THE AQUATIC PLANT COMMUNITY OF JORDAN LAKE, ADAMS COUNTY, WISCONSIN 2000-2012

Presented by Reesa Evans
Certified Lake Manager, Lake Specialist
Adams County Land & Water Conservation Department
P.O. Box 287, Friendship, WI 53934
608-339-4268

Executive Summary

I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Jordan Lake was conducted during the summer of 2012 by the Adams County Land and Water Conservation. Two aquatic surveys were done during the summer of 2012: one by the transect method, in order to match changes from prior transect survey results, and one by the point intercept method for comparison to prior point intercept surveys.

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 ongoing information that is important for effective management of the lake, including fish habitat improvement, protection of sensitive habitat, aquatic plant management and water quality protection. It will also allow tracking of any significant changes in the aquatic plant community that may indicate changes in the lake's overall health.

Background and History: Jordan Lake is located in the Town of Jackson, Adams County, Wisconsin. This natural seepage lake is over 213 surface acres in size. Maximum depth is 92 feet. According to an updated bathymetric map from 2007, 45% of the lake is over 20 feet deep. During the summer of 2012, when the most recent surveys were done, the lake was at slightly lower level than usual due to drought and very hot weather. There are public boat ramps located on the west and north sides of the lake. In 2002, the residents of the area formed the Jordan Lake District for carrying out programs to improve the lake. The Lake District completed a lake management plan in 2006 that was approved by the Wisconsin Department of Natural Resources. This plan is reviewed annually for needed updates.

Residential development around the lake is found along most of the lakeshore. The surface watershed is 17.4% residential, 21.3% non-irrigated agriculture, 8.8% irrigated agriculture; 2.7% open grasslands; 23.7% woodlands, and 26.6% water. The ground watershed contains 24.65% non-irrigated agriculture, 21.11% irrigated agriculture, 1.33% open grasslands, 26.2% woodlands, 16.6% residential, and 9.02% water. There are reports of banded killifish, an endangered species, in Jordan Lake. Native American burial mounds (Jordan Lake Group) are located on the north side of the lake. There are large wetland areas located east of the lake and on the northwest side of the lake.

A fish shocking survey in 2006 found a good panfish population, including bluegills, crappie and perch. Less common were largemouth bass and northern pike. Ciscos have been reported occasionally in Jordan Lake.

Soils directly around Jordan Lake tend to be sands or loamy sands of various slopes. Such soils tend to be excessively-drained, with infiltration of water being rapid to very rapid, and permeability also high. Such soils also usually have low water-holding and low organic matter content, thus making them difficult to establish vegetation on. These soils tend to be easily eroded by both water and wind.

Historically, management of aquatic plant growth has been by chemical treatments starting in 1981. Several different chemicals have been used, with up to half the lake being treated chemically at one time and multiple treatments within a year also occurring. Early treatments were broad-spectrum treatments that targeted all plant species and may have opened areas for invasion and colonization of the two exotic species now in the lake. Later treatments, from approximately 1980 onwards, were more selective, targeting Eurasian Watermilfoil (*Myriophyllum spicatum*). The lake has continued to use chemical treatment for Eurasian Watermilfoil management. Pre-and-post-treatment surveys are conducted every year by the Adams County Land & Water Conservation Department and a Jordan Lake volunteer.

A pre-treatment survey in 2012 found most of the Eurasian Watermilfoil in water depths of 6 to 12 feet towards the lake edges. In 2011 and 2012, chemical treatment was timed to occur once the lake had started stratifying for the summer. Residents have reported better control from this treatment timing. Residue tests have also been conducted. A post-treatment survey in 2012 found the invasive in only two spots.

Two other invasive aquatic plants have been found in Jordan Lake, but have remained in low frequency occurrence: Curly-Leaf Pondweed (*Potamogeton crispus*) and Reed Canarygrass (*Phalarais arundinacea*).

Two areas in Jordan Lake have been designated as “critical habitat areas”. Designation of critical habitat areas within lakes provides a holistic approach for assessing the ecosystem and for protecting those areas in and near a lake that are important for preserving the qualities of the lake. Wisconsin Rule 107.05(3)(i)(I) defines a “sensitive areas” as: “areas of aquatic vegetation identified by the department as offering critical or unique fish & wildlife habitat or offering water quality or erosion control benefits to the body of water. Thus, these sites are essential to support the wildlife and fish communities. They also provide mechanisms for protecting water quality within the lake, often containing high-quality plant beds. Finally, sensitive areas often can provide the peace, serenity and beauty that draw many people to lakes in the first place.

Area JO1

This area extends along approximately 2600 feet of the shoreline along the north side of the lake, extending up to the ordinary high water mark. 6% of the shore is wooded; 20% is native herbaceous cover. The balance of the shore is bare sand, cultivated lawn and hard structure. There is a shallow marsh area along this shoreline. Large woody cover (downed trees, branches, etc.) is present for habitat.

Seven emergent species were found in this area. Emergents provide important fish habitat and spawning areas, as well as food and cover for wildlife.

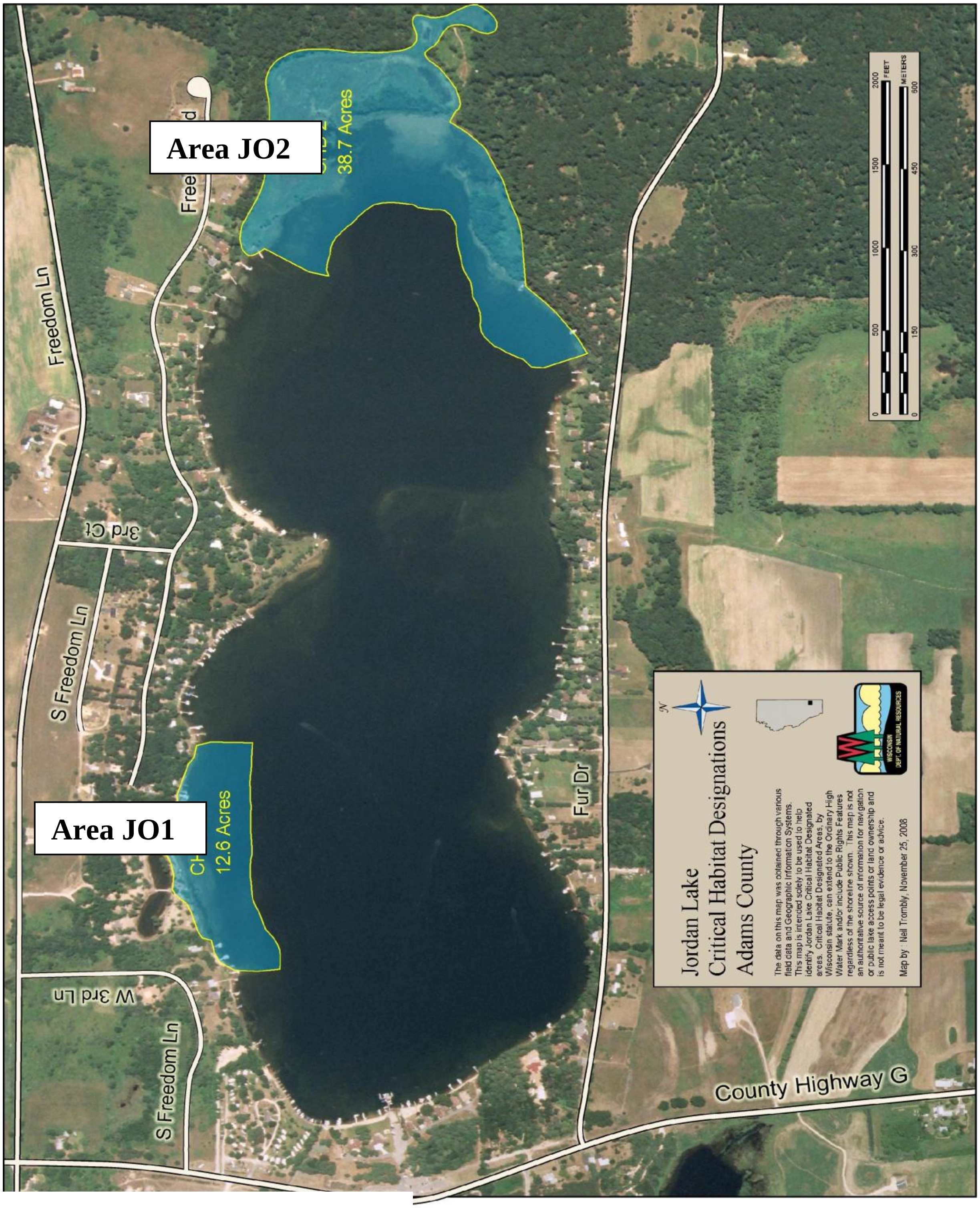


Figure 1: Critical Habitat Map for Jordan Lake

Free-floating plants were limited to Small Duckweed (*Lemna minor)*. Three species of rooted, floating-leaf plants were also found. Floating-leaf vegetation provides cover and dampens waves, protecting the shore. Nineteen species of submergent aquatic plants were present in this area. Such a diverse submergent community provides many benefits. One exotic invasive plant, *Myriophyllum spicatum*, was found in this area. With all three types of plant structure, this area provides much diversity.

Figure 2: Photo of Part of JO1

Critical Habitat Area JO2

This area extends along approximately 1800 feet of the shoreline on the far east end of the lake, up to the ordinary high water mark. Average water depth here is about 15 feet, with a steep dropoff. 11% of the shore is wooded; 6% has shrubs; 23% is native herbaceous cover. The remaining shore is bare sand, cultivated lawn and hard structures, which tend to be concentrated at the edges of this area. The middle area is almost entirely undeveloped and contains some shallow marsh. Large woody cover is present for habitat. With minimal human disturbance along this shoreline, the area has natural scenic beauty.

This area of some large woody cover, emergent aquatic vegetation, submergent and floating vegetation provides spawning and nursery areas for many types of fish. No exotic aquatic wildlife was noted in this area, i.e, no carp, smelt or rusty crayfish were seen. Shore development present in JO2 was confined to the ends.

Seen during the field survey were various types of waterfowl and songbirds. It appeared that all these took cover or shelter in this area, as well as nested and fed in this area. Downed logs serving as habitat were also seen. Muskrat and mink are known to use JO2 for cover, reproduction and feeding. Frogs and salamanders are known to use this area for shelter/cover, nesting and feeding. Turtles and snakes also use this area for cover or shelter in this area, as well as nested and fed in this area. Upland wildlife feed and nest here as well. Since human disturbance is relatively minimal in JO2, it provides high-quality habitat for many types of wildlife.

Maximum rooting depth in JO2 was 19 feet. No threatened or endangered species were found in this area. Two exotic invasives, Eurasian Watermilfoil and Curly-Leaf Pondweed were found in this area. Five emergent species were found, as well as one free-floating plant. Two floating-leaf rooted species were present. Fourteen species of submergent aquatic plants were also found. This community has a diversity of structure and species to support a diversity of fish and wildlife.

Figure 3: Photo of Part of JO2

II. METHODS

Field Methods

The transect 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 several equal segments, and a transect line, perpendicular to the shoreline, was randomly placed within each segment, 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 or a thatching rake on a rope, 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= the species was present on one rake sample at that site;
> A rating of 2 = the species was present on two rake samples at that site;
> A rating of 3 = it was present on three rake samples;
> A rating of 4 = it was present on all four rake samples;
> A rating of 5 = it was abundant on all four rake samples.

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 landward, was evaluated. The percent cover of each land use category within this 100' x 30' rectangle was visually estimated and recorded on a data sheet.

The second method used was the Point Intercept Method. This method involves calculating the surface area of a lake and dividing it (using a formula developed by the WDNR) into a grid of several points, always placed at the same interval from the next one(s). These points are related to a particular latitude and longitude reading. At each geographic point, the depth is noted and one rake is taken, with a score given between 1 and 3 to each species on the rake.

A rating of 1 = a small amount present on the rake;
A rating of 2 = moderate amount present on the rake;
A rating of 3 = large amount present on the rake.

A visual inspection was done between points to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording plants found.

Data Analysis

The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites). Relative frequency was calculated (number of occurrences of a species/sum of all species occurrences) .The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites). 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). The relative frequency and relative density of each species were summed to obtain a dominance value for each species. Species diversity was measured by Simpson's Diversity Index.

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols (Nichols, et al., 2000) was applied to Jordan Lake results. 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 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.

Jordan Lake has water quality records for a number of years. Water clarity readings go back to 1986, while total phosphorus levels records start in 1990 and cholorophyll-a results start in 1992.

Figure 4: Trophic Status of Jordan Lake

	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
Jordan Lake Growing Season 1986-2012		**17.3**	**2.4**	**13.2**

Nutrients

Phosphorus is a limiting nutrient in many Wisconsin lakes, including Jordan Lake, 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. Starting from 1990, the average growing season (May through September) for total phosphorus levels is 17.3 micrograms/liter, which is in the “good” category (see Figure 5). The lowest growing season total phosphorus average was 8 micrograms/liter in 2000; the highest average, 38 micrograms/liter, occurred in 1996.

Algae/Chlorophyll-a

Chlorophyll-a 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. The 1992-2012 Mean summer chlorophyll-a concentration in Jordan Lake was 2.4 micrograms/liter, in the "very good" range for chlorophyll-a levels (see Figure 6). The lowest average chlorophyll-a was 1.2 (in both 1999 and 2000); the highest average was 4.7 micrograms/liter in 1994.

Figure 5: Average Total Phosphorus Levels in Jordan Lake 1990-2012

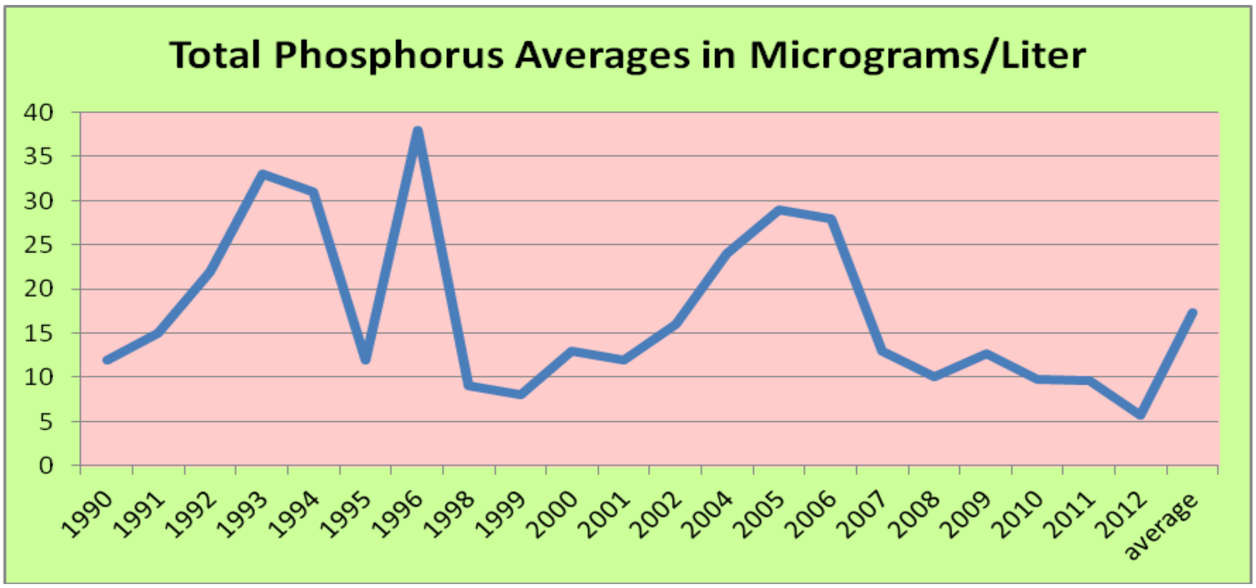
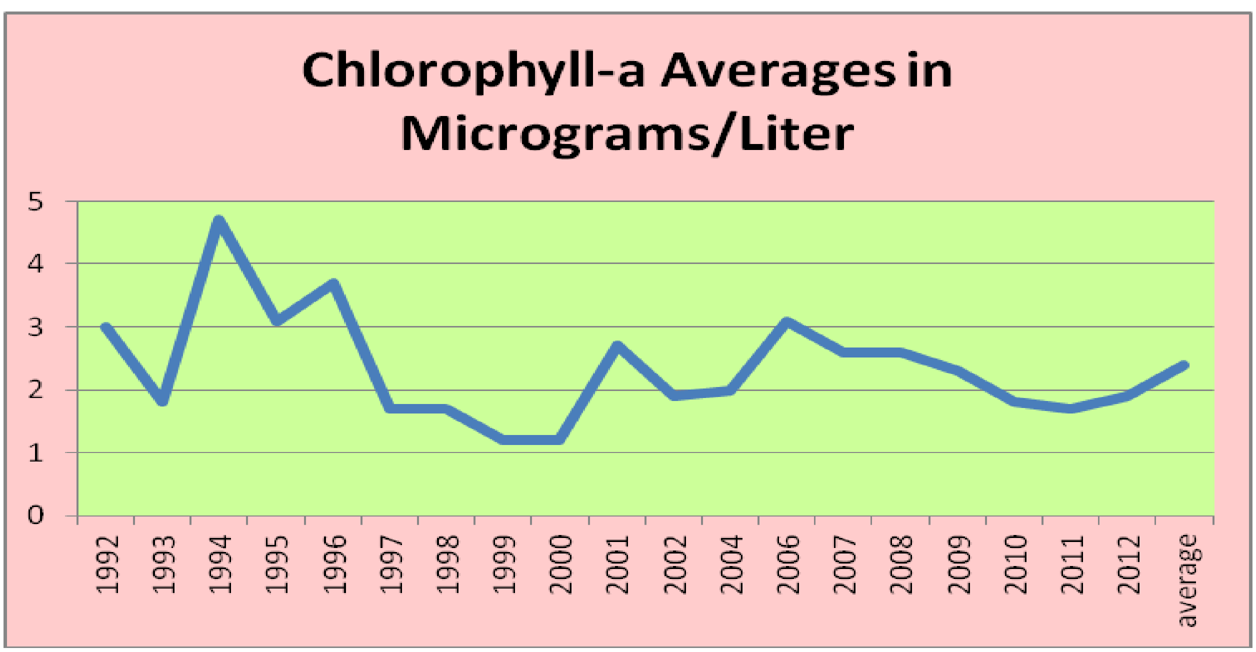


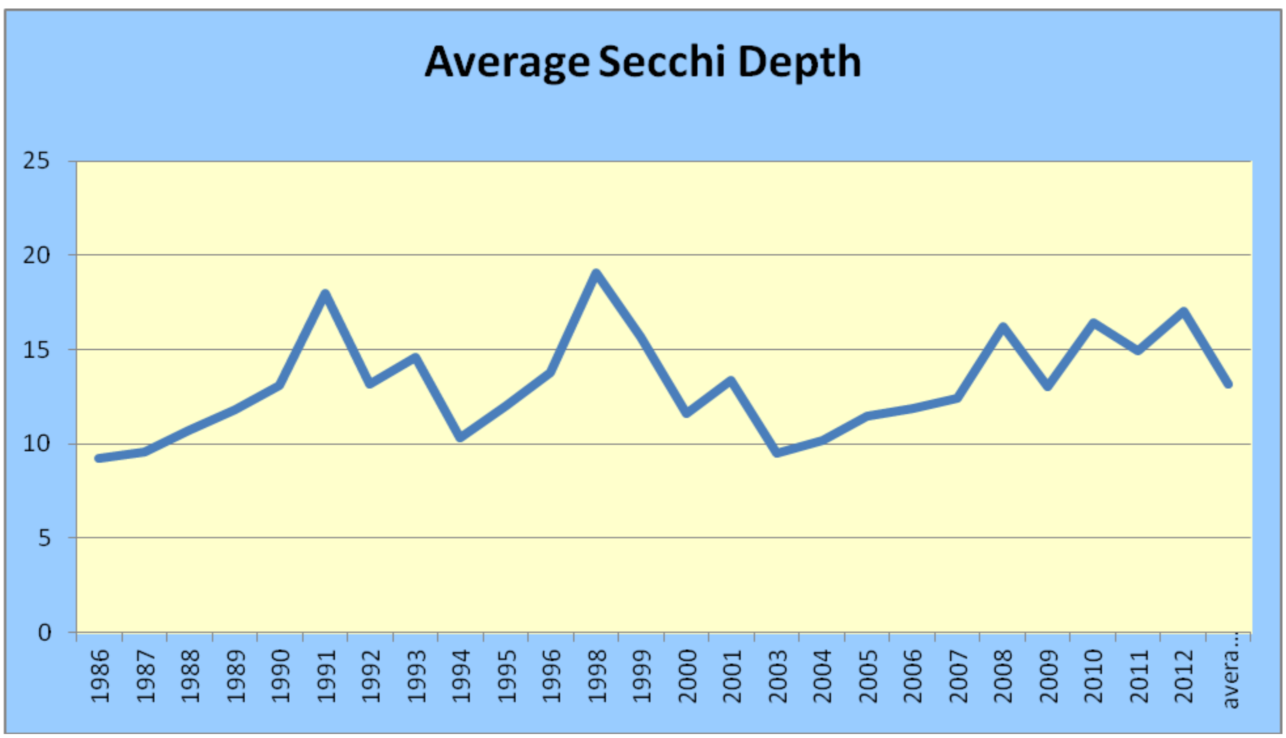
Figure 6: Average Chlorophyll-a Levels in Jordan Lake 1992-2012



Water Clarity

Water clarity is a critical factor for aquatic plants, because if they don't get more than 2% of surface illumination, they won't survive (Chambers and Kalff 1985, Duarte et. al. 1986, Kampa 1994). 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. The 1986-2012 Average Summer Secchi Disc clarity in Jordan Lake was 13.2 feet. This falls in the "very good" category (see Figure 7). The lowest growing season average was 9.2 feet in 1987; the highest was 19.1 feet in 1998.

Figure 7: Average Growing Season Secchi Depth 1986-2012



Overall Water Quality

The combination of phosphorus concentration, chlorophyll-a concentration and water clarity indicate that Jordan Lake is a borderline oligotrophic/mesotrophic lake with good-to-very good water quality and clarity. This trophic state should favor only moderate plant growth and occasional localized summer algal blooms.

Hardness

The hardness or mineral content of lake water also influences aquatic plant growth. The 1990-2006 hardness values in Jordan Lake ranged from of 112 to 124 milligrams/liter CaCO3, with an average of 118.5 micrograms/liter CaCO3. This is moderately hard water. Hard water lakes tend to support more plant growth than soft water lakes (B.Shaw, et al, p.13). While marl (calcium carbonate) in a lake precipitates and falls to the lake bottom, some of the marl in hard water lakes often coats the external surfaces of submersed plants (C.E.Boyd, p. 112). Marl formations absorb phosphorus, reducing its overall concentration and decreasing algal growth (B. Shaw et al, p. 7).

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).

Jordan Lake is an oval natural lake with several areas of sharply-dropping slopes, roughly divided into two basins. There is a sandbar in the middle of the lake that run from south to north, nearly bisecting the lake. In times of low water, some of this sand bar is exposed and the areas of it with water may only have water 2 feet deep. The south quarter of the lake has more steeply-sloped littoral zone, dropping to over 50 feet in depth. Gradual slopes provide a more stable rooting base and broader area of shallow water that would favor plant growth. With very good water clarity, the near-shore depths, and even some depths further out from shore in Jordan Lake would support plant growth, since the sun can reach much of the sediment to stimulate plant growth.

INFLUENCE OF SEDIMENT COMPOSITION

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). Mineral availability in sediments such as sand is often considerably reduced.

The most common sediment in Jordan Lake was sand (Figure 8). The shallower areas had more mixture of sediment types than the areas over 5 feet deep. With the low capacity of sand to hold nutrients, sand sediments in some instances can limit aquatic plant growth. However, with over 95% of its littoral zone vegetated, this does not seem to be the case at Jordan Lake.

Figure 8: Jordan Lake Bed Sediments

		Zone 1	Zone 2	Zone 3	Zone 4	Overall
Hard	Sand	60.87%	52.18%	100.00%	100.00%	78.26%
Sediments	Sand/Gravel	4.35%				1.09%
Mixed	Sand/Peat	4.35%	4.35%			2.17%
Sediments	Sand/Silt	4.35%				1.09%
Soft	Peat		34.78%			8.70%
Sediments	Peat/Silt	8.69%				2.17%
	Silt	13.04%	8.69%			5.43%
	Silt/Marl	4.35%				1.09%

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 occurring shoreline cover at the transect sites. Cultivated lawn and hard structure (boat docks, patios, retaining walls, etc.) also were frequently occurring (see Figure 9).

Frequency of occurrence does not always translate into amount of actual cover a shore type provides. For example, in 2012, although the most frequently-occurring shore type was herbaceous vegetation (91.3%), it only covered 31.6% of the shore. Similarly, although wooded vegetation had an occurrence frequency of 39.1% in 2012, it covered only 6.1% of the shore (see Figure 10).

Figure 9: Comparison of Shore Type Frequency of Occurrence

	2006	2012
Herbaceous Vegetation	78.3	91.3
Shrub Vegetation	13.0	52.2
Wooded Vegetation	21,7	39.1
Rock/RipRap	17.4	13.1
Bare sand	6.1	6.1
Cultivated Lawn	73.9	30.9
Hard Structure	87.0	82.6

Figure 10: Comparison of Shore Type Coverage

	2006	2012
Herbaceous Vegetation	20.2	31.6
Shrub Vegetation	2.0	3.1
Wooded Vegetation	6.1	8.7
Rock/RipRap	3.9	0.2
Bare sand	11.7	19.1
Cultivated Lawn	41.1	24.0
Hard Structure	15.0	13.3

The biggest change in the occurrence frequency occurred in cultivated lawn. Adams County has been making a concerted effort to restore natural vegetation to much of its lakeshores and has been offering cost-share agreements to waterfront landowners who want to install such vegetation. Several landowners on Jordan Lake have become involved in that program. This probably accounts for the 15% increase in the amount of shore covered by vegetation from 2006 to 2012.

MACROPHYTE DATA

SPECIES PRESENT

In the 2012 transect survey, 35 species of aquatic plants were found. Of these, two were invasive: the emergent Reed Canarygrass (*Phalaris arundinacea*) and the submergent Eurasian Watermilfoil (*Myriophyllum spicatum*). Included in the 33 native species were 8 emergent species, three rooted floating-leaf plants, and 22 submergent species. The 2012 PI survey had a similar result, with 37 species found. Three invasives were found during this survey: the two already mentioned plus Curly-Leaf Pondweed (*Potamogeton crispus*). The 34 native species included 10 emergent species, three rooted floating-leaf plants, and 21 submergents. In addition, both Aquatic Moss and Freshwater Sponges were found in Jordan Lake.

Figure 11: Jordan Lake Aquatic Plant Species in 2012

Scientific Names	Common Names	2012 PI	2012T
Brasenia schreberi	Watershield	x	x
Carex	Sedge	x	x
Ceratophyllum demersum	Coontail	x	x
Chara sp	Muskgrass	x	x
Eleocharis palustris	Common Spikerush	x	x
Elodea canadensis	Common Waterweed	x	x
Juncus sp	Rush	x	
Megalodonta beckii	Water Marigold	x	x
Myriophyllum sibiricum	Northern Milfoil	x	x
Myriophyllum spicatum	Eurasian Watermilfoil	x	x
Najas flexlis	Bushy Pondweed	x	x
Najas guadelupensis	Southern Naiad	x	x
Nitellla sp	Stonewort	x	x
Nymphaea odorata	White Water Lily	x	x
Phalaris arundinacea	Reed Canarygrass	x	x
Potamogeton amplifious	Large-Leaf Pondweed	x	x
Potamogeton crispus	Curly-Leaf Pondweed	x	x
Potamogeton friesii	Fries' Pondweed	x	x
Potamogeton gramineus	Variable-Leaf Pondweed	x	x
Potamogeton illinoensis	Illinois Pondweed	x	x
Potamogeton natans	Floating-Leaf Pondweed	x	x
Potamogeton praelongus	White-Stemmed Pondweed	x	x

Potamogeton pusillus	Small Pondweed	x	x
Potamogeton richardsonii	Clasping-Leaf Pondweed	x	x
Potamogeton robbinsii	Fern-Leaf Pondweed	x	x
Potamogeton zosteriformis	Flat-Stemmed Pondweed	x	x
Ranuculus aquatilis	White Water Crowfood	x	
Sagittaria latifolia	Common Arrowhead	x	x
Sagittaria rigida	Stiff Arrowhead	x	x
Salix spp	Willow	x	x
Schoenoplectus acutus	Hard-Stemmed Bulrush	x	x
Schoenoplectus pungens	Chairmaker's Rush	x	x
Schoenoplectus tabernaemontani	Soft-Stemmed Bulrush	x	x
Stuckenia pectinata	Sago Pondweed	x	x
Typha spp	Cattail	x	x
Vallisneriaa americana	Water Celery	x	x
Zosterella dubia	Water Stargrass	x	x
Aquatic Moss		x	
Freshwater Sponge		x	x

FREQUENCY OF OCCURRENCE

The same two aquatic species were the most frequently-occurring plants under in both 2012 surveys. Muskgrass (*Chara* spp.), a plant-like algae, was the most frequently-occurring species, with Variable-Leaf Pondweed (*Potamogeton gramineus*) a far second. In both surveys, the most frequently-occurring invasive was Eurasian Watermilfoil, but it only had about 2.4% occurrence frequency.

There are three ways of looking at frequency. One is the frequency of occurrence in the aquatic plant community overall. The second is to look at how frequent the plant is where it is present. The third way is to evaluate the relative frequency of a plant overall, i.e., what frequency percent is it relative to all the other plants in the aquatic plant community. Figures 12a and 12b show the first two methods for both the transect and PI surveys in 2012. Relative frequency will be discussed later in this report.

Figure 12a: Percent Frequency of Occurrence Overall and Where Present in 2012 (T)

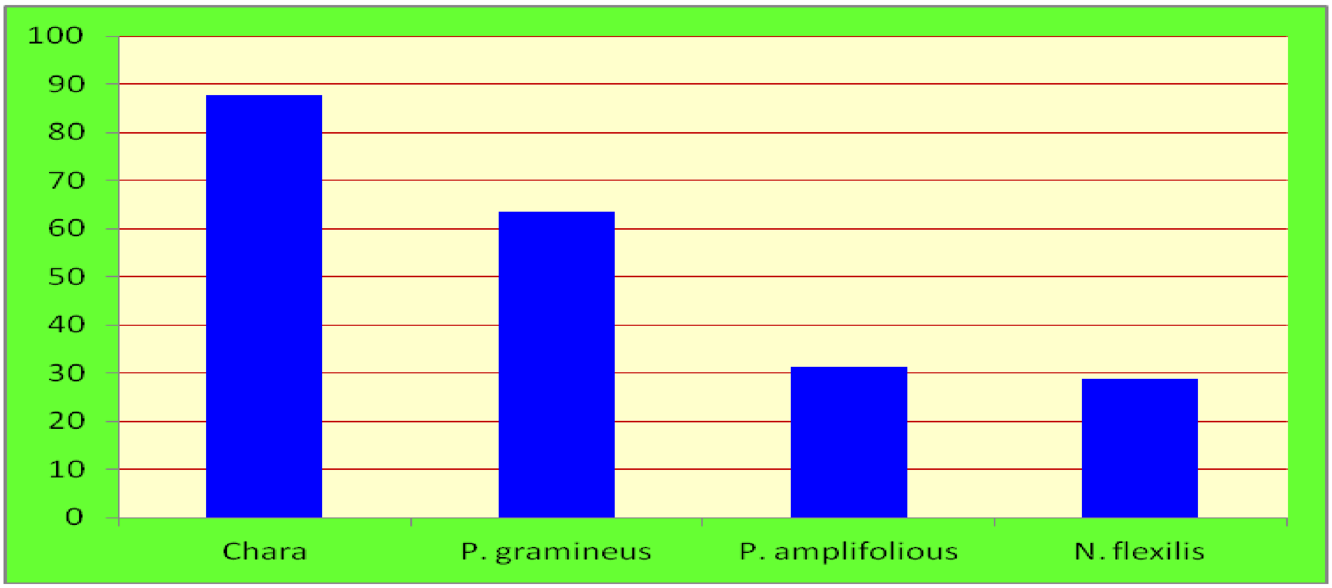
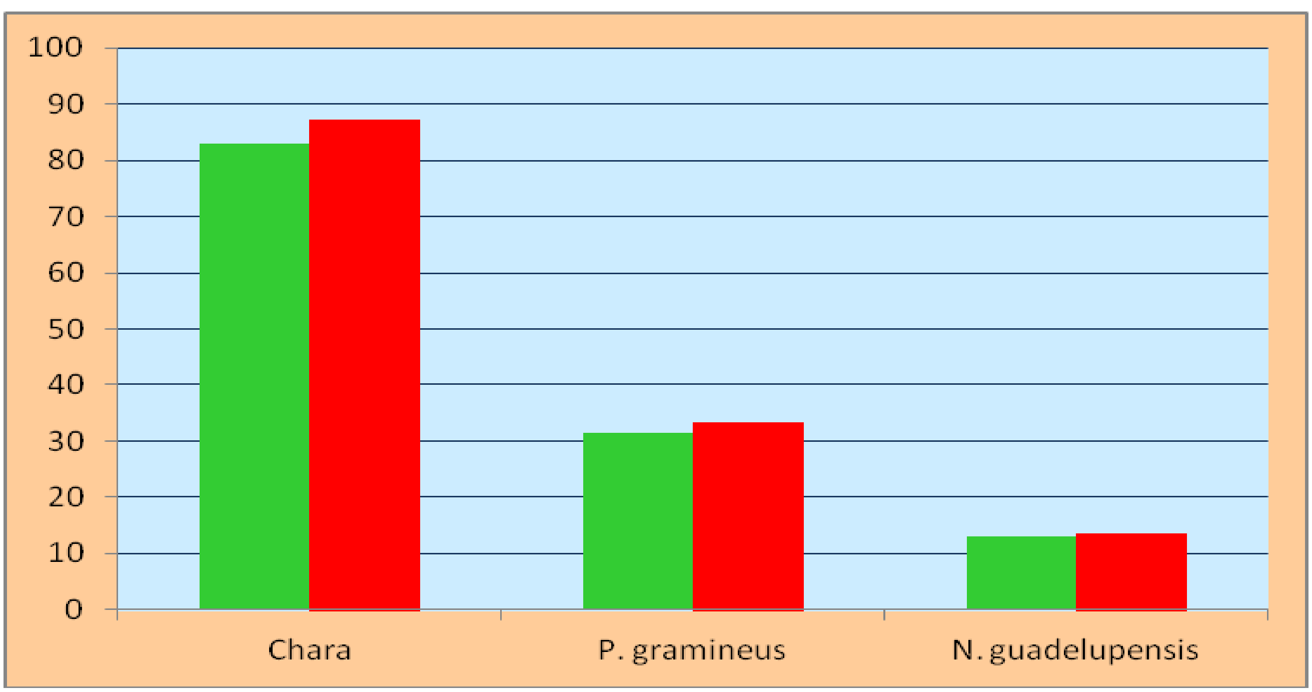


Figure 12b: Percent Frequency of Occurrence Overall and Where Present in 2012 (PI)



DENSITY

Besides the frequency at which particular species occurs, the density of growth for each plant type is also evaluated. Some plants occur mostly in beds of growth with their own kind—those would have a considerably higher growth density where present than in the lake overall. In other instances, a specie is found scattered throughout the lake, mixed with other species. For example, the most densely-growing aquatic species in the lake overall, in both 2012 surveys, was Muskgrass (*Chara* spp.). This had a fairly consistent density of growth throughout the lake. On the other hand, Southern Naiad tended to be found in beds, where its growth density was five times more than in the lake overall.

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. Based on the Dominance Value, Muskgrass was the dominant aquatic species in Jordan Lake in 2012 (Figures 13a and 13 b). The subdominant species in both surveys was Variable-Leaf Pondweed. All other species found were far behind these two.

In looking at dominance, it may also be relevant to look at what type of aquatic species dominates the “plant” community in a lake. In both 2012 surveys, submergent plants dominate the lake. Emergent species are the second most common plant type, with rooted floating-leaf plants the least common (Figures 14a and 14b).

Figure 13a: Dominance in 2012 (T)

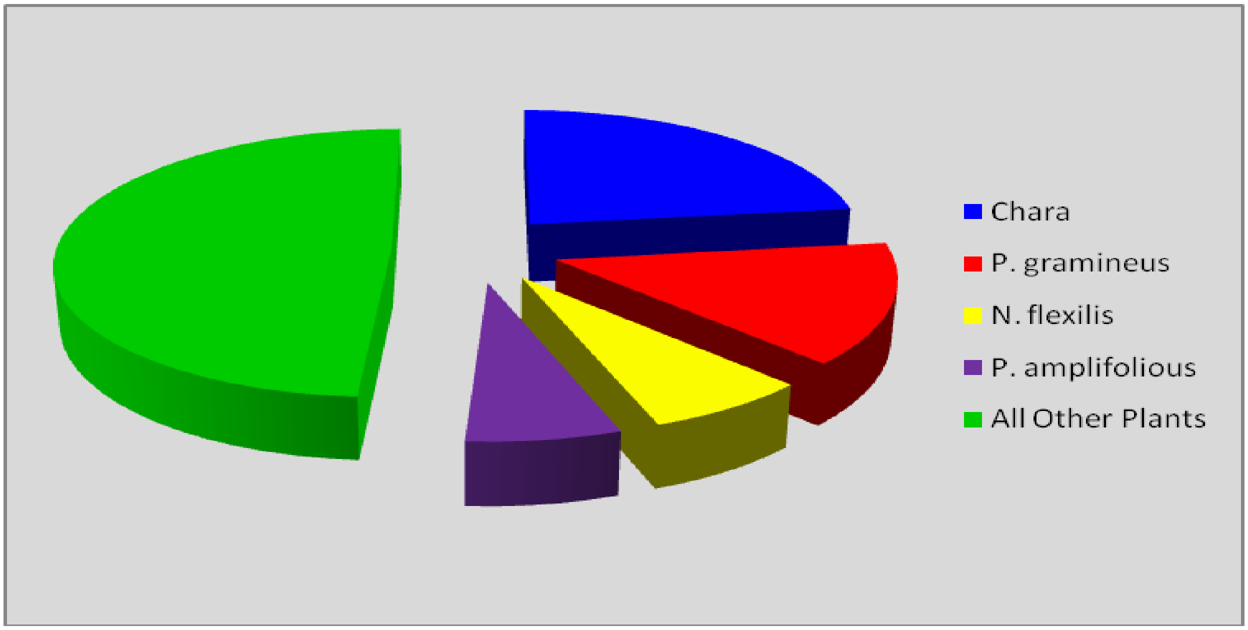


Figure 13b: Dominance in 2012 (PI)

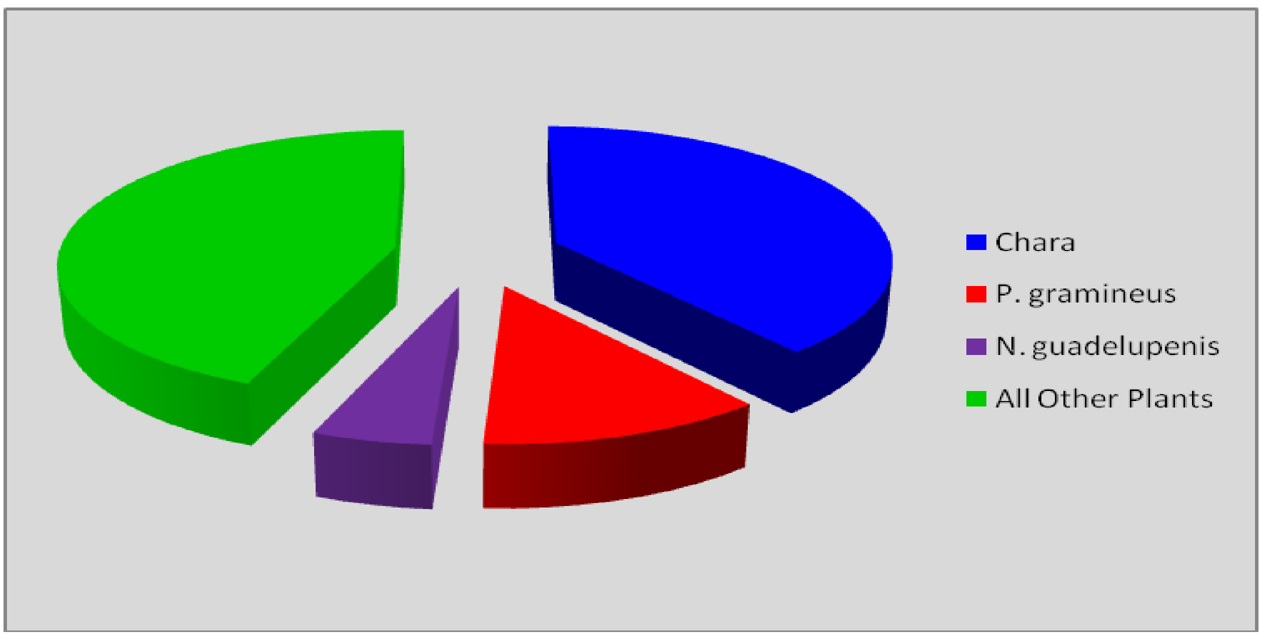


Figure 14a: Dominance by Plant Type (T)

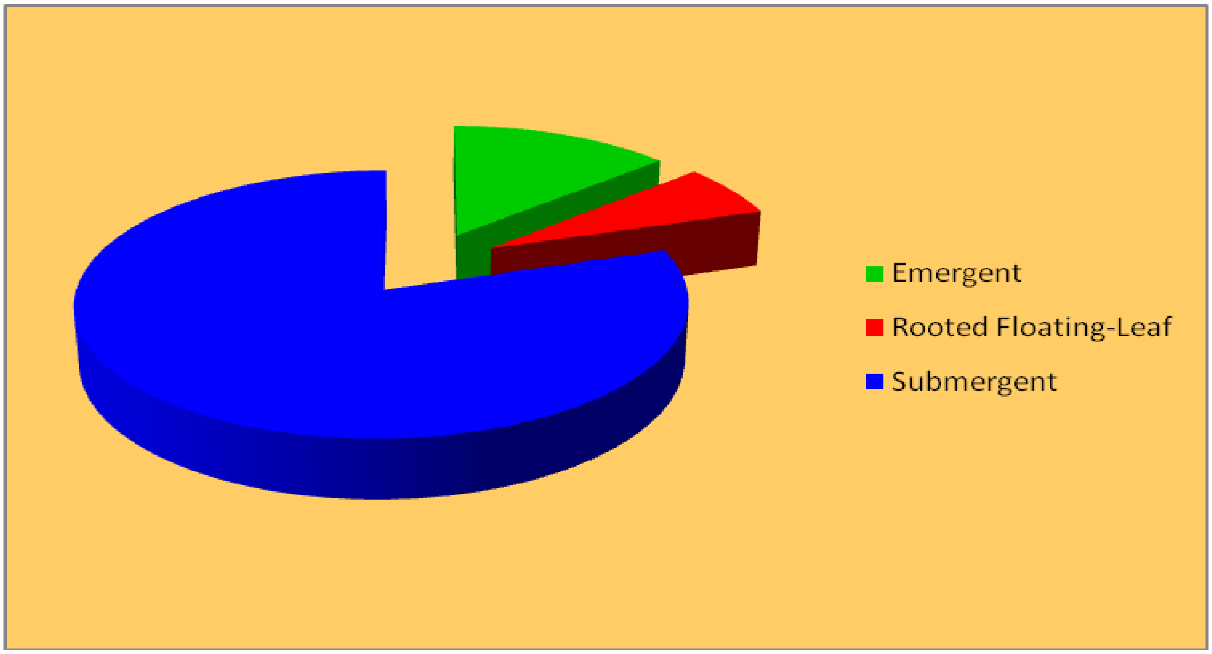
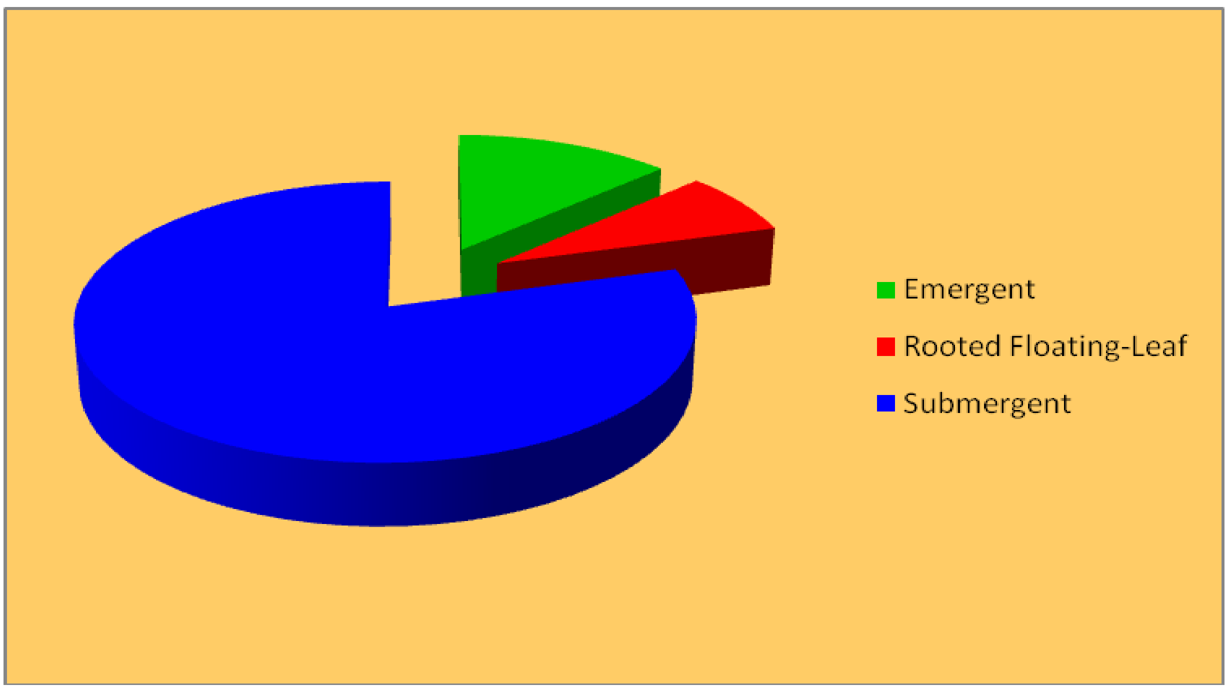


Figure 14b: Dominance by Plant Type (PI)



DISTRIBUTION

Aquatic plants were found throughout Jordan Lake in all the recorded surveys. In the transect survey, aquatic plants were found at over 97% of the sites; in the PI survey in 2012, they were found at 95% of the sites. Figures 15a, 15b and 15c show the distribution of various types of aquatic plants. Submergent plants covered the largest part of the lake among the three plant types found in Jordan Lake.

Figure 15a: Distribution of Emergent Plants 2012

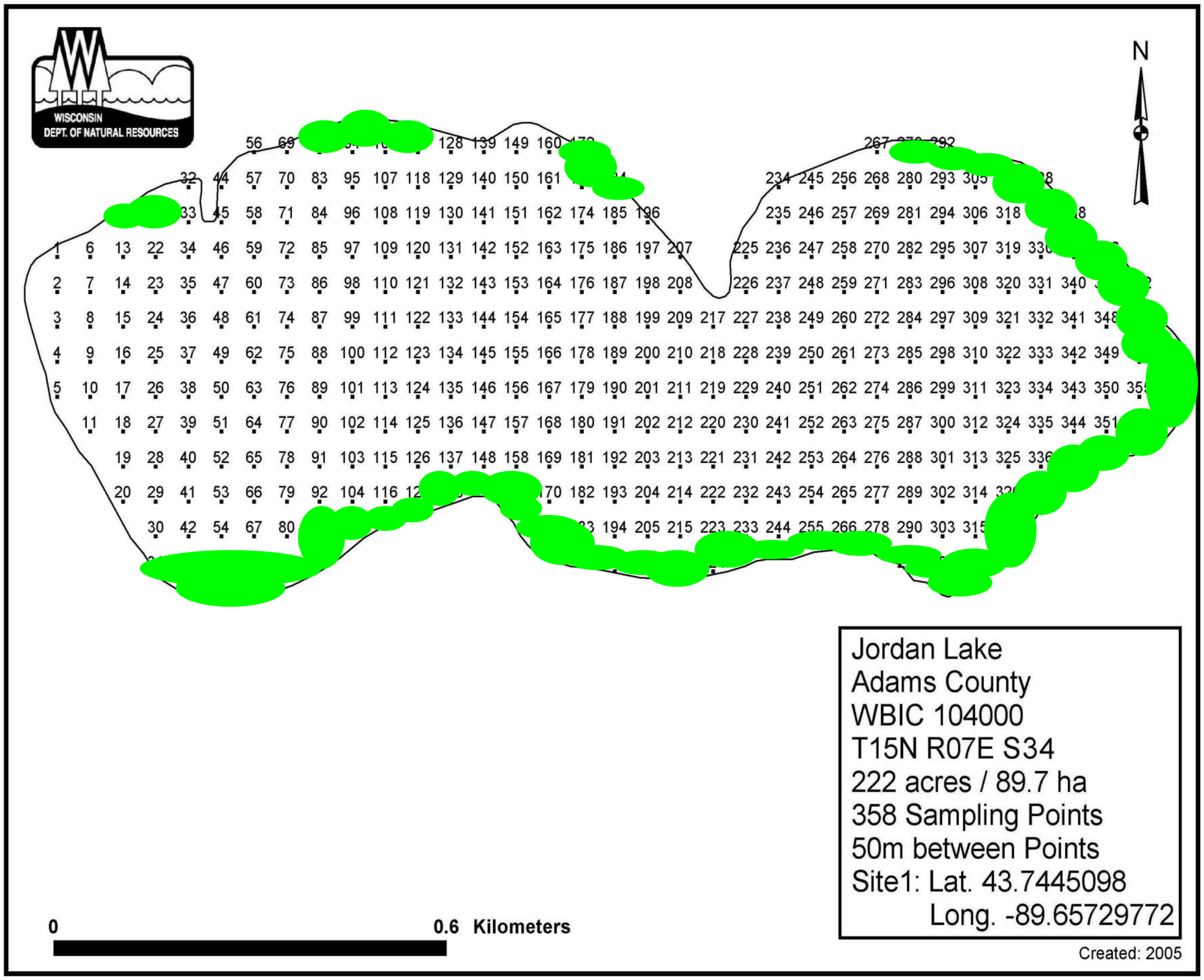


Figure 15b: Distribution of Rooted Floating-Leaf Plants 2012

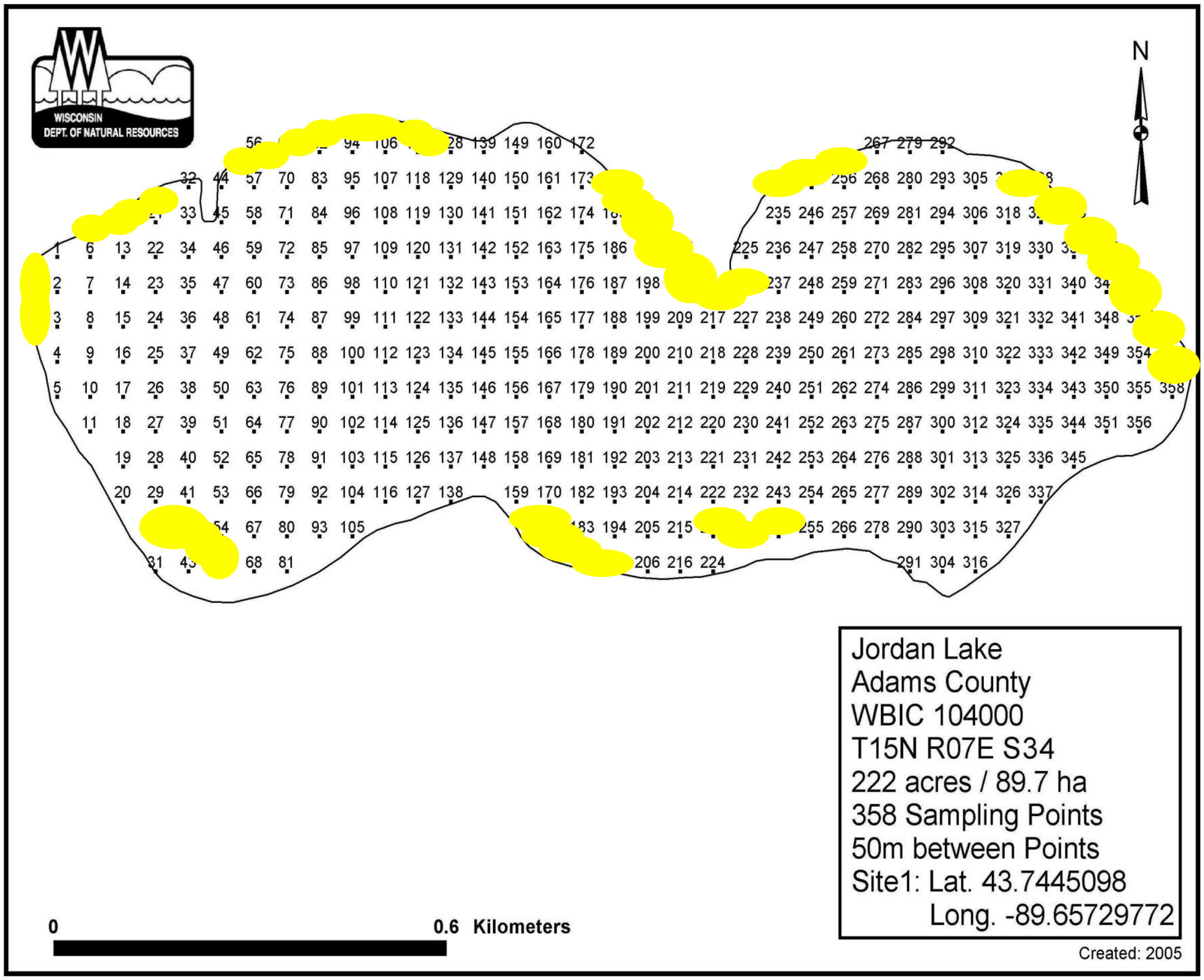
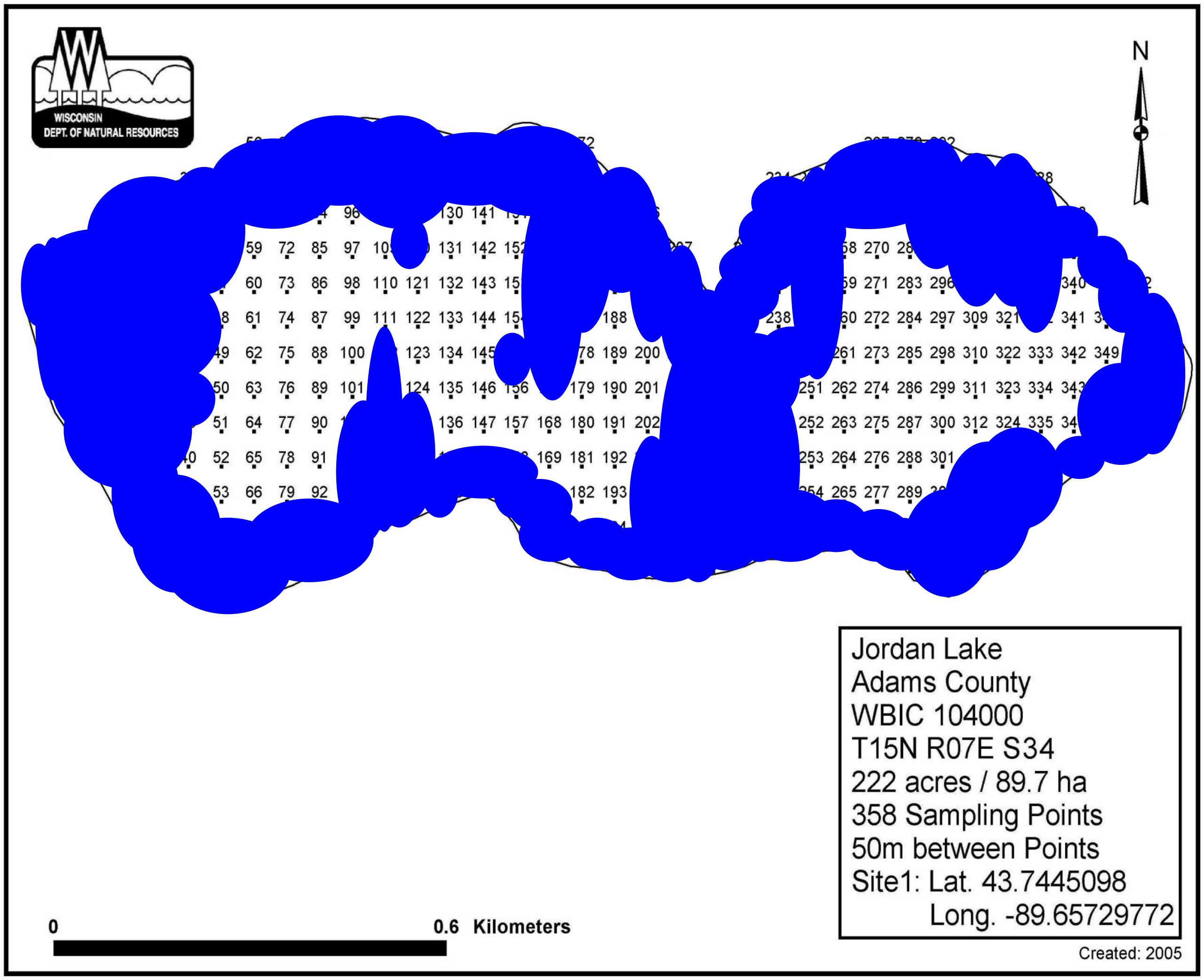
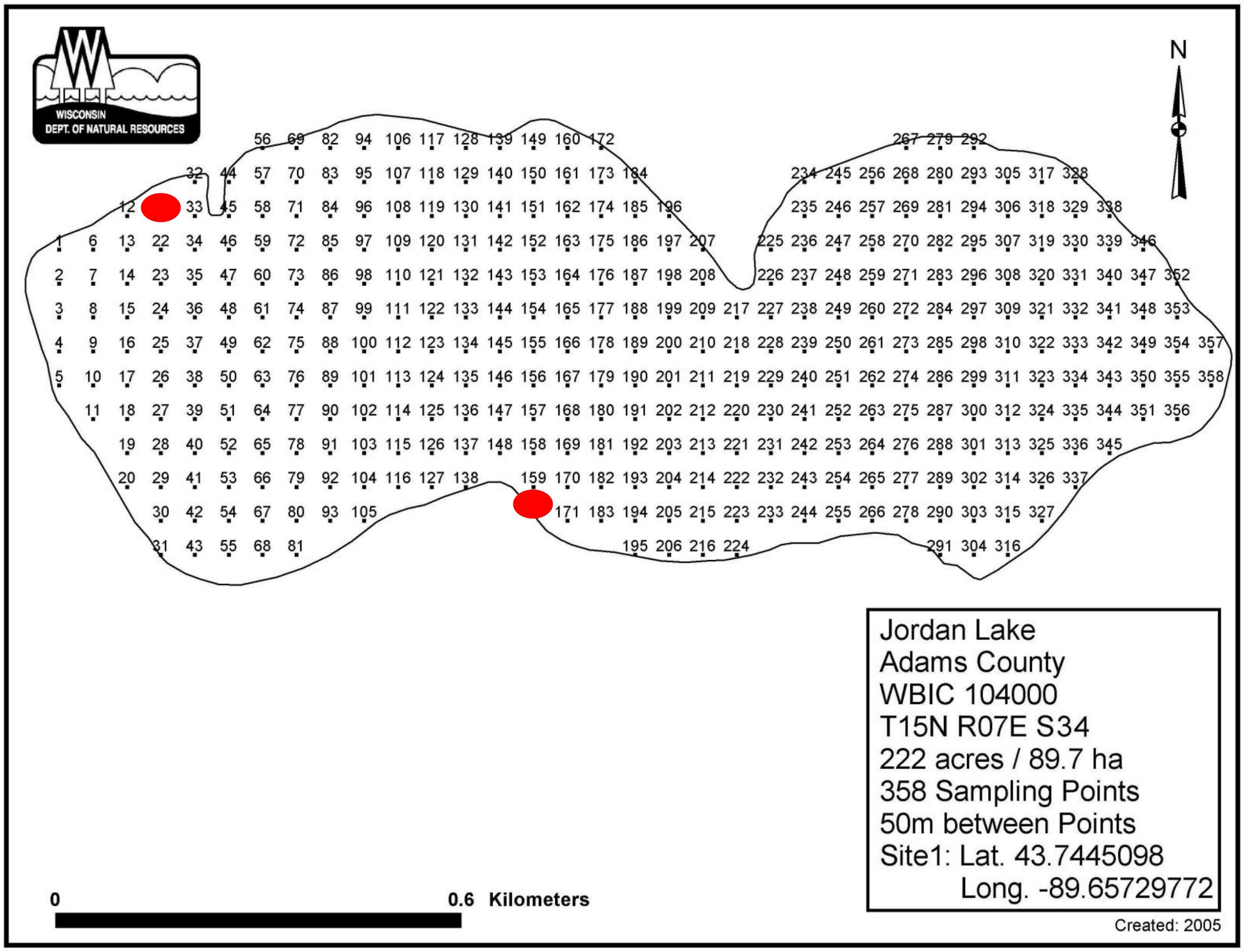


Figure 15c: Distribution of Submergent Plants 2012



Eurasian Watermilfoil has been consistently found in Jordan Lake for many years. This has been monitored every year both pre-and-post chemical treatment. Post-treatment in 2011, it was found in nine places on the lake. A chemical treatment was repeated in the late spring of 2012. Figure 16 shows that the treatment was very successful, with the invasive only found in two places during the 2012 PI survey.

Figure 16: Location of Eurasian Watermilfoil 2012



In 2007, a survey was done to look for the native weevil known to damage Eurasian watermilfoil, *Euhrychiopsis lecontei*, in Jordan Lake. Adult and larval stages of the weevil were found, along with significant damage to stems that could be attributed to weevil presence. Although the Jordan Lake District has expressed some interest in raising the weevils to increase the numbers present, the current protocol is extremely labor-intensive. Thus far, no one has volunteered at Jordan Lake to take on such a commitment.

The Jordan Lake District has actively pursued hand-pulling Eurasian Watermilfoil in areas that can be reached by wading or snorkeling. This has focused on the removal of individual plants or small isolated populations and continues each year.

Curly-Leaf Pondweed, has been found during the PI surveys since 2006, but it has remained a very low presence, varying being found at one or two spots only. It appears that at this time, this invasive is not a significant threat to the Jordan Lake aquatic plant community.

The same could be said for the third invasive plant found at Jordan Lake, Reed Canarygrass. Although it has been found for many years at Jordan Lake, it continues to be found in low frequency of occurrence and low density of growth.

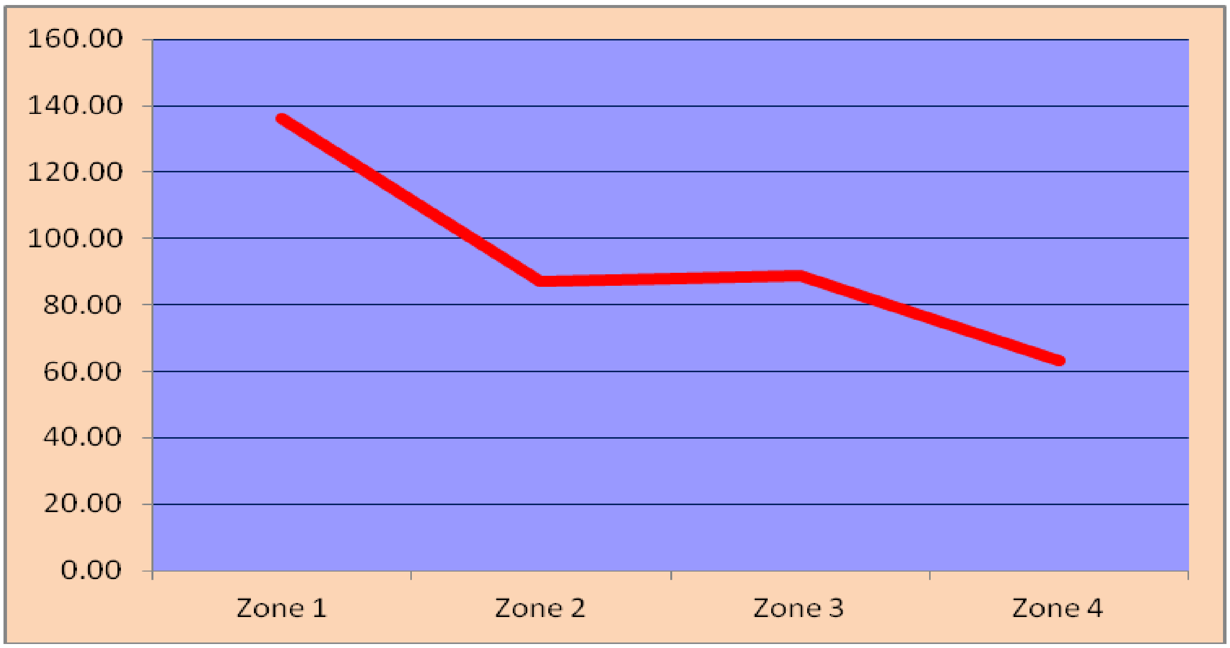
Secchi disc water clarity data can be used to calculate a predicted maximum rooting depth for plants in a lake (Dunst, 1982).

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

Based on the historical average growing season Secchi disc clarity, the predicted maximum rooting depth in Jordan Lake would be 18.8 ft. In the transect survey, the deepest rooted plant found (Eurasian watermilfoil) was found at 19.5 feet, while the deepest native rooted plants (Variable-Leaf Pondweed, White-Stemmed Pondweed, and Bushy Pondweed) were found at 17.5 feet. The maximum rooting depth for the 2012 PI survey was 18 feet. Thus, the actual maximum rooting depth in Jordan Lake in 2012 is roughly equal to the predicted maximum rooting depth based on water clarity.

As Figure 17 show, the transect survey results showed the greatest frequency of occurrence in Zone 1 (0 to 1.5 feet depth), with the least frequency of occurrence in the water over 10 feet deep. Zones 2 (1.5 to 5 feet) and Zone 2 (5 to 10 feet) has similar occurrence frequencies.

Figure 17: Frequency of Occurrence by Zone in 2012 (T)



No similar conclusions can be drawn from the PI results, since the data collection method differs. In many instances, the greatest diversity of aquatic plants is found in less than 5 feet of water.

THE COMMUNITY

The Simpson's Diversity Index (SI) for the transect 2012 survey was .91 and .83 for the 2012 PI method. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). All these figures place Jordan Lake in the upper quartile for diversity for all the lakes in Wisconsin and for the North Central Hardwoods Region. The transect SI score of .91 places Jordan Lake in the very good category for lakes in Wisconsin and in the North Central Hardwoods Region. However, the PI score of .83 is poor. Possible reasons for this variation will be discussed later in the report.

Species richness is the number of species in a given area. When looking at aquatic survey results, high species richness indicates a higher quality aquatic plant community. The overall 2012 transect species richness (See figure 18) was 4.2. Zone 1 (0-1.5 feet deep) had the highest species richness at 5.9, followed by Zone 2 (1.5-5 feet deep) had a species richness of 3.9. Species richness dropped slightly to 3.8 in Zone 3 (5 to 10 feet deep) and down to 2.9 for Zone 4 (10 to 20 feet deep) per sample site.

Since the PI method doesn't use depth zones for surveying, species richness calculations were done looking at overall species richness (all sample sites). The 2012 PI score was 2.4 overall.

The Average Coefficient of Conservation and Floristic Quality Index were calculated as outlined by Nichols (1998) to measure plant community disturbance (see Figure 18). A coefficient of conservation is an assigned value between 0 and 10 that measures the probability that the species will occur in an undisturbed habitat. The Average Coefficient of Conservationism is the mean of the coefficients for the species found in the lake.

The coefficient of conservatism is used to calculate the Floristic Quality Index (FQI), a measure of a plant community's closeness to an undisturbed condition. The

Floristic Quality Index is also a tool that can be used to identify areas of high conservation value, monitor sites over time, assess the anthropogenic (human-caused) impacts affecting an area and measure the ecological condition of an area (M. Bourdaghs, 2006).

The Average Coefficient of Conservatism for Jordan Lake was 5.6 for the transect method in 2012. The transect 5.6 Average Coefficient of Conservatism places Jordan Lake in the median of lakes for Average Coefficient of Conservatism for lakes in Wisconsin overall and the North Central Hardwoods Region. The results of the PI survey were slightly lower, with an Average Coefficient of Conservatism at 5.1. This figure would put Jordan Lake in the lowest quartile of lakes in Wisconsin and in the North Central Hardwoods Region.

The 2012 FQI from the transect method was 31.8. The FQI for the PI survey was 24.2. The transect Floristic Quality Index of the aquatic plant community in Jordan Lake was above average for Wisconsin lakes and in the highest quartile of North Central Hardwood Region lakes. The PI FQI score of 29.7 is also in the highest quartile for both all Wisconsin lakes and the North Central Hardwood Area. These figures indicate that the plant community in Jordan Lake is closer to an undisturbed condition than the average lake in Wisconsin and within the group of lakes in the region closest to an undisturbed condition.

Figure 18: Floristic Quality and Coefficient of Conservatism of Jordan 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
NCHR	5.2, 5.6, 5.8 *	17.0, 20.9, 24.4
Jordan Lake 2012	5.6 (T), 4.1 (PI)	31.8 (T), 29.7 (PI)

* - 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).

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 Jordan Lake are likely:

1) the introduction of non-native aquatic plant species;

2) the high use of the lake by jetskiers, waterskiers, tubers, and speedboats.

The Aquatic Macrophyte Community Index (AMCI) for Jordan Lake varies from 60 (PI survey) to 65 (transect survey), depending on the particular survey results used. Both these values are above average for lakes in the North Central Hardwoods Region (48 to 57) and Wisconsin (45 to 57) and indicate that the aquatic plant community in Jordan Lake is of above average quality.

COMPARISON TO PRIOR RESULTS

In 2006, 37 aquatic species were found in Jordan Lake, using the transect method. In 2012, the transect survey method found 35 species. During the summer of 2012, the lake level of Jordan Lake was considerably reduced, down in depth by over one foot, and 35 species were found. Despite this variance in water level, the aquatic plant community found in the 2012 transect community was much the same as that in the 2006 survey, with a split of percentages between emergent, rooted floating-leaf, and submergent species similar.

Figure 19: Comparison of 2006 and 2012 Transects Relative Frequency

	2006(t)	2012 (T)
Emergent	80.0%	80.0%
Rooted Free-Floating	7.5%	6.5%
Submergent	12.5%	13.5%

There were also transect surveys done on Jordan Lake before 2006, using the same transects. A look at some points of comparison between the 2012 transect survey results and those before suggest that in some ways, the aquatic plant community in Jordan Lake has remained somewhat stable, while in other ways, it has varied.

Figure 20: Macrophyte Community Changes (Transect)

Jordan	2000	2006	2008	2012
Number of Species	18	22	35	35
Maximum Rooting Depth	11	16	19	19.5
% of Littoral Zone Unvegetated	19	9	3	2.2
% Emergents (sites)	2.4%	2.9%	12.0%	15.0%
% Floating-Leaf (sites)	2.6%	4.9%	5.0%	7.0%
% Submergents (sites)	95.0%	92.2%	83.0%	78.0%
Simpson's Diversity Index	0.89	0.91	0.93	0.91
Species Richness	2.9	3.8	4.3	4.2
Floristic Quality	19.1	21.1	25.1	31.8
Average Coefficient of Conservatism	4.5	4.5	4.5	5.6
AMCI Index	52	55	62	65

The plant communities were compared by calculating coefficients of similarity (developed by Jaccard in 1901), using both actual frequency of occurrence and relative frequency of occurrence. Based on actual frequency of occurrence for the two transect methods, the 2006 and 2012 aquatic plant communities were 80.05% similar. Based on relative frequency, they were 80.95% similar. Coefficients of similarity over 75% suggest that the plant community is substantially the same, despite the difference in numbers of species.

New plants found in 2012 transect survey that were not found in 2006 are: Common Spikerush (*Eleocharis palustris)*, Rush (*Juncus* spp*)*, Water Marigold (*Megalodonta beckii*), Southern Naiad (*Najas guadelupensis)*, Fern Pondweed (*Potamogeton* *robbinsii)*, Stiff Arrowhead (*Sagittaria rigida)*, and Chairmaker's Rush (*Schoenoplectus pungens).* Plants found in 2006, but not in 2012, include Jewelweed (*Impatiens capensis)*, Lesser Duckweed (*Lemna minor)*, Water Smartweed (*Polygonum aquaticum*), Curly-Leaf Pondweed (*Potamogeton crispus)*, Common Arrowhead (*Sagittaria latifolia*), Goldenrod *(Solidago* spp*)*, and Bittersweet Nightshade (*Solanum ptycanthum).*

There are also multiple years of PI surveys, although most of them are from the last three years. The first one was done in 2006, followed by one in 2010, one in 2011, and the most recent on in 2012. Understandably, the results have been very similar.

Figure 22: Comparison of PI Surveys

Jordan--PI	2006	2010	2011	2012
Number of Species	25	30	30	34
Maximum Rooting Depth	18.0	26.0	22.5	18.0
% of Littoral Zone Vegetated	81.5	86.2	93.0	98.1
% Emergents (sites)	2%	4%	5%	12%
%Floating-Leaf (sites)	4%	4%	3%	5%
%Submergents (sites)	94%	92%	92%	83%
Simpson's Diversity Index	0.87	0.80	0.79	0.81
Species Richness	2.0	1.9	2.0	2.4
Floristic Quality	24.2	28.4	28.5	30.6
Average Coefficient of Conservatism	5.04	5.28	5.2	5.17
AMCI Index	58	58	58	60

V. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Jordan Lake is a borderline oligotrophic/mesotrophic lake with very good water clarity and good-to-very-good water quality. Adequate nutrients (including sediments), good water clarity, hard water, and the large shallow areas in the lake would favor plant growth. The steep slopes found in the two lobes of the lake would not favor plant growth. High traffic and a significant presence of aquatic invasive plants, especially Eurasian Watermilfoil, regularly disturb the aquatic plant community.

A visual comparison of the aquatic plants found in Jordan Lake since 2000 suggests that overall, the aquatic plant community is relatively stable.

Figure 23: Aquatic Plant List 2000-2012

Scientific Name	**Common Name**	2006 T	2006 PI	2010PI	2011PI	2012 T	2012PI
Brasenia schreberi	Watershield	x	x	x	x	x	x
Carex	Sedge spp	x	x	x		x	x
Carex comosa	Porcupine Sedge				x		
Ceratophyllum demersum	Coontail	x	x	x	x	x	x
Chara sp	Muskgrass	x	x	x	x	x	x
Eleocharis palustris	Common Spikerush				x	x	x
Elodea canadensis	Common Waterweed	x	x	x	x	x	x
Impatiens capensis	Jewelweed	x					
Juncus spp	Rush					x	x
Iris versicolor	Blue-Flag Iris				x		
Lemna minor	Lesser Duckweed	x					
Megalodonta beckii	Water Marigold			x		x	x
Myriophyllum sibiricum	Northern Milfoil	x	x	x	x	x	x
Myriophyllum spicatum	Eurasian Watermilfoil	x	x	x	x	x	x
Najas flexlis	Bushy Pondweed	x	x	x	x	x	x
Najas guadelupensis	Southern Naiad			x	x	x	x
Nitellla spp	Stonewort spp	x	x	x	x	x	x
Nymphaea odorata	White Water Lily	x	x	x	x	x	x
Phalaris arundinacea	Reed Canarygrass	x		x		x	x
Polygonum aquaticum	Water Smartweed	x					
Potamogeton amphifolius	Large-Leaf Pondweed	x	x	x	x	x	x
Potamogeton crispus	Curly-Leaf Pondweed	x	x	x	x		x
Potamogeton foliosus	Leafy Pondweed	x					
Potamogeton friesii	Fries' Pondweed		x	x		x	x
Potamogeton gramineus	Variable-Leaf Pondweed	x	x	x	x	x	x
Potamogeton illinoensis	Illinois Pondweed	x	x	x	x	x	x
Potamogeton natans	Floating-Leaf Pondweed	x	x	x	x	x	x
Potamogeton praelongus	White-Stemmed Pondweed	x	x	x	x	x	x
Potamogeton pusillus	Small Pondweed	x	x	x	x	x	x
Potamogeton richardsonii	Clasping-Leaf Pondweed	x	x	x	x	x	x
Potamogeton robbinsii	Fern-Leaf Pondweed					x	x
Potamogeton zosteriformis	Flat-Stemmed Pondweed	x	x	x	x	x	x
Ranuculus aquatilis	White Water Crowfoot			x	x	x	x
Ranunculus lonigirostris	Beaked Crowfoot	x					

Sagittaria latioflia	Common Arrowhead	x	x	x			x
Sagittaria rigidics	Stiff Arrowhead					x	x
Salix spp	Willow spp	x				x	x
Schoenoplectus acutus	Hard-Stemmed Bulrush	x		x	x	x	x
Schoenoplectus pungens	Chairmaker's Rush			x	x	x	x
Schoenoplectus tabernaemontani	Soft-Stemmed Bulrush	x	x	x	x	x	x
Solanum ptycanthum	Bittersweet Nightshade	x					
Solidago spp	Goldenrod	x					
Stuckenia pectinata	Sago Pondweed	x	x	x	x	x	x
Typha spp	Cattail spp	x	x	x	x	x	x
Vallisneriaa americana	Water Celery	x	x	x	x	x	x
Zosterella dubia	Water Stargrass	x			x	x	x

Aquatic moss and freshwater sponges are common in Jordan Lake. Aquatic mosses are small plants with delicate stems and small closely overlapping leaves. These plants can have branched, stem-like, and root-like structures. Although sponges are animals, they are included in this report because they are sometimes mistaken for aquatic plants or algae. Sponges are multicellular animals consisting of masses of cells embedded in a gelatinous matrix.

V. CONCLUSIONS

Jordan Lake is a mesotrophic/oligotrophic lake with good-to-very good water quality and very good water clarity. The aquatic plant community colonized over 95% of the littoral zone of the lake. The 0-1.5feet depth zone supported the most abundant aquatic plant growth. The 1.5 feet to 5 feet depth zone also had abundant plant growth. Rooted aquatic plants were found as deep as 19 feet (*Myriophyllum spicatum),* and macrophytic algae, *Chara* spp., was found in 40 feet of water.

Chara spp. was the dominant species found in both of the aquatic plant surveys in 2012, dominating all depth zones. Variable-Leaf Pondweed was sub-dominant in both 2012 surveys. All other species were found much less frequently and occurred in relatively low density of growth. No endangered or threatened species were found in Jordan Lake in 2012.

Three invasive aquatic plant species have been present in Jordan Lake for some time. Two of them, Curly-Leaf Pondweed and Reed Canarygrass, continue to be present only in low numbers. However, the third, Eurasian Watermilfoil, has been a problem treated with chemicals every spring for several years.

One of the goals of the Jordan Lake management plan was to get the treatment area reduced to three acres or less. To this end, some testing and timing experiments have been occurring at Jordan Lake since 2010. In the spring of 2009, a pre-treatment survey was done, with the results forwarded to the chemical applicator. The post-treatment survey, in the fall, showed that the chemical treatment had not been particularly successful and that there was even more Eurasian watermilfoil in the fall than there had been in the spring. The treatment in the spring of 2009 was spot treatment with 2,4-D.

It was then decided to take several residue samples after the spring treatment, starting in 2010. Four sites in the lake were selected, two that were treated and two that were not. Residue sampling was done at 3, 6, 24, 48 and 72 hours after treatment, as well as 5, 7, and 14 days after treatment. Results showed that within three hours of the initial treatment, the concentration of 2,4-D was the same in the treated and untreated sections. In other words, although the granular treatment was meant to be a ‘spot treatment,” the treatment quickly became a whole lake treatment, but at less than a therapeutic dose to significantly set back the Eurasian watermilfoil.

In an effort to perhaps slow down or prevent the quick dispersal of the chemical, regular water column temperatures were taken, starting in early May 2011. Only when it became clear that the lake was starting to stratify did chemical treatment occur.

Jordan Lake property owners expressed themselves very pleased with the results of the treatment that occurred after stratification had begun. This method was followed again in spring 2012. In the 2012 post-treatment evaluation, Eurasian watermilfoil was found at only two sites on the lake. This was down from nine sites found post-treatment in 2011.

The Jordan Lake aquatic plant community is characterized by at least average quality and good species diversity. Depending on the indices used, the plant community is either in the top quartile or median of lakes in the region, with an above average tolerance to disturbance.

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.

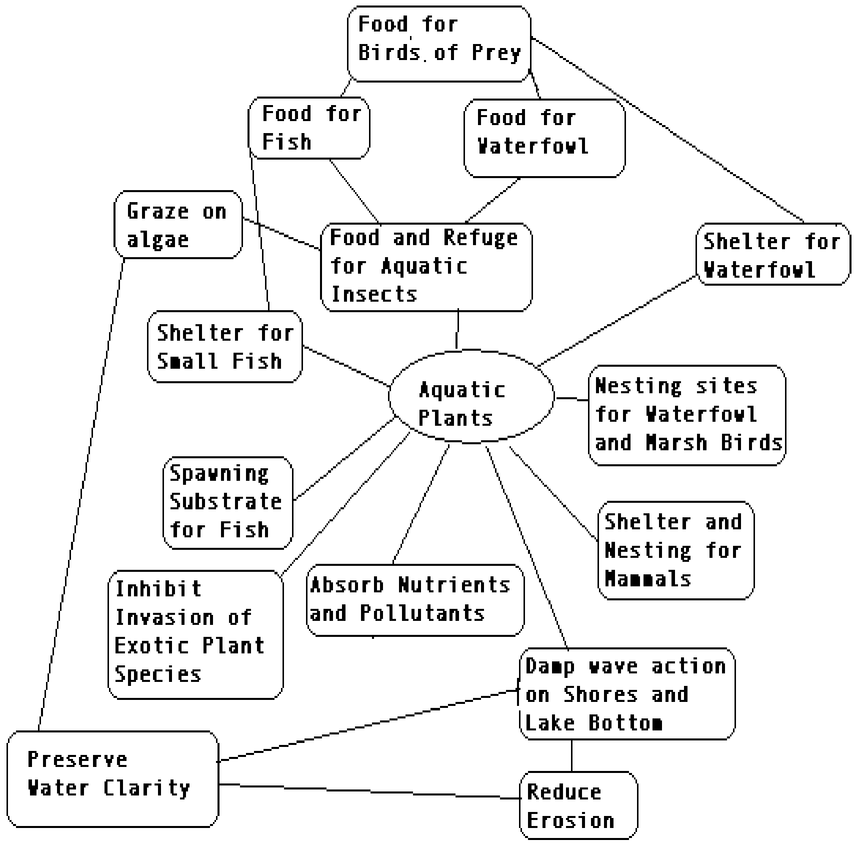


Figure 24: Aquatic Ecological Web

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 and are an essential part of the ecological web of a lake (Figure 25).

Lakes with diverse aquatic plant beds support larger, more diverse invertebrate populations that in turn 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 should practice best management on their lake properties. Jordan Lake is borderline between oligotrophic and mesotrophic. A small increase in nutrients could push the lake into another trophic state, resulting in noticeably worse water quality. Conversely, reducing nutrients could have a noticeable favorable impact on water quality.

- Keep septic systems cleaned and in proper condition;
- Use no lawn fertilizers;
- Clean up pet wastes;
- No composting should be done near the water nor should yard wastes & clippings be allowed to enter the lake (Do not compost near the water or allow yard wastes and clippings to enter the lake).

2) Continued involvement in regular water quality monitoring (through the Citizen Lake Monitoring Program) and aquatic invasive species monitoring should occur. This is important for keeping track of changes in the lake and also for evaluating the effect of the management plan activities.

3) Jordan Lake is heavily used for a number of recreational water activities. It has been very active in the Clean Boats, Clean Waters Program. It is important that this continue, especially since prior surveys have shown that many lake users come to Jordan Lake from superspreaders like Petenwell and Castle

Rock Lakes or the Wisconsin River. Small-scale grants have recently become available specifically to help with Clean Boats, Clean Waters activities.

4) With critical habitat areas designated, a map of these areas should be posted at the public boat ramp with a sign encouraging avoidance of motorboat disturbance to these areas. Education about what these areas mean to the lake would also be a good idea. Landowners on the lake should watch for disturbance of these areas and report any violations. These areas are very important for habitat, the high value aquatic plant community, maintaining the positive water quality, and for preserving endangered and rare species.

5) The Jordan Lake District should continue working with the Adams County Land & Water Conservation Department and the Wisconsin Department of Natural Resources in the ongoing Eurasian Watermilfoil removal project. Hand-pulling efforts should be continued.

6) Pre-and-post treatment monitoring for the presence of aquatic invasives should also continue. The pre-treatment monitoring, currently conducted by the Adams County Land & Water Conservation Department and a volunteer at Jordan Lake, permits accurate location of beds appropriate for treatment and also identifies isolated plants that could be hand-pulled. The post-treatment monitoring not only helps determine the success of the chemical treatment, but also provides a basis for likely treatment sites for the next year.

7) Lake residents should protect natural shoreline around Jordan Lake and install buffers practices in the areas that don't comply with the county shoreland zoning requirements. There are still several areas of cultivated lawn at the shore and also some areas of bare sand. Due to Adams County Shoreland

Zoning, buffers 35 feet landward must be installed by July 1, 2015. Cost-share funds to assist in installing such practices may be available for those who don’t wait until the last minutes to preserve their shores.

8) Steps should be taken to regulate boat speed and jetskis in the shallow water areas to reduce disturbance to plants. Water-skiing in these areas should be prohibited.

9) All lake users should protect the aquatic plant community in Jordan 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.

10) An aquatic plant survey should be repeated in 3 to 5 years in order to continue to track any changes in the community and the lake’s overall health.

11) The Jordan Lake District should consider approaching the landowners who own the undeveloped waterfront property on the lake and see if those landowners would be interested in conservation easements. If so, the Jordan Lake District Lake could apply for a WDNR grant to gain these easements.

LITERATURE CITED

Barko, J and R. Smart. 1986. Sediment-related mechanisms of growth limitation in submersed macrophytes. Ecology 61:1328-1340.

Boyd, C. E. 1974. Utilization of aquatic plants In Aquatic vegetation and its uses and control, D.S. Mitchell ed. Paris, Unesco, pp. 107-114).

Dennison, W., R. Orth, K. Moore, J. Stevenson, V. Carter, S. Kollar, P. Bergstrom and R. Batuik. 1993. Assessing water quality with submersed vegetation. BioScience 43(2):86-94.

Duarte, Carlos M. and J. Kalff. 1096. Littoral slope as a predictor of the maximum biomass of submerged macrophyte communities. Limnol. Oceanogr. 31(5):1072-1080.

Evans, Reesa. The aquatic plant community of Jordan Lake. 2006. Adams County Land & Water Conservation Department.

Fassett, N.C. 1957. A Manual of Aquatic Plants. University of Wisconsin Press. Madison, WI.

Gleason H. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada (2nd edition). New York Botanical Gardens. NY.

Jaccard, P. 1901. Etude comparative de la distribution florale dens une poitive des Alpes et des Jura (in translation). Bulletin de la Socrete Vaudoise des Sciences Naturalles.

Jessen, R and R. Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Minnesota Department of Conservation. Game Investigational Report No. 6.

Jester, L.L., M.A. Bozek, D.R. Helsel & S.P. Sheldon. 2000. *Euhrychiopsis lecontei* distribution, abundant and experimental augmentation for Eurasian watermilfoil control in Wisconsin lakes. Journal of Aquatic Plant Management 38:88-97.

Lillie, R. and J. Mason. 1983. Limnological Characteristics of Wisconsin Lakes. Wisconsin Department of Natural Resources Tech Bull #138. Madison, WI.

Newman, R.M., D.W. Ragsdale, A. Milles & C. Oien. 2001. Habitat and the relationship of overwinter to in-lake densities of the milfoil weevil, *Euhrychiopsis lecontei*, Eurasian watermilfoil biological control agent. Journal of Aquatic Plant Management 39:63-67.

Nichols, S., S. Weber, B. Shaw. 2000. A proposed aquatic plant community biotic index for Wisconsin lakes. Environmental Management 26:491-502.

Nichols, S. 1999. Distribution & Habitat Descriptions of Wisconsin Lake Plants. Wisconsin Geological and Natural History Survey, Bulletin 96. Madison, WI.

Nichols, S. 1998. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2):133-141.

Nichols, S. and J.G. Vennie. 1991. Attributes of Wisconsin Lake Plants. Wisconsin Geological and Natural history Survey. Information Circular 73.

Shaw, B., C. Mechnich and L. Klessig. 1993. Understanding Lake Data. University of Wisconsin-Extension. Madison, WI.