Aquatic Plant Survey of Pigeon Lake
during
High Water

August 2018
Bayfield County, Wisconsin

Project initiated by:
Pigeon Lake Association

Survey and report completed by:
Aquatic Plant & Habitat Services, LLC
Sara Hatleli
N4888 Beck Rd.
Taylor, WI 54659
715-299-4604
Sarahatleli97@gmail.com

Photos from Cover Page

1. **High water in Pigeon Lake floods County Highway N to the south.**
2. **Aquatic form of water smartweed (*Persicaria amphibia* var. *stipulacea)* occurred in Pigeon Lake.**
3. **Intermediate form of water smartweed that closely resembled the terrestrial variety (var. *emersa)* was common in Pigeon Lake.**

ABSTRACT

An aquatic plant survey was conducted on Pigeon Lake (WBIC 2489400) on August 31st, 2018 when the water level was 5 feet higher than normal. A total of 433 points were surveyed using methods from Hauxwell (2010) and vegetation was present at 117 sites. The maximum rooting depth was 22 feet, and the maximum depth recorded was 31 feet (normal maximum depth 26 feet, WDNR 2019). Most plant species were growing in depths ≤18 feet while nitella was the only species found 19-22 feet. Overall, the aquatic plant community of Pigeon Lake was somewhat sparse on a lake-wide scale but healthy. A total of 18 species of aquatic plants were found, one of which was "visual only" (i.e., within 6 feet of the survey point but not found on the rake) and another that was documented as part of the boat survey (> 6 feet from any survey point). Filamentous algae and aquatic moss are not counted as one of the 18 species and were documented at only one site each. There were no aquatic invasive species found during the survey. Variable pondweed (*Potamogeton gramineus)*, water smartweed (*Persicaria amphibia),* and muskgrass (*Chara sp.*), were the most common species found with relative frequencies of 28%, 25%, and 19%, respectively. Their combined relative frequency of 72% suggests a somewhat homogeneous plant community. The Simpson Diversity Index was moderately high at 0.81 on a scale from 0 to 1. The floristic quality index was 24.8 and was higher than average for the eco-region (24.3), which indicates the aquatic plant community is reflective of a lake with low human perturbations. Water smartweed was present on the rake at 48 sites plus 50 visual occurrences and was abundant in the western quarter of the lake. An intermediate form closely resembling the terrestrial form (var. *emersa)* was more common than the aquatic form and both forms were found at depths ranging 9 to 16 feet. There were 163 sites that presumably grew plants during normal lake levels but because of the high water, only dead vegetation occurred on the rake. Of these 163 sites, 155 were ≥14 feet deep at the time of the survey. Recommendations for aquatic plant management in Pigeon Lake are as follows: 1) Protect native aquatic plants, 2) Conduct watercraft inspections to prevent introduction of invasive species, 3) Continue volunteer water monitoring, 4) Initiate citizen-based aquatic invasive species monitoring, 5) Continue outreach and education to existing and new lake residents, 6) Pursue grant funding to create a comprehensive lake management plan.

TABLE OF CONTENTS

INTRODUCTION

Project Background

The Pigeon Lake Association (PLA) was awarded a grant from the DNR in 2018 to complete the first aquatic plant survey of the lake that same year. In the grant application, the association stated an interest in learning whether invasive species were present, initiating plans for comprehensive lake management, and educating the lake community. PLA partnered with Aquatic Plant and Habitat (APHS) services to complete a point-intercept aquatic plant survey of all species in 2018. Unfortunately, a major rain event in mid-June 2018 dumped 16 inches of rain and caused major flooding in the lake. Since Pigeon is a seepage lake there is no outlet for flood waters to escape, leading to high lake levels that caused significant erosion, flooding of homes and cabins, compromising of some wells and septic systems, and flooding of County Highway N[1]. Whether this aquatic plant survey should occur in 2018 was uncertain because the high water conditions would not be representative of a "normal" year. With input from the DNR and PLA, the plant survey did occur on August 31st, 2018 and provides information on the lake during high water conditions.

Study Site

Pigeon is a seepage lake with a normal maximum depth of 26 feet and mean depth of 12 feet. During the high-water conditions in 2018, the maximum depth recorded was actually 31 feet and mean depth was 19 feet. The lake is situated at the very "top" of the Upper St. Croix & Eau Claire Rivers watershed that drain to the Mississippi and not the White River watershed that drains to Lake Superior as previously thought.[2] Pigeon Lake is considered mesotrophic with a mean summer secchi depth of 16 feet, mean phosphorus of 16 µg/l, and mean summer chlorophyll TSI of 48 based on data collected by volunteers since 1998 (WDNR, 2019). Lower water clarity of 5 feet was recorded by volunteers in 2018 and during this survey a secchi depth of 10 feet was documented.

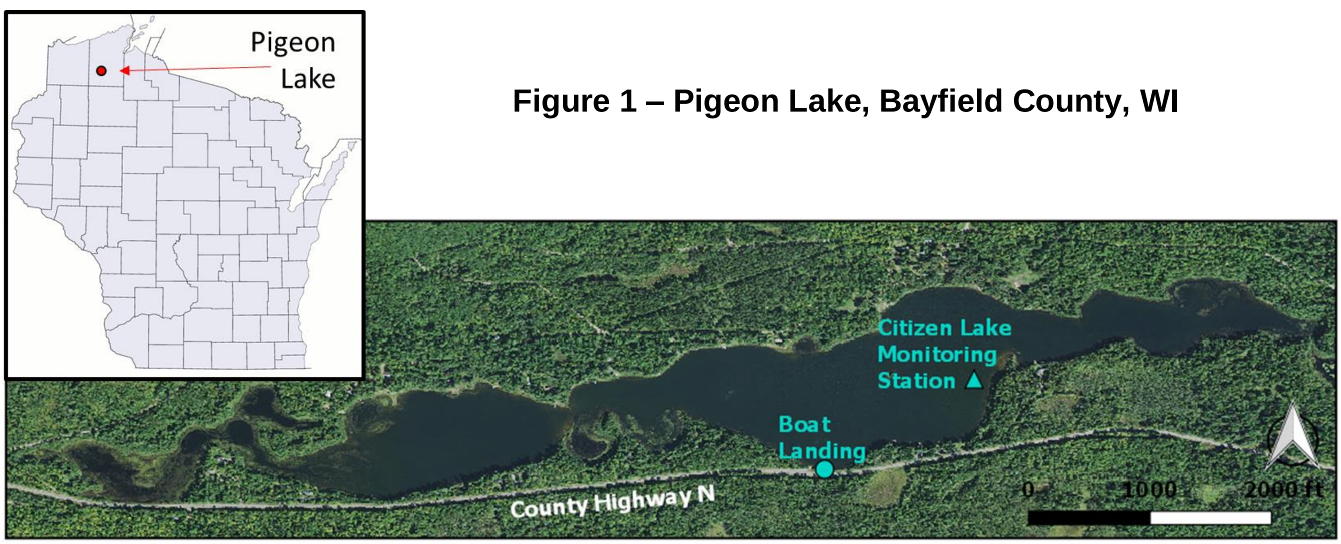


Figure 1 – Pigeon Lake, Bayfield County, WI

[1] High water persisted through the summer, fall, and into the winter 2018-19. At the time of writing this report, frozen lake water was still encroaching onto County Highway N and causing problems for several cabins/homes around the lake.

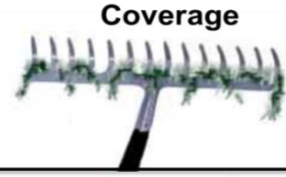
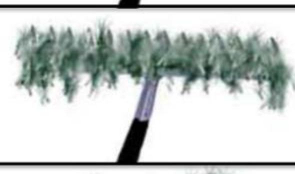
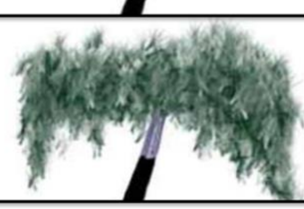
[2] Email correspondence with Pamela Toshner, WDNR. July 12, 2018.

METHODS

Field Methods

Field methods followed the standardized protocol developed by the Wisconsin Department of Natural Resources (WDNR) in Hauxwell et. al (2010) and the survey was completed August 31st, 2018. A grid of survey points that were 43 meters apart was provided by the DNR (Appendix A). Sampling of points 25 feet or shallower was done at the beginning of the survey and when no living vegetation was found at several sites of 25 feet, sampling depth was decreased by 1-foot increments until the maximum rooting depth of 22 feet was determined. The survey coordinates were uploaded to an iPhone using Avenza Maps application, allowing navigation to each survey point on the lake. A double-sided rake head on a telescopic pole was used to sample each point ≤15 feet deep for aquatic plants, depth, and dominant sediment type (muck, rock, or sand). Sonar was used to gauge depth at points that were greather than 15 feet deep and a weighted double-sided rake attached to a rope was used to sample aquatic plants at those points. Sediment type was recorded as “unknown” where the rope-rake assembly was used. The rake fullness rating for total coverage of plants on the rake and a separate rake fullness rating for each species present were recorded (Figure 2). Any inaccessible survey points were recorded as such and no sample was taken. Aquatic plants found within 6 feet of the sample point but not found on the rake were counted as visual observations. Occurrence of species greater than 6 feet from any survey point were recorded to note their presence as part of a boat survey, but were not counted in statistical calculations. Plant identification was verified using Skawinski (2014).

Figure 2 - Rake Fullness Rating Illustration

Rating	Coverage	Description
1		Few plants
2		Plants cover length of the rake but not tines
3		Rake completely covered, tines not visible

Data Analysis Methods

Survey data were used to calculate statistics including Simpson Diversity Index, species richness, Nichols (1999) Floristic Quality Index, frequencies, rake fullness, number of visual sightings, and other summary statistics. The "Aquatic Plant Survey Data Workbook" was downloaded from the UW-Extension Lakes webpage and the spreadsheet was populated with data collected from Pigeon Lake. Species that were recorded as visuals (i.e., within 6 feet of a survey point but not sampled with the rake) were not included in Simpson Diversity Index and FQI calculations. Also, filamentous algae was not used in any statistical calculations but was counted to gauge its frequency throughout the lake.

Summary Statistics

Summary statistics provide a general overview of the plant community and can be used to compare Pigeon Lake to itself in future years or to other lakes in the region or state. Floristic Quality Index (FQI) is summarized in Table 1, but elaborating on this metric developed by Nichols (1999) is worthwhile. Aquatic plant species native to Wisconsin have a Coefficient of Conservatism (C) ranging from 0 to 10. The C value estimates the likelihood of that plant species occurring in an environment that is relatively unaltered from pre-settlement conditions. As human disturbance increases, species with a lower C value occur more frequently while more sensitive species with a higher C value occur less frequently. To calculate floristic quality, the mean C value of all species found in the lake is multiplied by the square root of the total number of plant species in the lake. Only plants found on the rake are included in the calculations. Overall, the FQI metric helps us understand how close the aquatic plant community is to one of undisturbed conditions. A higher FQI value assumes a healthier aquatic plant community. Floristic quality values can be compared on a statewide value, but Nichols (1999) recommends comparing values within one of the four ecoregional-lake types. Pigeon Lake falls within the "Northern Central Hardwood Forests" eco-regional lake type.

Individual Species Statistics

Individual species statistics assess the plant species composition in Pigeon Lake and allow for comparisons of the plant community within the lake (Table 1). Relative frequency values are helpful because they consider the number of times a particular species is found divided by the total number of times vegetation occurred. Frequency of occurrence at sites shallower than the maximum rooting depth, or littoral frequency, is a helpful metric in comparing plant occurrence among different survey years.

Map Development

Aquatic plant survey data were uploaded to an open source geographic information systems (GIS) program known as QGIS (QGIS, 2018). Maps were created to illustrate depth ranges, sediment type, total rake fullness for all species, and individual plant species distribution. Some maps are part of the Results Section while the remainder are compiled in Appendix B.

Table 1 – Statistics Explanation Tables

Statistic		Explanation
1	Total number of sites visited	The total number of sites sampled, which is not necessarily equal to the number of survey points because some sites may not be accessible.
2	Total number of sites with vegetation	Number of sites where at least one plant was found on the rake (does not include moss, sponges, filamentous algae, or liverworts).
3	Maximum depth of plants	Depth of deepest site where at least one plant was found on the rake (does not include moss, sponges, filamentous algae, or liverworts).
4	Total number of sites shallower than maximum depth of plants	Number of sites where depth was less than or equal to the maximum depth where at least one plant was found on the rake.
5	Frequency of occurrence at sites shallower than maximum depth of plants	Total number of sites with vegetation (2) / Total number of sites shallower than maximum depth of plants (4).
6	Average number of species per site (split into four subcategories)	a) Shallower than maximum depth – the average number of species found per site at sites less than or equal to the maximum depth where at least one plant was found on the rake (4).
		b) Vegetated sites only – the average number of species found per site at sites where at least one plant was found on the rake (2).
		c) Native species shallower than maximum depth – Same explanation as 6(a), non-native species excluded from average.
		d) Native species at vegetated sites only – Same explanation as 6(b), non-native species excluded from average.
7	Species Richness (split into two subcategories)	a) Total number of species found on the rake at all sites (does not include moss, sponges, filamentous algae, or liverworts
		b) Including visuals – Same explanation as 7(a) and including visual observations within 6 feet of the sample sight
8	Simpson Diversity Index	Estimates the heterogeneity of a community by calculating the probability that two individuals randomly selected from the data set will be different species. The index ranges from 0-1, and the closer the value is to one, the more diverse the community. Visual observations (within 6 feet of sample point) are not included in calculation of index.
9	Coefficient of Conservatism (C)	This is not a statistical calculation, but rather a value assigned to each plant species based on how sensitive that species is to disturbance. C values range from 1 to 10 with higher values assigned to species that are more sensitive to disturbance (Nichols, 1999).
10	Floristic Quality Index	How similar the aquatic plant community is to one that is undisturbed (Nichols, 1999). This index only factors species raked at survey points and does not include non-native species. The FQI is calculated using coefficient of conservatism values (9).

Individual Statistic	Explanation
Average Rake Fullness	Mean rake fullness rating ranging from 1 to 3. See Rake Fullness Illustration.
Number of sites where a species was found	The total number of survey points where a particular species was found on the rake.
Number of visual sightings	The total number of times a particular species was visually observed within 6 feet of a sampling point, but not collected on the rake.
Frequency of Occurrence (split into two subcategories	a) Among vegetated sites only – The number of sites at which a particular species is found on the rake divided by the total number of vegetated sites (Table 2, #2).
	b) Among sites shallower than the maximum depth of plants – The number of sites at which a particular species is found on the rake divided by the total number of sites less than or equal to the maximum depth of plants (Table 2, #4).
Relative frequency (%)	This value represents the degree to which a particular species contributes to the total of all observations. The sum of all relative frequencies is 100%.

RESULTS

Point-Intercept Survey Results

A total of 433 predetermined survey points were visited in Pigeon Lake, but 115 of those points were deeper than the maximum rooting depth of 22 feet. Of the 318 points that were actually sampled with the rake, 117 had vegetation present (Table 2). The average number of species found at vegetated sites was 1.62 per site and the average rake fullness was 1.43.

A total of 18 species of aquatic plants were found, one of which was "visual only" (i.e., within 6 feet of the survey point but not found on the rake) and one of which was documented as part of the boat survey (> 6 feet from any survey point). Filamentous algae and aquatic moss are not counted in the tally of plant species. A complete list of species is in Table 3. The Simpson Diversity Index was calculated to be 0.81 on a scale from 0 to 1 (See Table 1, #8 for explanation).

Table 2 – Summary Statistics Results

Summary Statistic			Aug 31 2018
1	Total # of sites visited		433
2	Total # of sites with vegetation		117
3	Max. depth of plants (feet)		22.0
4	Total # of sites shallower than max. depth of plants		318
5	Frequency of occurrence at sites shallower than max. depth of plants		36.79
6	Average # of species per site	a) Shallower than max. depth	0.59
		b) Vegetated sites only	1.62
		c) Native shallower than max. depth	0.59
		d) Native species at vegetated sites only	1.62
7	Species Richness	a) Total # species on rake at all sites	16
		b) Including visuals	17
8	Simpson's Diversity Index		0.81
9	Mean Coefficient of Conservatism		6.2
10	Floristic Quality Index		24.8

Individual Plant Species Results

There were 18 aquatic plant species found during the plant survey, not including filamentous algae and aquatic moss (Table 3). No non-native aquatic invasive species were found. Sixteen native plant species were captured on the sampling rake. Variable pondweed was the most commonly found species in the lake with occurrence at 53 sites and relative frequency of 28% (Table 3, Figure 9). The next most common plant species was water smartweed at 48 sites and a relative frequency of 25% (Figure 3). The third most common "plant" was Chara, which is actually a macro algae that resembles vascular aquatic plants in appearance and structural function (Figure 9). There are many species of muskgrasses, but they are often identified simply to genus, as was done in this survey. The remaining plant species were found with much lower frequency than the aforementioned most common species. The total relative frequency of these three plants combined is 72%, which suggests a somewhat homogeneous plant community in the lake. This homogeneity contributes to a moderate Simpson Diversity Index score of 0.81.

Table 3 – Individual Plant Species Results

Common Name	Scientific Name	# Sites	Rel. Freq.	Freq. Occur. Veg. Sites	Freq. Occur ≤max depth	Avg. Rake Full.	# visual
Variable pondweed	*Potamogeton gramineus*	53	28.04	45.30	16.67	1.15	0
Water smartweed	*Polygonum amphibium*	48	25.40	41.03	15.09	1.52	50
Muskgrasses	*Chara sp.*	36	19.05	30.77	11.32	1.08	0
Floating-leaf pondweed	*Potamogeton natans*	19	10.05	16.24	5.97	1.26	3
Fern pondweed	*Potamogeton robbinsii*	6	3.17	5.13	1.89	1.33	0
Common waterweed	*Elodea canadensis*	5	2.65	4.27	1.57	1.00	0
Water star-grass	*Heteranthera dubia*	5	2.65	4.27	1.57	1.00	0
Watershield	*Brasenia schreberi*	3	1.59	2.56	0.94	1.00	2
Nitella	*Nitella sp.*	3	1.59	2.56	0.94	1.00	0
Coontail	*Ceratophyllum demersum*	2	1.06	1.71	0.63	1.00	0
Needle spikerush	*Eleocharis acicularis*	2	1.06	1.71	0.63	1.00	0
Northern water-milfoil	*Myriophyllum sibiricum*	2	1.06	1.71	0.63	1.00	0
Small bladderwort	*Utricularia minor*	2	1.06	1.71	0.63	1.00	3
Water marigold	*Bidens beckii*	1	0.53	0.85	0.31	1.00	0
Small pondweed	*Potamogeton pusillus*	1	0.53	0.85	0.31	1.00	0
Flat-stem pondweed	*Potamogeton zosteriformis*	1	0.53	0.85	0.31	1.00	0
Aquatic moss		1	*	0.85	0.31	2.00	0
Small duckweed	*Lemna minor*	-	-	-	-	-	1
Filamentous algae		-	-	-	-	-	1
Slender riccia	*Riccia fluitans*	***	***	***	***	***	***

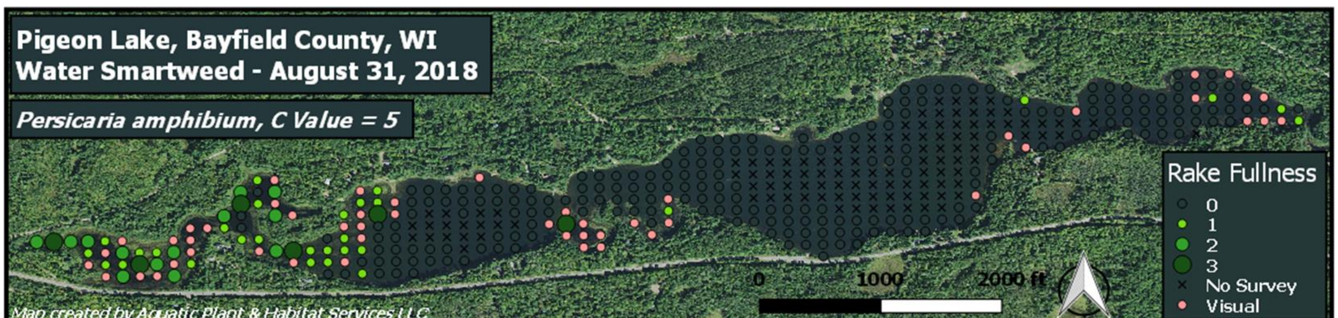
** Excluded from relative frequency analysis*

**** Boat Survey Only (not at survey points and greater than 6 feet from any survey point)*

Individual Plant Species Results (continued)

Although variable pondweed (*Potamogeton gramineus)* was the most commonly occurring plant on the rake, water smartweed (*Persicaria amphibia)* was a close second and had 50 visual observations, which are not counted when calculating statistics, and when combined with rake occurrence yields 98 observations of the plant. Water smartweed is highly variable with terrestrial, aquatic, and intermediate forms. The Consortium of Wisconsin Herbaria lumps the two forms on the same webpage without much distinction between the two (FOW, 2019) while some references treat the two forms as separate varieties (MNW, 2019, Crow & Hellquist, 2000). The terrestrial form (var. *emersa*) stands above the water's surface, has dense hair on the stems, hairy leaves that taper to a sharp point, and a slender flower cluster up to 4 inches long. The aquatic form (var. *stipulacea*) floats on the water's surface, has hairless and more oblong leaves, and shorter flower clusters. Although the aquatic form was present, the most commonly occurring form growing in Pigeon Lake was an intermediate form[3] growing up to 300 feet away from shore where water depths reached 16 feet. Sources suggest that smartweed will root in sediment at depths up to 7 feet. It was possible that plants occurring in deeper water were sourced by shallower plants sending out stolons (lateral stems above the lake sediment along which new vertical shoots can grow) During the survey, intermediate and aquatic forms were not counted separately but the intermediate form was clearly most abundant of the two.

Figure 3 – Water Smartweed Map & Photos



Above: **Aquatic** form of water smartweed (*Persicaria amphibia* var. *stipulacea)*. Its leaves float on the water's surface and are more oblong with a blunt tip. The flower clusters are shorter than the terrestrial form.

Right: **Intermediate** form of water smartweed that more closely resembles the terrestrial form (*Persicaria amphibia* var. *emersa)*. Its leaves stand above the water's surface and taper to a sharp point. The flower clusters are taller than the aquatic form.

[3] Paul Skawinski, aquatic botanist, identified the more emergent form of smartweed to be an intermediate between var. *emersa* and var. *stipulacea*. The truly terrestrial form (var. *emersa*) would be densely hairy on the stems and leaves to prevent water loss. Email correspondence January 25th, 2019.

Floristic Quality

Pigeon Lake is located within the Northern Central Forest eco-region. The Floristic Quality Index (FQI) only factors native species raked at survey points. Therefore, 16 species were included in the calculation, which is higher than the average number of species found in lakes in the same eco-region (13) and also higher than the statewide average (13) (Table 4). The overall floristic quality of Pigeon Lake was 24.8 compared to the slightly lower eco-region average of 24.3 and lower state average (22.2). The average C value for Pigeon Lake (6.2) was higher than state average of 6.0 but lower than the eco-region average of 6.7 (Nichols, 1999).

Table 4 – Floristic Quality Results

Common Name		Scientific Name		C Value
Variable pondweed		*Potamogeton gramineus*		7
Water smartweed		*Polygonum amphibium*		5
Muskgrasses		*Chara sp.*		7
Floating-leaf pondweed		*Potamogeton natans*		5
Fern pondweed		*Potamogeton robbinsii*		8
Common waterweed		*Elodea canadensis*		3
Water star-grass		*Heteranthera dubia*		6
Watershield		*Brasenia schreberi*		6
Nitella		*Nitella sp.*		7
Coontail		*Ceratophyllum demersum*		3
Needle spikerush		*Eleocharis acicularis*		5
Northern water-milfoil		*Myriophyllum sibiricum*		6
Small bladderwort		*Utricularia minor*		10
Water marigold		*Bidens beckii*		8
Small pondweed		*Potamogeton pusillus*		7
Flat-stem pondweed		*Potamogeton zosteriformis*		6
N	*Statewide 13*	*Region 13*	Pigeon	16
Mean C	*Statewide 6.0*	*Region 6.7*	Pigeon	6.2
FQI	*Statewide 22.2*	*Region 24.3*	Pigeon	24.8

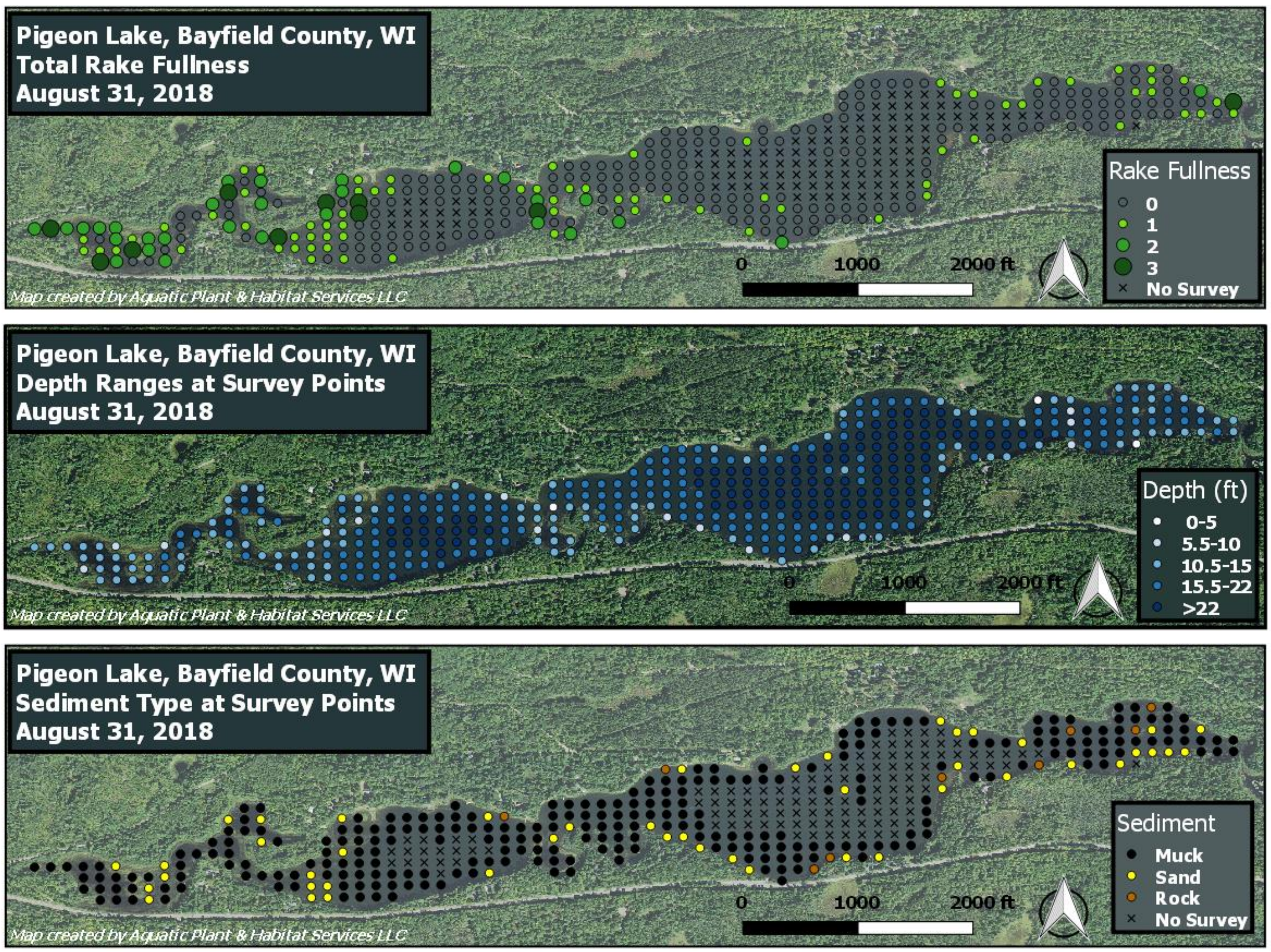
This table includes only those species that were found on the rake at survey points and those that are listed in Nichols (1999). Mean values are listed for statewide and eco-region comparisons to Pigeon Lake.

Plant Distribution, Depth, & Sediment

Plants were sparse in the eastern half of the lake with some areas of plant occurrence near shore and in the far eastern bay. The western quarter of the lake was abundant in vegetation (Figure 4), most noticeably intermediate water smartweed (Figure 3). All of the survey points were accessible but boating through the beds of water smartweed was slow at times. Although plants were found in water depths ranging from 4ft to 22ft, most vegetated sites were between 10 and 16 feet deep.

Points were only sampled if they were 22 feet or shallower. Depth was recorded at survey points that were greater than 22 feet but no sample was taken and the greatest depth recorded was 31 feet compared to maximum depth of 26 feet during normal water conditions. Sediment was recorded as "unknown" at sites >15 feet where the rope-rake assembly was required because it is difficult to discern the sediment type using a rope-rake while the pole-rake allows the surveyor to better "feel" for the sediment type. Most sites had a mucky bottom, some were sand, and few were rock (Figure 4).

Figure 4 – Total Rake Fullness, Depth & Sediment Maps



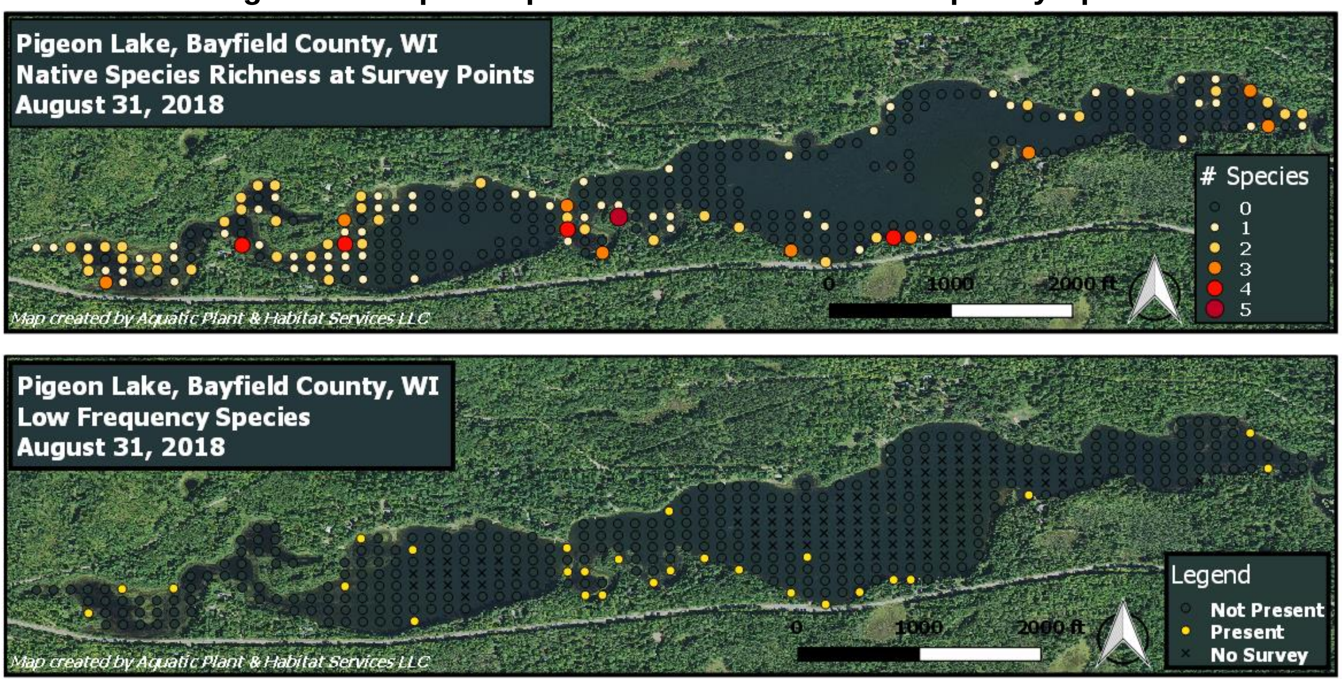
High Value, Sensitive, & Low Frequency Species

Fern pondweed, needle spikerush, and watershield are species identified in Wisconsin Administrative Code NR 109 as "high value species…….. known to offer important values in specific aquatic ecosystems." Fern pondweed was found at 6 sites, needle spikerush at 2 sites, and watershield at 3 sites (Figures 10 &11). None of the species found in Pigeon Lake are currently listed on the WDNR Natural Heritage Inventory list (NHI, 2018).

Small bladderwort was the only species with a high conservatism (C) value of 10 that was documented in the lake (Figure 11). The C value estimates the likelihood of that plant species occurring in an environment that is relatively unaltered from pre-settlement conditions. As human disturbance occurs, species with a low C value are more likely to dominate a lake.

Twelve native species occurred with especially low frequency (fewer than 10 occurrences, including visual observations). The locations of these species is illustrated in Figure 5 and includes fern pondweed, common waterweed, water star-grass, watershield, nitella, coontail, needle spikerush, northern watermilfoil, small bladderwort, water marigold, small pondweed, and flat-stem pondweed.

Figure 5 – Maps of Species Richness & Low Frequency Species



Filamentous Algae

Filamentous algae are single algal cells that are microscopic as individuals but they form long filaments of cells that become visible to the naked eye. The filaments entwine to form a mat that resembles wet wool or cotton and remain submerged until enough air is trapped among the filaments to cause a floating mat. Filamentous algae are found in backwaters and near shore areas where nutrients (especially phosphorus) are readily available. At non-nuisance levels, the algae can provide cover for small aquatic organisms that serve as food for fish. However, floating mats of algae are not aesthetically pleasing and they interfere with recreation such as swimming and fishing. Filamentous algae was found at only one site as a visual observation and therefore did not pose an issue for recreation like the photo shown in Figure 6.

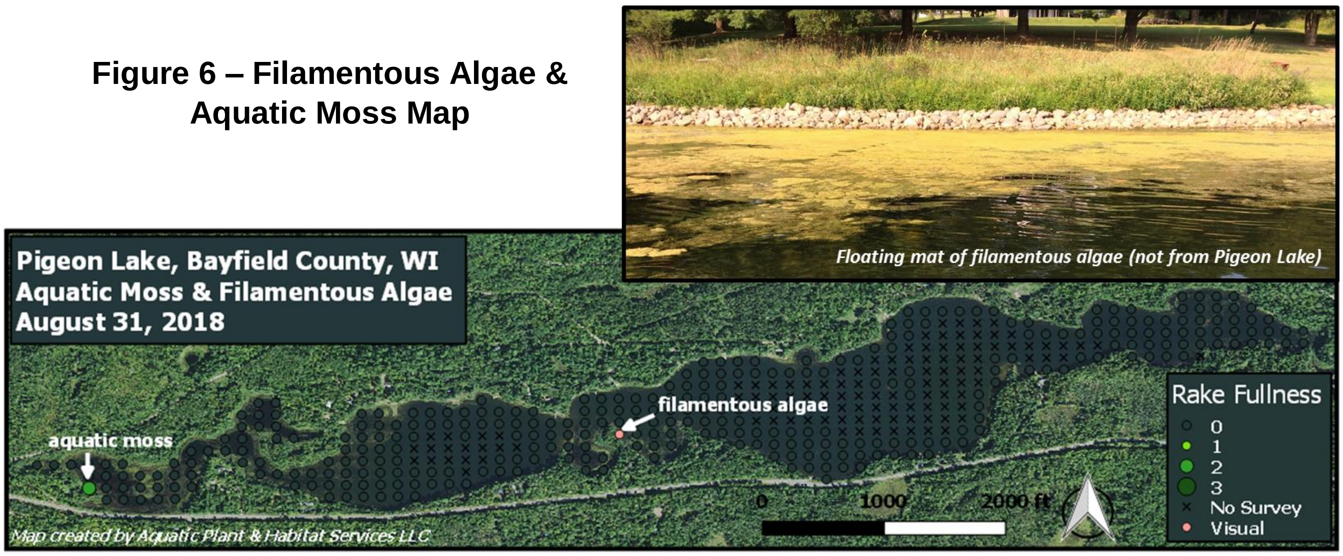


Figure 6 – Filamentous Algae & Aquatic Moss Map

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

Aquatic Plants are Necessary for Healthy Lakes

Aquatic plants serve important functions in lake systems. They provide structural habitat for small invertebrates that are an important food source for juvenile game fish and adult panfish. Plants provide structural habitat for small fish to hide from predators and vice versa as larger predators lurk amongst plants in wait of forage. They offer foraging and/or hiding structure for reptiles, amphibians, and waterfowl. The shorelines of lakes are buffered from wave action when aquatic plants absorb some of the wave energy. Aquatic plants are important consumers of nutrients that would otherwise be available for nuisance algal growth. For these reasons, native aquatic plants should be protected in lakes and a healthy aquatic plant community should be promoted.

There are times when native aquatic plants grow to nuisance levels that hinder the aforementioned functions. Overabundance can lead to dissolved oxygen depletion during respiration (aquatic plants actually USE oxygen at night) and as plants decompose, thereby reducing oxygen available to aquatic organisms. Although the natural growth and senescence of aquatic plants is an important part of the cycling of nutrients in lakes, too many plants may cause a release of excess nutrients as they die. The excess nutrients could then serve to increase vegetation and feed algae blooms.

The Aquatic Plant Community in Pigeon Lake

The aquatic plant community in Pigeon Lake is higher in species richness and floristic quality compared to other lakes in the Northern Central Hardwood Forests eco-region and statewide. The native plant species found in the lake have a slightly higher average conservatism (C) value compared to other lakes statewide but slightly lower compared to other lakes in the eco-region. In other words, the lake has moderate-to-high diversity and the species present are those more likely to be found in lakes with low-to-moderate human disturbance. The aquatic plant community is homogeneous with the three most common species accounting for 72% of the relative frequency and moderate Simpson's Diversity of 0.81. This means you are somewhat likely to find the same plant species across the lake and moderate species richness at survey points. The majority of vegetated survey points yielded one or two plant species, 9 survey points had three species, 4 survey points had four species, and one point had 5 species (Figure 5). Protecting biotic diversity is important for any lake and can be achieved, in part, by carefully managing the areas where high diversity and low frequency species occur. According to Figure 5, these areas are scattered but appear most often along the south central shoreline, the far eastern area, and western area.

It is particularly noteworthy that no aquatic invasive species were found during the survey. Protecting the native aquatic plant community from the introduction of invasive plants, especially Eurasian watermilfoil (*Myriophyllum spicatum),* is important. Initiating a Clean Boats Clean Waters program and citizen-based monitoring for aquatic invasive species are ways to prevent their introduction and provide early detection if a new infestation were to occur.

Water Smartweed in Western Pigeon Lake

The western quarter of Pigeon Lake was abundant in the intermediate form of water smartweed (see page 11 for more information on forms of smartweed). Figure 7 is an example of just one location where this occurred. One lake resident reported that during the summer of 2008, the lake level was low enough to walk across the lake bed from the north shore down to the south shore. The western section of the lake was cut off from the boat landing section. Smartweed, presumably the terrestrial form (var. *emersa),* was noticed growing on the dry lake bed. When water levels rose to normal levels the terrestrial form adapted well and is now ubiquitous as the intermediate form in that western quarter of the lake where significant sections of the lake bed were dry in 2008.

Water smartweed is reported to grow in water depths of 7 feet or shallower (FOW, 2019 and Partridge, 2001). It is interesting that the intermediate form was found where depths ranged from 9 to 16 feet deep. This is likely the result of plants rooted in shallow water sending stolons that emerge above the water surface where the lake happens to be much deeper. The plant is also reported to be well adapted to changing water levels (Partridge, 2001) and extremely variable (Crow & Hellquist, 2000). Although water smartweed is native to Wisconsin, it is found growing to levels in the far western section of the lake that some would interpret as "beneficial use impairment"[4]. It is also important to remember that aquatic plants provide important structural habitat for fish and invertebrates. This will likely be a topic of discussion if the Pigeon Lake Association moves toward more comprehensive lake management in the future.

Figure 7 – Water Smartweed (Intermediate Form), Survey Point 70 Looking SW

[4] According to the DNR Aquatic Plant Management Draft Strategic Analysis, beneficial use impairment is a situation in which aquatic plants prevent beneficial water use activities, including angling, boating, swimming, or other recreational water use activity.

High Water Levels & Impacts to Aquatic Plants in Pigeon Lake

As mentioned in the introduction, a major rain event in June 2018 dumped 16 inches of rain and caused significant flooding. This plant survey was intended to provide information on the aquatic plant community during high water conditions. The lake level was 5 feet higher than normal since June 2018 and persisted all summer, fall, and into winter. Some survey points that would have aquatic plant growth during normal water levels were too deep after the rain event for sufficient light to reach the plants and support continued growth. Hence, a 17-foot survey point during normal conditions was 22 feet during this survey and too deep for most plant growth to occur. To further explain, nitella was found at three sites total ranging from 19-22 feet, while the remaining plant species were found at 18-foot depths or shallower. Figure 8 charts the 163 survey points where only dead vegetation occurred on the rake. Many of those sites (89) were between 19 and 22 feet deep in 2018.

Figure 8 – Graph, Photo, & Map of Dead Vegetation on the Survey Rake

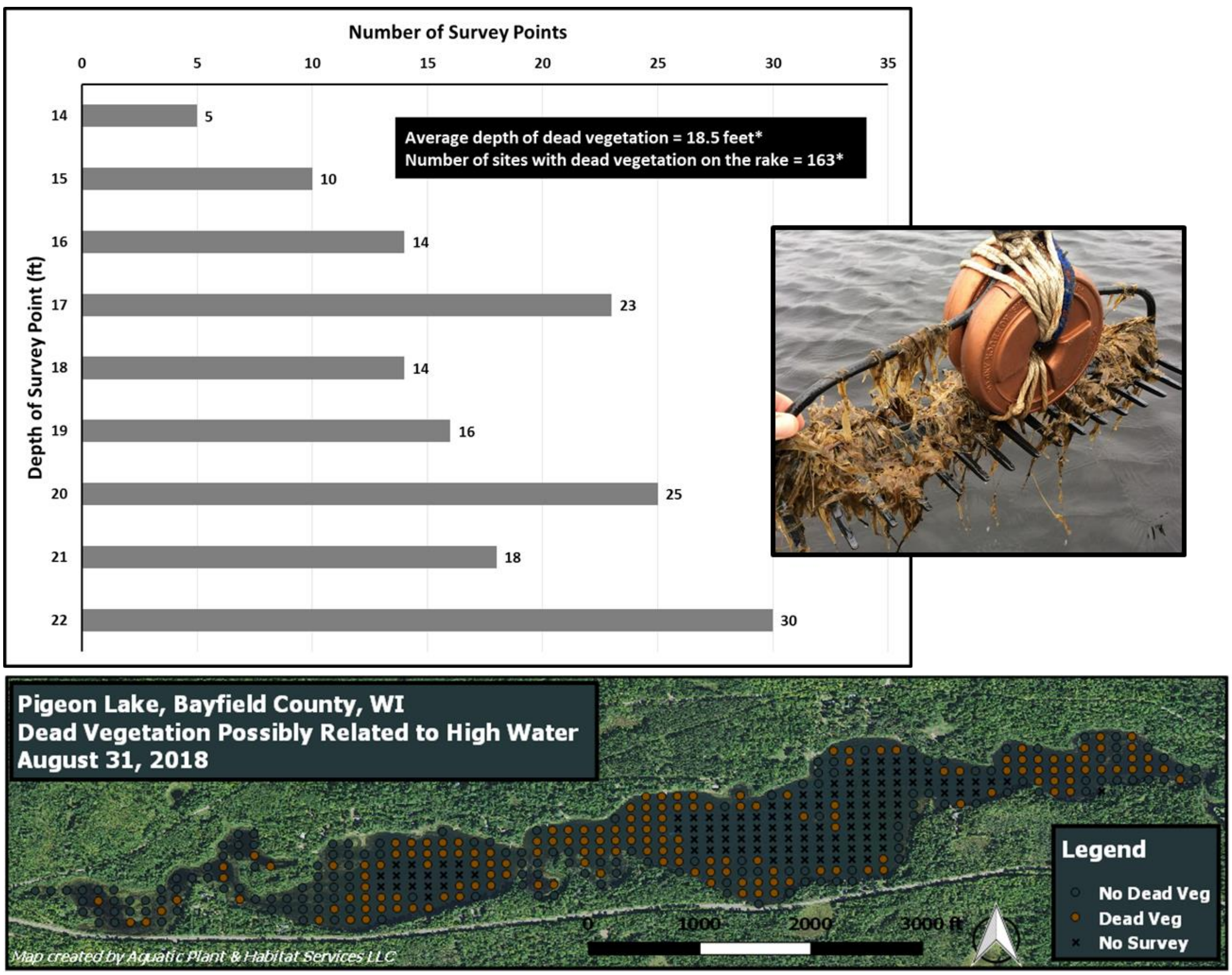


Table 5 - Management Recommendations

1. Protect native aquatic plants as they provide important structural habitat and contribute to a healthy lake system.
1. Conduct watercraft inspections and early detection efforts to prevent the introduction of new aquatic invasive species, particularly Eurasian watermilfoil.
2. Continue volunteer water chemistry and clarity monitoring.
3. Initiate citizen-based aquatic invasive species monitoring through the Citizen Lake Monitoring Network or continue informal monitoring, especially at the boat landing.
4. Continue outreach and education initiatives that are mentioned in the grant application (Pigeon Lake informational folders for new lake residents).
5. Pursue grant funding to create a comprehensive lake management plan.

REFERENCES

Crow, G.E. and C.B. Hellquist. 2000. Aquatic and Wetland Plants of Northeastern North America, Volumes 1 & 2. University of Wisconsin Press. Madison, Wisconsin.

Eichler, L.W., R.T. Bombard, J.W. Sutherland, C.W. Boyen. 1993. Suction Harvesting of Eurasian

FOW, 2019. Flora of Wisconsin, Consortium of Wisconsin Herbaria. Search for Persicaria amphibia. 24 January 2019. http://wisflora.herbarium.wisc.edu/taxa/index.php?taxon=15225

Hauxwell, J., S. Knight, K. Wagner, A. Mikulyuk, M. Nault, M. Porzky and S. Chase. 2010. Recommended baseline monitoring of aquatic plants in Wisconsin: sampling design, field and laboratory procedures, data entry and analysis, and applications. Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010. Madison, Wisconsin. 46pp.

MNW, 2019. Minnesota Wildflowers, a Field Guide to the Flora of Minnesota. Search for Persicaria amphibia. 24 January 2019. https://www.minnesotawildflowers.info/flower/swamp-smartweed.

NHI. 2018. Wisconsin Natural Heritage Working List. 29 November 2018. http://dnr.wi.gov/topic/nhi/wlist.html.

Nichols, S.A. 1999. Floristic Quality Assessment of Wisconsin Lake Plant Communities with Example Applications. Journal of Lake and Reservoir Management. 15(2):133-141.

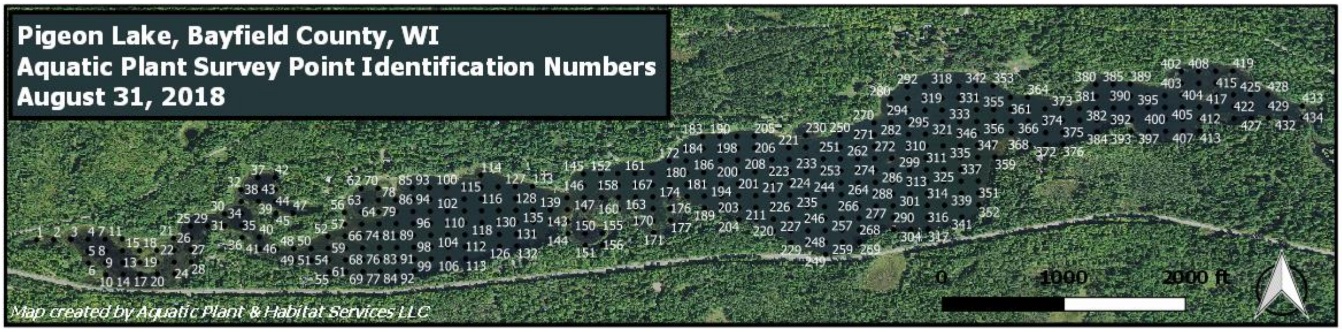
Partridge, J.W. 2001. Biotic Flora of the British Isles *Persicaria amphibia* (L.) Gray (*Polygonum amphibium* L.). Journal of Ecology (89) 487-501.

QGIS Development Team, 2018. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org.

Skawinski, P.M. 2014. Aquatic Plants of the Upper Midwest: A photographic field guide to our underwater forests. Second Edition.

WDNR. 2019. Wisconsin Department of Natural Resources. 25 January, 2019 http://dnr.wi.gov/lakes/lakepages/.

APPENDIX A – POINT INTERCEPT SURVEY MAP



APPENDIX B – AQUATIC PLANT SURVEY MAPS

Includes maps that are not incorporated in the main body of the report. Species maps are in order of relative frequency values in Table 3.

Figure 9 – Variable Pondweed & Muskgrasses Maps

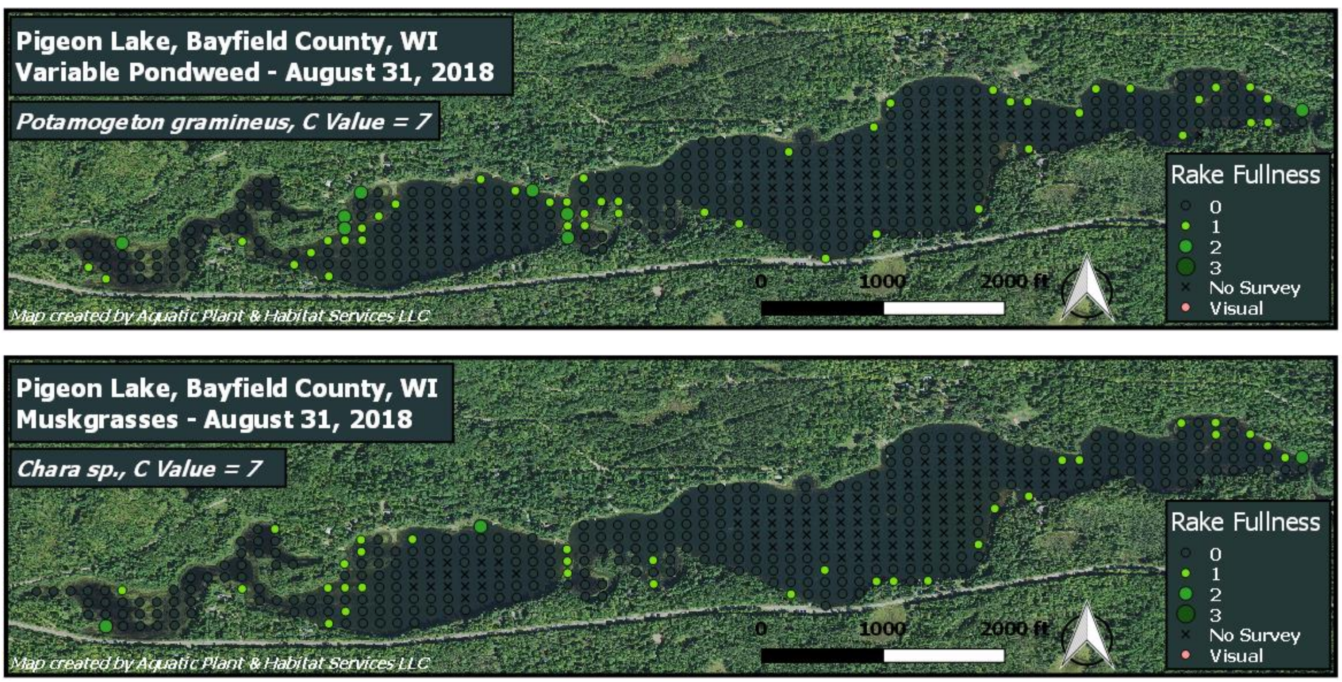
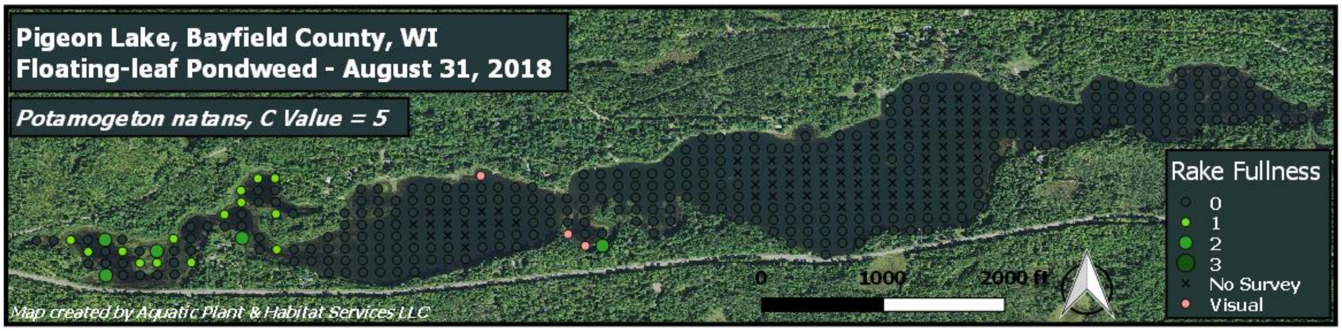
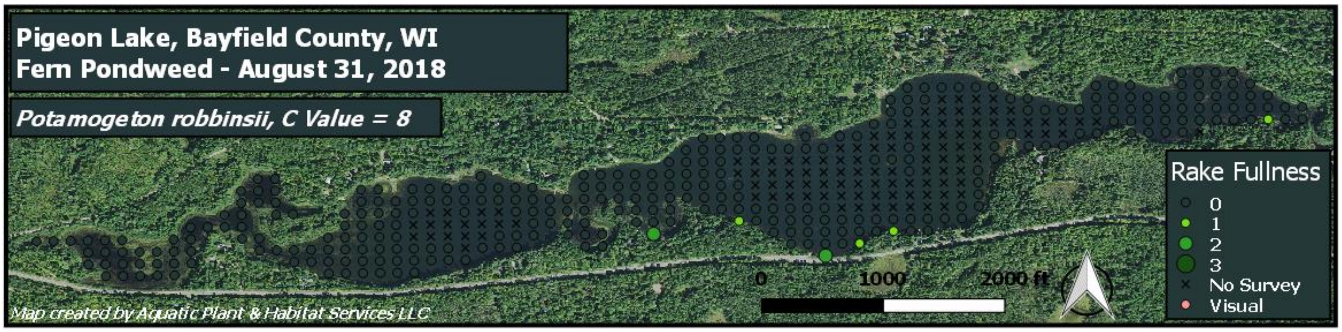
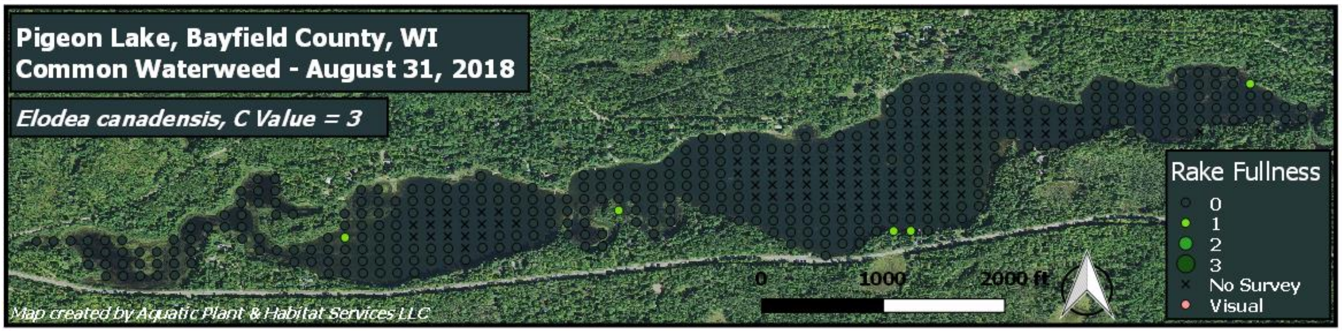


Figure 10 – Floating-Leaf & Fern Pondweeds, Common Waterweed, Water Star-grass, & Watershield Maps







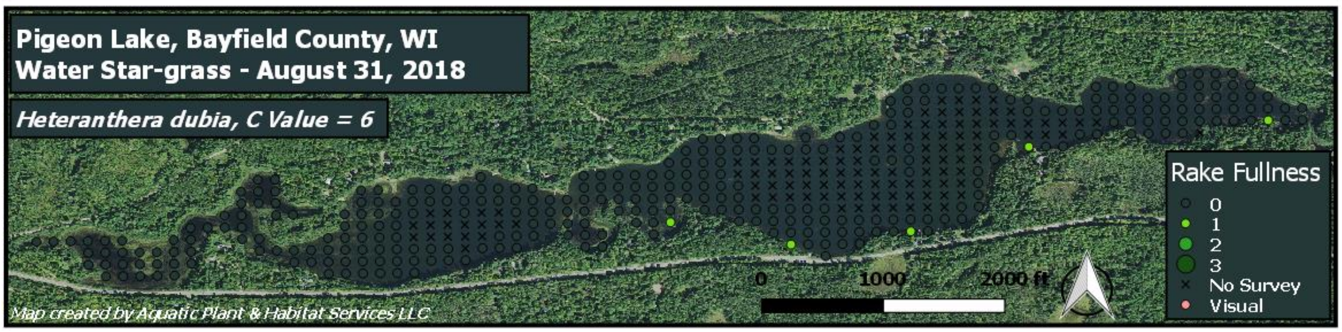


Figure 11 – Nitella, Coontail, Needle Spikerush, Northern Watermilfoil, & Small Bladderwort Maps

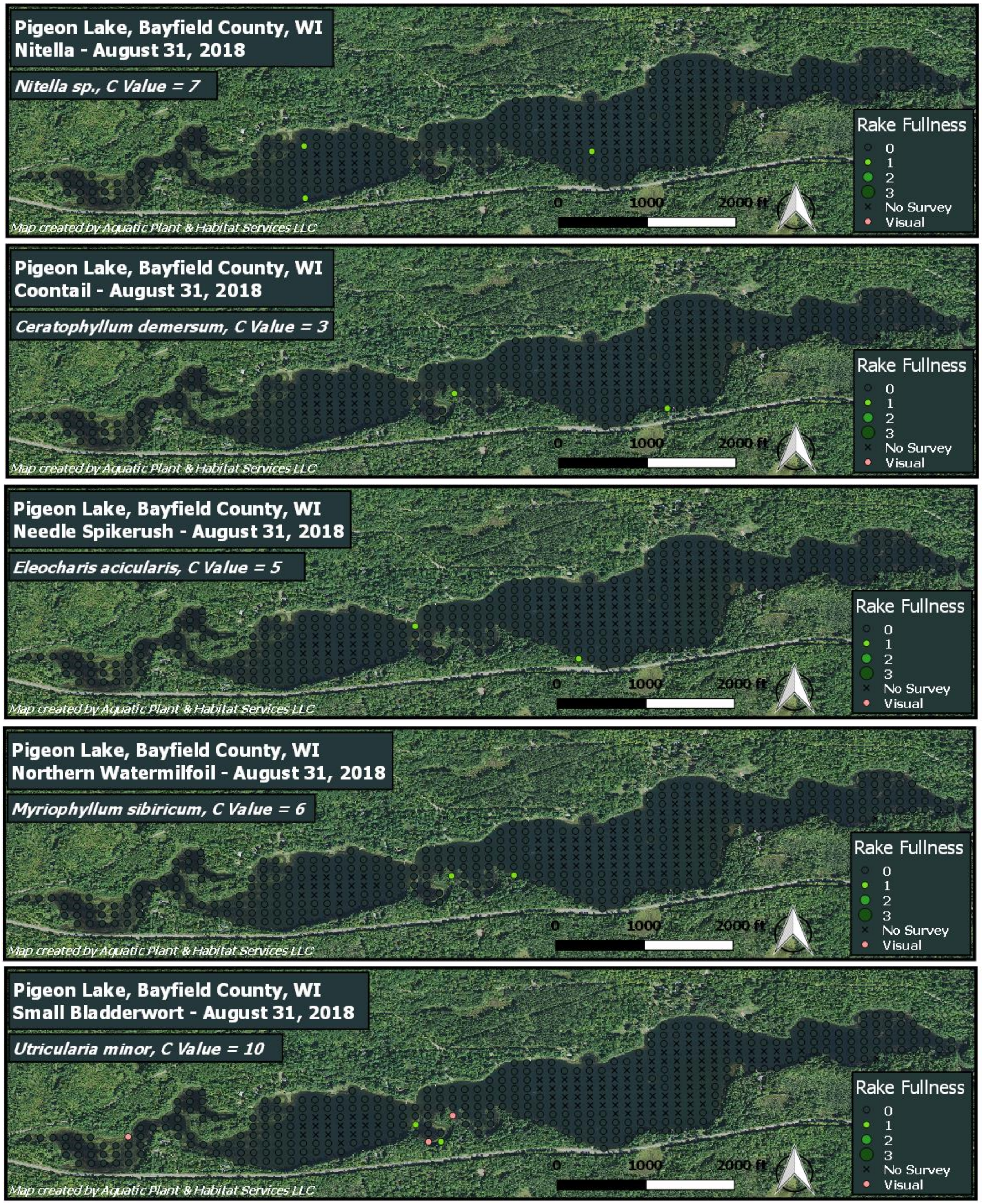


Figure 12 – Small Duckweed, Water Marigold, Flat-stem & Small Pondweeds Maps