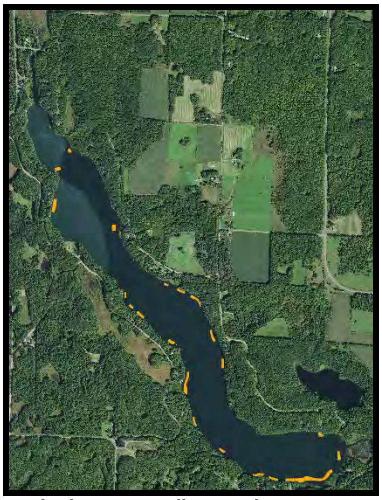
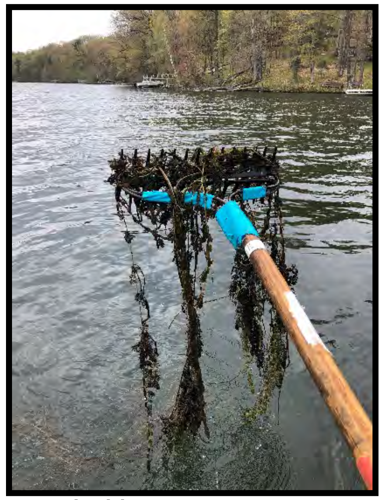
Eurasian water-milfoil (*Myriophyllum spicatum*) Pre/Posttreatment and Bed Mapping Surveys Sand Lake (WBIC: 2661100) Barron County, Wisconsin

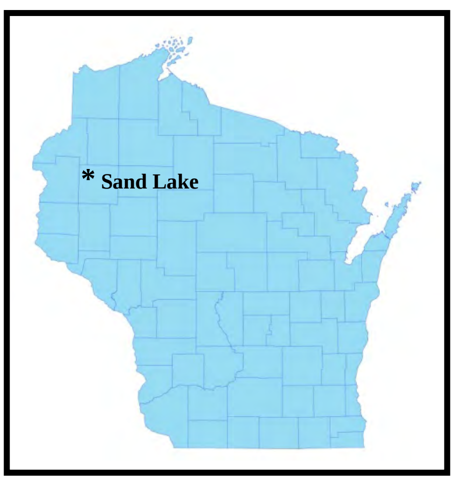

Sand Lake 2021 ProcellaCor study areas


Coontail and dense EWM 5/15/21


Dead EWM in control area 7/8/21

Project Initiated by:

The Sand Lake Management District, Lake Education and Planning Services, LLC, and the Wisconsin Department of Natural Resources




Herbicide burned but not killed Coontail in the control area 7/8/21

Surveys Conducted by and Report Prepared by:

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St. Croix Falls, Wisconsin
May 15, July 8, and September 26, 2021

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INTRODUCTION:

Sand Lake (WBIC 2661100) is a 322-acre drainage lake in northwestern Barron County, Wisconsin in the Town of Maple Plain (T36N R14W S17/20/21/28). It reaches a maximum depth of 57ft in the south basin and has an average depth of approximately 30ft Figure 1). Sand Lake is mesotrophic bordering on oligotrophic in nature with good to very good water clarity. From 1988 to 2021, summer Secchi readings have ranged from 9-18ft with an average of 13.2ft (WDNR 2021). The bottom substrate is predominately sand and sandy muck with scattered gravel primarily along the shoreline. Some areas of thick organic muck occur in bays on the west side of the lake and at the far north and south ends (Miller et al. 1965).

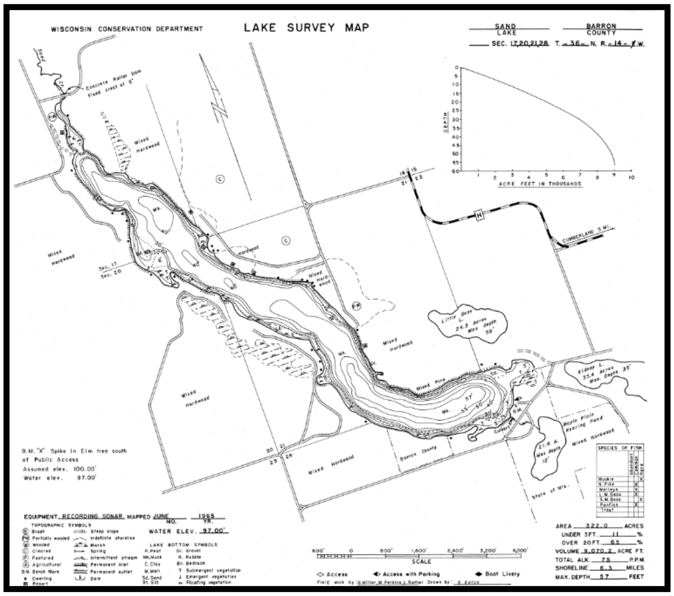


Figure 1: Sand Lake Bathymetric Map

BACKGROUND AND STUDY RATIONALE:

Eurasian water-milfoil (*Myriophyllum spicatum*) (EWM) was discovered in Sand Lake in 2002, and the Sand Lake Management District (SLMD) is engaged in active management using herbicides to control this invasive exotic plant species. Historically, fall bed mapping was used to determine where EWM control might be considered the following year. However, in 2016, LEAPS, the SLMD, and the Wisconsin Department of Natural Resources (WDNR) decided that an annual warm-water point-intercept survey at a higher resolution than the original WDNR survey grid would replace the annual pre/posttreatment monitoring and the fall bed mapping surveys. This change in methodology was made because a regular quantitative survey allowed for statistical year-over-year comparisons as a way to assess the effectiveness of the lake's active management while simultaneously providing a way to more closely measure any potential impacts on the lake's native plants. It was also chosen to better detect deep water beds that were occasionally missed due to poor water clarity in the fall. Following four years of this type of monitoring, it was decided that this intensive methodology did not provide significantly improved data relative to the cost. Because of this, it was decided to revert to pre/posttreatment and fall bed mapping surveys. This report is the summary analysis of these three surveys conducted on May 15, July 8, and September 26, 2021.

METHODS:

Pre/Post Herbicide Surveys:

LEAPS provided area shapefiles, and we generated pre/post survey points based on the size and shape of the proposed treatment and control areas (It should be noted that Bed 10 on the "reef" near Silo Bay was excluded from analysis because studying the 2,4-D treatment was not grant reimbursable). The 160-point regular offset sampling grid at 15m resolution was distributed across the 21 study areas covering 8.67 acres. This approximated to almost 18.5 pts/acre – well above the minimum of 4-10 pts/acre required by WDNR protocol for pre/post treatment surveys (Appendix I).

These points were uploaded to a handheld mapping GPS (Garmin 76CSx) and located on the lake. At each point, we recorded the depth and bottom substrate and used a rake to sample an approximately 2.5ft section of the bottom. EWM was assigned a rake fullness value of 1-3 as an estimation of abundance (Figure 2), and we also recorded visual sightings of EWM within six feet of the sample point. Because visual sightings are not calculated into the pre/post statistical formulas, we only assigned a rake fullness value for non-EWM plants. A cumulative rake fullness value was also noted.

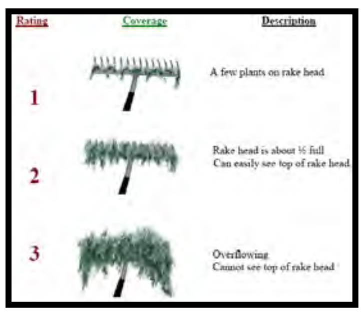


Figure 2: Rake Fullness Ratings

We entered all data collected into the standard WDNR APM spreadsheet (Appendix II). Data was analyzed using the linked statistical summary sheet and the WDNR pre/post analysis worksheet (UWEX 2010). For pre/post differences of 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 determined to be significant at $p<0.05$, moderately significant at $p<0.01$ and highly significant at $p<0.001$.

Eurasian Water-milfoil Bed Mapping Survey:

During the September survey, we searched the lake's visible littoral zone for Eurasian water-milfoil. When we found a "bed" where we estimated that EWM made up >50% of the plants and was generally continuous with clearly defined borders; we motored around the perimeter of the area, took GPS coordinates at regular intervals, documented the rake range and depth range of plants, and estimated the average rake fullness rating and depth of EWM within the bed. Using the WDNR's Forestry Tool's Extension to ArcGIS 9.3.1, we used these coordinates to generate bed shapefiles and determine the acreage to the nearest hundredth of an acre. Because plants were few in number, we also marked all individual EWM plants found.

RESULTS AND DISCUSSION:
Finalization of Treatment Areas:

The twenty-one treatment areas totaled 9.51 acres (2.95% of the lake's total surface area) (Figure 3) (Appendix I). Because the May 15th pretreatment survey found Eurasian water-milfoil at or inter-point in each area, the SLMD decided to go ahead with the treatment as originally planned.

Treatment occurred on June 2nd with Northern Aquatic Services (Dale Dressel - Dresser, WI) applying 2,4-D (Amine 4) at a rate of 4ppm and ProcellaCor at a rate of 6-8 pdu/acre ft. (490.02 total pdus – at 3.17 fl. oz./pdu) (Table 1). At the time of application, the reported water temperature was 69°F and the air temperature was 73°F. Wind speeds were clocked at 3-5mph out of the southwest.

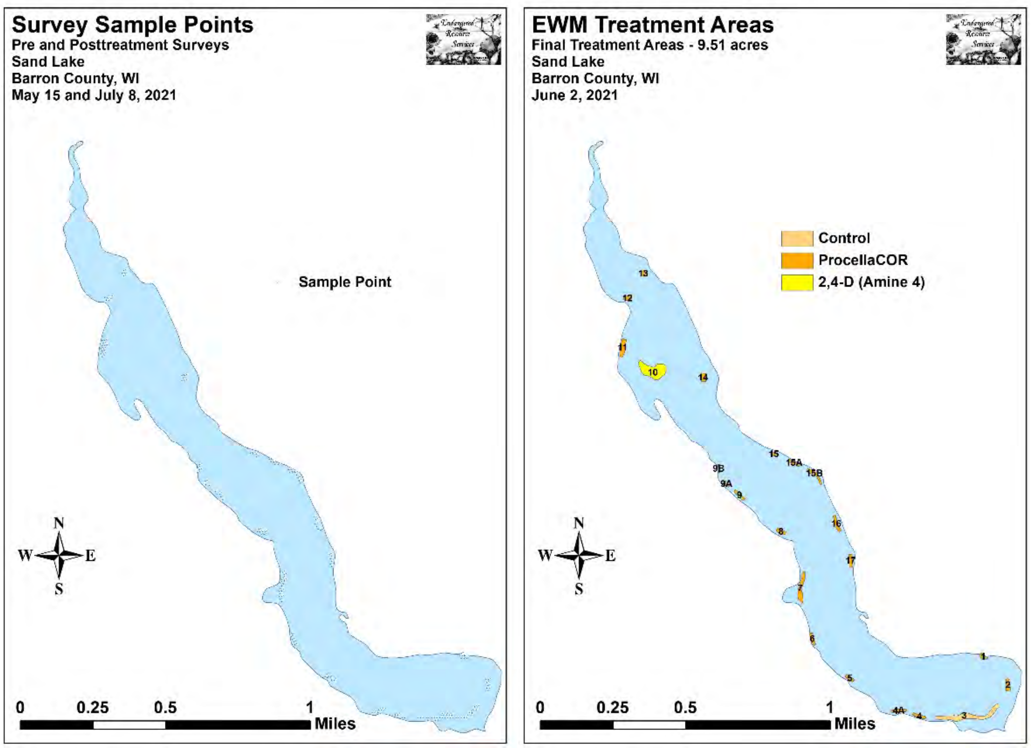


Figure 3: Pre/Post Survey Points and EWM Treatment Areas

Table 1: Spring Eurasian Water-milfoil Treatment Summary
Sand Lake, Barron County
June 2, 2021

Bed Number	Final Treatment Area (acres)	Chemical, Rate, and Total Volume
1	0.23	ProcellaCor – 8pdu/acre ft. – 16.56pdu
2	0.34	ProcellaCor – 8pdu/acre ft. – 21.76pdu
3	0	None – Control Area
4	0.29	ProcellaCor – 8pdu/acre ft. – 20.88pdu
4A	0.35	ProcellaCor – 8pdu/acre ft. – 25.20pdu
5	0.23	ProcellaCor – 8pdu/acre ft. – 16.56pdu
6	0.26	ProcellaCor – 8pdu/acre ft. – 18.72pdu
7	0.85	ProcellaCor – 5pdu/acre ft. – 38.25pdu
8	0.30	ProcellaCor – 8pdu/acre ft. – 21.60pdu
9	0.30	ProcellaCor – 8pdu/acre ft. – 21.60pdu
9A	0.17	ProcellaCor – 8pdu/acre ft. – 12.24pdu
9B	0.15	ProcellaCor – 8pdu/acre ft. – 10.80pdu
10	3.12	2,4-D (Amine 4) – 4ppm – 79.75 gallons
11	0.63	ProcellaCor – 6pdu/acre ft. – 34.02pdu
12	0.25	ProcellaCor – 8pdu/acre ft. – 16.00pdu
13	0.15	ProcellaCor – 8pdu/acre ft. – 10.80pdu
14	0.32	ProcellaCor – 8pdu/acre ft. – 23.04pdu
15	0.15	ProcellaCor – 8pdu/acre ft. – 10.80pdu
15A	0.27	ProcellaCor – 8pdu/acre ft. – 19.44pdu
15B	0.45	ProcellaCor – 6pdu/acre ft. – 24.30pdu
16	0.38	ProcellaCor – 7pdu/acre ft. – 23.94pdu
17	0.33	ProcellaCor – 8pdu/acre ft. – 23.76pdu
Total	**9.51**	**ProcellaCor – 5-8pdu/acre ft. – 490.02 total pdu/ 2,4-D (Amine 4) – 4ppm – 79.75 gallons**

Eurasian Water-milfoil Pre/Post Herbicide Surveys:

All survey points occurred in areas between 2.5ft and 24.5ft of water. Within the beds, plants grew at a mean of 8.2ft pretreatment and 8.1ft posttreatment with a nearly identical median depth of 8.0ft during both surveys (Table 2). Most Eurasian water-milfoil beds were established over nutrient-poor sandy muck although we also found some growing in pure sand and rocky substrate areas; albeit at lower densities (Figure 4) (Appendix III).

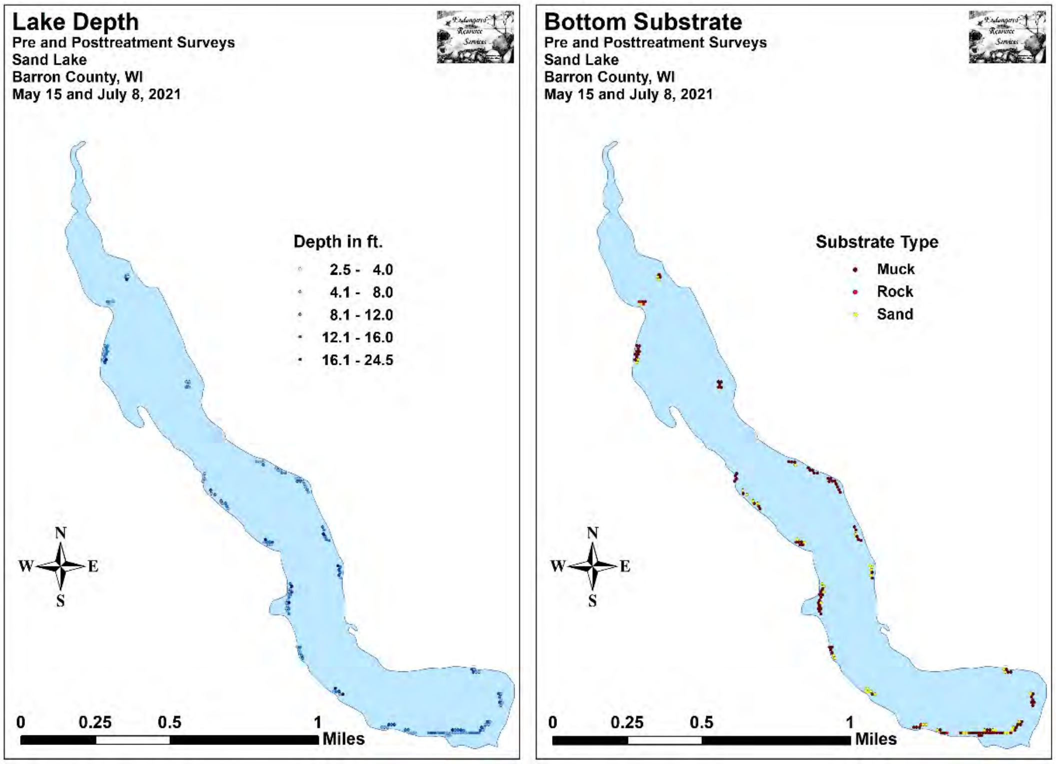


Figure 4: Treatment Area Depths and Bottom Substrate

Table 2: Pre/Posttreatment Surveys Summary Statistics
Sand Lake, Barron County
May 15 and July 8, 2021

Summary Statistics:	Pre	Post
Total number of points sampled	160	160
Total number of sites with vegetation	133	141
Total number of sites shallower than the maximum depth of plants	150	152
Freq. of occur. at sites shallower than max. depth of plants (in percent)	88.7	92.8
Simpson Diversity Index	0.87	0.88
Mean Coefficient of Conservatism	6.4	6.1
Floristic Quality Index	26.4	28.2
Maximum depth of plants (ft)	14.5	16.0
Mean depth of plants (ft)	8.2	8.1
Median depth of plants (ft)	8.0	8.0
Average number of all species per site (shallower than max depth)	2.37	2.62
Average number of all species per site (veg. sites only)	2.67	2.82
Average number of native species per site (shallower than max depth)	2.15	2.62
Average number of native species per site (sites with native veg. only)	2.50	2.82
Species Richness	18	21
Mean Rake Fullness (veg. sites only)	2.11	1.84

The littoral zone increased from 14.5ft pretreatment to 16.0ft posttreatment. The frequency of plant occurrence also increased from 133 points (88.7% pretreatment littoral coverage) to 141 points (92.8% posttreatment littoral coverage) (Figure 5) (Appendix IV). Total richness rose slightly from 18 species pretreatment to 21 species posttreatment; and the Simpson's Diversity Index also ticked up from a high pretreatment value of 0.87 to 0.88 posttreatment. The Floristic Quality Index (another measure of native plant community health) increased from 26.4 pretreatment to 28.2 posttreatment.

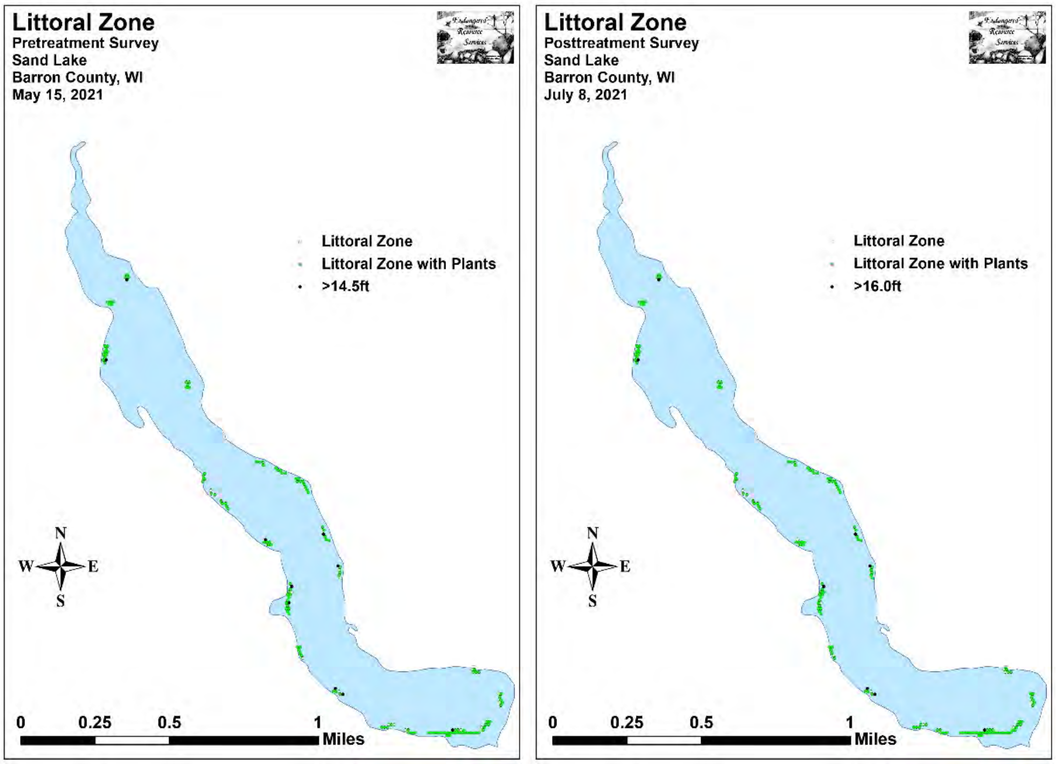


Figure 5: Pre/Posttreatment Littoral Zone

Mean native species richness at points with native vegetation demonstrated a significant increase **(*p*=0.02)** from 2.50 species/point pretreatment to 2.82/point posttreatment (Figure 6). Total mean rake fullness underwent a highly significant decline **(*p*<0.001)** from a moderate 2.11 pretreatment to 1.84 posttreatment (Figure 7) (Appendix IV).

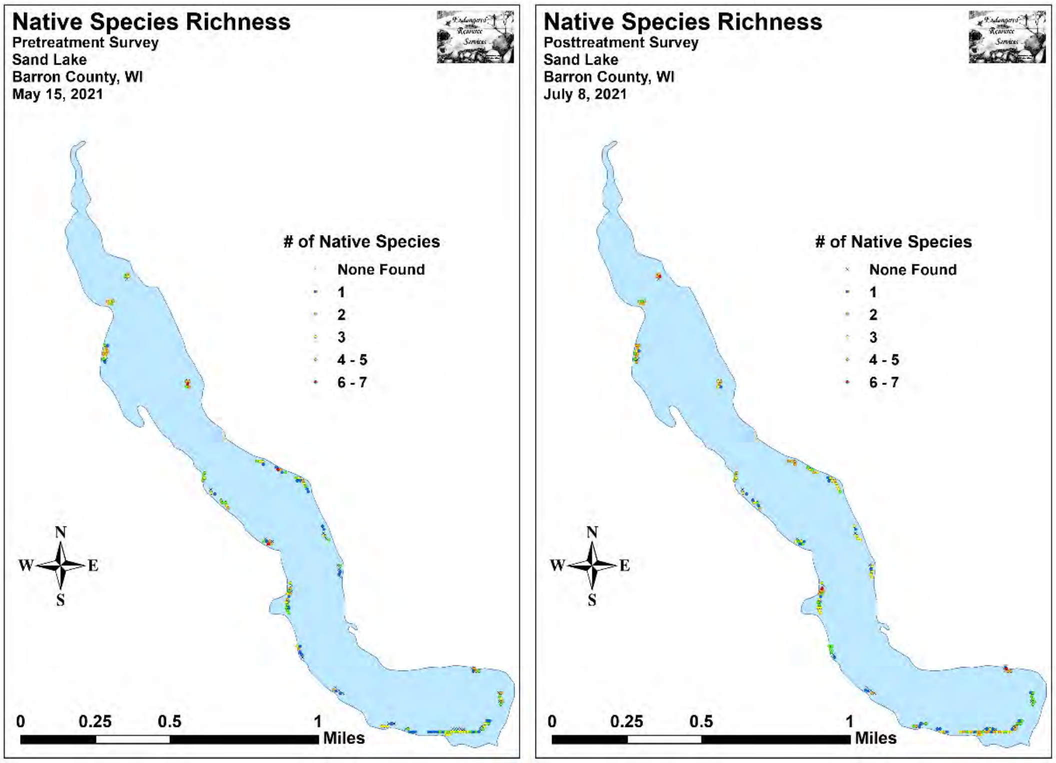


Figure 6: Pre/Posttreatment Native Species Richness

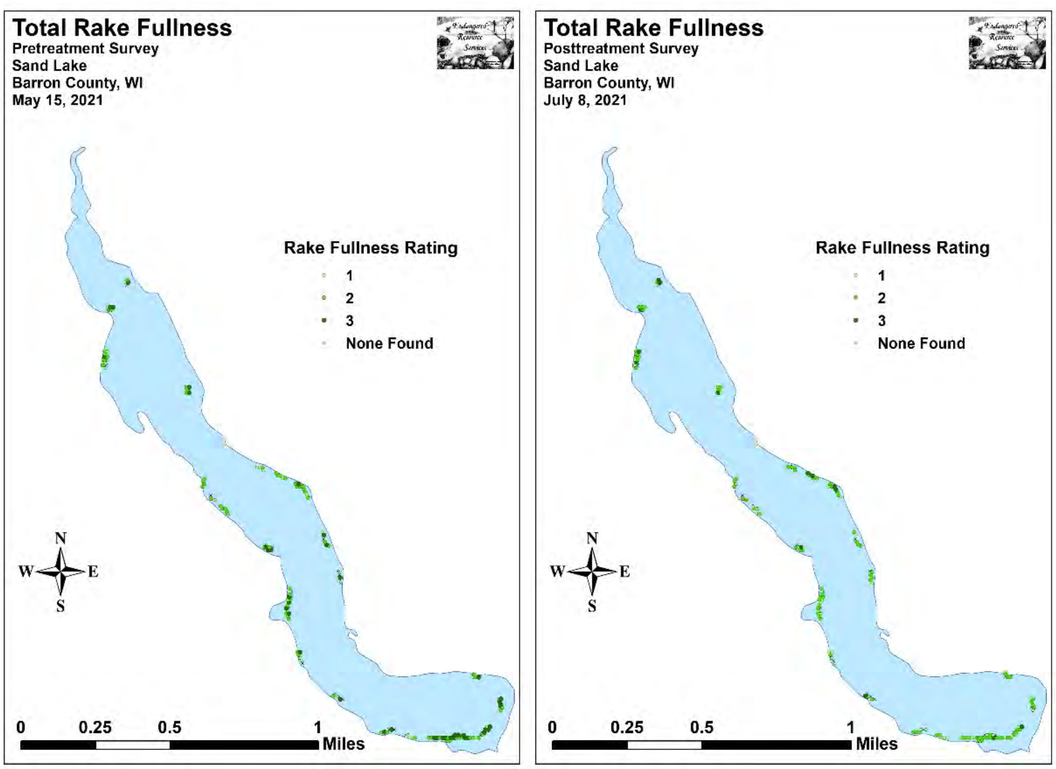


Figure 7: Pre/Posttreatment Total Rake Fullness

We found Eurasian water-milfoil occurred in scattered clusters and small beds throughout the treatment and control areas. During the pretreatment survey, it was present in the rake at 32 points (20.0% coverage within the study areas) with 25 additional visual sightings (Figure 8) (Appendix V). Of these, we rated 15 a 3, seven a 2, and ten a 1 for a mean rake fullness of 2.16. This suggested 13.8% of the study areas had a significant infestation (rake fullness 2 and 3). Posttreatment, despite doing additional exploratory raking in both the control and treatment beds, we saw no evidence of living EWM anywhere in the study areas. The only evidence we could find of the plant in the lake was a single highly-burned individual in the 2,4-D area on the reef where we didn't do any formal monitoring. We also found a few blackened fragments of EWM leaflets in what had been the densest part of the control area (see picture on cover of report). Statistically, these results produced a highly significant decline **(p<0.001)** in total density and distribution, rake fullness 3, and visual sightings; and a moderately significant decline in rake fullness 2 and 1 **(p=0.007/p=0.001)** (Figure 9).

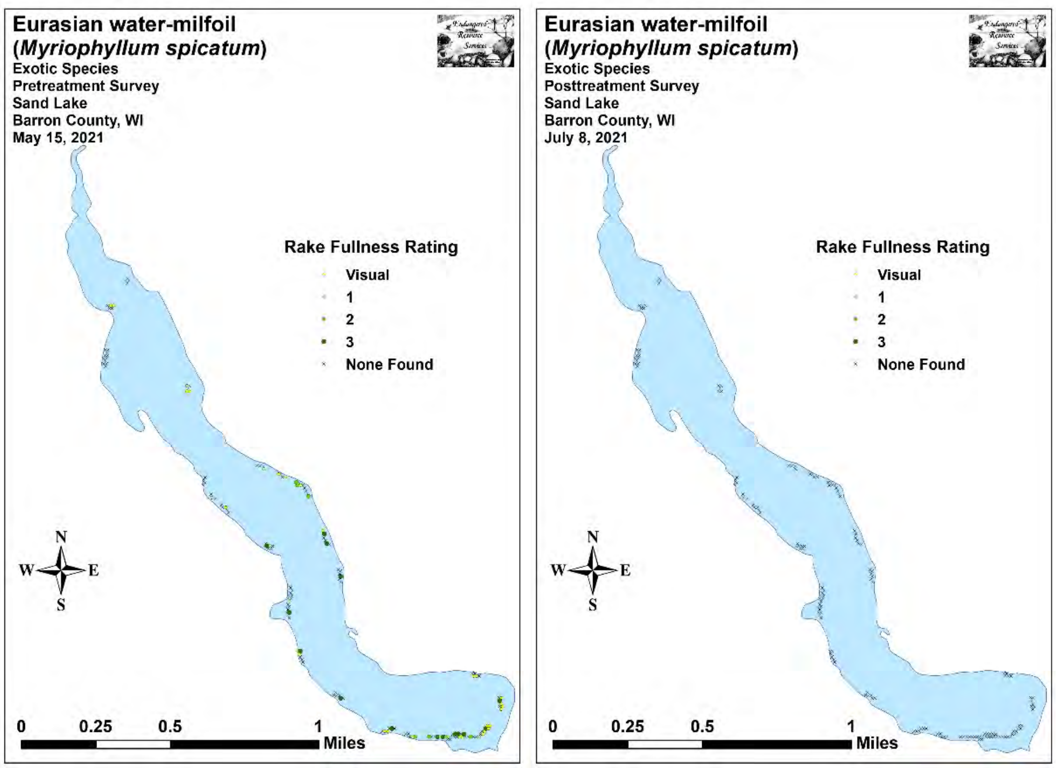
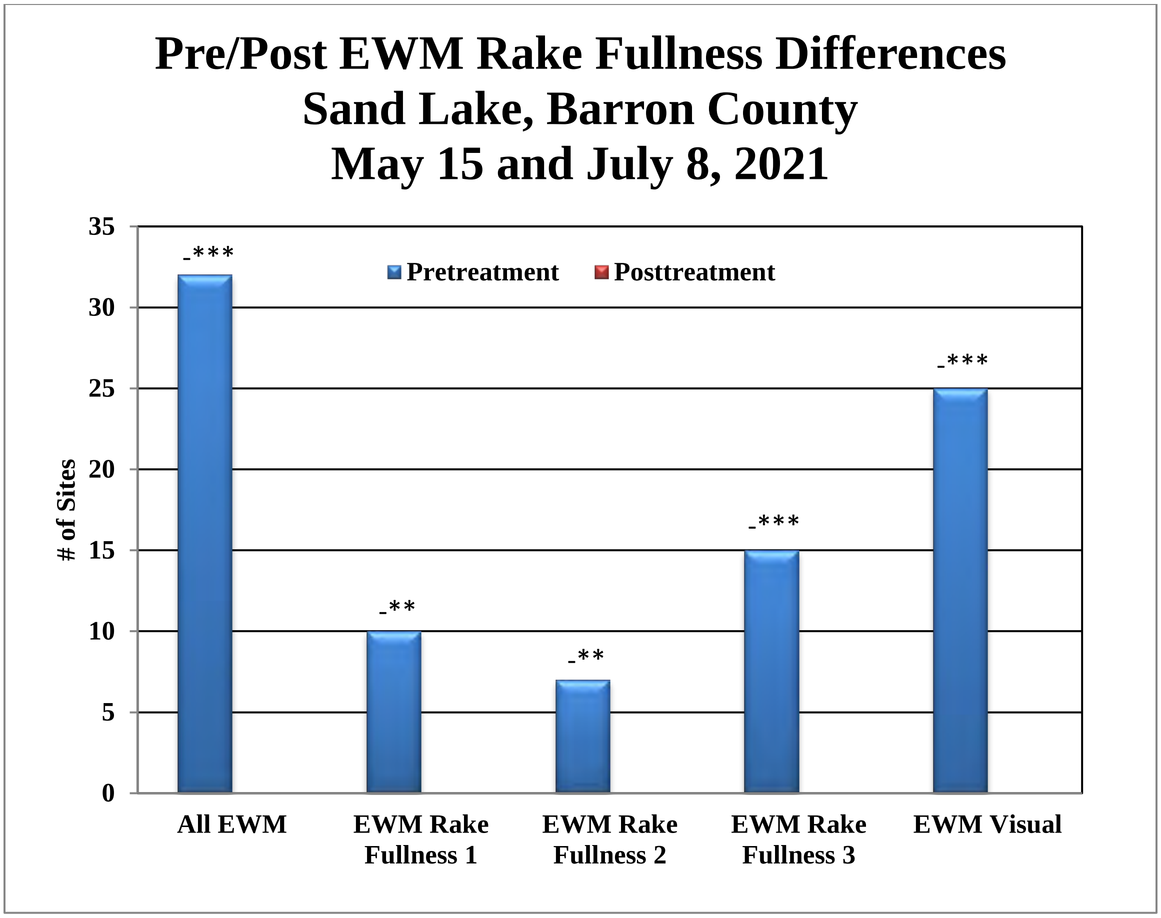


Figure 8: Pre/Posttreatment EWM Density and Distribution



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

Figure 9: Changes in Eurasian Water-milfoil Rake Fullness

Coontail (*Ceratophyllum demersum*) was the most widely-distributed native species in both the pretreatment and posttreatment surveys (Figure 10) (Tables 3 and 4). Although its reduction in distribution from 88 sites pretreatment to 85 sites posttreatment was not significant (*p*=0.74), it suffered a highly significant decline **(*p*<0.001)** in density from a mean rake fullness of 1.75 pretreatment to 1.29 posttreatment. Interestingly, this was especially noticeable in the control area where we documented plants with curled stems that were clearly burned by herbicide (see front cover of report).

Northern water-milfoil (*Myriophyllum sibiricum*) was the second most common species pretreatment, but just the eighteenth most common posttreatment. In May, it was present at 55 sites with a mean rake fullness of 1.62 (Figure 11). Following highly significant declines **(*p*<0.001)** in both density and distribution, it was present at two sites with a mean rake fullness of 1.00 posttreatment. At each point, we found single plants that had recently sprouted from turions, and this could potentially mean they weren't growing yet when the herbicide application occurred.

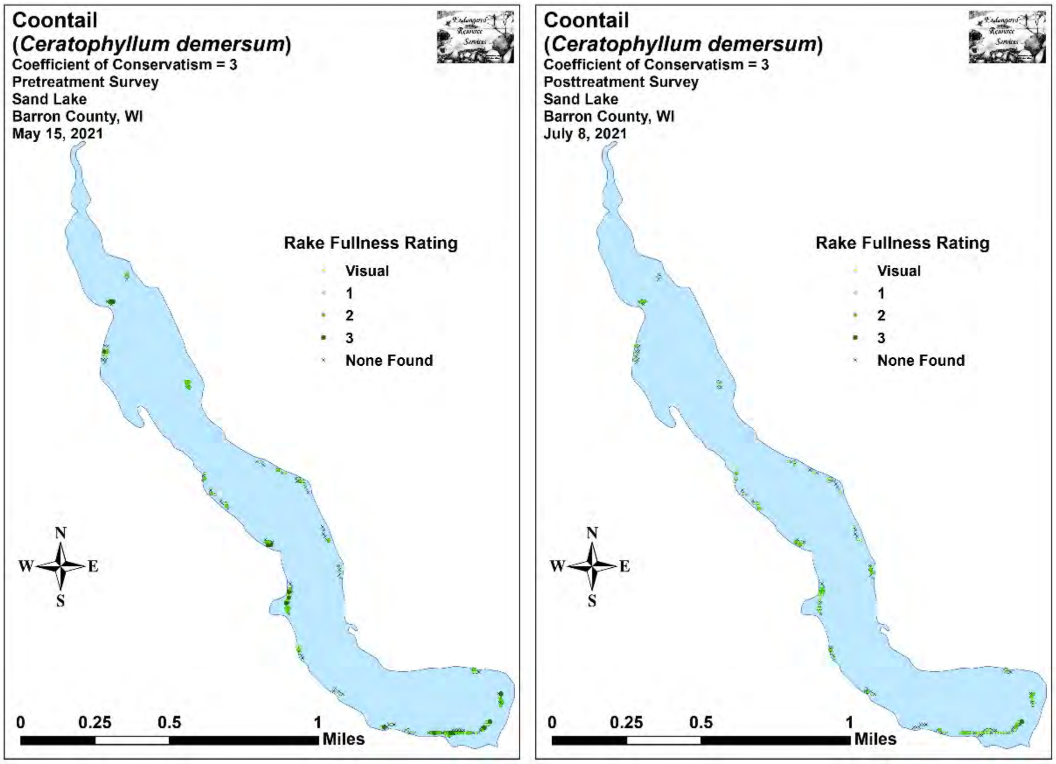


Figure 10: Pre/Posttreatment Coontail Density and Distribution

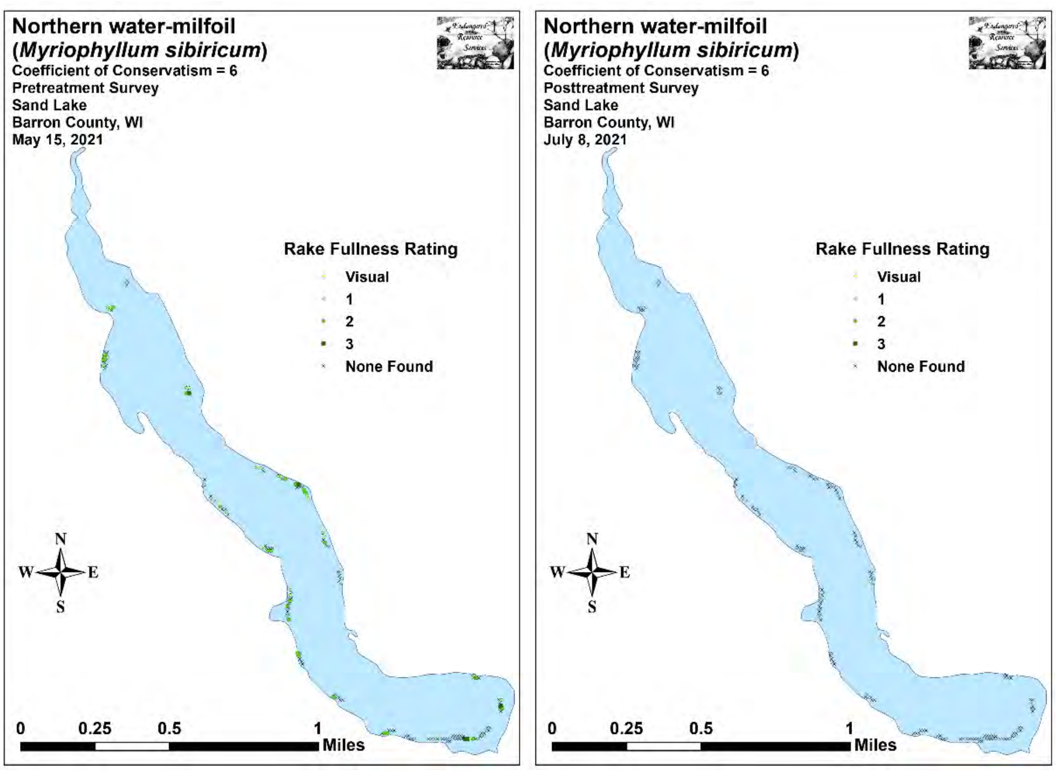


Figure 11: Pre/Posttreatment Northern Water-milfoil Density and Distribution

Table 3: Frequencies and Mean Rake Sample of Aquatic Macrophytes
Pretreatment Survey - Sand Lake, Barron County
May 15, 2021

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sites
Ceratophyllum demersum	Coontail	88	24.79	66.17	58.67	1.75	0
Myriophyllum sibiricum	Northern water-milfoil	55	15.49	41.35	36.67	1.62	0
Potamogeton robbinsii	Fern pondweed	43	12.11	32.33	28.67	1.56	0
Myriophyllum spicatum	**Eurasian water-milfoil**	**32**	**9.01**	**24.06**	**21.33**	**2.16**	**25**
Potamogeton zosteriformis	Flat-stem pondweed	29	8.17	21.80	19.33	1.21	0
Lemna trisulca	Forked duckweed	27	7.61	20.30	18.00	1.33	0
Potamogeton pusillus	Small pondweed	21	5.92	15.79	14.00	1.14	0
Elodea canadensis	Common waterweed	12	3.38	9.02	8.00	1.42	0
Potamogeton amplifolius	Large-leaf pondweed	12	3.38	9.02	8.00	1.33	0
Potamogeton richardsonii	Clasping-leaf pondweed	9	2.54	6.77	6.00	1.11	0
Potamogeton friesii	Fries' pondweed	8	2.25	6.02	5.33	1.13	0
Potamogeton illinoensis	Illinois pondweed	7	1.97	5.26	4.67	1.00	0
Heteranthera dubia	Water star-grass	4	1.13	3.01	2.67	1.25	0
Bidens beckii	Water marigold	2	0.56	1.50	1.33	1.50	0
Chara sp.	Muskgrass	2	0.56	1.50	1.33	2.00	0
Ranunculus aquatilis	White water crowfoot	2	0.56	1.50	1.33	1.50	0
Nitella sp.	Nitella	1	0.28	0.75	0.67	2.00	0
Potamogeton praelongus	White-stem pondweed	1	0.28	0.75	0.67	1.00	0

Table 4: Frequencies and Mean Rake Sample of Aquatic Macrophytes
Posttreatment Survey - Sand Lake, Barron County
July 8, 2021

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sites
Ceratophyllum demersum	Coontail	85	21.36	60.28	55.92	1.29	0
Potamogeton zosteriformis	Flat-stem pondweed	79	19.85	56.03	51.97	1.51	0
Potamogeton pusillus	Small pondweed	49	12.31	34.75	32.24	1.45	0
Potamogeton richardsonii	Clasping-leaf pondweed	37	9.30	26.24	24.34	1.51	0
	Filamentous algae	30	*	21.28	19.74	1.30	0
Potamogeton gramineus	Variable pondweed	22	5.53	15.60	14.47	1.36	0
Lemna trisulca	Forked duckweed	20	5.03	14.18	13.16	1.25	0
Potamogeton illinoensis	Illinois pondweed	15	3.77	10.64	9.87	1.07	0
Elodea canadensis	Common waterweed	13	3.27	9.22	8.55	1.54	0
Potamogeton robbinsii	Fern pondweed	13	3.27	9.22	8.55	1.31	0
Potamogeton amplifolius	Large-leaf pondweed	12	3.02	8.51	7.89	1.50	0
Potamogeton friesii	Fries' pondweed	10	2.51	7.09	6.58	1.00	0
Chara sp.	Muskgrass	9	2.26	6.38	5.92	1.44	0
Stuckenia pectinata	Sago pondweed	9	2.26	6.38	5.92	1.33	0
Vallisneria americana	Wild celery	7	1.76	4.96	4.61	1.14	0
Heteranthera dubia	Water star-grass	4	1.01	2.84	2.63	1.50	0
Najas flexilis	Slender naiad	4	1.01	2.84	2.63	1.25	0
Nuphar variegata	Spatterdock	3	0.75	2.13	1.97	2.00	0
Myriophyllum sibiricum	Northern water-milfoil	2	0.50	1.42	1.32	1.00	0
Nitella sp.	Nitella	2	0.50	1.42	1.32	1.50	0
Potamogeton praelongus	White-stem pondweed	2	0.50	1.42	1.32	1.50	0
Ranunculus aquatilis	White water crowfoot	1	0.25	0.71	0.66	1.00	0

* Excluded from the relative frequency calculation

Despite being historically uncommon in the lake based on previous point-intercept surveys, Fern pondweed (*Potamogeton robbinsii*) was the third most widely-distributed native species in the pretreatment survey (43 sites/mean rake 1.56). We documented a highly significant decline **(*p*<0.001)** in distribution to 13 sites posttreatment as it fell to become the eighth most common species in the community. The corresponding decline in density to a mean rake of 1.31 was, however, only nearly significant (*p*=0.07) (Figure 12).

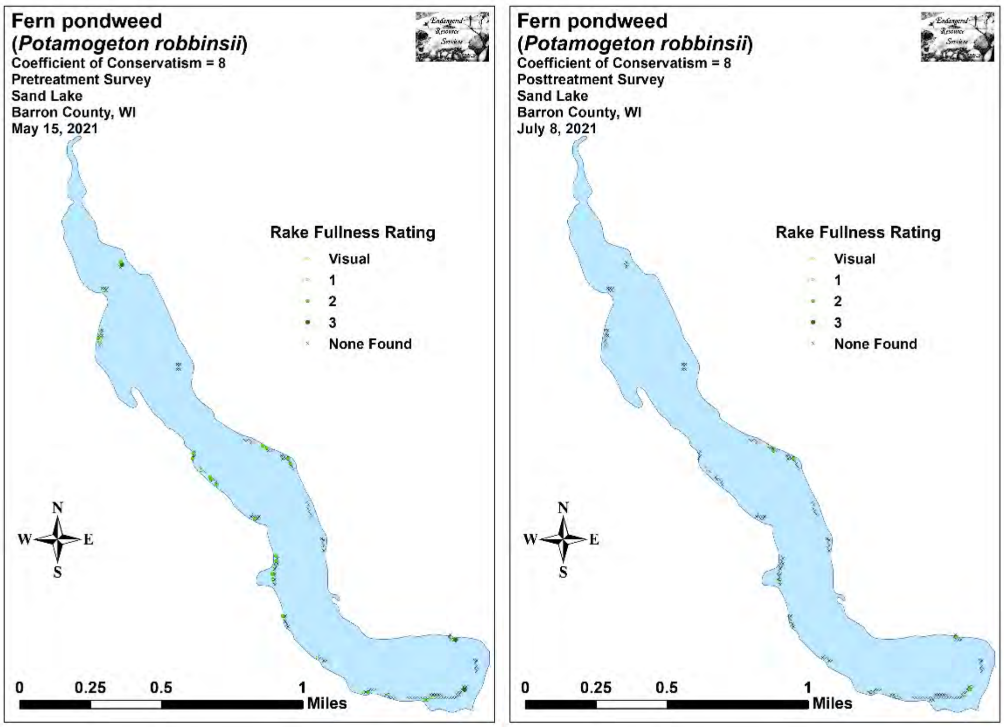


Figure 12: Pre/Posttreatment Fern Pondweed Density and Distribution

Flat-stem pondweed (*Potamogeton zosteriformis*) was the fourth most widely-distributed native species pretreatment (29 sites/mean rake 1.21) (Figure 13). Posttreatment, it was the second most common species as we documented a highly significant increase **(*p*<0.001)** in distribution (79 sites) and a moderately significant increase **(*p*=0.002)** in density (mean rake 1.51). It appeared to exploit the outer edge of the rooted littoral zone in areas occupied by NWM and EWM prior to the treatment.

Small pondweed (*Potamogeton pusillus*) (Figure 14) and Clasping-leaf pondweed (*Potamogeton richardsonii*) (Figure 15) underwent similar posttreatment expansions. Small pondweed was present at 21 sites with a mean rake fullness of 1.14 in May when it was the sixth most common native species. After undergoing a highly significant increase **(*p*<0.001)** in distribution (49 sites) and a moderately significant increase **(*p*=0.008)** in density (mean rake 1.45), it became the third most common species posttreatment. During the pretreatment survey, Clasping-leaf pondweed was present at nine sites with a mean rake of 1.11. Following its own highly significant increase **(*p*<0.001)** in distribution (37 sites) and a moderately significant increase **(*p*=0.006)** in density (mean rake 1.51), it jumped from the ninth to the fourth most common native species.

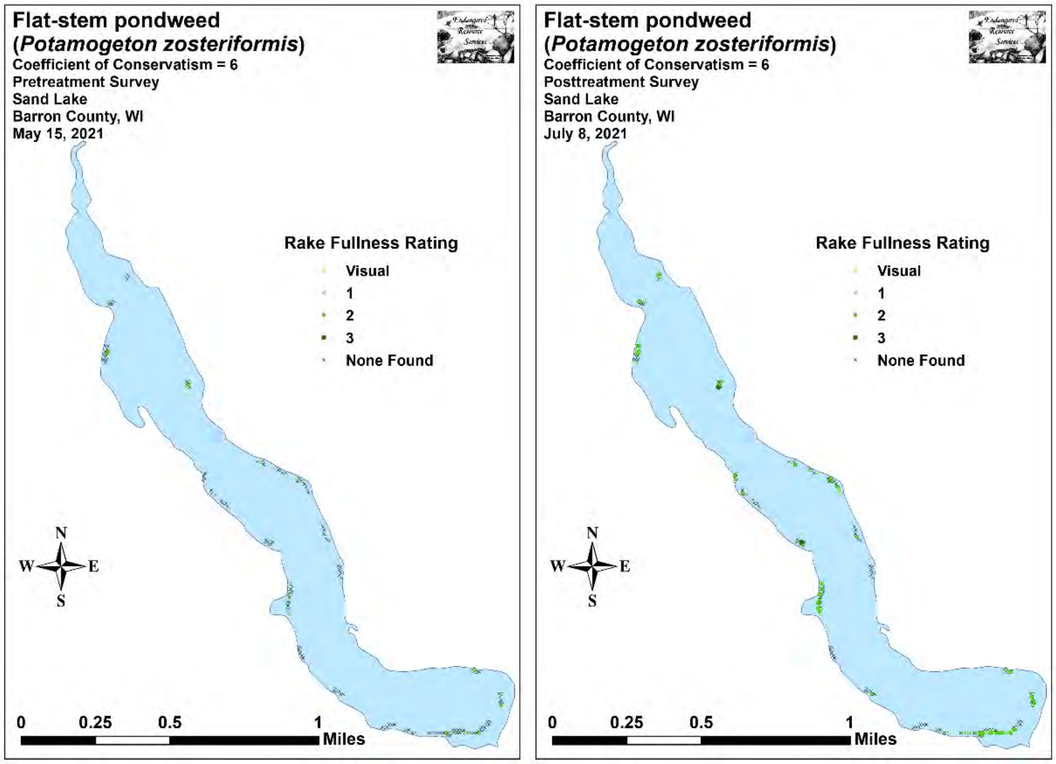


Figure 13: Pre/Posttreatment Flat-stem Pondweed Density and Distribution

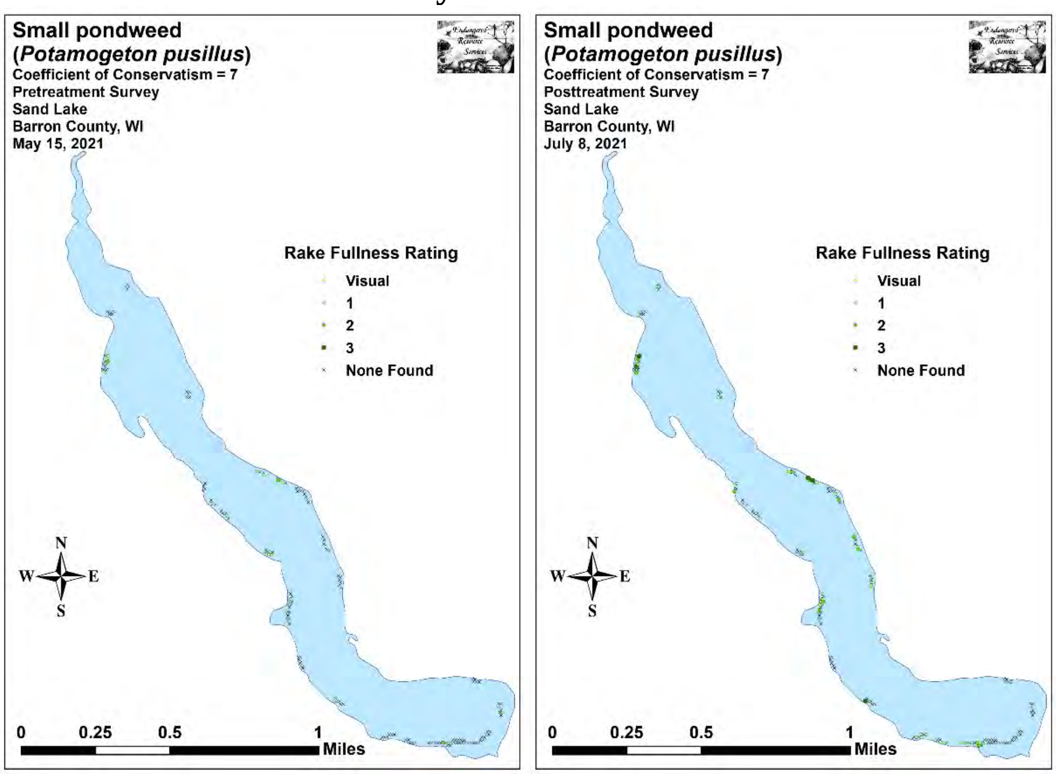


Figure 14: Pre/Posttreatment Small Pondweed Density and Distribution

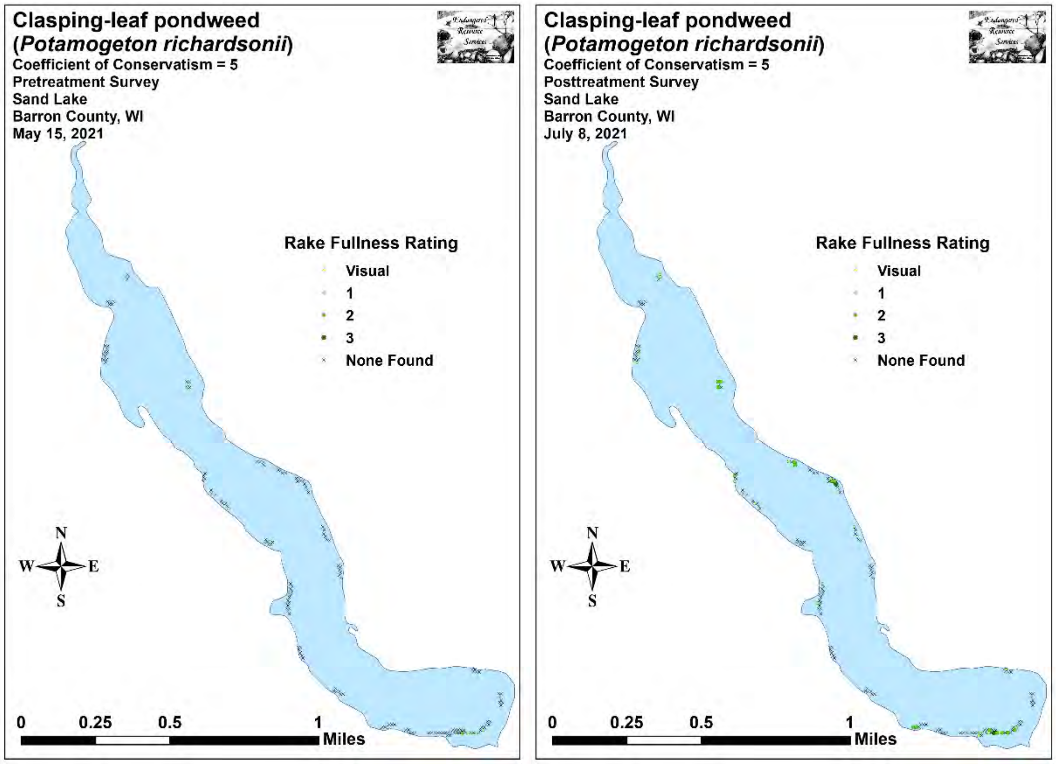
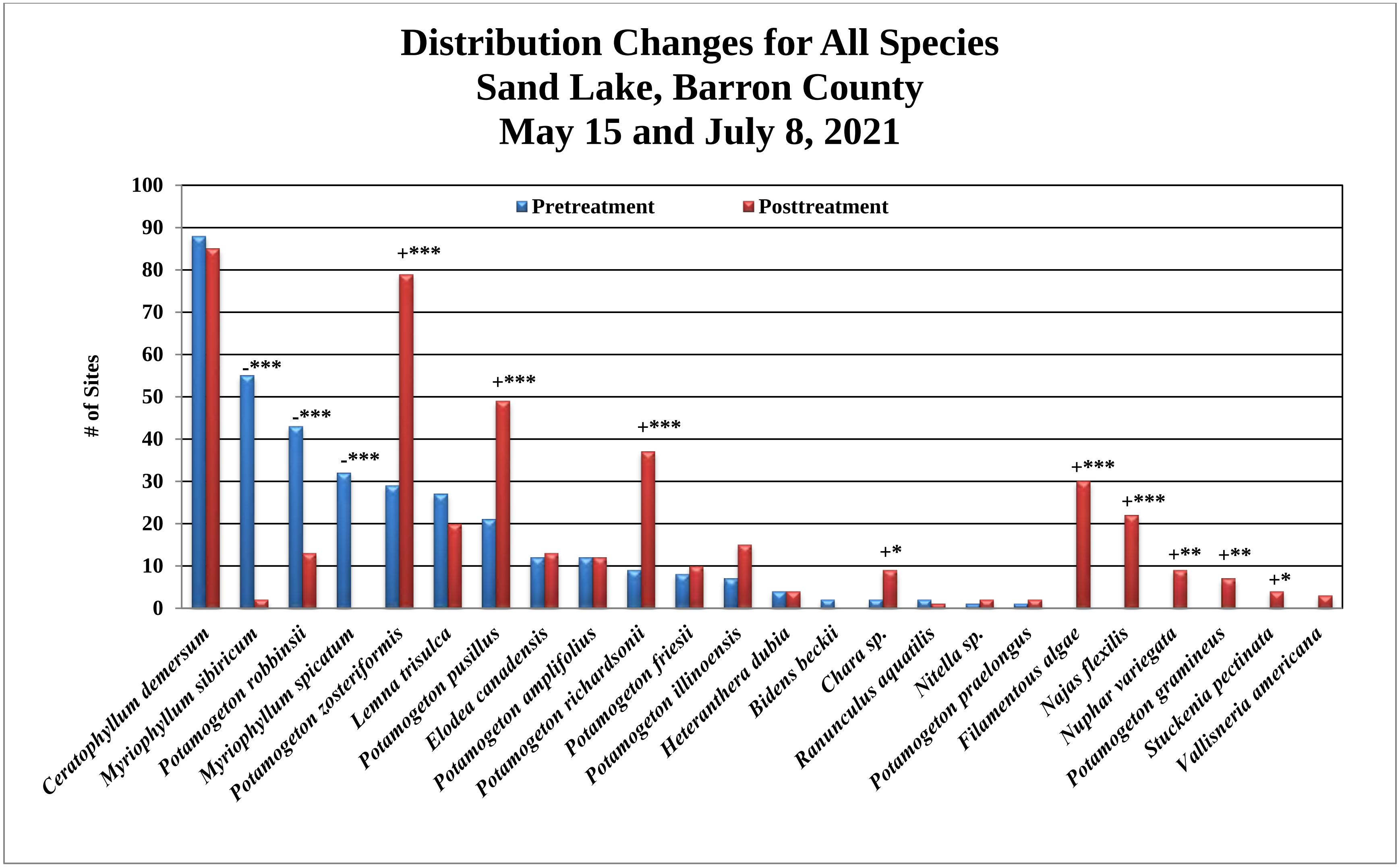


Figure 15: Pre/Posttreatment Clasping-leaf Pondweed Density and Distribution

Other than the previously mentioned Eurasian water-milfoil, Northern water-milfoil, and Fern pondweed, no species suffered significant declines in distribution posttreatment. However, in addition to Flat-stem pondweed, Small pondweed, and Clasping-leaf pondweed, Slender naiad (*Najas flexilis*) and filamentous algae enjoyed highly significant increases **(*p*<0.001)** in distribution; Spatterdock (*Nuphar variegata*) and Variable pondweed (*Potamogeton gramineus*) demonstrated moderately significant increases **(*p*=0.002/0.007)**; and Muskgrass (*Chara* sp.) and Sago pondweed (*Stuckenia pectinata*) saw significant increases **(*p*=0.03/0.04)** (Figure 16) (Maps for all native species from the pre and posttreatment surveys can be found in Appendixes VI and VII).



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

Figure 16: Pre/Posttreatment Macrophyte Changes

Fall Eurasian Water-milfoil Bed Mapping Survey:

On September 26th, we surveyed transects covering 13.5km (8.4 miles) spending extra time in the 2021 control and treatment areas (Figure 17). We had mostly sunny skies and calm winds which allowed us to see down approximately 7-8ft into the water column – slightly more than we have typically been able to at this time of year. We did **NOT** find any evidence of Eurasian water-milfoil within or around the 2021 treatment areas and raking at the core of these former beds didn't produce any surviving plants either. Amazingly, the only evidence we found of EWM in the lake was eight plants scattered throughout the navigation channel in the beaver lodge bay in the lake's southeast bay (Figure 18) (Appendix VIII).

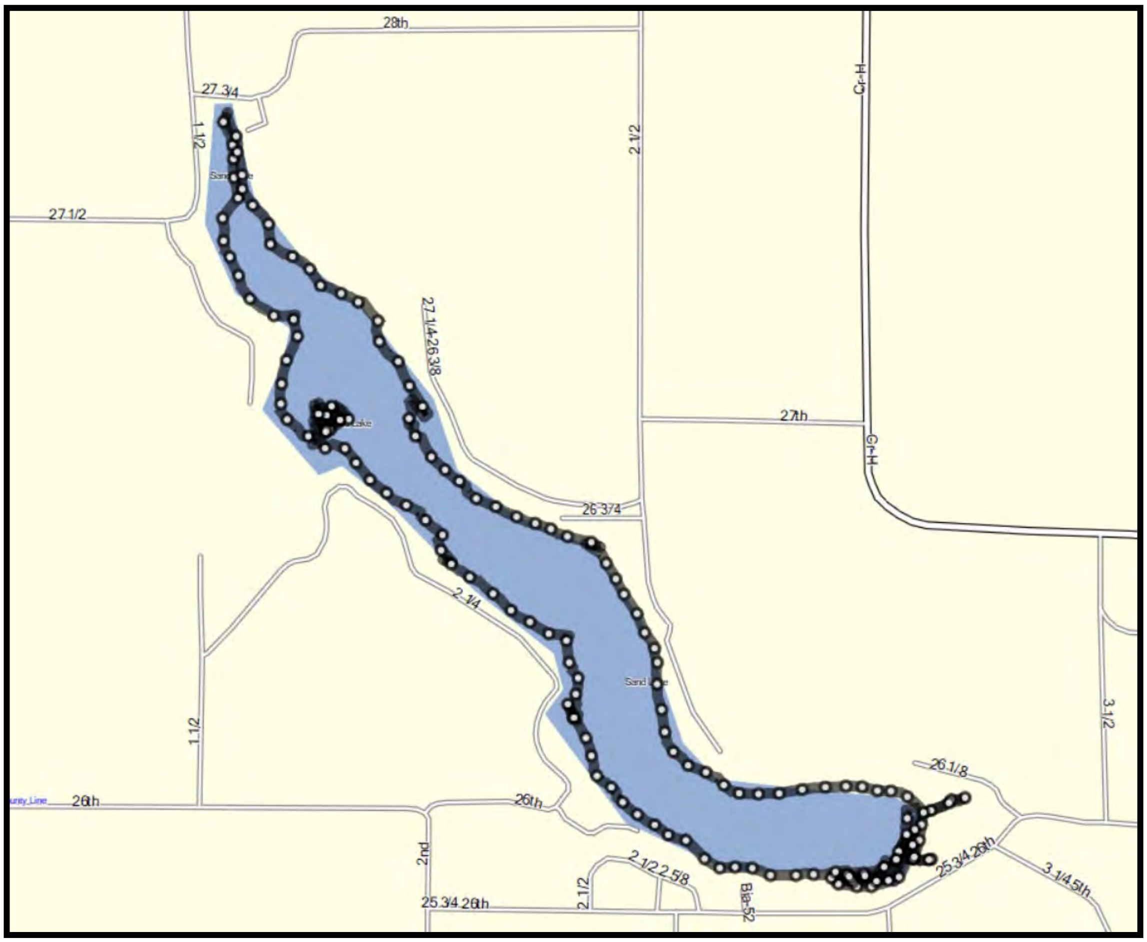
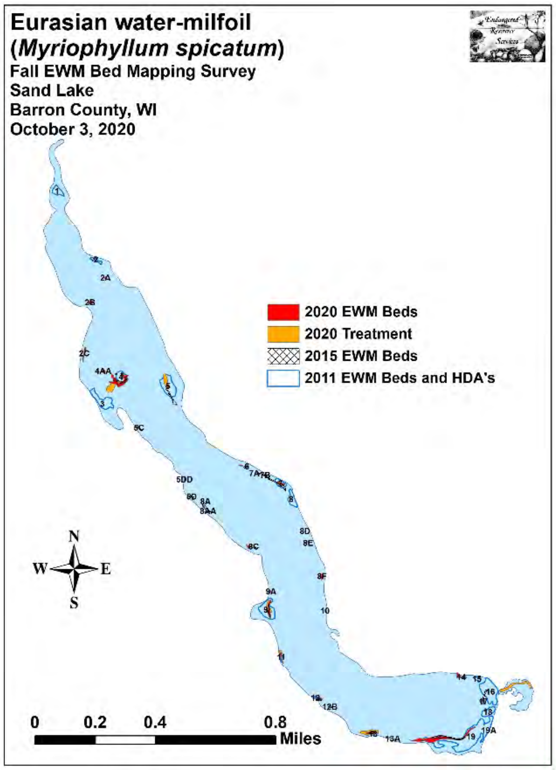


Figure 17: September 2021 Littoral Zone EWM Survey Transects



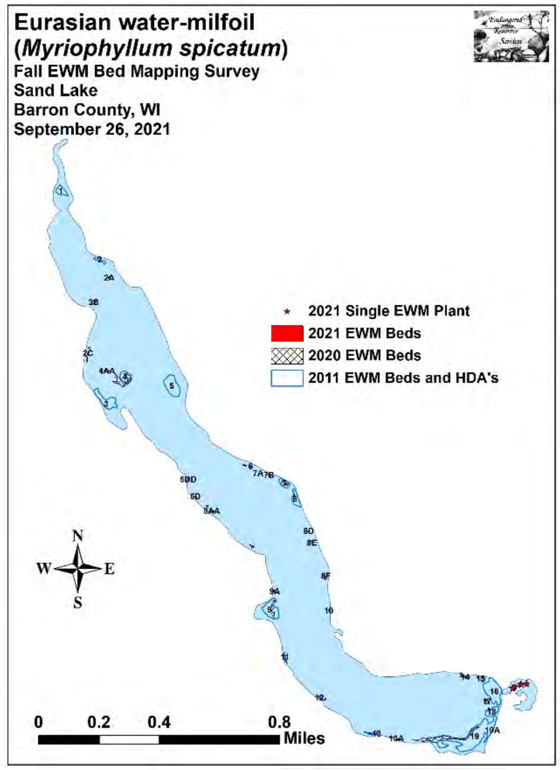


Figure 18: 2020 and 2021 Fall EWM Bed Maps

The 2021 fall survey represented a -100% reduction from our 2020 survey when we mapped 30 beds ranging in size from <0.01 acre (Beds 19A) to 1.04 acres (Bed 19). Collectively, they totaled 3.18 acres – an increase of 1.43 acres (+81.71%) from the 1.75 acres we mapped in 2015 and 2014 (Table 5).

Table 5: Fall Eurasian Water-milfoil Bed Mapping Summary
Sand Lake, Barron County 2011-2015, 2020-2021

HDA/ Bed Number	2021 Fall Bed Acreage	2020 Fall Bed Acreage	2015 Fall Bed Acreage	2014 Fall Bed Acreage	2013 Fall Bed Acreage	2012 Fall Bed Acreage	2011 Fall Bed Acreage	2021 Acreage Change
1	0	0	0	0	0	0	0.48	0
2	0	0	0.08	<0.01	0.05	0	0.17	0
2A and AA	0	0.03	0	<0.01	<0.01	0	0	-0.03
2B	0	0.08	0	0	0	0	0	-0.08
2C	0	0.12	0	0	0	0	0	-0.12
3	0	0	0	0	0	0	1.27	0
4	0	0.64	0.20	1.01	0	0	0.66	-0.64
4A, 4AA, and 4B	0	0.07	0.04	0	0	0	0	-0.07
5	0	0.04	0.19	0	<0.01	0	1.61	-0.04
5C and 5CC	0	0	0.06	<0.01	0	0	0	0
5D and 5DD	0	0.06	0.03	0.07	0.04	0	0	-0.06
6	0	0.03	0.03	0	0	0	0.03	-0.03
7, 7A, 7B, and 8	0	0.17	0.31	0	0	0	0.44	-0.17
8A, 8AA, and 8B	0	0.05	0.13	<0.01	0.01	0	0	-0.05
8C	0	0.05	0.04	0	0	0	0	-0.05
8D and 8E	0	0.03	0	0	0	0	0	-0.03
8F	0	0.06	0	0	0	0	0	-0.06
9	0	0.23	0.11	0	0	0	1.49	-0.23
9A	0	0.02	0	0	0	0	0	-0.02
10	0	0	0	0	0	0	0.02	0
11	0	0.05	0	0	0	0	0.06	-0.05
12	0	0.06	0.03	0.05	0.04	0	0.02	-0.06
12B	0	0	0.03	0	0	0	0	0
13	0	0.15	0.08	0.33	<0.01	0	0.10	-0.15
13A	0	0.04	0	0	0	0	0	-0.04
14	0	0.09	0	0	0	0	0.08	-0.09
15	0	0	0	0	0	0	0.16	0
16	0	0	0.11	0.23	0	0	2.12	0
17	0	0.03	0	0	0	0	0.09	-0.03
18	0	0.01	0	0.02	0	0	0.56	-0.01
19 and 19A	0	1.05	0.32	0	0.03	0	5.29	-1.05
Total Acres	**0.00**	**3.18**	**1.75**	**1.75**	**0.22**	**0.00**	**15.25**	**-3.18**

CONSIDERATIONS FOR MANAGEMENT:

Future Active Management:

Eurasian water-milfoil occupies only a small percentage of the lake's surface area, but it is widely-established making eradication an unrealistic expectation. With this in mind, continuing to work to control its spread in the most cost-effective manner possible, while simultaneously minimizing its impact on the lake's aquatic ecosystem will likely continue to be important goals for the Sand Lake Management District moving forward.

ProcellaCor is expensive relative to other herbicide options, but it has produced impressive results in apparently eliminating EWM from areas where it has been used on Sand Lake. Because even "spot" treatment areas of <0.50 acre have resulted in complete control, it may become the chemical of choice on the lake. Regardless of what control measures are used in the future, the lack of any obvious EWM outside the beaver lodge bay channel may mean 2022 is a year with little or no active management.

LITERATURE CITED

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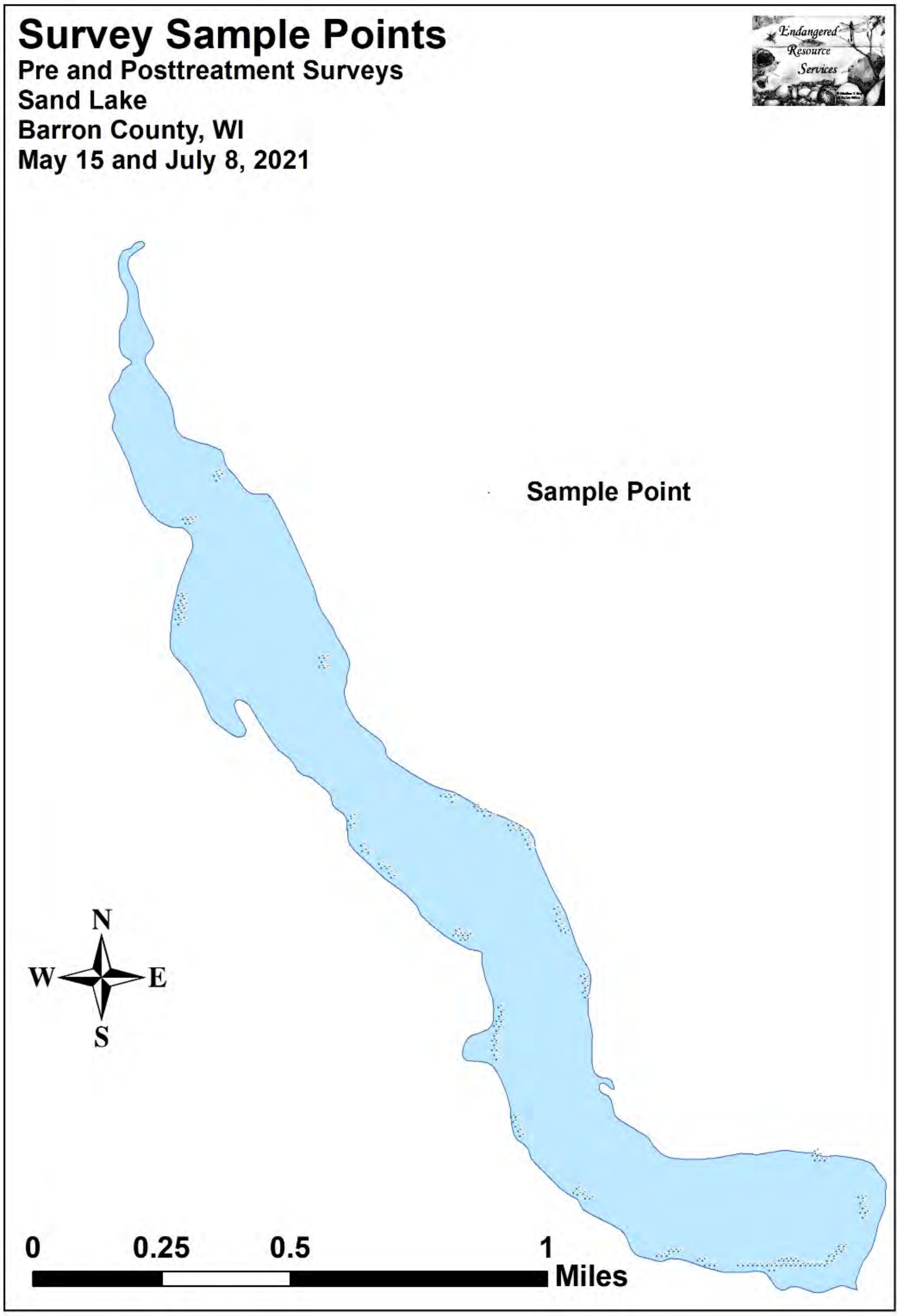
UWEX Lakes Program. [online]. 2010. Aquatic Plant Management in Wisconsin. Available from http://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/ecology/aquaticplants/default.aspx (2021 June).

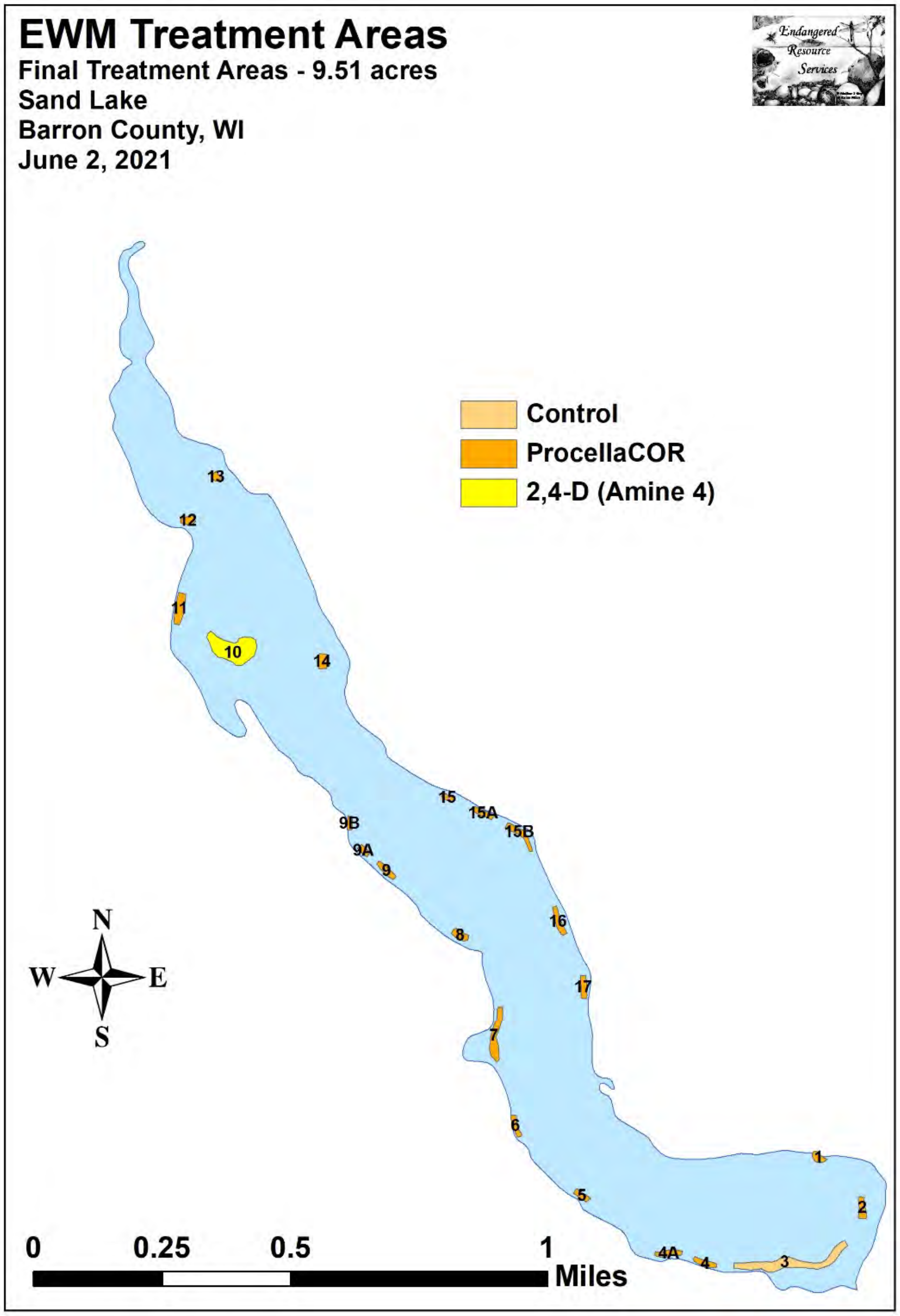
UWEX Lakes Program. [online]. 2010. Pre/Post Herbicide Comparison. Available from http://www.uwsp.edu/cnr-ap/UWEXLakes/Documents/ecology/Aquatic%20Plants/Appendix-D.pdf (2021 June).

WDNR. [online]. 2021. Sand Lake - Citizen Lake Water Quality Monitoring Database. Available from http://dnr.wi.gov/lakes/waterquality/Station.aspx?id=033143 (2021, October).

WDNR. [online]. 2021. Wisconsin Lakes Information – Sand Lake – Barron County. https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2661100 (2021, October).

Appendix I: EWM Pre/Post Survey Sample Points and Treatment Areas

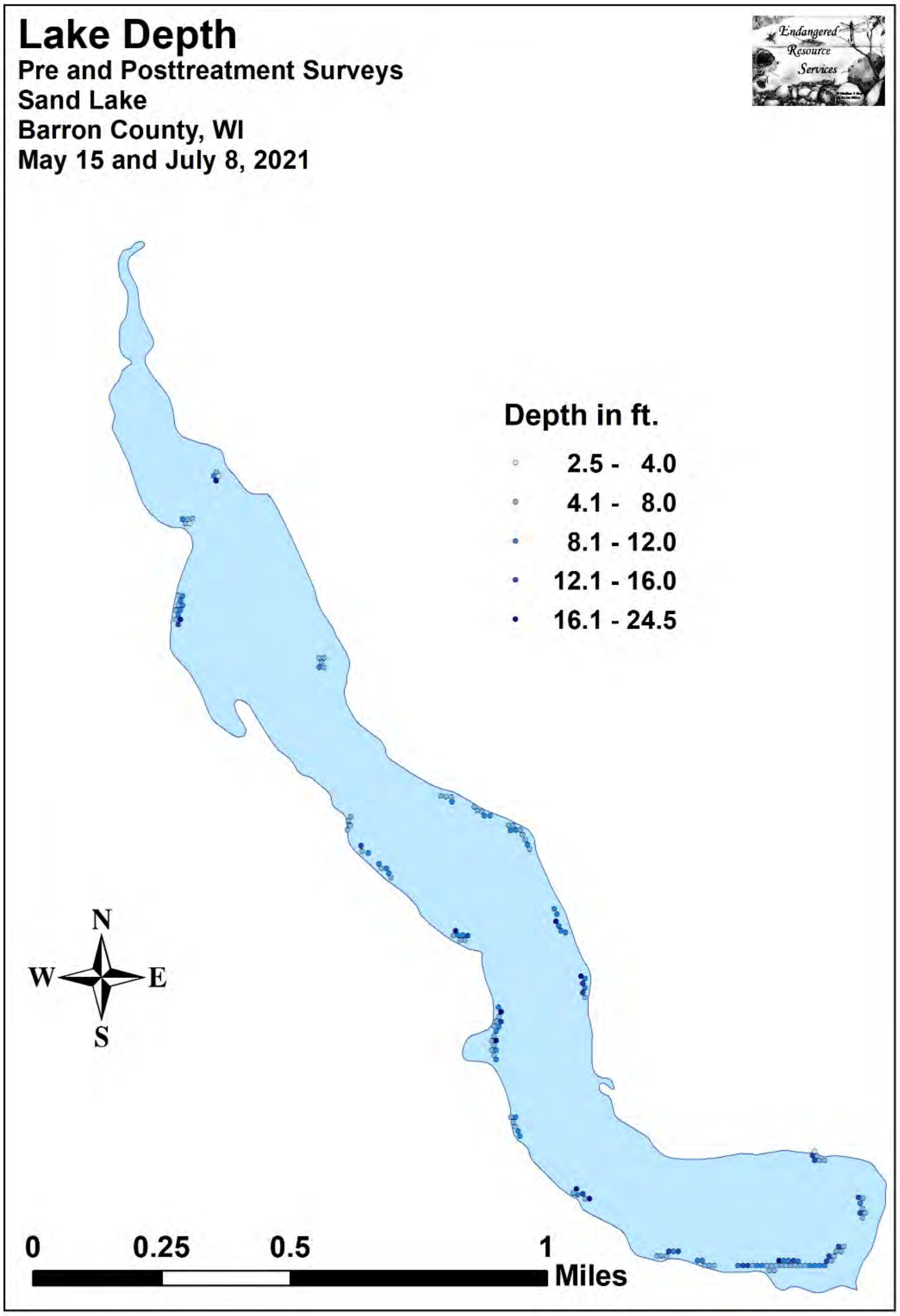

Survey Sample Points
Pre and Posttreatment Surveys
Sand Lake
Barron County, WI
May 15 and July 8, 2021
Endangered Resource Services
Sample Point
N
W
E
S
0
0.25
0.5
1
Miles

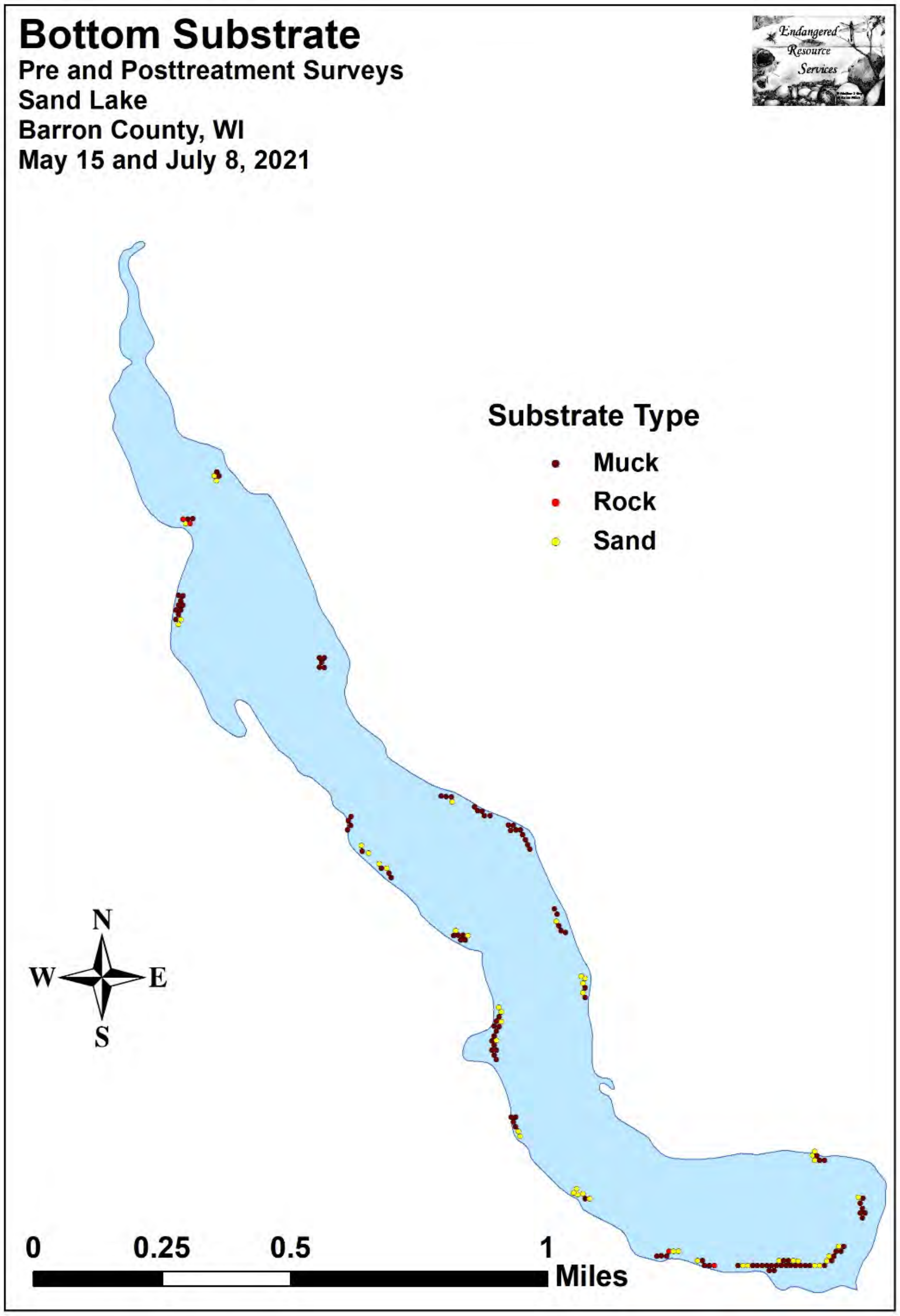

EWM Treatment Areas
Final Treatment Areas - 9.51 acres
Sand Lake
Barron County, WI
June 2, 2021
Endangered Resource Services
Control
ProcellaCOR
2,4-D (Amine 4)
13
12
11
10
14
15
15A
15B
9B
9A
9
8
16
17
7
6
5
1
2
4A
4
3
N
W
E
S
0
0.25
0.5
1
Miles

Appendix II: Vegetative Survey Datasheet

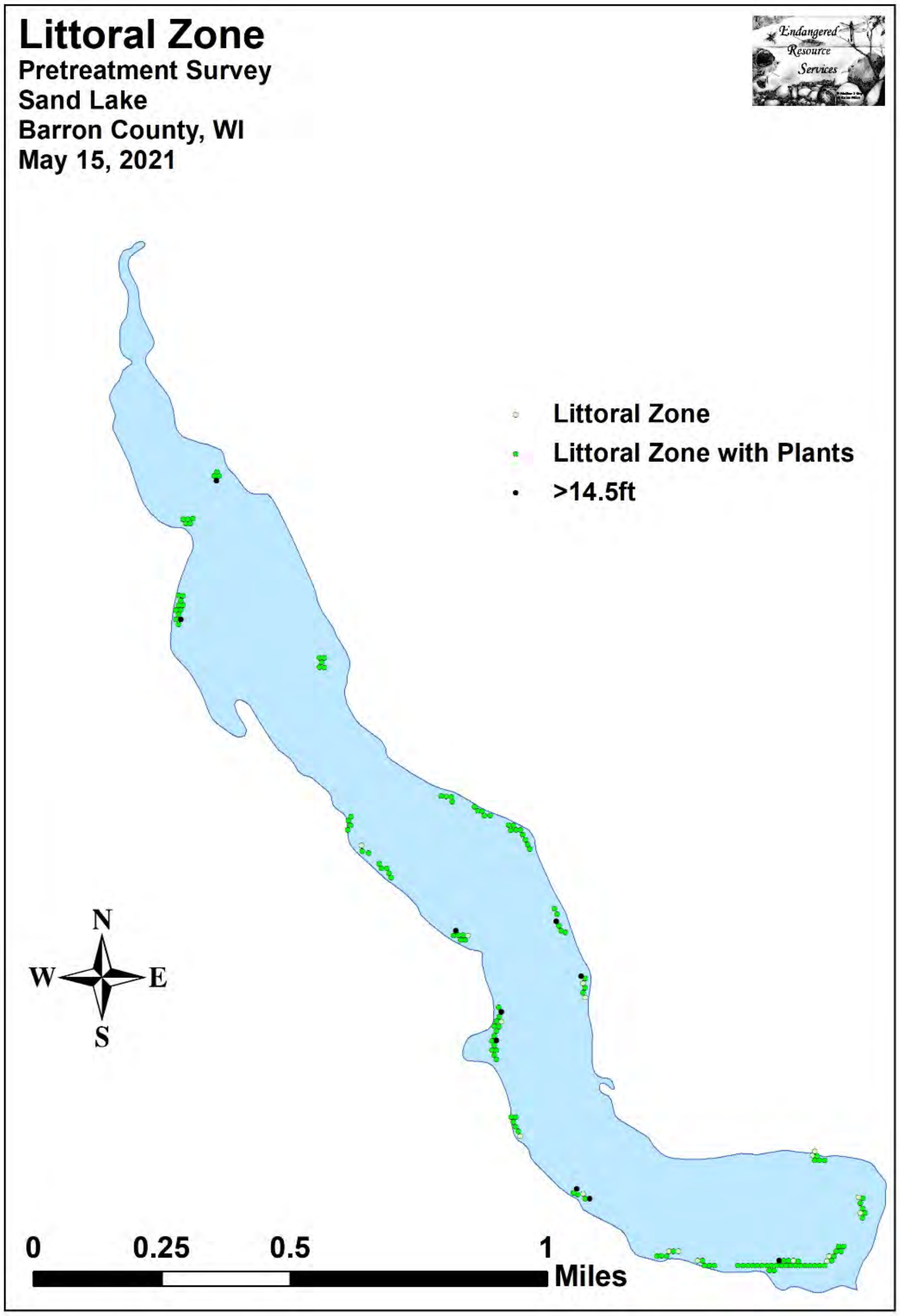
Observers for this lake: names and hours worked by each:																									
Lake:									WBIC									County						Date:	
Site #	Depth (ft)	Muck (M), Sand (S), Rock (R)	Rake pole (P) or rake rope (R)	Total Rake Fullness	EWM	EWM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1																	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

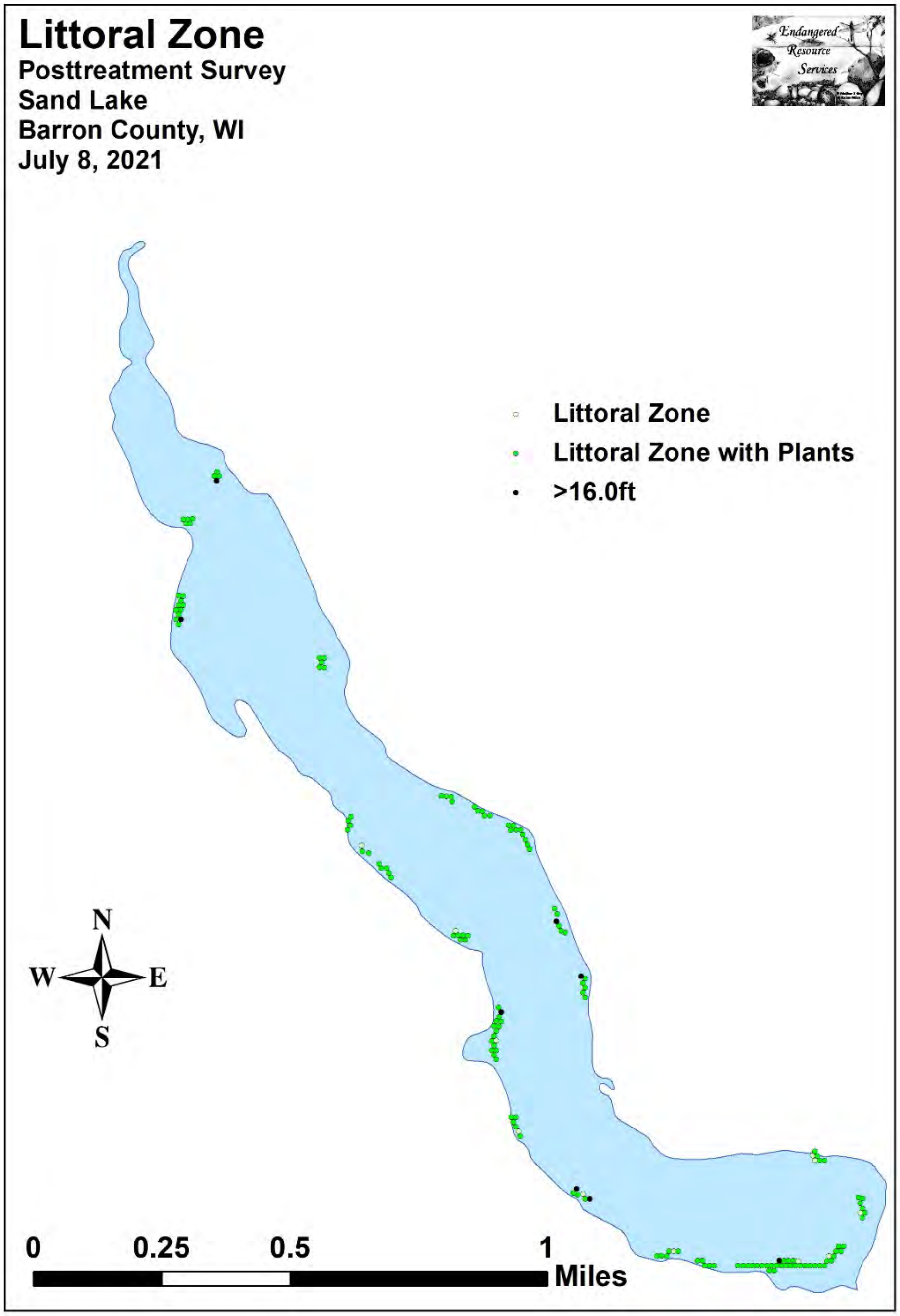
Appendix III: Pre/Post Habitat Variables

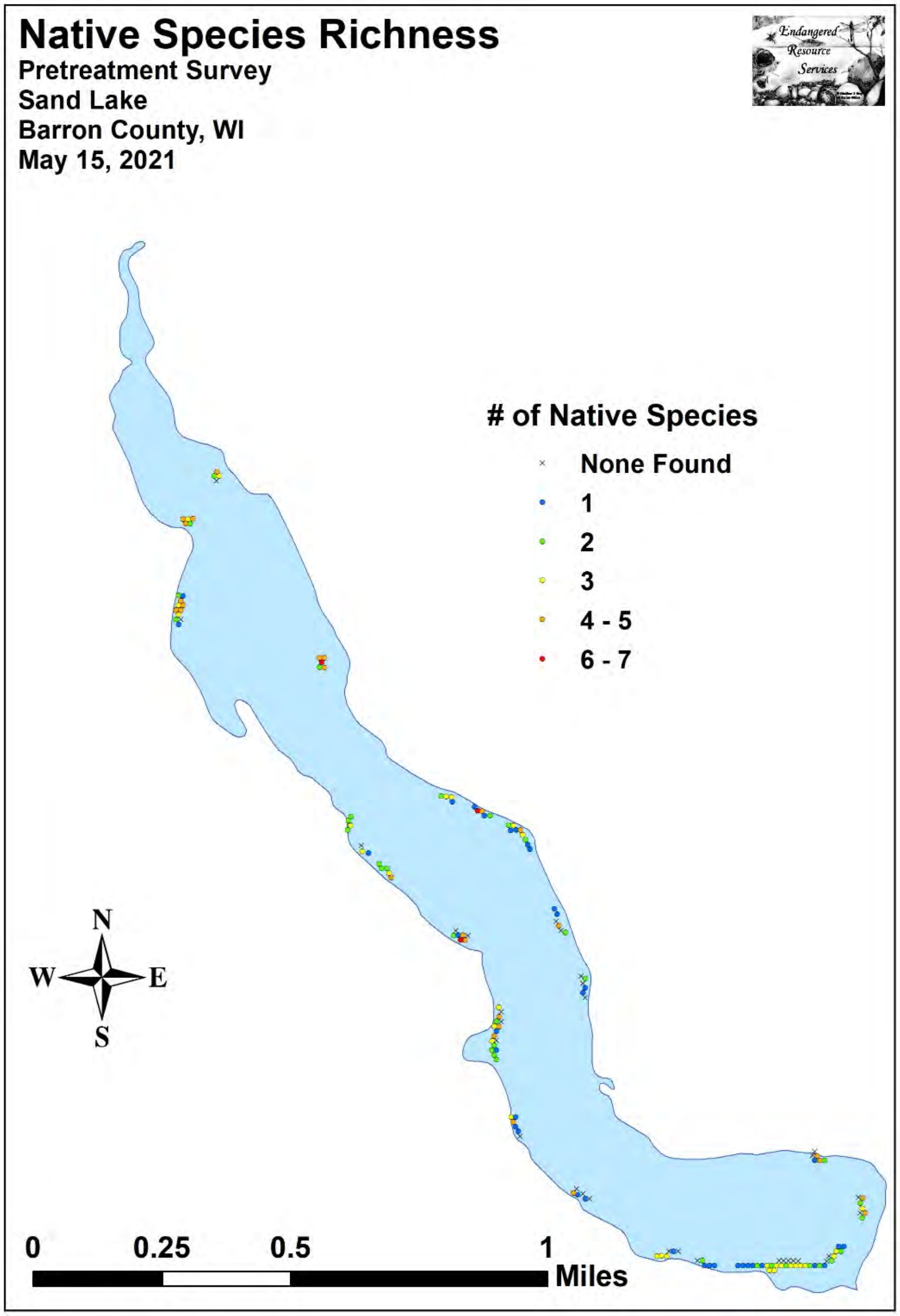

Lake Depth
Pre and Posttreatment Surveys
Sand Lake
Barron County, WI
May 15 and July 8, 2021
Endangered Resource Services
Depth in ft.
2.5 - 4.0
4.1 - 8.0
8.1 - 12.0
12.1 - 16.0
16.1 - 24.5
N
W
E
S
0
0.25
0.5
1
Miles

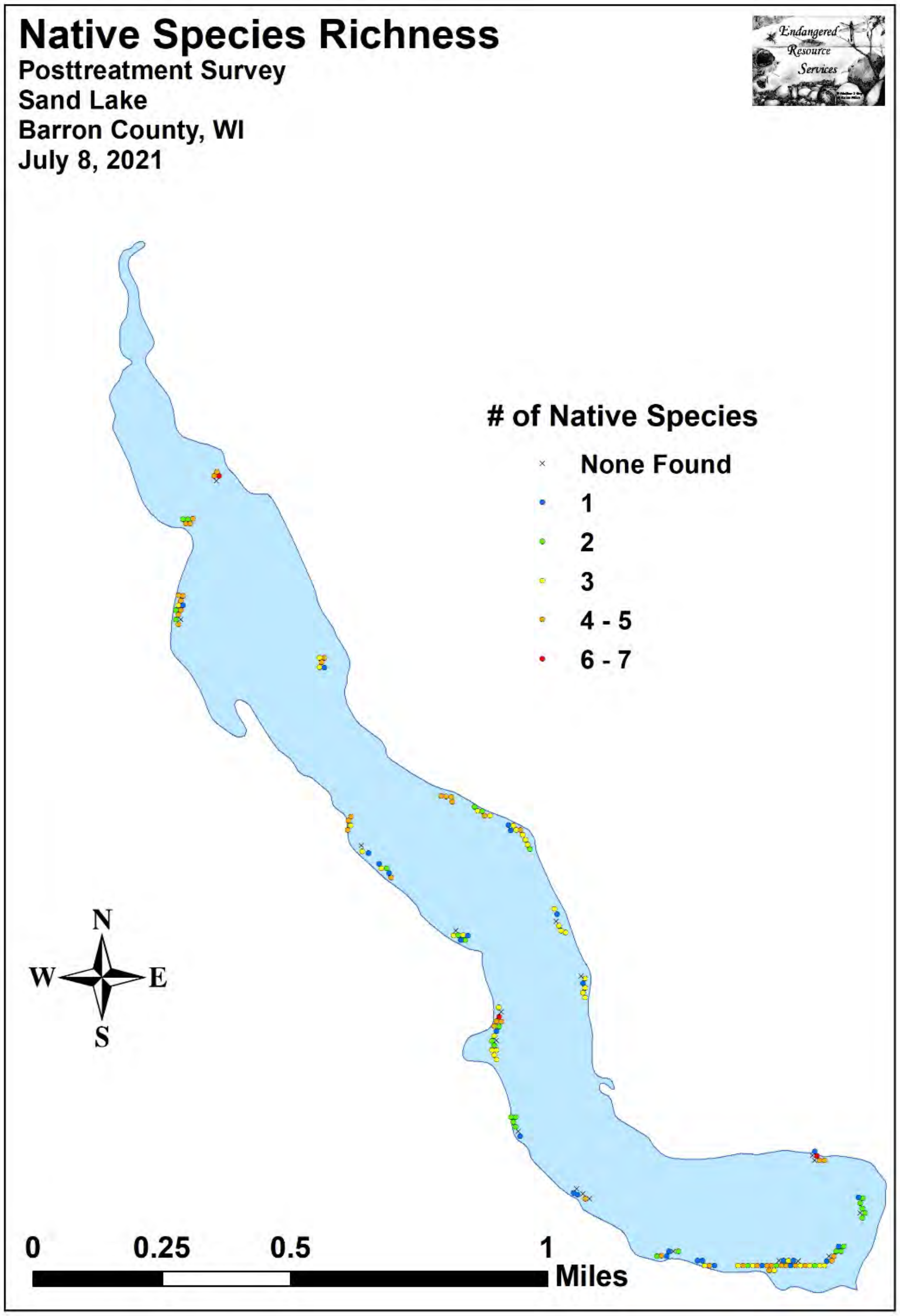

Bottom Substrate
Pre and Posttreatment Surveys
Sand Lake
Barron County, WI
May 15 and July 8, 2021
Endangered Resource Services
Substrate Type
Muck
Rock
Sand
N
W
E
S
0
0.25
0.5
1
Miles

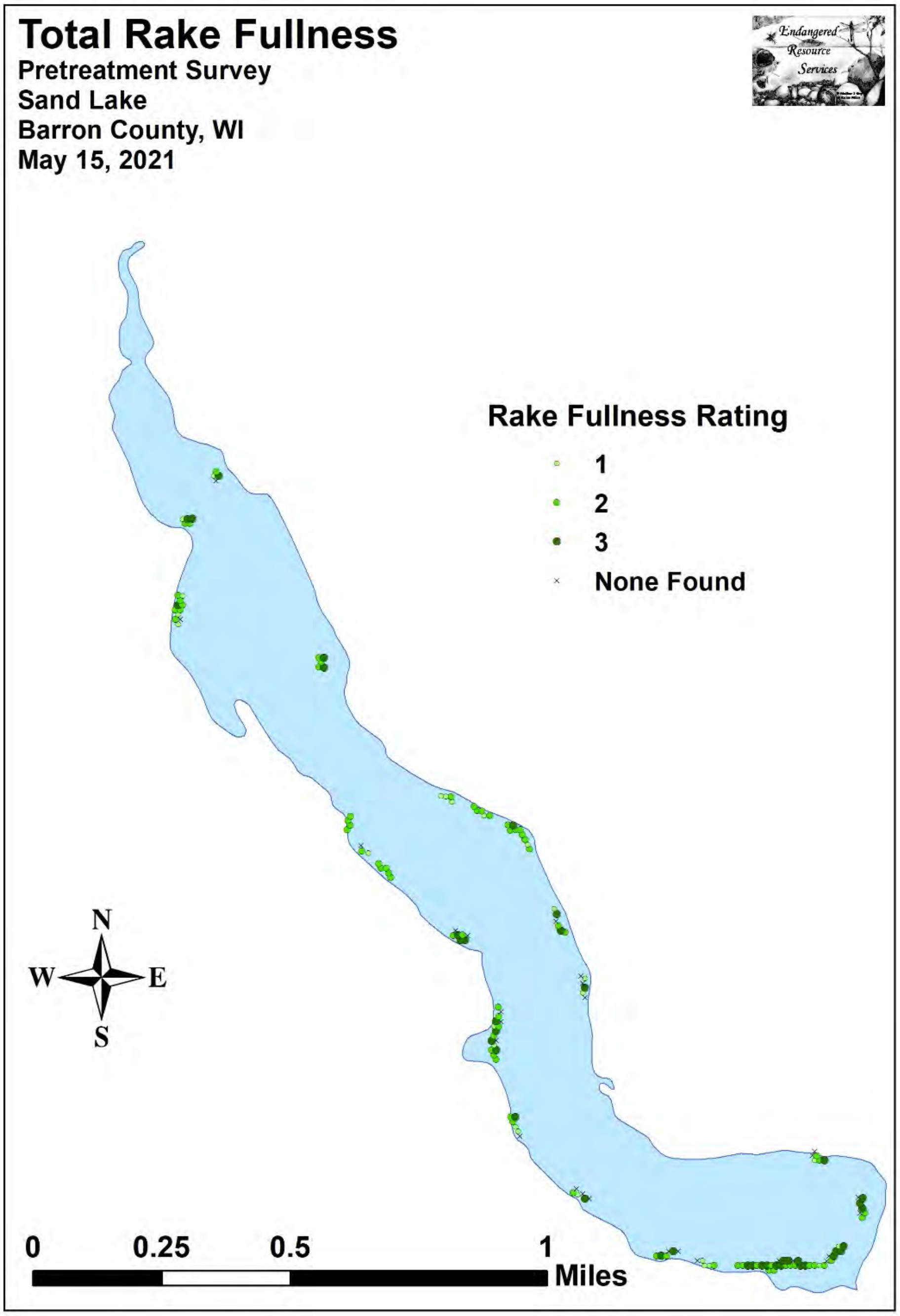
Appendix IV: Pre/Post Littoral Zone, Native Species Richness and Total Rake Fullness

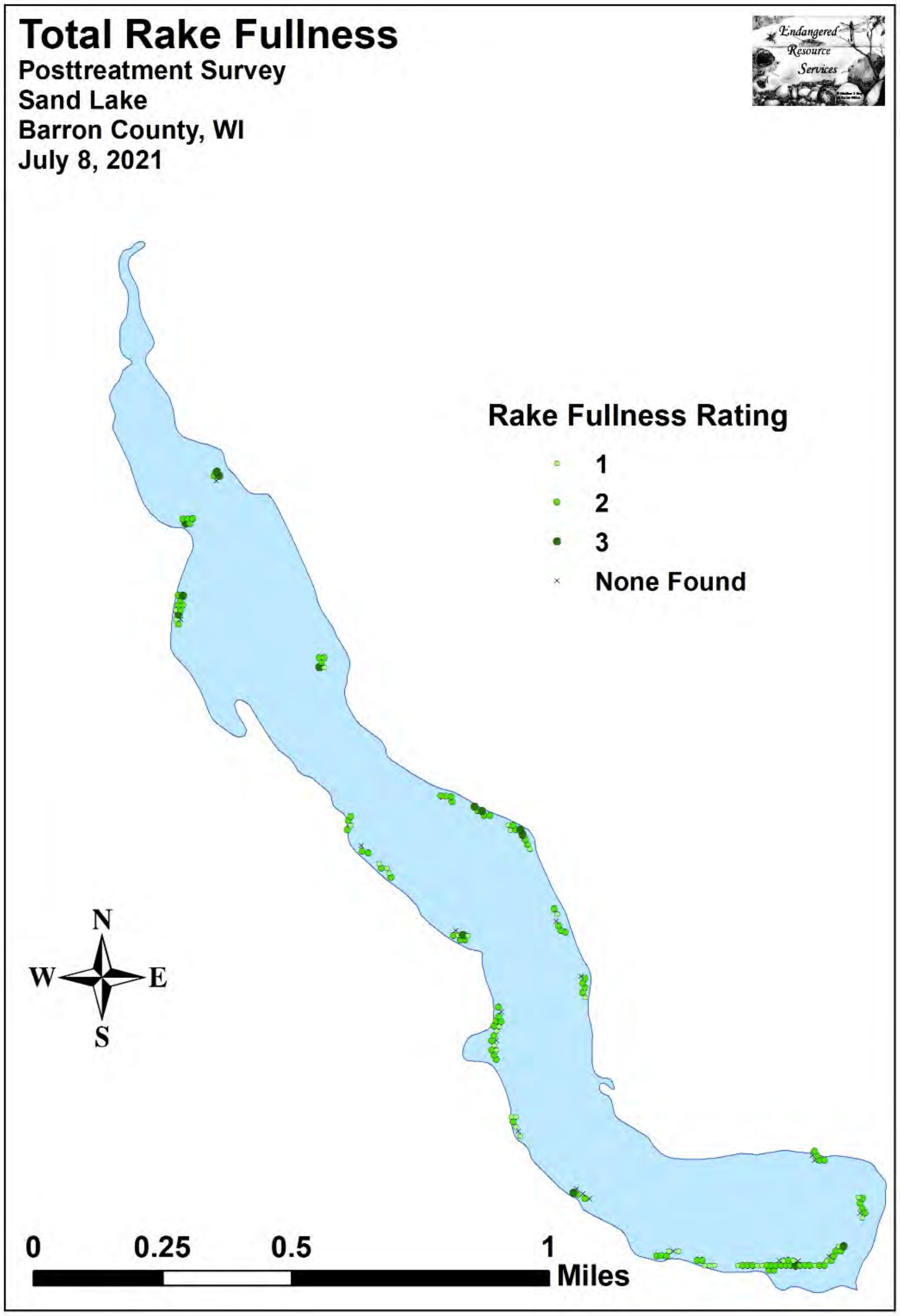

Littoral Zone
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Littoral Zone
Littoral Zone with Plants
>14.5ft
N
W
E
S
0
0.25
0.5
1
Miles


Littoral Zone
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered
Resource
Services
Littoral Zone
Littoral Zone with Plants
>16.0ft
N
W
E
S
0
0.25
0.5
1
Miles

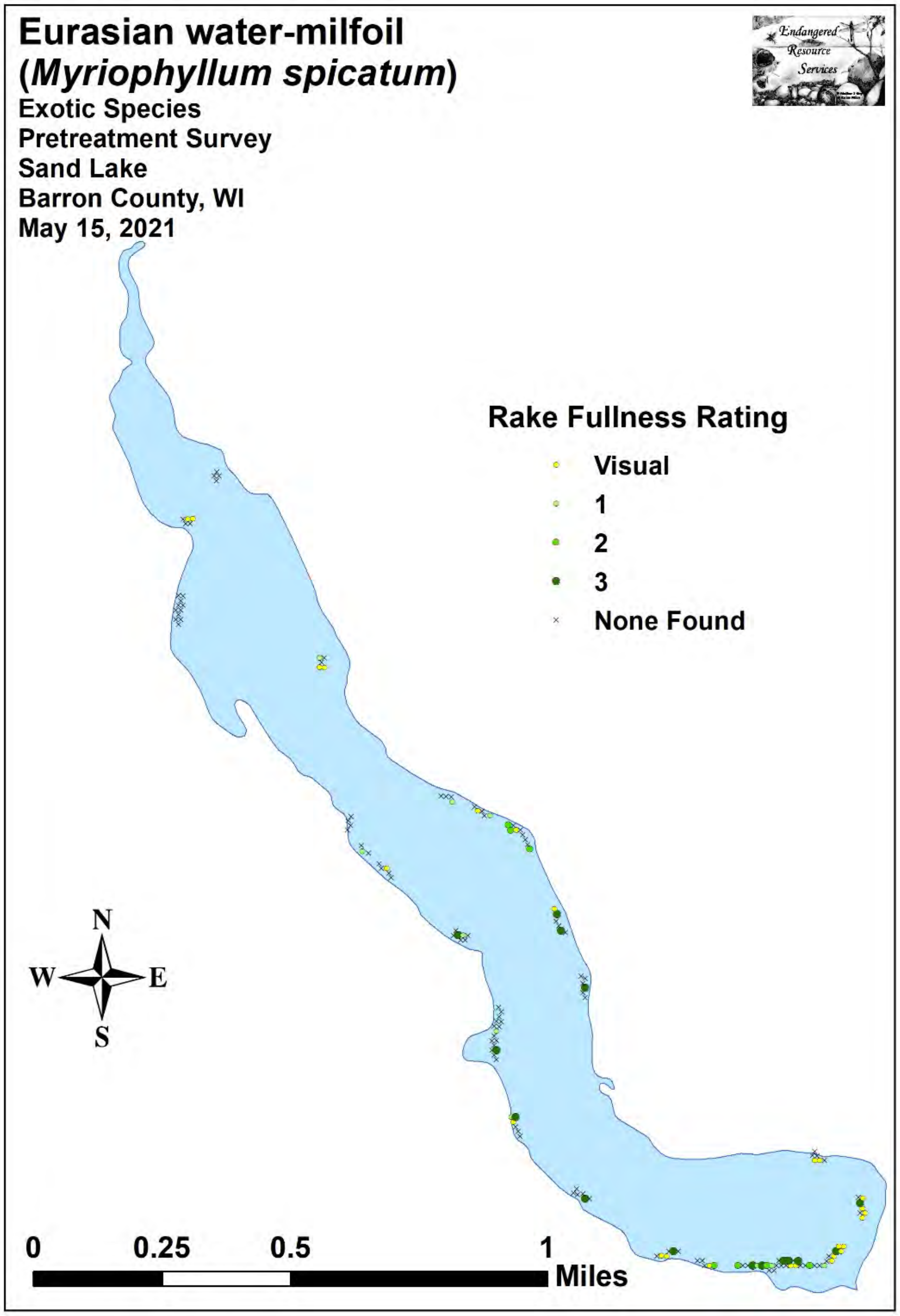

Native Species Richness
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered
Resource
Services
# of Native Species
None Found
1
2
3
4 - 5
6 - 7
N
W
E
S
0
0.25
0.5
1
Miles

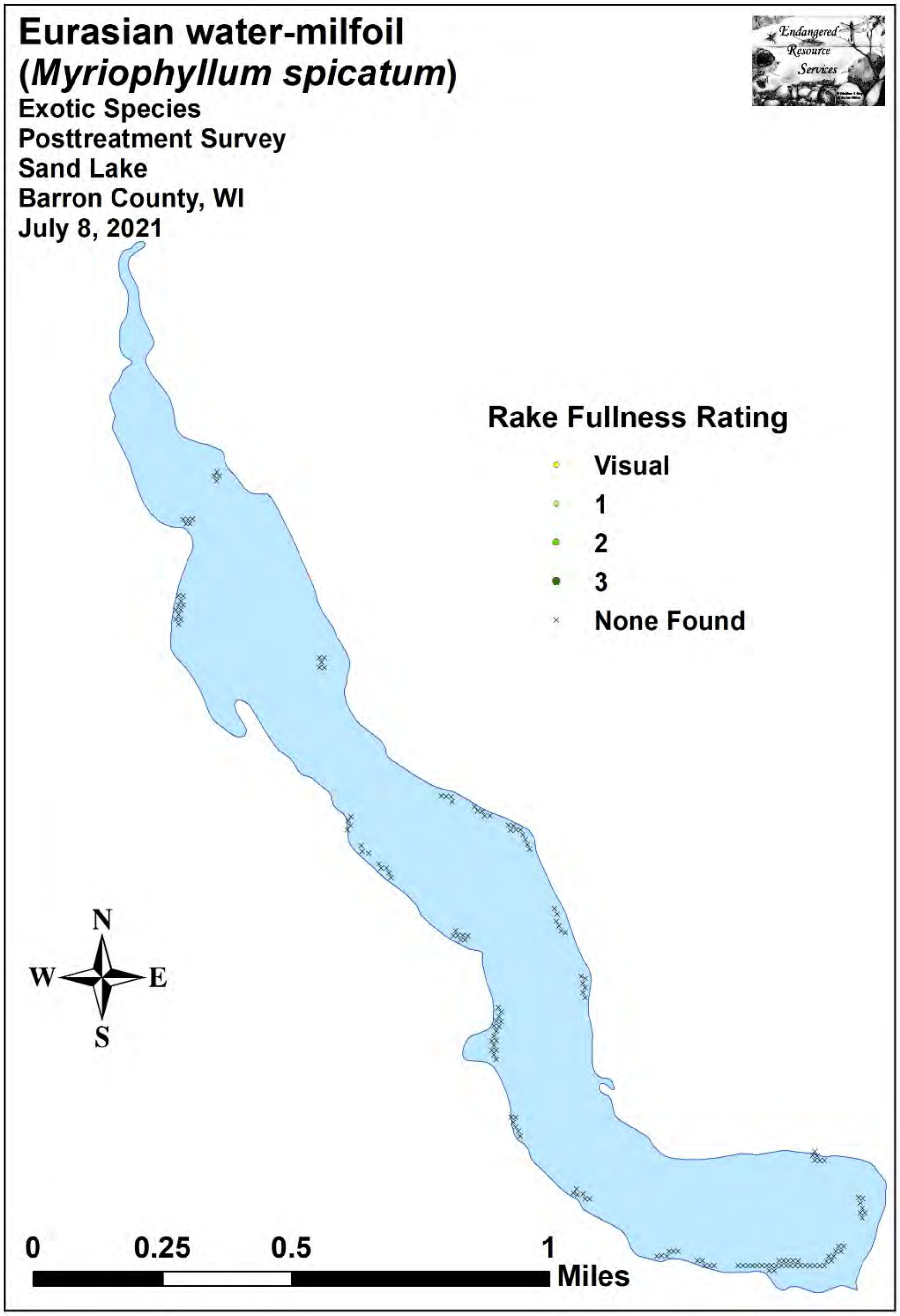

Native Species Richness
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
# of Native Species
None Found
1
2
3
4 - 5
6 - 7
N
W
E
S
0
0.25
0.5
1
Miles


Total Rake Fullness
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

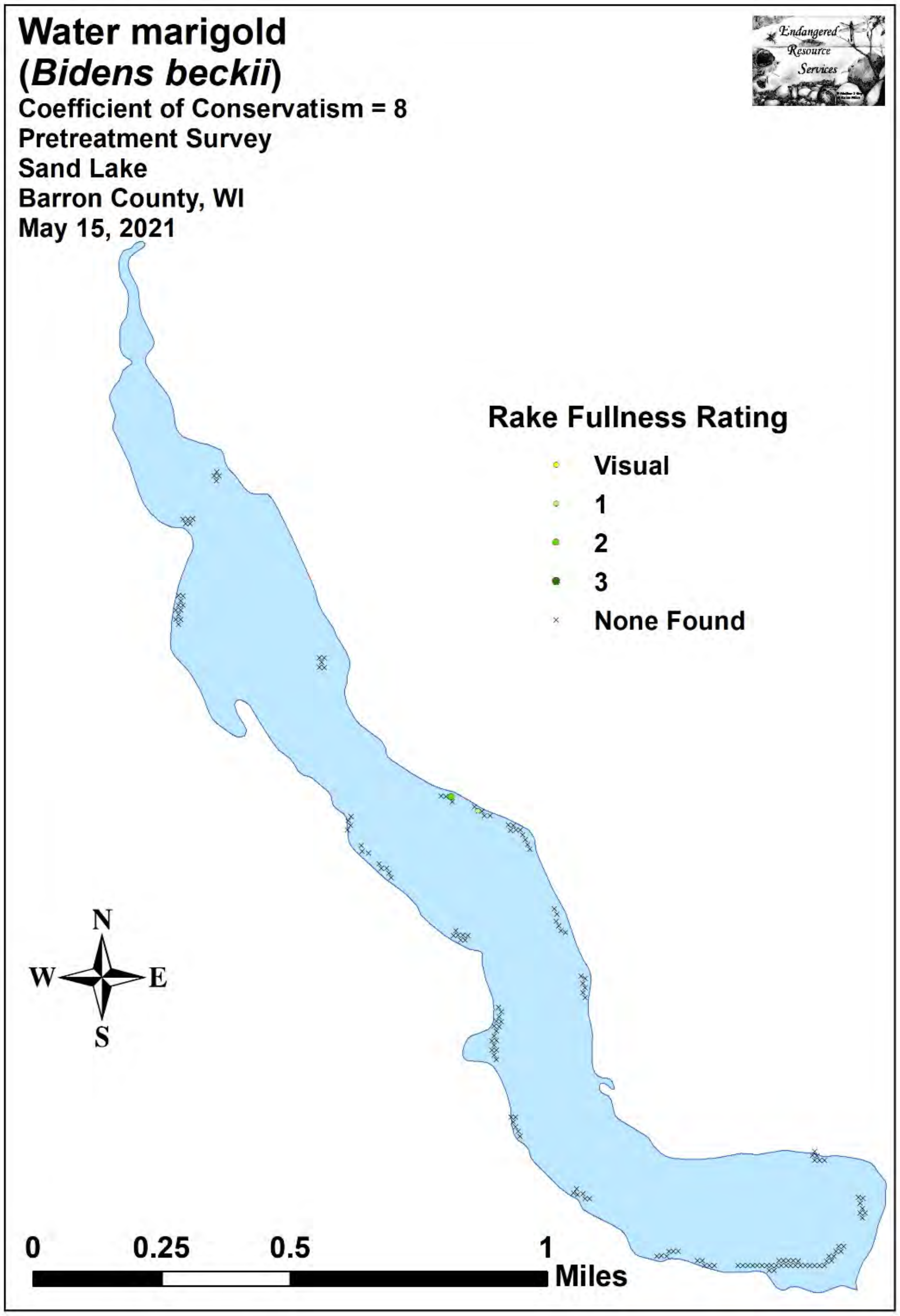

Total Rake Fullness
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

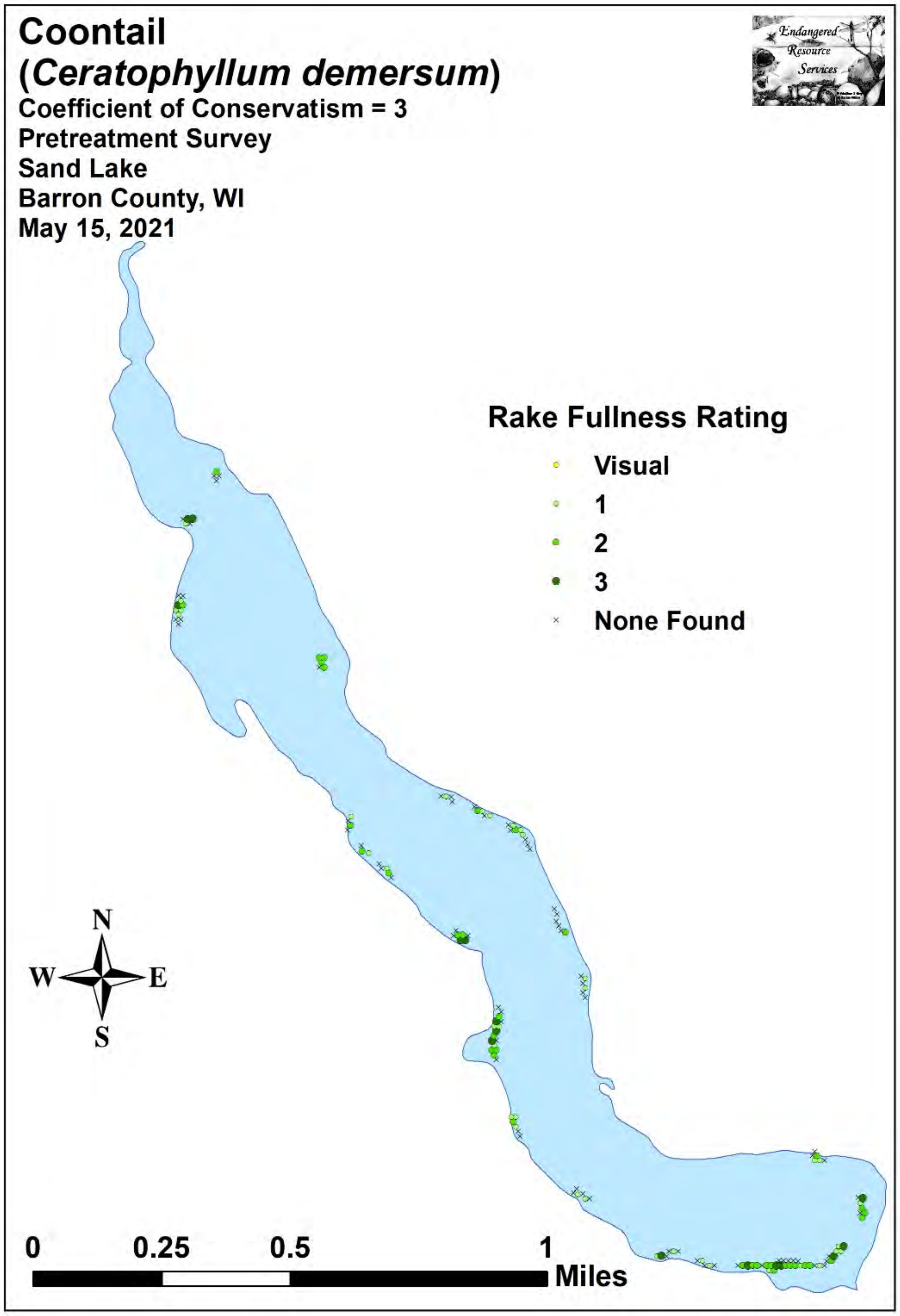
Appendix V: EWM Pre/Posttreatment Density and Distribution

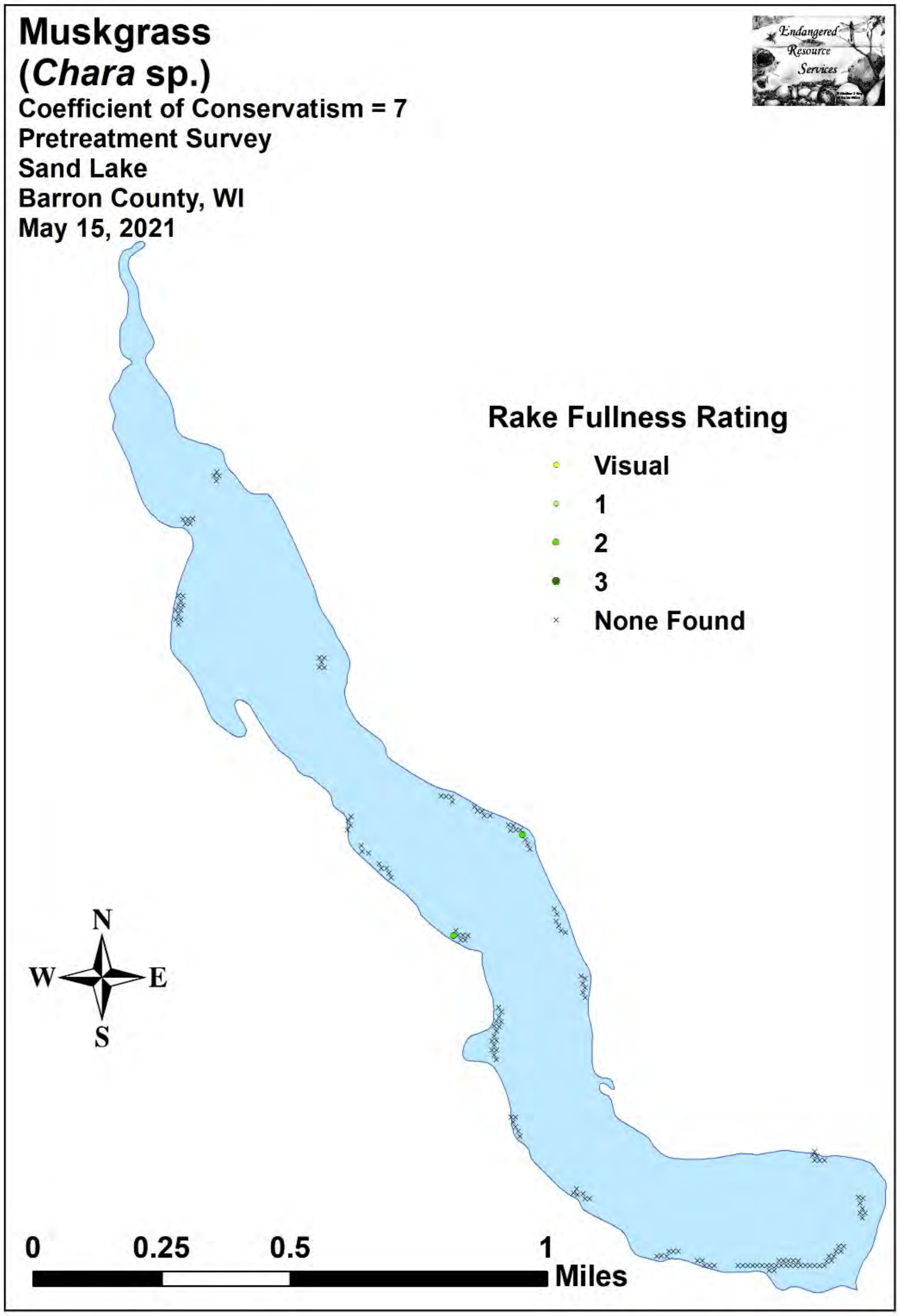

Eurasian water-milfoil
(*Myriophyllum spicatum*)
Exotic Species
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

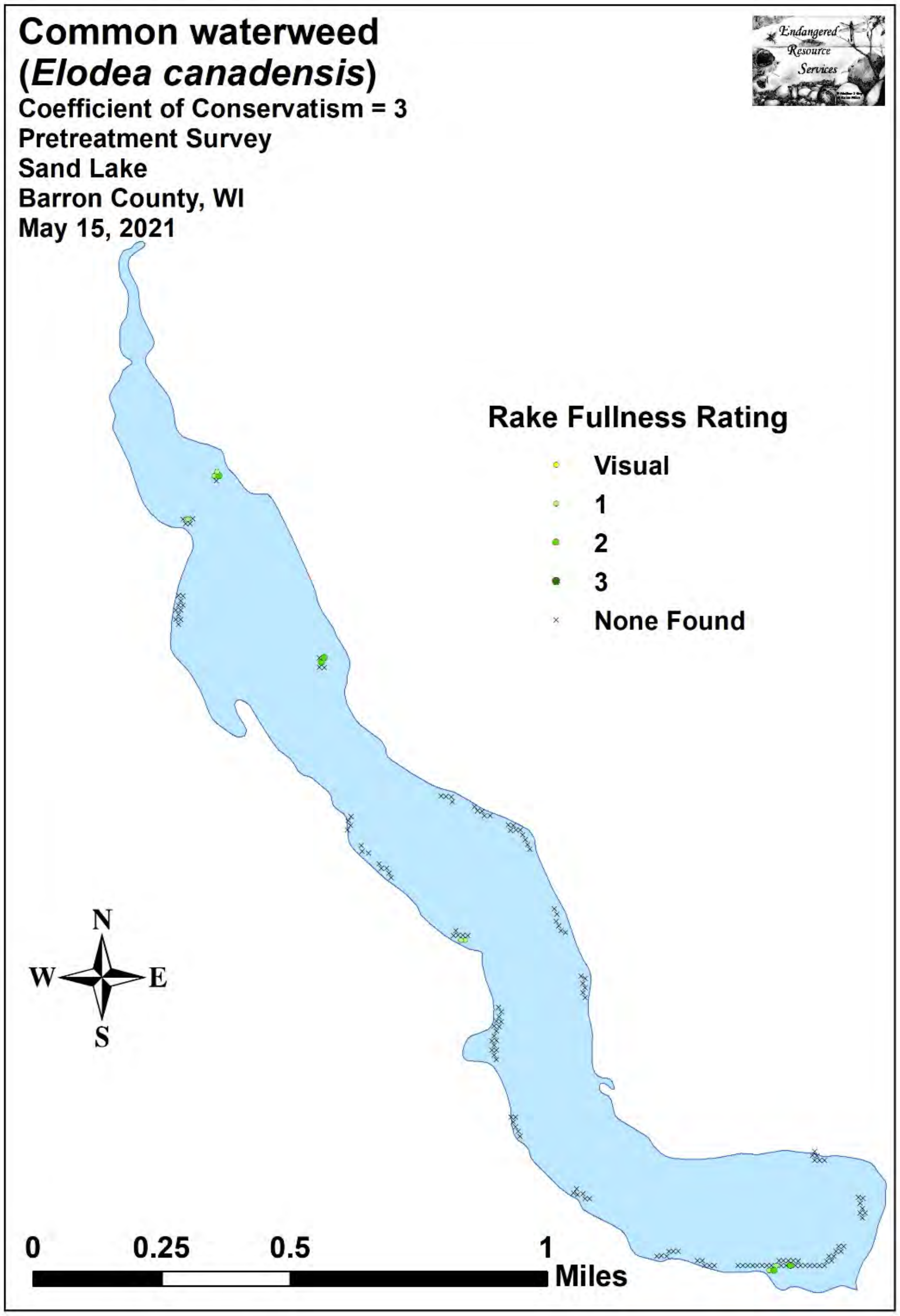

Eurasian water-milfoil
(Myriophyllum spicatum)
Exotic Species
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

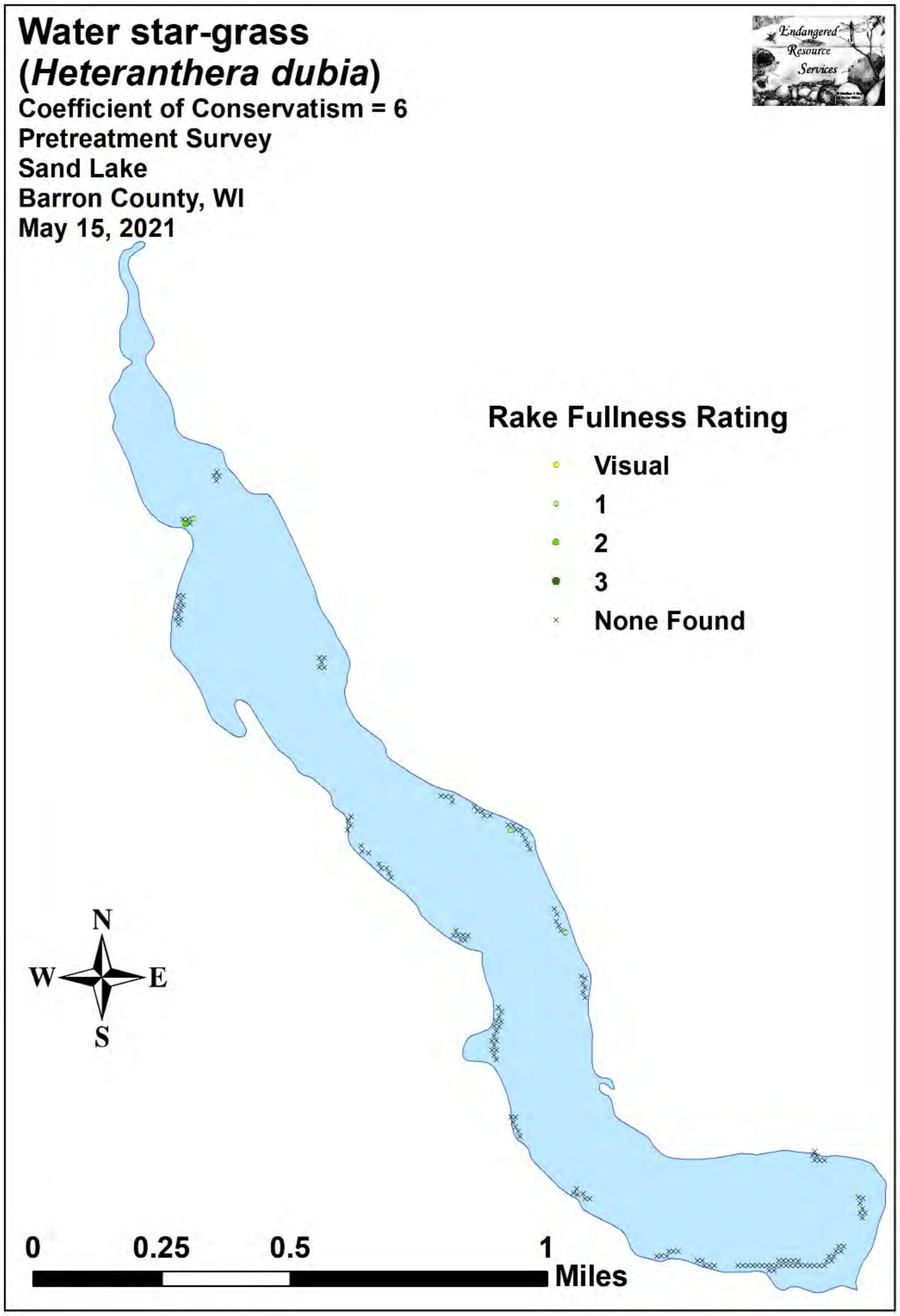
Appendix VI: Pretreatment Native Species Density and Distribution

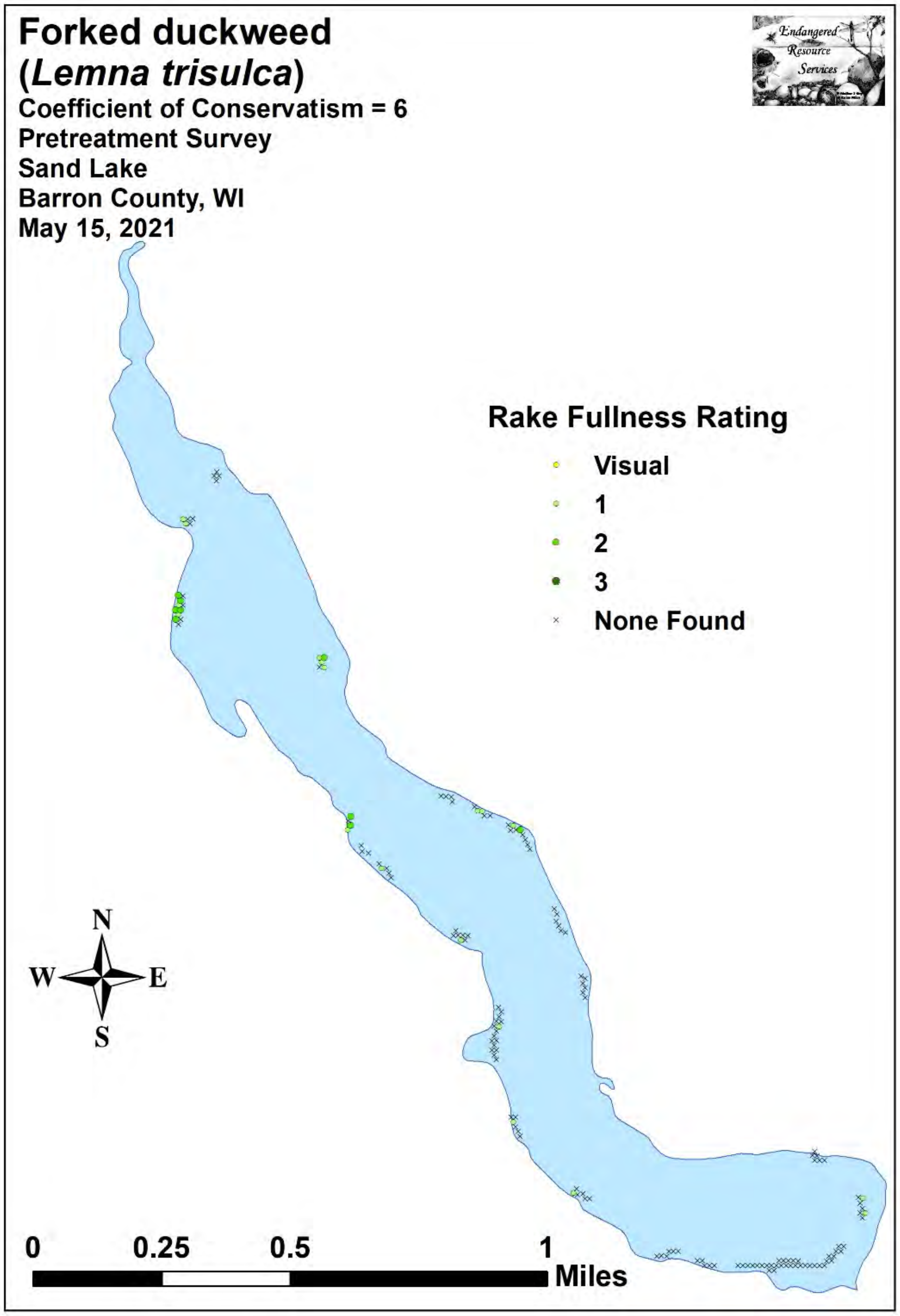

Water marigold
(*Bidens beckii*)
Coefficient of Conservatism = 8
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

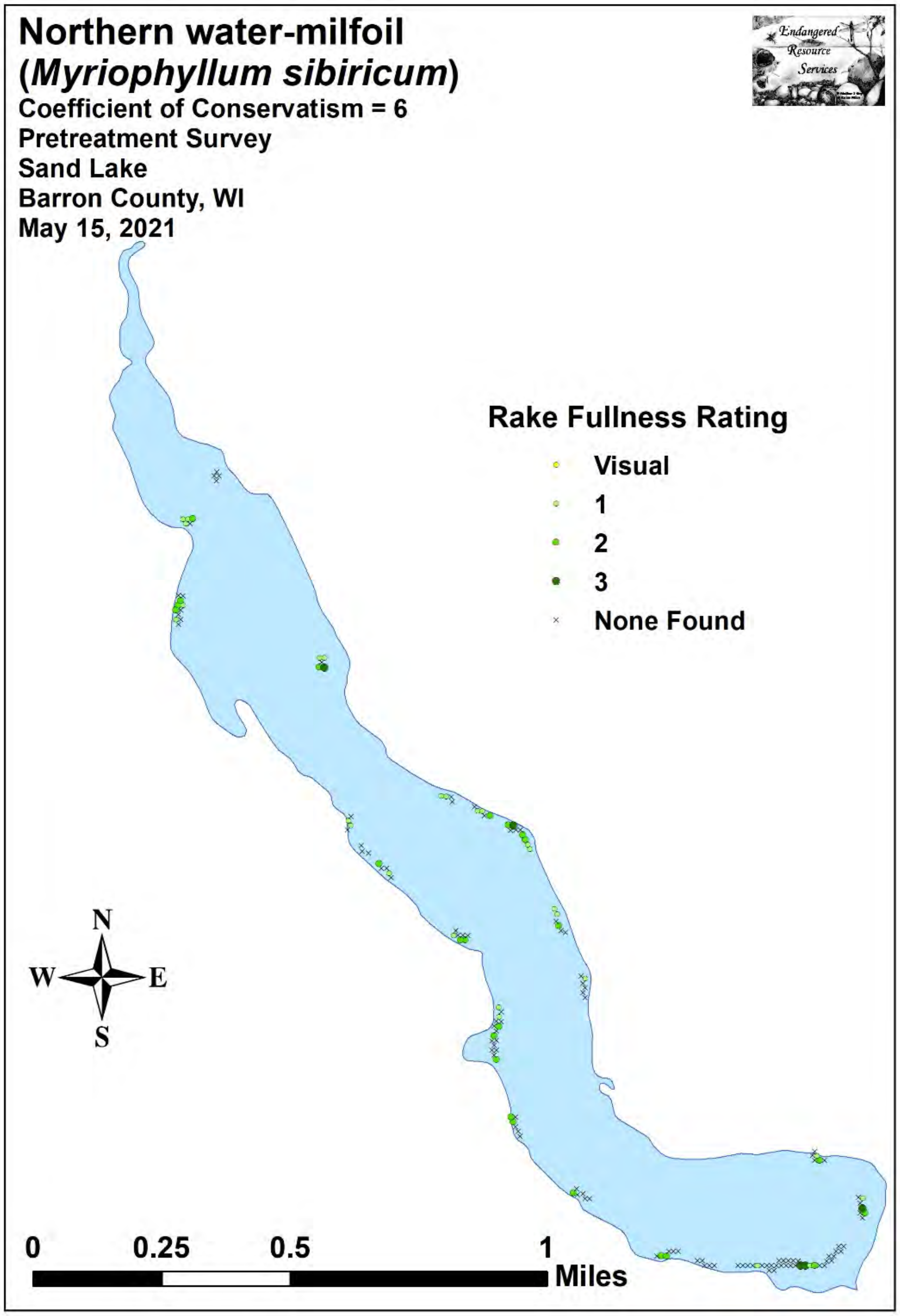

Coontail
(*Ceratophyllum demersum*)
Coefficient of Conservatism = 3
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

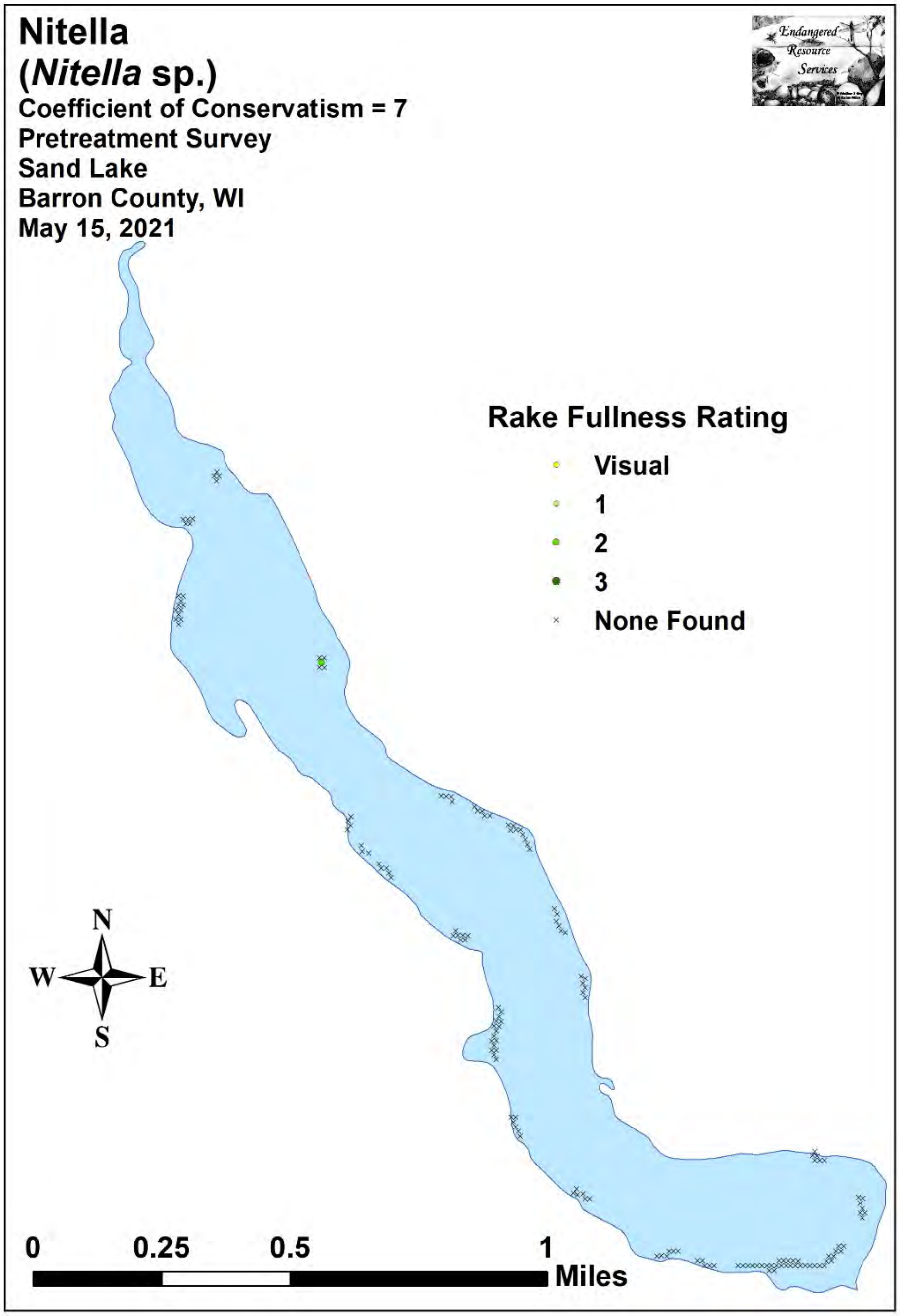

Muskgrass
(*Chara* sp.)
Coefficient of Conservatism = 7
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

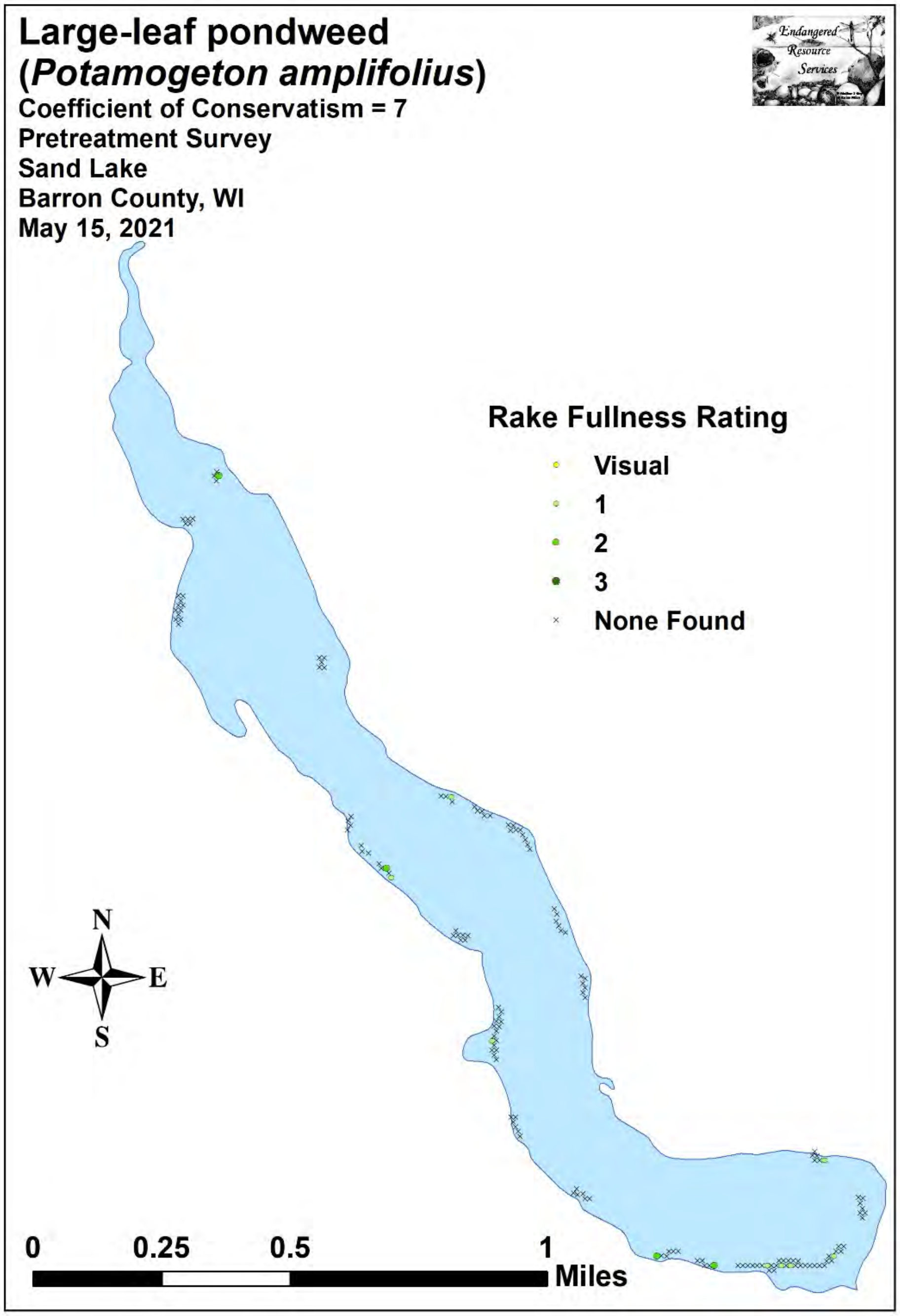

Common waterweed
(Elodea canadensis)
Coefficient of Conservatism = 3
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

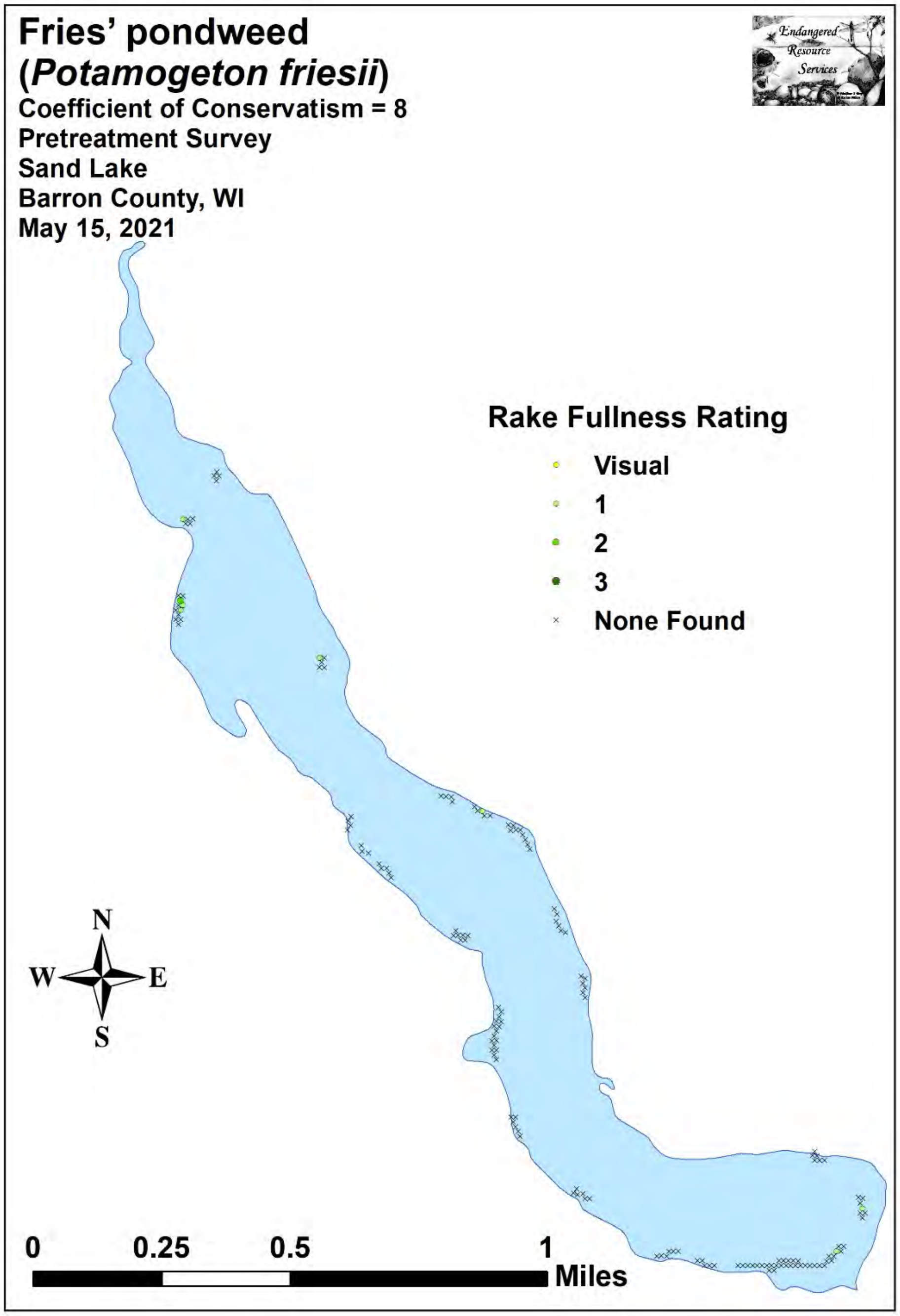

Water star-grass
(Heteranthera dubia)
Coefficient of Conservatism = 6
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

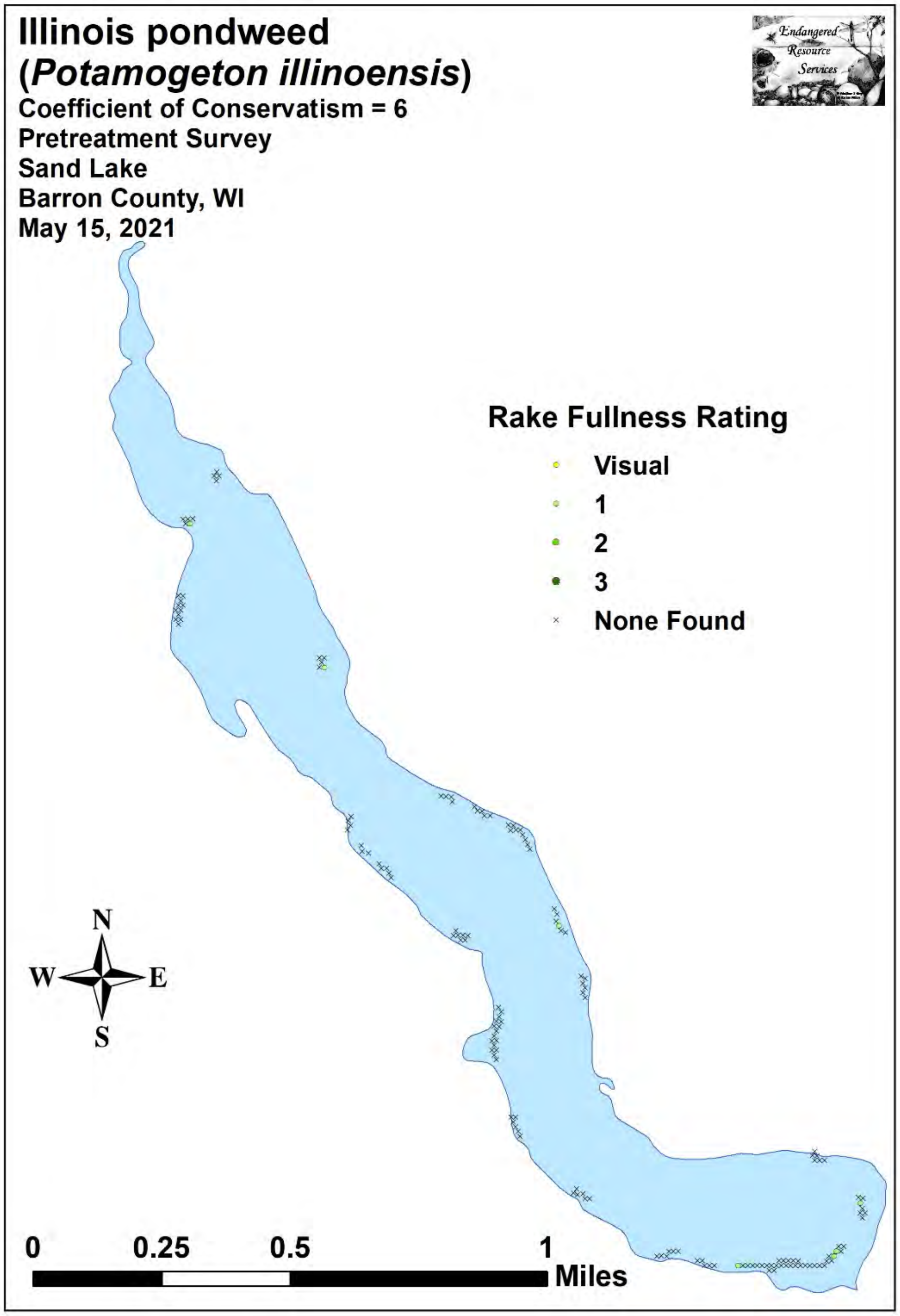

Forked duckweed
(*Lemna trisulca*)
Coefficient of Conservatism = 6
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles


Northern water-milfoil
(Myriophyllum sibiricum)
Coefficient of Conservatism = 6
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles


Nitella
(*Nitella* sp.)
Coefficient of Conservatism = 7
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles


Large-leaf pondweed
(Potamogeton amplifolius)
Coefficient of Conservatism = 7
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles


Fries' pondweed
(*Potamogeton friesii*)
Coefficient of Conservatism = 8
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles


Illinois pondweed
(*Potamogeton illinoensis*)
Coefficient of Conservatism = 6
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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3
None Found
N
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0.5
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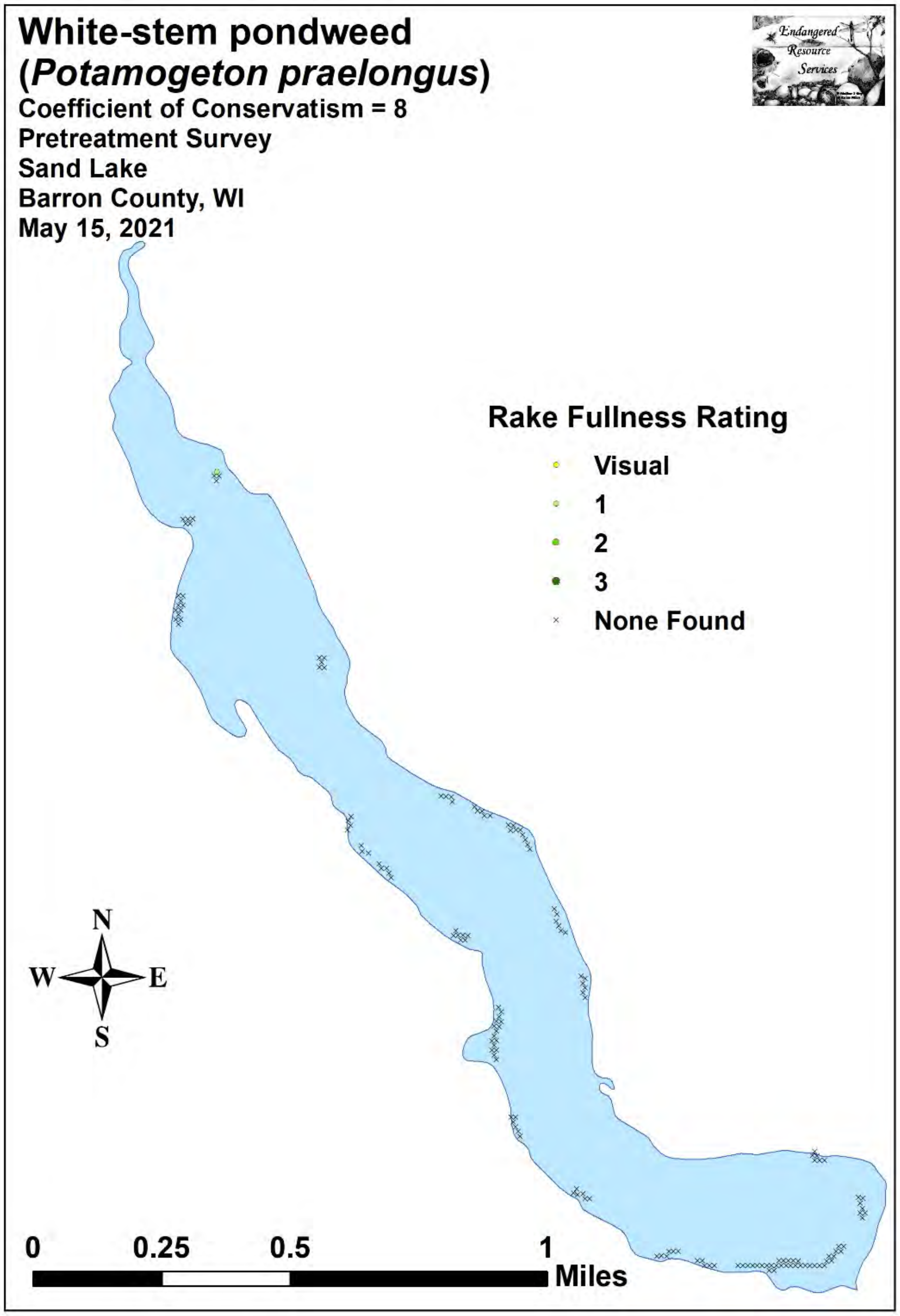
Miles


White-stem pondweed
(*Potamogeton praelongus*)
Coefficient of Conservatism = 8
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
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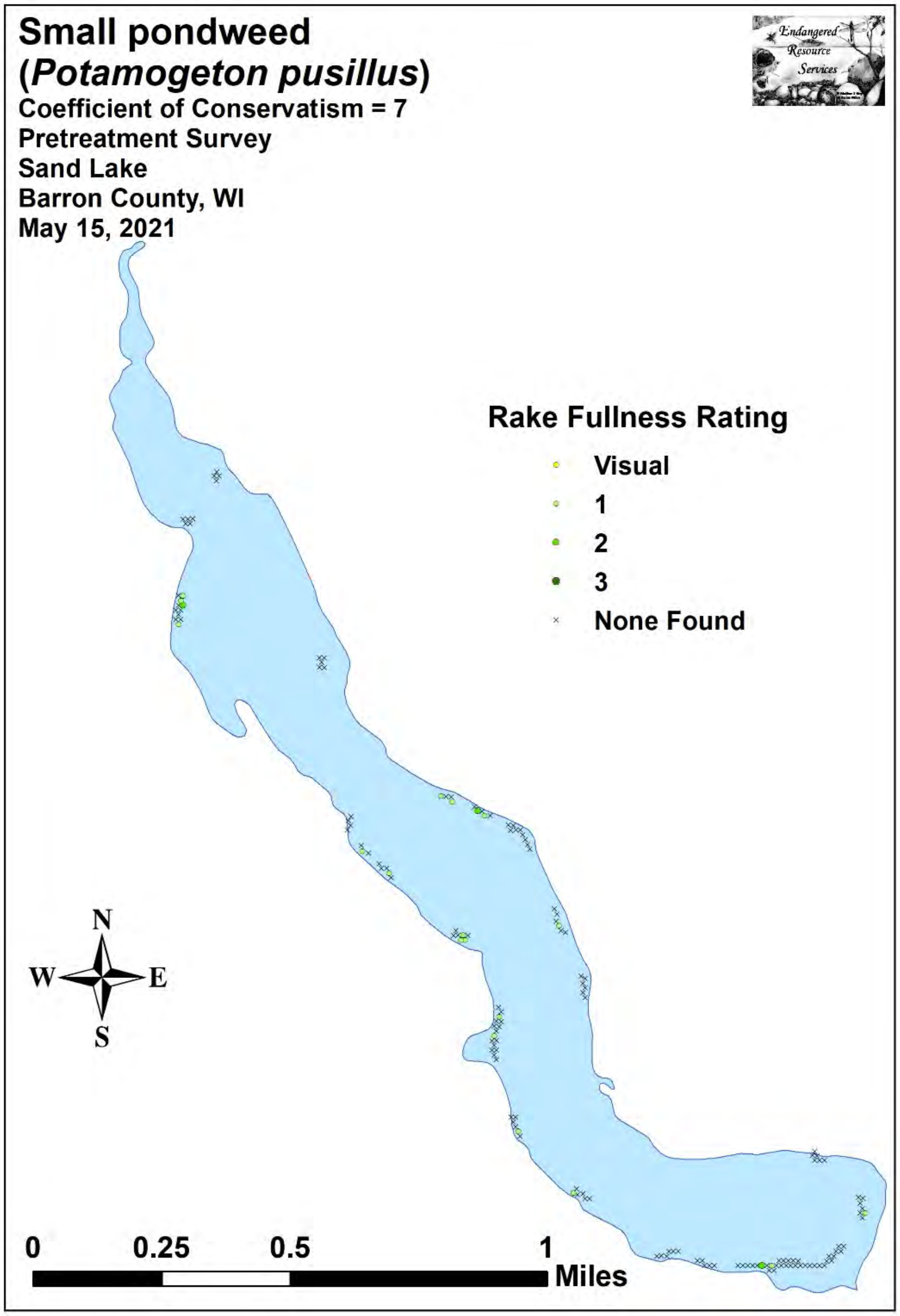
Miles


Small pondweed
(*Potamogeton pusillus*)
Coefficient of Conservatism = 7
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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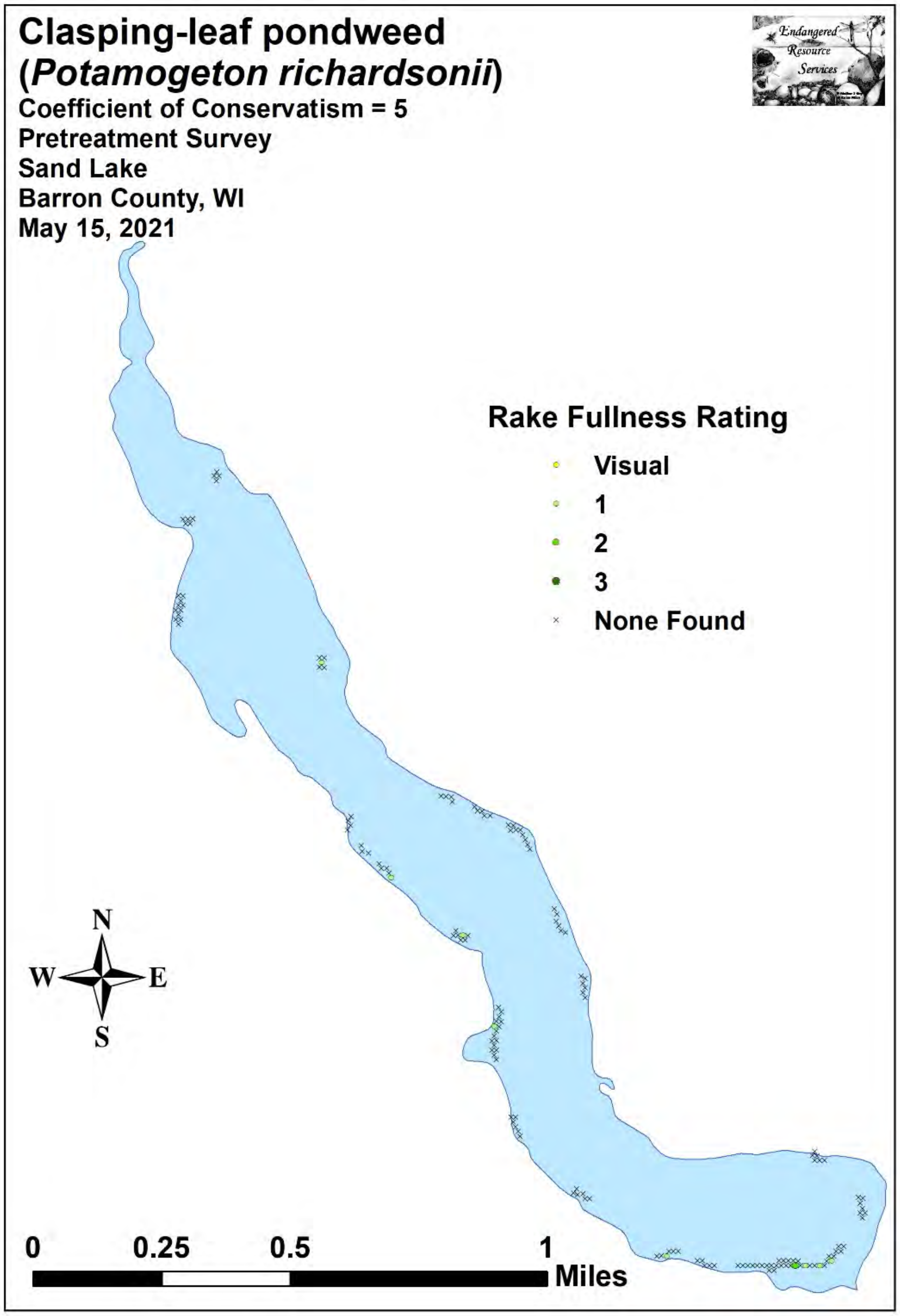
Miles



Clasping-leaf pondweed
(Potamogeton richardsonii)
Coefficient of Conservatism = 5
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
N
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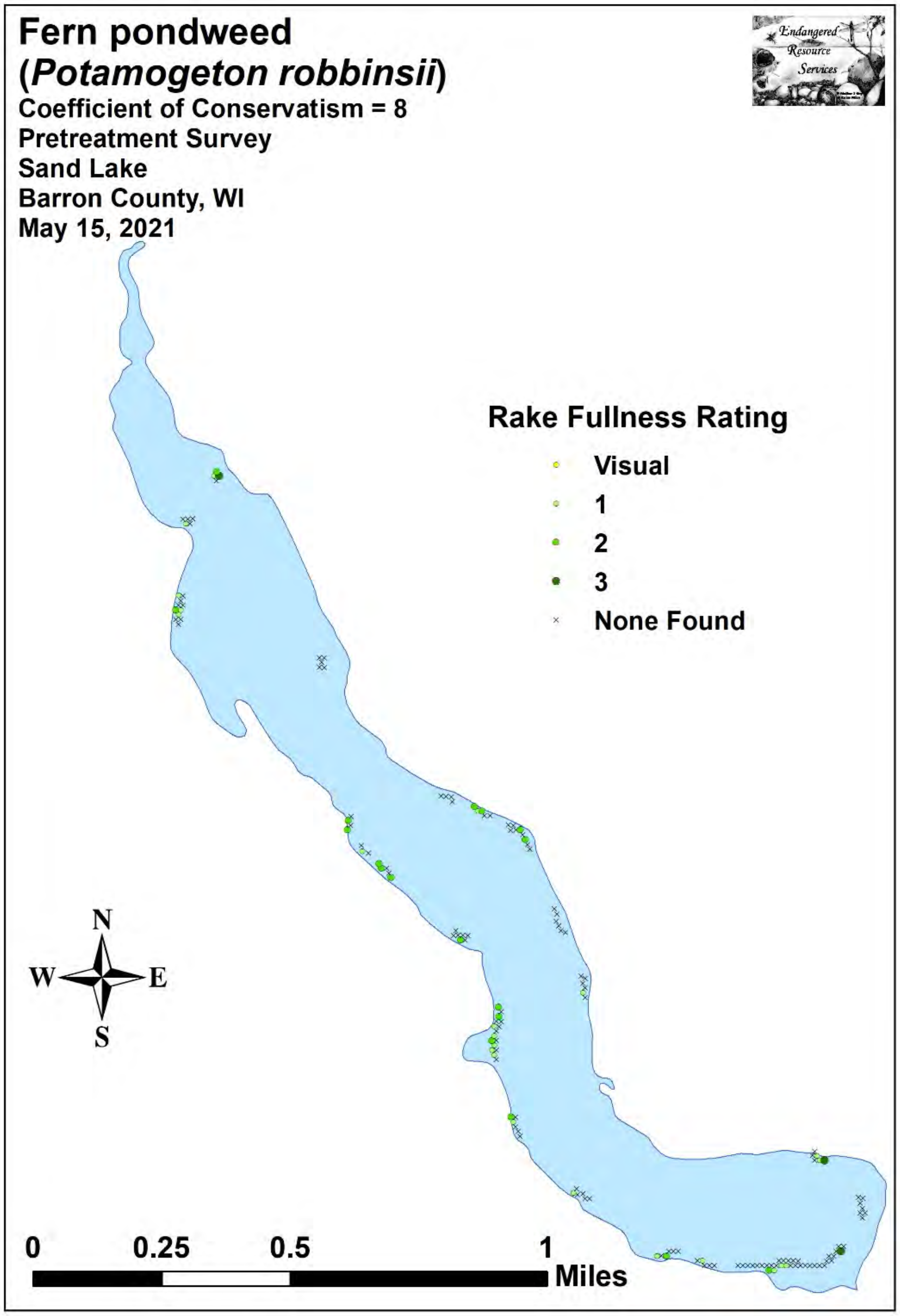
0.25
0.5
1
Miles



Fern pondweed
(*Potamogeton robbinsii*)
Coefficient of Conservatism = 8
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
N
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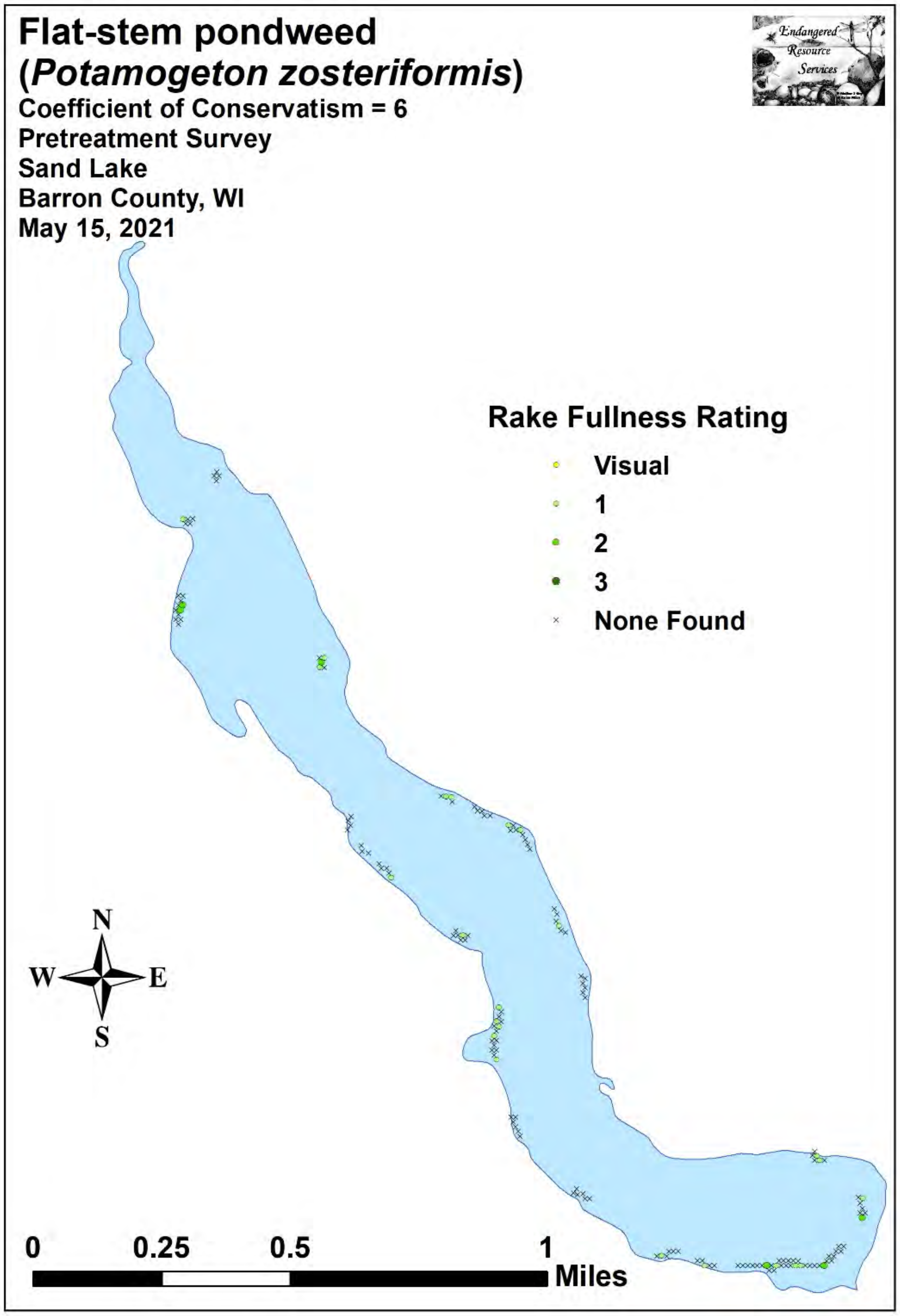
0.5
1
Miles


Flat-stem pondweed
(Potamogeton zosteriformis)
Coefficient of Conservatism = 6
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
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None Found
N
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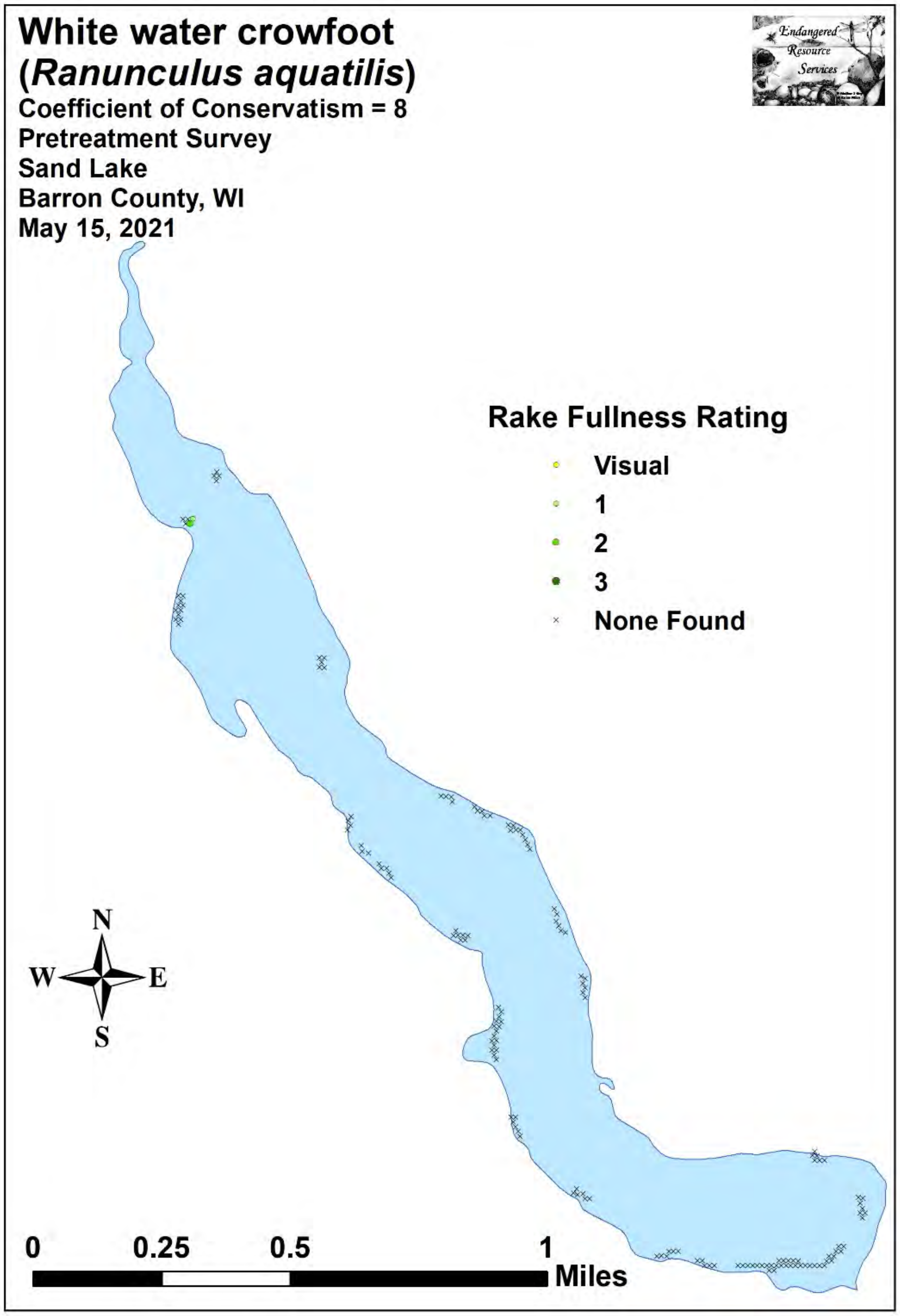
1
Miles


White water crowfoot
(Ranunculus aquatilis)
Coefficient of Conservatism = 8
Pretreatment Survey
Sand Lake
Barron County, WI
May 15, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
N
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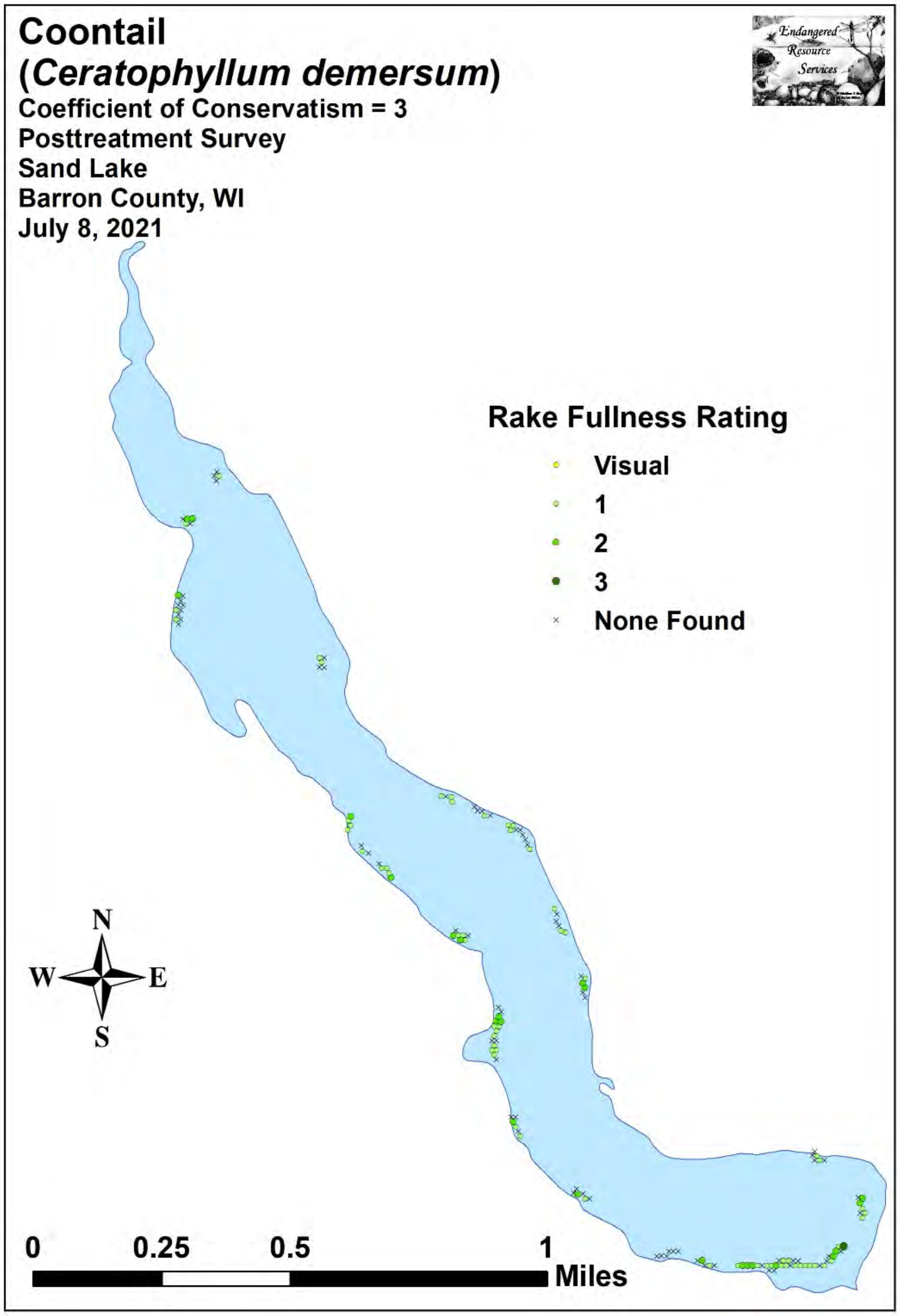
0
0.25
0.5
1
Miles

Appendix VII: Posttreatment Native Species Density and Distribution


Coontail
(Ceratophyllum demersum)
Coefficient of Conservatism = 3
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
N
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0.5
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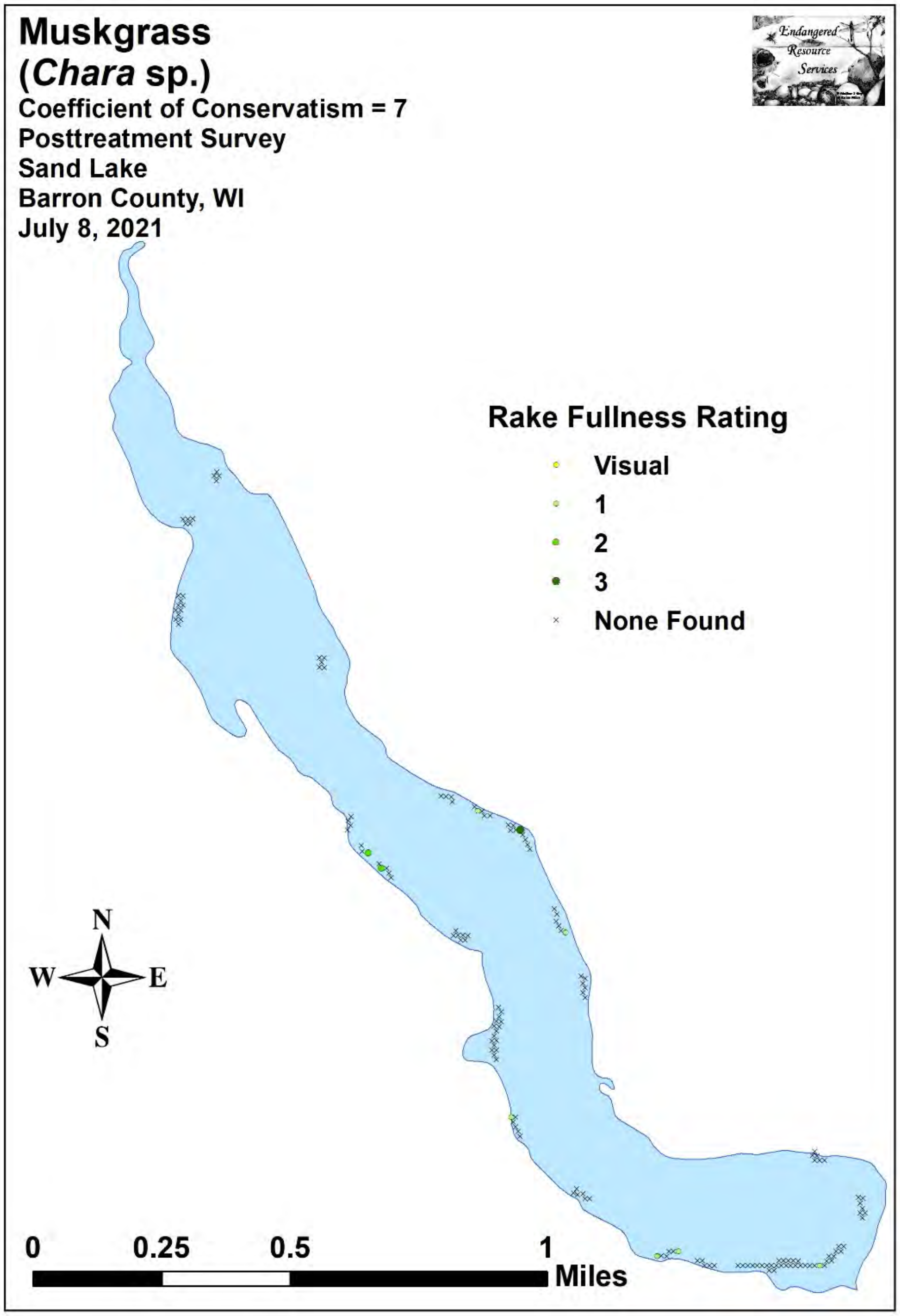
Miles



Muskgrass
(*Chara* sp.)
Coefficient of Conservatism = 7
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
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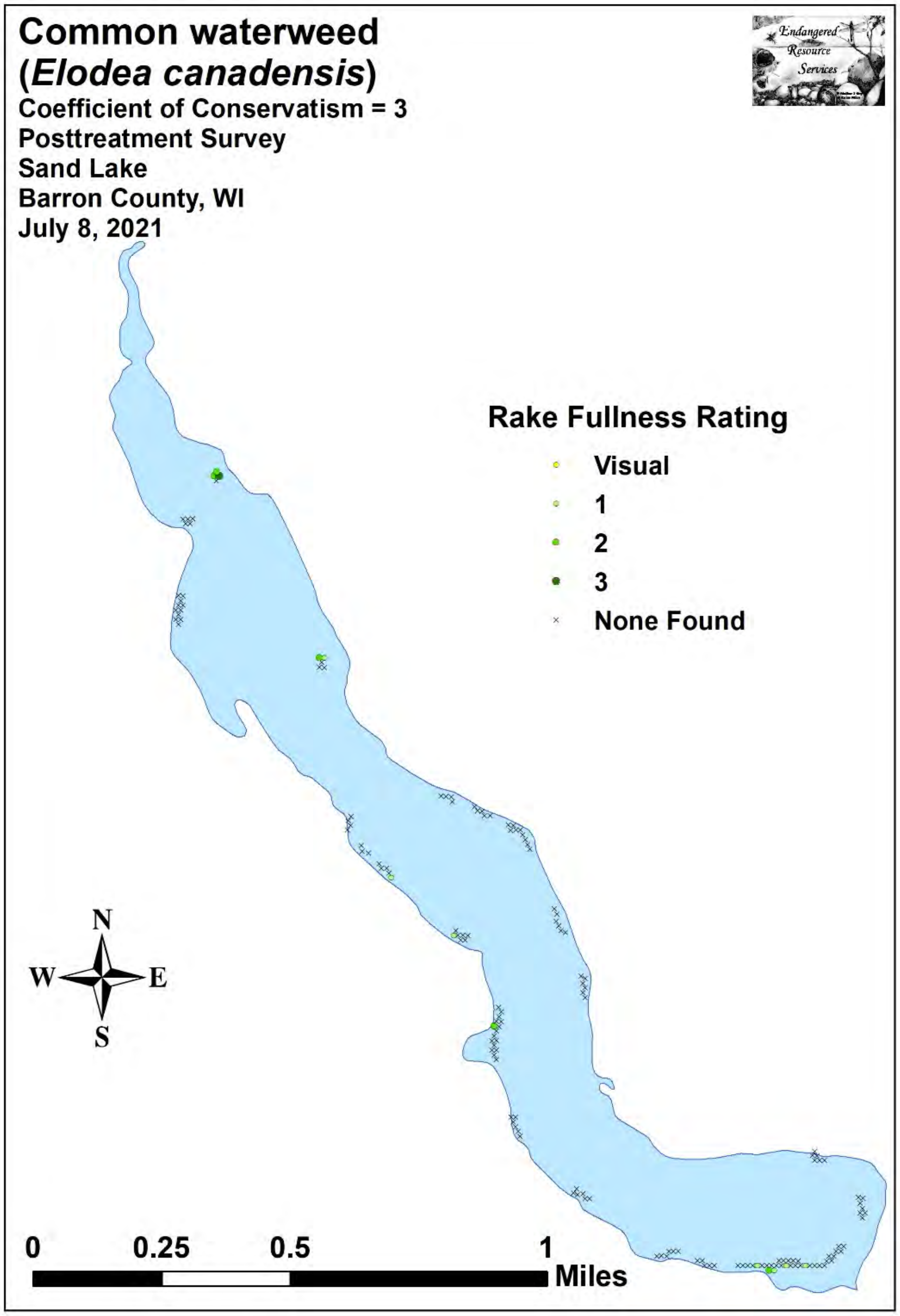
0.25
0.5
1
Miles


Common waterweed
(*Elodea canadensis*)
Coefficient of Conservatism = 3
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Rake Fullness Rating
Visual
1
2
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None Found
N
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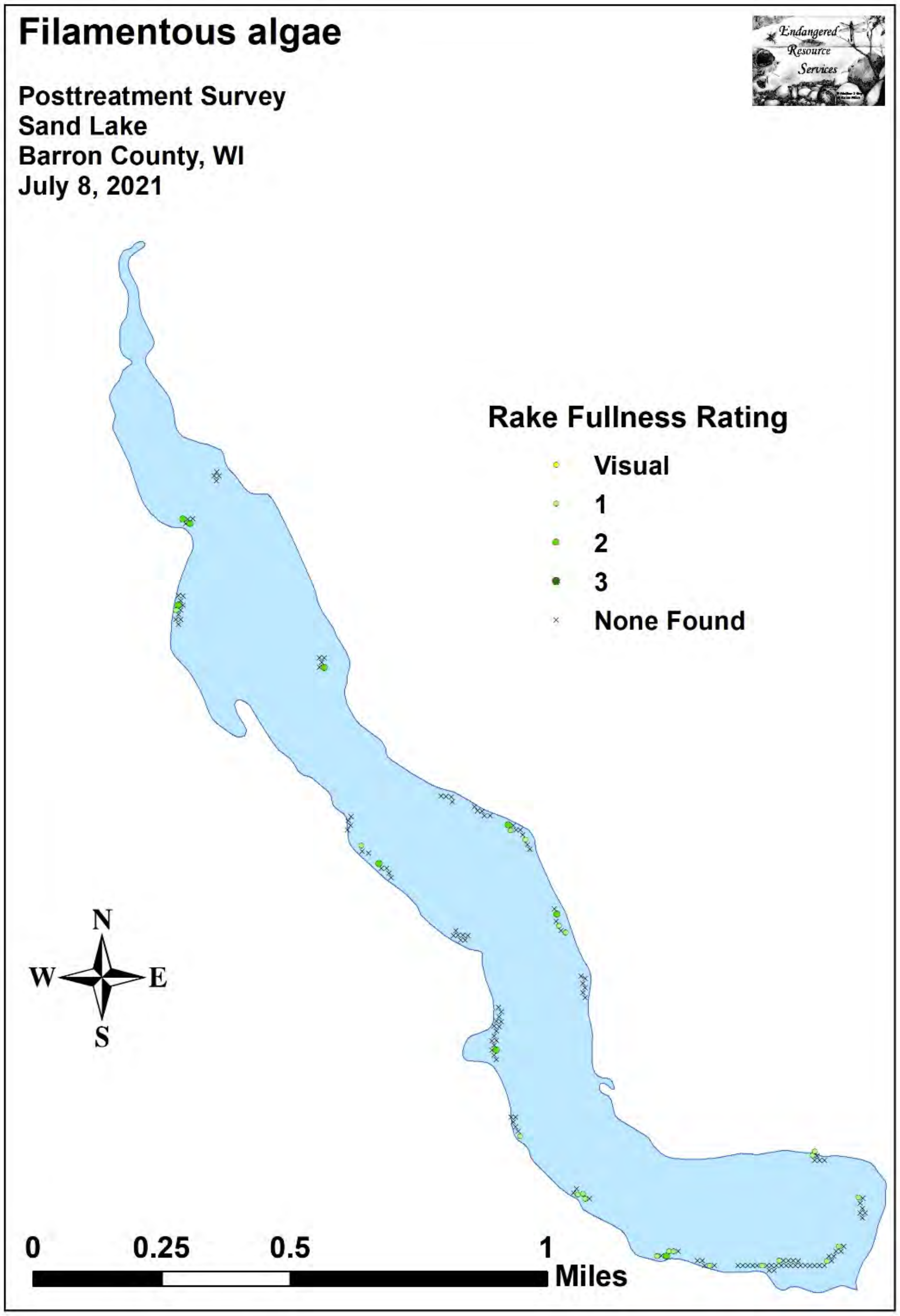
Miles



Filamentous algae
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Rake Fullness Rating
Visual
1
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None Found
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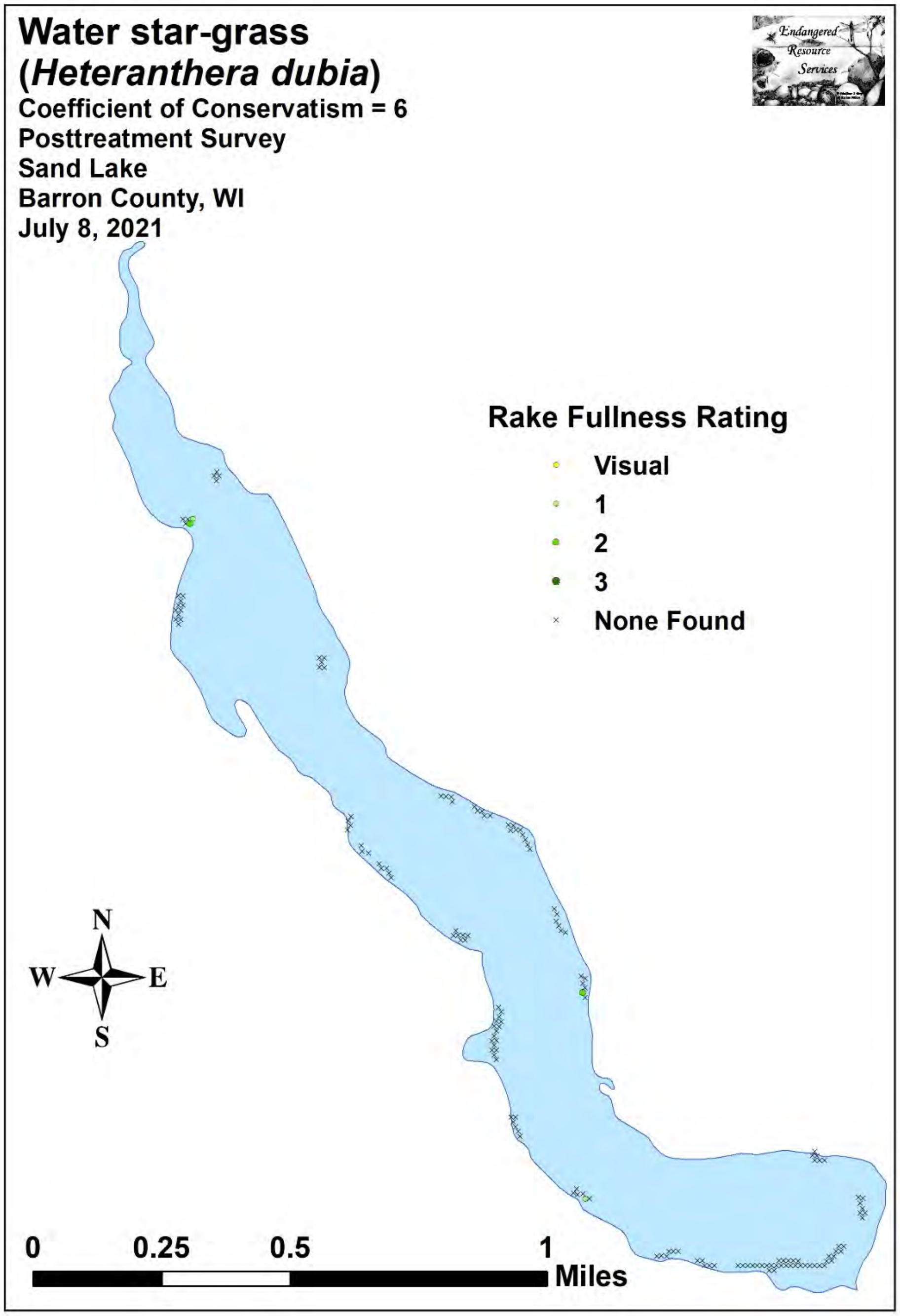
0.25
0.5
1
Miles


Water star-grass
(Heteranthera dubia)
Coefficient of Conservatism = 6
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Rake Fullness Rating
Visual
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None Found
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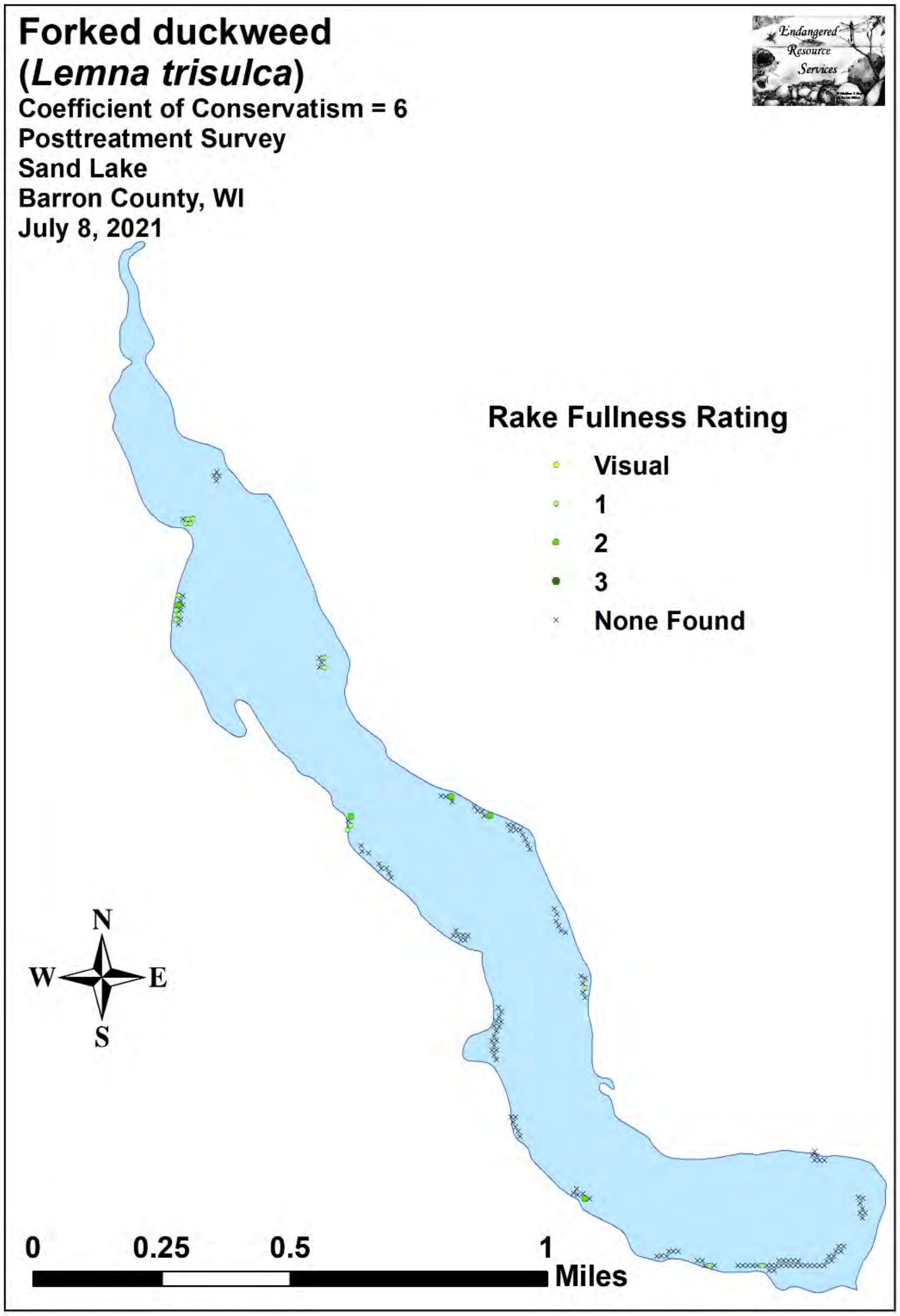
1
Miles


Forked duckweed
(*Lemna trisulca*)
Coefficient of Conservatism = 6
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
N
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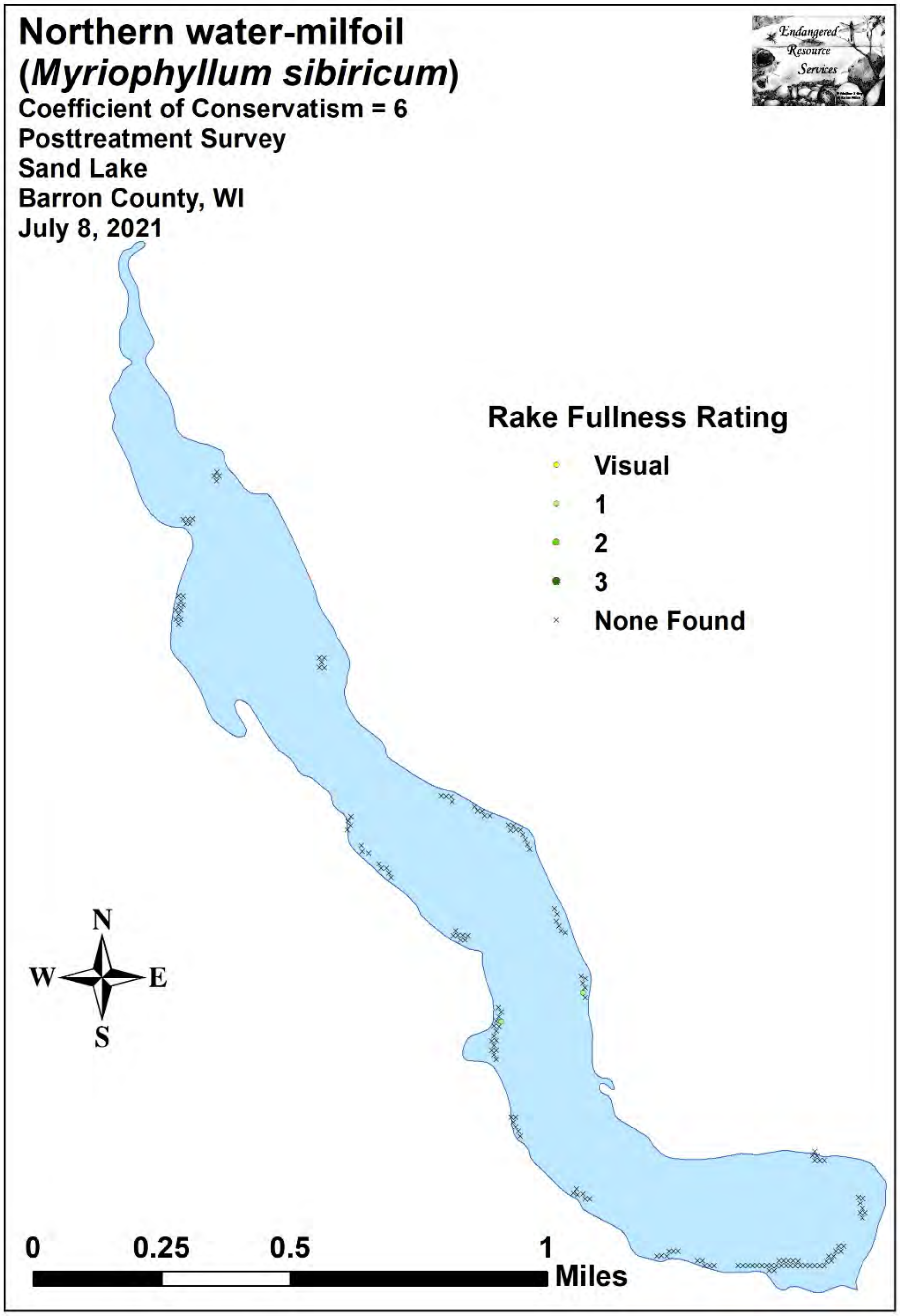
1
Miles


Northern water-milfoil
(*Myriophyllum sibiricum*)
Coefficient of Conservatism = 6
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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3
None Found
N
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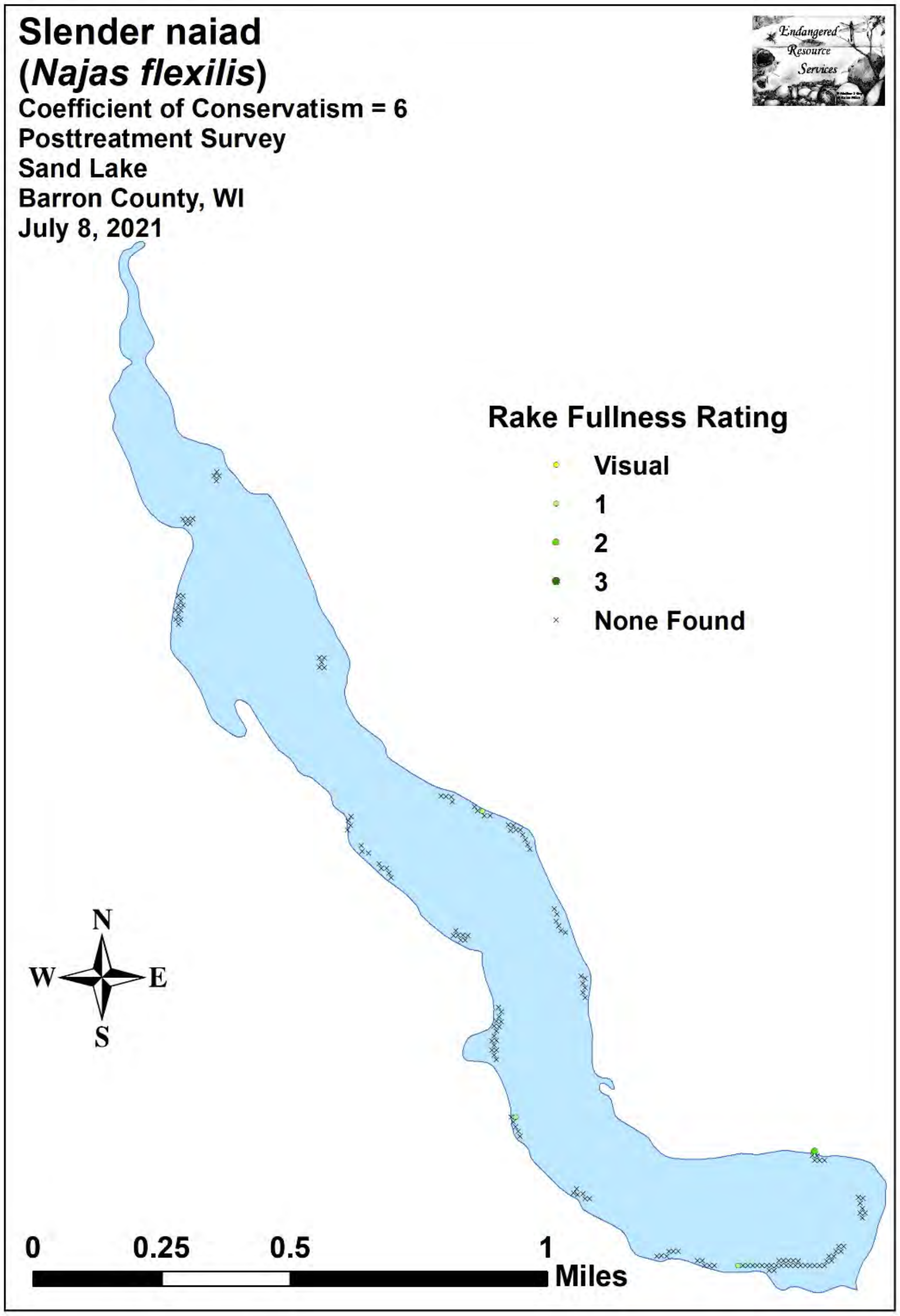
Miles


Slender naiad
(*Najas flexilis*)
Coefficient of Conservatism = 6
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
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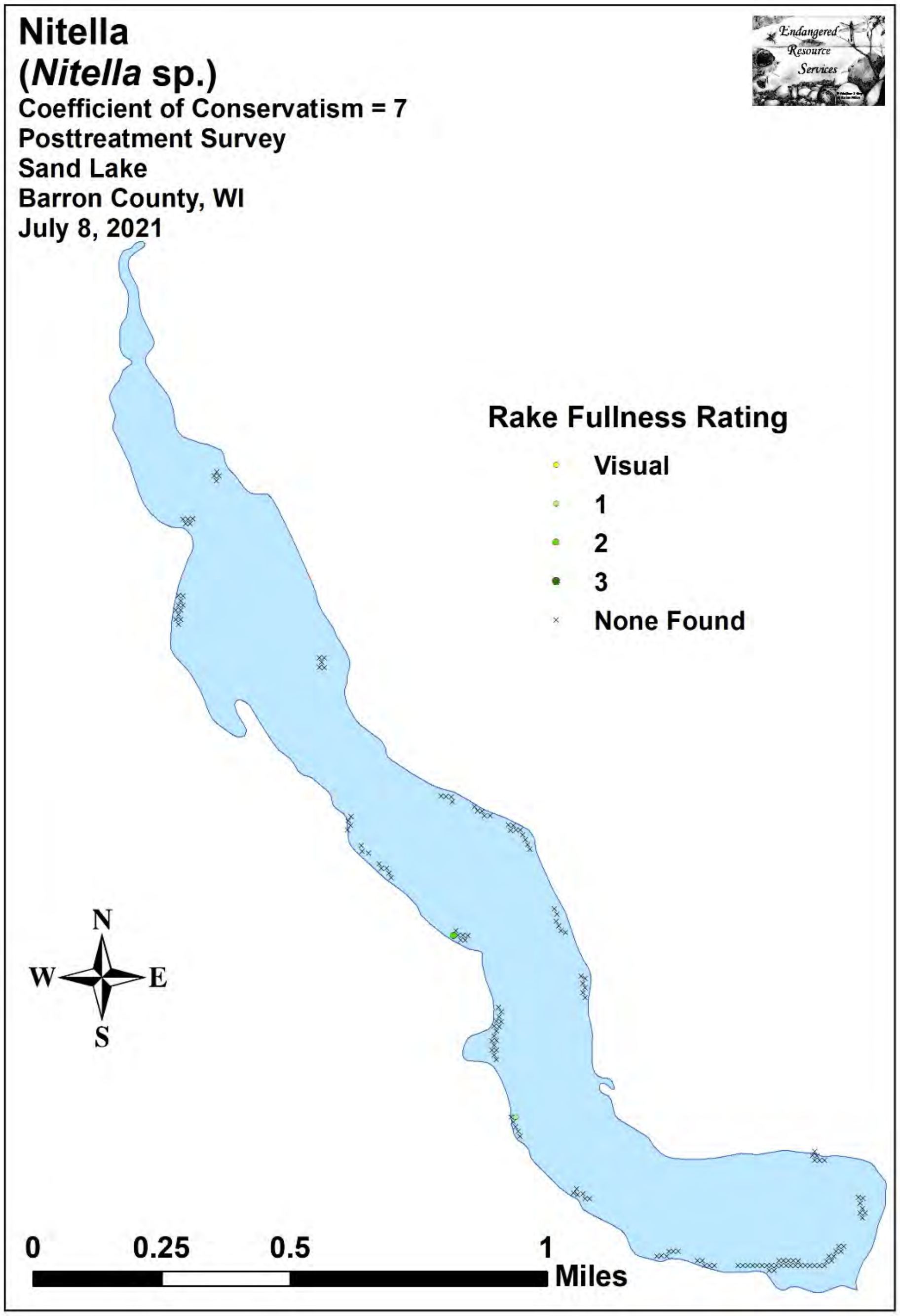
Miles


Nitella
(*Nitella* sp.)
Coefficient of Conservatism = 7
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
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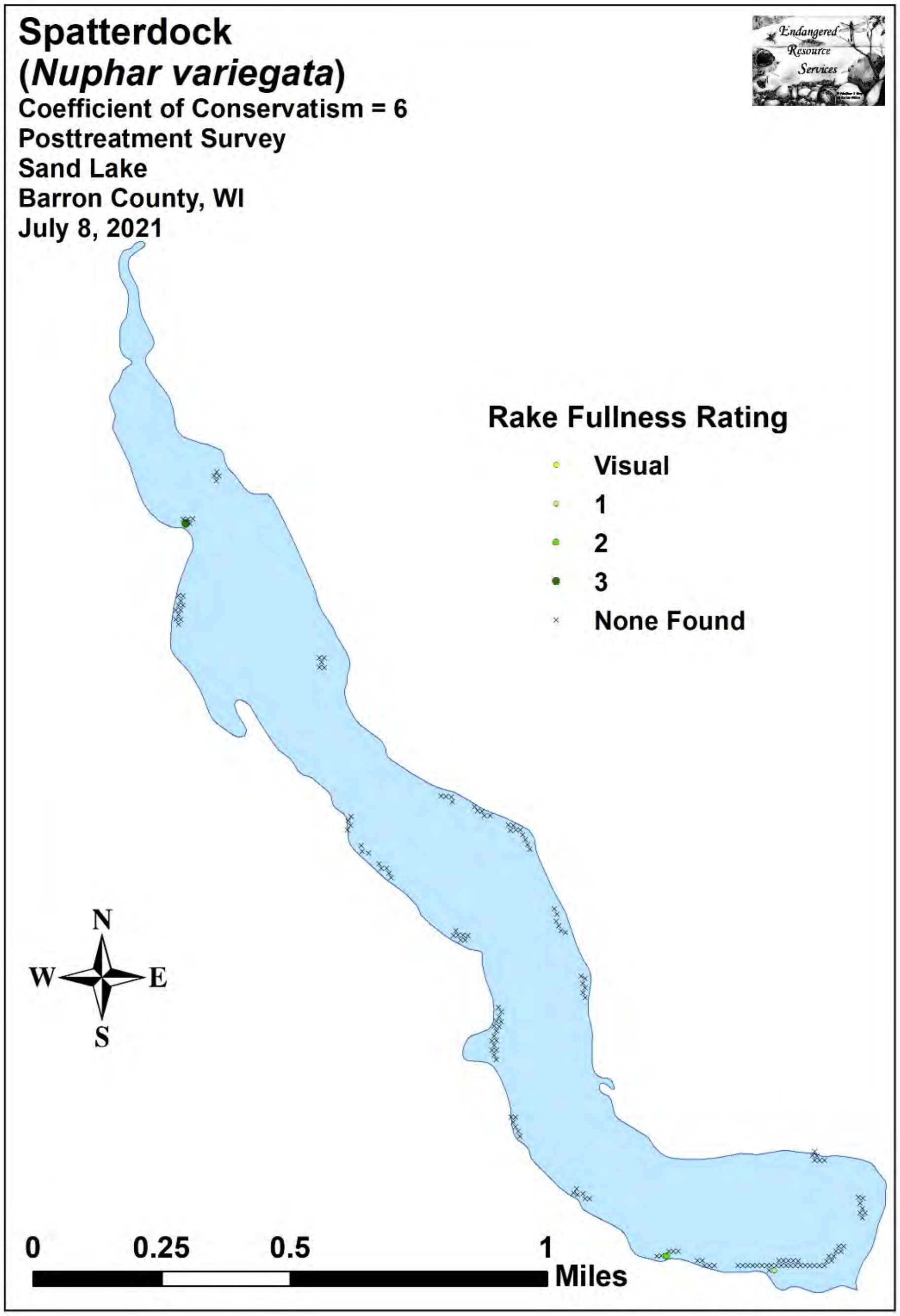
Miles


Spatterdock
(*Nuphar variegata*)
Coefficient of Conservatism = 6
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
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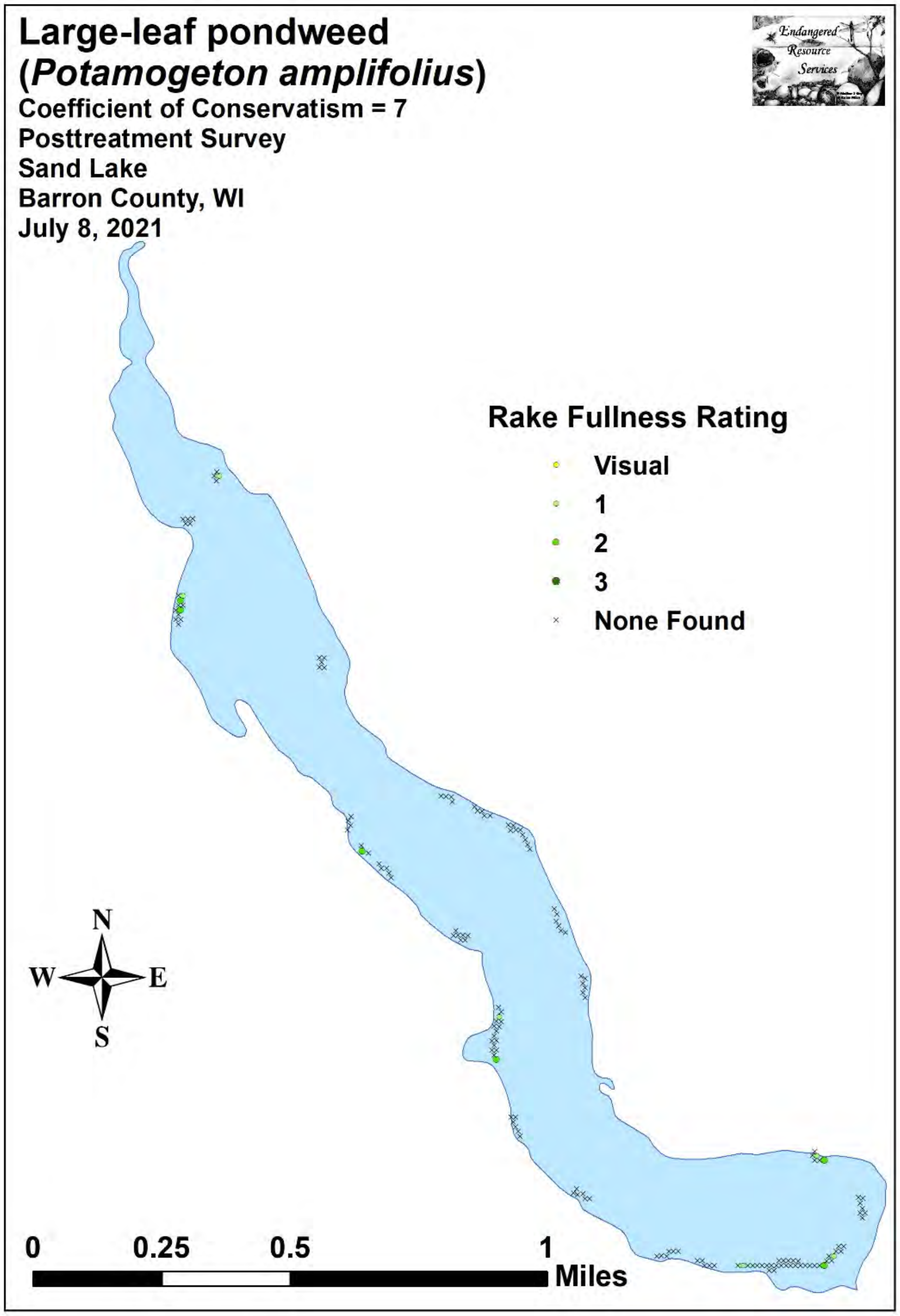
Miles


Large-leaf pondweed
(*Potamogeton amplifolius*)
Coefficient of Conservatism = 7
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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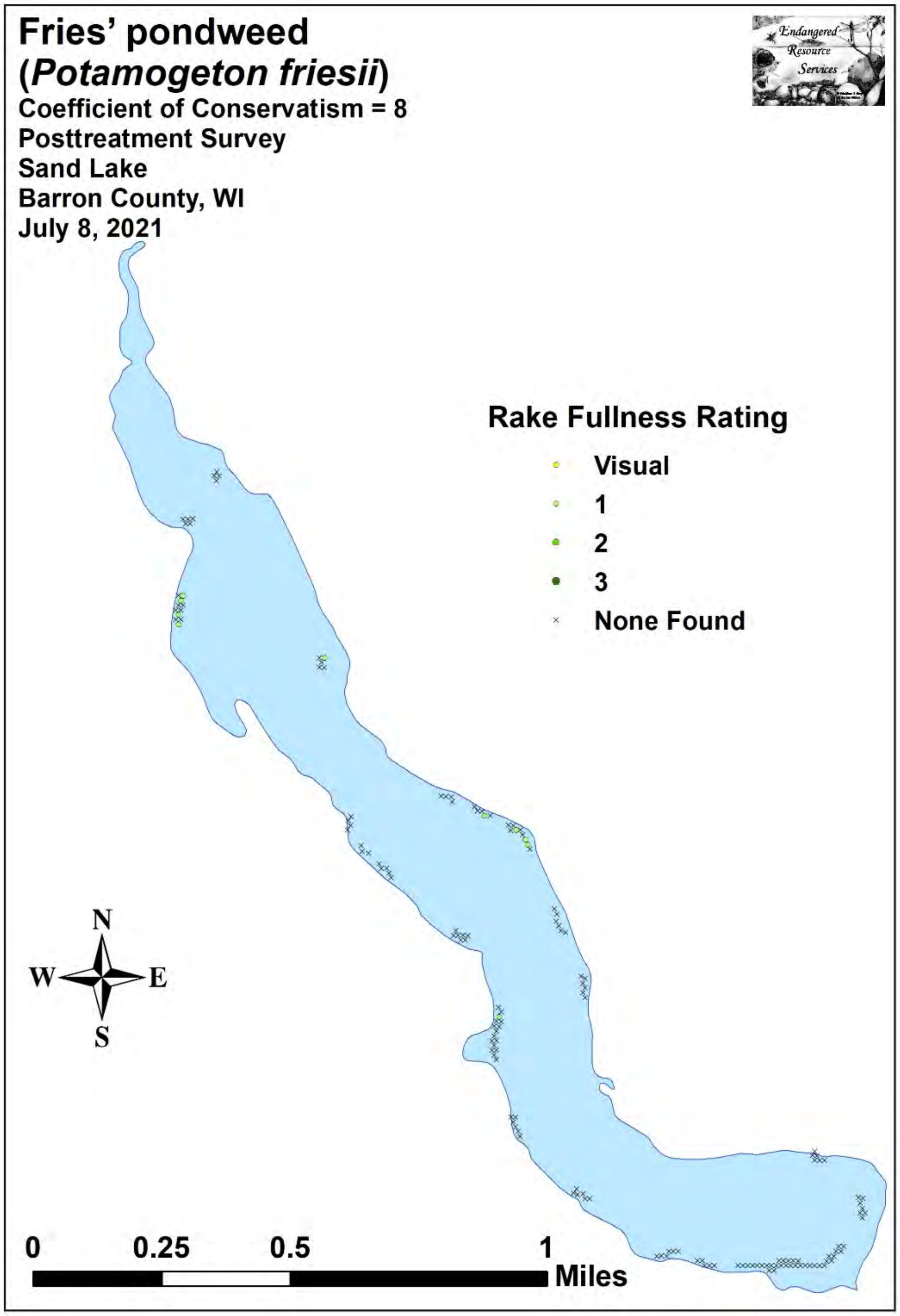
Miles


Fries' pondweed
(Potamogeton friesii)
Coefficient of Conservatism = 8
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
N
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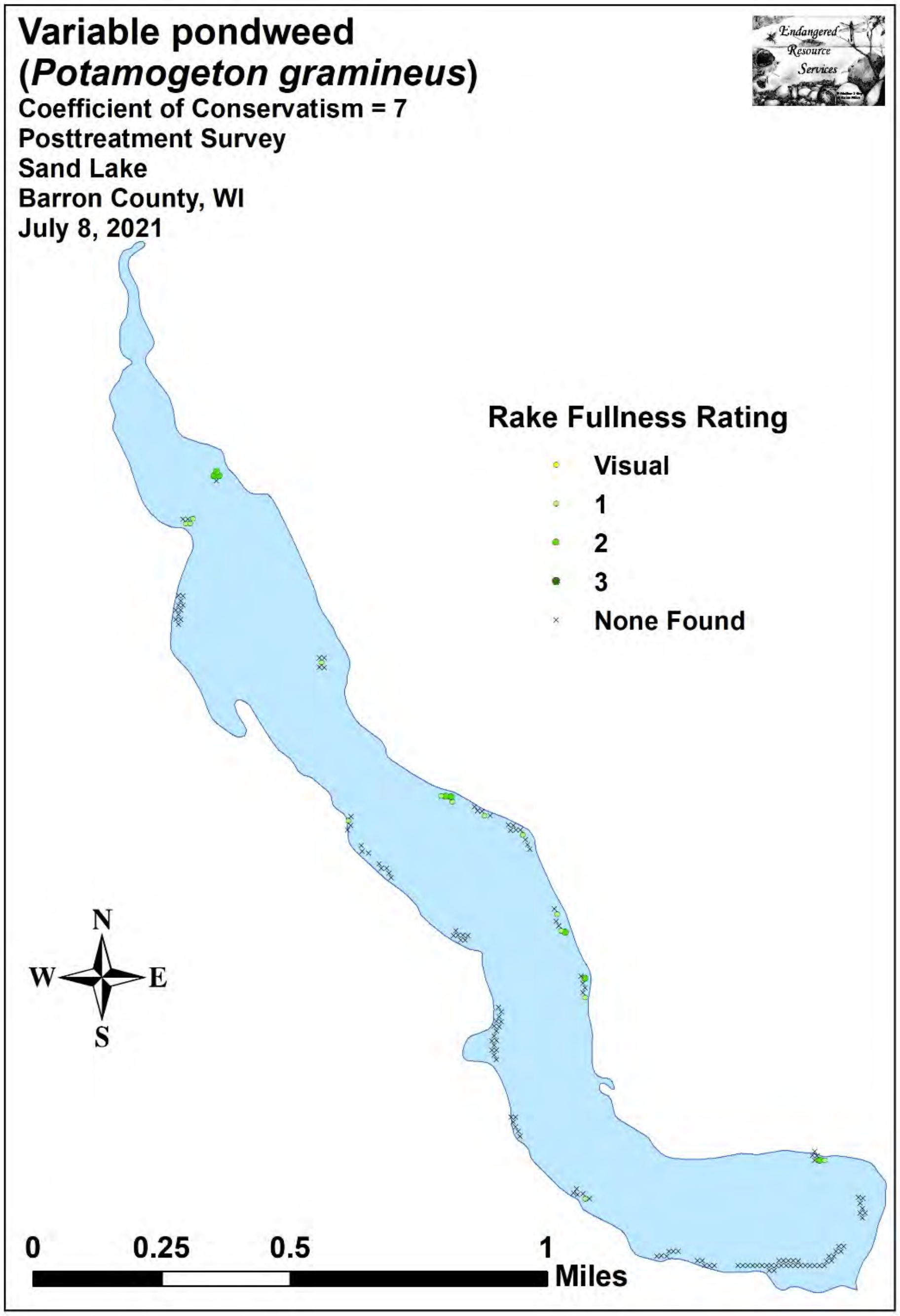
Miles


Variable pondweed
(Potamogeton gramineus)
Coefficient of Conservatism = 7
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
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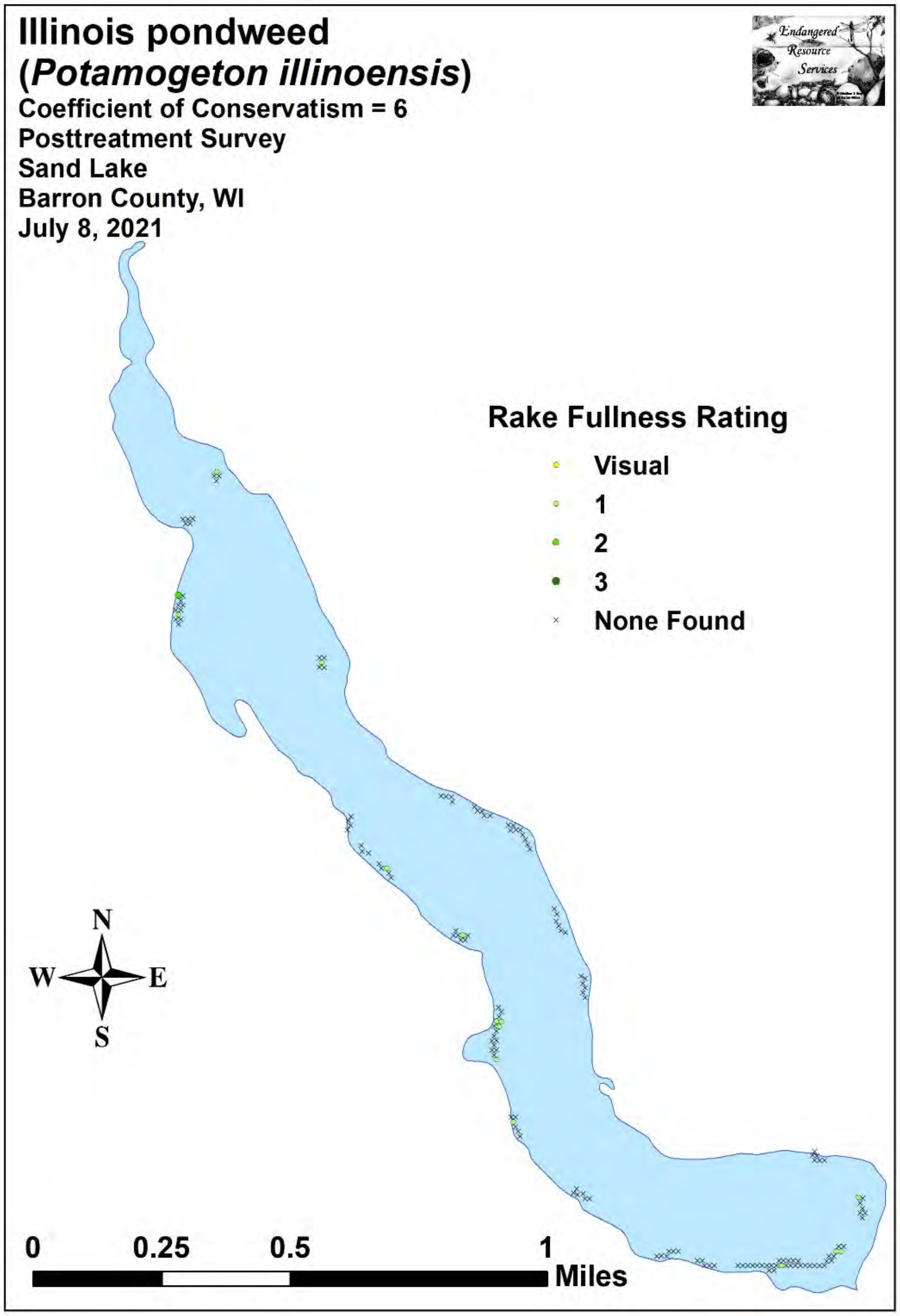
0.25
0.5
1
Miles


Illinois pondweed
(Potamogeton illinoensis)
Coefficient of Conservatism = 6
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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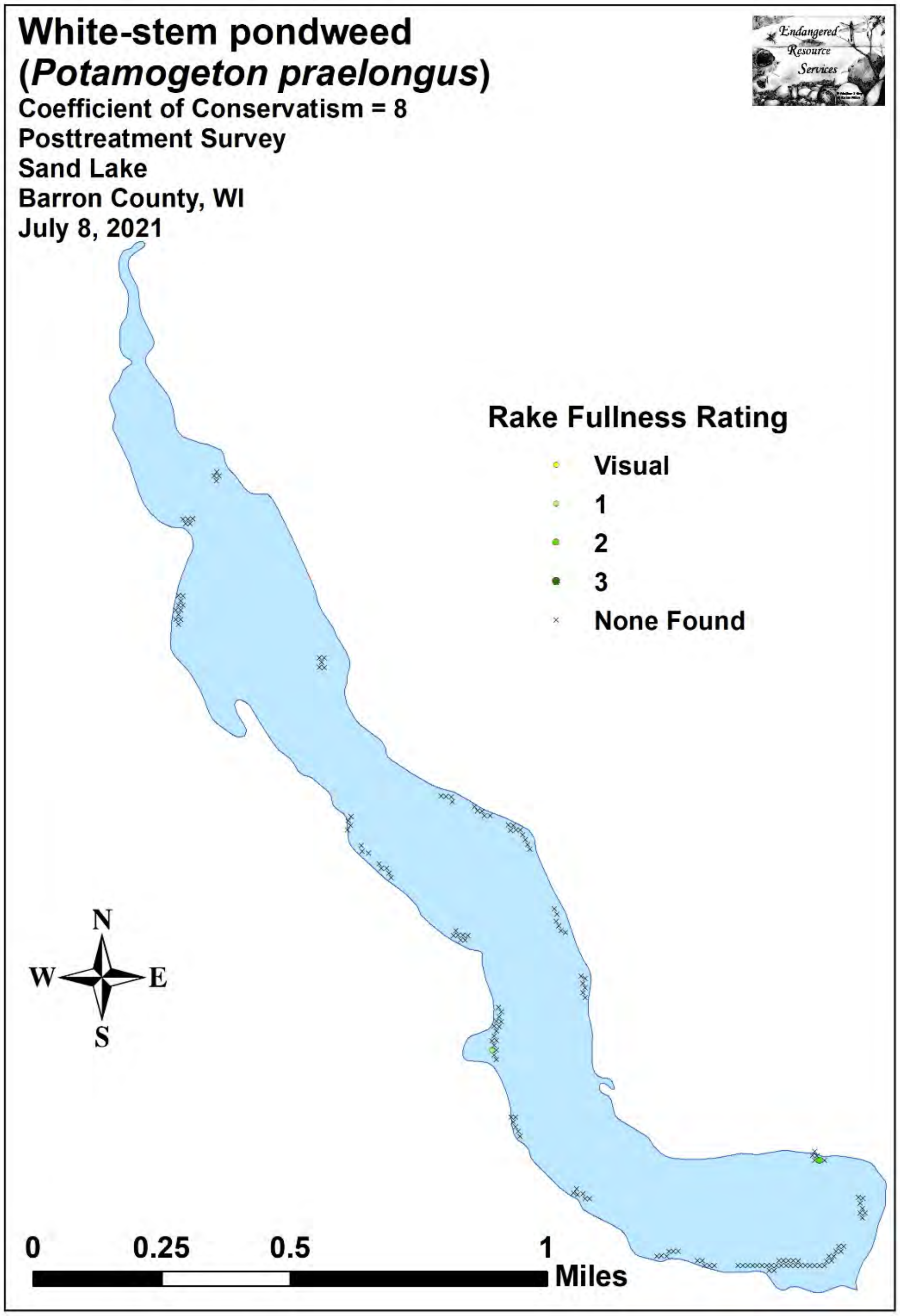
Miles


White-stem pondweed
(Potamogeton praelongus)
Coefficient of Conservatism = 8
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
N
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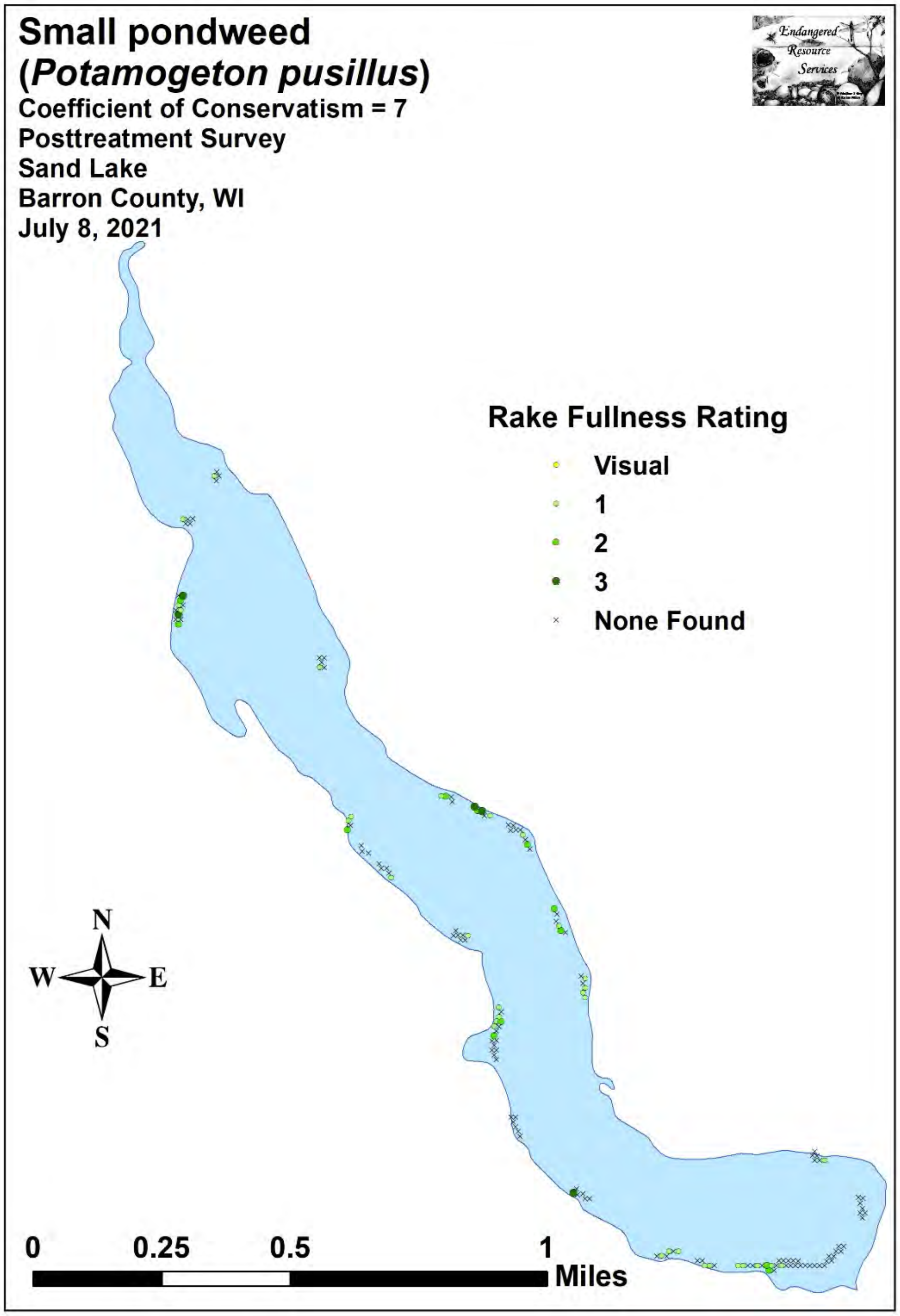
Miles


Small pondweed
(*Potamogeton pusillus*)
Coefficient of Conservatism = 7
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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3
None Found
N
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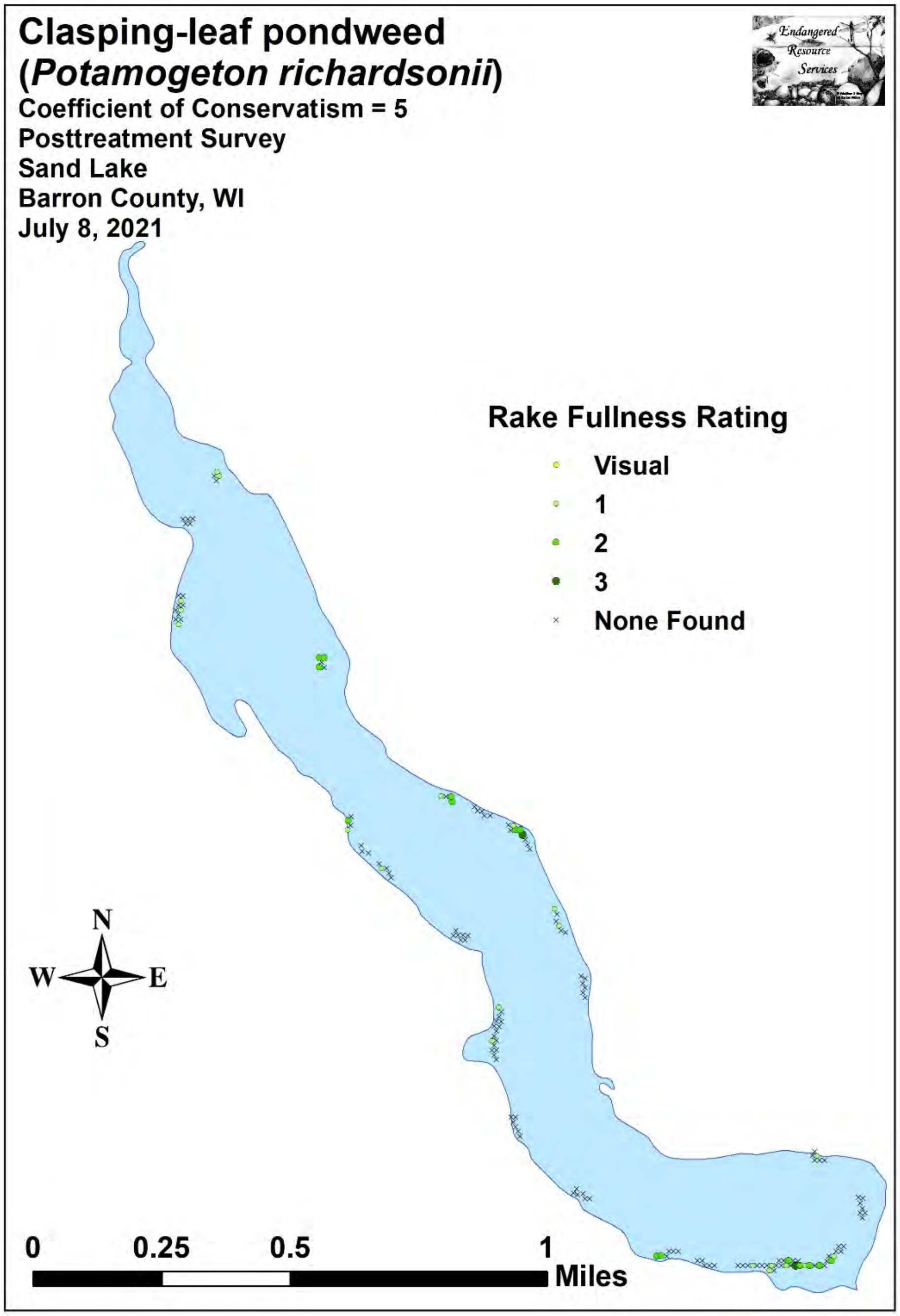
0.25
0.5
1
Miles


Clasping-leaf pondweed
(Potamogeton richardsonii)
Coefficient of Conservatism = 5
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Rake Fullness Rating
Visual
1
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3
None Found
N
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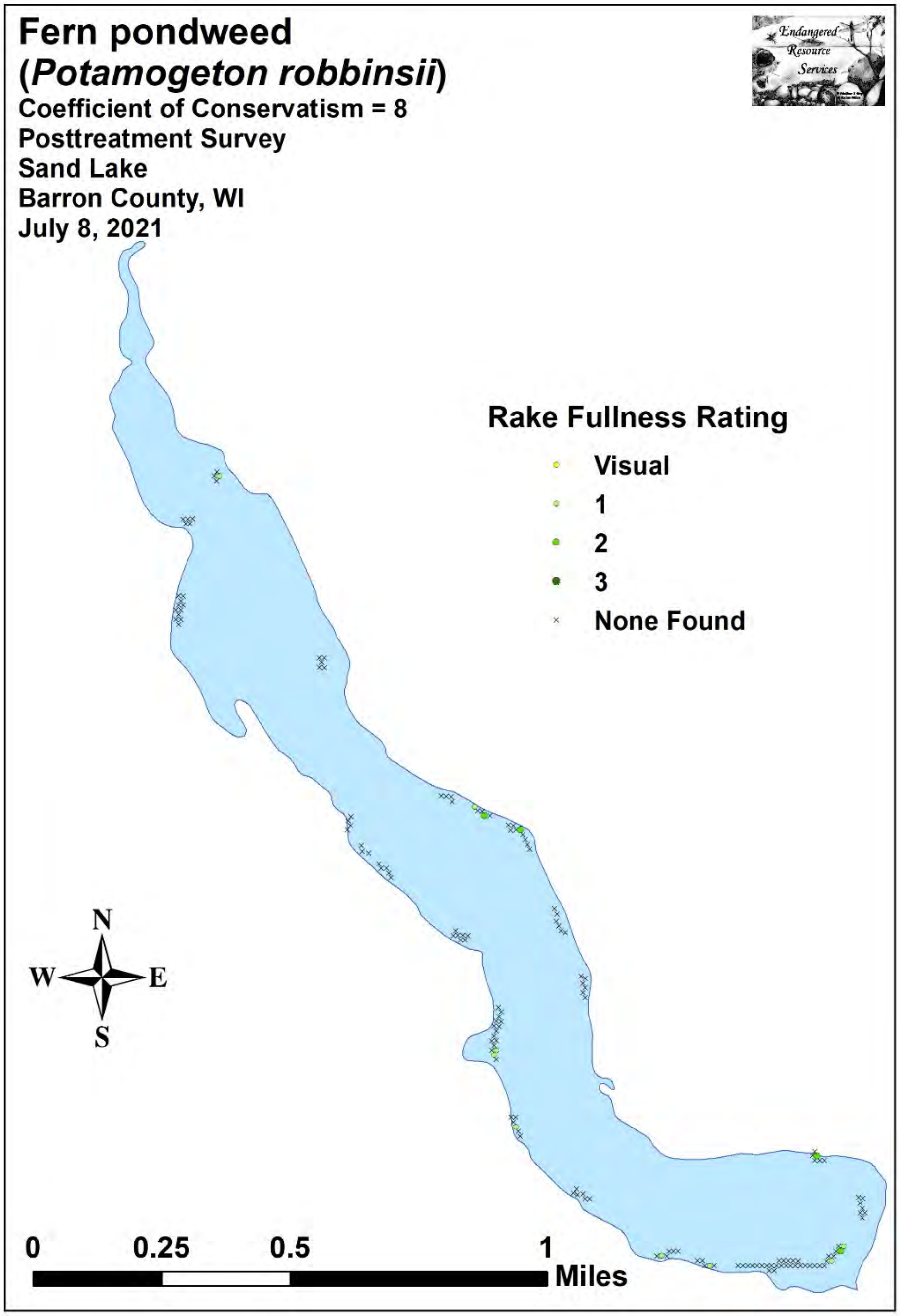
Miles


Fern pondweed
(*Potamogeton robbinsii*)
Coefficient of Conservatism = 8
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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3
None Found
N
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0.5
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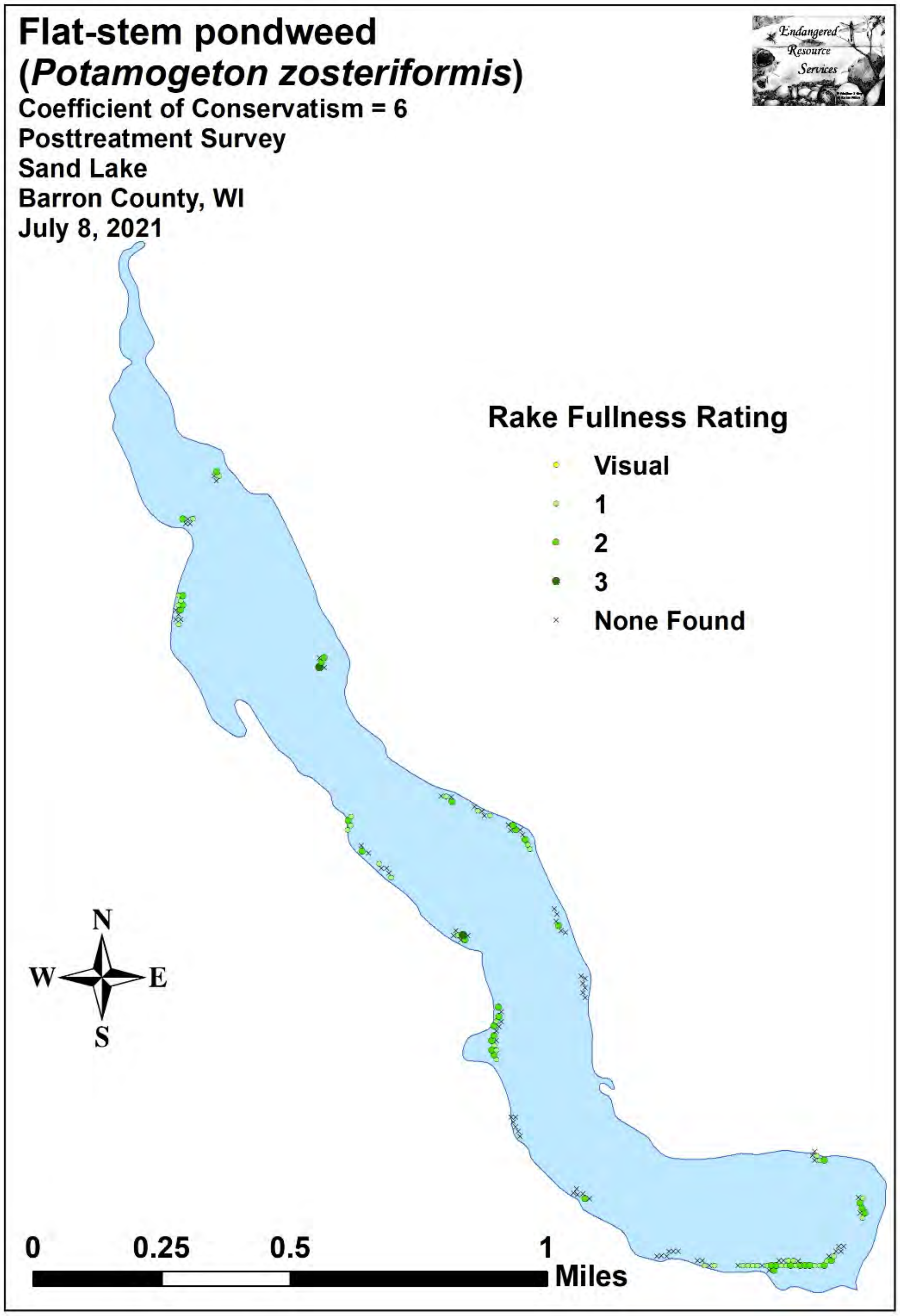
Miles


Flat-stem pondweed
(Potamogeton zosteriformis)
Coefficient of Conservatism = 6
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
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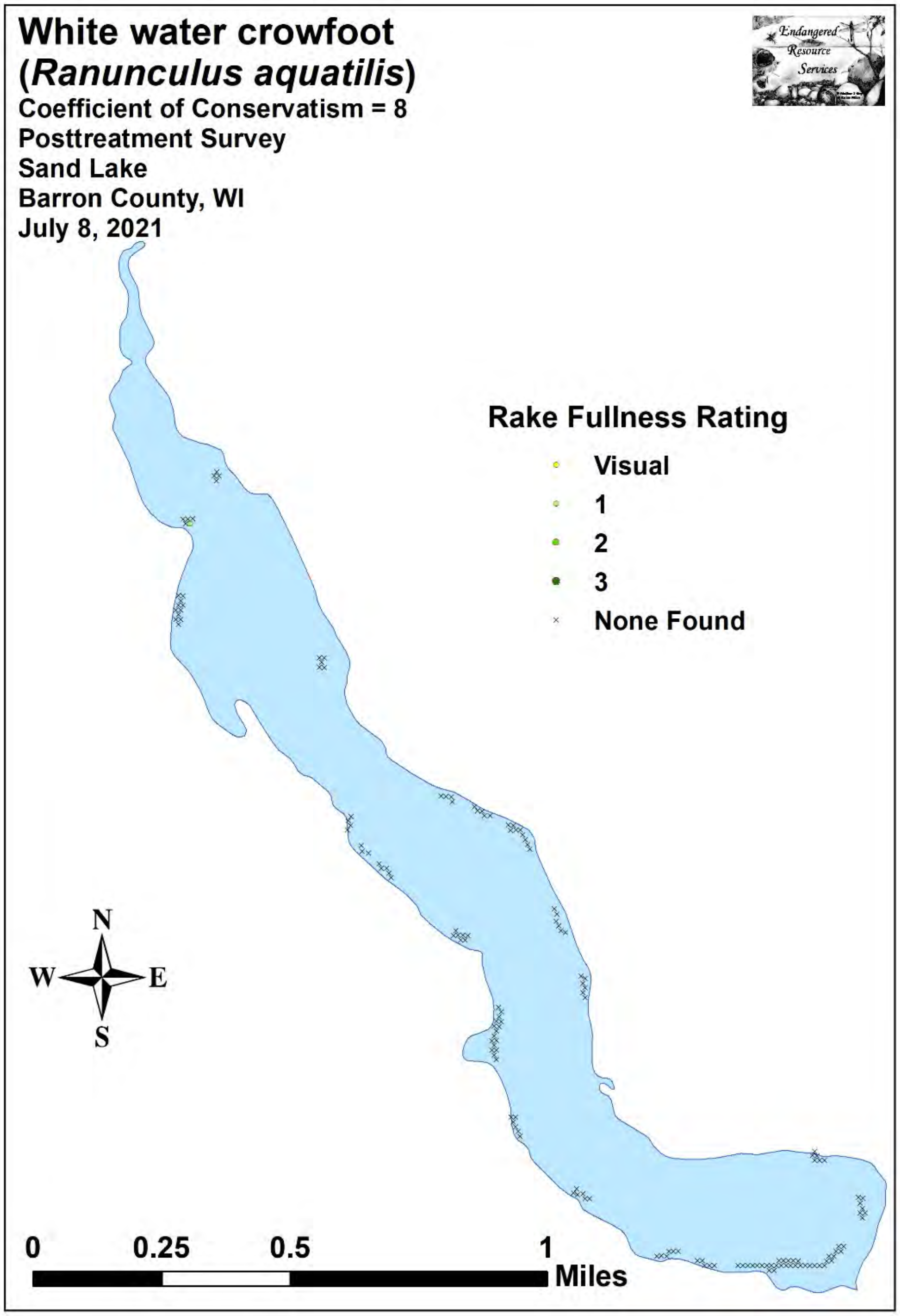
0.25
0.5
1
Miles


White water crowfoot
(*Ranunculus aquatilis*)
Coefficient of Conservatism = 8
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
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None Found
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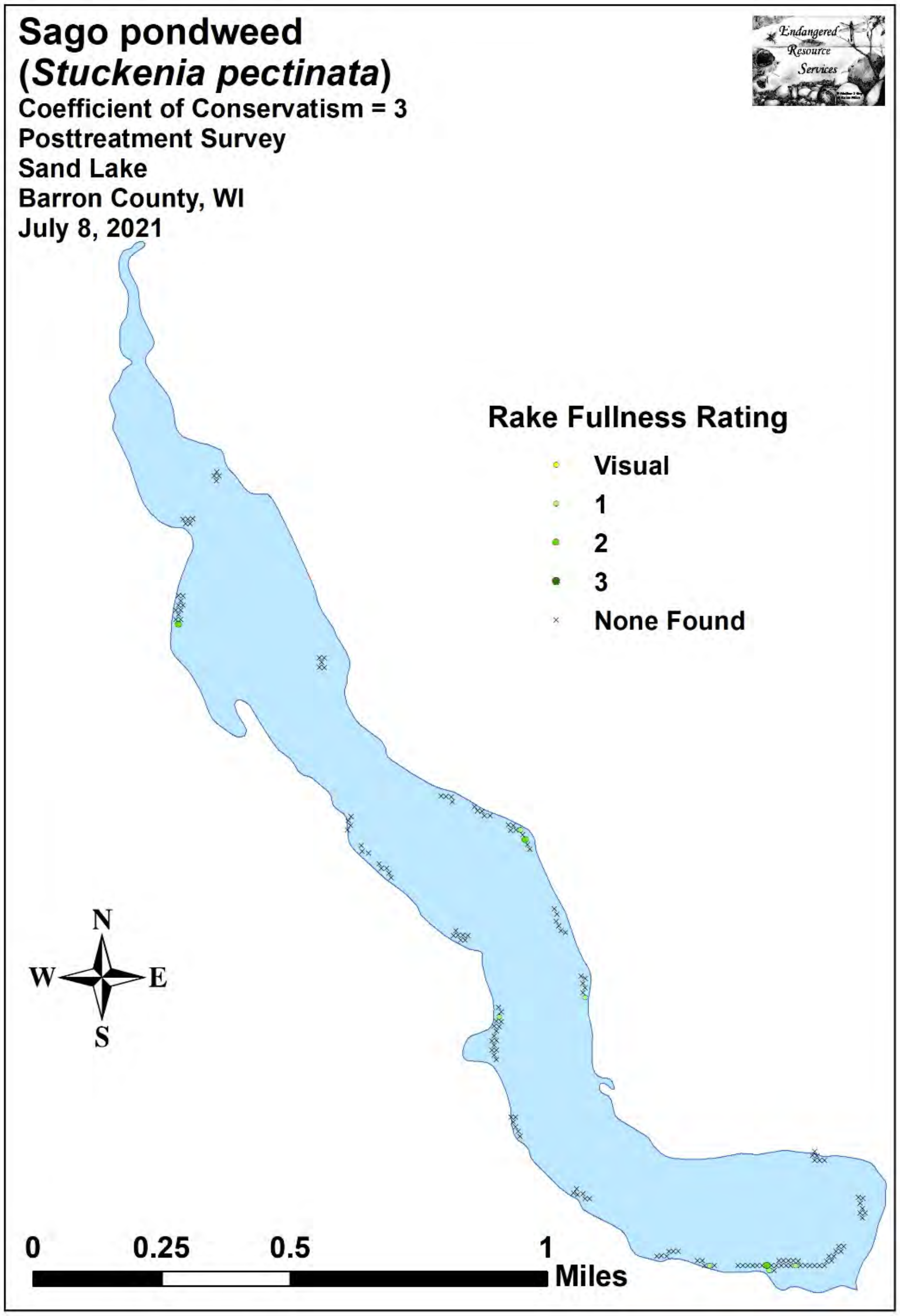
0.25
0.5
1
Miles


Sago pondweed
(*Stuckenia pectinata*)
Coefficient of Conservatism = 3
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
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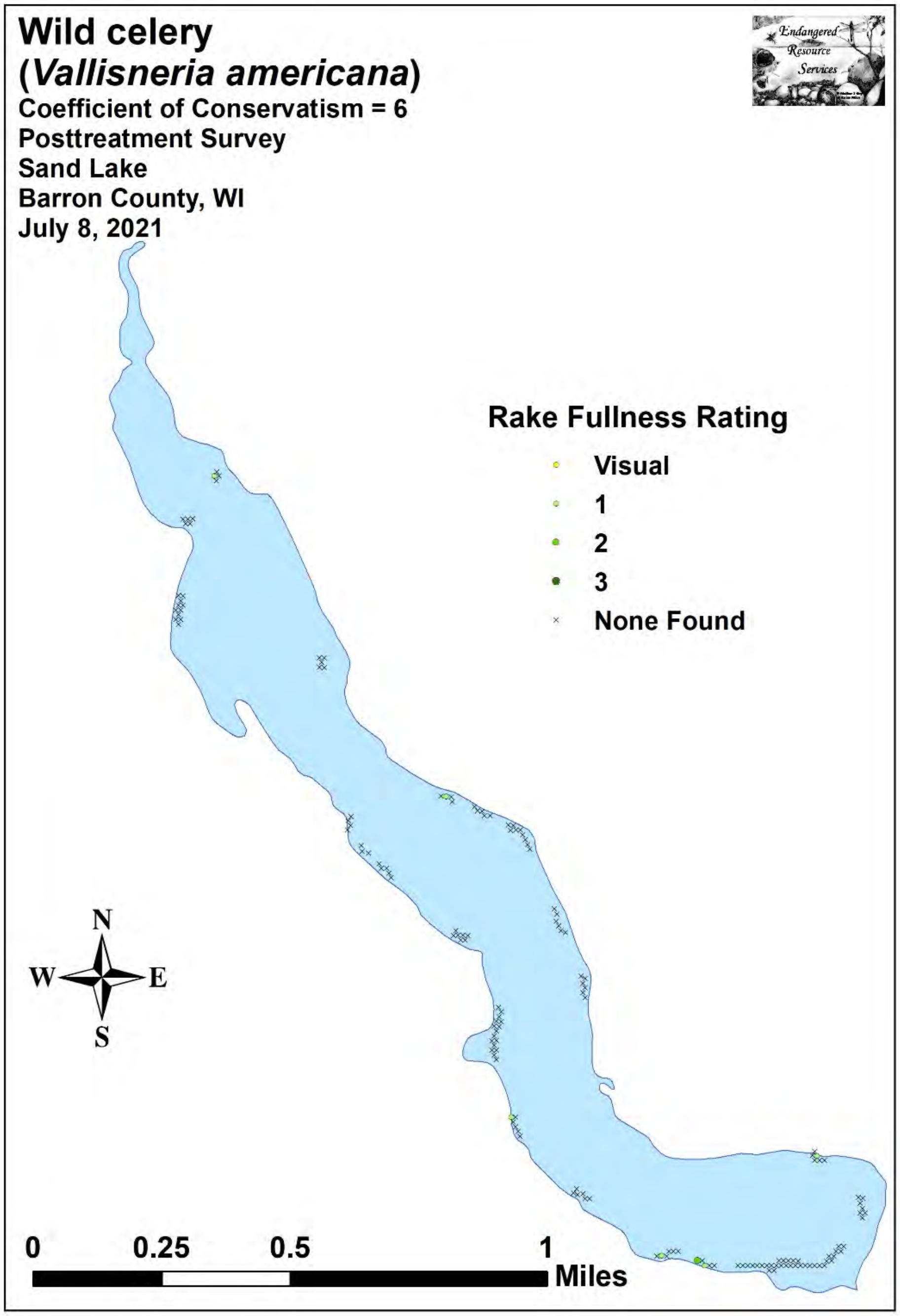
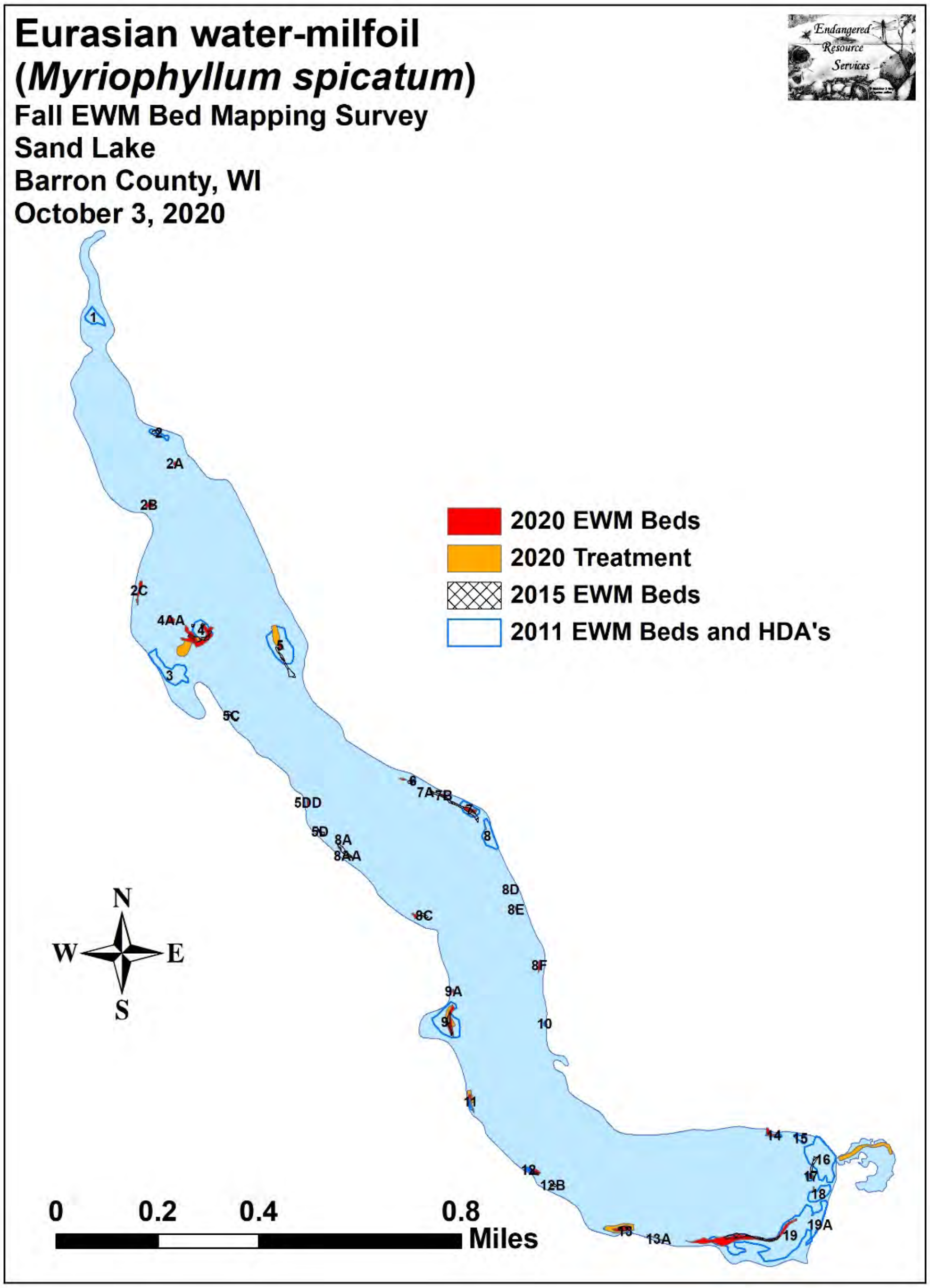
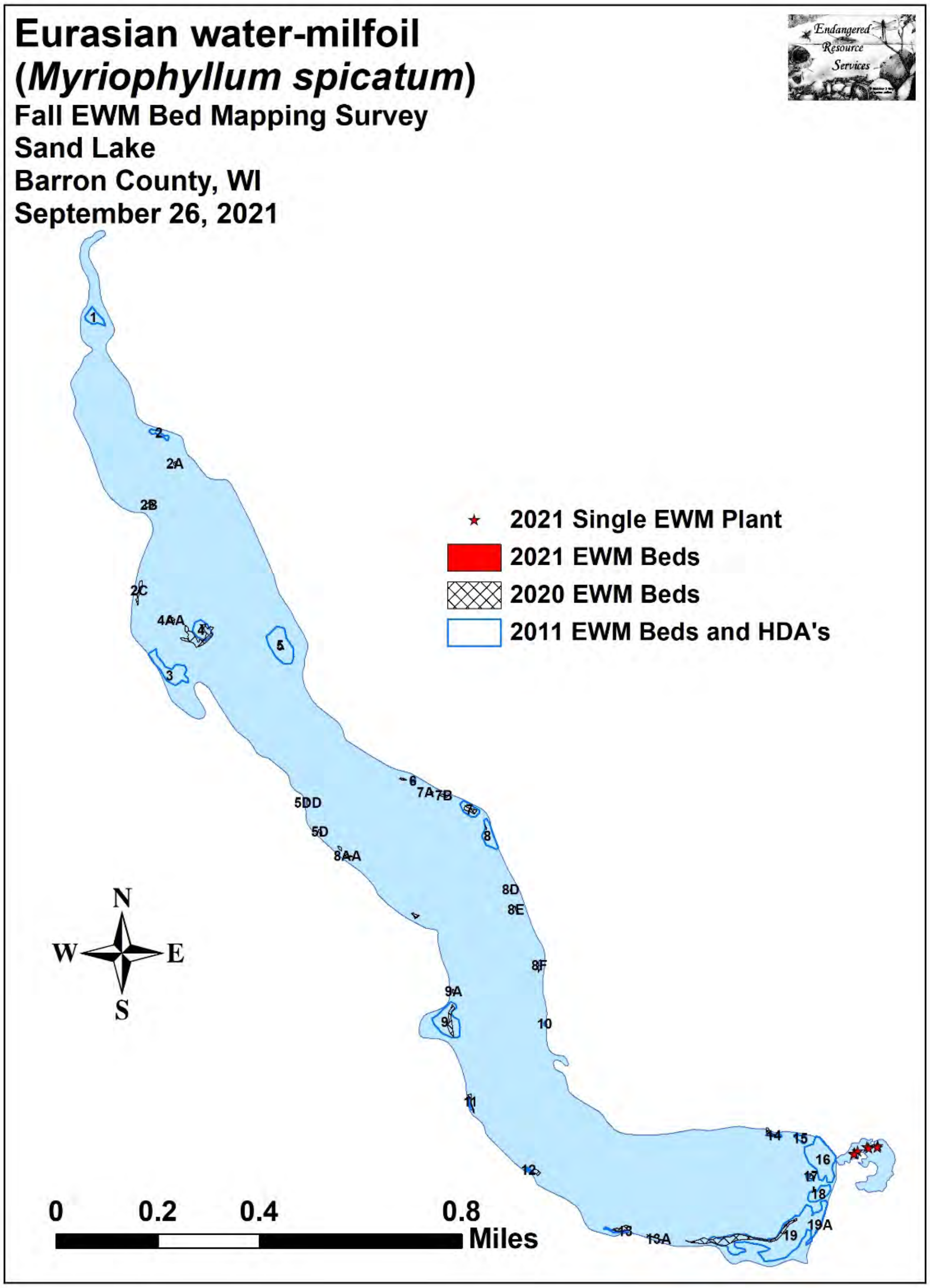
0.25
0.5
1
Miles



Wild celery
(*Vallisneria americana*)
Coefficient of Conservatism = 6
Posttreatment Survey
Sand Lake
Barron County, WI
July 8, 2021
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.25
0.5
1
Miles

Appendix VIII: 2020 and 2021 EWM Fall Bed Maps


Eurasian water-milfoil
(Myriophyllum spicatum)
Fall EWM Bed Mapping Survey
Sand Lake
Barron County, WI
October 3, 2020
Endangered Resource Services
2020 EWM Beds
2020 Treatment
2015 EWM Beds
2011 EWM Beds and HDA's
N
W
E
S
0
0.2
0.4
0.8
Miles
1
2
2A
2B
2C
4AA
4
5
3
5C
6
7A
7B
7
8
5DD
5D
8A
8AA
8D
8E
8C
8F
9A
9
10
11
12
12B
13
13A
14
15
16
17
18
19
19A


Eurasian water-milfoil
(*Myriophyllum spicatum*)
Fall EWM Bed Mapping Survey
Sand Lake
Barron County, WI
September 26, 2021
Endangered Resource Services
2021 Single EWM Plant
2021 EWM Beds
2020 EWM Beds
2011 EWM Beds and HDA's
N
W
E
S
0
0.2
0.4
0.8
Miles