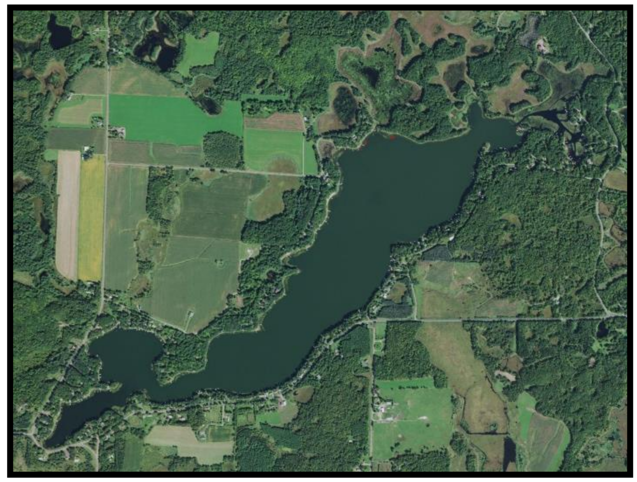
Warm-water Point-intercept Macrophyte Survey
Horseshoe Lake - WBIC: 2630100
Polk/Barron Counties, Wisconsin

Hybrid water-milfoil (Nackerud 2008)



Late Summer 2020 (red) Hybrid Water-milfoil High Density Areas

Project Initiated by:

Horseshoe Lake Improvement Association, Lake Education and Planning Services, LLC, and the Wisconsin Department of Natural Resources

Purple loosestrife in Buckwald Bay – 8/16/20

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August 16-17, 2020

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ABSTRACT

Horseshoe Lake (WBIC 2630100) is a 398-acre stratified seepage lake located on the border of Polk and Barron Counties in northwest Wisconsin. Following the discovery of Hybrid water-milfoil (*Myriophyllum sibiricum* X *spicatum*) (HWM) in 2006, the Horseshoe Lake Improvement Association (HLIA), under the direction of Dave Blumer (Lake Education and Planning Services, LLC), developed Aquatic Plant Management Plans using data from the lake's 2008 and 2013 point-intercept surveys. As a prerequisite to updating their plan in 2021 and to compare how the lake's vegetation may have changed since the last point-intercept surveys, the HLIA and the Wisconsin Department of Natural Resources authorized a full point-intercept survey for all aquatic macrophytes on August 16-17, 2020 (although Curly-leaf pondweed (*Potamogeton crispus*) is present in the lake, no spring survey was conducted in 2020 as previous early-season surveys found it occurs at extremely low levels). During the August 2020 survey, we found macrophytes growing at 246 of 539 sites (45.6% of surveyed points and 76.9% of the 18.5ft littoral zone). This was a highly significant decline **(p<0.001)** from 2013 when plants were present at 329 points (63.9% of surveyed points/88.4% of the then 21.5ft littoral zone) and 2008 when they were growing at 309 points (60.0% of surveyed points/79.4% of the then 24.5ft littoral zone). Overall diversity was exceptionally high with a Simpson Diversity Index value of 0.93 – down from 0.94 in 2013, but identical to 2008. Species richness was also very high with 68 species found growing in and immediately adjacent to the water – up sharply from 59 total species found in 2013/54 in 2008. Although total richness increased, mean native species richness at sites with native vegetation experienced a moderately significant decline **(p=0.002)** from 3.28/site in 2008 to 2.80/site in 2013, and a further significant decline **(p=0.03)** to 2.51/site in 2020. Total rake fullness experienced a highly significant decline **(p<0.001)** from an estimated high mean density of 2.60 in 2008 to a moderate 2.21 in 2013. In 2020, this trend reversed as we found a highly significant increase **(p<0.001)** to a moderately high mean rake of 2.44. In August 2008, Common waterweed (*Elodea canadensis*), Fern pondweed (*Potamogeton robbinsii*), Nitella (*Nitella* sp.), and Creeping bladderwort (*Utricularia gibba*) were the most common macrophyte species (Aquatic moss was the fourth most common species, but it was excluded from analysis as it is not included in the relative frequency calculation). Present at 52.75%, 48.22%, 27.51%, and 18.77% of survey points with vegetation, these species accounted for 44.48% of the total relative frequency. The August 2013 survey identified Fern pondweed, Nitella, Common waterweed, and Small pondweed (*Potamogeton pusillus*) as the most common species. They were found at 39.21%, 28.88%, 24.01%, and 22.80% of sites with vegetation and accounted for 40.78% of the total relative frequency. Lakewide, 17 species showed significant changes in distribution from 2008 to 2013. Common waterweed, Creeping bladderwort, Flat-stem pondweed (*Potamogeton zosteriformis*), and Small duckweed (*Lemna minor*) suffered highly significant declines **(p<0.001)**; Aquatic moss **(p=0.003)**, Coontail **(p=0.001)**, and Large duckweed (*Spirodela polyrhiza*) **(p=0.001)** experienced moderately significant declines; and Fern pondweed **(p=0.02)**, Water star-grass (*Heteranthera dubia*) **(p=0.01)**, and Hybrid water-milfoil **(p=0.02)** demonstrated significant declines. Conversely, Northern naiad (*Najas gracillima*) **(p=0.002)**, Whorled water-milfoil (*Myriophyllum verticillatum*) **(p=0.005)**, and Small bladderwort (*Utricularia minor*) **(p=0.001)** saw moderately significant increases; and filamentous algae **(p=0.02)**, Clasping-leaf

pondweed (*Potamogeton richardsonii*) **(*p*<0.05)**, Slender naiad (*Najas flexilis*) **(*p*=0.02)**, and Water-thread pondweed (*Potamogeton diversifolius*) **(*p*=0.02)** showed significant increases. The August 2020 survey identified Fern pondweed (41.06% of points with vegetation), Watershield (*Brasenia schreberi*) (23.17%), White water lily (*Nymphaea odorata*) (22.76%), and Wild celery (*Vallisneria americana*) (16.67%) as the most common species with a combined relative frequency of 41.26%. From 2013 to 2020, 20 species underwent significant changes in distribution. Common waterweed, Nitella, Aquatic moss, Small pondweed, Vasey's pondweed (*Potamogeton vaseyi*), and Clasping-leaf pondweed suffered highly significant declines **(*p*<0.001)**; and Sessile-fruited arrowhead (*Sagittaria rigida*) **(*p*=0.04)**, Reed canary grass (*Phalaris arundinacea*) **(*p*=0.02)**, Whorled-water-milfoil **(*p*=0.04)**, and Small bladderwort **(*p*=0.01)** saw significant declines. Despite these loses, Watershield, Wild celery, and Small duckweed enjoyed highly significant increases **(*p*<0.001)**; Creeping bladderwort **(*p*=0.002)**, and Spotted pondweed (*Potamogeton pulcher*) **(*p*=0.004)** underwent moderately significant increases; and Coontail **(*p*=0.02)**, Flat-stem pondweed **(*p*=0.03)**, Common bladderwort (*Utricularia vulgaris*) **(*p*=0.02)**, Bald spikerush (*Eleocharis erythropoda*) **(*p*=0.01)**, and Narrow-leaved woolly sedge (*Carex lasiocarpa*) **(*p*=0.02)** had significant increases. Many of the changes seen from 2013 to 2020 appear to have occurred on the outer edge of the littoral zone. The poor clarity we saw during the 2020 survey may be the best explanation of why deepwater species like Nitella and Aquatic moss had largely disappeared, and why other species like Small pondweed and Vasey's pondweed had already set turions and senesced. Conversely, several species that saw significant gains like Watershield, the bladderworts, Bald spikerush, and sedges were dominant species in shallow, previously inaccessible areas. The 49 native index species found in the rake during the August 2020 survey (similar to 47 in 2013/up from 43 in 2008) produced a much above average mean Coefficient of Conservatism of 6.6 (similar to 6.7 in both 2013 and 2008). The Floristic Quality Index of 45.9 (similar to 46.2 in 2013/44.2 in 2008) was also more than double the median FQI for this part of the state. In 2020, filamentous algae were present at 19 sites with a mean rake of 1.63. This was a non-significant decline (*p*=0.94) in distribution but a significant increase **(*p*=0.02)** in density compared to the 26 points (mean rake 1.31) in 2013, and generally similar to the 11 points with a mean rake of 2.09 in 2008. The August 2008 survey found HWM in the rake at five points (mean rake 1.60) with 12 additional visual sightings. Both the August 2013 and 2020 surveys noted HWM was difficult to find as we recorded it as a visual at a single point during each of these follow-up surveys. Statistically, from 2008 to 2013, this demonstrated a moderately significant decline **(*p*=0.008)** in total HWM; a significant reduction in total distribution **(*p*=0.02)**; and a moderately significant decline **(*p*=0.001)** in visual sightings. These results suggest the lake's current management strategy of targeted small-scale herbicide treatments coupled with manual removal is holding HWM in check. Other than CLP and EWM, Purple loosestrife (*Lythrum salicaria*), Reed canary grass, and Hybrid cattail (*Typha* X *glauca*) were the only other exotic plant species found.

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INTRODUCTION:

Horseshoe Lake (WBIC 2630100) is a 398-acre mesotrophic trending towards eutrophic stratified seepage lake located on the border of Polk and Barron Counties in northwest Wisconsin in the Towns of Beaver/Almena (T34N R14/15W). The lake reaches a maximum depth of 57ft in the central basin and has an average depth of approximately 25ft under normal water conditions. The bottom is predominately sand and rock on the margins of the central basin before transitioning to nutrient-poor sandy muck with increased depth. Nutrient-rich organic muck occurs in the lake's sheltered bays on the northeast end (Holt et al. 1968) (Figure 1). From 1995-2020, mean summer Secchi readings have averaged 8.0ft (WDNR 2020). This fair to good water clarity produced a littoral zone that extended to at least 18.5ft in 2020.

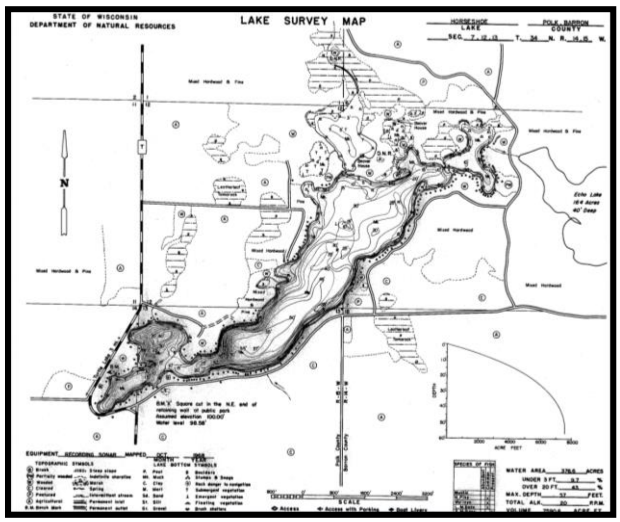


Figure 1: Horseshoe Lake Bathymetric Map

BACKGROUND AND STUDY RATIONALE:

In 2006, the Wisconsin Department of Natural Resources identified the presence of Hybrid water-milfoil (HWM) – a cross between Northern and Eurasian water-milfoils (*Myriophyllum sibiricum* X *Myriophyllum spicatum*) in the lake. Since then, the Horseshoe Lake Improvement Association (HLIA) has been actively working to control this invasive exotic species with herbicides and manual removal as outlined in their Wisconsin Department of Natural Resources (WDNR) approved 2009 and 2014 Aquatic Plant Management Plans (APMP).

Per WDNR expectations (Pamela Toshner/Alex Smith, WDNR – pers. comm.), whole-lake plant surveys on actively managed lakes are normally repeated every five to seven years to remain current. In anticipation of updating their plan in 2021, the HLIA, under the direction of Dave Blumer (Lake Education and Planning Services, LLC), requested a warm-water point-intercept survey of all macrophytes. The survey's objectives were to document current levels of HWM and the lake's native macrophyte community; compare those results to the original 2008 survey and the most recent 2013 survey; and determine if any significant changes had occurred to the lake's vegetation over that time. This report is the summary analysis of that field survey conducted on August 16-17, 2020.

METHODS:
Warm-water Full Point-intercept Macrophyte Survey:
Using a standard formula that takes into account the shoreline shape and distance, water clarity, depth, and total acreage, Jennifer Hauxwell (WDNR) generated a 548-point sampling grid for Horseshoe Lake (Appendix I) that was used during the 2008, 2013, and 2020 surveys. Prior to beginning the August point-intercept survey, we conducted a general boat survey to regain familiarity with the lake's macrophytes (Appendix II). All plants found were identified (Voss 1996, Boreman et al. 1997; Chadde 2002; Crow and Hellquist 2006; Skawinski 2019), and a datasheet was built from the species present.

During the survey, we located each point with a GPS (Garmin 76CSx), recorded a depth reading with a metered pole, and took a rake sample. All plants on the rake, as well as any that were dislodged by the rake, were identified and assigned a rake fullness value of 1-3 as an estimation of abundance (Figure 2). We also recorded visual sightings of all plants within six feet of the sample point not found in the rake. In addition to a rake rating for each species, a total rake fullness rating was also noted. Substrate (bottom) type was assigned at each site where the bottom was visible or it could be reliably determined using the rake.

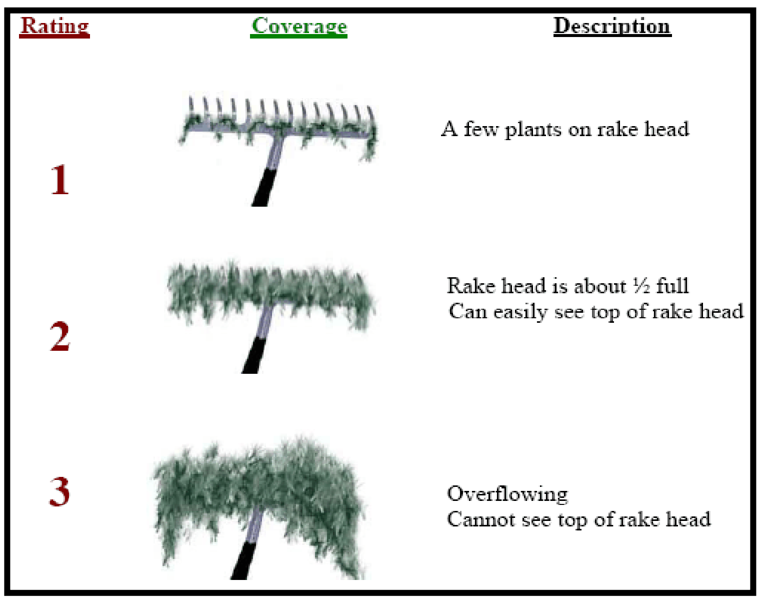


Figure 2: Rake Fullness Ratings (UWEX 2010)

DATA ANALYSIS:

In an effort to visualize the changes on the lake since the first point-intercept survey in 2008, we included summary statistics and maps from each prior survey in the 2020 report and linked folders. We also updated pre-2010 data to the current standard aquatic plant management spreadsheet (Appendix II) (UWEX 2010). Using this same sheet for our 2020 survey, we entered all data collected in the field and calculated the following:

Total number of sites visited: This included the total number of points on the lake that were accessible to be surveyed by boat or kayak.

Total number of sites with vegetation: These included all sites where we found vegetation after doing a rake sample. For example, if 20% of all sample sites have vegetation, it suggests that 20% of the lake has plant coverage.

Total number of sites shallower than the maximum depth of plants: This is the number of sites that are in the littoral zone. Because not all sites that are within the littoral zone actually have vegetation, we use this value to estimate how prevalent vegetation is throughout the littoral zone. For example, if 60% of the sites shallower than the maximum depth of plants have vegetation, then we estimate that 60% of the littoral zone has plants.

Frequency of occurrence: The frequency of all plants (or individual species) is generally reported as a percentage of occurrences within the littoral zone. It can also be reported as a percentage of occurrences at sample points with vegetation.

Frequency of occurrence example:

Plant A is sampled at 70 out of 700 total littoral points = 70/700 = .10 = 10%

This means that Plant A's frequency of occurrence = 10% when considering the entire littoral zone.

Plant A is sampled at 70 out of 350 total points with vegetation = 70/350 = .20 = 20%

This means that Plant A's frequency of occurrence = 20% when only considering the sites in the littoral zone that have vegetation.

From these frequencies, we can estimate how common each species was at depths where plants were able to grow, and at points where plants actually were growing.

Note the second value will be greater as not all the points (in this example, only ½) had plants growing at them.

<u>Simpson's Diversity Index:</u> A diversity index allows the entire plant community at one location to be compared to the entire plant community at another location. It also allows the plant community at a single location to be compared over time thus allowing a measure of community degradation or restoration at that site. With Simpson's Diversity Index, the index value represents the probability that two individual plants (randomly selected) will be different species. The index values range from 0 -1 where 0 indicates that all the plants sampled are the same species to 1 where none of the plants sampled are the same species. The greater the index value, the higher the diversity in a given location. Although many natural variables like lake size, depth, dissolved minerals, water clarity, mean temperature, etc. can affect diversity, in general, a more diverse lake indicates a healthier ecosystem. Perhaps most importantly, plant communities with high diversity also tend to be **more resistant** to invasion by exotic species.

<u>Maximum depth of plants:</u> This indicates the deepest point that vegetation was sampled. In clear lakes, plants may be found at depths of over 20ft, while in stained or turbid locations, they may only be found in a few feet of water. While some species can tolerate very low light conditions, others are only found near the surface. In general, the diversity of the plant community decreases with increased depth.

<u>Mean and median depth of plants:</u> The mean depth of plants indicates the average depth in the water column where plants were sampled. Because a few samples in deep water can skew this data, median depth is also calculated. This tells us that half of the plants sampled were in water shallower than this value, and half were in water deeper than this value.

<u>Number of sites sampled using rope/pole rake:</u> This indicates which rake type was used to take a sample. We use a 20ft pole rake and a 35ft rope rake for sampling.

<u>Average number of species per site:</u> This value is reported using four different considerations. 1) **shallower than maximum depth of plants** indicates the average number of plant species at all sites in the littoral zone. 2) **vegetative sites only** indicate the average number of plants at all sites where plants were found. 3) **native species shallower than maximum depth of plants** and 4) **native species at vegetative sites only** excludes exotic species from consideration.

<u>Species richness:</u> This value indicates the number of different plant species found in and directly adjacent to (on the waterline) the lake. Species richness alone only counts those plants found in the rake survey. The other two values include those seen at a sample point during the survey but not found in the rake, and those that were only seen during the initial boat survey or inter-point. **Note: Per WDNR protocol, filamentous algae, freshwater sponges, aquatic moss and the aquatic liverworts *Riccia fluitans* and *Ricciocarpus natans* are excluded from these totals.**

<u>Average rake fullness:</u> This value is the average rake fullness of all species in the rake. It only takes into account those sites with vegetation (Table 1).

Relative frequency: This value shows a species' frequency relative to all other species. It is expressed as a percentage, and the total of all species' relative frequencies will add up to 100%. Organizing species from highest to lowest relative frequency value gives us an idea of which species are most important within the macrophyte community (Tables 2-4).

Relative frequency example:

Suppose that we sample 100 points and found four species of plants with the following results:

Plant A was located at 70 sites. Its frequency of occurrence is thus 70/100 = 70%
Plant B was located at 50 sites. Its frequency of occurrence is thus 50/100 = 50%
Plant C was located at 20 sites. Its frequency of occurrence is thus 20/100 = 20%
Plant D was located at 10 sites. Its frequency of occurrence is thus 10/100 = 10%

To calculate an individual species' relative frequency, we divide the number of sites a plant is sampled at by the total number of times all plants were sampled. In our example that would be 150 samples (70+50+20+10).

Plant A = 70/150 = .4667 or 46.67%
Plant B = 50/150 = .3333 or 33.33%
Plant C = 20/150 = .1333 or 13.33%
Plant D = 10/150 = .0667 or 6.67%

This value tells us that 46.67% of all plants sampled were Plant A.

Floristic Quality Index (FQI): This index measures the impact of human development on a lake's aquatic plants. The 124 species in the index are assigned a Coefficient of Conservatism (C) which ranges from 1-10. The higher the value assigned, the more likely the plant is to be negatively impacted by human activities relating to water quality or habitat modifications. Plants with low values are tolerant of human habitat modifications, and they often exploit these changes to the point where they may crowd out other species. The FQI is calculated by averaging the conservatism value for each native index species found in the lake during the point-intercept survey** and multiplying it by the square root of the total number of plant species (N) in the lake ($FQI=(\Sigma(c1+c2+c3+\ldots cn)/N)*\sqrt{N}$). Statistically speaking, the higher the index value, the healthier the lake's macrophyte community is assumed to be. Nichols (1999) identified four eco-regions in Wisconsin: Northern Lakes and Forests, North Central Hardwood Forests, Driftless Area and Southeastern Wisconsin Till Plain. He recommended making comparisons of lakes within ecoregions to determine the target lake's relative diversity and health. Horseshoe Lake is in the North Central Hardwood Forests Ecoregion (Tables 5-7).

**** Species that were only recorded as visuals or during the boat survey, and species found in the rake that are not included in the index are excluded from FQI analysis.**

Comparison to Past Surveys: We compared data from our 2008, 2013, and 2020 warm-water point-intercept surveys (Figure 8) to see if there were any significant changes in the lake's vegetation. For individual plant species as well as count data, we used the Chi-square analysis on the WDNR Pre/Posttreatment survey worksheet. For comparing averages (mean species/point and mean rake fullness/point), we used t-tests. Differences were considered significant at *p*<0.05, moderately significant at *p*<0.01 and highly significant at *p*<0.001 (UWEX 2010). It should be noted that we used the number of littoral points with plants (309 in 2008/329 in 2013/246 in 2020) as the basis for comparisons.

RESULTS:

Warm-water Full Point-intercept Macrophyte Survey:

Of the 548 points on the Horseshoe Lake survey grid (Appendix I), nine points were terrestrial or occurred in inaccessible cattail marshes. The 539 points surveyed in 2020 were a highly significant increase **(*p*<0.001)** from the 515 points surveyed in both 2008 and 2013 when low water levels prevented us from reaching three shallow northern bays. Depth soundings taken at these points revealed the main basin was a generally steep-sided wedge that steadily increased in depth from northeast to southwest before bottoming out at approximately 54 ft near the eastern narrows on the lake's west side. The small western basin also dropped off rapidly from shore and reached 40ft. Conversely, the northern bays were generally <8ft deep and sloped gradually from shore (Figure 3) (Appendix III).

Of the 408 points where we could determine the bottom, we characterized the lake's substrate as 66.7% organic and sandy muck (272 points), 23.0% pure sand (94 points), and 10.3% rock (42 points). Most sandy areas occurred along the shoreline; especially around the central basin. These areas quickly transitioned to nutrient-poor sandy muck at most depths over 6ft. More nutrient-rich muck occurred in "Mud Lake", Buckwald Bay, and the many other small unnamed northeast side bays. Rocky areas dominated sunken islands, exposed points, and stretches of the southern shoreline (Figure 3) (Appendix III).

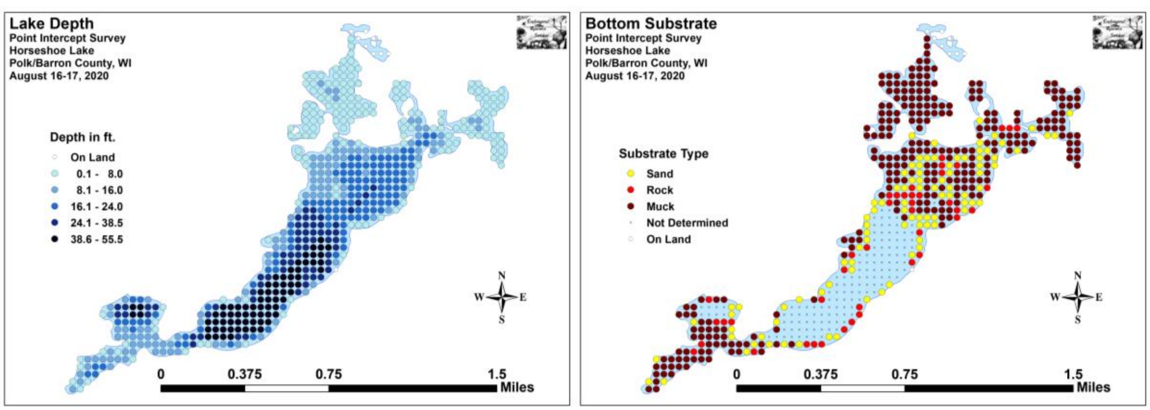


Figure 3: Lake Depth and Bottom Substrate

In 2020, we found plants growing to 18.5ft (down sharply from 21.5ft in 2013 and 24.5ft in 2008) (Table 1) (Figure 4). The 246 points with vegetation (approximately 45.6% of the surveyed points and 76.9% of the littoral zone) was a highly significant decline **(*p*<0.001)** from both the 2013 survey when plants were present at 329 sites (63.9% of surveyed points/88.4% of the littoral zone) and the 2008 survey when we found plants at 309 points (60.0% of the surveyed points/79.4% of the littoral zone) (Appendix IV).

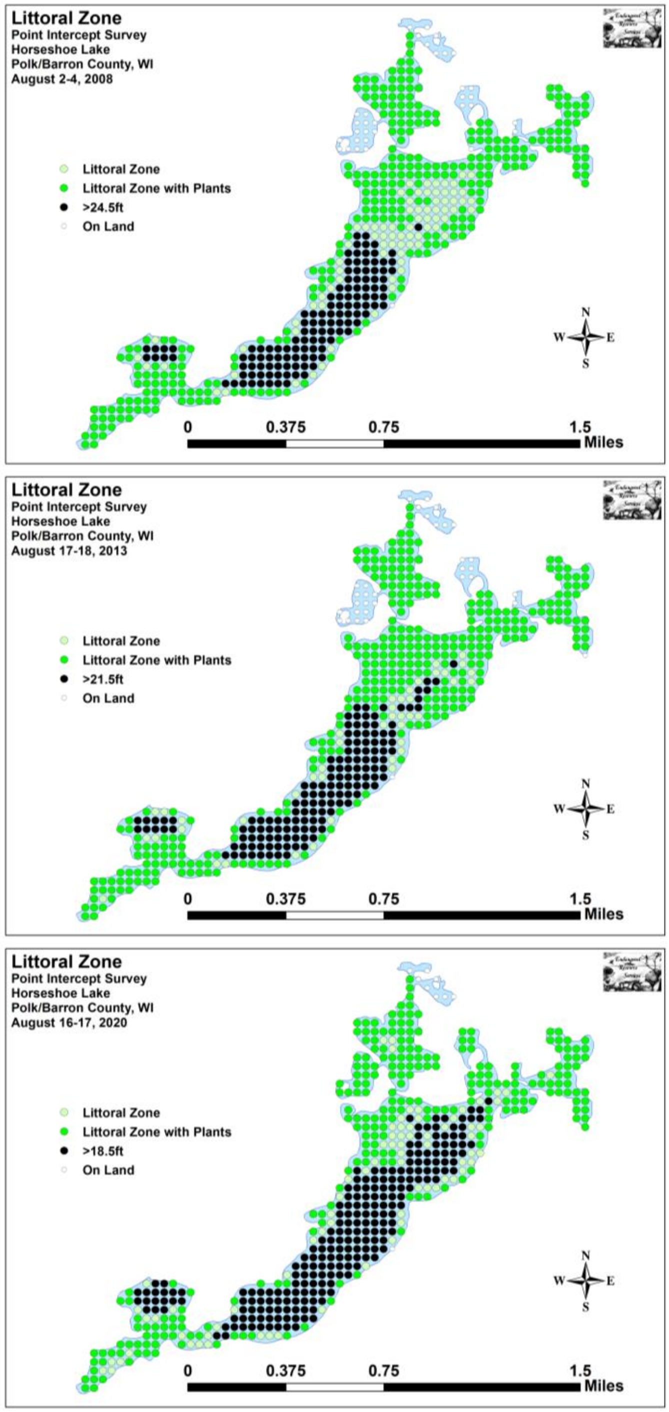


Figure 4: 2008, 2013, and 2020 Littoral Zone

Table 1: Aquatic Macrophyte P/I Survey Summary Statistics
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 2-4, 2008, August 17-18, 2013, and August 16-17, 2020

Summary Statistics:	2008	2013	2020
Total number of points sampled	515	515	539
Total number of sites with vegetation	309	329	246
Total number of sites shallower than the max. depth of plants	389	372	320
Freq. of occurrence at sites shallower than max. depth of plants	79.4	88.4	76.9
Simpson Diversity Index	0.93	0.94	0.93
Maximum depth of plants (ft)	24.5	21.5	18.5
Mean depth of plants (ft)	7.9	8.0	7.0
Median depth of plants (ft)	6.5	7.0	6.5
Ave. number of all species per site (shallower than max depth)	2.63	2.49	1.93
Ave. number of all species per site (veg. sites only)	3.31	2.82	2.51
Ave. number of native species per site (shallower than max depth)	2.61	2.47	1.93
Ave. number of native species per site (sites with native veg. only)	3.28	2.80	2.51
Species richness	47	52	54
Species richness (including visuals)	51	54	60
Species richness (including visuals and boat survey)	54	59	68
Mean rake fullness (veg. sites only)	Est. 2.60	2.21	2.44

Plant growth in 2020 was slightly skewed to deep water as the mean plant depth of 7.0ft was more than the median depth of 6.5ft. This mean was sharply lower than both 2008 and 2013 (7.9ft/8.0ft) while the median was identical to 2008 and down from 7.0ft in 2013 (Figure 5).

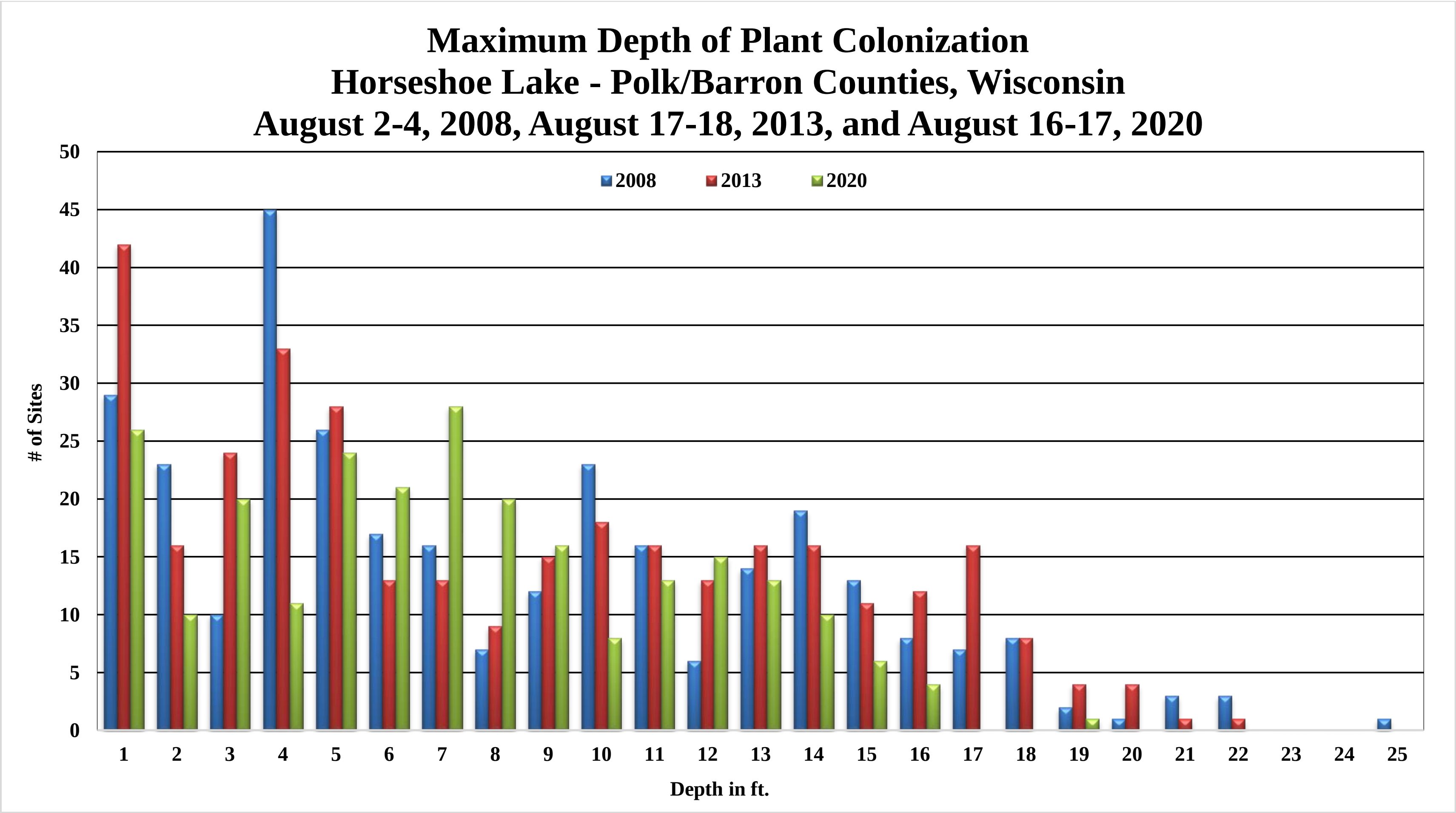


Figure 5: 2008, 2013, and 2020 Plant Colonization Depth Chart

Plant diversity was exceptionally high in 2020 with a Simpson Index value of 0.93 – down from 0.94 in 2013, but identical to 2008. Richness was also very high for such a small lake with 54 species found in the rake (similar to 52 in 2013/47 in 2008). This total increased to 68 when including visuals and plants seen during the boat survey (up sharply from 59 in 2013/54 in 2008). Although total richness increased, mean native species richness at sites with native vegetation experienced a moderately significant decline **(p=0.002)** from 3.28/site in 2008 to 2.80/site in 2013, and a further significant decline **(p=0.03)** to 2.51/site in 2020 (Figure 6) (Appendix IV).

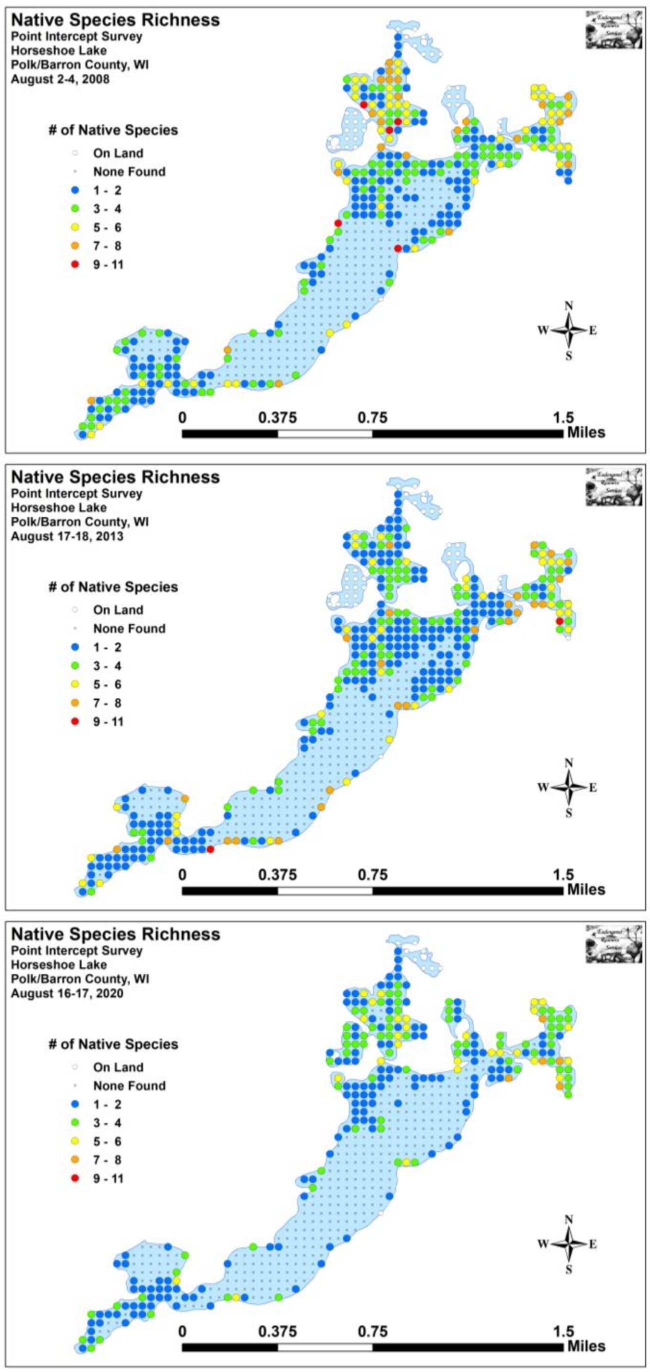


Figure 6: 2008, 2013, and 2020 Native Species Richness

Total rake fullness experienced a highly significant decline **(p<0.001)** from an estimated high mean density of 2.60 in 2008 to a moderate 2.21 in 2013 (Figure 7). In 2020, this trend reversed as we found a highly significant increase **(p<0.001)** to a moderately high mean rake of 2.44 (Appendix IV).

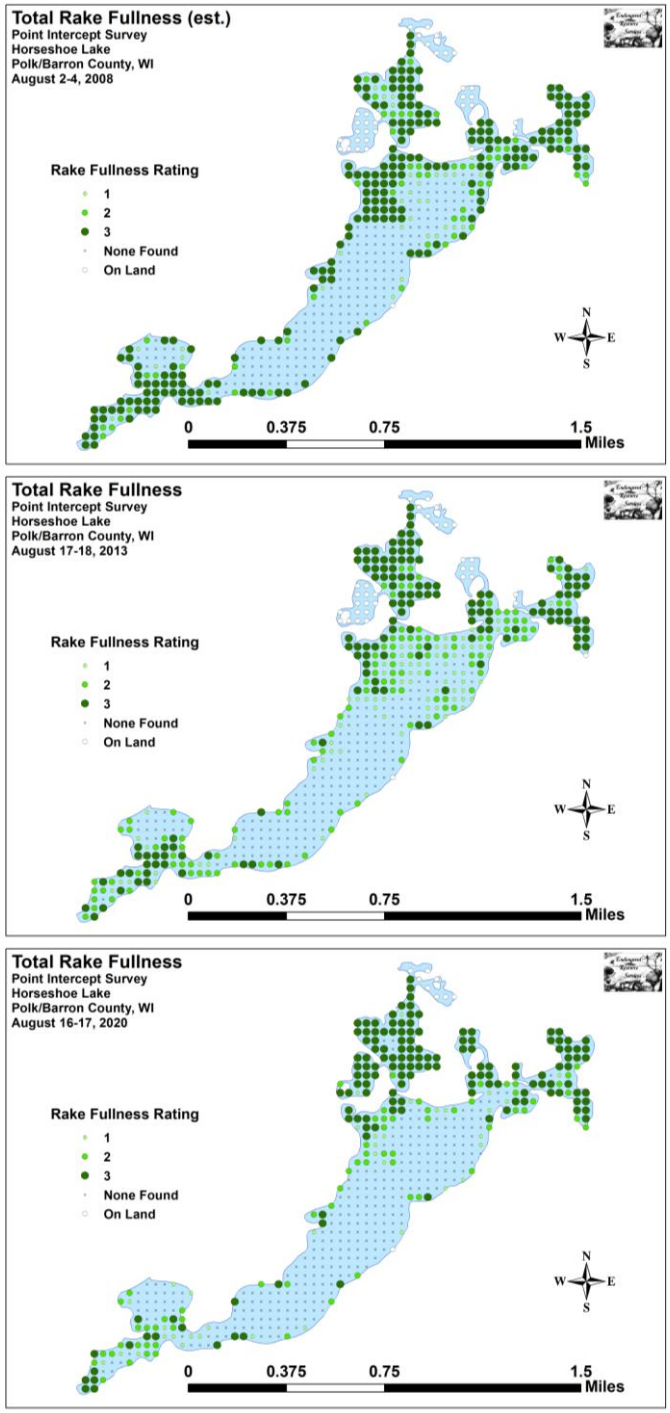


Figure 7: 2008, 2013, and 2020 Total Rake Fullness

Horseshoe Lake Plant Community:

The Horseshoe Lake ecosystem is home to an exceptionally rich and diverse plant community with many species that are typical of mesotrophic lakes with fair to good water clarity. Notably, the lake also supports several extremely rare species that are at the edge of their northern and western range in the United States. This community can be subdivided into four distinct zones (emergent, floating-leaf, shallow submergent, and deep submergent) with each zone having its own characteristic functions in the aquatic ecosystem. Depending on the local bottom type (sand, rock, sandy muck, or nutrient-rich organic muck), these zones often had somewhat different species present.

In shallow areas, beds of emergent plants prevent erosion by stabilizing the shoreline, break up wave action, provide a nursery for baitfish and juvenile gamefish, offer shelter for amphibians, and give waterfowl and predatory wading birds like herons a place to hunt. These areas also provide important habitat for invertebrates like dragonflies and mayflies.

Exposed rocky shorelines had few emergents, but in sheltered areas with firm sand and gravel, we found scattered beds of River bulrush (*Bolboschoenus fluviatilis*), Common rush (*Juncus effusus*), Reed canary grass (*Phalaris arundinacea*), and Common reed (*Phragmites australis americanus*) at the immediate shoreline with patches of Creeping spikerush (*Eleocharis palustris*) and Hardstem bulrush (*Schoenoplectus acutus*) expanding into water several feet deep.

River bulrush (Ratzlaff 2008)

Common rush (Ranger 2011)

Creeping spikerush (Legler 2013)

Hardstem bulrush (Dziuk 2015)

In sandy muck areas in water up to 2ft deep, especially along undeveloped shorelines, we found expansive beds of Pickerelweed (*Pontederia cordata*) with scattered Grass-leaved arrowhead (*Sagittaria graminea*), Sessile-fruited arrowhead (*Sagittaria rigida*), Softstem bulrush (*Schoenoplectus tabernaemontani*), and Branched bur-reed (*Sparganium androcladum*) mixed in.

Pickerelweed (Texas A&M 2012)

Sessile-fruited arrowhead (Chayka 2013)

Softstem bulrush (Schwarz 2011)

Branched bur-reed (Sulman 2008)

Along the shoreline of the lake's northeast bays and in the flooded "sedge meadows" that we were first able to access in 2020, we found the soil was often a more nutrient-rich organic muck. This habitat supported large stands of Narrow-leaved woolly sedge (*Carex lasiocarpa*), Common yellow lake sedge (*Carex utriculata*), Three-way sedge (*Dulichium arundinaceum*), Bald spikerush (*Eleocharis erythropoda*), and Hybrid cattail (*Typha* X *glauca*).

Narrow-leaved woolly sedge (Navratil 2016)

Common yellow lake sedge (Lavin 2011)

Three-way sedge (GMNRI 2016)

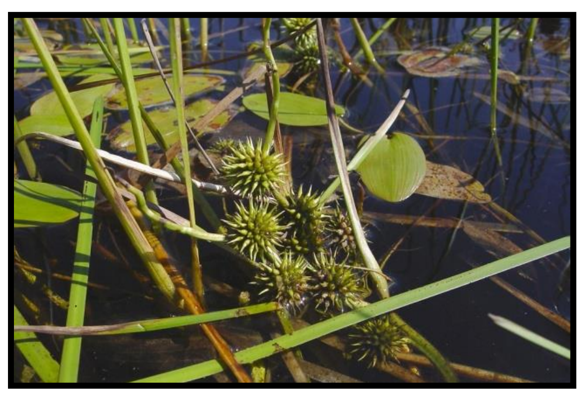
Bald spikerush (Schipper 2019)

Scattered among these dominant species, we noted lesser amounts of Bottle brush sedge (*Carex comosa*), Rice cut-grass (*Leersia oryzoides*), Purple loosestrife (*Lythrum salicaria*), Common arrowhead (*Sagittaria latifolia*), Short-stemmed bur-reed (*Sparganium emersum*), Torrey's three-square bulrush (*Schoenoplectus torreyi*), Woolgrass (*Scirpus cyperinus*), and Broad-leaved cattail (*Typha latifolia*).

Bottle brush sedge (Penta 2008)

Rice cut-grass (Wallis 2019)

Common arrowhead (Young 2006)



Short-stemmed bur-reed (Cameron 2016)

Torrey's three-square bulrush (Rothrock 2018)

Woolgrass (Colby 2012)

Shallow boggy areas and floating muck mats supported the lake's rarest plants. In this habitat, we found Bright green spikerush (*Eleocharis flavescens*), Robbins' spikerush (*Eleocharis robbinsii*), Long-beaked bald rush (*Rhynchospora scirpoides*), Pursh's bulrush (*Schoenoplectus purshianus*), and Water bulrush (*Schoenoplectus subterminalis*).

Bright green spikerush showing diagnostic achenes (Berg 2020)

Robbins spikerush (Chayka 2014)

Long-beaked bald rush showing diagnostic achenes (Berg 2020)

Long-beaked bald rush (Garrett 2020)

Pursh's bulrush (Pogacnik 2020)

Water bulrush (Dziuk 2016)

Nearshore nutrient-poor substrates rarely provided habitat for floating-leaf species. In this environment, we found just a few widely-scattered Northern manna-grass (*Glyceria borealis*). Areas with sandy muck supported species with small floating leaves like Water-thread pondweed (*Potamogeton diversifolius*), Spiral-fruited pondweed (*Potamogeton spirillus*), and Vasey's pondweed (*Potamogeton vaseyi*). This environment also had species that only occasionally produce floating-leaves like Variable pondweed (*Potamogeton gramineus*) and Illinois pondweed (*Potamogeton illinoensis*).

Northern manna grass (Fewless 2010)

Water-thread pondweed near the narrows (Berg 2013)

Spiral-fruited pondweed (Cameron 2019)

Vasey's pondweed (Cameron 2016)

Variable pondweed (Koshere 2002)

Illinois pondweed (Dziuk 2017)

In the most nutrient-rich areas, we found dense beds containing Watershield (*Brasenia schreberi*), Spatterdock (*Nuphar variegata*), White water lily (*Nymphaea odorata*), and Water smartweed (*Polygonum amphibium*).

Watershield (WED 2019)

Spatterdock (CBG 2014)

White water lily (Falkner 2009)

Water smartweed (Someya 2009)

These organic muck areas also supported species that occasionally produce floating leaves like Large-leaf pondweed (*Potamogeton amplifolius*) and Ribbon-leaf pondweed (*Potamogeton epihydrus*). Around floating-muck bogs, we also found a handful of Oakes' pondweed (*Potamogeton oakesianus*) and throughout "Mud Lake" and Buckwald Bay, what appeared to be Spotted pondweed (*Potamogeton pulcher*) or a hybrid between this species and Illinois or Large-leaf pondweed. The protective canopy cover this entire group provides is often utilized by panfish and bass.

Large-leaf pondweed (Dziuk 2018)

Ribbon-leaf pondweed (Petroglyph 2007)

Oakes' pondweed (Cameron 2020)

Spotted pondweed – potentially hybrid (Berg 2020)

Growing among these floating-leaf species, especially in boggy bays, we also found Spiny hornwort (*Ceratophyllum echinatum*), Farwell's water-milfoil (*Myriophyllum farwellii*), and Whorled water-milfoil (*Myriophyllum verticillatum*). Along with these larger plants, we noted several floating "duckweeds" including Large duckweed (*Spirodela polyrhiza*), Small duckweed (*Lemna minor*), and Slender riccia (*Riccia fluitans*).

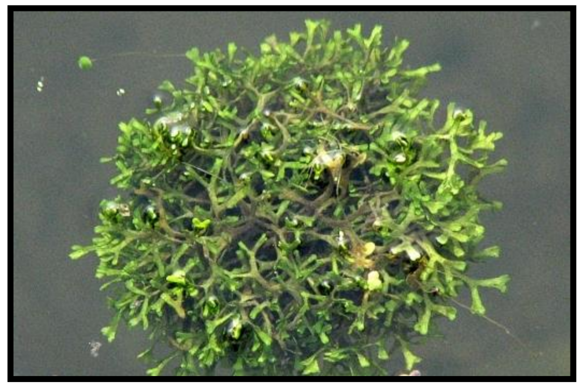
Spiny hornwort (Chayka 2019)

Farwell's water-milfoil (Dziuk 2015)

Dense bed of Farwell's water-milfoil (Berg 2012)

Whorled water-milfoil (Cameron 2018)

Large duckweed (Thomas 2014) and Small duckweed (Kramer 2013)



Slender riccia (Barth 2018)

This environment also supported a variety of carnivorous bladderworts including Creeping bladderwort (*Utricularia gibba*), Flat-leaf bladderwort (*Utricularia intermedia*), Small bladderwort (*Utricularia minor*), and Common bladderwort (*Utricularia vulgaris*). Rather than drawing nutrients up through roots like other plants, bladderworts trap zooplankton and minute insects in their bladders, digest their prey, and use the nutrients to further their growth.

Creeping bladderwort showing bladders for catching prey (Eyewed 2010)

Flat-leaf bladderwort (Woods 2012)

Small bladderwort (Cameron 2019)

Common bladderwort flowers among lilypads (Hunt 2010)

The lake's shallow pure sand and gravel areas tended to have low total biomass as these nutrient-poor substrates provide habitat most suited to fine-leaved "isoetid" turf-forming species like Muskgrass (*Chara* sp.), Waterwort (*Elatine minima*), Needle spikerush (*Eleocharis acicularis*), Spiny-spored quillwort (*Isoetes echinospora*), Northern naiad (*Najas gracillima*), and Grass-leaved arrowhead (*Sagittaria graminea*). All of these shallow submergent species, along with the emergents, stabilize the bottom and prevent wave action erosion.

Muskgrass (Penuh 2007)

Waterwort (Fewless 2005)

Needle spikerush (Fewless 2005)

Spiny-spored quillwort (Fewless 2005)

Northern naiad (Apipp 2008)

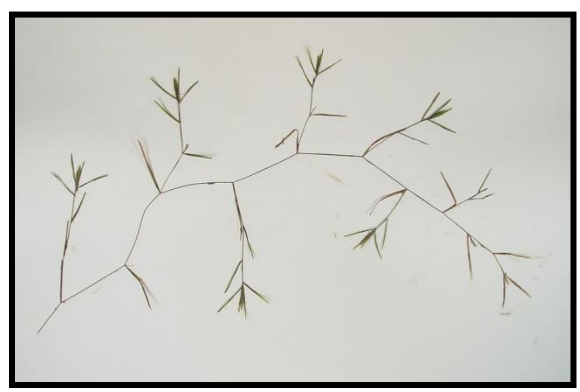
Grass-leaved arrowhead (Flaigg 2003)

In areas with sandy muck, in water up to 8ft deep, we found scattered patches of Water star-grass (*Heteranthera dubia*), Hybrid water-milfoil, Slender naiad (*Najas flexilis*), Small pondweed (*Potamogeton pusillus*), Clasping-leaf pondweed (*Potamogeton richardsonii*), and Wild celery (*Vallisneria americana*). The roots, shoots, and seeds of these species are heavily utilized by both resident and migratory waterfowl for food. They also provide important habitat for the lake's fish throughout their lifecycles, as well as a myriad of invertebrates like scuds, dragonfly and mayfly nymphs, and snails.

Water star-grass (Mueller 2010)

Canopied Hybrid water-milfoil (Berg 2020)

Slender naiad (Cameron 2013)



Small pondweed (Cameron 2013)

Clasping-leaf pondweed (Cameron 2013)

Wild celery (Dalvi 2008)

Organic and sandy muck areas in water greater than 8ft were dominated by Coontail (*Ceratophyllum demersum*) and Fern pondweed (*Potamogeton robbinsii*) with lesser amounts of Common waterweed (*Elodea canadensis*) and Flat-stem pondweed (*Potamogeton zosteriformis*). Predatory fish like the lake's Northern pike (*Esox lucius*) are often found along the edges of these beds waiting in ambush.

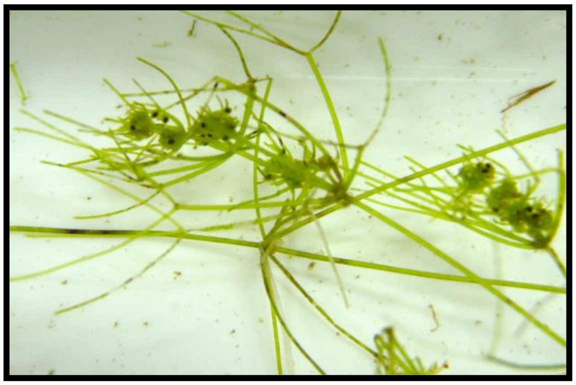
Coontail (Hassler 2011)

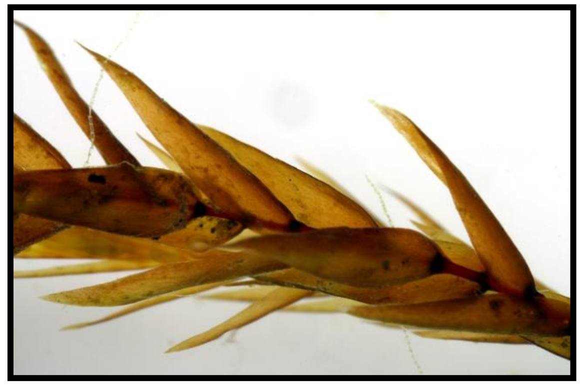
Fern pondweed (Apipp 2011)

Common waterweed (Pinkka 2013)

Flat-stem pondweed (Dziuk 2019)

In water over 15ft to the outer littoral limit of 18.5ft, Nitella (*Nitella* sp. likely *flexilis*) and Aquatic moss were normally the only macrophytes found. Although these species were often abundant in past surveys in water up to 24.5ft, extensive rake dragging at these depths produced nothing, and, even when present in 2020, they were seldom abundant.


Nitella (USGS 2008)


Aquatic moss leaves magnified 5X (Kleinman 2010)

Comparison of Native Macrophyte Species in 2008, 2013, and 2020:

The August 2008 survey found Common waterweed, Fern pondweed, Nitella, and Creeping bladderwort were the most common macrophyte species (Aquatic moss was the fourth most common species, but it was excluded from analysis as it is not included in the relative frequency calculation) (Table 2). They were present at 52.75%, 48.22%, 27.51%, and 18.77% of survey points with vegetation respectively and accounted for 44.48% of the total relative frequency. Small pondweed (5.57%), Coontail (4.40%), White water lily (4.40%), and Flat-stem pondweed (4.20%) also had relative frequencies over 4.0% (Maps for all species found in August 2008 are located in the project folder).

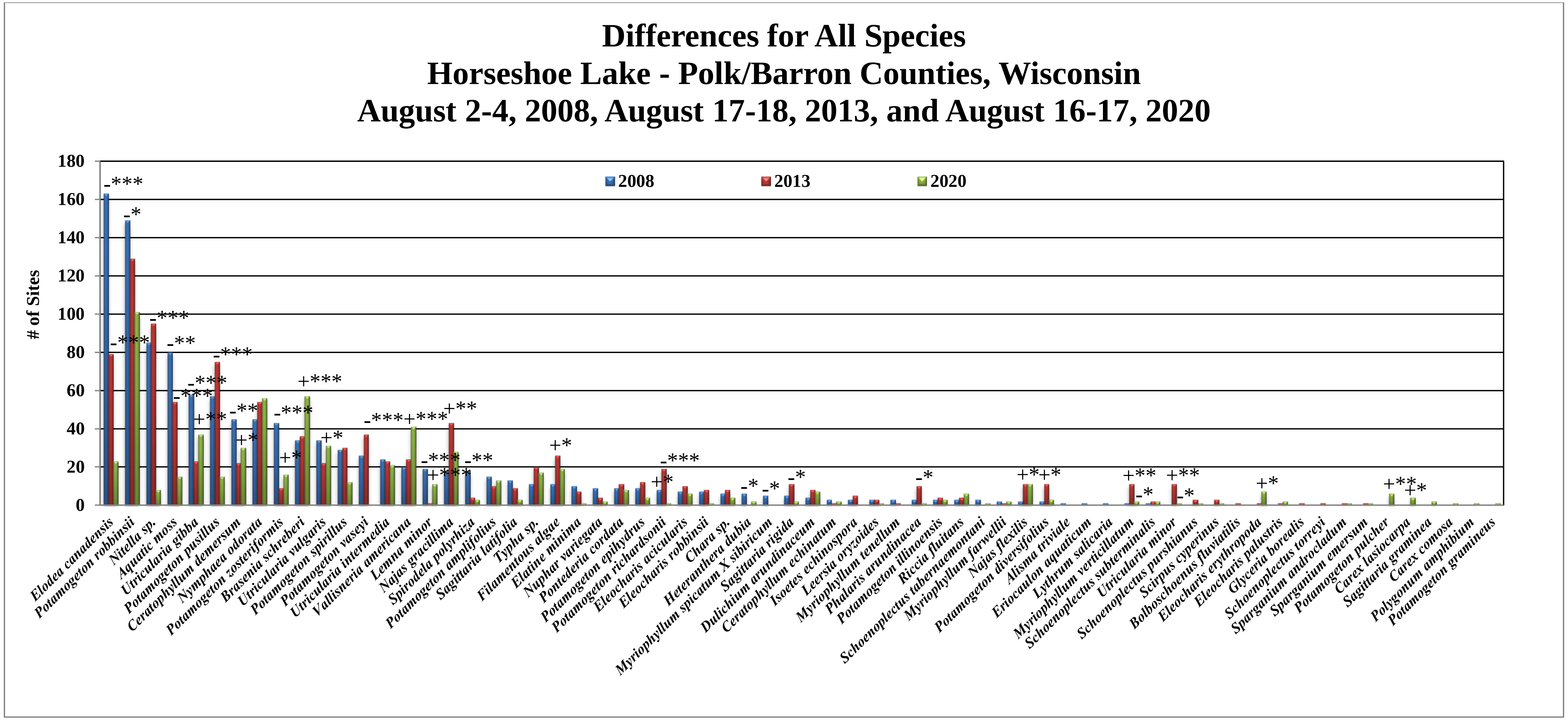
In August 2013, we identified Fern pondweed, Nitella, Common waterweed, and Small pondweed as the most common species (Table 3). Present at 39.21%, 28.88%, 24.01%, and 22.80% of sites with vegetation, they accounted for 40.78% of the total relative frequency. White water lily (5.83%) and Northern naiad (4.64%) also had relative frequencies over 4.0% (Maps for all species found in August 2013 are located in the project folder).

Lakewide, seventeen species showed significant changes in distribution from 2008 to 2013 (Figure 8). Common waterweed, Creeping bladderwort, Flat-stem pondweed, and Small duckweed suffered highly significant declines **(p<0.001)**; Aquatic moss **(p=0.003)**, Coontail **(p=0.001)**, and Large duckweed **(p=0.001)** experienced moderately significant declines; and Fern pondweed **(p=0.02)**, Water star-grass **(p=0.01)**, and Hybrid water-milfoil **(p=0.02)** demonstrated significant declines. Conversely, Northern naiad **(p=0.002)**, Whorled water-milfoil **(p=0.005)**, and Small bladderwort **(p=0.001)** saw moderately significant increases; and filamentous algae **(p=0.02)**, Clasping-leaf pondweed **(p<0.05)**, Slender naiad **(p=0.02)**, and Water-thread pondweed **(p=0.02)** showed significant increases.

The August 2020 survey identified Fern pondweed (41.06% of points with vegetation), Watershield (23.17%), White water lily (22.76%), and Wild celery (16.67%) as the most common species with a combined relative frequency of 41.26% (Table 4). Creeping bladderwort (5.99%), Common bladderwort (5.02%), Coontail (4.85%), and Northern naiad (4.53%) also had relative frequencies over 4.00% (Density and distribution maps for all native plant species found in 2020 are located in Appendix V).

From 2013 to 2020, twenty species underwent significant changes in distribution (Figure 8). Common waterweed, Nitella, Aquatic moss, Small pondweed, Vasey's pondweed, and Clasping-leaf pondweed suffered highly significant declines **(p<0.001)**; and Sessile-fruited arrowhead **(p=0.04)**, Reed canary grass **(p=0.02)**, Whorled-water-milfoil **(p=0.04)**, and Small bladderwort **(p=0.01)** saw significant declines. Despite these loses, Watershield, Wild celery, and Small duckweed enjoyed highly significant increases **(p<0.001)**; Creeping bladderwort **(p=0.002)**, and Spotted pondweed **(p=0.004)** underwent moderately significant increases; and Coontail **(p=0.02)**, Flat-stem pondweed **(p=0.03)**, Common bladderwort **(p=0.02)**, Bald spikerush **(p=0.01)**, and Narrow-leaved woolly sedge **(p=0.02)** had significant increases.

Many of the changes seen from 2013 to 2020 appear to have occurred on the outer edge of the littoral zone. The poor clarity we saw during the 2020 survey may be the best explanation of why deepwater species like Nitella and Aquatic moss had largely disappeared, and why other species like Small pondweed and Vasey's pondweed had already set turions and senesced. Conversely, several species that saw significant gains like Watershield, the bladderworts, Bald spikerush, and sedges were dominant species in shallow, previously inaccessible areas.



Significant differences = * p<0.05, ** p<0.01, *** p<0.001

Figure 8: Macrophytes Showing Significant Changes from 2008-2013-2020

Table 2: Frequencies and Mean Rake Sample of Aquatic Macrophytes Horseshoe Lake - Polk/Barron Counties, Wisconsin August 2-4, 2008

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Elodea canadensis	Common waterweed	163	15.93	52.75	41.90	2.06	1
Potamogeton robbinsii	Fern pondweed	149	14.57	48.22	38.30	2.25	0
Nitella sp.	Nitella	85	8.31	27.51	21.85	1.79	0
	Aquatic moss	80	*	25.89	20.57	1.80	1
Utricularia gibba	Creeping bladderwort	58	5.67	18.77	14.91	1.40	4
Potamogeton pusillus	Small pondweed	57	5.57	18.45	14.65	1.35	4
Ceratophyllum demersum	Coontail	45	4.40	14.56	11.57	1.64	1
Nymphaea odorata	White water lily	45	4.40	14.56	11.57	2.24	11
Potamogeton zosteriformis	Flat-stem pondweed	43	4.20	13.92	11.05	1.40	3
Brasenia schreberi	Watershield	34	3.32	11.00	8.74	2.26	6
Utricularia vulgaris	Common bladderwort	34	3.32	11.00	8.74	1.56	7
Potamogeton spirillus	Spiral-fruited pondweed	29	2.83	9.39	7.46	1.76	3
Potamogeton vaseyi	Vasey's pondweed	26	2.54	8.41	6.68	1.46	8
Utricularia intermedia	Flat-leaf bladderwort	24	2.35	7.77	6.17	1.92	1
Vallisneria americana	Wild celery	20	1.96	6.47	5.14	2.05	2
Lemna minor	Small duckweed	19	1.86	6.15	4.88	1.16	0
Najas gracillima	Northern naiad	18	1.76	5.83	4.63	1.61	3
Spirodela polyrhiza	Large duckweed	18	1.76	5.83	4.63	1.28	0
Potamogeton amplifolius	Large-leaf pondweed	15	1.47	4.85	3.86	1.33	15
Sagittaria latifolia	Common arrowhead	13	1.27	4.21	3.34	1.85	2
Typha latifolia	Broad-leaved cattail	11	1.08	3.56	2.83	2.73	3
	Filamentous algae	11	*	3.56	2.83	2.09	0
Elatine minima	Waterwort	10	0.98	3.24	2.57	1.80	0

* Excluded from relative frequency analysis **Exotic species in bold**

Table 2 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 2-4, 2008

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Nuphar variegata	Spatterdock	9	0.88	2.91	2.31	1.56	1
Pontederia cordata	Pickerelweed	9	0.88	2.91	2.31	2.00	11
Potamogeton epihydrus	Ribbon-leaf pondweed	9	0.88	2.91	2.31	1.33	9
Potamogeton richardsonii	Clasping-leaf pondweed	8	0.78	2.59	2.06	1.63	12
Eleocharis acicularis	Needle spikerush	7	0.68	2.27	1.80	1.57	0
Eleocharis robbinsii	Robbins' spikerush	7	0.68	2.27	1.80	2.86	2
Chara sp.	Muskgrass	6	0.59	1.94	1.54	1.17	0
Heteranthera dubia	Water star-grass	6	0.59	1.94	1.54	1.00	0
Myriophyllum spicatum* X *sibiricum	**Hybrid water-milfoil**	**5**	**0.49**	**1.62**	**1.29**	**1.60**	**12**
Sagittaria rigida	Sessile-fruited arrowhead	5	0.49	1.62	1.29	1.00	0
Dulichium arundinaceum	Three-way sedge	4	0.39	1.29	1.03	1.25	0
Ceratophyllum echinatum	Spiny hornwort	3	0.29	0.97	0.77	1.00	2
Isoetes echinospora	Spiny spored-quillwort	3	0.29	0.97	0.77	1.33	0
Leersia oryzoides	Rice cut-grass	3	0.29	0.97	0.77	1.33	1
Myriophyllum tenellum	Dwarf water-milfoil	3	0.29	0.97	0.77	1.67	0
Phalaris arundinacea	**Reed canary grass**	**3**	**0.29**	**0.97**	**0.77**	**1.33**	**0**
Potamogeton illinoensis	Illinois pondweed	3	0.29	0.97	0.77	1.00	1
Riccia fluitans	Slender riccia	3	*	0.97	0.77	1.33	0
Schoenoplectus tabernaemontani	Softstem bulrush	3	0.29	0.97	0.77	1.33	2
Myriophyllum farwellii	Farwell's water-milfoil	2	0.20	0.65	0.51	1.00	0
Najas flexilis	Slender naiad	2	0.20	0.65	0.51	1.00	0
Potamogeton diversifolius	Water-thread pondweed	2	0.20	0.65	0.51	1.50	2

* Excluded from relative frequency analysis **Exotic species in bold**

Table 2 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 2-4, 2008

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Alisma triviale	Northern water-plantain	1	0.10	0.32	0.26	1.00	0
Eriocaulon aquaticum	Pipewort	1	0.10	0.32	0.26	1.00	0
Lythrum salicaria	**Purple loosestrife**	**1**	**0.10**	**0.32**	**0.26**	**1.00**	**0**
Myriophyllum verticillatum	Whorled water-milfoil	1	0.10	0.32	0.26	1.00	3
Schoenoplectus subterminalis	Water bulrush	1	0.10	0.32	0.26	2.00	1
Eleocharis ovata	Oval spikerush	**	**	**	**	**	1
Juncus pelocarpus f. submersus	Brown-fruited rush	**	**	**	**	**	1
Schoenoplectus purshianus	Pursh's bulrush	**	**	**	**	**	1
Sparganium emersum	Short-stemmed bur-reed	**	**	**	**	**	2
Eleocharis palustris	Creeping spikerush	***	***	***	***	***	***
Juncus effusus	Common rush	***	***	***	***	***	***
Potamogeton amplifolius X *illinoensis*?	Large-leaf X Illinois pondweed?	***	***	***	***	***	***
Potamogeton crispus	**Curly-leaf pondweed**	****	****	****	****	****	****

** Visual only   *** Boat survey only   **** Spring CLP survey only   **Exotic species in bold**

Table 3: Frequencies and Mean Rake Sample of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 17-18, 2013

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Potamogeton robbinsii	Fern pondweed	129	13.92	39.21	34.68	1.91	0
Nitella sp.	Nitella	95	10.25	28.88	25.54	1.47	0
Elodea canadensis	Common waterweed	79	8.52	24.01	21.24	1.18	0
Potamogeton pusillus	Small pondweed	75	8.09	22.80	20.16	1.21	1
Nymphaea odorata	White water lily	54	5.83	16.41	14.52	2.13	4
	Aquatic moss	54	*	16.41	14.52	1.15	0
Najas gracillima	Northern naiad	43	4.64	13.07	11.56	1.42	1
Potamogeton vaseyi	Vasey's pondweed	37	3.99	11.25	9.95	1.46	5
Brasenia schreberi	Watershield	36	3.88	10.94	9.68	2.58	6
Potamogeton spirillus	Spiral-fruited pondweed	30	3.24	9.12	8.06	1.37	2
	Filamentous algae	26	*	7.90	6.99	1.31	0
Vallisneria americana	Wild celery	24	2.59	7.29	6.45	1.29	2
Utricularia gibba	Creeping bladderwort	23	2.48	6.99	6.18	1.04	1
Utricularia intermedia	Flat-leaf bladderwort	23	2.48	6.99	6.18	1.35	1
Ceratophyllum demersum	Coontail	22	2.37	6.69	5.91	1.73	1
Utricularia vulgaris	Common bladderwort	22	2.37	6.69	5.91	1.05	7
Potamogeton richardsonii	Clasping-leaf pondweed	19	2.05	5.78	5.11	1.58	8
Typha* X *glauca	**Hybrid cattail**	**15**	**1.62**	**4.56**	**4.03**	**3.00**	**0**
Potamogeton epihydrus	Ribbon-leaf pondweed	12	1.29	3.65	3.23	1.17	3
Myriophyllum verticillatum	Whorled water-milfoil	11	1.19	3.34	2.96	1.27	4
Najas flexilis	Slender naiad	11	1.19	3.34	2.96	1.09	0
Pontederia cordata	Pickerelweed	11	1.19	3.34	2.96	1.18	4
Potamogeton diversifolius	Water-thread pondweed	11	1.19	3.34	2.96	1.18	1

* Excluded from relative frequency analysis **Exotic species in bold**

Table 3 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 17-18, 2013

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Sagittaria rigida	Sessile-fruited arrowhead	11	1.19	3.34	2.96	1.00	1
Utricularia minor	Small bladderwort	11	1.19	3.34	2.96	1.18	0
Eleocharis acicularis	Needle spikerush	10	1.08	3.04	2.69	1.50	0
Phalaris arundinacea	**Reed canary grass**	**10**	**1.08**	**3.04**	**2.69**	**2.00**	**1**
Potamogeton amplifolius	Large-leaf pondweed	10	1.08	3.04	2.69	1.20	0
Potamogeton zosteriformis	Flat-stem pondweed	9	0.97	2.74	2.42	1.11	2
Sagittaria latifolia	Common arrowhead	9	0.97	2.74	2.42	1.22	2
Chara sp.	Muskgrass	8	0.86	2.43	2.15	1.38	0
Dulichium arundinaceum	Three-way sedge	8	0.86	2.43	2.15	1.75	2
Eleocharis robbinsii	Robbins' spikerush	8	0.86	2.43	2.15	1.25	0
Elatine minima	Waterwort	7	0.76	2.13	1.88	1.14	0
Isoetes echinospora	Spiny spored-quillwort	5	0.54	1.52	1.34	1.00	0
Typha latifolia	Broad-leaved cattail	5	0.54	1.52	1.34	2.00	3
Nuphar variegata	Spatterdock	4	0.43	1.22	1.08	1.75	0
Potamogeton illinoensis	Illinois pondweed	4	0.43	1.22	1.08	1.50	0
Riccia fluitans	Slender riccia	4	*	1.22	1.08	1.00	0
Spirodela polyrhiza	Large duckweed	4	0.43	1.22	1.08	1.00	1
Leersia oryzoides	Rice cut-grass	3	0.32	0.91	0.81	3.00	0
Schoenoplectus purshianus	Pursh’s bulrush	3	0.32	0.91	0.81	2.00	0
Scirpus cyperinus	Woolgrass	3	0.32	0.91	0.81	1.00	3
Schoenoplectus subterminalis	Water bulrush	2	0.22	0.61	0.54	1.00	1
Bolboschoenus fluviatilis	River bulrush	1	0.11	0.30	0.27	1.00	0
Ceratophyllum echinatum	Spiny hornwort	1	0.11	0.30	0.27	1.00	1

* Excluded from relative frequency analysis **Exotic species in bold**

Table 3 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 17-18, 2013

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Eleocharis erythropoda	Bald spikerush	1	0.11	0.30	0.27	2.00	0
Eleocharis palustris	Creeping spikerush	1	0.11	0.30	0.27	1.00	4
Glyceria borealis	Northern manna grass	1	0.11	0.30	0.27	1.00	1
Lemna minor	Small duckweed	1	0.11	0.30	0.27	1.00	1
Myriophyllum farwellii	Farwell's water-milfoil	1	0.11	0.30	0.27	1.00	2
Myriophyllum tenellum	Dwarf water-milfoil	1	0.11	0.30	0.27	2.00	0
Schoenoplectus torreyi	Torrey's three-square bulrush	1	0.11	0.30	0.27	1.00	0
Sparganium androcladum	Branched bur-reed	1	0.11	0.30	0.27	2.00	0
Sparganium emersum	Short-stemmed bur-reed	1	0.11	0.30	0.27	2.00	1
Lindernia dubia	False pimpernel	**	**	**	**	**	1
Myriophyllum spicatum* X *sibiricum	**Hybrid water-milfoil**	**	**	**	**	**	1
Heteranthera dubia	Water star-grass	***	***	***	***	***	***
Juncus effusus	Common rush	***	***	***	***	***	***
Lythrum salicaria	**Purple loosestrife**	***	***	***	***	***	***
Schoenoplectus tabernaemontani	Softstem bulrush	***	***	***	***	***	***
Potamogeton illinoensis X *richardsonii*?	Hybrid pondweed	***	***	***	***	***	***
Potamogeton crispus	**Curly-leaf pondweed**	****	****	****	****	****	****

** Visual only   *** Boat survey only   **** Spring CLP survey only   **Exotic species in bold**

Table 4: Frequencies and Mean Rake Sample of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 16-17, 2020

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Potamogeton robbinsii	Fern pondweed	101	16.34	41.06	31.56	1.88	0
Brasenia schreberi	Watershield	57	9.22	23.17	17.81	2.63	7
Nymphaea odorata	White water lily	56	9.06	22.76	17.50	1.93	11
Vallisneria americana	Wild celery	41	6.63	16.67	12.81	2.05	2
Utricularia gibba	Creeping bladderwort	37	5.99	15.04	11.56	1.24	4
Utricularia vulgaris	Common bladderwort	31	5.02	12.60	9.69	1.52	10
Ceratophyllum demersum	Coontail	30	4.85	12.20	9.38	2.53	1
Najas gracillima	Northern naiad	28	4.53	11.38	8.75	1.32	0
Elodea canadensis	Common waterweed	23	3.72	9.35	7.19	1.30	2
Utricularia intermedia	Flat-leaf bladderwort	21	3.40	8.54	6.56	1.33	3
	Filamentous algae	19	*	7.72	5.94	1.63	0
Potamogeton zosteriformis	Flat-stem pondweed	16	2.59	6.50	5.00	1.44	3
Potamogeton pusillus	Small pondweed	15	2.43	6.10	4.69	1.27	0
Typha* X *glauca	**Hybrid cattail**	**15**	**2.43**	**6.10**	**4.69**	**2.93**	**2**
	Aquatic moss	15	*	6.10	4.69	1.27	0
Potamogeton amplifolius	Large-leaf pondweed	13	2.10	5.28	4.06	1.62	0
Potamogeton spirillus	Spiral-fruited pondweed	12	1.94	4.88	3.75	1.33	1
Lemna minor	Small duckweed	11	1.78	4.47	3.44	1.00	0
Najas flexilis	Slender naiad	11	1.78	4.47	3.44	1.27	0
Nitella sp.	Nitella	8	1.29	3.25	2.50	1.13	0
Pontederia cordata	Pickerelweed	8	1.29	3.25	2.50	1.50	11
Dulichium arundinaceum	Three-way sedge	7	1.13	2.85	2.19	1.43	5
Eleocharis erythropoda	Bald spikerush	7	1.13	2.85	2.19	2.29	1

* Excluded from relative frequency analysis **Exotic species in bold**

Table 4 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 16-17, 2020

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Eleocharis acicularis	Needle spikerush	6	0.97	2.44	1.88	1.50	0
Potamogeton pulcher	Spotted pondweed (hybrid?)	6	0.97	2.44	1.88	1.33	3
Riccia fluitans	Slender riccia	6	*	2.44	1.88	1.17	0
Carex lasiocarpa	Narrow-leaved woolly sedge	4	0.65	1.63	1.25	1.25	0
Chara sp.	Muskgrass	4	0.65	1.63	1.25	1.00	1
Potamogeton epihydrus	Ribbon-leaf pondweed	4	0.65	1.63	1.25	1.25	2
Potamogeton diversifolius	Water-thread pondweed	3	0.49	1.22	0.94	1.00	1
Potamogeton illinoensis	Illinois pondweed	3	0.49	1.22	0.94	2.00	1
Sagittaria latifolia	Common arrowhead	3	0.49	1.22	0.94	1.00	5
Spirodela polyrhiza	Large duckweed	3	0.49	1.22	0.94	1.00	1
Ceratophyllum echinatum	Spiny hornwort	2	0.32	0.81	0.63	1.50	1
Eleocharis palustris	Creeping spikerush	2	0.32	0.81	0.63	1.50	2
Heteranthera dubia	Water star-grass	2	0.32	0.81	0.63	1.50	0
Myriophyllum farwellii	Farwell's water-milfoil	2	0.32	0.81	0.63	1.00	0
Myriophyllum verticillatum	Whorled water-milfoil	2	0.32	0.81	0.63	1.00	3
Nuphar variegata	Spatterdock	2	0.32	0.81	0.63	1.00	5
Sagittaria graminea	Grass-leaved arrowhead	2	0.32	0.81	0.63	1.00	0
Sagittaria rigida	Sessile-fruited arrowhead	2	0.32	0.81	0.63	1.50	0
Schoenoplectus subterminalis	Water bulrush	2	0.32	0.81	0.63	1.00	0
Typha latifolia	Broad-leaved cattail	2	0.32	0.81	0.63	2.50	1
Carex comosa	Bottle brush sedge	1	0.16	0.41	0.31	1.00	1
Elatine minima	Waterwort	1	0.16	0.41	0.31	2.00	0
Eleocharis robbinsii	Robbins' spikerush	1	0.16	0.41	0.31	1.00	2
Leersia oryzoides	Rice cut-grass	1	0.16	0.41	0.31	1.00	1

* Excluded from relative frequency analysis

Table 4 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 16-17, 2020

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Phalaris arundinacea	**Reed canary grass**	**1**	**0.16**	**0.41**	**0.31**	**3.00**	**1**
Polygonum amphibium	Water smartweed	1	0.16	0.41	0.31	1.00	2
Potamogeton gramineus	Variable pondweed	1	0.16	0.41	0.31	2.00	0
Potamogeton richardsonii	Clasping-leaf pondweed	1	0.16	0.41	0.31	1.00	1
Schoenoplectus purshianus	Pursh's bulrush	1	0.16	0.41	0.31	1.00	0
Schoenoplectus tabernaemontani	Softstem bulrush	1	0.16	0.41	0.31	1.00	2
Scirpus cyperinus	Woolgrass	1	0.16	0.41	0.31	1.00	2
Sparganium androcladum	Branched bur-reed	1	0.16	0.41	0.31	1.00	3
Sparganium emersum	Short-stemmed bur-reed	1	0.16	0.41	0.31	1.00	1
Utricularia minor	Small bladderwort	1	0.16	0.41	0.31	1.00	1
Carex utriculata	Common yellow lake sedge	**	**	**	**	**	1
Isoetes echinospora	Spiny spored-quillwort	**	**	**	**	**	1
Myriophyllum spicatum* X *sibiricum	**Hybrid water-milfoil**	**	**	**	**	**	**1**
Potamogeton oakesianus	Oakes' pondweed	**	**	**	**	**	1
Potamogeton vaseyi	Vasey's pondweed	**	**	**	**	**	1
Schoenoplectus torreyi	Torrey's three-square bulrush	**	**	**	**	**	1
Bolboschoenus fluviatilis	River bulrush	***	***	***	***	***	***
Eleocharis flavescens	Bright green spikerush	***	***	***	***	***	***
Glyceria borealis	Northern manna grass	***	***	***	***	***	***
Juncus effusus	Common rush	***	***	***	***	***	***
Lythrum salicaria	**Purple loosestrife**	***	***	***	***	***	***
Phragmites australis americanus	Common reed	***	***	***	***	***	***
Rhynchospora scirpoides	Long-beaked bald-rush	***	***	***	***	***	***
Schoenoplectus acutus	Hardstem bulrush	***	***	***	***	***	***

* Excluded from relative frequency analysis   ** Visual only   *** Boat survey only   **Exotic species in bold**

Common waterweed was the most common macrophyte species in 2008 and the second most common in 2013 when it was found in most areas with sandy muck (Figure 9). From 2008 to 2013, it underwent highly-significant declines **(p<0.001)** in both distribution (163 sites in 2008/79 sites in 2013) and density (mean rake fullness of 2.06 in 2008/1.18 in 2013). In 2020, we documented a further highly-significant decline **(p<0.001)** in distribution to 23 sites as it fell to the ninth-ranked species; however, the density underwent a non-significant increase (p=0.13) to a mean rake fullness of 1.30.

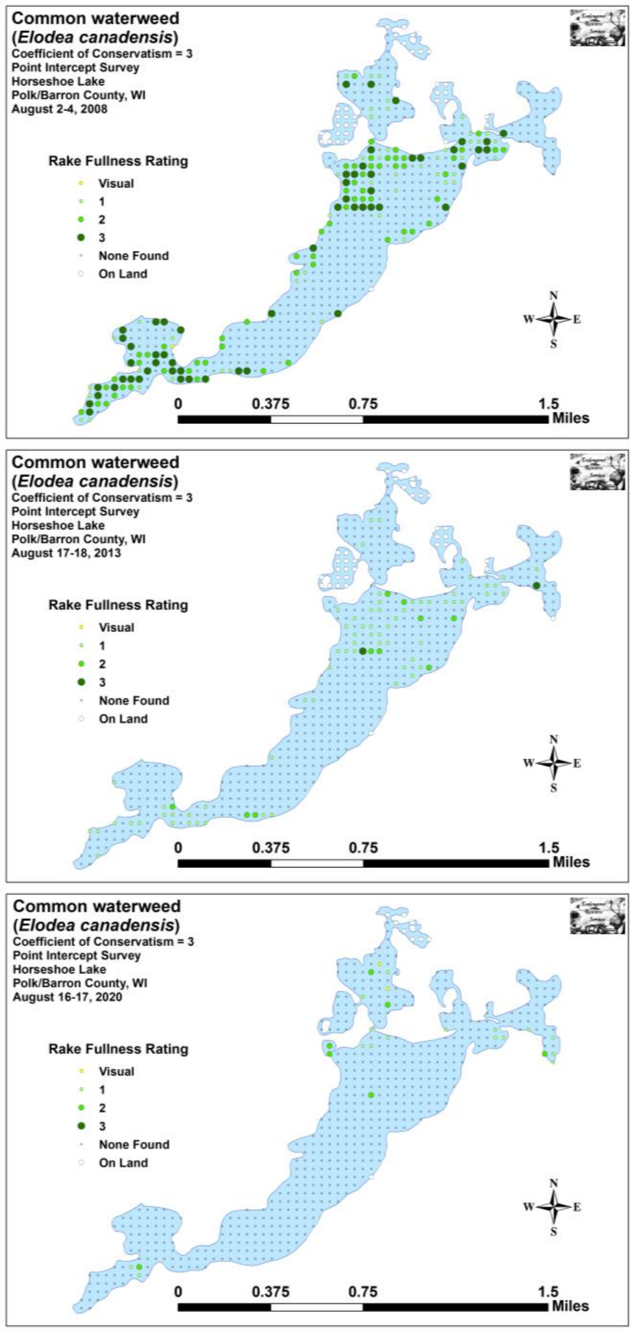


Figure 9: 2008, 2013, and 2020 Common Waterweed Density and Distribution

Fern pondweed was the second most common species in 2008 and the most common in both 2013 and 2020 (Figure 10). Despite gaining in community rank, from 2008 to 2013, it experienced a significant decline **(p=0.02)** in distribution (149 sites in 2008/129 sites in 2013) and a highly significant decline **(p<0.001)** in density (mean rake of 2.25 in 2008/1.91 in 2013). The 2020 survey documented further non-significant declines (p=0.65/p=0.40) in distribution (101 sites) and density (mean rake of 1.88).

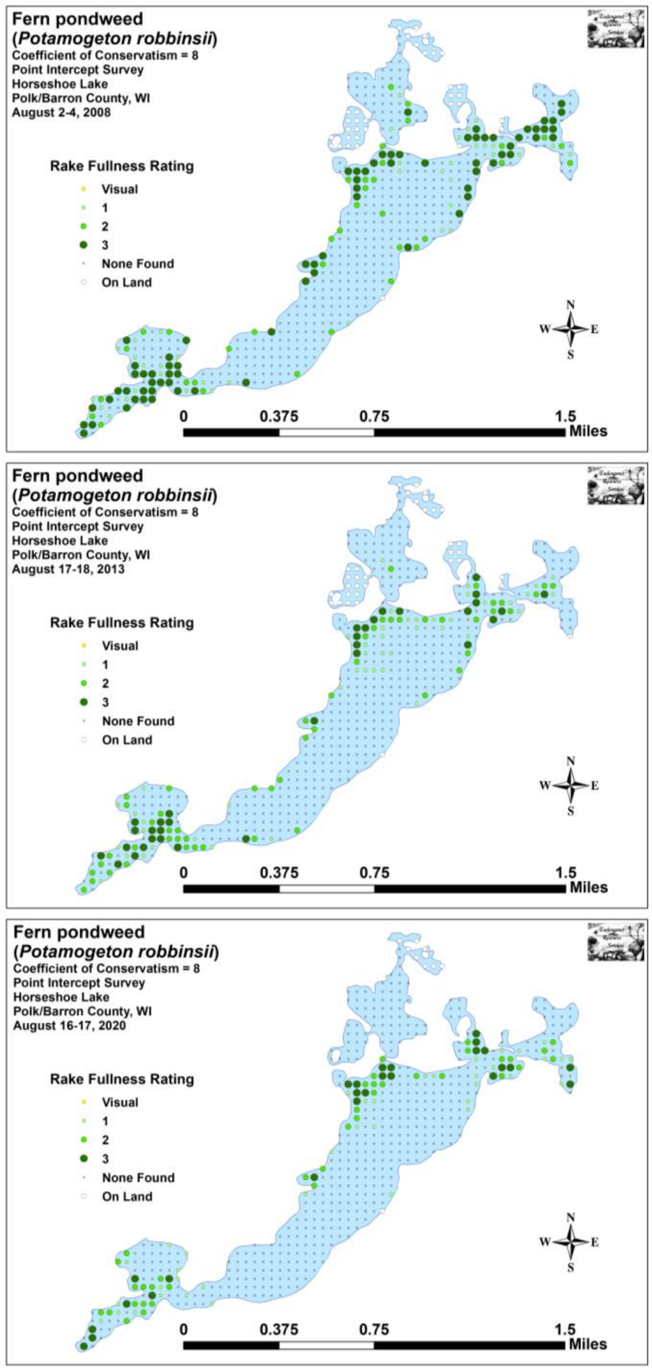


Figure 10: 2008, 2013, and 2020 Fern Pondweed Density and Distribution

We found Nitella was the third most common species in 2008 and the second most common in 2013 when dense colonies dominated the outer edge of the littoral zone around the lake's main basin (Figure 11). Over this time, it experienced a non-significant increase in (p=0.70) in distribution (85 sites in 2008/95 sites in 2013) but suffered a moderately significant decline **(p=0.003)** in density (mean rake of 1.79 in 2008/1.47 in 2013). In 2020, after undergoing a highly-significant decline **(p<0.001)** in distribution (eight sites) and a significant decline **(p =0.02)** in density (mean rake of 1.13), it fell to the eighteenth ranked plant in the community.

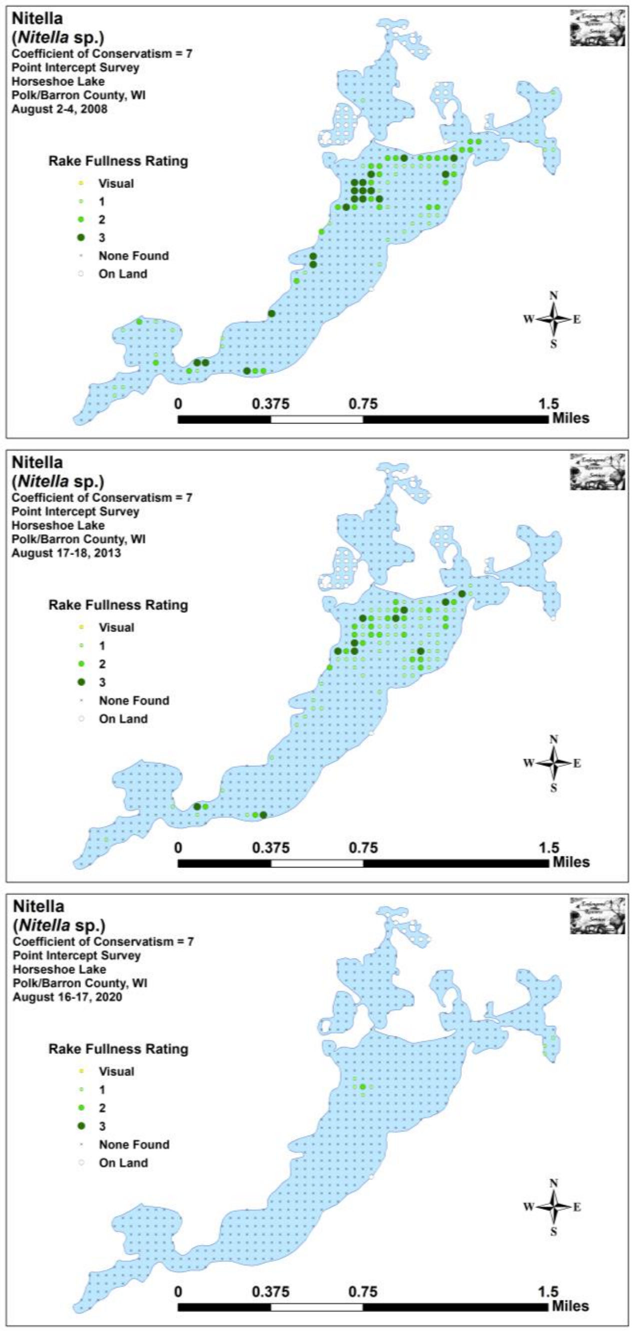


Figure 11: 2008, 2013, and 2020 Nitella Density and Distribution

Small pondweed was the sixth most common species during the 2008 survey when it was common throughout the lake (Figure 12). After experiencing a non-significant increase (p=0.18) in distribution (57 sites in 2008/75 sites in 2013) and a nearly-significant decline (p=0.08) in density (mean rake fullness of 1.35 in 2008/1.21 in 2013), it increased to the fourth most common species in 2013. Similar to many other fine-leaved pondweeds, the 2020 survey documented a highly-significant decline **(p<0.001)** in distribution (15 sites) as it fell to the 12th most common species. Despite these loses, the decline in density (mean rake 1.27) was not significant (p=0.35).

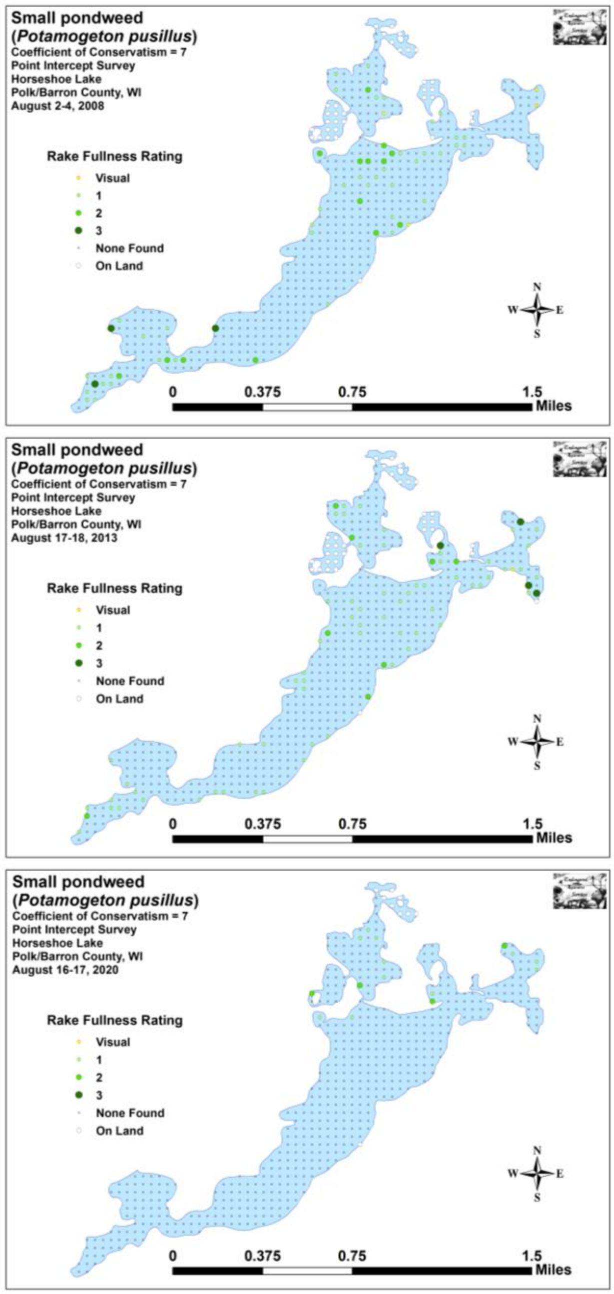


Figure 12: 2008, 2013, and 2020 Small Pondweed Density and Distribution

Comparison of Floristic Quality Indexes in 2008, 2013, and 2020:

In 2008, we identified a total of 43 **native index species** in the rake during the point-intercept survey (Table 5). They produced a mean Coefficient of Conservatism of 6.7 and a Floristic Quality Index of 44.2.

Table 5: Floristic Quality Index of Aquatic Macrophytes Horseshoe Lake - Polk/Barron Counties, Wisconsin August 2-4, 2008

Species	Common Name	C
Alisma triviale	Northern water-plantain	4
Brasenia schreberi	Watershield	6
Ceratophyllum demersum	Coontail	3
Ceratophyllum echinatum	Spiny hornwort	10
Chara sp.	Muskgrass	7
Dulichium arundinaceum	Three-way sedge	9
Elatine minima	Waterwort	9
Eleocharis acicularis	Needle spikerush	5
Elodea canadensis	Common waterweed	3
Eriocaulon aquaticum	Pipewort	9
Heteranthera dubia	Water star-grass	6
Isoetes echinospora	Spiny-spored quillwort	8
Lemna minor	Small duckweed	4
Myriophyllum farwellii	Farwell's water-milfoil	8
Myriophyllum tenellum	Dwarf water-milfoil	10
Myriophyllum verticillatum	Whorled water-milfoil	8
Najas flexilis	Slender naiad	6
Najas gracillima	Northern naiad	7
Nitella sp.	Nitella	7
Nuphar variegata	Spatterdock	6
Nymphaea odorata	White water lily	6
Pontederia cordata	Pickerelweed	8
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton diversifolius	Water-thread pondweed	8
Potamogeton epihydrus	Ribbon-leaf pondweed	8
Potamogeton illinoensis	Illinois pondweed	6
Potamogeton pusillus	Small pondweed	7
Potamogeton richardsonii	Clasping-leaf pondweed	5
Potamogeton robbinsii	Fern pondweed	8
Potamogeton spirillus	Spiral-fruited pondweed	8
Potamogeton vaseyi	Vasey's pondweed	10
Potamogeton zosteriformis	Flat-stem pondweed	6
Riccia fluitans	Slender riccia	7
Sagittaria latifolia	Common arrowhead	3
Sagittaria rigida	Sessile-fruited arrowhead	8
Schoenoplectus subterminalis	Water bulrush	9
Schoenoplectus tabernaemontani	Softstem bulrush	4
Spirodela polyrhiza	Large duckweed	5

Table 5 (continued): Floristic Quality Index of Aquatic Macrophytes Horseshoe Lake - Polk/Barron Counties, Wisconsin August 2-4, 2008

Species	Common Name	C
Typha latifolia	Broad-leaved cattail	1
Utricularia gibba	Creeping bladderwort	9
Utricularia intermedia	Flat-leaf bladderwort	9
Utricularia vulgaris	Common bladderwort	7
Vallisneria americana	Wild celery	6
N		**43**
Mean C		**6.7**
FQI		**44.2**

Our 2013 point-intercept survey found a total of 47 **native index plants** in the rake. They produced a mean Coefficient of Conservatism of 6.7 and a Floristic Quality Index of 46.2 (Table 6).

Table 6: Floristic Quality Index of Aquatic Macrophytes Horseshoe Lake - Polk/Barron Counties, Wisconsin August 17-18, 2013

Species	Common Name	C
Bolboschoenus fluviatilis	River bulrush	6
Brasenia schreberi	Watershield	6
Ceratophyllum demersum	Coontail	3
Ceratophyllum echinatum	Spiny hornwort	10
Chara sp.	Muskgrass	7
Dulichium arundinaceum	Three-way sedge	9
Elatine minima	Waterwort	9
Eleocharis acicularis	Needle spikerush	5
Eleocharis erythropoda	Bald spikerush	3
Eleocharis palustris	Creeping spikerush	6
Elodea canadensis	Common waterweed	3
Glyceria borealis	Northern manna grass	8
Isoetes echinospora	Spiny-spored quillwort	8
Lemna minor	Small duckweed	4
Myriophyllum farwellii	Farwell's water-milfoil	8
Myriophyllum tenellum	Dwarf water-milfoil	10
Myriophyllum verticillatum	Whorled water-milfoil	8
Najas flexilis	Slender naiad	6
Najas gracillima	Northern naiad	7
Nitella sp.	Nitella	7
Nuphar variegata	Spatterdock	6
Nymphaea odorata	White water lily	6

Table 6 (continued): Floristic Quality Index of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 17-18, 2013

Species	Common Name	C
Pontederia cordata	Pickerelweed	8
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton diversifolius	Water-thread pondweed	8
Potamogeton epihydrus	Ribbon-leaf pondweed	8
Potamogeton illinoensis	Illinois pondweed	6
Potamogeton pusillus	Small pondweed	7
Potamogeton richardsonii	Clasping-leaf pondweed	5
Potamogeton robbinsii	Fern pondweed	8
Potamogeton spirillus	Spiral-fruited pondweed	8
Potamogeton vaseyi	Vasey's pondweed	10
Potamogeton zosteriformis	Flat-stem pondweed	6
Riccia fluitans	Slender riccia	7
Sagittaria latifolia	Common arrowhead	3
Sagittaria rigida	Sessile-fruited arrowhead	8
Schoenoplectus subterminalis	Water bulrush	9
Sparganium androcladum	Branched bur-reed	8
Sparganium emersum	Short-stemmed bur-reed	8
Spirodela polyrhiza	Large duckweed	5
Typha latifolia	Broad-leaved cattail	1
Typha X *glauca*	Hybrid cattail	1
Utricularia gibba	Creeping bladderwort	9
Utricularia intermedia	Flat-leaf bladderwort	9
Utricularia minor	Small bladderwort	10
Utricularia vulgaris	Common bladderwort	7
Vallisneria americana	Wild celery	6
N		**47**
Mean C		**6.7**
FQI		**46.2**

The 2020 point-intercept survey had 49 **native index plants** in the rake. They produced a mean Coefficient of Conservatism of 6.6 and a Floristic Quality Index of 45.9 (Table 7). Nichols (1999) reported an average mean C for the North Central Hardwood Forests Region of 5.6 putting Horseshoe Lake well above average for this part of the state. The FQI was also more than double the median FQI of 20.9 for the North Central Hardwood Forests (Nichols 1999). High value index plants of note included Spiny hornwort (C = 10), Three-way sedge (C = 9), Waterwort (C = 9), **the State Endangered Species** Spotted pondweed (C = 10), Grass-leaved arrowhead (C = 9), Water bulrush (C = 9), Creeping bladderwort (C = 9), Flat-leaf bladderwort (C = 9), and Small bladderwort (C = 10). We also documented six other high-value species during our survey – **the State Species of Special Concern** ** Vasey's pondweed (C = 10) was only recorded as a visual while the five other species were not included in the index. They included Torrey's three-square bulrush and Robbins' spikerush (C = 10) – two other state special concern species, Long-beaked bald rush (C = 10) – a **State Threatened Species**, and Narrow-leaved woolly sedge (C = 9) and Pursh's bulrush (C = 9).

** "Special Concern" species like Robbins' spikerush, Vasey's pondweed and Torrey's three-square bulrush are those species about which some problem of abundance or distribution is suspected but not yet proved. The main purpose of this category is to focus attention on certain species before they become threatened or endangered.

Table 7: Floristic Quality Index of Aquatic Macrophytes Horseshoe Lake - Polk/Barron Counties, Wisconsin August 16-17, 2020

Species	Common Name	C
Brasenia schreberi	Watershield	6
Carex comosa	Bottle brush sedge	5
Ceratophyllum demersum	Coontail	3
Ceratophyllum echinatum	Spiny hornwort	10
Chara sp.	Muskgrass	7
Dulichium arundinaceum	Three-way sedge	9
Elatine minima	Waterwort	9
Eleocharis acicularis	Needle spikerush	5
Eleocharis erythropoda	Bald spikerush	3
Eleocharis palustris	Creeping spikerush	6
Elodea canadensis	Common waterweed	3
Heteranthera dubia	Water star-grass	6
Lemna minor	Small duckweed	4
Myriophyllum farwellii	Farwell's water-milfoil	8
Myriophyllum verticillatum	Whorled water-milfoil	8
Najas flexilis	Slender naiad	6
Najas gracillima	Northern naiad	7
Nitella sp.	Nitella	7
Nuphar variegata	Spatterdock	6
Nymphaea odorata	White water lily	6
Polygonum amphibium	Water smartweed	5
Pontederia cordata	Pickerelweed	8
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton diversifolius	Water-thread pondweed	8

Table 7 (continued): Floristic Quality Index of Aquatic Macrophytes
Horseshoe Lake - Polk/Barron Counties, Wisconsin
August 16-17, 2020

Species	Common Name	C
Potamogeton epihydrus	Ribbon-leaf pondweed	8
Potamogeton gramineus	Variable pondweed	7
Potamogeton illinoensis	Illinois pondweed	6
Potamogeton pulcher	Spotted pondweed	10
Potamogeton pusillus	Small pondweed	7
Potamogeton richardsonii	Clasping-leaf pondweed	5
Potamogeton robbinsii	Fern pondweed	8
Potamogeton spirillus	Spiral-fruited pondweed	8
Potamogeton zosteriformis	Flat-stem pondweed	6
Riccia fluitans	Slender riccia	7
Sagittaria graminea	Grass-leaved arrowhead	9
Sagittaria latifolia	Common arrowhead	3
Sagittaria rigida	Sessile-fruited arrowhead	8
Schoenoplectus subterminalis	Water bulrush	9
Schoenoplectus tabernaemontani	Softstem bulrush	4
Sparganium androcladum	Branched bur-reed	8
Sparganium emersum	Short-stemmed bur-reed	8
Spirodela polyrhiza	Large duckweed	5
Typha latifolia	Broad-leaved cattail	1
Typha sp.	Cattail	1
Utricularia gibba	Creeping bladderwort	9
Utricularia intermedia	Flat-leaf bladderwort	9
Utricularia minor	Small bladderwort	10
Utricularia vulgaris	Common bladderwort	7
Vallisneria americana	Wild celery	6
N		**47**
Mean C		**6.7**
FQI		**46.2**

Comparison of Filamentous Algae in 2008, 2013, and 2020:

Filamentous algae are normally associated with excessive nutrients in the water column from such things as runoff, internal nutrient recycling, and failed septic systems. In 2008, these algae were located at 11 points with a mean rake fullness of 2.09 (Figure 13). The 2013 survey documented them at 26 points with a mean rake of 1.31 – a significant increase **(p=0.02)** in distribution, but a moderately significant decline **(p=0.006)** in density. The 2020 survey found a non-significant decline (p=0.94) in distribution to 19 sites, and a significant increase **(p=0.02)** in density to a mean rake of 1.63.

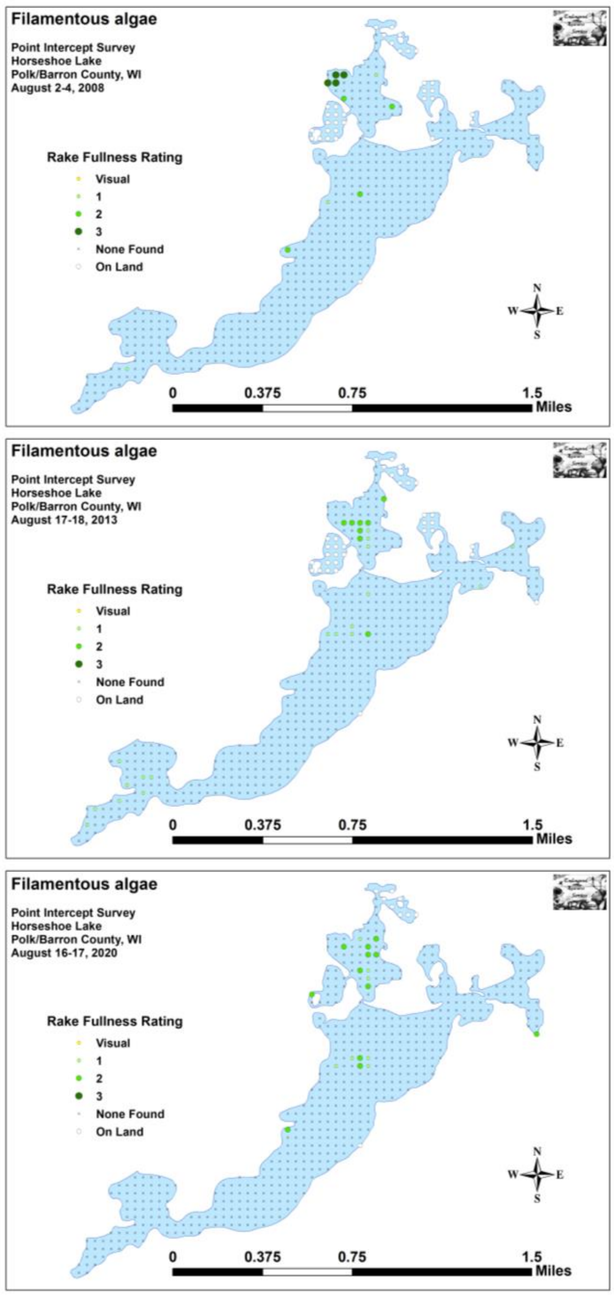


Figure 13: 2008, 2013, and 2020 Filamentous Algae Density and Distribution

Comparison of Midsummer HWM in 2008, 2013, and 2020:

The August 2008 survey found Hybrid water-milfoil in the rake at five points with 12 additional visual sightings (Figure 14) (Appendix VI). Of these, one had a rake fullness of 3, one was a 2, and the remaining three were a 1 for a mean rake fullness of 1.60. This suggested 0.97% of surveyed points and 1.29% of the littoral zone had HWM present.

Following years of aggressive active management, both our August 2013 and 2020 surveys noted it was difficult to find HWM in the lake. During each survey, we recorded HWM as a visual at a single point (Figure 14) (Appendix VI).

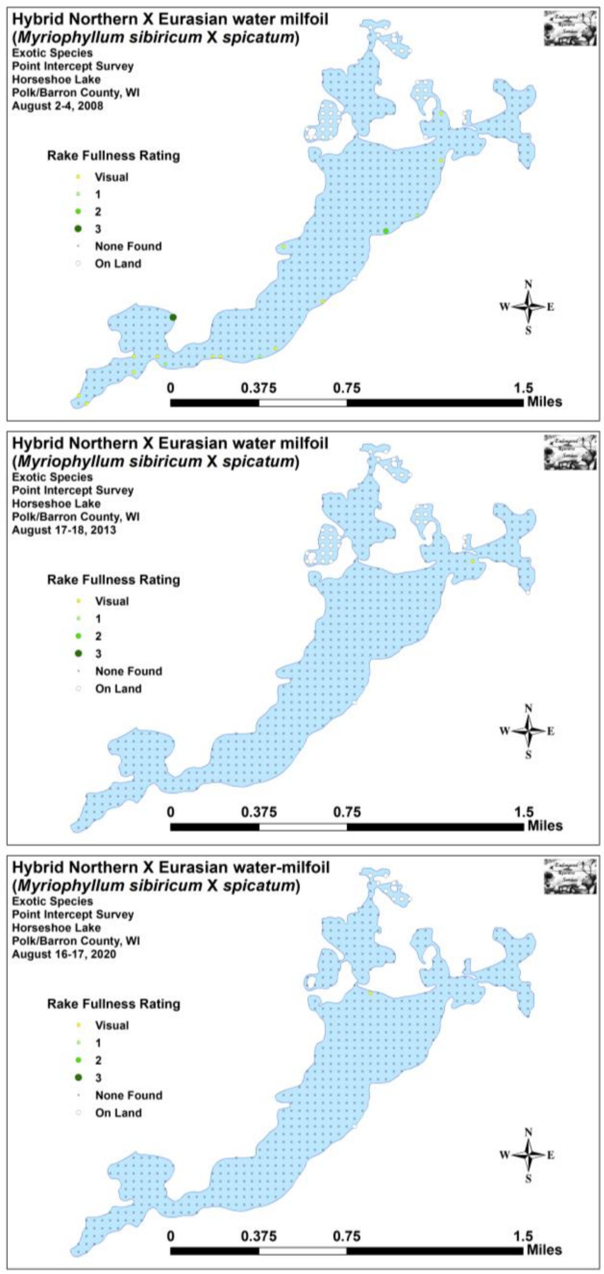
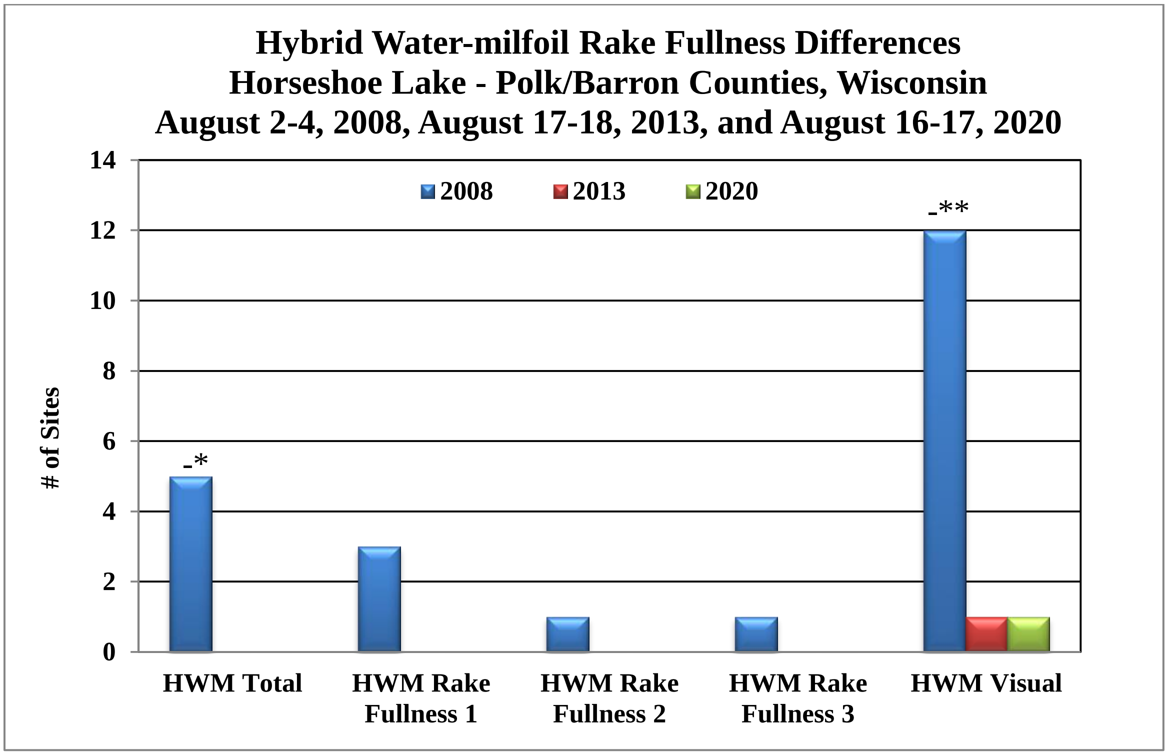


Figure 14: 2008, 2013, and 2020 Hybrid Water-milfoil Density and Distribution

From 2008 to 2013, these results demonstrated a moderately significant decline **(*p*=0.008)** in total Hybrid water-milfoil density. They also documented a significant reduction in total distribution **(*p*=0.02)** and a moderately significant decline **(*p*=0.001)** in visual sightings (Figure 15).



Significant differences = * *p*<0.05, ** *p*<0.01, * *p*<0.001**

Figure 15: 2008, 2013, and 2020 Changes in HWM Rake Fullness

Other Exotic Plant Species:

In addition to Hybrid water-milfoil, we documented three other exotic species in Horseshoe Lake: Purple loosestrife, Reed canary grass, and Hybrid cattail (Appendix VII). Purple loosestrife was scattered around Buckwald Bay with most plants occurring near points 513 and 536 (Figure 16). Reed canary grass was often a dominant plant just beyond the lakeshore despite only being found at a single survey point (Figure 17). We noticed patches in adjacent wetlands and next to mowed and otherwise disturbed shorelines. A ubiquitous plant in the state, there's likely little that can be done about it. Hybrid cattail was present along much of the Mud Lake shoreline. Present at 15 survey points with a mean rake fullness of 2.93, it dominated the marsh on the north end of the "lake" (Figure 18). Besides having narrower leaves, the exotics can be told from our native cattails by having a relatively narrower and longer "hotdog-shaped" tan colored female cattail flower whereas our native species tends to produce a fatter and shorter "bratwurst-shaped" dark chocolate colored female flower. Narrow-leaved cattail and its hybrids also have a male flower that is separated from the female flower by a thin green stem, while the native Broad-leaved cattail has its male and female flowers connected (Figure 19).

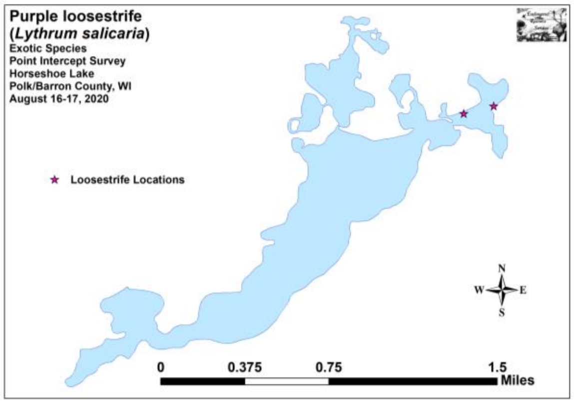


Figure 16: 2020 Purple Loosestrife Distribution

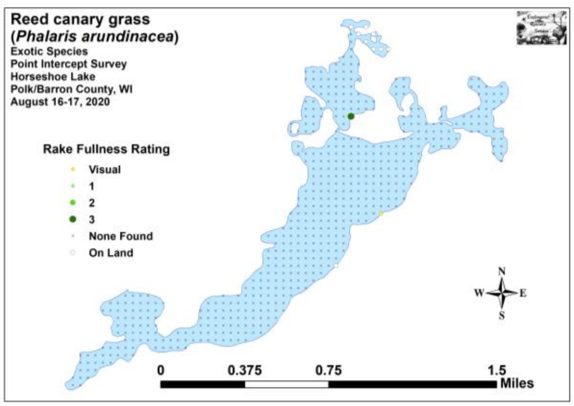
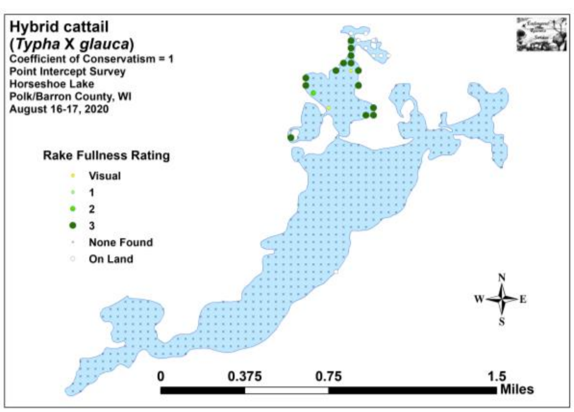


Figure 17: 2020 Reed Canary Grass Density and Distribution

Figure 18: 2020 Hybrid Cattail Density and Distribution



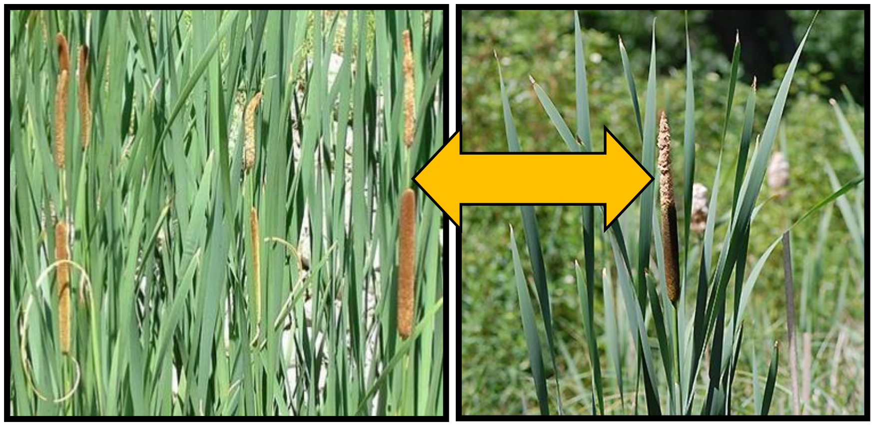


Figure 19: Exotic Narrow-leaved Cattail vs. Native Broad-leaved Cattail

Curly-leaf pondweed, another exotic species found during both the 2008 and 2013 spring surveys (Figure 20), was not seen during the single late-summer survey in 2020. A historically rare species in the lake, most CLP plants undergo their annual senescence by early July. Because of this, it isn't surprising that we didn't find it in August of 2020 (For more information on a sampling of aquatic exotic invasive plant species, see Appendix VIII).

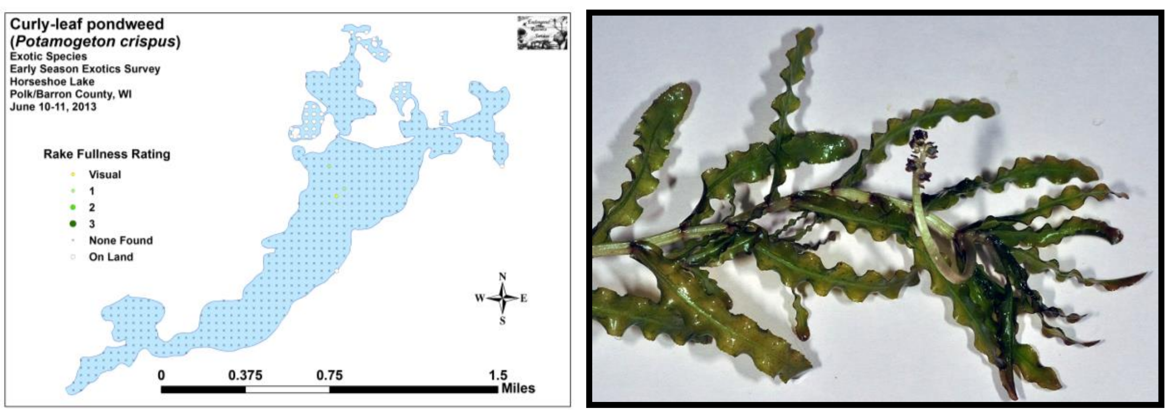


Figure 20: 2013 June Curly-leaf Pondweed Density and Distribution

The only other plant we found that was of potential concern was Common reed which occurred in a single bed at the inlet to Mud Lake (Figure 21). Although this species can be highly invasive in its exotic form, careful analysis of the plants present showed their leaf sheaths were detached, and the culms (stems) were red in color (Figure 22). These characteristics show it is the native subspecies *americanus* which is NOT generally invasive.

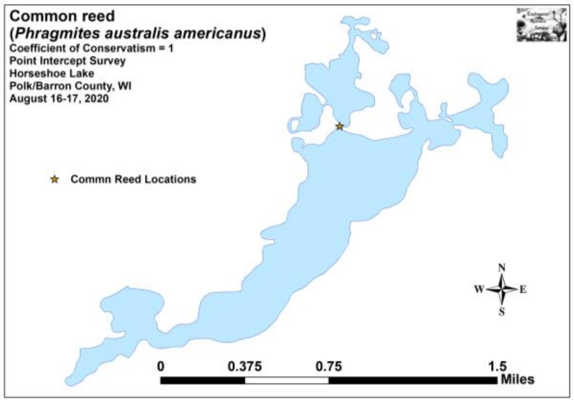


Figure 21: 2020 Common Reed Distribution

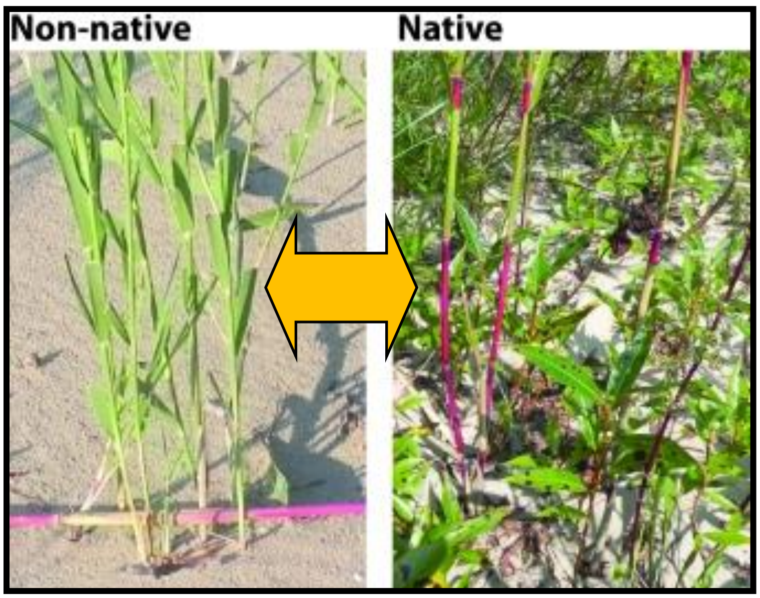


Figure 22: Stem Pattern on Exotic vs. Native Common Reed

DISCUSSION AND CONSIDERATIONS FOR MANAGEMENT:

Native Aquatic Macrophytes:

Aquatic plants are the basis of a lake's ecosystem and are as important to the aquatic environment as trees are to a forest. They provide habitat for fish and other aquatic organisms, serve as food sources for waterfowl and other wildlife, stabilize the shoreline, and work to improve clarity by absorbing excess nutrients from the water. Although several members of Horseshoe Lake's truly rare and sensitive native plant community have shown significant declines since the original 2008, most of these species were found in Mud Lake and Buckwald Bay in areas that have never been chemically treated. Because of this, we believe these changes are likely in response to the lake's fluctuating clarity and water levels over that time rather than in relation to the lake's management program.

Hybrid Eurasian Water Milfoil:

Since 2006, Hybrid Eurasian water milfoil has impacted Horseshoe Lake in both ecological and economic terms. However, following years of active management, levels of HWM have been lowered significantly, and periodic herbicide treatments normally target <2% of the lake's surface area. Although changing conditions in the lake occasionally result in a resurgence of plants, it appears the current management strategy of hand removal and limited herbicide applications has been highly effective in minimizing HWM's impact on the lake's native plant community. Based on our findings, we feel the lake is justified in continuing with the status quo in regards to active management.

Curly-leaf pondweed:

Early-season Curly-leaf pondweed surveys in 2007, 2008, and 2013 found plants at three, zero, and two points respectively, and each of these samples had a rake fullness of 1. This low-density coverage coupled with the fact that the 2013 bed mapping survey found a total of 21 plants and the summer 2020 survey didn't find any suggests that CLP does not have suitable habitat to grow at levels that will likely ever cause navigation issues in the lake. Based on this, we believe any management of CLP should be limited to hand pulling or raking of plants. We further recommend that time, money, and effort should NOT be spent surveying CLP during future PI surveys.

Purple Loosestrife:

Purple loosestrife continues to be uncommon around the margins of Horseshoe Lake's north bays, and the number of plants is likely not high enough to support a Galerucella beetle population at this time. However, this species has the ability to quickly expand and come to dominate lowland areas. To prevent further infestation, residents should watch for and remove plants in August and September when the bright fuchsia candle-shaped flower spikes are easily seen. Plants should be bagged and disposed of well away from any wetland. Also, because the plants have an extensive root system, care should be taken to remove the entire plant as even small root fragments can survive and produce new plants the following year.

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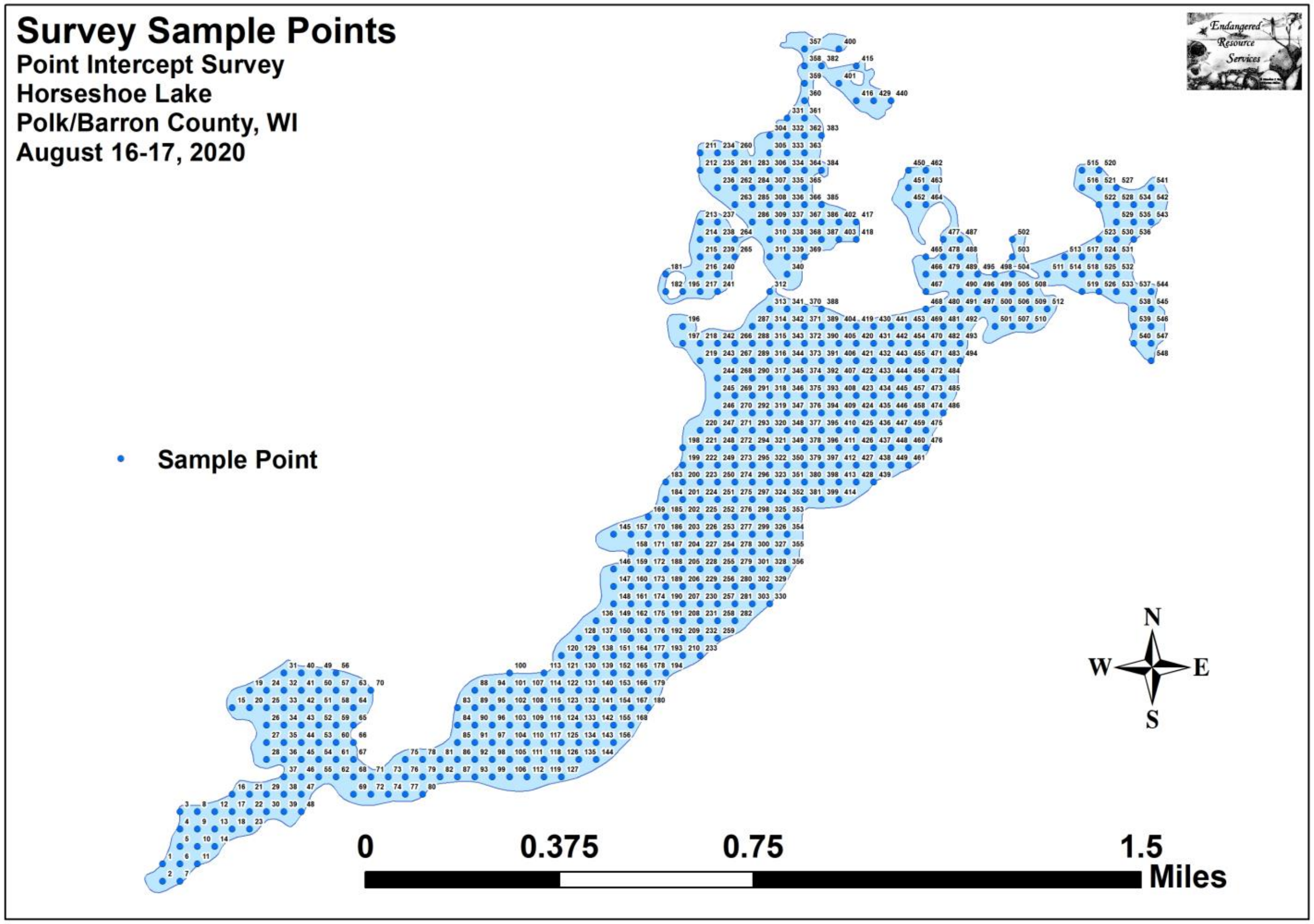
WDNR. [online]. 2010. Purple loosestrife fact sheet. http://dnr.wi.gov/invasives/fact/loosestrife.htm (2010, August).

WDNR. [online]. 2010. Reed canary grass fact sheet. http://dnr.wi.gov/invasives/fact/reed_canary.htm (2010, August).

Appendix I: Survey Sample Points Map

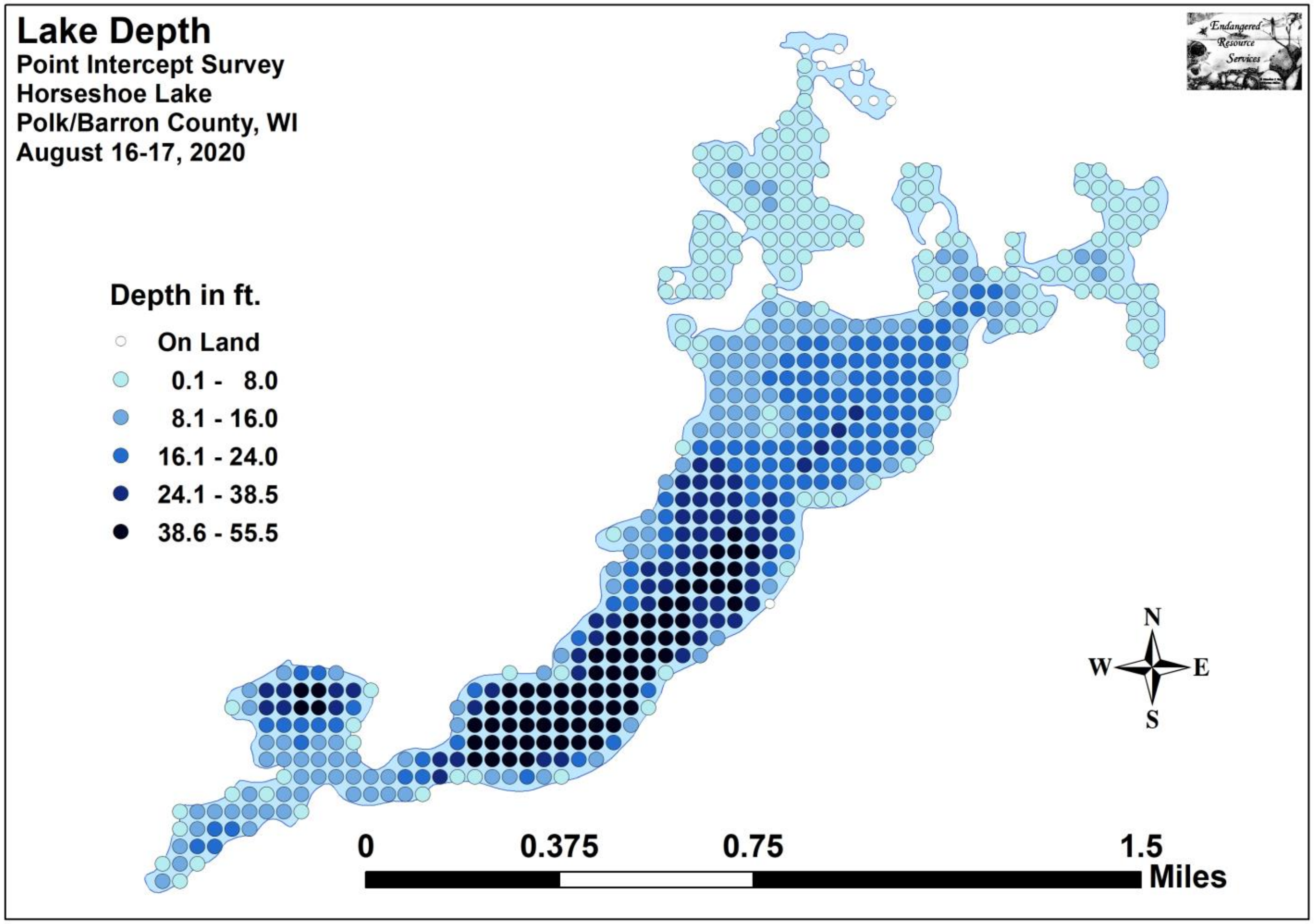

Survey Sample Points
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Sample Point
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles

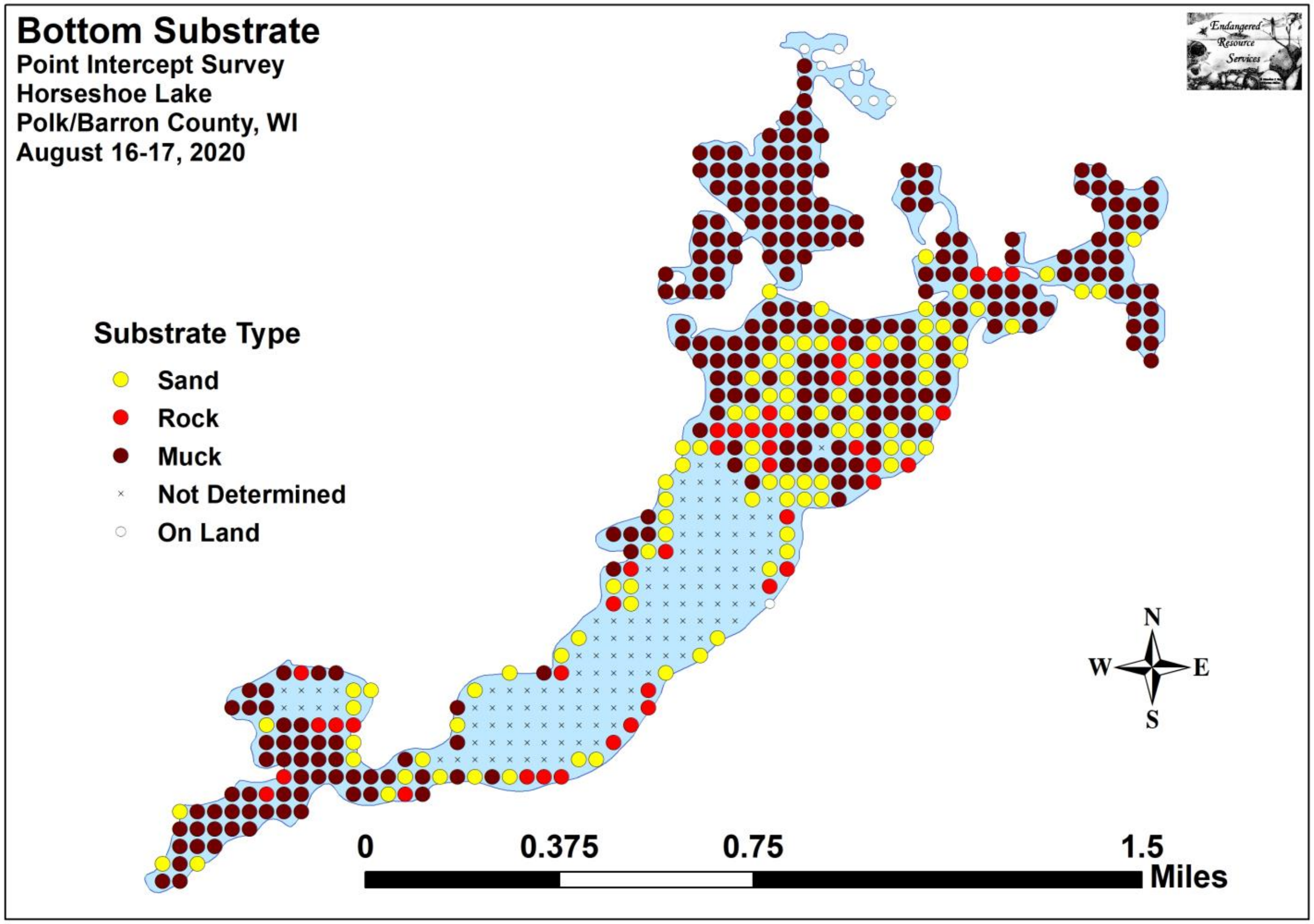
Appendix II: Boat and Vegetative Survey Datasheets

Boat Survey	
Lake Name	
County	
WBIC	
Date of Survey	
(mm/dd/yy)	
workers	
Nearest Point	**Species seen, habitat information**

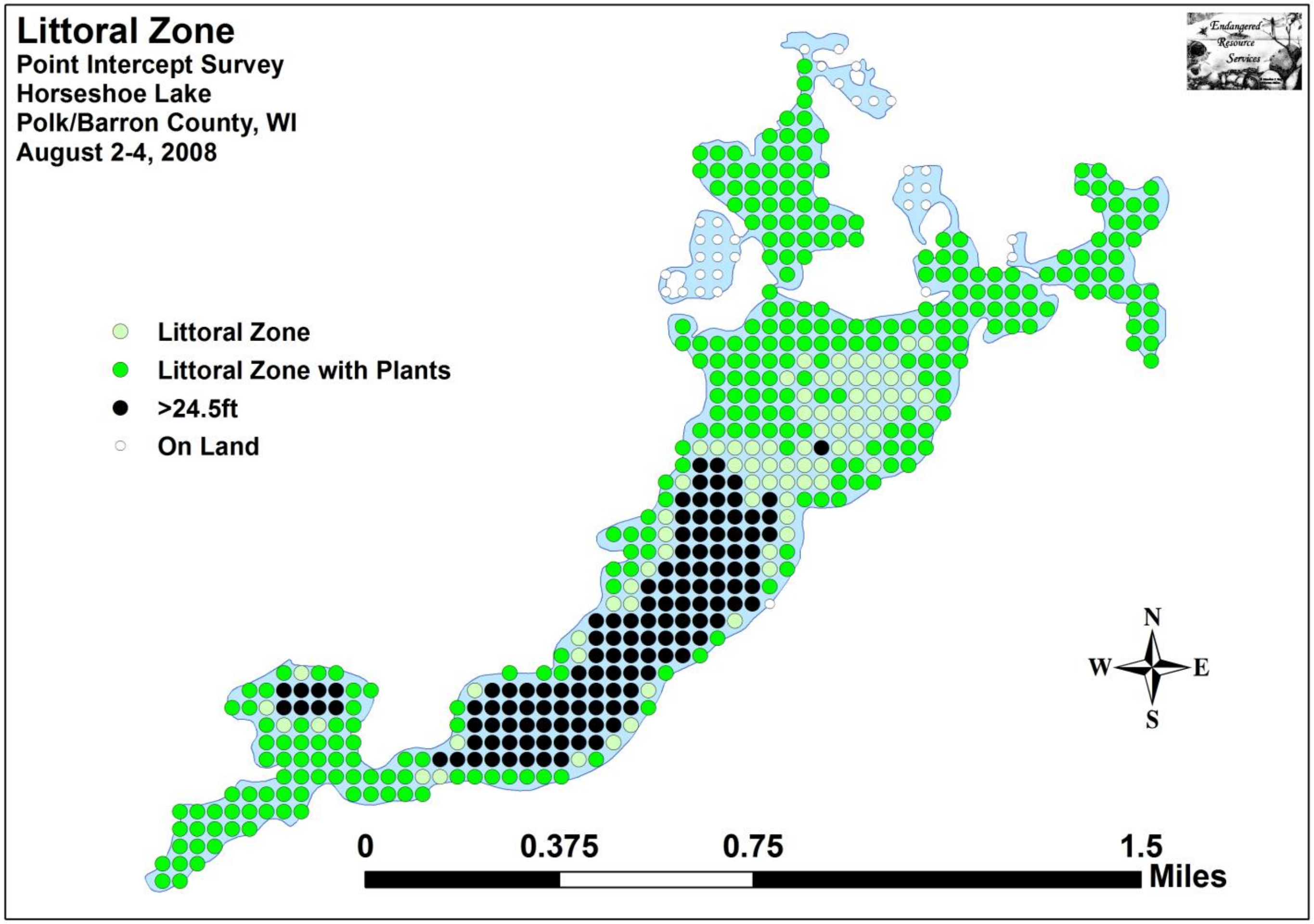
Observers for this lake: names and hours worked by each:																									
Lake:									**WBIC**									**County**						**Date:**	
Site #	**Depth (ft)**	**Muck (M), Sand (S), Rock (R)**	**Rake pole (P) or rake rope (R)**	**Total Rake Fullness**	**EWM**	**CLP**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									
11																									
12																									
13																									
14																									
15																									
16																									
17																									
18																									
19																									
20																									

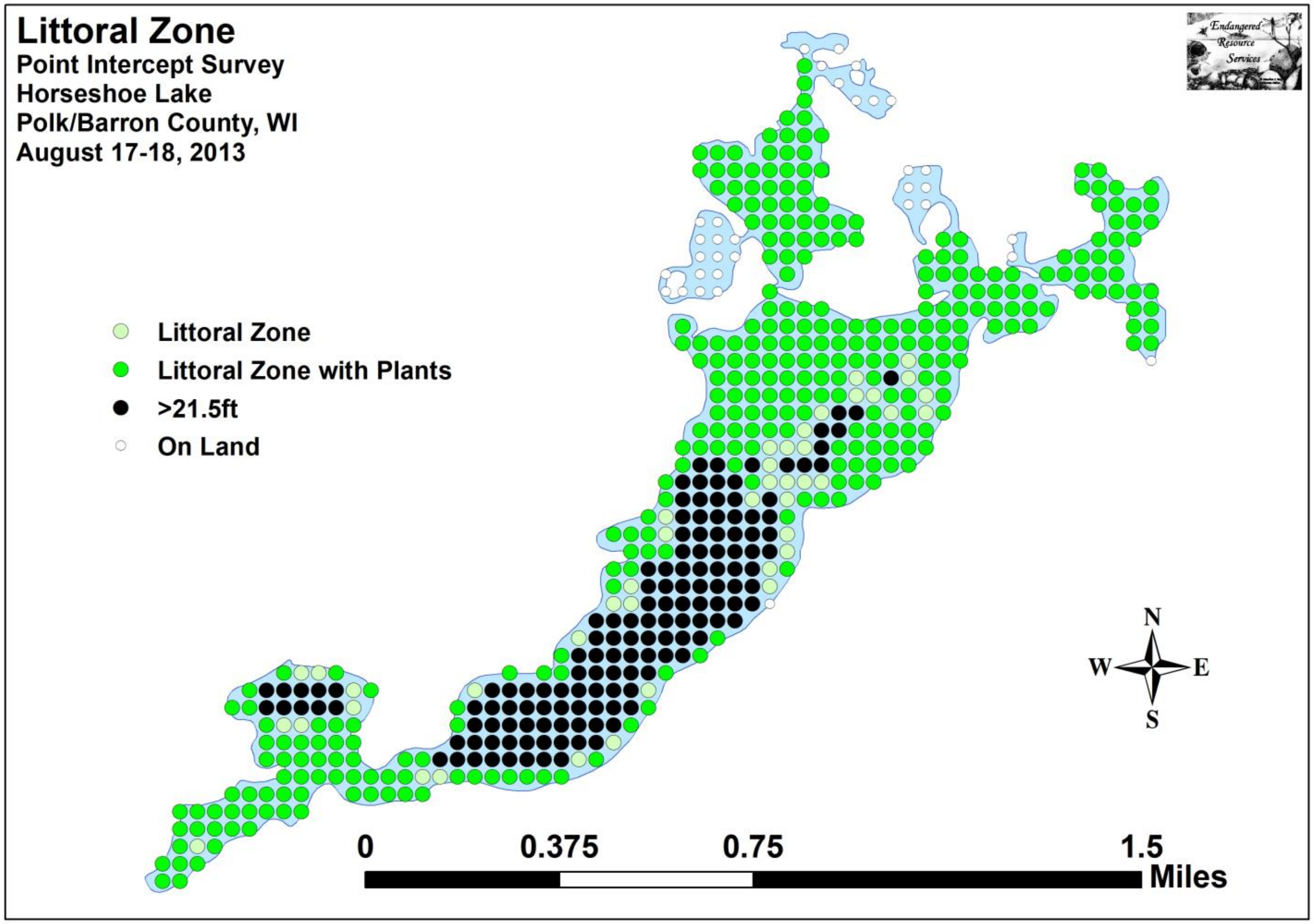
Appendix III: Habitat Variable Maps

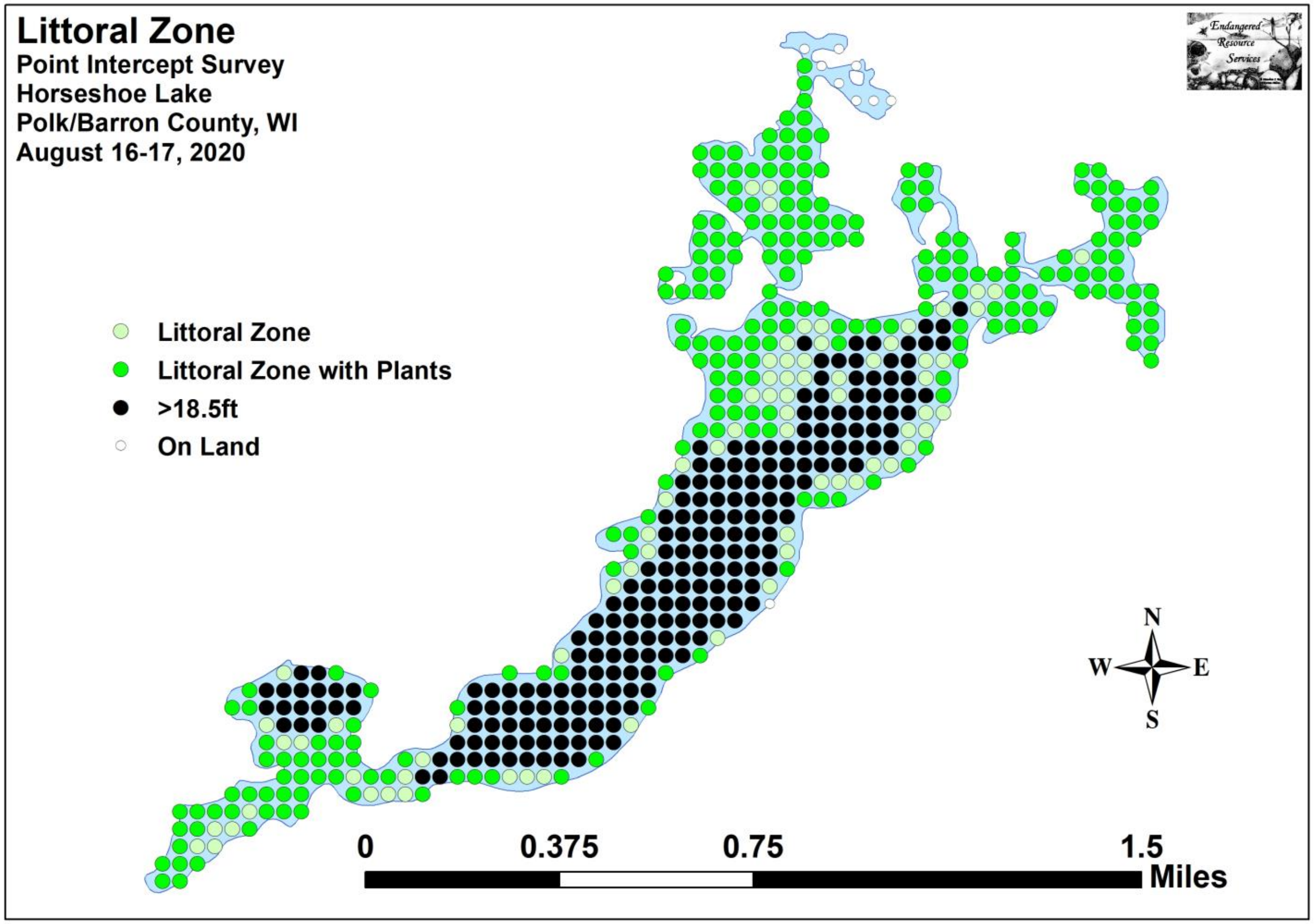

Lake Depth
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Endangered Resource Services
Depth in ft.
On Land
0.1 - 8.0
8.1 - 16.0
16.1 - 24.0
24.1 - 38.5
38.6 - 55.5
N
W
E
S
0
0.375
0.75
1.5
Miles

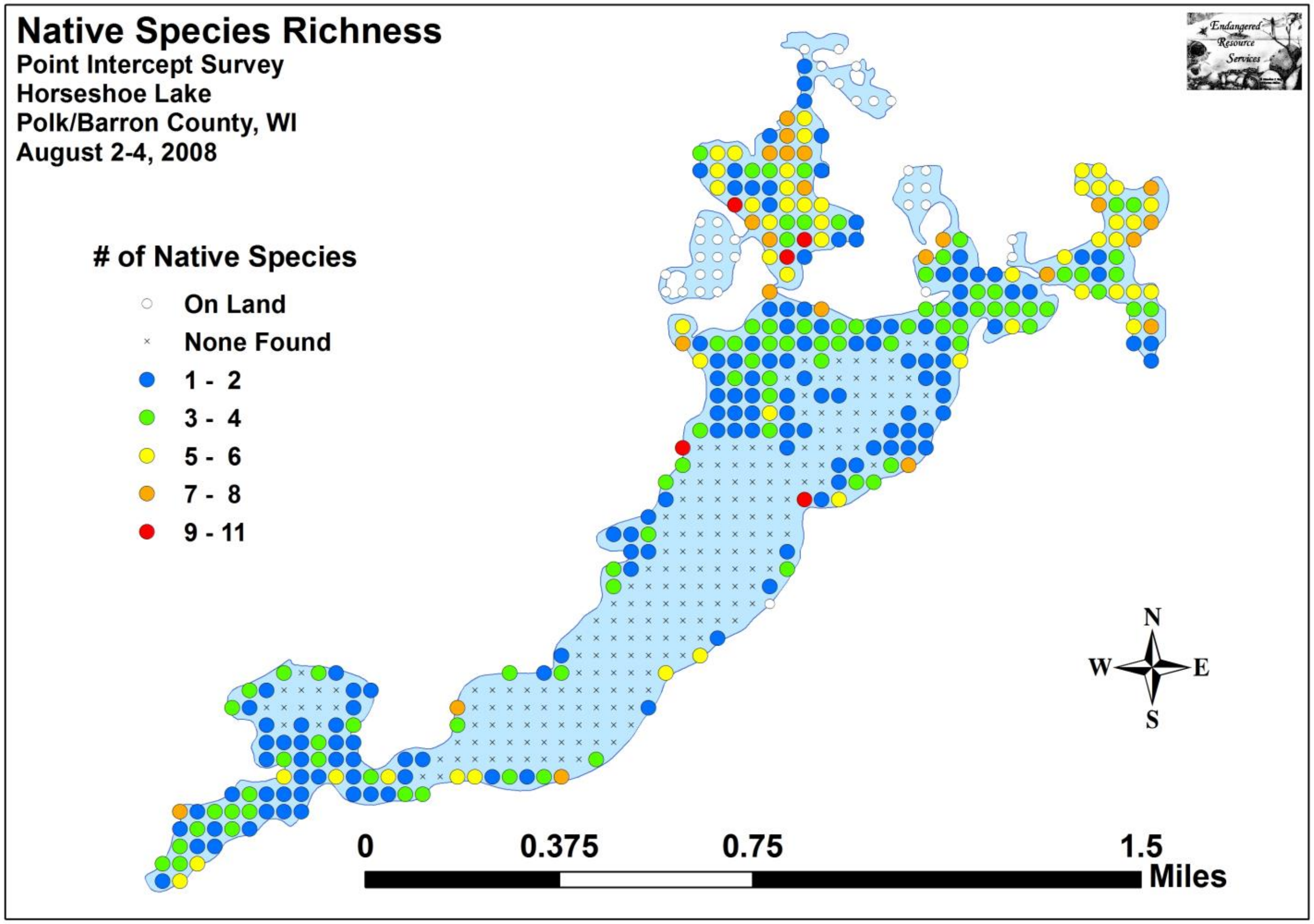

Bottom Substrate
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Substrate Type
Sand
Rock
Muck
Not Determined
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles

Appendix IV: 2008, 2013, and 2020 Littoral Zone, Native Species Richness, and Total Rake Fullness Maps

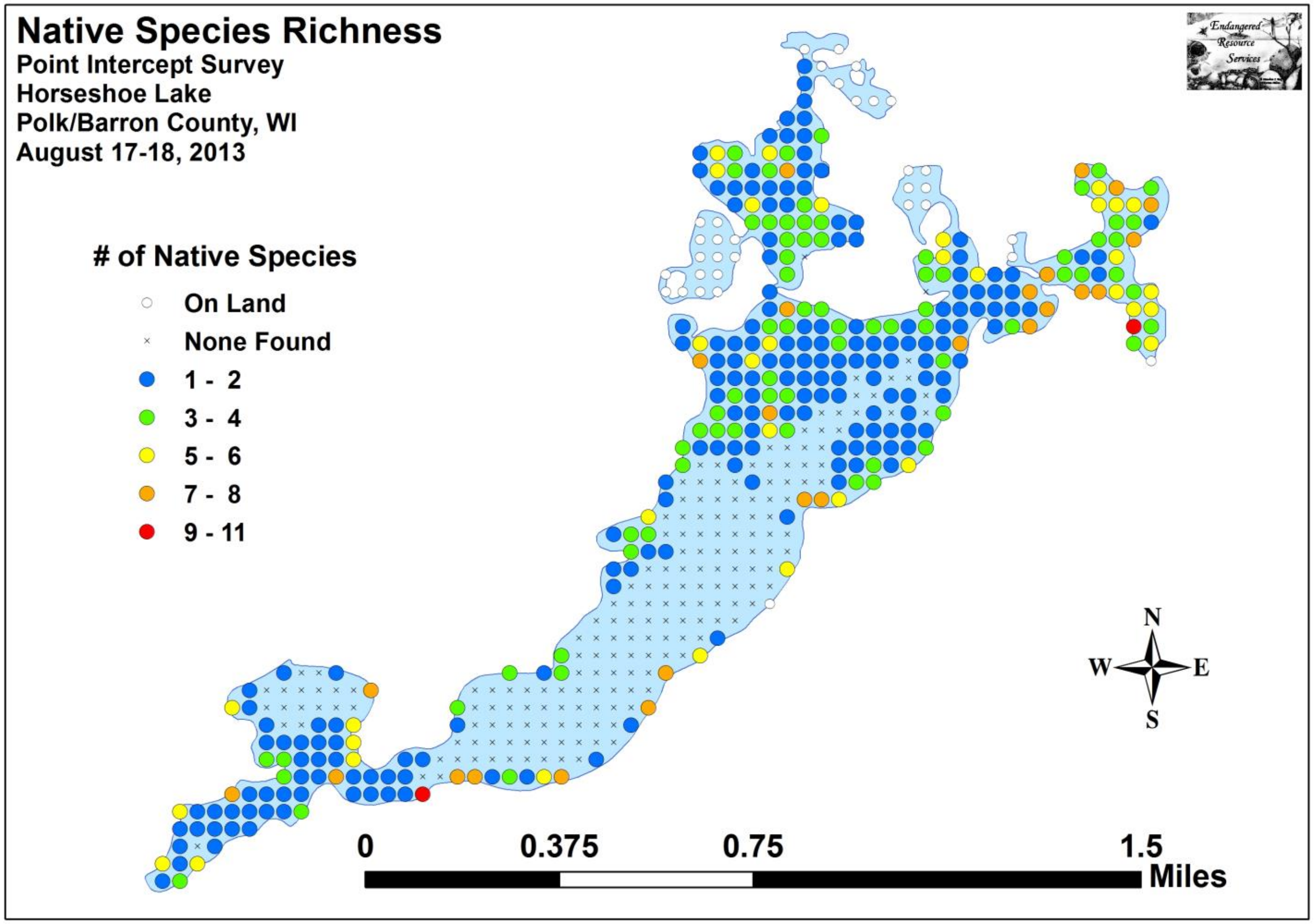

Littoral Zone
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 2-4, 2008
Littoral Zone
Littoral Zone with Plants
>24.5ft
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles


Littoral Zone
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 17-18, 2013
Endangered Resource Services
Littoral Zone
Littoral Zone with Plants
>21.5ft
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

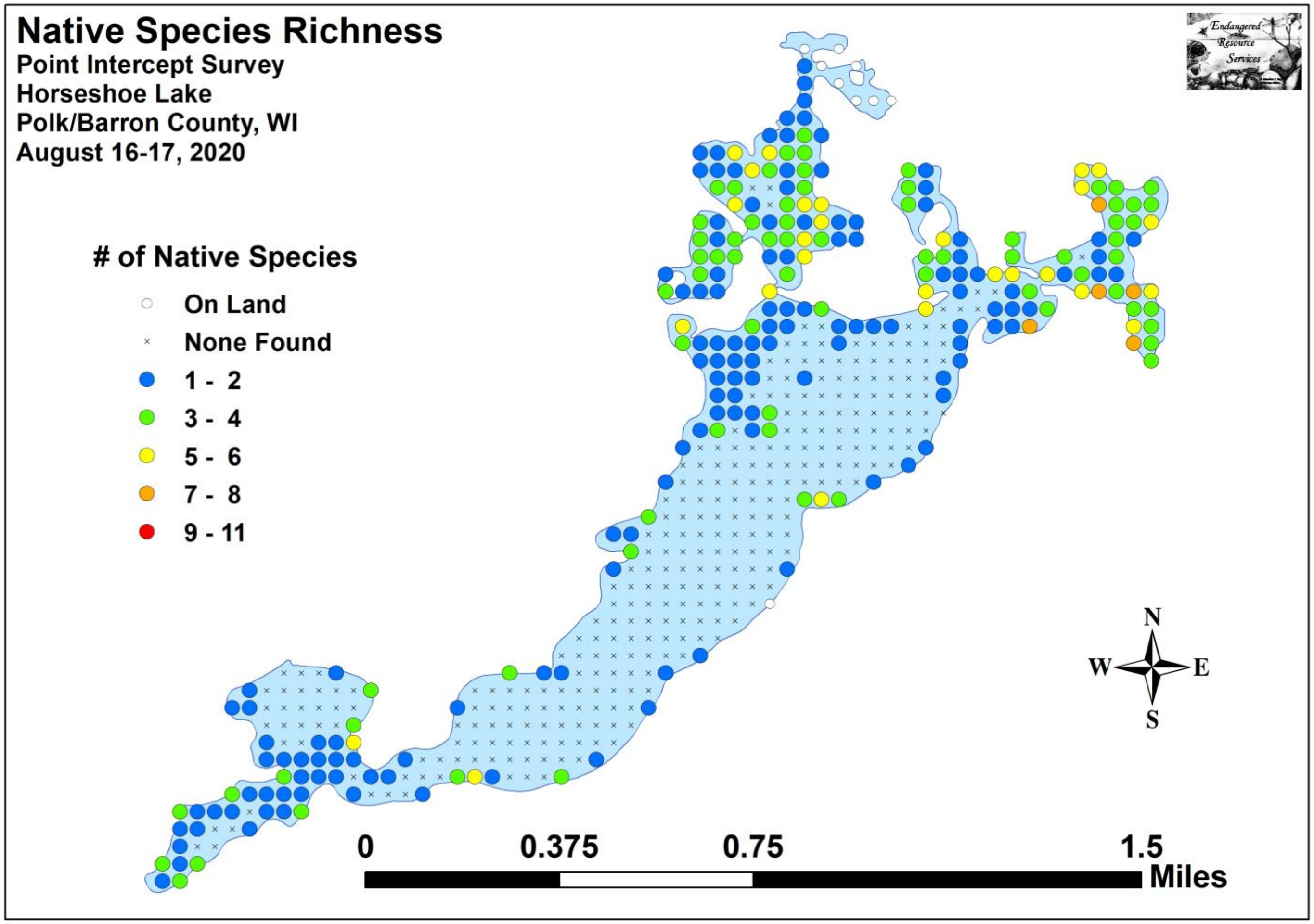

Littoral Zone
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Littoral Zone
Littoral Zone with Plants
>18.5ft
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles
Endangered Resource Services

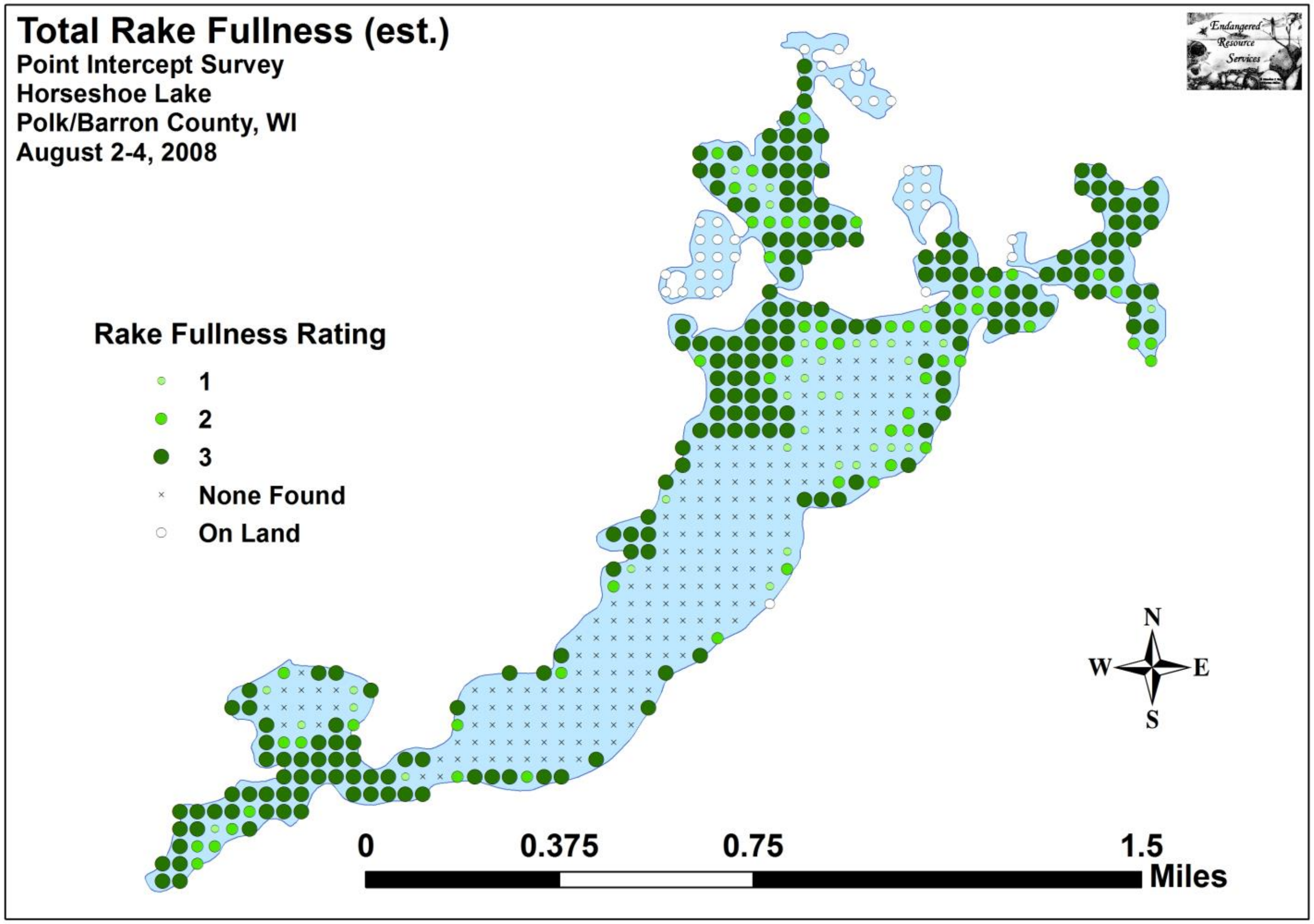


Native Species Richness
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 2-4, 2008
# of Native Species
On Land
None Found
1 - 2
3 - 4
5 - 6
7 - 8
9 - 11
N
W
E
S
0
0.375
0.75
1.5
Miles
Endangered Resource Services

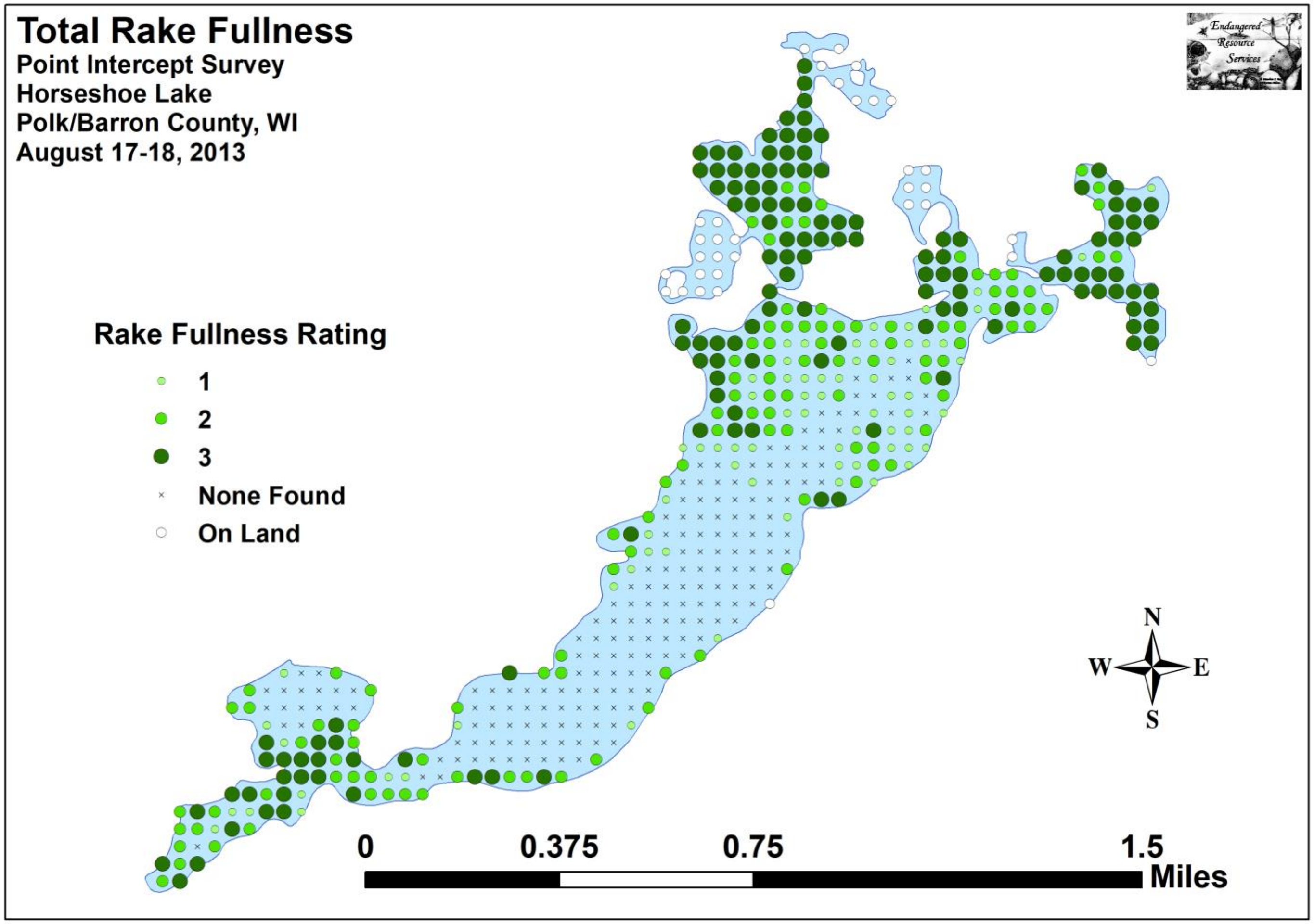


Native Species Richness
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 17-18, 2013
# of Native Species
On Land
None Found
1 - 2
3 - 4
5 - 6
7 - 8
9 - 11
0
0.375
0.75
1.5
Miles
N
W
E
S
Endangered Resource Services

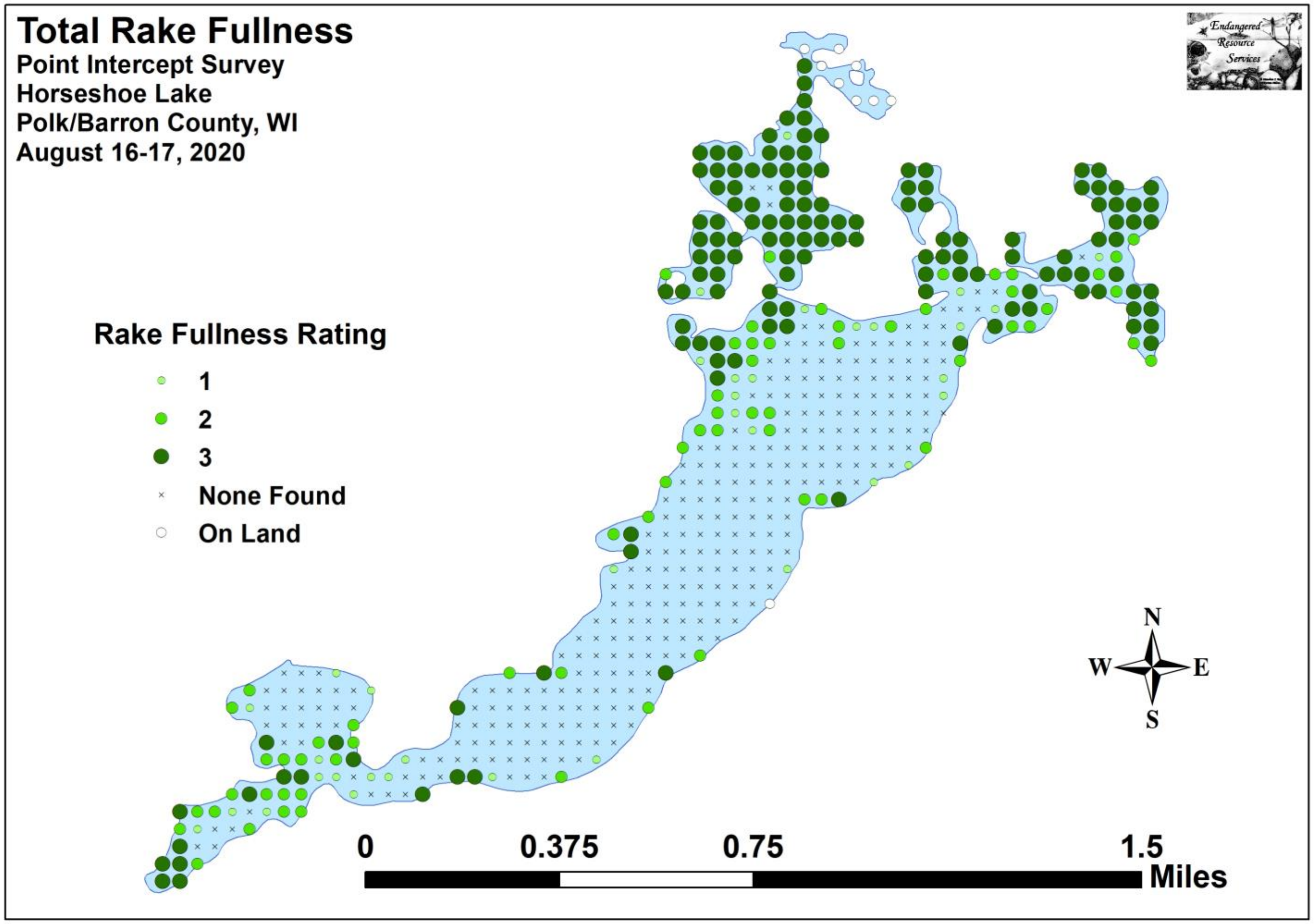

Native Species Richness
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
# of Native Species
On Land
None Found
1 - 2
3 - 4
5 - 6
7 - 8
9 - 11
0
0.375
0.75
1.5
Miles
N
W
E
S
Endangered
Resource
Services



Total Rake Fullness (est.)
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 2-4, 2008
Rake Fullness Rating
1
2
3
None Found
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles

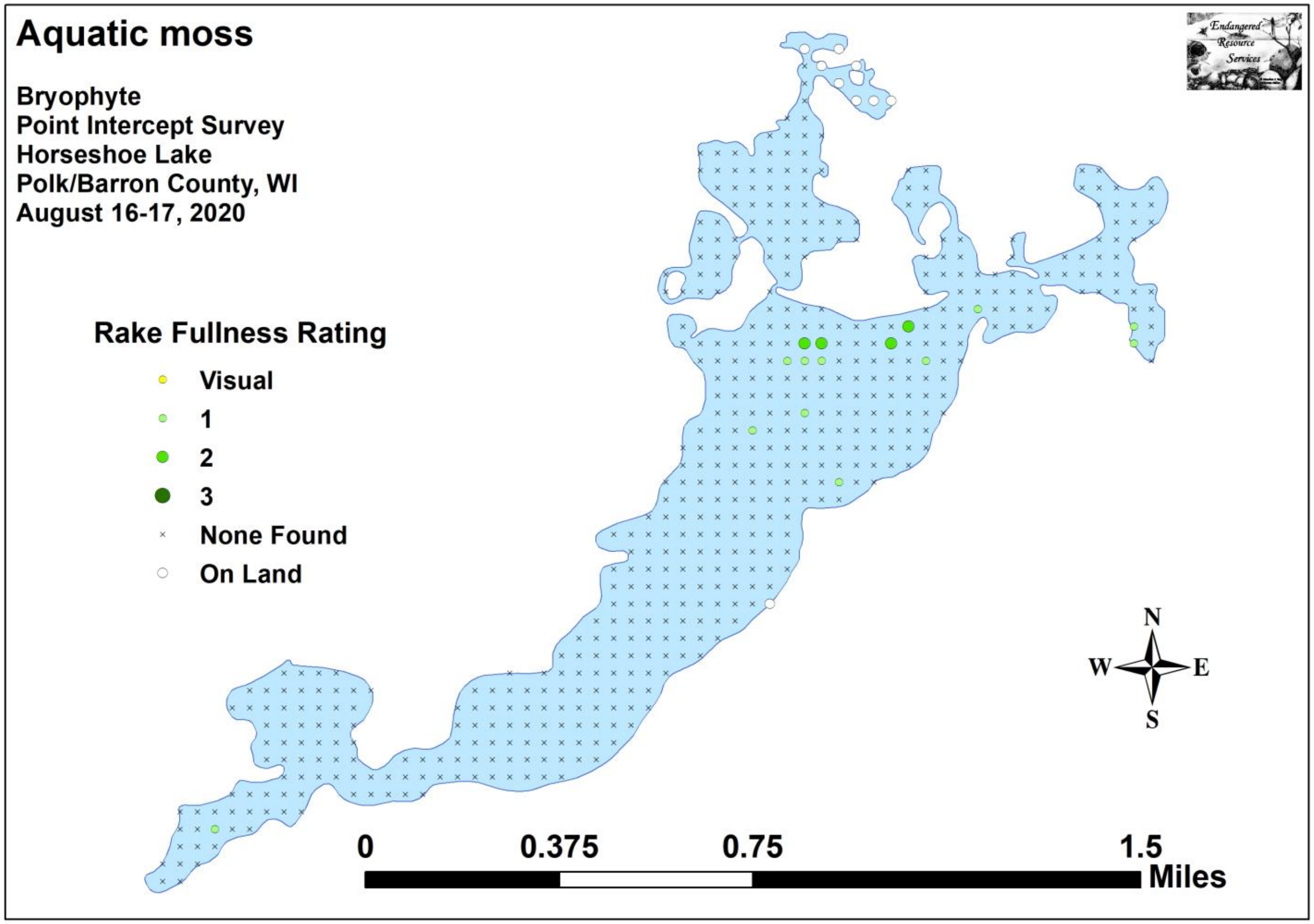


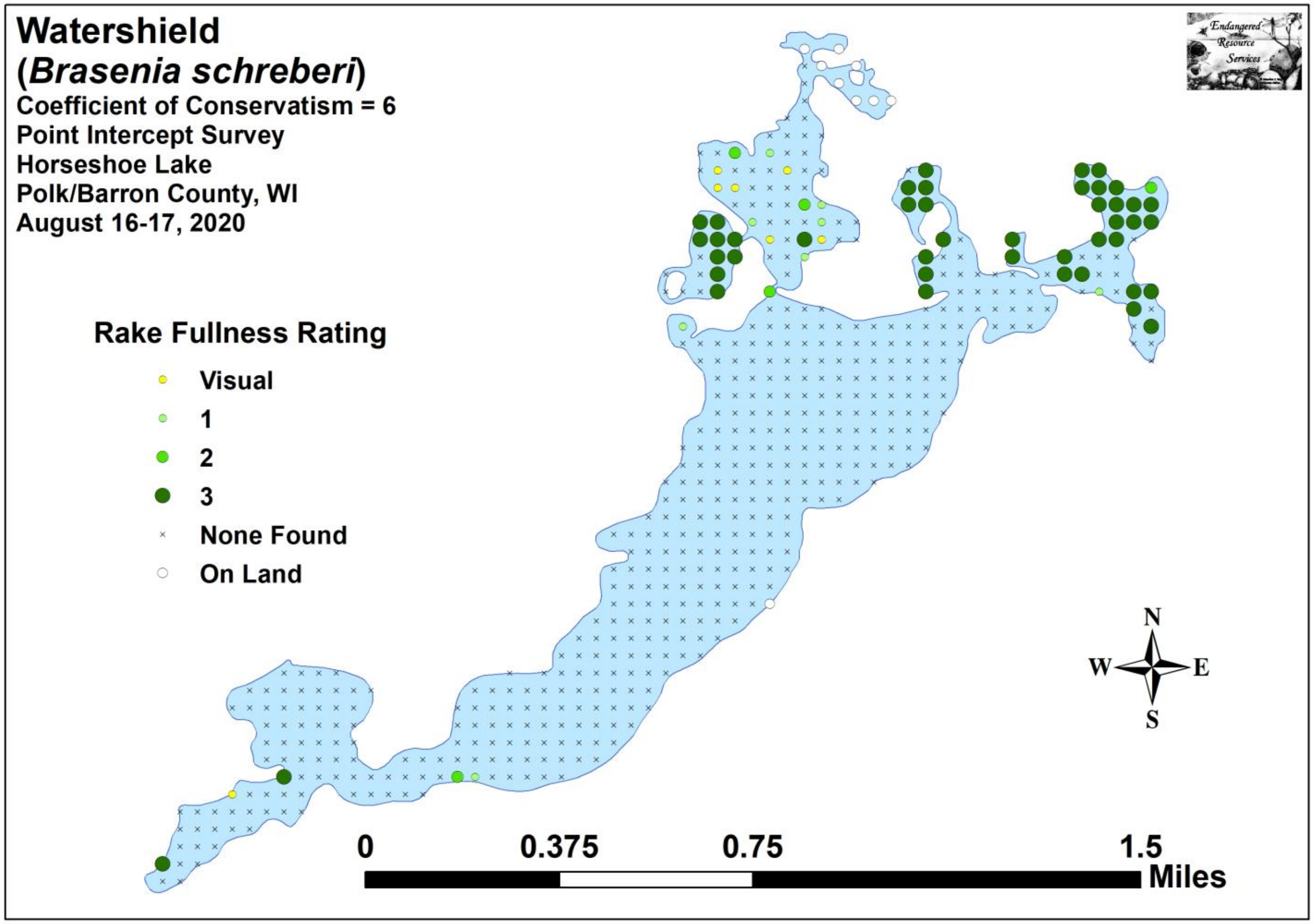
Total Rake Fullness
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 17-18, 2013
Endangered Resource Services
Rake Fullness Rating
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles



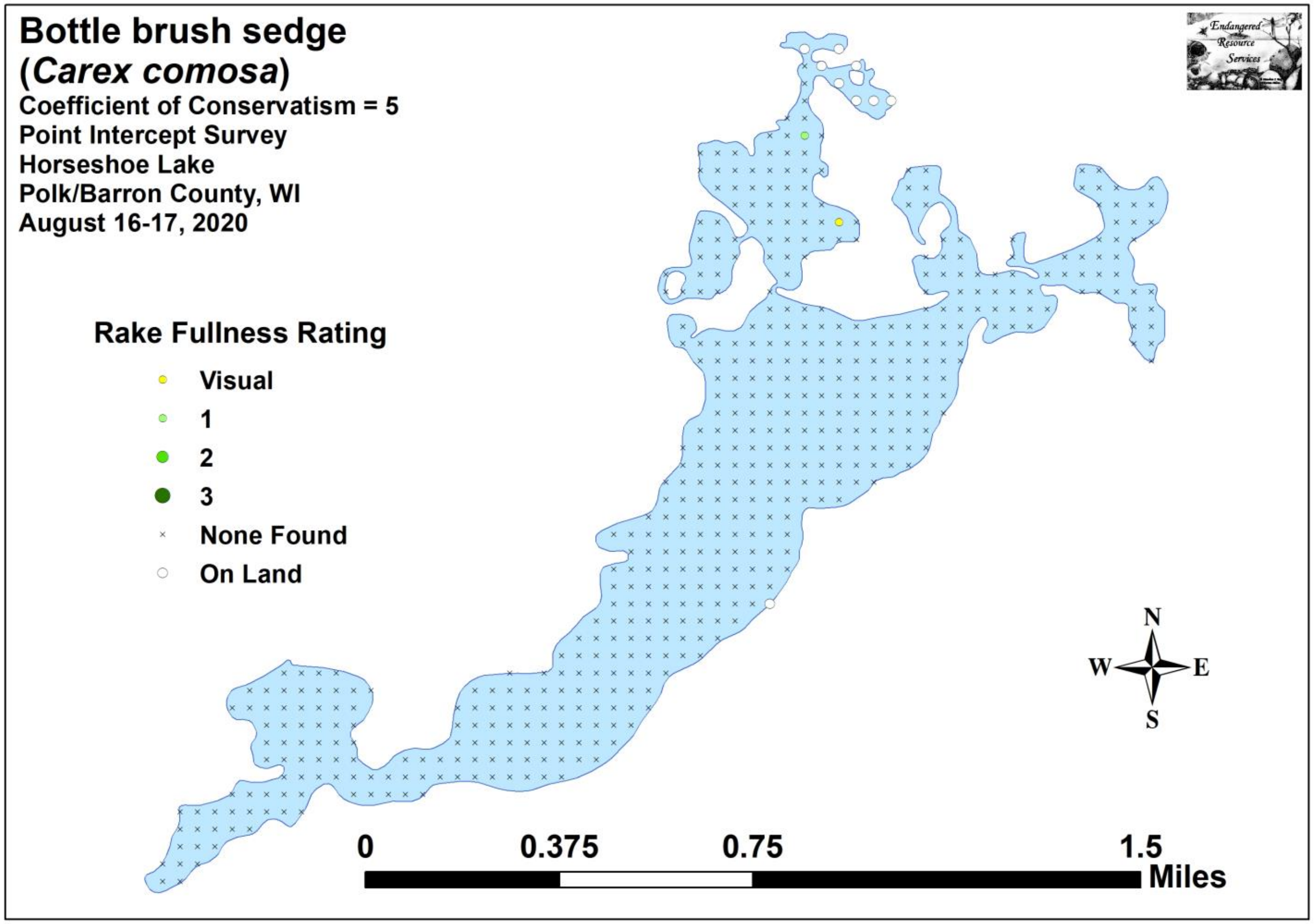
Total Rake Fullness
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

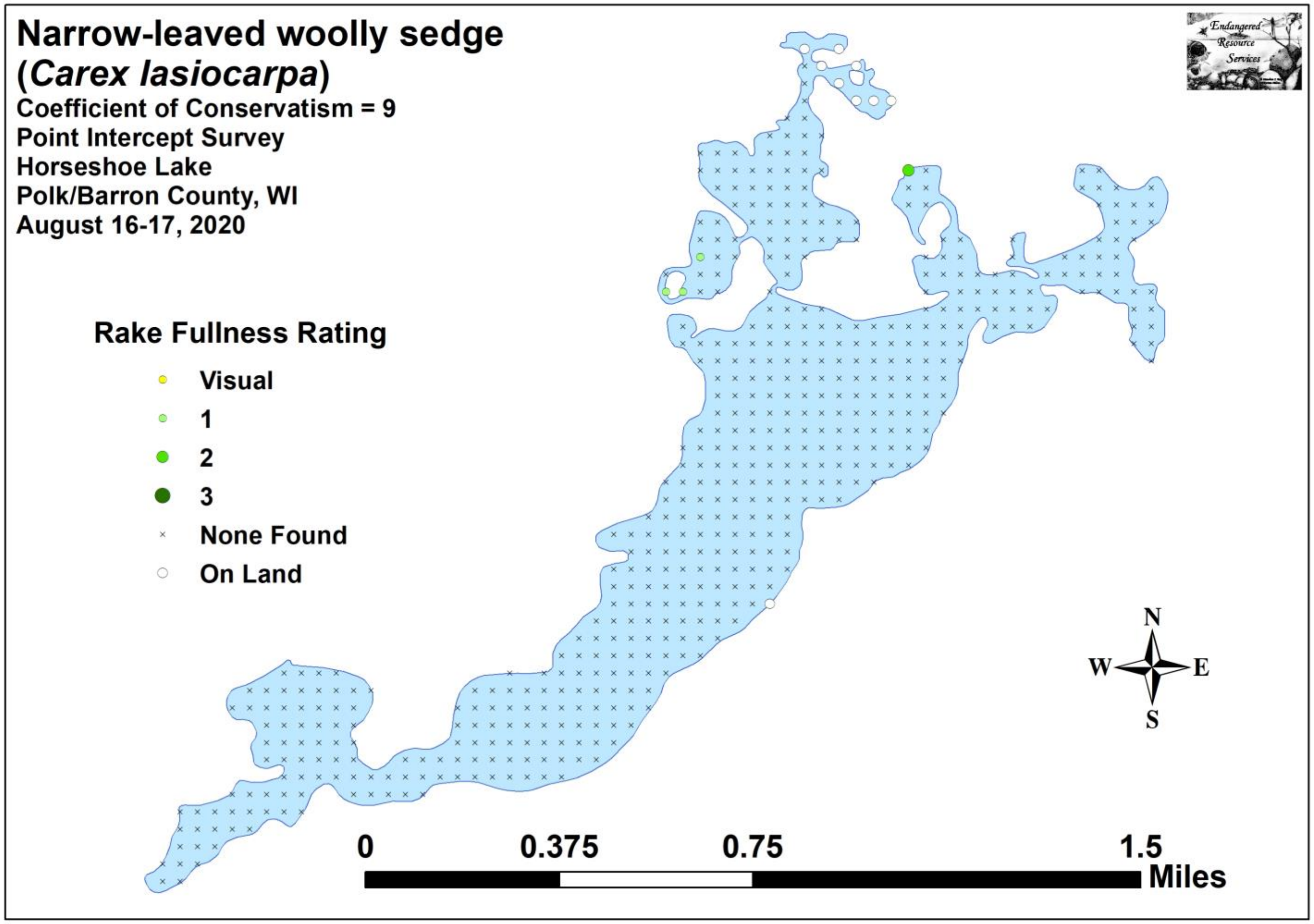
Appendix V: August 2020 Native Species Density and Distribution Maps

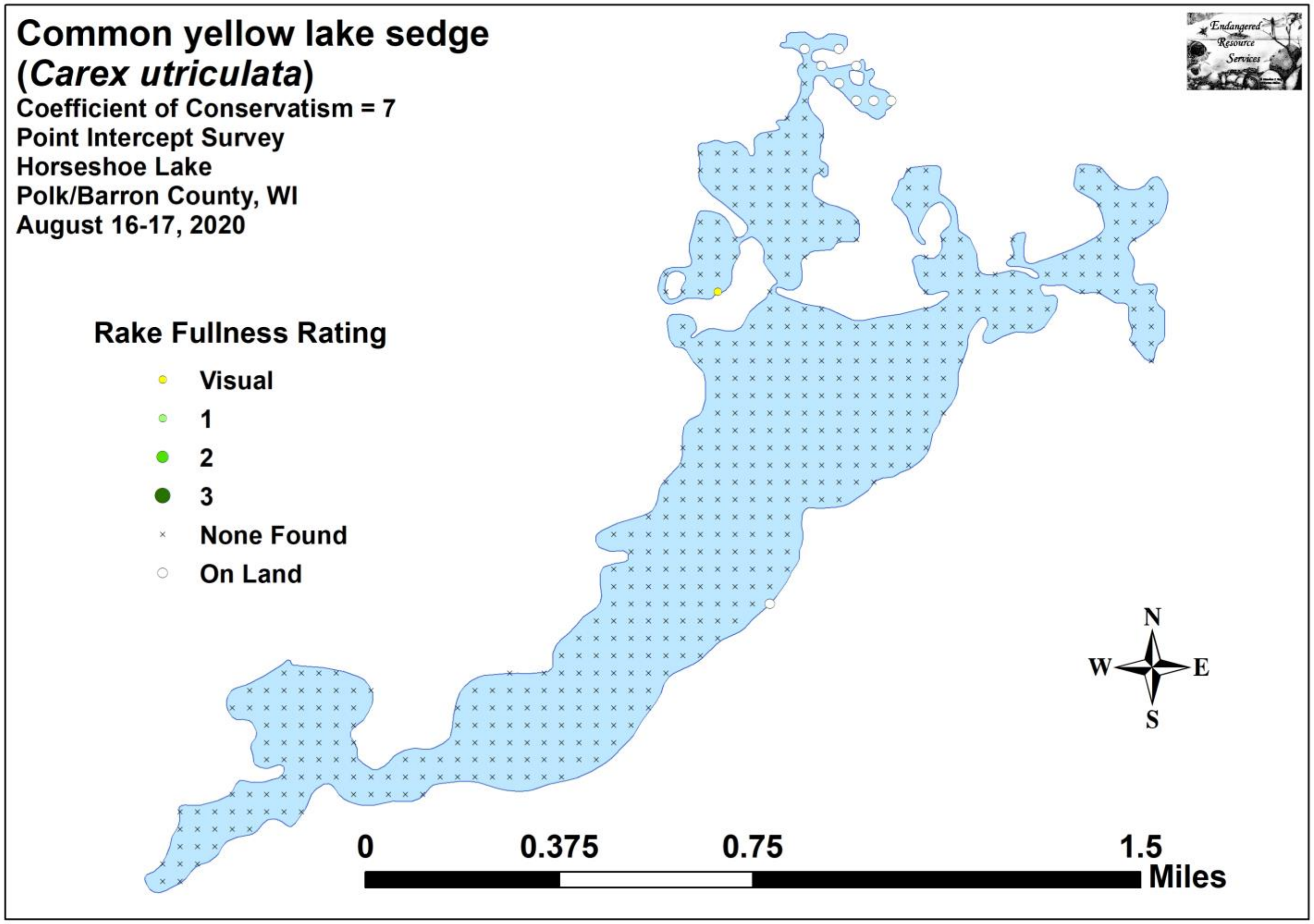

Aquatic moss
Bryophyte
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles

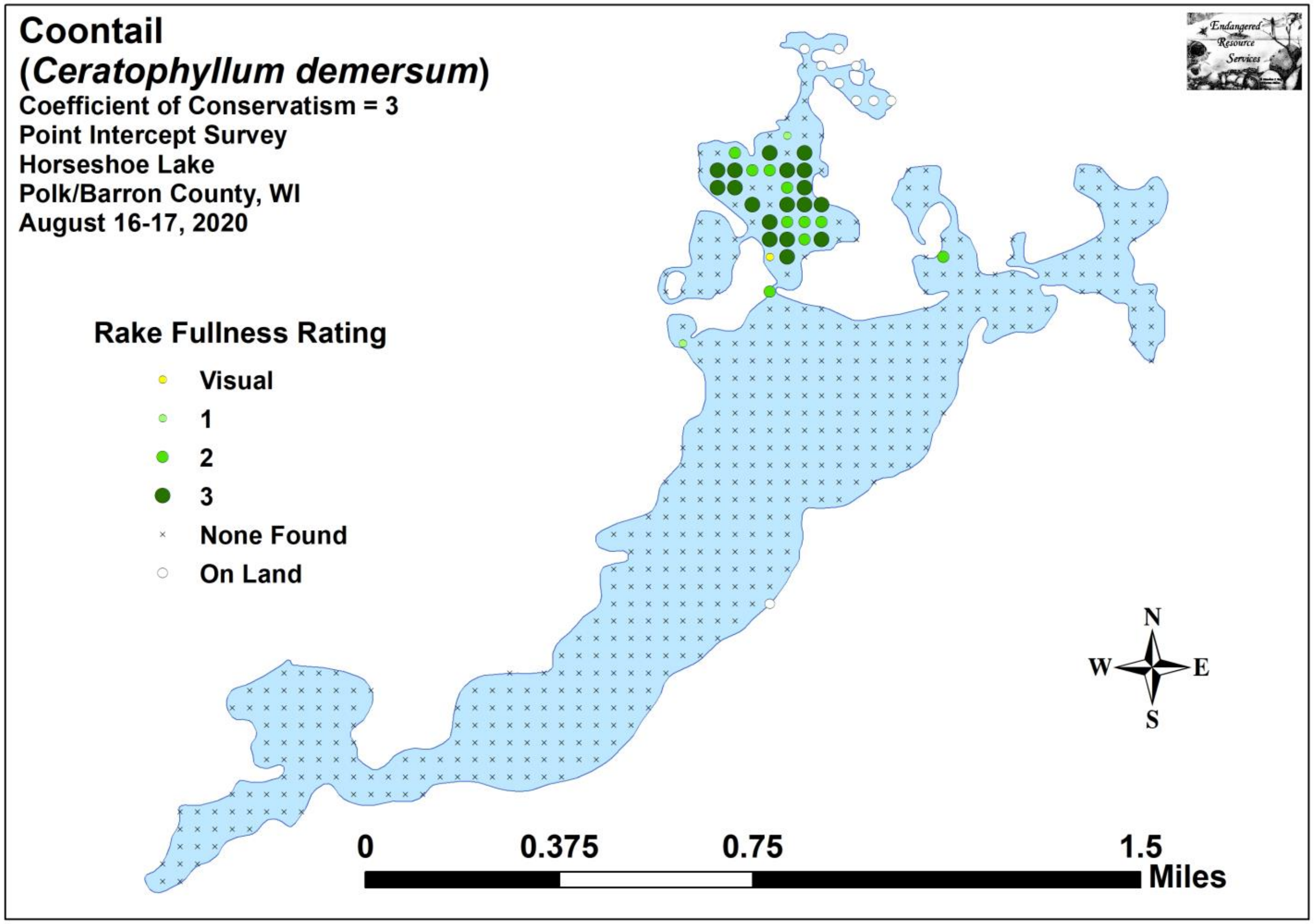


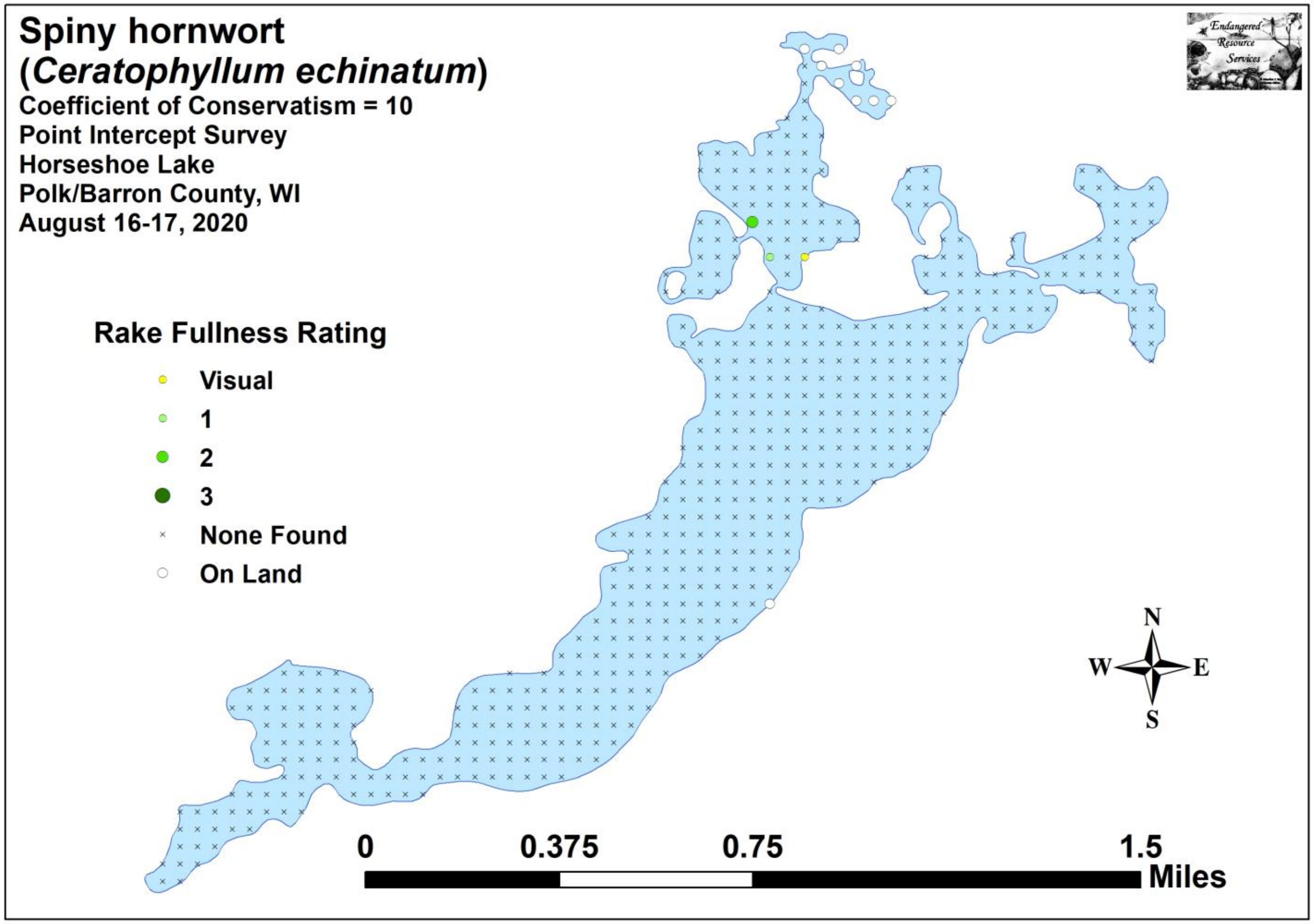
Watershield
(*Brasenia schreberi*)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

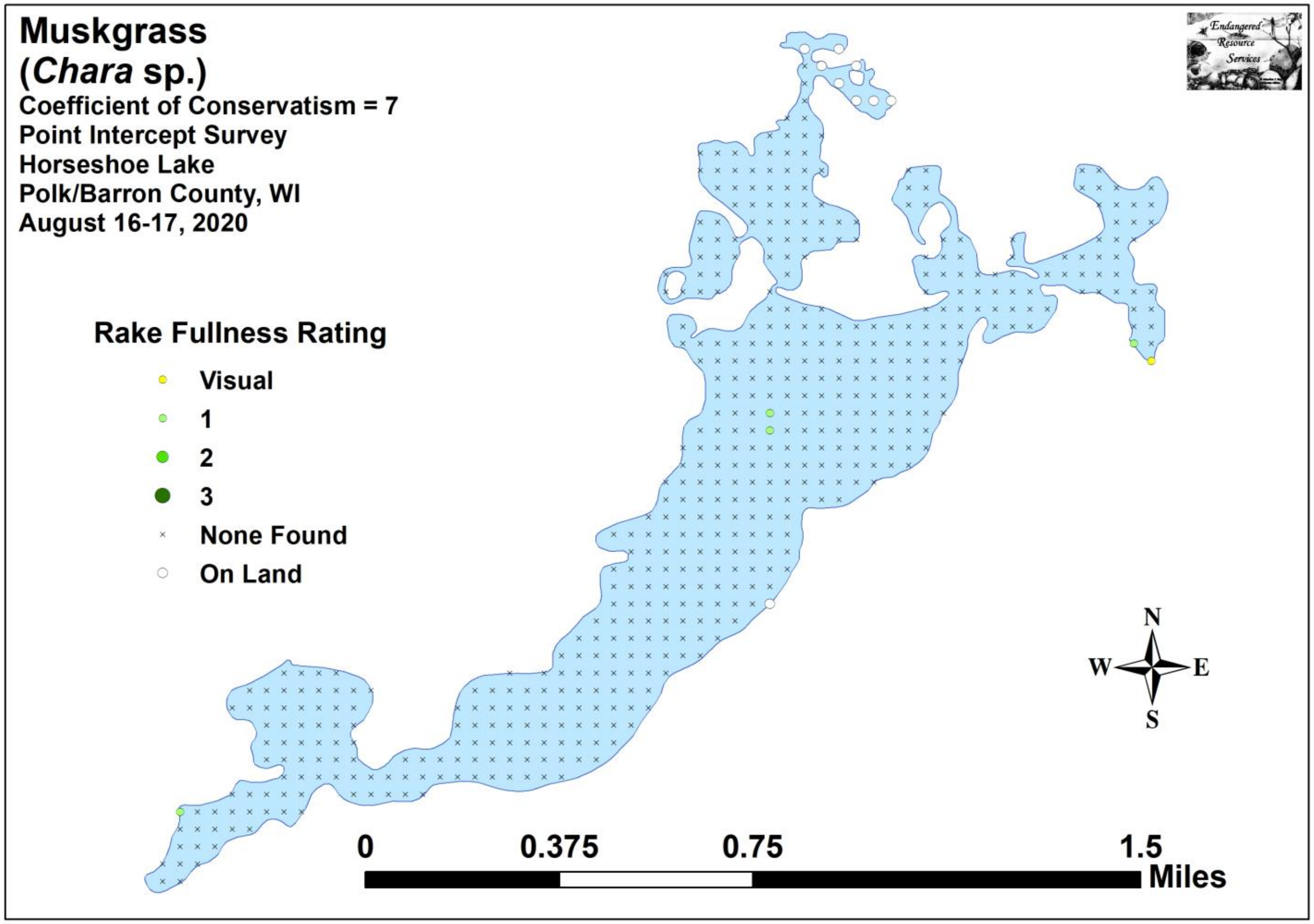

Bottle brush sedge
(Carex comosa)
Coefficient of Conservatism = 5
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

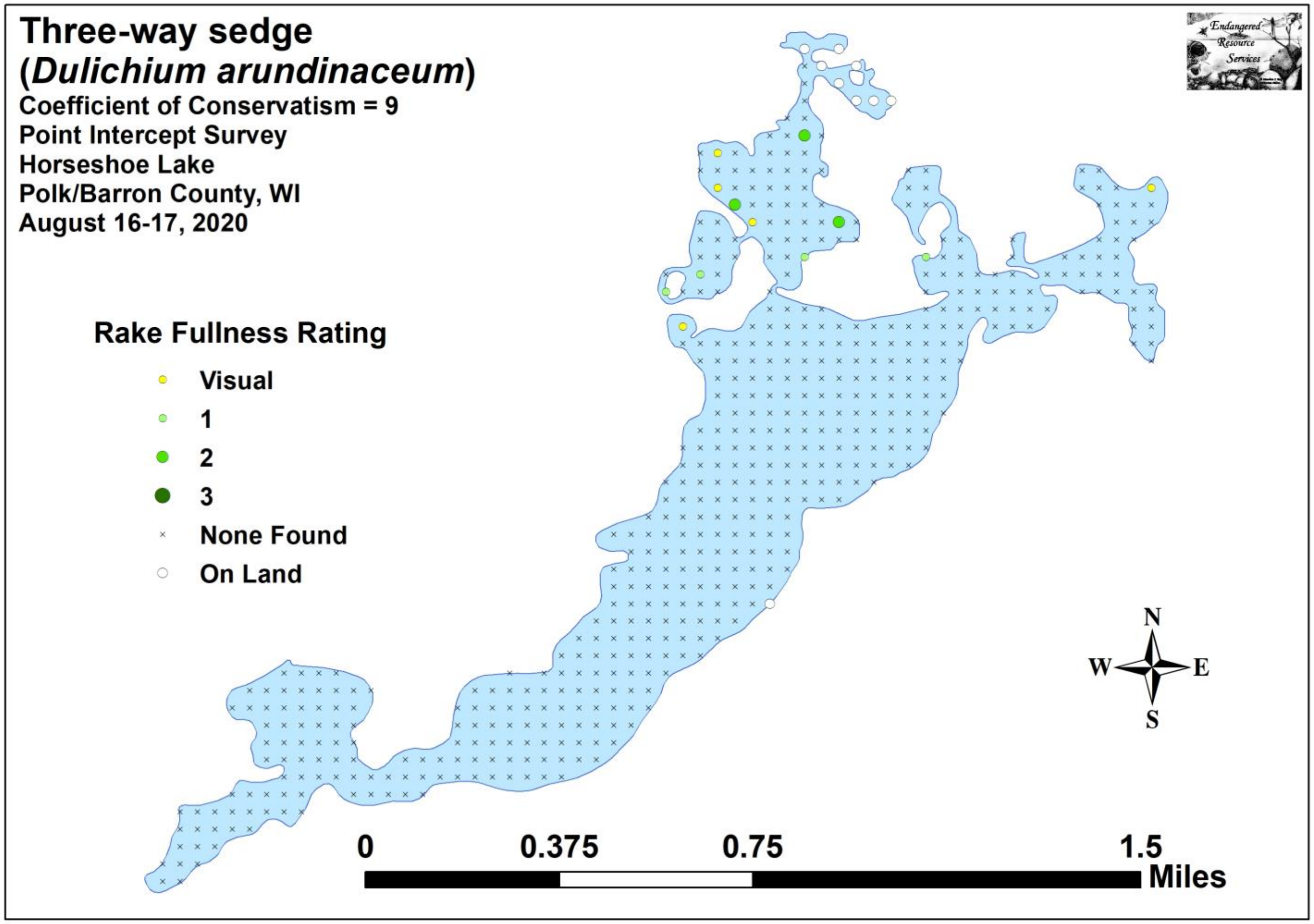

Narrow-leaved woolly sedge
(Carex lasiocarpa)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles


Common yellow lake sedge
(*Carex utriculata*)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

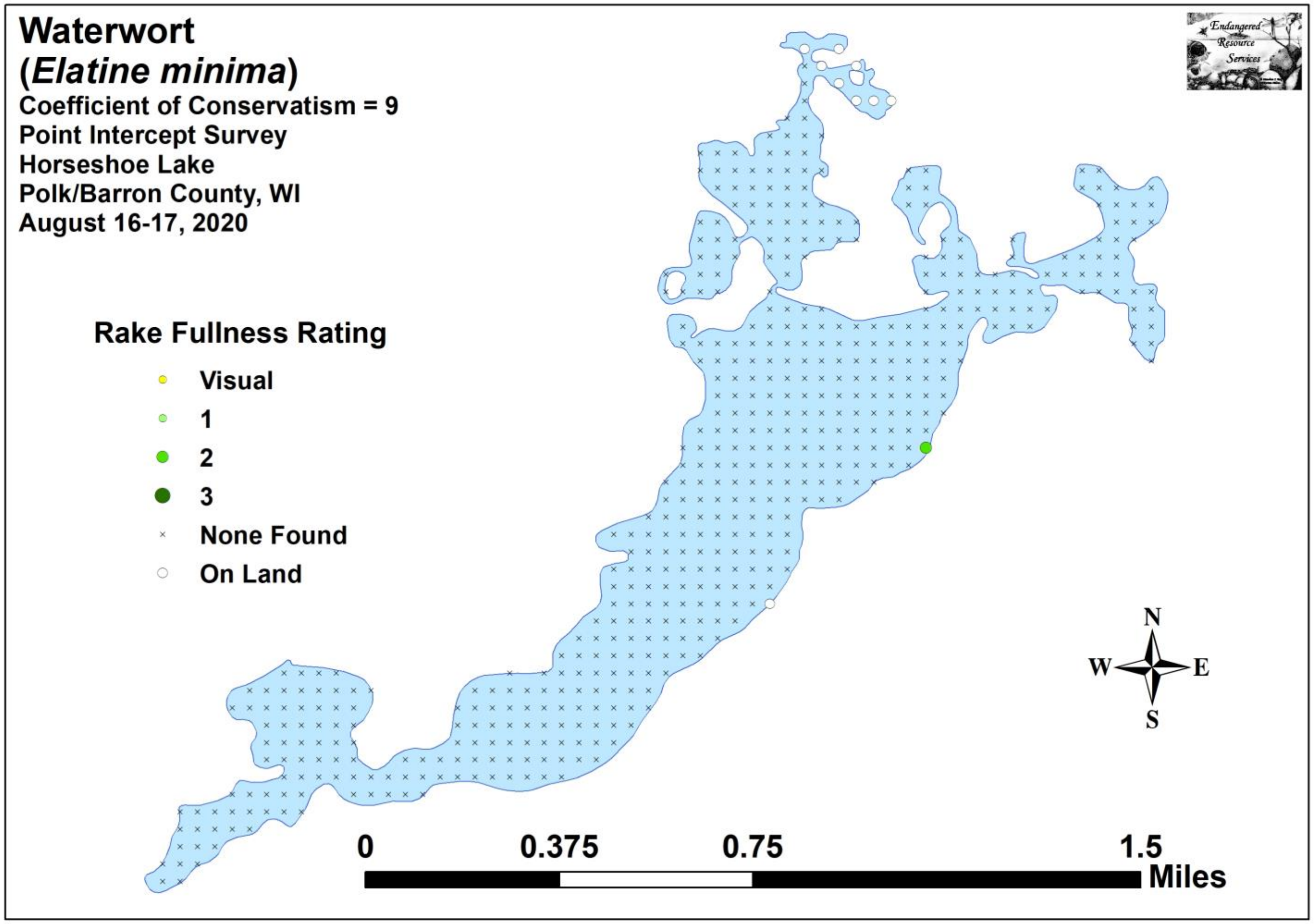

Coontail
(Ceratophyllum demersum)
Coefficient of Conservatism = 3
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

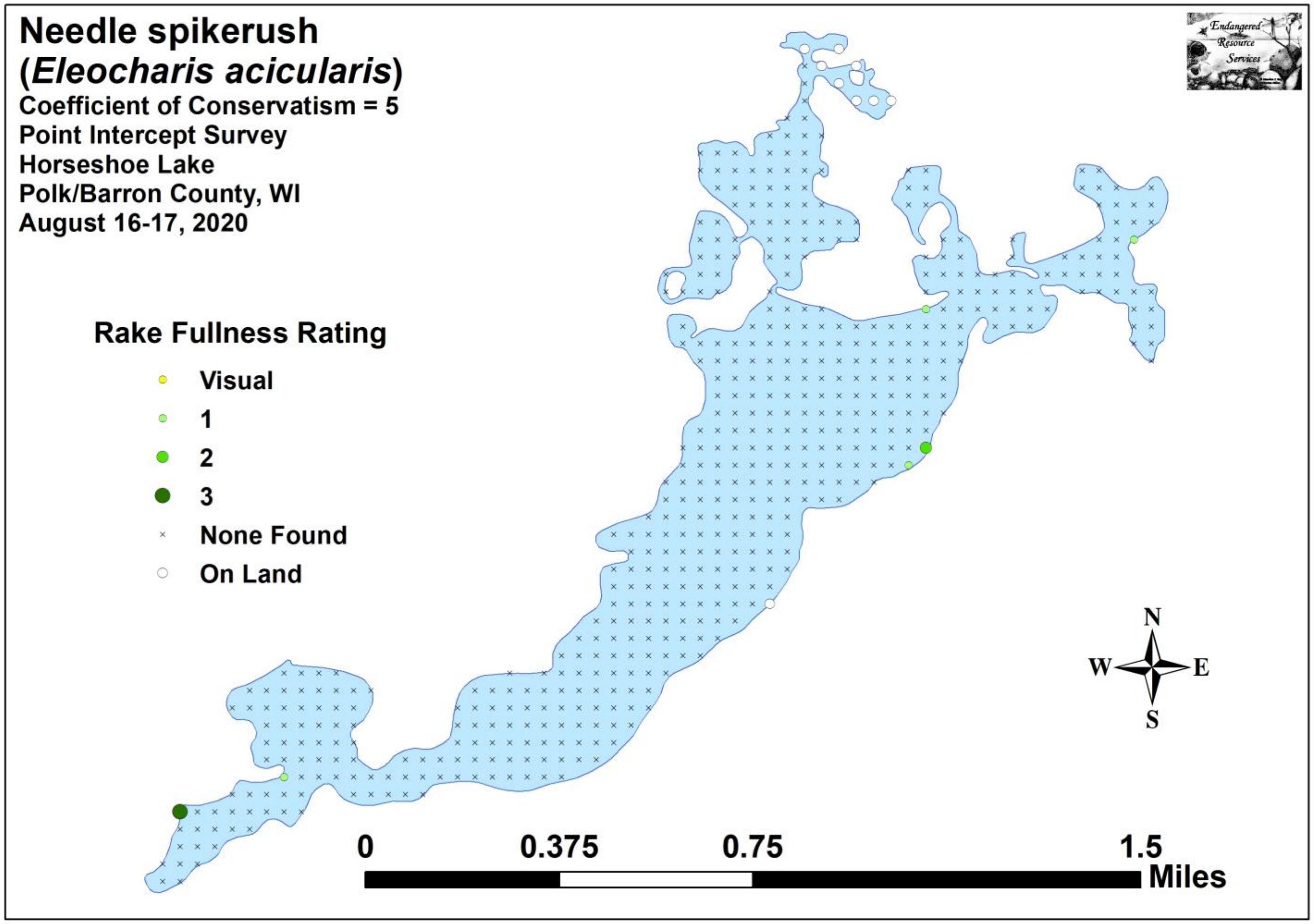

Spiny hornwort
(Ceratophyllum echinatum)
Coefficient of Conservatism = 10
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

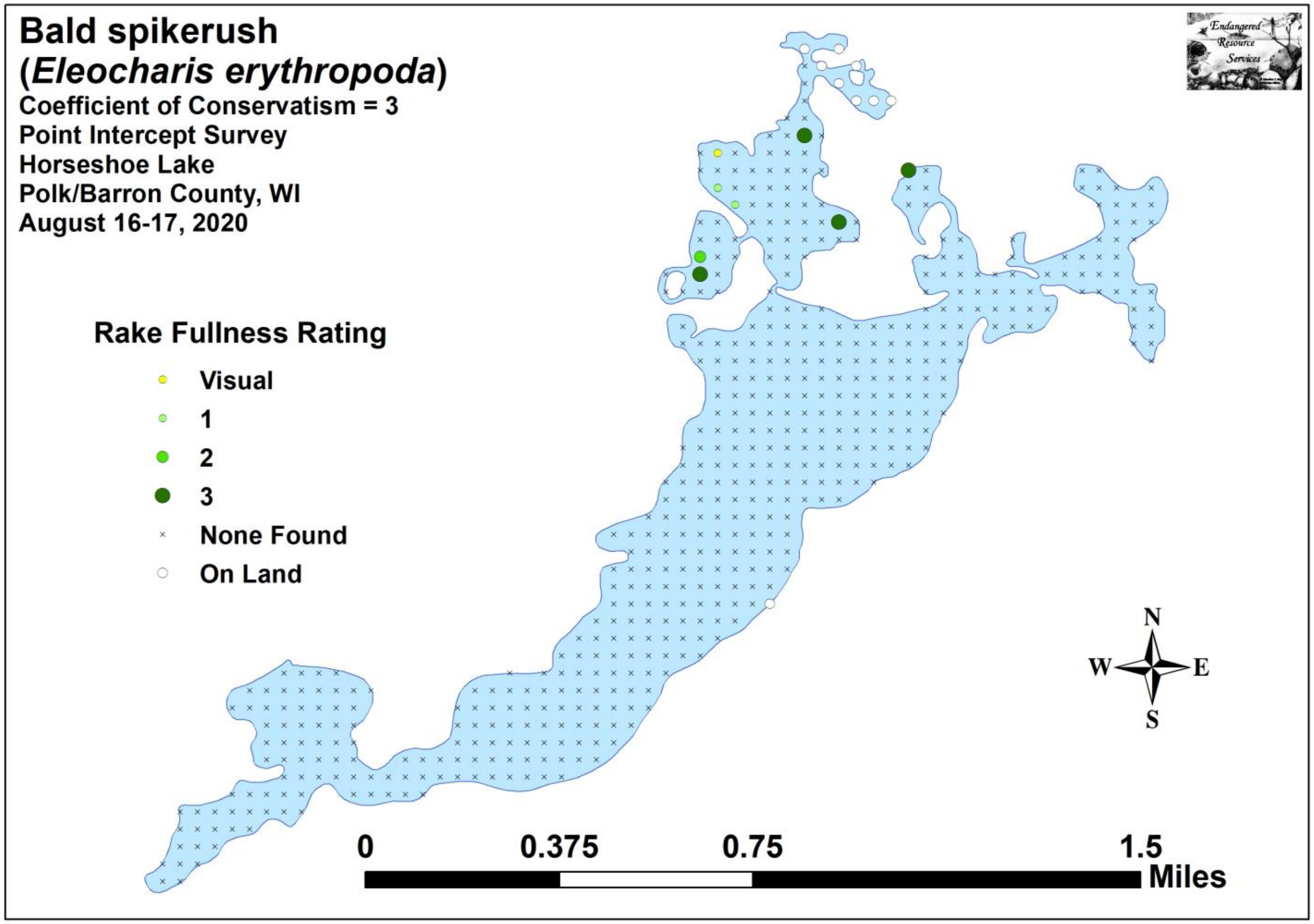

Muskgrass
(Chara sp.)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles



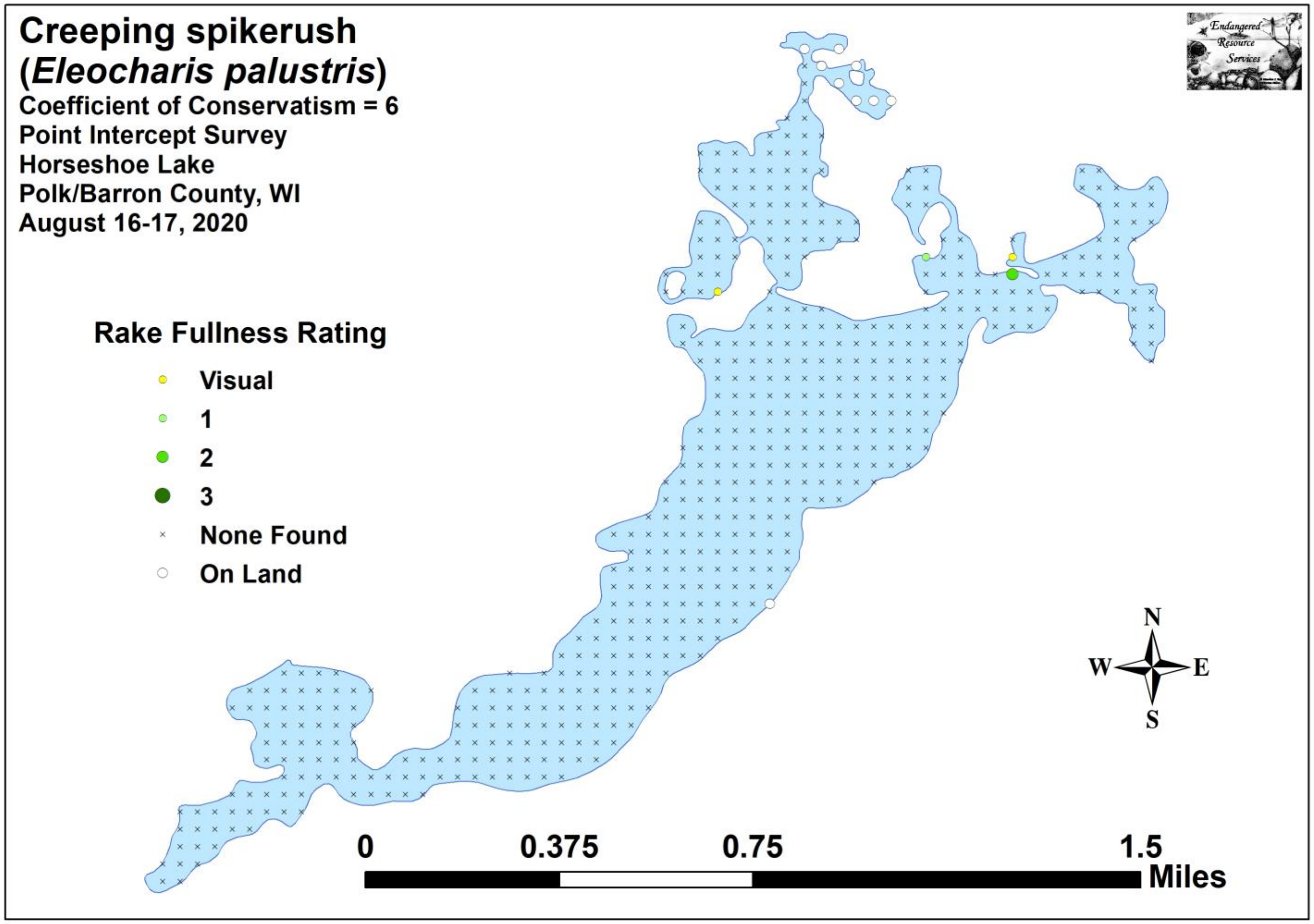
Three-way sedge
(*Dulichium arundinaceum*)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles


Waterwort
(Elatine minima)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles
Endangered Resource Services


Needle spikerush
(*Eleocharis acicularis*)
Coefficient of Conservatism = 5
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles
Endangered Resource Services



Bald spikerush
(*Eleocharis erythropoda*)
Coefficient of Conservatism = 3
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles



Creeping spikerush
(*Eleocharis palustris*)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
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None Found
On Land
N
W
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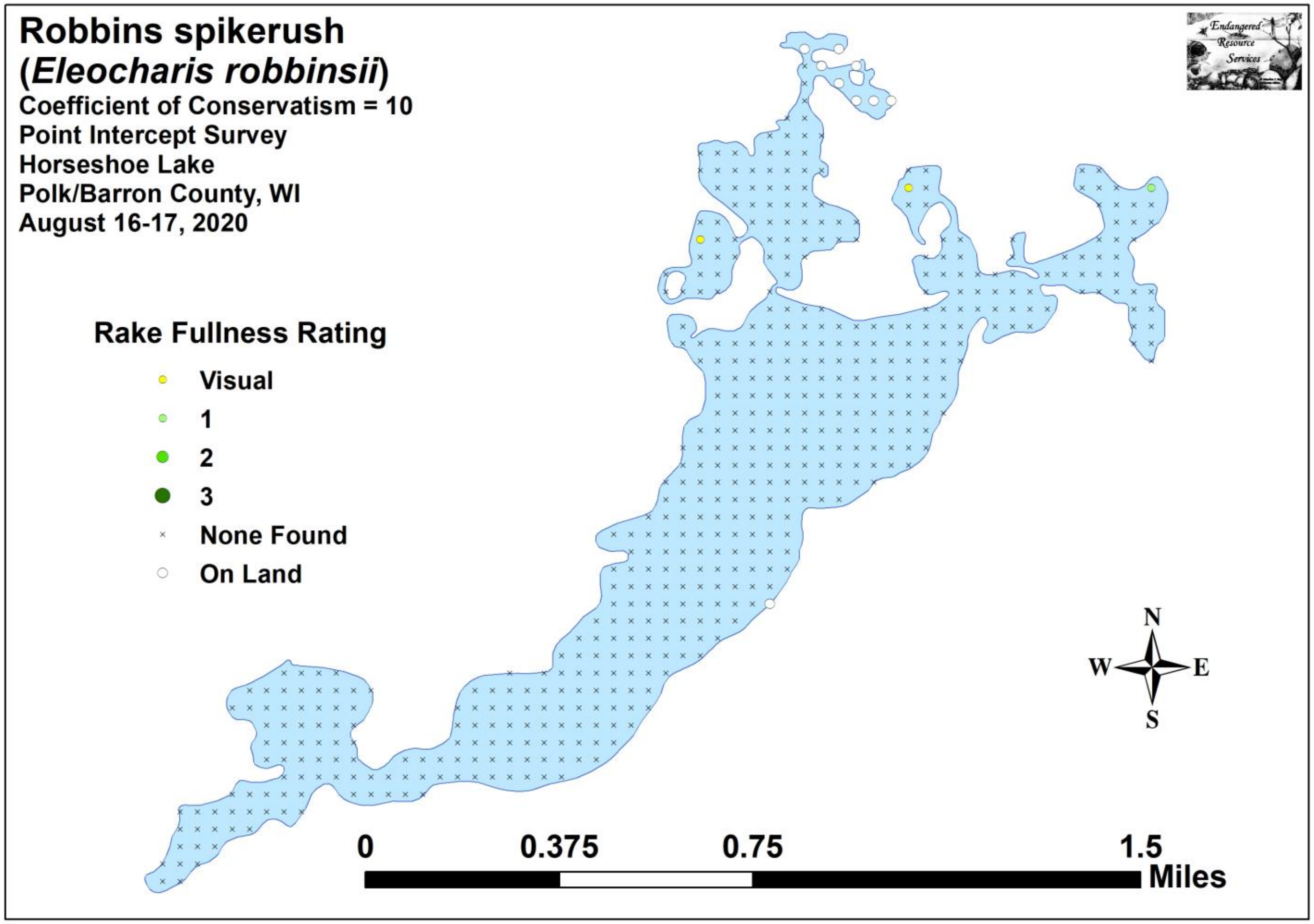
0
0.375
0.75
1.5
Miles


Robbins spikerush
(Eleocharis robbinsii)
Coefficient of Conservatism = 10
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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0.375
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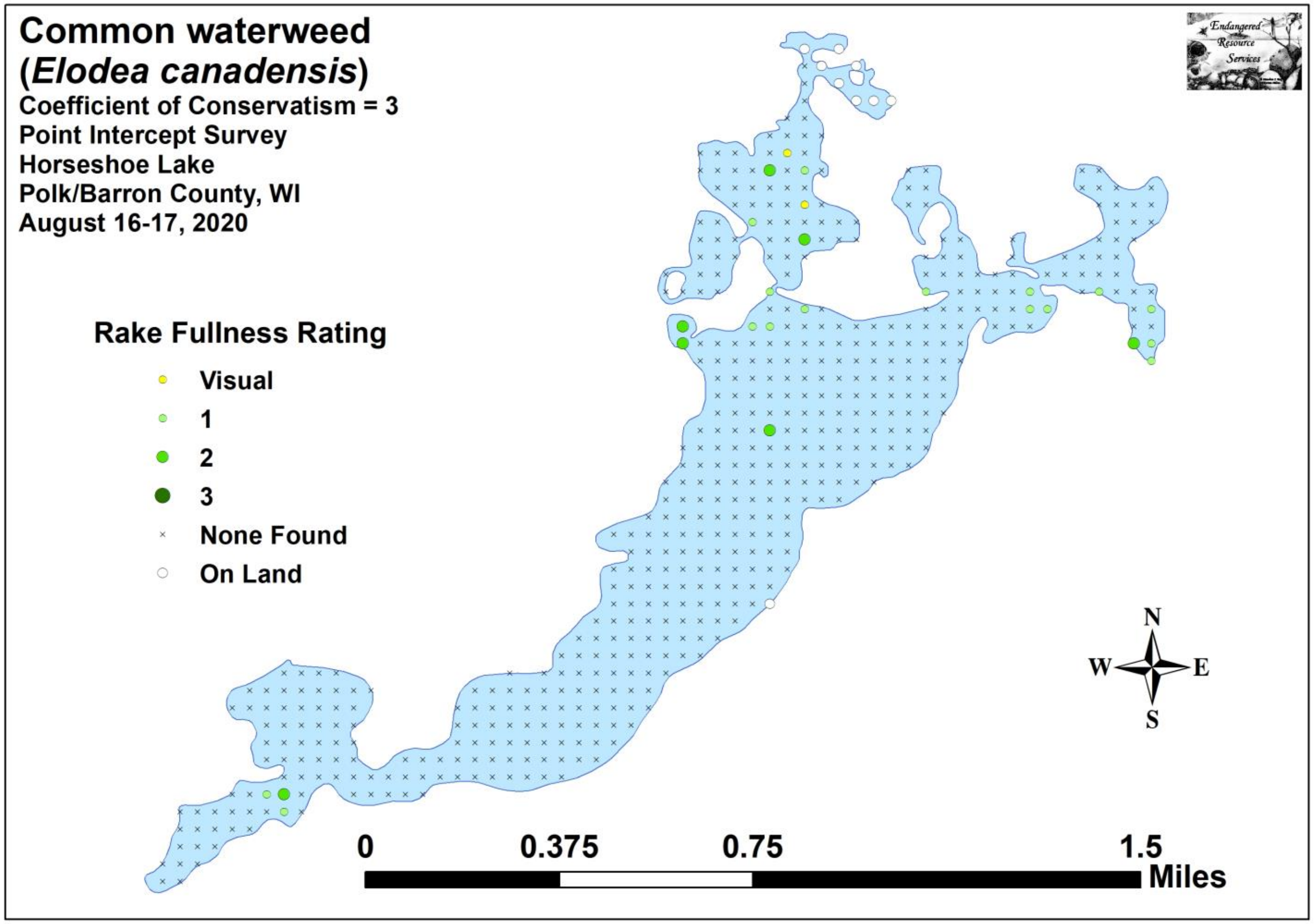
1.5
Miles


Common waterweed
(Elodea canadensis)
Coefficient of Conservatism = 3
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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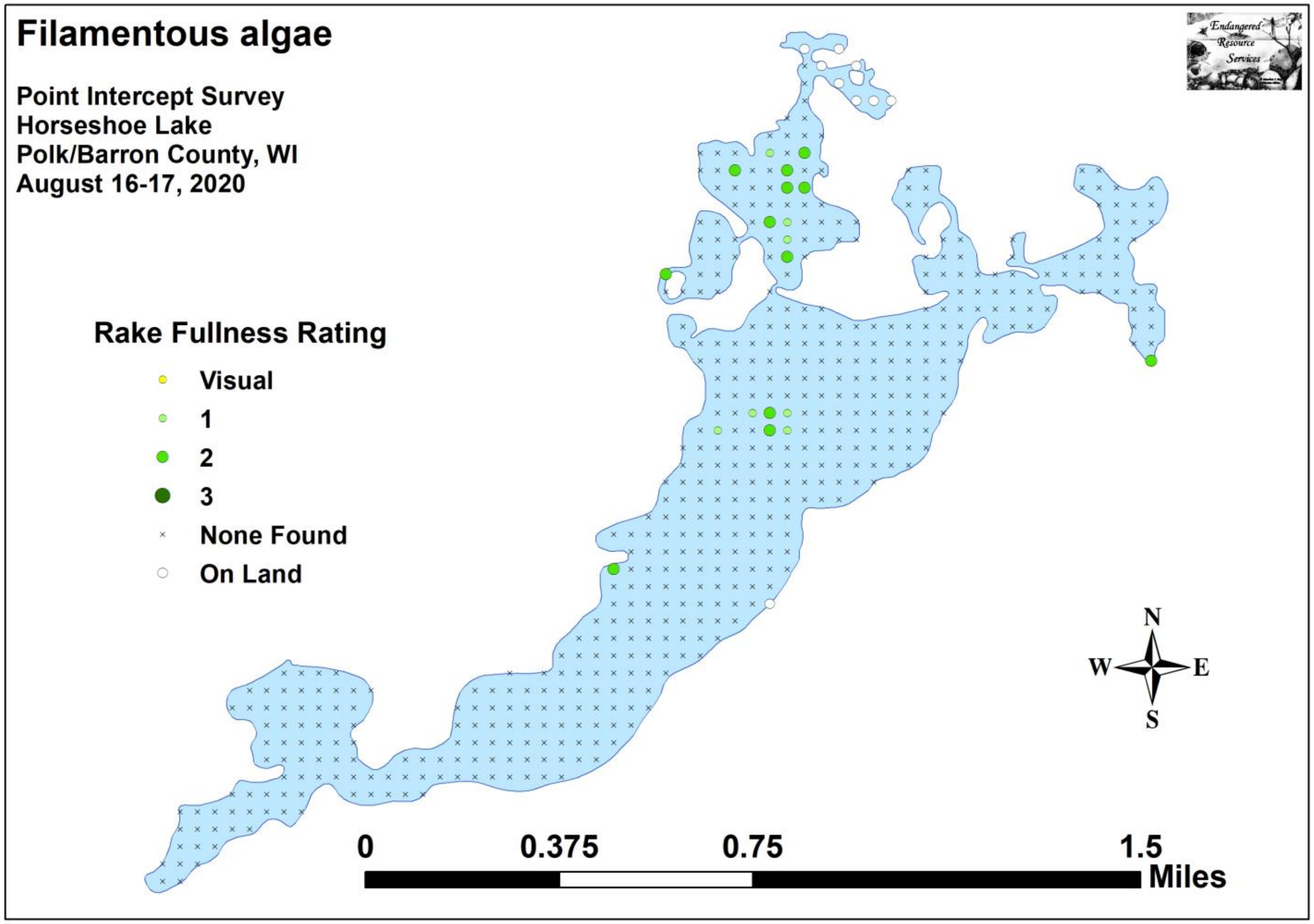
1.5
Miles



Filamentous algae
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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0.375
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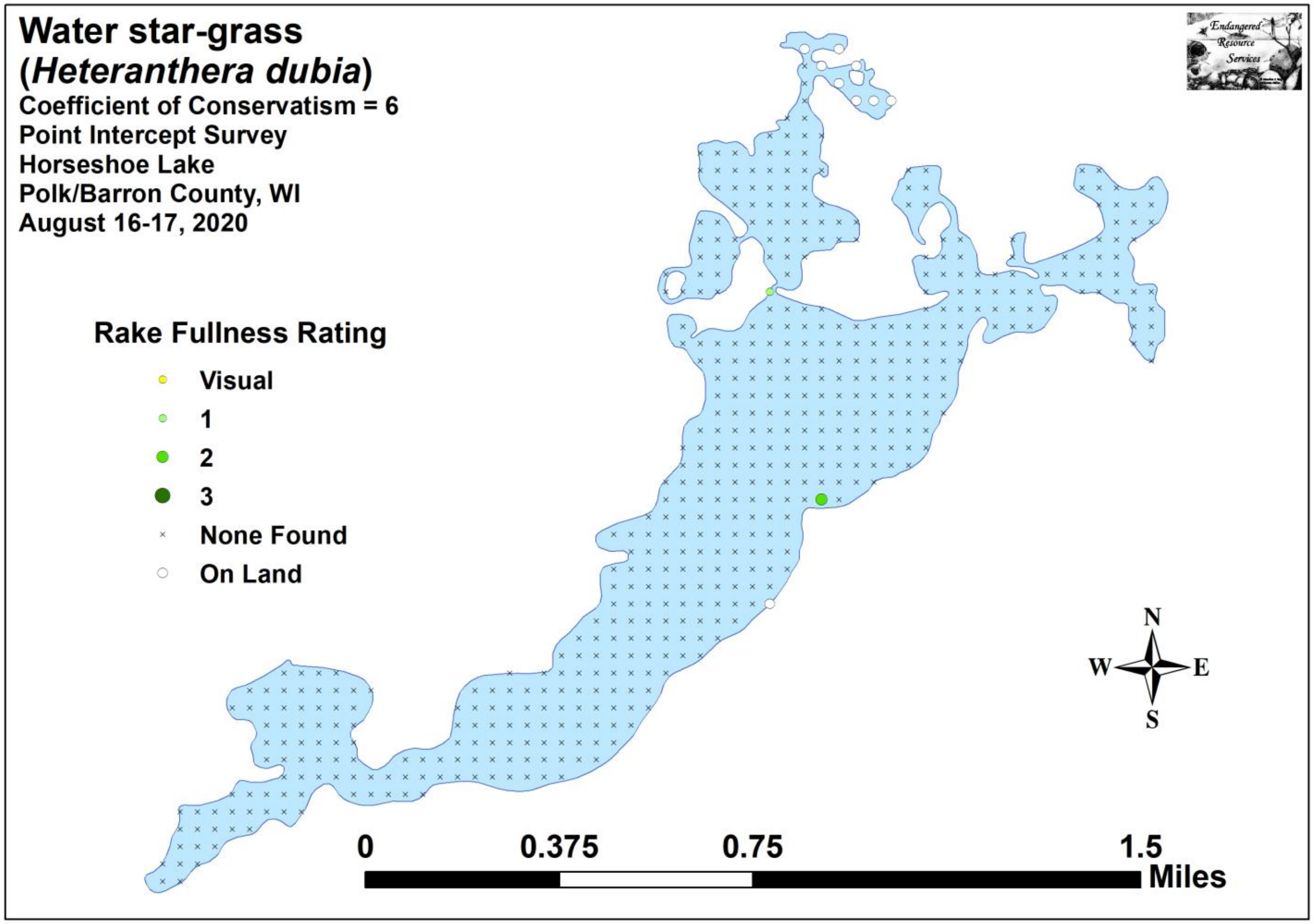
1.5
Miles
Endangered Resource Services


Water star-grass
(Heteranthera dubia)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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0.375
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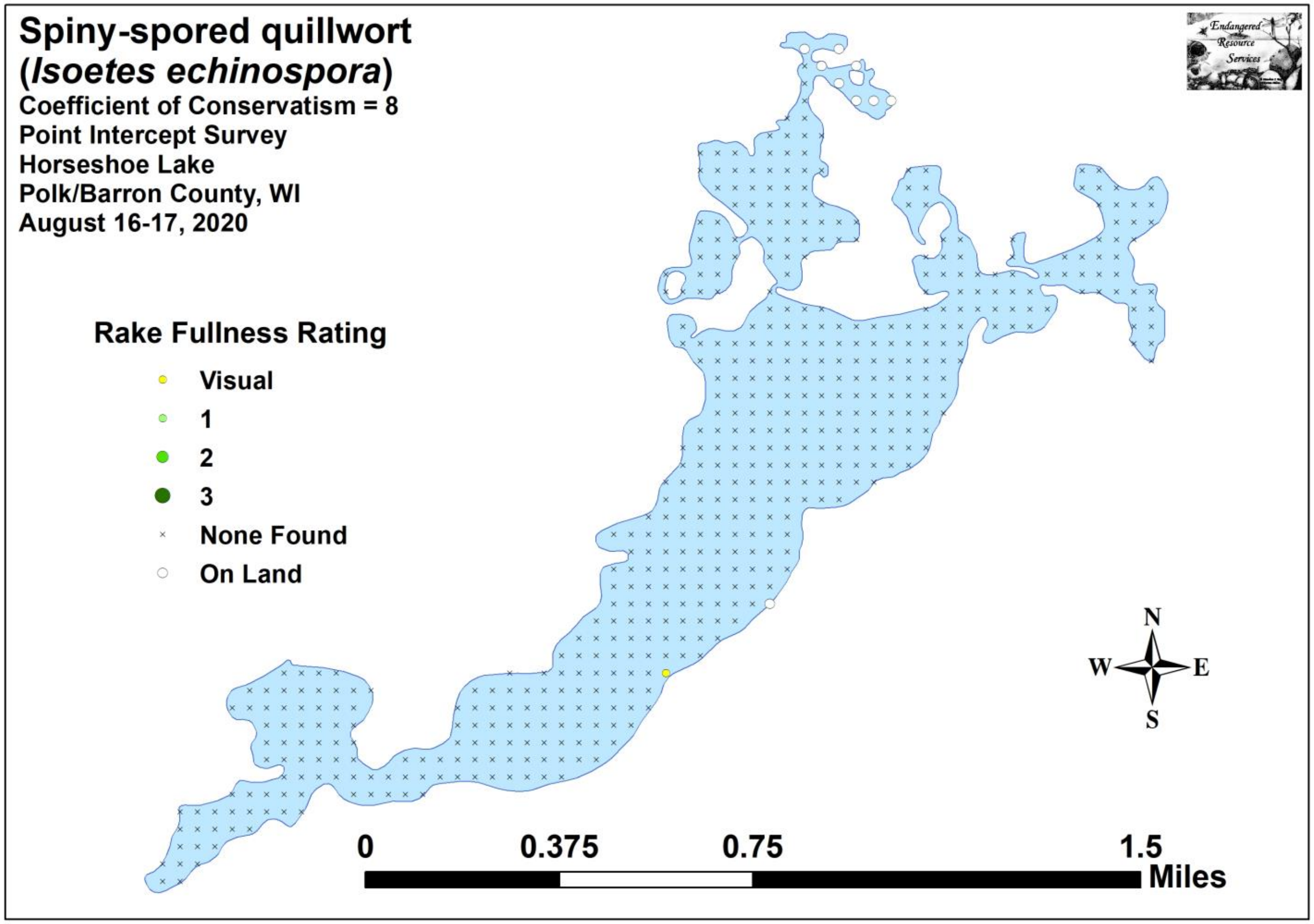
1.5
Miles
Endangered Resource Services


Spiny-spored quillwort
(*Isoetes echinospora*)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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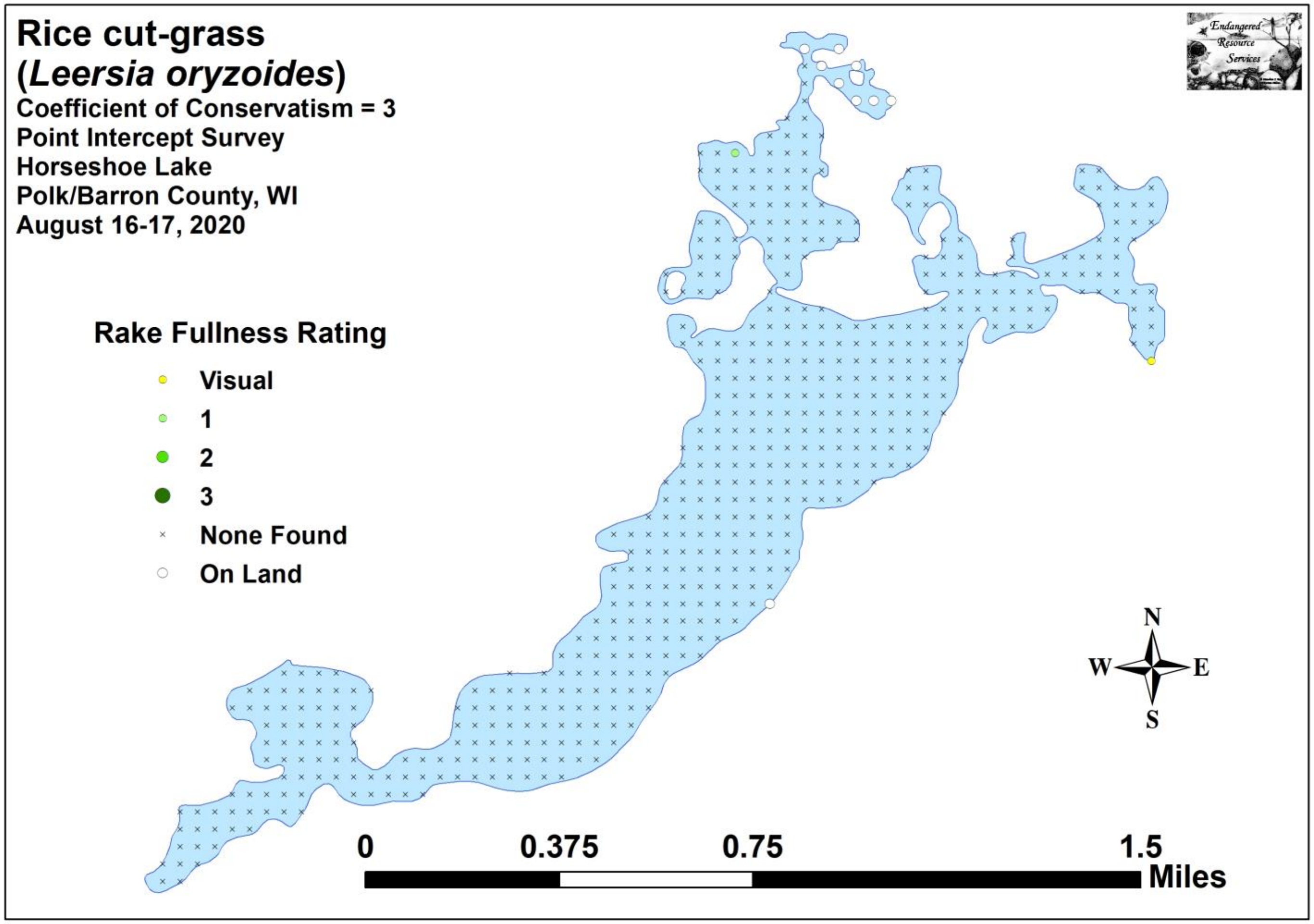
1.5
Miles


Rice cut-grass
(*Leersia oryzoides*)
Coefficient of Conservatism = 3
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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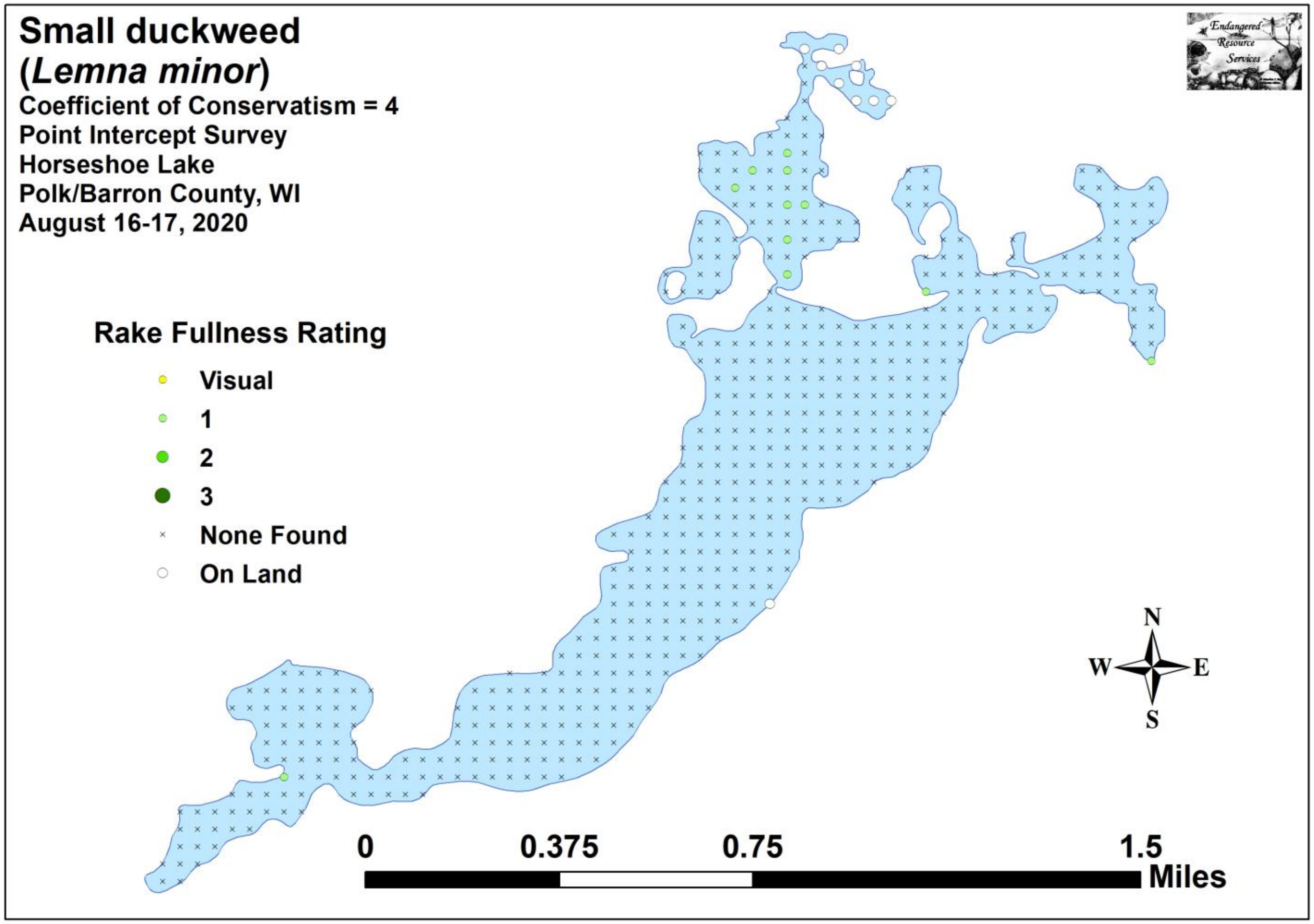
1.5
Miles


Small duckweed
(*Lemna minor*)
Coefficient of Conservatism = 4
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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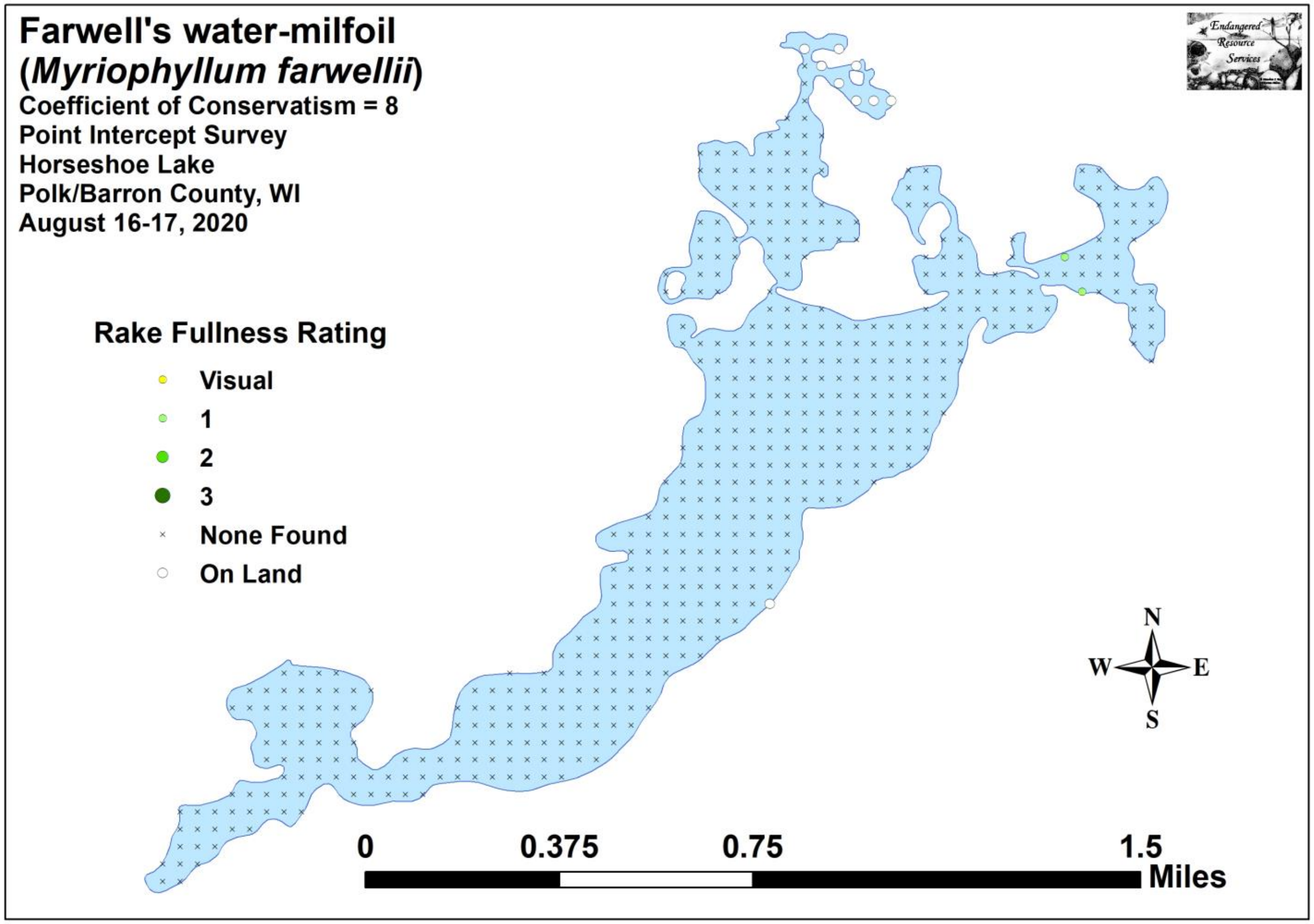
Miles



Farwell's water-milfoil
(*Myriophyllum farwellii*)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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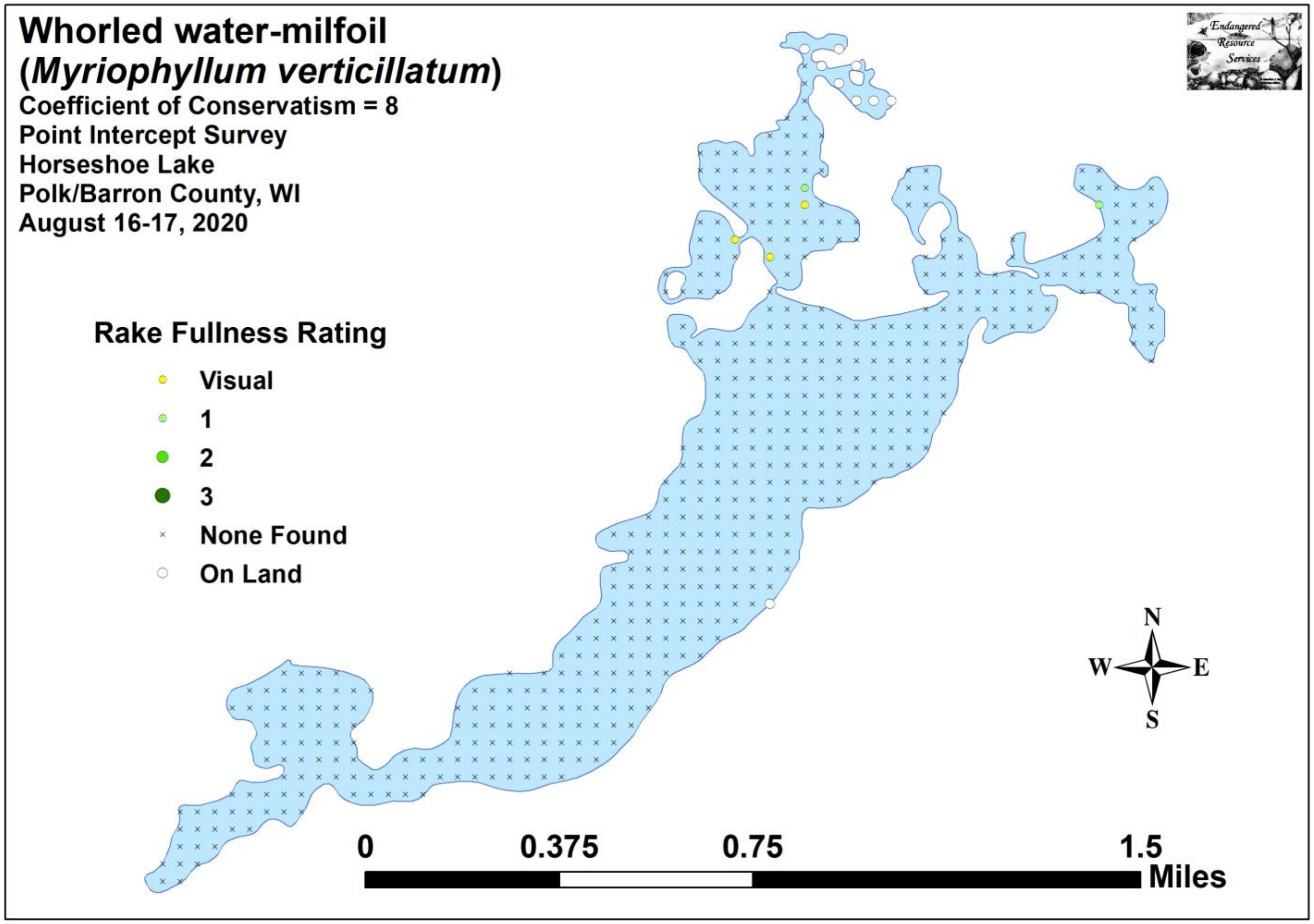
Miles


Whorled water-milfoil
(Myriophyllum verticillatum)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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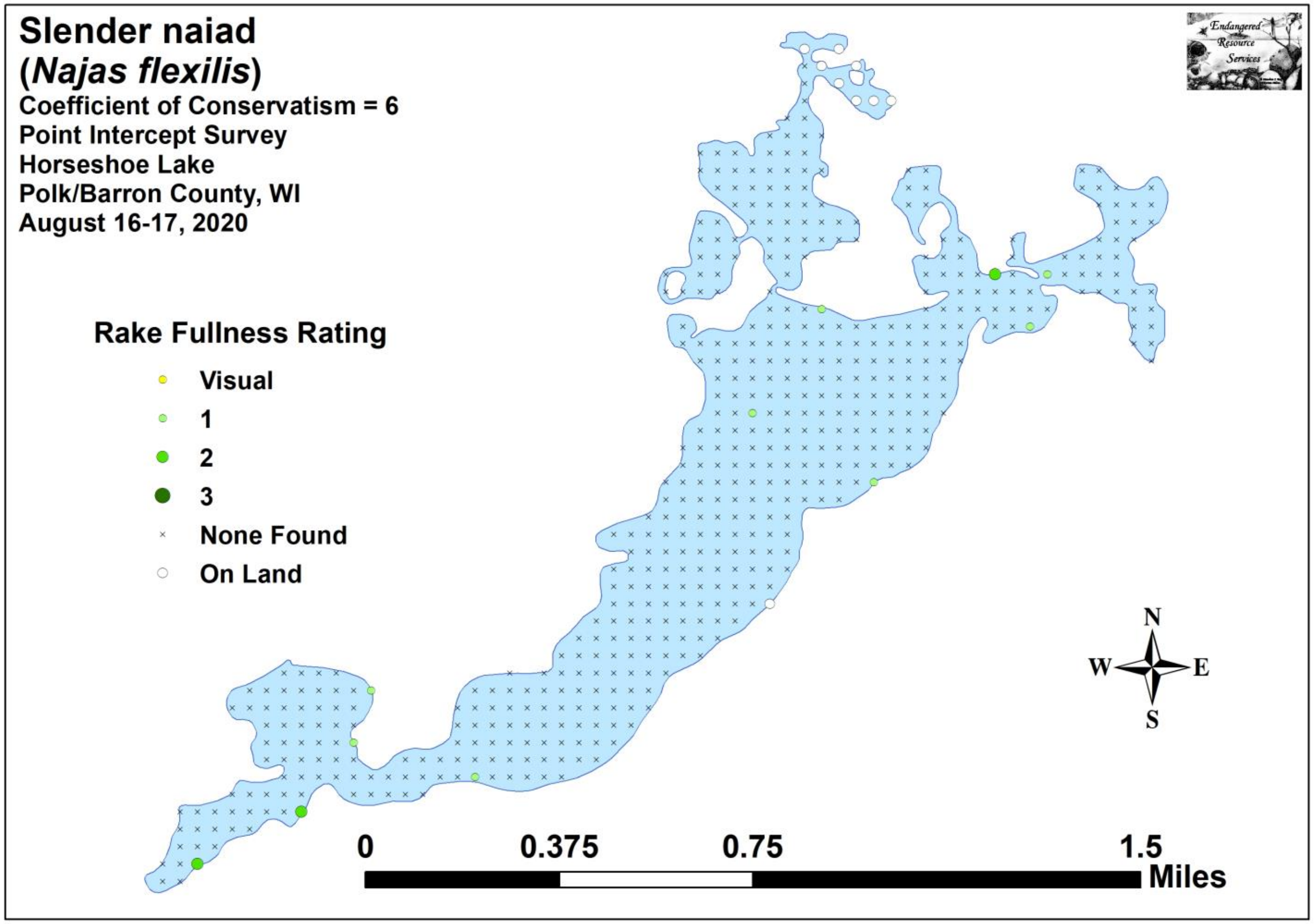
1.5
Miles
Endangered
Resource
Services


Slender naiad
(Najas flexilis)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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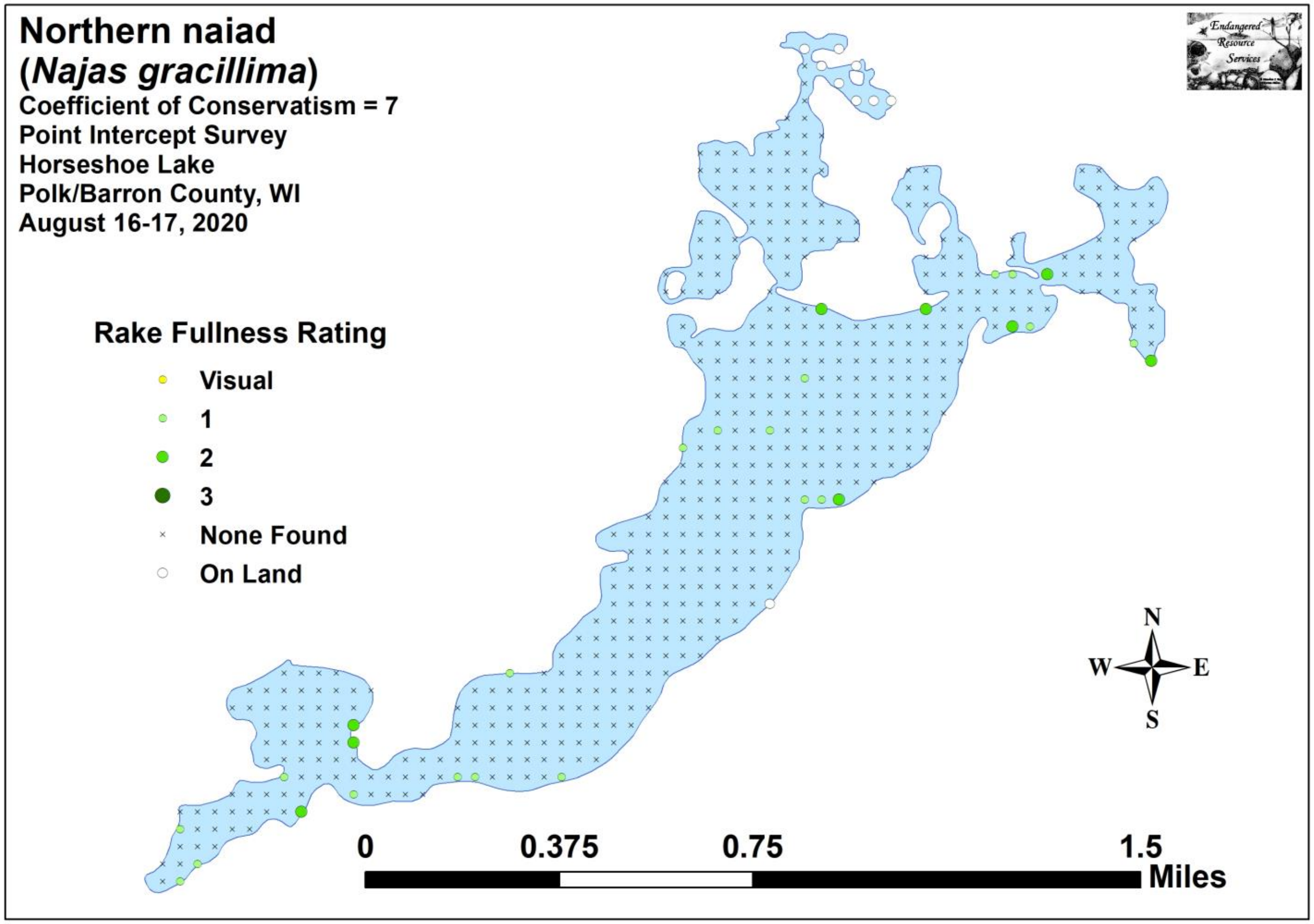
Miles


Northern naiad
(*Najas gracillima*)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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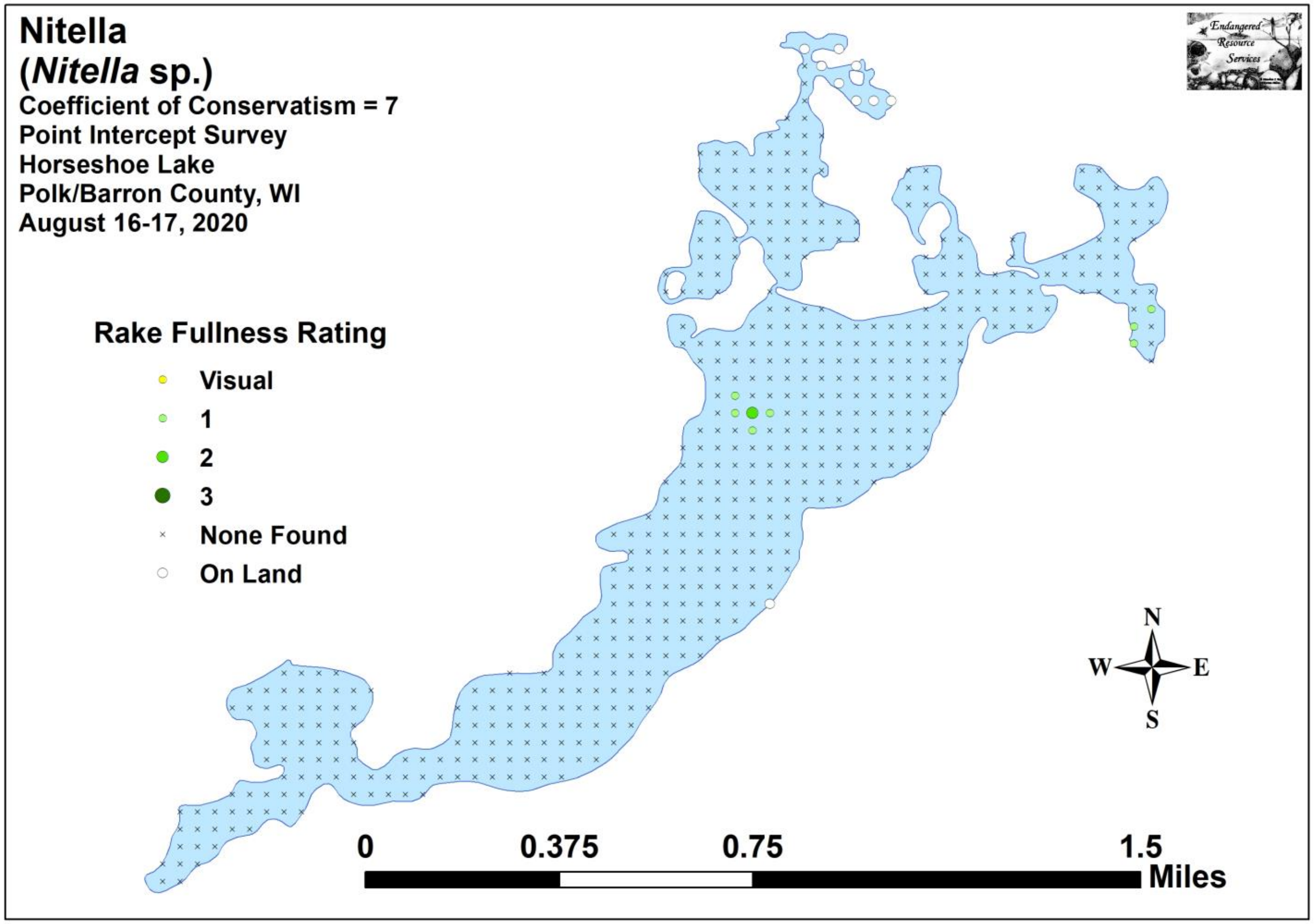
Miles



Nitella
(*Nitella* sp.)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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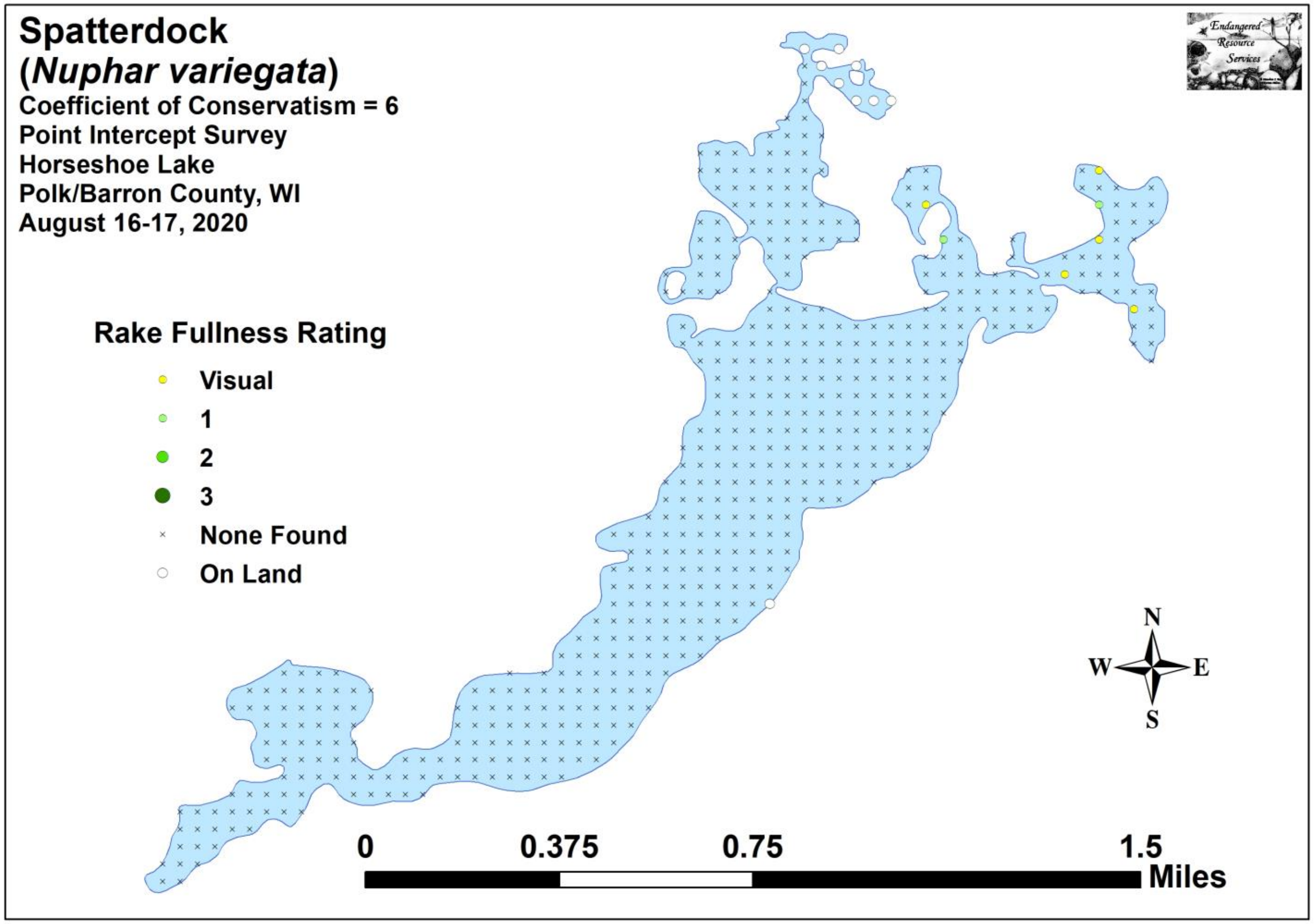
Miles


Spatterdock
(Nuphar variegata)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Endangered Resource Services
Rake Fullness Rating
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None Found
On Land
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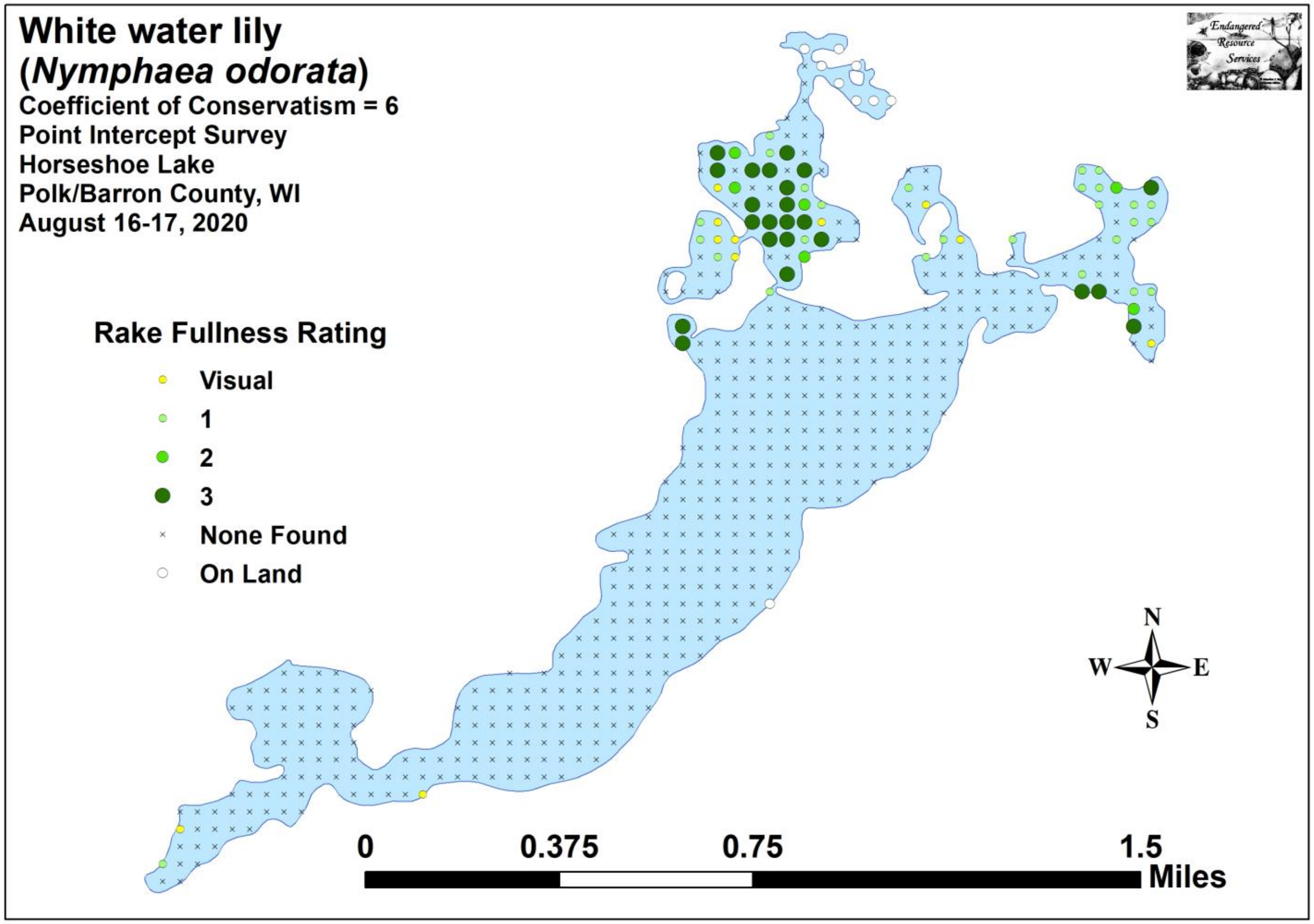
Miles



White water lily
(*Nymphaea odorata*)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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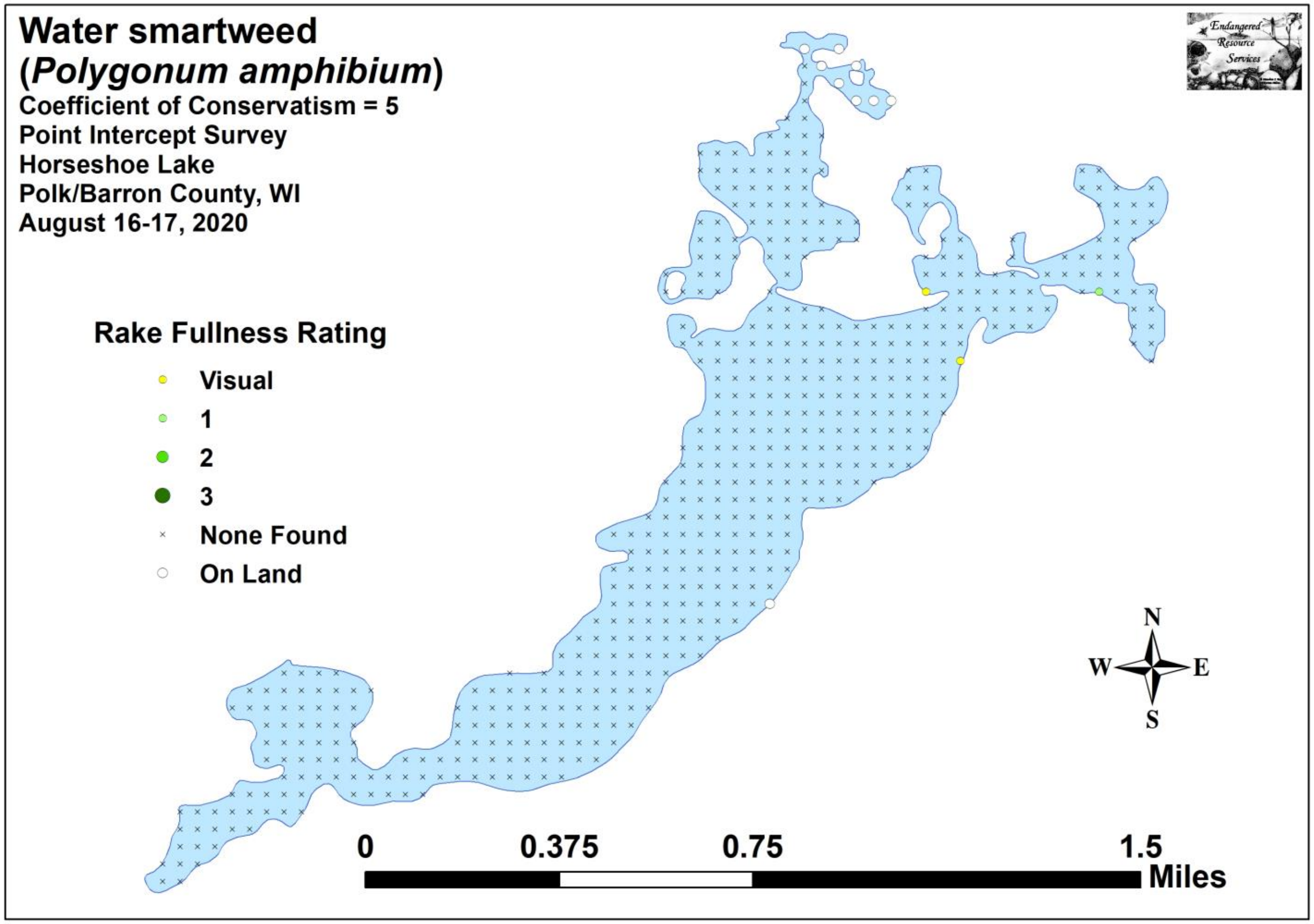
Miles


Water smartweed
(*Polygonum amphibium*)
Coefficient of Conservatism = 5
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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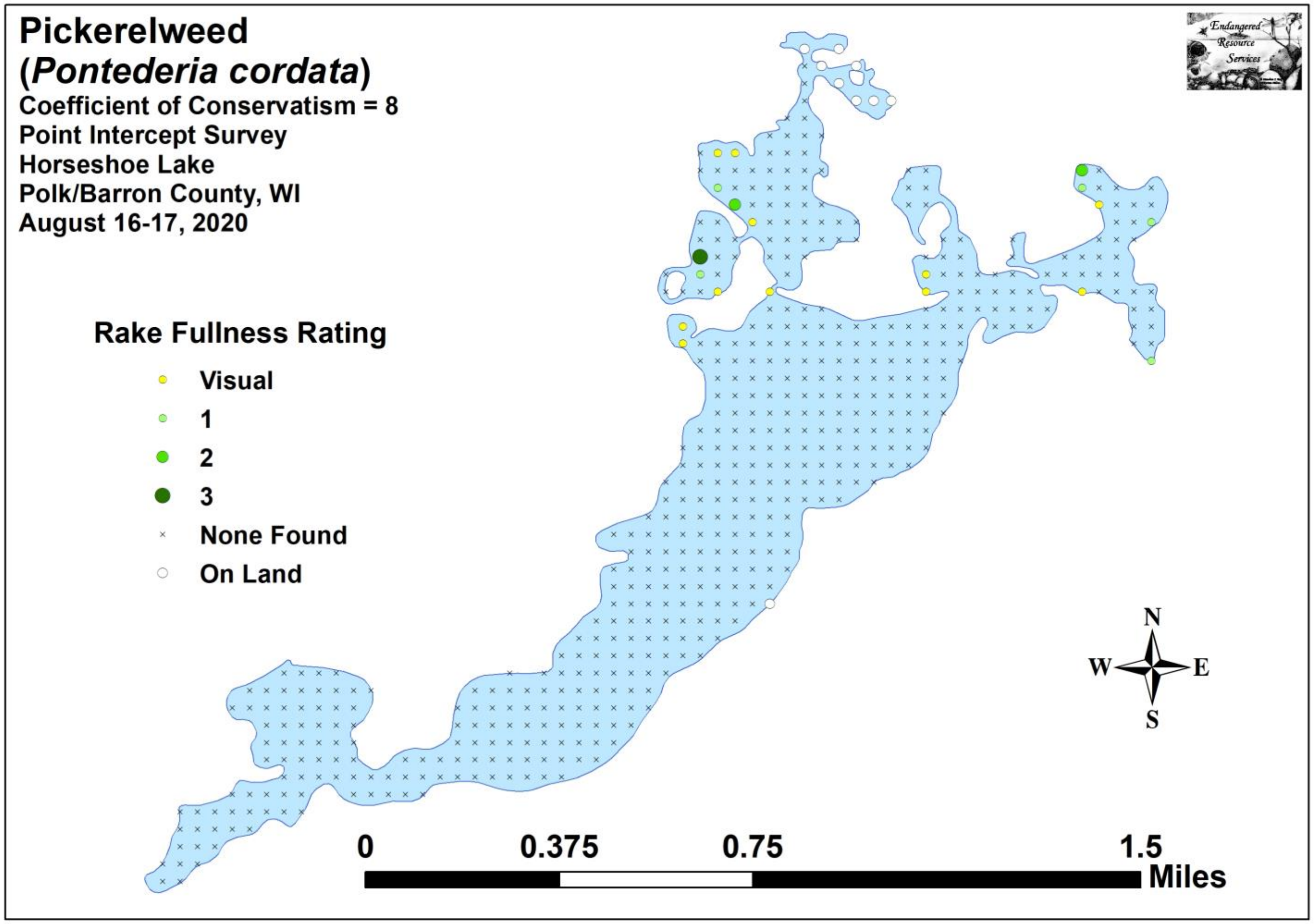
Miles
Endangered Resource Services


Pickerelweed
(*Pontederia cordata*)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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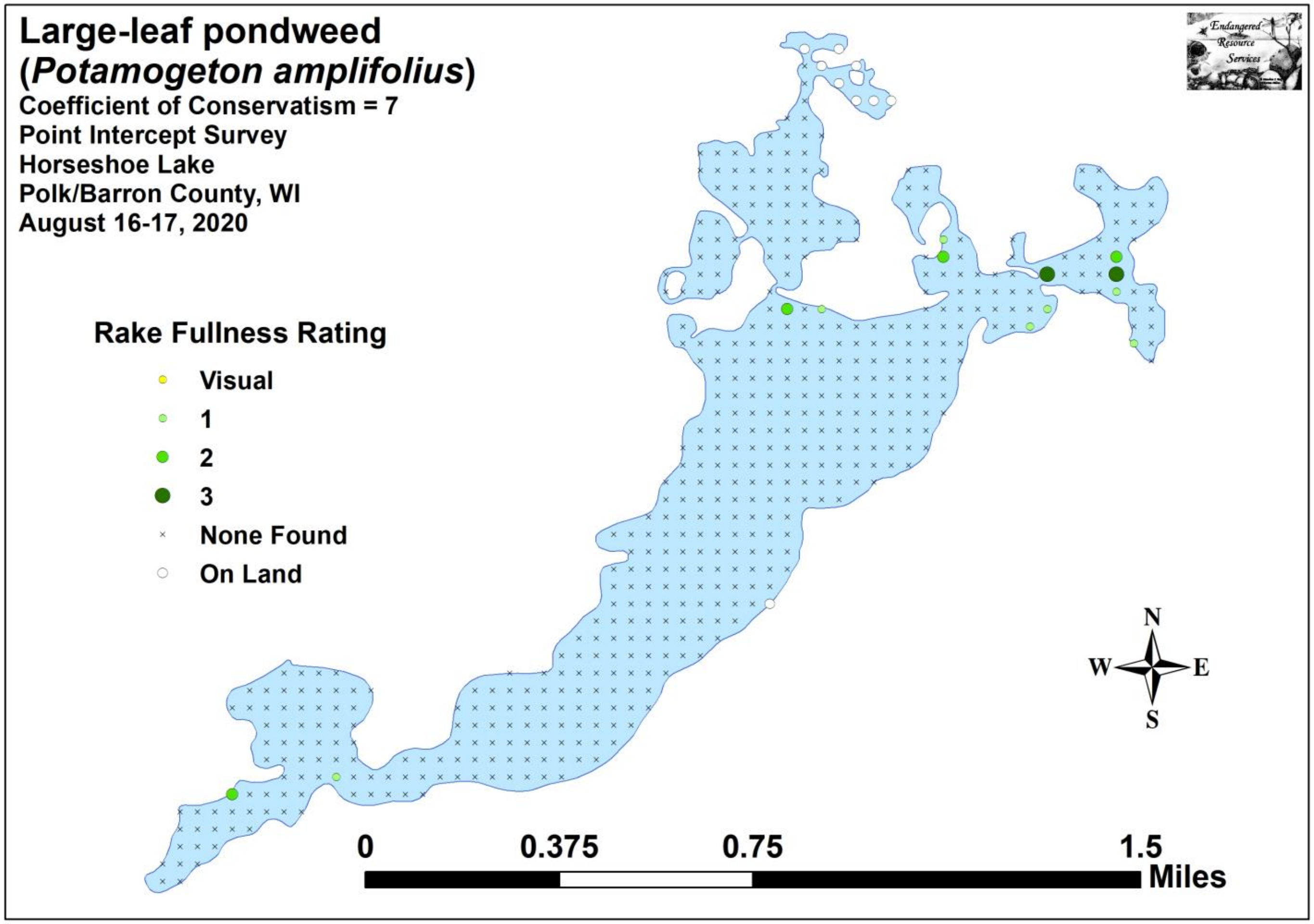
Miles


Large-leaf pondweed
(*Potamogeton amplifolius*)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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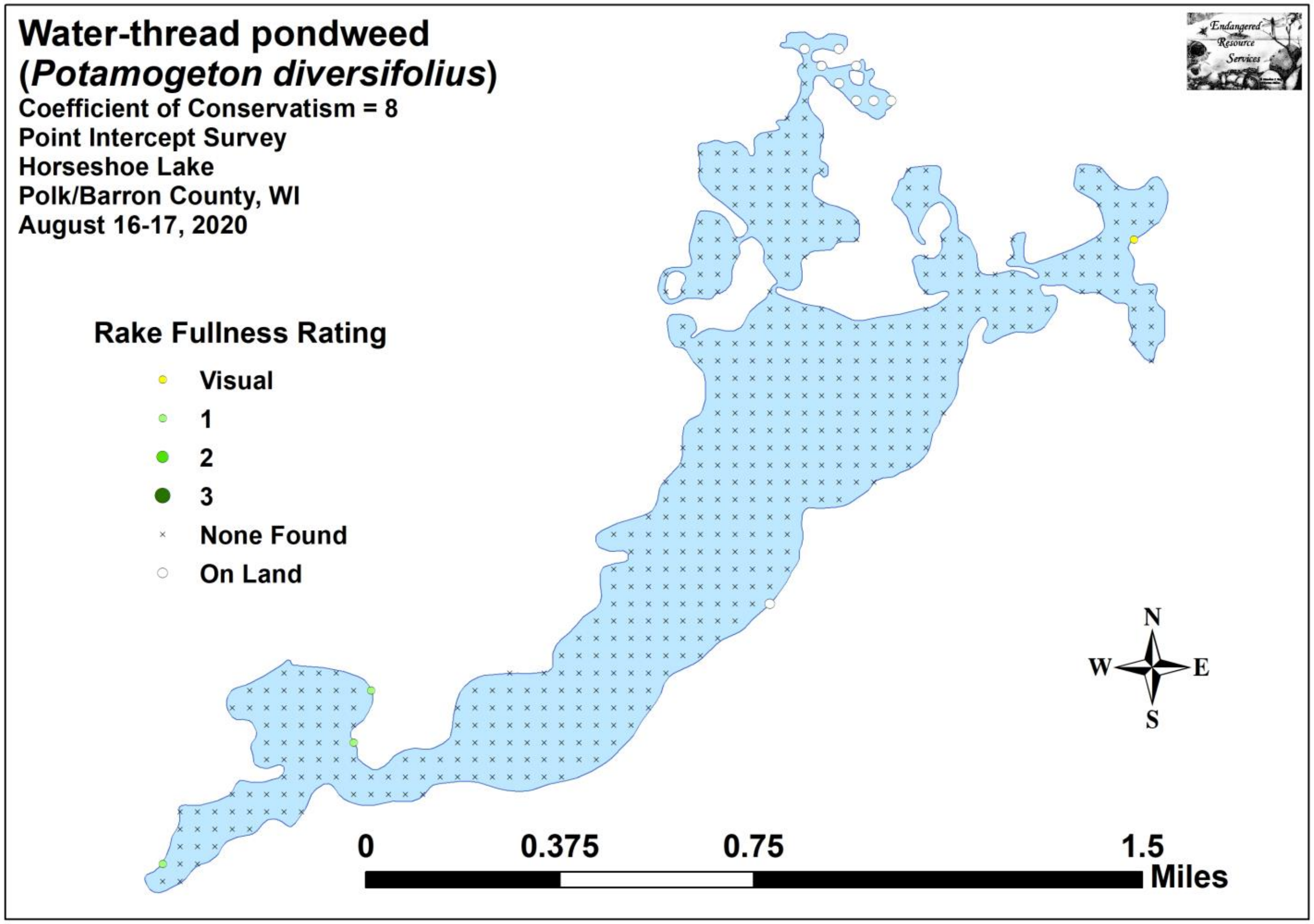
Miles



Water-thread pondweed
(Potamogeton diversifolius)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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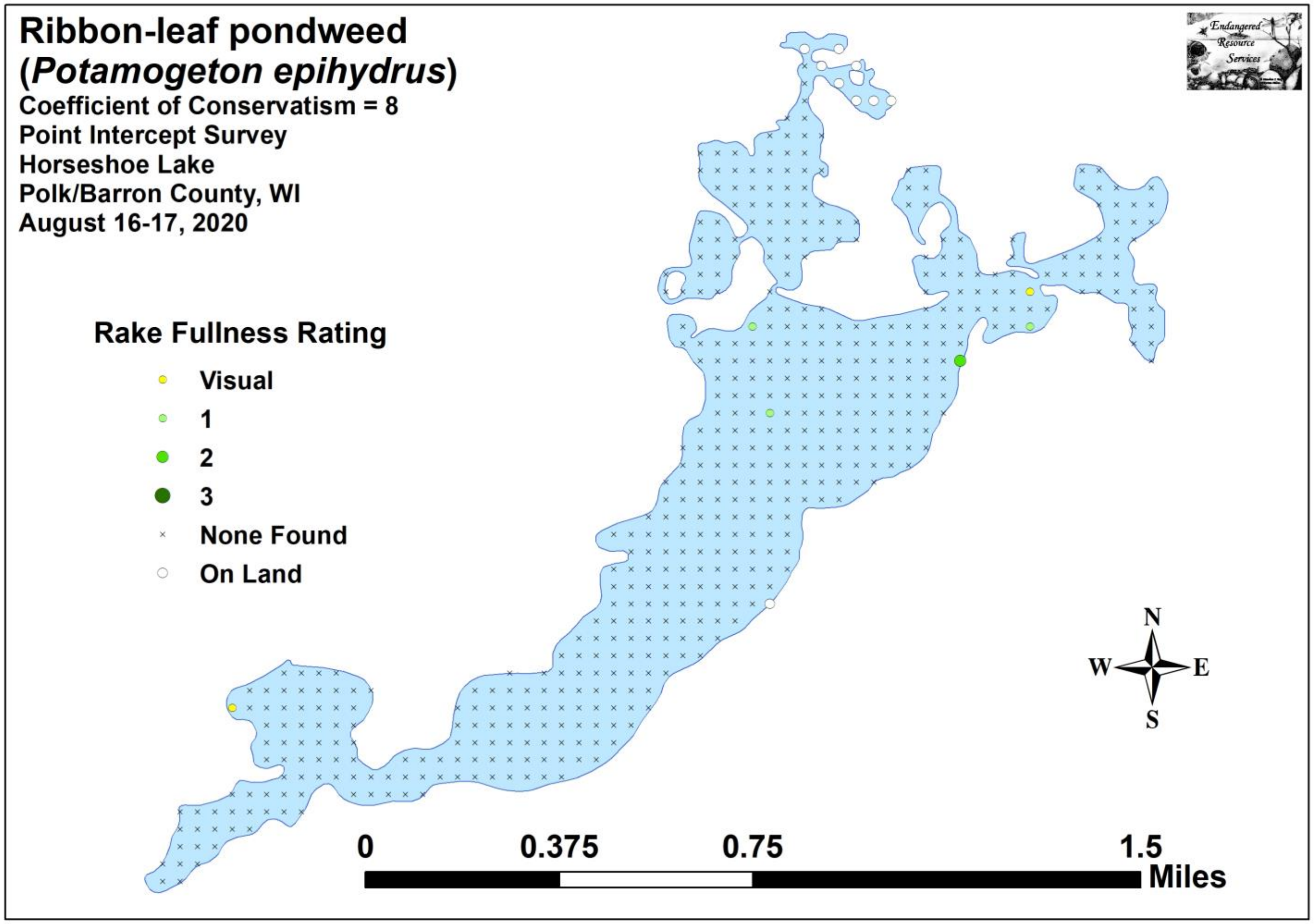
Miles



Ribbon-leaf pondweed
(*Potamogeton epihydrus*)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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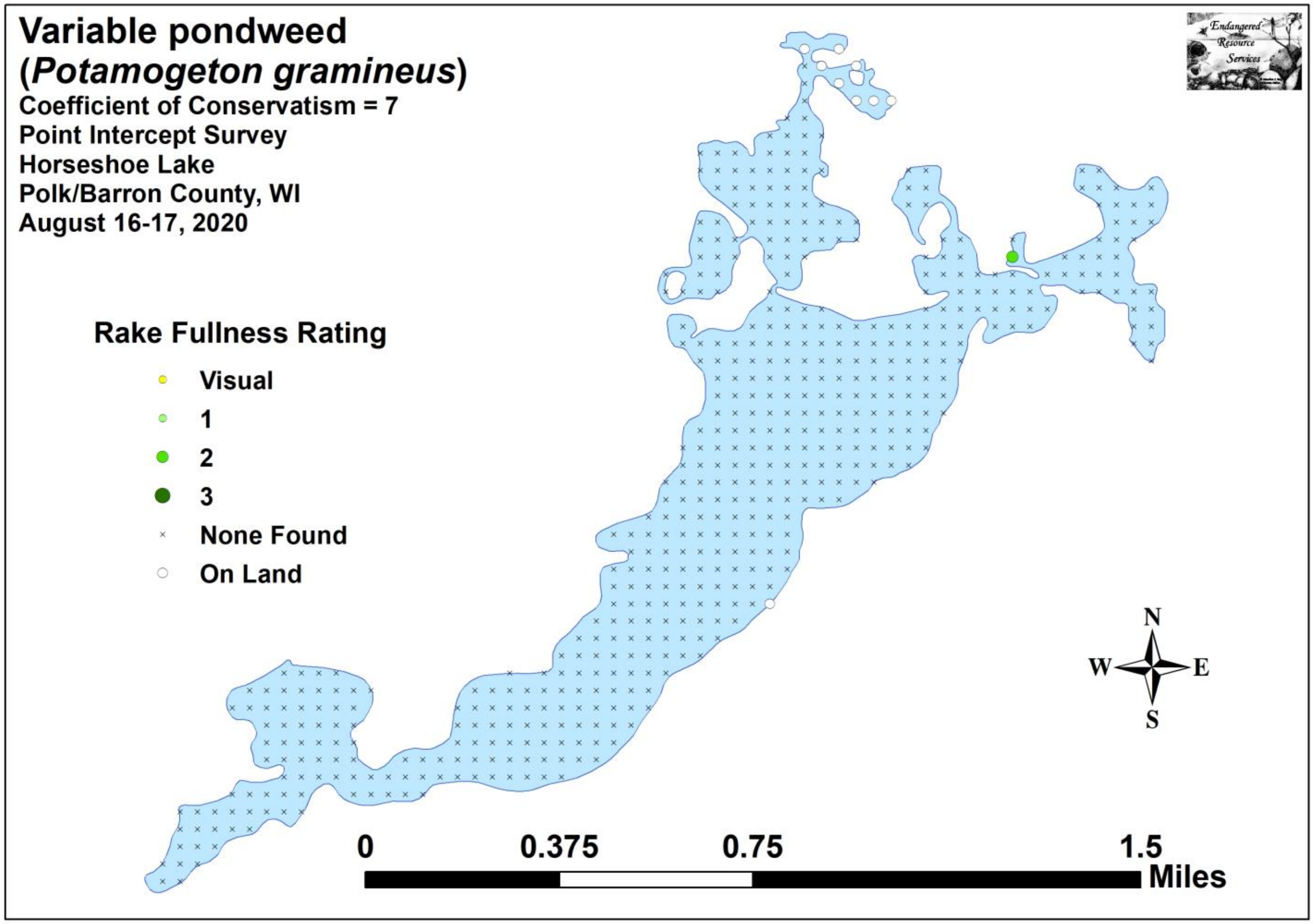
Miles


Variable pondweed
(*Potamogeton gramineus*)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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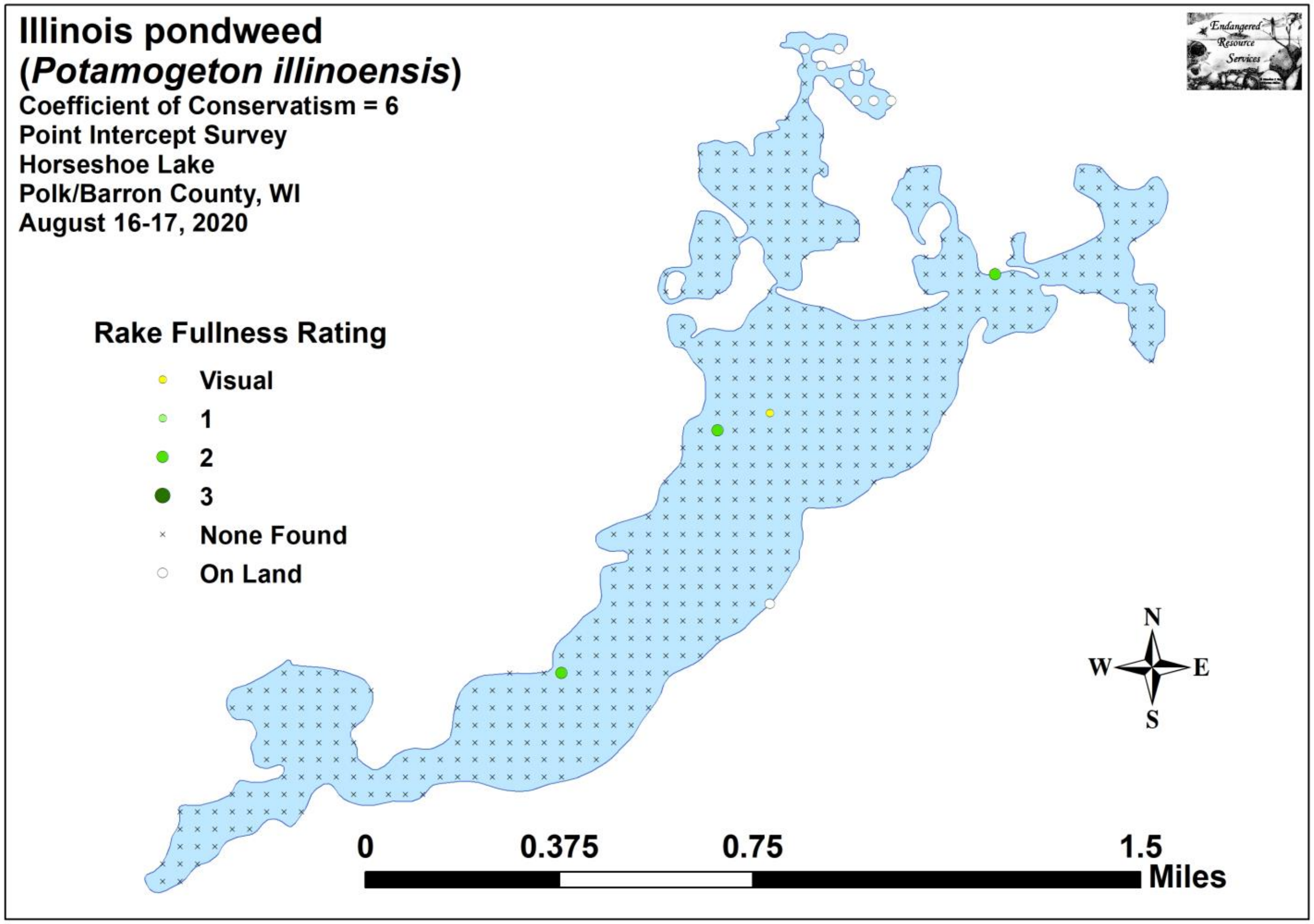
Miles


Illinois pondweed
(*Potamogeton illinoensis*)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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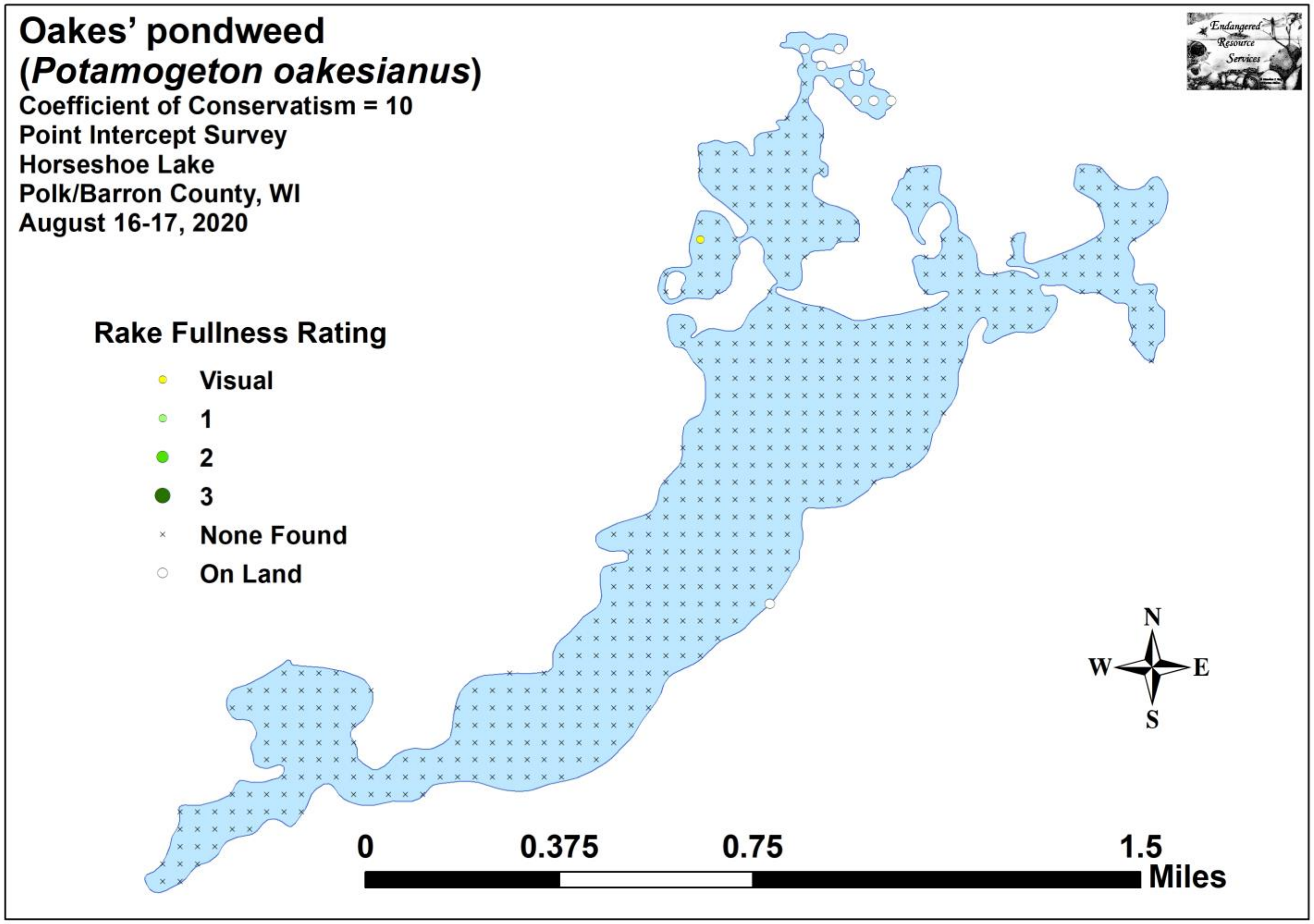
Miles


Oakes' pondweed
(*Potamogeton oakesianus*)
Coefficient of Conservatism = 10
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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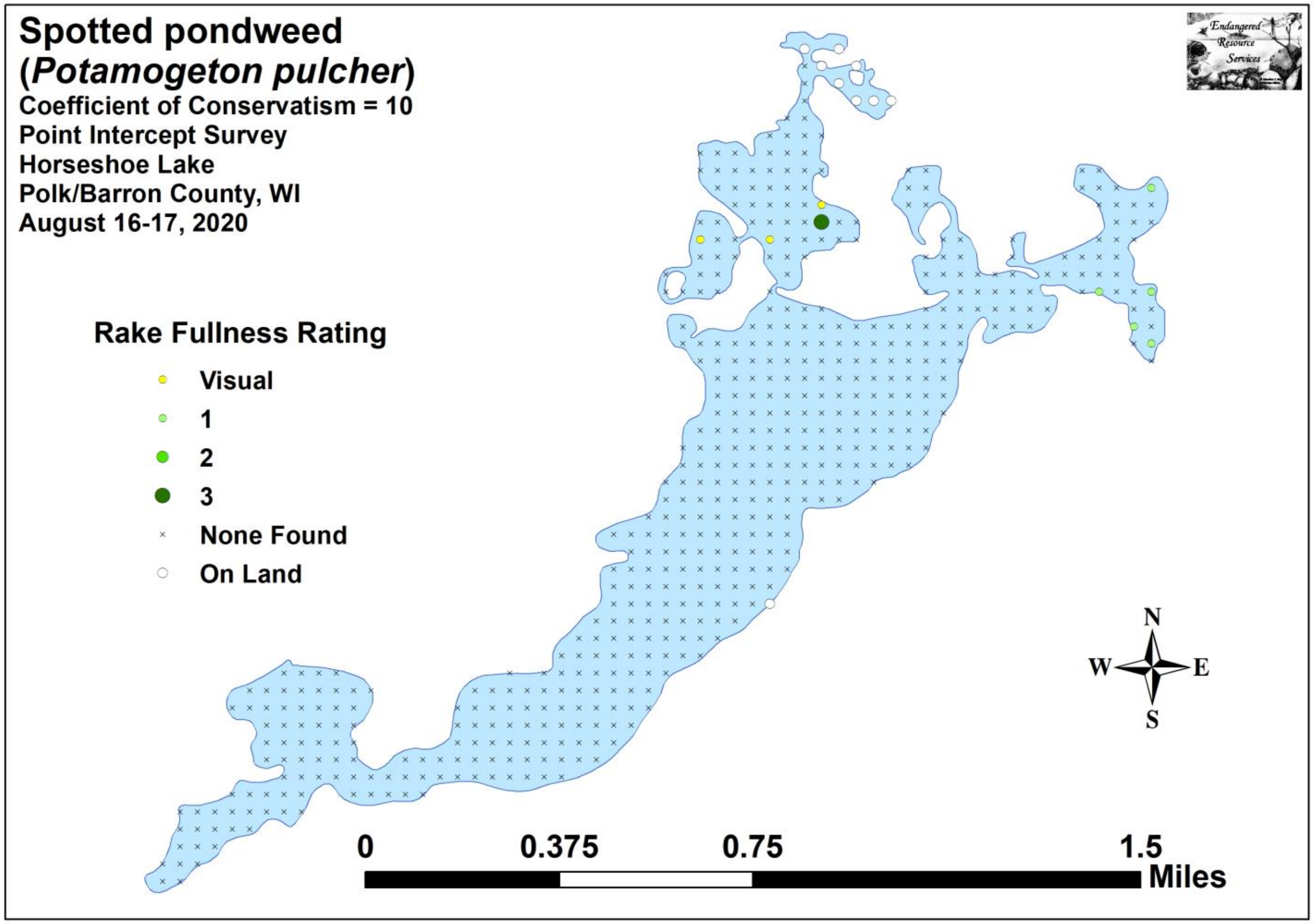
Miles


Spotted pondweed
(*Potamogeton pulcher*)
Coefficient of Conservatism = 10
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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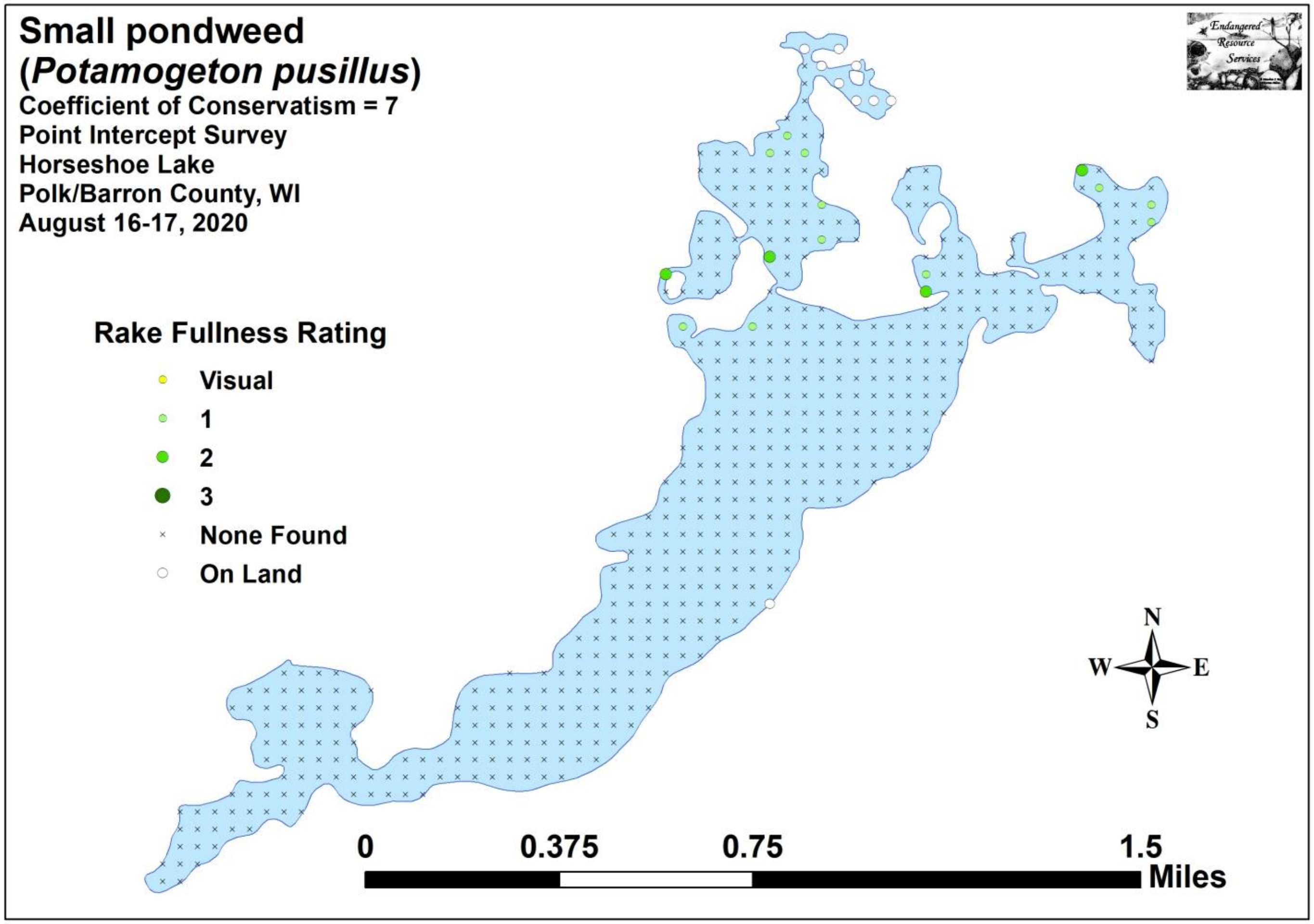
Miles



Small pondweed
(*Potamogeton pusillus*)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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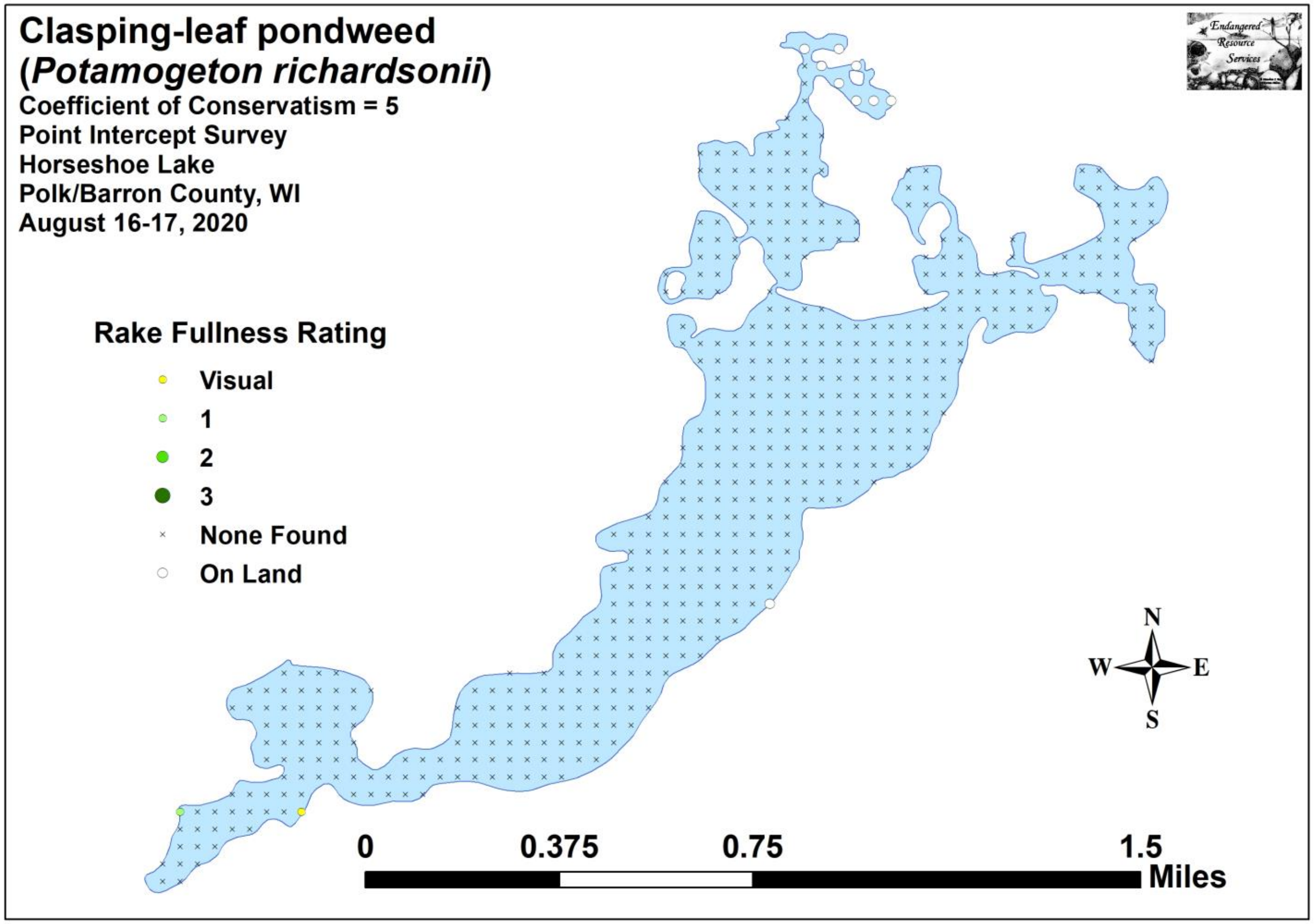
Miles


Clasping-leaf pondweed
(*Potamogeton richardsonii*)
Coefficient of Conservatism = 5
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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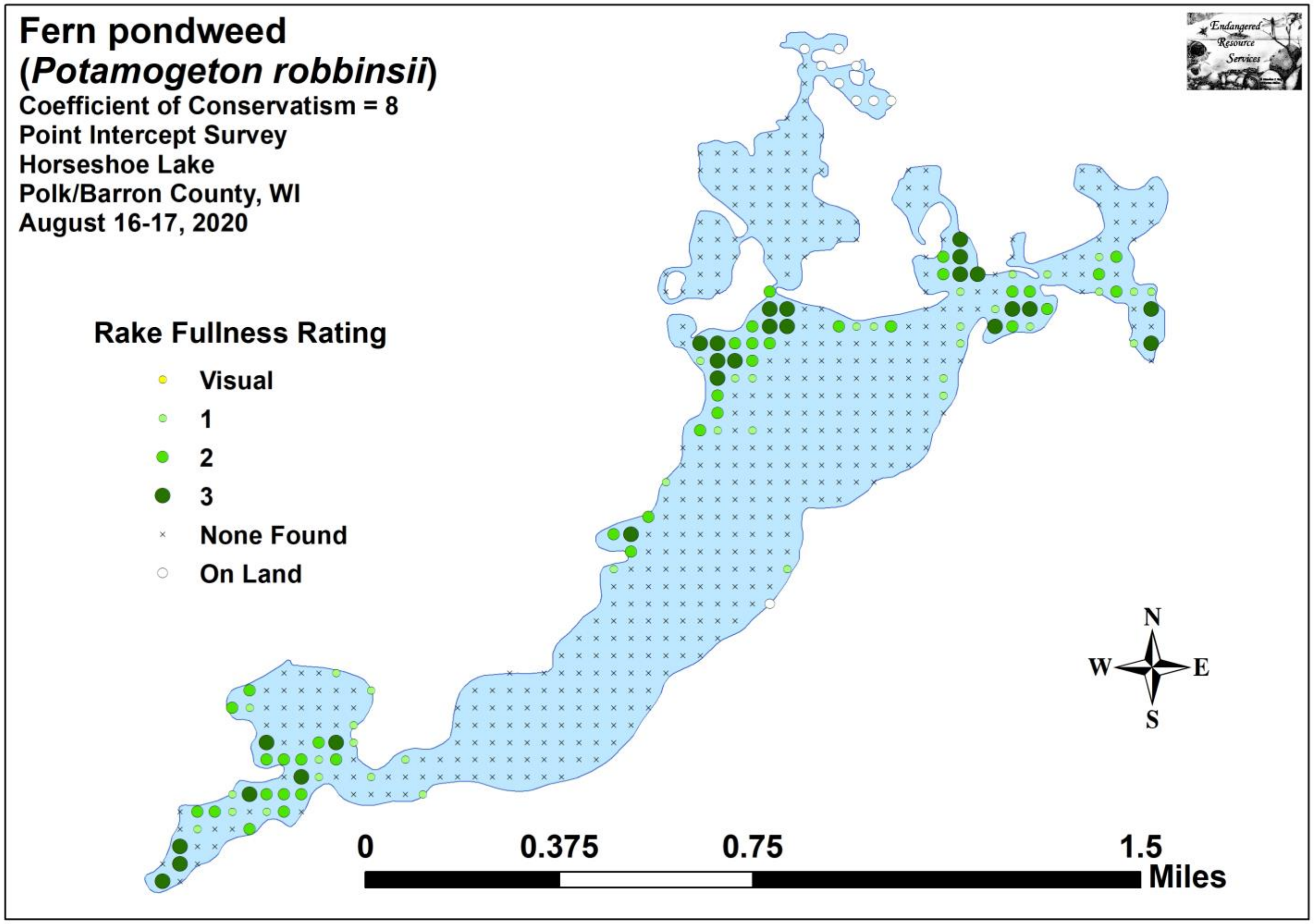
Miles


Fern pondweed
(*Potamogeton robbinsii*)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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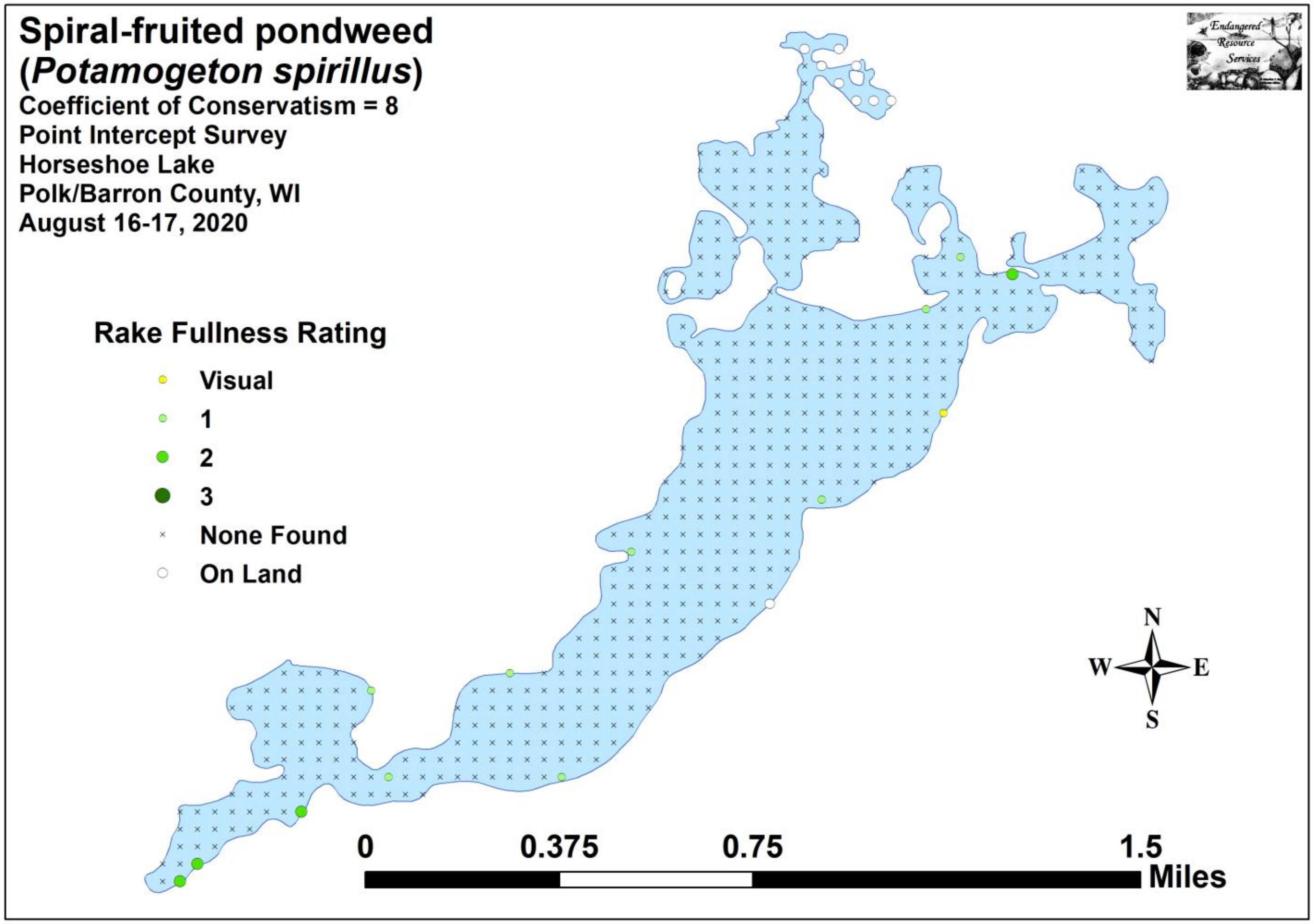
Miles


Spiral-fruited pondweed
(Potamogeton spirillus)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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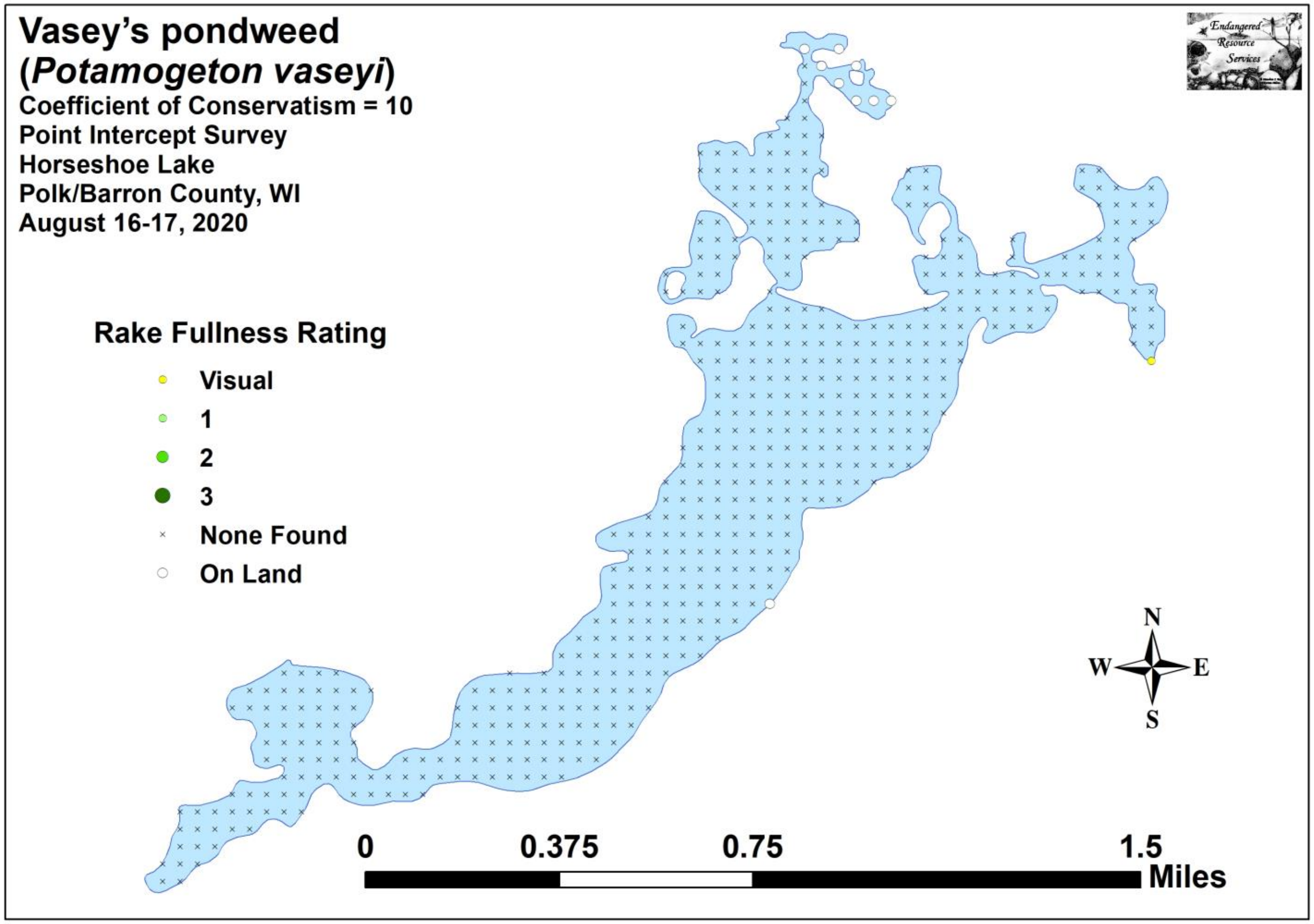
Miles
Endangered Resource Services


Vasey's pondweed
(*Potamogeton vaseyi*)
Coefficient of Conservatism = 10
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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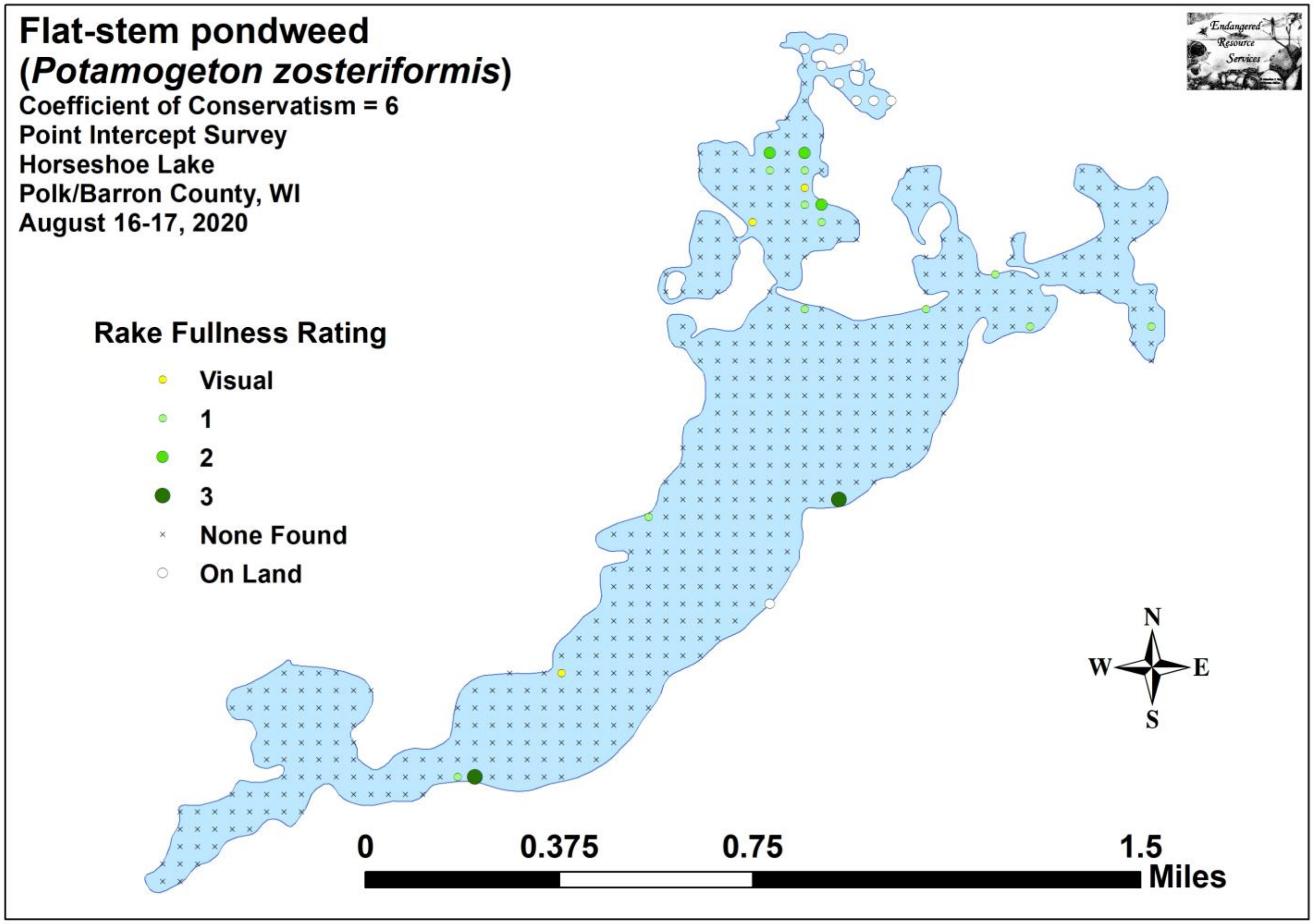
Miles


Flat-stem pondweed
(Potamogeton zosteriformis)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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Miles
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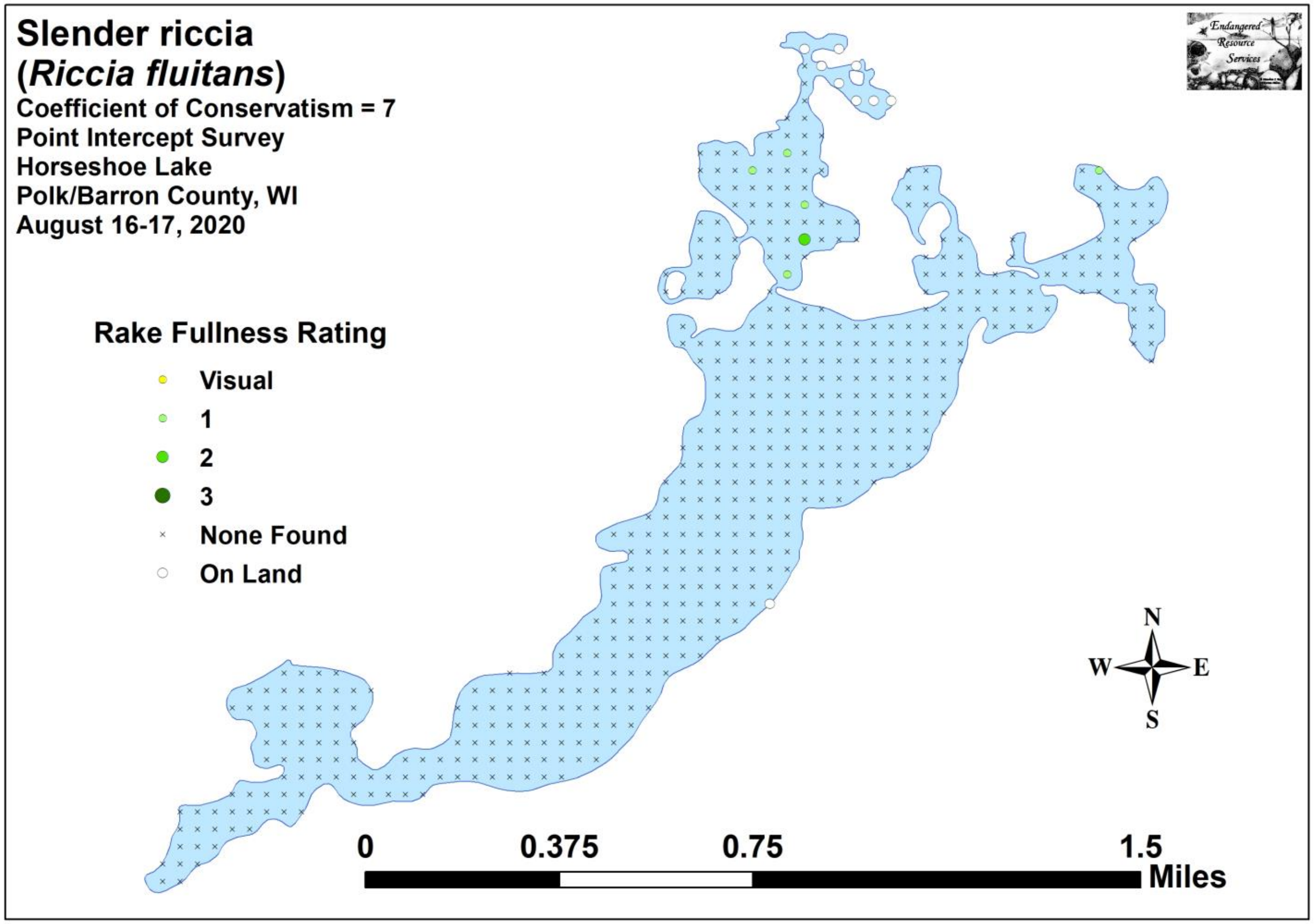
Slender riccia
(Riccia fluitans)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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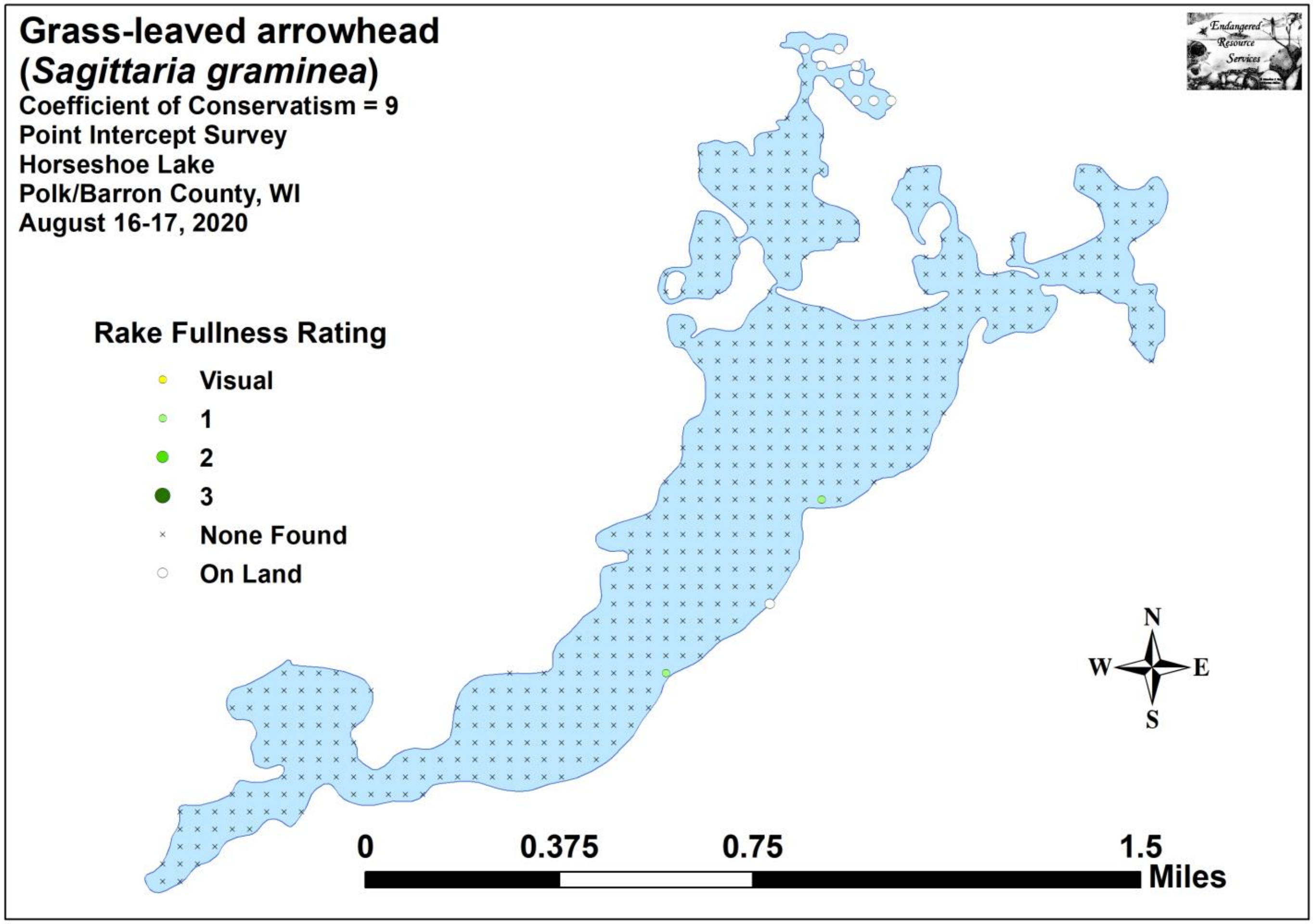
Miles


Grass-leaved arrowhead
(*Sagittaria graminea*)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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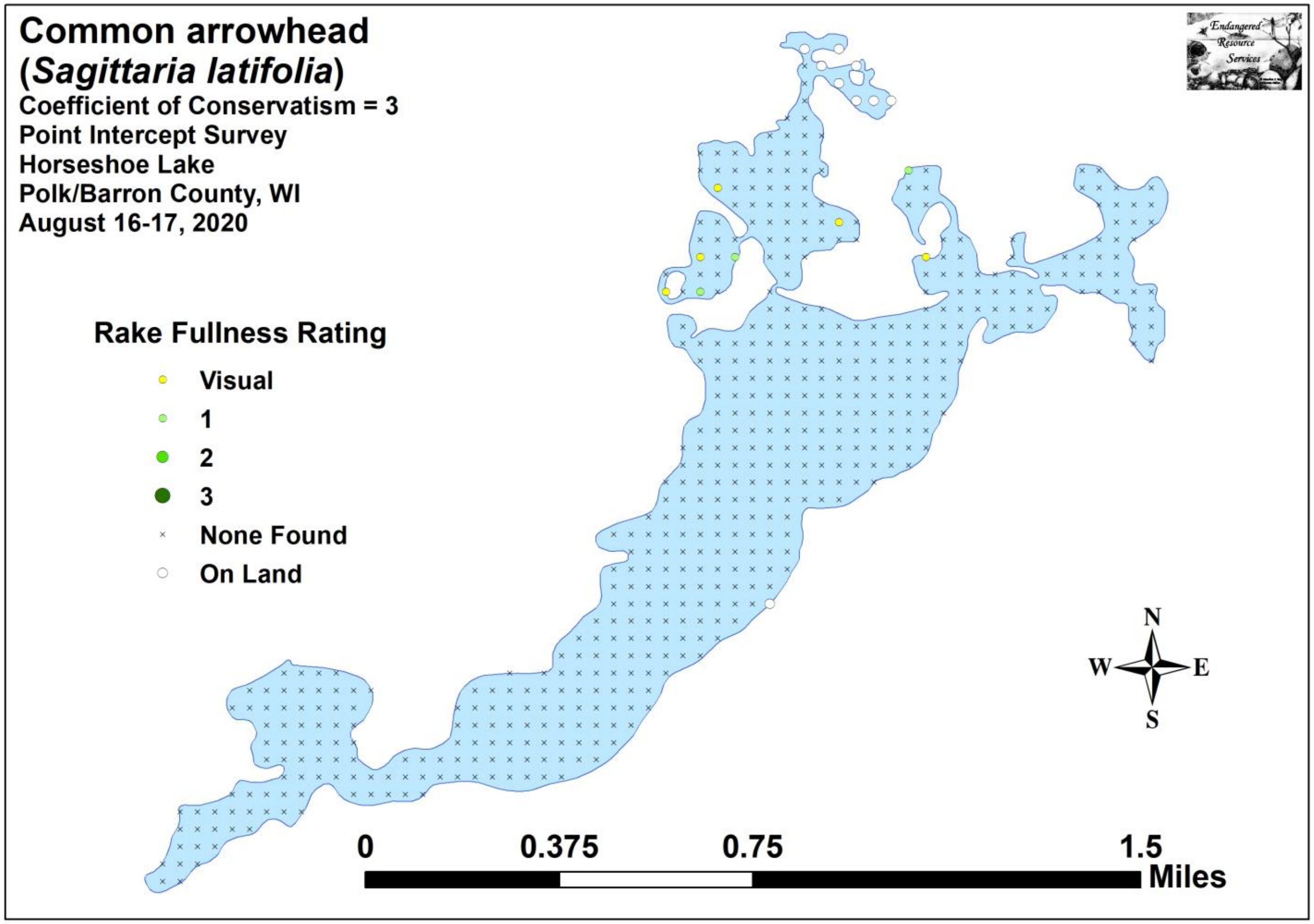
Miles


Common arrowhead
(*Sagittaria latifolia*)
Coefficient of Conservatism = 3
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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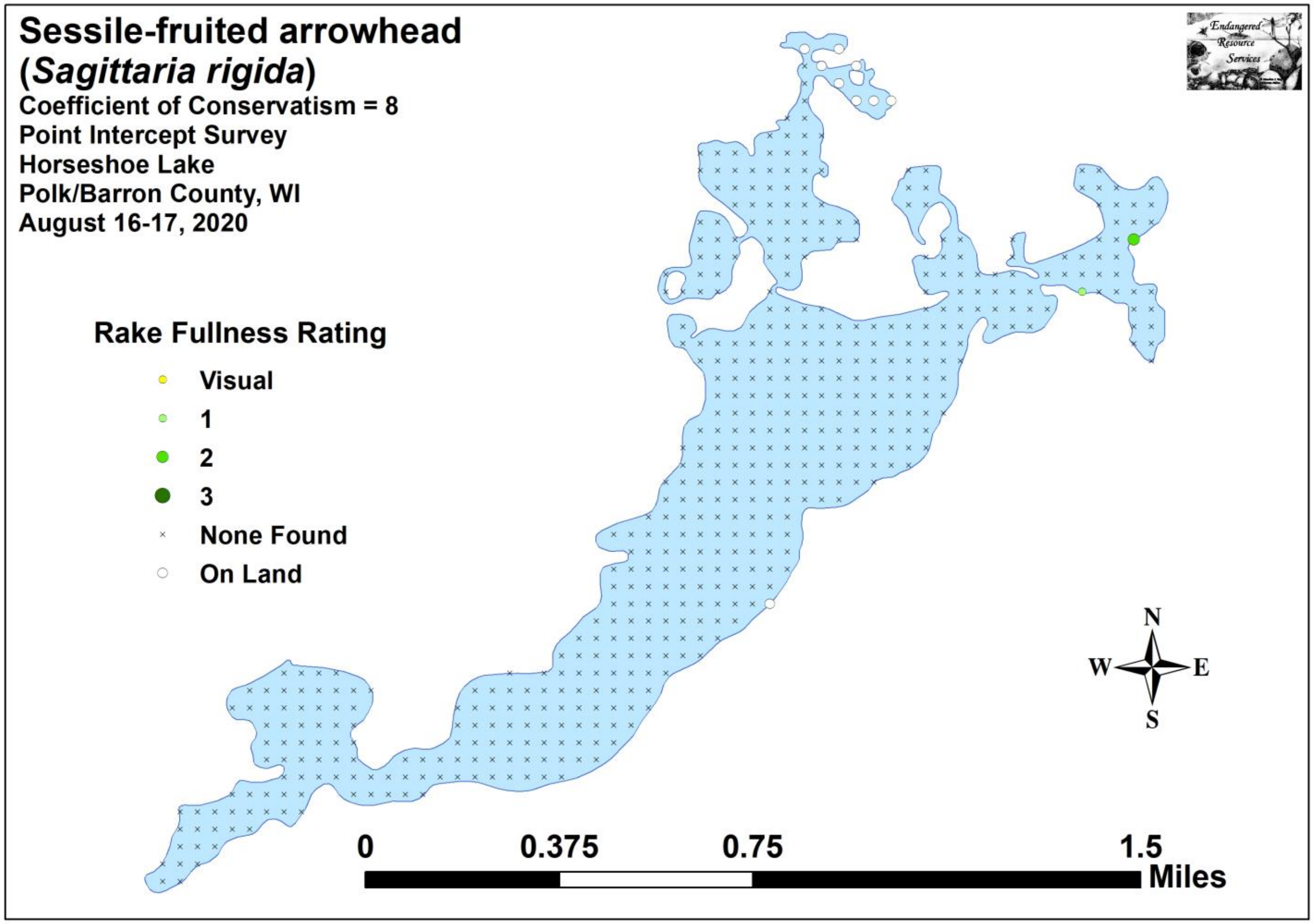
Miles


Sessile-fruited arrowhead
(Sagittaria rigida)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
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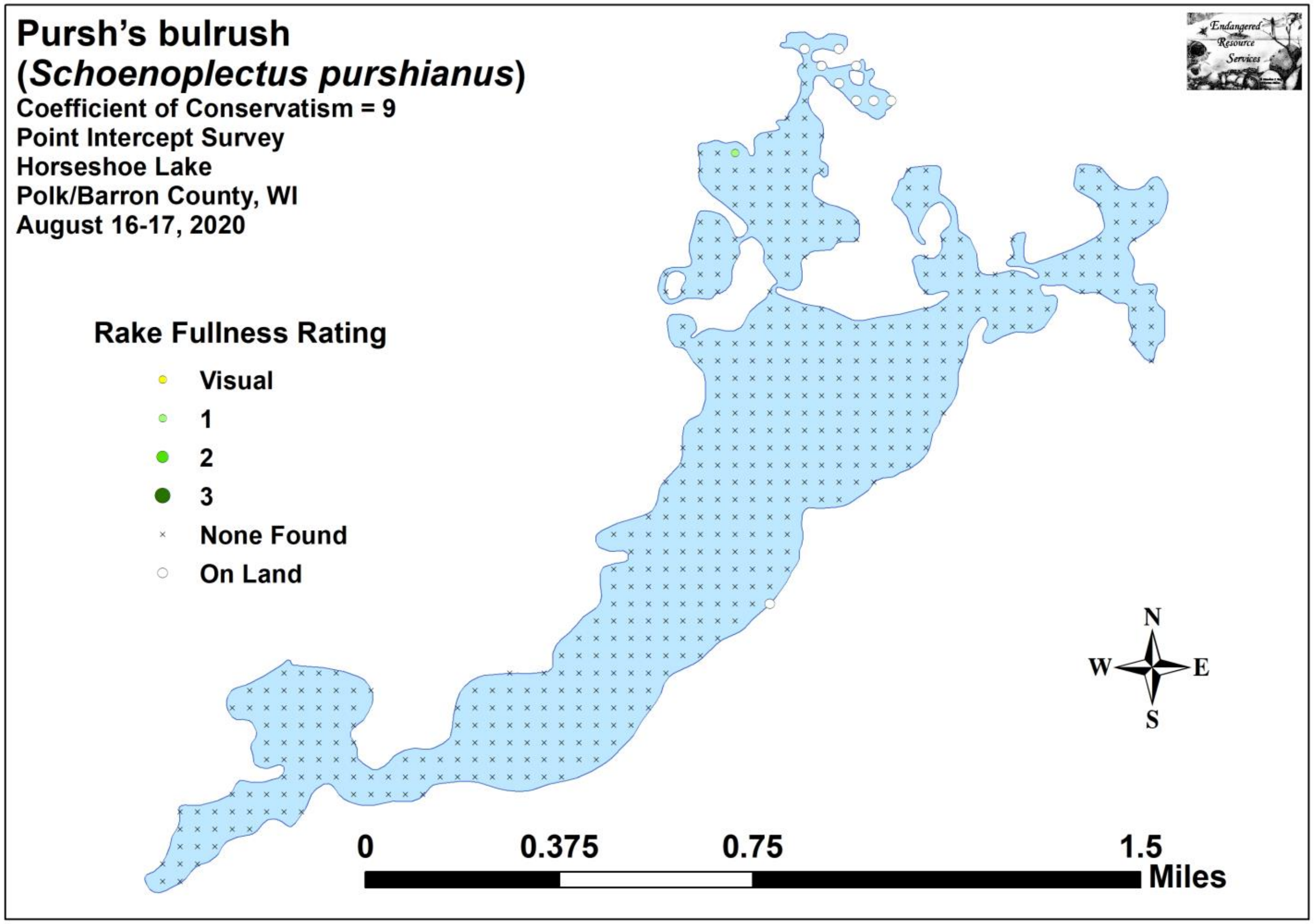
Miles


Pursh's bulrush
(Schoenoplectus purshianus)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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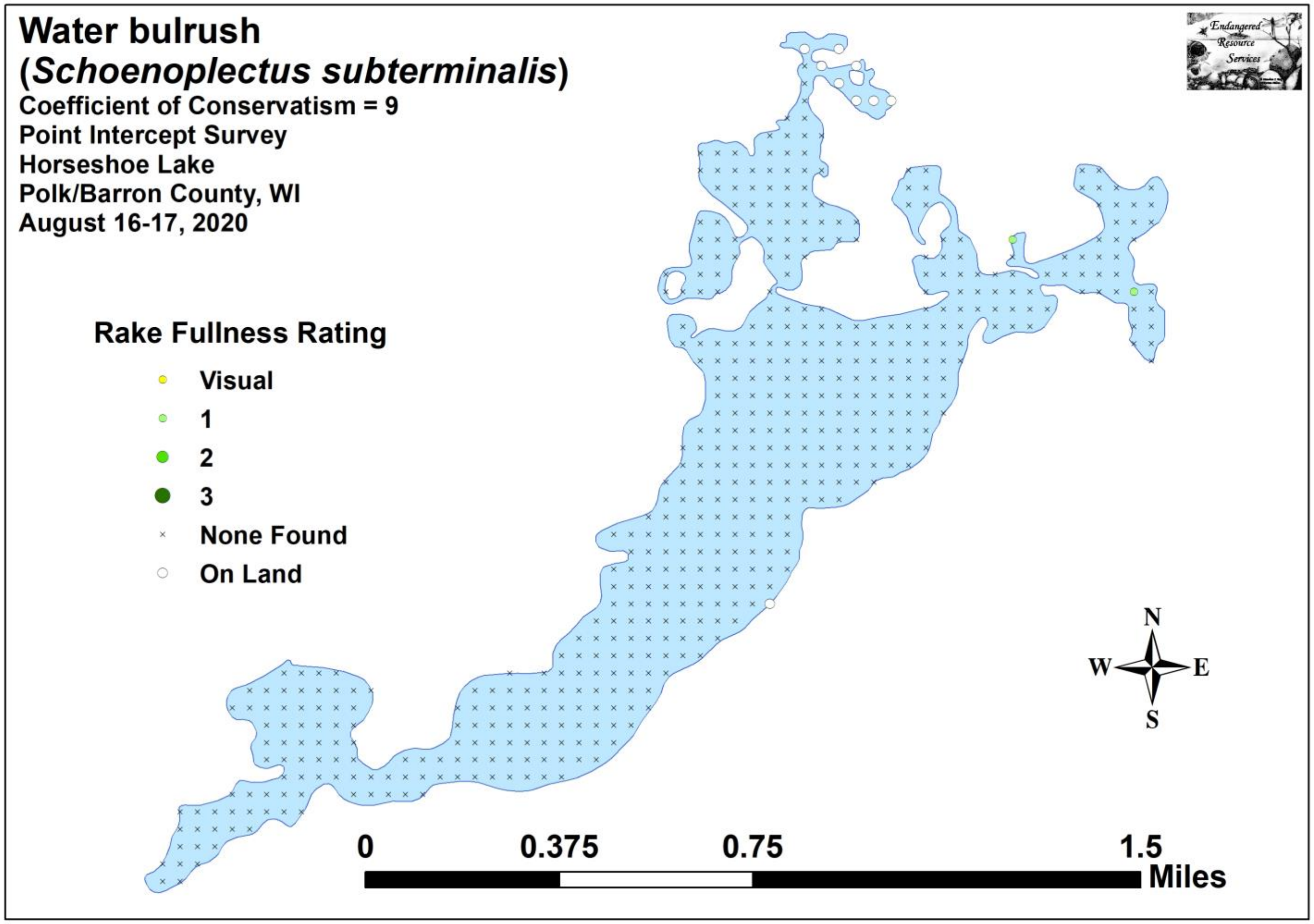
Miles
Endangered Resource Services


Water bulrush
(Schoenoplectus subterminalis)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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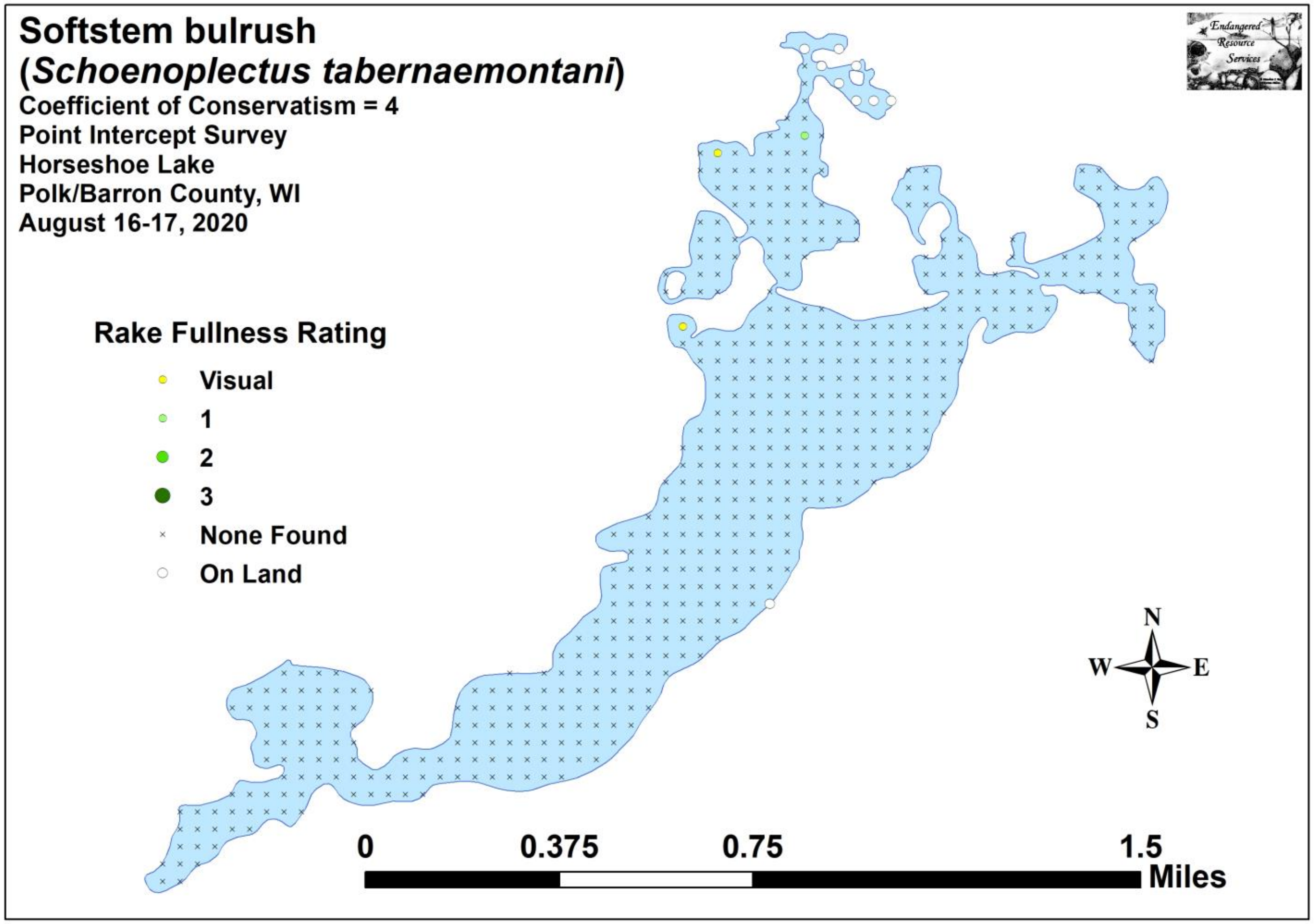
Miles



Softstem bulrush
(Schoenoplectus tabernaemontani)
Coefficient of Conservatism = 4
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
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None Found
On Land
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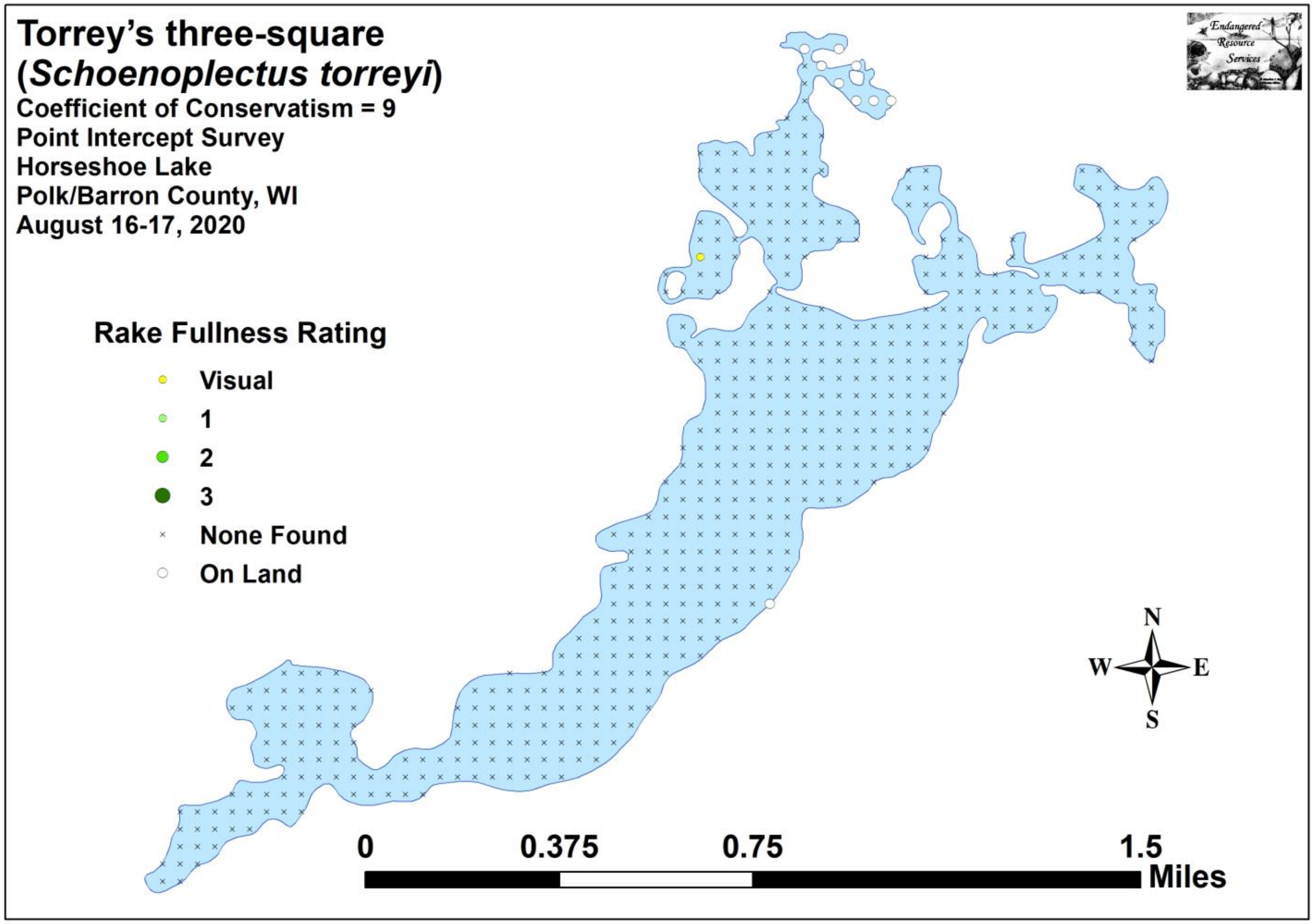
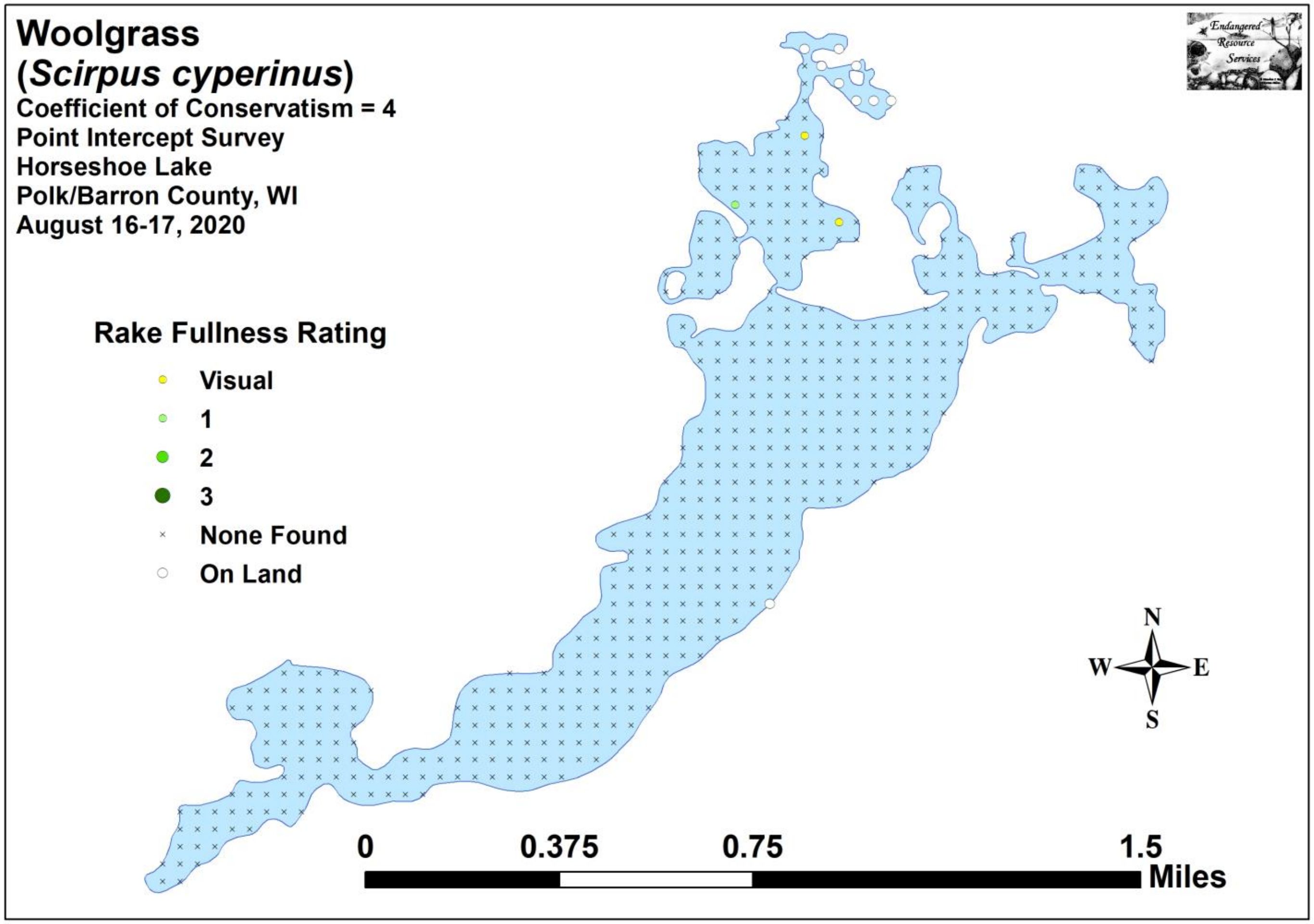
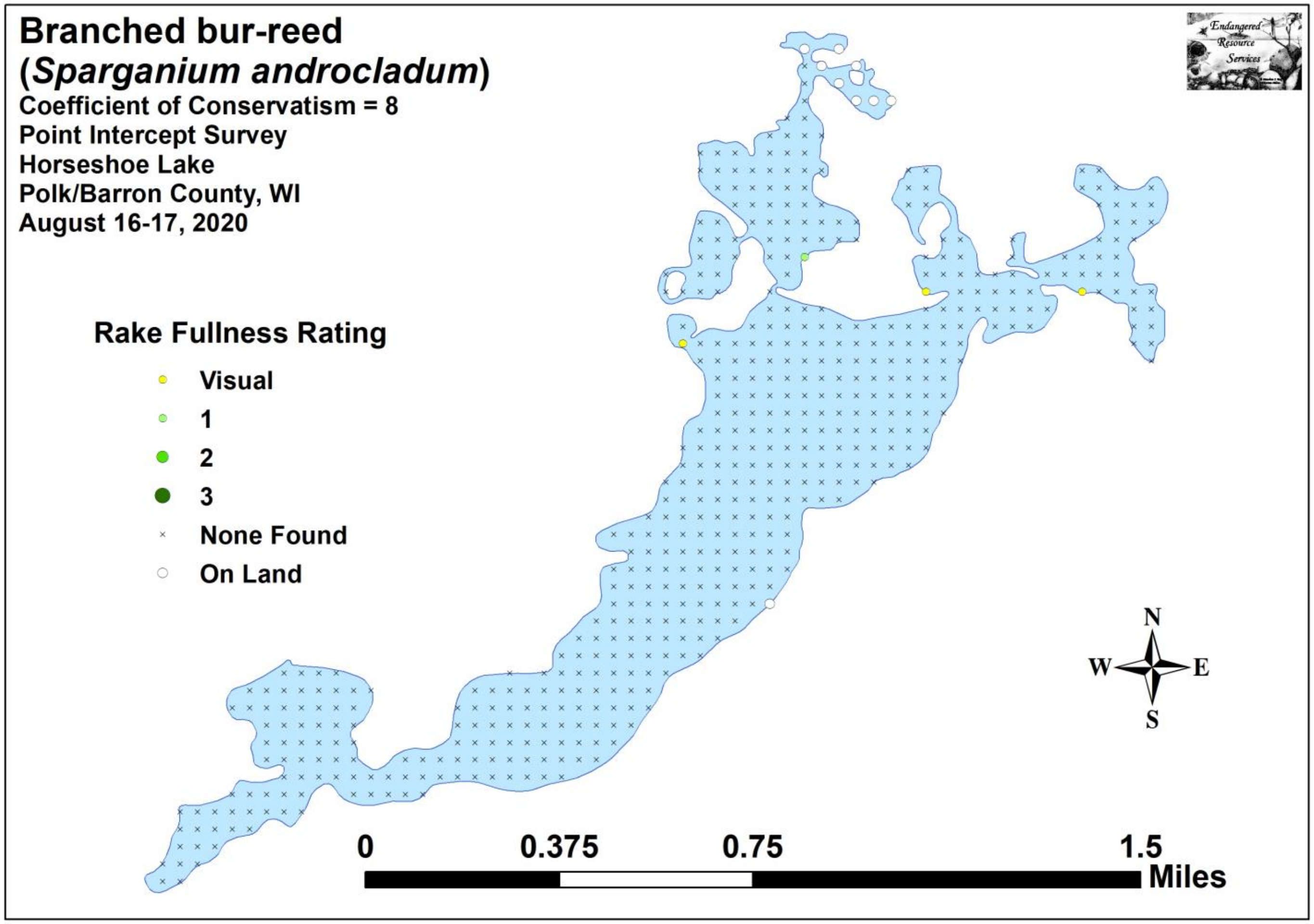
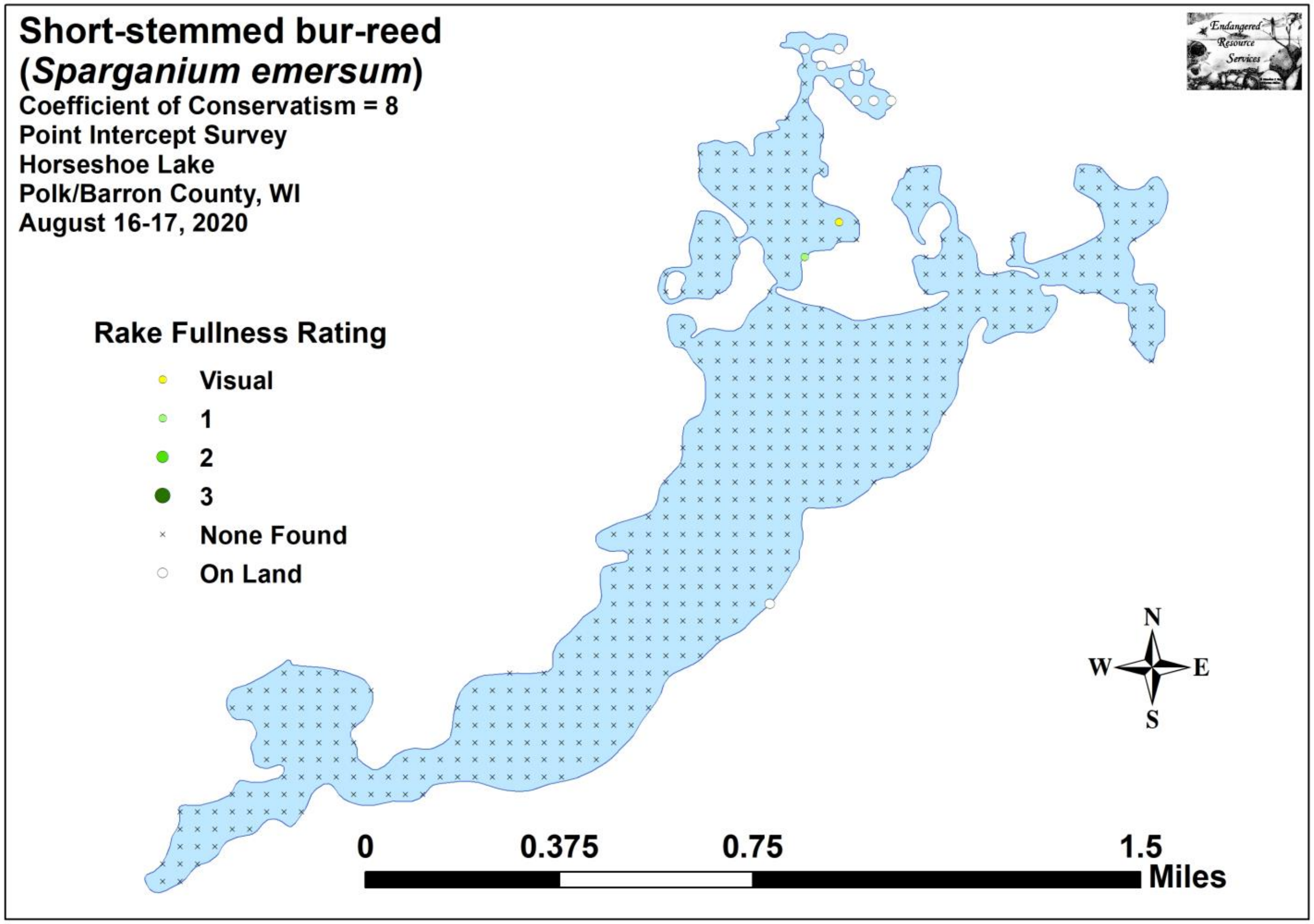
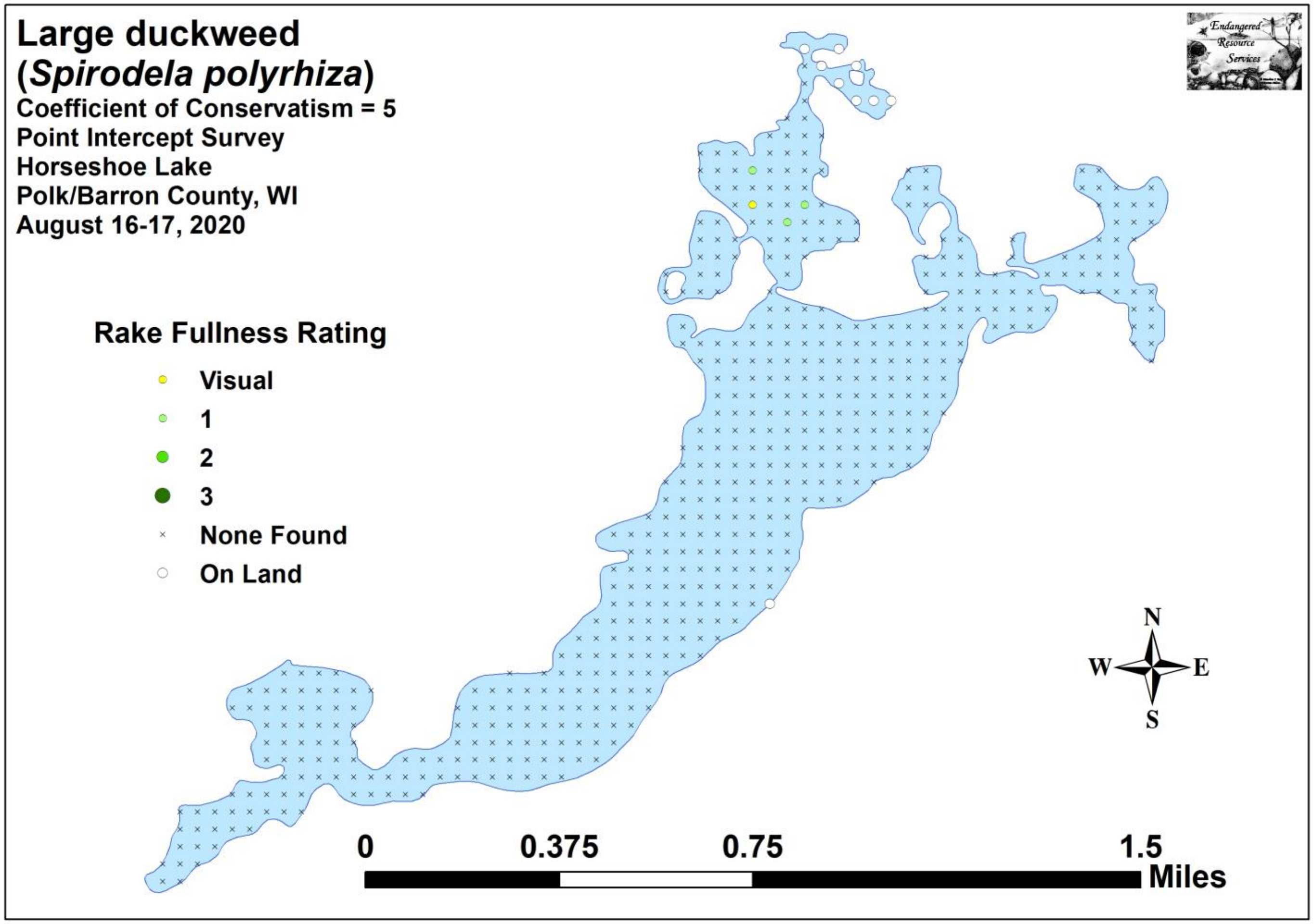
1.5
Miles

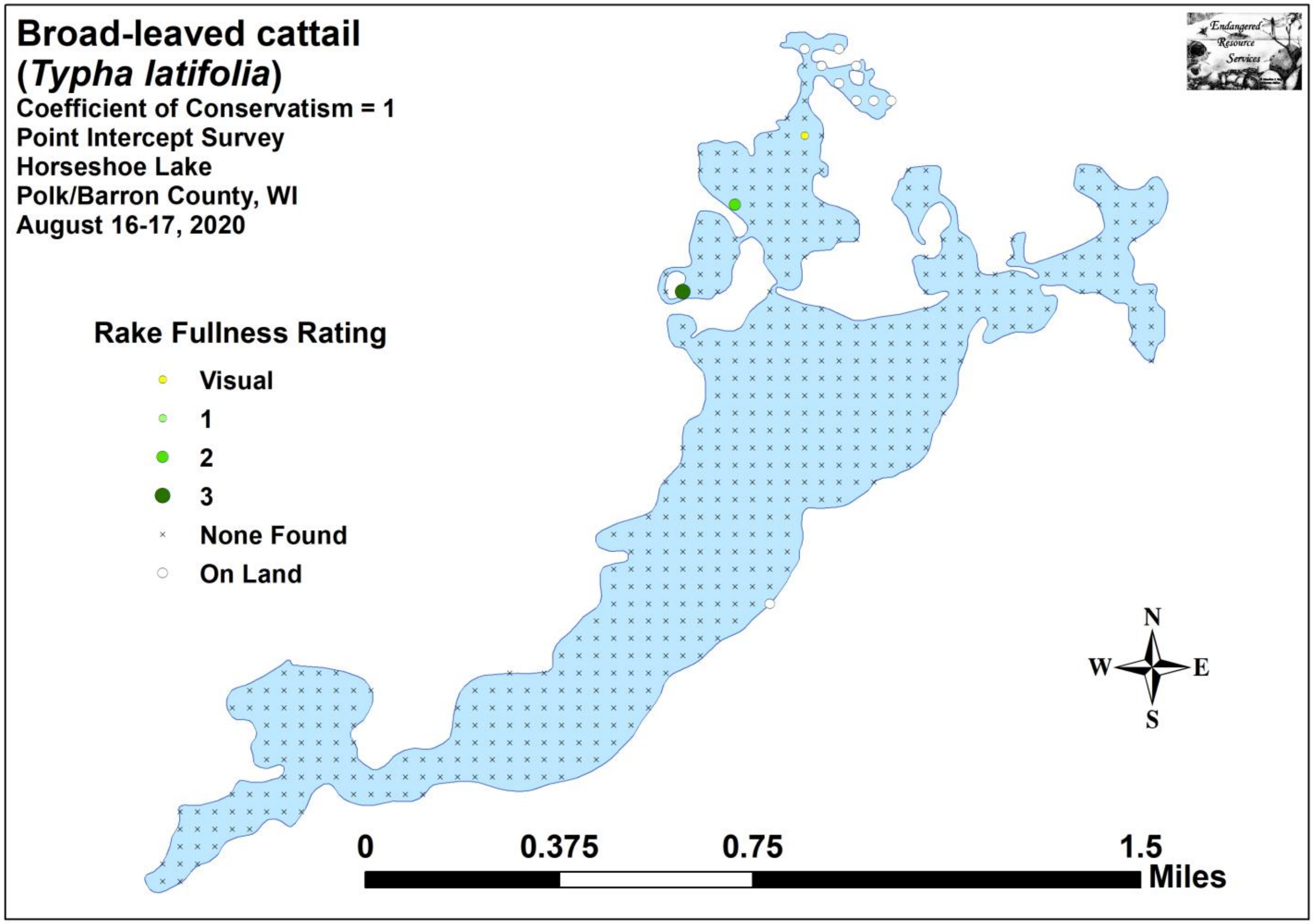

Torrey's three-square
(*Schoenoplectus torreyi*)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles


Woolgrass
(Scirpus cyperinus)
Coefficient of Conservatism = 4
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

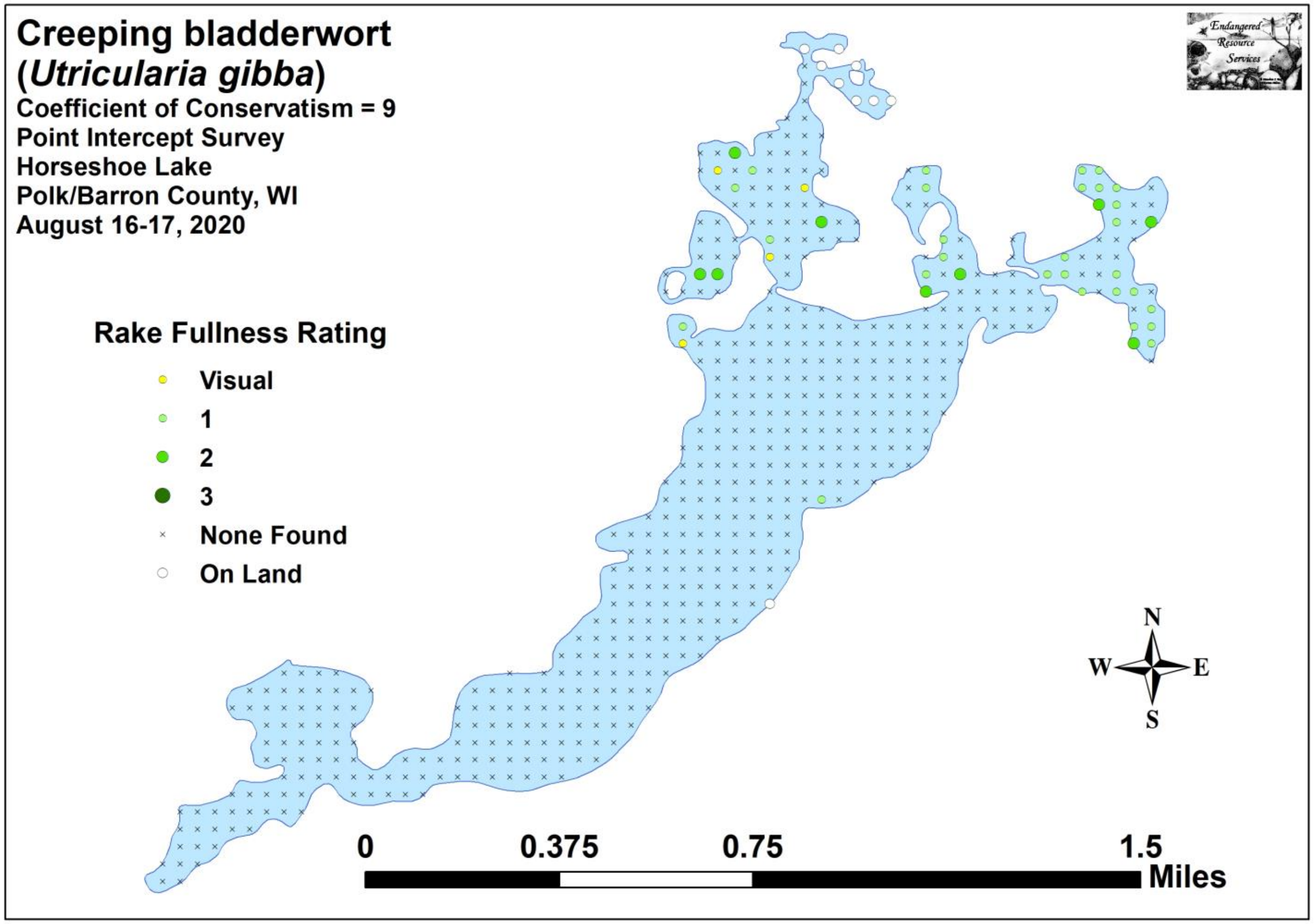

Branched bur-reed
(Sparganium androcladum)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles


Short-stemmed bur-reed
(*Sparganium emersum*)
Coefficient of Conservatism = 8
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

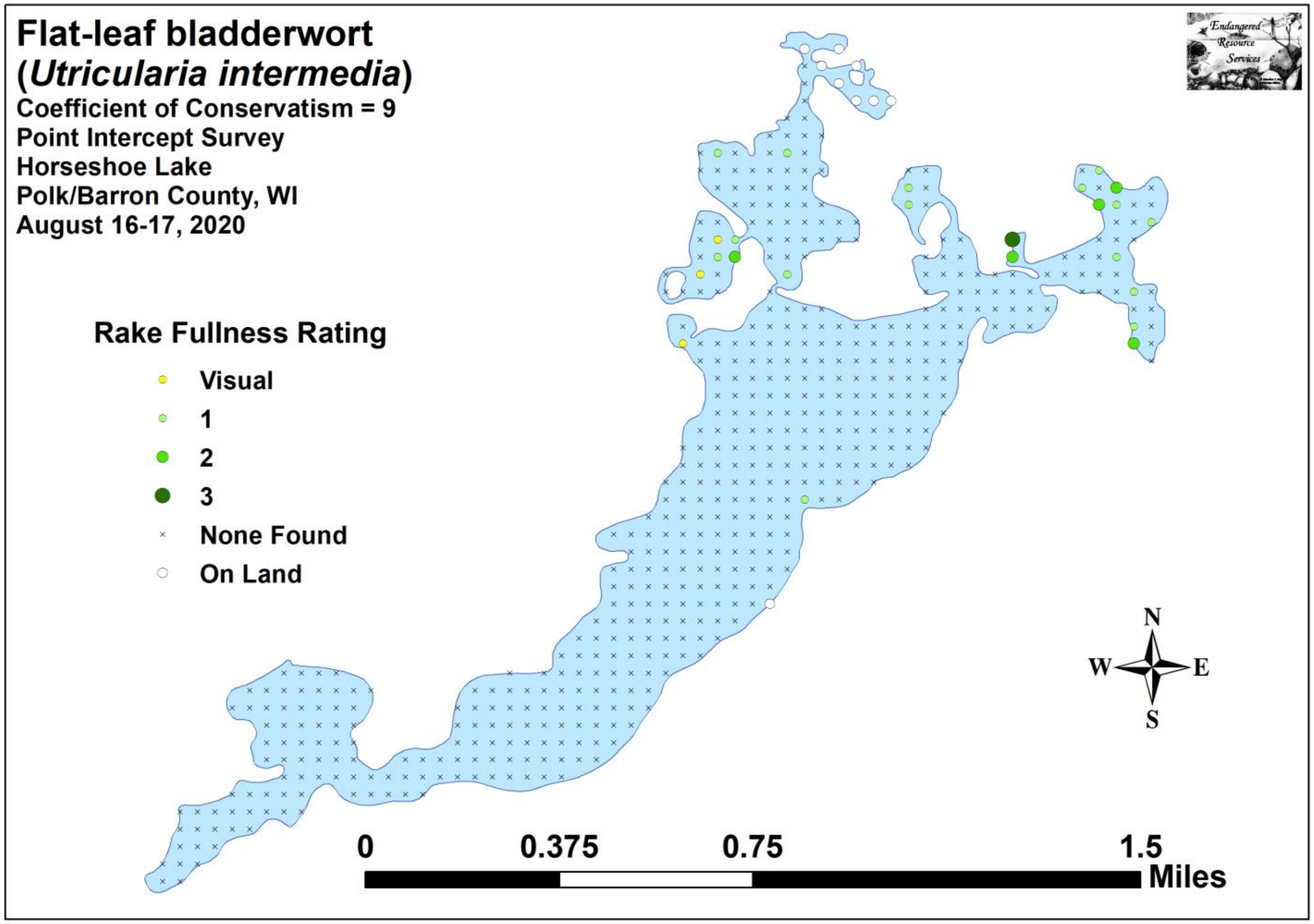

Large duckweed
(Spirodela polyrhiza)
Coefficient of Conservatism = 5
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles
Endangered Resource Services

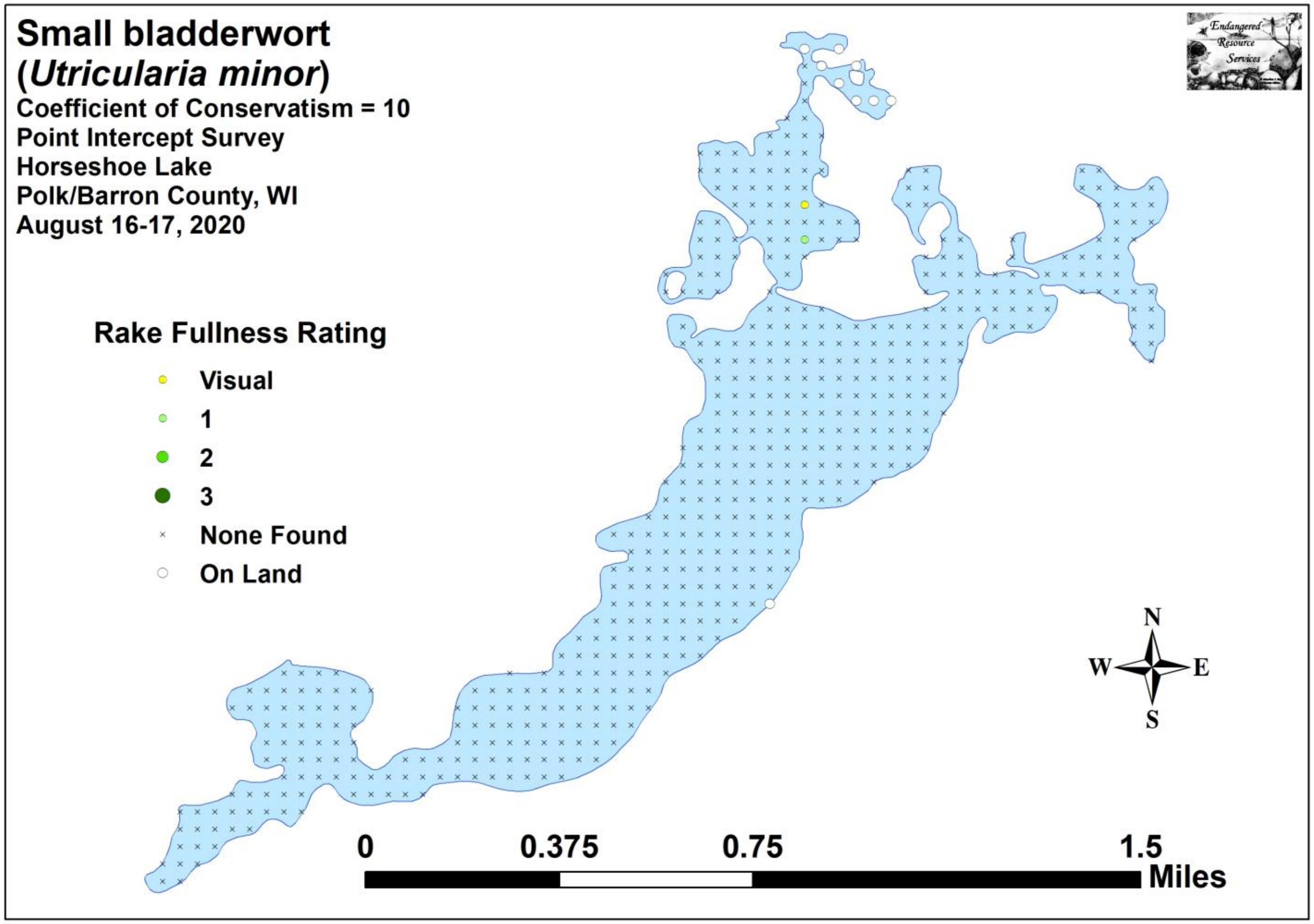


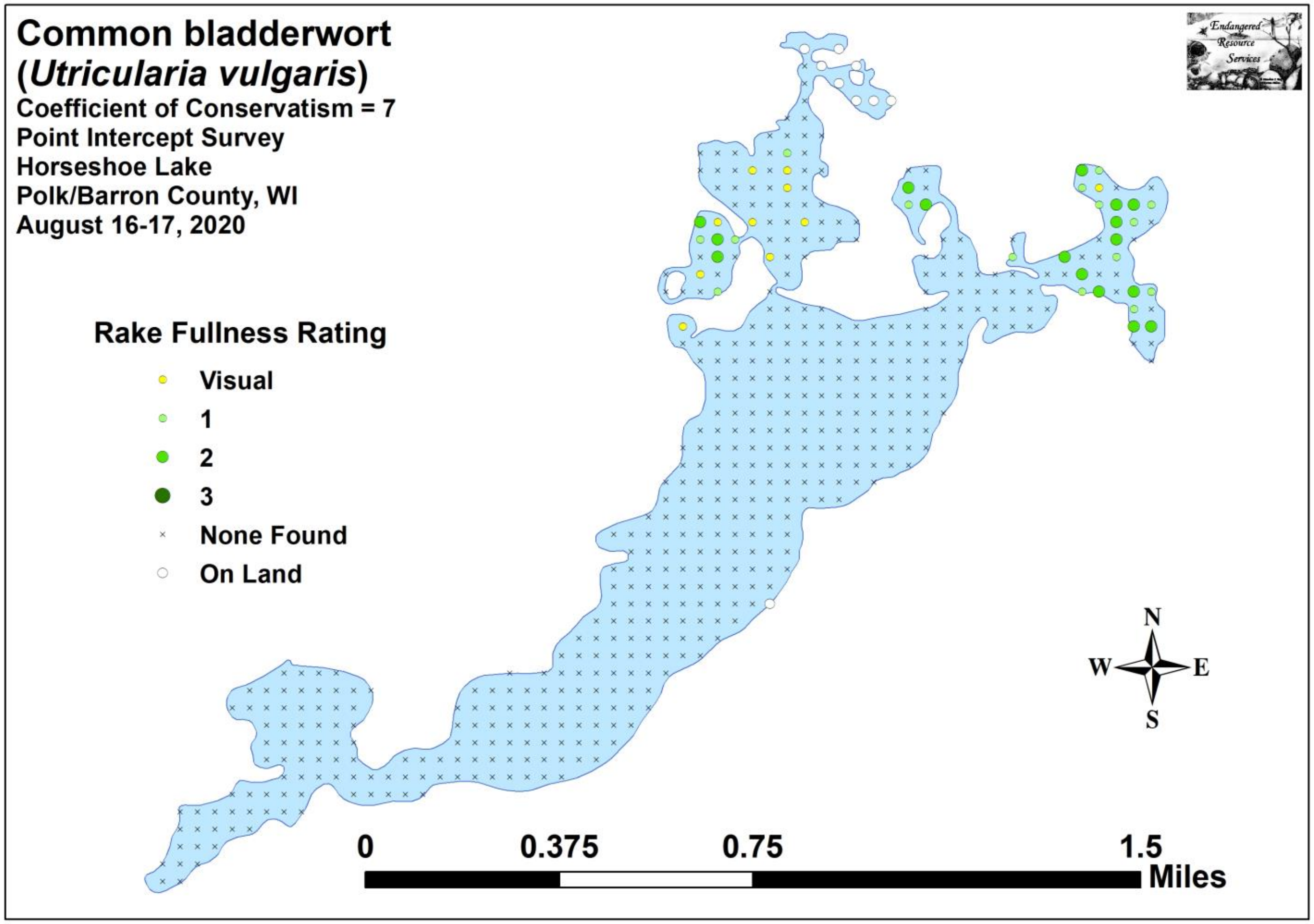
Broad-leaved cattail
(*Typha latifolia*)
Coefficient of Conservatism = 1
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

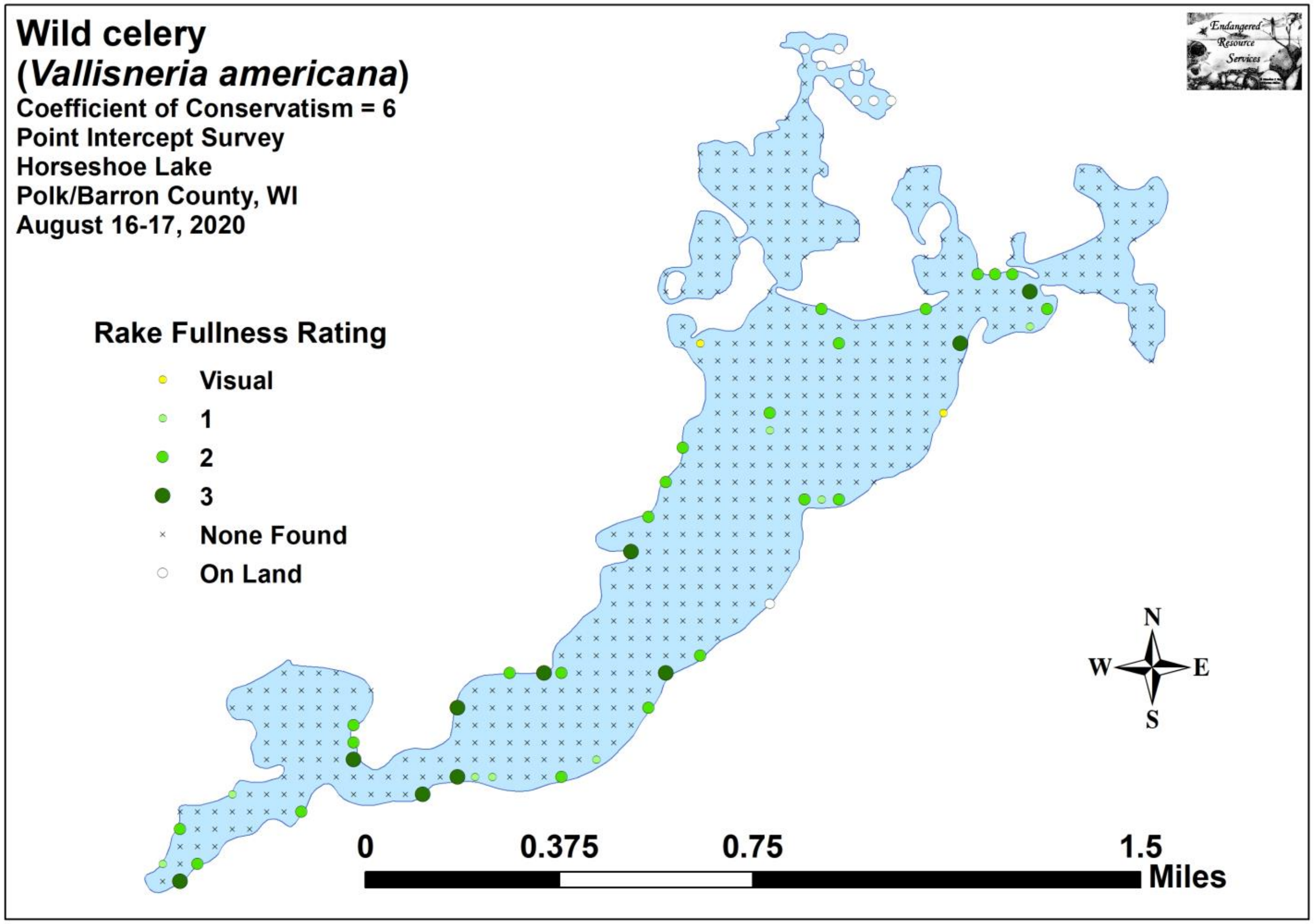


Creeping bladderwort
(*Utricularia gibba*)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles

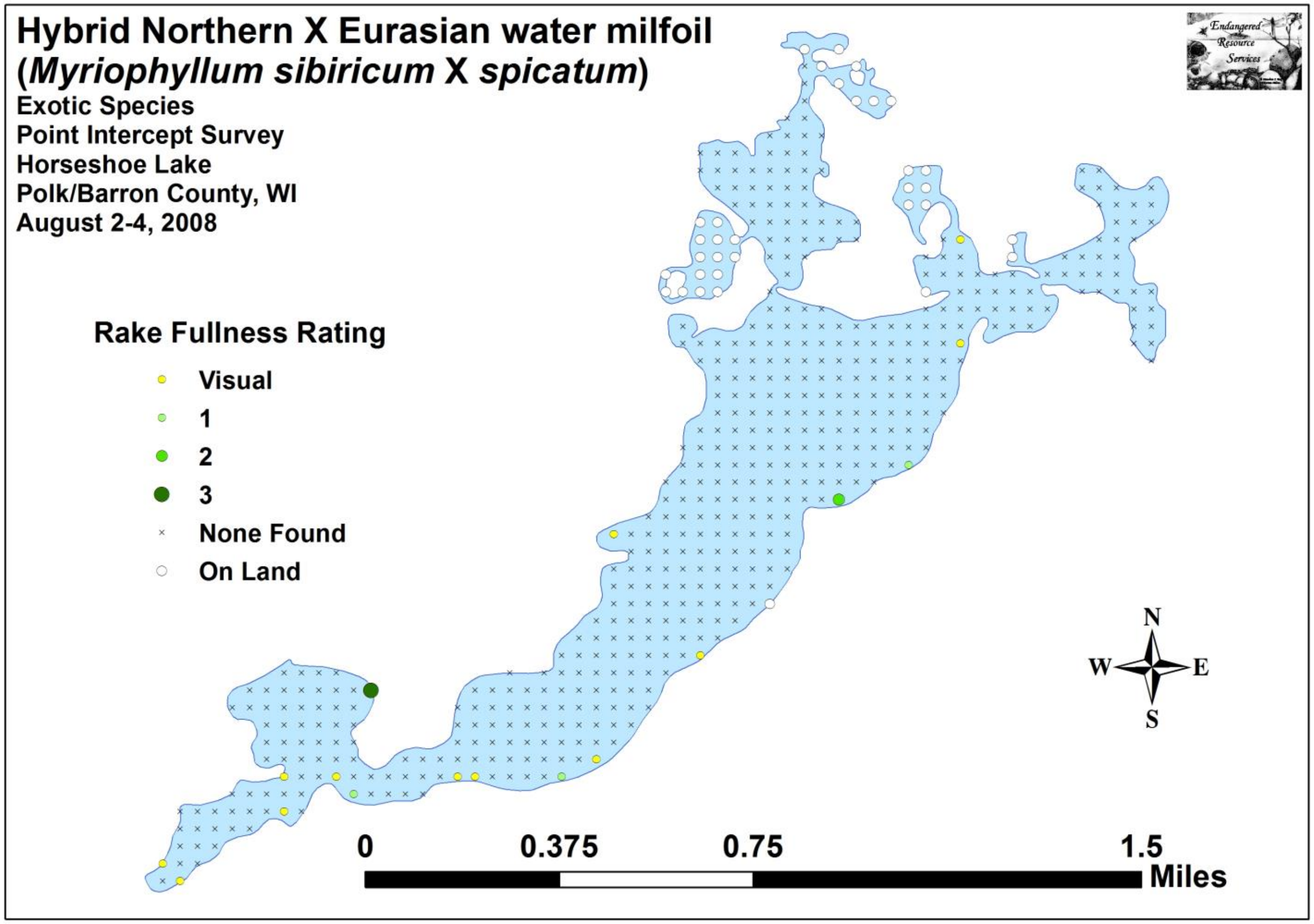

Flat-leaf bladderwort
(*Utricularia intermedia*)
Coefficient of Conservatism = 9
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

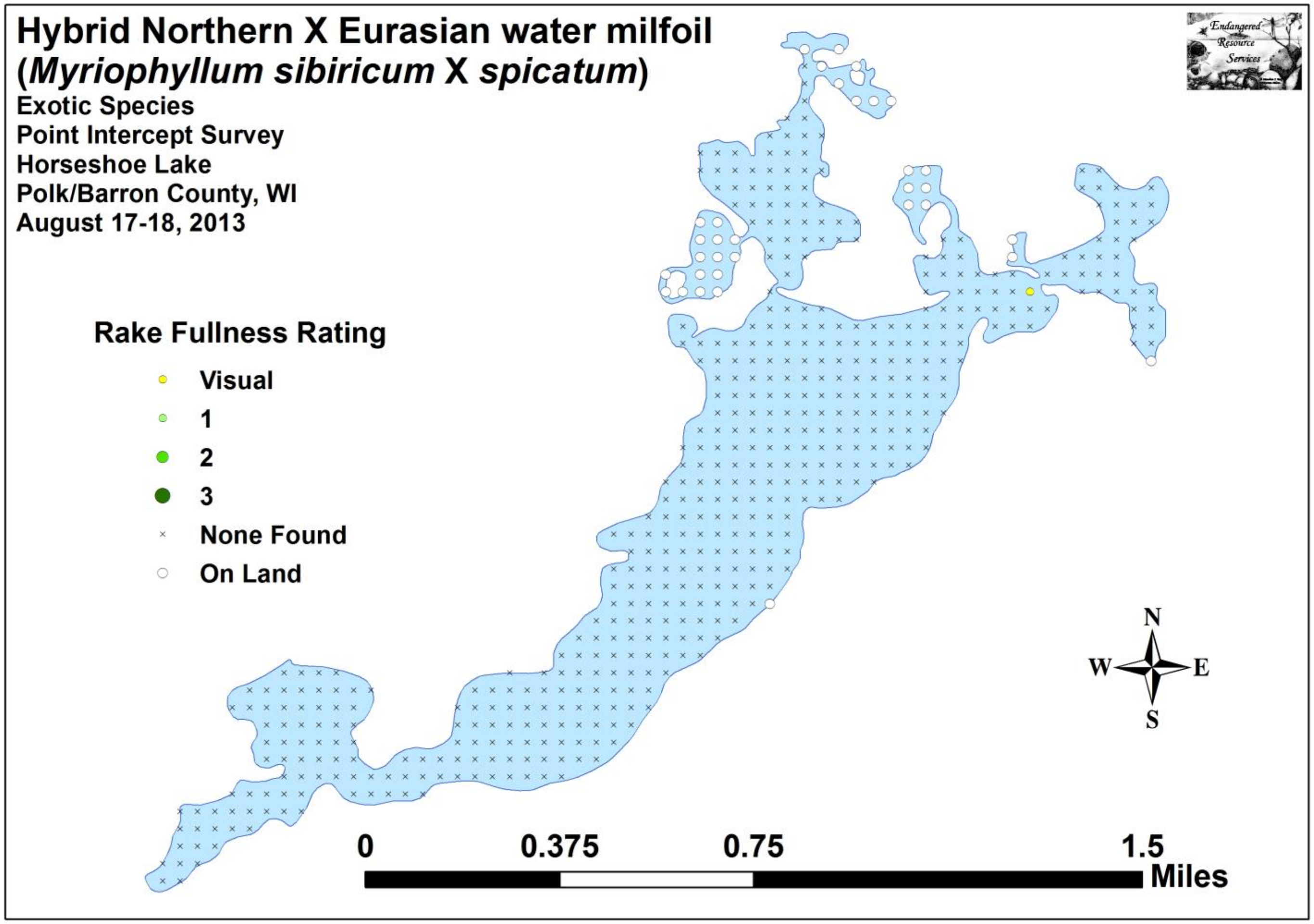

Small bladderwort
(Utricularia minor)
Coefficient of Conservatism = 10
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles


Common bladderwort
(Utricularia vulgaris)
Coefficient of Conservatism = 7
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles

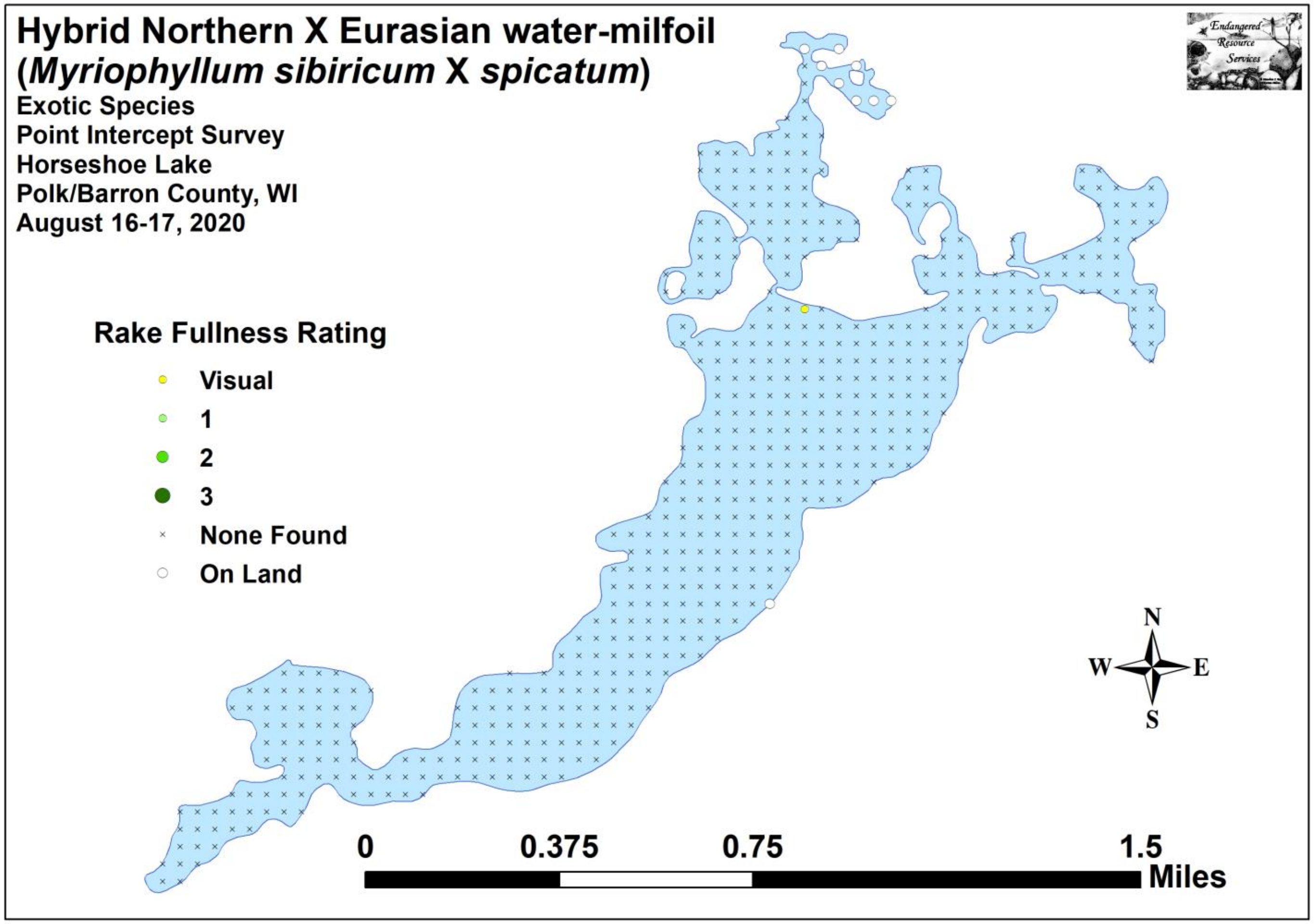

Wild celery
(Vallisneria americana)
Coefficient of Conservatism = 6
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

Appendix VI: 2008, 2013, and 2020 August Hybrid Water-milfoil Density and Distribution Maps

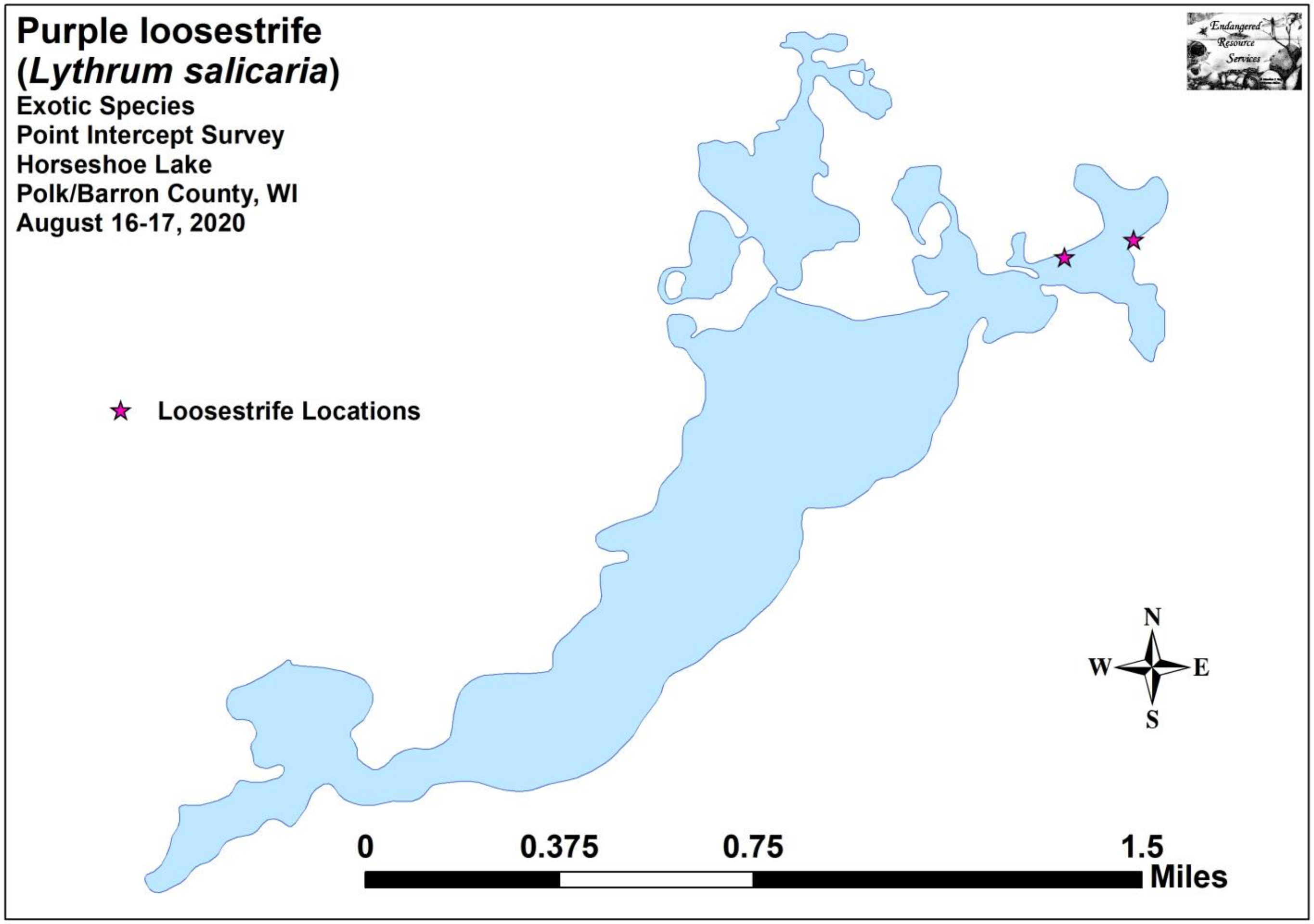

Hybrid Northern X Eurasian water milfoil
(*Myriophyllum sibiricum* X *spicatum*)
Exotic Species
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 2-4, 2008
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles
Endangered Resource Services

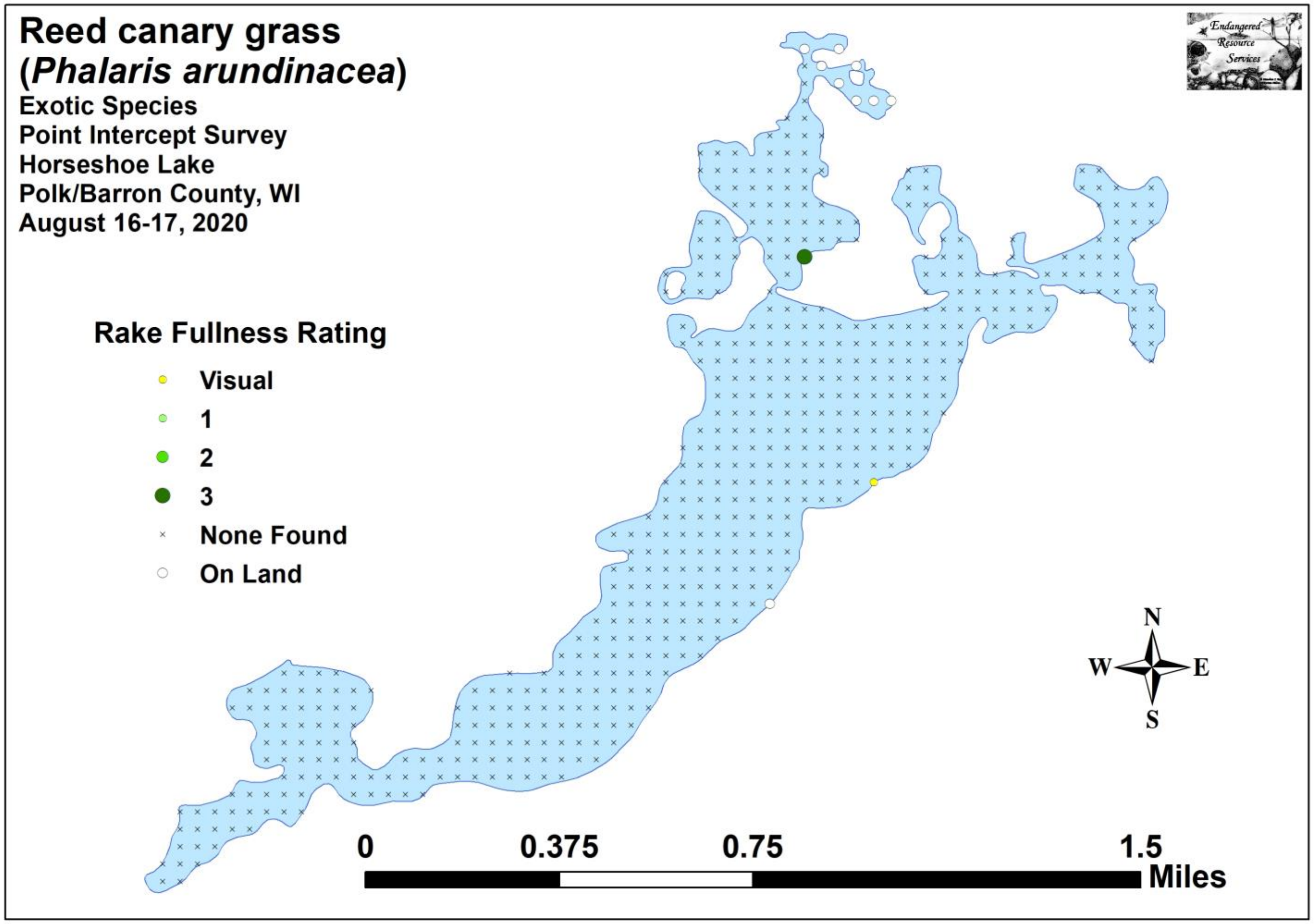


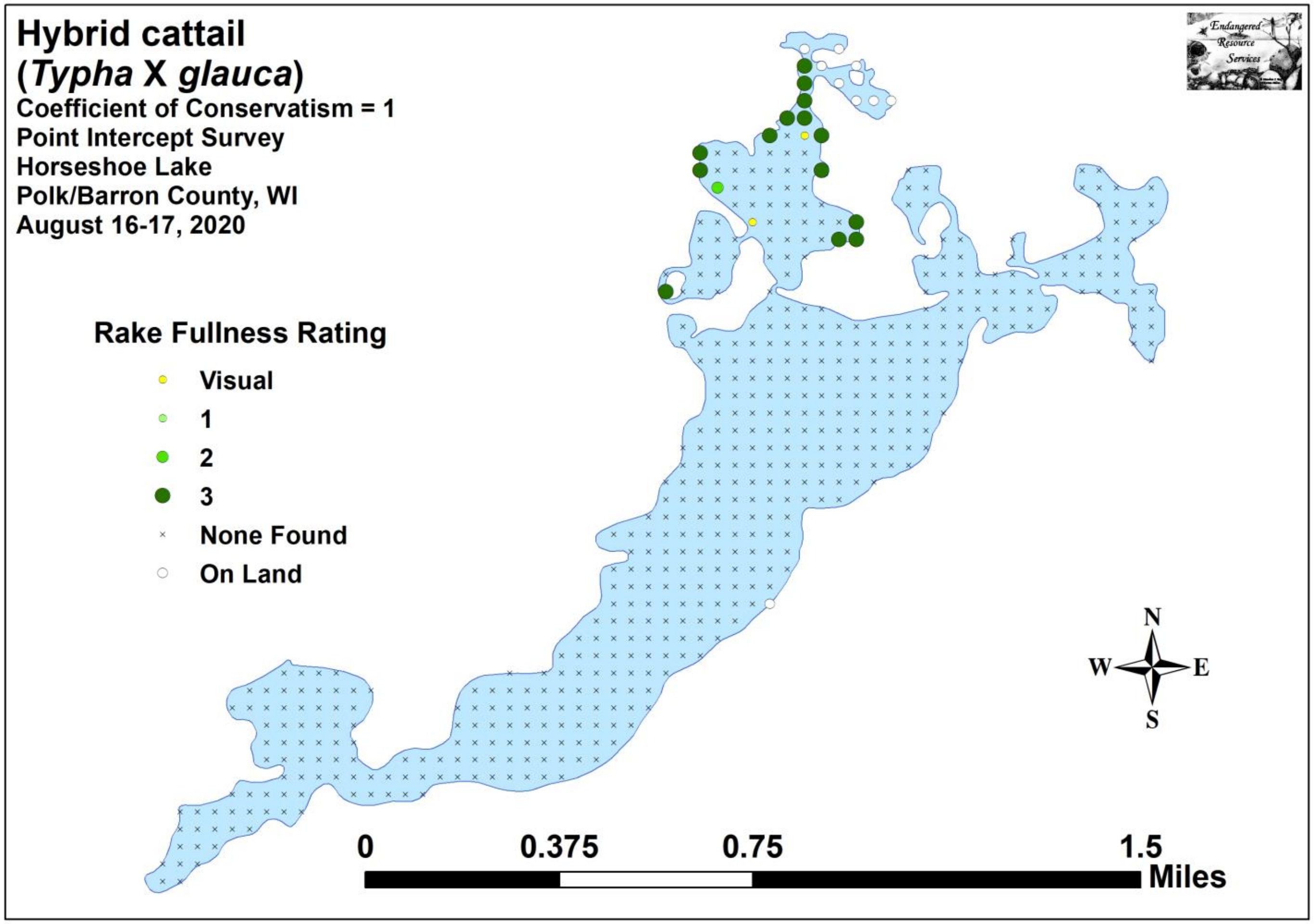
Hybrid Northern X Eurasian water milfoil
(*Myriophyllum sibiricum* X *spicatum*)
Exotic Species
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 17-18, 2013
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles


Hybrid Northern X Eurasian water-milfoil
(*Myriophyllum sibiricum* X *spicatum*)
Exotic Species
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
Endangered Resource Services
N
W
E
S
0
0.375
0.75
1.5
Miles

Appendix VII: 2020 August Exotic Species Density and Distribution Maps


Purple loosestrife
(*Lythrum salicaria*)
Exotic Species
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Loosestrife Locations
N
W
E
S
0
0.375
0.75
1.5
Miles
Endangered Resource Services


Reed canary grass
(*Phalaris arundinacea*)
Exotic Species
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles


Hybrid cattail
(*Typha* X *glauca*)
Coefficient of Conservatism = 1
Point Intercept Survey
Horseshoe Lake
Polk/Barron County, WI
August 16-17, 2020
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.375
0.75
1.5
Miles

Appendix VIII: Aquatic Exotic Invasive Plant Species Information

Eurasian Water-milfoil

DESCRIPTION: Eurasian Water-milfoil is a submersed aquatic plant native to Europe, Asia, and northern Africa. It is the only non-native milfoil in Wisconsin. Like the native milfoils, the Eurasian variety has slender stems whorled by submersed feathery leaves and tiny flowers produced above the water surface. The flowers are located in the axils of the floral bracts, and are either four-petaled or without petals. The leaves are threadlike, typically uniform in diameter, and aggregated into a submersed terminal spike. The stem thickens below the inflorescence and doubles its width further down, often curving to lie parallel with the water surface. The fruits are four-jointed nut-like bodies. Without flowers or fruits, Eurasian Water-milfoil is nearly impossible to distinguish from Northern Water-milfoil. Eurasian Water-milfoil has 9-21 pairs of leaflets per leaf, while Northern milfoil typically has 7-11 pairs of leaflets. Coontail is often mistaken for the milfoils, but does not have individual leaflets.

DISTRIBUTION AND HABITAT: Eurasian milfoil first arrived in Wisconsin in the 1960's. During the 1980's, it began to move from several counties in southern Wisconsin to lakes and waterways in the northern half of the state. As of 1993, Eurasian milfoil was common in 39 Wisconsin counties (54%) and at least 75 of its lakes, including shallow bays in Lakes Michigan and Superior and Mississippi River pools.

Eurasian Water-milfoil grows best in fertile, fine-textured, inorganic sediments. In less productive lakes, it is restricted to areas of nutrient-rich sediments. It has a history of becoming dominant in eutrophic, nutrient-rich lakes, although this pattern is not universal. It is an opportunistic species that prefers highly disturbed lake beds, lakes receiving nitrogen and phosphorous-laden runoff, and heavily used lakes. Optimal growth occurs in alkaline systems with a high concentration of dissolved inorganic carbon. High water temperatures promote multiple periods of flowering and fragmentation.

LIFE HISTORY AND EFFECTS OF INVASION: Unlike many other plants, Eurasian Water-milfoil does not rely on seed for reproduction. Its seeds germinate poorly under natural conditions. It reproduces vegetatively by fragmentation, allowing it to disperse over long distances. The plant produces fragments after fruiting once or twice during the summer. These shoots may then be carried downstream by water currents or inadvertently picked up by boaters. Milfoil is readily dispersed by boats, motors, trailers, bilges, live wells, or bait buckets, and can stay alive for weeks if kept moist.

Once established in an aquatic community, milfoil reproduces from shoot fragments and stolons (runners that creep along the lake bed). As an opportunistic species, Eurasian Water-milfoil is adapted for rapid growth early in spring. Stolons, lower stems, and roots persist over winter and store the carbohydrates that help milfoil claim the water column early in spring, photosynthesize, divide, and form a dense leaf canopy that shades out native aquatic plants. Its ability to spread rapidly by fragmentation and effectively block out sunlight needed for native plant growth often results in monotypic stands. Monotypic stands of Eurasian milfoil provide only a single habitat, and threaten the integrity of aquatic communities in a number of ways; for example, dense stands disrupt predator-prey relationships by fencing out larger fish, and reducing the number of nutrient-rich native plants available for waterfowl.

Dense stands of Eurasian Water-milfoil also inhibit recreational uses like swimming, boating, and fishing. Some stands have been dense enough to obstruct industrial and power generation water intakes. The visual impact that greets the lake user on milfoil-dominated lakes is the flat yellow-green of matted vegetation, often prompting the perception that the lake is "infested" or "dead". Cycling of nutrients from sediments to the water column by Eurasian Water-milfoil may lead to deteriorating water quality and algae blooms of infested lakes. (Taken in its entirety from WDNR, 2010 http://www.dnr.state.wi.us/invasives/fact/milfoil.htm)

Curly-leaf pondweed

DESCRIPTION: Curly-leaf pondweed is an invasive aquatic perennial that is native to Eurasia, Africa, and Australia. It was accidentally introduced to United States waters in the mid-1880s by hobbyists who used it as an aquarium plant. The leaves are reddish-green, oblong, and about 3 inches long, with distinct wavy edges that are finely toothed. The stem of the plant is flat, reddish-brown and grows from 1 to 3 feet long. The plant usually drops to the lake bottom by early August

DISTRIBUTION AND HABITAT: Curly-leaf pondweed is commonly found in alkaline and high nutrient waters, preferring soft substrate and shallow water depths. It tolerates low light and low water temperatures. It has been reported in all states but Maine

LIFE HISTORY AND EFFECTS OF INVASION: Curly-leaf pondweed spreads through burr-like winter buds (turions), which are moved among waterways. These plants can also reproduce by seed, but this plays a relatively small role compared to the vegetative reproduction through turions. New plants form under the ice in winter, making curly-leaf pondweed one of the first nuisance aquatic plants to emerge in the spring.

It becomes invasive in some areas because of its tolerance for low light and low water temperatures. These tolerances allow it to get a head start on and out compete native plants in the spring. In mid-summer, when most aquatic plants are growing, curly-leaf pondweed plants are dying off. Plant die-offs may result in a critical loss of dissolved oxygen. Furthermore, the decaying plants can increase nutrients which contribute to algal blooms, as well as create unpleasant stinking messes on beaches. Curly-leaf pondweed forms surface mats that interfere with aquatic recreation. (Taken in its entirety from WDNR, 2010 http://www.dnr.state.wi.us/invasives/fact/curlyleaf_pondweed.htm)

Reed canary grass

DESCRIPTION: Reed canary grass is a large, coarse grass that reaches 2 to 9 feet in height. It has an erect, hairless stem with gradually tapering leaf blades 3 1/2 to 10 inches long and 1/4 to 3/4 inch in width. Blades are flat and have a rough texture on both surfaces. The lead ligule is membranous and long. The compact panicles are erect or slightly spreading (depending on the plant's reproductive stage), and range from 3 to 16 inches long with branches 2 to 12 inches in length. Single flowers occur in dense clusters in May to mid-June. They are green to purple at first and change to beige over time. This grass is one of the first to sprout in spring, and forms a thick rhizome system that dominates the subsurface soil. Seeds are shiny brown in color.

Both Eurasian and native ecotypes of reed canary grass are thought to exist in the U.S. The Eurasian variety is considered more aggressive, but no reliable method exists to tell the ecotypes apart. It is believed that the vast majority of our reed canary grass is derived from the Eurasian ecotype. Agricultural cultivars of the grass are widely planted.

Reed canary grass also resembles non-native orchard grass (*Dactylis glomerata*), but can be distinguished by its wider blades, narrower, more pointed inflorescence, and the lack of hairs on glumes and lemmas (the spikelet scales). Additionally, bluejoint grass (*Calamagrostis canadensis*) may be mistaken for reed canary in areas where orchard grass is rare, especially in the spring. The highly transparent ligule on reed canary grass is helpful in distinguishing it from the others. Ensure positive identification before attempting control.

DISTRIBUTION AND HABITAT: Reed canary grass is a cool-season, sod-forming, perennial wetland grass native to temperate regions of Europe, Asia, and North America. The Eurasian ecotype has been selected for its vigor and has been planted throughout the U.S. since the 1800's for forage and erosion control. It has become naturalized in much of the northern half of the U.S., and is still being planted on steep slopes and banks of ponds and created wetlands.

Reed canary grass can grow on dry soils in upland habitats and in the partial shade of oak woodlands, but does best on fertile, moist organic soils in full sun. This species can invade most types of wetlands, including marshes, wet prairies, sedge meadows, fens, stream banks, and seasonally wet areas; it also grows in disturbed areas such as bergs and spoil piles.

LIFE HISTORY AND EFFECTS OF INVASION: Reed canary grass reproduces by seed or creeping rhizomes. It spreads aggressively. The plant produces leaves and flower stalks for 5 to 7 weeks after germination in early spring, then spreads laterally. Growth peaks in mid-June and declines in mid-August. A second growth spurt occurs in the fall. The shoots collapse in mid to late summer, forming a dense, impenetrable mat of stems and leaves. The seeds ripen in late June and shatter when ripe. Seeds may be dispersed from one wetland to another by waterways, animals, humans, or machines.

This species prefers disturbed areas, but can easily move into native wetlands. Reed canary grass can invade a disturbed wetland in less than twelve years. Invasion is associated with disturbances including ditching of wetlands, stream channelization, deforestation of swamp forests, sedimentation, and intentional planting. The difficulty of selective control makes reed canary grass invasion of particular concern. Over time, it forms large, monotypic stands that harbor few other plant species and are subsequently of little use to wildlife. Once established, reed canary grass dominates an area by building up a tremendous seed bank that can eventually erupt, germinate, and recolonize treated sites. (Taken in its entirety from WDNR, 2010 http://www.dnr.state.wi.us/invasives/fact/reed_canary.htm)

Purple loosestrife
(Photo Courtesy Brian M. Collins)

DESCRIPTION: Purple loosestrife is a perennial herb 3-7 feet tall with a dense bushy growth of 1-50 stems. The stems, which range from green to purple, die back each year. Showy flowers vary from purple to magenta, possess 5-6 petals aggregated into numerous long spikes, and bloom from August to September. Leaves are opposite, nearly linear, and attached to four-sided stems without stalks. It has a large, woody taproot with fibrous rhizomes that form a dense mat.

This species may be confused with the native wing-angled loosestrife (*Lythrum alatum*) found in moist prairies or wet meadows. The latter has a winged, square stem and solitary paired flowers in the leaf axils. It is generally a smaller plant than the Eurasian loosestrife.

By law, purple loosestrife is a nuisance species in Wisconsin. It is illegal to sell, distribute, or cultivate the plants or seeds, including any of its cultivars.

DISTRIBUTION AND HABITAT: Purple loosestrife is a wetland herb that was introduced as a garden perennial from Europe during the 1800's. It is still promoted by some horticulturists for its beauty as a landscape plant, and by beekeepers for its nectar-producing capability. Currently, about 24 states have laws prohibiting its importation or distribution because of its aggressively invasive characteristics. It has since extended its range to include most temperate parts of the United States and Canada. The plant's reproductive success across North America can be attributed to its wide tolerance of physical and chemical conditions characteristic of disturbed habitats, and its ability to reproduce prolifically by both seed dispersal and vegetative propagation. The absence of natural predators, like European species of herbivorous beetles that feed on the plant's roots and leaves, also contributes to its proliferation in North America

LIFE HISTORY AND EFFECTS OF INVASION: Purple loosestrife can germinate successfully on substrates with a wide range of pH. Optimum substrates for growth are moist soils of neutral to slightly acidic pH, but it can exist in a wide range of soil types. Most seedling establishment occurs in late spring and early summer when temperatures are high.

Purple loosestrife spreads mainly by seed, but it can also spread vegetatively from root or stem segments. A single stalk can produce from 100,000 to 300,000 seeds per year. Seed survival is up to 60-70%, resulting in an extensive seed bank. Mature plants with up to 50 shoots grow over 2 meters high and produce more than two million seeds a year. Germination is restricted to open, wet soils and requires high temperatures, but seeds remain viable in the soil for many years. Even seeds submerged in water can live for approximately 20 months. Most of the seeds fall near the parent plant, but water, animals, boats, and humans can transport the seeds long distances. Vegetative spread through local perturbation is also characteristic of loosestrife; clipped, trampled, or buried stems of established plants may produce shoots and roots. Plants may be quite large and several years old before they begin flowering. It is often very difficult to locate non-flowering plants, so monitoring for new invasions should be done at the beginning of the flowering period in mid-summer.

Any sunny or partly shaded wetland is susceptible to purple loosestrife invasion. Vegetative disturbances such as water drawdown or exposed soil accelerate the process by providing ideal conditions for seed germination. Invasion usually begins with a few pioneering plants that build up a large seed bank in the soil for several years. When the right disturbance occurs, loosestrife can spread rapidly, eventually taking over the entire wetland. The plant can also make morphological adjustments to accommodate changes in the immediate environment; for example, a decrease in light level will trigger a change in leaf morphology. The plant's ability to adjust to a wide range of environmental conditions gives it a competitive advantage; coupled with its reproductive strategy, purple loosestrife tends to create monotypic stands that reduce biotic diversity.

Purple loosestrife displaces native wetland vegetation and degrades wildlife habitat. As native vegetation is displaced, rare plants are often the first species to disappear. Eventually, purple loosestrife can overrun wetlands thousands of acres in size, and almost entirely eliminate the open water habitat. The plant can also be detrimental to recreation by choking waterways. (Taken in its entirety from WDNR, 2010 http://www.dnr.state.wi.us/invasives/fact/loosestrife.htm)

Appendix IX: Glossary of Biological Terms (Adapted from UWEX 2010)

Aquatic:
: organisms that live in or frequent water.

Cultural Eutrophication:
: accelerated eutrophication that occurs as a result of human activities in the watershed that increase nutrient loads in runoff water that drains into lakes.

Dissolved Oxygen (DO):
: the amount of free oxygen absorbed by the water and available to aquatic organisms for respiration; amount of oxygen dissolved in a certain amount of water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water.

Diversity:
: number and evenness of species in a particular community or habitat.

Drainage lakes:
: Lakes fed primarily by streams and with outlets into streams or rivers. They are more subject to surface runoff problems but generally have shorter residence times than seepage lakes. Watershed protection is usually needed to manage lake water quality.

Ecosystem:
: a system formed by the interaction of a community of organisms with each other and with the chemical and physical factors making up their environment.

Eutrophication:
: the process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae growth. This process includes physical, chemical, and biological changes that take place after a lake receives inputs for plant nutrients--mostly nitrates and phosphates--from natural erosion and runoff from the surrounding land basin. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Exotic:
: a non-native species of plant or animal that has been introduced.

Habitat:
: the place where an organism lives that provides an organism's needs for water, food, and shelter. It includes all living and non-living components with which the organism interacts.

Limnology:
: the study of inland lakes and waters.

Littoral:

the near shore shallow water zone of a lake, where aquatic plants grow.

Macrophytes:

Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

Nutrients:

elements or substances such as nitrogen and phosphorus that are necessary for plant growth. Large amounts of these substances can become a nuisance by promoting excessive aquatic plant growth.

Organic Matter:

elements or material containing carbon, a basic component of all living matter.

Photosynthesis:

the process by which green plants convert carbon dioxide (CO2) dissolved in water to sugar and oxygen using sunlight for energy. Photosynthesis is essential in producing a lake's food base, and is an important source of oxygen for many lakes.

Phytoplankton:

microscopic plants found in the water. Algae or one-celled (phytoplankton) or multicellular plants either suspended in water (Plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll a (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provides the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short.

Plankton:

small plant organisms (phytoplankton and nanoplankton) and animal organisms (zooplankton) that float or swim weakly though the water.

ppm:

parts per million; units per equivalent million units; equal to milligrams per liter (mg/l)

Richness:
number of species in a particular community or habitat.

Rooted Aquatic Plants:
(macrophytes) Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

Runoff:
water that flows over the surface of the land because the ground surface is impermeable or unable to absorb the water.

Secchi Disc:
An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration). The disc is lowered into water until it disappears from view. It is then raised until just visible. An average of the two depths, taken from the shaded side of the boat, is recorded as the Secchi disc reading. For best results, the readings should be taken on sunny, calm days.

Seepage lakes:
Lakes without a significant inlet or outlet, fed by rainfall and groundwater. Seepage lakes lose water through evaporation and groundwater moving on a down gradient. Lakes with little groundwater inflow tend to be naturally acidic and most susceptible to the effects of acid rain. Seepage lakes often have long, residence times. and lake levels fluctuate with local groundwater levels. Water quality is affected by groundwater quality and the use of land on the shoreline.

Turbidity:
degree to which light is blocked because water is muddy or cloudy.

Watershed:
the land area draining into a specific stream, river, lake or other body of water. These areas are divided by ridges of high land.

Zooplankton:
Microscopic or barely visible animals that eat algae. These suspended plankton are an important component of the lake food chain and ecosystem. For many fish, they are the primary source of food.

Appendix X: 2020 Raw Data Spreadsheets

HorseshoeLakeBarronPolkCoWBIC2630100PISurveyFinalData816-172020MBergERSLLC.xlsx