5 | 4.2 |
|  | 1.5-5ft Depth Zone | 4.0 | 3.4 |
|  | 5-10ft Depth Zone | 5.0 | 4.3 |
|  | 10-17ft Depth Zone | 5.0 | 2.0 |
| **Cover of vegetation** | **Submergent** | 82% | 71% |
| **Exotic** | **reed canary grass** | 4.5% Frequency  1% Rel. Frequency | 14.3% Frequency  4% Rel. Frequency |

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Category** | **Natural Shoreline** | | **Disturbed Shoreline** | |
| **Maximum Rooting Depth** | 3.0 meters | 5 | 3.6 meters | 6 |
| **% Littoral Zone Vegetated** | 100% | 10 | 100% | 10 |
| **Simpson's Diversity** | 0.83 | 5 | 0.84 | 6 |
| **# of Species** | 13 | 6 | 13 | 6 |
| **% Submergent Species** | 33% Rel. Freq. | 5 | 27% Rel. Freq. | 3 |
| **Exotic Species** | 1% Rel. Freq. | 6 | 4% Rel. Freq. | 6 |
| **% Sensitive Species** | 0 % | 3 | 1% Rel. Freq. | 1 |
| **Totals** |  | 40 |  | 38 |

**Changes: 1991-2006**

There has been a significant change in the aquatic plant community in Glen Loch Lake between 1991 and 2006 as measured by Coefficients of Community Similarity. The 1991 and 2006 aquatic plant communities are only 71% similar.

The dominant species in Glen Loch was *Lemna minor* (small duckweed) both years, but sub-dominance shifted from *Elodea canadensis* (common waterweed) in 1991 to *Wolffia columbiana* (common watermeal) in 2006*.* The depth zone that supported the greatest amount of aquatic plant growth shifted from the 1.5-5ft depth zone in 1991 to the 0-1.5ft depth zone in 2006.

Nearly every measure of the aquatic plant community increased from 1991-2006:

1. The percent of vegetated sites, the cover of vegetation, increased.
2. The coverage of all vegetative structural types occurring in Glen Loch increased: free-floating vegetation, submergent vegetation and emergent vegetation. The occurrence of emergent vegetation more than doubled.
3. Total occurrence and total density of plant growth increased.
4. The quality of the aquatic plant community increased slightly as measured by the AMCI index.
5. The diversity of the aquatic plant community increased as measured in three different ways.
   1. Species Richness (number of species per sample site) increased.
   2. Simpson’s Diversity Index increased from very poor diversity to poor diversity.
   3. The number of species recorded during the survey increased, especially emergent species.
6. Sensitivity to disturbance increased from a plant community within the 25% of lakes in the state and region most tolerant of disturbance in 1991 to a lake only more tolerant of disturbance than the average lake.
7. The lakes closeness to an undisturbed condition increased, from a lake within the 25% of lakes in the state and region farthest from an undisturbed condition to a lake closer to an undisturbed condition than the average lake.
8. The maximum rooting depth increased.
9. Four aquatic plant species increased in frequency and density: *Ceratophyllum demersum* (coontail) increased two to six-fold; *Potmogeton nodosus* (long-leaf pondweed) increased 3-5-fold; *Sparganium eurycarpum* (giant bur-reed) doubled and *Wolffia columbiana* (common watermeal) increased from not-detected in 1991 to sub-dominant in 2006.

**V. CONCLUSIONS**

Glen Loch is a eutrophic impoundment with poor water quality and very poor clarity. Filamentous algae was abundant, occurring only in the 0-10ft depth zones, but occurring at more than three-quarters of the sites. Filamentous algae has increased since 1991.

The aquatic plant community colonizes the entire littoral zone (54% of the lake surface) to a maximum rooting depth of 12 feet. The greatest amount of plant growth occurred in the 0-1.5ft depth zone. *Lemna minor* (small duckweed) was the dominant species in 2006, especially in the 0-1.5ft depth zones, occurring at nearly all sites and exhibiting a growth form of above average density. *Wolffia columbiana* (common watermeal) was the sub-dominant species in the community, also occurring at nearly all the sites and exhibiting a growth form of above average density.

The low quality aquatic plant community in Glen Loch Lake is characterized by poor species diversity, a higher than average tolerance of disturbance and a condition closer to an undisturbed condition than the average lake in Wisconsin and the North Central Hardwoods Region.

**Changes in the community 1991-2006**

The aquatic plant community changed significantly between 1991 and 2006 as measured by the Coefficient of Similarity.

1. Sub-dominance in the community shifted from a rooted submerged species to a free-floating duckweed. The community is now dominated by two free-floating duckweed species.
2. The zone of most abundant plant growth has shifted into shallower water, from the 1.5-5ft depth zone to the 0-1.5ft depth zone.
3. Every measure of the aquatic plant community has increased.

These changes may signify increased nutrients. Nutrients may be feeding increased plant growth and increased algae (planktonic and filamentous). The increased planktonic algae may be reducing water clarity that is pushing plant growth into shallower water and favoring free-floating species that can take nutrients directly from the water.

A healthy aquatic plant community plays a vital role within the lake community (Figure 12). This is due to the role plants play 1) improving water quality 2) providing valuable habitat resources for fish and wildlife 3) resisting invasions of non-native species and 4) checking excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.

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



**Figure 12. Benefits of aquatic plants in the lake ecosystem.**

Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table 10).

Aquatic plant cover within Glen Loch is 100% of the littoral zone (54% of the entire lake), which is appropriate to support a balanced fishery. Game fish populations have been found to decline when submerged aquatic vegetation cover is less than 10% and greater than 60% (Valley et. al. 2004).

**Table 10. Wildlife and Fish Uses of Aquatic Plants in Glen Loch**

| **Aquatic Plants** | **Fish** | **Water**  **Fowl** | **Song and Shore**  **Birds** | | **Upland Game**  **Birds** | **Muskrat** | **Beaver** | **Deer** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Submergent Plants** |  |  |  | |  |  |  |  |
| *Ceratophyllum demersum* | F,I\*, C, S | F(Seeds\*), I, C |  | |  | F |  |  |
| *Elodea canadensis* | C, F, I | F(Foliage) I |  | |  |  |  |  |
| *Nitella* sp. |  | F, I\* |  | |  |  |  |  |
| *Potamogeton nodosus* | F, I, S\*,C | F\*(Seeds) |  | |  | F\* | F | F |
| *Potamogeton pusillus* | F, I, S\*,C | F\*(All) |  | |  | F\* | F | F |
|  |  |  |  | |  |  |  |  |
| **Floating-leaf Plants** |  |  |  | |  |  |  |  |
| *Lemna minor* | F | F\*, I | F | | F | F | F |  |
| *Spirodela polyrhiza* | F | F |  | | F |  |  |  |
| *Wolffia columbiana* |  | F |  | |  | F |  |  |
|  |  |  |  | |  |  |  |  |
| **Emergent Plants** |  |  |  | |  |  |  |  |
| *Alnus incana* |  |  |  | | F, C |  | F | F |
| *Bidens connata* |  | F (Seeds), | F | | F | F |  |  |
| *Calamagrostis spp.* |  |  |  | |  | F\* |  | F\* |
| *Carex spp.* | S\* | F\*(Seeds), C | F\*(Seeds) | | F\*(Seeds) | F | F | F |
| *Sagittaria latifolia* |  | F, C | F(Seeds), C | | F | F | F |  |
| *Scirpus validus* | F, C, I | F (Seeds)\*, C | F(Seeds, Tubers), C | | F (Seeds) | F | F | F |
| *Sparganium eurycarpum* | I | F(Seeds), C | F, C |  | | F |  | F\* |
| *Typha latifolia* | I, C, S | F(Entire), C | F(Seeds), C, Nest | | Nest | F\* (Entire), C\*, Lodge | F |  |
| *Zizania aquatica* | F, C | F\*, C | F, C | | F, C | F\* |  | 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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Compared to non-vegetated lake bottoms, aquatic plant beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of plants support 3-8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).

**Recommendations**

1. Lake shore residents protect natural shoreline buffers that protect water quality and provide habitat. In 2006, natural native shoreline covered more than three-quarters of the shore, but disturbed shore was commonly encountered. Hard structure was especially common. Increased run-off to the lake from hard structure is not filtered and can carry toxics and debris. Disturbed shoreline appears to have already impacted the aquatic plant community in those areas of disturbance. A comparison of sample sites at developed shoreline and natural sites indicate:
   1. The Average Coefficient of Conservatism and Floristic Quality Index confirm that disturbance is a factor. Aquatic plant communities at disturbed shore are more tolerant of disturbance and farther from an undisturbed condition.
   2. Another clue that disturbance is responsible for differences is that the most sensitive species in the lake had a lower occurrence at the disturbed shoreline sites and the most sensitive species did not occur at disturbed shore sites.
   3. Disturbance on shore appears to be impacting the quality of the aquatic plant community. The quality of the plant community was lower at the disturbed shoreline sites than the natural shore sites.
   4. Disturbance on shore may be impacting the quality of the habitat in the lake. Disturbed shoreline sites had less species richness and less cover of submerged vegetation; this results in a less total habitat and a less diverse habitat which supports less diversity in the fish and wildlife communities.
   5. Disturbance may be facilitating the spread of exotic species. The exotic, invasive species, reed-canary grass, had a higher occurrence at developed shoreline sites.
2. Lake shore residents use best management practices on shoreland property to prevent nutrient enrichment and stormwater run-off to the lake.
   1. Eliminate fertilization near shoreline
   2. Use no-phosphorus fertilizer on remainder of the property
   3. Minimize use of toxic chemicals and no disposal of chemicals in the lake
   4. Use and maintain erosion barriers during any construction
   5. Inspect and maintain septic systems
   6. Reduce size of areas with hard surface
   7. Design landscaping so that stormwater run-off runs away from the lake, onto porous land cover and/or into rain barrels or rain gardens
3. Residents and agencies initiate and cooperate with programs that protect land in the watershed and reduce nutrient input from the watershed.
4. Lakeshore residents become involved in the Citizen Lake Monitoring Program, monitoring water quality in Glen Loch.
5. Lake residents and DNR maintain exotic species signs at boat landing to educate lake users on the spread of exotic species and prevent the introduction of other exotic species into Glen Loch.

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**Appendix VII. Location of Aquatic Plant Study Transects on Glen loch, 1991-2006.** 

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