The Aquatic Plant Community of Jacqueline Lake, Portage County, Wisconsin

2006

Wisconsin Department of Natural Resources
Eau Claire, WI
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Submitted by:

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Executive Summary

Jacqueline Lake is a shallow mesotrophic lake with fair water quality. No filamentous algae was seen during the July 2006 study.

The aquatic plant community colonized nearly the entire littoral zone, more than half of the total lake area, to a maximum depth of 9.5 feet. The 0-1.5 ft. depth zone supported the most abundant aquatic plant growth. The aquatic plant community in Jacqueline Lake is a soft water community characterized by average-to-above average quality, good species diversity, a high intolerance to disturbance and a condition close to an undisturbed condition.

Utricularia purpurea (purple bladderwort) was the dominant species within the Jacqueline Lake aquatic plant community, especially in the 1.5-12ft depth zones, occurring at more than three-quarters of the sample sites and exhibiting a dense growth form. *U. purpurea* is listed as a Special Concern Species. *Nymphaea odorata* (white water lily) was the sub-dominant species, occurring at approximately half of the sites and at an above average density. Another listed Special Concern Species was commonly occurring in Jacqueline Lake, *Eleocharis robbinsii* (Robbin's spikerush).

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play 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 out-compete sensitive species, thus reducing diversity.

Management Recommendations

1) Update management plan for Jacqueline Lake, based on 2006 plant study and Critical Habitat Area Designations.
2) Lake property owner preserve the natural shoreline cover that occurs on three-quarters of Jacqueline Lake shoreline.
3) Restore natural shoreline buffers that have been cleared. Negative impacts to the aquatic plant community were measured at developed shorelines using FQI. Disturbed shoreline aquatic plant communities were of lower quality provided less cover and less diverse habitat.
4) Lakes residents use best management practices on shoreland property to prevent nutrient enrichment and stormwater run-off to the lake.
5) Lake residents begin monitoring the water quality through the Citizen Lake Monitoring Program.
6) DNR to designate Critical Habitat Areas within Jacqueline Lake.
7) Lake District and DNR maintain exotic species educational signs at the landing.
8) Consider designating Jacqueline Lake as a slow-no-wake lake. Jacqueline is very susceptible to impacts from motor boats.
9) Do not resume chemical treatments for aquatic plant control in Jacqueline Lake.
10) If plant control is needed in Jacqueline Lake, continue with mechanical harvesting. In contrast to chemical treatments, it appears that harvesting has improved water quality in Jacqueline Lake.
11) Leave bogs in place to protect the shoreline of the lake.

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I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Jacqueline Lake was conducted during July 2006 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR). This was the first quantitative vegetation study of Jacqueline Lake by the DNR. A qualitative assessment of the aquatic plant community was conducted by the WI-DNR in 1982 for a feasibility study and grant application. Direct comparisons can not be made between these studies, only general comparisons.

A study of the diversity, density and distribution of aquatic plants is an essential component of understanding a lake due to the important ecological role of aquatic vegetation in the lake ecosystem 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 (including algae) - the beginning of the food chain. Aquatic plants provide food and shelter for fish, wildlife and the invertebrates that in turn provide food for other organisms. Plants 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 future plant inventories and offer insight into any changes occurring in the lake.

Background and History: Jacqueline Lake is a 40-acre seepage lake in northeast Portage County, Wisconsin. Jacqueline Lake has a maximum depth of 11-12 feet and a mean depth of 4 feet. A large bog/wetland complex forms the north shore of the lake and two scattered bog islands are found in the south end of the lake.

The watershed of Jacqueline Lake is small relative to the lake size. With a 111-acre watershed, the watershed to lake ratio is only 2.8/1 and would not have a major impact on the lake.

The Jacqueline Lake District was established in 1978.

Aquatic herbicides have been applied to the lake in past years, 1968-1993, with the heaviest chemical use in the late 1980's to early 1990's (Table 1).

Table 1. Herbicides Used on Jacqueline Lake, 1968-1993.

	2, 4-5T (gal.)	2, 4-D (gal).	2, 4-D (lbs.)	Rodeo (gal).	Copper Sulfate (lbs.)	Aquathol + (lbs.)	Aquathol K (gal).	acres	# of treatments
1968	120					400		8	2
1972					130			10	2
1987		15		2.9	25			18	3
1988				6.5	50			10	1
1989		5		7	25		2	11	2
1990				7.5				8	2
1991			10	3.75				8	3
1992		8						4	1
1993		7.5	150					6	2
Totals	120	35.5	160	27.65	230	400	2		18

Several types of chemicals have been applied to Jacqueline Lake. 2, 4, 5-T, applied in 1968, is a phenoxy compound that has since been banned due to toxicity; 2, 4-D compounds applied in 1987-1993 are selective broad-leaf control herbicides; rodeo applied in 1987-1991 is a glyphosate compound used on emergents and floating-leaf vegetation, aquathol applied in 1968-1989 is an endothall product that is a broad-spectrum, contact herbicide (kills everything it contacts); copper sulfate applied in 1972-1989 is an algaecide. Copper does not break down further and remains in the sediments, rendering them toxic to many forms of aquatic life (Table 1).

The drawbacks to the herbicide treatments are that:

1) most herbicides also kill the aquatic insects that are part of the foundation of the food chain in a lake
2) the plant material decays in the water, releasing nutrients that feed algae blooms
3) the plant material decays in the water, using oxygen needed by aquatic life
4) the plant material decays in the water, enriching the sediments at the site to promote more plant growth
5) the treatment clears areas that are then vulnerable to invasion by exotic species if introduced
6) no herbicide is proven safe, always leading to risks. As an example is the 2,4,5-T applied in 1968 that is now banned.

Water quality monitoring during 1976-1981, indicated that Jacqueline Lake is a eutrophic waterbody. Alkalinity in the same time period ranged from 9.26-14.3 mg/l CaCO3. This makes Jacqueline a soft water lake, the lake with the softest water in Portage County. Soft water lakes tend to support less plant growth than hard water lakes.

Jacqueline Lake started a mechanical harvesting program to cut channels in plant beds to provide navigation in the lake. Records exist only for recent years (Table 2). 1999 was the last year that bog removal was contracted.

Table 2. Mechanical Harvesting in Jacqueline Lake, 1995-2005.

	Estimated Cut		Acres	Hours	Number of cuts
	yds^3	tons			
1995		25	7		
1996	50			100	5
1997		27	7		
1998	40		4.5	150	3
1999	40		4.5	150	3
2000	48		4.5	150	3
2001		25	3	150	3
2002	40		4.5	150	3
2003		40	3	150	3
2004	40		5	150	3
2005	40		5	150	3
Totals	298	117		1300	29

A circa 1982 aquatic plant assessment found that bog and its emergent vegetation colonized 10 acres, floating-leaf vegetation colonized 5 acres and submergent species colonized 22 acres to a maximum rooting depth of 9 feet, leaving 2-3 acres without aquatic vegetation. A list of floating-leaf and submergent aquatic plant species was generated at that time (Table 3).

Table 3. Aquatic Plant Species Recorded in Jacqueline Lake, circa 1982.

Scientific Name	Common Name
Emergent Species	
Not included in the listing	
Floating-leaf Species	
*1) *Brasenia schreberi*	watershield
2) *Nuphar variegata*	bull-head pond lily
*3) *Nymphaea odorata*	white water lily
Submergent Species	
4) *Elodea occidentalis*	waterweed
5) *Eriocaulon septangulare*	pipewort
6) *Najas* spp.	bushy pondweed
*7) *Nitella* sp.	stonewort
8) *Potamogeton amplifolius*	large-leaf pondweed
9) *Potamogeton berchtoldi*.	pondweed
10) *Potamogeton epihydrus*	ribbon-leaf pondweed
*11) *Sparganium angustifolium*	narrow-leaf burreed
*12) *Utricularia* spp.	bladderwort

* abundant

Water levels appear to fluctuate on Jacqueline Lake; in 1994-95 when gauge data was reported, the lake level fluctuated between 10 and 12 feet (Figure 1).

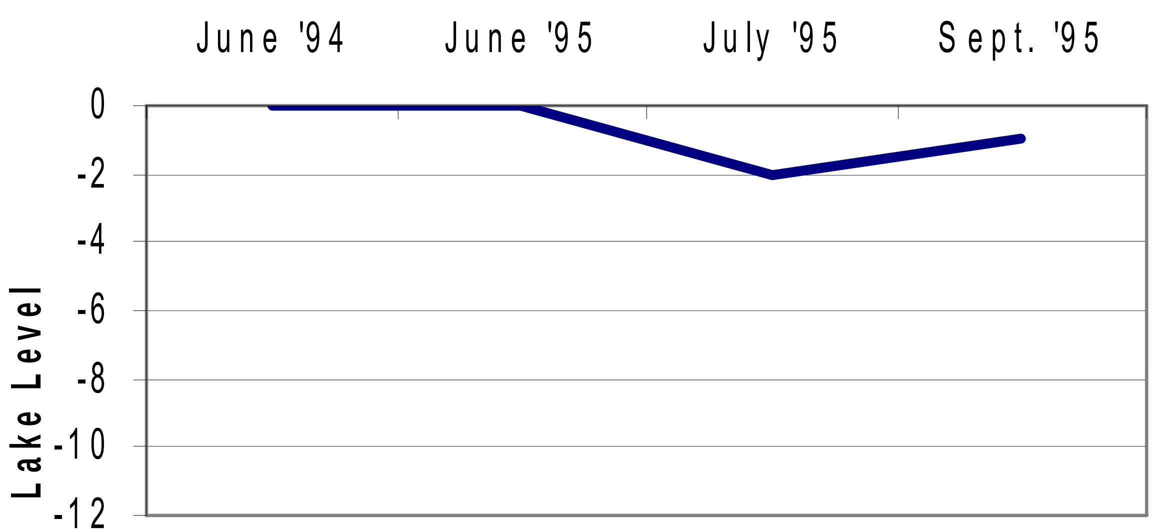

Figure 1. Change in Lake Level in Jacqueline Lake, 1994-1995.

II.METHODS

Field Methods

The study design was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines. The shoreline was divided into 14 equal segments and a transect, perpendicular to the shoreline, was randomly placed within each segment (Appendix IV), using a random numbers table.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a long-handled, steel, thatching rake, four rake samples were taken at each sampling site, 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 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 deep was evaluated. The percentage of each shore cover type within this 100' x 30' rectangle was visually estimated and verified by a second researcher.

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 that species occurred) (Appendix II). The relative frequency and relative density of each species was summed to obtain a dominance value for each species (Appendix III). Species diversity was measured by calculating Simpson's Diversity Index $1-(\sum(\text{Relative Frequency}^2))$ (Appendix I).

The Aquatic Macrophyte Community Index (AMCI) developed for Wisconsin Lakes by Nichols (2000) was applied to Jacqueline Lake (Table 9) to quantify the quality of the aquatic plant community. Values between 0 and 10 are given for each of seven categories that characterize a plant community and summed.

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

III. RESULTS

PHYSICAL DATA

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

WATER QUALITY - The trophic state of a lake is an indication of its water quality. Phosphorus concentration, chlorophyll a concentration 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 nutrient concentration in a lake. Increases in phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth.

2002-03 Mean summer phosphorus concentration in Jacqueline Lake was 33ug/l

The concentration of phosphorus in Jacqueline Lake was indicative of a mesotrophic lake (Table 4).

Table 4. Trophic Status

	Quality Index	Phosphorus ug/l	Chlorophyll a ug/l	Satellite Estimated 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
Jacqueline Lake – 2002-03	**Fair**	**33 ug/l**	**3.0-19.6ug/l (1976-1981)**	**4.5-7.5ft (1999-2001)**

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

Algae

Chlorophyll a concentrations measure 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.
The only chlorophyll data found for Jacqueline Lake was during 1976-1981 (WI-DNR 1982). The values fluctuated between 3.0 and 19.6ug/l during that time period, but there was no record as to the time of year the chlorophyll was monitored. This represents a fluctuation between oligotrophic and mesotrophic conditions (Table 4).

Filamentous algae was not found in Jacqueline Lake during the 2006 plant study.

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 was found in bits and pieces, sporadically, from various sources over the past 30 years (Figure 2). A Department of Natural Resources report reported Secchi Data for 1976-1981 (WI-DNR 1982); volunteers with the Self-Help Volunteer Lake Monitoring Program recorded water clarity and water level data in 1994-95; satellite data was used to estimate water clarity for 1999-2001.

Water clarity has fluctuated from mesotrophic to hypereutrophic conditions in Jacqueline Lake during these years (Figure 2, Table 4).

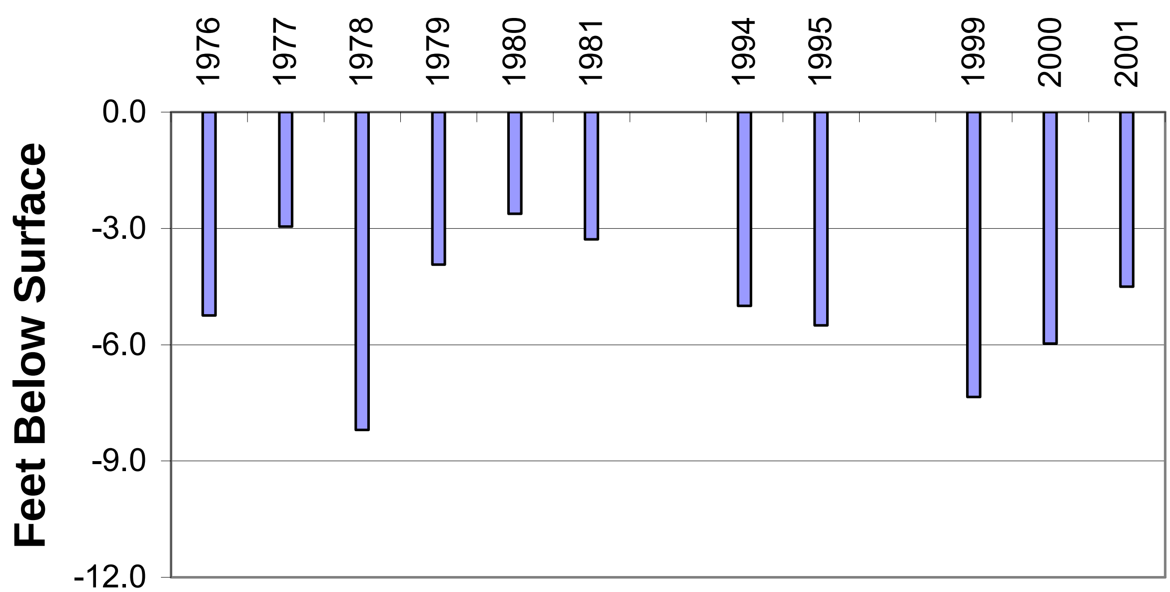

Figure 2. Water Clarity data from various sources, Jacqueline Lake, 1976-2001.

The most recent data, phosphorus concentration, indicates that Jacqueline Lake is a mesotrophic lake with fair water quality. This trophic state would favor moderate plant growth and occasional algae blooms.

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

Jacqueline Lake is a shallow lake with a very gradually-sloped littoral zone (Appendix IV). The gentle slopes provide a more stable substrate for aquatic plant growth and a broader band of shallow waters favorable for plant growth.

SEDIMENT COMPOSITION – The dominant sediment in Jacqueline Lake was a silt/peat mixture, dominant at depths of 0-10ft (Table 5). Peat sediment was common in the 5-10ft depth zone and the only sediment found at the deep hole (Figure 3).

Table 5. Sediment Composition in Jacqueline 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/Peat	64%	92%	67%		74%
	Peat			33%	100%	9%
	Silt	7%	8%			6%
Mixed Sediments	Sand/Silt	14%				6%
	Sand/Peat	14%				6%

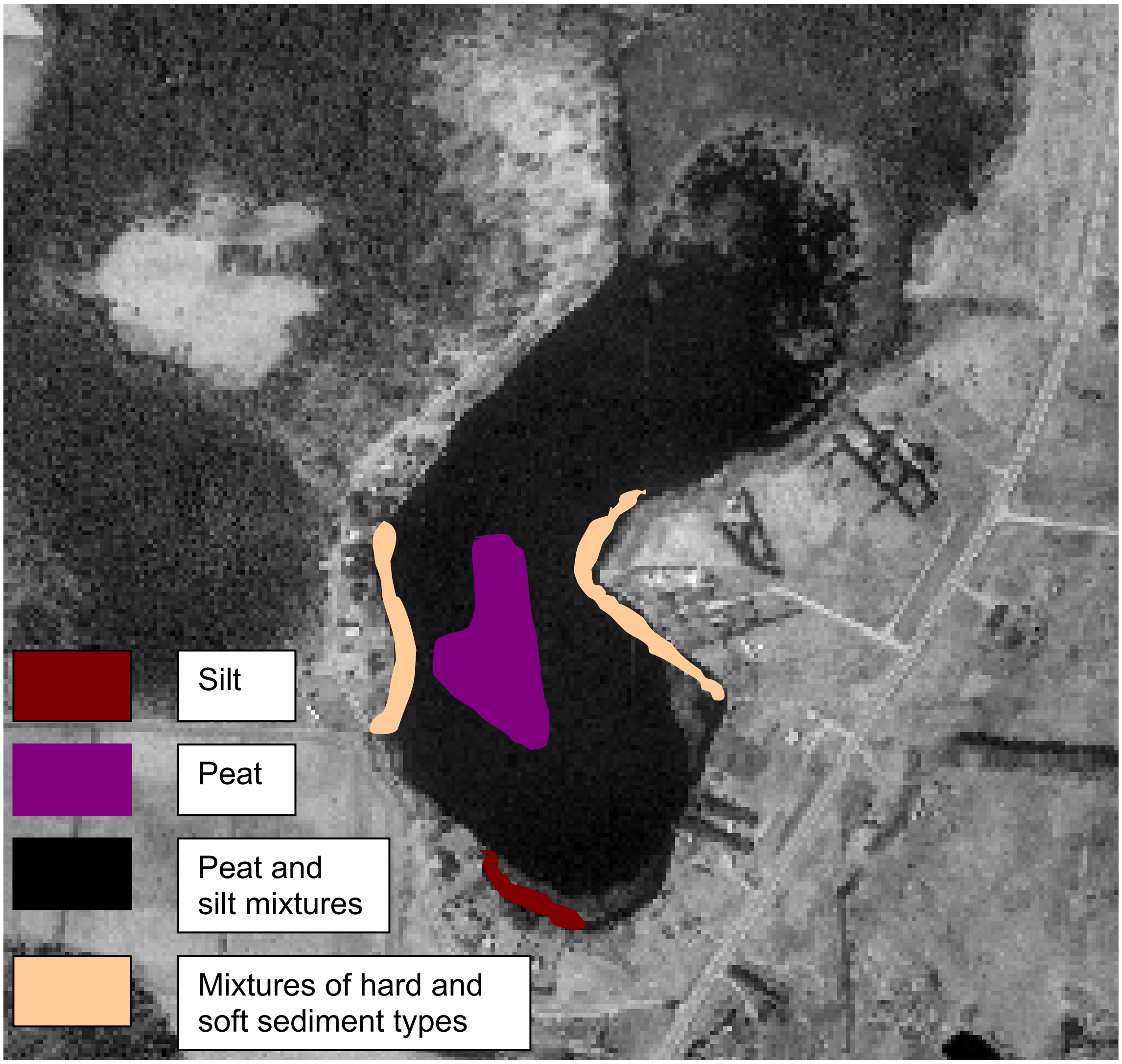

Figure 3. Sediment distribution in Jacqueline Lake, 2006.

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 plant species that can survive in a location.

A silt/peat mixture was the dominant sediment found in Jacqueline Lake. Peat may be limiting for plant growth due its flocculent nature, resulting in an unstable rooting substrate. Because peat is so flocculent, it is easily suspended into the water and remains in suspension longer than other sediment types, causing murkiness when disturbed. Silt sediments are intermediate density sediments and considered most favorable for plant growth because of their intermediate density. The availability of mineral nutrients for growth is highest in sediments of intermediate density (Barko and Smart 1986). Vegetation occurred at 92% of the sites with silt/peat mixtures (Table 6). The mixture of silt with peat may have provided enough stability to support plant growth.

Pure peat supported the lowest rate of vegetation, 67% (Table 6).

Table 6. Vegetation Occurrence by Sediment Type, 2006

Sediment Type		Percent of all Sample Sites	Percent Vegetated
Soft Sediments	Silt/Peat	74%	92%
	Peat	9%	67%
	Silt	6%	100%
Mixed Sediments	Sand/Silt	6%	100%
	Sand/Peat	6%	100%

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

Native herbaceous plant growth was the most frequently encountered shoreline cover at the transects and had the highest mean coverage (Table 7). Several sphagnum and tamarack bogs make up part of the shoreline of Jacqueline Lake. The occurrence of wooded shoreline and shrub growth was also high (Table 7). However, disturbed shoreline types (cultivated lawn and hard structures) also had a high occurrence and lawn covered nearly 20% of the shoreline (Table 7). Run-off is increased on cultivated lawn and hard structures without filtering of the run-off. Run-off from lawn can carry pesticides, pet wastes, nutrients and toxics into the lake.

Natural shoreline of some type and amount occurred at all of the sample sites and protected 74% of the shoreline. Disturbed shoreline of some type and amount (cultivated lawn, hard structures, rip-rap) was found at 64% of the sample sites and impacts 26% of the shoreline.

Table 7. Shoreline Land Use

Cover Type		Frequency of Occurrences at Transects	Mean % Coverage
Natural Shoreline	Native Herbaceous	93%	30%
	Shrub	43%	19%
	Wooded	36%	16%
	Sand	43%	7%
	Rock	28%	2%
Total Natural			74%
Disturbed Shoreline	Cultivated Lawn	42%	18%
	Hard Structures	35%	7%
	Rip-rap	7%	1%
Total Disturbed			26%

MACROPHYTE DATA

SPECIES PRESENT

Of the 23 species found in Jacqueline Lake, 13 were emergent species, 3 were floating-leaf species and 7 were submergent species (Table 8). The majority of the species found were species adapted to soft water habitats.

No non-native species were found.

Two Species of Special Concern were found: *Eleocharis robbinsii* (Robbin's spikerush) and *Utricularia purpurea* (purple bladderwort). Special Concern Species are species with which there is some 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 8. Jacqueline Lake Aquatic Plant Species, 2006

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Carex* spp .	sedge	carco
2) *Chamaedaphne calyculata* (L.) Moench.	leatherleaf	chaca
3) *Cicuta bulbifera* L.	bulb-bearing water hemlock	cicbu
4) *Dulichium arundinaceum* (L.) Britton	three-way sedge	dular
5) *Eleocharis smallii* Britt.	creeping spikerush	elesm
6) *Eriocaulon aquaticum* (Hill) Druce.	pipewort	eriaq
7) *Juncus brevicaudatus* (Engelman.) Fern.	rush	junbr
8) *Lycopus virginicus* L.	water horehound	lycvi
9) *Sagittaria* spp.	arrowhead	sagsp
10) *Spiraea tomentosa L*.	steeple-bush	spito
11) *Triadenum fraseri* (Spach) Gleason	marsh St. John's-wort	trifr
12) *Typha latifolia* L.	common cattail	typla
13) *Xyris montana* Ries.	yellow-eyed-grass	xyrmo
Floating-leaf Species		
14) *Brasenia schreberi* J. F. Gmelin.	watershield	brasc
15) *Nuphar variegata* Durand.	yellow pond lily	nupva
16) *Nymphaea odorata* Aiton.	white water lily	nymod
Submergent Species		
17) *Eleocharis robbinsii* Oakes	Robbin's spikerush	elero
18) *Juncus pelocarpus* E. Meyer.	brown-fruited rush	junpe
19) *Najas flexilis* (Willd.) Rostkov and Schmidt	slender water-nymph	najfl
20) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
21) *Potamogeton epihydrus* Raf.	ribbon-leaf pondweed	potep
22) *Scirpus subterminalis* Torr.	water bulrush	scisu
23) *Utricularia purpurea* Walt.	purple bladderwort	utrpu

FREQUENCY OF OCCURRENCE

Utricularia purpurea (purple bladderwort) was the most frequently occurring species in Jacqueline Lake in 2006, (85% of sample sites) (Figure 4). *Brasenia scherberi, Eleocharis robbinsii* and *Nymphaea odorata* were also commonly occurring species, (44%, 24%, 53%) (Figure 4).

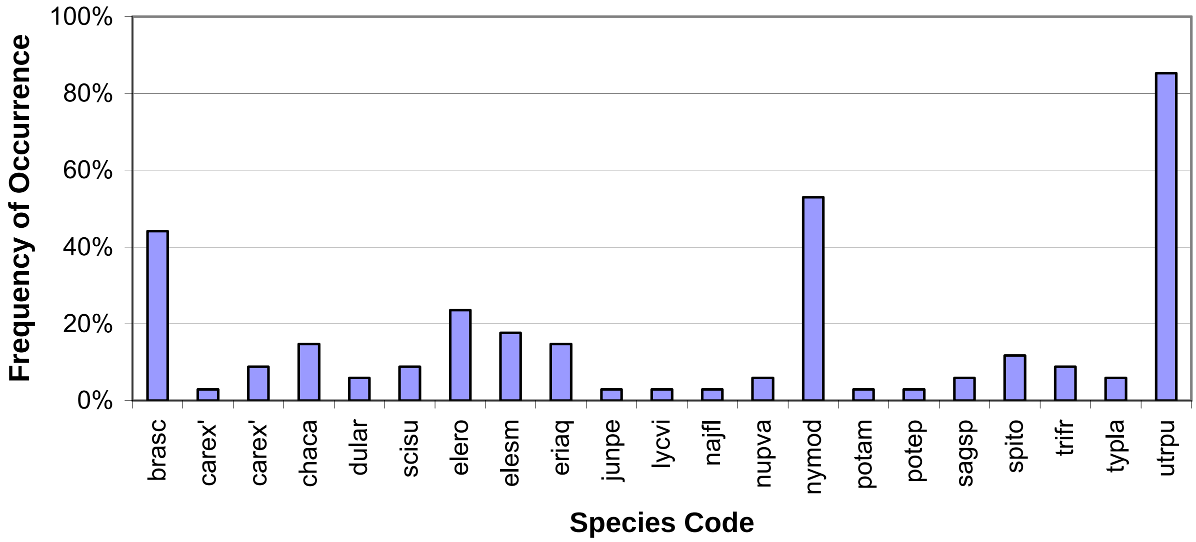

Figure 4. Frequency of aquatic plant species in Jacqueline Lake, 2006.

DENSITY

Utricularia purpurea (purple bladderwort) was also the species with the highest mean density (2.12 on a density scale of 1-4) in Jacqueline Lake (Figure 5).

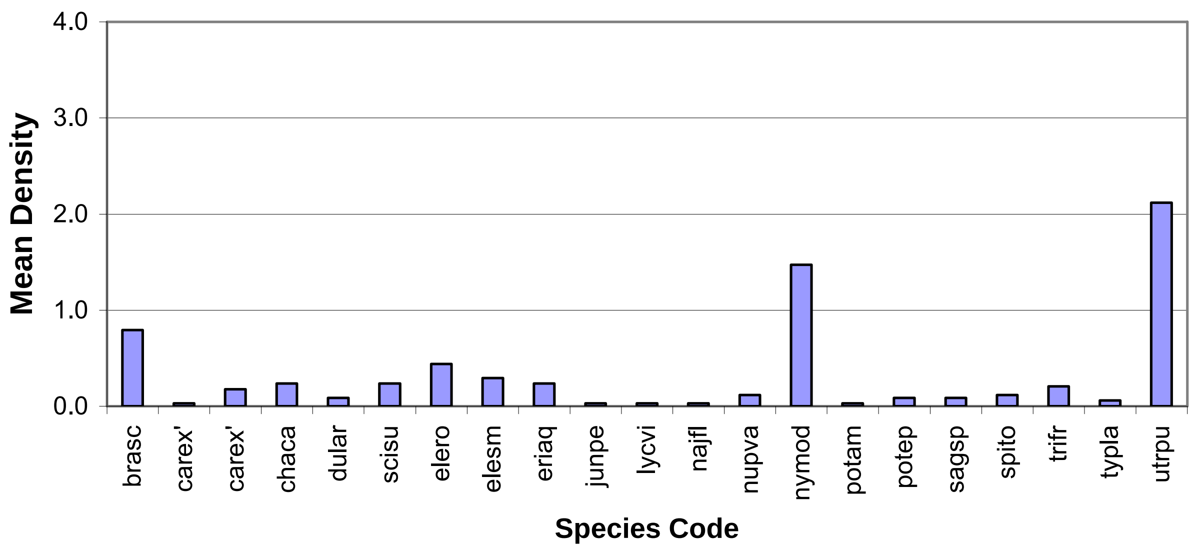

Figure 5. Densities of aquatic plant species in Jacqueline Lake, 2006.

Potamogeton epihydrus (ribbon-leaf pondweed) had a “mean density where present” of 3.00 (Figure 6). Its “mean density where present” indicates that where *P. epihydrus* occurred, it exhibited a growth form of above average density in Jacqueline Lake

(Appendix II). However, it only occurred in limited locations. *Nymphaea odorata* (white water lily) and *Scirpus subterminalis* (water bulrush) were other species in Jacqueline Lake that had “densities where present” of 2.5 or more, indicating that they exhibited an aggregated growth form or a growth form of above average density (Appendix II). However, only *N. odorata* was commonly occurring and *S. subterminalis* was aggregated in only a few locations.

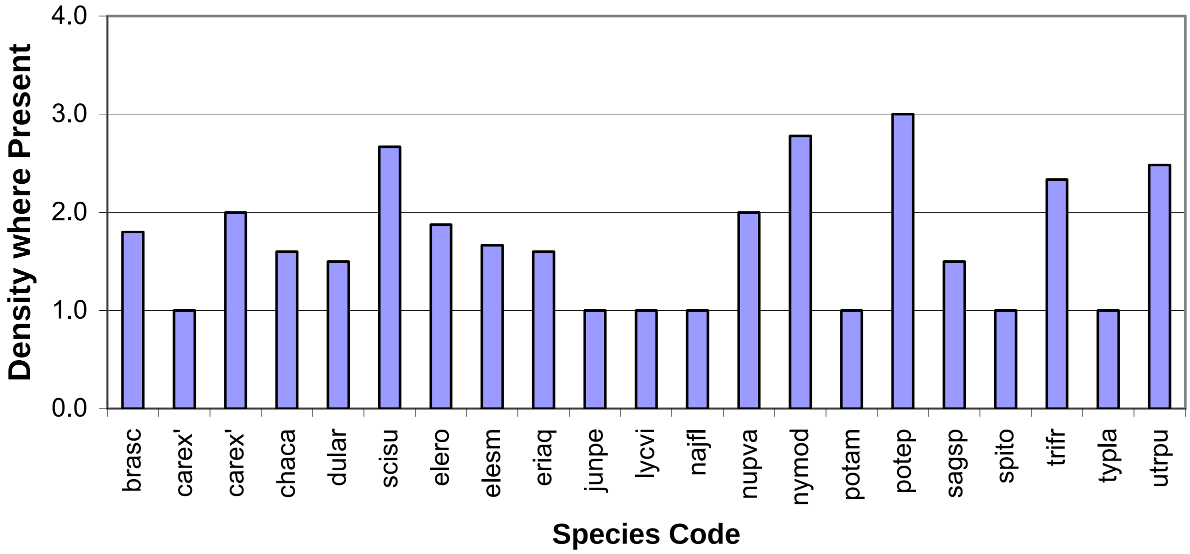

Figure 6. “Density where Present” of species in Jacqueline Lake, 2006.

DOMINANCE

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant a species is within the plant community (Appendix III). Based on the Dominance Value, *Utricularia purpurea* (purple bladderwort) was the dominant aquatic plant species in Jacqueline Lake (Figure 7). *Nymphaea odorata* (white water lily) was sub-dominant.

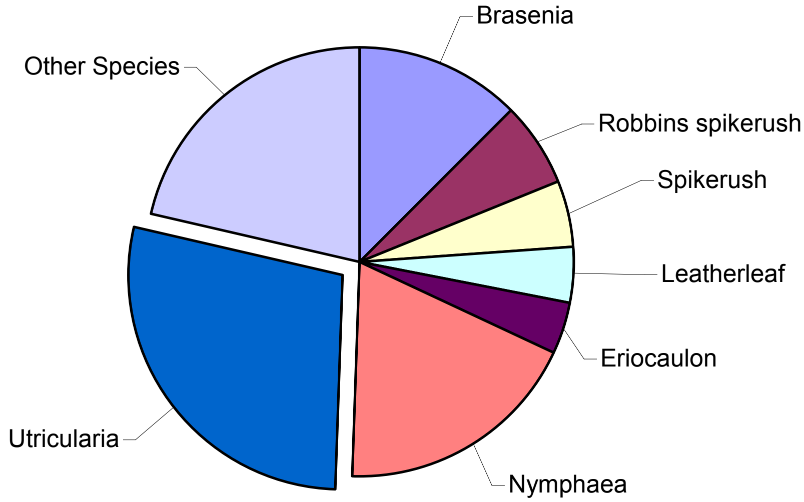

Figure 7. Dominance within the plant community, of the most prevalent species in Jacqueline Lake, 2006.

Utricularia purpurea, the dominant species, nearly dominated all depth zones and occurred at its highest frequency in the 0-1.5ft depth zone and its highest density in the 1.5-5ft depth zone (Appendices I, II) (Figure 8, 9). *Nymphaea odorata,* the sub-dominant species, was the species with the highest density in the 0-1.5ft depth zone and occurred at its highest frequency and density in this depth zone (Appendices I, II) (Figure 8, 9).

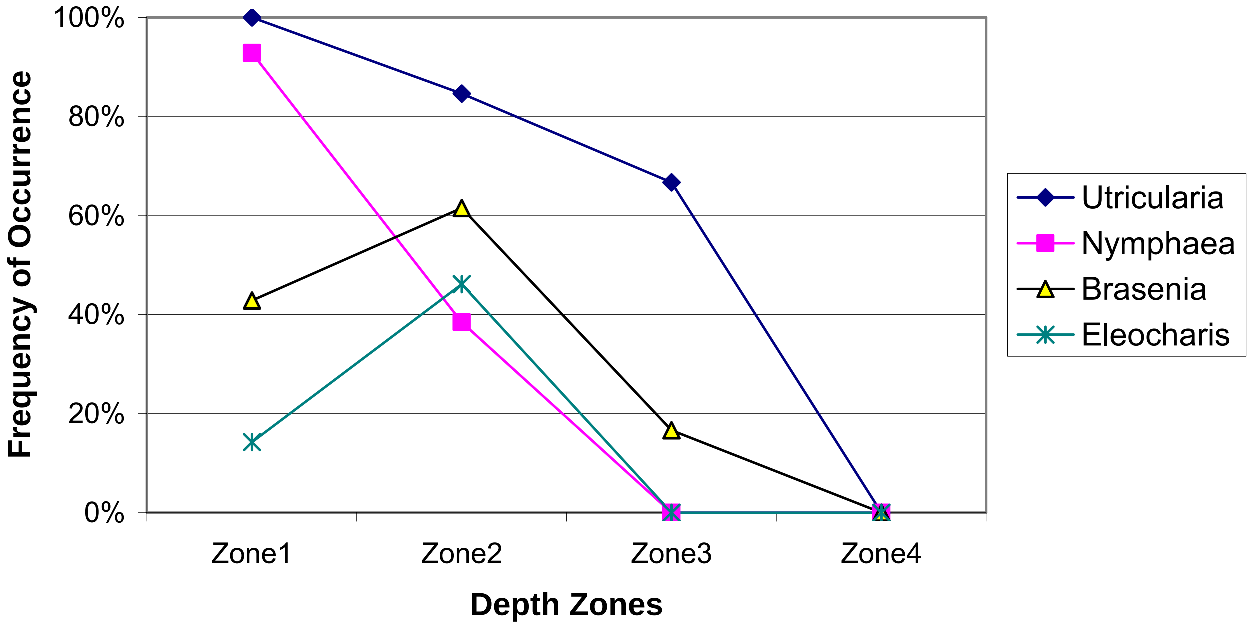

Figure 8. Frequency of most prevalent species in Jacqueline Lake, by depth.

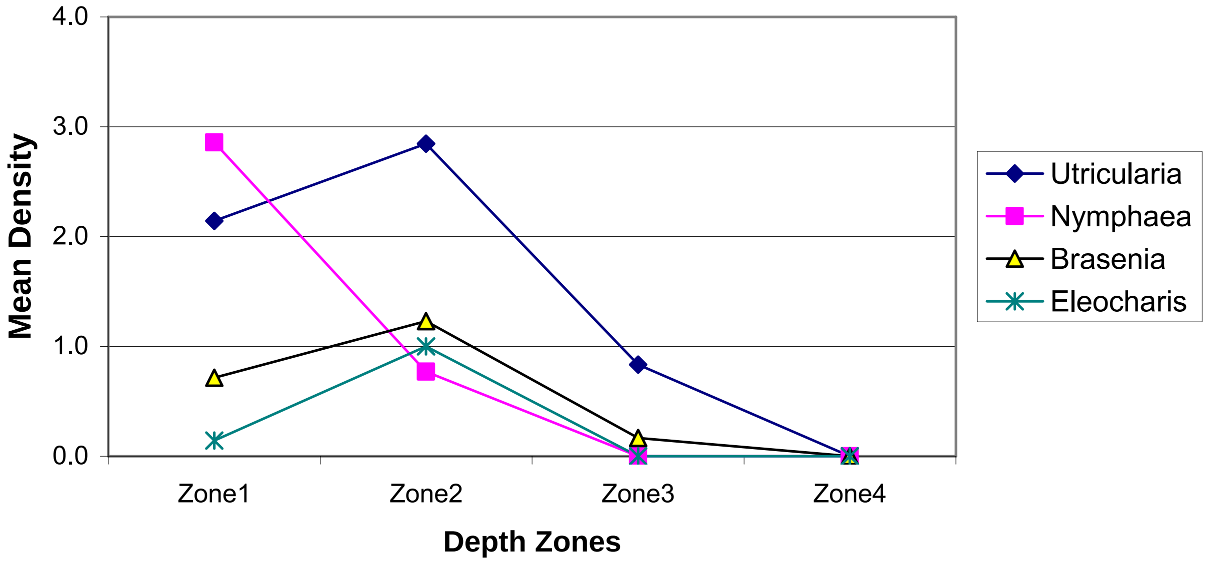

Figure 9. Density of the most prevalent plant species, by depth zone.

DISTRIBUTION

Aquatic plants occurred throughout Jacqueline Lake to a maximum rooting depth of 9.5 feet. *Utricularia purpurea* (purple bladderwort) was found at the maximum rooting depth.

Over the whole lake, 91% of the littoral zone (sampling sites) was vegetated. Approximately 61% of the entire lake was vegetated (25 acres). Submergent vegetation colonized 16.8 acres (41%of lake surface, 88% of the littoral zone); floating-leaf vegetation colonized about 11 acres (26% of lake surface, 65% of littoral zone) and emergent vegetation colonized about 8 acres (19% of lake surface, 24% of littoral zone) (Figure 10).

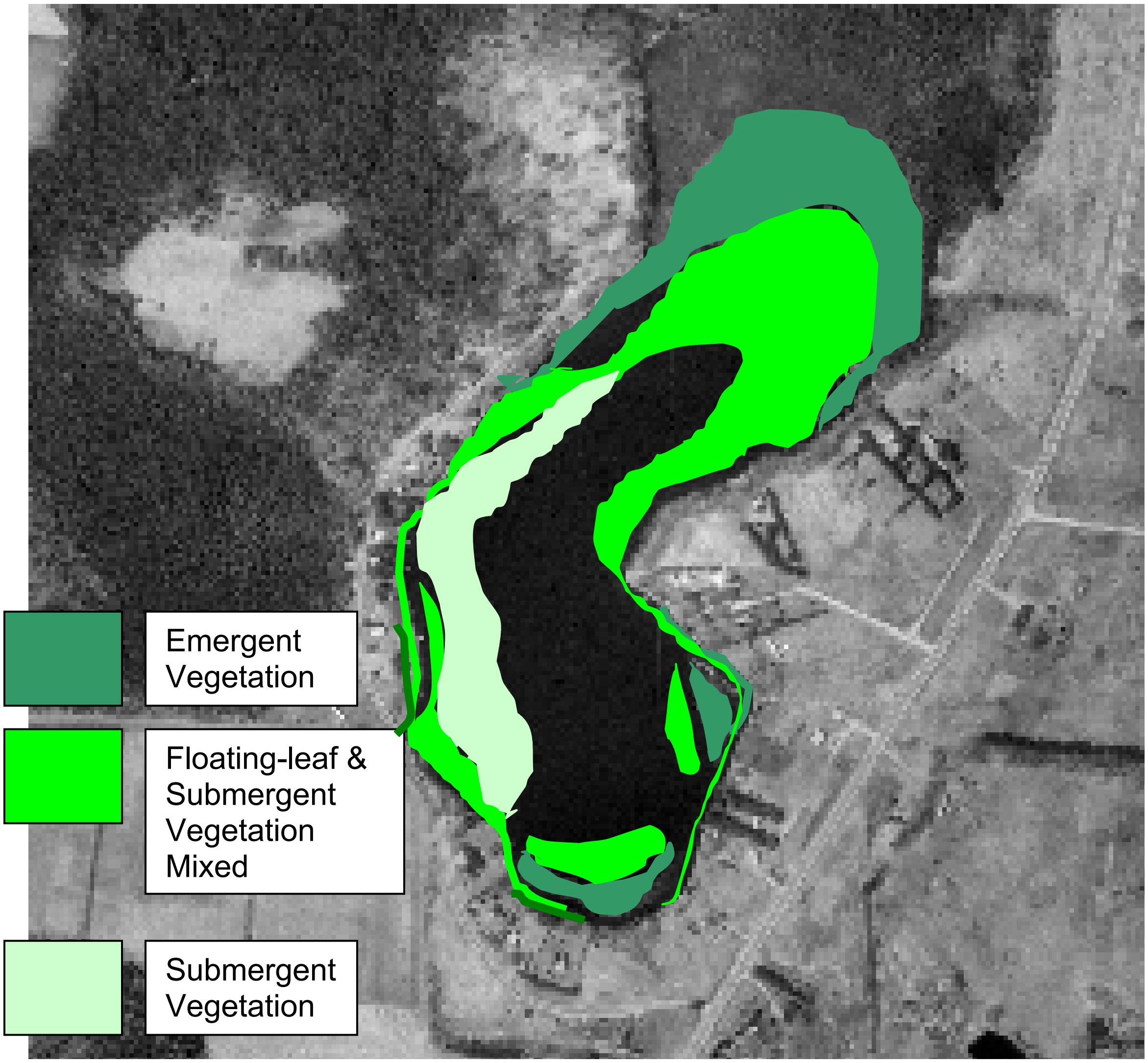

Figure 10. Distribution of aquatic plants in Jacqueline Lake, Portage County, 2006.

The dominant and common species in Jacqueline Lake were found distributed throughout the littoral zone.

Water clarity data can be used to calculate a predicted maximum rooting depth for plants in a lake (Dunst 1982).

Predicted Rooting Depth (ft.) = (water clarity (ft.) * 1.22) + 2.73

Based on the 2001 summer satellite water clarity (4.5ft), the predicted maximum

rooting depth in Jacqueline Lake would be 8.2 ft.
The maximum rooting depth of 9.5 feet is greater than the predicted maximum rooting depth based on water clarity. This may be due to better water clarity early in the spring or summer when aquatic plant growth is first starting its growth toward the surface.

The highest total occurrence and total density of plant growth was recorded in the 0-1.5ft depth zone and declined rapidly with increasing depth (Figure 11).

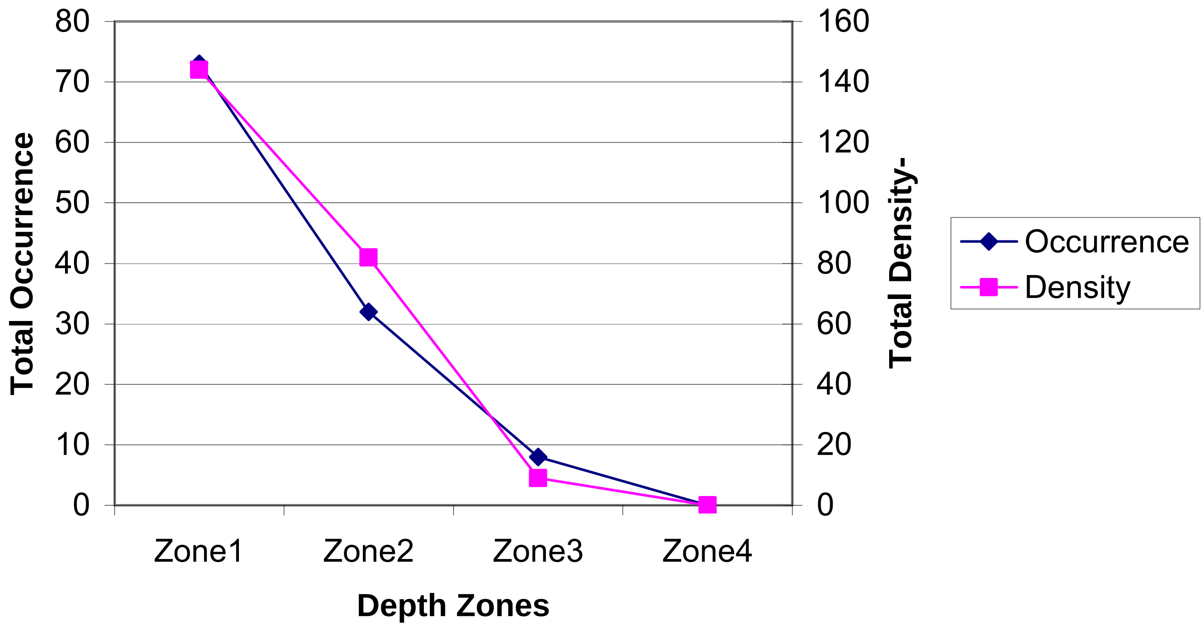

Figure 11. Total occurrence and total density of aquatic plants by depth zone in Jacqueline Lake, 2006.

The highest percentage of vegetated sites was found in the 0-5ft depth zone and the greatest species richness (mean number of species per site) was found in the 0-1.5 ft. depth zone (Figure 12). Overall Species Richness in Jacqueline Lake was 3.3.

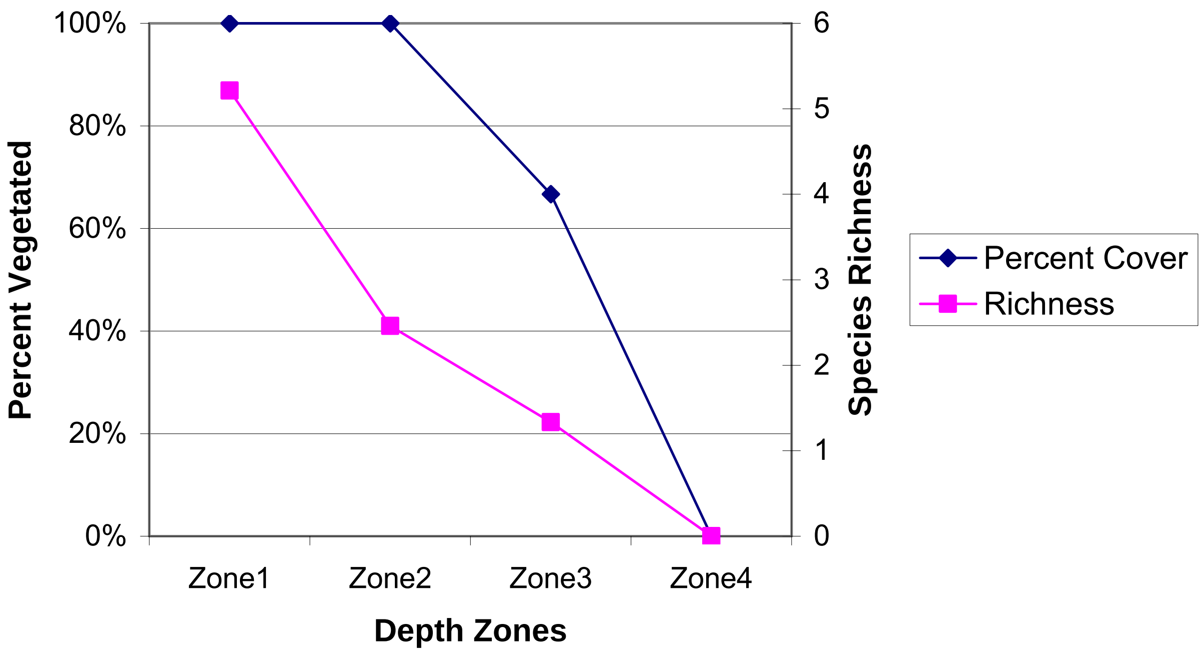

Figure 12. Percentage of vegetated site and mean number of species per site (Species Richness) in Jacqueline Lake, by depth zone.

THE COMMUNITY

Simpson's Diversity Index was 0.87 (Appendix I), indicating good 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 Jacqueline Lake (Table 9) is 53. This value indicates Jacqueline Lake has an above average quality aquatic plant community compared to lakes in Wisconsin and an average quality aquatic plant community compared to lakes in the North Central Harwood Region of the state.

Table 9. Aquatic Macrophyte Community Index: Jacqueline Lake

Category		Value
Maximum Rooting Depth	2.89 meters	4
% Littoral Zone Vegetated	91%	10
% Submergent Species	44% Rel. Freq.	3
# of Species	23	9
% Exotic species	0	10
Simpson's Diversity	0.87	7
% Sensitive Species	52% Relative Freq.	10
Totals		53

The highest value for this index is 70.

The Average Coefficient of Conservatism for Jacqueline Lake was in the upper quartile for lakes in the North Central Hardwood Region and in Wisconsin (Table 10). This suggests that the aquatic plant community in Jacqueline Lake is among the group of lakes in the North Central Hardwoods Region least tolerant of disturbance.

Table 10. Floristic Quality and Coefficient of Conservatism of Jacqueline Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	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
Jacqueline Lake 2006	7.38	33.82

* - 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 Jacqueline Lake was in the upper quartile of lakes in Wisconsin and the North Central Hardwood Lakes Region (Table 10). This suggests that the plant community in Jacqueline Lake among the group of lakes in the state and region closest to an undisturbed condition.

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 from wave action and boat traffic, 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.

Disturbance in Jacqueline Lake could include fluctuating water levels, past chemical treatments, mechanical harvesting and shoreline development.

IV. DISCUSSION

Jacqueline Lake is a 40-acre shallow seepage lake with a maximum depth of 11-12 feet. Based on 2002-03 phosphorus data, Jacqueline Lake is a mesotrophic lake with fair water quality. No filamentous algae was found during the survey. The small watershed relative to lake size (3:1) would not be a major impact to water quality.

The adequate nutrients (trophic state), dominance of fertile silt/peat sediment mixture, gradually-sloped littoral zone and shallow depths in most of Jacqueline Lake would favor plant growth. The soft water and fluctuating water levels in Jacqueline Lake may limit plant growth. Aquatic plants colonized 61% of the lake surface, occurring throughout the lake at 91% of the sites, to a maximum depth of 9.5 feet.

Jacqueline Lake is very susceptible to impacts from motor boats. A 50-hp motor can mix and resuspend sediment to a depth of 15 feet (Wagner 1990); this means that the entire lake bottom of Jacqueline Lake (maximum depth of only 11-12 feet) would be susceptible to impacts by a small 50-hp motor. The flocculent, organic sediments in Jacqueline Lake are susceptible to resuspension, settle very slowly, and release nutrients as they settle. Boating impact studies conducted on other lakes with flocculent peat sediments found that phosphorus increased and clarity decreased after high boating-use weekends (Asplund 1995). Jacqueline Lake also is a community of sensitive species; compromising the health of these species may result in a shift to more nuisance-causing species and open lake bed to the invasion of any exotic species introduced into the lake.

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The greatest amount of plant growth occurred in the shallowest depth zone, 0-1.5ft. The highest total occurrence of plants, highest total density of plants and the greatest species richness occurred in the shallowest depth zone (0-1.5ft). The greatest percentage of vegetated sites occurred in the 0-5ft depth zone.

Twenty-three (23) aquatic plant species were recorded in Jacqueline Lake; the majority of the species are species adapted to soft water conditions. Purple bladderwort, *Utricularia purpurea,* a Special Concern Species, was the overall dominant plant species in Jacqueline Lake, occurring at more than three-quarters of the sample sites. *U. purpurea* dominated the 1.5-12ft depth zones. Another species of special concern, *Eleocharis robbinsii* (Robbin's spikerush) was common in Jacqueline Lake. *Nymphaea odorata* (white water lily) was the sub-dominant plant species in Jacqueline Lake, occurring at approximately one-half of the sites and exhibiting a growth form of above average density in Jacqueline Lake. *N. odorata* was the species with the highest density in the 0-1.5ft depth zone. Two (2) other species exhibited a dense or aggregated growth form in Jacqueline Lake; they were aggregated in limited locations in Jacqueline Lake. The dominant and common species were found throughout the lake.

The Aquatic Macrophyte Community Index (AMCI) for Jacqueline Lake was 53, indicating that Jacqueline Lake's aquatic plant community is of above average quality compared to other Wisconsin lakes and average quality compared to lakes in the North Central Region. The Simpson's Diversity Index (0.87) indicates that the aquatic plant community had a good diversity of species. Species Richness was 3.3 species per sample site.

The Average Coefficient of Conservatism and the Floristic Quality Index suggests that Jacqueline Lake has a high intolerance to disturbance and is in the group of lakes in Wisconsin and in the North Central Hardwoods Region of Wisconsin least tolerant of disturbance and closest to an undisturbed condition.

Jacqueline Lake is protected by natural shoreline cover (wooded, shrub, native herbaceous growth and tamarack bog) at nearly three-quarters of the shore. Unfortunately, disturbed shore types (hard structures and cultivated lawn) occurred at more than half of the sites and covered one-quarter of the lake shore. Cultivated lawn alone occurred at nearly half of the sites and covered nearly 20% of the lakeshore. Hard structure is found at one-third of the sites. Run-off is increased on cultivated lawn and hard structures without filtering of the run-off. Run-off from lawn can carry pesticides, pet wastes and nutrients and both can carry toxics into the lake. Preserving and increasing the natural shoreline is critical to maintaining water quality and wildlife habitat.

To quantify the impacts disturbance at the shoreline may have in Jacqueline Lake, transects at shoreline with 100% natural cover were separated from transects that had any amount of disturbed cover and these two sets were analyzed as separate communities (Appendices V-VI), a few measures of the aquatic plant community were different (Table 11).

The Floristic Quality Index measures a plant community's closeness to an undisturbed condition, therefore measuring the impact of disturbance on the community. In Jacqueline Lake, the natural shoreline community Floristic Quality Index was higher than the disturbed shore community, suggesting more disturbance had impacted the disturbed shore community (Table 11). Natural shore community was in the quartile of lakes closest to an undisturbed condition while disturbed shore community was closer than average to an undisturbed condition.

The quality of the aquatic plant community was higher at the natural shoreline community, as measured by the AMCI (Table 11). The natural shoreline community was of above average quality, while the disturbed shore community was of below average quality (Table 12).

The natural shoreline community in Jacqueline Lake supported more cover of vegetation and a deeper maximum rooting depth (Table 11). This results in more habitat at natural shore sites.

Diversity in the aquatic plant community has been impacted by disturbance. The number of species, the Simpson's Diversity Index, Species Richness overall and Species Richness in all depth zones were all higher at the natural shoreline community (Table 11). The natural shoreline community has very good species diversity while the disturbed shore community has very poor species diversity. Greater diversity in the plant community supports greater diversity in the fish and wildlife community and provides a more stable community.

The cover of all structural types was higher at natural shoreline sites, emergent and floating-leaf vegetation are particularly important components of quality habitat (Table 11).

Table 11. Comparison of the Jacqueline Lake Aquatic Plant Community at Natural and Disturbed Shorelines.

	Natural	**Disturbed**
Floristic Quality Index	31.87	25.32
AMCI (quality of plant community) (Table 12)	52	46
% of Littoral Zone Vegetated	94%	89%
Maximum rooting depth	9 feet	6 feet
Simpson's Diversity Index	0.90	0.81
Number of species	19	11
Species Richness		
Overall	4.11	2.22
0-1.5ft depth zone	6.71	3.83
1.5-5ft depth zone	2.86	2.0
5-10ft depth zone	1.5	1.0
Cover of structural vegetation types in the littoral zone		
Cover of emergent vegetation	35%	11%
Cover of floating-leaf vegetation	71%	56%
Cover of submergent vegetation	88%	61%
Cover of submerged rosette vegetation	29%	6%

Table 12. Comparison of AMCI at Natural vs. Disturbed Shoreline.

Category	Natural Shore Community	Disturbed Shore Community
Maximum Rooting Depth	4	2
% Littoral Zone Vegetated	10	10
% Submergent Species	2	4
# of Species	8	5
% Exotic species	10	10
Simpson's Diversity	8	5
% Sensitive Species	10	10
Totals	52	46

The highest value for this index is 70.

Changes in the Aquatic Plant Community

The trophic status of Jacqueline Lake appears to have changed. Data suggest that lJacqueline Lake was eutrophic in 1976-1981 and shifted to mesotrophic in 2002-03. This change in status would result in less abundant plant growth and less frequent algae blooms. In a natural lake with a small watershed, it is possible to harvest and remove sufficient nutrients via plant removal from the water to change the nutrient threshold.

Chemical treatments were used in the past to control plant growth; five different classes of chemicals have been applied and one has since been banned. Treatments had been conducted up to 3 times a year and covering up to one-half of the lake. Chemical use for aquatic plant control have many drawbacks. Most herbicides also kill the aquatic insects that are part of the foundation of the food chain in a lake; the plant material decays in the water, releasing nutrients that feed algae blooms; the plant material decays in the water, using oxygen needed by aquatic life; the plant material decays in the water, enriching the sediments at the site to promote more plant growth; the treatment clears areas that are then vulnerable to invasion by exotic species; no herbicide is proven safe, always leading to risks.

Mechanical harvesting has been used since 1995 to control plant growth and provide navigation. At least 300 tons of aquatic plant material has been removed from Lake Jacqueline in that time period.

The cover of aquatic plant material has changed since the estimates in 1982. The difference in total plant cover decreased by 12 acres since 1982 (Table 13). Although the cover of floating-leaf vegetation increased, the cover of emergent and submergent vegetation decreased (Table 13). The decrease in emergent vegetation is likely the result of bog removal in the 1990’s. Mechanical harvesting is the likely reason for the decrease in submergent vegetation and is less effective for permanent removal of floating-leaf vegetation.

Table 12. Change in Aquatic Plant Cover, 1982-2006.

	1982 (Acres)	**2006 (Acres)**	**Change (Acres)**
Emergent and Bog Vegetation	10	8	-2
Rooted Floating-leaf Vegetation	5	11	+6
Submergent Vegetation	22	17	-5
Total Plant Cover	37	25	-12

Comparing the species list compiled during the species list from 1982, it appears that some species have disappeared and new species have appeared (Table 14). It is not known how common the species were that disappeared. No trend was seen in either the type of species lost or gained.

Table 14. Changes in Jacqueline Lake Aquatic Plant Species, 1982-2006

Occurrence 1982	2006	Scientific Name	Common Name
		Emergent Species	
	X	*Carex* spp .	sedge
	X	*Chamaedaphne calyculata* (L.) Moench.	leatherleaf
	X	*Cicuta bulbifera* L.	bulb-bearing water hemlock
	X	*Dulichium arundinaceum* (L.) Britton	three-way sedge
	X	*Eleocharis smallii* Britt.	creeping spikerush
X	*x*	*Eriocaulon aquaticum* (Hill) Druce.	pipewort
	X	*Juncus brevicaudatus* (Engelman.) Fern.	rush
	X	*Lycopus virginicus* L.	water horehound
	X	*Sagittaria* spp.	arrowhead
	X	*Spiraea tomentosa L*.	steeple-bush
	X	*Triadenum fraseri* (Spach) Gleason	marsh St. John's-wort
	X	*Typha latifolia* L.	common cattail
	X	*Xyris montana* Ries.	Yellow-eyed-grass
		Floating-leaf Species	
X	***X***	*Brasenia schreberi* J. F. Gmelin.	watershield
X	*X*	*Nuphar variegata* Durand.	bull-head pond lily
X	***X***	*Nymphaea odorata* Aiton.	white water lily
X		*Sparganium angustifolium*	ribbon-leaf bur-reed
		Submergent Species	
	X	*Eleocharis robbinsii* Oakes	triangle spikerush
X		*Elodea occidentalis*	waterweed
	X	*Juncus pelocarpus* E. Meyer.	brown-fruited rush
X	*X*	*Najas flexilis* (Willd.) Rostkov and Schmidt	slender water-nymph
X		*Nitella* spp.	stonewort
X	*X*	*Potamogeton amplifolius* Tuckerman.	large-leaf pondweed
X		*Potamogeton berchtoldi*	pondweed
X	*X*	*Potamogeton epihydrus* Raf.	ribbon-leaf pondweed
	X	*Scirpus subterminalis* Torr.	water bulrush
X	***X***	*Utricularia purpurea* Walt.	purple bladderwort

Bold indicates abundant at the time of survey

V. CONCLUSIONS

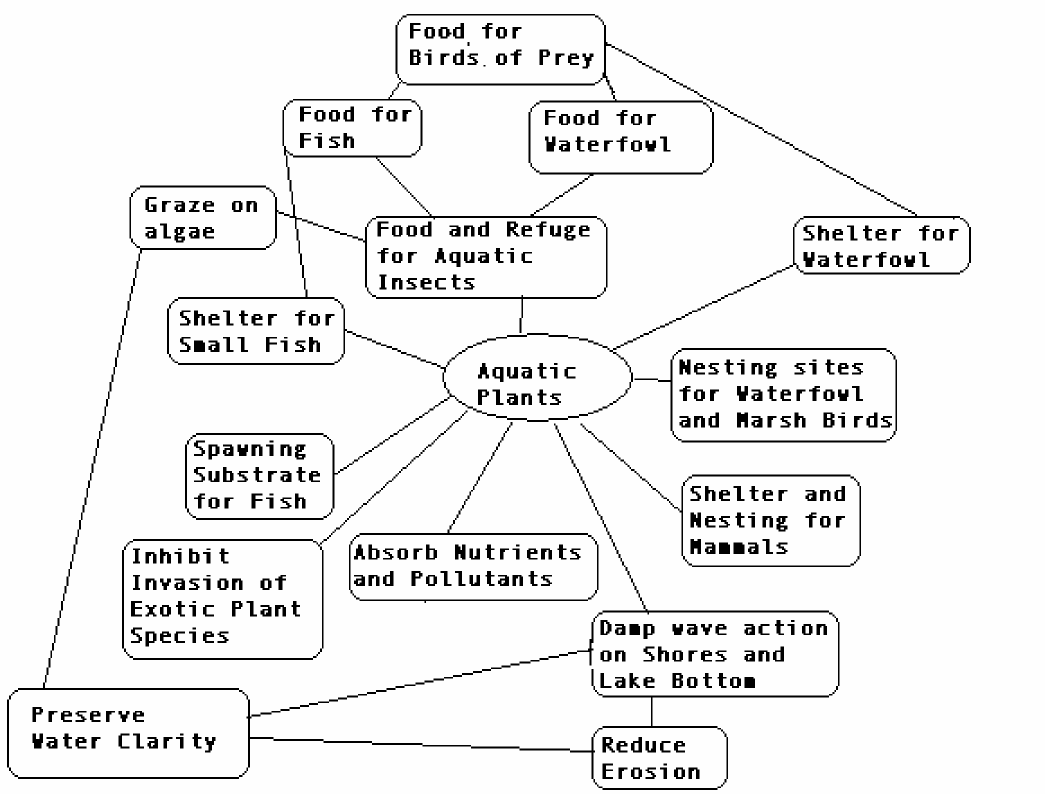
Jacqueline Lake is a 40-acre shallow mesotrophic lake with fair water quality. No filamentous algae was seen during the July 2006 study.

The aquatic plant community colonized nearly the entire littoral zone, more than half of the total lake area, to a maximum depth of 9.5 feet. The 0-1.5 ft. depth zone supported the most abundant aquatic plant growth.

The aquatic plant community in Jacqueline Lake is a soft water community characterized by average-to-above average quality, good species diversity, a high intolerance to disturbance and a condition close to an undisturbed condition.

Twenty-three (23) aquatic plant species were recorded in Jacqueline Lake. *Utricularia purpurea* (purple bladderwort) was the dominant species within the plant community, especially in the 1.5-12ft depth zones, occurring at more than three-quarters of the sample sites and exhibiting a dense growth form. *U. purpurea* is listed as a Special Concern Species, a species with which there is concern about its distribution and population. *Nymphaea odorata* (white water lily) was the sub-dominant species, occurring at approximately half of the sites and at an above average density. Another Special Concern Species, *Eleocharis robbinsii* (Robbin's spikerush), was commonly occurring in Jacqueline 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 out compete sensitive species, thus reducing diversity.



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

2) Aquatic plant communities provide important fishery and wildlife resources. Plants (including 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 15). Plant cover within the littoral zone of Jacqueline Lake is 91% and over the entire lake is 61%. This is appropriate (25-85%) to support a balanced fishery.

Compared to non-vegetated lake bottoms, 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).

Management Recommendations

1) Lake District update management plan for Jacqueline Lake, based on 2006 plant study and Critical Habitat Area Designations.
2) Lake property owner preserve the natural shoreline cover that is found around Jacqueline Lake. Wooded cover, shrubs and native herbaceous growth protected three-quarters of the shoreline. Maintaining natural shoreline cover is critical to maintaining water quality and wildlife habitat.
3) Lake residents restore the buffer of natural shoreline vegetation where it has been cleared. Negative impacts to the aquatic plant community were seen at developed shorelines.
    a. Disturbance has been measured as a negative impact to the aquatic plant community. Developed shoreline plant communities had a lower Floristic Quality Index than natural shoreline communities.
    b. Disturbance has impacted the quality of the aquatic plant community. The quality of the plant community (AMCI Index) at disturbed shoreline communities is lower.
    c. The impacts to the plant community have negatively impacted the habitat on the lake. Disturbed shore communities provided less cover, less cover of important emergent and floating-leaf vegetation and less diversity than natural shore communities. Less diverse plant communities are less stable and support less diverse fish and wildlife communities.
4) Lakes residents use best management practices on shoreland property to prevent nutrient enrichment and stormwater run-off to the lake.
5) Lake residents begin monitoring the water quality through the Self-Help Volunteer Lake Monitoring Program. Monitor water quality to expand knowledge of water quality in Jacqueline Lake.
6) DNR to designate Critical Habitat Areas within Jacqueline Lake. These are areas that are most important for habitat and maintaining water quality.
7) Lake District and DNR maintain exotic species educational signs at the boat landing to prevent the spread of exotic species into Jacqueline Lake.
8) Consider designating Jacqueline Lake as a slow-no-wake lake. Jacqueline is very susceptible to impacts from motor boats. The flocculent, organic sediments in Jacqueline Lake are susceptible to resuspension, settle very slowly, and release nutrients as they settle. The shallow depth of Jacqueline Lake means that the entire lake bottom of Jacqueline Lake would be susceptible to impacts by a small motor. Jacqueline Lake also is a community of sensitive species; compromising the health of these species may result in a shift to more nuisance-causing species and open lake bed to the invasion of any exotic species introduced into the lake.
9) Do not resume chemical treatments for aquatic plant control in Jacqueline Lake. Most herbicides also kill the aquatic insects; the plant material decays in the water, releasing nutrients that feed algae blooms, using oxygen needed by aquatic life, enriching the sediments at the site to promote more plant growth; the treatment clears areas that are then vulnerable to invasion by exotic species if introduced.
10) If plant control is needed in Jacqueline Lake, continue with mechanical

harvesting. In contrast to chemical treatments, it appears that harvesting has removed sufficient nutrients from the lake to change the trophic state. This is possible in a natural lake with a small watershed such as Jacqueline Lake. Plant cover appears to have been reduced also.

11) Leave bogs in place to protect the shoreline of the lake.