Aquatic Macrophyte Survey

Rice Lake, Barron County Wisconsin

WBIC: 2103900

August, 2018

Sponsored by: Rice Lake Protection and Rehabilitation District

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Abstract

An aquatic macrophyte survey utilizing the point intercept method (based upon Wisconsin Dept. of Natural Resources protocol) was conducted on Rice Lake, Barron County Wisconsin in August 2018. An early season survey to evaluate *Potamogeton crispus* was not conducted due to timing of survey request. The August survey resulted in 42 species of macrophytes sampled and identified. Two invasive species (*Potamogeton crispus* and *Typha angustifolia*) were viewed or sampled at sample points. The Simpson's diversity index was 0.87. A floristic quality index (FQI) was calculated and found to be higher than the eco-region median (39.66 vs 23.5) and was slightly higher than the FQI in 2008. Comparing the frequency of occurrence to a 2008 survey using a chi-square analysis resulted in statistically significant increase for five species and decrease for 10 species. The 2018 survey also showed a decrease in plant coverage, with 303 sample points (out of 843) with plants in 2018 vs 362 with plants in 2008.

Introduction

In August 2018, a full lake aquatic macrophyte survey was conducted using the point intercept (PI) method on Rice Lake, Barron County Wisconsin. The survey followed the protocol established by the Wisconsin Dept. of Natural Resources. Rice Lake has an area of 859 acres with a maximum depth of 19 feet and a mean depth of nine feet. It is a flowage (Red Cedar River) with a eutrophic trophic status.

This report presents a summary and analysis of data collected in a point intercept aquatic macrophyte survey. The primary goal of the survey is to compare this PI survey with ones conducted in 2008 and 2013 for the long-term monitoring of aquatic plant populations and allow for the evaluation of any changes that may occur long-term. These changes may be due to human activities such as management of *Potamogeton crispus* (curly-leaf pondweed), which has occurred on Rice Lake. In addition, invasive species presence and location monitoring is an integral part of this survey. Hybrid watermilfoil (*Myriophyllum spicatum* X *Myriophyllum sibiricum*) was discovered before the survey and this survey was to help determine any other locations or distribution of this invasive species. This survey is acceptable for aquatic plant management planning.

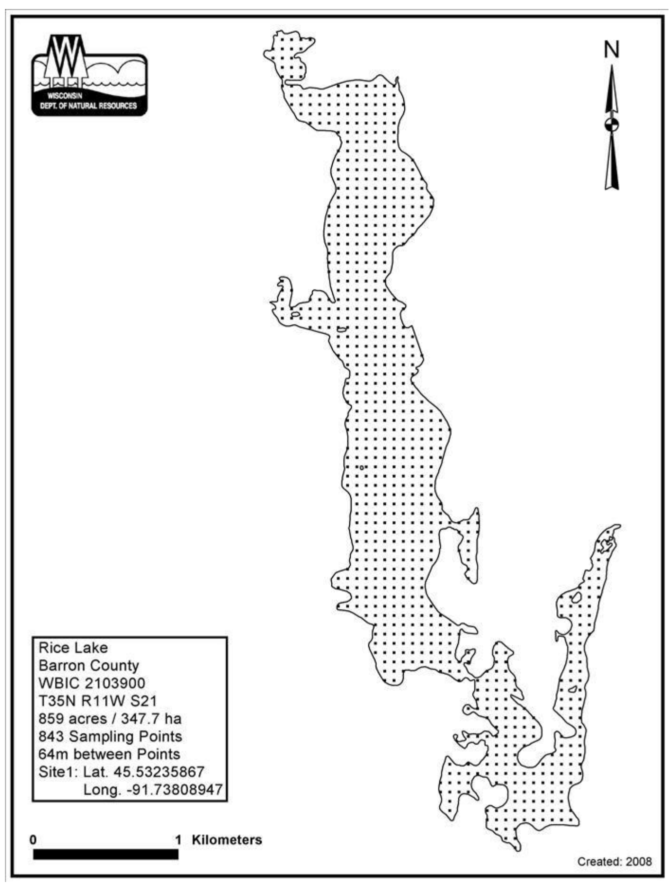

Figure 1: Point intercept grid for Rice Lake aquatic macrophyte survey

Field Methods

A point intercept method was employed for the aquatic macrophyte sampling. The Wisconsin Department of Natural Resources (Wisconsin DNR) generated the sampling point grids for the lake. All points were initially sampled for depth only. Once the maximum depth of plant growth was established, only points at that depth (or less) were sampled. If no plants were sampled, one point beyond that was sampled for plants. In areas such as bays that appear to be under-sampled, a boat or shoreline survey was conducted to record plants that may have otherwise been missed. This involved surveying that area for plants and recording the species viewed and/or sampled. The type of habitat is also recorded. These data are not used in the statistical analysis nor is the density recorded. Only plants sampled at predetermined points were used in the statistical analysis. In addition, any plant within 6 feet of the boat was recorded as "viewed." A Global Positioning System (GPS) located the sampling points in the field. The Wisconsin DNR guidelines for point location accuracy were followed with a 50-foot resolution window and the location arrow covering the point.

At each sample location, a double-sided fourteen-tine rake was used to rake a 1meter tow off the bow of the boat. All plants present on the rake and those that were seen falling off the rake were identified and rated for rake fullness. The rake fullness value was used based on the criteria contained in the diagram and table below. Those plants that were within 6 feet were recorded as "viewed," but no rake fullness rating was given. Any under-surveyed areas such as bays and/or areas with unique habitats were monitored. These areas are referred to as a "boat survey or shoreline survey."

The rake density criteria used:

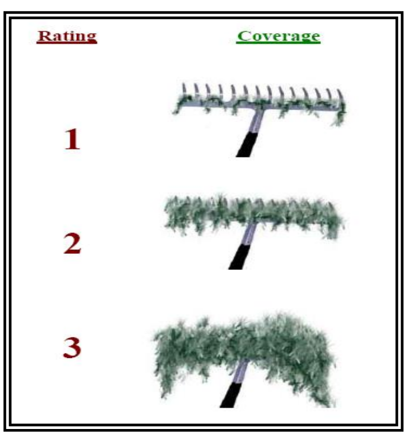

Figure 2: Rake fullness reference.

Rake fullness rating	Criteria for rake fullness rating
1	Plant present occupies less than ½ of tine space
2	Plant present occupies more than ½ tine space
3	Plant present occupies all or more than tine space
v	Plant not sampled but observed within 6 feet of boat

Table 1: Rake fullness description.

The depth and predominant sediment type were also recorded for each sample point. Caution must be used in using the sediment type since in deeper water as it is difficult to discern between muck and sand with a rope rake. All plants needing verification were bagged and cooled for later examination. Each news species (compared to previous surveys) was mounted and pressed for a voucher collection and submitted to the Freckmann Herbarium (UW-Stevens Point) for review. On rare occasions a single plant may be needed for verification, not allowing it to be used as a voucher specimen and may be missing from the collection if lake organization requests voucher.

An early season, aquatic invasive species (AIS) (emphasis on *Potamogeton crispus*-curly leaf pondweed) survey is completed to pick up any potential growth before native plants are robust. Curly leaf pondweed grows in the spring, only to senesce in early July before the main survey is typically conducted. This was not done on Rice Lake. The request for this survey was based upon concern over hybrid watermilfoil presence and occurred after June.

Data analysis methods

Data collected and analyzed resulting in the following information:

- The frequency of occurrence in sample points with vegetation (littoral zone)
- Relative frequency
- Total points in sample grid
- Sample points with vegetation
- Simpson's diversity index
- Maximum plant depth
- Species richness
- Floristic Quality Index

An explanation of each of these data is provided below.

The frequency of occurrence for each species- Frequency is expressed as a percentage by dividing the number of sites the plant is sampled by the total number of sites, which calculates to two possible values. The first value is the percentage of all sample points that a particular plant was sampled at depths less than maximum depth plants (littoral zone), regardless of vegetation presence. The second is the percentage of sample points that a particular plant was sampled at only points containing vegetation. The first value shows how often the plant would be encountered in the defined littoral zone (by depth), while the second value shows how frequent the plant is only where plants grow. In either case, the greater this value, the more frequent the plant is present in the lake. When comparing frequency in the littoral zone, plant frequency is observed at maximum depth. This frequency value allows one to analyze the occurrence and location of plant growth based on depth. The frequency of occurrence is usually reported using sample points where vegetation was present.

Frequency of occurrence example:

Plant A sampled at 35 of 150 littoral points = 35/150 = 0.23 = 23%

Plant A's frequency of occurrence = 23% considering littoral zone depths.

Plant A sampled at 12 of 40 vegetated points = 12/40 = 0.3 = 30%

Plant A's frequency of occurrence = 30% in vegetated areas

These two frequencies can tell us how common the plant was sampled in the littoral zone or how common the plant was sampled at points plants actually grow. Generally the second will have a higher frequency since that is where plants are actually growing as opposed to where they could grow. This analysis will consider vegetated sites for frequency of occurrence only.

Relative frequency-This value shows, as a percentage, the frequency of a particular plant relative to other plants. This is not dependent on the number of points sampled. The relative frequency of all plants totals 100%. If plant A had a relative frequency of 30%, it occurred 30% of the time compared to all plants sampled or makes up 30% of all plants sampled. This value allows us to see which plants are the dominant species in the lake. The higher the relative frequency, the more common the plant compared to the other plants and thus more frequent in the plant community.

Relative frequency example:

Suppose we were sampling 10 points in a very small lake and got the following results:

	Frequency sampled
Plant A present at 3 sites	3 of 10 sites
Plant B present at 5 sites	5 of 10 sites
Plant C present at 2 sites	2 of 10 sites
Plant D present at 6 sites	6 of 10 sites

So one can see that Plant D is the most frequent sampled at all points with 60% (6/10) of the sites having plant D. However, the relative frequency allows us to see what the frequency is compared the other plants, without taking into account the number of sites. It is calculated by dividing the number of times a plant is sampled by the total of all plants sampled. If all frequencies are added (3+5+2+6), the sum is 16. The relative frequency calculated by dividing the individual frequencies by 16 in this case.

Plant A = 3/16 = 0.1875 or 18.75%
Plant B = 5/16 = 0.3125 or 31.25%
Plant C = 2/16 = 0.125 or 12.5%
Plant D = 6/16 = 0.375 or 37.5%

Now the plants can be compared to one another. Plant D is still the most frequent, but the relative frequency tells us that of all plants sampled at those 10 sites, 37.5% of them are Plant D. This is much lower than the frequency of occurrence (60%) because although Plant D was sampled at 6 of 10 sites, many other plants were sampled too, thereby giving a lower frequency when compared to those other plants. This then gives a true measure of the dominant plants present.

Total points in sample grid- The Wisconsin DNR establish a sample point grid that covers the entire lake. Each GPS coordinate is mapped and used to locate the points.

Sample sites less than the maximum depth of plants-The maximum depth at which a plant is sampled is recorded. This defines the depth plants can grow (littoral zone). Any sample point with a depth less than, or equal to this depth is recorded as a sample point less than the maximum depth of plants. This depth is used to determine the potential littoral zone and is therefore referred to as the littoral zone.

Sample sites with vegetation- This is the number of sites where plants were actually sampled. This gives a good projection of plant coverage on the lake. If 10% of all sample points had vegetation, it implies about 10% coverage of plants in the whole lake, assuming an adequate number of sample points have been established. We also observe the number of sample sites with vegetation in the littoral zone. If 10% of the littoral zone had sample points with vegetation, then the estimated plant coverage in the littoral zone would is 10%.

Simpson's diversity index-Simpson's diversity index is used to measure the diversity of the plant community. This value can run from 0 to 1.0. The greater the diversity index value, the more diverse the plant community. In theory, the value is the chance that two species sampled are different. An index of "1" means that the two will always be different (diverse) and a "0" would indicate that the species will never be different (only one found). The higher the diversity in the native plant community, the healthier the lake ecosystem.

Simpson's diversity example:

If a lake was sampled and observed just one plant, the Simpson's diversity would be "0" because if two plants were randomly sampled, there would be a 0% chance of them being different, since there is only one plant.

If every plant sampled were different, then the Simpson's diversity would be "1." This is because if two plants were randomly sampled, there would be a 100% chance they would be different since every plant is different.

These are extreme and theoretical scenarios, but they demonstrate how this index works. The greater the Simpson's index for a lake, the more likelihood two plants sampled are different.

Maximum depth of plants-This depth indicates the deepest that plants were sampled. Generally, more clear lakes have a greater depth of plants, while lower water clarity limits light penetration and reduces the depth at which plants are found.

Species richness-The number of different individual species found in the lake. There is a value for the species richness of plants sampled, and another value that takes into account plants viewed but not actually sampled during the survey.

Floristic Quality Index-The Floristic Quality Index (FQI) is an index developed by Dr. Stanley Nichols of the University of Wisconsin-Extension. This index is a measure of the plant community in response to development (and human influence) on the lake. It considers the species of aquatic plants sampled and their tolerance for changing water quality and habitat quality. The index uses a conservatism value assigned to various plants ranging from 1 to 10. A higher conservatism value indicates that a plant is intolerant, while a lower value indicates tolerance.

Those plants with higher values are more apt to respond adversely to water quality and habitat changes, largely due to human influence (Nichols, 1999). The FQI is calculated using the number of species and the average conservatism value of all species used in the index.

The formula is: FQI = Mean C $\cdot\sqrt{N}$

Where C is the conservatism value and N is the number of species (only species sampled on a rake).

Therefore, a higher FQI indicates a healthier aquatic plant community, which is an indication of better plant habitat. This value can then be compared to the median for other lakes in the assigned eco-region. There are four eco-regions used throughout Wisconsin: Northern Lakes and Forests, Northern Central Hardwood Forests, Driftless Area, and Southeastern Wisconsin Till Plain. 2007, 2012 and 2017 values from past aquatic plant surveys will also be compared in this analysis.

Summary of North Central Hardwood Forests for Floristic Quality Index:

(Nichols, 1999)

	Northern Lakes and Forests	Flowages
Median species richness	13	23.5
Median conservatism	6.7	6.2
Median Floristic Quality	24.3	28.3

*Floristic Quality has a significant correlation with area of lake (+), alkalinity(-),

conductivity(-), pH(-) and Secchi depth(+). In a positive correlation, as that value increases so will FQI, while with a negative correlation, as a value decreases, the FQI will decrease.

Results

Table 2 summarizes various data from the full lake point intercept survey on Rice Lake. The coverage of plants in Rice Lake is moderate. In many bays, there is extensive plant growth. However, in many areas of the littoral zone within the main lake basins, the growth is rather limited. The density of plants can be high in a few areas/bays and near the Red Cedar River inlet. Many areas have little or no density of plants.

Total number of sites in full lake grid	843
Total number of sites shallower than maximum depth of plants	653
Total number of sites with vegetation	303 (325)
% of sample points shallower than maximum depth of plants	77.5%
% of sample points with plant growth within littoral zone depth	49.8%
Simpson Diversity Index	0.87
Maximum depth of plants	13.50 feet
Mean depth of plants	4.1 feet
Average number of all species per site (shallower than max depth)	1.19
Average number of all species per site (veg. sites only)	2.74
Average number of native species per site (shallower than max depth)	1.17
Average number of native species per site (veg. sites only)	2.72
Species Richness	42
Species Richness (including visuals)	46

Table 2: Summary of survey data in 2018.

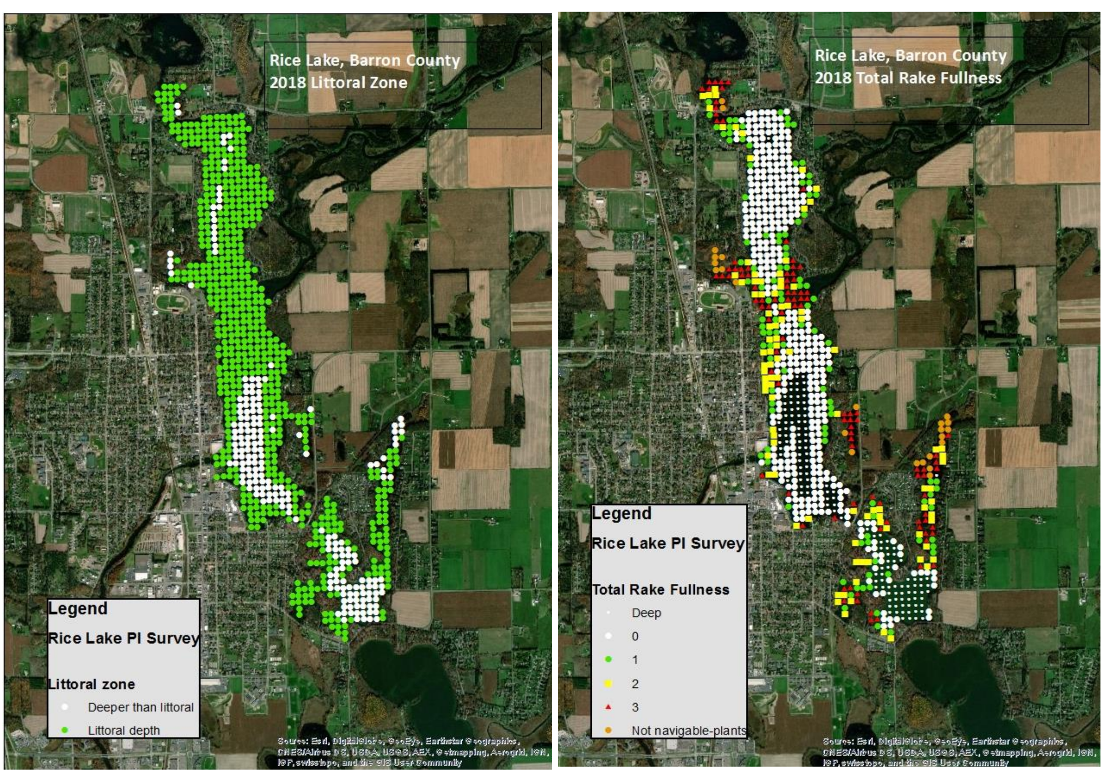

Figure 3: Littoral zone map and total rake fullness at each sample point.

Maximum depth of plants was moderate at 13.5 feet. The mean depth of plants was 4.1 feet. Figure 4 shows the depth distribution of plant growth.

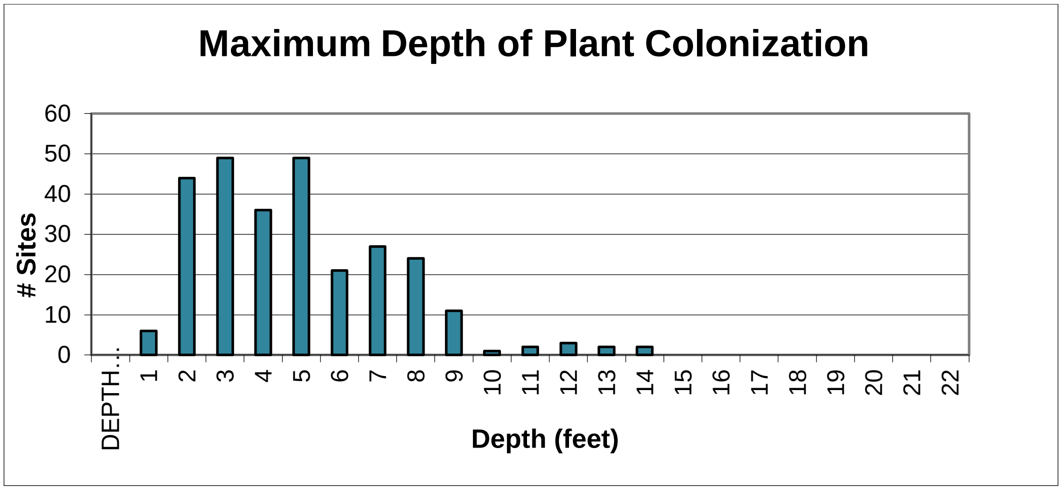

Figure 4: Depth distribution of plants graph.

The diversity of plants is also moderate. The species richness is quite high at 42 species. However, the Simpson's diversity index is not very high at 0.87. Most of the diversity occurs in a few bays and in shallow, high nutrient sediment area.

Table 3: Species richness with frequency of occurrence (FOO) and density data.

Species	FOO Veg.	FOO Littoral	Relative Freq.	# sampled	Mean Rake Fullness	# viewed
Ceratophyllum demersum, Coontail	73.6	35.12	29.42	223	1.43	
Vallisneria americana, Wild celery	31.35	14.96	12.53	95	1.21	4
Potamogeton zosteriformis, Flat-stem pondweed	26.07	12.44	10.42	79	1.08	1
Nymphaea odorata, White water lily	12.87	6.14	5.15	39	1.28	10
Elodea canadensis, Common waterweed	11.88	5.67	4.75	36	1.11	1
Lemna trisulca, Forked duckweed	9.24	4.41	3.69	28	1.00	
Myriophyllum sibiricum, Northern water-milfoil	9.24	4.41	3.69	28	1.04	4
Potamogeton richardsonii, Clasping-leaf pondweed	8.91	4.25	3.56	27	1.11	6
Potamogeton robbinsii, Fern pondweed	8.91	4.25	3.56	27	1.41	
Lemna minor, Small duckweed	7.92	3.78	3.17	24	1.00	
Wolffia columbiana, Common watermeal	7.59	3.62	3.03	23	1.00	1
Elodea nuttallii, Slender waterweed	5.94	2.83	2.37	18	1.11	
Spirodela polyrhiza, Large duckweed	5.28	2.52	2.11	16	1.00	
Nuphar variegata, Spatterdock	3.63	1.73	1.45	11	1.00	2
Potamogeton amplifolius, Large-leaf pondweed	2.31	1.10	0.92	7	1.00	5

Species	FOO Veg.	FOO Littoral	Relative Freq.	# sampled	Mean Rake Fullness	# viewed
Utricularia gibba, Creeping bladderwort	1.98	0.94	0.79	6	1.00	1
Utricularia intermedia, Flat-leaf bladderwort	1.98	0.94	0.79	6	1.00	
Utricularia vulgaris, Common bladderwort	1.98	0.94	0.79	6	1.00	2
Heteranthera dubia, Water star-grass	1.65	0.79	0.66	5	1.00	
Nitella sp., Nitella	1.65	0.79	0.66	5	1.00	
Potamogeton pusillus, Small pondweed	1.65	0.79	0.66	5	1.00	1
Bidens beckii , Water marigold	1.32	0.63	0.53	4	1.00	1
Najas flexilis, Slender naiad	1.32	0.63	0.53	4	1.00	
Chara sp., Muskgrasses	0.99	0.47	0.40	3	1.00	
Myriophyllum verticillatum, Whorled water-milfoil	0.99	0.47	0.40	3	1.33	1
Pontederia cordata, Pickerelweed	0.99	0.47	0.40	3	1.00	1
Potamogeton praelongus, White-stem pondweed	0.99	0.47	0.40	3	1.00	
Typha angustifolia, Narrow-leaved cattail	0.99	0.47	0.40	3	1.00	1
Dulichium arundinaceum, Three-way sedge	0.66	0.31	0.26	2	1.00	
Eleocharis acicularis, Needle spikerush	0.66	0.31	0.26	2	1.00	1
Najas guadalupensis, Southern naiad	0.66	0.31	0.26	2	1.00	
Ranunculus aquatilis, White water crowfoot	0.66	0.31	0.26	2	1.00	
Sagittaria rigida, Sessile-fruited arrowhead	0.66	0.31	0.26	2	1.00	
Sparganium eurycarpum, Common bur-reed	0.66	0.31	0.26	2	1.50	1
Stuckenia pectinata, Sago pondweed	0.66	0.31	0.26	2	1.00	1
Carex comosa, Bottle brush sedge	0.33	0.16	0.13	1	1.00	2
Potamogeton epihydrus, Ribbon-leaf pondweed	0.33	0.16	0.13	1	1.00	
Potamogeton foliosus, Leafy pondweed	0.33	0.16	0.13	1	1.00	
Potamogeton illinoensis, Illinois pondweed	0.33	0.16	0.13	1	1.00	
Sagittaria latifolia, Common arrowhead	0.33	0.16	0.13	1	1.00	
Typha latifolia, Broad-leaved cattail	0.33	0.16	0.13	1	1.00	
Zizania palustris, Northern wild rice	0.33	0.16	0.13	1	1.00	
Freshwater sponge	0.33	0.16	n/a	1	1.00	
Filamentous algae	10.56	5.04	n/a	32	1.03	
Potamogeton crispus, Curly-leaf pondweed	Viewed only					2
Schoenoplectus tabernaemontani, Softstem bulrush	Viewed only					1
Cicuta bulbifera, Bulb bearing water hemlock	Viewed only					1
Sagittaria cuneata, arum leaved arrowhead	Viewed only					1

The most common species present are common, desirable aquatic plants in Wisconsin lakes. The most common was *Ceratophyllum demersum*-coontail, which often dominates in lakes with high nutrients. The relative frequency of coontail was nearly 30%, indicating that nearly 1 in 3 plants sampled were coontail. *Vallisneria americana*-wild celery and *Potamogeton zosteriformis*-flat-stem pondweed were second in third in regard to relative frequency. Both are common aquatic plants and serve important roles in the lake ecosystem. Table 3 lists species and frequencies.

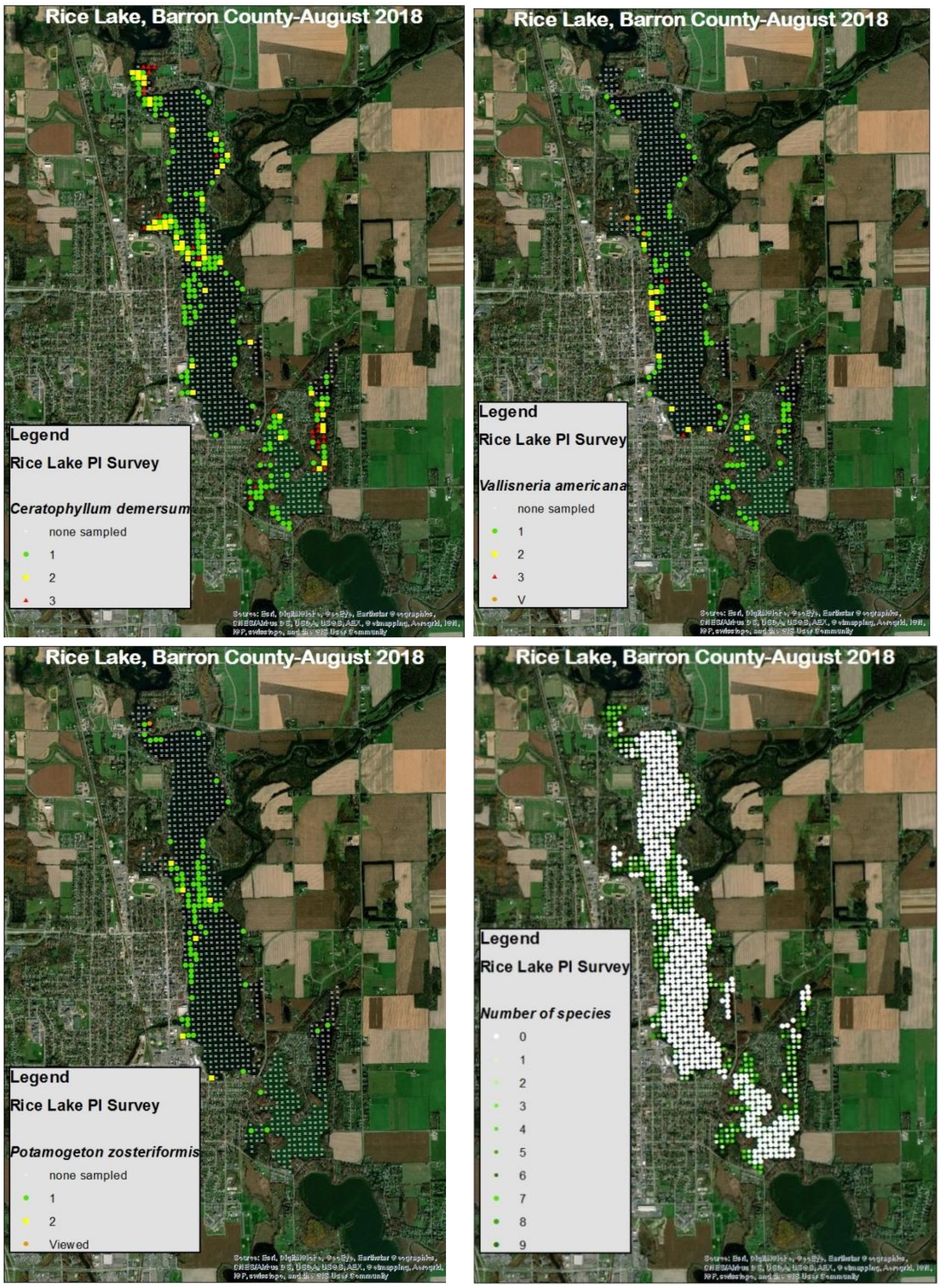

Figure 5: The three most common sampled plants in survey (based upon relative frequency) and species richness at each sample point.

A boat survey was also conducted to attempt to observed plants in areas under represented by the sample grid. Four species, two of which are invasive and one is a species of special concern, were observed. Table 4 lists those species and any special significance.

Lythrum salicaria, Purple loosestrife	Invasive species
Najas gracillima, Northern naiad	Species of special concern
Rumex Britannica, Aquatic dock	
Phalaris arundinacea, Reed canary grass	Invasive species

Table 4: Species and potential significance observed in boat survey.

The floristic quality index can indicate any adverse changes to the plant habitat, attributed to human activity on and around the lake. Highly sensitive plants have higher conservatism values and are more likely to be reduced from human impact. The FQI for Rice Lake was higher than the eco-region median (38.1 vs 28.3). This appears to be due to the high species richness as the mean conservatism value is slightly lower than the eco-region median. This indicates that there is more diversity, but slightly less sensitive plants than the median of other lakes in region.

FQI Parameter	Rice Lake 2018	Eco-region Median
Number of species in FQI	42	23.5
mean Conservatism	6.12	6.2
FQI	**39.66**	**28.3**

Table 5: Floristic Quality Index (FQI) data.

Species of special concern

One species of special concern was observed in a boat survey, but not sampled at a sample point. This species is *Najas gracillima*, Northern naiad. This plant has been sampled in a previous survey (2008). At that time (2008), this species was not considered special concern but in 2018, it was listed as a species of special concern. The Wisconsin DNR has the location record for this species as a map will not be provided here.

Non-native/invasive species

One invasive species was sampled, *Typha angustifolia* (narrow leaved cattail) and one invasive species was viewed, *Potamogeton crispus* (curly leaf pondweed). An early season survey was not conducted when curly leaf pondweed would have been at peak growth. Rice Lake has a long history of CLP presence/growth and has been managed for several years.

Figure 6: Maps showing locations of invasive species sampled within sample point grid.

Two invasive species were observed from a boat survey. These were *Lythrum salicaria* (purple loosestrife) and *Phalaris arundinacea* (reed canary grass). Purple loosestrife was observed in one location (a few plants) and was mapped (see below). Reed canary grass is a very common invasive species and was seen in a few areas scattered around the lake in disturbed areas.

Figure 7: Location of purple loosestrife.

Survey Comparisons

A main rationale of periodic plant surveys is to compare the results and evaluate if there are changes trending. Table 6 summarizes the surveys from 2008, 2013 and 2018.

PI Survey Statistics	**2008**	**2013**	**2018**
Total number of sites with vegetation	368	342	303
Frequency of occurrence at sites shallower than maximum depth of plants	55.93%	58.29%	49.8%
Simpson Diversity Index	0.89	0.89	0.87
Maximum depth of plants	16.20 ft	14.10 ft	13.50 ft
Average number of native species per site (shallower than max depth)	1.81	1.46	1.17
Average number of native species per site (veg. sites only)	3.42	2.88	2.72
Species Richness (only sampled on rake)	41	41	42

Table 6: Survey statistic comparison from 2008, 2013 and 2018.

Since 2008, the coverage of plants has changed rather significantly. The number of sites with vegetation has declined by 65 sample points. The coverage within the littoral zone has also decreased. Species richness has remained basically unchanged (slight increase); the Simpson's diversity index has decreased slightly.

In order to determine if individual species have changed in frequency, a chi-square analysis was conducted. There are various sources for the frequency of occurrence change. Those possible sources are as follows:

1. Management practices such as herbicide treatments can cause reductions. Typically if herbicide treatments of invasive species are utilized, a pretreatment and post-treatment analysis is conducted in those specific areas. To determine if this is a cause of a reduction in the full lake survey, the treatment areas would need to be evaluated using the point-intercept sample grid. Furthermore, if herbicide reduces the native species, it is dependent upon the type and concentration of the herbicide. A single species reduction is unlikely and more likely multiple species would be affected.

2. Sample variation can also occur. The sample grid is entered into a GPS unit. The GPS allows the surveyor to get close to the same sample point each time, but there is a possible error of 20 feet or more (the arrow icon is 16 feet in real space). Since the distribution of various plants is not typically uniform but more likely clumped, sampling variation could result in that plant not being sampled in a particular survey. Plants with low frequency could give significantly different values with surveys conducted within the same year.

3. Each year, the timing for aquatic plants coming out of dormancy can vary widely. A late or early ice-out may affect the size of plants during a survey from one year to the next. For example, a lake with a high density of a plant one year could have a very low density another year. The type

of plant reproduction can affect this immensely. If the plant grows from seed or a rhizome each year, the timing can be paramount as to the frequency and density is shown in a survey.

4. Identification differences can lead to frequency changes. The small pond weeds such as *Potamogeton pusillus, Potamogeton foliosus, Potamogeton friesii,* and *Potamogeton strictifolious* can easily be mistaken for one plant or another. It may be best to look at the overall frequency of all of the small pondweeds to determine if a true reduction has occurred. All small pondweeds collected were magnified and closely scrutinized in the 2017 survey.

5. Habitat changes and plant dominance changes can lead to plant declines. If an area received a large amount of sediment from human activity the plant community may respond. For this to occur in 5-7 years may be unlikely. If a plant emerges as a more dominant plant over time, that plant may reduce another plant's frequency and /or density.

6. Large plant coverage reduction that is not species specific can occur from an infestation in the non-native rusty crayfish or common carp.

Management of curly leaf pondweed has been taking place for many years. For this reason, any reduction in frequency could be due to herbicide use over time. There is no conclusive evidence that herbicide is the only source of any reductions. Also, there were numerous significant increases as well. Herbicide application did not occur in 2018, but mechanical harvest did.

Table 7: Chi-square summary for surveys occurring in 2008, 2013 and 2018.

Species (in order of highest FOO-2008)	**FOO 2008**	**FOO 2013**	**FOO 2018**	**Δ 2008-2013**	**P value**	**Δ 2013-2018**	**P value**	**Δ 2008-2018**	**P value**
Ceratophyllum demersum, Coontail	86.14%	73.10%	73.6%	decrease	$1.5 X10^{-5}$	increase	0.89	decrease	$8X10^{-5}$
Potamogeton crispus, Curly-leaf pondweed*	63.86%	44.74%	0.00%*	decrease*	$3.2X10^{-7}$	n/a	n/a	n/a	n/a
Elodea canadensis, Common waterweed	44.84%	20.47%	11.88%	decrease	$5.4X10^{-12}$	decrease	0.03	decrease	$2.8X10^{-20}$
Potamogeton zosteriformis, Flat-stem pondweed	36.68%	30.70%	26.07%	decrease	0.090	decrease	0.19	decrease	0.004
Lemna trisulca, Forked duckweed	21.47%	6.43%	9.24%	decrease	$1.0X10^{-8}$	increase	0.18	decrease	$2.0X10^{-5}$
Vallisneria americana, Wild celery	20.11%	19.88%	31.35%	decrease	0.940	increase	0.0008	increase	$6.9X10^{-4}$
Potamogeton robbinsii, Fern pondweed	18.48%	11.11%	8.91%	decrease	0.006	decrease	0.35	decrease	$4.6X10^{-4}$
Myriophyllum sibiricum, Northern water-milfoil	16.58%	13.16%	9.24%	decrease	0.200	decrease	0.12	decrease	0.006
Potamogeton pusillus, Small pondweed	14.67%	4.97%	1.65%	decrease	$1.7X10^{-5}$	decrease	0.02	decrease	$3.5X10^{-9}$
Potamogeton richardsonii, Clasping-leaf pondweed	8.70%	12.87%	8.91%	increase	0.070	decrease	0.11	increase	0.90
Lemna minor, Small duckweed	6.79%	7.31%	7.92%	n/c		increase	0.77	increase	0.56

Species **(in order of highest FOO-2008)**	**FOO 2008**	**FOO 2013**	**FOO 2018**	**Δ 2008-2013**	**P value**	**Δ 2013-2018**	**P value**	**Δ 2008-2018**	**P value**
Nymphaea odorata, White water lily	5.43%	12.57%	12.87%	increase	0.001	increase	0.91	increase	$6.4X10^{-4}$
Heteranthera dubia, Water star-grass	4.62%	1.75%	1.65%	decrease	0.030	decrease	0.92	decrease	0.03
Nuphar variegata, Spatterdock	4.08%	3.80%	3.63%	decrease	0.850	decrease	0.91	decrease	0.78
Potamogeton amplifolius, Large-leaf pondweed	4.08%	2.05%	2.31%	decrease	0.120	increase	0.82	decrease	0.21
Najas flexilis, Slender naiad	3.26%	5.85%	1.32%	increase	0.100	decrease	0.002	decrease	0.10
Spirodela polyrhiza, Large duckweed	2.99%	4.39%	5.28%	increase	0.320	increase	0.60	increase	0.13
Potamogeton foliosus, Leafy pondweed	2.99%	2.34%	0.33%	decrease	0.590	decrease	0.03	decrease	0.01
Potamogeton freisii, Fries' pondweed	2.99%	0.58%	0.00%	decrease	0.020	decrease	0.18	decrease	0.002
Nitella sp., Nitella	2.72%	2.05%	1.65%	decrease	0.560	decrease	0.71	decrease	0.21
Wolffia columbiana, Common watermeal	2.45%	5.56%	7.59%	increase	0.030	increase	0.30	increase	0.19
Bidens beckii, Water marigold	2.17%	0.58%	1.32%	decrease	0.070	increase	0.33	decrease	0.41
Stuckenia pectinata, Sago pondweed	1.90%	3.22%	0.66%	increase	0.260	decrease	0.02	decrease	0.17
Chara sp., Muskgrasses	1.63%	0.58%	0.99%	decrease	0.190	increase	0.56	decrease	0.48
Utricularia vulgaris, Common bladderwort	1.09%	0.88%	1.98%	decrease	0.780	increase	0.23	increase	0.34
Potamogeton praelongus, White-stem pondweed	1.09%	0.29%	0.99%	decrease	0.200	increase	0.26	decrease	0.91
Elodea nuttallii, Slender waterweed	0.54%	2.05%	5.95%	increase	0.070	increase	0.01	increase	$4X10^{-5}$
Typha angustifolia, Narrow-leaved cattail	0.54%	0.29%	0.99%	decrease	0.600	increase	0.26	increase	0.50
Ranunculus aquatilis, White water crowfoot	0.54%	0.29%	0.66%	decrease	0.610	increase	0.49	increase	0.84
Sagittaria cuneata, arum leaved arrowhead	0.54%	0.00%	0.00%	decrease	0.600	n/c	---	decrease	0.20
Brasenia schreberi, watershield	0.54%	1.17%	0.00%	increase	0.360	decrease	0.05	decrease	0.20
Potamogeton epihydrous, ribbon leaf pondweed	0.54%	0.00%	0.33%	decrease	0.170	increase	0.30	decrease	0.20
Utricularia gibba, Creeping bladderwort	0.27%	0.88%	1.98%	increase	0.280	increase	0.23	increase	0.03
Sparganium eurycarpum, Common bur-reed	0.27%	1.17%	0.66%	increase	0.160	decrease	0.50	increase	0.45
Schoenoplectus acutus	0.27%	0.00%	0.00%	decrease	0.300	n/c	---	decrease	0.37
Najas gracillima, Northern naiad	0.27%	0.29%	0.00%	n/c	---	decrease	0.37	decrease	0.37
Sagittaria rigida, sessile	0.27%	0.88%	0.66%	increase	0.60	decrease	0.75	increase	0.45

Species (in order of highest FOO-2008)	**FOO 2008**	**FOO 2013**	**FOO 2018**	**Δ 2008-2013**	**P value**	**Δ 2013-2018**	**P value**	**Δ 2008-2018**	**P value**
fruited arrowhead									
Potamogeton natans, floating leaf pondweed	0.27%	0.00%	0.00%	decrease	0.300	n/c	---	decrease	0.37
Utricularia intermedia, Flat-leaf bladderwort	0.00%	0.29%	1.98%	increase	0.300	increase	0.04	increase	0.007
Myriophyllum verticillatum, whorled water-milfoil	0.00%	0.00%	0.99%	n/a	---	increase	0.06	increase	0.055
Pontederia cordata, Pickerelweed	0.00%	0.58%	0.99%	increase	0.140	increase	0.56	increase	0.055
Carex comosa, Bottle brush sedge	0.00%	0.29%	0.33%	increase	0.300	increase	0.49	increase	0.27
Dulichium arundinaceum, Three-way sedge	0.00%	0.00%	0.66%	n/a	---	increase	0.13	increase	0.12
Eleocharis acicularis, Needle spikerush	0.00%	0.00%	0.66%	n/a	---	increase	0.13	increase	0.12
Najas guadalupensis, Southern naiad	0.00%	0.00%	0.66%	n/a	---	increase	0.13	increase	0.12
Potamogeton illinoensis, Illinois pondweed	0.00%	0.00%	0.33%	n/a	---	increase	0.29	increase	0.27
Sagittaria latifolia, Common arrowhead	0.00%	0.00%	0.33%	n/a	---	increase	0.29	increase	0.27
Typha latifolia, Broad-leaved cattail	0.00%	0.00%	0.33%	n/a	---	increase	0.29	increase	0.27
Zizania palustris, northern wild rice	0.00%	0.29%	0.33%	increase	0.300	increase	0.93	increase	0.27
Eleocharis palustris, creeping spikerush	0.00%	0.29%	0.00%	increase	0.300	decrease	0.35	n/c	n/c

*CLP survey FOO is based upon spring survey, which was not conducted in 2018.

Summary of chi-square	**2008-2013**	**2013-2018**	**2008-2018**
Significant decrease	8 species	5 species	10 species
Significant increase	2 species	3 species	5 species

Table 8: Summary of chi-square analysis in regard to decreases and increases in plant species.

Tables 7 and 8 indicate that numerous species decreases (that are statistically significant) have occurred (as reflected by the chi-square analysis of the three surveys). This is coupled with some increases, but fewer numbers of species have increased. For species that have a lower frequency of occurrence (FOO), sampling variation can be a big factor in showing significant change. However, there are three species with high FOO (coontail, common waterweed, and flat-stem pondweed) that had significant reduction. This could be cause for concern in regard to herbicide use and mechanical harvest (both of which have been used for plant management on Rice Lake). One species, wild celery, had a significant increase over the years and also has a high FOO.

Since Rice Lake has a large watershed, with large amounts of nutrients entering externally, aquatic plants can help maintain better water clarity in the lake. A reduction in plant coverage has occurred in the main basins and should be considered in management practices. However, there is still good diversity being maintained and is an indicator of a relatively healthy plant community.

FQI Comparison	Number of species	Mean conservatism	FQI
2008	38	6.2	38.21
2013	39	6.2	38.59
2018	42	6.12	39.66

Table 9: FQI comparison of three plant surveys.

The FQI in Rice Lake remains high and has even improved slightly. This indicates a healthy plant community. Although coverage has decreased some, diversity and less tolerant plant species are being maintained.

Summary

The 2018 macrophyte survey resulted in a moderate to high diversity of plant species. Two invasive species were sampled/viewed and two invasive species were observed in a boat survey. There was no hybrid watermilfoil sampled, which had been discovered earlier in the summer 2018. A chi-square analysis comparing previous surveys reflected a decrease in the FOO of 10 species and an increase in FOO in five species (statistically comparing 2008 to 2018). The coverage of plants has decreased since 2008. The diversity indicators and FQI basically remained unchanged.

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