Aquatic Macrophyte Survey

Bone Lake, Polk County, Wisconsin July, 2017

Fieldwork and analysis conducted by: Ecological Integrity Service, LLC Amery, WI

Abstract

In June and July 2017, a full lake point intercept aquatic macrophyte survey was conducted on Bone Lake in Polk County WI. On June 1 and 2, the invasive plant *Potamogeton crispus*-curly leaf pondweed, was sampled with a frequency of occurrence of 36.04%. In July, the point intercept survey was repeated resulting in a species richness of 35 native species and a Simpson's diversity index of 0.91. Four invasive species (including curly leaf pondweed) were observed but not sampled in the survey. The maximum plant depth was 18.6 feet and mean depth of 4.98 feet. The defined littoral zone by depth was 28.7% of the sample points and within that depth 72.82% of the sample points had plants. The mean rake fullness (scale of 1-3 where plants present) was 1.04. In comparing the 2017 survey to previous surveys (2007 and 2012), there was a statistically significant reduction in four native species from 2012 to 2017, and five native species from 2007 to 2017. A statistically significant increase was found with four species from 2012 to 2017 and three species from 2007 to 2017. There was little to no change in species richness, Simpson's diversity index and FQI when comparing these three survey years.

Introduction

In June and July 2017, a full lake aquatic macrophyte survey was conducted using the point intercept (PI) method on Bone Lake in Polk County Wisconsin. Bone Lake is a 1667-acre drainage lake with a maximum depth of 43 feet and mean depth of 23 feet. Development around Bone Lake is extensive with much of the lakeshore/riparian zone being developed and/or disturbed from an original native riparian zone. The lake is eutrophic based upon the Carlson 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 2012 and 2007 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 been occurring on Bone Lake. In addition, invasive species presence and location monitoring is an integral part of this survey. This survey is acceptable for aquatic plant management planning.

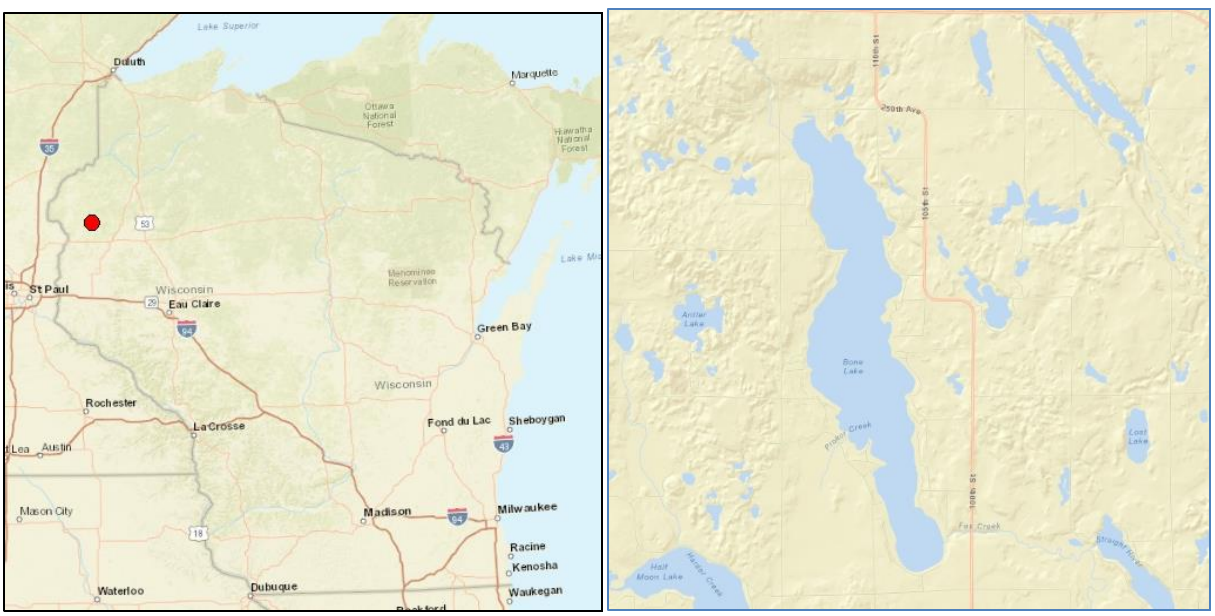


Figure 1: Map of Bone Lake location in Wisconsin and closer surrounding area.

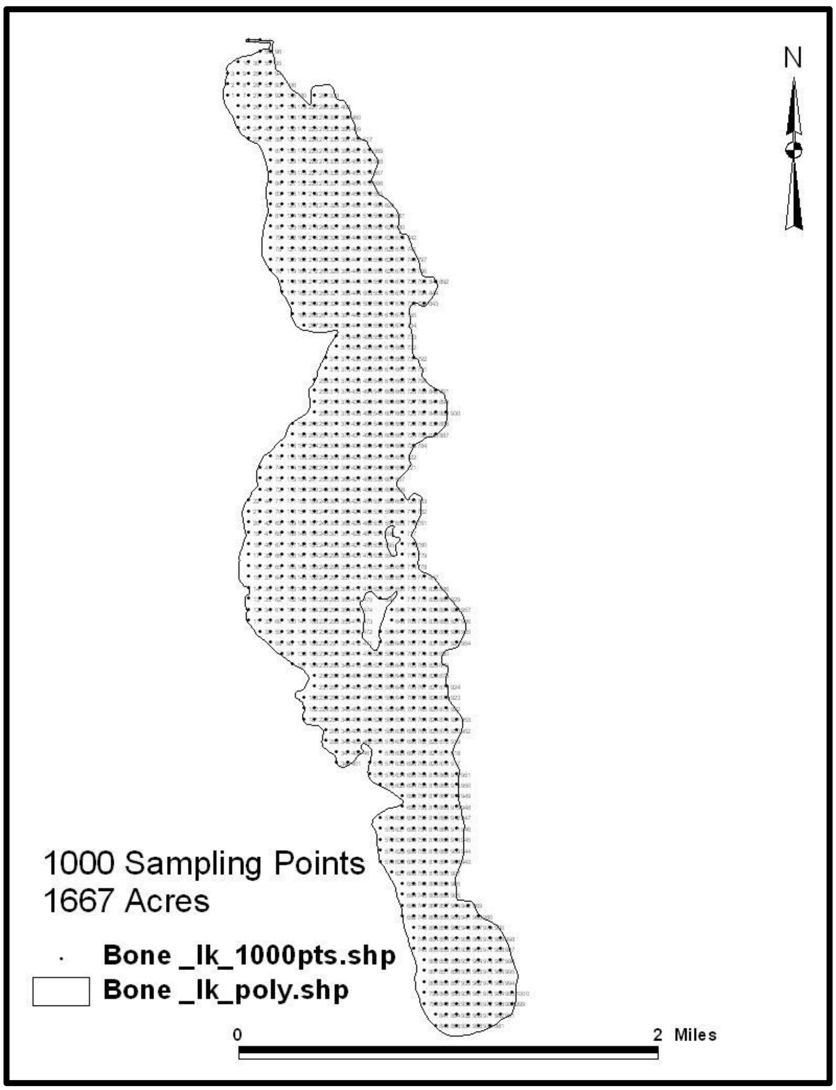
Field Methods

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 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 handheld Global Positioning System (GPS) located the sampling points in the field. The Wisconsin DNR guidelines for point location accuracy were followed with an 80 foot resolution window and the location arrow touching the point.

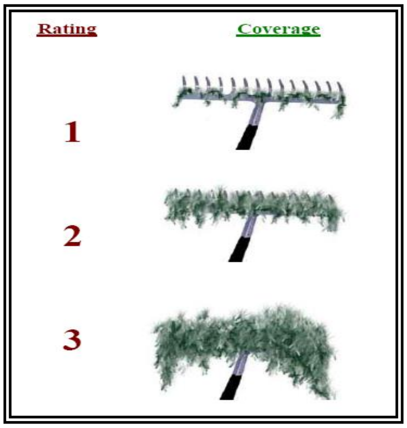
A June survey was conducted to determine the frequency of *Potamogeton crispus*-curly leaf pondweed since this plant tends to senesce before the later season survey. The later season survey was conducted in July in which the plants are actively growing.

Figure 2: Point intercept sample grid for Bone Lake



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 fell 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:



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

The depth and predominant sediment type was 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 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.

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.

Data analysis methods

Data collected and analyzed resulting in the following information:

- Frequency of occurrence 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.

<u>Frequency of occurrence for each species</u>- 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 then maximum depth plants (littoral zone), regardless if vegetation was present. 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. 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 total 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 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 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 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 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. The 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)

	<u>Northcentral Hardwood Forests</u>
Median species richness	14
Median conservatism	5.6
Median Floristic Quality	20.9

*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 2017 Bone Lake point intercept survey revealed a healthy, diverse aquatic plant community. There were 35 native species sampled, one invasive species (*Potamogeton crispus*-curly leaf pondweed) sampled and one non-native species (-reed canary grass) was viewed. The Simpson's diversity index was 0.90, which indicates more diversity. The coverage of plants in Bone Lake is limited to a narrow littoral zone that borders the lake. Of the 1000 sample locations, only 222 had vegetation, which is 22.2% of the lake. Within that small defined littoral zone, 77.35% of this area had plants present. Figure 3 shows where plants are present and the rake density at each location.

Plants were found growing as deep as 18.6 feet, with a mean depth of 4.98 feet. Although water clarity is an issue during some growing seasons in Bone Lake, light penetration is adequate to sustain plant life at relatively deep depths.

Total number of sample points in full survey	1000
Total number of sites with vegetation	209
Total number of sites shallower than maximum depth of plants	287
Frequency of occurrence at sites shallower than maximum depth of plants	72.82
Simpson Diversity Index	0.91
Maximum depth of plants	18.60 ft.
Mean depth of plants	4.98 ft.
Average number of all species per site (veg. sites only)	2.53
Average number of native species per site (veg. sites only)	2.43
Species Richness	35
Species Richness (including visuals)	38
Mean rake fullness	1.04

Table 1: Summary of data summarizing the 2017 PI survey results.

On a scale of 1-3 of where plants are present the density of plants is low with a mean rake fullness of 1.04. Figure 4 shows the species richness at each point. The diversity is higher in most bays, with the highest being in the north end of the lake, and some smaller bays on the west side. It is common for bays to have the higher diversity since there is a more stable habitat for plant growth and often higher nutrient sediment available. Much of Bone Lake sediment is dominated by sand and rock, which can limit plant growth.

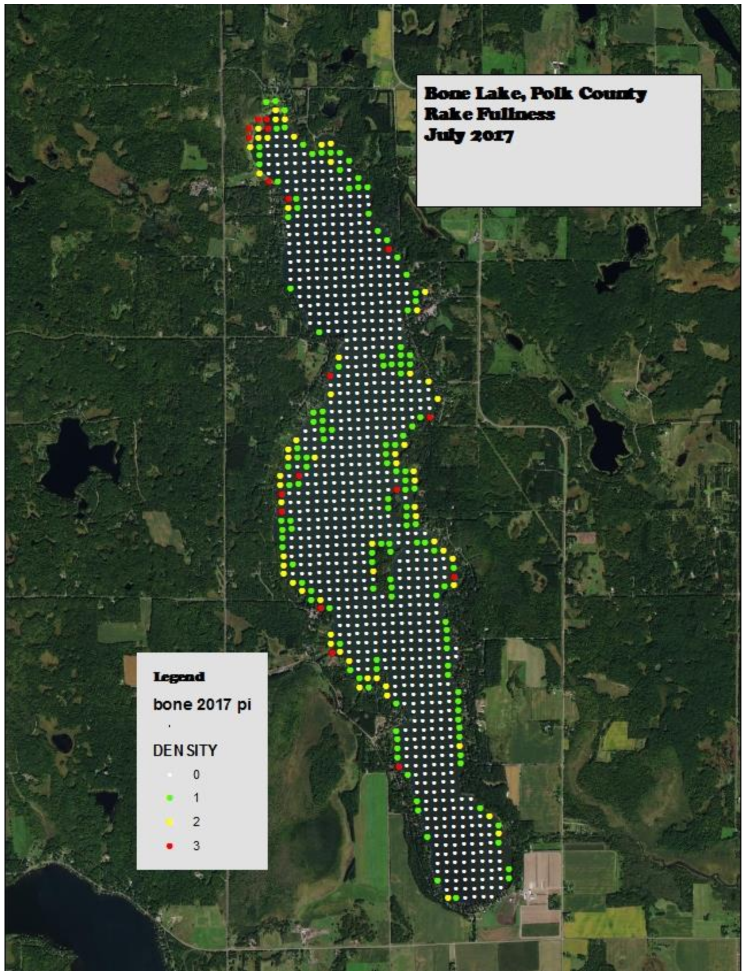


Figure 3: Map of plant density at each sample site in July, 2017.

Table 2: Species list with frequency of occurrence (FOO) in vegetated areas, littoral zone (depth less than maximum with plants, relative frequency and mean density.

Species (Sampled July 13-17)	**FOO (vegetated areas)**	**FOO (littoral)**	**Relative freq.**	**# sampled**	**Mean Density**	**# viewed**
Chara sp., Muskgrasses	52.70	40.77	22.1	117	1.33	
Potamogeton crispus,Curly-leaf pondweed (invasive)	18.66	13.59	7.4	80	1.74	
Vallisneria americana, Wild celery	33.33	25.78	14.0	74	1.03	1
Najas flexilis, Slender naiad	15.77	12.20	6.6	35	1.03	
Ceratophyllum demersum, Coontail	15.32	11.85	6.4	34	1.06	
Lemna trisulca, Forked duckweed	15.32	11.85	6.4	34	1.03	
Potamogeton pusillus, Small pondweed	8.56	6.62	3.6	19	1.11	1
Potamogeton zosteriformis, Flat-stem pondweed	8.56	6.62	3.6	19	1.00	1
Stuckenia pectinata, Sago pondweed	8.11	6.27	3.4	18	1.00	3

Species (Sampled July 13-17)	**FOO (vegetated areas)**	**FOO (littoral)**	**Relative freq.**	**# sampled**	**Mean Density**	**# viewed**
Myriophyllum sibiricum, Northern water-milfoil	7.66	5.92	3.2	17	1.00	3
Heteranthera dubia, Water star-grass	4.95	3.83	2.1	11	1.00	
Nitella sp., Nitella	4.50	3.48	1.9	10	1.00	
Potamogeton richardsonii, Clasping-leaf pondweed	4.50	3.48	1.9	10	1.00	1
Lemna minor, Small duckweed	4.05	3.14	1.7	9	1.00	
Potamogeton friesii, Fries' pondweed	4.05	3.14	1.7	9	1.00	
Potamogeton gramineus, Variable pondweed	4.05	3.14	1.7	9	1.00	2
Spirodela polyrhiza, Large duckweed	4.05	3.14	1.7	9	1.00	
Wolffia columbiana, Common watermeal	3.60	2.79	1.5	8	1.00	
Potamogeton illinoensis, Illinois pondweed	3.15	2.44	1.3	7	1.00	
Nymphaea odorata, White water lily	2.70	2.09	1.1	6	1.17	2
Ranunculus aquatilis, White water crowfoot	2.70	2.09	1.1	6	1.00	
Nuphar variegata, Spatterdock	2.25	1.74	0.9	5	1.00	1
Potamogeton praelongus, White-stem pondweed	2.25	1.74	0.9	5	1.00	
Elodea canadensis, Common waterweed	1.80	1.39	0.8	4	1.00	
Schoenoplectus acutus, Hardstem bulrush	1.35	1.05	0.6	3	1.00	1
Bidens beckii, Water marigold	0.90	0.70	0.4	2	1.00	
Eleocharis palustris, Creeping spikerush	0.90	0.70	0.4	2	1.00	
Eleocharis acicularis, Needle spikerush	0.45	0.35	0.2	1	1.00	
Isoetes echinospora, Spiny spored-quillwort	0.45	0.35	0.2	1	1.00	
Potamogeton foliosus, Leafy pondweed	0.45	0.35	0.2	1	1.00	
Potamogeton strictifolius, Stiff pondweed	0.45	0.35	0.2	1	1.00	
Sagittaria rigida, Sessile-fruited arrowhead	0.45	0.35	0.2	1	1.00	
Schoenoplectus pungens, Three-square bulrush	0.45	0.35	0.2	1	1.00	
Sparganium eurycarpum, Common bur-reed	0.45	0.35	0.2	1	1.00	1
Zizania palustris, Northern wild rice	0.45	0.35	0.2	1	1.00	
Filamentous algae	25.68	19.86		57	1.00	
Carex comosa, Bottle brush sedge						1
Phalaris arundinacea, Reed canary grass (invasive)						1
Potamogeton amplifolius, Large-leaf pondweed						1

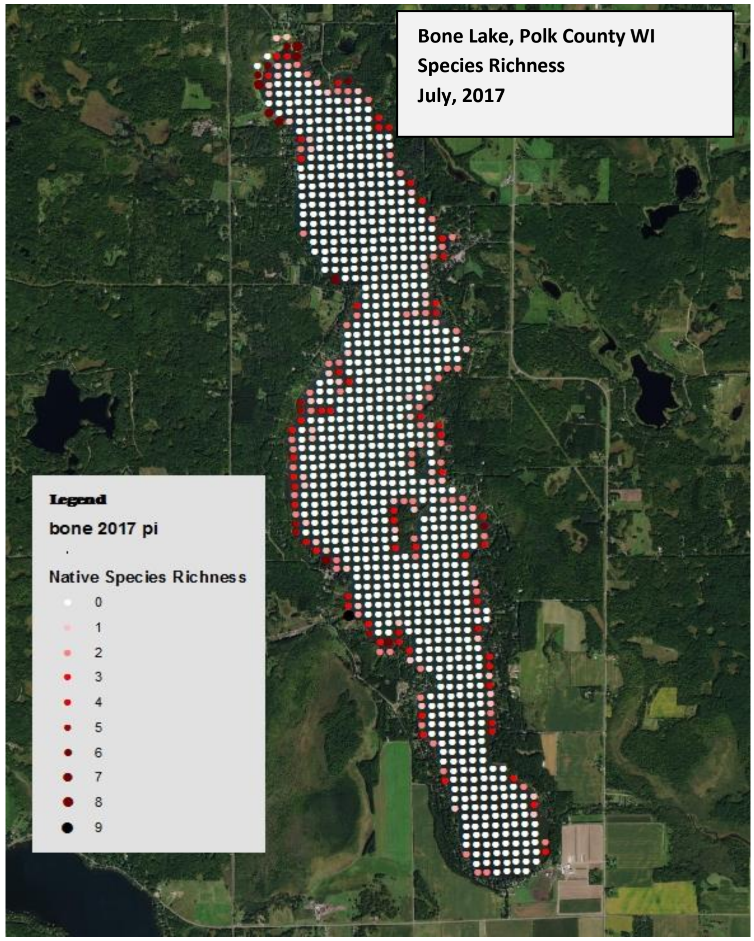
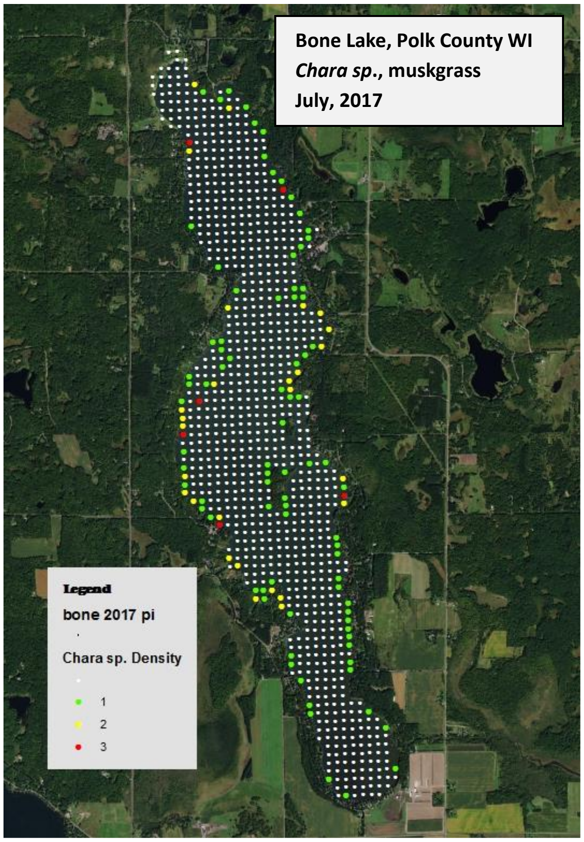
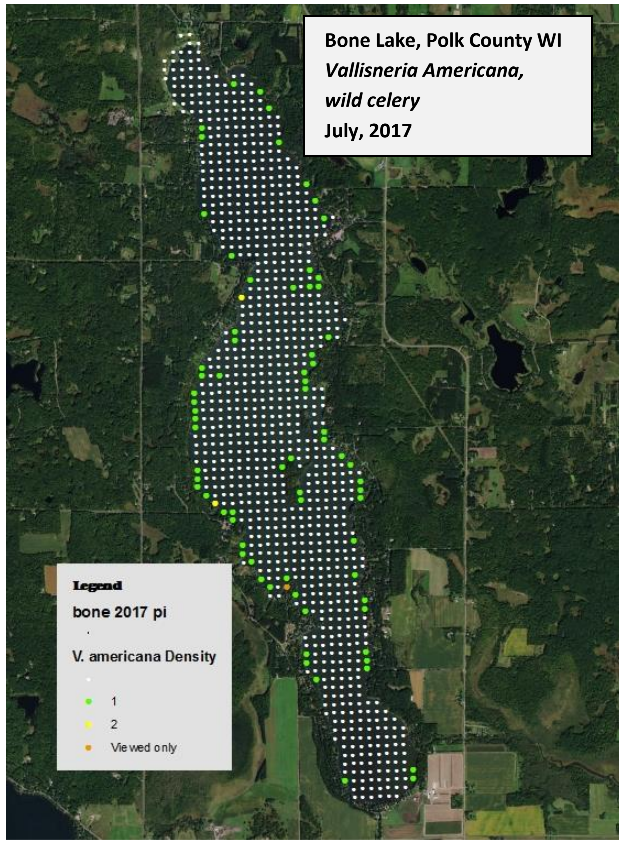


Figure 4: Species richness map at each sample point July 2017.

The most common plant sampled was *Chara sp.*, known as muskgrass. This "plant" (actually a green algae species that has morphology giving it a plant like appearance) is common in Wisconsin lakes and desirable. The second most common plant sampled was the invasive species *Potamogeton crispus* or curly leaf pondweed. This was the frequency found in June, since the plant is usually much less common in July. The second and third most common native plants sampled were *Vallisneria americana*, wild celery and *Najas flexilis*, slender naiad, which are often found in Wisconsin lakes. They provide key food for various organisms and habitat for invertebrates and fish. Figure 5 shows the distribution of the three most common native plant species.





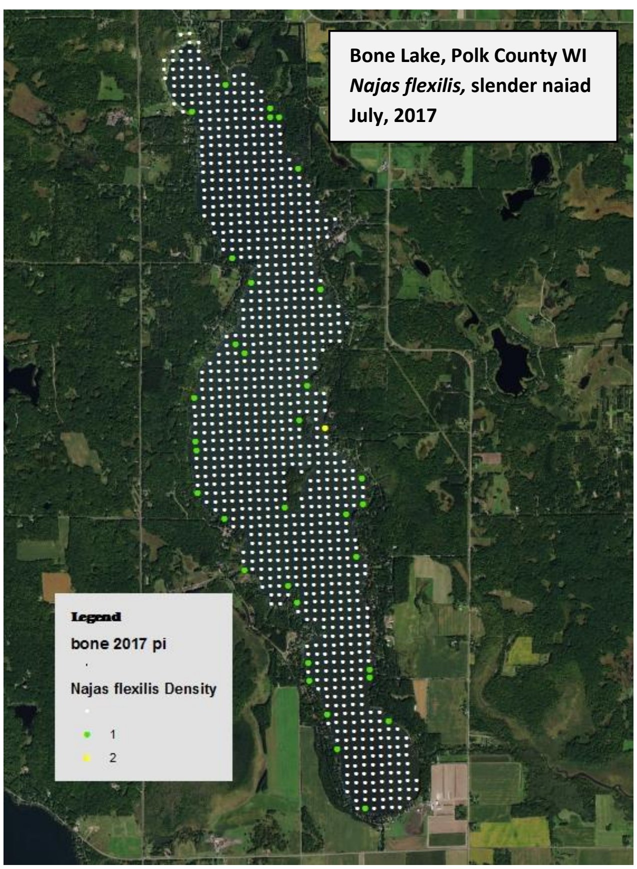


Figure 5: Native species with highest relative relative frequencies in Bone Lake July 2017. *Chara sp.* was most common followed by *Vallisneria americana* and *Najas flexilis* respectively.

Northern wild rice has been a plant of concern, historically found in the furthest north end of Bone Lake. The growth of this plant is variable from year to year and seems to be related to water depths. Past surveys have shown limited frequency based upon the sample grid, with no more than two sample points having rice. In 2017, only one site had wild rice. The growth was limited in this bay and little wild rice was observed emerging. There was submerged wild rice, but again not appearing dense. Figure 6 shows the location of the wild rice sample.

Figure 6: Distribution map of northern wild rice. The frequency and location of wild rice is of concern in regard to use of herbicide for managing curly leaf pondweed.

In addition to sampling sites in the grid, a boat survey is conducted. This surveys areas that have plant growth in under surveyed areas or unique habitat that may hold plants that the grid will not reflect. One goal is to look for sensitive and/or invasive species. These plants are not used in the survey statistics but can provide a biodiversity list as well as invasive species of concern. Table 3 lists the plants observed in this survey. Those with * indicate non-native, restricted invasive species.

Species viewed only on boat survey
Asclepias incarnate-swamp milkweed
Calla palustris-wild calla
Carex sp.-sedges
Dulichium arundinaceum-three-way sedge
Pontederia cordata-pickerelweed
Rumex orbiculatus-aquatic dock
**Typha augustifolia*-narrow leaf cattail
Typha latifolia-broad leaf cattail
Sagittaria latifolia-common arrowhead
Schoenoplectus tabernaemontani-softstem bulrush
Iris versicolor-blue flag iris
Schoenoplectus fluviatilis-river bulrush
**Myosotis scorpoiodes*-aquatic forgetmenot

Table 3: List of plant species observed outside of sample grid (* indicates not native).

Floristic quality Index

The floristic quality index (FQI) may help evaluate any changes that occur in regard to plant habitat from human activities. A reduction could be the result of smaller number of species or the reduction in more sensitive (less tolerant) species. The comparison of the FQI in a lake to the ecoregion median is typical for analysis. However, it is not as reflective as comparing the FQI to previous surveys that can show change within that lake over several years. This comparison is done later in this analysis. In regard to the 2017 survey and the ecoregion median, Bone Lake FQI data is higher in all categories than the median of lakes in the North Central Hardwood Forests ecoregion. Table 4 summarizes the 2017 FQI data.

Parameter	Bone Lake 2017	Ecoregion median(Nichols, 1999).
Number of species in FQI	34	14
Mean conservatism	6.08	5.6
FQI	35.5	20.9

Table 4: Floristic quality index data from Bone Lake, 2017 and the ecoregion median in which Bone Lake is located.

Non-native/Invasive species

There were four non-native species that are listed as restricted invasive species by the Wisconsin DNR. *Potamogeton crispus*-curly leaf pondweed (CLP) is the most extensive and has been managed by the Bone Lake District for several years. Figure 7 shows the sample locations in June 2017. Figures 8 show beds of CLP present in June 2017. There was 51.1 acres of CLP mapped in June, 2017.

<u>Non-native/invasive species observed:</u>

Potamogeton crispus-curly leaf pondweed (sampled)
Myosotis scorpiodes-aquatic forget-me-not (observed only)
Phalaris arundinacea, Reed canary grass (viewed at sample point)
Typha augustifolia-narrow leaf cattail (observed only)

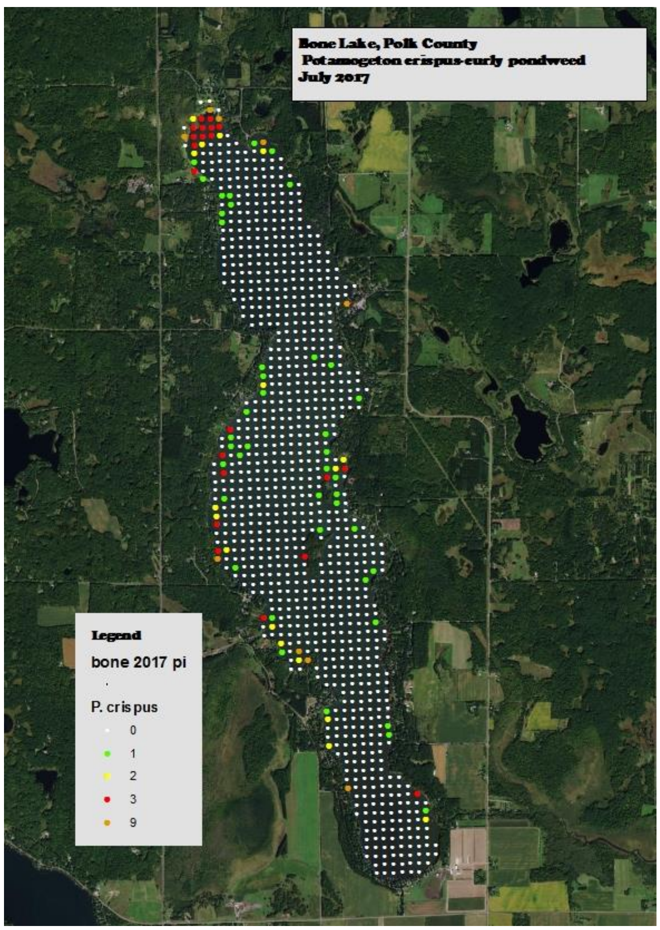


Figure 7: Map of distribution and density of *Potamogeton crispus*-curly leaf pondweed (CLP), June 2017. This survey was completed shortly after herbicide application and should reflect CLP presence before any treated areas died off.

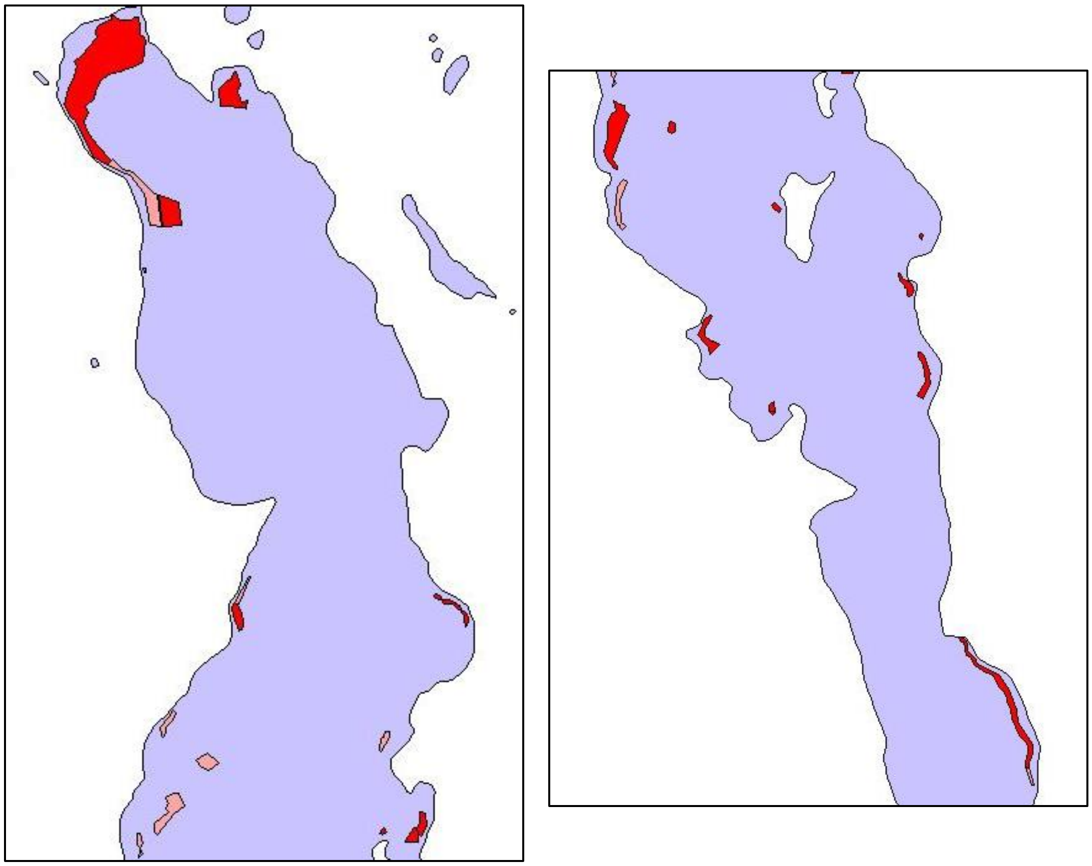


Figure 8: Map of CLP beds, north and south on Bone Lake in June 2017.

On June 1-2, 2017 a point intercept survey for *Potamogeton crispus*-CLP was conducted. The following frequency data was collected:

FOO in vegetated areas: 36.04%
FOO in littoral zone: 27.87%
Number of sample points with CLP sampled: 80
Number of sample points viewed: 9
This survey allows for future CLP frequency comparison when CLP is actively growing.

Reed canary grass was viewed at one sample site. It was also observed at various locations around the lake, largely where disturbances have occurred. These locations were not mapped. Aquatic forget-me-not was also observed in two locations during the boat survey. These locations are indicated in Figure 9. Narrow leaf cattail was briefly observed in other locations as well, but not mapped.

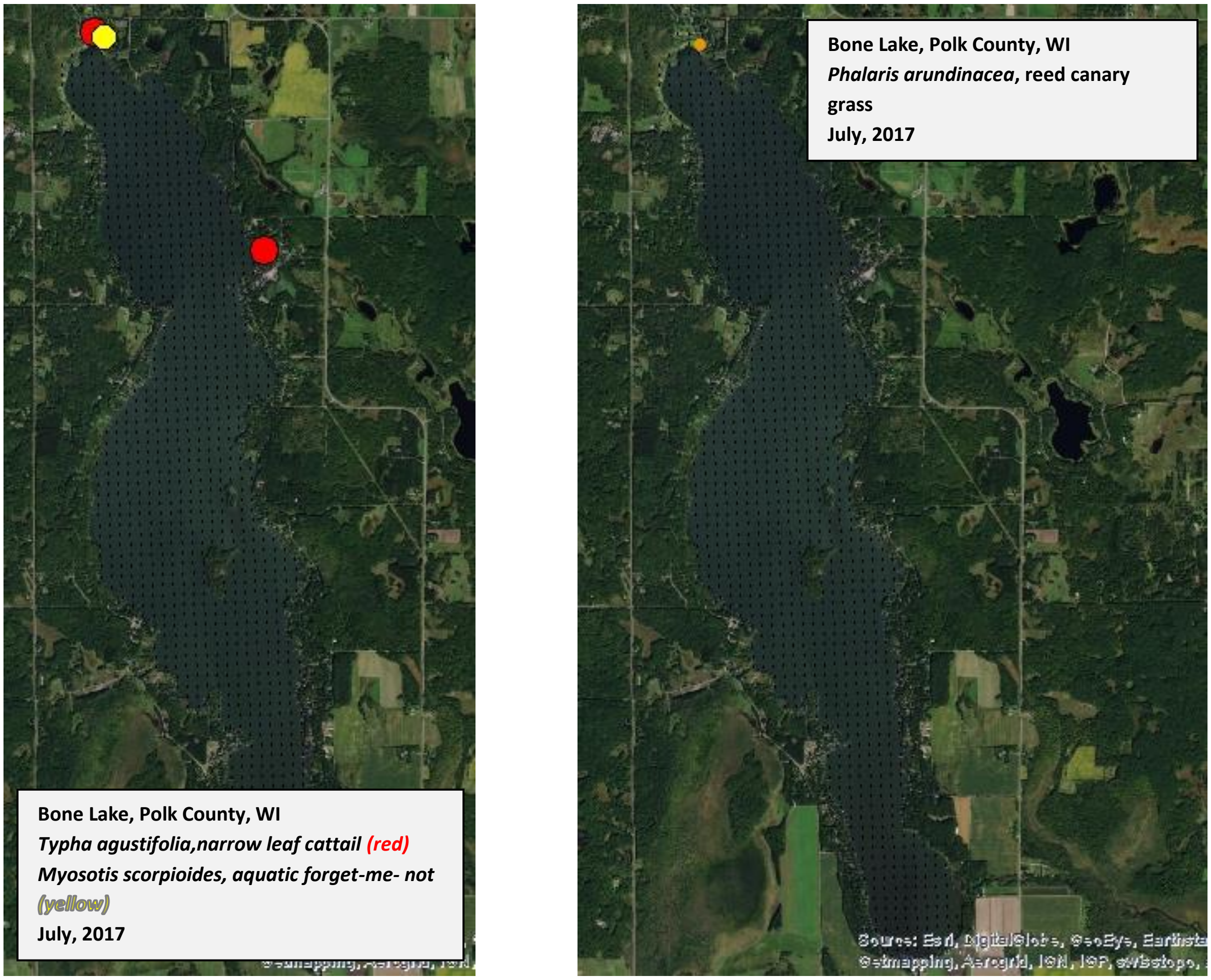


Figure 9: Location of two restricted invasive species (reed canary grass and aquatic forget-me-not) on Bone Lake, July 2017.

Comparsion of 2017 Survey to 2007 and 2012 Surveys

An important function of point intercept aquatic plant surveys on lakes is to to evaluate any changes in the plant community of previous years. Two previous surveys, 2007 and 2012, are available for comparison to the 2017 survey. Table 5 summarizes some key data from these surveys.

Parameter	2007	2012	2017
Species richness	31	36	35
Simpson's diversity	0.92	0.92	0.91
Max depth of plants	17.9	20.7	18.6
FBI	33.8	35.5	35.2
Dominant plant species	*Vallisneria americana*	*Chara sp.*	*Chara sp.*
Relative frequency of dominant species	12.9%	14.4%	22.1%
% of all PI pts with plants	22.60%	19.20%	20.9%

Table 5: Summary of survey data from 2007, 2012, and 2017.

As this data shows over the course of ten years, the plant community as a whole had little change. All parameters are similar, with only minor differences. Overall, it appears that human activity and management of CLP has had little impact on the plants.

A more in-depth comparison is to evaluate the frequency of occurrence (FOO) changes with individual species. A chi-square analysis can indicate if the change in frequency is statistically significant ($P<0.05$). The further below 0.05 the P value, the more significant the reduction. This indicates that chance variation is unlikely and that some other factor is causing the change. The native species were compared between 2012 and 2017 as well as 2007 and 2017. Table 6 summarizes the FOO, change and statistical significance.

The potential sources of native plant reductions over the course of several years 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 are 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 will allow the surveyors to get close to the same sample point each time, but there is 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 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 *Potamgeton 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. However, the same surveyor conducted both surveys so this discrepancy is less likely.

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 suspect. 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.

Table 6: Frequency of occurrence (FOO) comparison and chi-square analysis results.

Native Species Significant decrease Significant increase *Unshaded not significant*	2007 FOO	2012 FOO	2017 FOO	Change 2012-2017	Change 2007-2017
Chara sp., Muskgrasses	37.17	36.46	52.70	+ p=0.001	+ P<0.001
Vallisneria americana, Wild celery	42.04	33.33	33.18	-	-
Najas flexilis, Slender naiad	35.84	21.35	15.70	-	- P<0.001
Ceratophyllum demersum, Coontail	19.91	28.65	15.25	- p=0.001	-
Lemna trisulca, Forked duckweed	15.04	8.33	15.25	+ p=0.03	+
Potamogeton pusillus, Small pondweed	5.31	8.85	8.52	-	+
Potamogeton zosteriformis, Flat-stem pondweed	31.86	18.23	8.52	- P=0.004	- P<0.001
Stuckenia pectinata, Sago pondweed	6.19	8.85	8.07	-	+
Myriophyllum sibiricum, Northern water-milfoil	6.19	16.67	7.62	- P=0.005	+
Heteranthera dubia, Water star-grass	7.08	1.04	4.93	+ P=0.02	-
Nitella sp., Nitella	0.00	1.04	4.48	+ P=0.04	+ P=0.001
Potamogeton richardsonii, Clasping-leaf pondweed	13.27	9.90	4.48	- P=0.03	- P=0.01
Lemna minor, Small duckweed	3.10	7.81	4.05	-	+
Potamogeton friesii, Fries' pondweed	3.10	2.60	4.05	+	+
Potamogeton gramineus, Variable pondweed	2.21	2.08	4.05	+	+
Spirodela polyrhiza, Large duckweed	0.00	6.25	4.05	-	+ P=0.01
Wolffia columbiana, Common watermeal	2.21	6.77	3.59	-	+
Potamogeton illinoensis, Illinois pondweed	18.58	6.77	3.14	-	- P<0.001
Nymphaea odorata, White water lily	1.33	3.13	2.69	-	+
Ranunculus aquatilis, White water crowfoot	1.77	1.04	2.69	+	+
Nuphar variegata, Spatterdock	1.33	3.65	2.24	-	+
Potamogeton praelongus, White-stem pondweed	3.54	1.56	2.24	+	-
Elodea canadensis, Common waterweed	2.65	0.52	1.79	+	-

Native Species Significant decrease Significant increase *Unshaded not significant*	2007 FOO	2012 FOO	2017 FOO	Change 2012-2017	Change 2007-2017
Schoenoplectus acutus, Hardstem bulrush	0.44	2.60	1.35	-	+
Bidens beckii, Water marigold	3.54	0.52	0.90	+	-
Eleocharis palustris, Creeping spikerush	0.00	0.52	0.90	+	+
Eleocharis acicularis, Needle spikerush	0.00	0.00	0.45	+	+
Isoetes echinospora, Spiny spored-quillwort	0.44	0.52	0.45	-	+
Potamogeton foliosus, Leafy pondweed	1.77	1.56	0.45	-	-
Potamogeton strictifolius, Stiff pondweed	0.44	0.00	0.45	+	+
Sagittaria rigida, Sessile-fruited arrowhead	0.00	0.52	0.45	-	+
Schoenoplectus pungens, Three-square bulrush	0.00	0.00	0.45	+	+
Sparganium eurycarpum, Common bur-reed	0.00	0.52	0.45	-	+
Zizania palustris, Northern wild rice	0.44	1.04	0.45	-	+
Filamentous algae	18.58	21.35	25.56	+	+
Eleocharis erythropoda, bald spikerush	0.00	1.04	0.00	-	
Potamogeton amplifolius, large leaf pondweed	9.73	1.04	0.00	-	- P<0.001
Sagittaria cuneata, sessile fruited arrowhead	0.00	0.52	0.00	-	

The FOO data shows a significant decrease in four native species from 2012 to 2017. There was a significant increase in four native species in 2012 to 2017. In comparing 2007 to 2017, there was a decrease in five native species and an increase in three native species. The most dramatic decreases in the ten years (2007-2017) were in *Potamogeton amplifolius*, *Potamogeton illinoensis. Potamogeton zosteriformis*, and *Najas flexilis*. All of these native species are quite common lake plants in Wisconsin lakes and are desirable plants for fish and invertebrate habitat. The reduction in these plants is of some concern, but the definitive cause is unknown. Table 7 summarizes the increases and decreases in native species from past surveys. The negative affect of herbicide use for CLP management might have on native plants is of concern. It is possible this use is a factor in native plant reductions. Native plants are monitored in treatment surveys when herbicide is used. There are other factors cited earlier that could also contribute to these changes. There were also some increases in native plant frequencies, so natural variation within the plant community, could be a factor.

	2012-2017	2007-2017
Significant decreases (4 native species 20012-2017) (5 native species 2007-2017)	*Ceratophyllum demersum* *Potamogeton zosteriformis* *Myriophyllum sibiricum* *Potamogeton richardsonii*	*Najas flexilis* *Potamogeton zosteriformis* *Potamogeton richardsonii* *Potamogeton illinoensis* *Potamogeton amplifolius*
Significant increases (4 native species 2012-2017) (2 native species 2007-2017)	*Chara sp.* *Lemna trisulca* *Heteranthera dubia* *Nitella sp.*	*Chara sp.* *Nitella sp.* *Spirodela polyrhiza*

Table 7: List of species with significant changes (chi-square P value < 0.05) from 2012 to 2017 and 2007 to 2017.

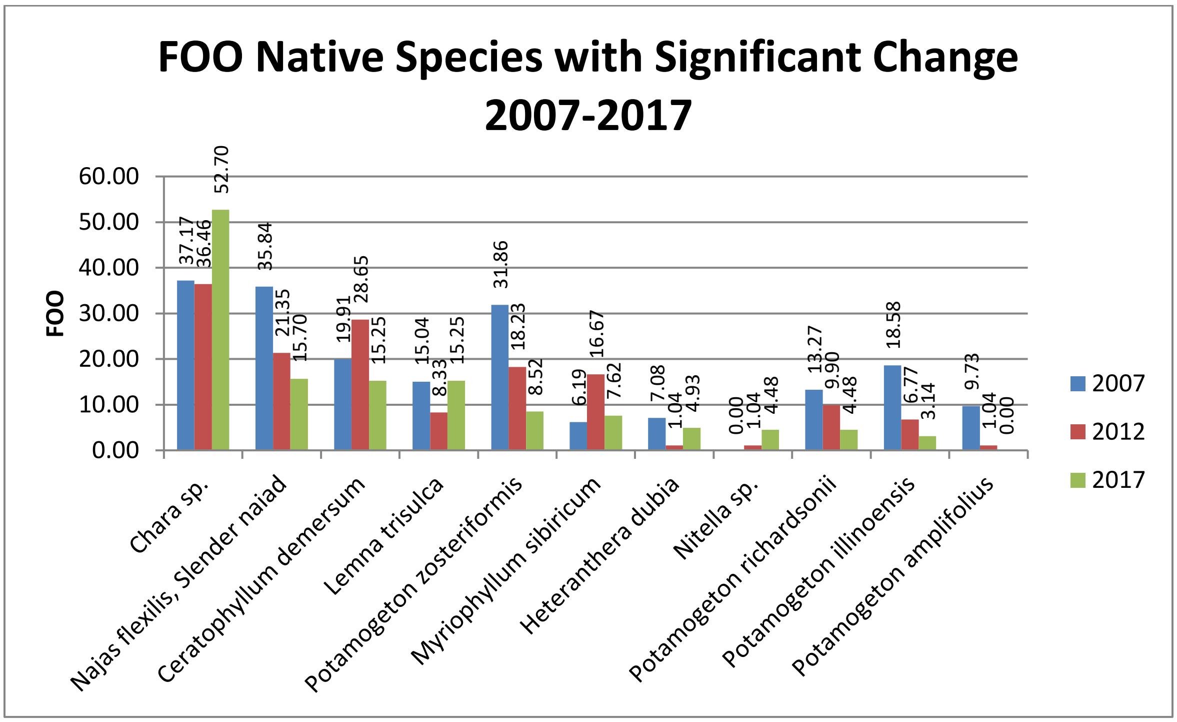


Figure 10: Frequency of occurrence (FOO) of native species with a significant change between 2017 and 2007/2012. This includes increases and decreases. FOO changes not significant are not included in this graph.

Potamogeton cripus-CLP has been managed for several years. In 2017, an early full lake point intercept survey was conducted to evaluate the frequency of CLP near peak growth. Unfortunately this was not conducted in 2007 or 2012. However, using the maps of CLP in those years, a frequency was estimated as though a full lake survey had occurred. This may allow for a rough comparison, but should be used with caution since sampling was not actually conducted.

CLP Freq. Comparison	2007	2012	2017
FOO of CLP(within littoral zone depth)June Survey	47.5% (estimated)	37.1% (estimated)	27.9%
FOO of CLP (within littoral zone depth) July/August Survey	8.6%	5.03%	13.6% (survey was 10-14 days earlier than 2007 and 2012 surveys which could affect frequency of CLP)

Table 8: Comparison of frequency of CLP in various year surveys.

If these estimates are somewhat accurate, it does reflect a decrease in CLP coverage. This decrease may be attributed to the management practices for CLP reduction but could also be natural variation.

Discussion

The 2017 full lake point intercept survey found Bone Lake's aquatic plant community diverse and healthy. The diversity index indicated rather high diversity (0.90) and the species richness was moderately high at 35. There was no one plant dominating the frequency sampled and all native plants sampled are desirable plants. The littoral zone in Bone Lake is narrow and limited, making up a small portion of the lake. For this reason, there are limited areas for plants to thrive. Most diversity and growth occurs in bays and in the north end of the lake. As a result, the plant community could be susceptible to habitat changes and/or reductions. This should be considered in management decisions.

There was one invasive plant sampled (*Potamogeton crispus*-CLP) which was previously present and has been managed for several years. One invasive, reed canary grass, was viewed at one sample point, but was observed scattered in various disturbed locations around the lake. Two other invasive plants, aquatic forget-me-not and narrow leaf cattail were observed. It is common in Wisconsin Lakes for narrow leaf cattail to dominate cattail beds once occupied by the native broad leaf cattail (also observed in Bone Lake). Narrow leaf cattail tends to have the ability to grow in deeper water than the native broad leaf cattail. Cattail species can also hybridize. These species should be monitored in the future.

In comparing to previous surveys, statistically significant reductions occurred in four species from 2012 to 2017 and five species in 2007 to 2017. There was also a statistically significant increase in four species from 2012 to 2017 and three species from 2007 to 2017. The concern over reductions is related to herbicide use. Although this could be a contributor to the reductions, it may not be the only factor, as outlined in the comparison section of this analysis. Continued monitoring is necessary through pretreatment and post treatment surveys as well as full lake point intercept surveys as long as herbicide use for management is being utilized. It does appear that CLP management has reduced CLP coverage in Bone Lake.

Overall, it appears the plant community has demonstrated little change in ten years. This is desirable as human activities can adversely affect the aquatic plant community over time. The plant community is vital to the health of the lake ecosystem. Continued monitoring of the macrophyte community as well as invasive plant introduction/spreading are paramount.

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