Aquatic Macrophyte Survey-Point Intercept Method

Bear Trap Lake (WBIC: 2618100)

Lake Wapogasset (WBIC: 2618000)

Polk County Wisconsin

June/July 2020

Sponsored by Lake Wapogasset/Bear Trap Lake Sanitary District with financial support from the Wisconsin Dept. of Natural Resources

Data collected and analyzed by Ecological Integrity Service, LLC-Amery, WI

Survey Summary

The 2020 aquatic macrophyte surveys on Bear Trap Lake and Lake Wapogasset showed moderate diversity of aquatic plants. The species richness (number of species sampled) in the survey was 22 native species and one non-native species in Bear Trap Lake and 26 native species and one non-native species in Lake Wapogasset. The Simpson's diversity index in Bear Trap Lake was 0.89 and 0.91 in Lake Wapogasset. The same invasive species (*Potamogeton crispus* (curly-leaf pondweed) was sampled in both lakes. The greatest depth with plants in Bear Trap Lake was 18 feet and in Lake Wapogasset 21.8 feet.

The floristic quality index (FQI) for both Bear Trap Lake (FQI=27.7) and Lake Wapogasset (FQI=30.2) was higher than the median (FQI=20.3) for lakes studied in the eco-region. Both the number of species and the mean conservatism value were higher in Bear Trap Lake and Lake Wapogasset than the median of lakes studied in the eco-region.

A chi-square analysis comparing species frequencies between 2007, 2014, and 2020 showed several statistically significant decreases in native plants. In Bear Trap Lake, between 2007 and 2020, there was a significant decrease in seven native species, and a significant decrease in the invasive species curly-leaf pondweed. The Lake Wapogasset comparison from 2007 to 2020 showed a significant decrease in seven species of native plants and the invasive species curly-leaf pondweed. Comparing 2014 to the 2020 frequencies, there was a significant decrease in two native species in Bear Trap Lake and Lake Wapogasset, a significant decrease in seven native species, and the invasive plant curly-leaf pondweed.

In Bear Trap Lake from 2007 to 2014, there was an increase that was significant in one species, while in Lake Wapogasset three native plant species significantly increased. From 2014 to 2020, significant increases occurred in four native species in Bear Trap Lake and seven native species in Lake Wapogasset.

Introduction

In June and August 2020, an aquatic macrophyte survey was conducted on Bear Trap Lake (WBIC: 2618100) and Lake Wapogasset (WBIC: 2618000) in Polk County Wisconsin using the point intercept method developed by the Wisconsin Department of Natural Resources. Bear Trap Lake is a 247-acre lake with a maximum depth of 25 feet and a mean depth of 17 feet. Lake Wapogasset is an 1189-acre lake with a maximum depth of 32 feet and a mean depth of 17 feet. Both lakes are designated as drainage lakes and have a eutrophic trophic status. Development around the lakes is extensive with little of the riparian zone undeveloped.

This report presents a summary and analysis of data collected in 2020 and allows for the comparison to the 2007 and 2014 aquatic macrophyte surveys. 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.

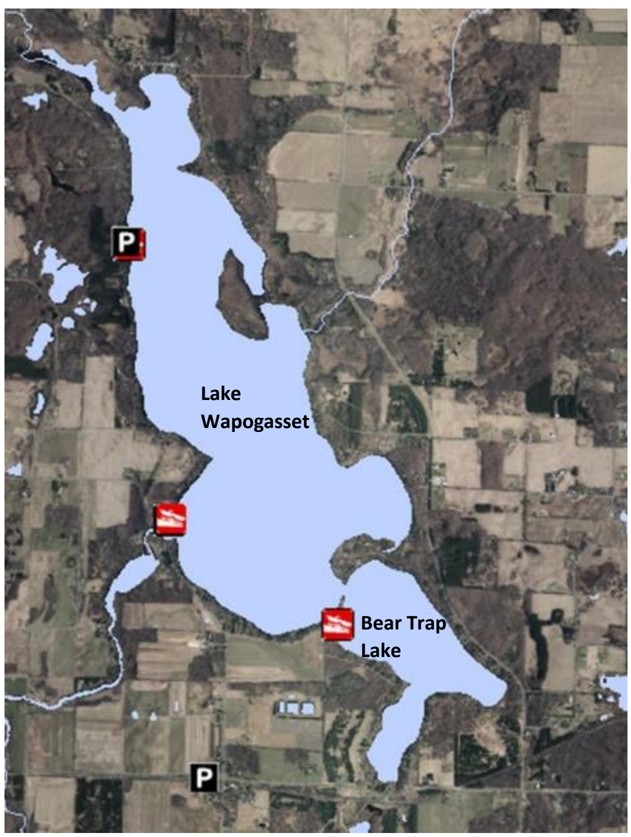

Figure 1: Aerial photo of Lake Wapogasset and Bear Trap Lake.

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 depth 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 as well as habitat type. 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 2020. 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 (late July and early August) and most aquatic plants are actively growing.

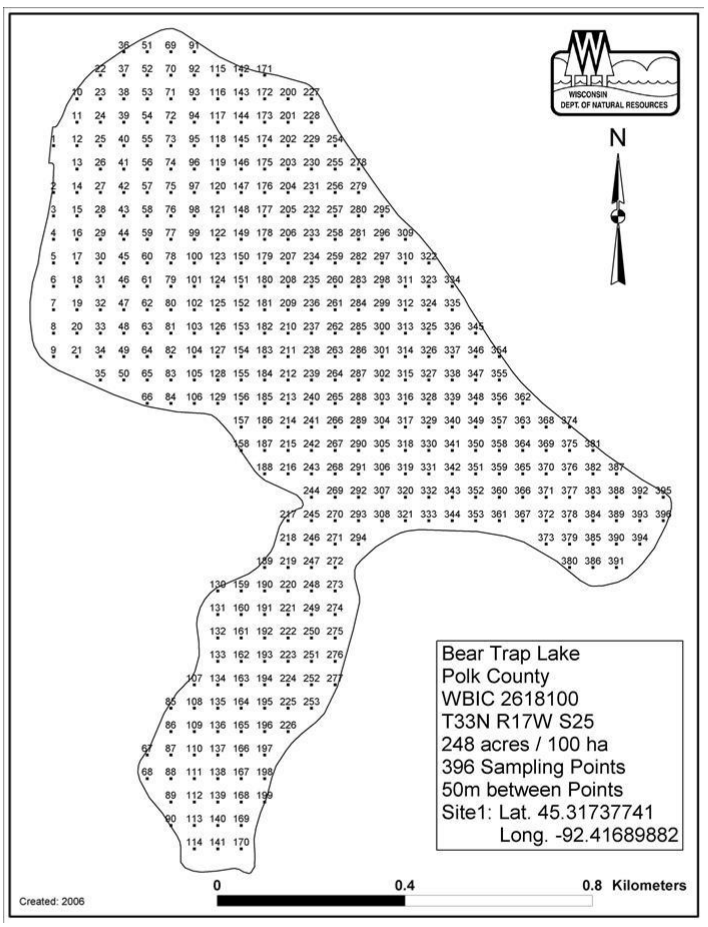

Figure 2: Point intercept sample grid for Bear Trap Lake.

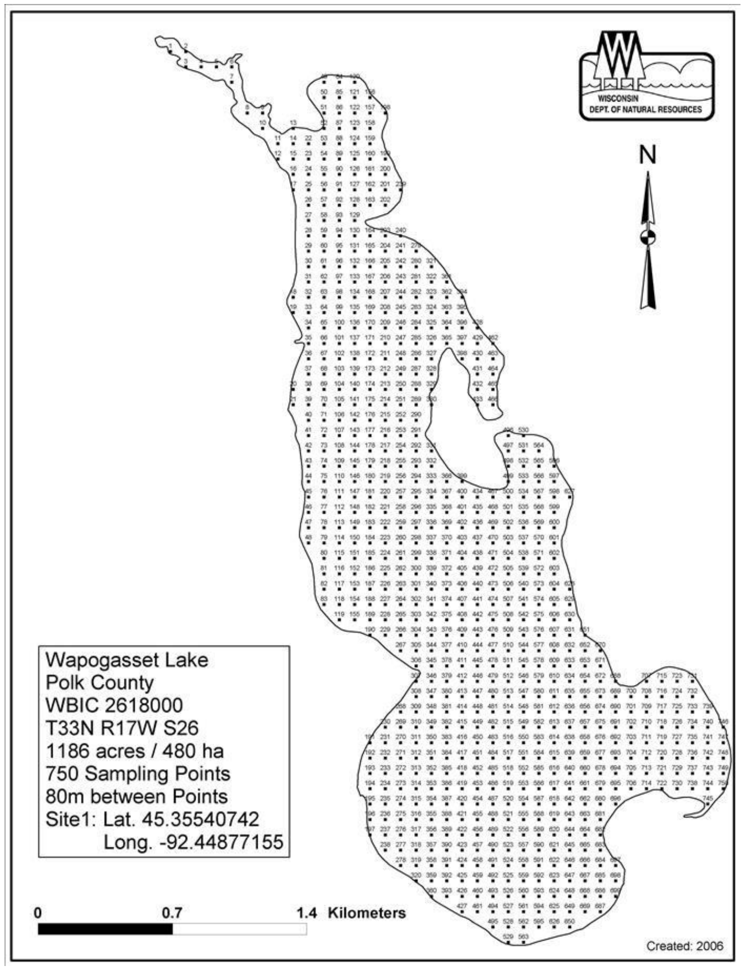

Figure 3: Point intercept sample grid for Lake Wapogasset.

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:

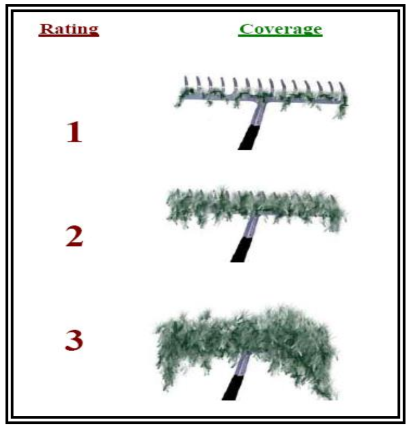

Figure 4: Rake fullness diagram

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. Discerning between muck and sand with a rope rake is difficult, so caution must be used in determining the sediment type data especially in deeper water. All plants needing verification were bagged and cooled for later examination. Each species was mounted, pressed, for a voucher collection, and submitted to the Freckmann Herbarium (UW-Stevens Point) for review. On rare occasions, a single plant sampled may be needed for verification. This may not allow this plant 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 a particular plant was sampled at depths less than 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. 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%

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 grow. Generally, the second will have a higher frequency since that is where plants are 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 accounts for 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 in comparison to the other plants.

Relative frequency example:

Suppose 10 points were sampled in a small lake with 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 in comparing the other plants without considering the number of sites. Relative frequency 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 is 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%). 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 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 were 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 they would have to be the same species.

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. The FQI is a measure of the plant community in response to development (and human influence) on the lake which 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 (sampled on rake only).

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. This analysis also compares the 2007 and 2014 values from past aquatic plant surveys.

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Summary of Northern Central Hardwood Forests Median Values for Floristic Quality Index:

(Nichols, 1999)

	Northern Central Hardwood Forests
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 rises, so will FQI; while with a negative correlation as a value rises, the FQI will decrease.

Results

Bear Trap Lake

The 2020 aquatic macrophyte survey reflects a moderate coverage and diversity of aquatic plants in Bear Trap Lake. The species richness was 22 native species and one non-native species (*Potamogeton crispus*) sampled on the rake. Simpson's diversity index was 0.89 which shows the plant community is relatively diverse. Within the defined littoral zone (by the maximum depth of plants) 58% had plants growing and sampled at those sample points.

Bear Trap Lake 2020 Aquatic Plant Survey Summary Stats	
Total number of sample points	396
Total number of sites with vegetation	112
Total number of sites shallower than the maximum depth of plants	193
Frequency of occurrence at sites shallower than the maximum depth of plants	58.03%
Simpson Diversity Index	0.89
Maximum depth of plants	18 ft
Mean depth of plants	6.6 ft
Average number of all species per site (shallower than max depth)	1.81
Average number of all species per site (veg. sites only)	3.13
Average number of native species per site (shallower than max depth)	1.63
Average number of native species per site (veg. sites only)	2.85
Species Richness	23
Species Richness (including visuals)	24
Mean rake fullness where plants present	1.9

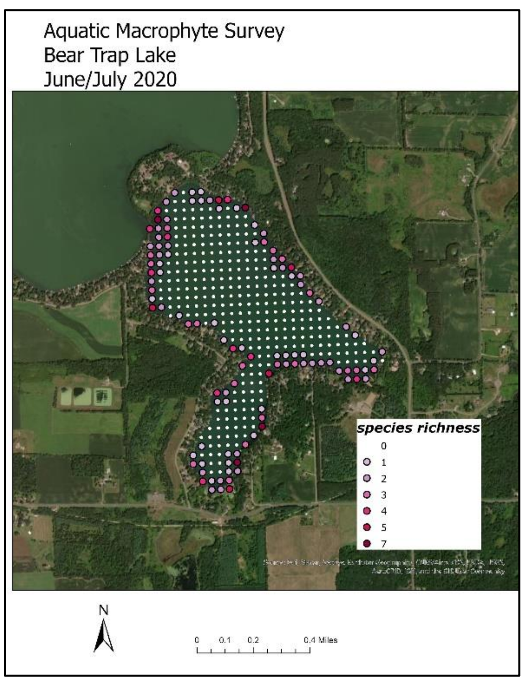


Figure 5: Species richness map for Bear Trap Lake, 2020.

Bear Trap Lake has a rather narrow littoral zone resulting in only a small portion of the lake with depths plants can grow. Where plants are growing, the density is moderately high with a mean rake fullness of all plants of 1.9 (on a scale from 0-3). The deepest depth plants were sampled was 18.0 feet and the mean depth plants were sampled was 6.6 feet.

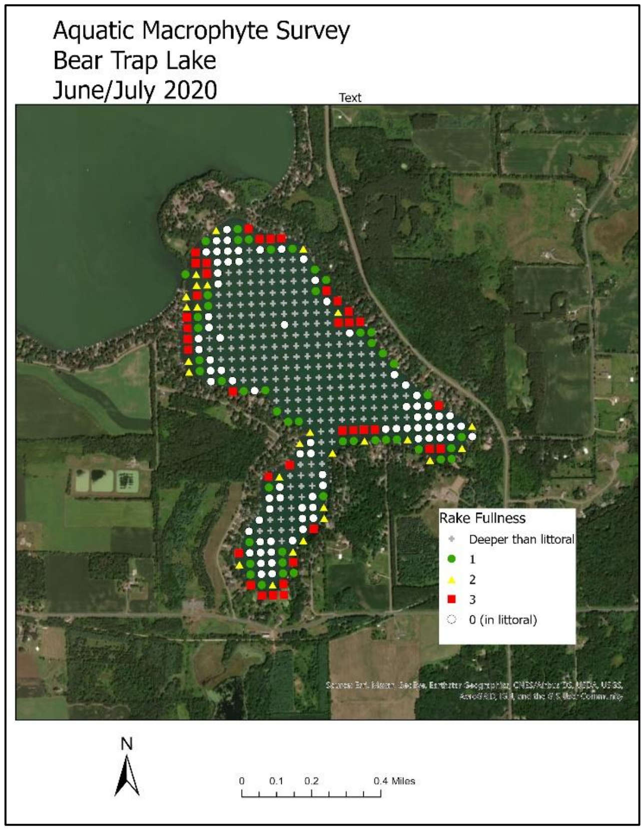


Figure 6: Rake fullness map for Bear Trap Lake, 2020.

The most common plant species sampled in July (late season) survey were coontail (*Ceratophyllum demersum),* wild celery (*Vallisneria americana*), clasping leaf pondweed (*Potamogeton richardsonii*), and flat-stem pondweed (*Potamogeton zosteriformis*) respectively. All are common, desirable plants in Wisconsin lakes. Table 3 summarizes the frequency of various species sampled as well as the rake fullness.

Figure 7 Pictures of common plants (left to right): coontail, wild celery, clasping pondweed, and flat-stem pondweed. (photos from Paul Skawinski, Aquatic Plants of the Upper Midwest, used with permission.

No endangered species, threatened species, or species of special concern were sampled or viewed in Bear Trap Lake.

Bear Trap Lake Species	**Foo Vegetated Sites**	**FOO Littoral zone**	**Relative Freq**	**# sampled**	**mean rake fullness**	**# viewed**
Ceratophyllum demersum, Coontail	73.21	42.49	23.43	82	1.59	
Vallisneria americana, Wild celery	40.18	23.32	12.86	45	1.27	
Potamogeton richardsonii, Clasping-leaf pondweed	33.93	19.69	10.86	38	1.00	4
Potamogeton zosteriformis, Flat-stem pondweed	23.21	13.47	7.43	26	1.12	
Heteranthera dubia, Water star-grass	22.32	12.95	7.14	25	1.12	
Myriophyllum sibiricum, Northern watermilfoil	13.39	7.77	4.29	15	1.07	2
Stuckenia pectinata, Sago pondweed	12.50	7.25	4.00	14	1.00	2
Najas flexilis, Slender naiad	9.82	5.70	3.14	11	1.00	
Potamogeton pusillus, Small pondweed	9.82	5.70	3.14	11	1.00	
Elodea canadensis, Common waterweed	8.93	5.18	2.86	10	1.30	
Ranunculus aquatilis, White water crowfoot	8.04	4.66	2.57	9	1.11	
Chara sp., Muskgrasses	6.25	3.63	2.00	7	1.14	
Potamogeton illinoensis, Illinois pondweed	6.25	3.63	2.00	7	1.00	1
Nymphaea odorata, White water lily	4.46	2.59	1.43	5	1.00	1
Potamogeton crispus, Curly-leaf pondweed	3.57	2.07	1.14	4	1.00	
Potamogeton friesii, Fries' pondweed	1.79	1.04	0.57	2	1.00	
Sagittaria rigida, Sessile-fruited arrowhead	1.79	1.04	0.57	2	1.00	
Lemna trisulca, Forked duckweed	0.89	0.52	0.29	1	1.00	
Potamogeton praelongus, White-stem pondweed	0.89	0.52	0.29	1	1.00	1
Potamogeton robbinsii, Fern pondweed	0.89	0.52	0.29	1	1.00	
Potamogeton strictifolius, Stiff pondweed	0.89	0.52	0.29	1	1.00	
Sagittaria cristata, Crested arrowhead	0.89	0.52	0.29	1	1.00	
Filamentous algae	10.71	6.22		12	1.00	
Potamogeton gramineus, Variable pondweed	viewed	only	------	-------		1
Potamogeton crispus, Curly-leaf pondweed June Survey	28.57	16.58	9.14	32	2.09	11

Table 3: Bear Trap Lake species list with frequency data.

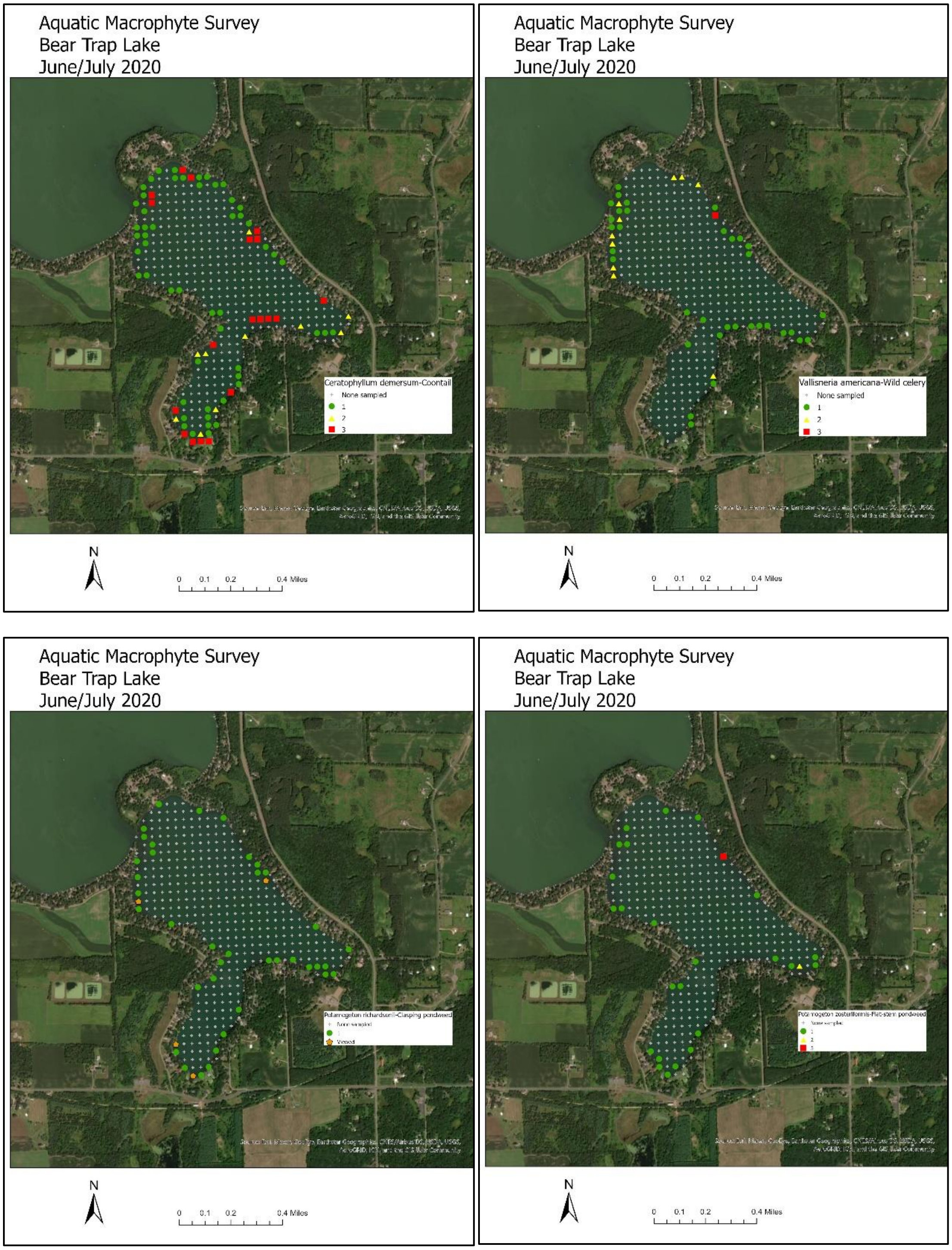


Figure 8: The four most common plants sampled in Bear Trap Lake 2020. These plants were in order: Coontail, wild celery, clasping pondweed, and flat-stem pondweed.

FQI

The floristic quality index (FQI) for Bear Trap Lake shows a higher number of species as well as a higher mean conservatism value than the eco-region median. This results in a higher FQI for Bear Trap Lake than the eco-region median (Nichols, 1999). FQI can indicate changes in the plant community from human activity. This index is also a sufficient parameter for evaluating plant community changes.

FQI Parameter	Bear Trap Lake 2020	Eco-region Median
Number of species in FQI	20	14
Mean conservatism	6.2	5.6
FQI	27.7	20.9

Table 4: Floristic quality index information for Bear Trap Lake 2020.

The FQI shows that the Bear Trap Lake plant community is not degrading from human activity to a high degree.

The highest conservatism value for any plant sampled in Bear Trap Lake was eight (ten is the highest value possible). The list of plants with a conservatism value of eight is as follows:

Potamogeton freisii-Fries' pondweed
Potamogeton praelongus-White-stem pondweed
Potamogeton robbinsii-Fern pondweed
Potamogeton strictifolius-Stiff pondweed
Ranunculus aquatilis-Whitewater
Sagittaria rigida-Sessile fruited crowfoot arrowhead

Invasive species

The invasive species curly-leaf pondweed was sampled frequently in June and minimally in July. No other invasive species were sampled or viewed in the survey.

Bear Trap Lake has had curly-leaf pondweed managed the last 4 years with the mechanical harvest. Changes in curly-leaf pondweed in Bear Trap Lake are discussed later in the survey comparison section of this analysis.

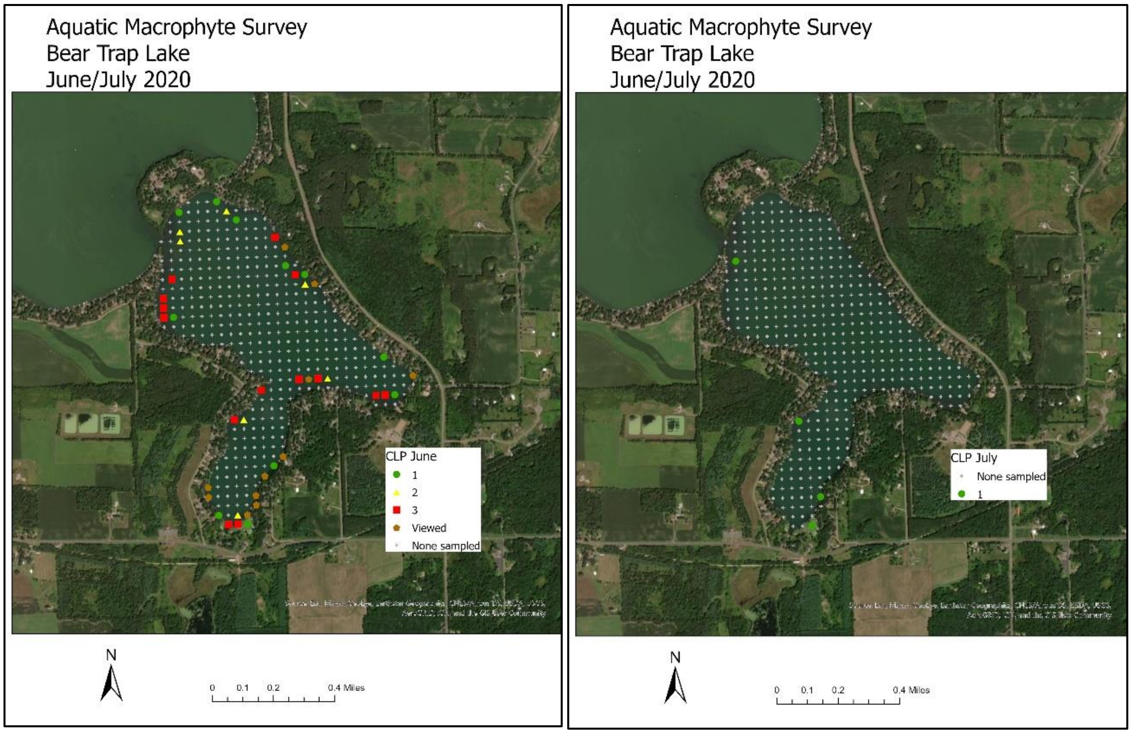


Figure 9 Distribution maps with the density of CLP at point intercept points in early June (left) and late July (right). The June map reflects CLP at peak growth for this early season growing invasive plant.

In a boat survey, a few invasive species were observed. They included yellow iris (*Iris pseudacorus*), narrow-leave cattail (*Typha angustifolia*), and reed canary grass (*Phalaris arundinacea*). Although these plants were not seen commonly, there was no in-depth survey targeting these species. More precise mapping of these species should be considered to evaluate any changes in their coverage, especially yellow iris, which could spread into emergent plant beds that are limited in Bear Trap Lake.

Narrow-leaved cattail has become common in lakes and serves a similar role as the native broad-leaved cattail but can become an issue. Reed canary grass is widespread around North America. Populations are a mixture of cultivars that are non-native (from Europe) and indigenous to North America. Reed canary can become invasive, especially in disturbed areas. Due to the extensive distribution, it is often not mitigated unless in infiltrates a restoration project.

Figure 10: Invasive species observed in boat survey: (left to right) yellow iris, narrow-leaved cattail, and reed canary grass. (Photos from Wisconsin DNR invasive species website (dnr.wi.gov)

Lake Wapogasset

The results of the Lake Wapogasset survey indicate a moderately high diversity of plants with species richness of 26 native species and one non-native species sampled on the rake. Simpson's diversity index supports diversity with a value of 0.91. The coverage of plants is moderate with 64.5% of the littoral zone having plants present in July 2020. The mean rake fullness was 1.71 (on a scale from 0-3). To visualize, a typical rake sample would have more than ½ tine space with plants when sampled.

The maximum depth with plants growing was 21.8 feet and a mean depth of 6.3 feet. This a greater depth than may be expected as Lake Wapogasset has a history of poor water clarity. The coverage of plants is moderate with plants occurring in 64.5% of the sample points within the depth defined littoral zone (less than 21.8 ft).

Lake Wapogasset Aquatic Plant Survey Summary Stats	
Total number of sample points	750
Total number of sites with vegetation	269
Total number of sites shallower than the maximum depth of plants	417
Frequency of occurrence at sites shallower than the maximum depth of plants	64.51
Simpson Diversity Index	0.91
Maximum depth of plants	21.8 ft
Mean depth of plants	6.3 ft
Average number of all species per site (shallower than max depth)	1.59
Average number of all species per site (veg. sites only)	2.46
Average number of native species per site (shallower than max depth)	1.28
Average number of native species per site (veg. sites only)	2.45
Species Richness	27
Species Richness (including visuals)	28
Mean rake fullness where plants were present	1.71

Table 5: Summary of the survey statistics for Lake Wapogasset, July 2020.

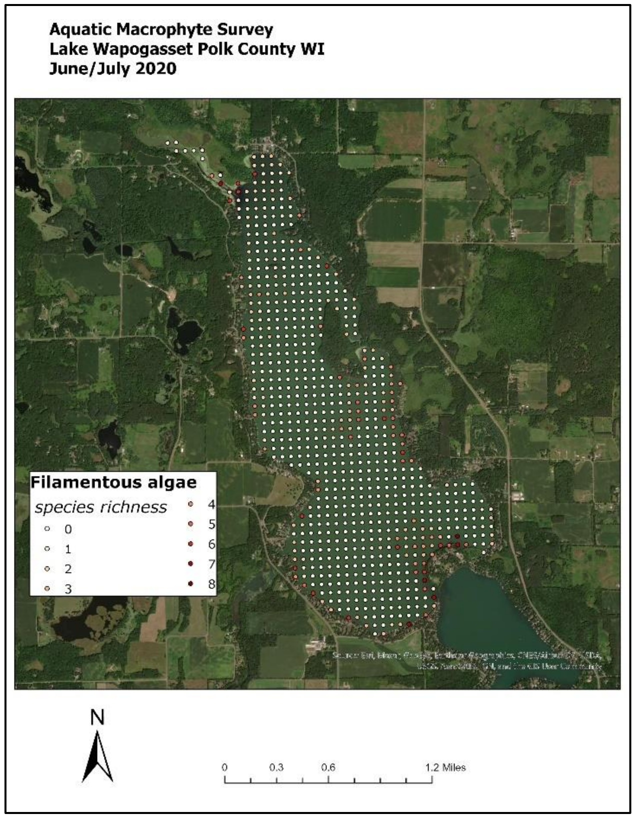


Figure 11: Species richness in Lake Wapogasset July 2020.

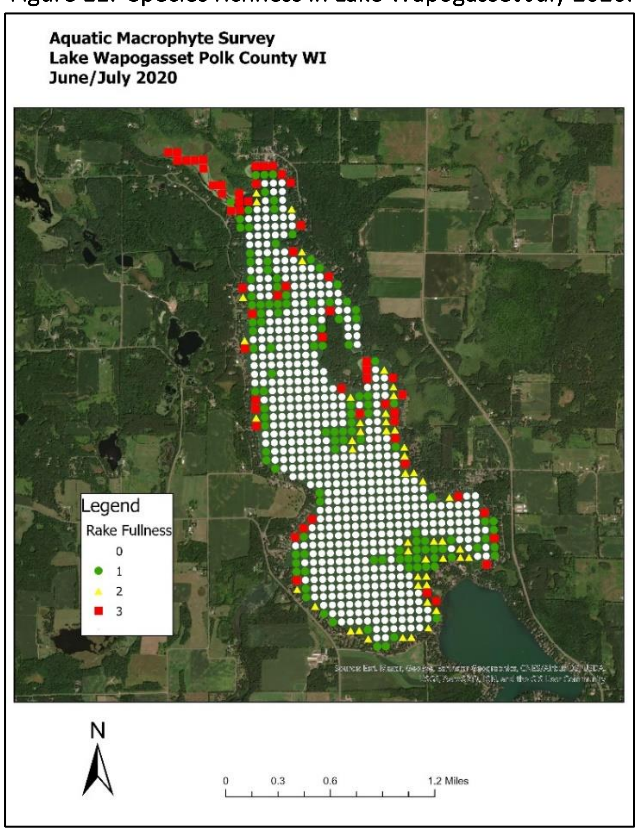


Figure 12 Map showing rake fullness in Lake Wapogasset, July 2020.

Species	FOO Vegetated sites	FOO Littoral zone	Relative freq.	# sampled	Mean rake fullness	# viewed
Ceratophyllum demersum, Coontail	46.47	29.98	18.88	125	1.5	1
Myriophyllum sibiricum, Northern watermilfoil	20.45	13.19	8.31	55	1.2	
Vallisneria americana, Wild celery	19.33	12.47	7.85	52	1.1	
Ranunculus aquatilis, White water crowfoot	13.01	8.39	5.29	35	1.1	1
Najas flexilis, Slender naiad	12.64	8.15	5.14	34	1.1	
Potamogeton richardsonii, Clasping-leaf pondweed	12.64	8.15	5.14	34	1.1	1
Potamogeton pusillus, Small pondweed	10.41	6.71	4.23	28	1.0	
Potamogeton zosteriformis, Flat-stem pondweed	9.67	6.24	3.93	26	1.0	
Heteranthera dubia, Water star-grass	9.29	6.00	3.78	25	1.1	2
Elodea canadensis, Common waterweed	7.43	4.80	3.02	20	1.4	
Chara sp., Muskgrasses	7.06	4.56	2.87	19	1.1	
Potamogeton crispus, Curly-leaf pondweed	6.32	4.08	2.57	17	1.0	
Stuckenia pectinata, Sago pondweed	5.20	3.36	2.11	14	1.0	
Lemna trisulca, Forked duckweed	4.09	2.64	1.66	11	1.0	
Potamogeton friesii, Fries' pondweed	3.72	2.40	1.51	10	1.0	
Zizania palustris, Northern wild rice	3.72	2.40	1.51	10	2.7	1
Potamogeton gramineus, Variable pondweed	2.97	1.92	1.21	8	1.0	1
Lemna minor, Small duckweed	2.23	1.44	0.91	6	1.0	
Spirodela polyrhiza, Large duckweed	2.23	1.44	0.91	6	1.0	
Nymphaea odorata, White water lily	1.49	0.96	0.60	4	1.3	4
Potamogeton illinoensis, Illinois pondweed	1.49	0.96	0.60	4	1.0	3
Wolffia columbiana, Common watermeal	1.12	0.72	0.45	3	1.0	
Potamogeton praelongus, White-stem pondweed	0.74	0.48	0.30	2	1.0	
Nuphar variegata, Spatterdock	0.37	0.24	0.15	1	1.0	
Potamogeton strictifolius, Stiff pondweed	0.37	0.24	0.15	1	1.0	
Sagittaria rigida, sessile fruited arrowhead	0.37	0.24	0.15	1	1.0	
Filamentous algae	26.39	17.03		71	1.0	
Sagittaria cuneata, Arum-leaved arrowhead	viewed	only	n/a			1
Potamogeton crispus, Curly-leaf pondweed June survey	41.26	26.62	16.77	111	2.0	9

Table 6: Lake Wapogasset species list with survey frequency data for each species.

The most dominant plant surveyed was coontail (*Ceratophyllum demersum*) with a relative frequency of 18.9%. This is quite high for relative frequency indicating nearly one in five plants sampled were coontail. This is a common plant to dominate frequency in high nutrient lakes such as Lake Wapogasset.

In addition to coontail, the most common plants were northern watermilfoil (*Myriophyllum sibiricum*), wild celery (*Vallisneria americana*), and whitewater crowfoot (*Ranunculus aquatilis*) respectively. All of these native plants are common and desirable in Wisconsin lakes. All serve an important role in the lake ecosystem.

Figure 13 Pictures of common plants (left to right): coontail, northern watermilfoil, wild celery, and whitewater crowfoot. (photos from Paul Skawinski, Aquatic Plants of the Upper Midwest, used with permission)

No endangered or threatened species and no species of special concern were sampled or observed in Lake Wapogasset.

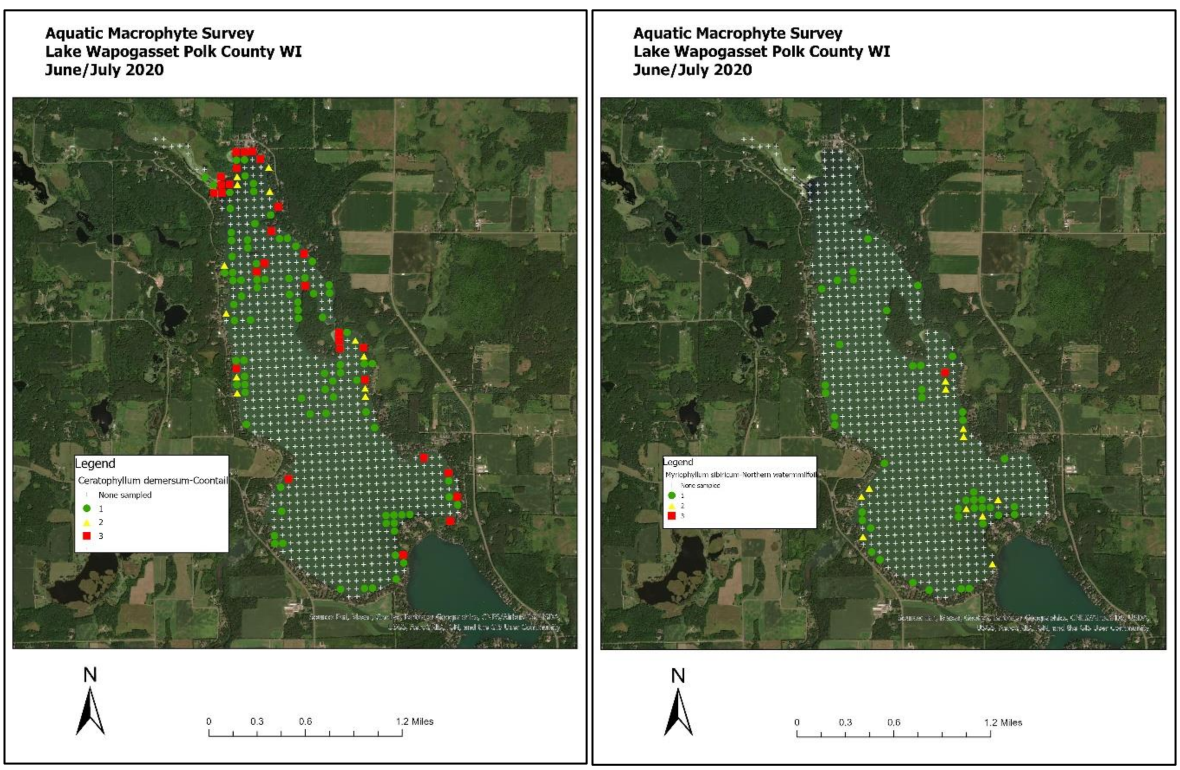
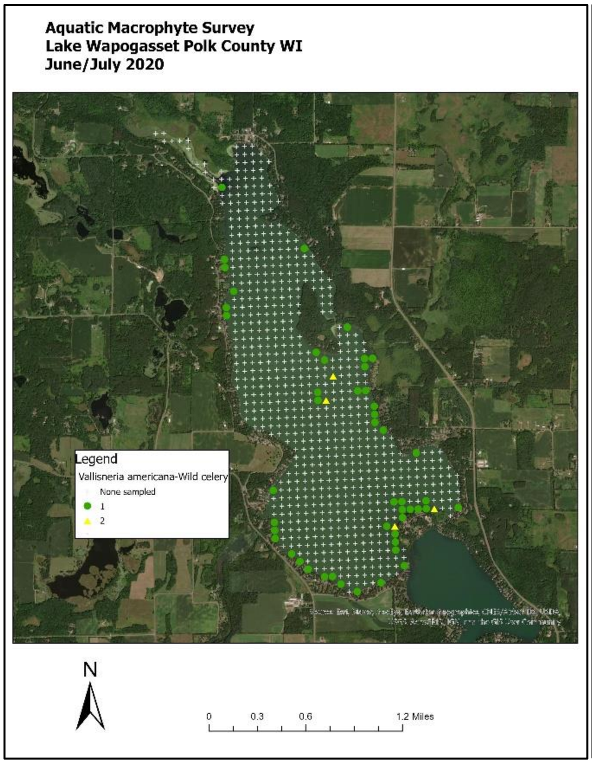


Figure 14 The most common (four) aquatic plants sampled in Lake Wapogasset. These are coontail (*Ceratophyllum demersum*), northern watermilfoil (*Myriophyllum sibiricum*), wild celery (*Vallisneria americana*), and whitewater crowfoot (*Ranunculus aquatilis*) respectively.



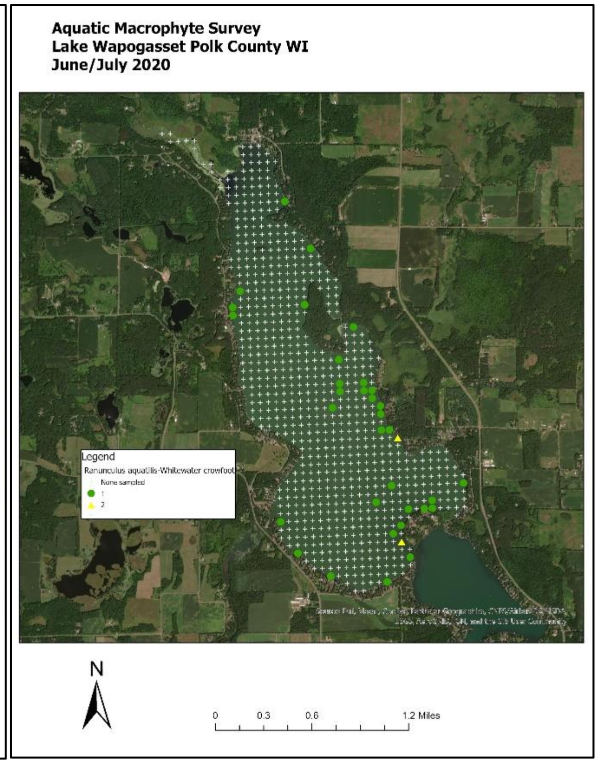


Figure 14 continued: The most common (four) aquatic plants sampled in Lake Wapogasset. These are coontail (*Ceratophyllum demersum*), northern watermilfoil (*Myriophyllum sibiricum*), wild celery (*Vallisneria americana*), and whitewater crowfoot (*Ranunculus aquatilis*) respectively.

FQI

The floristic quality index can be a suitable indicator of changes in plant habitat related to human activity. The number of species, mean conservatism, and FQI values were all higher than the eco-region median. The eco-region median is data collected in other lakes within the eco-region (Nichols, 1999). This shows that the plant community is quite healthy in Lake Wapogasset, even with the limited water clarity in the later months of the growing season.

FQI Parameter	Lake Wapogasset 2020	Eco-region Median
Number of species in FQI	25	14
Mean conservatism	6.04	5.6
FQI	30.2	20.9

Table 7: Floristic quality index data for Lake Wapogasset 2020.

The highest conservatism value for any plant sampled in Lake Wapogasset was eight (ten is the highest value possible). The list of plants with a conservatism value of eight is as follows:

Potamogeton freisii-Fries' pondweed
Potamogeton praelongus-White-stem pondweed
Potamogeton robbinsii-Fern pondweed
Potamogeton strictifolius-Stiff pondweed
Ranunculus aquatilis-Whitewater
Sagittaria rigida-Sessile fruited crowfoot arrowhead
Zizania palustris-Northern wild rice

Invasive species

There was one invasive species sampled in Lake Wapogasset, curly-leaf pondweed (CLP)-*Potamogeton crispus*. This plant has been in Lake Wapogasset for several years and is presently being managed through mechanical harvest in May-June. In June during peak growth, the coverage and density of CLP are extensive especially in the north end of the lake.

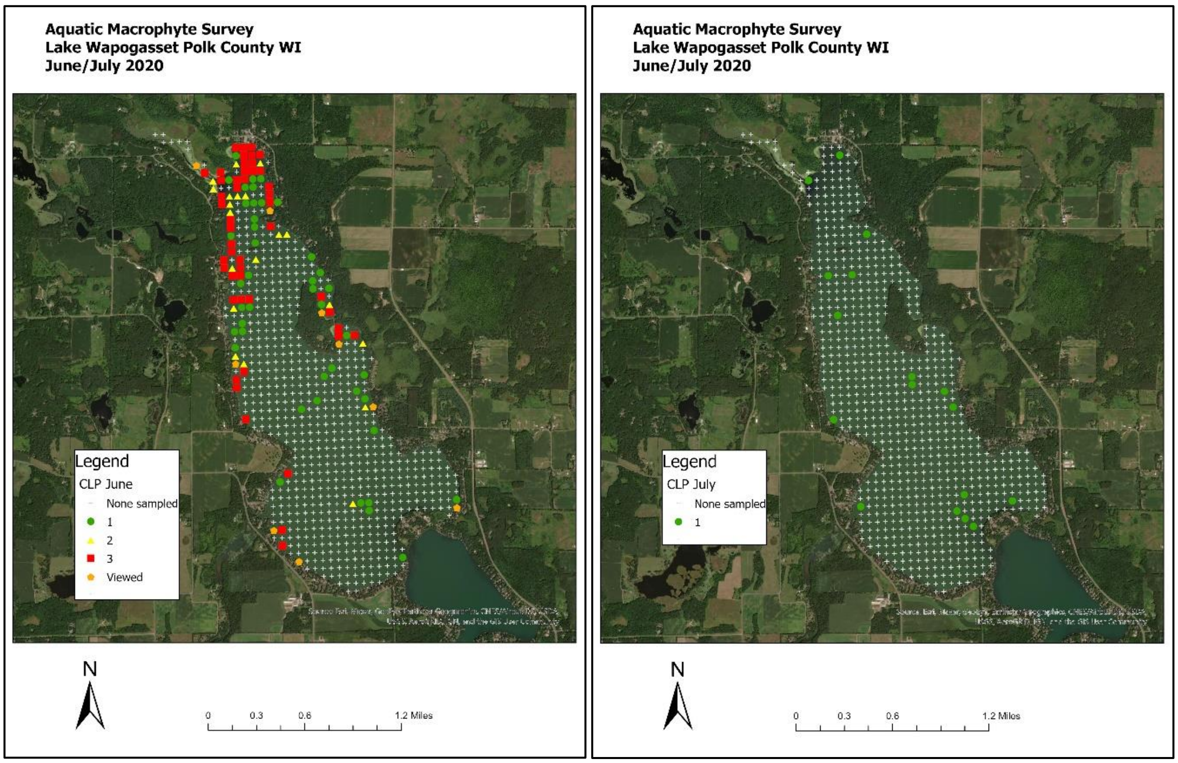


Figure 15: Distribution maps with density for CLP in early June (left) and late July (right). Early June is when CLP is at peak growth which is why the coverage and density are greater.

There were a few other non-native, invasive species observed in the lake but not sampled or viewed at sample points. The plants include narrow-leaved cattail (*Typha angustifolia*), reed canary grass (*Phalaris arundinacea),* and aquatic for-get-me-not (*Myosotis scorpioides*) which were all observed in previous years. No formal mapping has occurred for these species, so any changes in coverage have not been evaluated. None of these plants appear to be inundating the lakebed.

Another plant, yellow iris (*Iris pseudacorus*), was observed in Bear Trap. None was documented in Lake Wapogasset; however, if a survey was conducted focusing only on this plant, there is a high probability that some would be observed.

Figure 16: Invasive species observed in boat survey (left to right): narrow-leaved cattail, reed canary grass, and aquatic for get me not.

Wild Rice

Near the mouth of the inlet Balsam Branch, there has been extensive growth of northern wild rice (*Zizania palustris*). The wild rice bed in this area is of high concern and a point of emphasis in plant management plans. Therefore, monitoring occurs every three years as part of the plant management plan. In support of this effort, an updated map for the wild rice distribution from the point intercept survey is provided.

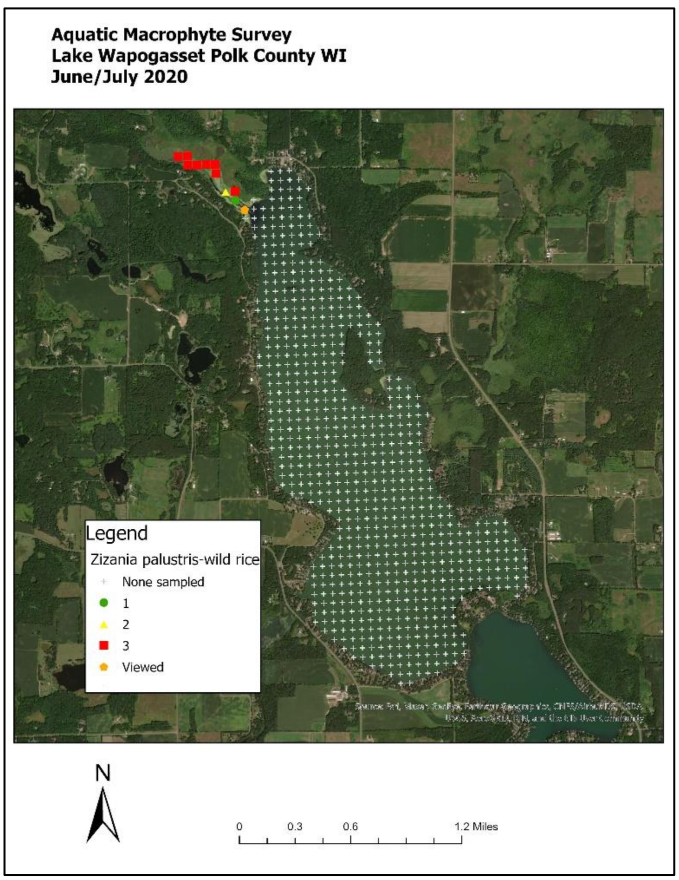


Figure 17: Distribution map of wild rice in Lake Wapogasset, July 2020.

The wild rice frequency was similar in 2014 and 2020 with 12 locations sampled in 2014 and 10 locations sampled in 2020. The main bed appears unchanged. The variability occurs at the end of the mouth where deeper water occurs.

Comparison to previous surveys

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 causing 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, the reduction 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 move 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, a plant may not be sampled in a survey due to sampling variation. Plants with low frequency could show significantly different values in surveys conducted within the same year.

3. Each year, aquatic plants come out of dormancy in widely various timelines. 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 could have high density of a plant one year and low density another year. The type of plant reproduction can immensely affect plant density. If the plant grows from a 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* are incredibly similar, which can easily lead to identification error. To determine if a true reduction has occurred, observe the overall frequency of the small pondweeds combined. In the 2020 survey, all small pondweeds collected were magnified and closely scrutinized.

5. Habitat 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. However, for this to occur in 5-7 years is unlikely. If a plant emerges more dominant 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. Although the Wisconsin DNR does not mention invasive rusty crayfish in Bear Trap Lake and Lake Wapogasset, there is a reported robust population of carp in these lakes.

Bear Trap Lake

The various statistics that summarize the three plant surveys show similar results. The plant coverage (number of sample points with plants) decreased by 16 points from 2007 to 2014 but rebounded within six sample points from 2007 to 2020. The FQI decreased slightly but not an amount to cause for concern. The diversity has remained quite stable.

Bear Trap Lake Parameter	2007	2014	2020
Number of sample points with plants	118	102	112
Species richness	23	22	23
Simpson's diversity index	0.91	0.88	0.89
Maximum depth of plants	17.6 ft	18.4 ft	18.0 ft
FOO in littoral zone depths	63.8%	52.31%	58.03%
FQI	28.3	27.3	27.7

Table 8: Various survey data compared between the three surveys conducted on Bear Trap Lake.

A chi-square analysis was completed to compare the frequencies of aquatic plants in Bear Trap Lake from the 2014 to 2020 surveys and the 2007 to 2020 surveys. In a previous survey in 2014, this same analysis was conducted between 2007 and 2014. This was not carried over since the 2007 to 2020 comparison is a better long-term comparison. Table 9 lists the statistically significant decreases and table 10 lists the statistically significant increases in survey comparisons.

Bear Trap Statistically significant decrease in **species**	FOO 2007	FOO 2014	FOO 2020	Significant decrease **2014-2020**	Significant decrease **2007-2020**
Potamogeton zosteriformis- Flat-stem pondweed	46.6%	30.4%	23.2%	No	Yes (p=0.0002)
Potamogeton pusillus- Small pondweed	22.9%	14.7%	9.8%	No	Yes (p=0.008)
Najas flexilis- Slender naiad	22.9%	8.8%	9.8%	No	Yes (p=0.008)
Ranunculus aquatilis- White water crowfoot	27.1%	8.8%	8.0%	No	Yes (p=0.00015)
Potamogeton illinoensis- Illinois pondweed	21.2%	2.9%	6.2%	No	Yes (p=0.001)
Elodea canandensis- Common waterweed	17.8%	1.0%	8.9%	No	Yes (p=0.05)
Potamogeton friesii- Fries pondweed	7.6%	1.0%	1.8%	No	Yes (p=0.04)
Potamogeton foliosus- Leafy pondweed	2.5%	5.9%	0.0%	Yes (p=0.009)	No
Potamogeton crispus- Curly-leaf pondweed July Survey*	9.8%%	9.8%%	3.6%	Yes (p=0.04)	Yes (p=0.04)
Potamogeton crispus- Curly-leaf pondweed June Survey	n/a	35.7%	28.6%	No (p=0.2)	n/a

*Curly-leaf pondweed typically undergoes senescence by early July, so sampling this plant in late July is highly variable and may not indicate any effect on the distribution throughout the lake.

Table 9: List of species with a statistically significant decrease in Bear Trap Lake. This is from a chi-square analysis.

Bear Trap Statistically significant increase in **species**	FOO 2007	FOO 2014	FOO 2020	Significant increase **2014-2020**	Significant increase **2007-2020**
Myriophyllum sibiricum- Northern watermilfoil	3.4%	9.8%	13.4%	No	Yes (p=0.006)
Potamogeton richardsonii- Clasping pondweed	24.6%	21.6%	33.9%	Yes (p=0.04)	No
Vallisneria americana- Wild celery	44.1%	12.7%	44.1%	Yes (p=0.00001)	No
Heteranthera dubia- Water stargrass	19.5%	7.8%	22.3%	Yes (p=0.003)	No
Elodea canadensis- Common waterweed	17.8%	1.0%	8.9%	Yes (p=0.008)	No

Table 10: A list of species with a statistically significant increase from a chi-square analysis.

Most of the significant decreases are reflected in the 2007 to 2020 comparison. Some of these species had high frequencies of occurrence in 2007 with most decreases in 2014 and maintained in 2020, or in some cases, decreased even more. There was a decrease in seven species of native plants. The most profound decreases were in flat-stem pondweed (*Potamogeton zosteriformis*), whitewater crowfoot (*Ranunculus aquatilis*), and Illinois pondweed (*Potamogeton illinoensis*). The cause for these decreases is unknown. In the three surveys that have occurred, the plant community in Bear Trap Lake has shown to be quite variable.

Mechanical harvest has been occurring in May-June to target CLP, but some non-targeted native species are removed in the mechanical harvest. When managing invasive plants, decreases in native species is often a concern. However, if these decreases were largely due to mechanical harvest, more significant decreases should have occurred between 2014 and 2020, since harvest did not start until 2016. Leafy pondweed-*Potamogeton foliosus* was the only species with a significant decrease from 2014 to 2020. The frequency of this plant was already low, so this does not strongly suggest mechanical harvest has had a detrimental effect on the native plants.

In the comparison of CLP sampled in only July from 2014 to 2020, a statistically significant decrease occurred in CLP. Since CLP dies in early/mid-July, the growth of CLP in late July can immensely vary. Therefore, attributing this decline to mechanical harvest is not prudent. Although this harvest could be a factor, that conclusion cannot be drawn. The June CLP survey showed no significant decrease from 2014 to 2020.

There was only one species with a statistically significant increase from 2007 to 2020 (northern watermilfoil-Myriophyllum sibiricum). There were four increases from 2014 to 2020. The survey in 2014 showed decreases in coverage and several native species. Some of these species' frequency rebounded in the 2020 survey resulting in significant increases from 2014 to 2020. One of these species, common waterweed (*Elodea canadensis*), showed a statistical decrease from 2007 to 2020 regardless of the increase from 2014 to 2020.

Lake Wapogasset

Other than a large decrease in plant coverage from 2007 to 2014, all three survey statistics show little change in the plant community overall. The diversity and FQI remain nearly identical, showing the plant community overall demonstrates little change.

Lake Wapogasset Parameter	2007	2014	2020
Number of sample points with plants	265	235	269
Species richness	30	27	27
Simpson's diversity index	0.91	0.89	0.91
Maximum depth of plants	21.2	20.1 ft	21.8 ft
FOO in littoral zone depths	65.9%	59.8%	64.51%
FQI	31.2	30.2	30.2

Table 11: Various survey data compared from three surveys conducted on Lake Wapogasset.

Individual species' frequencies indicate some changes. In terms of significant decreases, seven native species decreased from 2007 to 2020. From 2014 to 2020, seven species had significant decreases. Most of the 2014 to 2020 decreases were with species that have relatively low frequencies, so smaller changes can be statistically significant. The major changes in higher frequency species were from 2007 to 2020 which is not desirable considering the water clarity in Lake Wapogasset.

Lake Wapogasset Statistically significant decrease in **species**	FOO 2007	FOO 2014	FOO 2020	Significant decrease **2014-2020**	Significant decrease **2007-2020**
Vallisneria americana- Wild celery	35.8%	17.9%	19.3%		Yes ($p=1.9X10^{-5}$)
Ceratophyllum demersum- Coontail	63.4%	17.4%	46.5%		Yes ($p=8.5X10^{-5}$)
Potamogeton zosteriformis- Flat-stem pondweed	38.1%	15.7%	9.7%	Yes (p=0.04)	Yes ($p=1.2X10^{-14}$)
Potamogeton pusillus- Small pondweed	34.0%	14.9%	10.4%		Yes ($p=5.4X10^{-11}$)
Najas flexilis- Slender naiad	24.5%	14.0%	12.6%		Yes (p=0.0004)
Potamogeton friesii- Fries' pondweed	15.5%	6.8%	3.7%		Yes ($p=3.8X10^{-6}$)
Elodea canadensis- Common waterweed	14.3%	1.3%	7.4%		Yes (p=0.01)
Potamogeton foliosus- Leafy pondweed	2.3%	9.4%	0.0%	Yes ($p=2.9X10^{-7}$)	No
Lemna minor- Small pondweed	3.4%	7.2%	2.2%	Yes (p=0.007)	No
Potamogoten amplifolius- Large-leaf pondweed	0.8%	1.7%	0.0%	Yes (p=0.03)	No
Nitella sp.- Nitella	0.4%	4.2%	0.0%	Yes (p=0.0006)	No
Nymphaea odordata- White water lily	0.8%	5.1%	1.5%	Yes (p=0.02)	No

Lake Wapogasset Statistically significant decrease in **species**	FOO 2007	FOO 2014	FOO 2020	Significant decrease **2014-2020**	Significant decrease **2007-2020**
Potamogeton strictifolius- Stiff pondweed	0.0%	3.8%	0.4%	Yes (p=0.005)	No
Potamogeton crispus- Curly-leaf pondweed July Survey*	17.5%	18.6%	6.3%	Yes (p=0.00002)	Yes (p=0.00005)
Potamogeton crispus- Curly-leaf pondweed June Survey	n/a	58.4%	41.3%	Yes (p=0.00007)	n/a

* Curly-leaf pondweed typically undergoes senescence by early July, so sampling this plant in late July is highly variable and may not indicate any effect on the distribution throughout the lake.

Table 12: A list of species with a statistically significant increase from the chi-square analysis of Lake Wapogasset.

There were three native species with significant increases from 2007 and 2014 to 2020. The most profound increase was with northern watermilfoil (*Myriophyllum sibiricum).* Also, two species (coontail and common waterweed) had significant increases from 2014 to 2020, though these same species decreased significantly from 2007 to 2020. These two plants rebounded from major decreases from 2007 to 2014, but had not returned to 2007 frequencies in 2020.

Lake Wapogasset Statistically significant increase in **species**	FOO 2007	FOO 2014	FOO 2020	Significant increase **2014-2020**	Significant increase **2007-2020**
Myriophyllum sibiricum- Northern watermilfoil	5.7%	1.6%	20.4%	Yes ($p=5.0X10^{-5}$)	Yes ($p=4.2X10^{-7}$)
Heteranthera dubia- Water stargrass	2.3%	3.0%	9.3%	Yes (p=0.004)	Yes (p=0.005)
Potamogeton gramineus- Variable pondweed	0.0%	0.0%	3.0%	Yes (p=0.008)	Yes (p=0.005)
Ceratophyllum demersum- Coontail	63.4%	17.4%	46.5%	Yes ($p=4.6X10^{-12}$)	No
Elodea canadensis- Common waterweed	14.3%	1.3%	7.4%	Yes (p=0.00095)	No
Lemna trisulca- Forked duckweed	4.5%	0.8%	4.1%	Yes (p=0.02)	No
Ranunculus aquatilis- White water crowfoot	12.5%	0.0%	13.0%	Yes ($p=9.9X10^{-9}$)	No

Table 13: A list of species with a statistically significant increase from the chi-square analysis of Lake Wapogasset.

The invasive species CLP showed a significant decrease from 2007 and 2014 to 2020 in the late-July frequency. As stated earlier, this July growth can immensely vary, so a conclusion cannot be drawn about the reduction due to harvest. However, CLP significantly decreased in the June surveys from 2014 to 2020, which could indicate reductions due to the harvesting of CLP. Since CLP growth can vary from year, there is no certainty the reduction is from harvest. The p-value is small, so the decrease is significant.

Discussion

The results of the 2020 aquatic macrophyte survey on Bear Trap Lake and Lake Wapogasset show a moderately diverse plant community dominated by common aquatic plants in Wisconsin lakes. Coontail (*Ceratophyllum demersum*) has a high relative frequency in both lakes with nearly 1 in 4 (Bear Trap Lake) and 1 in 5 (Lake Wapogasset) plants sampled being coontail. Lake Wapogasset shows higher diversity than Bear Trap Lake. This would be expected since Bear Trap Lake has a narrower littoral zone with a less diverse habitat than Lake Wapogasset. The FQI indicates both lakes have relatively healthy plant communities and little change due to human activity. In both lakes, there have been several significant reductions in native species over the past three surveys. This plant community needs continued monitoring with full lake aquatic macrophyte surveys occurring every 5-6 years in accordance with the previous scheduled surveys.

Mechanical harvest has been utilized the past four summers. Although this could contribute to decreased frequency in some plant species, most reductions occurred from 2007 to 2014, which is prior to the use of mechanical harvest. The data from the 2020 survey does not lead to any recommendation for ceasing the use of mechanical harvest. However, continued monitoring is important and targeting only CLP in the harvest process is also important for protecting native plants.

CLP (*Potamogeton crispus*) is the only invasive species sampled and has been managed the past four years using mechanical harvest. In Lake Wapogasset, there is some indication that this harvest may be reducing CLP in frequency. Some other invasive plants were observed around the lake, and a more formal AIS survey may be warranted to map any changes over time. None of these plants were sampled at sample points. Except for CLP, these invasive plants have not had all locations recorded or mapped. Narrow-leaved cattail and reed canary grass has likely been present in these two lakes for some time. However, the yellow iris was just documented in 2020 and with the wetland areas around these lakes, this plant should be monitored more formally. The best time to identify yellow iris is in July when it flowers (bright yellow) and is more easily decerned from the native blue flag iris.

Protection of the native plant communities in Bear Trap Lake and Lake Wapogasset should be preserved. Any management of invasive species needs to strongly consider impacts on the native plants. In any given year, both lakes have marginal water clarity later in the summer. The native plant coverage could be limited in areas if consistently low water clarity occurs annually. Therefore, any other sources of reduction could adversely affect the plant community. Furthermore, native aquatic plants can absorb some of the excess phosphorus in the water column and the sediments, potentially helping increased water quality.

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