Aquatic Macrophyte Survey-Point Intercept Method

Lake Owen, Bayfield County Wisconsin

WBIC: 2900200

August 2019

Survey and analysis conducted by: Ecological Integrity Service, LLC

Amery, WI

Abstract

An aquatic macrophyte survey using the point intercept method was conducted on Lake Owen, Bayfield County Wisconsin in July/August 2019. The survey resulted in a species richness of 41 and a Simpson's diversity index of 0.93. Of the species, all 41 are native. The plant coverage was 68.3% within the depth defined littoral zone (very small littoral zone) and 27.9% of the entire lake (of sample point grid). The maximum depth with plants was 27.2 feet and a mean of 8.35 feet. There were three species of special concern sampled: *Littorella uniflora* (littorella), *Najas gracillima* (northern naiad) and *Stuckenia filiformis* (fine leaved pondweed). No invasive plant species were sampled or viewed, but three invasive species were observed in a boat survey. These species were *Iris pseudacorus* (yellow iris), *Myosotis scorpioides* (aquatic for-get-me-not) and *Phragmites australis ssp. australis* (common reed). The calculated floristic quality index (FQI) for 2019 was 43.0. A chi-square analysis resulted in statistically significant increases in nine species since 2013. There was a statistically significant decrease in two species since 2013. The species richness was similar from 2013 to 2019 (38 species to 41 species). Simpson's diversity index increased from 0.91 to 0.93, while the FQI rose from 38.5 to 43.0 from 2013 to 2019.

Introduction

In June and August 2019, an aquatic macrophyte survey was conducted on Lake Owen (WBIC: 2900200), in Bayfield County Wisconsin using the point intercept method developed by the Wisconsin Department of Natural Resources. Lake Owen is a 1250-acre lake with a maximum depth of 95 feet and a mean depth of 27 feet. The lake is designated as a spring lake and has an oligotrophic trophic status. Development around the lakes is limited with much of the riparian zone undeveloped.

This report presents a summary and analysis of data collected in 2019 and allows for the comparison to the 2013 baseline aquatic macrophyte survey. The primary goal of the survey is to conduct long-term monitoring of aquatic plant populations and allow for the evaluation of any changes that may occur from human impact. Invasive species presence and locations are key components to a survey of this type. This survey is acceptable for aquatic plant management purposes.

Figure 1: Map of Lake Owen.

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 each 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. 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. The process 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. Any plant within 6 feet of the boat was recorded as "viewed." A handheld 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 touching the point.

The sample grid was surveyed twice in 2019. The first survey occurred in June to mostly survey for the invasive species *Potamogeton crispus* (curly-leaf pondweed). This plant grows early and has typically senesced when the late-season survey is conducted, which occurred in late July and early August when most aquatic plants are actively growing.

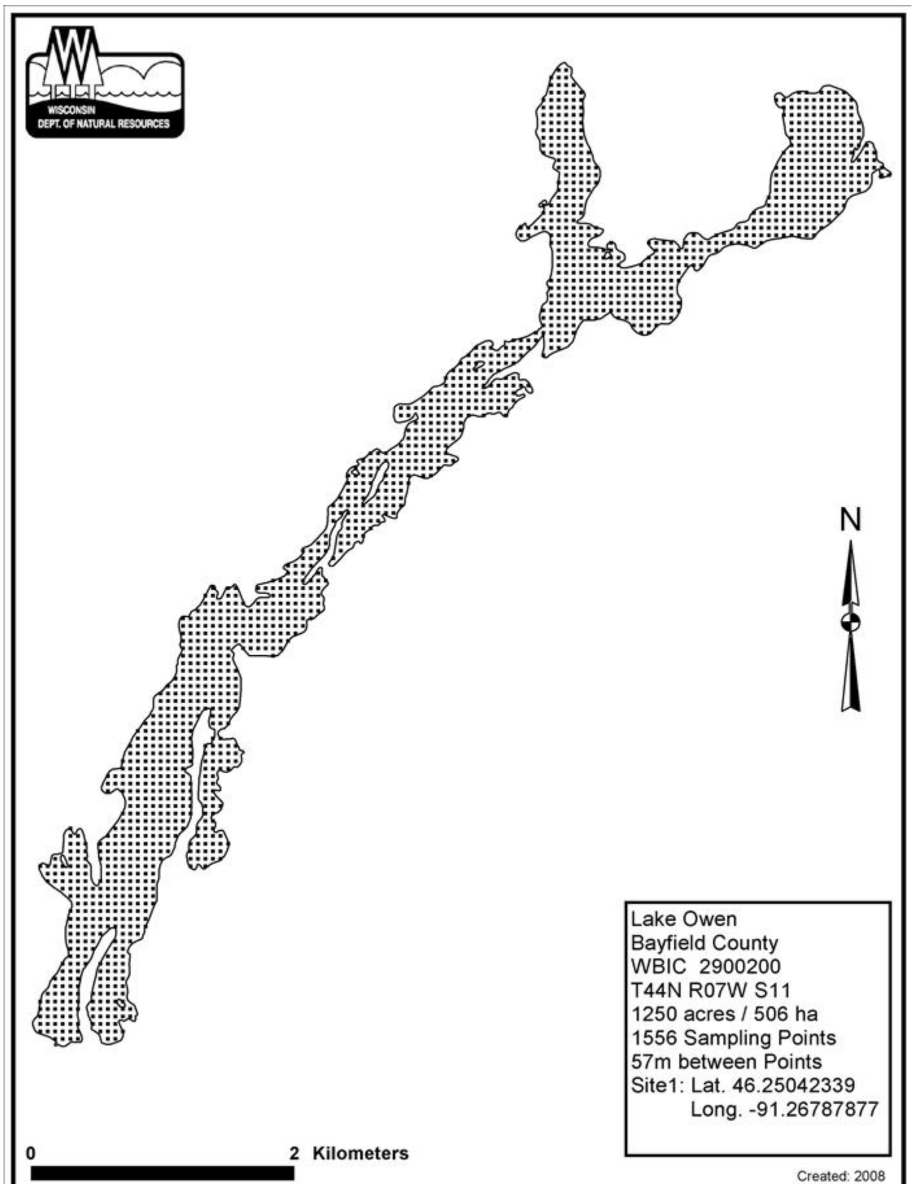


Figure 2: Point intercept sample grid for Lake Owen.

At each sample location, a double-sided fourteen-tine rake was used to rake a 1-meter tow off the bow of the boat. All plants present on the rake and those that fell off the rake were identified and rated for rake fullness. The rake fullness value was used based on the criteria contained in figure 3 and table 1 below. The 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:

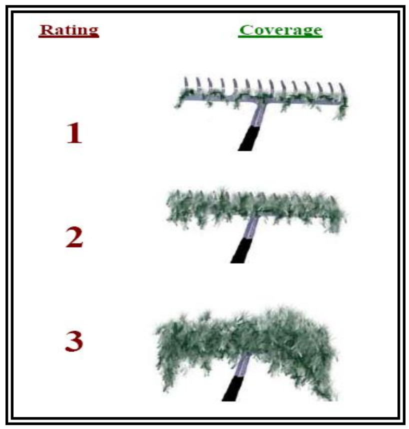


Figure 3: Rake fullness diagram

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 criteria descriptions.

The depth and predominant sediment types were also recorded for each sample point. Caution must be used in determining the sediment type data 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 species 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.

Data analysis methods

Data collected and analyzed resulting in the following information:

- Frequency of occurrence (FOO) in sample points with vegetation (littoral zone)
- Relative frequency
- Total points in sample grid
- Total points sampled
- 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.

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 of a particular plant was sampled at depths less then maximum depth plants (littoral zone), regardless if vegetation was present. The second is the percentage of sample points of a particular plant at only points containing vegetation. The first value shows how often the plant would be present in the defined littoral zone (by depth), while the second value shows the frequency of the plant in vegetated areas. 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 is used to analyze the occurrence and location of plant growth based on depth. 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%

These two frequencies will show 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 (FOO) in most cases.

Relative frequency-This value shows a percentage of 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 or makes up 30% of all plants sampled. This value demonstrates which plants are the dominant species in the lake. The higher the relative frequency, the more frequent the plant compared to the other plants.

Relative frequency example:

Suppose 10 points were sampled 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

Results show Plant D is the most frequent sampled plant at all points with 60% (6/10) of the sites having plant D. However, the relative frequency displays 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. In this case, the relative frequency calculated by dividing the individual frequencies by 16.

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%

In comparing plants, 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 shows the true value of the dominant plants present.

Total points in sample grid- The Wisconsin DNR establishes 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.

Sample sites with vegetation- The number of sites where plants were actually sampled, which gives a projection of plant coverage on the lake. Vegetation in 10% of all sample points implies about 10% coverage of plants in the whole lake, assuming an adequate number of sample points have been established. The littoral zone is observed for the number of sample sites with vegetation. If 10% of the littoral zone had sample points with vegetation, then the estimated plant coverage in the littoral zone 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 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" indicates that the two will always be different (diverse) and a "0" indicates 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 greatest depth that plants were sampled. Generally, 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 documents plants viewed but not 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: $FQI = \text{Mean } C \cdot \sqrt{N}$

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

Therefore, a higher FQI indicates a healthier aquatic plant community, which is an indication of a 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. This analysis also compares the 2013 and 2019 macrophyte surveys.

Summary of Northern Lakes and Forests for Floristic Quality Index:

(Nichols, 1999)

	Northern Lakes and Forests
Median species richness	13
Median conservatism	6.7
Median Floristic Quality	24.3

*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

The data from the 2019 whole lake aquatic macrophyte survey on Lake Owen reflects a diverse plant community with limited coverage of plants. The plant growth is limited to several bays. The littoral zone is quite narrow which limits the habitat for plant growth. This is reflected by having plants sampled in only 68.3% of the littoral zone and 27.9% of the entire lake sample grid. The 27.2 feet (mean depth of 8.35 feet) of plant growth supports they high water clarity.

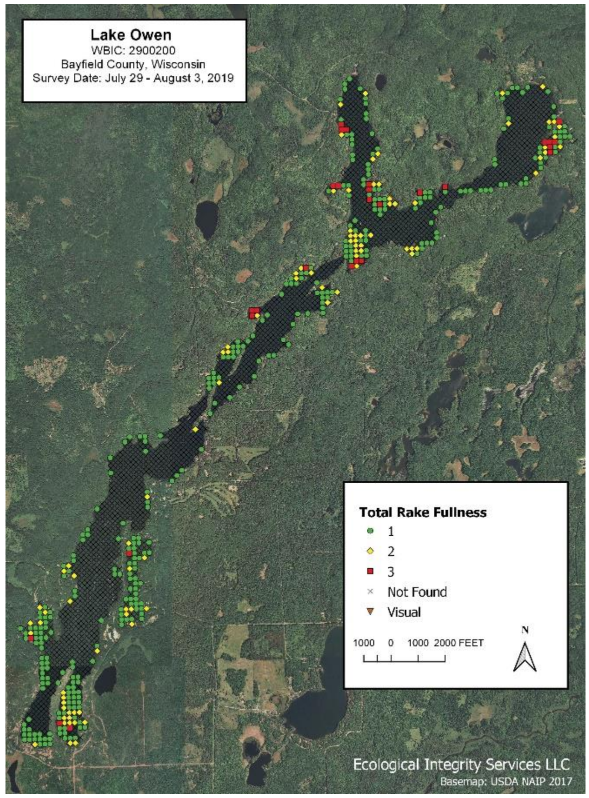
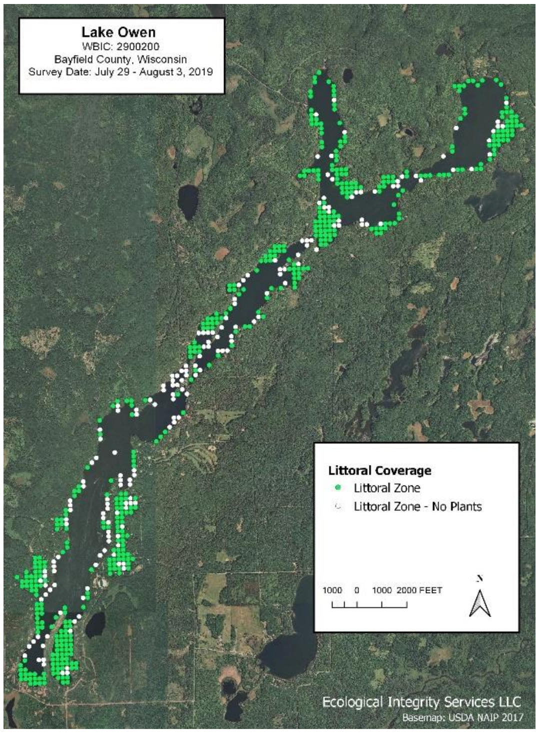


Figure 3: Total rake fullness at each sample point.

The species richness was 42 species sampled on the rake, all of which are native species. Simpson's diversity index is high at 0.93. There was an average of 2.73 species sampled at each rake sample where plants were growing.

Total number of sites whole lake grid	1556
Total number of sites with vegetation	435
Total number of sites shallower than the maximum depth of plants (less than 27.2 ft)	637
Frequency of occurrence at sites shallower than the maximum depth of plants	68.3%
Frequency of occurrence in the entire lake	27.9%
Simpson Diversity Index	0.93
Maximum depth of plants	27.20 ft.
Mean depth of plants	8.35 ft
The average number of all species per site (shallower than maximum depth with plants)	1.85
The average number of all species per site (vegetated sites only)	2.73
Species Richness	41
Species Richness (including visuals)	42

Table 1: Various stats for Lake Owen 2019 aquatic macrophyte survey.



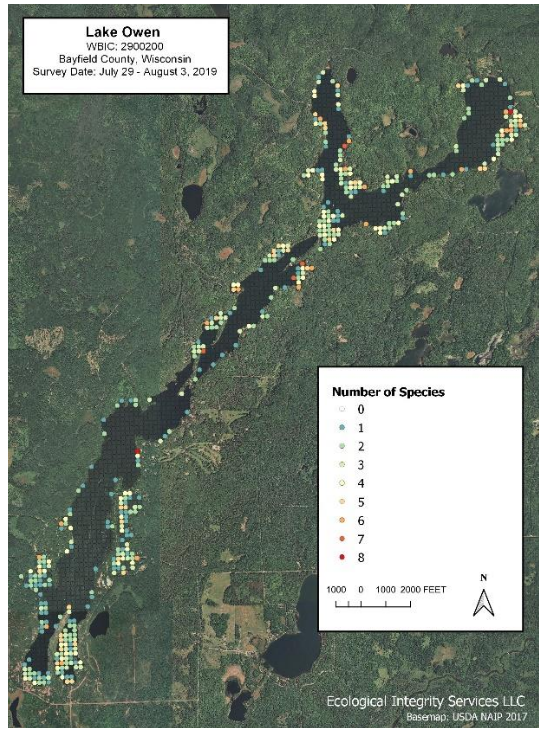


Figure 4: Map of plant coverage (littoral zone) and species richness in Lake Owen, 2019.

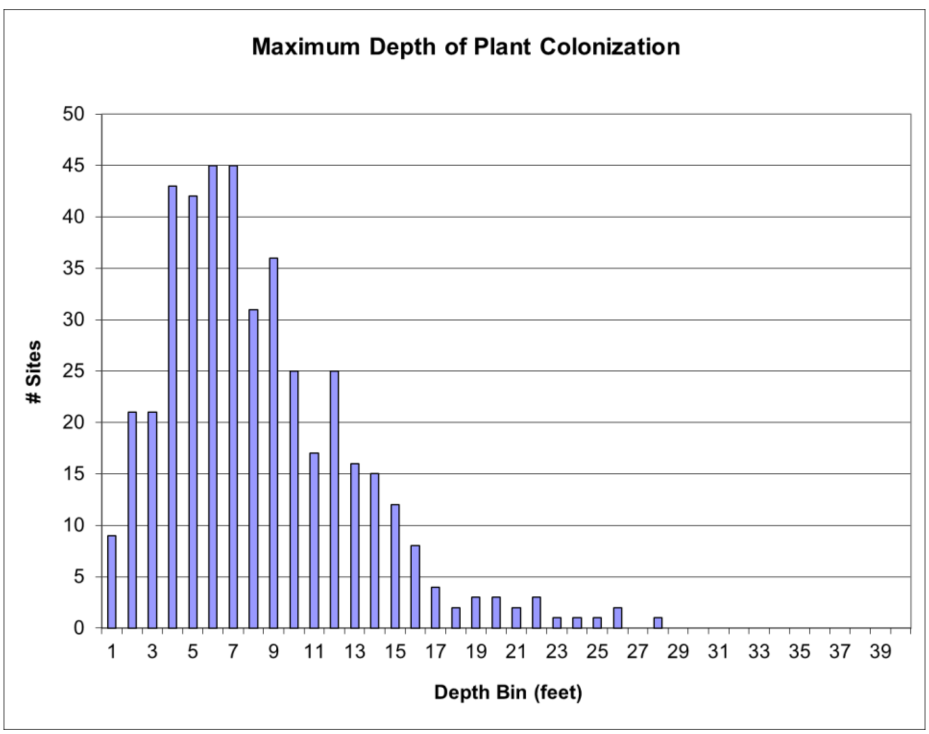


Figure 5: Number of plants sampled at particular depths in Lake Owen.

Table 2: Species list for Lake Owen with a frequency of occurrence (FOO) and fullness data.

Species	FOO in vegetated littoral	FOO in littoral by the depth	Relative frequency	Number sampled	Mean rake fullness	Number viewed
Vallisneria americana, Wild celery	33.79	23.08	12.35	147	1.05	4
Elodea canadensis, Common waterweed	28.05	19.15	10.25	122	1.05	
Potamogeton robbinsii, Fern pondweed	25.29	17.27	9.24	110	1.07	
Potamogeton gramineus, Variable pondweed	23.91	16.33	8.74	104	1.02	2
Myriophyllum sibiricum, Northern water-milfoil	23.45	16.01	8.57	102	1.11	3
Chara sp., Muskgrasses	20.46	13.97	7.48	89	1.00	
Potamogeton zosteriformis, Flat-stem pondweed	15.40	10.52	5.63	67	1.16	
Najas flexilis, Slender naiad	15.17	10.36	5.55	66	1.02	
Bidens beckii, Water marigold	11.49	7.85	4.20	50	1.00	
Ceratophyllum demersum, Coontail	11.49	7.85	4.20	50	1.16	
Potamogeton amplifolius, Large-leaf pondweed	8.28	5.65	3.03	36	1.03	5
Potamogeton pusillus, Small pondweed	7.59	5.18	2.77	33	1.03	
Sagittaria cristata, Crested arrowhead	7.13	4.87	2.61	31	1.03	
Potamogeton richardsonii, Clasping-leaf pondweed	5.06	3.45	1.85	22	1.00	4
Elodea nuttallii, Slender waterweed	4.83	3.30	1.76	21	1.00	
Potamogeton strictifolius, Stiff pondweed	4.60	3.14	1.68	20	1.00	
Eleocharis acicularis, Needle spikerush	4.37	2.98	1.60	19	1.00	
Nymphaea odorata, White water lily	3.91	2.67	1.43	17	1.00	4
Potamogeton natans, Floating-leaf pondweed	2.30	1.57	0.84	10	1.00	1
Potamogeton illinoensis, Illinois pondweed	2.07	1.41	0.76	9	1.00	
Potamogeton praelongus, White-stem pondweed	2.07	1.41	0.76	9	1.00	
Polygonum amphibium, Water smartweed	1.61	1.10	0.59	7	1.00	
Nitella sp., Nitella	1.15	0.78	0.42	5	1.00	
Littorella uniflora, Littorella	0.92	0.63	0.34	4	1.00	
Ranunculus aquatilis, White water crowfoot	0.92	0.63	0.34	4	1.25	
Stuckenia pectinata, Sago pondweed	0.92	0.63	0.34	4	1.00	
Heteranthera dubia, Water star-grass	0.69	0.47	0.25	3	1.00	
Isoetes echinospora, Spiny spored-quillwort	0.69	0.47	0.25	3	1.00	
Juncus pelocarpus f. submersus, Brown-fruited rush	0.69	0.47	0.25	3	1.33	
Myriophyllum tenellum, Dwarf water-milfoil	0.69	0.47	0.25	3	1.00	
Potamogeton foliosus, Leafy pondweed	0.69	0.47	0.25	3	1.00	
Brasenia schreberi, Watershield	0.46	0.31	0.17	2	1.00	
Myriophyllum alterniflorum, Alternate-flowered water-milfoil	0.46	0.31	0.17	2	1.00	
Najas gracillima, Northern naiad	0.46	0.31	0.17	2	1.00	
Ranunculus flammula, Creeping spearwort	0.46	0.31	0.17	2	1.00	
Stuckenia filiformis, Fine-leaved pondweed	0.46	0.31	0.17	2	1.00	

Species	FOO in vegetated littoral	FOO in littoral by the depth	Relative frequency	Number sampled	Mean rake fullness	Number viewed
Dulichium arundinaceum, Three-way sedge	0.23	0.16	0.08	1	1.00	
Nuphar variegata, Spatterdock	0.23	0.16	0.08	1	1.00	
Potamogeton friesii, Fries' pondweed	0.23	0.16	0.08	1	1.00	
Schoenoplectus acutus, Hardstem bulrush	0.23	0.16	0.08	1	1.00	
Sparganium natans, Floating bur-reed	0.23	0.16	0.08	1	1.00	
Aquatic moss	0.23	0.16	n/a	1	1.00	
Freshwater sponge	0.23	0.16	n/a	1	1.00	
Filamentous algae	2.07	1.41	n/a	9	1.00	
Sparganium eurycarpum, common bur-reed	viewed	only				1

The most common species sampled was *Vallisneria americana* (wild celery). The relative frequency was only 12.32%, so although sampled most frequently, it is not completely dominating the plant community. *Elodea canadensis* (common waterweed) and *Potamogeton robbinsii* (fern pondweed) were the second and third most sampled, respectively. All three aquatic plants are common in Wisconsin lakes. They serve important roles in the lake ecosystem, including providing important habitat for invertebrates and fish.

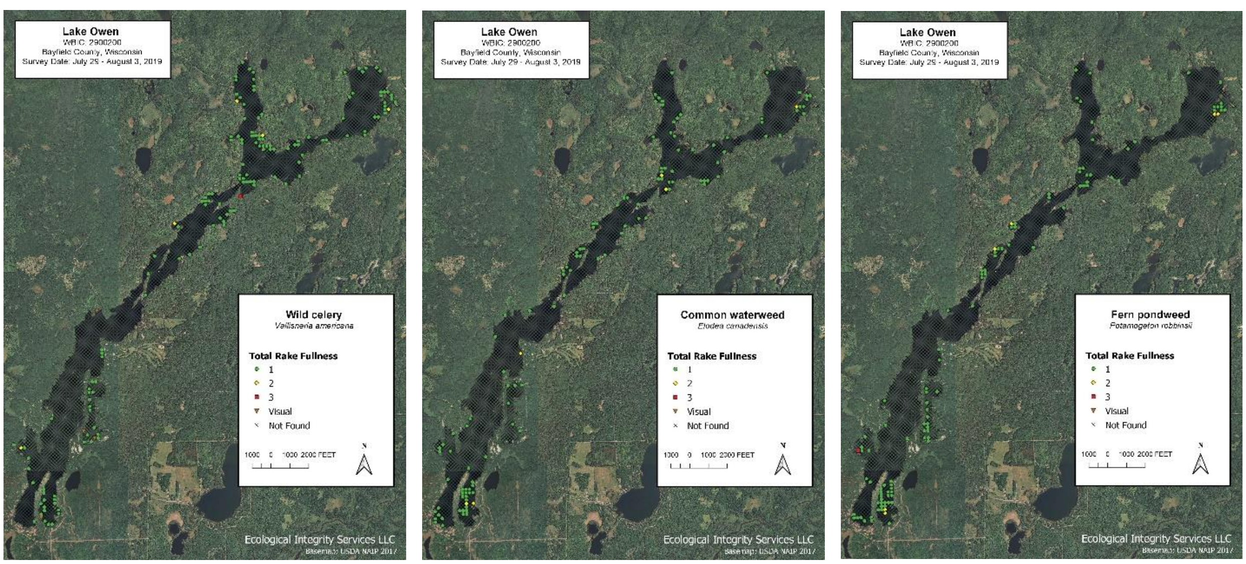


Figure 6: Distribution maps of the three most common species sampled in Lake Owen, 2019.

Figure 7: Pictures of the three most common species sampled. *Vallisneria americana*-wild celery (photo from Paul Skawinski, *Aquatic Plants of the Upper Midwest*, used with permission), *Elodea canandensis*-common waterweed (photo from Paul Skawinski, Aquatic Plants of the Upper Midwest, used with permission) and *Potamogeton robbinsii*-fern pondweed (photo from Paul Skawinski, *Aquatic Plants of the Upper Midwest*, used with permission).

Species of special concern

There were two species of special concern sampled in Lake Owen in 2019. Species of special concern are species whose distribution is limited or they have specific habitat needs. These species are typically sensitive to changes in the lake that may be attributed to human activity.

Species of special concern	FOO	Number sampled and/or viewed
Littorella uniflora, Littorella	0.92%	4
Najas gracillima, Northern naiad	0.46%	2
Stuckenia filiformis, Fine-leaved pondweed	0.46%	2

Table 3: List of species of special concern sampled in Lake Owen, 2019.

Littorella uniflora was sampled at only four locations. However, there was fairly large aerial coverage in some of these locations with littorella covering some sandy shallow areas.

Figure 8: Pictures of *Littorella uniflora* (left), *Najas gracillima* (middle) and *Stuckenia filiformis* (right). Paul Skawinski, *Aquatic Plants of the Upper Midwest*, used with permission.

Invasive species

There were no non-native invasive species sampled or viewed from the survey grid. However, there were three species observed in a boat survey conducted in the early summer and late summer. The three plants were *Iris pseudacorus* (yellow iris), *Myosotis scorpioides* (aquatic for-get-me-not), and *Phragmites australis ssp. australis* (common reed). After this plant survey occurred, the yellow iris was treated with herbicide and will be evaluated in 2020. The aquatic for-get-me-not locations were recorded and mapped, with no management at this time. The common reed is an isolated bed and should be managed.

Figure 9: Pictures of the yellow iris (left) and aquatic for-get-me-not (middle) and non-native common reed (right). Photos from Wisconsin DNR website-invasive species.

Figure 10: Map showing locations of the yellow iris (top), aquatic for-get-me-not (middle) in June, 2019.

Figure 11: Map showing locations of common reed in August.

Floristic quality index

The floristic quality index data for Lake Owen in 2019 also reflects a healthy plant community with many sensitive plants. The conservatism value of a plant indicates the sensitivity a plant has to habitat changes in the lake. Most of these changes are presumably due to human activity on and around the lake. The mean conservatism value for Lake Owen was higher than the eco-region (Northern Lakes and Forests) median. The FQI calculated much higher than the eco-region median mostly due to the higher number of species sampled. The FQI was 43, which is high for a lake, thus demonstrating a healthy, diverse plant community that human activity does not seem to have affected.

Floristic quality index parameter	**Lake Owen 2019**	**Median for Northern Lakes and Forests Eco-region**
Number of species in FQI	40	13
Mean Conservatism value	6.8	6.7
FQI	43.00	24.3

Table 4: Floristic quality index data for Lake Owen 2019.

Comparison of 2013-2019 Data

Comparing periodic aquatic macrophyte surveys is important to determine if any changes in the plant community have occurred. An aquatic macrophyte survey was conducted on Lake Owen in 2013. This allows for a comparison between 2013 and 2019.

Statistic	Lake Owen 2013	Lake Owen 2019
Species richness	38	42
Simpson's diversity index	0.91	0.93
Maximum depth with plants	22.9 ft	27.2 ft
Mean conservatism value	6.81	6.80
FQI	38.50	43.00
Sample points with plants	393	435

Table 5: Comparison statistics for 2013 and 2019 surveys.

The general statistics of 2013 and 2019 are similar. The species richness is slightly higher in 2019 as well as the Simpson's diversity index. The maximum depth of plants was 4.3 feet deeper in 2019 as compared to 2013. The mean conservatism was basically the same and the FQI was somewhat higher in 2019. There were 42 more sites with plants in 2019 than in 2013. There is no indication of any changes to be concerned within the plant community over the past six years.

For a more in-depth analysis of change, the frequency of occurrence of individual species was analyzed using a chi-square analysis. If the frequency change is statistically significant, the p-value derived from the chi-square will be less than 0.05. The lower the p-value, the more statistically significant the change.

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.

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 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 2019 survey.

5. Habitat changes and plant dominance changes can lead to plant declines. If an area receives a large amount of sediment from human activity, the plant community may respond. For this to occur in 5-7 years is 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 of the non-native rusty crayfish or common carp. Crayfish are abundant in Lake Owen, but there is no mention of the invasive rusty crayfish with the Wisconsin DNR in Lake Owen.

Table 7 lists all species sampled in both the 2013 and 2019 surveys and the number of times sampled. The p-value from the chi-square indicates the significance of any change, whether positive (increase) or negative (decrease).

Table 6: Chi-square analysis results of frequency for each species 2013 and 2019 surveys.

Species	Number sampled 2013	Number sampled 2019	Change	Significance (n.s="not significant")	P-value
Vallisneria americana, Wild celery	147	147	n/c	**n/a**	
Elodea sp.(*E. canadensis* and *E. nutalli* combined)*	161	143	-	**n.s.**	
Potamogeton robbinsii, Fern pondweed	124	110	-	**n.s.**	
Potamogeton gramineus, Variable pondweed	54	104	+	**significant**	0.0001
Myriophyllum sibiricum, Northern water-milfoil	102	102	n/c	**n/a**	
Chara sp., Muskgrasses	42	89	+	**significant**	7×10^{-5}
Potamogeton zosteriformis, Flat-stem pondweed	40	67	+	**significant**	0.02
Najas flexilis, Slender naiad	43	66	+	**significant**	0.05
Bidens beckii, Water marigold	23	50	+	**significant**	0.003
Ceratophyllum demersum, Coontail	49	50	+	**n.s.**	
Potamogeton amplifolius, Large-leaf pondweed	63	36	-	**significant**	0.002
Potamogeton pusillus, Small pondweed	9	33	+	**significant**	0.0004
Sagittaria cristata, Crested arrowhead	21	31	+	**n.s.**	
Potamogeton richardsonii, Clasping-leaf pondweed	20	22	+	**n.s.**	
Potamogeton strictifolius, Stiff pondweed	3	20	+	**significant**	0.0006
Eleocharis acicularis, Needle spikerush	23	19	-	**n.s.**	
Nymphaea odorata, White water lily	7	17	+	**n.s.**	
Potamogeton natans, Floating-leaf pondweed	6	10	+	**n.s.**	
Potamogeton illinoensis, Illinois pondweed	15	9	-	**n.s.**	
Potamogeton praelongus, White-stem pondweed	0	9	+	**significant**	0.003
Polygonum amphibium, Water smartweed	0	7	+	**significant**	0.01

Species	**Number sampled 2013**	**Number sampled 2019**	**Change**	**Significance (n.s=”not significant”)**	**P-value**
Nitella sp., Nitella	1	5	**+**	**n.s.**	
Littorella uniflora, Littorella	0	4	**+**	**n.s.**	
Ranunculus aquatilis, White water crowfoot	1	4	**+**	**n.s.**	
Stuckenia pectinata, Sago pondweed	0	4	**+**	**n.s.**	
Heteranthera dubia, Water star-grass	0	3	**+**	**n.s.**	
Isoetes echinospora, Spiny spored-quillwort	2	3	**+**	**n.s.**	
Juncus pelocarpus f. submersus, Brown-fruited rush	1	3	**+**	**n.s.**	
Myriophyllum tenellum, Dwarf water-milfoil	2	3	**+**	**n.s.**	
Potamogeton foliosus, Leafy pondweed	10	3	**-**	**significant**	0.04
Brasenia schreberi, Watershield	1	2	**+**	**n.s.**	
Myriophyllum alterniflorum, Alternate-flowered water-milfoil	0	2	**+**	**n.s.**	
Najas gracillima, Northern naiad	1	2	**+**	**n.s.**	
Ranunculus flammula, Creeping spearwort	0	2	**+**	**n.s.**	
Stuckenia filiformis, Fine-leaved pondweed	7	2	**-**	**n.s.**	
Dulichium arundinaceum, Three-way sedge	0	1	**+**	**n.s.**	
Nuphar variegata, Spatterdock	0	1	**+**	**n.s.**	
Potamogeton friesii, Fries' pondweed	3	1	**-**	**n.s.**	
Schoenoplectus acutus, Hardstem bulrush	0	1	**+**	**n.s.**	
Sparganium emersum, Short-stemmed bur-reed	2	1	**-**	**n.s.**	
Potamogeton vaseyi, Vasey's pondweed	1	0	**-**	**n.s.**	
Sagittaria latifolia, common arrowhead	1	0	**-**	**n.s.**	
Utricularia resupinata, Small purple bladderwort	1	0	**-**	**n.s.**	
Ceratophyllum echinatum, spiny hornwort	1	0	**-**	**n.s.**	

* *Elodea* species were combined for comparison as very easy to interchange identification of these two species.

The chi-square analysis resulted in a statistically significant increase in nine plant species. There was a statistically significant decrease in two native species. Most of the significant changes occurred with plants with fairly high frequency (more than just a few sampled). This may indicate that the changes are a natural variation of plant growth as well as sampling variation.

Species with a significant increase from 2013-2019	P-value
Potamogeton gramineus, Variable pondweed	0.0001
Chara sp., Muskgrasses	7 X 10^{-5}
Potamogeton zosteriformis, Flat-stem pondweed	0.02
Najas flexilis, Slender naiad	0.05
Bidens beckii, Water marigold	0.003
Potamogeton pusillus, Small pondweed	0.0004
Potamogeton strictifolius, Stiff pondweed	0.0006
Potamogeton praelongus, White-stem pondweed	0.003
Polygonum amphibium, Water smartweed	0.01

Species with a significant decrease from 2013-2019	P-value
Potamogeton amplifolius, Large-leaf pondweed	0.002
Potamogeton foliosus, Leafy pondweed	0.04

Table 7: Summary of species with a significant increase or decrease in 2013-2019.

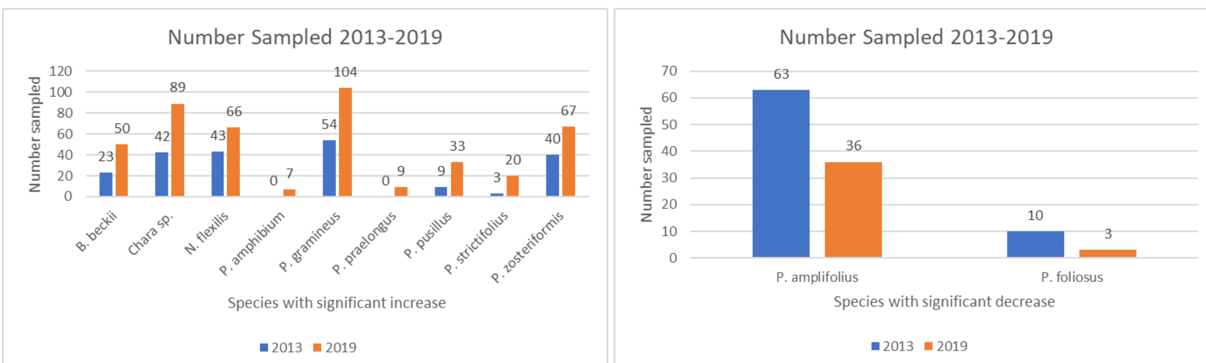


Figure 12: Graphs of number sampled for each species with significant increase (left) and significant decrease (right).

Although the chi-square analysis did not indicate significant decreases and each only sampled once, there were three sensitive plants (two of which are species of special concern) sampled in 2013 but not in 2019. These plants were *Potamogeton vaseyi* (Vasey's pondweed), *Utricularia resupinate* (Small purple bladderwort) and *Ceratophyllum echinatum* (Spiny hornwort). The GPS location of these plants from 2013 was carefully sampled in 2019 to survey if these plants would still be present. None of them were sampled or observed. It is possible they are still living in Lake Owen, but their coverage is likely limited.

Discussion

Lake Owen is an oligotrophic lake that has exceptionally clear water and low productivity. As a result, plants can grow in deep water. The coverage of plants in the lake is limited as the lake is deep, and in most areas near shore, the depth changes rapidly to levels plants cannot grow. Much of the dominant substrate is sand and rock, which can harbor only certain plants. Therefore, the plant community in Lake Owen is important to preserve. Since there are limited areas that provide important habitat for organisms near the bottom of the food web, it is imperative that these areas continue to thrive.

The susceptibility of Lake Owen to AIS, such as Eurasian water-milfoil, is likely lower than many other lakes. This is due to limited high nutrient sediments in shallow water regions for these plants to thrive. However, since these areas make up the vast majority of plant growth in Lake Owen, the introduction of AIS plants into these limited plant areas would be detrimental to the lake ecosystem. Native plants can reduce the success of AIS taking hold in the lake. Therefore, it is important to help maintain a diverse, native plant community in Lake Owen. Figure 13 shows a map designating areas of high concern due to susceptibility of AIS plant species. These areas are highlighted due to present plant growth, sediment type, boat traffic and/or proximity boat launches.

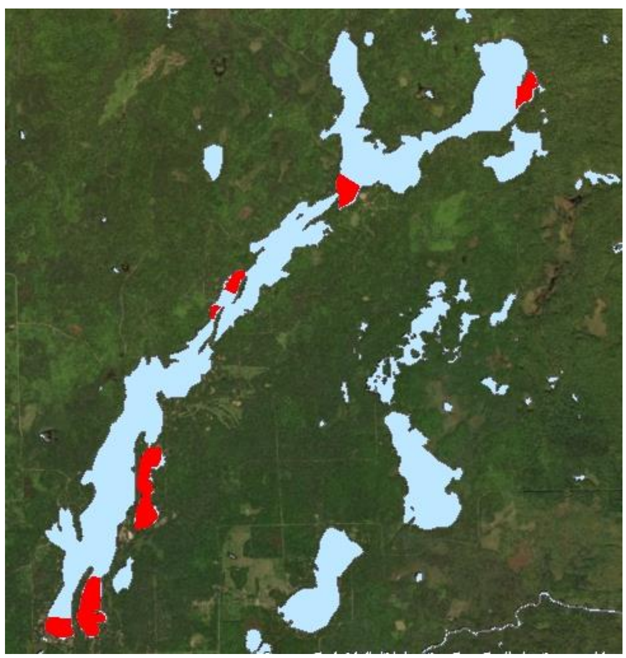


Figure 13: Areas of high concern for AIS susceptibility, Lake Owen.

Lake Owen contains many sensitive plants (high conservatism value), including three species of special concern sampled in 2019 and five if combining samples in 2013 with 2019. These plants are most susceptible to changes in the lake, including habitat changes such as sedimentation of low nutrient substrates or water chemistry. These changes are generally driven by human activity in and around the lake. It is important to continue monitoring the Lake Owen aquatic plant community to aid in evaluating changes potentially occurring in the Lake Owen ecosystem.

Critical plant habitat

Plants play a critical role in the lake ecosystem. They provide habitat for plankton and invertebrates, which provide food for fish. Plants provide cover for bait fish, which predatory fish can forage on. Floating and emergent vegetation (plants that penetrate beyond the water surface such as cattail) provide sediment and shoreline stability by reducing energy in waves. Emergent plants also provide cover and nesting areas for amphibians, reptiles, birds and mammals. Sensitive plants tend to inhabit low nutrient sediments where other plants are not adapted for this substrate.

Since Lake Owen has limited areas plant coverage, the areas that do have plants are very important. Areas with high number species richness, floating and/or emergent vegetation, and areas with sensitive plants should be considered critical plant habitat. In reviewing locations of plant habitat that reflect these criteria, a map showing these areas was generated. These areas should be monitored for any changes and further scrutinized in a broader critical habitat analysis.

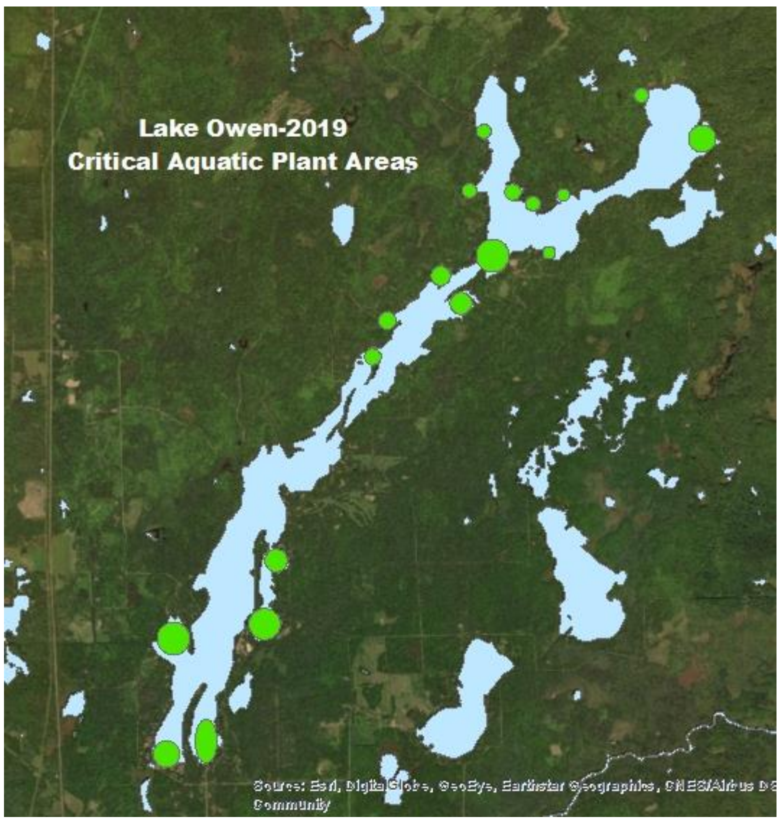


Figure 14: Map showing critical plant habitat areas (green) based upon species richness, floating/emergent plant presence, and sensitive plants (plants with high conservatism values).

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