Executive Summary

Patrick Lake is a 50-acre mesotrophic/oligotrophic lake with good-to-very good water quality and good water clarity. Water clarity has decreased since 1983. Filamentous algae is common to abundant throughout Patrick Lake.

The Patrick Lake aquatic plant community colonized approximately three-quarters of the entire lake area to a maximum rooting depth of 13 feet. Within the important shallow water littoral zone, Patrick Lake, 100% of the sites were vegetated. The 0-1.5ft depth zone supported the most abundant aquatic plant growth. The aquatic plant community is characterized by high quality, good species diversity, an average sensitivity to disturbance and a condition closer than average to an undisturbed condition.

Najas guadalupensis was the dominant species within the 17-species aquatic plant community, especially in the 1.5-10ft depth zone. *Chara* spp. was sub-dominant. *Nymphaea odorata* was the most abundant species in the 0-1.5ft depth zone. *Potamogeton praelongus* was the most abundant specie in the 10-20ft depth zone.

Eurasian watermilfoil has been introduced in Patrick Lake, but after lake-wide treatments for the milfoil began in spring 2005, Eurasian watermilfoil was not found in the July 2005 survey. A 0.5-acre colony was found and re-treated in September 2005.

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 the most tolerant species.

Management Recommendations

1) All lake residents shall practice best management on their lake properties. Keep septic systems cleaned and in proper condition, use no lawn fertilizers, clean up pet wastes and do not compost near the water or allow yard wastes and clippings to enter the lake
2) Residents should resume involvement in the Volunteer Lake Monitoring Program.
3) Adams County to should designate sensitive areas within Patrick Lake.
    a. Lake residents protect natural shoreline around Patrick Lake to provide habitat and protect water quality in the lake. Disturbed shoreline (cultivated lawn and hard structures) is common, covering 20% of the shore. Comparison of the plant communities at natural shoreline and disturbed shoreline indicate that disturbance is already impacting the aquatic plant community and the habitat.
4) All lake users shall protect the aquatic plant community in Patrick Lake.
5) Lake District should maintain exotic species signs at the boat landings.
6) Lake Association shall continue monitoring Eurasian watermilfoil.
    a. Continue early-season treatments with a specific chemical on larger areas
    b. Hand pull scattered plants and small colonies.

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The Aquatic Plant Community in Patrick Lake, Adams County 2005

I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Patrick Lake was conducted during July 2005 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and Adams County Land and Water Conservation. This was the first quantitative vegetation study of Patrick Lake by the DNR. DNR personnel conducted a qualitative assessment in 1978 and Northern Lakes Services did a qualitative survey in 1983.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake ecosystem due to the important ecological role of aquatic vegetation in the lake and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

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

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

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

Background and History: Patrick Lake is a 50-acre seepage lake in southeast Adams County, Wisconsin. Patrick Lake has a maximum depth of 21 feet and a mean depth of 10 feet.

Complaints about aquatic plant growth started in 1957. The first chemical treatments started in 1958, using arsenic, a very toxic substance that does not degrade, but remains in the sediments.

Table 1. Herbicide Treatments 1958-2005

	Acres	Sodium Arsenite (lbs)	Hydrothol * (lbs)	Diquat (gal)	Cutrine (gal)	2, 4-D lbs.
1958	11.4	1100				
1959	11.5	1200				
1979	2.3		450			
1980	2			2	1	
1981	2.5			5	3	
1983	0.06					10
2005	17					1865
Totals		2300	450	7	4	1875

* Hydrothol is an endotahall product more damaging to young fish than Aquathol.

An assessment of the lake was conducted in 1978 by DNR staff due to complaints concerning plant growth. *Najas* spp, was the most abundant species. *Myriophyllum* spp., *Potamogeton nodosus* and *P. richardsonii* were common; *Chara* was present; *Brasenia* and *Nymphaea* occurred in one area.

At some point Eurasian watermilfoil was introduced into Patrick Lake; its introduction and spread may have been facilitated by broad spectrum treatments in the past that opened up areas for colonization of the exotic species. By 2004, Eurasian watermilfoil had colonized about 17-acres of the lake (Cason and Roost 2004) (Appendix IX). Herbicide treatments for controlling the Eurasian watermilfoil were conducted in spring 2005 (Table 1). The July 2005 survey did not find any Eurasian watermilfoil, but new colonies could resprout. A 0.5-acre area was found and treated in September 2005. Residents need to be watchful of new Eurasian watermilfoil colonies for several years.

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 15 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, one 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 at that site
- a rating of 2 indicates that a species was present on two rake samples at that site
- 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 <u>abundantly</u> present on all 4 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 each side of the transect intercept with the shore and 30 feet deep was evaluated. The percent cover of each land use category 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/sum of all species occurrences) (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/sum of all plant densities). "Mean density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendix II). The relative frequency and relative density of each species were summed to obtain a dominance value for each species (Appendix III). Species diversity was measured by Simpson's Diversity Index $1-(\sum(\text{Relative Frequency}^2))$ (Appendix I).

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols (2000) was applied to Patrick Lake. Measures for each of seven categories that characterize a plant community are converted to values between 0 and 10 and summed to measure the quality of the plant community.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for all species found in the lake. The 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, water clarity and water hardness 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. Phosphorus concentration, chlorophyll 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 nutrient enrichment in a lake. Increases in phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth.

2005 Mean Summer Phosphorus concentration in Patrick Lake was 13 ug/l

This concentration of phosphorus in Patrick Lake is indicative of a mesotrophic lake (Table 2).

Table 2. 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
Patrick Lake 2005 Mean Summer	Very Good	**13**	**3.81**	**10.5**

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

Algae

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

2005 Mean summer chlorophyll concentration in Patrick Lake was 3.8 ug/l.

The chlorophyll concentration in Patrick Lake was in the oligotrophic range (Table 2). Filamentous algae occurred at 38% of all sample sites. In 2005, filamentous algae occurred at:

47% of the sites in the 0-1.5ft depth zone
33% of the sites in the 1.5-5ft depth zone
33% of the sites in the 5-10ft depth zone
50% of the sites in the 10-20ft depth zone

Water Clarity

Water clarity is a critical factor for aquatic plants. When plants receive less than 1 - 2% of the surface illumination, they cannot 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

2005 Mean Summer Secchi Disc clarity in Patrick Lake was 10.5 feet.

Water clarity indicates (Table 2) that Patrick Lake was an oligotrophic lake with good water clarity.

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicates that Patrick Lake is an oligotrophic/mesotrophic lake with good-to-very good water quality. This trophic state should favor sparse to moderate plant growth and occasional summer algae blooms.

Volunteers in the Self-Help Volunteer Lake Monitoring Program have monitored Patrick Lake in the past. The volunteer data is valuable because it is generally collected more frequently during the year and over a time period of more years than DNR data can be collected. Oral Vierck collected water clarity data 1986-89 and 1991. Steve Zoulek collected water clarity and water chemistry data in 1996 and 1997.

Staff in the Adams County Land and Water Conservation Department have collected water chemistry and water clarity data 2003-2005.

Variations in the concentration of phosphorus and chlorophyll concentrations are caused by variations in weather and rain events from year to year. As expected the chlorophyll variations from year to year generally follow the variations in phosphorus as algae use available nutrients to multiple (Figure 1).

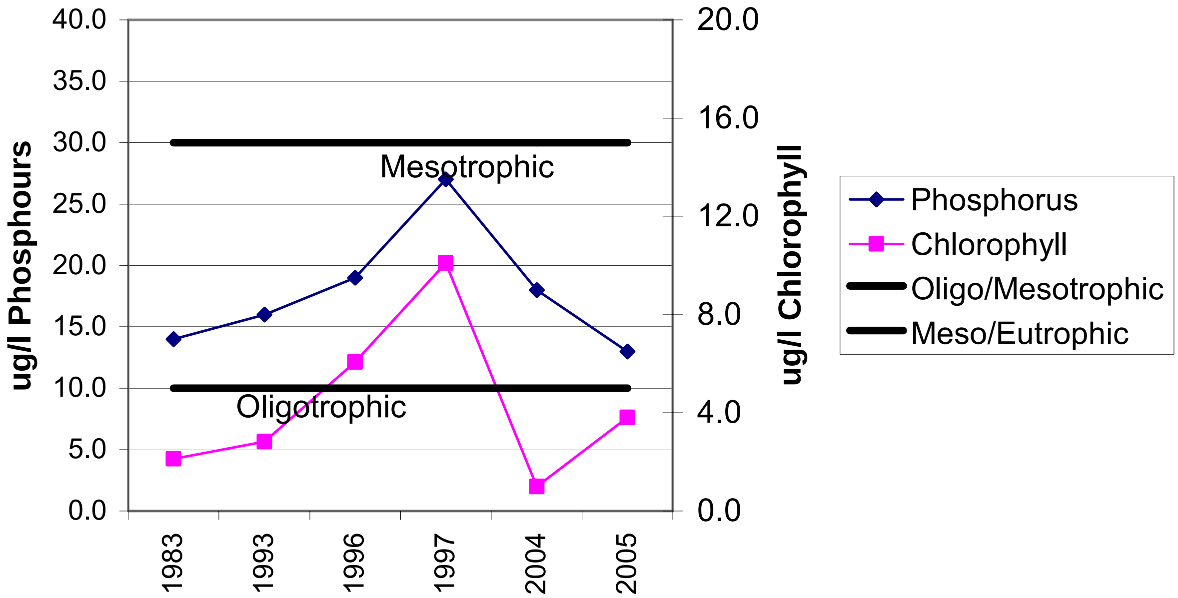


Figure 1. Mean summer phosphorus and chlorophyll in Patrick Lake, 1983-2005.

Water clarity in Patrick Lake varies from year to year (Figure 2). The lowest mean summer water clarity recorded was in 1996 and the best clarity was recorded in 1986. Linear regression trend analysis indicates there has been an overall decline in water clarity since 1983.

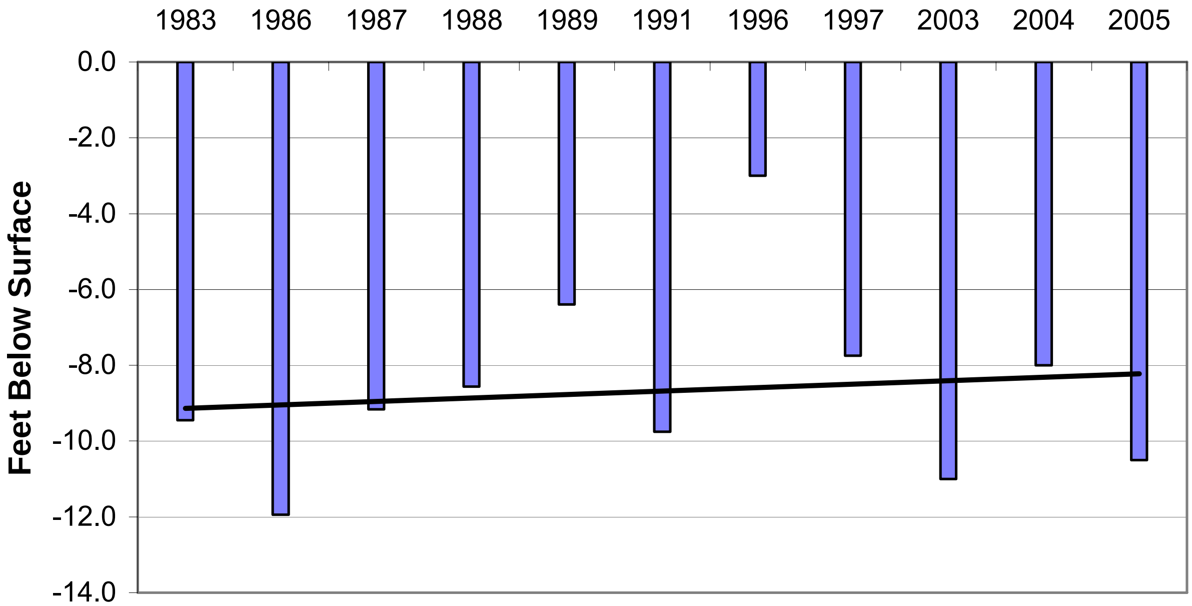


Figure 2. Change in summer mean water clarity in Patrick Lake, 1983-2005

Data collected at the same time during the year was averaged. Water clarity in Patrick

Lake is good early in the growing season and decreases to fair clarity in the summer as the water warms. As the water cools again in the fall, clarity increases to very good clarity (Figure 3).

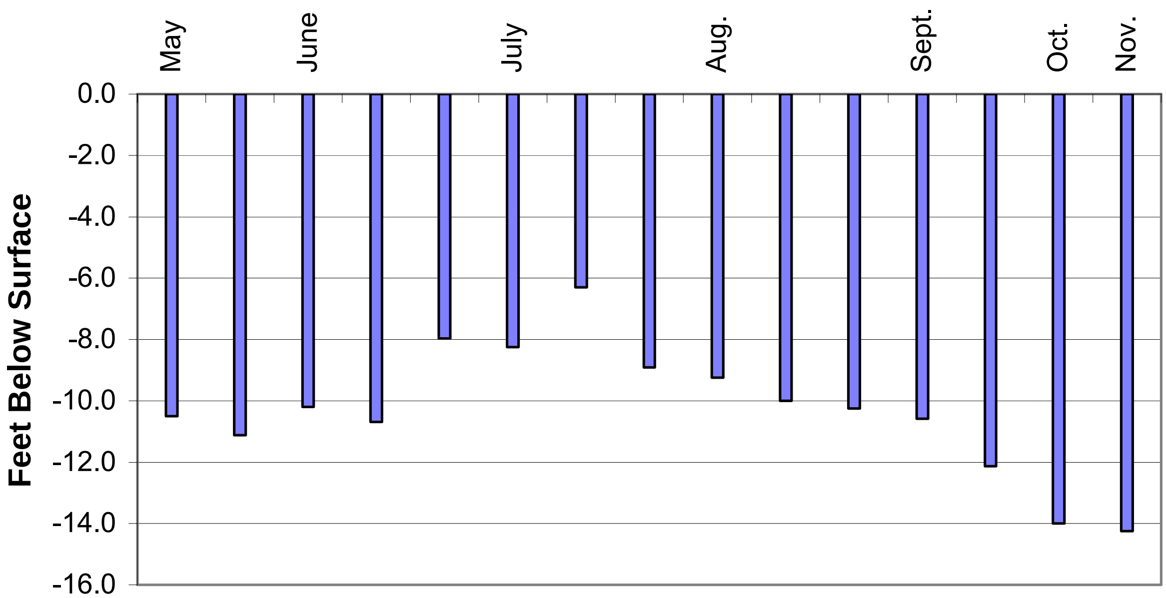


Figure 3. Change in water clarity during in the growing season in Patrick Lake, 1986-2005.

Hardness

The hardness or mineral content of lake water also influences aquatic plant growth. Hardness values in Patrick Lake were 80-123mg/l CaCO3 during 1983-2005. Lakes with hardness values of 61-120mg/l CaCO3 are considered moderately hard water lakes. Hard water lakes tend to support more plant growth than soft 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).

Patrick Lake has an irregularly-shaped basin with a gradually-sloped littoral zone and shallow depths in most of the lake (Appendix IV). Gradual slopes provide a more stable rooting base and broader area of shallow water that would favor plant growth.

SEDIMENT COMPOSITION – The dominant sediment in Patrick Lake was peat, especially at depths greater than 5 feet (Table 3). Mixtures of silt with peat were common overall and dominant in the 1.5-5ft depth zone. Sand, a hard, high-density sediment, was common in the shallow zone, as was silt (Figure 4).

Table 3. Sediment Composition: Patrick Lake, 2005

Sediment Type		0-1.5' Depth	1.5-5' Depth	5-10' Depth	10-20' Depth	Percent of all Sample Sites
Soft Sediments	Peat		33%	47%	100%	30%
	Silt/Peat	7%	40%	27%		23%
	Silt	13%	7%	27%		15%
	Silt/Muck	7%				2%
Mixed Sediments	Sand/Silt	33%				11%
	Peat/Sand		13%			4%
	Sand/Muck	7%				2%
Hard Sediments	Sand	33%	7%			13%

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. The availability of mineral nutrients for growth is highest in sediments of intermediate density, such as silt, so these sediments are considered most favorable for plant growth (Barko and Smart 1986).

Peat was the overall dominant sediment found in Patrick Lake and could be limiting for plant growth due its flocculent nature. All sites were vegetated in Patrick Lake, irregardless of the sediment type (Table 3). It appears that sediment is not a major factor determining plant distribution in Patrick Lake.

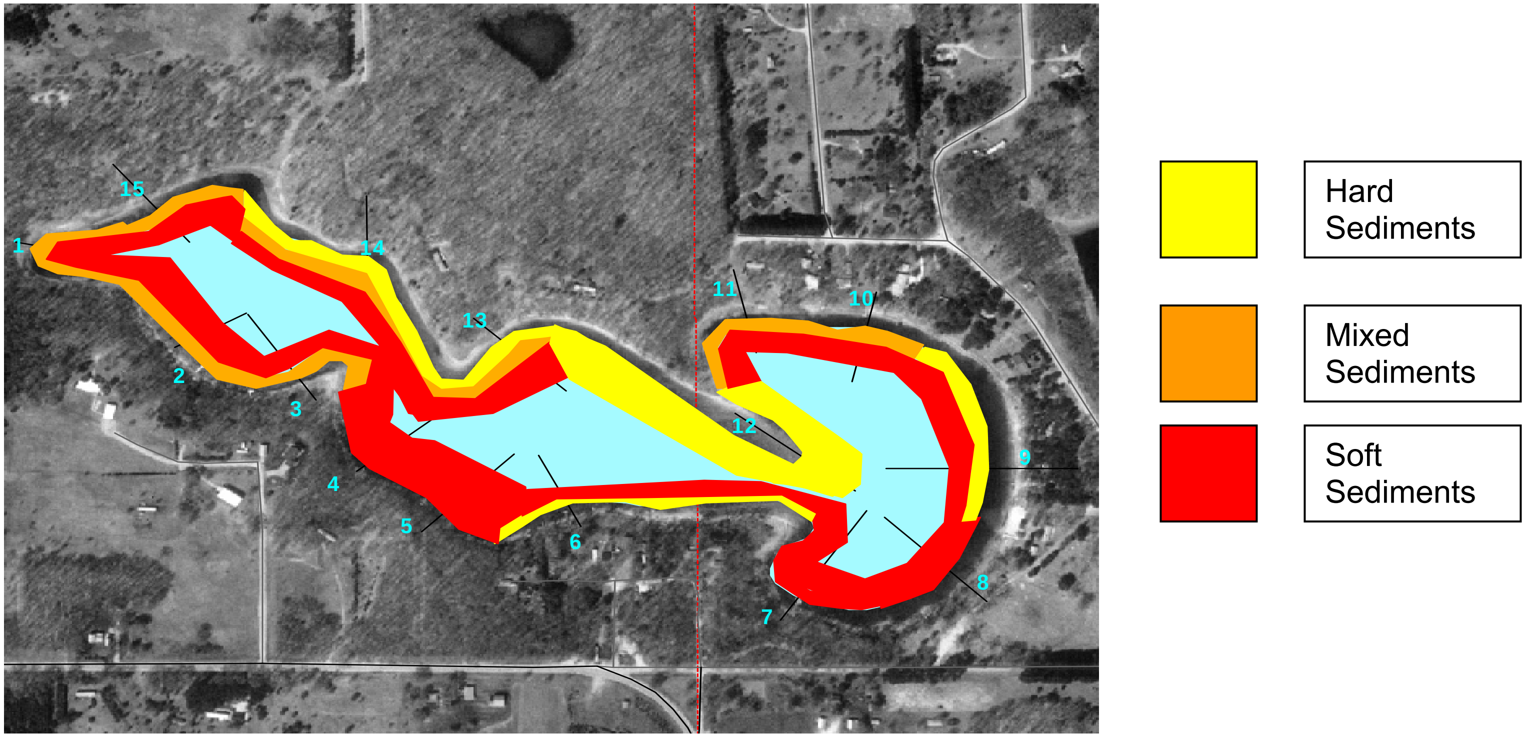


Figure 4. Distribution of sediment types in Patrick Lake, 2005 (Evans 2006).

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 through 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 cover was the most frequently encountered shoreline cover at the transects and had the highest mean coverage. Shrub cover and wooded cover were also commonly occurring (Table 4).

Cultivated lawn had a high occurrence and hard structures were common (Table 4).

Table 4. Shoreline Land Use - Patrick Lake, 2005

Cover Type		Frequency of Occurrences at Transects	Mean % Coverage
Natural Shoreline	Native Herbaceous	100%	65%
	Wooded	27%	9%
	Shrub	33%	6%
Total Natural			80%
Disturbed Shoreline	Cultivated Lawn	40%	17%
	Hard Structures	27%	3%
Total Disturbed			20%

Some type of natural shoreline (wooded, shrub, native herbaceous) was found at all of the sites, having a mean coverage of 80%.

Some type of disturbed shoreline (cultivated lawn and hard structures) was found at 40% of the sites and had a mean coverage of 20%.

MACROPHYTE DATA
SPECIES PRESENT

Of the 17 species found in Patrick Lake, 3 were emergent species, 3 were floating-leaf species and 11 were submergent species (Table 5).
No threatened or endangered species were found.
One exotic invasive species was reported: *Myriophyllum spicatum*

Table 5. Patrick Lake Aquatic Plant Species, 2005

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Carex* spp.	sedge	carsp
2) *Scirpus validus* Vahl.	softstem bulrush	sciva
3) *Typha* spp.	cattail	typsp
Floating-leaf Species		
4) *Brasenia schreberi* J. F. Gmelin.	watershield	brasc
5) *Nuphar variegata* Durand.	bull-head pond lily	nupva
6) *Nymphaea odorata* Aiton.	white water lily	nymod
Submergent Species		
7) *Chara* sp.	muskgrass	chasp
8) *Myriophyllum spicatum* L.	Eurasian water milfoil	myrsp
9) *Najas flexilis* (Willd.) Rostkov & Schmidt.	slender naiad	najfl
10) *Najas guadalupensis* (Spreng.) Magnus.	common water-nymph	najgu
11) *Nitella* sp.	nitella	nitsp
12) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
13) *Potamogeton gramineus* L.	variable-leaf pondweed	potgr
14) *Potamogeton illinoensis* Morong.	Illinois pondweed	potil
15) *Potamogeton natans* L.	floating-leaf pondweed	potna
16) *Potamogeton praelongus* Wulf.	white-stem pondweed	potpr
17) *Potamogeton richardsonii* (Ar. Benn.) Rydb.	clasping-leaf pondweed	potri

FREQUENCY OF OCCURRENCE

Najas guadalupensis was the most frequently occurring species in Patrick Lake in 2005, (68% of sample sites) (Figure 5). *Chara* spp., *Nymphaea odorata, Potamogeton illinoensis,* and *P. richardsonii* were also commonly occurring species, (49%, 36%, 28%, 36% respectively).

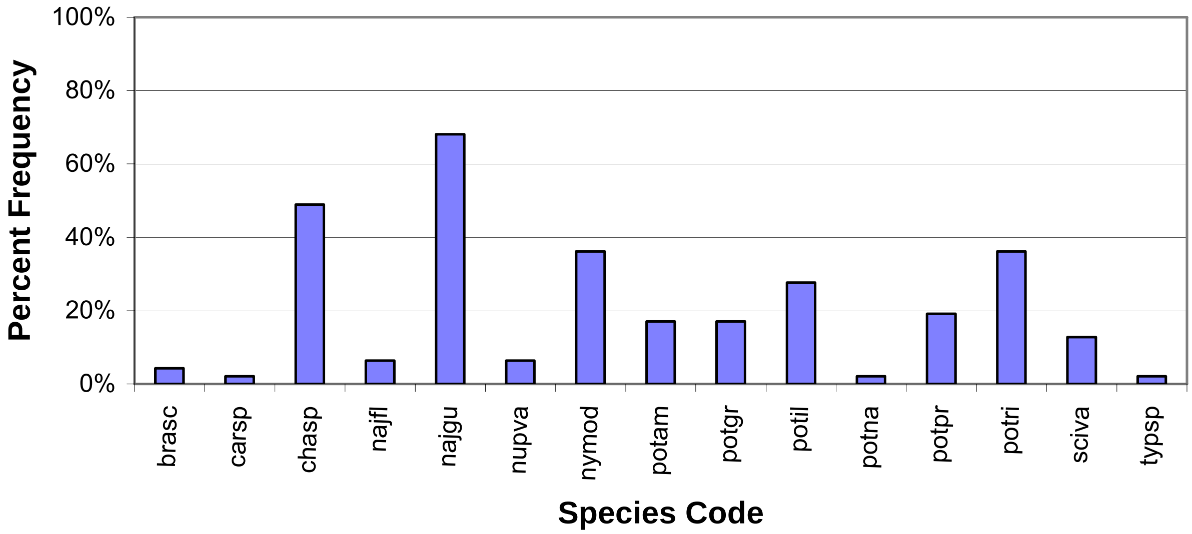


Figure 5. Frequency of occurrence of aquatic plant species in Patrick Lake, 2005.

DENSITY

Najas guadalupensis was the species with the highest mean density in Patrick Lake (1.96 on a density scale of 0-4) (Figure 6). *N. guadalupensis* had a "mean density where present" of 2.88 (Figure 5) (Appendix II). The "mean density where present" indicates that, where *N. guadalupensis* occurred, it exhibited a growth form of above average density in Patrick Lake. *Chara* spp. and *Nymphaea odorata* also had "densities where present" of 2.5 or more, indicating that they also exhibited an aggregated growth form or a growth form of above average density (Appendix II).

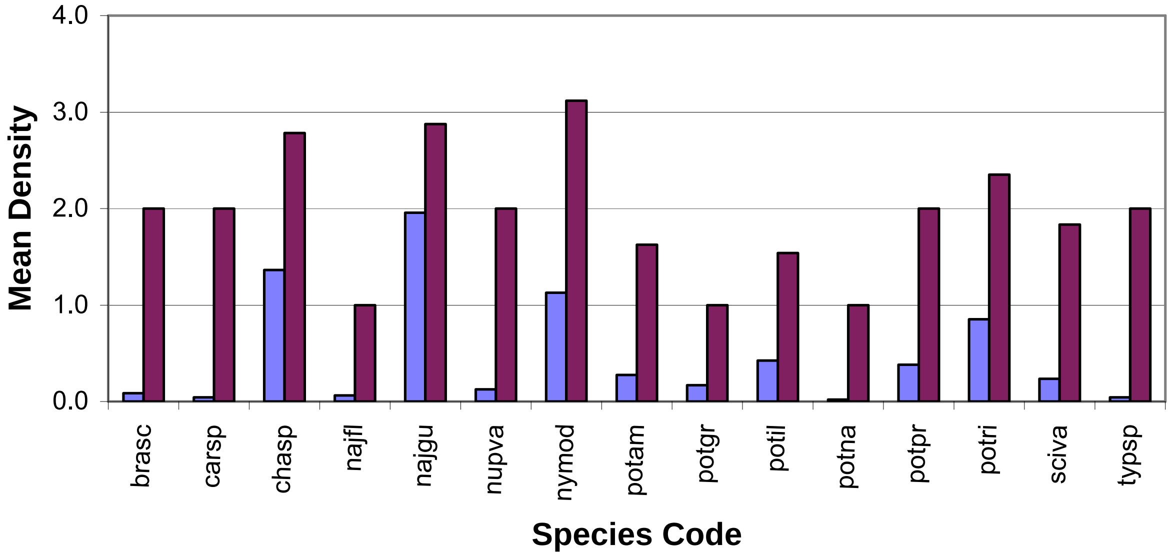


Figure 6. Mean density of aquatic plant species in Patrick Lake, July 2005.

DOMINANCE

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community (Appendix III). Based on the Dominance Value, *Najas guadalupensis* was the dominant aquatic plant species in Patrick Lake (Figure 7). *Chara* spp. was sub-dominant.

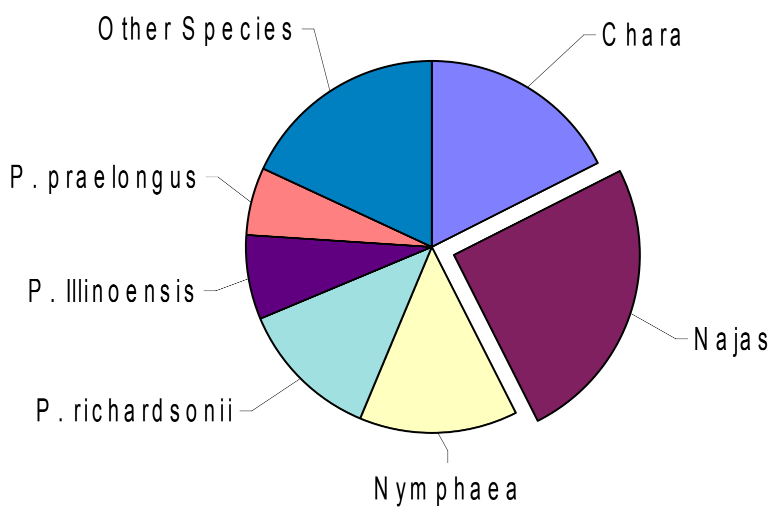


Figure 7. Dominance within the aquatic plant community, of the most prevalent plants in Patrick Lake, 2005.

Najas guadalupensis was the dominant species overall and was dominant in the 1.5-10ft depth zone. *N. guadaluepnsis* occurred at its highest frequency and density in the 5-10ft depth zone (Figure 8, 9). *Nymphaea odorata* was the dominant species in the 0-1.5ft depth zone, occurring at its highest frequency and density in this depth zone (Figure 8, 9). *Potamogeton praelongus* was the dominant species in the 10-20ft depth zone, occurring at its highest frequency and density in this depth zone.

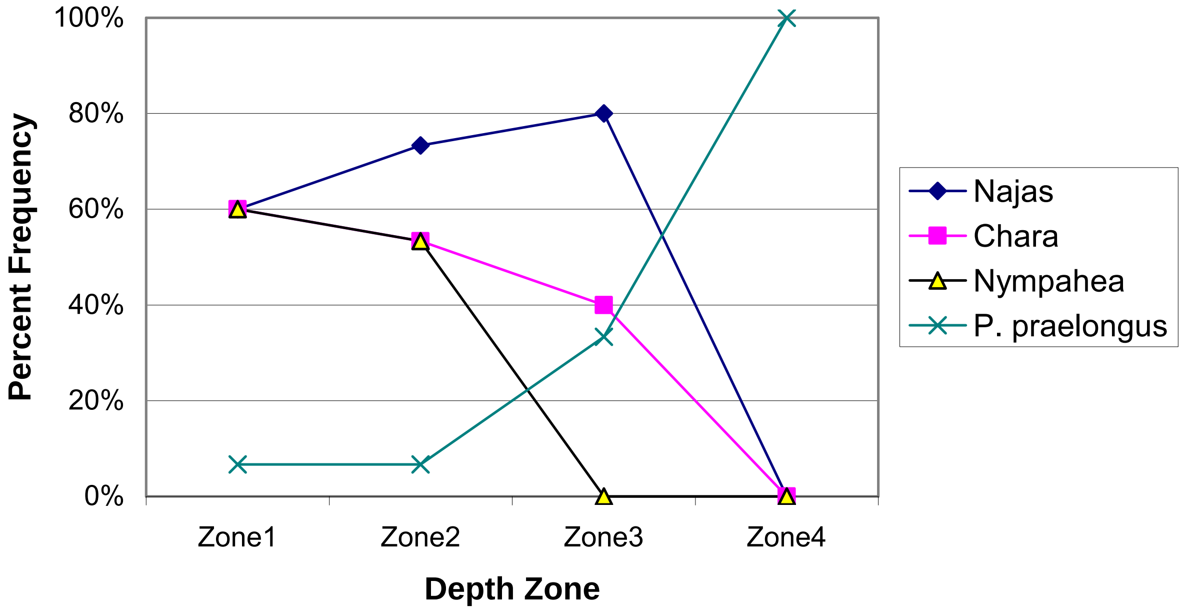


Figure 8. Frequency of occurrence of prevalent aquatic plant species in Patrick Lake, by depth zone, 2005.

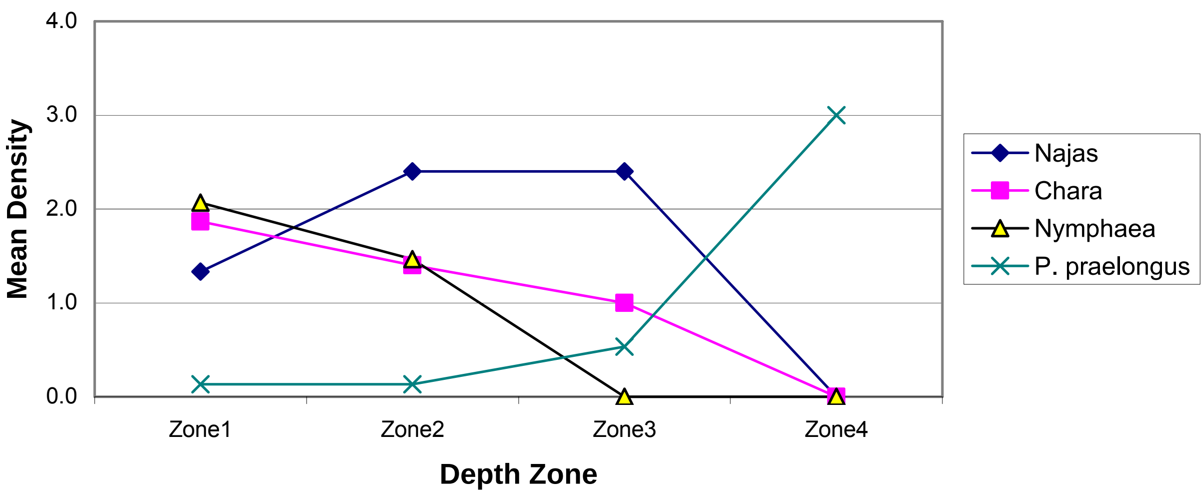


Figure 9. Density of prevalent plant species in Patrick Lake by depth zone, 2005.

Figure 10. Distribution of Aquatic Vegetation in Patrick Lake, 2005 (Evans 2006).

DISTRIBUTION

Aquatic plants occurred throughout the entire littoral zone of Patrick Lake, at all of the sampling sites to a maximum depth of 13 feet (Figure 10). Approximately 39 acres of the entire lake (78%) was vegetated. *Potamogeton illinoensis, P. praelongus* and *P. richardsonii* occurred at the maximum rooting depth.

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

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

Based on the 2005 Secchi disc clarity, the predicted maximum rooting depth in Patrick Lake would be 15.5 ft.

The actual maximum rooting depth in 2005 was less than predicted based on 2005 water clarity (Figure 11). However, the actual maximum rooting depth in 2005 was close to the predicted depth based on the 2004 water clarity. The water clarity was less in 2004. When water clarity increased from 2004 to 2005, aquatic plants can not immediately spread to deeper waters in order to take advantage of better clarity.

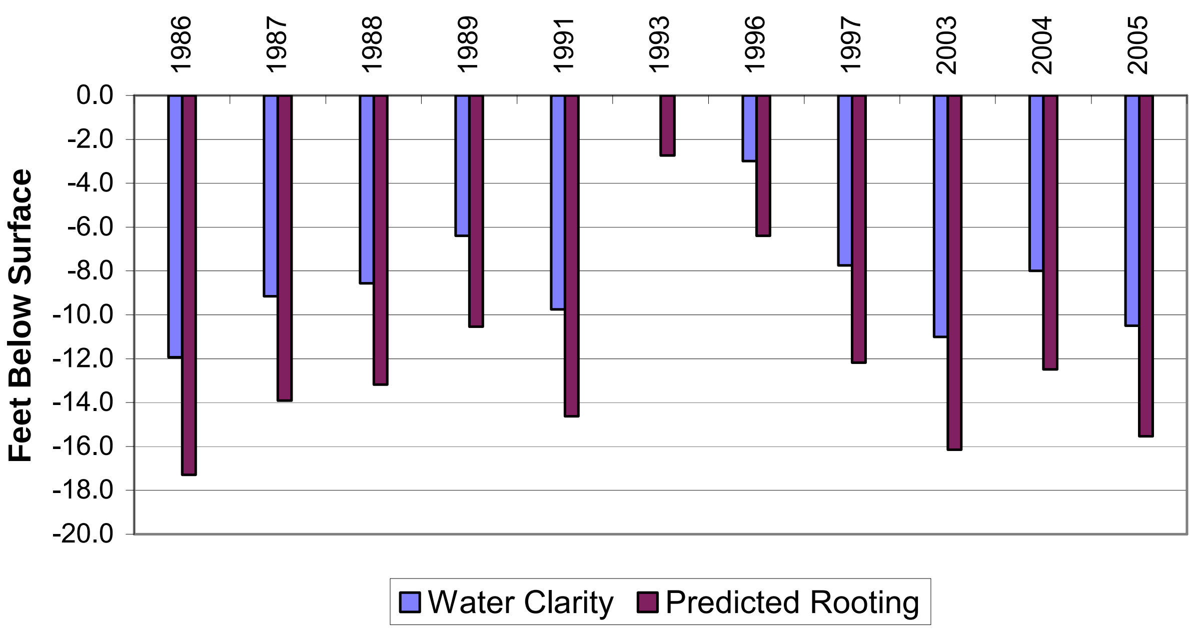


Figure 11. Predicted maximum rooting depth based on water clarity, 1990-2005.

The dominant and common plant species were found throughout the lake except one. *Potamogeton richardsonii,* a common species, was found only in the south half of the lake.

Myriophyllum spicatum, which was treated in the spring, did not occur in the July 2005 survey.

The highest total occurrence of plants, total density of plant growth and species richness were recorded in the 0-1.5ft depth zone (Figure 12, 13). However, total occurrence, total density and species richness decline very gradually in the 0-10ft depth zone and did not significantly decline until depths were greater than 10 feet. Overall species richness in Patrick Lake was 3.06 species per site.

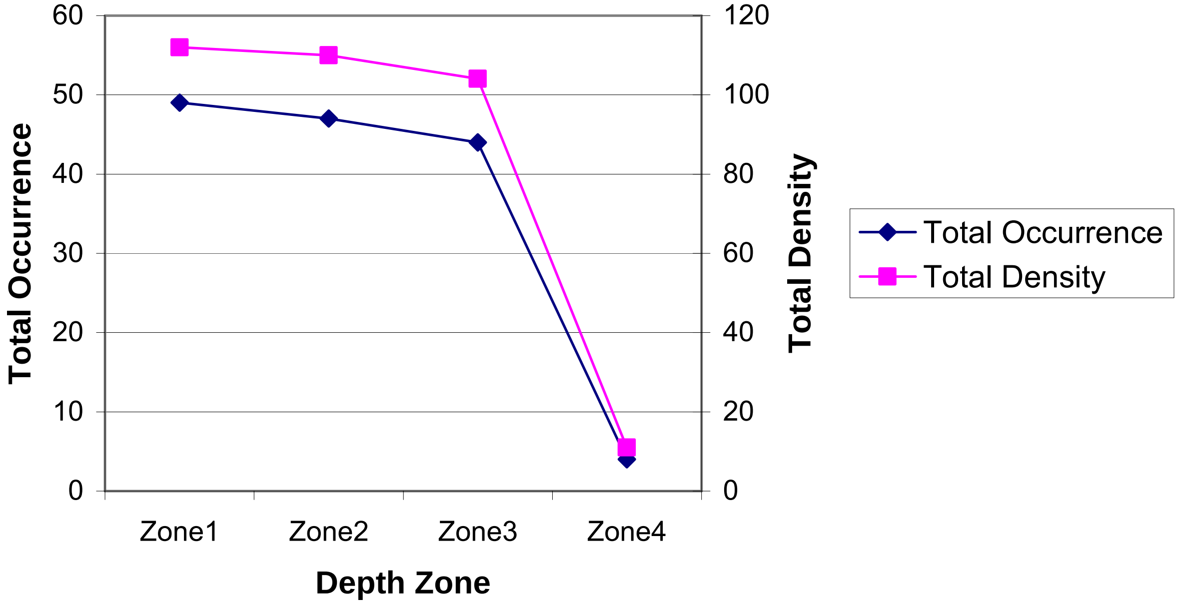


Figure 12. Total occurrence and total density of plants in Patrick Lake by depth zone.

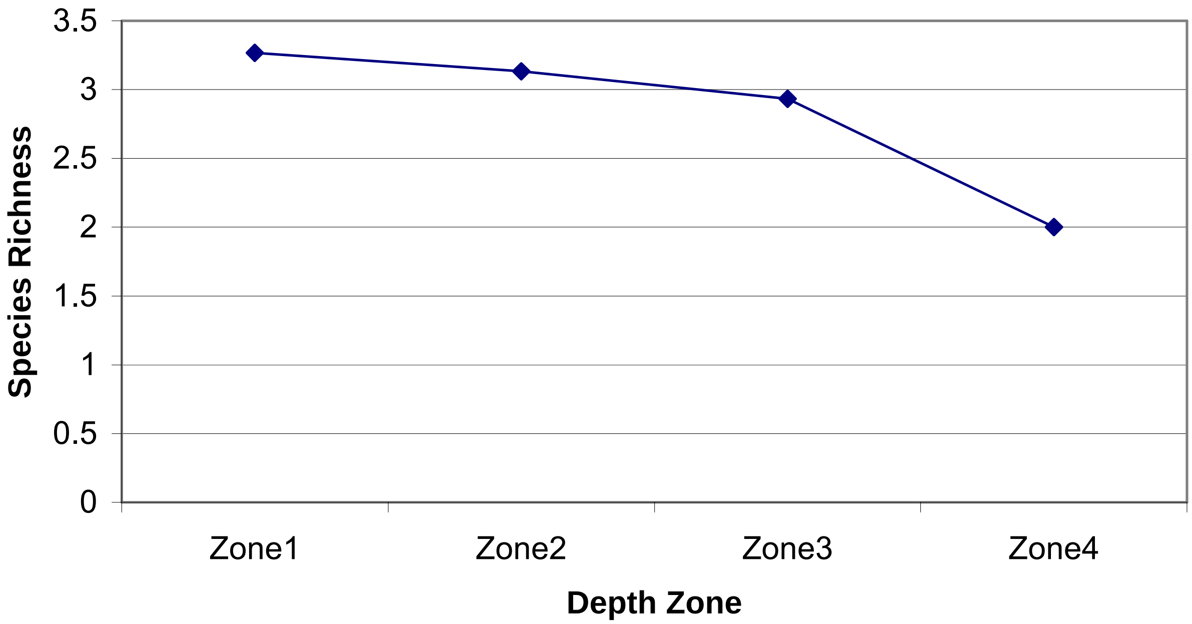


Figure 13. Species richness in Patrick Lake, by depth zone, 2005.

THE COMMUNITY

Simpson's Diversity Index was 0.876, indicating good species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable).

The Aquatic Macrophyte Community Index (AMCI) for Patrick Lake (Table 6) is 58. This is in the upper quartile of lakes in Wisconsin and the North Central Hardwoods Region of the state. This value places Patrick Lake in the top 25% of lakes in the state and region with the highest quality aquatic plant communities.

Table 6. Aquatic Macrophyte Community Index, Patrick Lake 2005

Category		Value
Maximum Rooting Depth	3.96 meters	7
% Littoral Zone Vegetated	100%	10
% Submergent Species	79.3% Relative Freq.	10
# of Species	17	8
% Exotic Species	present	6
Simpson's Diversity Index	0.876	8
% Sensitive Species	26.5% Relative Freq.	9
Totals		58

* The highest value for this index is 70.

The Average Coefficient of Conservatism for Patrick Lake was below average for Wisconsin lakes and in the upper quartile for lakes in the North Central Hardwood Region (Table 7). This suggests that the aquatic plant community in Patrick Lake is less sensitive to disturbance than the average lake in the state, but among the lakes in the region most sensitive to disturbance.

Table 7. Floristic Quality and Coefficient of Conservatism of Patrick Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	Average Coefficient of Conservatism †	Floristic Quality ‡	
			Based on Relative Frequency
Wisconsin Lakes	5.5, 6.0, 6.9 *	16.9, 22.2, 27.5	
NCHR	5.2, 5.6, 5.8 *	17.0, 20.9, 24.4	
Patrick Lake 2005	5.86	21.92	23.75

***** - 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 aquatic plant community in Patrick Lake was below average for Wisconsin lakes and above average for lake in the North Central Hardwood Region (Table 7). This indicates that the plant community in Patrick Lake is as close to an undisturbed condition as the average lake.

However, this calculation was based only on the presence or absence of sensitive and tolerant species; their occurrence or dominance in the community was not taken into consideration. The Floristic Quality Index was recalculated, weighting each species coefficient with its relative frequency in the community. The resulting index was slightly different. The recalculated FQI was above average for lakes in both the North Central Hardwood Region and in the state. This suggests that Patrick Lake is closer to an undisturbed condition than the average lake in the state or region.

Disturbances can be of many types:

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

The major disturbances in Patrick Lake are likely:
Past broad-spectrum treatments of aquatic vegetation, the introduction of non-native aquatic plant species and the subsequent selective chemical treatments, shoreline development and fluctuating water levels

IV. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Patrick Lake is an oligotrophic/mesotrophic lake with good water clarity and good-to-very good water quality. Water clarity has decreased since 1986. Filamentous algae occurred at 38% of the sites, common to abundant in all depth zones.

Adequate nutrients, the good water clarity, moderately hard water, shallow depths and the gradually-sloped littoral zone in Patrick Lake would favor plant growth.

Aquatic plants occurred throughout the entire littoral zone, 78% of the lake surface (40 acres), to a maximum depth of 13-feet. The highest total occurrence of plants, highest total density of plants and the greatest species richness occurred in the 0-1.5ft depth zone. Overall species richness was 3.06.

Seventeen (17) species of aquatic plants were recorded in Patrick Lake in 2005. *Najas guadalupensis* was the overall dominant plant species in Patrick Lake, especially in the 1.5-10ft depth zone, colonizing more than half of the littoral zone and exhibiting a growth form of above average density in Patrick Lake. *Chara* spp. was sub-dominant in Patrick Lake, also exhibiting a growth form of above average density. *Nymphaea odorata* was dominant in the 0-1.5ft depth zone and also exhibited a growth form of above average density. *Potamogeton praelongus* dominated the lake at depths greater than 10 feet.

Four (4) other species were commonly occurring In Patrick Lake. The dominant and common species, except *Potamogeton richardsonii,* were found throughout the lake.

Eurasian watermilfoil has been introduced in Patrick Lake. A lake-wide treatment (targeting Eurasian milfoil wherever it was found in the lake) was conducted in spring 2005. In July 2005, Eurasian watermilfoil was not recorded at the sites, although a 0.5-acre area was found and retreated in September 2005.

Arsenic treatments conducted in 1958 to 1959 and other broad-spectrum chemical treatments in 1979-1981 may have opened up areas in the lake that made ideal conditions for the invasion of exotic species. In addition, arsenic does not degrade further and remains in the sediment as a toxic component.

The Aquatic Macrophyte Community Index (AMCI) for Patrick Lake was 58, indicating that the quality of the plant community in Patrick Lake is high, in the top quartile of lakes in Wisconsin and the North Central Hardwoods Region. Simpson's Diversity Index (0.876) indicates that the aquatic plant community had a good diversity of plant species.

The Average Coefficient of Conservatism and the Floristic Quality Index indicate that Patrick Lake has an average sensitivity to disturbance and is closer to an undisturbed condition than the average lake in the state or region.

Shoreline Impacts

Patrick Lake has some protection from natural shoreline cover (wooded, shrub, native herbaceous growth), but disturbed shoreline covered 20% of the shore. Cultivated lawn was abundant and hard structures were commonly occurring at the shoreline.

Shorelines with cultivated lawn can impact the plant community through increased run-off of lawn fertilizers, pesticides and pet wastes into the lake. Hard structures and mowed lawn also speed run-off to the lake without filtering these pollutants. Expanding and protecting the buffer of natural vegetation along the shore will help prevent shoreline erosion and reduce additional nutrient/chemical run-off that can add to algae growth and sedimentation of the lake bottom.

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

The quality of the aquatic plant community (as measured by the AMCI) is higher at the natural shoreline communities (Table 8).

Table 8. Aquatic Macrophyte Community Index: Natural vs. Disturbed Shoreline Sites, 2005

Category	Natural	Disturbed
Maximum Rooting Depth	7	3
% Littoral Zone Vegetated	10	10
% Submergent Species	10	9
# of Species	8	8
% Exotic Species	6	6
Simpson's Diversity Index	8	7
% Sensitive Species	10	10
Totals	59	53

* The highest value for this index is 70.

The natural shoreline communities supported better diversity in the plant community which will provide a more diverse habitat for more diverse wildlife and fish communities. This is seen in the higher Simpson's Diversity Index and the greater Species Richness both overall and in all depth zones at natural shoreline sites (Table 9).

Several parameters point to disturbance as the likely factor for the difference in the plant communities.

1) The most sensitive species in Patrick Lake (*Potamogeton praelongus*) (Nichols 2000) occurred at a higher frequency, grew at a higher density and had a higher dominance at the sites near natural shoreline (Table 9). Conversely, the most tolerant species in Patrick Lake (*Typha latifolia)* was found only at disturbed shoreline sites.
2) The Average Coefficient of Conservatism was higher at the natural shoreline communities (Table 9). The natural shoreline sites are less tolerant to disturbance than the average lake in the state and the disturbed shoreline sites are more tolerant to disturbance than the average lake in the state, this is likely due to selection by past disturbance.
3) The Floristic Quality Index is also higher at the natural shoreline sites. The natural shoreline sites are closer to an undisturbed condition than the average lake in the state and the disturbed shoreline sites are farther from an undisturbed condition than the average lake in the state (Table 9).

This corroborates the impact disturbed shoreline has on the aquatic plant community.

The natural shoreline communities provide more habitat. The percent cover of submergent plant species is higher at natural shoreline sites and the maximum rooting depth is greater, providing a wider band of habitat (Table 9).

Table 9. Comparison of the Aquatic Plant Community at Natural Shoreline Sites and Disturbed Shoreline Sites.

Parameter		**Natural Shoreline**	**Disturbed Shoreline**
Simpson's Diversity Index		0.875	0.871
Species Richness (mean number of species per site)	Overall	3.17	2.89
	0-1.5ft Depth Zone	3.44	3.0
	1.5-5ft Depth Zone	3.22	3.0
	5-10ft Depth Zone	3.11	2.67
	10-20ft Depth Zone	2.0	0
Amount of Habitat	Maximum Rooting Depth	13 feet	7.5 feet
	% Cover of Submergent Species	96%	94%
Most Sensitive Species: *Potamogeton praelongus*	Overall Dominance	0.13	0.10
	Frequency	21%	17%
	Mean Density	0.45	0.28
Most Tolerant Species: *Typha latifolia*	Frequency	0	6%
Average Coefficient of Conservatism		6.23	5.91
Floristic Quality Index		23.31	21.33

Changes in the Aquatic Plant Community, 1978-2005
The assessments conducted in 1978 and 1983 were qualitative and the study conducted in 2005 was quantitative, so that direct comparisons cannot be made.

Najas was still the most abundant species. *Potamogeton richardsonii* was still common, but *P. nodosus* was not found in 2005. *Chara* spp. is still present.

In 2005: *Brasenia schreberi* still only occurred in one area of the lake, the northeast corner, but *Nymphaea odorata* is now found throughout the lake and not in just one areas. Ten species that were found in 2005 were not mentioned in the 1978 survey.

Many differences between the 2002/04 and 2005 surveys can be attributed to the difference in timing during the growing season (Table 9) since aquatic plants reach their full growth in Mid-June to July. After the 2002 and 2003 treatment for Eurasian watermilfoil, the only species that showed significant changes (Cason and Roost 2004) were significant increases in *Elodea canadensis, Potamogeton crispus, P. illinoensis, P. zosteriformis* and a significant decrease in *Myriophyllum spicatum* (Table 9). The decrease in *M. spicatum* was expected since the treatments were conducted to control this species. The increase in the other species are likely due to these species spreading and colonizing areas previously colonized by *M. spicatum. Potamogetons* and *Elodea* are not impacted by the chemical used for *M. spicatum.* There have been significant but temporary increases of *Elodea* on other lakes in the area after watermilfoil treatments.

Table 10. Change in Aquatic Plant Species in Patrick Lake, 1978-2005.

Scientific Name	1978*	1983	July 2005
Emergent Species			
1) *Carex* spp.			Present
2) *Scirpus validus*	Common	Scattered	Scattered
3) *Typha angustifolia*		Scarce	Scarce
Floating-leaf Species			
4) *Brasenai schreberi*	Present	Present	Present
5) *Nuphar variegata*			Present
6) *Nymphaea odorata*	Present	Common	Abundant
7) *Polygonum amphibium*	Present		
Submergent Species			
8) *Chara* sp.	Present	Common	Sub-Dominant
9) *Elodea canadensis*	Common	Scarce	
10) *Myriophyllum* spp.	Common	Common	
11) *Najas guadalupensis*	Dominant	Abundant	Dominant
12) *Nitella* sp.		Scattered	Scattered
13) *Potamogeton amplifolius*		Scattered	Scattered
14) *Potamogeton gramineus*			Scattered
15) *Potamogeton illinoensis*			Common
16) *Potamogeton natans (nodosus?)*	Common		Scarce
17) *Potamogeton pectinatus*		Scattered	
18) *Potamogeton praelongus*		Scarce	Abundant
19) *Potamogeton richardsonii*	Common		Common

V. CONCLUSIONS

Patrick Lake is a 50-acre mesotrophic/oligotrophic lake with good-to-very good water quality and good water clarity. Water clarity has decreased since 1983. Filamentous algae is common to abundant throughout Patrick Lake.

The aquatic plant community colonized approximately three-quarters total are of Patrick Lake to a maximum rooting depth of 13 feet. 100% of the littoral zone is vegetated. The 0-1.5ft depth zone supported the most abundant aquatic plant growth.

Najas guadalupensis was the dominant species within the 17-species aquatic plant community, especially in the 1.5-10ft depth zone. *Chara* spp. was sub-dominant. *Nymphaea odorata* was the most abundant species in the 0-1.5ft depth zone. These three species exhibited growth forms of above average density in Patrick Lake. *Potamogeton praelongus* was the most abundant specie in the 10-20ft depth zone.

Eurasian watermilfoil has been introduced in Patrick Lake, but after lake-wide treatments for the milfoil began in spring 2005, Eurasian watermilfoil was not found in the July 2005 survey. A 0.5-acre colony was found and re-treated in September 2005.

The Patrick Lake aquatic plant community is characterized by high quality and good species diversity. The plant community has an average sensitivity to disturbance and closer to an undisturbed condition than the average lake in the state or region.

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

Aquatic plant communities improve water quality in many ways (Engel 1985):

- 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.

Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table 11). Plant cover within the littoral zone of Patrick Lake is 100% and over the whole lake is 78% and is appropriate (25-85%) to support a balanced fishery.

Table 11. Wildlife and Fish Uses of Aquatic Plants in Patrick Lake

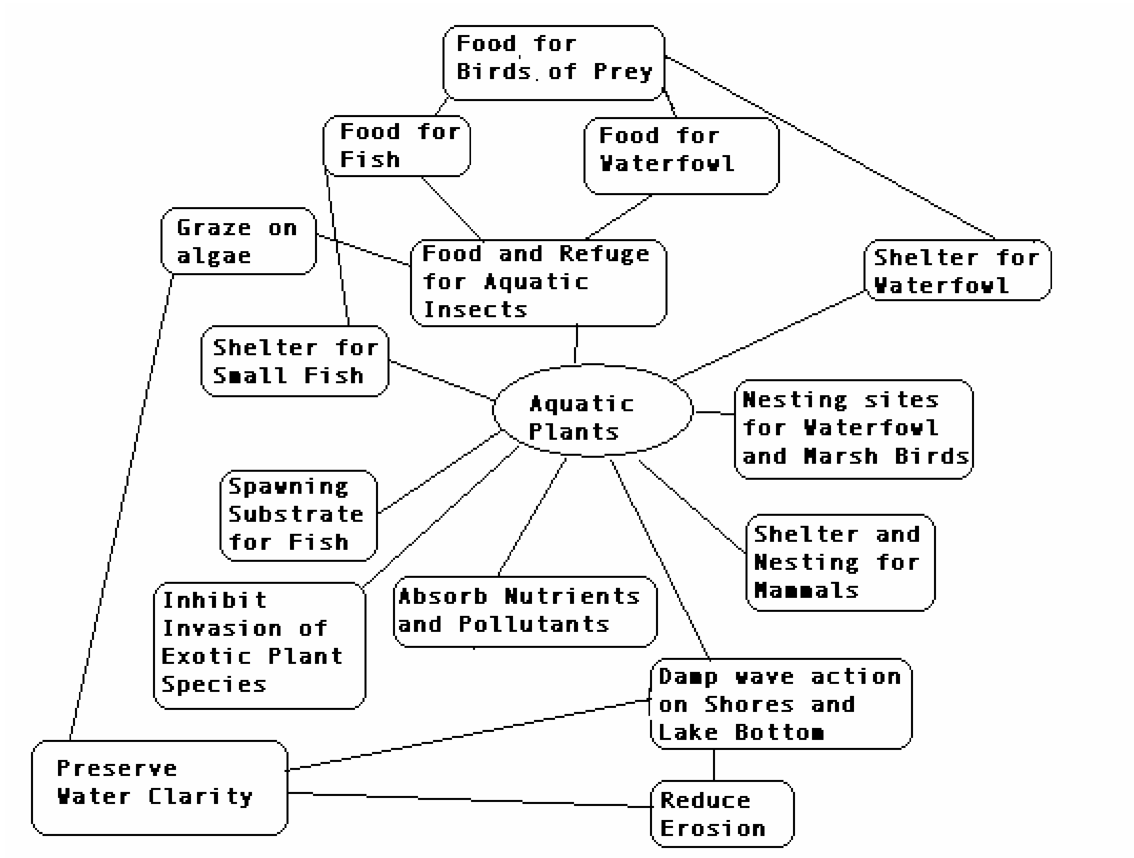
Aquatic Plants	Fish	Water Fowl	Song and Shore Birds	Upland Game Birds	Muskrat	Beaver	Deer
Submergent Plants							
Chara sp.	F*, S	F*, I*					
Myriophyllum spicatum	F, C						
Najas flexilis	F, C	F*(Seeds, Foliage)	F(Seeds)				
Najas guadalupensis	F, C	F*(Seeds, Foliage)					
Nitella sp.		F, I*					
Potamogeton amplifolius	F, I, S*,C	F*(Seeds)			F*	F	F
Potamogeton gramineus	F, I, S*,C	F*(Seeds, Tubers)			F*	F	F
Potamogeton illinoensis	F, I, S*,C	F*(Seeds)	F		F*	F	F
Potamogeton natans	F, I, S*,C	F*(Seeds, Tubers)			F*	F	F
Potamogeton praelongus	F, I, S*,C	F*(All)			F*	F	F
Potamogeton richardsonii	F, I, S*,C	F*(All)			F*	F	F
Floating-leaf Plants							
Brasenia schreberi	S, I, C	F(Seeds)			F	F	F
Nuphar variegata	F,C, I, S	F, I	F		F*	F	F*
Nymphaea odorata	F,I, S, C	F(Seeds)	F		F	F	F

Aquatic Plants	Fish	Water Fowl	Song and Shore Birds	Upland Game Birds	Muskrat	Beaver	Deer
<u>**Emergent Plants**</u>							
Carex spp.	S*	F* (Seeds), C	F*	F* (Seeds)	F (Roots, Sprouts)	F	F
Scirpus validus	F, C, I	F (Seeds)*, C	F(Seeds, Tubers), C	F (Seeds)	F	F	F
Typha spp.	I, C, S	F(Entire), C	F(Seeds), C, Nest	Nest	F* (Entire), C*, Lodge	F	F

F=Food, I= Shelters Invertbrates, a valuble 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.

After: Fassett, N. C. 1957. A Manual of Aquatic Plants. University of Wisconsin Press. Madison, WI
Nichols, S. A. 1991. Attributes of Wisconsin Lake Plants. Wisconsin Geological and Natural History Survey. Info. Circ. #73

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 aquatic 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. Aquatic plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).



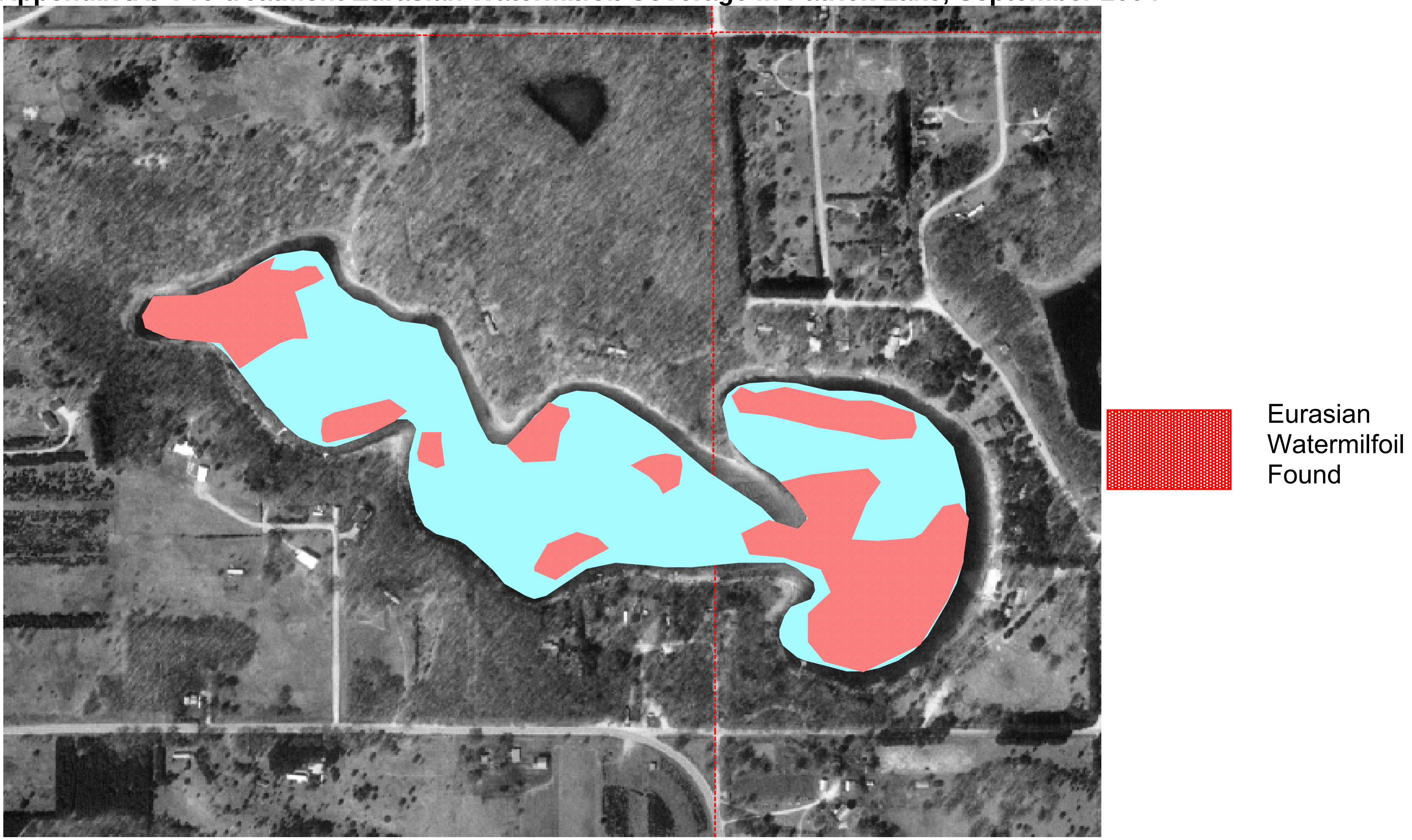
Management Recommendations

1) All lake residents shall practice best management on their lake properties. Decreased water clarity since 1983 may be a warning that water quality is being impacted by shoreline development. The watershed of Patrick Lake is relatively small and would not likely contribute significant nutrients.
    a) Keep septic systems cleaned and in proper condition
    b) Use no lawn fertilizers
    c) Clean up pet wastes
    d) Do not compost near the water or allow yard wastes and clippings to enter the lake
2) Residents should resume involvement in the Volunteer Lake Monitoring Program, monitoring water quality to track seasonal and year-to-year changes.
3) Adams County should designate sensitive areas within Patrick Lake. These are areas within the lake that are most important for habitat and maintaining water

4) quality.
5) Lake residents shall protect natural shoreline around Patrick Lake to provide habitat and protect water quality in the lake. Patrick Lake has protection from natural shoreline buffers on large areas of the lake, but disturbed shoreline (cultivated lawn and hard structures) is common, covering 20% of the shore. Unmowed native vegetation reduces shoreline erosion and run-off into the lake and filters the run-off that does enter the lake. Comparison of the plant communities at natural shoreline and disturbed shoreline suggest shoreline disturbance is already impacting the aquatic plant community. Evidence that disturbance on shore is impacting the plant community in the water is that the disturbed shoreline plant species assemblage is more tolerant of disturbance and farther from an undisturbed condition than the natural shoreline community. Disturbed shoreline sites in Patrick Lake support lower frequency and density of the most sensitive species and the most tolerant species are found only at the disturbed shoreline sites. Disturbed shoreline sites support an aquatic plant community:
    a. That provides less habitat. There is a lower coverage of submergent species and a less maximum rooting depth, resulting in a narrower band of habitat.
    b. That is less diverse resulting in a less diverse habitat that will support a lower diversity in the fish and wildlife population.
    c. A lower quality aquatic plant community as measured by the AMCI Index.
6) All lake users shall protect the aquatic plant community in Patrick Lake. The standing-water emergent community, floating-leaf community and submergent plant community are all unique plant communities. Each of these plant communities provides their own benefits for fish and wildlife habitat and water quality protection.
7) Lake District should maintain exotic species signs at the boat landings to educate lake users. The DNR should be contacted if the signs are missing or damaged.
8) Lake District shall continue monitoring Eurasian watermilfoil. It appears to be declining at present. However, some colonies may be able to rebound over the next few years.
    a. Continue early-season treatments with a specific chemical on larger areas
    b. Hand pull scattered plants and small colonies as chemical is less effective on these scattered individuals and clumps.

Appendices

Appendix IX. Pre-treatment Eurasian Watermilfoil Coverage in Patrick Lake, September 2004



Appendix IV. Transect Locations on Patrick Lake, 2005