June and August SCUBA Dive Assessment and August Warm-water Point-intercept Survey for Eurasian water milfoil (*Myriophyllum spicatum*) George Lake - WBIC: (2465700) Bayfield County, Wisconsin

Eurasian water milfoil (Berg 2007)

George Lake Aerial Photo (2010)

Project Initiated by: The Town of Barnes, Bayfield County Land and Water Conservation, and the Wisconsin Department of Natural Resources (Grant AIRR-112-12)

Vasey's pondweed (Skawinski 2010)

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ABSTRACT

George Lake (WBIC 2465700) is a 50 acre oligotrophic seepage lake located in west-central Bayfield County, Wisconsin. The lake's average depth is 16ft, and the bottom substrate is predominantly sand and sandy/muck. Water clarity is good to very good with Secchi values averaging 13.0ft from 2000-2015. In July 2011, Eurasian water milfoil (*Myriophyllum spicatum*) was discovered in the lake. Because of this, the Town of Barnes and the Wisconsin Department of Natural Resources commissioned an initial full point-intercept macrophyte survey on August 4, 2011. This was followed by a June 5, 2012 herbicide treatment. Despite many volunteer surveys to look for EWM in both 2012 and 2013, no evidence of surviving plants was found. Because of this, the TOB requested a follow up full point-intercept survey and SCUBA search of the treatment areas on August 19, 2013, SCUBA surveys in 2014, and two SCUBA and a final point-intercept survey in 2015. We also found no evidence of EWM in the lake during any of these SCUBA or point-intercept surveys. During the August 11, 2015 point-intercept survey, we found macrophytes are 141 points or 69.1% of the entire lake bottom and in 89.2% of the 26ft littoral zone - a significant increase from 2013 when there were plants at 116 sites in the then 28ft littoral zone, and a further increase over 2011 when plants were located at 109 points in the then 24ft littoral zone. The 40 species in the rake (up from 36 in 2013 and 35 in 2011) produced an exceptionally high Simpson Diversity Index value of 0.93 (identical to 2013 and 2011). However, localized richness was relatively low at 2.54 mean native species/site with vegetation (a moderately significant increase from 2.03 in 2013 and 2.06 in 2011). Just as in 2013 and 2011, our 2015 survey again found Slender naiad (*Najas flexilis*) to be the most common species present at 39.01% of sites with vegetation. Small pondweed (*Potamogeton pusillus*) was the second most common at 36.88% sites; Northern naiad (*Najas gracillima*) the third most common at 21.28% of sites; and Variable pondweed (*Potamogeton gramineus*) the fourth most common at 16.31% of sites. Similar to previous years, the total relative frequency of these top four species was 44.69%. Compared with the 2013 survey, Small pondweed experienced a highly significant increase; and Variable pondweed and Baltic rush (*Juncus arcticus*) both had significant increases. Four other species - filamentous algae, Slender waterweed (*Elodea nuttallii*), Softstem bulrush (*Schoenoplectus tabernaemontani*), and Coontail (*Ceratophyllum demersum*) - experienced significant declines. As no active management has occurred on the lake since 2012, the most likely explanation for these changes is rising water levels. The 27 native index species found in the rake during the 2015 August survey produced an average mean Coefficient of Conservatism of 6.7 and a Floristic Quality Index of 34.8 that was much above the median FQI for this part of the state (up from 24 species with a mean Coefficient of Conservatism of 6.8 and a Floristic Quality Index of 33.1 in 2013; and 26 species with a mean C of 6.4 and an FQI of 32.8 during the 2011 survey. A few patches of Narrow-leaved cattail (*Typha angustifolia*) growing along the shoreline were the only exotic species found.

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INTRODUCTION:

George Lake (WBIC 2465700) is a 50 acre seepage lake on the west-central edge of Bayfield County, Wisconsin in the Town of Barnes (T45N R9W S18 SE SW). It reaches a maximum depth of 50ft at the southwest end of the southern basin and has an average depth of approximately 16ft (WDNR 2009). The lake is oligotrophic bordering on mesotrophic in nature with Secchi readings from 2000 to 2015 averaging 13.0ft (WDNR 2015). This good to very good water clarity produced a littoral zone that extended to 26ft in August of 2015. The bottom substrate is predominately sand along the shoreline, but this gradually transitions to sandy muck at most depths over 6ft (Figure 1) (Sather et al. 1971).

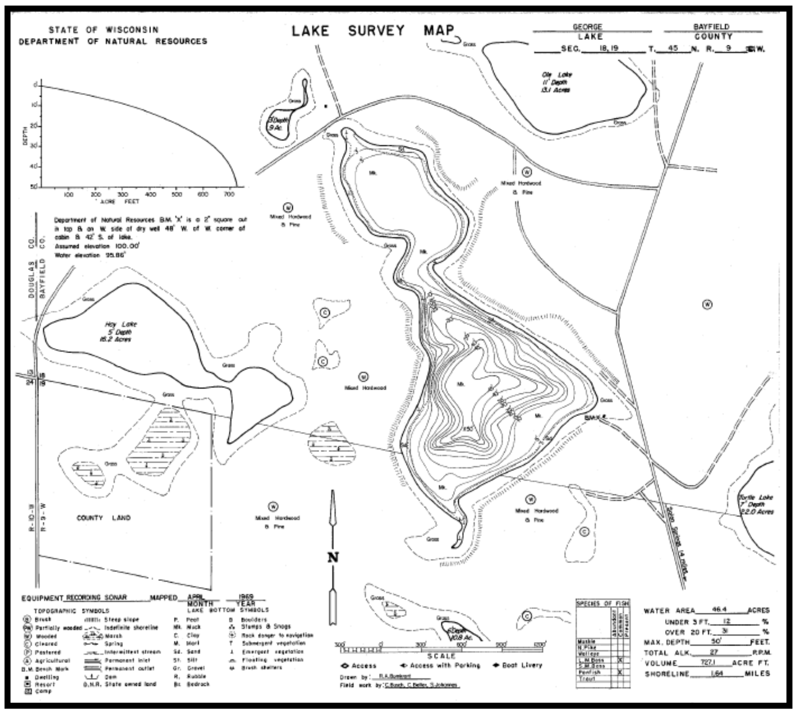


Figure 1: George Lake Bathymetric Map

Eurasian water milfoil (*Myriophyllum spicatum*) (EWM) is an exotic invasive plant species that is a growing problem in the lakes and rivers of northwestern Wisconsin. Present in nearby Tomahawk and Sandbar Lakes since 2004, EWM was first found in George Lake in July, 2011. Because of this discovery, the Town of Barnes (TOB) and the Wisconsin Department of Natural Resources (WDNR) authorized a lakewide systematic point-intercept macrophyte survey on August 4th, 2011. This survey was used to help plan an herbicide treatment on June 5th, 2012. Although volunteers have searched the lake many times since that treatment, they have been unable to locate any surviving EWM. A follow-up point-intercept survey in 2013, and dive surveys in 2013 and 2014 also failed to locate any surviving EWM. Prior to their grant expiring, another point-intercept survey was requested for August 2015 by the TOB and WDNR. The goals of the survey were to again look for EWM and further quantify any changes in the lake's vegetation since the treatment. They also requested two transect SCUBA surveys in the south basin to look for any EWM the point-intercept surveys may have missed. This report is the summary analysis of these three field surveys.

METHODS:

June and August EWM Shoreline Transect and SCUBA Survey:

In June and prior to the August point-intercept survey, we searched the entire visible littoral zone on the lake looking for any evidence of Eurasian water-milfoil. Following the boat survey, we used SCUBA to look for EWM plants around the south basin; especially focusing on the southeastern shoreline where EWM was known to have occurred prior to the herbicide treatment. Joined by John Kudlas – George Lake resident and Ingemar Ekstrom – TOB Board, we swam transects parallel to shore throughout the littoral zone.

August Warm-water Full Point-intercept Survey:

Using a standard formula that takes into account the shoreline shape and distance, water clarity, depth, and total lake acres, Michelle Nault (WDNR) generated the 224 point sampling grid for George Lake that was used during the 2011, 2013, and 2015 surveys (Appendix I). Prior to beginning the point-intercept survey, we conducted a rapid boat survey of the lake to regain familiarity with the species present (Appendix II). All plants found were identified, and, if it was a species not found in 2011 or 2013, two vouchers were pressed and mounted with one to be sent to the state herbarium in Stevens Point for identification confirmation and another to be retained by the TOB. During the point-intercept survey, we located each sampel point using a handheld mapping GPS unit (Garmin 76CSX) and recorded a depth reading with a metered pole rake or hand held sonar (Vexilar LPS-1). At each of these points, we used the rake to sample an approximately 2.5ft section of the bottom. 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 plants within six feet of the sample point. In addition to a rake rating for each species, a total rake fullness rating was also noted. Substrate type (lake bottom) was assigned at each site where the bottom was visible or it could be reliably determined using the rake.

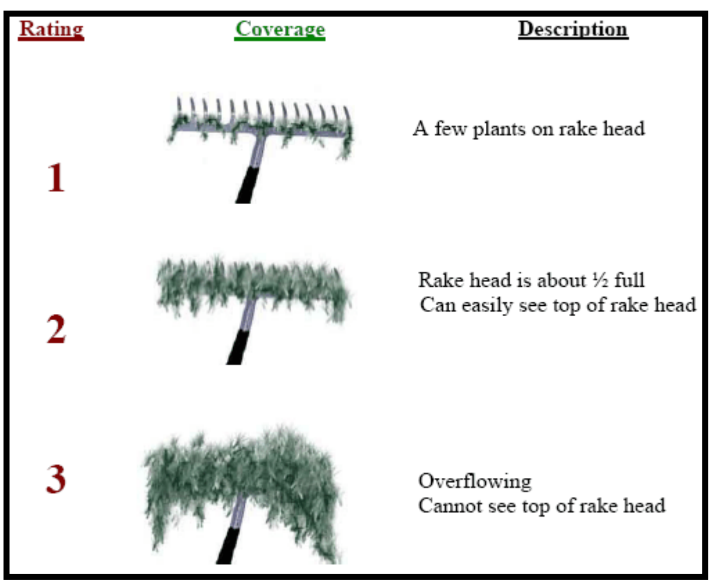


Figure 2: Rake Fullness Ratings (UWEX 2010)

DATA ANALYSIS:

We entered all data collected into the standard APM spreadsheet (Appendix II) (UWEX, 2010). From this, we calculated the following:

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

Total number of sites with vegetation: These included all sites where vegetation was found 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, this value is used 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 lake's 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 individuals (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>Number of sites sampled using rope/pole rake:</u> This indicates which rake type was used to take a sample. As is standard protocol, we use a 15ft pole rake and a 25ft rope rake for sampling.

<u>Average number of species per site:</u> This value is reported using four different considerations. 1) **shallower than the 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 the 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 additional visual species seen at a point but not found in the rake, and additional species found during the initial boat survey or between points.

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>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 (Table 1).

Relative frequency: This value shows species' frequency relative to all other species. It is expressed as a percentage, and the total of all species' relative frequency 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 5 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 an area'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, Northern 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. George Lake is in the Northern Lakes and 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 2011, 2013, and 2015 surveys 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/Post Survey Worksheet. For comparing averages (mean species/point and mean rake fullness/point), we used t-tests. Differences were considered significant at $p < .05$, moderately significant at $p < .01$ and highly significant at $p < .005$ (UWEX 2010). It should be noted that we used the number of littoral points as the basis for "sample points" in the statistical calculation as changing water levels and clarity resulted in a changing littoral zone (2011 – 139 littoral points; 2013 – 146 littoral points; 2015 – 158 littoral points).

RESULTS:

June and August EWM Shoreline Transect and SCUBA Surveys:

On June 17th, we searched the visible littoral zone of the lake and completed two SCUBA transects around the south basin following the 5ft and 10ft contour. Visibility was excellent, and we could see 10-15ft in each direction. In 2011, there were a very few lilypad beds in water over 4ft and the bulk of the Eurasian water-milfoil plants in the south basin was found around them. Despite taking an especially slow and careful looks at the bottom throughout these areas, we again turned up nothing to suggest that EWM was still present anywhere in the lake. Water marigold (*Bidens beckii*), the only near look alike to EWM in the lake, was present in a very narrow habitat band from approximately 6-8ft (Figure 3). It was more common than in either 2011 or 2013, but it never canopies and is not bed forming making it relatively easy to identify.

On August 11th, we again searched the entire visible littoral zone by boat and repeated the SCUBA transect survey. We again found no evidence of EWM - either rooted plants or floating fragments.

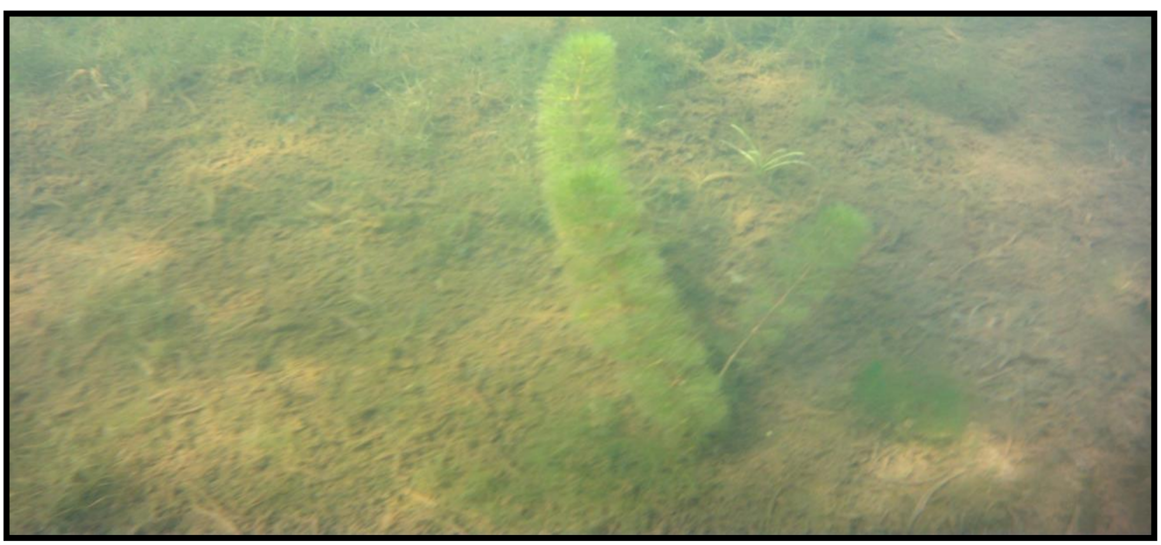


Figure 3: Water Marigold – EWM Look-alike

August Warm-water Full Point-intercept Survey:

The George Lake survey grid contained 224 points (Figure 4); however, due to years of prolonged drought, 20 of these points were terrestrial at the time of the 2015 survey (down from 36 terrestrial points in 2013 and 38 points in 2011). Depth soundings taken at these points revealed the north bay is a shallow flat that has a maximum depth of 5.0ft. Conversely, the southern basin is a bowl that drops off rapidly from shore with the deep hole on the southwest side reaching 51.5ft at the time of the 2015 survey (Figure 4) (Appendix III).

Sugar sand lined the margins of the majority of the lake. This quickly transitioned to sandy muck at most depths beyond 6ft. The only dark organic muck occurred in parts of the north bay, and in the east and south bays of the south basin. Of the 158 survey points where we could determine the substrate, 67.7% were muck and sandy muck, 32.6% were pure sand, and a single nearshore point (0.7%) was gravel (Figure 4) (Appendix III).

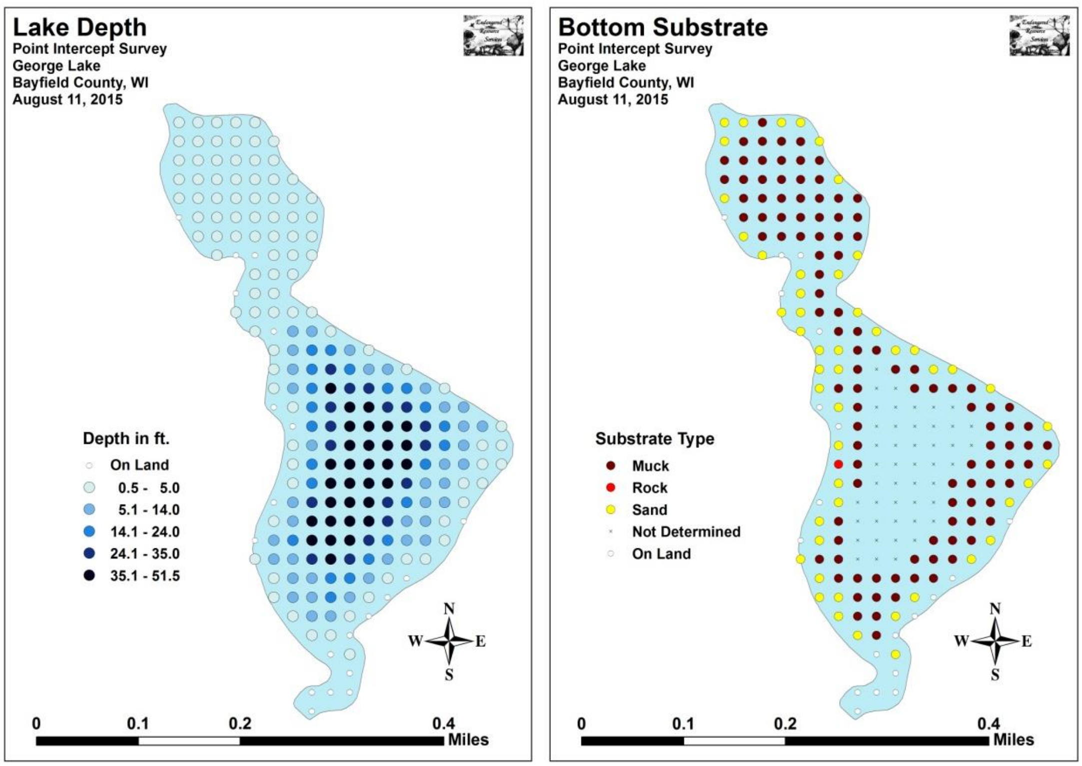


Figure 4: Lake Depth and Bottom Substrate

In 2015, we found plants growing at 141 sites which equated to 69.1% of the current lake bottom and in 89.2% of the 26.0ft littoral zone (Table 1). This was a significant increase over the 116 sites with plants (61.7% of the 188 submerged points in 2013 and 79.5% of the then 28.0ft littoral zone. It was also a further increase over 2011 when plants were located at 109 points, and covered 58.6% of the lake bottom (186 submerged points) and 78.4% of the 24.0ft littoral zone (Figure 5). As in past years, growth was strongly skewed to deep water as the mean depth was 7.1ft (identical to 7.1 in 2013 and up from 6.5 in 2011), but the median depth was only 4.0ft (down from 4.5ft in 2013 but up from 3.5ft in 2011) (Appendix IV).

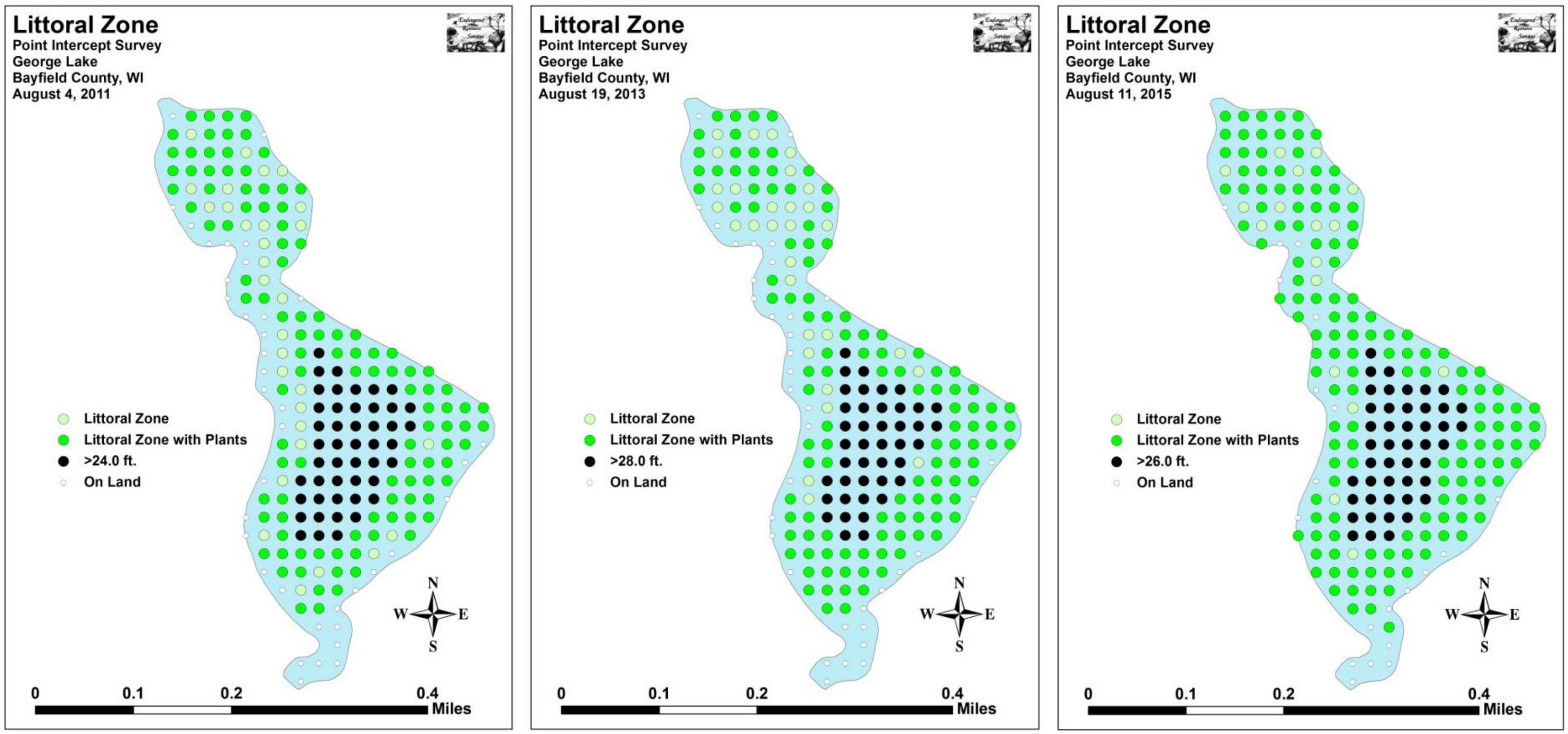


Figure 5: 2011, 2013, and 2015 Littoral Zone

Table 1: Aquatic Macrophyte P/I Survey Summary Statistics
George Lake, Bayfield County
August 4, 2011, August 19, 2013, and August 11, 2015

Summary Statistics:	2011	2013	2015	*p*
Total number of points sampled	186	188	204	n.s.
Total number of sites with vegetation	109	116	141	+*
Total number of sites shallower than the maximum depth of plants	139	146	158	n.s.
Frequency of occurrence at sites shallower than maximum depth of plants	78.4	79.5	89.24	+*
Simpson Diversity Index	0.93	0.93	0.93	n.s.
Maximum depth of plants (ft)	24.0	28.0	26.0	n.s.
Mean depth of plants (ft)	6.5	7.1	7.1	n.s.
Median depth of plants (ft)	3.5	4.5	4.0	n.s.
Average number of all species per site (shallower than max depth)	1.61	1.64	2.27	+***
Average number of all species per site (veg. sites only)	2.06	2.06	2.54	+**
Average number of native species per site (shallower than max depth)	1.55	1.64	2.27	+***
Average number of native species per site (veg. sites only)	2.03	2.06	2.54	+**
Species richness	36	35	40	n.s.
Species richness (including visuals)	40	38	44	n.s.
Species richness (including visuals and boat survey)	45	44	46	n.s.
Mean rake fullness (veg. sites only)	1.81	1.61	1.92	+***

Significant differences = * $p < .05$, ** $p < .01$, *** $p < .005$

Plant diversity on George Lake continues to be exceptionally high as we documented a Simpson Diversity Index value of 0.93 in 2011, 2013, and 2015. Total richness, after falling from 36 species in the rake in 2011 to 35 in 2013, jumped to 40 in 2015. In total, we found 46 species in and immediately adjacent to the lake (similar to 45 in 2011 and 44 in 2013). Despite this high total richness value, localized native species richness at sites with vegetation was relatively low at 2.54 species in 2015. This was, however, a moderately significant jump from 2.03 in 2011/2.06 in 2013 (Figure 6) (Appendix V).

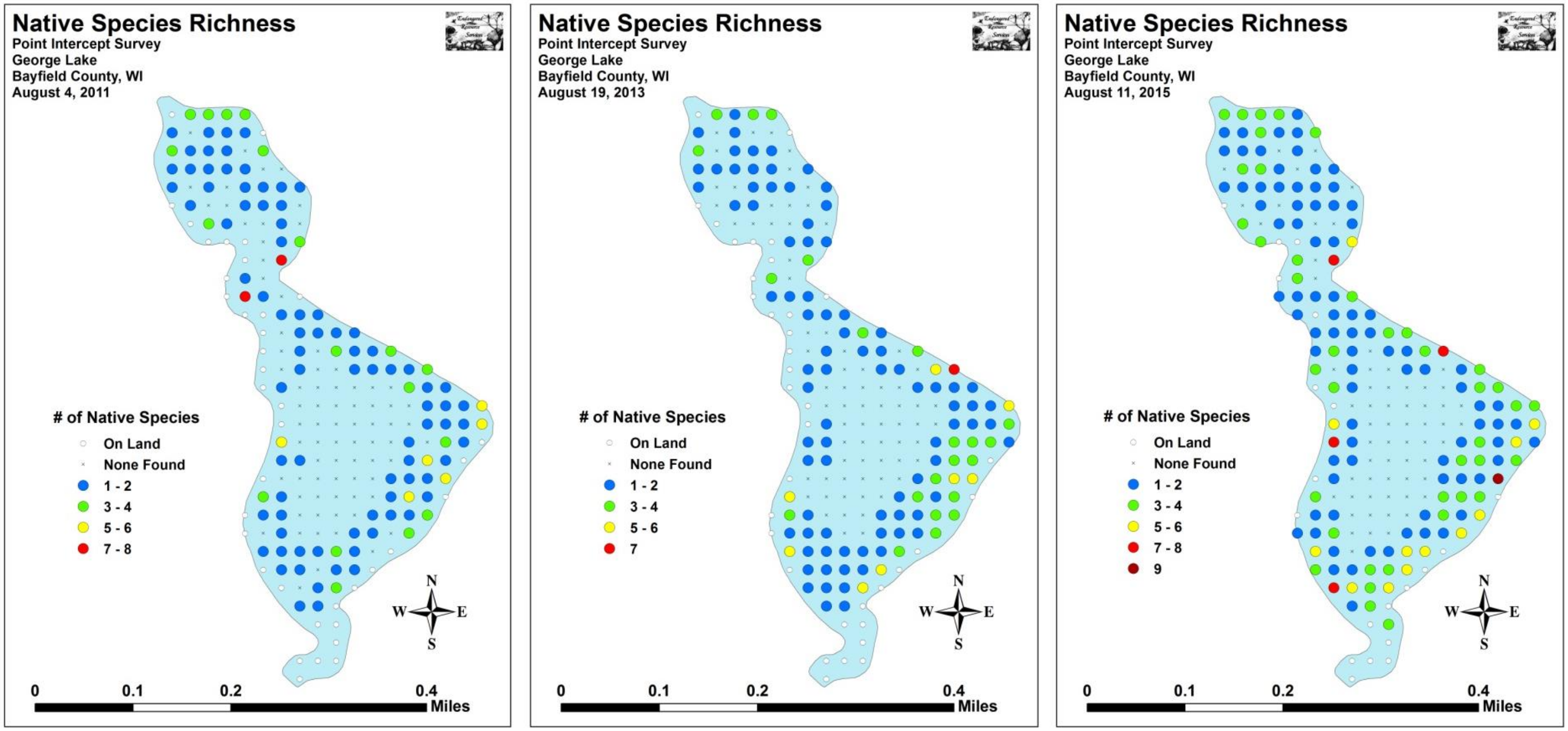


Figure 6: 2011, 2013, and 2015 Native Species Richness

Mean total rake fullness was moderately low in 2011 at 1.81. This dropped to a low 1.61 in 2013 before demonstrating a highly significant increase to a more moderate value of 1.92 in 2013. Most of this increase occurred along the southeastern shoreline and in the pinch point between the north bay and the southern basin (Figure 7) (Appendix V).

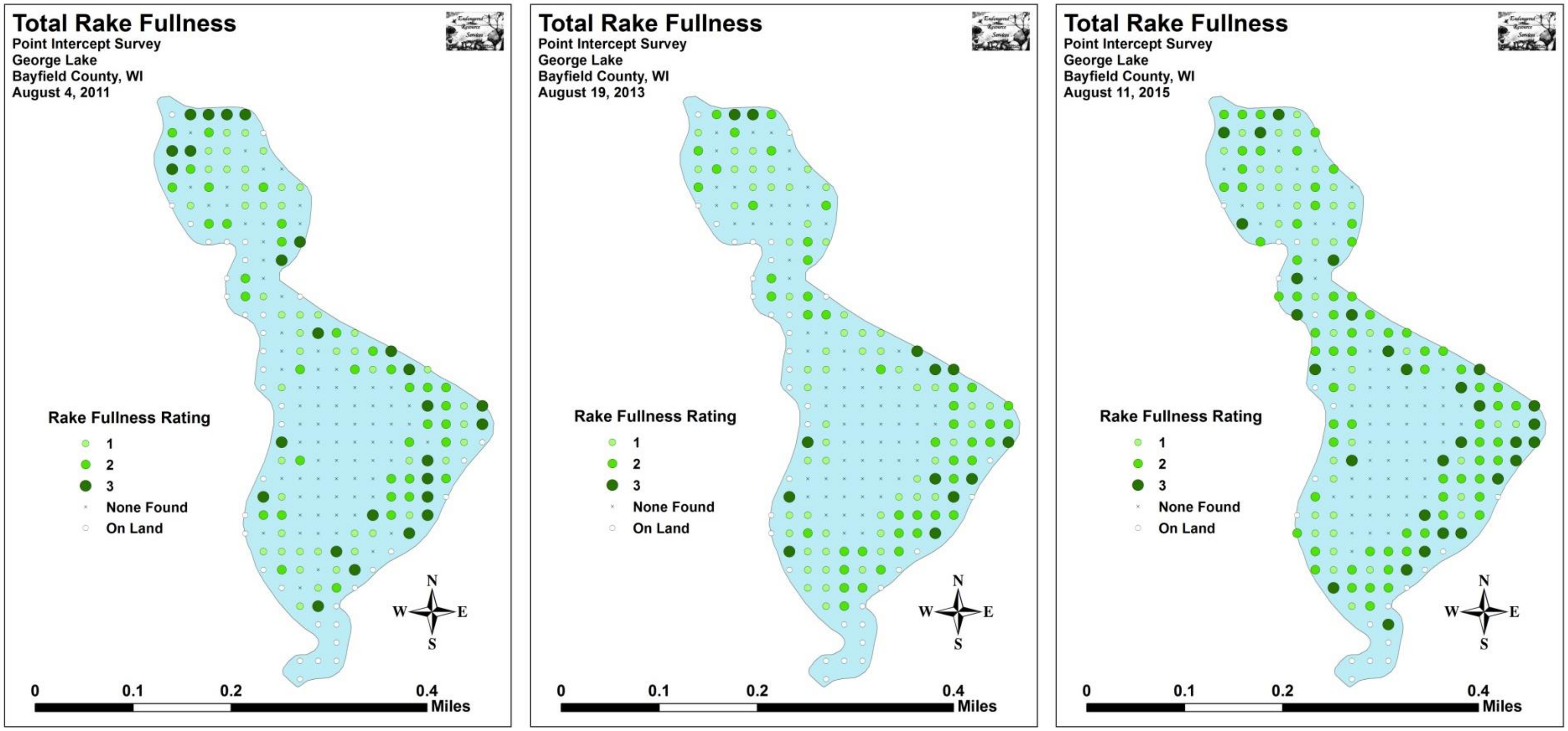


Figure 7: 2011, 2013, and 2015 Total Rake Fullness

Comparison of EWM in 2011, 2013, and 2015:

The 2011 point-intercept survey found EWM at just three points (2.75% of the littoral zone) which resulted in a relative frequency of 1.34 (Table 2). Of these, one had a rake fullness of 3, and the remaining two a 1 which produced a mean rake fullness of 1.67. EWM was also reported as a visual at six additional points (Figure 8) (Appendix V). Following the June 5, 2012 herbicide treatment, we found no evidence of EWM during either the 2013 or 2015 point-intercept surveys (Figure 8). Although only the drop in visual sightings from 2011 to 2013 was statistically significant (Figure 9), these results were obviously highly significant from a management standpoint.

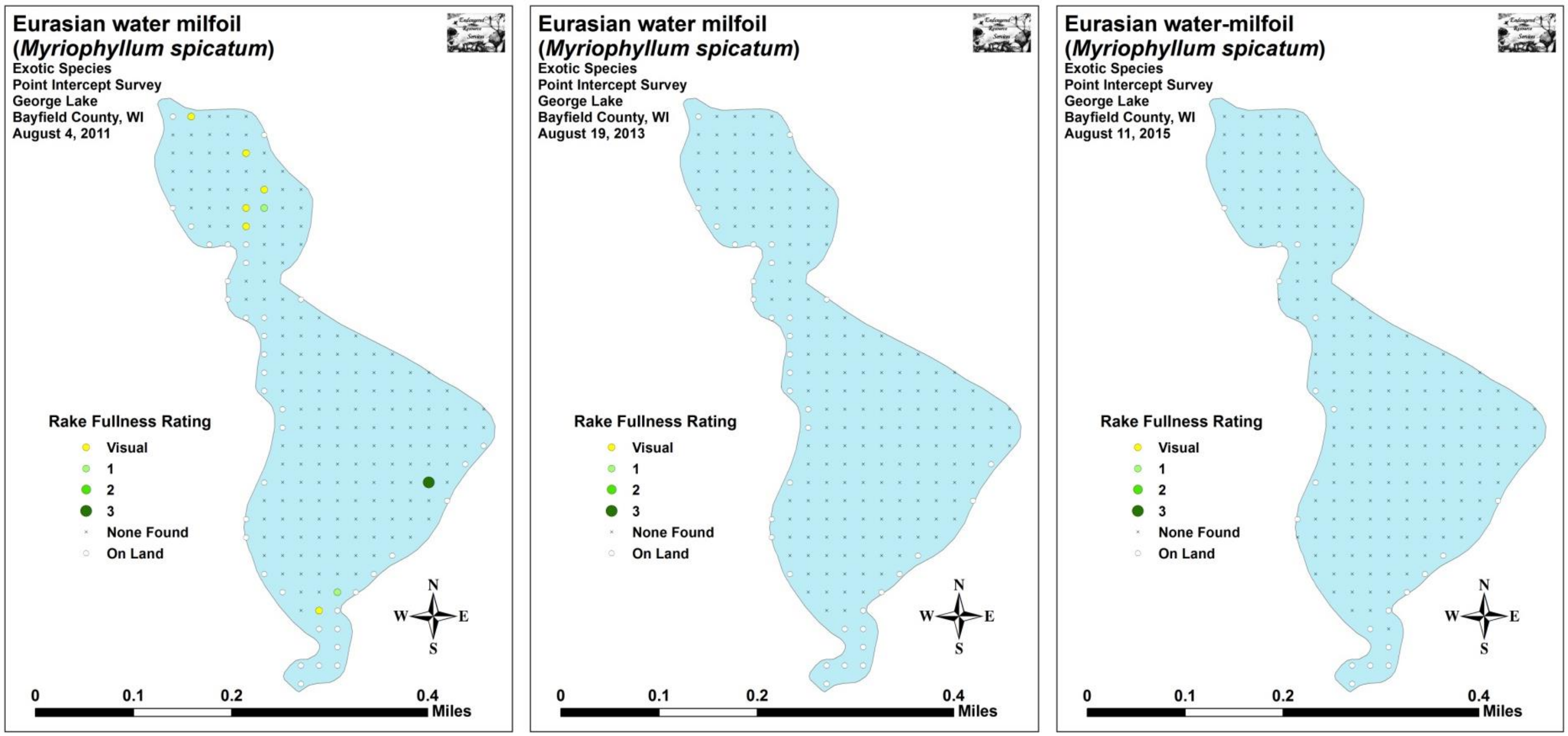
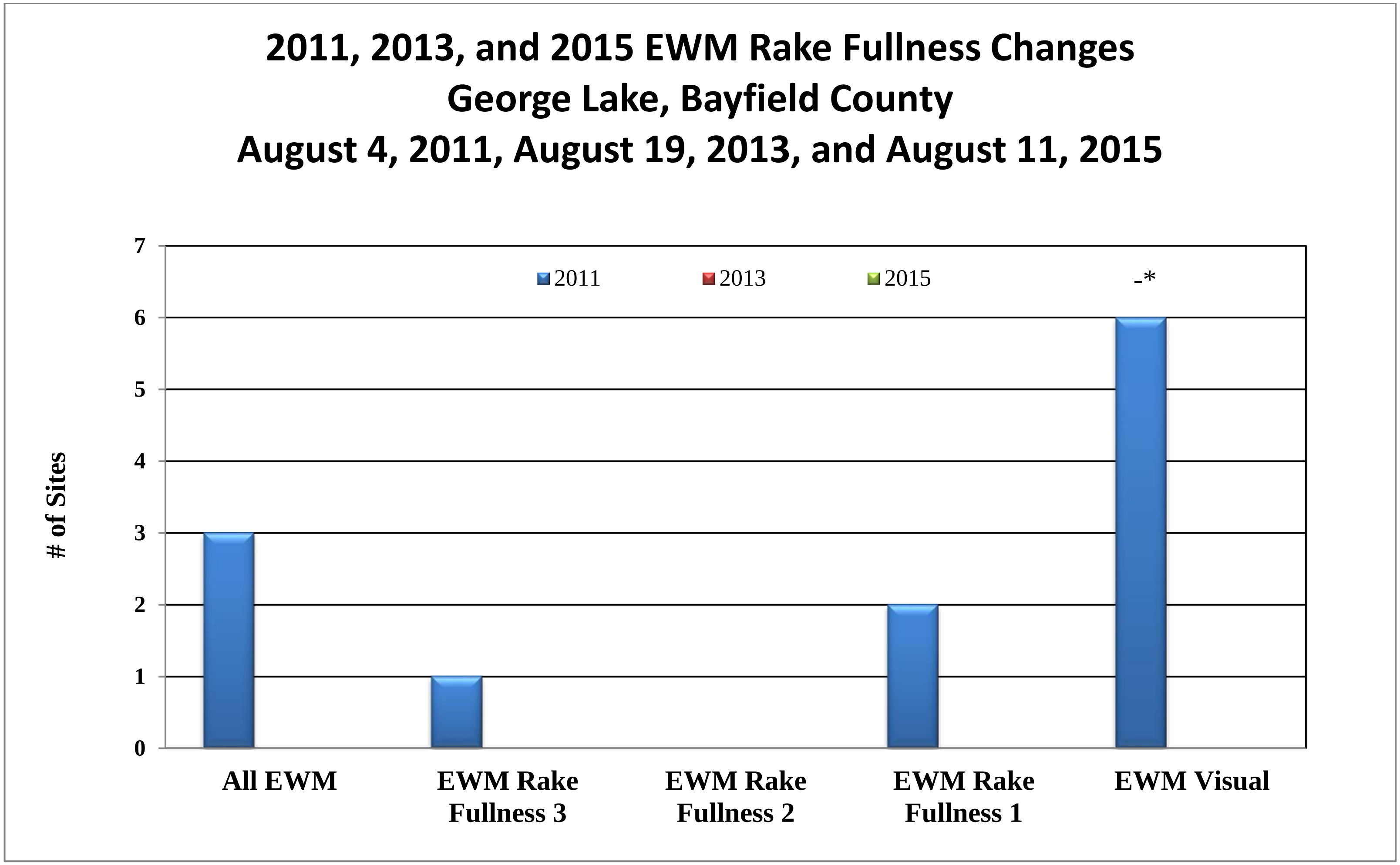


Figure 8: 2011, 2013, 2015 EWM Density and Distribution



Significant differences = * *p* < .05, ** *p* < .01, * *p* < .005**

Figure 9: 2011, 2013, and 2015 Changes in EWM Rake Fullness

Comparison of Native Species in 2011, 2013, and 2015:

In 2011, Slender naiad (*Najas flexilis*), Nitella (*Nitella* sp.), Small pondweed (*Potamogeton pusillus*), and White water lily (*Nymphaea odorata*) were the most common species (Table 2). They were found at 31.19%, 21.10%, 20.18% and 16.51% of survey points with vegetation respectively. Collectively, they accounted for 43.30% of the total relative frequency. Muskgrass (*Chara* sp.) (5.36), Needle spikerush (*Eleocharis acicularis*) (4.46), and Fern pondweed (*Potamogeton robbinsii*) (4.02) were the only other species with relative frequency values over 4.0 (Maps for species found in 2011 are available in the CD attached to this report).

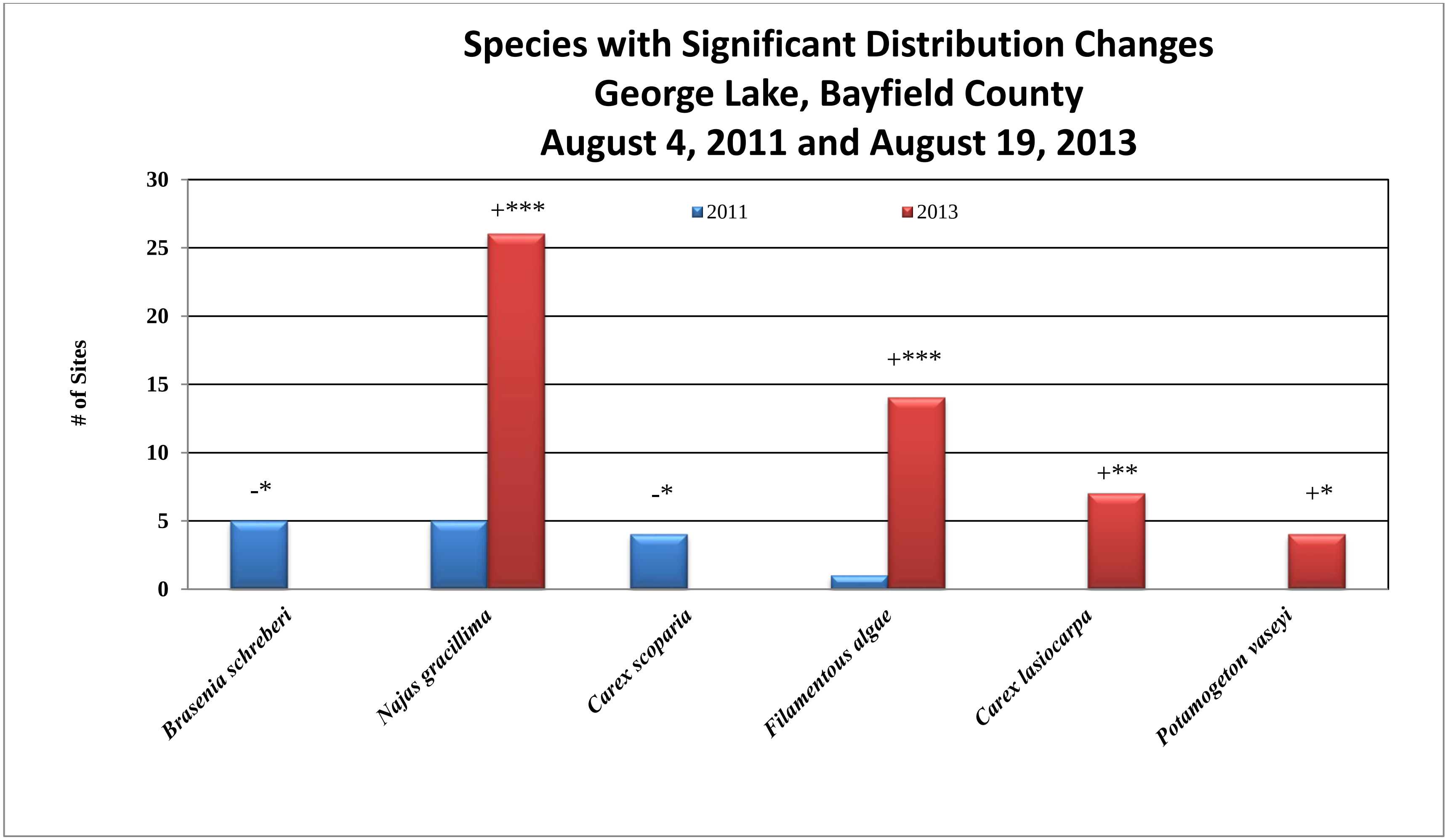
In 2013, Slender naiad, Northern naiad (*Najas gracillima*), Nitella, and Small pondweed were the most common native species being found at 31.90%, 22.41%, 19.83%, and 16.38% of sites with vegetation (Table 3). Similar to 2011, the top four species accounted for 43.93% of the total relative frequency (Table 3). White water lily (5.86), Muskgrass (4.60), Slender waterweed (4.60), Creeping spikerush (*Eleocharis palustris*) (4.18), and Variable pondweed (*Potamogeton gramineus*) (4.18) (Maps for all species found in 2011 and 2013 along with habitat descriptions are located in the CD attached to this report).

Our 2015 survey again found Slender naiad to be the most common species present at 39.01% of sites with vegetation (Table 4). Small pondweed was the second most common at 36.88%; Northern naiad the third most common at 21.28% of sites; and Variable pondweed the fourth most common at 16.31%. Similar to previous years, the total relative frequency of these top four species was 44.69%. White water lily (6.15), Nitella (5.31), Muskgrass (5.03), Creeping spikerush (5.03), and Hardstem bulrush (*Schoenoplectus acutus*) (4.75) also had relative frequencies over 4.0 (Maps for all species found in 2015 are located in Appendix VI).

From 2011 to 2013, six species showed significant changes in distribution (Figure 10). We documented a highly significant increase in Northern naiad and filamentous algae; a moderately significant increase in Narrow-leaved woolly sedge (*Carex lasiocarpa*); and a significant increase in Vasey's pondweed (*Potamogeton vaseyi*). Conversely, Watershield (*Brasenia schreberi*) and Broom sedge (*Carex scoparia*) showed significant decreases.

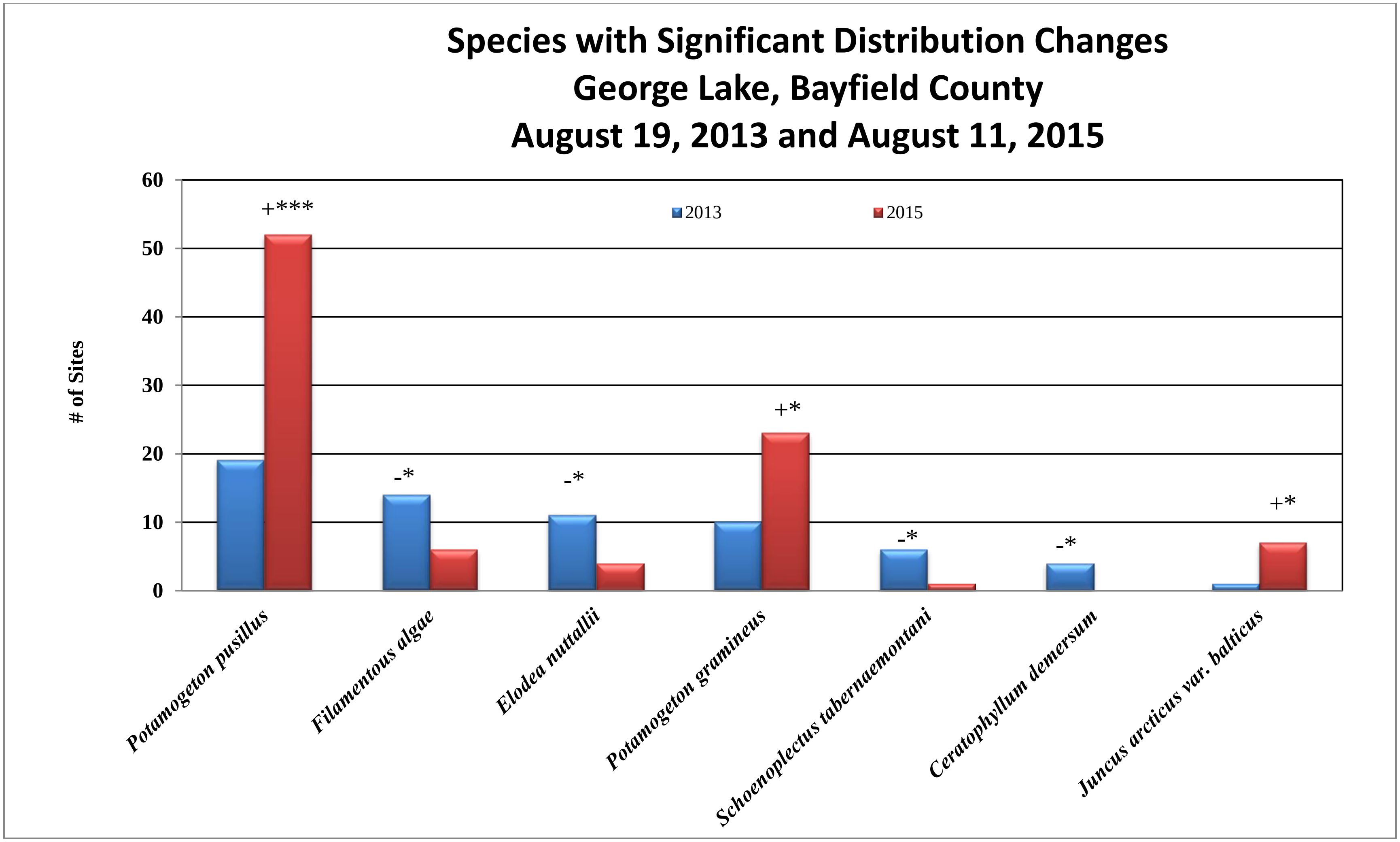
The increase/decrease in the different species of sedge is likely due to shifting water levels as we noted several new sedges in 2013 not seen in 2011 as well as several sedges present in 2011 that were not located in 2013. We can offer no explanation about the increases in Northern naiad and Vasey's pondweed other than the changing water levels may have allowed seeds/nutlets in the substrate to germinate. Watershield, a dicot, may have been negatively impacted by the 2012 herbicide treatment, but, other than White water lily, we didn't note any other native species that seem to have declined posttreatment.

Following the 2015 survey, we found seven species demonstrated significant changes since the 2013 survey (Figure 11). Small pondweed experienced a highly significant increase; and Variable pondweed and Baltic rush (*Juncus arcticus*) both had significant increases. The other four species, filamentous algae, Slender waterweed (*Elodea nuttallii*), Softstem bulrush (*Schoenoplectus tabernaemontani*), and Coontail (*Ceratophyllum demersum*) all experienced significant declines. As no active management has occurred on the lake since 2012, the most likely explanation for these changes is rising water levels.



Significant differences = * p < .05, ** p < .01, *** p < .005

Figure 10: Macrophytes Showing Significant Distribution Changes from 2011-2013



Significant differences = * *p* < .05, ** *p* < .01, * *p* < .005**

Figure 11: Macrophytes Showing Significant Distribution Changes from 2013-2015

Table 2: Frequencies and Mean Rake Sample of Aquatic Macrophytes
George Lake, Bayfield County
August 4, 2011

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Najas flexilis	Slender naiad	34	15.18	31.19	24.46	1.35	7
Nitella sp.	Nitella	23	10.27	21.10	16.55	1.57	0
Potamogeton pusillus	Small pondweed	22	9.82	20.18	15.83	1.14	0
Nymphaea odorata	White water lily	18	8.04	16.51	12.95	1.78	13
Chara sp.	Muskgrass	12	5.36	11.01	8.63	1.33	0
Eleocharis acicularis	Needle spikerush	10	4.46	9.17	7.19	1.00	0
Potamogeton robbinsii	Fern pondweed	9	4.02	8.26	6.47	1.67	0
Eleocharis palustris	Creeping spikerush	8	3.57	7.34	5.76	1.38	3
Potamogeton X *spathuliformis*	Illinois pondweed hybrid	8	3.57	7.34	5.76	1.38	1
Juncus canadensis	Canada rush	7	3.13	6.42	5.04	1.71	3
Schoenoplectus tabernaemontani	Softstem bulrush	7	3.13	6.42	5.04	1.86	9
Brasenia schreberi	Watershield	5	2.23	4.59	3.60	1.80	3
Ceratophyllum demersum	Coontail	5	2.23	4.59	3.60	1.80	0
Leersia oryzoides	Rice cut-grass	5	2.23	4.59	3.60	1.40	6
Najas gracillima	Northern naiad	5	2.23	4.59	3.60	1.20	0
Potamogeton spirillus	Spiral-fruited pondweed	5	2.23	4.59	3.60	1.60	0
Carex scoparia	Broom sedge	4	1.79	3.67	2.88	1.25	0
Carex utriculata	Common yellow lake sedge	4	1.79	3.67	2.88	2.50	1
Elodea nuttallii	Slender waterweed	4	1.79	3.67	2.88	1.00	0
Potamogeton gramineus	Variable pondweed	4	1.79	3.67	2.88	1.50	1
Juncus effusus	Common rush	3	1.34	2.75	2.16	2.00	0
Juncus pelocarpus	Brown-fruited rush	3	1.34	2.75	2.16	1.00	1
Myriophyllum spicatum	Eurasian water milfoil	3	1.34	2.75	2.16	1.67	6
Carex cryptolepis	Small yellow sedge	2	0.89	1.83	1.44	2.00	2
Potamogeton amplifolius	Large-leaf pondweed	2	0.89	1.83	1.44	1.00	2

Table 2 (cont'): Frequencies and Mean Rake Sample of Aquatic Macrophytes
George Lake, Bayfield County
August 4, 2011

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Schoenoplectus acutus	Hardstem bulrush	2	0.89	1.83	1.44	2.50	4
Bidens beckii	Water marigold	1	0.45	0.92	0.72	1.00	0
Carex lurida	Shallow sedge	1	0.45	0.92	0.72	2.00	0
Dulichium arundinaceum	Three-way sedge	1	0.45	0.92	0.72	1.00	0
Juncus brevicaudatus	Narrow-panicled rush	1	0.45	0.92	0.72	1.00	0
Nuphar variegata	Spatterdock	1	0.45	0.92	0.72	2.00	1
Polygonum amphibium	Water smartweed	1	0.45	0.92	0.72	1.00	1
Potamogeton foliosus	Leafy pondweed	1	0.45	0.92	0.72	2.00	1
Sagittaria latifolia	Common arrowhead	1	0.45	0.92	0.72	2.00	0
Scirpus cyperinus	Woolgrass	1	0.45	0.92	0.72	1.00	2
Sparganium angustifolium	Narrow-leaved bur-reed	1	0.45	0.92	0.72	1.00	3
	Filamentous algae	1	*	0.92	0.72	1.00	0
Drosera rotundifolia	Round-leaved sundew	**	**	**	**	**	1
Eleocharis ovata	Oval spikerush	**	**	**	**	**	1
Potamogeton epihydrus	Ribbon-leaf pondweed	**	**	**	**	**	1
Typha latifolia	Broad-leaved cattail	**	**	**	**	**	2
Carex viridula	Green yellow sedge	***	***	***	***	***	***
Juncus arcticus var. balticus	Baltic rush	***	***	***	***	***	***
Lipocarpha micrantha	Small-flowered hemicarpha	***	***	***	***	***	***
Myriophyllum sibiricum	Northern water milfoil	***	***	***	***	***	***
Typha angustifolia	Narrow-leaved cattail	***	***	***	***	***	***

* Algae are excluded from the Relative Frequency Calculation   ** Visual Only   *** Boat Survey Only

Table 3: Frequencies and Mean Rake Sample of Aquatic Macrophytes
George Lake, Bayfield County
August 19, 2013

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Najas flexilis	Slender naiad	37	15.48	31.90	25.34	1.27	3
Najas gracillima	Northern naiad	26	10.88	22.41	17.81	1.42	0
Nitella sp.	Nitella	23	9.62	19.83	15.75	1.30	0
Potamogeton pusillus	Small pondweed	19	7.95	16.38	13.01	1.21	3
Nymphaea odorata	White water lily	14	5.86	12.07	9.59	1.36	15
	Filamentous algae	14	*	12.07	9.59	1.00	0
Chara sp.	Muskgrass	11	4.60	9.48	7.53	1.18	0
Elodea nuttallii	Slender waterweed	11	4.60	9.48	7.53	1.36	1
Eleocharis palustris	Creeping spikerush	10	4.18	8.62	6.85	1.80	3
Potamogeton gramineus	Variable pondweed	10	4.18	8.62	6.85	1.10	3
Potamogeton X *spathuliformis*	Illinois pondweed hybrid	8	3.35	6.90	5.48	1.25	1
Carex lasiocarpa	Narrow-leaved woolly sedge	7	2.93	6.03	4.79	1.43	3
Schoenoplectus acutus	Hardstem bulrush	7	2.93	6.03	4.79	1.71	4
Juncus canadensis	Canada rush	6	2.51	5.17	4.11	1.50	1
Potamogeton robbinsii	Fern pondweed	6	2.51	5.17	4.11	1.50	0
Schoenoplectus tabernaemontani	Softstem bulrush	6	2.51	5.17	4.11	1.33	2
Ceratophyllum demersum	Coontail	4	1.67	3.45	2.74	1.25	0
Eleocharis acicularis	Needle spikerush	4	1.67	3.45	2.74	1.00	0
Potamogeton vaseyi	Vasey's pondweed	4	1.67	3.45	2.74	1.25	0
Carex atherodes	Hairy-leaved lake sedge	3	1.26	2.59	2.05	1.67	2
Potamogeton spirillus	Spiral-fruited pondweed	3	1.26	2.59	2.05	1.00	1
Carex utriculata	Common yellow lake sedge	2	0.84	1.72	1.37	2.50	1
Juncus brevicaudatus	Narrow-panicled rush	2	0.84	1.72	1.37	1.00	1
Leersia oryzoides	Rice cut-grass	2	0.84	1.72	1.37	1.00	0

* Excluded from the Relative Frequency Calculation

Table 3 (cont'): Frequencies and Mean Rake Sample of Aquatic Macrophytes
George Lake, Bayfield County
August 19, 2013

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Scirpus cyperinus	Woolgrass	2	0.84	1.72	1.37	1.00	0
Sparganium angustifolium	Narrow-leaved bur-reed	2	0.84	1.72	1.37	1.00	1
Calamagrostis canadensis	Blue-joint	1	0.42	0.86	0.68	1.00	0
Dulichium arundinaceum	Three-way sedge	1	0.42	0.86	0.68	1.00	2
Glyceria borealis	Northern manna grass	1	0.42	0.86	0.68	1.00	1
Glyceria canadensis	Rattlesnake manna grass	1	0.42	0.86	0.68	1.00	0
Juncus arcticus var. balticus	Baltic rush	1	0.42	0.86	0.68	1.00	0
Juncus effusus	Common rush	1	0.42	0.86	0.68	3.00	1
Juncus pelocarpus	Brown-fruited rush	1	0.42	0.86	0.68	1.00	0
Nuphar variegata	Spatterdock	1	0.42	0.86	0.68	2.00	0
Polygonum amphibium	Water smartweed	1	0.42	0.86	0.68	1.00	0
Potamogeton amplifolius	Large-leaf pondweed	1	0.42	0.86	0.68	1.00	5
Brasenia schreberi	Watershield	**	**	**	**	**	1
Carex scoparia	Broom sedge	**	**	**	**	**	3
Utricularia minor	Small bladderwort	**	**	**	**	**	2
Bidens beckii	Water marigold	***	***	***	***	***	***
Carex cryptolepis	Small yellow sedge	***	***	***	***	***	***
Eleocharis ovata	Oval spikerush	***	***	***	***	***	***
Sagittaria latifolia	Common arrowhead	***	***	***	***	***	***
Typha angustifolia	Narrow-leaved cattail	***	***	***	***	***	***
Typha latifolia	Broad-leaved cattail	***	***	***	***	***	***

** Visual Only *** Boat Survey Only

Table 4: Frequencies and Mean Rake Sample of Aquatic Macrophytes
George Lake, Bayfield County
August 11, 2015

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Najas flexilis	Slender naiad	55	15.36	39.01	34.81	1.33	2
Potamogeton pusillus	Small pondweed	52	14.53	36.88	32.91	1.44	1
Najas gracillima	Northern naiad	30	8.38	21.28	18.99	1.27	0
Potamogeton gramineus	Variable pondweed	23	6.42	16.31	14.56	1.39	4
Nymphaea odorata	White water lily	22	6.15	15.60	13.92	1.32	21
Nitella flexilis	Nitella	19	5.31	13.48	12.03	2.00	0
Chara sp.	Muskgrass	18	5.03	12.77	11.39	1.39	0
Eleocharis palustris	Creeping spikerush	18	5.03	12.77	11.39	1.56	2
Schoenoplectus acutus	Hardstem bulrush	17	4.75	12.06	10.76	1.94	7
Juncus canadensis	Canada rush	10	2.79	7.09	6.33	1.80	3
Carex lasiocarpa	Narrow-leaved woolly sedge	9	2.51	6.38	5.70	1.56	3
Potamogeton robbinsii	Fern pondweed	9	2.51	6.38	5.70	1.44	0
Juncus arcticus var. balticus	Baltic rush	7	1.96	4.96	4.43	1.29	0
Potamogeton vaseyi	Vasey's pondweed	7	1.96	4.96	4.43	1.86	1
Eleocharis acicularis	Needle spikerush	6	1.68	4.26	3.80	1.33	0
	Filamentous algae	6	*	4.26	3.80	1.00	0
Juncus brevicaudatus	Narrow-panicle rush	5	1.40	3.55	3.16	1.60	4
Calamagrostis canadensis	Blue-joint	4	1.12	2.84	2.53	2.00	3
Elodea nuttallii	Slender waterweed	4	1.12	2.84	2.53	1.75	0
Potamogeton foliosus	Leafy pondweed	4	1.12	2.84	2.53	1.00	0
Bidens beckii	Water marigold	3	0.84	2.13	1.90	1.00	0
Carex lacustris	Lake sedge	3	0.84	2.13	1.90	1.33	3
Juncus pelocarpus f. submersus	Brown-fruited rush	3	0.84	2.13	1.90	1.33	0
Potamogeton amplifolius	Large-leaf pondweed	3	0.84	2.13	1.90	1.00	9

* Excluded from the Relative Frequency Calculation

Table 4 (cont'): Frequencies and Mean Rake Sample of Aquatic Macrophytes
George Lake, Bayfield County
August 11, 2015

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Potamogeton X spathuliformis	Illinois pondweed hybrid	3	0.84	2.13	1.90	1.33	1
Scirpus cyperinus	Woolgrass	3	0.84	2.13	1.90	1.33	1
Carex utriculata	Common yellow lake sedge	2	0.56	1.42	1.27	3.00	3
Glyceria borealis	Northern manna grass	2	0.56	1.42	1.27	2.00	0
Nuphar variegata	Spatterdock	2	0.56	1.42	1.27	1.50	3
Polygonum amphibium	Water smartweed	2	0.56	1.42	1.27	1.50	6
Potamogeton spirillus	Spiral-fruited pondweed	2	0.56	1.42	1.27	2.00	0
Sparganium angustifolium	Narrow-leaved bur-reed	2	0.56	1.42	1.27	1.00	3
	Freshwater sponge	2	*	1.42	1.27	1.00	0
Brasenia schreberi	Watershield	1	0.28	0.71	0.63	1.00	2
Carex scoparia	Broom sedge	1	0.28	0.71	0.63	1.00	1
Glyceria canadensis	Rattlesnake manna-grass	1	0.28	0.71	0.63	1.00	2
Iris versicolor	Northern blue flag	1	0.28	0.71	0.63	1.00	2
Juncus effusus	Common rush	1	0.28	0.71	0.63	1.00	0
Leersia oryzoides	Rice cut-grass	1	0.28	0.71	0.63	3.00	1
Schoenoplectus tabernaemontani	Softstem bulrush	1	0.28	0.71	0.63	1.00	1
Typha angustifolia	Narrow-leaved cattail	1	0.28	0.71	0.63	1.00	0
Utricularia minor	Small bladderwort	1	0.28	0.71	0.63	1.00	1
Ceratophyllum demersum	Coontail	**	**	**	**	**	1
Dulichium arundinaceum	Three-way sedge	**	**	**	**	**	1
Potamogeton epihydrus	Ribbon-leaf pondweed	**	**	**	**	**	1
Potamogeton natans	Floating-leaf pondweed	**	**	**	**	**	1
Typha latifolia	Broad-leaved cattail	***	***	***	***	***	***
Utricularia vulgaris	Common bladderwort	***	***	***	***	***	***

* Excluded from the Relative Frequency Calculation ** Visual Only *** Boat Survey Only

Slender naiad was the most common species in 2011, 2013, and 2015. From 2011 to 2013, it was almost unchanged in distribution (34 sites in 2011/37 in 2013) and density (mean rake of 1.35 in 2011 and 1.37). Although this density was nearly identical at 1.33 in 2015, the species distribution experienced a nearly significant ($p = 0.07$) increase to 55 sites (Figure 12). Visual analysis of the maps showed most of this increase was in the north bay.

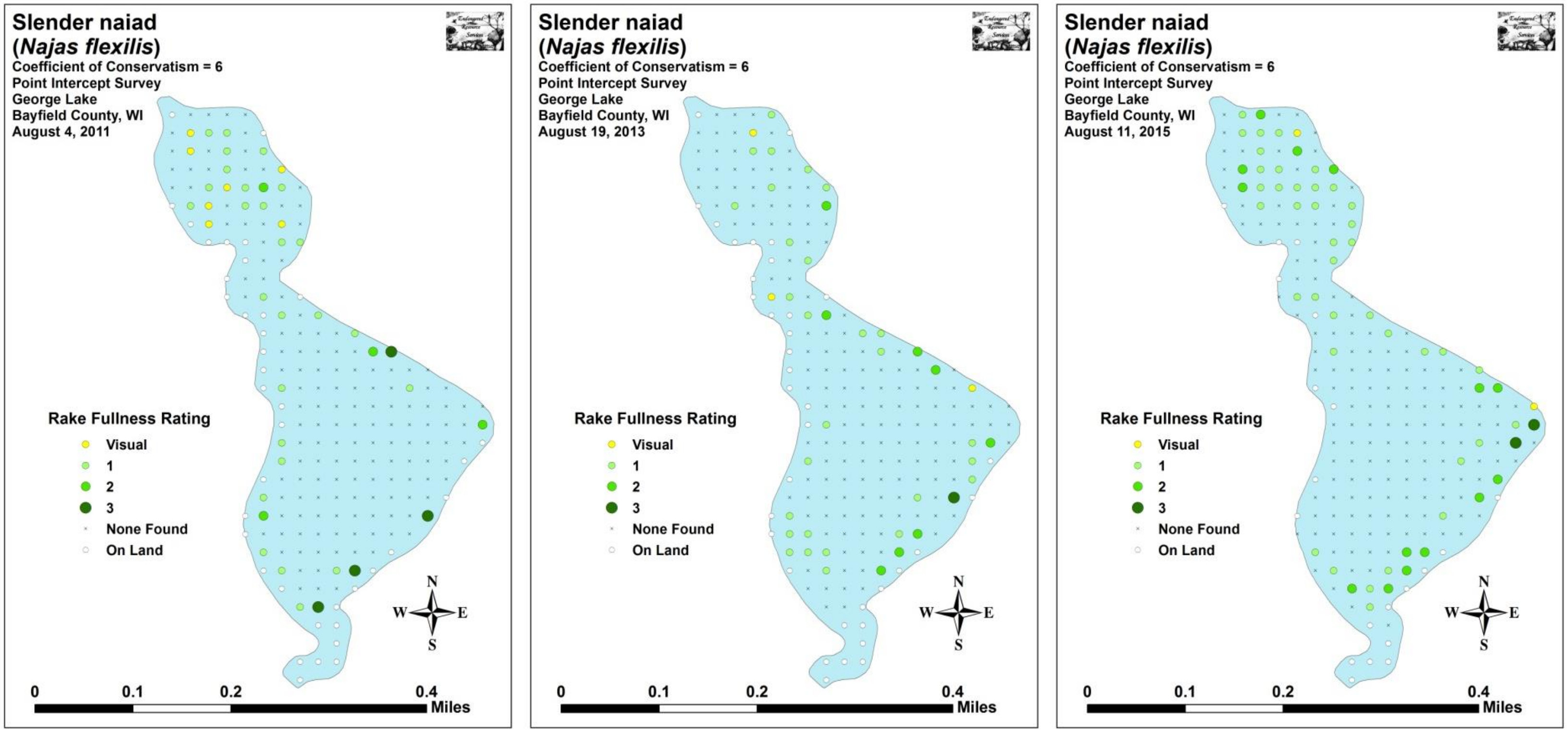


Figure 12: 2011, 2013, and 2015 Slender Naiad Density and Distribution

Nitella was the second most common species in 2011 and the third most common in 2013 (Figure 13). It was unchanged in distribution (23 sites in both 2011 and 2013), but suffered a nearly significant ($p = 0.07$) decline in density from a mean rake of 1.57 in 2011 to 1.30 in 2013. In 2015, it was only the sixth most common species being found at 19 sites. Although this was a non-significant decline in distribution, density experienced a highly significant **increase** ($p = 0.002$) to a mean rake fullness of 2.00. This dense growth occurred in a band around the southern basin and likely simply reflects a shift in the location of optimum growing conditions. This assumption is based on our finding a similar band of dense Nitella in the lake each year from 2011-2015 during our dive surveys.

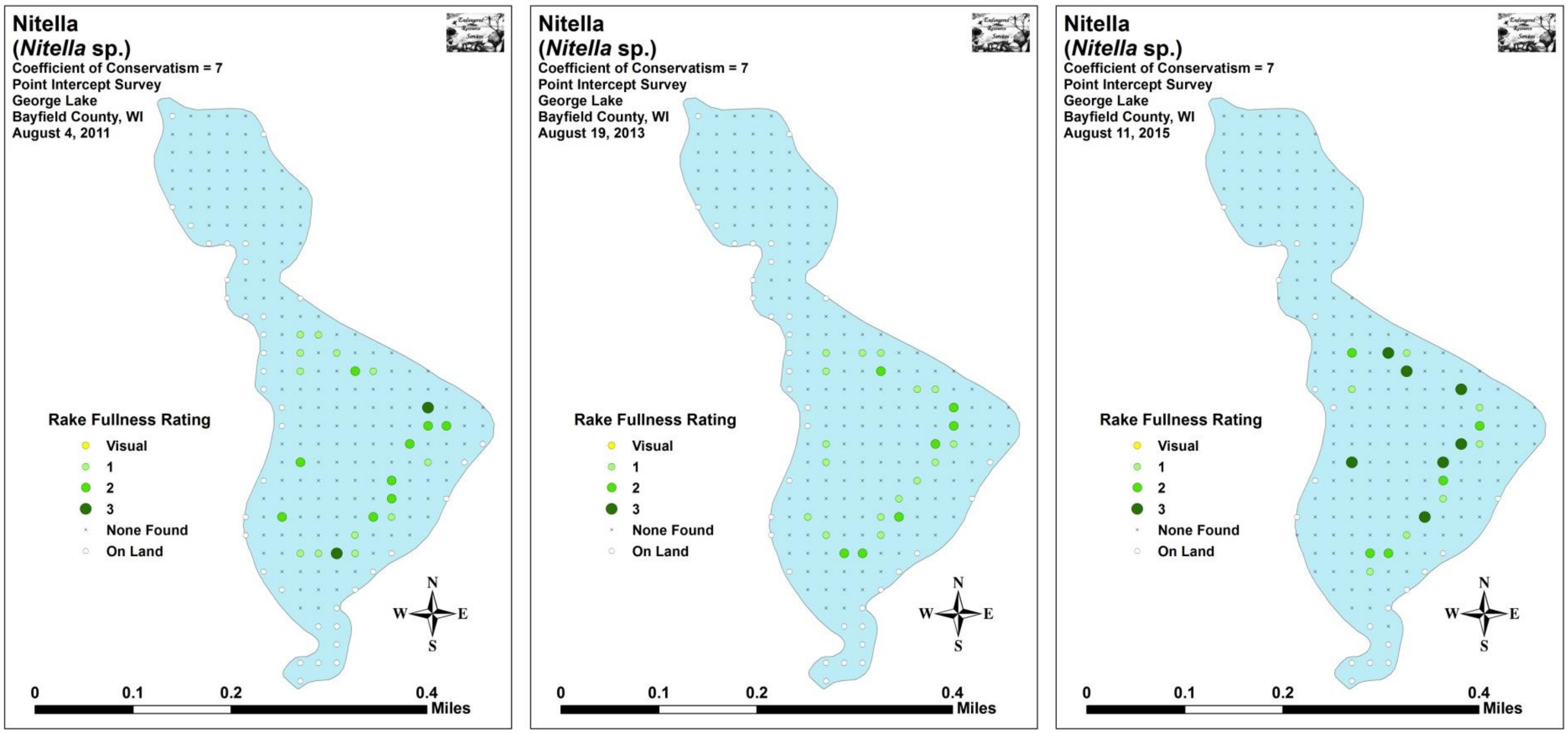


Figure 13: 2011, 2013, and 2015 Nitella Density and Distribution

Small pondweed was the third most common species in 2011, the fourth most common in 2013, and the second most common in 2015 (Figure 14). In 2011, it was present at 22 points with a mean rake fullness of 1.14. In 2013, it experienced an insignificant decline in distribution to 19 sites and an insignificant increase in density to 1.21. However, in 2015, this species underwent a highly significant increase ($p < 0.001$) in distribution (52 sites) and a significant increase ($p = 0.04$) in density (mean rake of 1.44). The majority of this expansion occurred along the eastern shoreline of the south basin, but, for the first time, we also found plants scattered in the north bay.

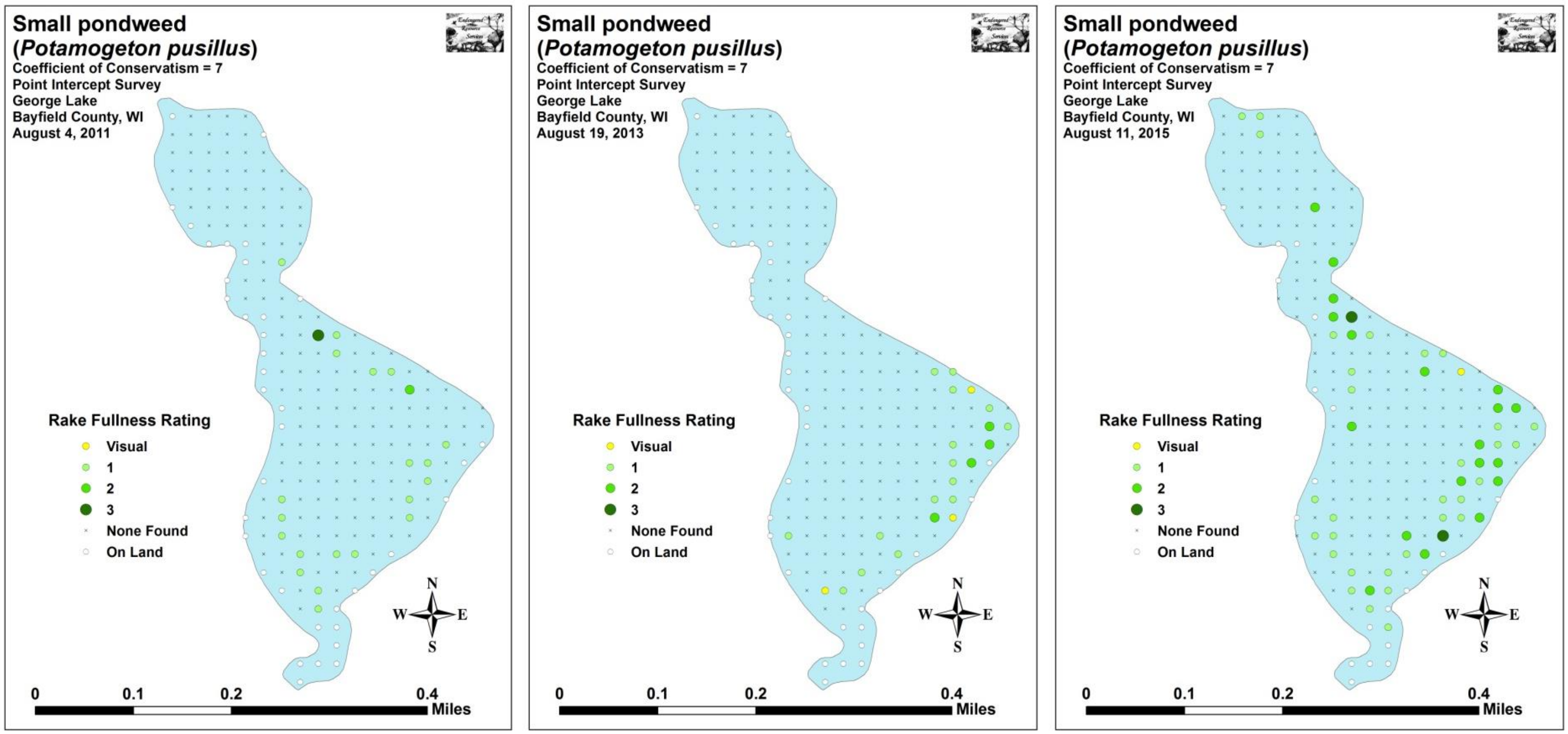


Figure 14: 2011, 2013, and 2015 Small Pondweed Density and Distribution

White water lily, the fourth most common species in 2011, was present at 18 sites with a mean rake fullness of 1.78 (Figure 15). Following the 2012 herbicide application, it was the fifth most common species, and experience a non-significant decline in distribution to 14 sites, but a significant increase (p = 0.02) in density to a mean rake of 1.36. In 2015, we again found it to be the fifth most common species when it was present at 22 sites - a non-significant increase – with a slight decrease in density to 1.32. Most of this increase in distribution occurred in the north bay.

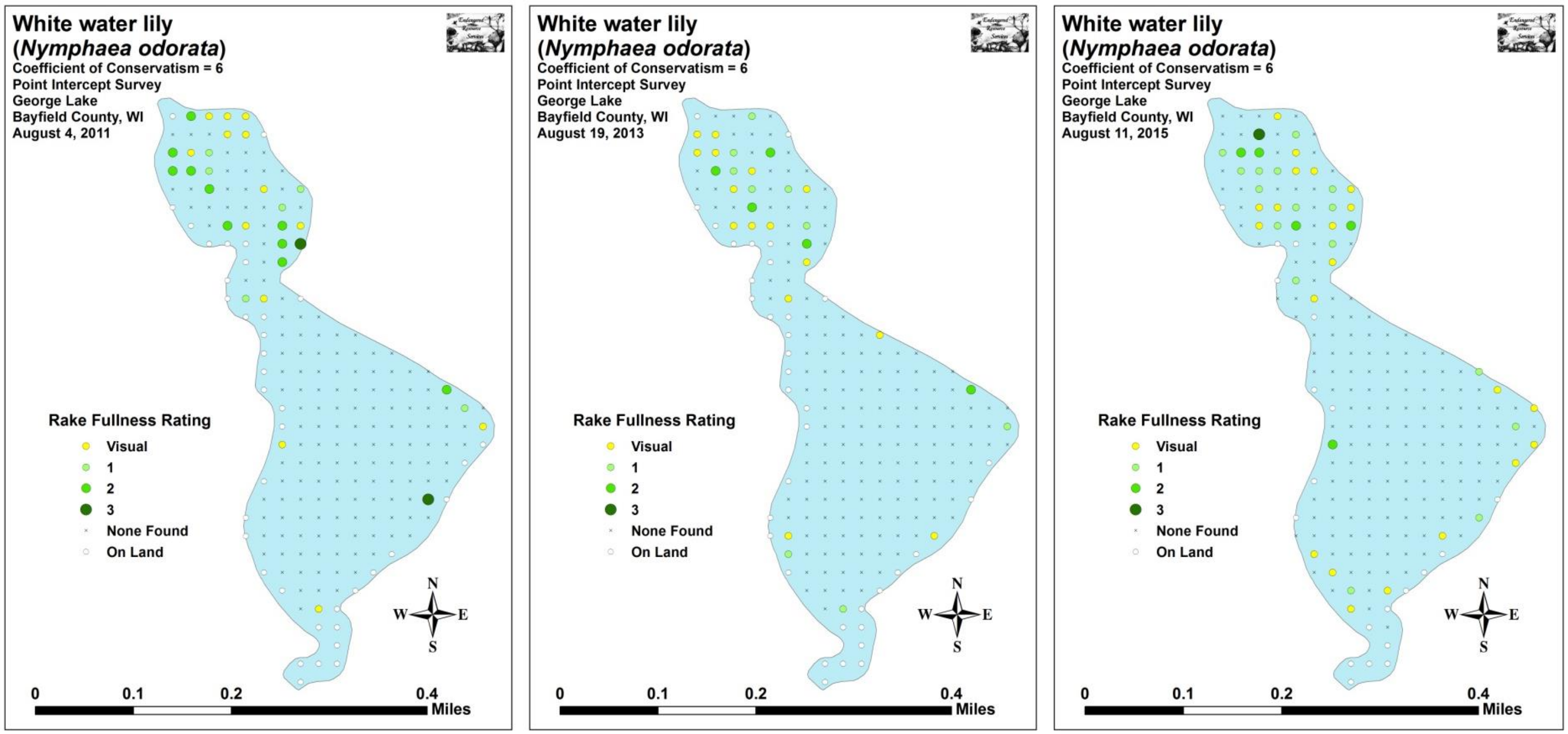


Figure 15: 2011, 2013, and 2015 White Water Lily Density and Distribution

Comparison of Filamentous Algae in 2011, 2013, and 2015:

Filamentous algae, normally associated with excessive nutrients in the water column, were located at 14 survey points in 2011 - a highly significant increase ($p < 0.001$) from 2011 when we found them at a single point (Figure 16). In 2015, these algae experienced a significant decline ($p = 0.04$) and were found at just six sites. As no point in any of the three years had a density higher than a rake fullness of 1, this is probably not of concern, and may be simply related to local nutrient recycling from decomposing plants.

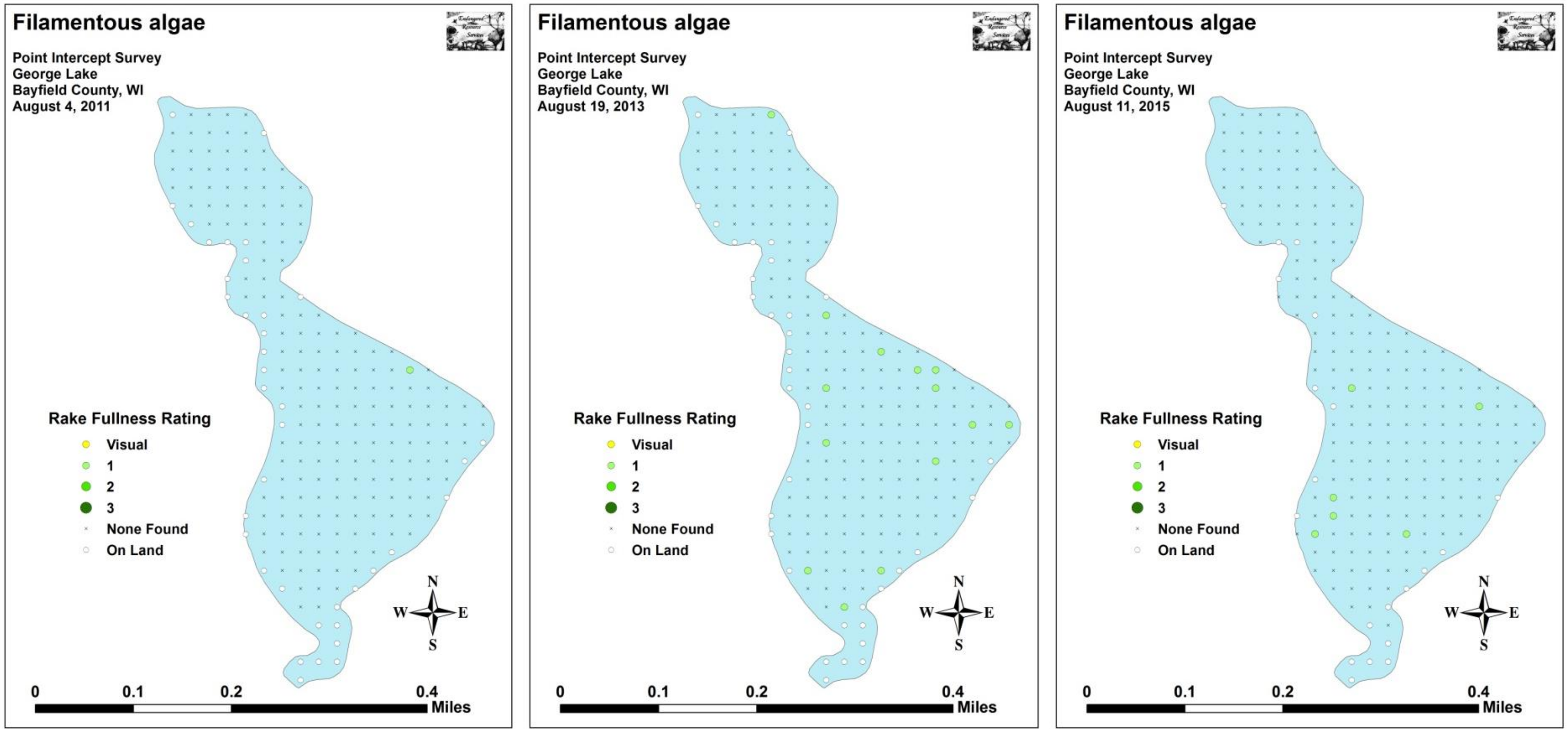


Figure 16: 2011, 2013, and 2015 Filamentous Algae Density and Distribution

Comparison of Floristic Quality Indexes in 2011, 2013 and 2015:

In 2011, we identified a total of 26 **native index species** in the rake during the point-intercept survey (Table 5). They produced a mean Coefficient of Conservatism of 6.4 and a Floristic Quality Index of 32.8.

Table 5: Floristic Quality Index of Aquatic Macrophytes
George Lake, Bayfield County
August 4, 2011

Species	Common Name	C
Bidens beckii	Water marigold	8
Brasenia schreberi	Watershield	6
Ceratophyllum demersum	Coontail	3
Chara sp.	Muskgrass	7
Dulichium arundinaceum	Three-way sedge	9
Eleocharis acicularis	Needle spikerush	5
Eleocharis palustris	Creeping spikerush	6
Elodea nuttallii	Slender waterweed	7
Juncus pelocarpus	Brown-fruited rush	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
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton foliosus	Leafy pondweed	6
Potamogeton gramineus	Variable pondweed	7
Potamogeton X *spathuliformis*	Illinois pondweed hybrid	6
Potamogeton pusillus	Small pondweed	7
Potamogeton robbinsii	Fern pondweed	8
Potamogeton spirillus	Spiral-fruited pondweed	8
Sagittaria latifolia	Common arrowhead	3
Schoenoplectus acutus	Hardstem bulrush	6
Schoenoplectus tabernaemontani	Softstem bulrush	4
Sparganium angustifolium	Narrow-leaved bur-reed	9
N		**26**
Mean C		**6.4**
FQI		**32.8**

In 2013, we identified a total of 24 **native index plants** on the rake during the point-intercept survey. They produced a mean Coefficient of Conservatism of 6.8 and a Floristic Quality Index of 33.1 (Table 6). These values were nearly identical to the 2011 survey totals.

Table 6: Floristic Quality Index of Aquatic Macrophytes George Lake, Bayfield County August 19, 2013

Species	Common Name	C
Ceratophyllum demersum	Coontail	3
Chara sp.	Muskgrass	7
Dulichium arundinaceum	Three-way sedge	9
Eleocharis acicularis	Needle spikerush	5
Eleocharis palustris	Creeping spikerush	6
Elodea nuttallii	Slender waterweed	7
Glyceria borealis	Northern manna grass	8
Juncus pelocarpus	Brown-fruited rush	8
Najas flexilis	Slender naiad	6
Najas gracillima	Northern naiad	7
Nitella flexilis	Nitella	7
Nuphar variegata	Spatterdock	6
Nymphaea odorata	White water lily	6
Polygonum amphibium	Water smartweed	5
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton gramineus	Variable pondweed	7
Potamogeton X *spathuliformis*	Illinois pondweed hybrid	6
Potamogeton pusillus	Small pondweed	7
Potamogeton robbinsii	Fern pondweed	8
Potamogeton spirillus	Spiral-fruited pondweed	8
Potamogeton vaseyi	Vasey's pondweed	10
Schoenoplectus acutus	Hardstem bulrush	6
Schoenoplectus tabernaemontani	Softstem bulrush	4
Sparganium angustifolium	Narrow-leaved bur-reed	9
N		**24**
Mean C		**6.8**
FQI		**33.1**

In 2015, we identified a total of 27 **native index plants** on the rake during the point-intercept survey. They produced a mean Coefficient of Conservatism of 6.7 and a Floristic Quality Index of 34.8 (Table 7). Nichols (1999) reported an average mean C for the Northern Lakes and Forest Region of 6.7 putting George Lake exactly average for this part of the state. The FQI of 33.1 was above the median FQI of 24.3 for the Northern Lakes and Forest Region (Nichols 1999). High value species of note included Narrow-leaved bur-reed (*Sparganium angustifolium*) (C = 9), and Small bladderwort (*Utricularia minor*) (C = 10), and the State Species of Special Concern ** Vasey's pondweed (C = 10).

** "Special Concern" species like Vasey's pondweed 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 George Lake, Bayfield County August 11, 2015

Species	Common Name	C
Bidens beckii	Water marigold	8
Brasenia schreberi	Watershield	6
Chara sp.	Muskgrass	7
Eleocharis acicularis	Needle spikerush	5
Eleocharis palustris	Creeping spikerush	6
Elodea nuttallii	Slender waterweed	7
Glyceria borealis	Northern manna grass	8
Juncus pelocarpus	Brown-fruited rush	8
Najas flexilis	Slender naiad	6
Najas gracillima	Northern naiad	7
Nitella flexilis	Nitella	7
Nuphar variegata	Spatterdock	6
Nymphaea odorata	White water lily	6
Polygonum amphibium	Water smartweed	5
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton foliosus	Leafy pondweed	6
Potamogeton gramineus	Variable pondweed	7
Potamogeton X *spathuliformis*	Illinois pondweed hybrid	6
Potamogeton pusillus	Small pondweed	7
Potamogeton robbinsii	Fern pondweed	8
Potamogeton spirillus	Spiral-fruited pondweed	8
Potamogeton vaseyi	Vasey's pondweed	10
Schoenoplectus acutus	Hardstem bulrush	6
Schoenoplectus tabernaemontani	Softstem bulrush	4
Sparganium angustifolia	Narrow-leaved bur-reed	9
Typha angustifolium	Narrow-leaved cattail	1
Utricularia minor	Small bladderwort	10
N		**27**
Mean C		**6.7**
FQI		**34.8**

Other Exotic Plant Species:

Since the 2012 herbicide treatment, no evidence of Eurasian water milfoil has been found in George Lake. Likewise, we have never found any evidence of other common aquatic and semi-aquatic exotic invasive species like Curly-leaf pondweed (*Potamogeton crispus*), Purple loosestrife (*Lythrum salicaria*), or Reed canary grass (*Phalaris arundinacea*) (For more information on these exotic invasive plant species, see Appendix VII).

The only exotic species other than EWM found in any of the three surveys was Narrow-leaved cattail (*Typha angustifolia*) – a species that is native to southern but not northern Wisconsin. It is potentially invasive and often excludes the native Broad-leaved cattail (*Typha latifolia*) from places where the two are found together. Because of this, there is the potential that it will continue to spread beyond the single point it was found at during the 2015 survey (Figure 17), and the small bed located on the east shoreline near the entrance of the north bay.

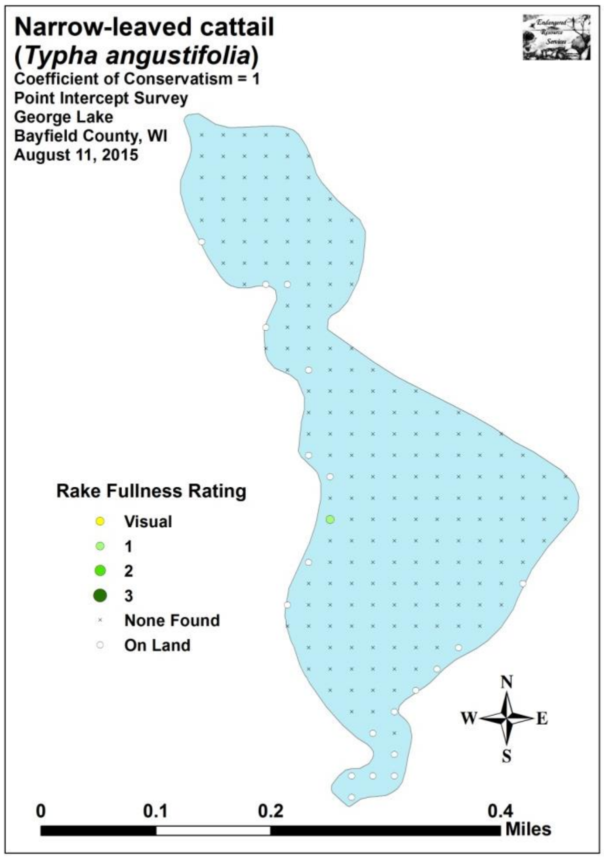


Figure 17: 2015 Narrow-leaved Cattail Density and Distribution

DISCUSSION AND CONSIDERATIONS FOR MANAGEMENT:

George Lake continues to have a rich and diverse plant community that is unique to sand bottomed, seepage lakes with good water clarity and quality. That no Eurasian water milfoil has been found since the 2012 treatment continues to be an unexpected and encouraging development. With no EWM to treat or pull and a willing lake resident with experience identifying EWM, it seems the most likely course of action is to simply continue visible littoral zone monitoring on a regular basis to see if plants come back. It appears a seed bank was never established in the sediment, and, after finding no evidence of EWM for three years, we are becoming increasingly optimistic that the plant was eradicated from the lake.

If EWM plants are found again in the future, we believe working to immediately control them will continue to be the best policy. With that in mind, any suspicious looking plants should be investigated to determine species. If any lake resident or boater discovers a plant they even suspect may be EWM, they are invited to contact Matthew Berg, ERS, LLC Research Biologist at (715) 338-7502 saintcroixdfly@gmail.com and/or Pamela Toshner/Alex Smith, Regional Lakes Management Coordinators in the Spooner DNR office at 715-635-4073 for identification confirmation. If possible, a specimen, a jpg, and the accompanying GPS coordinates of the location it was found at should be included.

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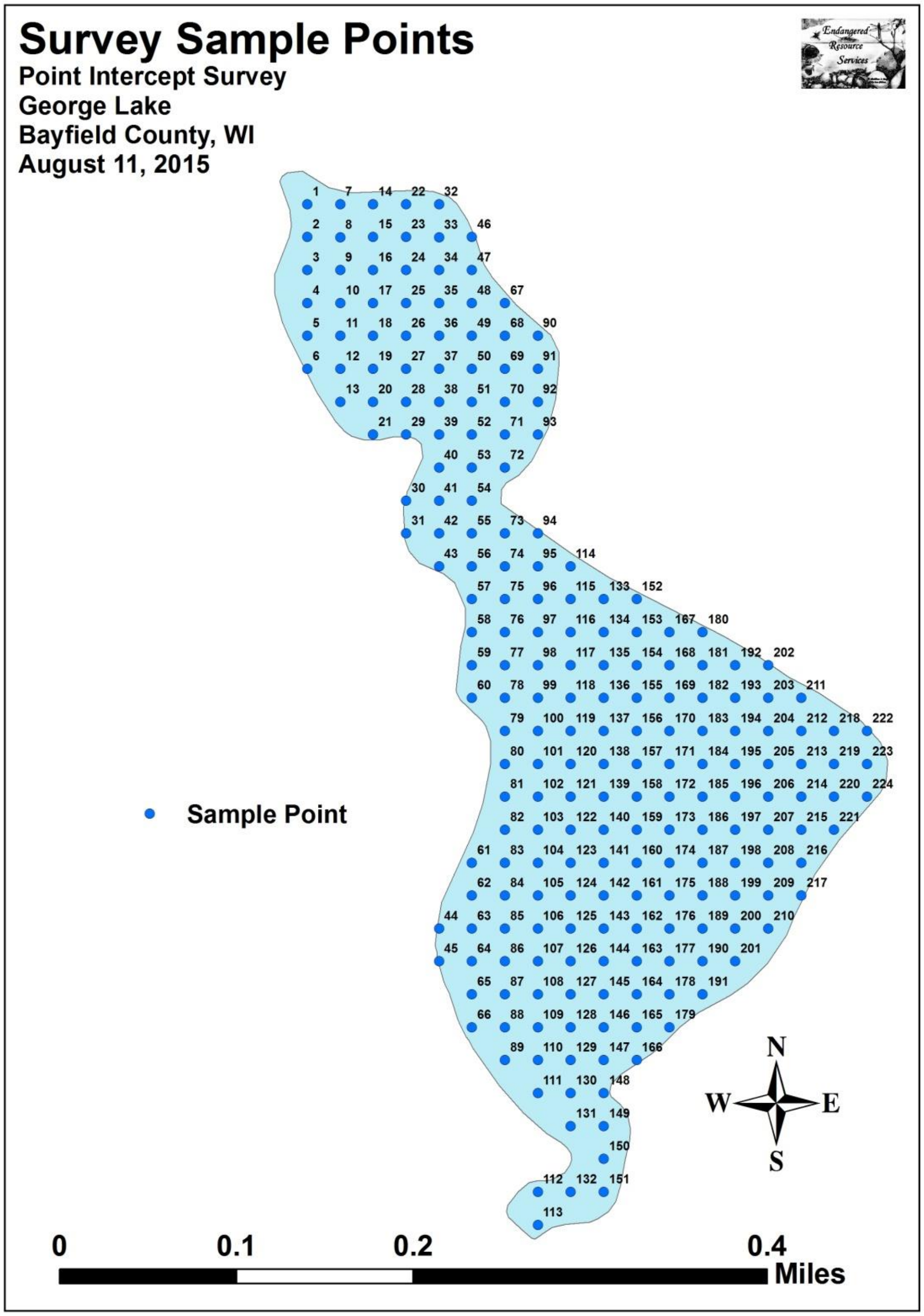
Appendix I: Point-intercept Survey Sample Point Map

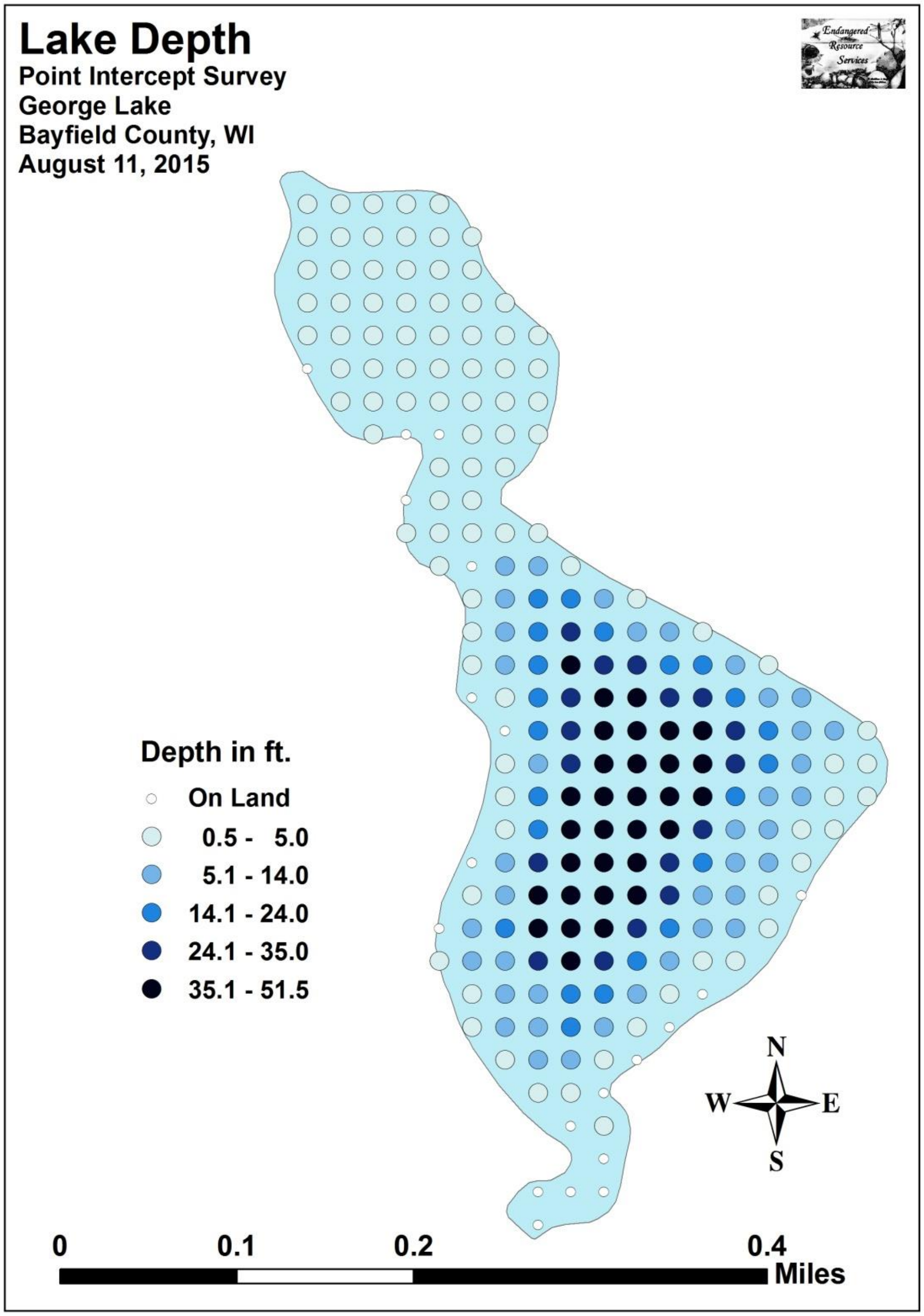

Survey Sample Points
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Sample Point
N
W
E
S
0
0.1
0.2
0.4
Miles

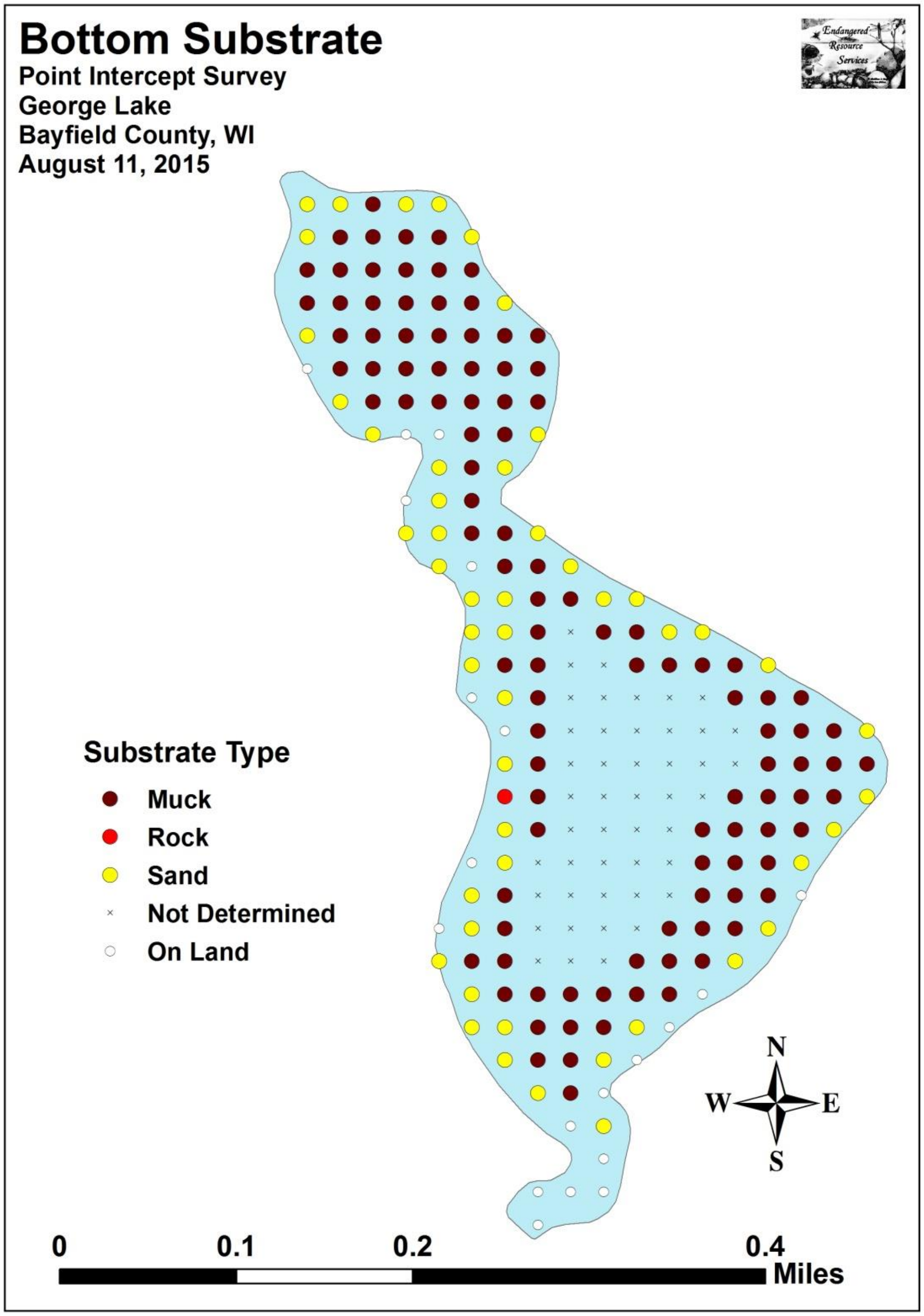
Appendix II: Boat and Vegetative Survey Data Sheets

# 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																									

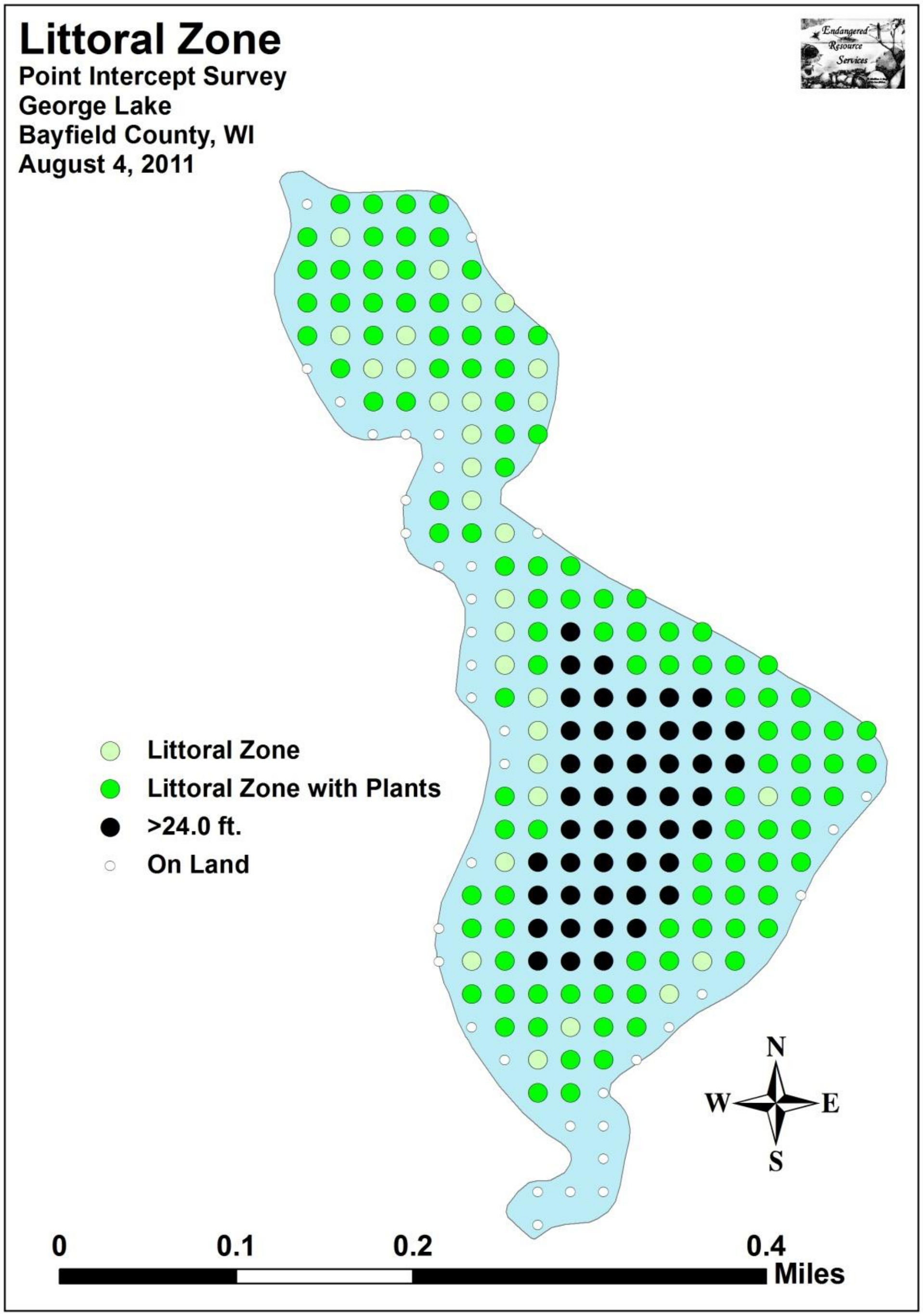
Appendix III: Habitat Variable Maps

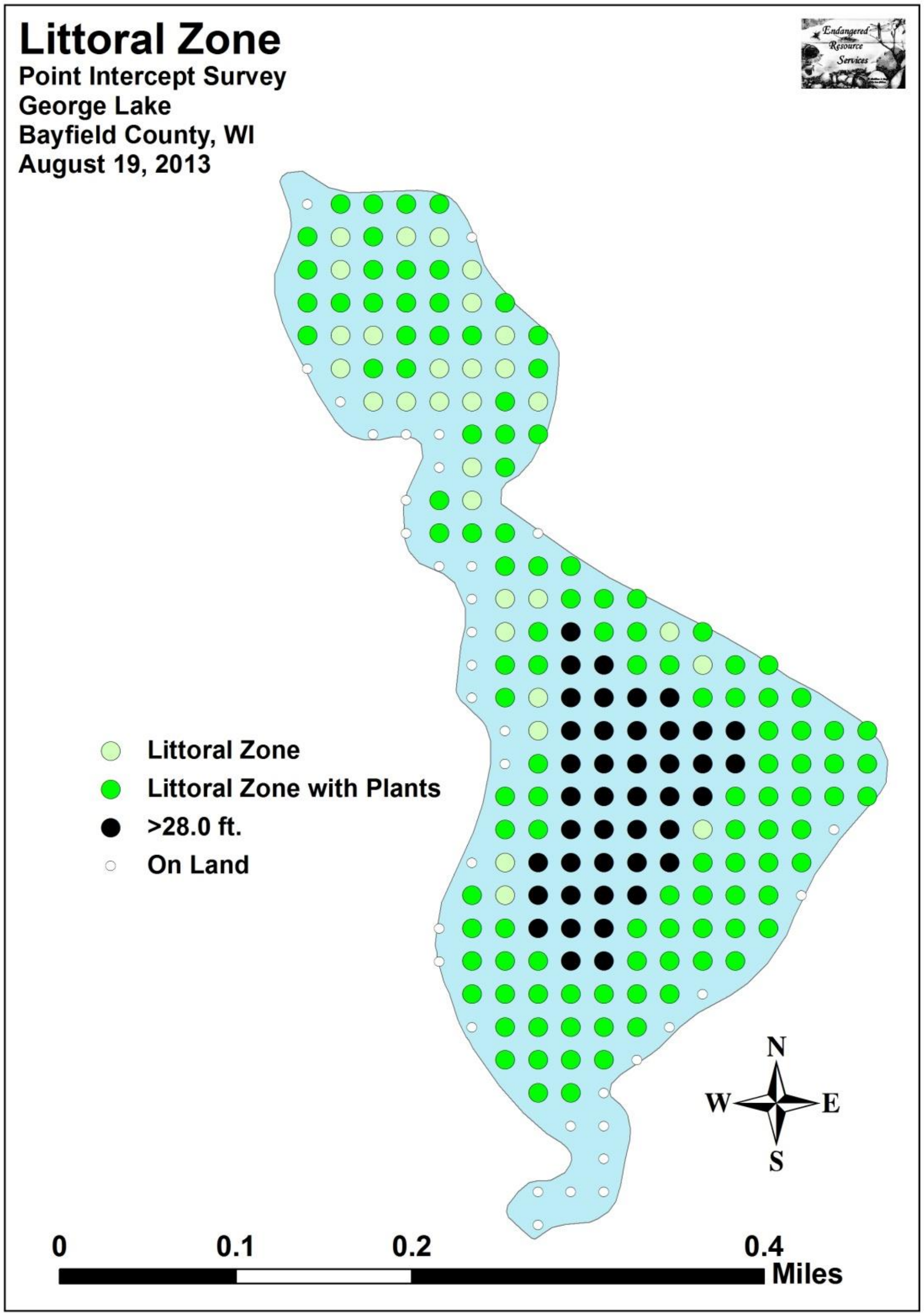

Lake Depth
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Depth in ft.
On Land
0.5 - 5.0
5.1 - 14.0
14.1 - 24.0
24.1 - 35.0
35.1 - 51.5
N
W
E
S
0
0.1
0.2
0.4
Miles

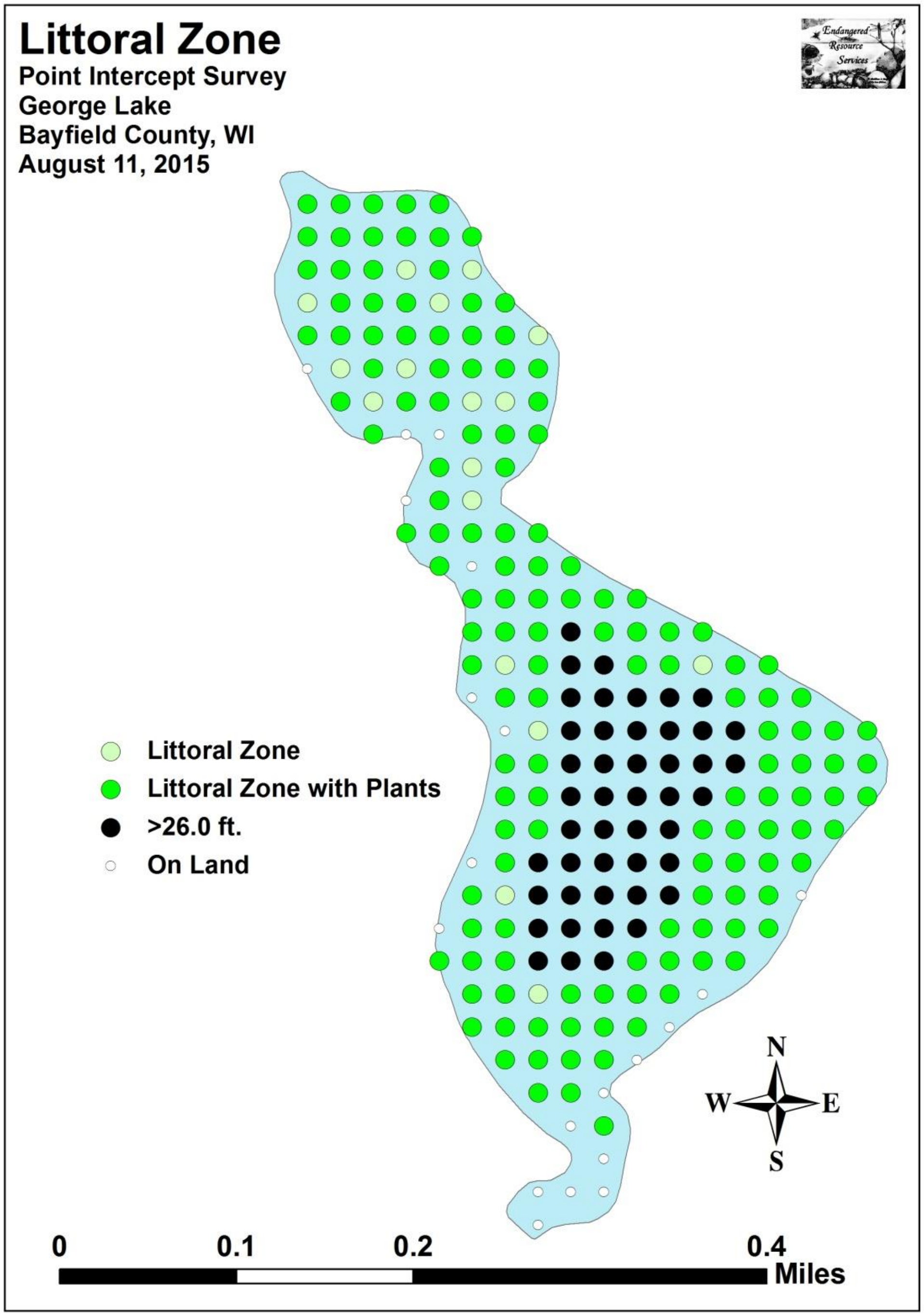


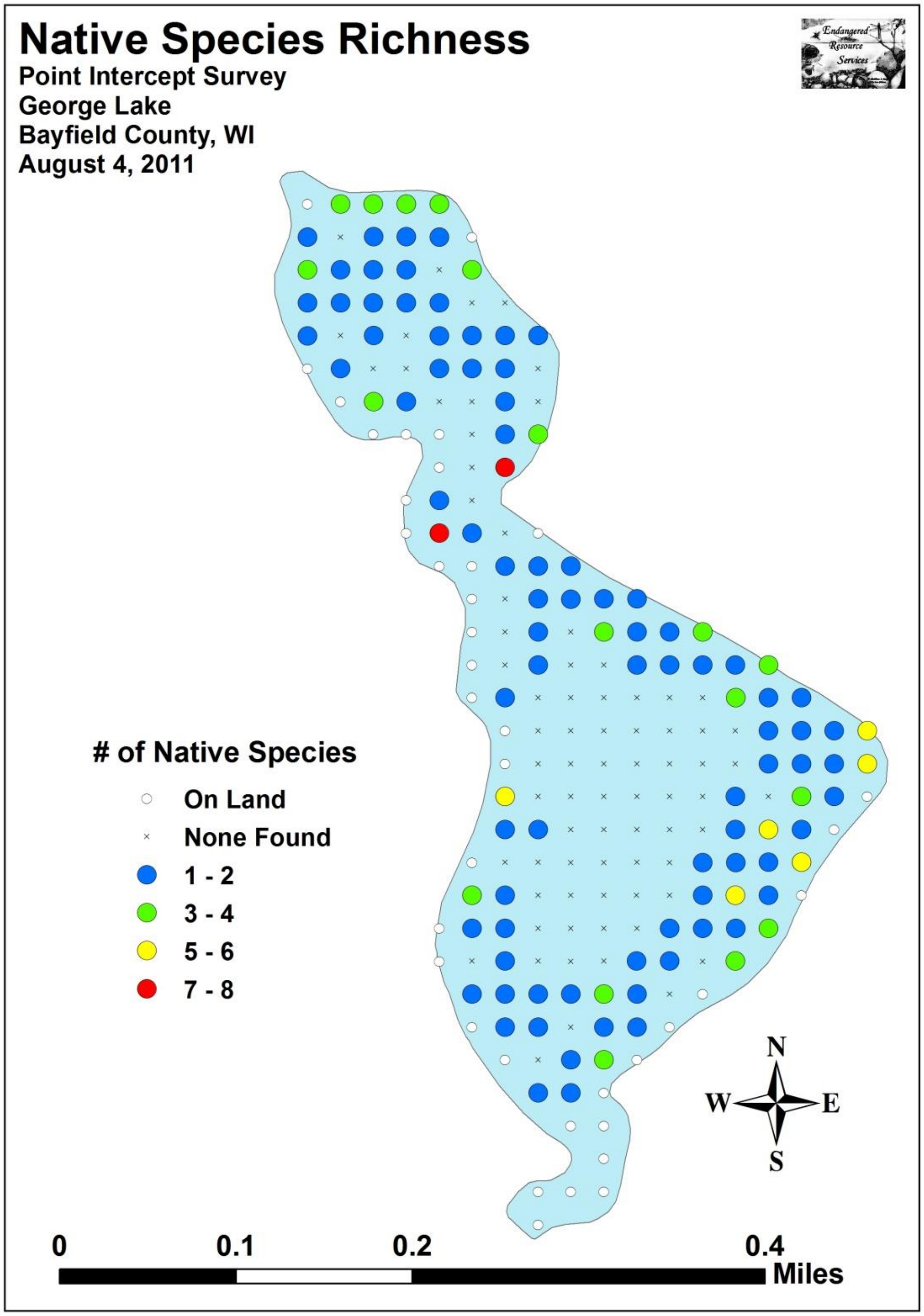
Bottom Substrate
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Substrate Type
Muck
Rock
Sand
Not Determined
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

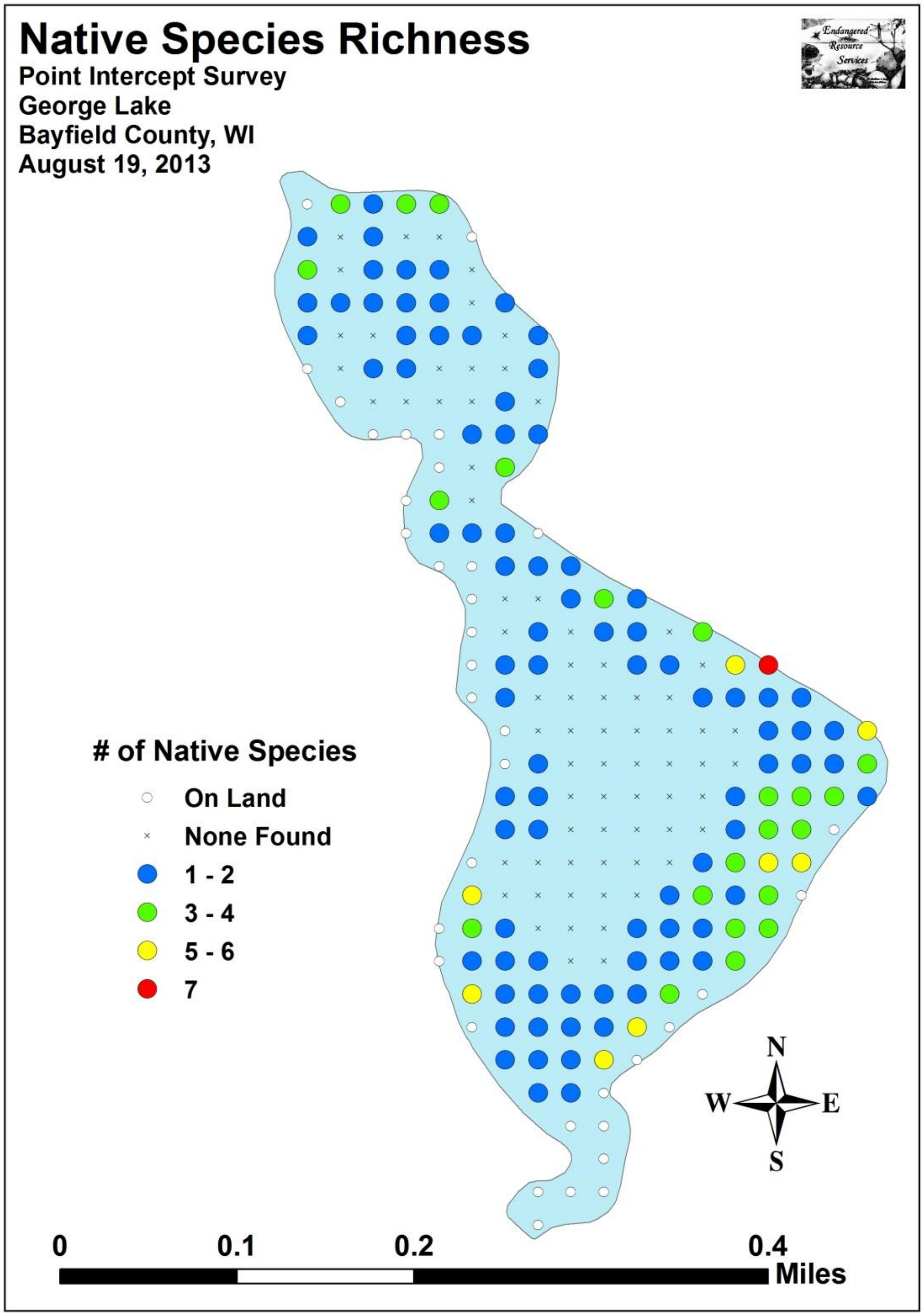
Appendix IV: 2011, 2013, and 2015 Littoral Zone, Native Species Richness and Total Rake Fullness Maps

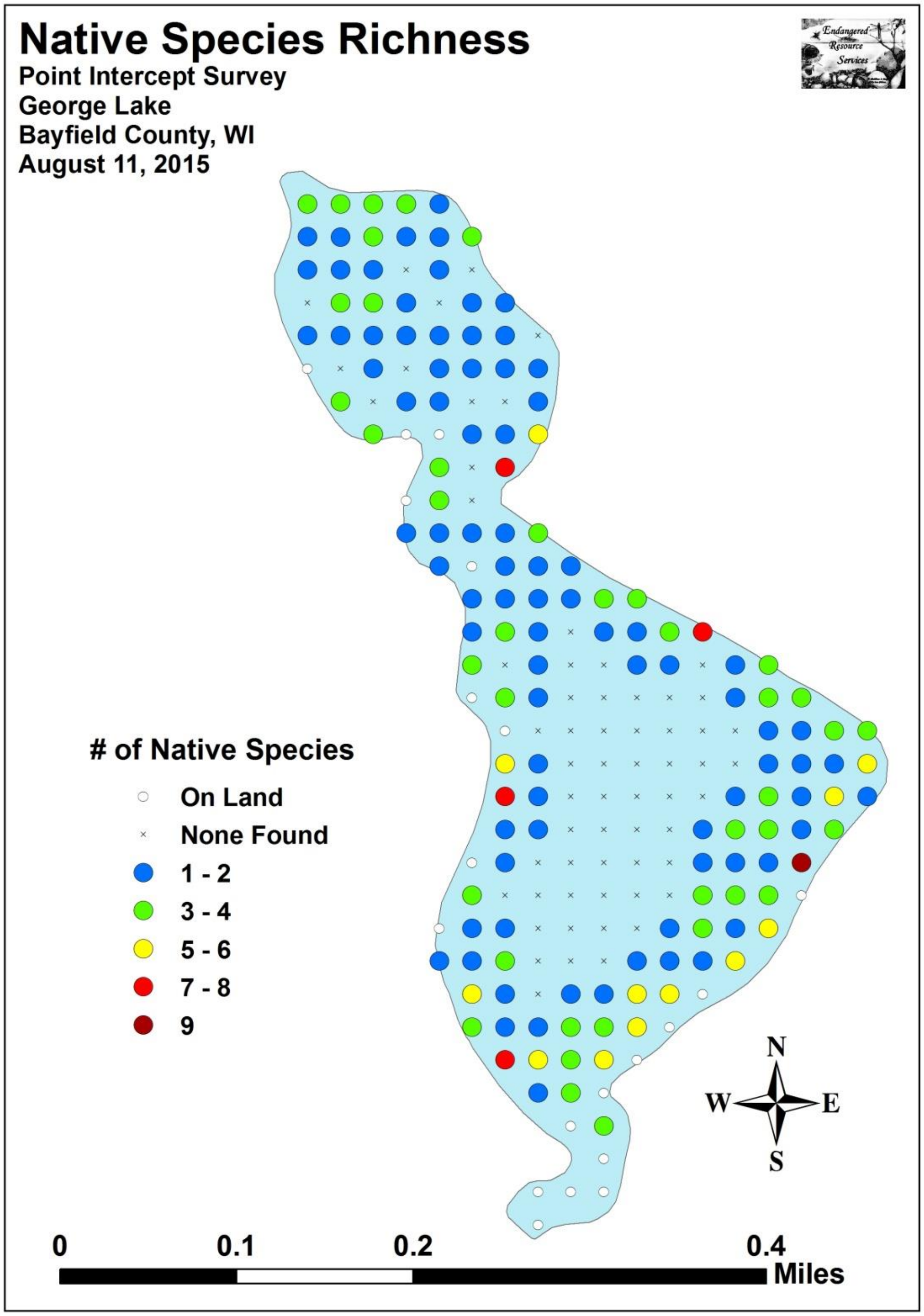

Littoral Zone
Point Intercept Survey
George Lake
Bayfield County, WI
August 4, 2011
Littoral Zone
Littoral Zone with Plants
>24.0 ft.
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

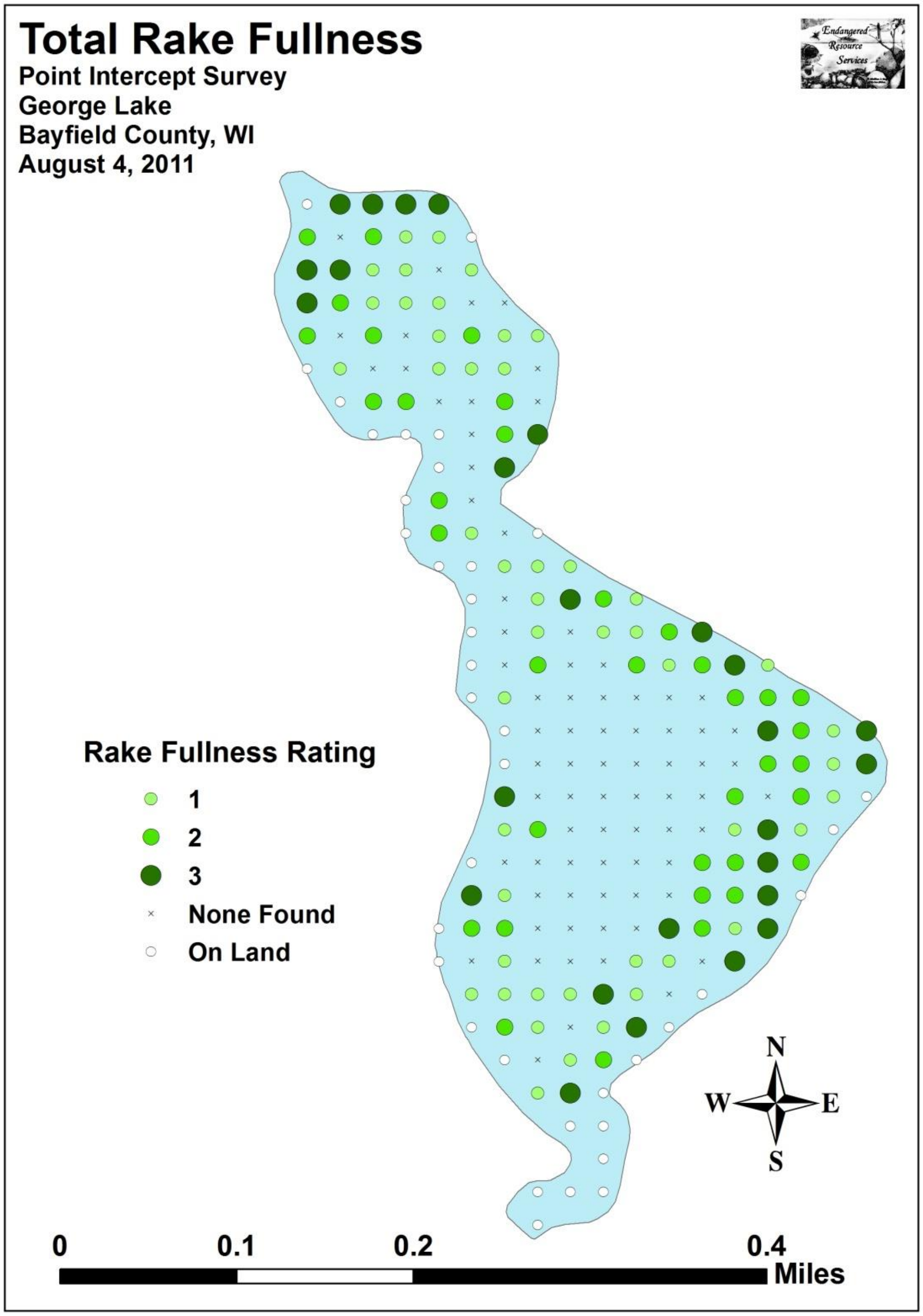

Littoral Zone
Point Intercept Survey
George Lake
Bayfield County, WI
August 19, 2013
Littoral Zone
Littoral Zone with Plants
>28.0 ft.
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

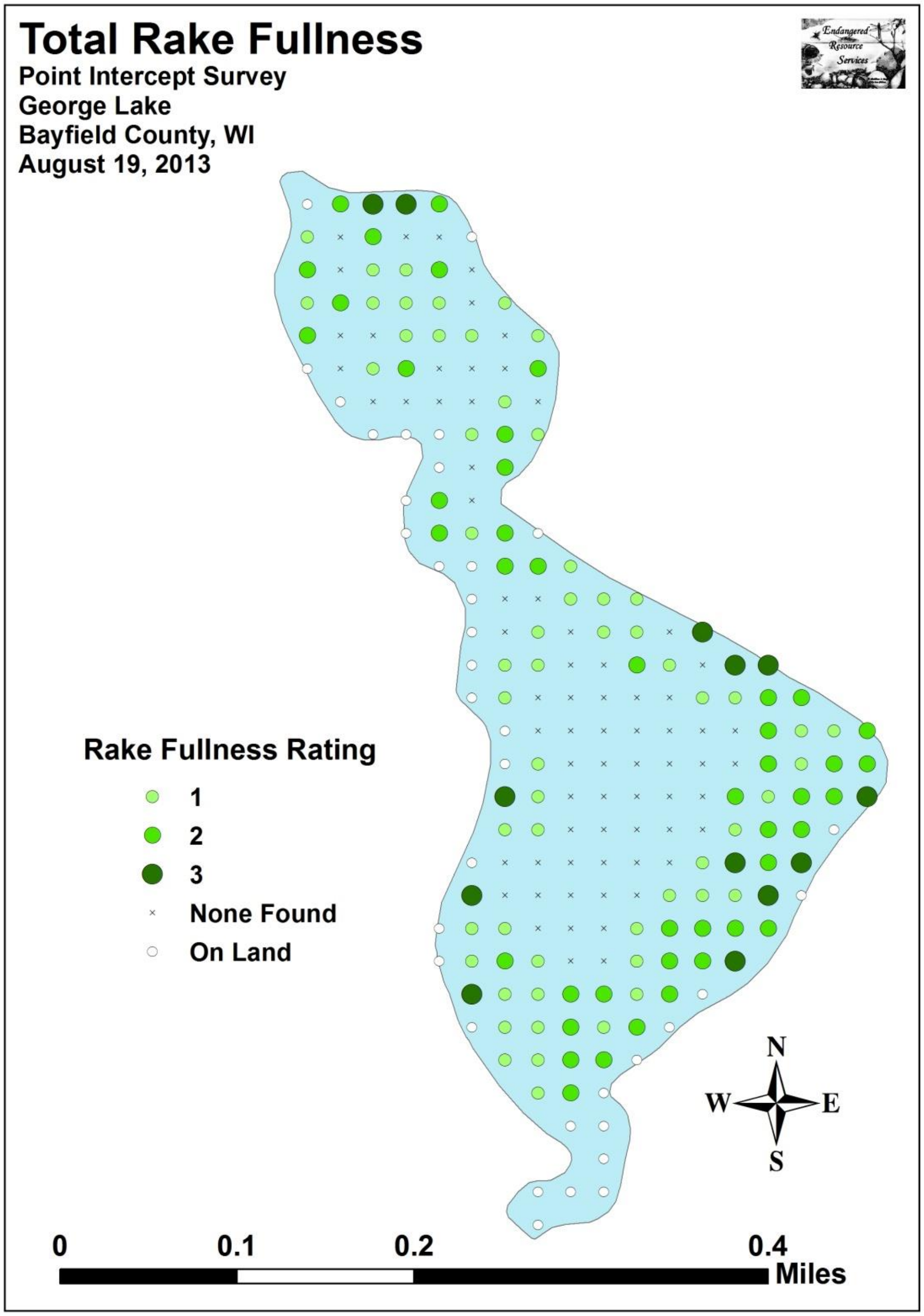

Littoral Zone
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Littoral Zone
Littoral Zone with Plants
>26.0 ft.
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles


Native Species Richness
Point Intercept Survey
George Lake
Bayfield County, WI
August 4, 2011
Endangered Resource Services
# of Native Species
On Land
None Found
1 - 2
3 - 4
5 - 6
7 - 8
N
W
E
S
0
0.1
0.2
0.4
Miles

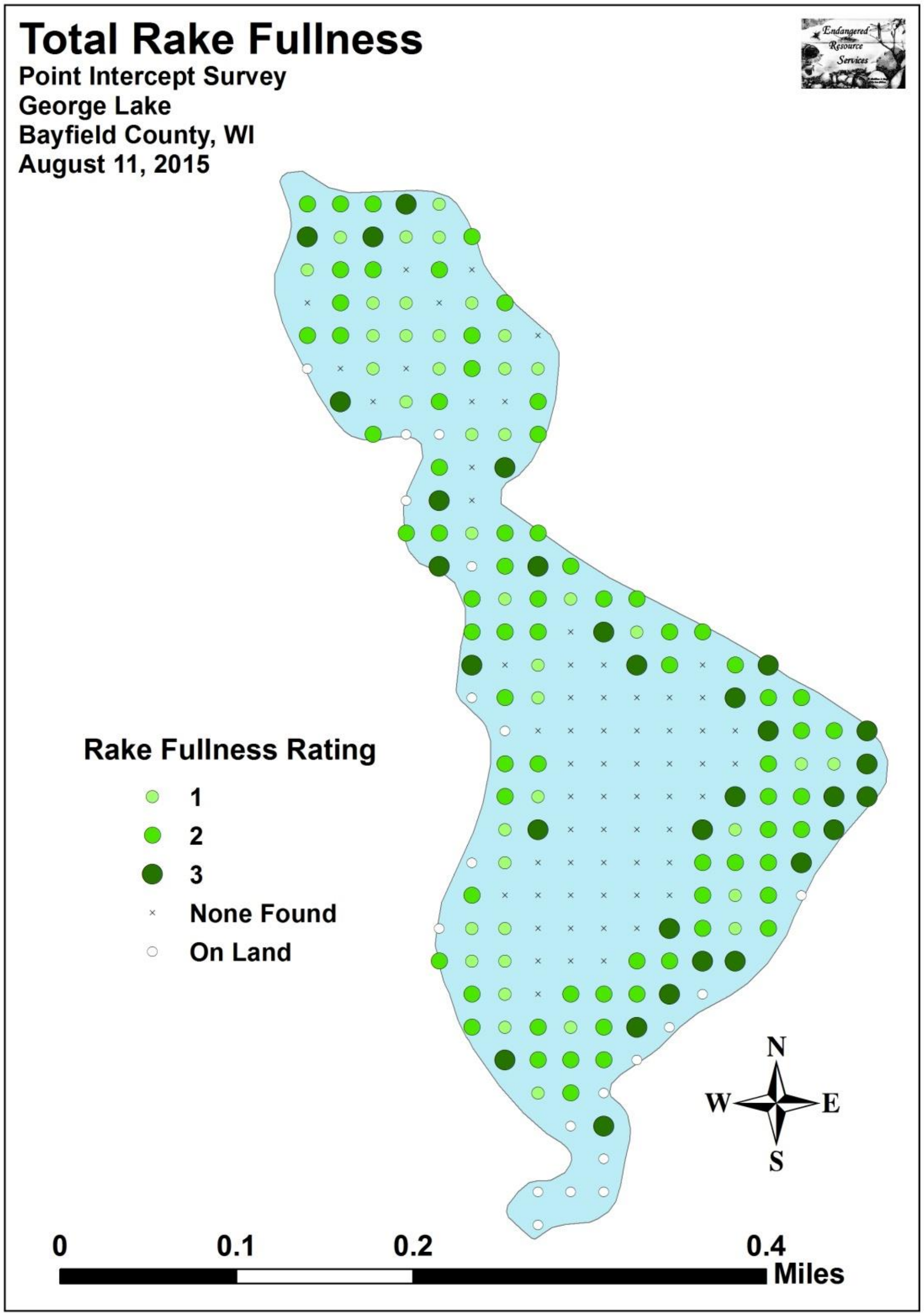

Native Species Richness
Point Intercept Survey
George Lake
Bayfield County, WI
August 19, 2013
# of Native Species
On Land
None Found
1 - 2
3 - 4
5 - 6
7
N
W
E
S
0
0.1
0.2
0.4
Miles


Native Species Richness
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
# of Native Species
On Land
None Found
1 - 2
3 - 4
5 - 6
7 - 8
9
N
W
E
S
0
0.1
0.2
0.4
Miles

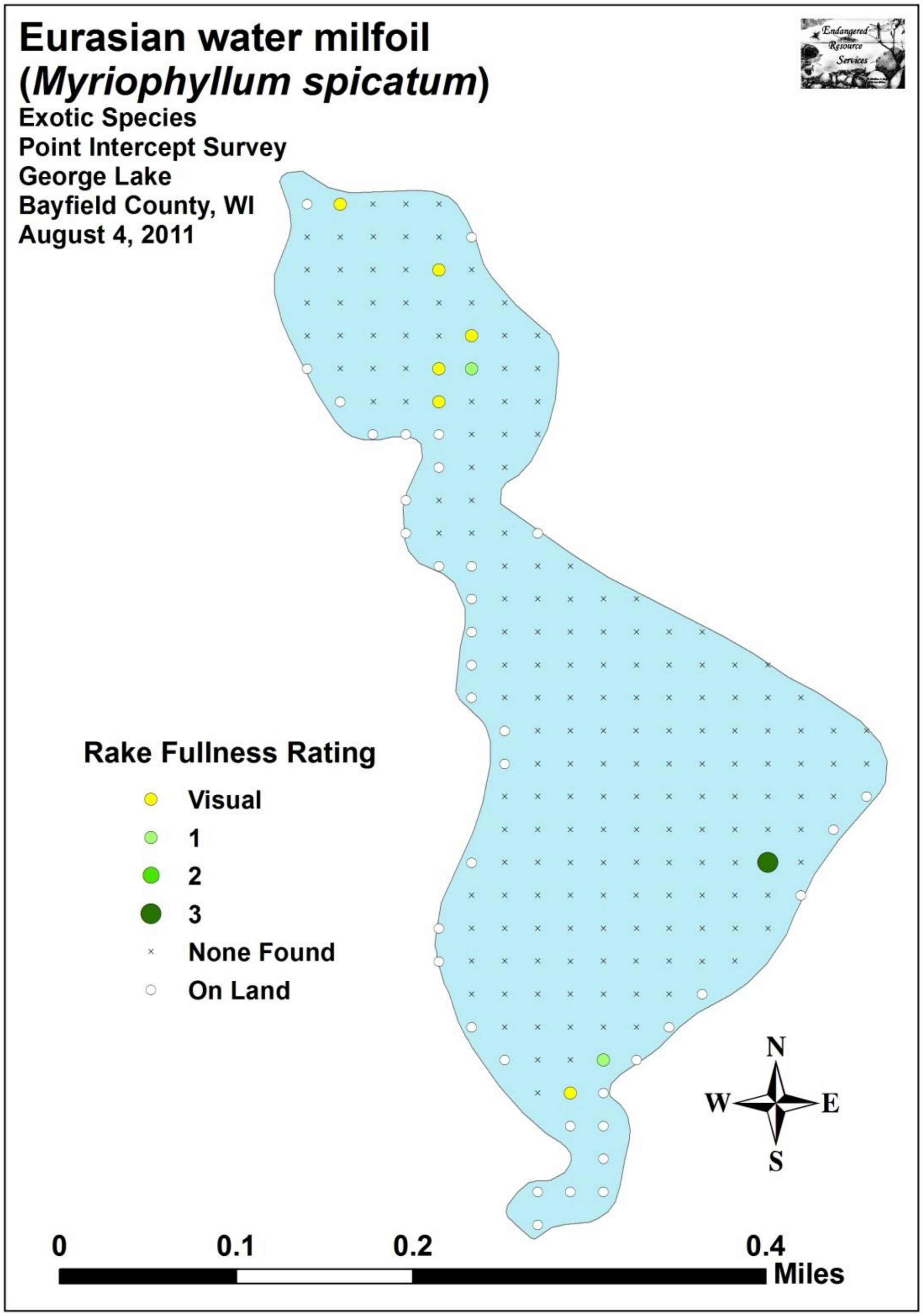

Total Rake Fullness
Point Intercept Survey
George Lake
Bayfield County, WI
August 4, 2011
Endangered Resource Services
Rake Fullness Rating
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

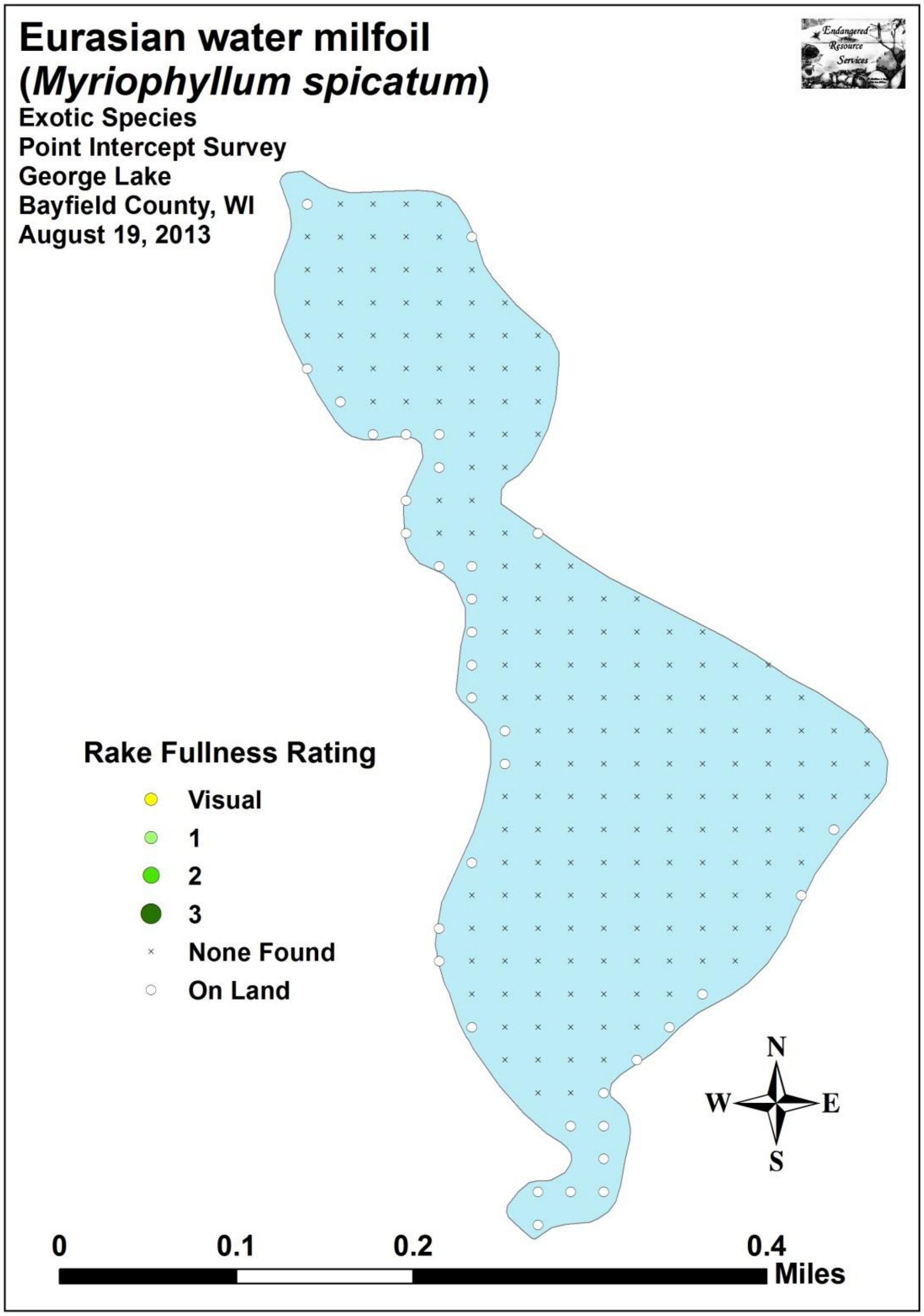


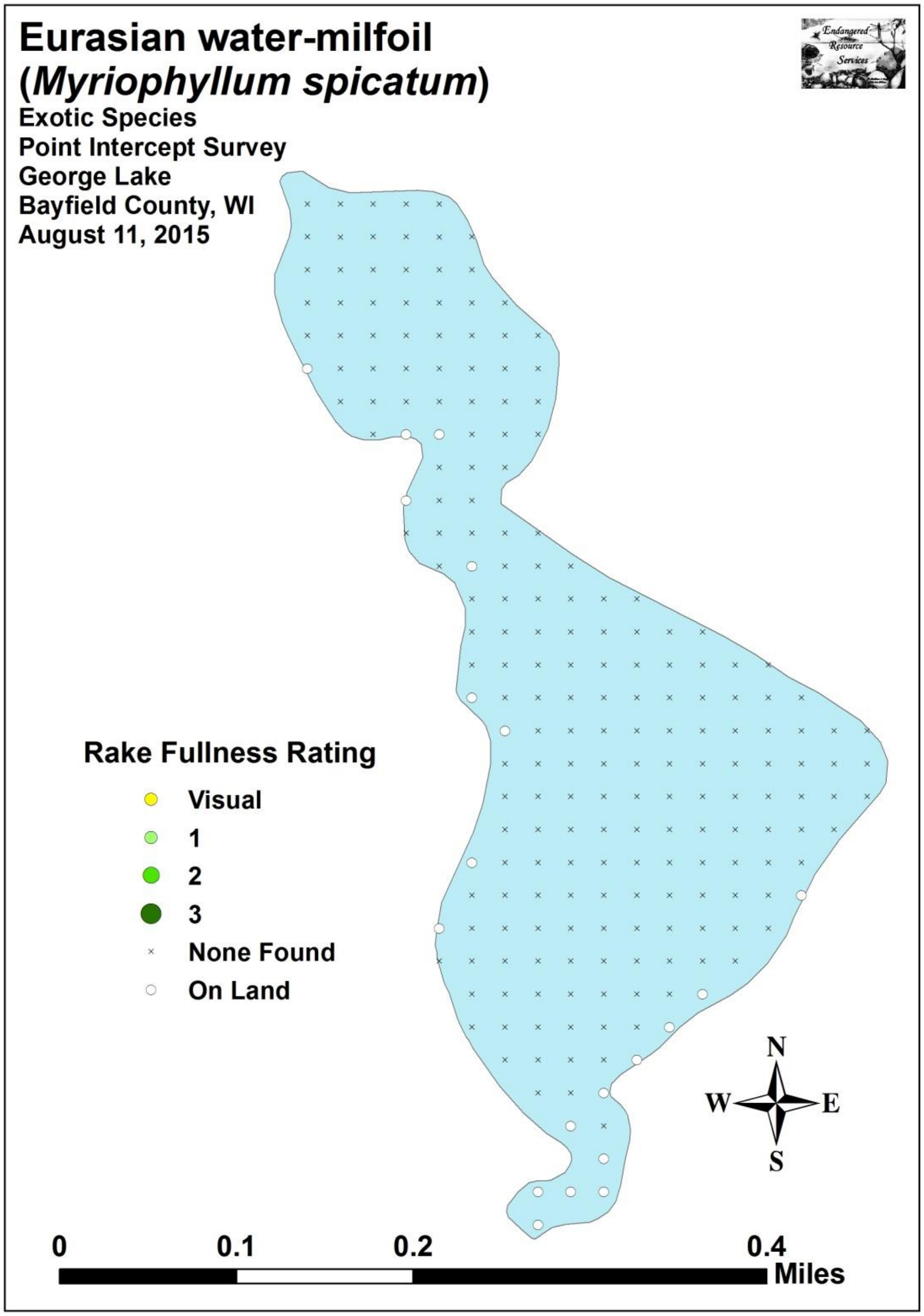
Total Rake Fullness
Point Intercept Survey
George Lake
Bayfield County, WI
August 19, 2013
Rake Fullness Rating
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles


Total Rake Fullness
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

Appendix V: 2011, 2013, and 2015 EWM Density and Distribution Maps

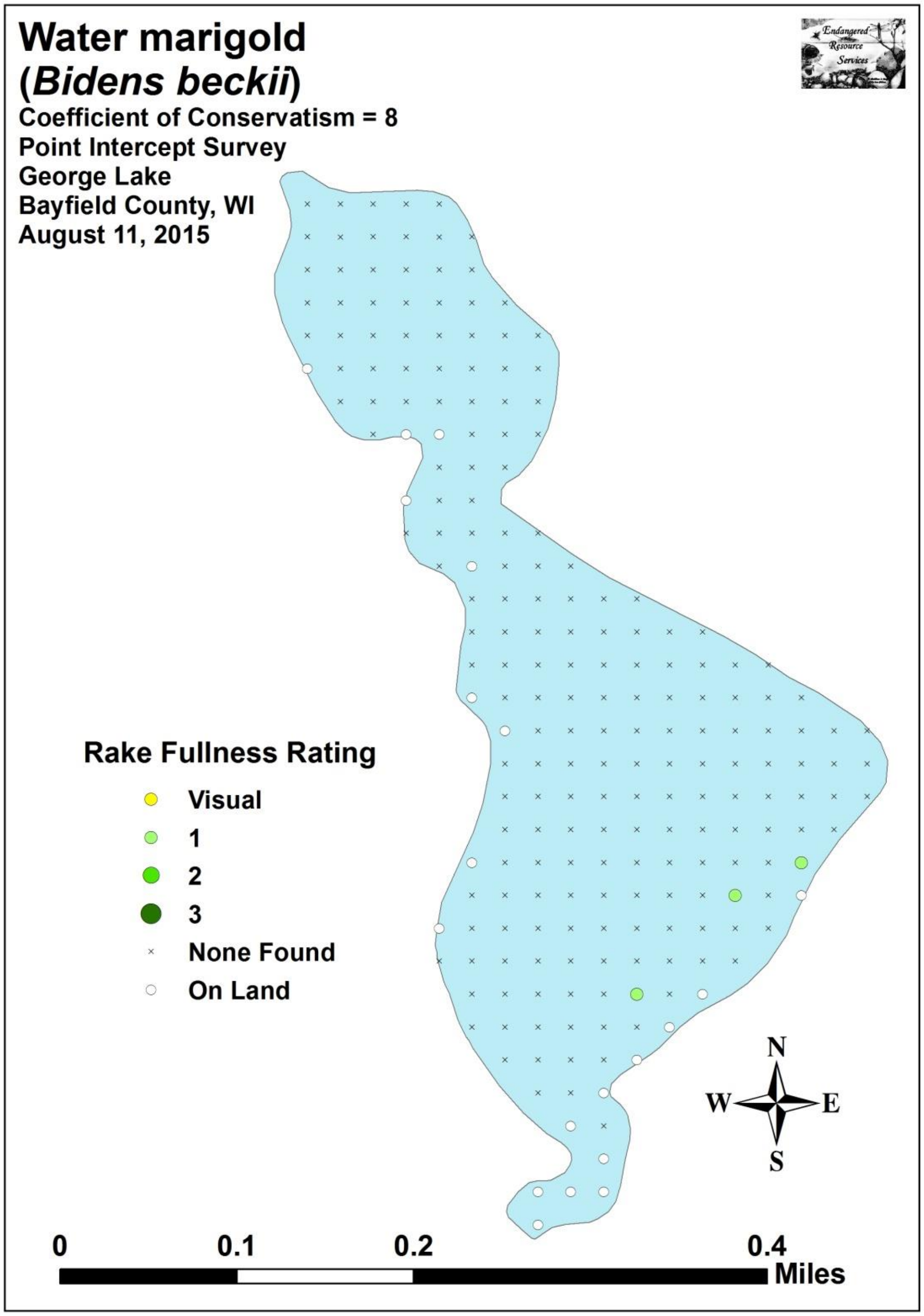

Eurasian water milfoil
(*Myriophyllum spicatum*)
Exotic Species
Point Intercept Survey
George Lake
Bayfield County, WI
August 4, 2011
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

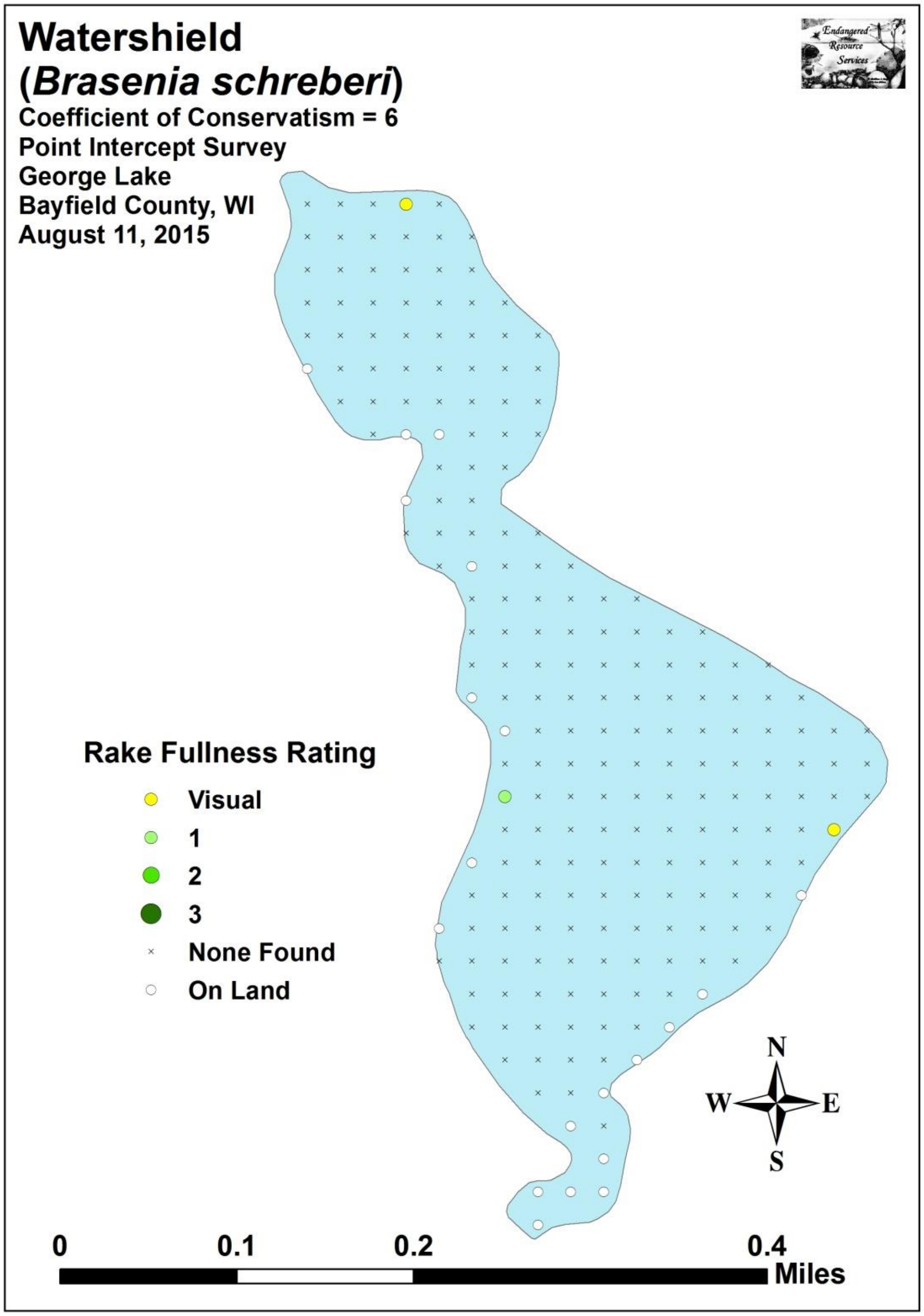

Eurasian water milfoil
(Myriophyllum spicatum)
Exotic Species
Point Intercept Survey
George Lake
Bayfield County, WI
August 19, 2013
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

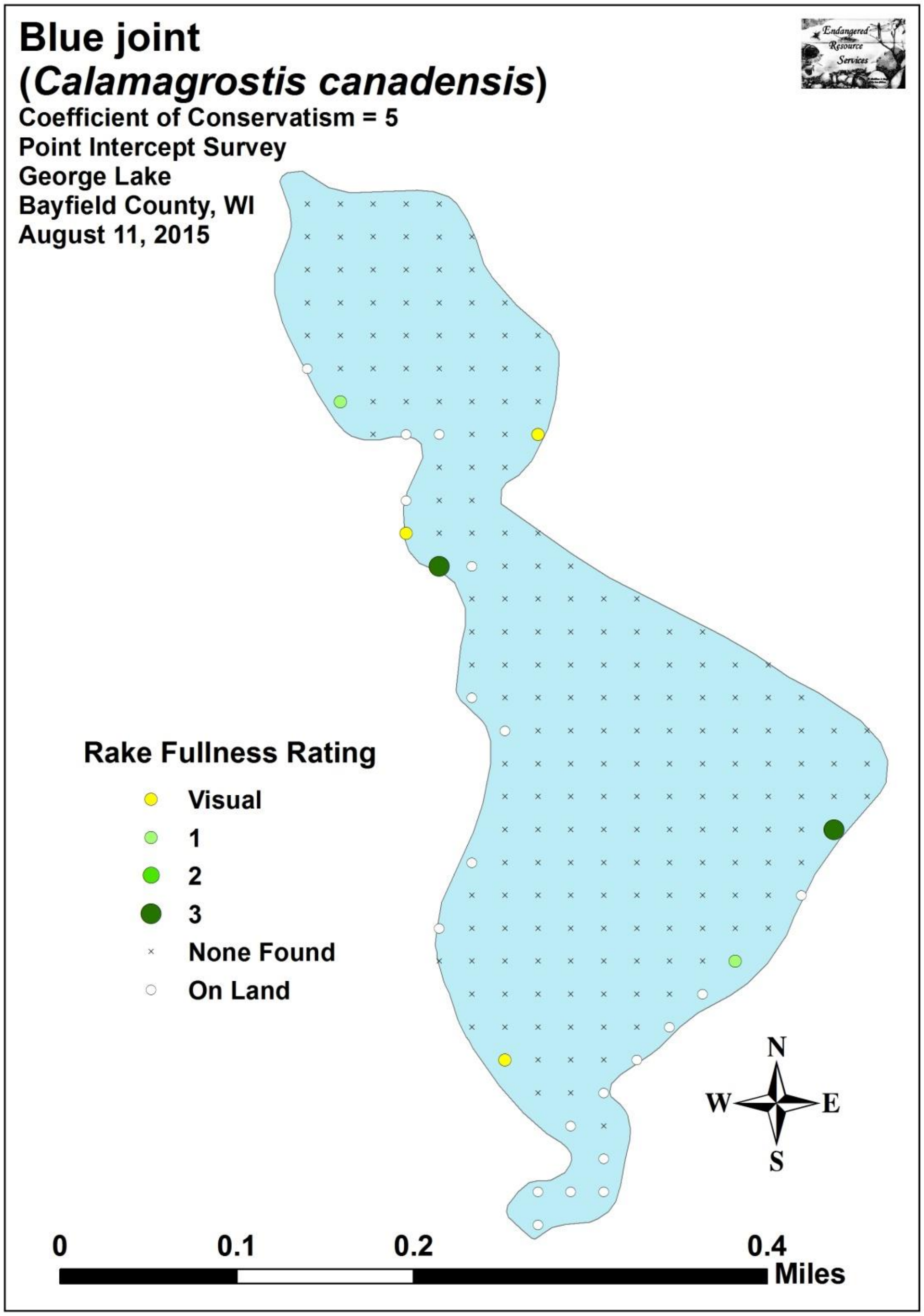


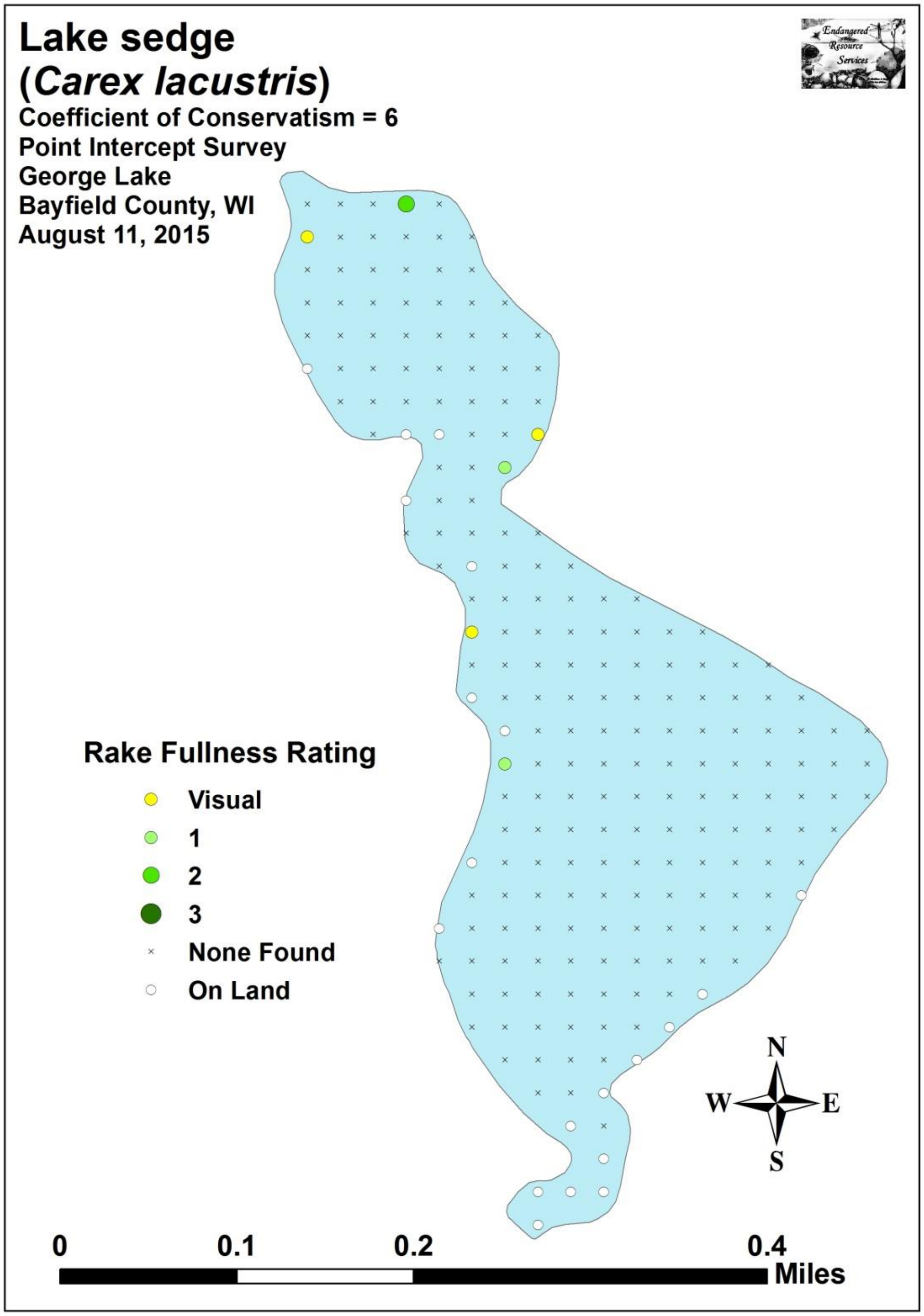
Eurasian water-milfoil
(*Myriophyllum spicatum*)
Exotic Species
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

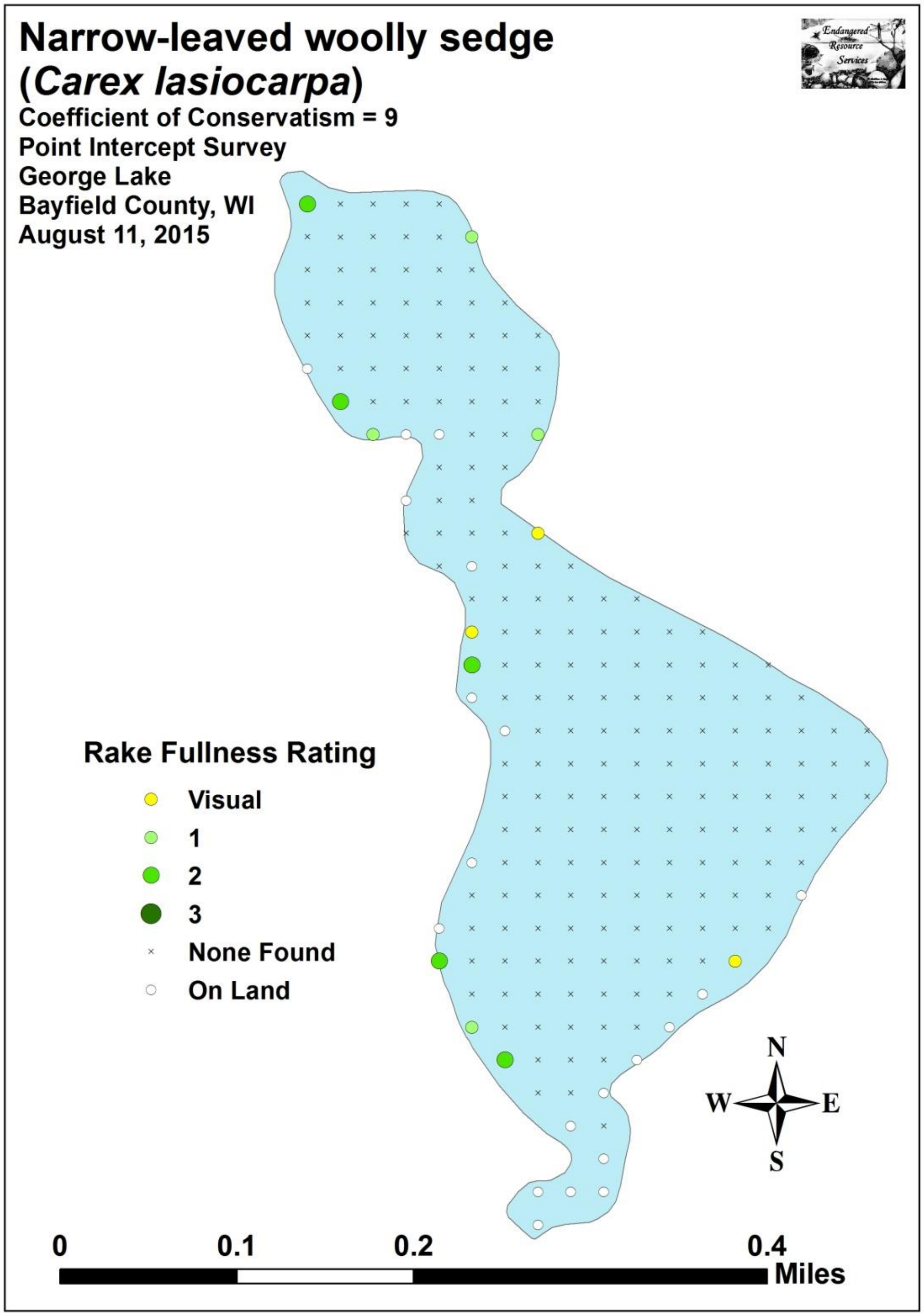
Appendix VI: 2015 Species Density and Distribution Maps

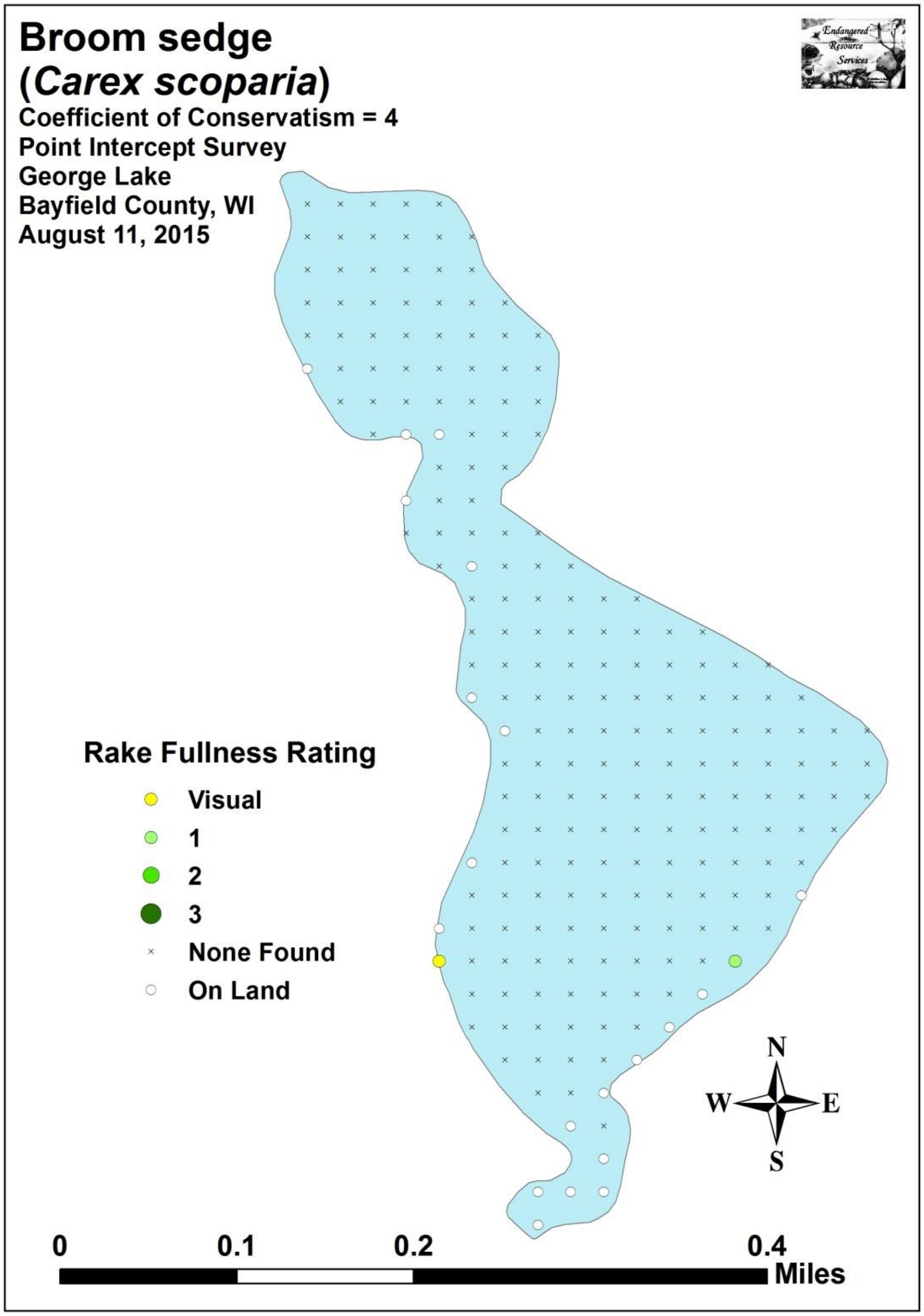

Water marigold
(*Bidens beckii*)
Coefficient of Conservatism = 8
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

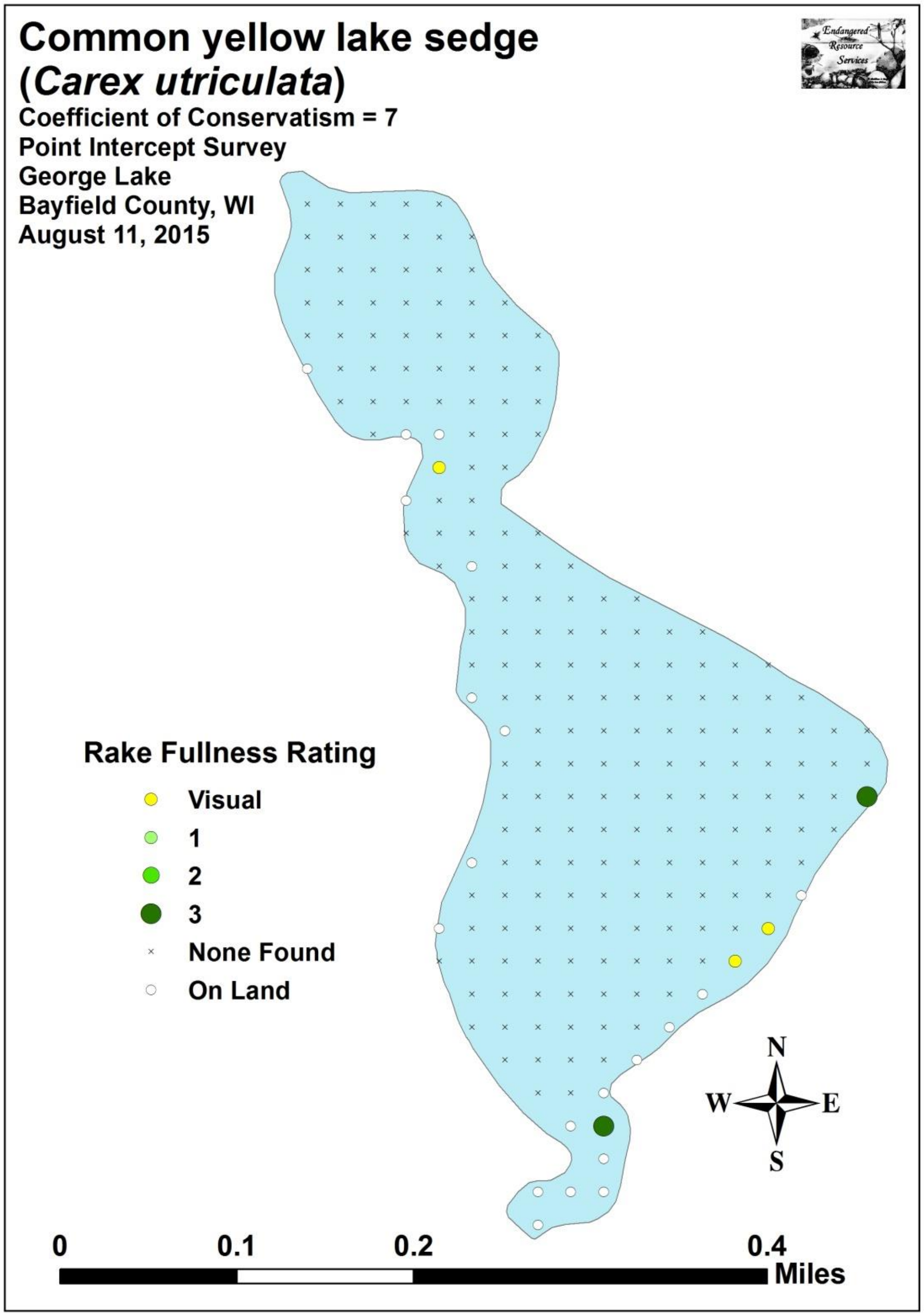

Watershield
(*Brasenia schreberi*)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

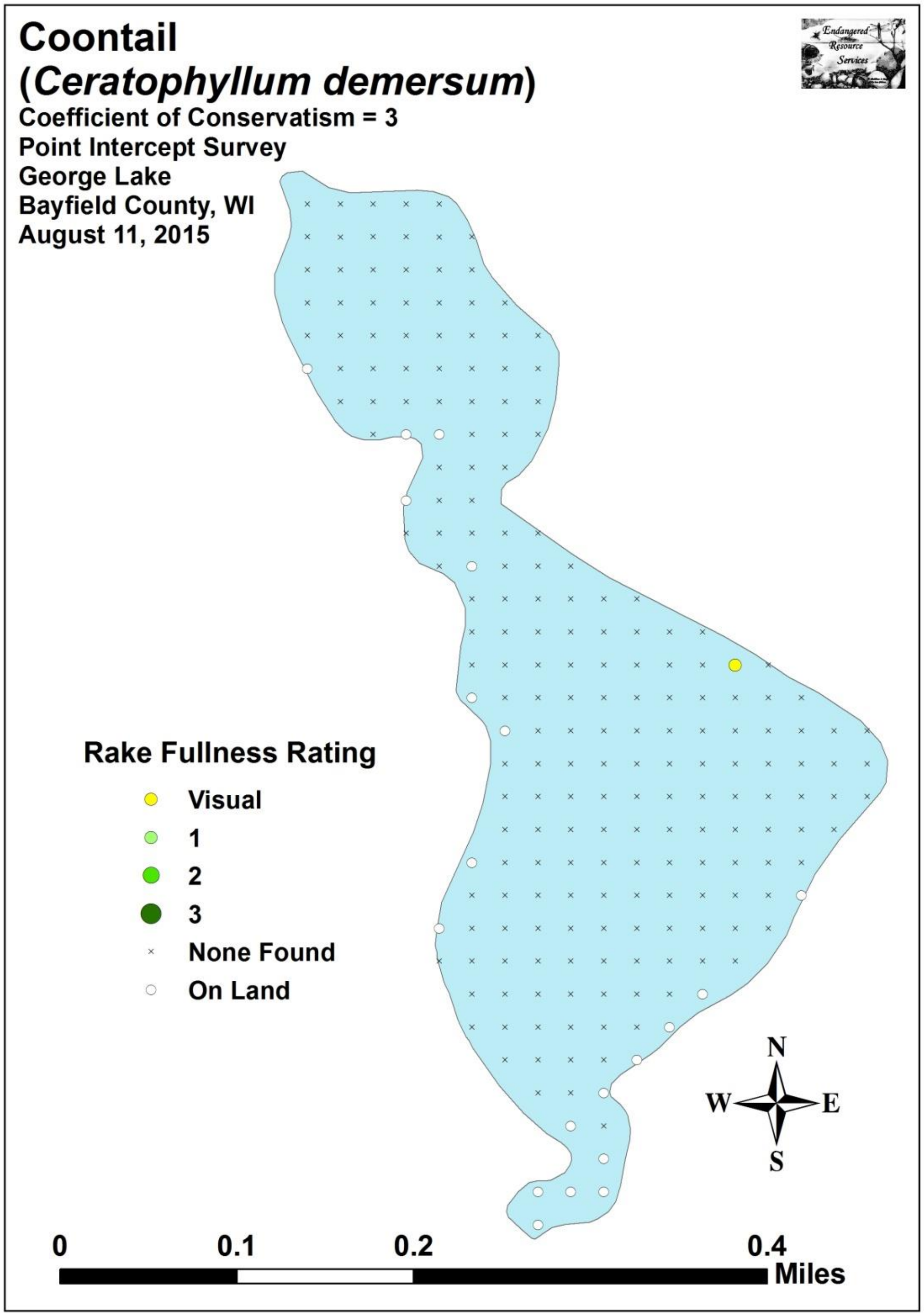

Blue joint
(*Calamagrostis canadensis*)
Coefficient of Conservatism = 5
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles


Lake sedge
(Carex lacustris)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

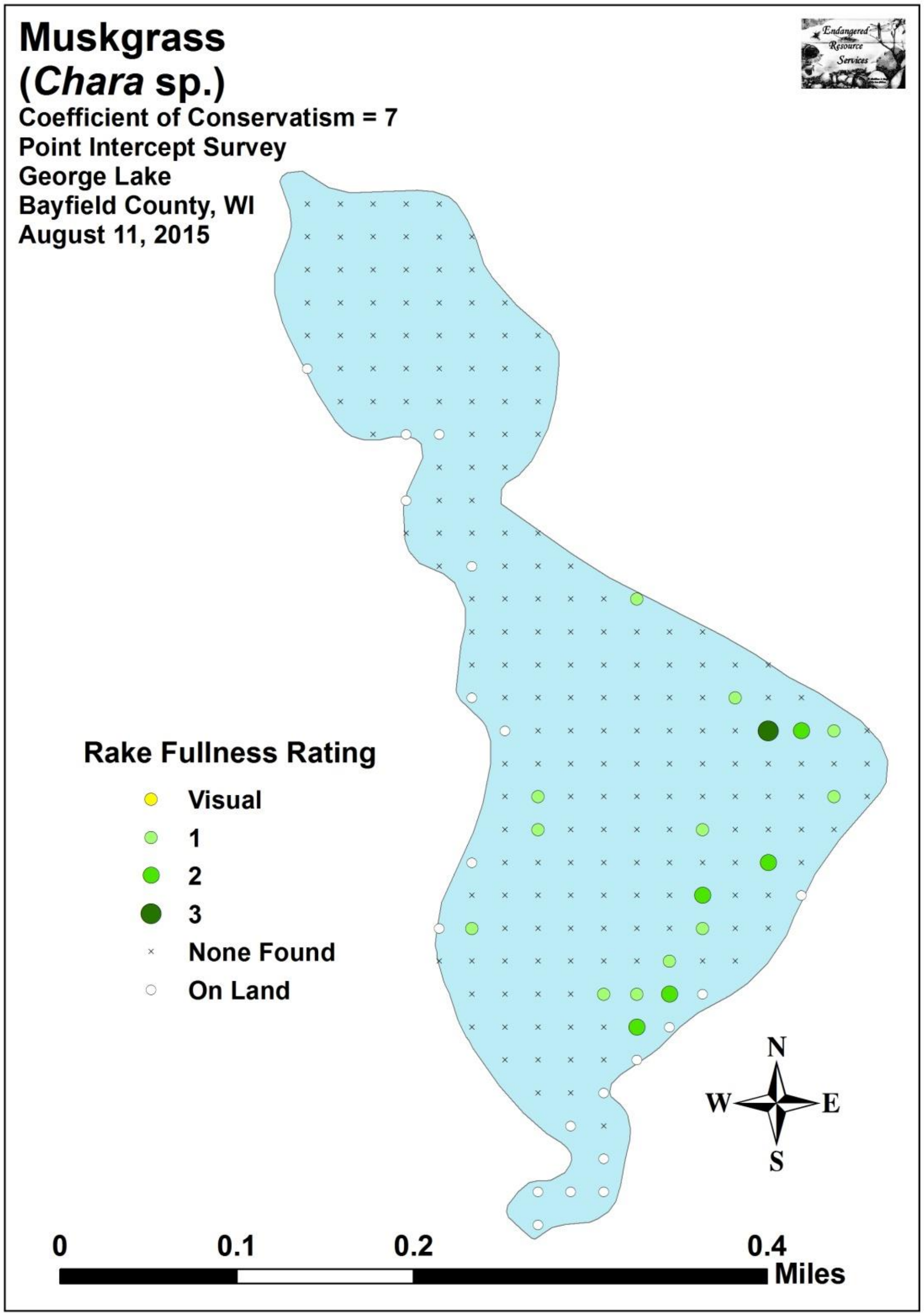

Narrow-leaved woolly sedge
(*Carex lasiocarpa*)
Coefficient of Conservatism = 9
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

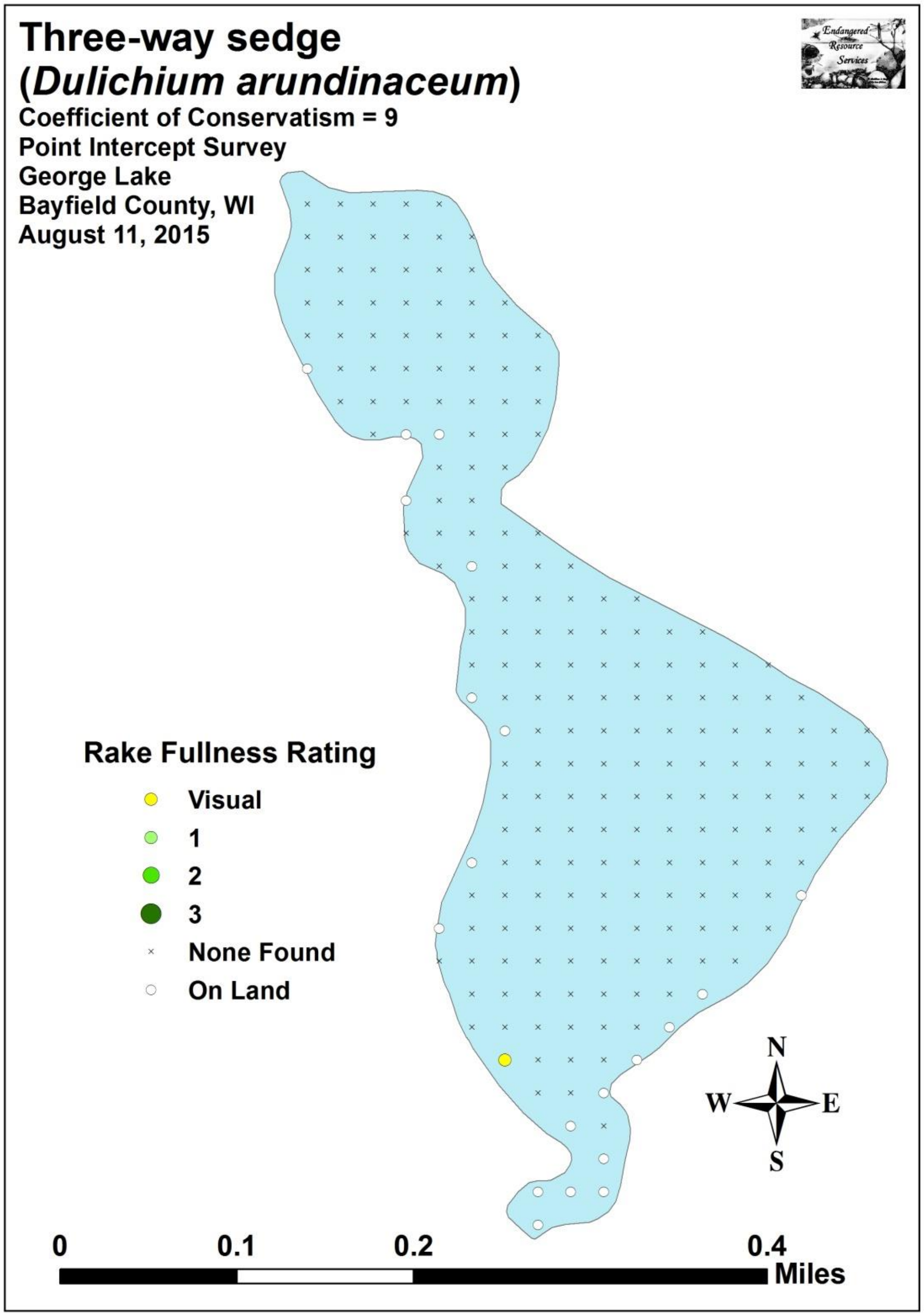

Broom sedge
(*Carex scoparia*)
Coefficient of Conservatism = 4
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

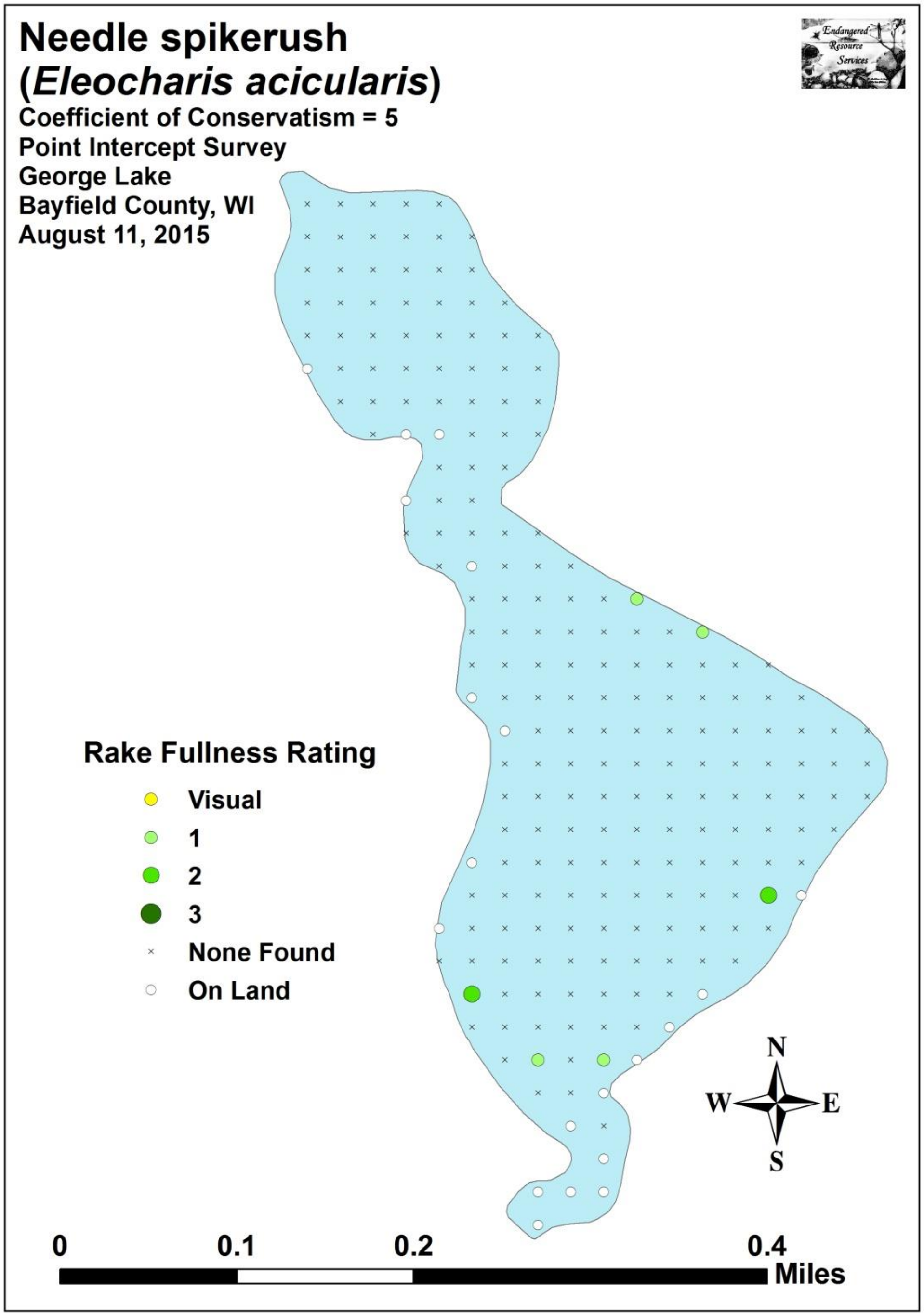

Common yellow lake sedge
(Carex utriculata)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

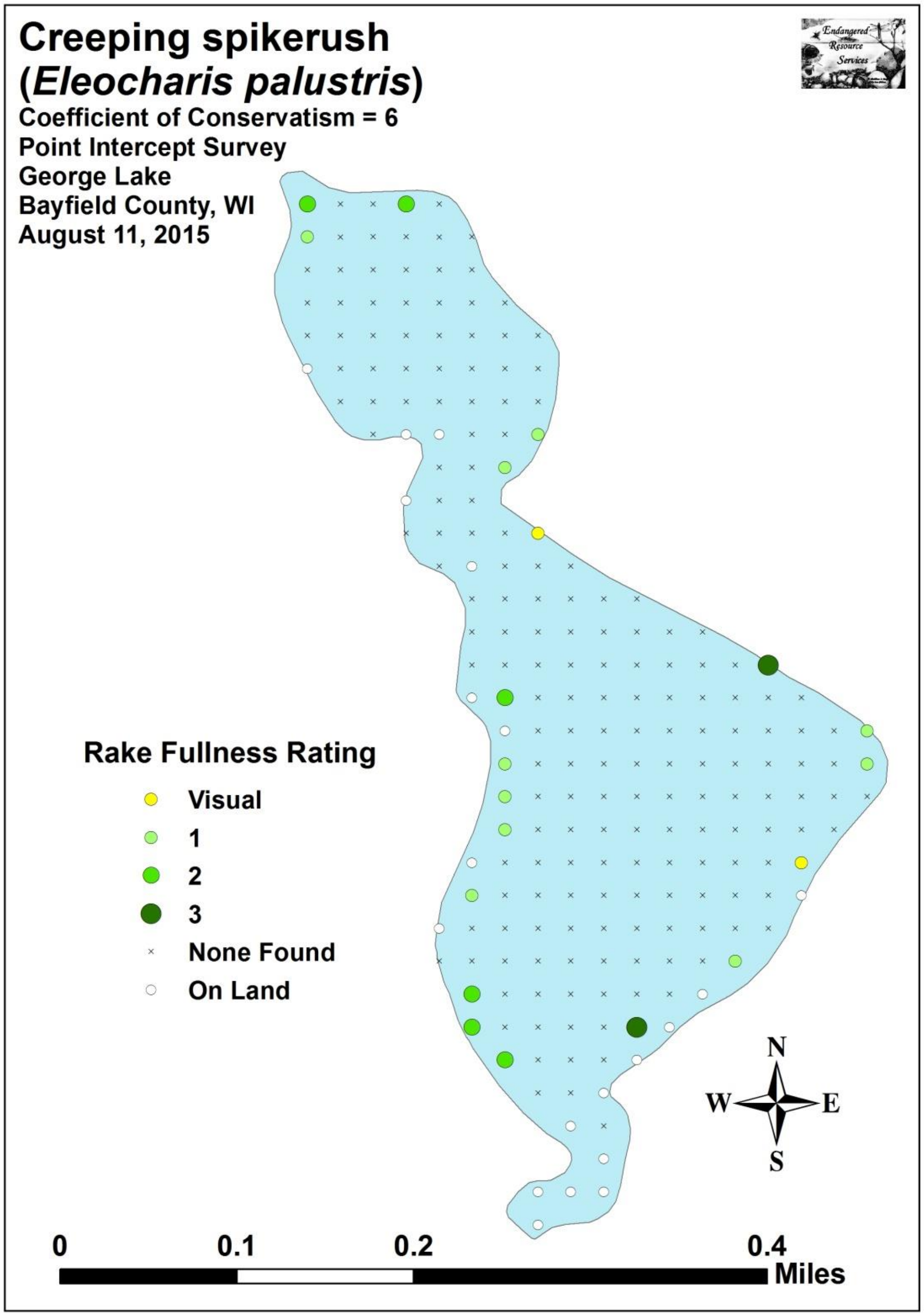


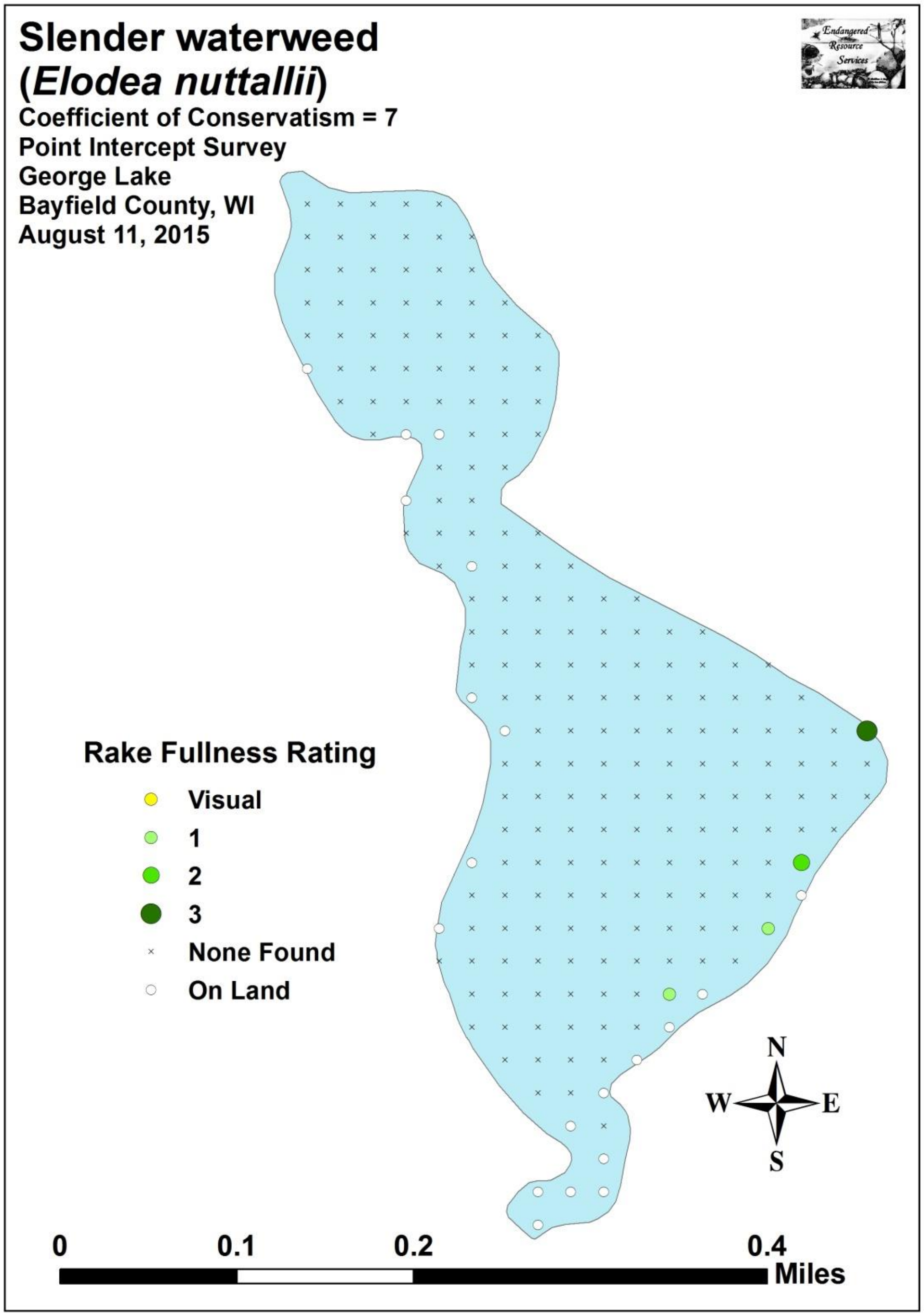
Coontail
(*Ceratophyllum demersum*)
Coefficient of Conservatism = 3
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

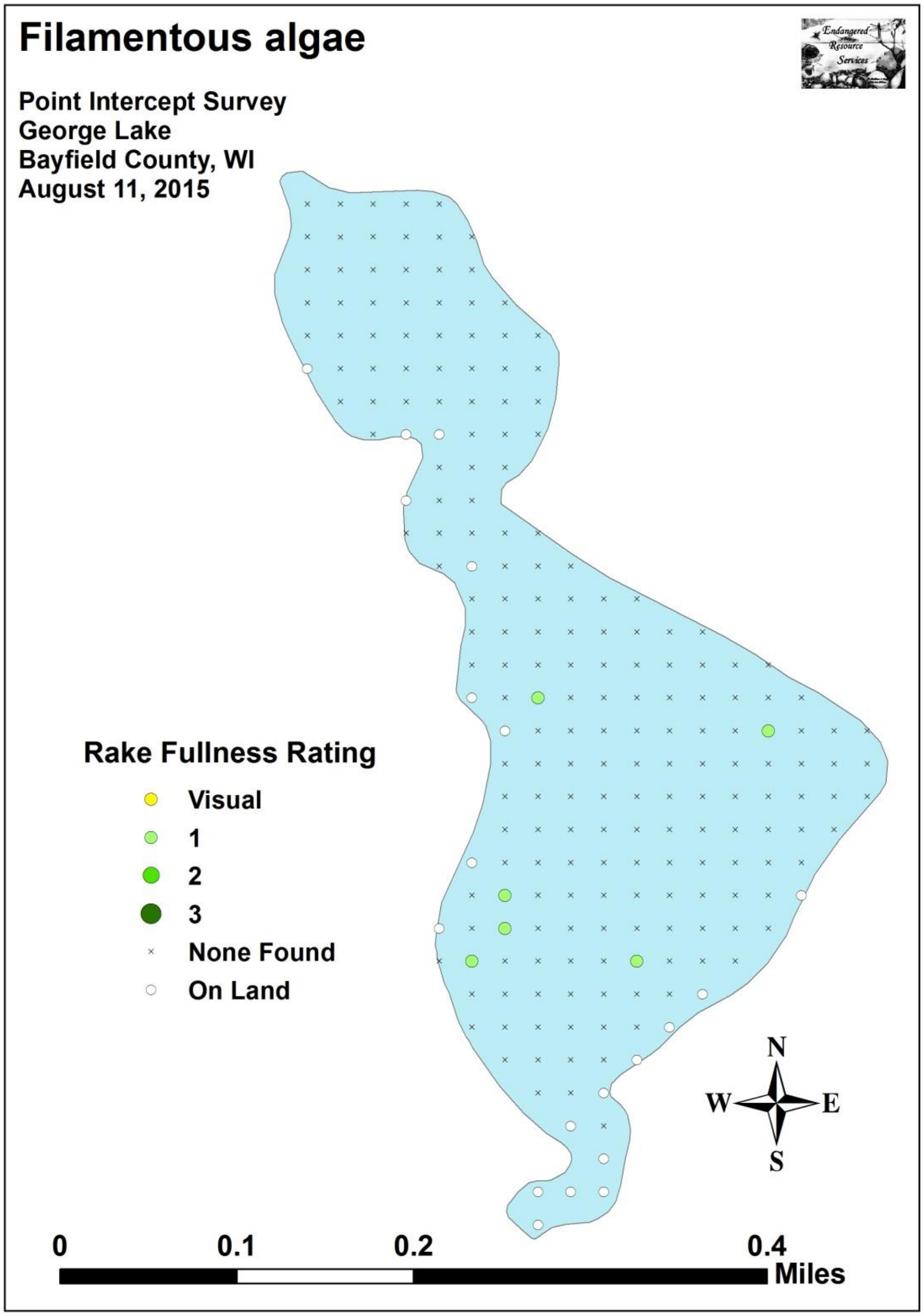

Muskgrass
(*Chara* sp.)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

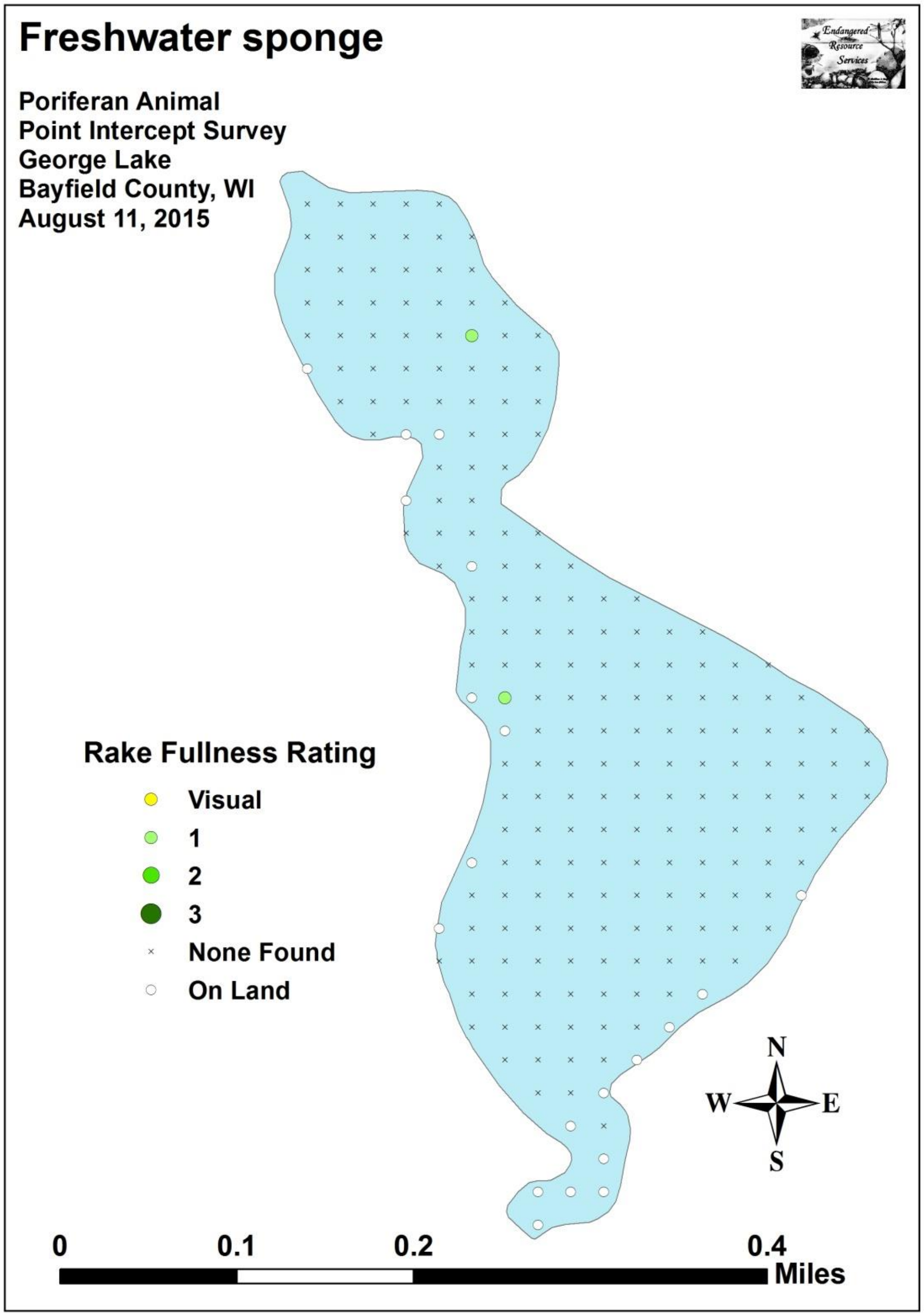

Three-way sedge
(*Dulichium arundinaceum*)
Coefficient of Conservatism = 9
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles


Needle spikerush
(*Eleocharis acicularis*)
Coefficient of Conservatism = 5
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles

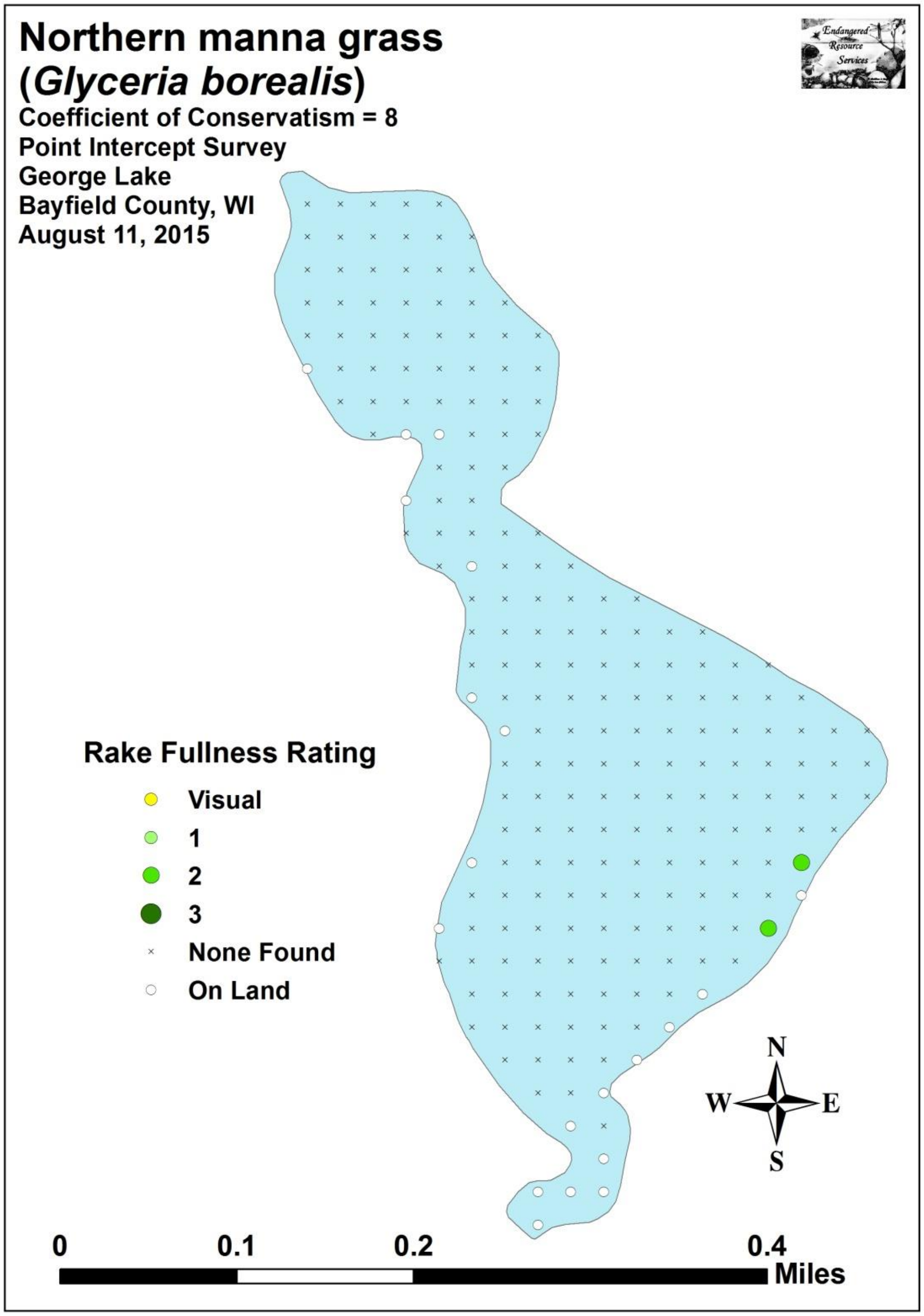

Creeping spikerush
(Eleocharis palustris)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles


Slender waterweed
(*Elodea nuttallii*)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles


Filamentous algae
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles



Freshwater sponge
Endangered Resource Services
Poriferan Animal
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
Visual
1
2
3
None Found
On Land
N
W
E
S
0
0.1
0.2
0.4
Miles


Northern manna grass
(Glyceria borealis)
Coefficient of Conservatism = 8
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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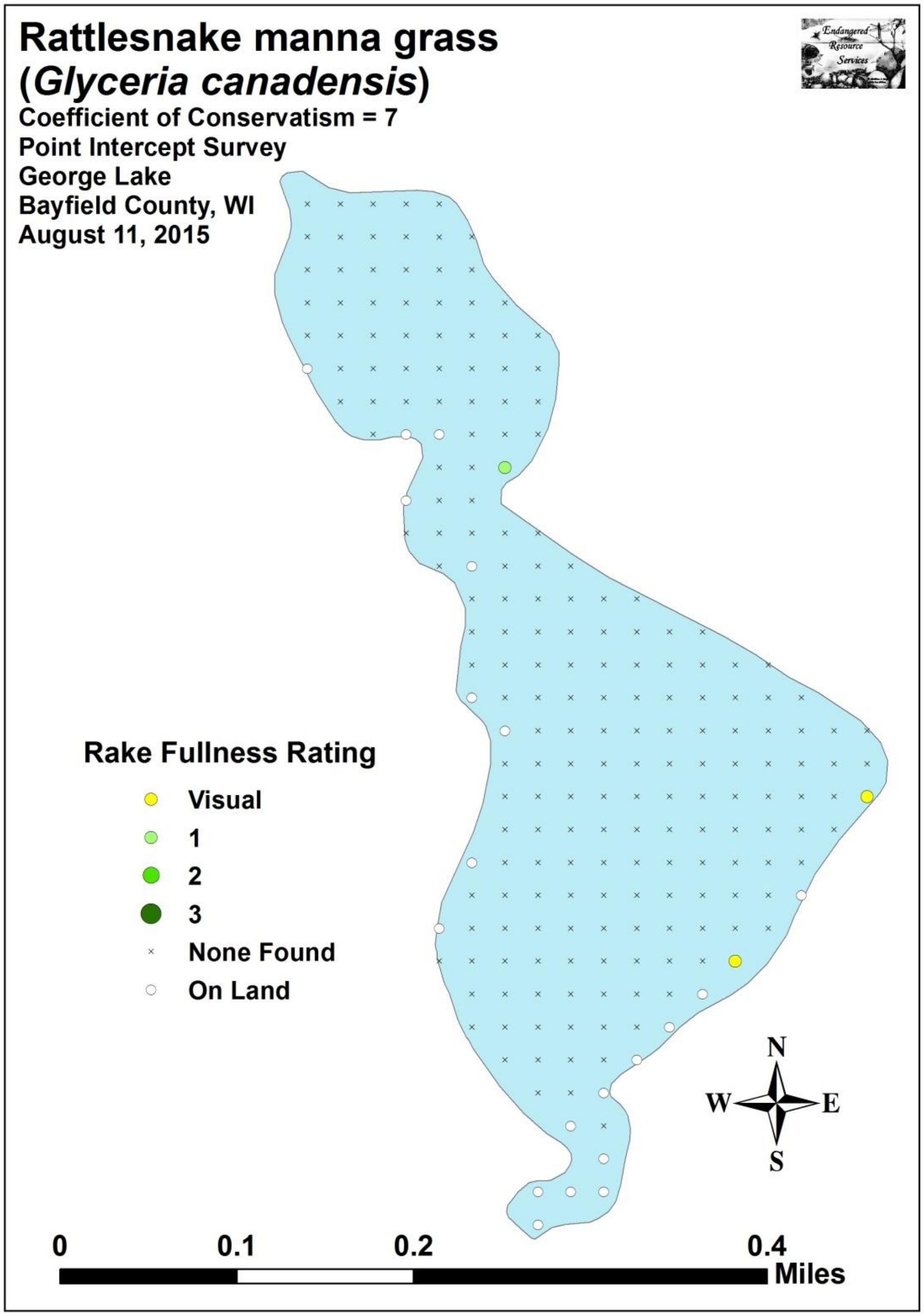
Miles


Rattlesnake manna grass
(Glyceria canadensis)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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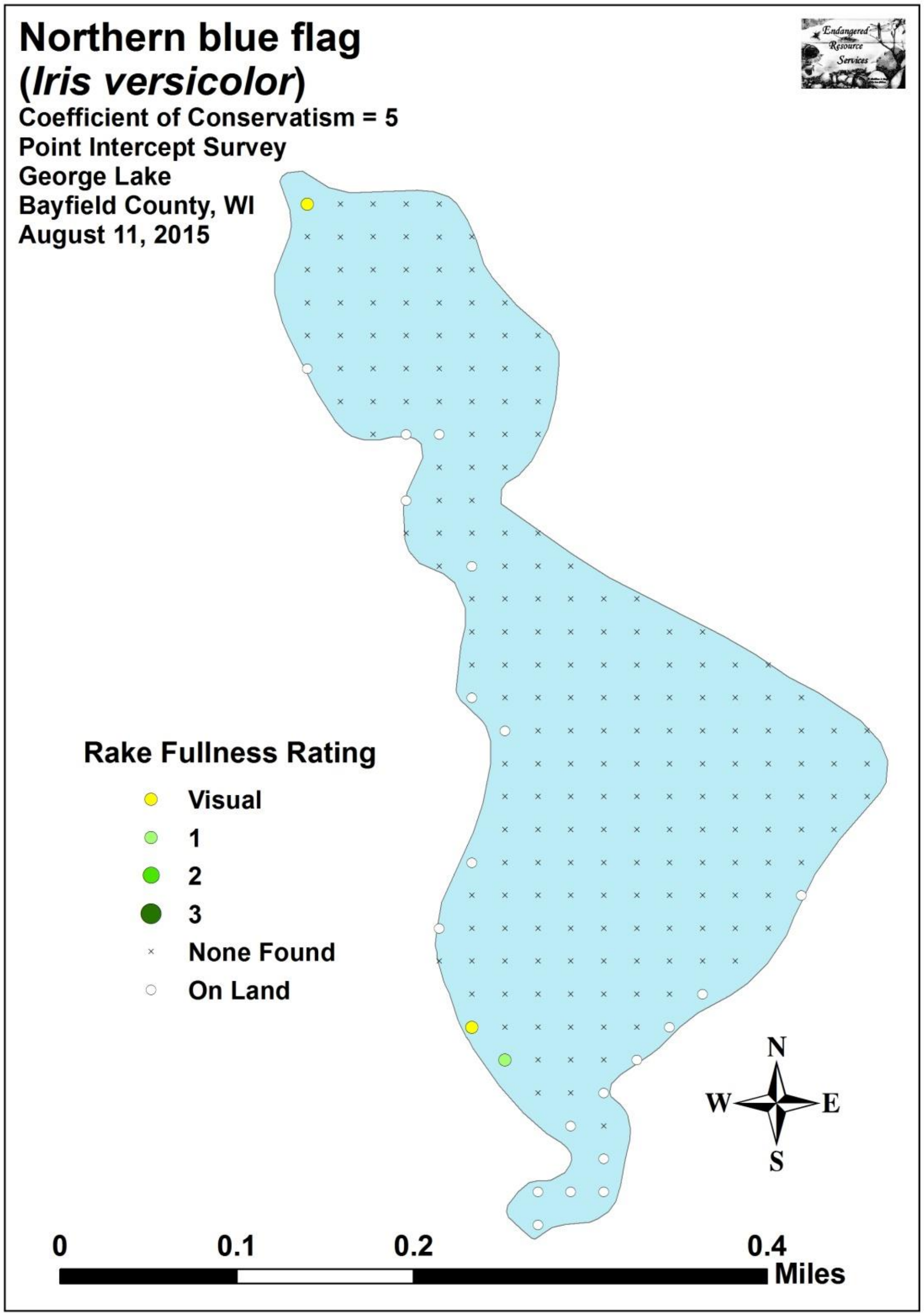
Miles


Northern blue flag
(Iris versicolor)
Coefficient of Conservatism = 5
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
Visual
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None Found
On Land
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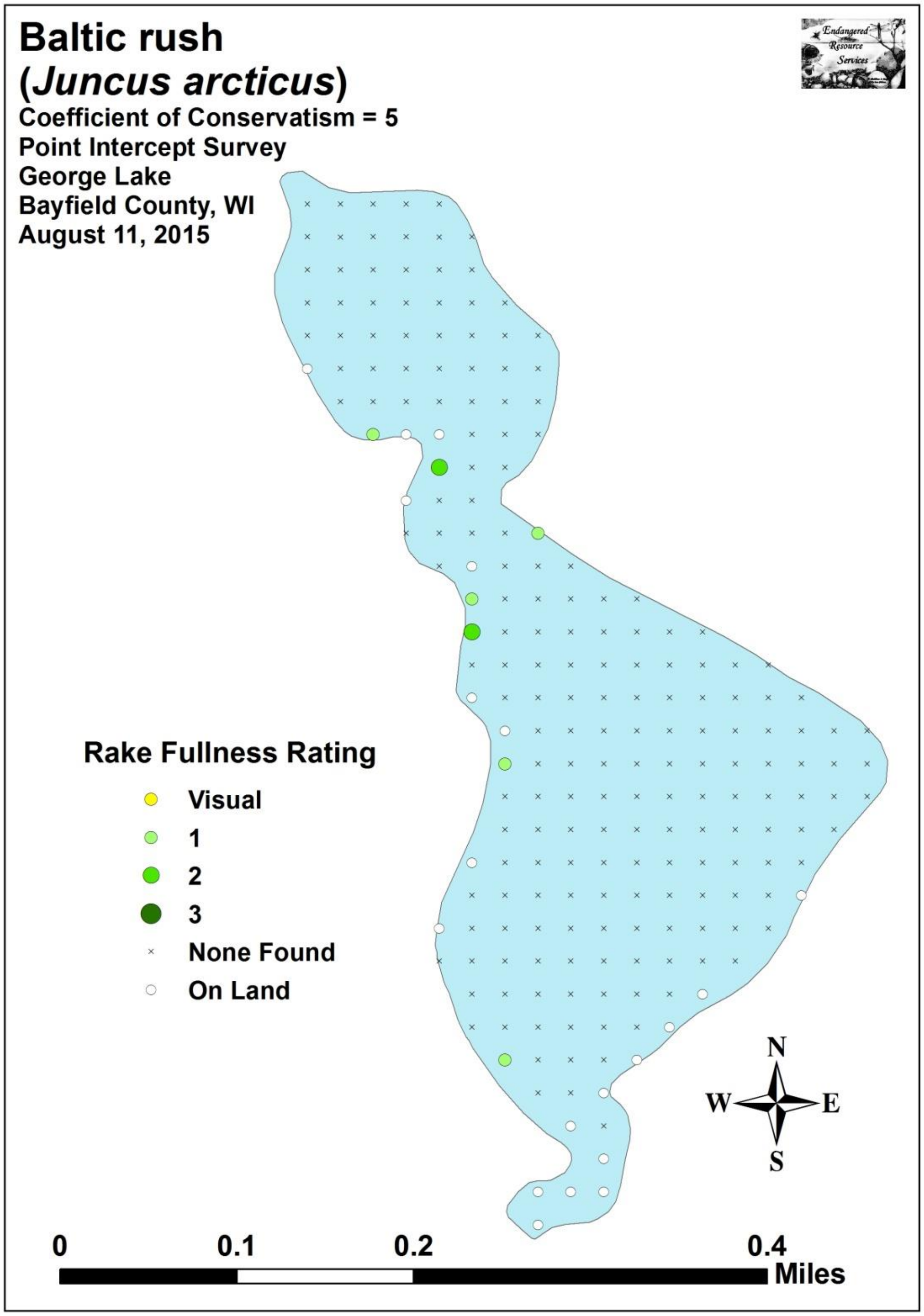
Miles


Baltic rush
(Juncus arcticus)
Coefficient of Conservatism = 5
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
Visual
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None Found
On Land
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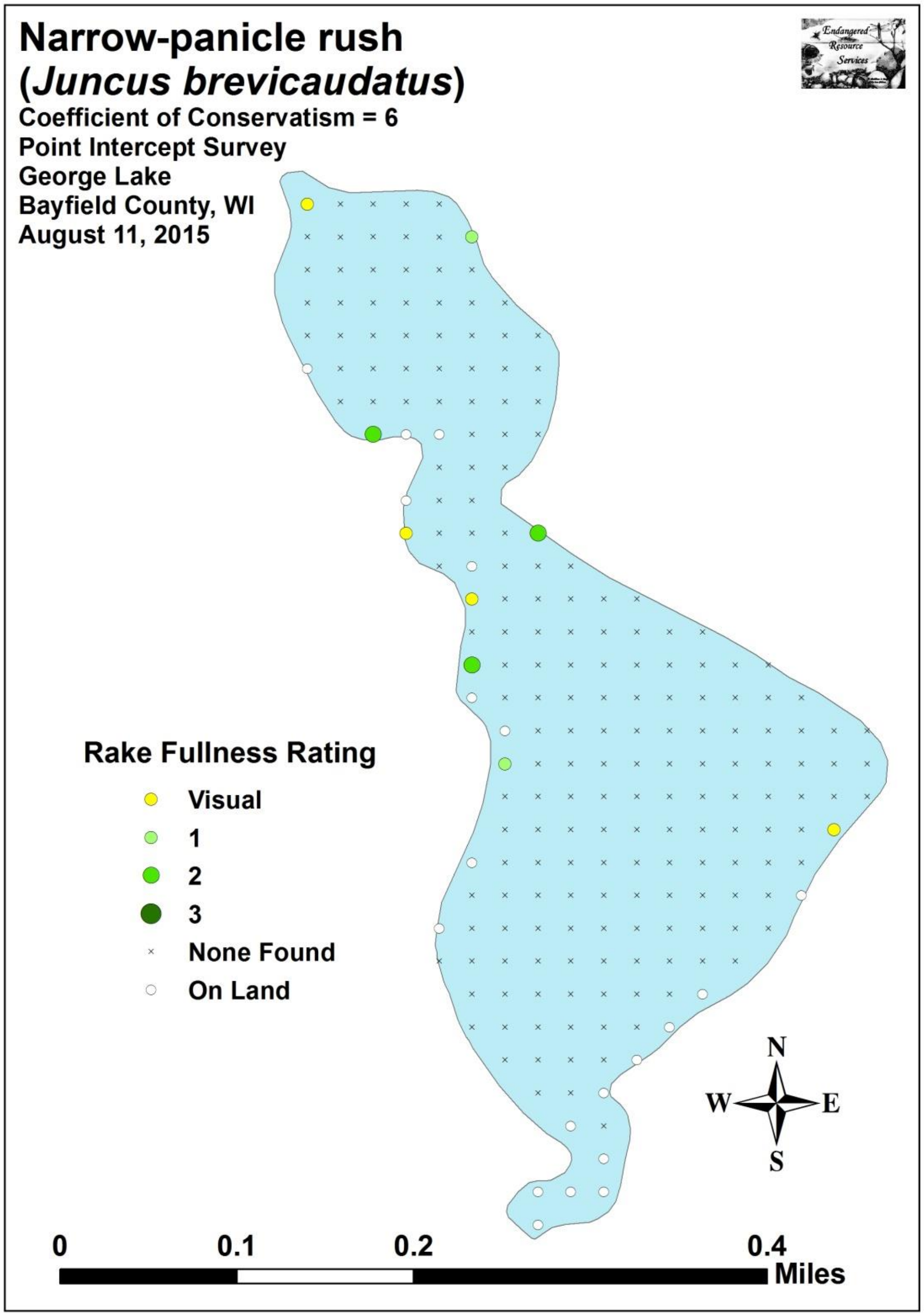
Miles



Narrow-panicle rush
(Juncus brevicaudatus)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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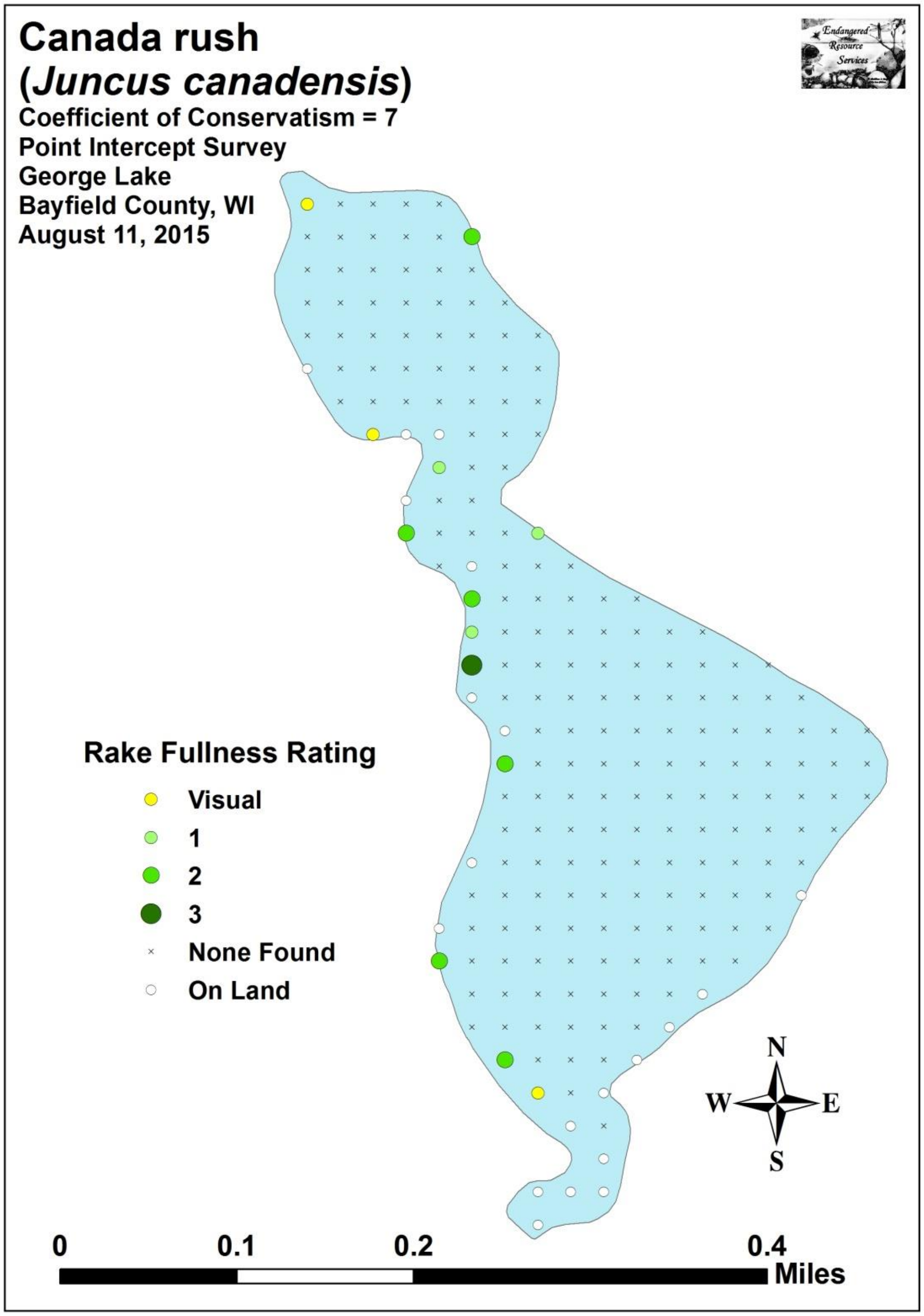
Miles


Canada rush
(Juncus canadensis)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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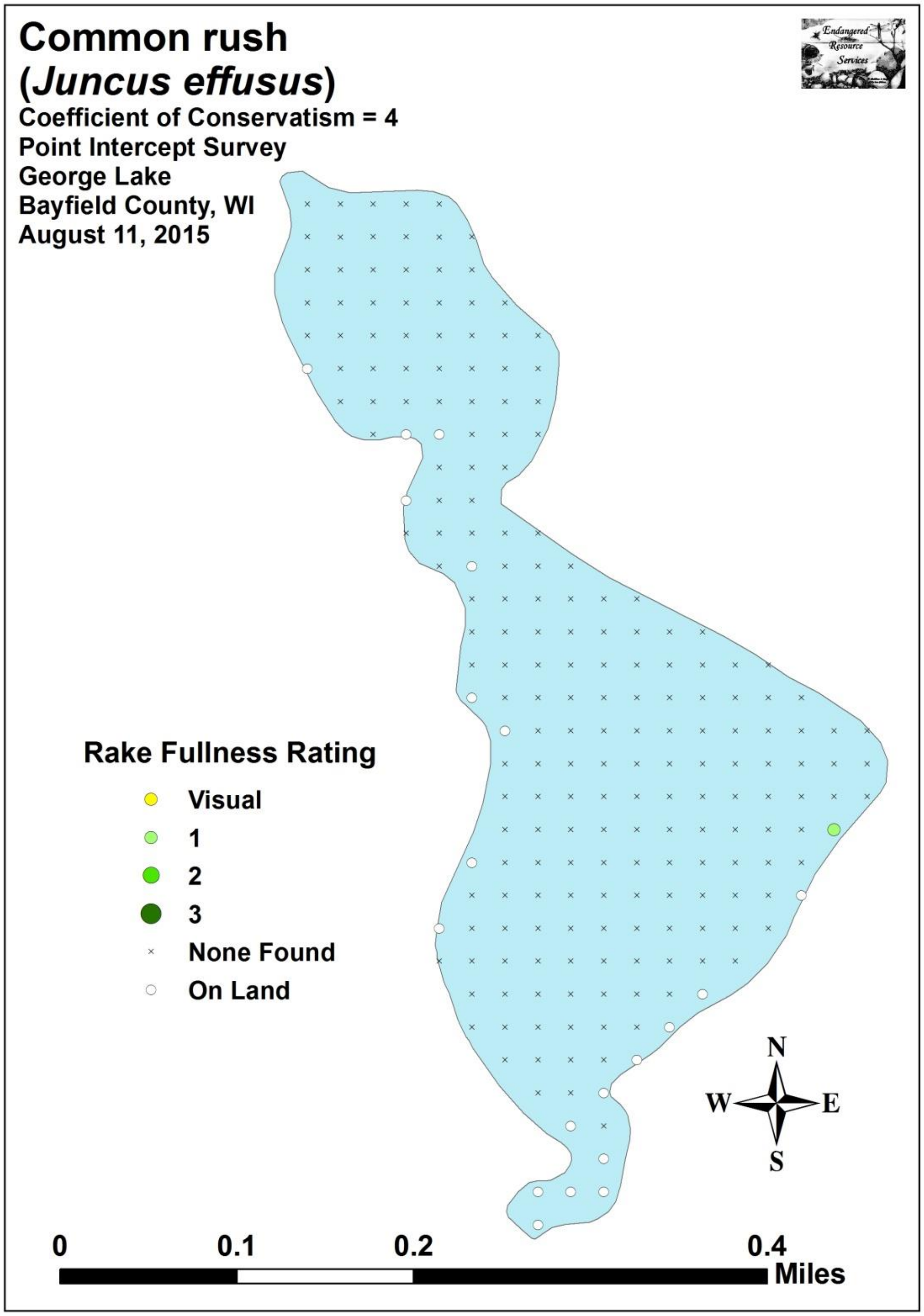
Miles



Common rush
(*Juncus effusus*)
Coefficient of Conservatism = 4
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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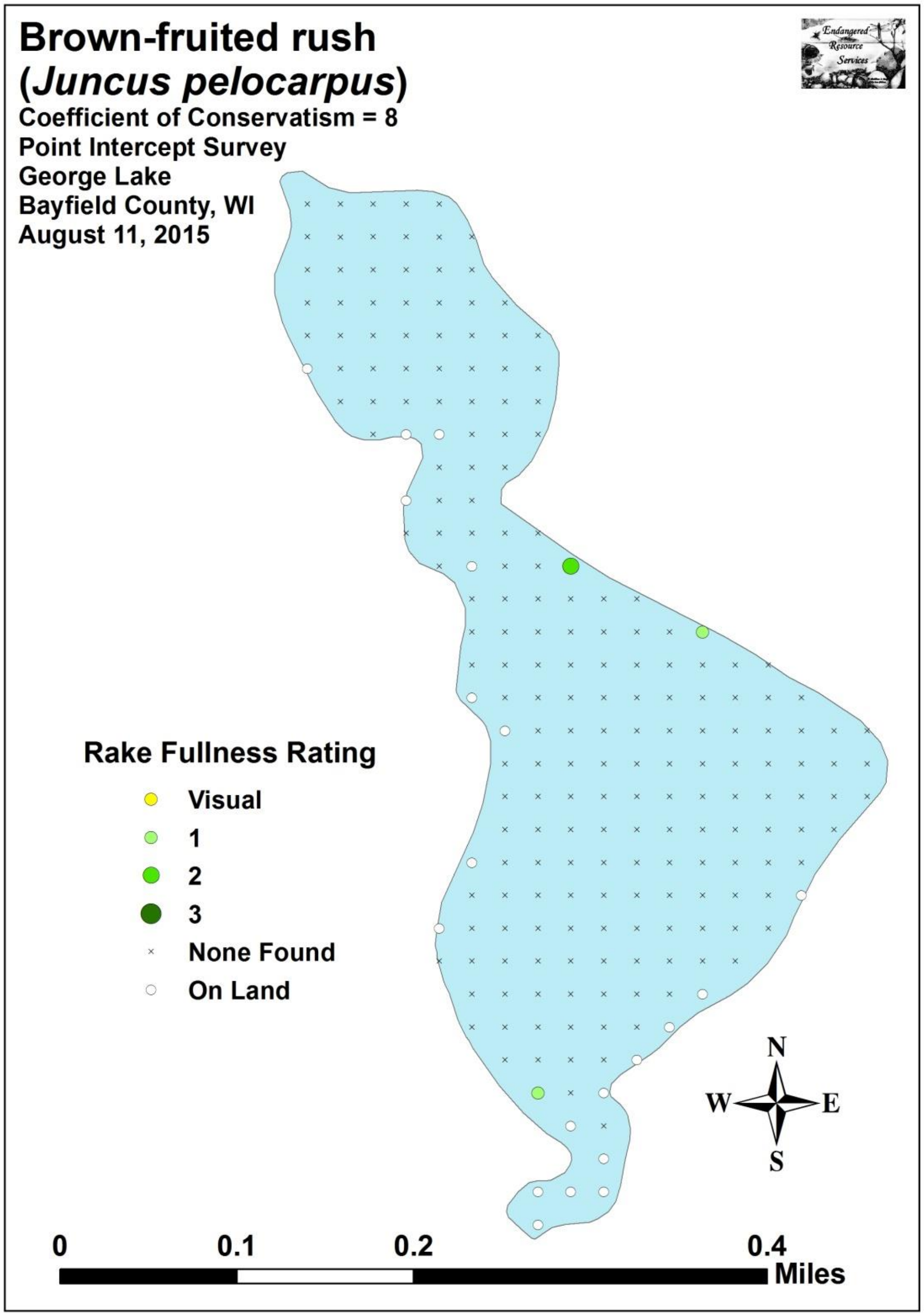
Miles



Brown-fruited rush
(Juncus pelocarpus)
Coefficient of Conservatism = 8
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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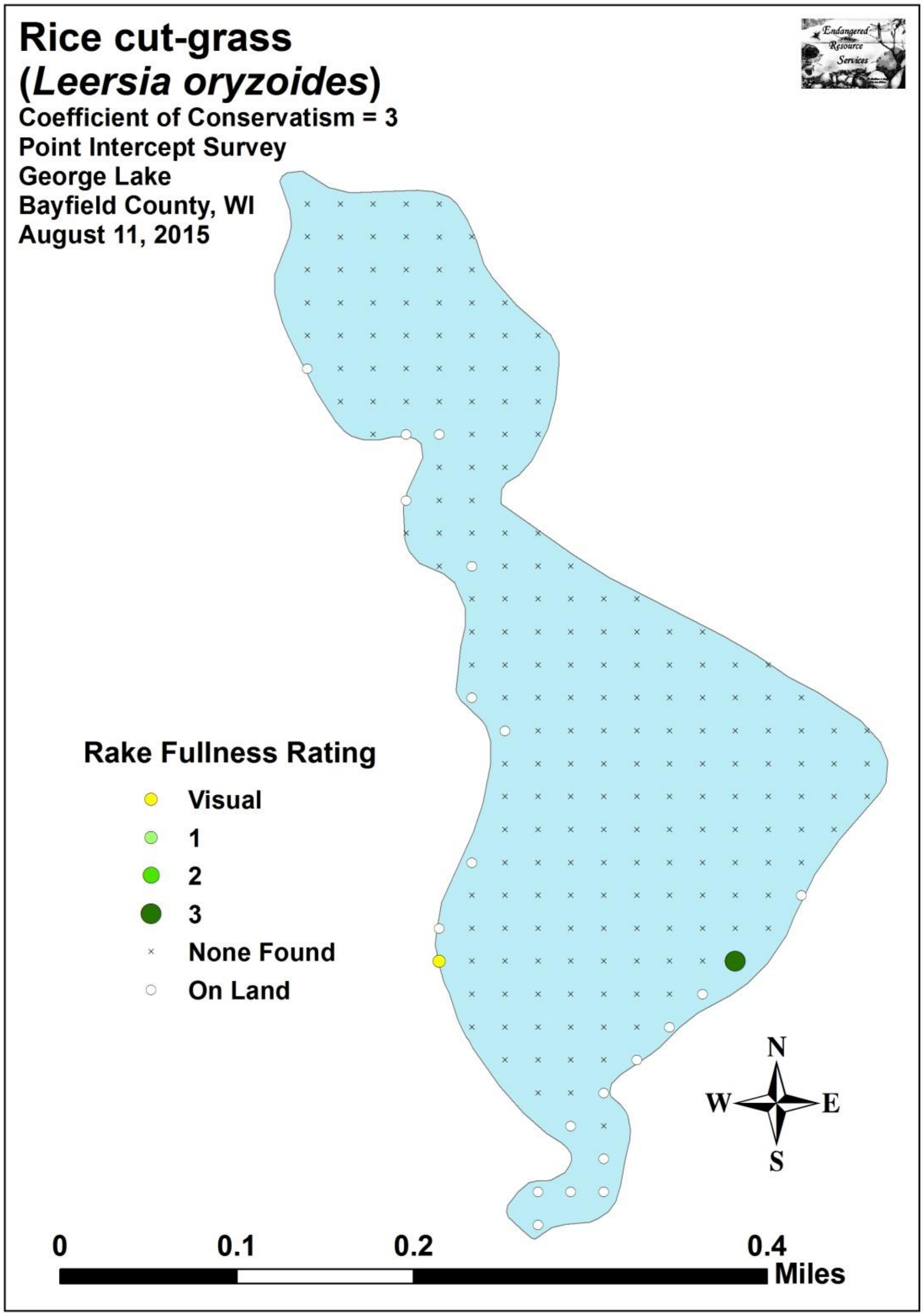
Miles


Rice cut-grass
(*Leersia oryzoides*)
Coefficient of Conservatism = 3
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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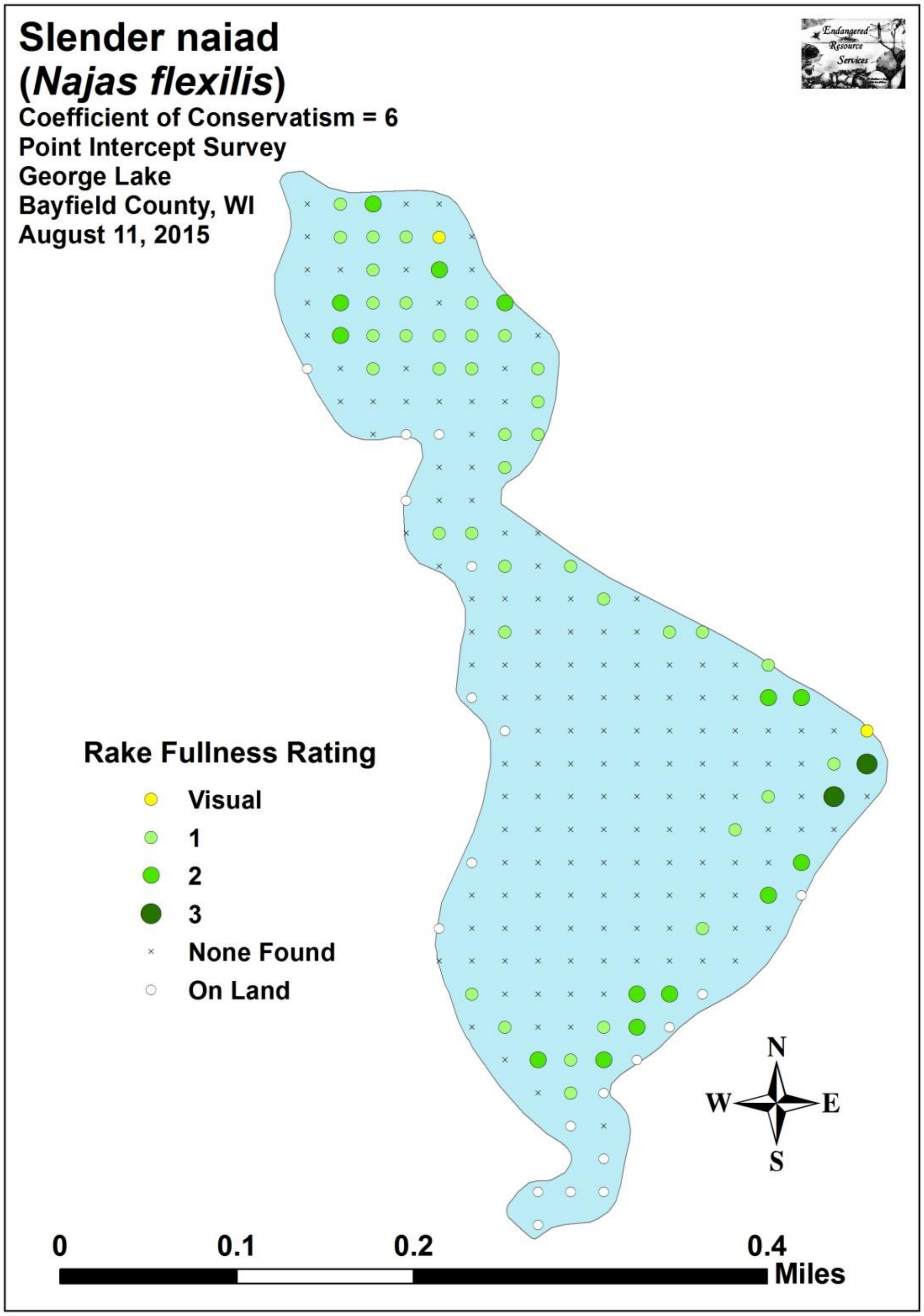
Miles


Slender naiad
(Najas flexilis)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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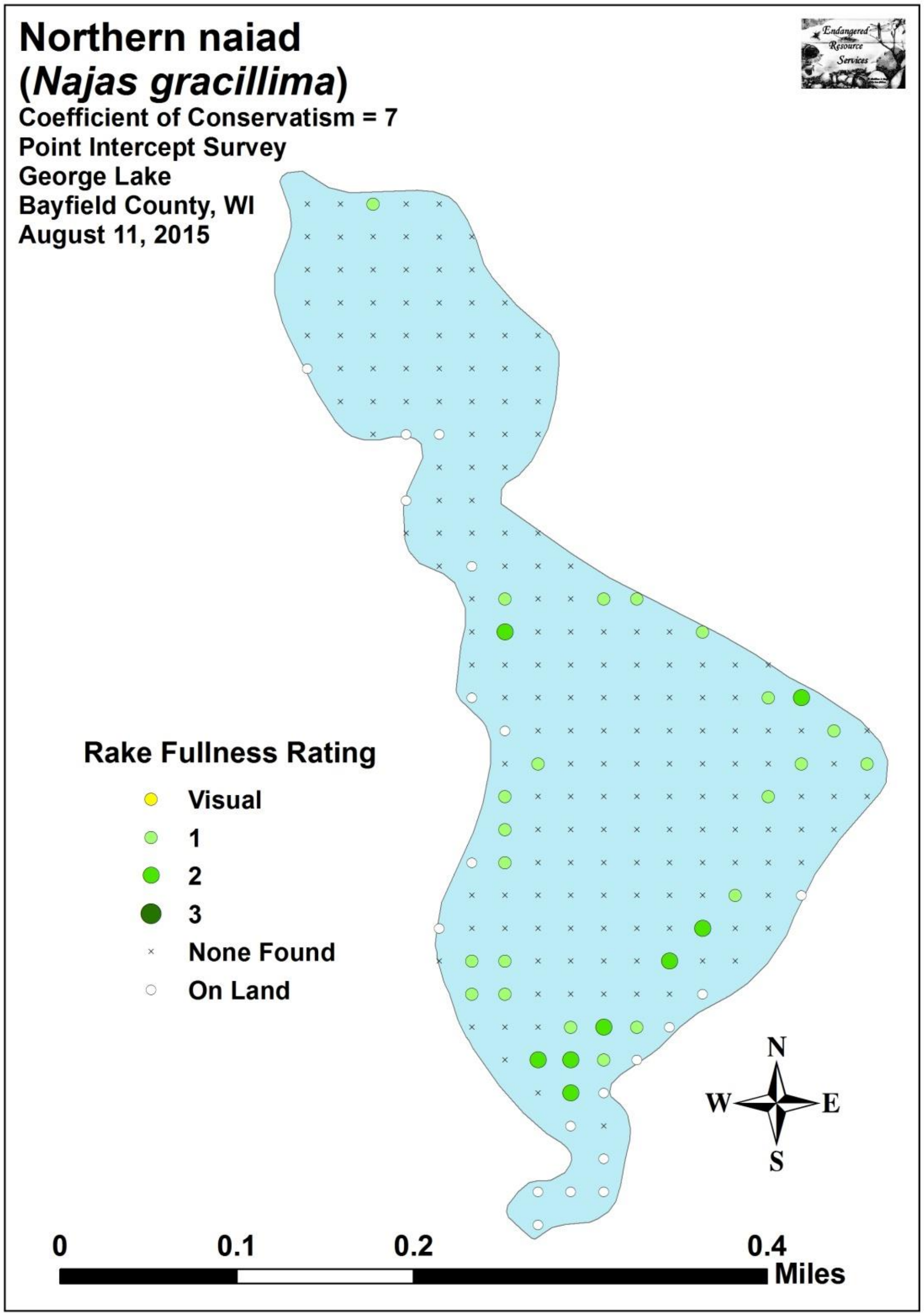
Miles


Northern naiad
(Najas gracillima)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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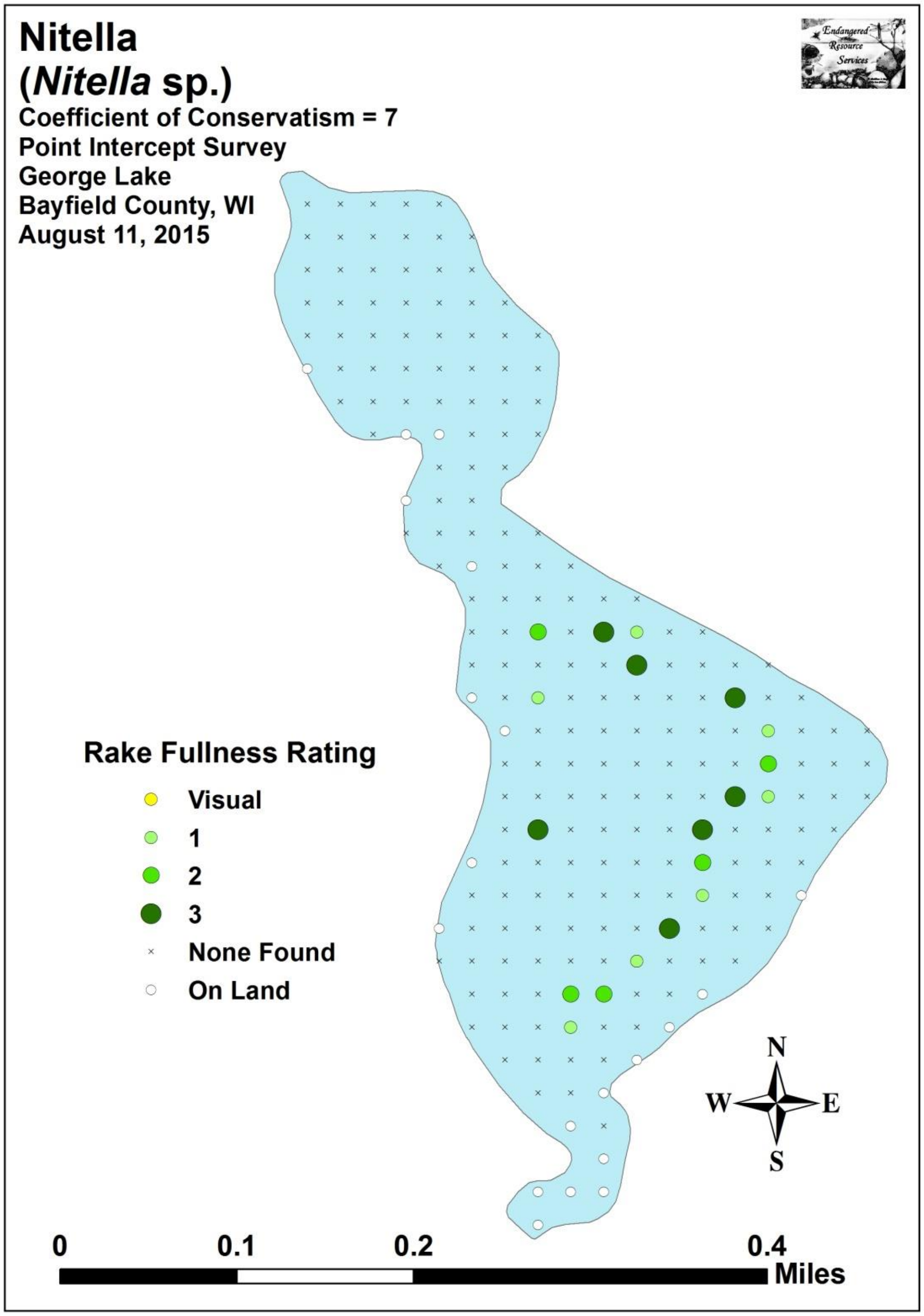
Miles


Nitella
(*Nitella* sp.)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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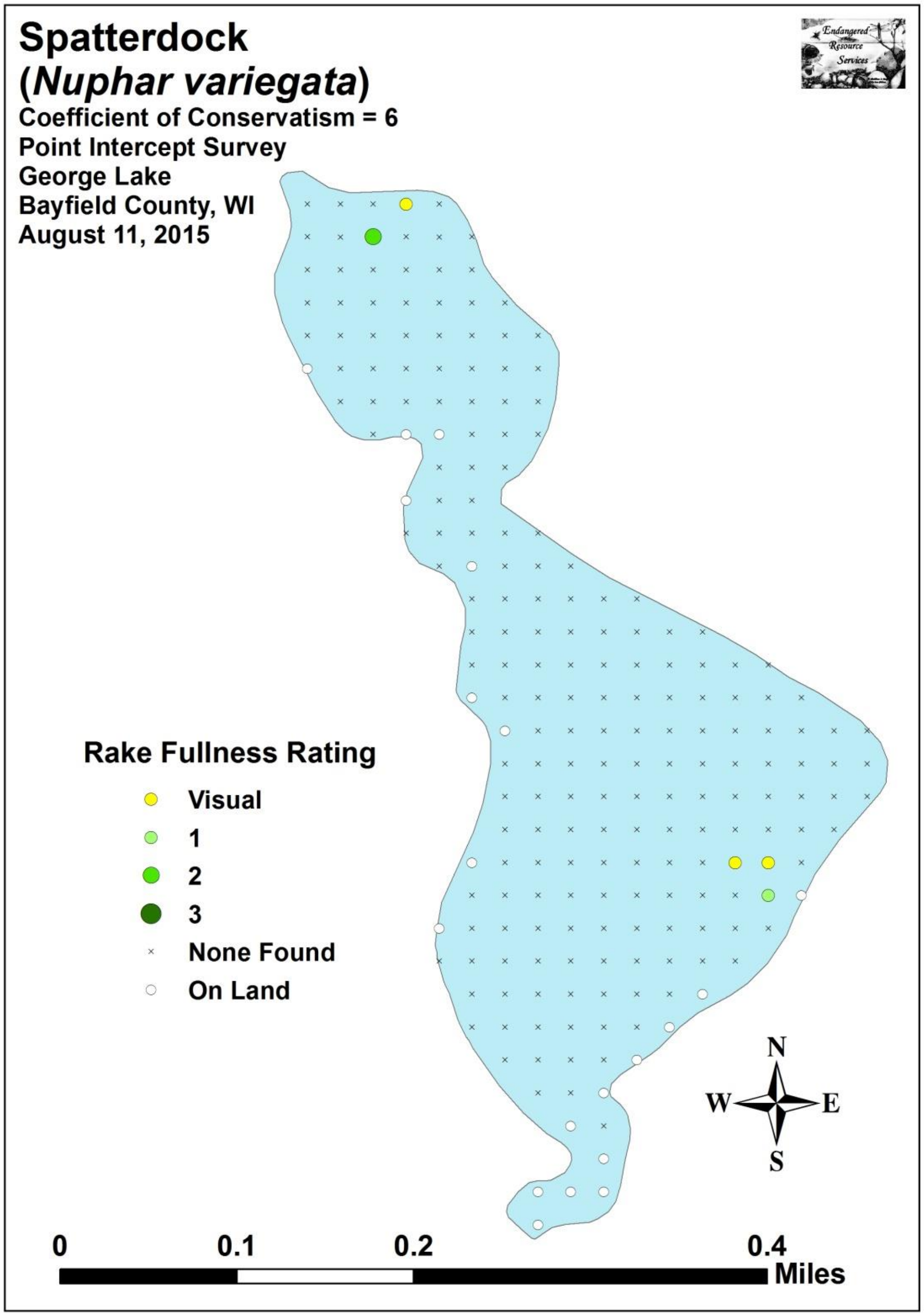
Miles



Spatterdock
(Nuphar variegata)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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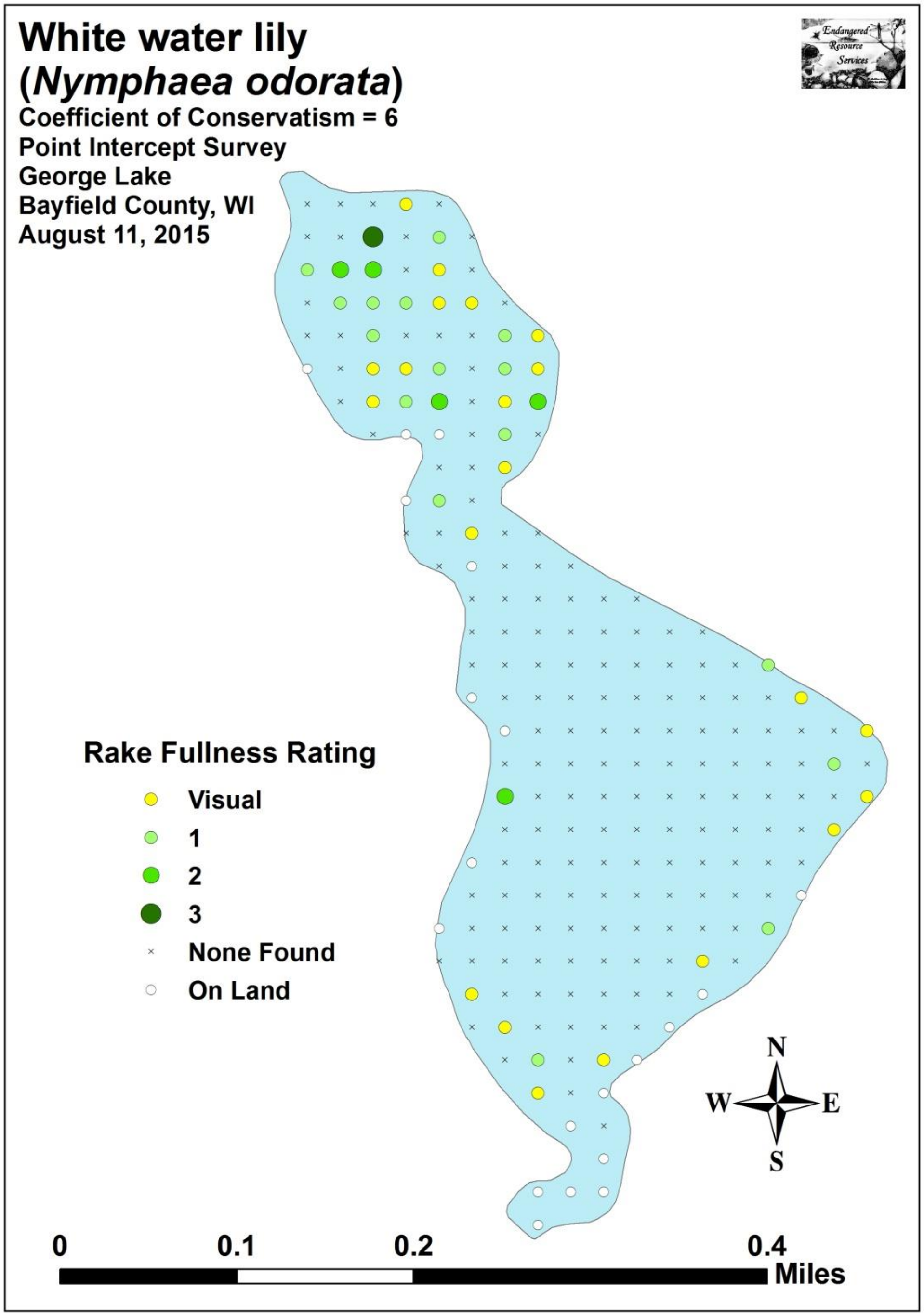
Miles


White water lily
(Nymphaea odorata)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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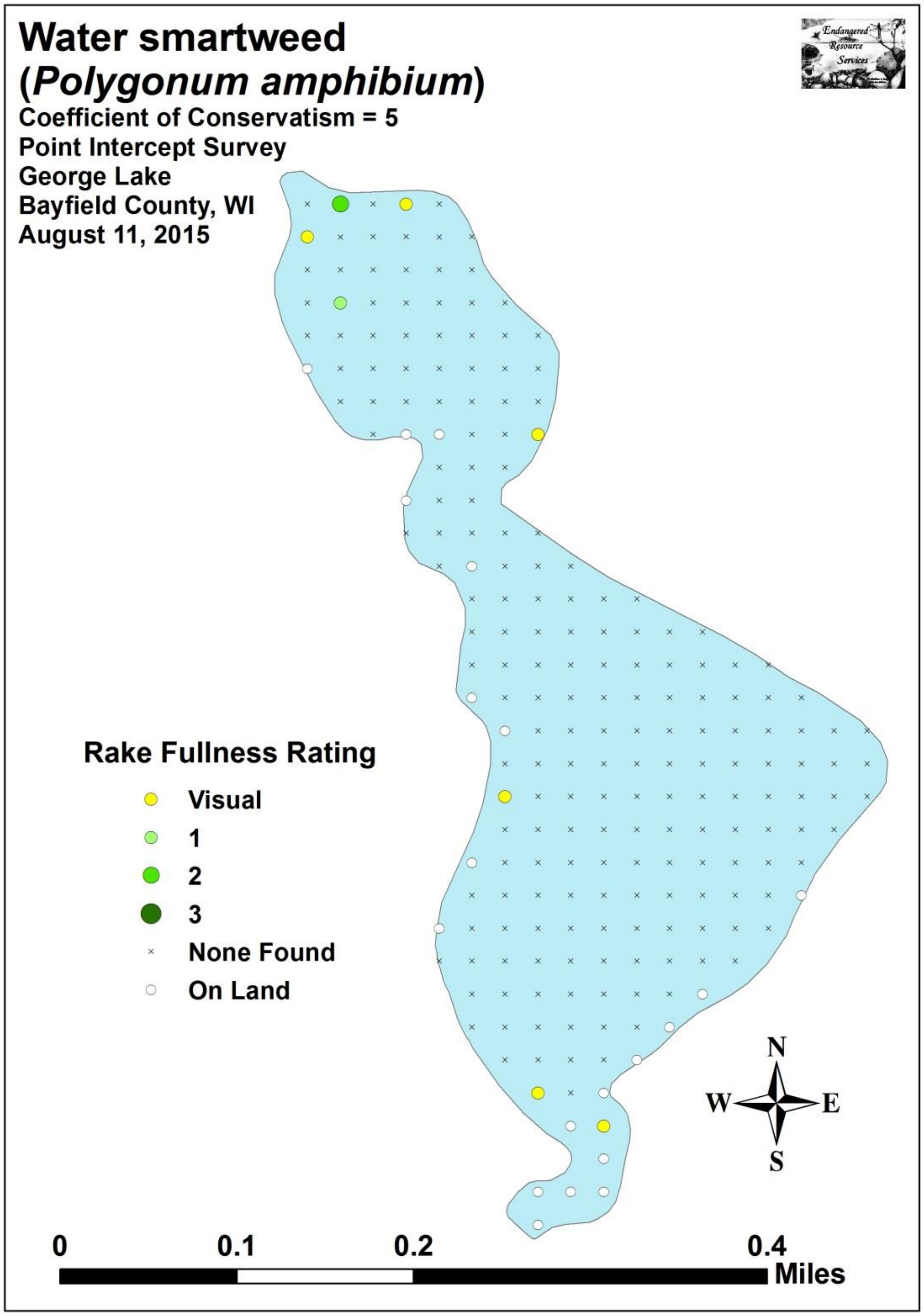
Miles


Water smartweed
(Polygonum amphibium)
Coefficient of Conservatism = 5
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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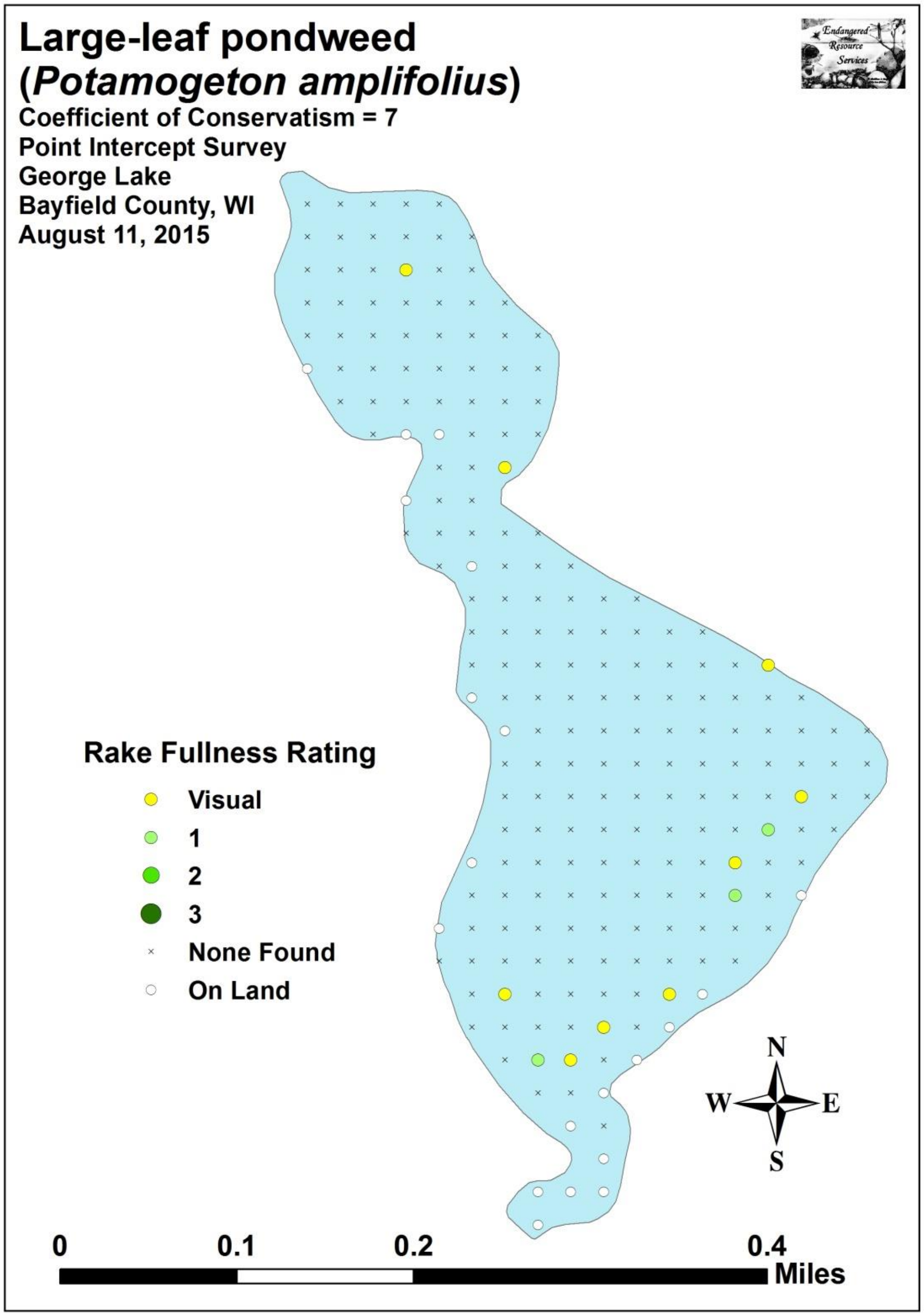
Miles


Large-leaf pondweed
(Potamogeton amplifolius)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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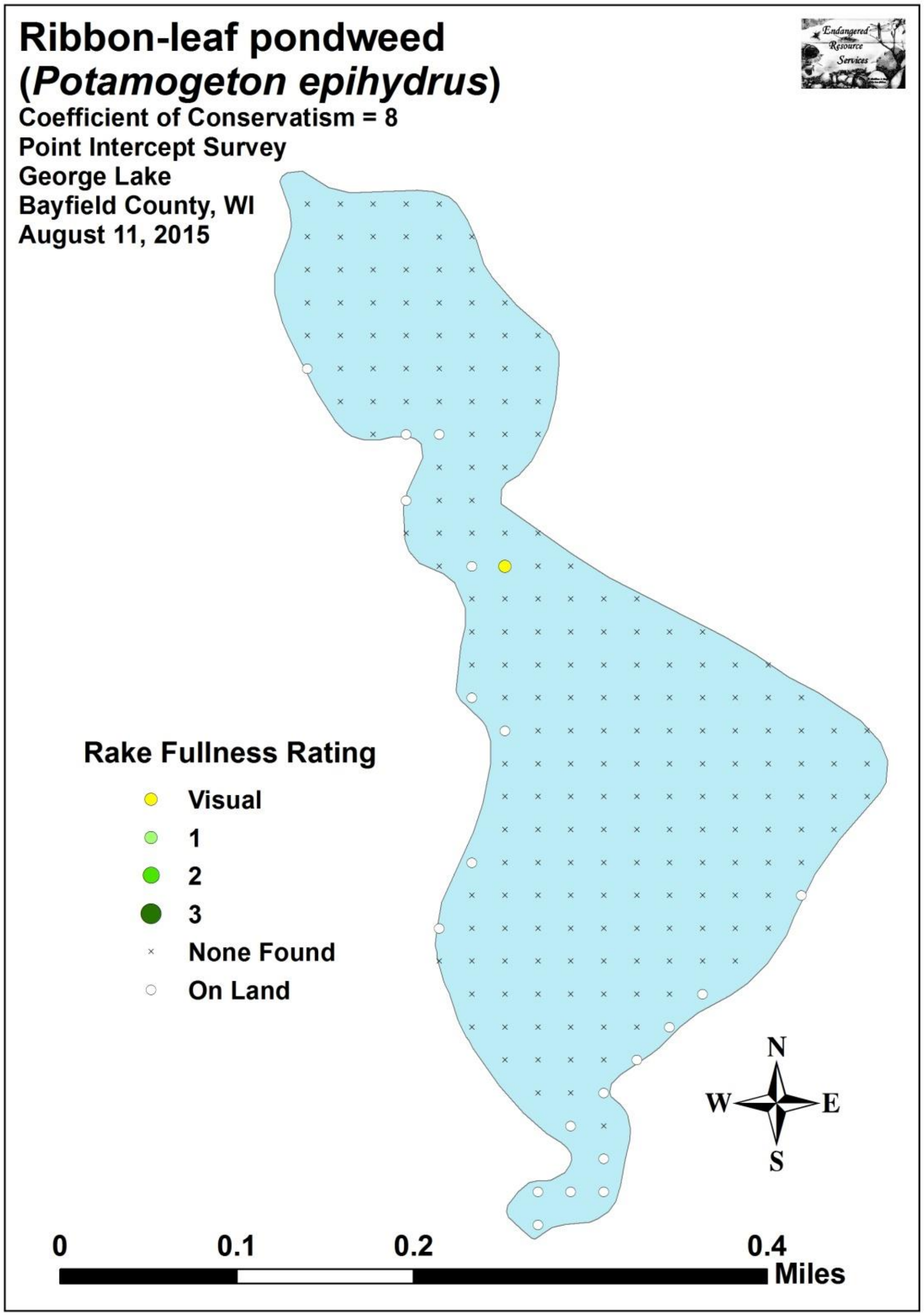
Miles


Ribbon-leaf pondweed
(*Potamogeton epihydrus*)
Coefficient of Conservatism = 8
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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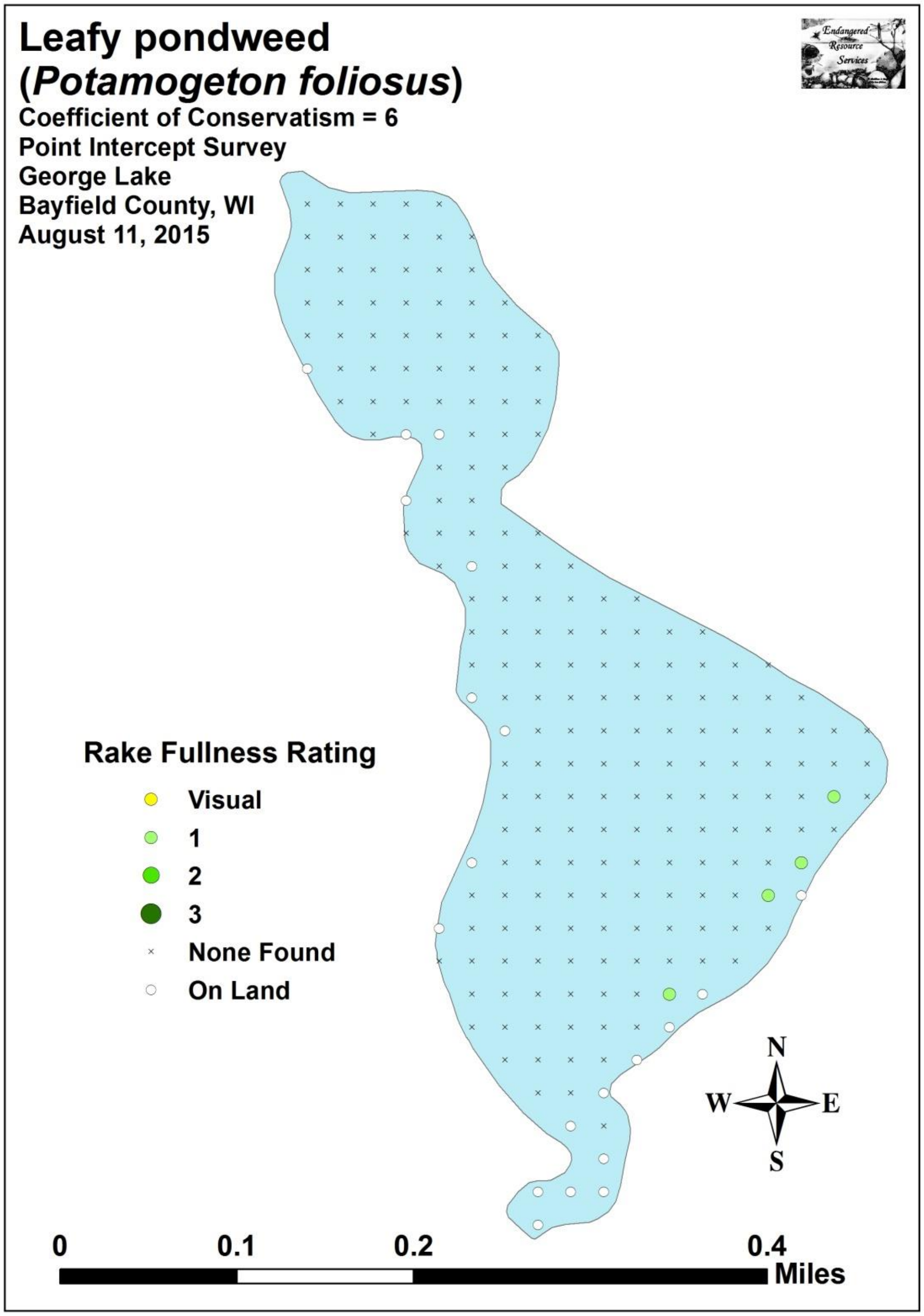
Miles


Leafy pondweed
(Potamogeton foliosus)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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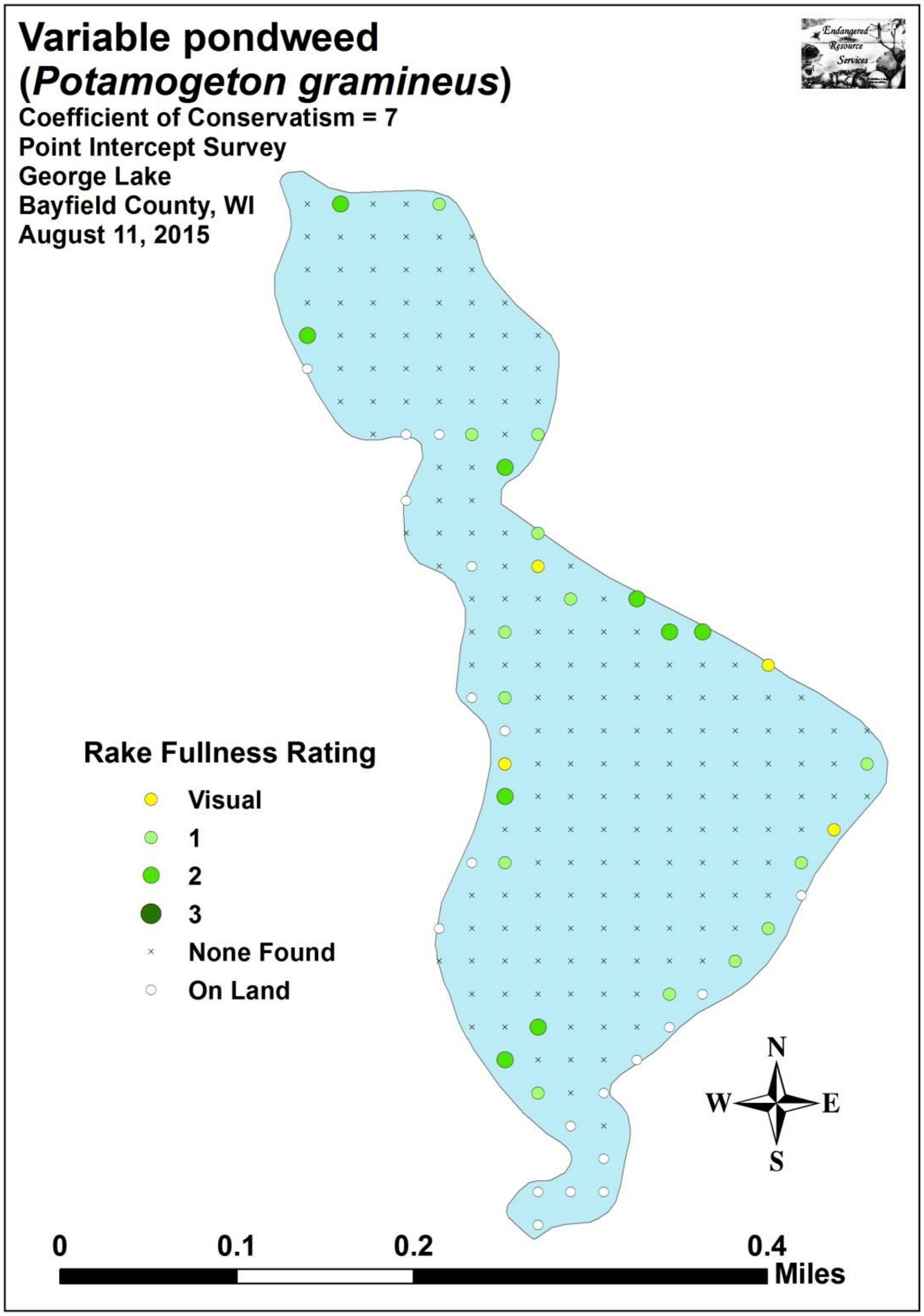
Miles


Variable pondweed
(*Potamogeton gramineus*)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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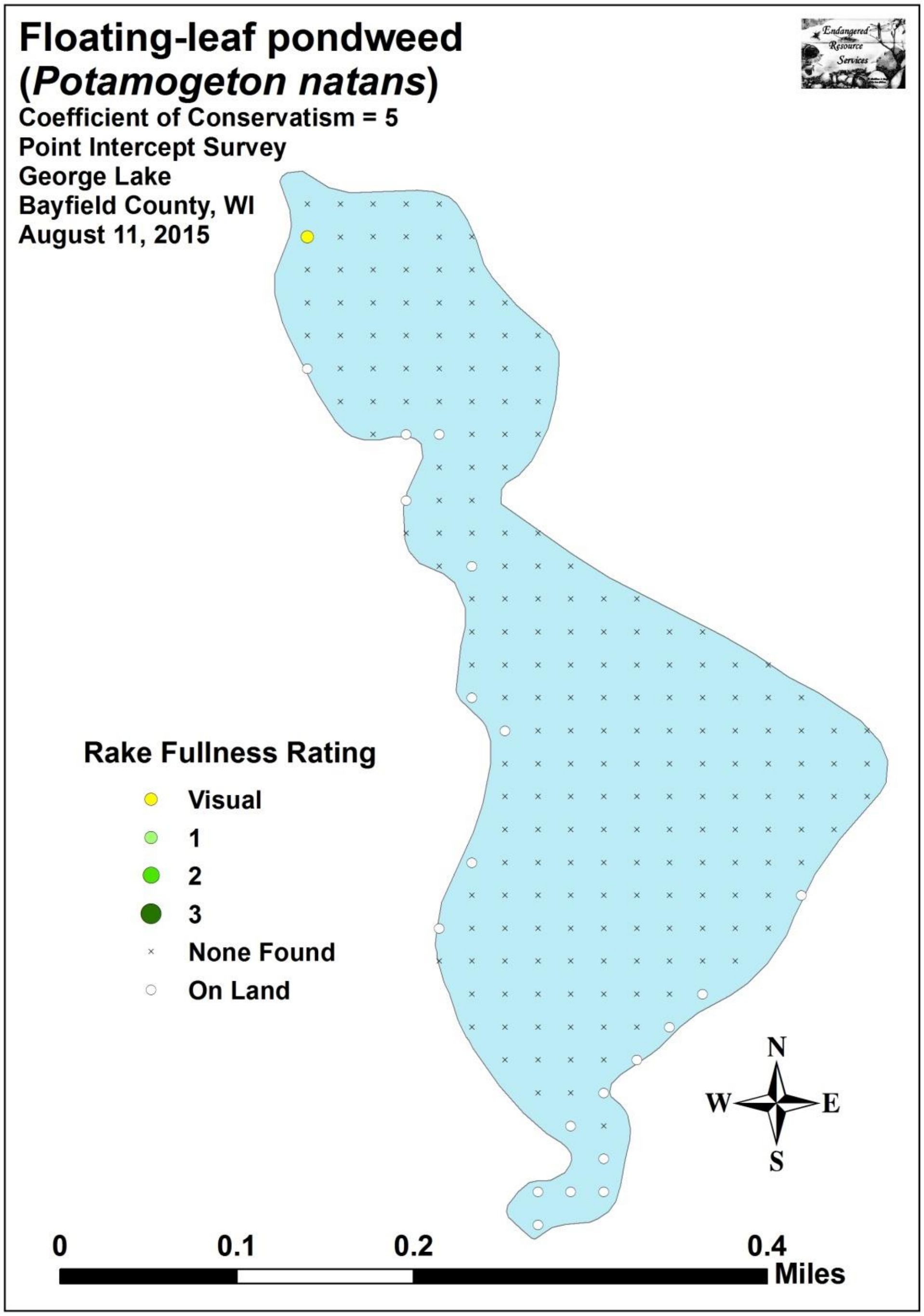
Miles


Floating-leaf pondweed
(Potamogeton natans)
Coefficient of Conservatism = 5
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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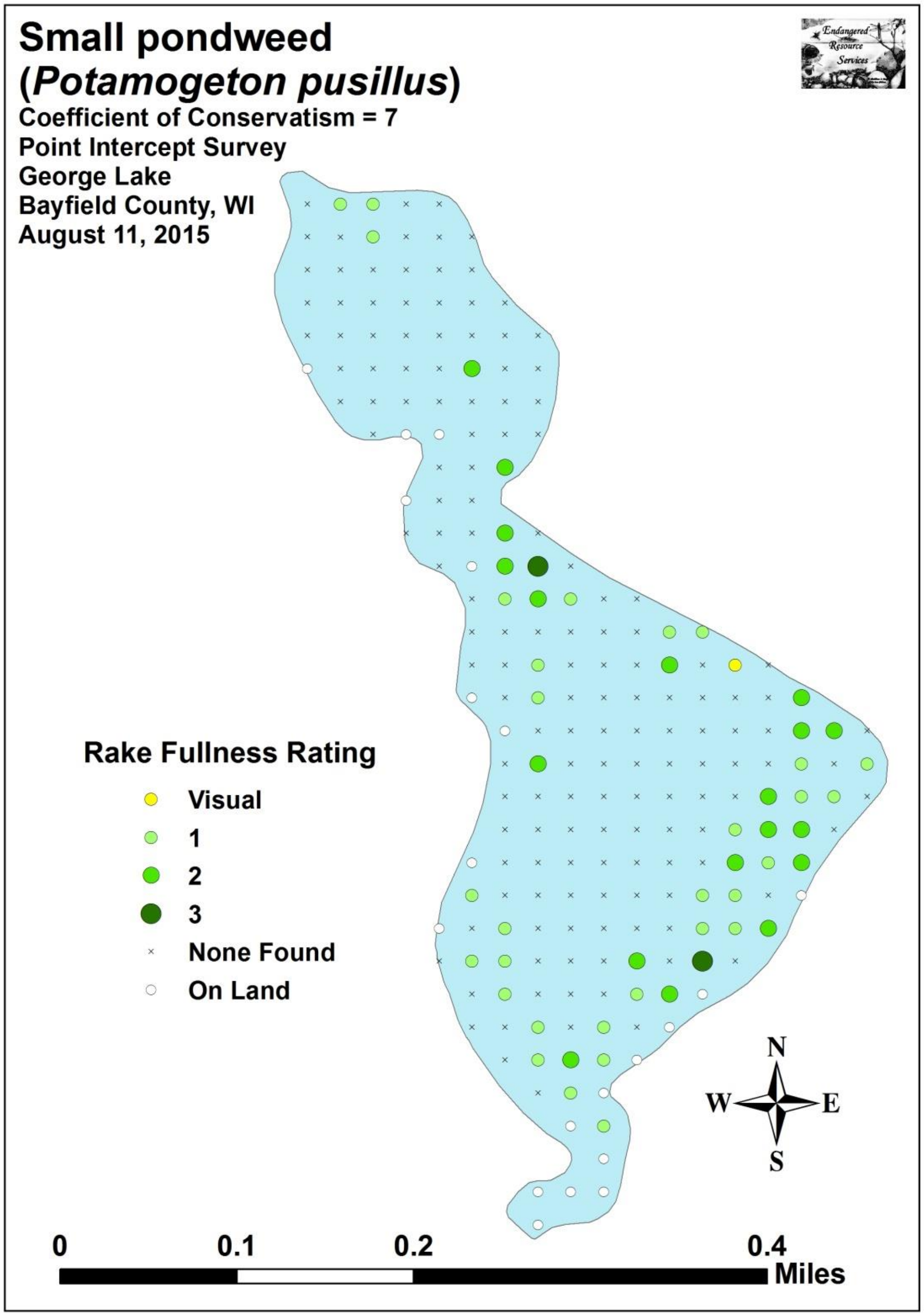
Miles



Small pondweed
(Potamogeton pusillus)
Coefficient of Conservatism = 7
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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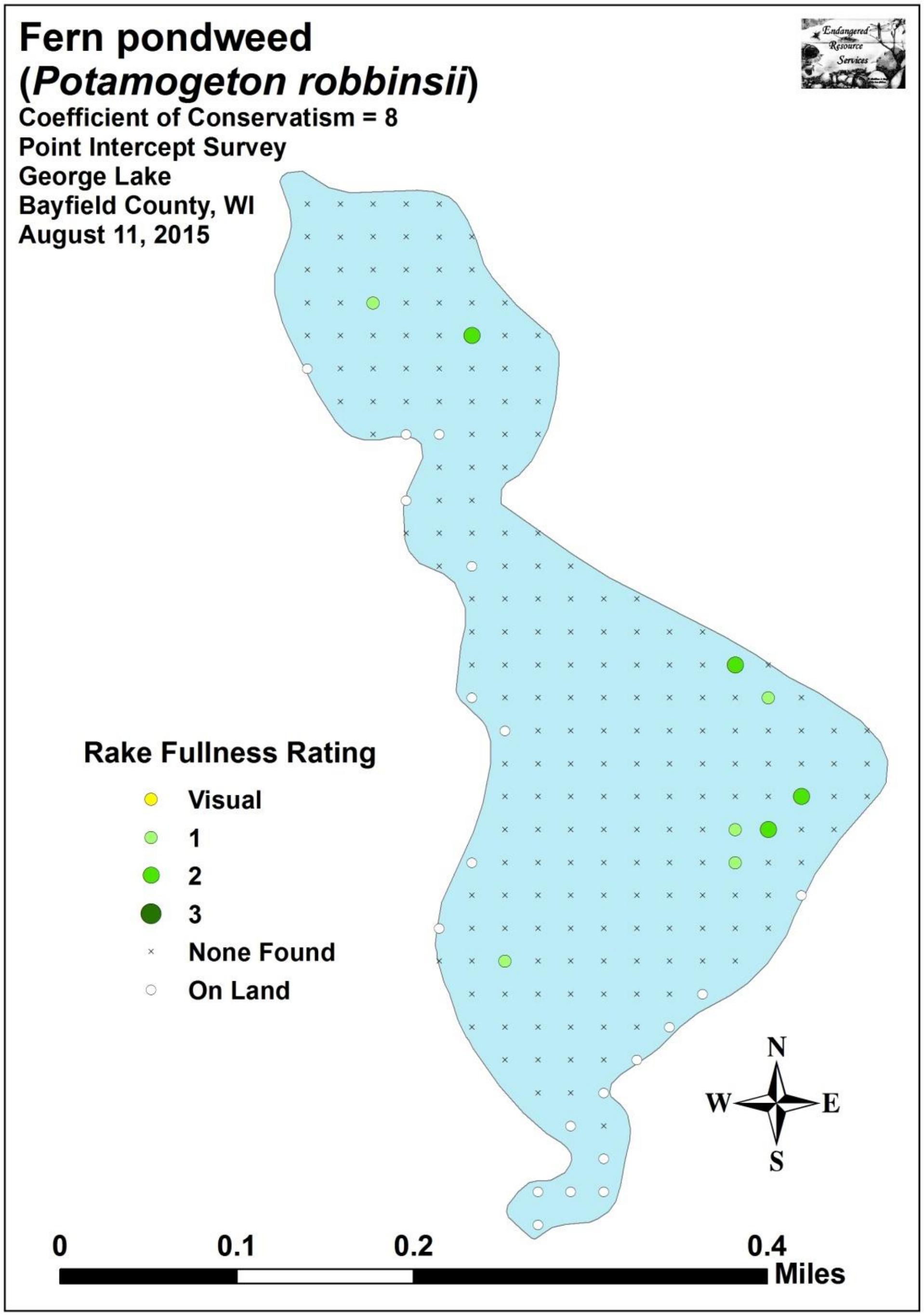
Miles


Fern pondweed
(*Potamogeton robbinsii*)
Coefficient of Conservatism = 8
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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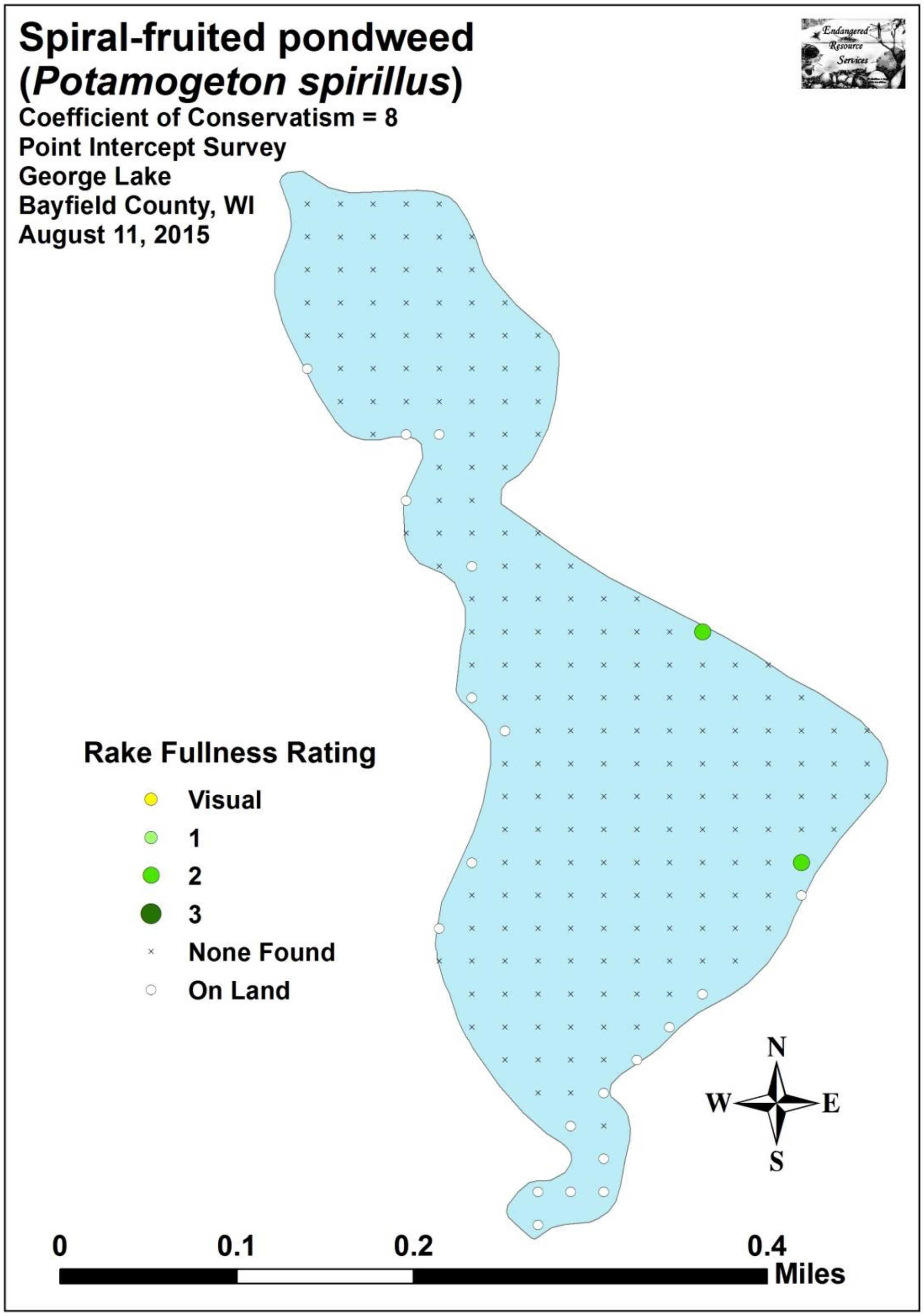
Miles



Spiral-fruited pondweed
(Potamogeton spirillus)
Coefficient of Conservatism = 8
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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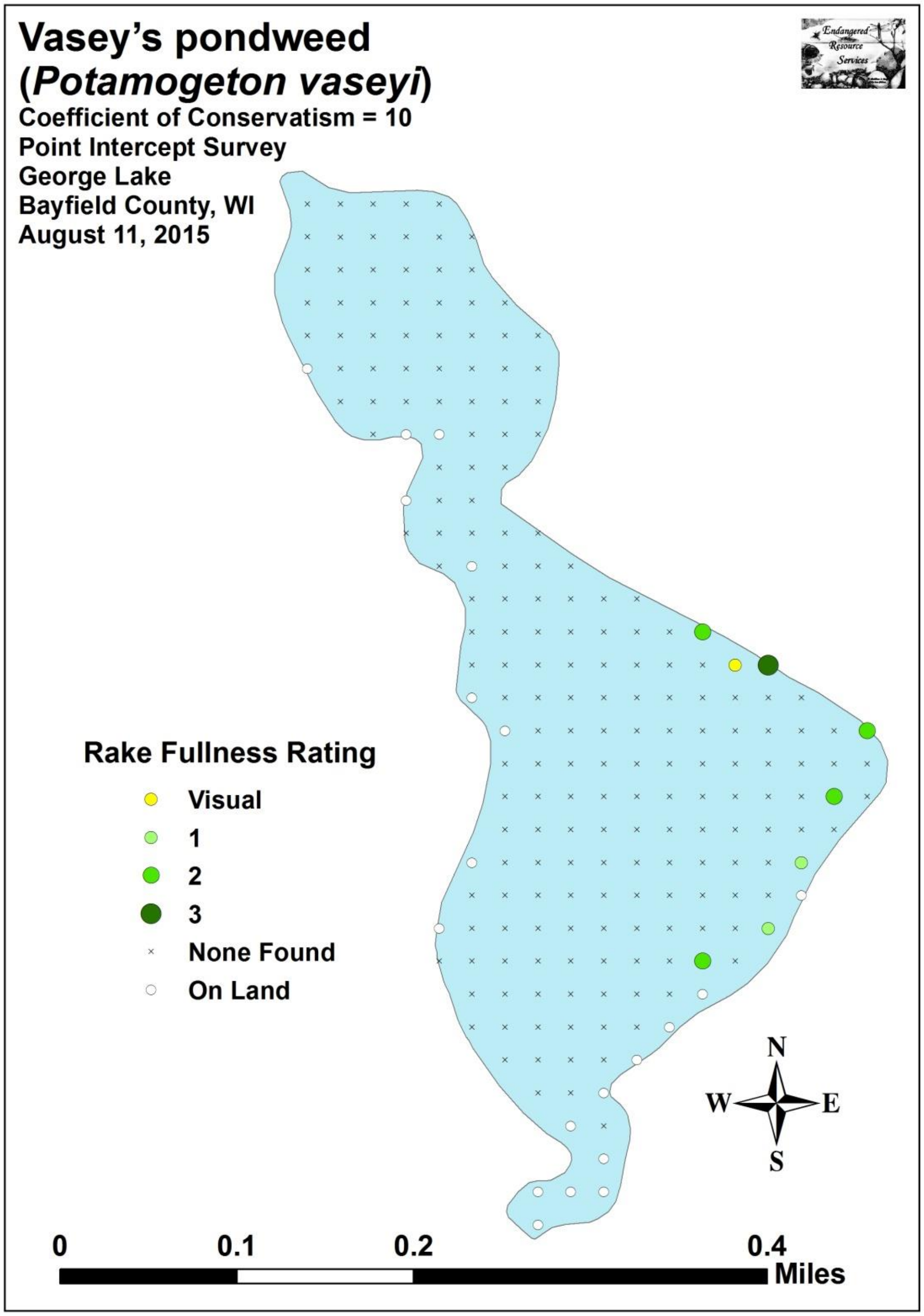
Miles


Vasey's pondweed
(Potamogeton vaseyi)
Coefficient of Conservatism = 10
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Rake Fullness Rating
Visual
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None Found
On Land
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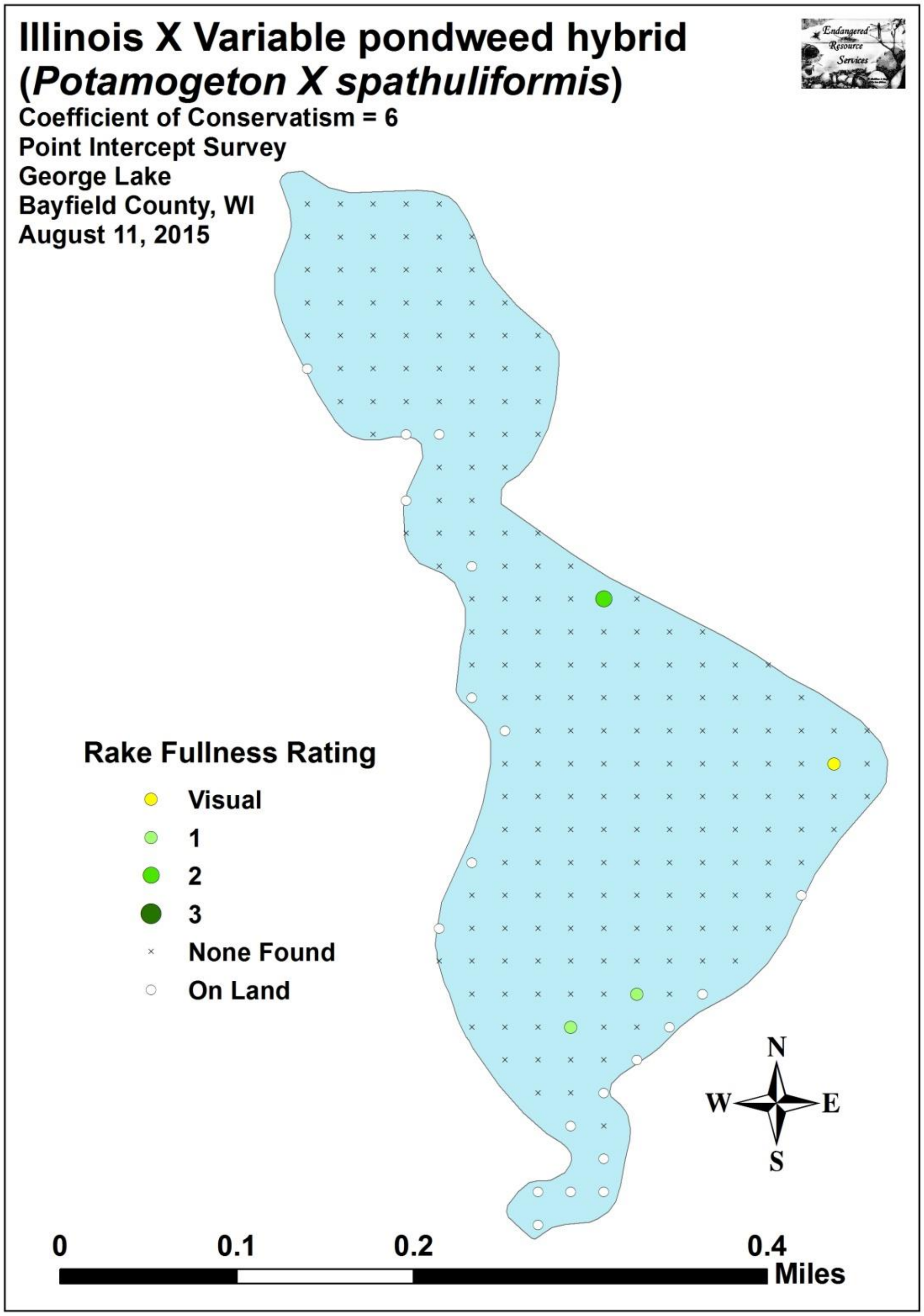
Miles


Illinois X Variable pondweed hybrid
(Potamogeton X spathuliformis)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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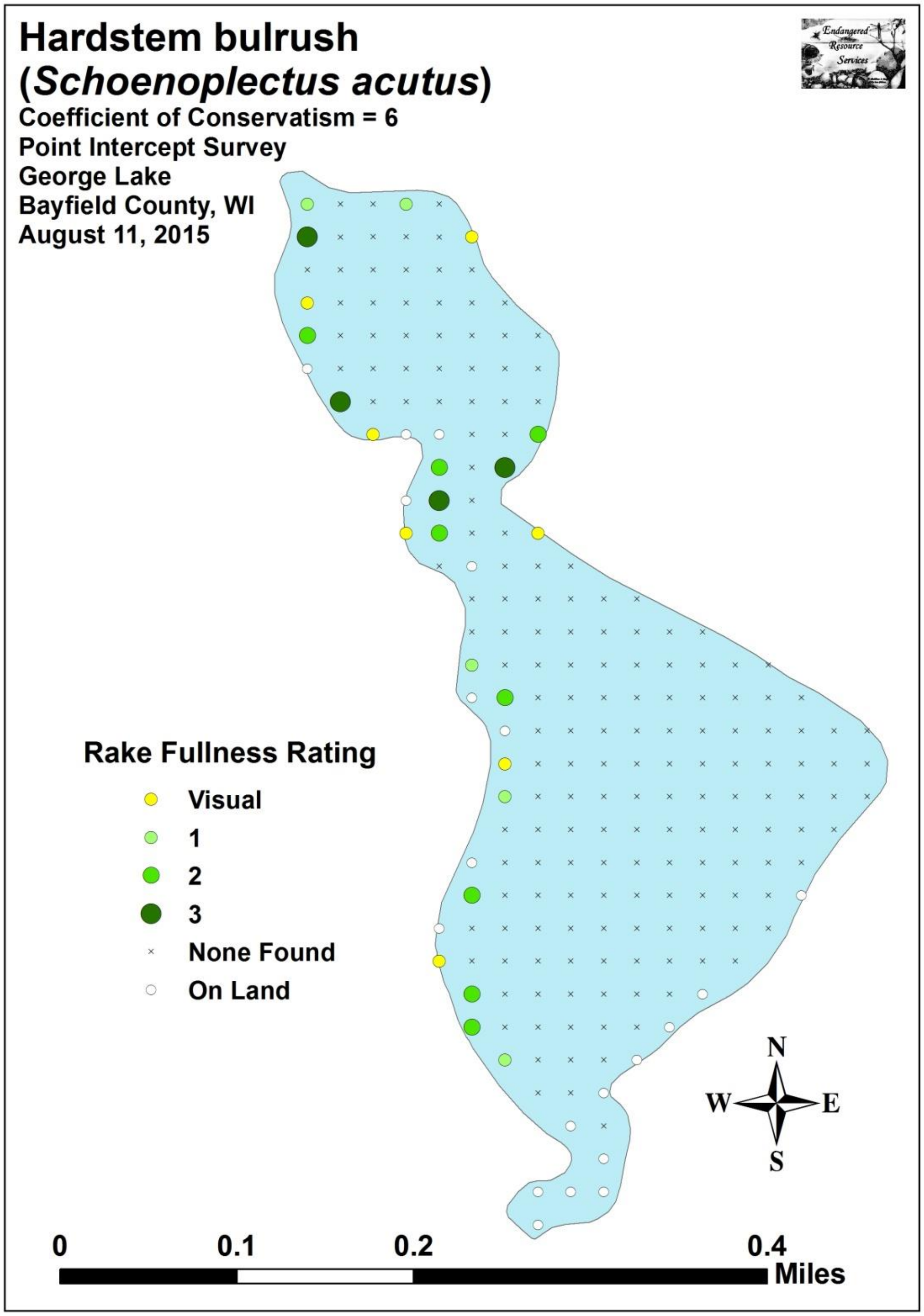
Miles


Hardstem bulrush
(Schoenoplectus acutus)
Coefficient of Conservatism = 6
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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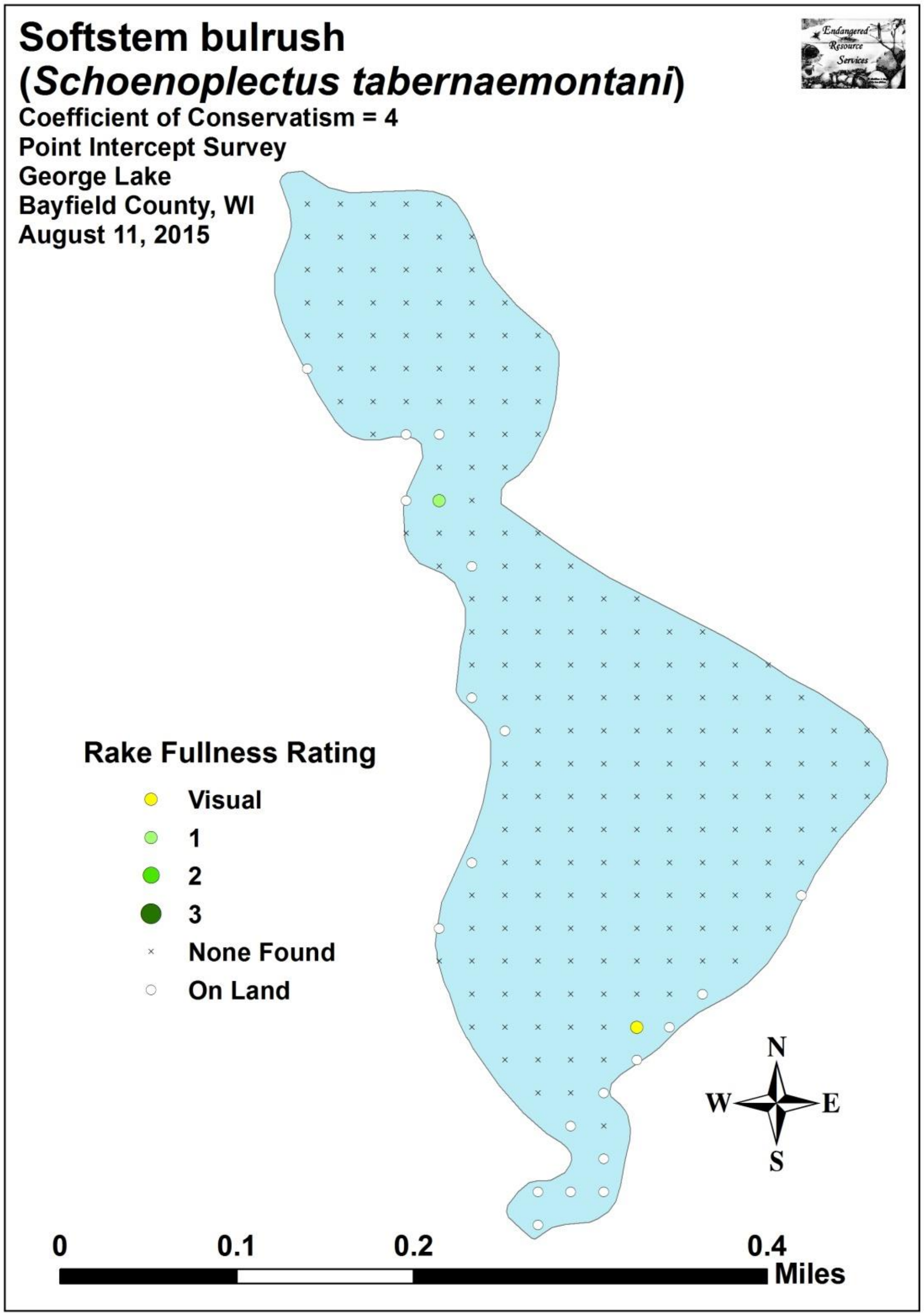
Miles


Softstem bulrush
(Schoenoplectus tabernaemontani)
Coefficient of Conservatism = 4
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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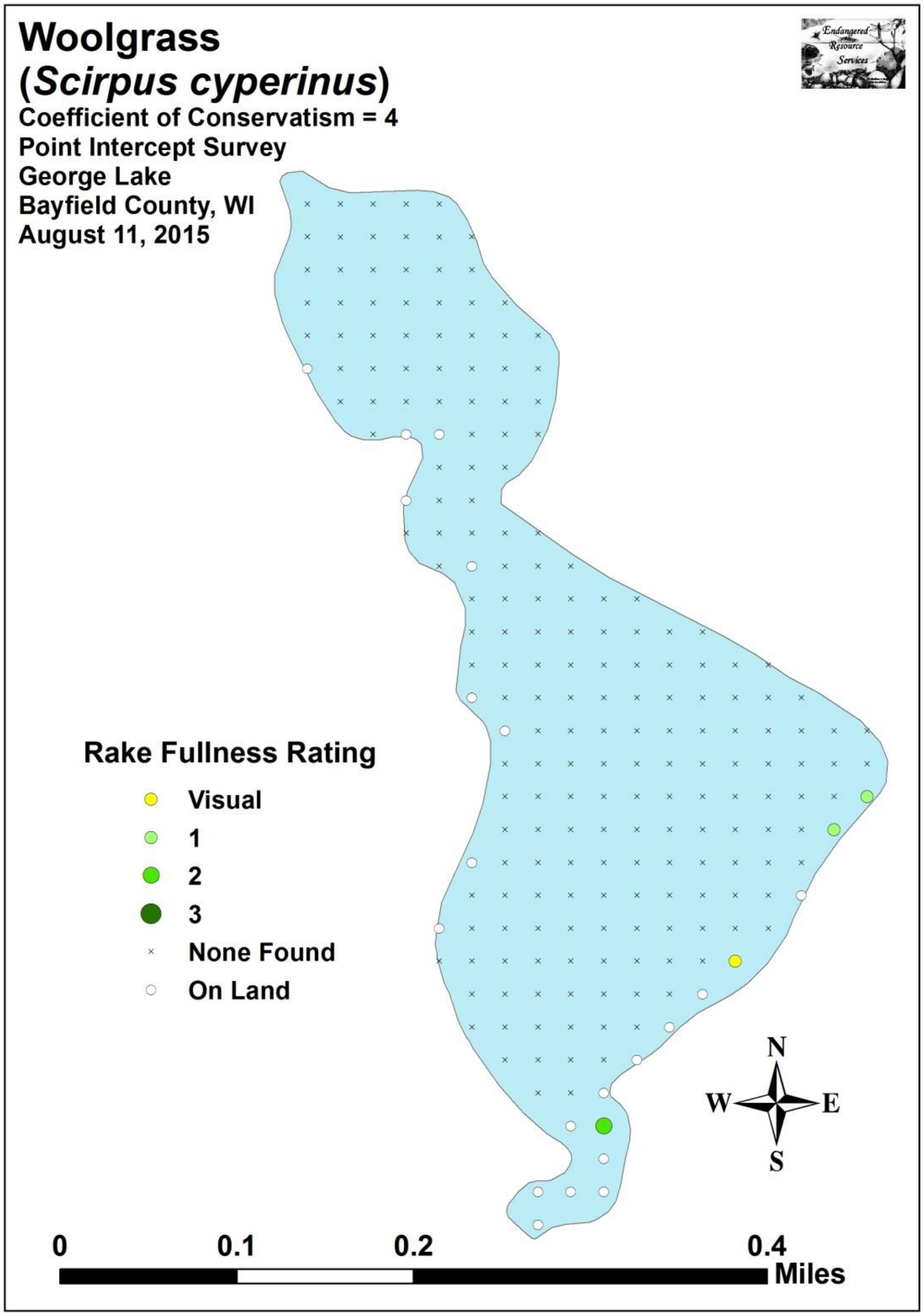
Miles


Woolgrass
(Scirpus cyperinus)
Coefficient of Conservatism = 4
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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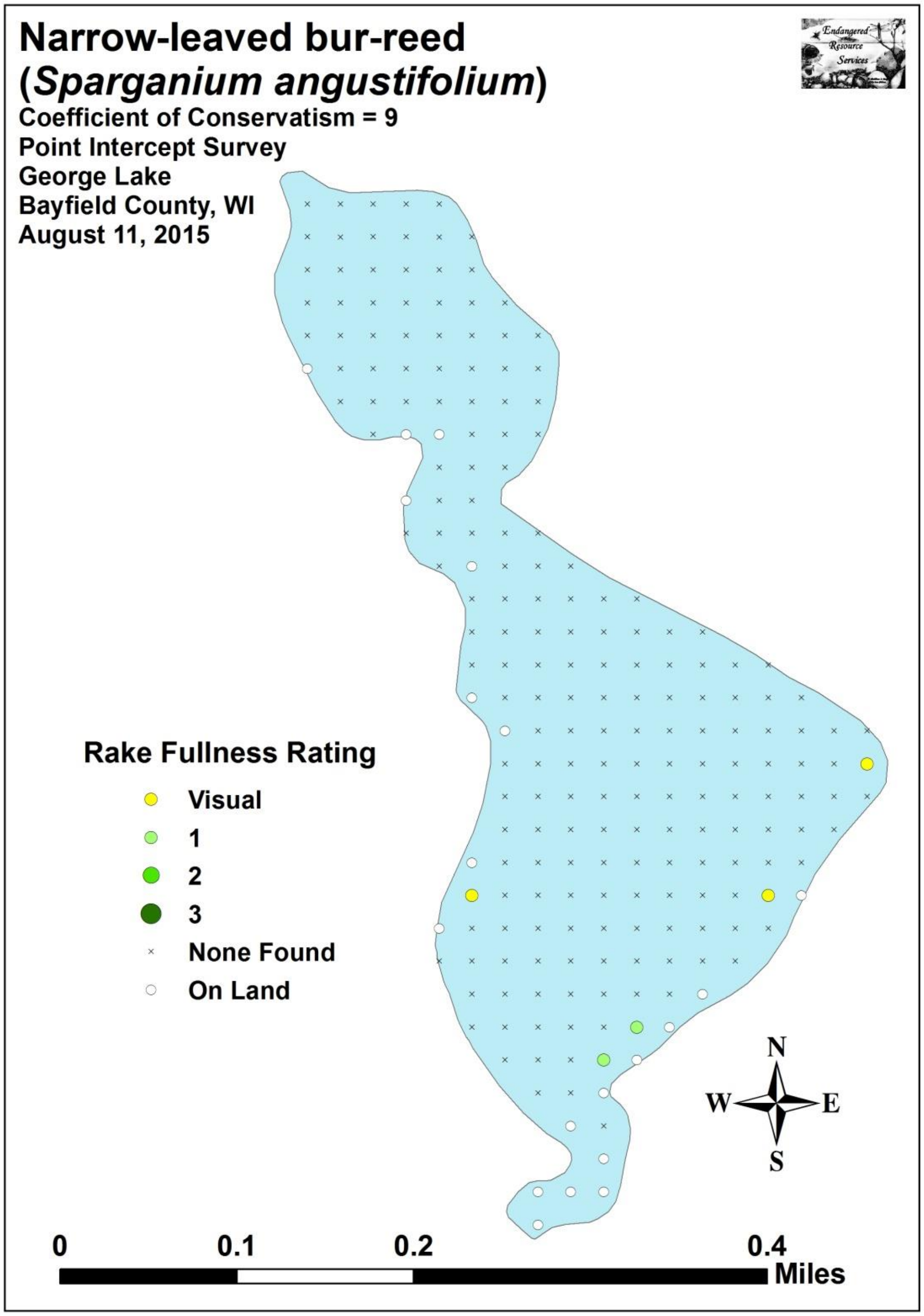
Miles


Narrow-leaved bur-reed
(*Sparganium angustifolium*)
Coefficient of Conservatism = 9
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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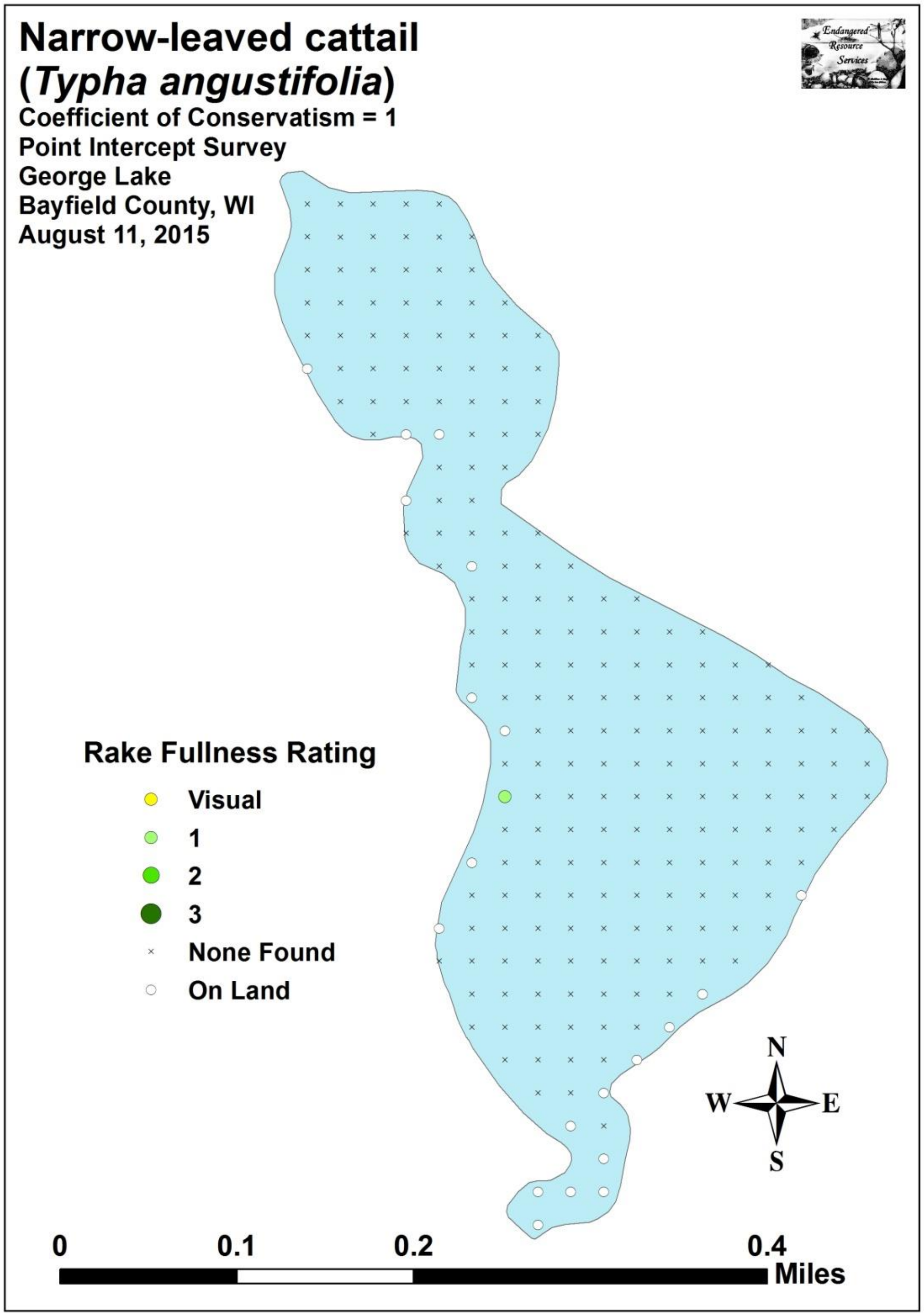
Miles


Narrow-leaved cattail
(Typha angustifolia)
Coefficient of Conservatism = 1
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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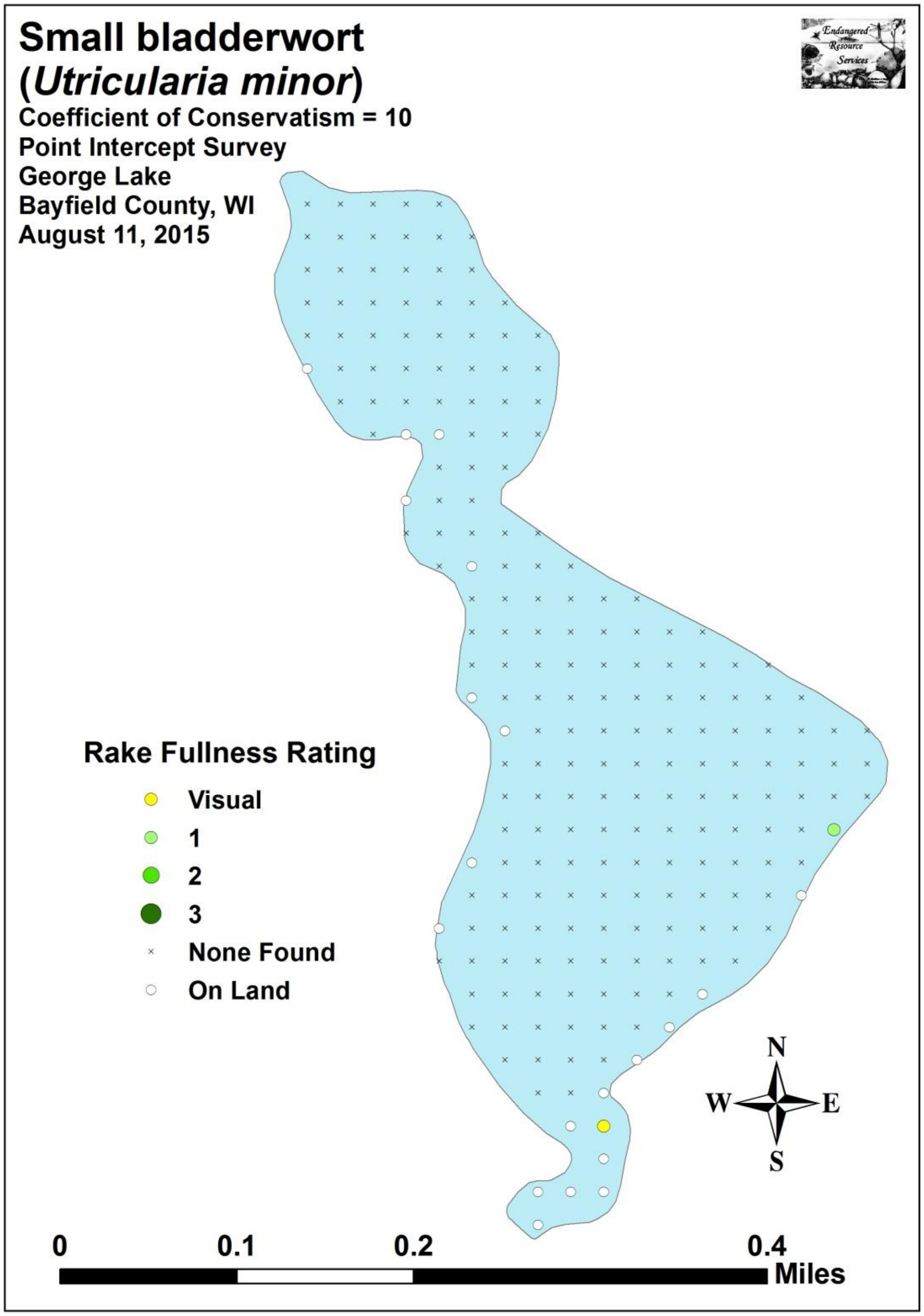
Miles


Small bladderwort
(*Utricularia minor*)
Coefficient of Conservatism = 10
Point Intercept Survey
George Lake
Bayfield County, WI
August 11, 2015
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
On Land
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Appendix VII: 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.

Purple loosestrife was first detected in Wisconsin in the early 1930's, but remained uncommon until the 1970's. It is now widely dispersed in the state, and has been recorded in 70 of Wisconsin's 72 counties. Low densities in most areas of the state suggest that the plant is still in the pioneering stage of establishment. Areas of heaviest infestation are sections of the Wisconsin River, the extreme southeastern part of the state, and the Wolf and Fox River drainage systems.

This plant's optimal habitat includes marshes, stream margins, alluvial flood plains, sedge meadows, and wet prairies. It is tolerant of moist soil and shallow water sites such as pastures and meadows, although established plants can tolerate drier conditions. Purple loosestrife has also been planted in lawns and gardens, which is often how it has been introduced to many of our wetlands, lakes, and rivers.

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 VIII: 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 IX: 2015 Raw Data Spreadsheets