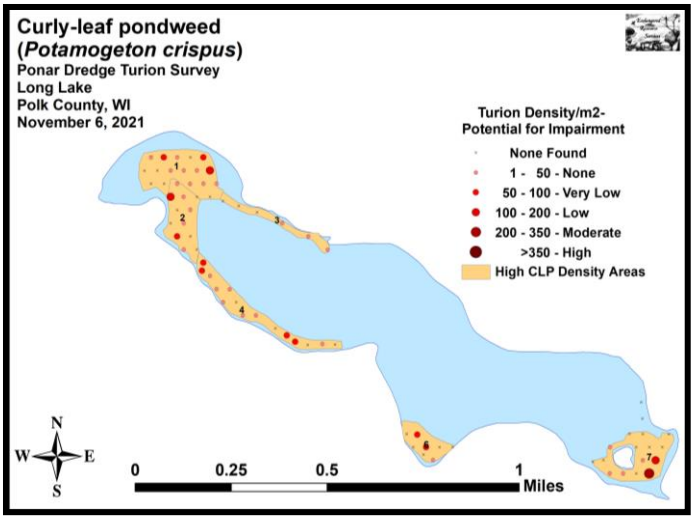
Curly-leaf pondweed (*Potamogeton crispus*)
Fall Turion Survey
Long Lake – WBIC: 2478200
Polk County, Wisconsin

Sieve with Turions (Berg 2013)



2021 Fall Turion Density and Distribution

Project Initiated by:

Long Lake Protection and Rehabilitation District, Harmony Environmental, and the Wisconsin Department of Natural Resources – (Grant ACEI20218)

Sprouting CLP Turion (Berg 2013)

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November 6, 2021

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

INTRODUCTION:

Long Lake (WBIC 2478200) is a 272-acre seepage lake in central Polk County, Wisconsin in the Town of Balsam Lake (T34N R17W S5, 6, 7, and 8). It reaches a maximum depth of just over 17ft in the central basin and has an average depth of approximately 11ft (Busch et al. 1969) (Figure 1). The lake is eutrophic trending toward hypereutrophic, and visibility is generally poor with summer Secchi readings averaging 5.1ft since 1992; however, **the 2021 mean reading of 12.0ft was the highest since records began** (WDNR 2021). The bottom substrate in the lake's bays and central basin is predominately thick organic muck, while exposed points and most north/south shorelines are dominated by gravel and sand.

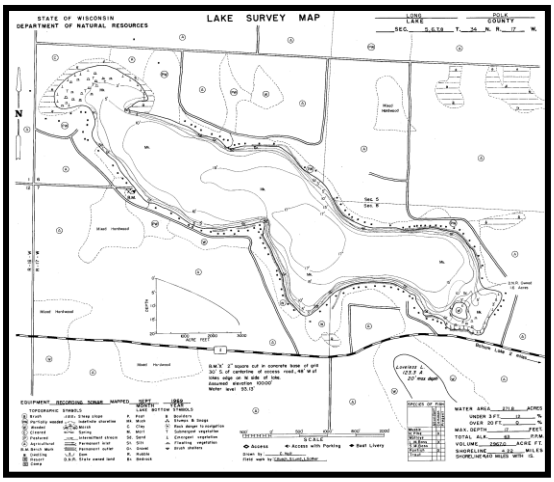

Figure 1: Long Lake Bathymetric Map

BACKGROUND AND STUDY RATIONALE:

Long Lake and the Long Lake Protection and Rehabilitation District (LLPRD) have an extended history of battling Curly-leaf pondweed (*Potamogeton crispus*) (CLP) - an exotic invasive plant species that thrives in the nutrient-rich sediments found in many parts of the lake. In the past, CLP often grew so densely in the spring and early summer that it made lake access and boating difficult for residents. CLP's late-June to early-July senescence was also cited in past studies by Barr Engineering and the Polk County Land and Water Conservation Department (PCLWCD) as a significant contributor to the lake's overall phosphorus load, and it was at least partially responsible for the lake's frequent late-summer toxic blue-green algae blooms.

In 2010, after years of study, the LLPRD and the Wisconsin Department of Natural Resources (WDNR) authorized an initial lakewide herbicide treatment of over 65 acres of CLP. The LLPRD treated nearly 57 acres again in 2011, and 58 acres in 2012. After updating the District's WDNR approved Aquatic Plant Management Plan (APMP) in 2012, it was decided to treat just 27 acres in 2013, and only 20 acres in 2014. Although **the 2010-2013 treatments resulted in highly significant reductions** in both CLP coverage and density on the lake, **the 2014 treatment showed no significant change from pretreatment levels**. A follow-up survey of CLP turions in the lake's sediment also suggested 2015 CLP levels would likely be very low in most parts of the lake. Based on these data, and following a discussion with the lake's executive board and APMP director Cheryl Clemens (Harmony Environmental) in the fall of 2014, it was decided **not to treat CLP in 2015**.

Because both the 2015 June CLP point-intercept monitoring survey and the fall CLP turion sediment data suggested CLP had made a significant rebound throughout much of the lake, **it was decided that herbicide treatments (not to exceed 35 acres) would resume in the future**. Ultimately, the LLPRD decided to treat 34.97 acres in 2016 and 33.65 acres in 2017. However, due to low spring CLP levels, the planned treatments in 2018, 2019, and 2020 were cancelled. Following an uptick in turions detected during the fall 2020 survey and after the spring 2021 pretreatment survey found significant CLP germination, it was decided to resume limited treatment in the worst 8.61 acres of Areas 1 and 2. On May 24, Lake Restoration (Jim Bartlett) applied Aquathol K to this area of the lake's northwest bay (Figure 2).

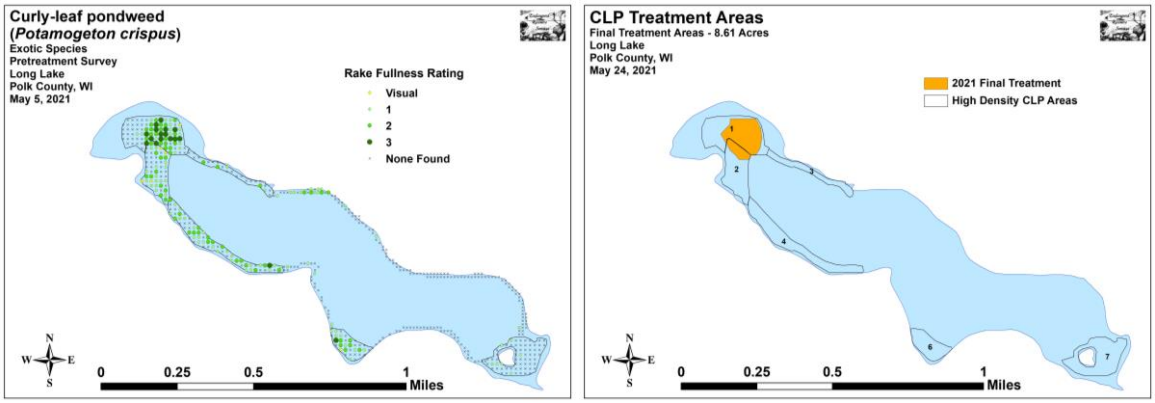

Figure 2: 2021 Pretreatment CLP Density and Distribution and Final CLP Treatment Area

CLP LIFE HISTORY AND STUDY OBJECTIVES:

Although Curly-leaf pondweed occasionally reproduces by seed, the vast majority of plants resprout from stiff overwintering buds called turions that are normally produced in number by the plants prior to their late June/early July senescence (Figure 3). After the pinecone-like turions germinate in late fall or early winter, plants continue to grow slowly under the ice. Following ice out, growth accelerates, and plants rapidly canopy allowing them a competitive advantage over slower growing native species (Capers 2005).

Figure 3: Germinating CLP Turion

Research suggests approximately 50% of turions germinate in a growing season while the rest remain dormant until the following growing season when another 50% will germinate (Johnson 2012). Depending on the level of turions at a given location and knowing that latent turions may be able to survive for over 5 years in the sediment, it may take several years of control to exhaust the "turion bank" (R. Newman – U of M unpublished data).

Following the 2020 summer growing season, we conducted a fall turion survey. The goals of the survey were to determine the level of remaining CLP turions within the lake's historic high density CLP areas; and, if there were any present, to predict whether their numbers suggested there would likely be enough to cause navigation issues in 2022. This report is the summary analysis of that survey conducted on November 6, 2021.

METHODS:

Fall Ponar Dredge Turion Survey:

Within the initial 2013 proposed treatment area shapefile, we used Hawth's Analysis Tools Extension to ArcGIS 9.3.1 to generate offset regular points at the rate of 2/acre. We also added 10 additional points in thin areas of the polygons where there were no points, or in areas that fell outside the polygons that we thought had the potential for CLP growth. This same sampling grid was used annually from 2014-2021 to allow for the most accurate comparisons possible (Figure 4) (Appendix I). For ease in determining the total impact of the current treatment program, we also left the 2013-2020 narratives in the results section of this report.

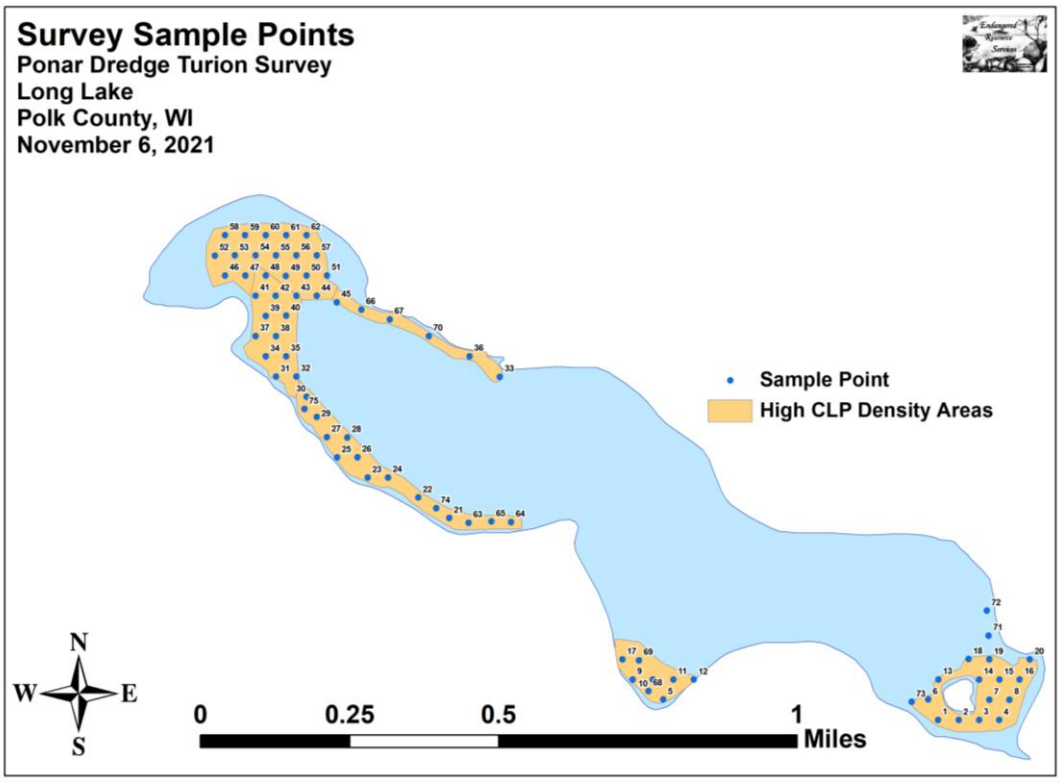

Figure 4: Turion Survey Sample Points

During the surveys, we located each point with a handheld mapping GPS unit (Garmin 76CSx) and used a Petite Ponar dredge with a 0.0232m^2 (36in^2) sample area to take a bottom sediment grab from each side of the boat at each location. These samples were then rinsed in a fine sieve to separate out the sediment (Figure 5). Samples with high numbers of turions or significant amounts of detritus were bagged for later analysis; at which time we discarded all rotten turions, tallied all live turions, and multiplied the combined total live turions from the two samples by 21.53 to estimate turions/m^2 at each location. This value gives an idea of how many CLP plants will germinate in an area during the 2022 growing season.

Figure 5: Ponar Grab and Turion Sieving

DATA ANALYSIS:

We entered all data collected into an Excel spreadsheet and used standard formulas in the data analysis tool pack to calculate the following:

Total number of points sampled: This value is the total number of points on the lake within each study area. We took **two** Ponar samples at each point.

Total number of live turions: This value includes all live turions found at all sites within a study area.

Total number of points with live turions: This number includes all survey sites that had at least one turion in **either** of the Ponar samples taken at the site.

Frequency of occurrence: The frequency of turions is generally reported as a percentage of occurrences at all sample points. The value is used to extrapolate coverage within the study area. For example, if 20% of all sample sites have turions, it suggests that 20% of the study area will have at least some Curly-leaf pondweed coverage the following year.

Points at or above nuisance level: This value gives the number of survey sites within the study area that were above the predicted nuisance threshold (Figure 6). Research suggests that when the turion density is at or above 200/m^2, the following year's CLP growth has the potential to at least moderately impair navigation (Johnson 2012).

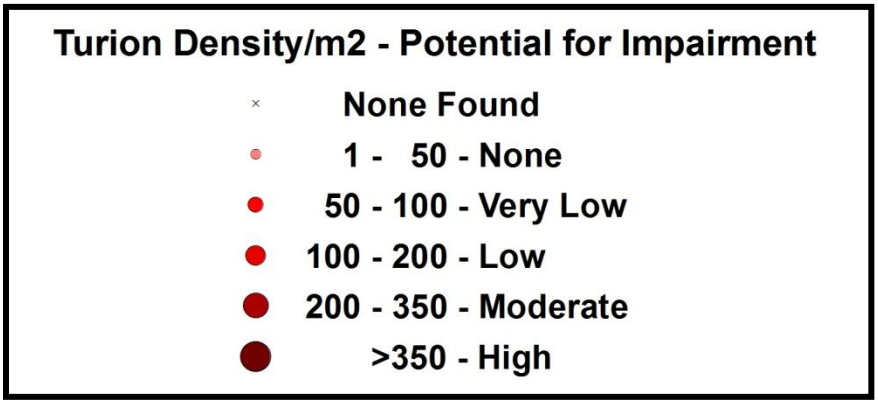

Figure 6: Predicted Navigation Impairment Based on Turion Density

Percent nuisance level: The percentage of nuisance points divided by the total number of survey points can be extrapolated to determine what percent of the study area has the potential to have at least moderate navigation impairment during the next growing season.

Mean turions/m^2: This value is the average number of turions/m^2 when pooling the data from all survey sites regardless of whether or not they had turions present.

Standard deviation of turions/m^2: This value tells us how far apart the data is from the mean. A low standard deviation suggests most points have a turion density that was similar to the mean, while a high value suggests there was greater variability in turion density within the sample area.

Year-over-year Significant Differences:
Data from the 2013-2021 surveys was compared using paired t-tests as we returned to the same sites during each survey. Year-over-year differences were determined to be significant at $p<0.05$, moderately significant at $p<0.01$, and highly significant at $p<0.001$ (Tables 1-8).

RESULTS AND DISCUSSION:
2013 Fall Ponar Dredge CLP Turion Survey:
During the November 10, 2013 Ponar dredge survey, we counted a total of 56 CLP turions at 28 of 75 survey points (37.3% coverage). Of these, none exceeded the expected "nuisance level" of 200/m^2, and only six points topped 50/m^2 (Figure 7) (Appendix II).

We found the overall mean density was just 16.07 turions/m^2 with Area 1 having the highest mean density at 34.19 turions/m^2. These low values suggest that, even at its worst, CLP was unlikely to cause significant navigation impairment in 2014. Broken down by area, it appeared the latent turion bank in Areas 3, 4, and 7 may have been nearly exhausted. We also noted that the deeper edges of Areas 2 and 6 looked to be nearly turion free. Only Area 1 seemed likely to have CLP over most of its area in 2014.

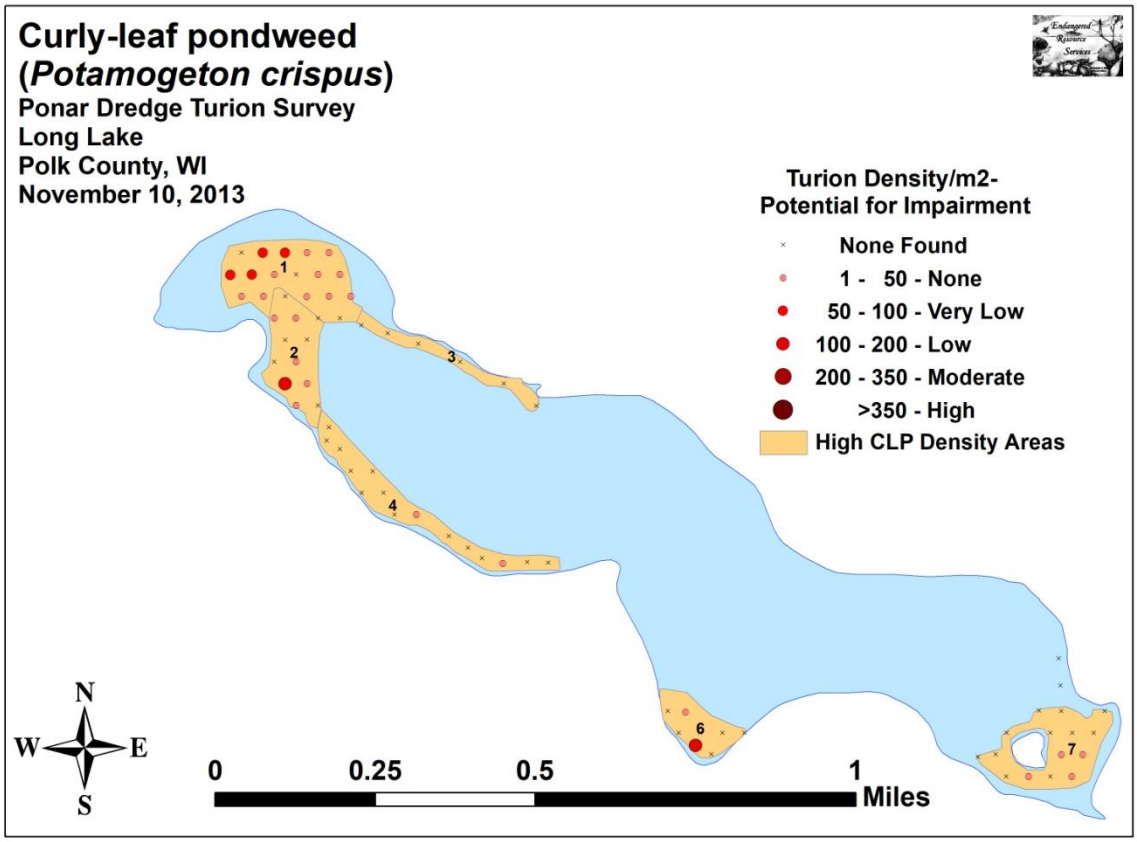

Figure 7: 2013 Fall CLP Turion Survey Density and Distribution

2014 Fall Ponar Dredge CLP Turion Survey:

Following the unsuccessful herbicide treatment in the spring of 2014, we found a total of 59 CLP turions at 27 of 75 survey points (36.0% coverage) during the October 19, 2014 survey (nearly identical to the 56 turions found at 28 points in 2013). Of these, none exceeded the expected "nuisance level" of 200/m^2, and just eight points (up from six in 2013) topped 50 turions/m^2 (Figure 8) (Appendix II). Comparing these results to the 2013 turion survey, we found that the increase in lakewide turion levels was not significant (p=0.43) as the mean density/m^2 increased only slightly from 16.07 turions/m^2 in 2013 to 16.94 turions/m^2 in 2014 (Table 1).

As in 2013, Area 1 had the highest mean density (32.92/m^2), and four points suggested the possibility of at least some very low to low navigation impairment. Areas 6 experienced a slight increase in density that was not significant (p=0.46), and Area 7 showed a nearly significant increase (p=0.05); however, neither of these two areas had any points that suggested there might be anything greater than a very low chance of navigation impairment in 2015. Area 2 also had regular turions, and, although the turion survey did not capture the data, the exploratory and posttreatment surveys suggested that CLP was reestablishing in the central and eastern ends of Area 4.

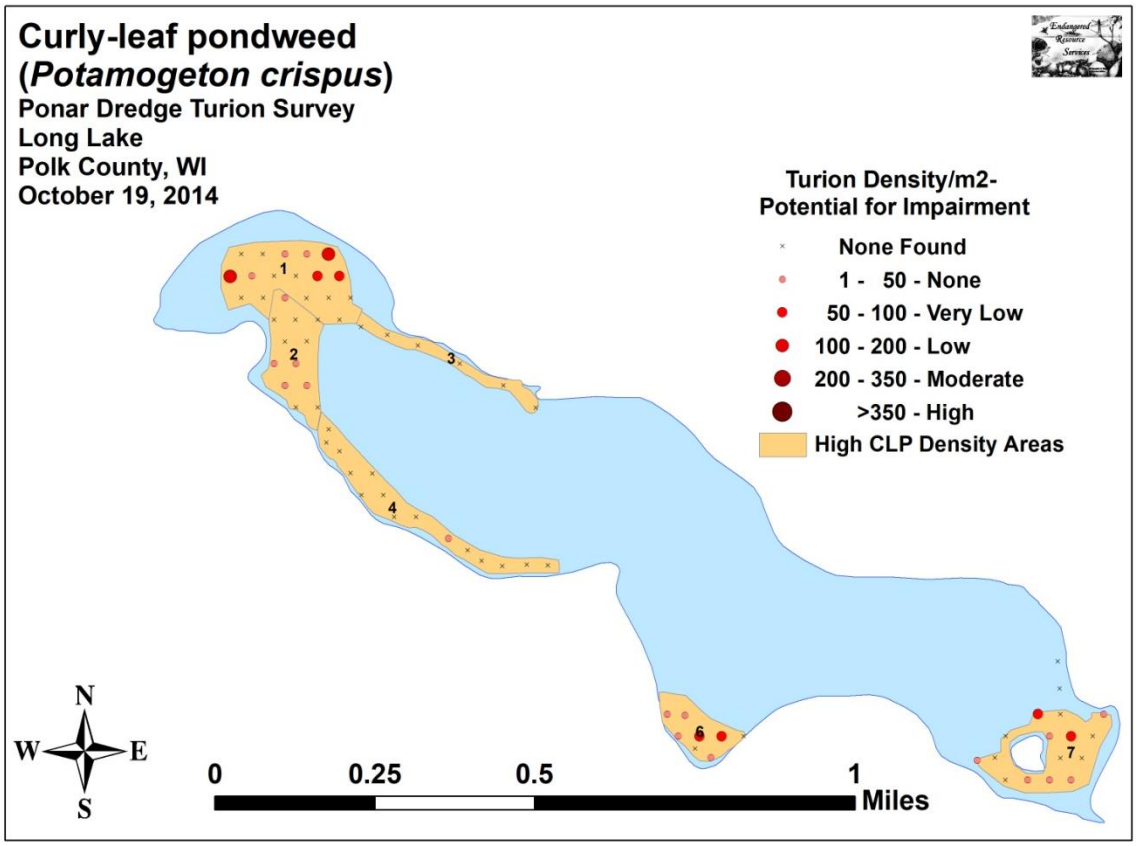

Figure 8: 2014 Fall CLP Turion Survey Density and Distribution

Table 1: CLP Turion Surveys - Summary Statistics
Long Lake, Polk County
November 10, 2013 and October 19, 2014

	2013							2014						
Summary Statistics:	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7
Total number of points sampled	75	17	12	6	15	8	17	75	17	12	6	15	8	17
Total live turions	56	27	12	0	2	10	5	59	26	6	0	1	11	15
Total # of points with live turions	28	14	6	0	2	2	4	27	7	5	0	1	6	8
Freq. of occurrence (in percent)	37.3	82.4	50.0	0.0	13.3	25.0	23.5	36.0	41.2	41.7	0.0	6.7	75.0	47.1
# at/above nuis. level (+200/m^2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% nuisance level	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum turions/m^2	194	86	108	0	22	194	43	172	172	43	0	22	65	86
Mean turions/m^2	16.07	34.19	21.53	0.00	2.87	26.91	6.33	16.94	32.92	10.76	0.00	1.44	29.60	19.00
Standard deviation/m^2	31.07	27.50	31.80	0.00	7.57	67.83	12.66	33.63	58.02	14.51	0.00	5.56	25.57	26.24
Standard error of the paired diff.								0.23	0.65	0.44	0.00	0.12	1.37	0.34
Degrees of freedom								74	16	11	5	14	7	16
t-statistic								+0.18	-0.09	-1.15	Div/0	-0.56	+0.09	+1.71
p - value								0.43	0.46	0.14	Div/0	0.29	0.46	0.05

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

2015 Fall Ponar Dredge CLP Turion Survey:

Following a year without management, we found Curly-leaf pondweed turion numbers experienced a dramatic increase. During the October 25, 2015 survey, we counted 167 CLP turions at 55 of 75 survey points (73.3% coverage). This was nearly triple the total turions and double the distribution of CLP when compared to the 2014 and 2013 surveys (59 turions found at 27 survey points (36.0% coverage) in 2014 and 56 turions at 28 points (37.3% coverage) in 2013). In 2015, only one point (in Bed 1) exceeded the expected "navigation nuisance level" of 200/m^2, but 27 (up from eight in 2014 and six in 2013) topped 50/m^2 (Figure 9) (Appendix II).

As expected, the lakewide increase in mean density from 16.94 turions/m^2 in 2014 (16.07 in 2013) to 47.94 turions/m^2 in 2015 was highly significant **($p<0.001$)** (Table 2). We also noticed that the standard deviation in 2015 (51.11 turions/m^2) was only slightly higher than the mean, while the standard deviation in 2014 (33.63 turions/m^2) had been over twice the mean. This suggested that CLP coverage was more uniform in 2015 than in 2014.

Broken down by polygon, we found that the mean turion density increase in each of the six areas. This increase was highly significant in Area 4 **($p<0.001$)**, and significant in Area 1 **($p=0.02$)**, Area 3 **($p=0.04$)**, and Area 6 **($p=0.02$)**.

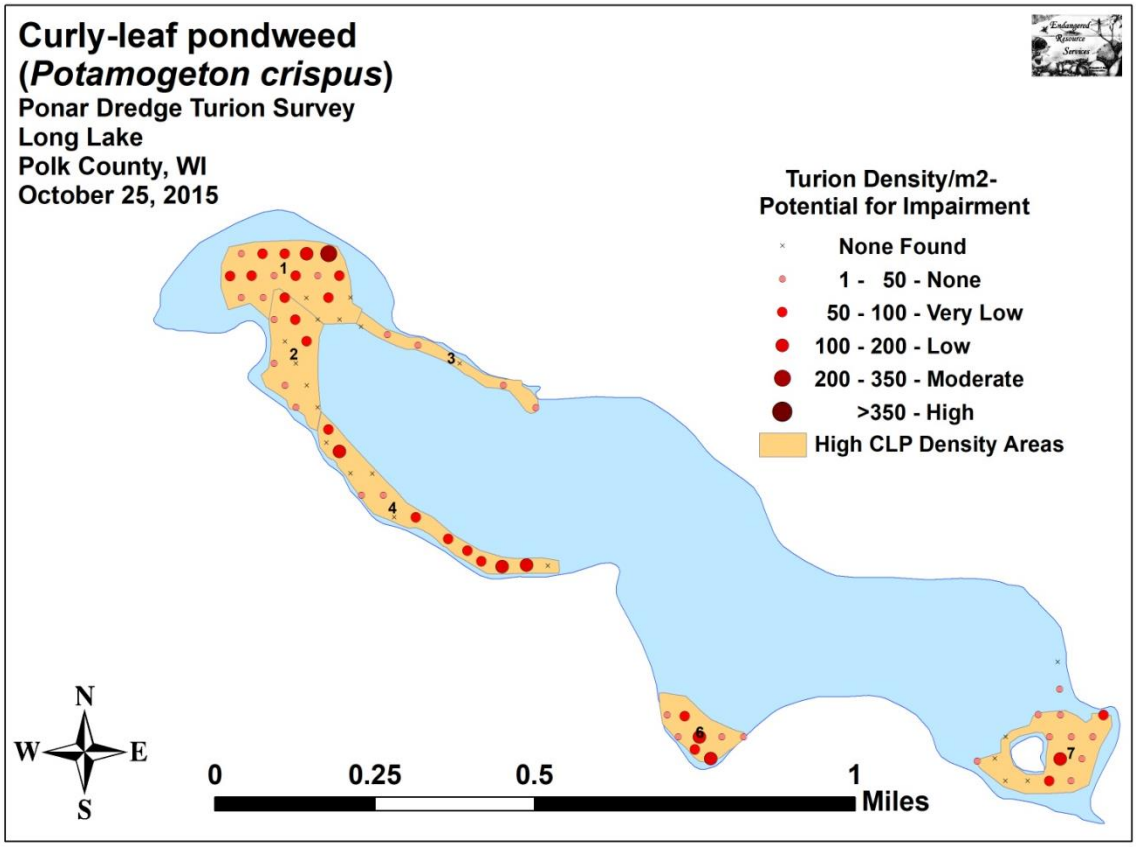

Figure 9: 2015 Fall CLP Turion Survey Density and Distribution

Table 2: CLP Turion Surveys - Summary Statistics
Long Lake, Polk County
October 19, 2014 and October 25, 2015

	2014							2015						
Summary Statistics:	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7
Total number of points sampled	75	17	12	6	15	8	17	75	17	12	6	15	8	17
Total live turions	59	26	6	0	1	11	15	167	45	15	5	43	30	29
Total # of points with live turions	27	7	5	0	1	6	8	55	14	7	4	10	8	12
Freq. of occurrence (in percent)	36.0	41.2	41.7	0.0	6.7	75.0	47.1	73.3	82.4	58.3	66.7	66.7	100.0	70.6
# at/above nuis. level (+200/m^2)	0	0	0	0	0	0	0	1	1	0	0	0	0	0
% nuisance level	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	5.9	0.0	0.0	0.0	0.0	0.0
Maximum turions/m^2	172	172	43	0	22	65	86	237	237	86	43	194	194	194
Mean turions/m^2	16.94	32.92	10.76	0.00	1.44	29.60	19.00	47.94	56.99	26.91	17.94	61.71	80.73	36.72
Standard deviation/m^2	33.63	58.02	14.51	0.00	5.56	25.57	26.24	51.11	55.90	30.62	16.21	60.27	54.89	46.15
Standard error of the paired diff.								0.28	0.51	0.49	0.31	0.73	0.96	0.63
Degrees of freedom								74	16	11	5	14	7	16
t-statistic								+5.19	+2.18	+1.52	+2.71	+3.86	+2.47	+1.32
p - value								*****<0.001**	***0.02**	0.08	***0.04**	*****<0.001**	***0.02**	0.10

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

2016 Fall Ponar Dredge CLP Turion Survey:

The 2016 spring treatment produced a highly significant reduction in CLP throughout the lake's entire littoral zone. Consequently, our October 28-29, 2016 survey found Curly-leaf pondweed turion numbers were greatly reduced. In total, we tallied 89 turions at 37 survey points (49.3% coverage). Although this was down sharply from the 2015 survey which found 167 turions at 55 of 75 survey points (73.3% coverage), it was still well above the 59 turions recorded at 27 points (36.0% coverage) in 2014 and the 56 turions at 28 points (37.3% coverage) in 2013. Our 2016 survey didn't find any points that were above the "navigation nuisance level" of 200/m^2, but 15 predicted 50 turions/m^2 or higher (Figure 10) (Appendix II). This was also down from 27 in 2015, but still much above the eight in 2014 and six in 2013.

The lakewide decline in mean density from 47.94 turions/m^2 (standard deviation of 51.11 turions/m^2) in 2015 to 25.55 turions/m^2 in 2016 (standard deviation of 38.40 turions/m^2) was highly significant **(p<0.001)** (Table 3). All areas experienced a year-over-year reduction in turion levels with the exception of Area 2 which was unchanged. Area 4 saw a moderately significant decline **(p<0.001)**, and Areas 3 and 7 showed significant declines **(p=0.02)**. Area 1's decline was also nearly significant (p=0.05).

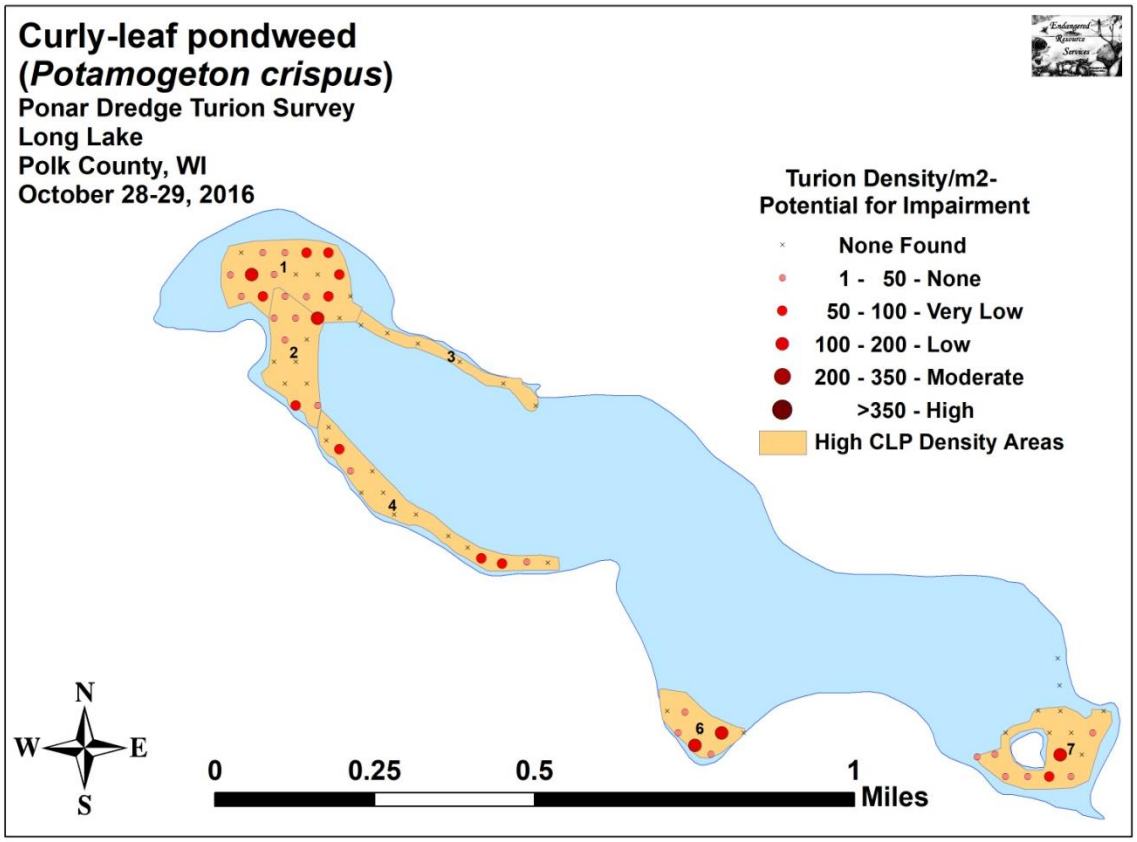

Figure 10: 2016 Fall CLP Turion Survey Density and Distribution

Table 3: CLP Turion Surveys - Summary Statistics
Long Lake, Polk County
October 25, 2015 and October 28-29, 2016

	2015							2016						
Summary Statistics:	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7
Total number of points sampled	75	17	12	6	15	8	17	75	17	12	6	15	8	17
Total live turions	167	45	15	5	43	30	29	89	28	15	0	12	16	18
Total # of points with live turions	55	14	7	4	10	8	12	37	12	7	0	5	5	8
Freq. of occurrence (in percent)	73.3	82.4	58.3	66.7	66.7	100.0	70.6	49.3	70.6	58.3	0.0	33.3	62.5	47.1
# at/above nuis. level (+200/m^2)	1	1	0	0	0	0	0	0	0	0	0	0	0	0
% nuisance level	1.3	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum turions/m^2	237	237	86	43	194	194	194	172	108	129	0	65	151	172
Mean turions/m^2	47.94	56.99	26.91	17.94	61.71	80.73	36.72	25.55	35.46	26.91	0.00	17.22	43.06	22.79
Standard deviation/m^2	51.11	55.90	30.62	16.21	60.27	54.89	46.15	38.40	33.99	37.99	0.00	27.23	60.89	42.70
Standard error of the paired diff.								0.28	0.58	0.70	0.31	0.61	1.50	2.18
Degrees of freedom								74	16	11	5	14	7	16
t-statistic								-3.78	-1.74	0.00	-2.57	-3.37	-1.17	-2.18
p - value								***<0.001	0.05	0.50	**0.02	**0.002	0.28	**0.02

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

2017 Fall Ponar Dredge CLP Turion Survey:

As in 2016, the May 2017 treatment of 33.65 acres produced a highly significant decline in Curly-leaf pondweed throughout the lake's entire littoral zone. During the October 27-28, 2017 survey, we found 54 turions at 31 survey points (41.3% coverage). This was a further reduction from the 89 turions at 37 points (49.3% coverage) we found in 2016 after the peak of 167 turions at 55 of 75 survey points (73.3% coverage) in 2015. It also represented a return to levels seen prior to the 2015 interruption in the treatment program (59 turions found at 27 points (36.0% coverage) in 2014 and 56 turions at 28 points (37.3% coverage) in 2013). Similar to 2016, our 2017 survey didn't find any points that were above the "navigation nuisance level" of 200/m^2; and the five points predicted to have 50 turions/m^2 or higher (Figure 11) (Appendix II) was the lowest since surveying began (15 in 2016; 27 in 2015; eight in 2014; and six in 2013).

The lakewide decline in mean density from 25.55 turions/m^2 in 2016 (standard deviation of 38.40 turions/m^2) in 2016 to 15.50 turions/m^2 in 2017 (standard deviation of 24.92 turions/m^2) was significant **(p=0.02)** (Table 4). All polygons experienced a year-over-year decline, but this was not significant for any one individual area.

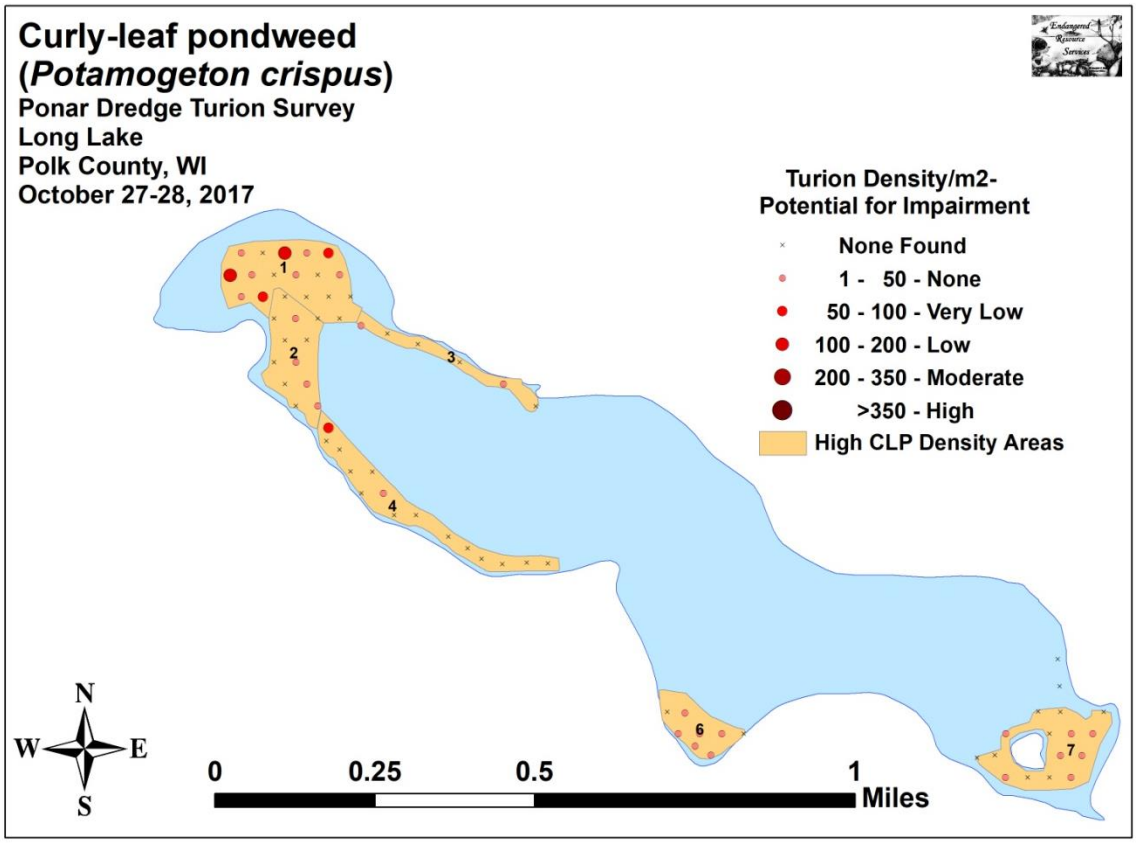

Figure 11: 2017 Fall CLP Turion Survey Density and Distribution

Table 4: CLP Turion Surveys - Summary Statistics
Long Lake, Polk County
October 28-29, 2016 and October 27-28, 2017

	2016							2017						
Summary Statistics:	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7
Total number of points sampled	75	17	12	6	15	8	17	75	17	12	6	15	8	17
Total live turions	89	28	15	0	12	16	18	54	26	6	2	5	8	7
Total # of points with live turions	37	12	7	0	5	5	8	31	10	4	2	2	6	7
Freq. of occurrence (in percent)	49.3	70.6	58.3	0.0	33.3	62.5	47.1	41.3	58.8	33.3	33.3	13.3	75.0	41.2
# at/above nuis. level (+200/m^2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% nuisance level	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum turions/m^2	172	108	129	0	65	151	172	108	108	43	22	86	43	22
Mean turions/m^2	25.55	35.46	26.91	0.00	17.22	43.06	22.79	15.50	32.92	10.76	7.18	7.18	21.53	8.86
Standard deviation/m^2	38.40	33.99	37.99	0.00	27.23	60.89	42.70	24.92	38.15	17.17	11.12	22.53	16.27	10.92
Standard error of the paired diff.								0.23	0.50	0.63	0.21	0.47	1.00	0.47
Degrees of freedom								74	16	11	5	14	7	16
t-statistic								-2.03	-0.24	-1.19	1.58	-1.00	-1.00	-1.38
p - value								***0.02**	0.41	0.13	0.09	0.17	0.18	0.09

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

2018 Fall Ponar Dredge CLP Turion Survey:

After a year with no active management, the expectation would be that 2018 fall turion levels would experience a highly significant increase over 2017 levels. However, this turned out not to be the case and seemed to support our anecdotal observations during the June follow-up survey that many plants in deep water didn't form turions as they grew only a few feet before falling over and dying. During the October 27-28, 2018 survey, we found 68 turions at 30 of 75 survey points (40.0% coverage). This was an increase from 54 total turions found in 2017, but a reduction from the 31 survey points with turions (41.3% coverage) seen in 2017. Although this was higher than the posttreatment levels documented in 2013 (56 turions at 28 points - 37.3% coverage) and 2014 (59 turions found at 27 points - 36.0% coverage), it was still far less than the peak values observed in 2015 (167 turions at 55 points - 73.3% coverage) and 2016 (89 turions at 37 points - 49.3% coverage).

Similar to our 2016 and 2017 surveys, we didn't find any points that were above the "navigation nuisance level" of 200/m^2. The 12 points that were predicted to have 50 turions/m^2 or higher (Figure 12) (Appendix II) was up from five points in 2017, but still less than the 15 points above this level in 2016 and 27 points in 2015.

The lakewide increase in mean density from 15.50 turions/m^2 in 2017 (standard deviation of 24.92 turions/m^2) to 19.52 turions/m^2 in 2018 (standard deviation of 31.49 turions/m^2) was NOT significant (p=0.16) (Table 5). Broken out by polygon, Areas 1, 2, 4, and 7 all increased, although only Area 2's increase was significant **(p=0.04)**. Conversely, Areas 3 and 6 actually declined, but neither was significant.

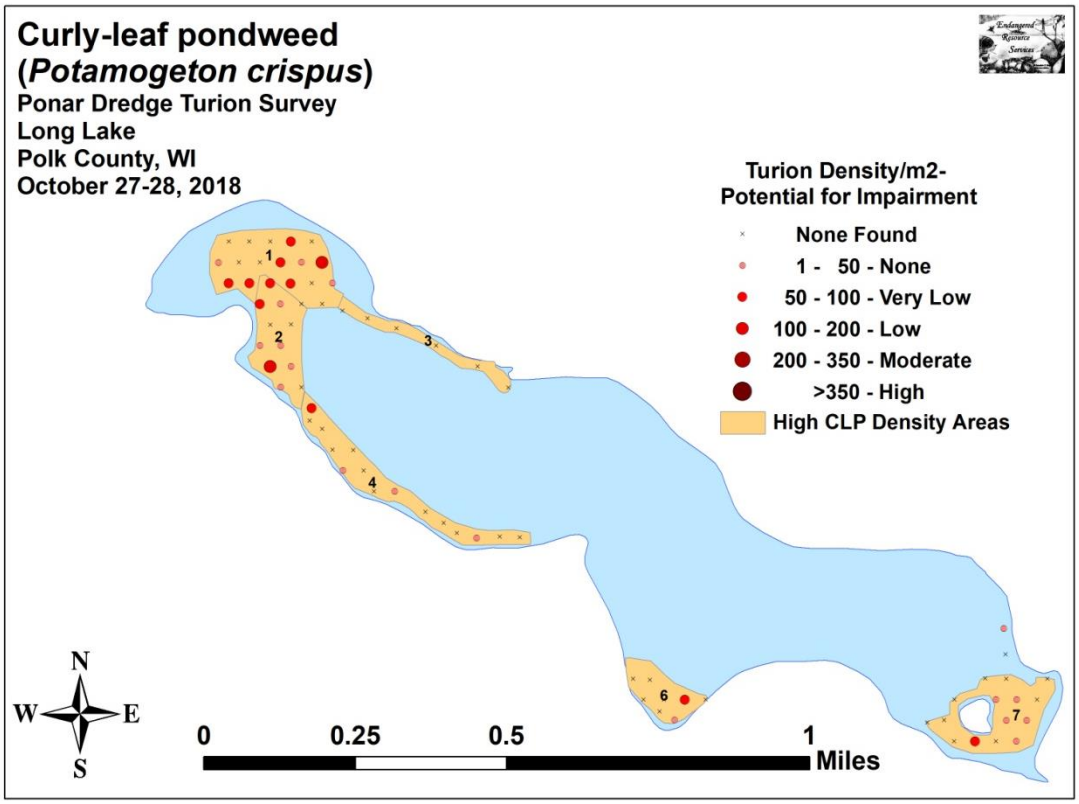

Figure 12: 2018 Fall CLP Turion Survey Density and Distribution

Table 5: CLP Turion Surveys - Summary Statistics
Long Lake, Polk County
October 27-28, 2017 and October 27-28, 2018

	2017							2018						
Summary Statistics:	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7
Total number of points sampled	75	17	12	6	15	8	17	75	17	12	6	15	8	17
Total live turions	54	26	6	2	5	8	7	68	26	20	0	7	5	10
Total # of points with live turions	31	10	4	2	2	6	7	30	9	8	0	4	2	7
Freq. of occurrence (in percent)	41.3	58.8	33.3	33.3	13.3	75.0	41.2	40.0	52.9	66.7	0.0	26.7	25.0	41.2
# at/above nuis. level (+200/m^2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% nuisance level	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum turions/m^2	108	108	43	22	86	43	22	129	129	129	0	65	86	65
Mean turions/m^2	15.50	32.92	10.76	7.18	7.18	21.53	8.86	19.52	32.92	35.88	0	10.05	13.45	12.66
Standard deviation/m^2	24.92	38.15	17.17	11.12	22.53	16.27	10.92	31.49	41.07	40.36	0	19.71	30.31	18.73
Standard error of the paired diff.								0.19	0.58	0.63	0.21	0.19	0.53	0.23
Degrees of freedom								74	16	11	5	14	7	16
t-statistic								+0.98	0.00	+1.86	-1.58	+1.69	-0.70	+0.77
p - value								0.16	0.50	***0.04**	0.09	0.25	0.50	0.23

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

2019 Fall Ponar Dredge CLP Turion Survey:

Following two years without active management, turions levels rose sharply. During the October 27-28, 2019 survey, we found 128 turions at 51 of 75 survey points (68.0% coverage) – the highest total since the 2015 peak of 167 turions at 55 points (73.3% coverage). It was also nearly double the 2018 survey when we found 68 total turions at 30 points (40% coverage), and a further increase from 2017 when 31 points (41.3% coverage) had 54 total turions.

Similar to our 2016, 2017, and 2018 surveys, we didn't find any points that were above the "navigation nuisance level" of 200/m^2. The 21 points that were predicted to have 50 turions/m^2 or higher (Figure 13) (Appendix II) was up from 12 points in 2018, five points in 2017, and 15 points in 2016; however, it was still below the 27 points at this level in 2015.

The lakewide change in mean density from 19.52 turions/m^2 in 2018 (standard deviation of 31.49 turions/m^2) to 36.74 turions/m^2 in 2019 (standard deviation of 40.93 turions/m^2) represented a **highly significant increase (p<0.001)** (Table 6). Broken out by polygon, Areas 1, 3, 4, 6, and 7 all increased, although only the changes in Area 1, 3 and 7 were significant **(p=0.02/p=0.02/p=0.03)**. Conversely, Area 2 actually declined, but it was not significant.

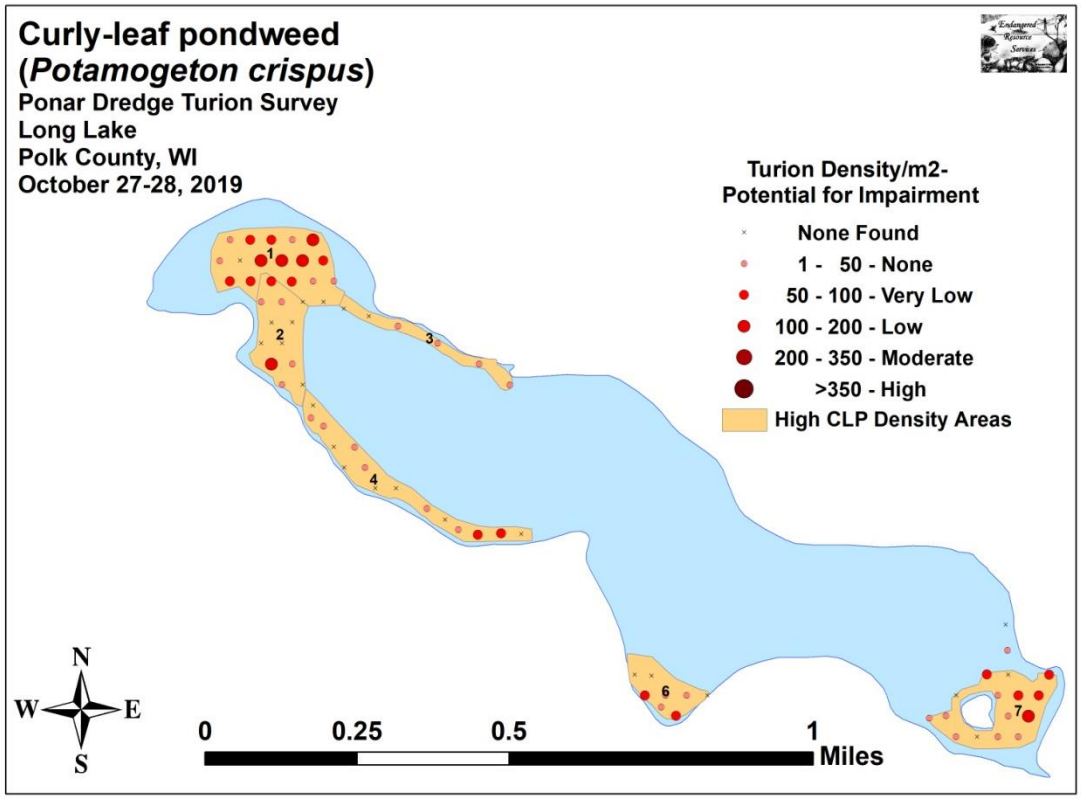

Figure 13: 2019 Fall CLP Turion Survey Density and Distribution

Table 6: CLP Turion Surveys - Summary Statistics
Long Lake, Polk County
October 27-28, 2018 and October 27-28, 2019

	2018							2019						
Summary Statistics:	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7
Total number of points sampled	75	17	12	6	15	8	17	75	17	12	6	15	8	17
Total live turions	68	26	20	0	7	5	10	128	47	17	7	15	12	30
Total # of points with live turions	30	9	8	0	4	2	7	51	15	6	4	8	5	13
Freq. of occurrence (in percent)	40.0	52.9	66.7	0.0	26.7	25.0	41.2	68.0	88.2	50.0	66.7	53.3	62.5	76.5
# at/above nuis. level (+200/m^2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% nuisance level	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum turions/m^2	129	129	129	0	65	86	65	194	129	172	43	86	86	194
Mean turions/m^2	19.52	32.92	35.88	0	10.05	13.45	12.66	36.74	59.52	30.50	25.12	21.53	32.29	37.99
Standard deviation/m^2	31.49	41.07	40.36	0	19.71	30.31	18.73	40.93	40.65	49.82	21.17	26.99	36.39	46.63
Standard error of the paired diff.								0.22	0.56	0.33	0.40	0.39	0.77	0.57
Degrees of freedom								74	16	11	5	14	7	16
t-statistic								+3.57	+1.75	-0.76	+2.91	+1.37	+1.14	+2.06
p - value								***<0.001	*__0.02__	0.23	*__0.02__	0.10	0.15	*__0.03__

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

2020 Fall Ponar Dredge CLP Turion Survey:

After three years without active management, we expected that turions levels would have again increased significantly, but this did not turn out to be the case. During the October 17, 2020 survey, we found 154 turions at 41 of 75 survey points (54.7% coverage). Although this was the highest total number of turions since the 2015 peak of 167 turions at 55 points (73.3% coverage), it represented a 19.6% decline in distribution from 2019 when we found 128 turions at 51 points (68.0% coverage). Most of the areas that showed lower turions numbers relative to 2019 anecdotally had large amounts of Northern water-milfoil (*Myriophyllum sibiricum*). It may be that increased competition from this native species is limiting CLP growth.

Unlike our 2016, 2017, 2018, and 2019 surveys when we didn't have any points that were above the "navigation nuisance level" of 200/m^2, in 2020 we found four points that exceeded this threshold – three in Area 1 in the northwest bay, and one in the south-central bay in Area 6. Despite this increase, there were still only 20 points that predicted any navigation impairment (50 turions/m^2 or higher) (Figure 14) (Appendix II). This was down from 21 points in 2019, but up from 12 points in 2018, five points in 2017, and 15 points in 2016. It was, however, still below the high mark of 27 points at this level in 2015.

The lakewide increase in mean density from 36.74 turions/m^2 in 2019 (standard deviation of 40.93 turions/m^2) to 44.20 turions/m^2 in 2020 (standard deviation of 66.30 turions/m^2) was not significant (p=0.18) (Table 7). Broken out by polygon, Areas 1, 2, 4, and 6 all increased, while Areas 3 and 7 actually declined; however, none of these changes were significant.

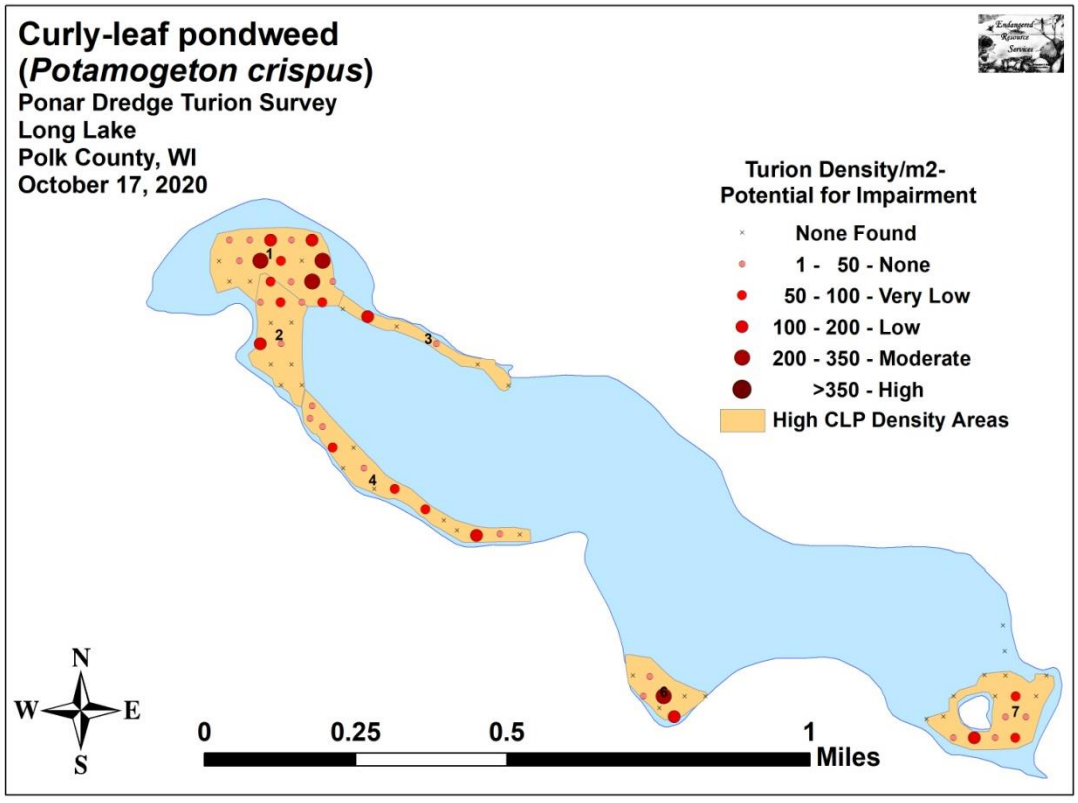

Figure 14: 2020 Fall CLP Turion Survey Density and Distribution

Table 7: CLP Turion Surveys - Summary Statistics
Long Lake, Polk County
October 27-28, 2019 and October 17, 2020

	2019							2020						
Summary Statistics:	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7
Total number of points sampled	75	17	12	6	15	8	17	75	17	12	6	15	8	17
Total live turions	128	47	17	7	15	12	30	154	65	19	6	26	18	20
Total # of points with live turions	51	15	6	4	8	5	13	41	13	6	2	9	4	7
Freq. of occurrence (in percent)	68.0	88.2	50.0	66.7	53.3	62.5	76.5	54.7	76.5	50.0	33.3	60.0	50.0	41.2
# at/above nuis. level (+200/m^2)	0	0	0	0	0	0	0	4	3	0	0	0	1	0
% nuisance level	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	17.6	0.0	0.0	0.0	12.5	0.0
Maximum turions/m^2	194	129	172	43	86	86	194	323	323	172	108	194	237	129
Mean turions/m^2	36.74	59.52	30.50	25.12	21.53	32.29	37.99	44.20	82.31	34.09	21.53	37.31	48.44	25.33
Standard deviation/m^2	40.93	40.65	49.82	21.17	26.99	36.39	46.63	66.30	93.91	50.66	43.06	51.76	84.36	38.23
Standard error of the paired diff.								0.38	1.04	1.01	1.11	0.52	1.41	0.72
Degrees of freedom								74	16	11	5	14	7	16
t-statistic								+0.91	+1.02	+0.16	-0.15	+1.41	+0.53	-0.82
p - value								0.18	0.16	0.44	0.44	0.09	0.31	0.21

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

2021 Fall Ponar Dredge CLP Turion Survey:

Limited active management in the northwest bay in 2021 produced a significant decline in total turions, but no change in turion distribution. During the November 6, 2021 survey, we found 98 turions at 41 of 75 survey points (54.7% coverage). This was a decline from 154 turions at an identical 41 points in 2020. We were again somewhat surprised that areas that weren't actively managed showed little year-over-year change in turion density and/or distribution. We also noted that most of the areas that showed low to no turions numbers continued to have dense beds of Northern water-milfoil (*Myriophyllum sibiricum*). It may be that increased competition from this native species for both nutrients and space is limiting CLP growth.

In 2020, three out of four predicted "navigation nuisance level" of 200+ turions/m^2 occurred in the 2021 treatment area in the northwest bay. The single nuisance point in 2021 occurred in the channel southeast of the island in an area where there was little Northern water-milfoil. Collectively, there were only 13 points that were predicted to cause any navigation impairment in 2022 (50 turions/m^2 or higher) (Figure 15) (Appendix II). This was down from 20 points in 2020, 21 points in 2019, and similar to 12 points in 2018.

The lakewide decline in mean density from 44.20 turions/m^2 in 2020 (standard deviation of 66.30 turions/m^2) to 28.13 turions/m^2 in 2021 (standard deviation of 39.41 turions/m^2) was significant **(*p*=0.02)** (Table 8). Broken out by polygon, Areas 1 (treated) was the only area with a significant decline **(*p*=0.02)**. All other areas either showed non-significant declines in density (Areas 2, 4, and 6) or were unchanged (Areas 4 and 7) when compared to 2020.

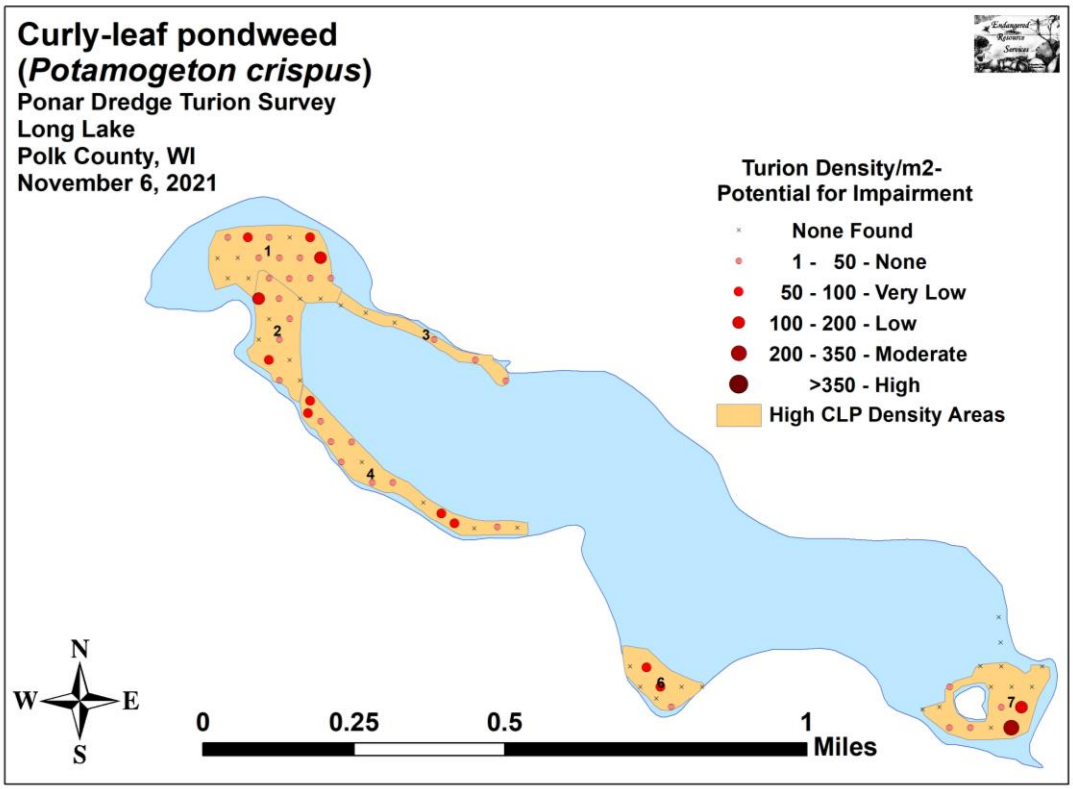

Figure 15: 2021 Fall CLP Turion Survey Density and Distribution

Table 8: CLP Turion Surveys - Summary Statistics
Long Lake, Polk County
October 17, 2020 and November 6, 2021

	2020							2021						
Summary Statistics:	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7	All	HDA 1	HDA 2	HDA 3	HDA 4	HDA 6	HDA 7
Total number of points sampled	75	17	12	6	15	8	17	75	17	12	6	15	8	17
Total live turions	154	65	19	6	26	18	20	98	25	14	4	26	9	20
Total # of points with live turions	41	13	6	2	9	4	7	41	11	7	3	11	3	6
Freq. of occurrence (in percent)	54.7	76.5	50.0	33.3	60.0	50.0	41.2	54.7	64.7	58.3	50.0	73.3	37.5	35.3
# at/above nuis. level (+200/m^2)	4	3	0	0	0	1	0	1	0	0	0	0	0	1
% nuisance level	5.3	17.6	0.0	0.0	0.0	12.5	0.0	1.3	0.0	0.0	0.0	0.0	0.0	5.9
Maximum turions/m^2	323	323	172	108	194	237	129	215	150	108	43	86	86	215
Mean turions/m^2	44.20	82.31	34.09	21.53	37.31	48.44	25.33	28.13	31.66	25.12	14.35	37.31	24.22	25.33
Standard deviation/m^2	66.30	93.91	50.66	43.06	51.76	84.36	38.23	39.41	38.15	32.88	17.58	29.86	35.35	58.08
Standard error of the paired diff.								0.37	0.97	0.83	0.99	0.85	0.97	0.61
Degrees of freedom								74	16	11	5	14	7	16
t-statistic								-2.04	-2.43	-0.50	-0.34	0.00	-1.16	0.00
p - value								***0.02**	***0.01**	0.50	0.37	0.50	0.14	0.50

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

CONSIDERATIONS FOR FUTURE MANAGMENT:

The 2021 turion survey suggests there will again be Curly-leaf pondweed throughout much of Long Lake in 2022, although any navigation impairment caused by CLP is likely to be low. In retrospect, this likely also means the decision to actively manage just a small area in the spring of 2021 was the correct one as 2022 CLP densities in Areas 2 and 4 – the other locations considered for chemical treatment in the spring of 2021 – are not expected to cause more than minor navigation impairment even though they weren't actively managed.

We continue to be optimistic that these generally low CLP impairment levels, coupled with the strong regrowth and increasing richness and diversity of native species, mean that the lake is trending towards a more balanced plant community that won't require significant active management in the future. Although treatment is still an option for 2022 (pers. comm. with LLPRD board), the low turion levels, especially in deep water, suggest that the total surface acreage and volume of water treated would again likely be limited. Ultimately, the results of the 2022 pretreatment survey coupled with the level of CLP growth the board is comfortable with will determine how much, if any, of the lake is chemically treated.

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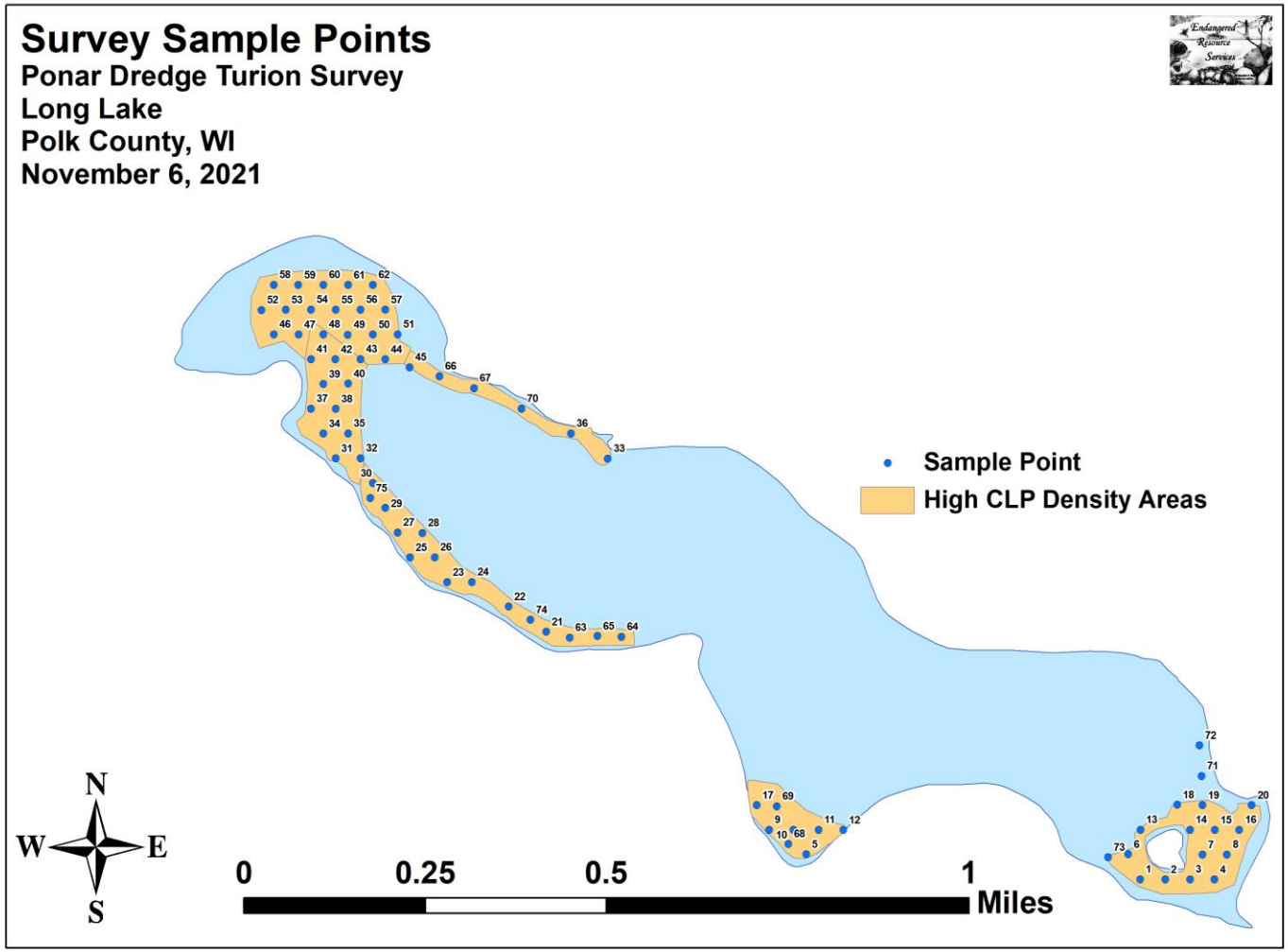
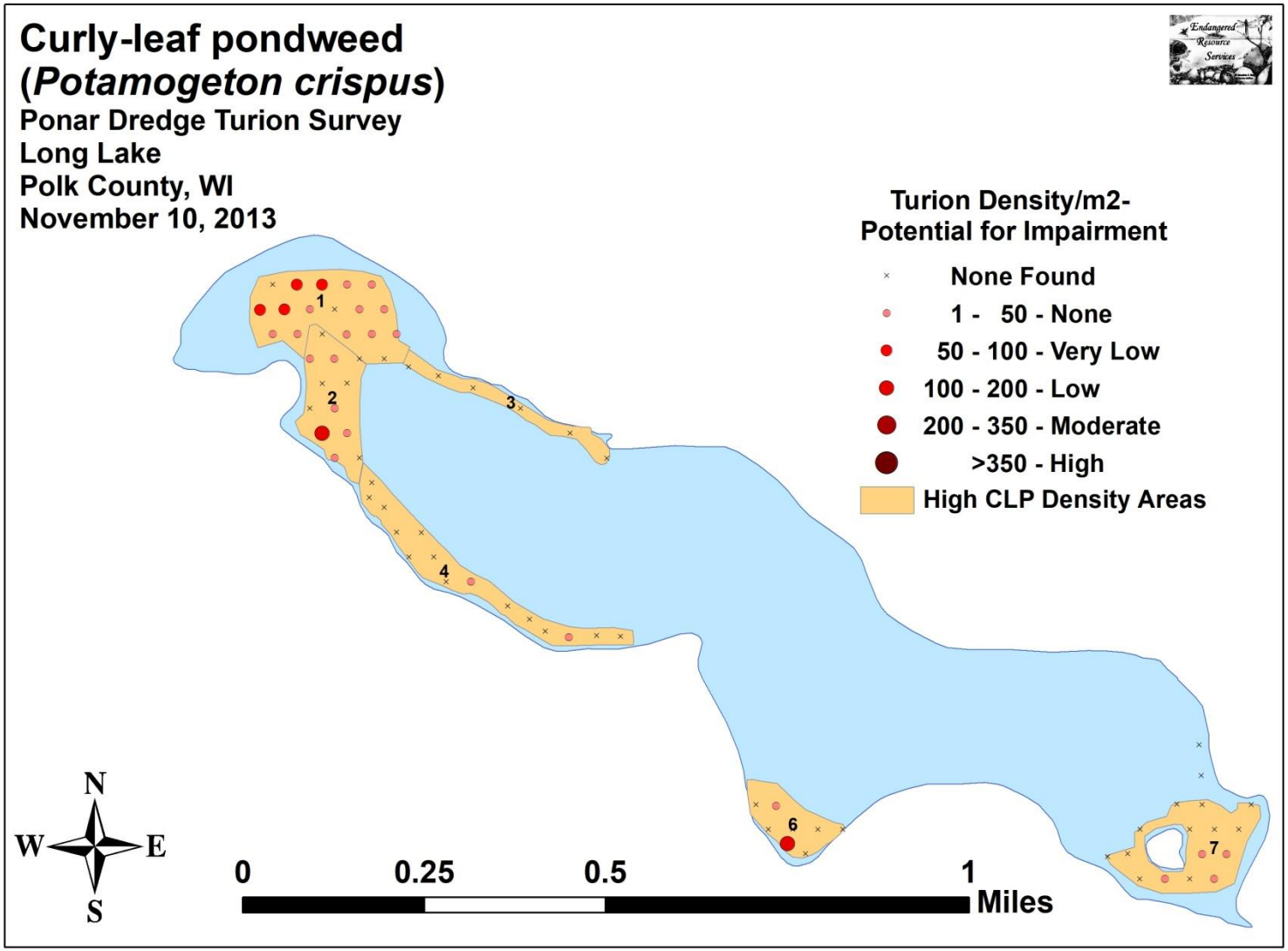
Appendix I: Survey Sample Points in Historic High CLP Density Areas


Survey Sample Points
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
November 6, 2021
Endangered Resource Services
Sample Point
High CLP Density Areas
N
W
E
S
0
0.25
0.5
1
Miles

Appendix II: 2013-2021 Fall CLP Turion Density and Distribution Maps


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
November 10, 2013
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
2
3
4
6
7
N
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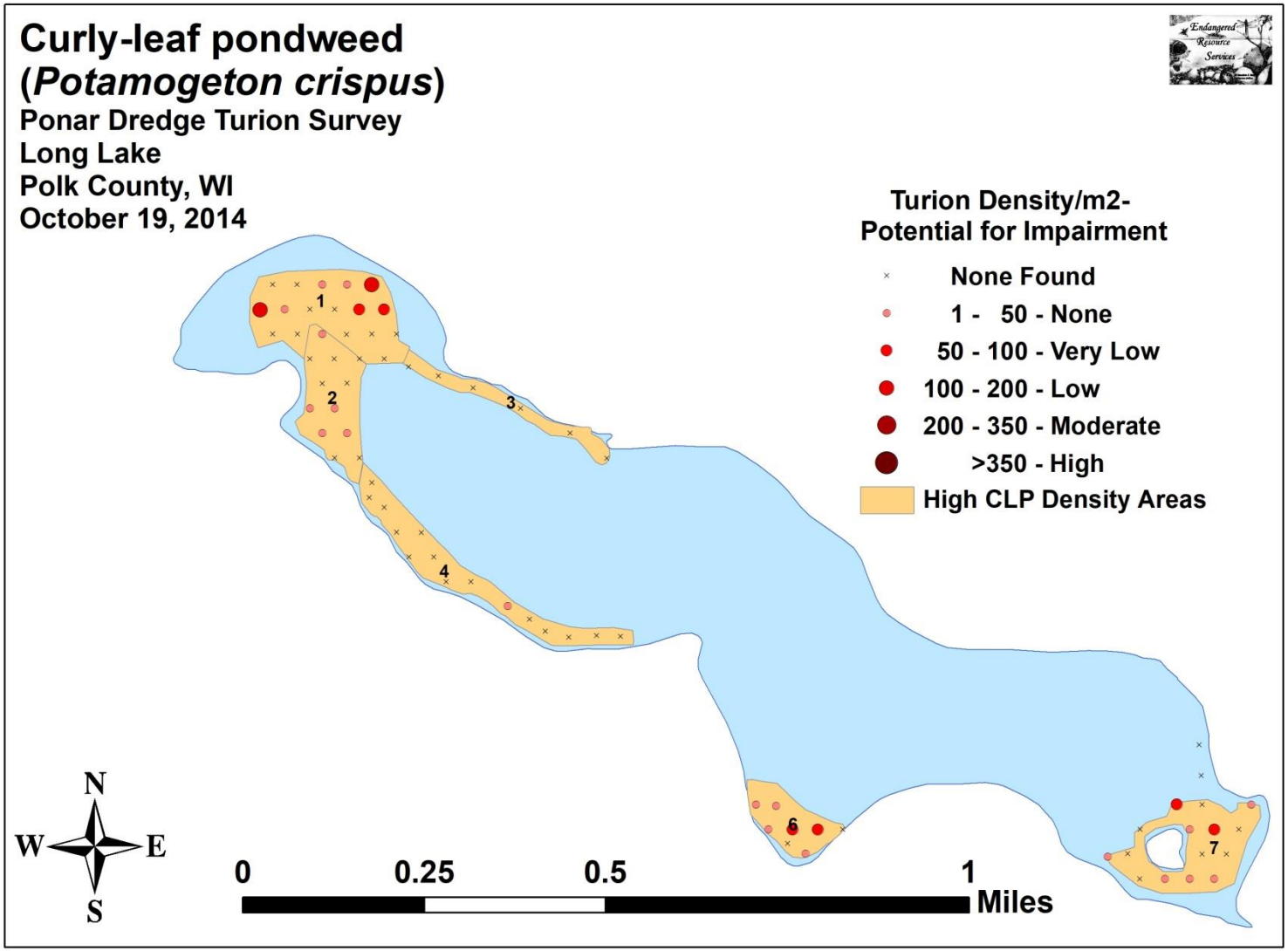
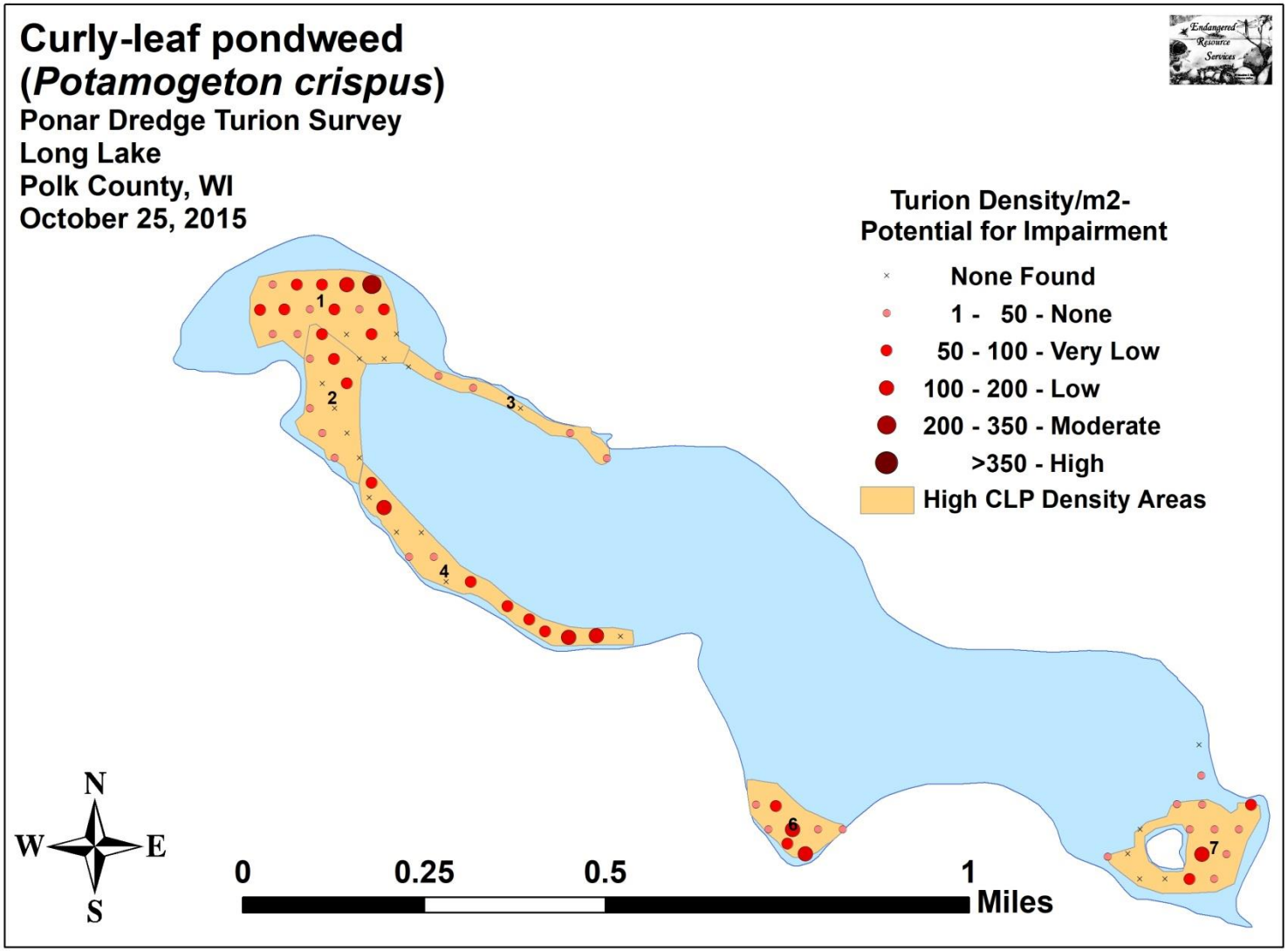
0
0.25
0.5
1
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
October 19, 2014
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
2
3
4
6
7
N
W
E
S
0
0.25
0.5
1
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
October 25, 2015
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
2
3
4
6
7
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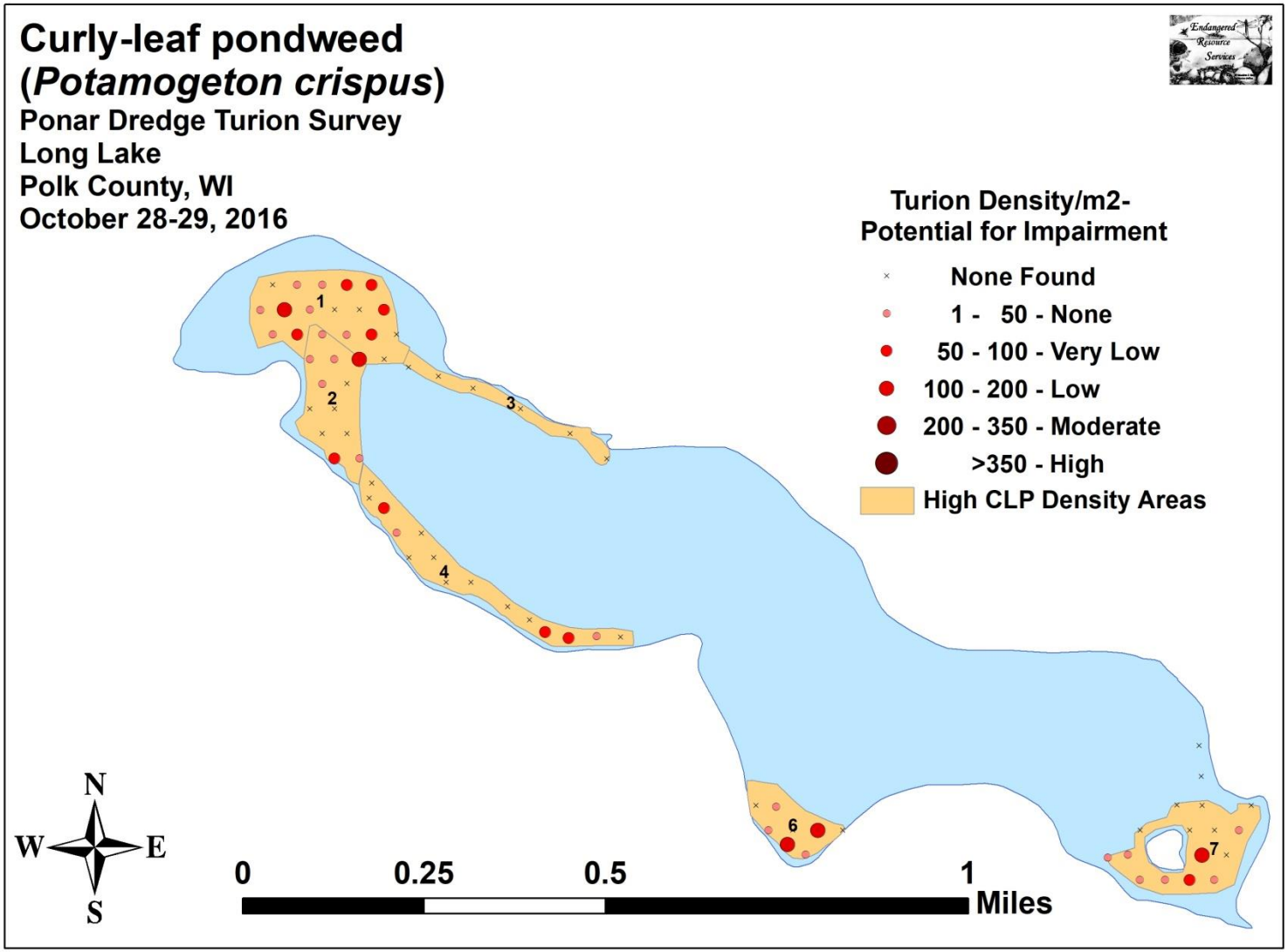
W
E
S
0
0.25
0.5
1
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
October 28-29, 2016
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
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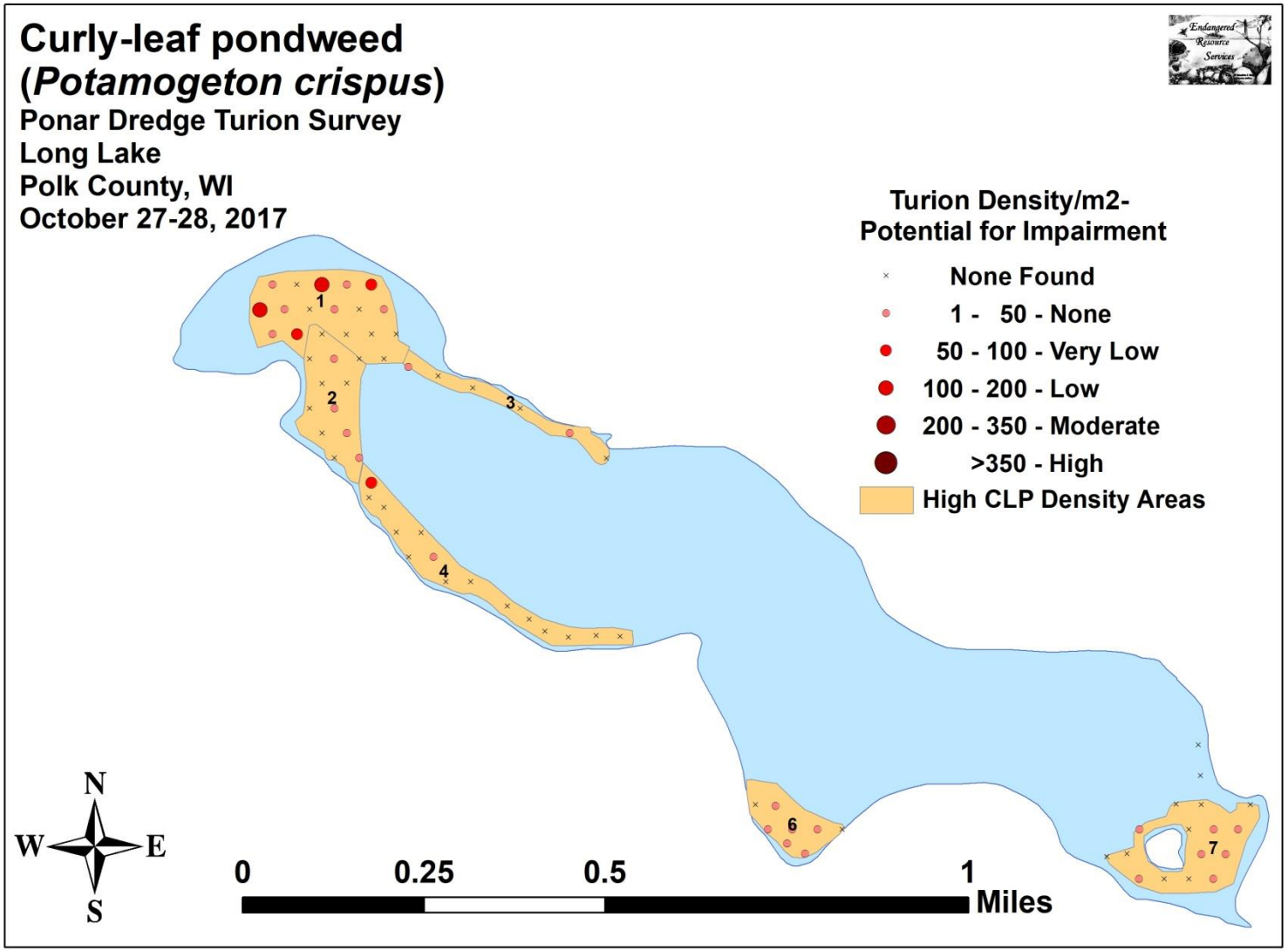
0.5
1
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
October 27-28, 2017
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
2
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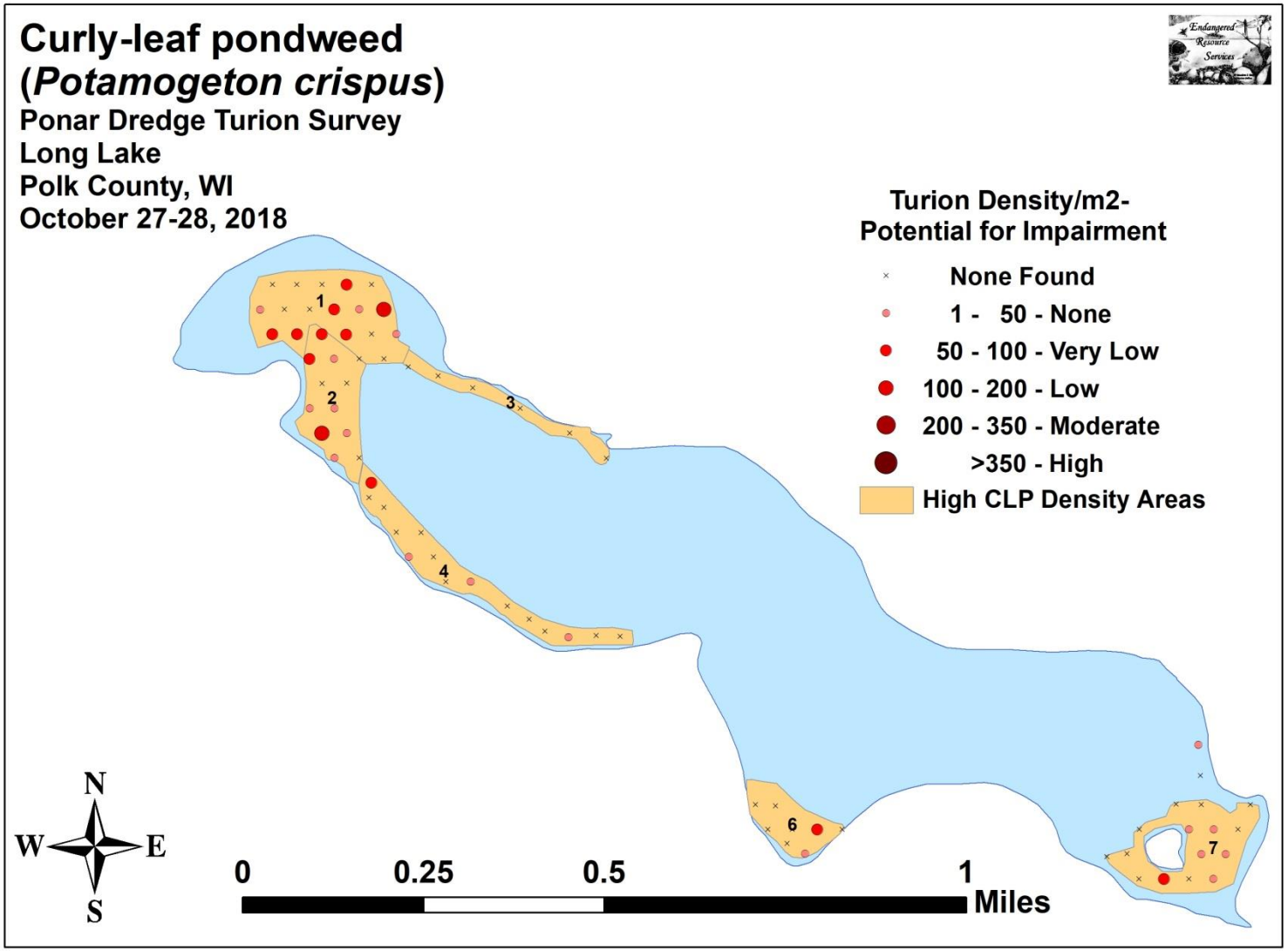
0.5
1
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
October 27-28, 2018
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
2
3
4
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N
W
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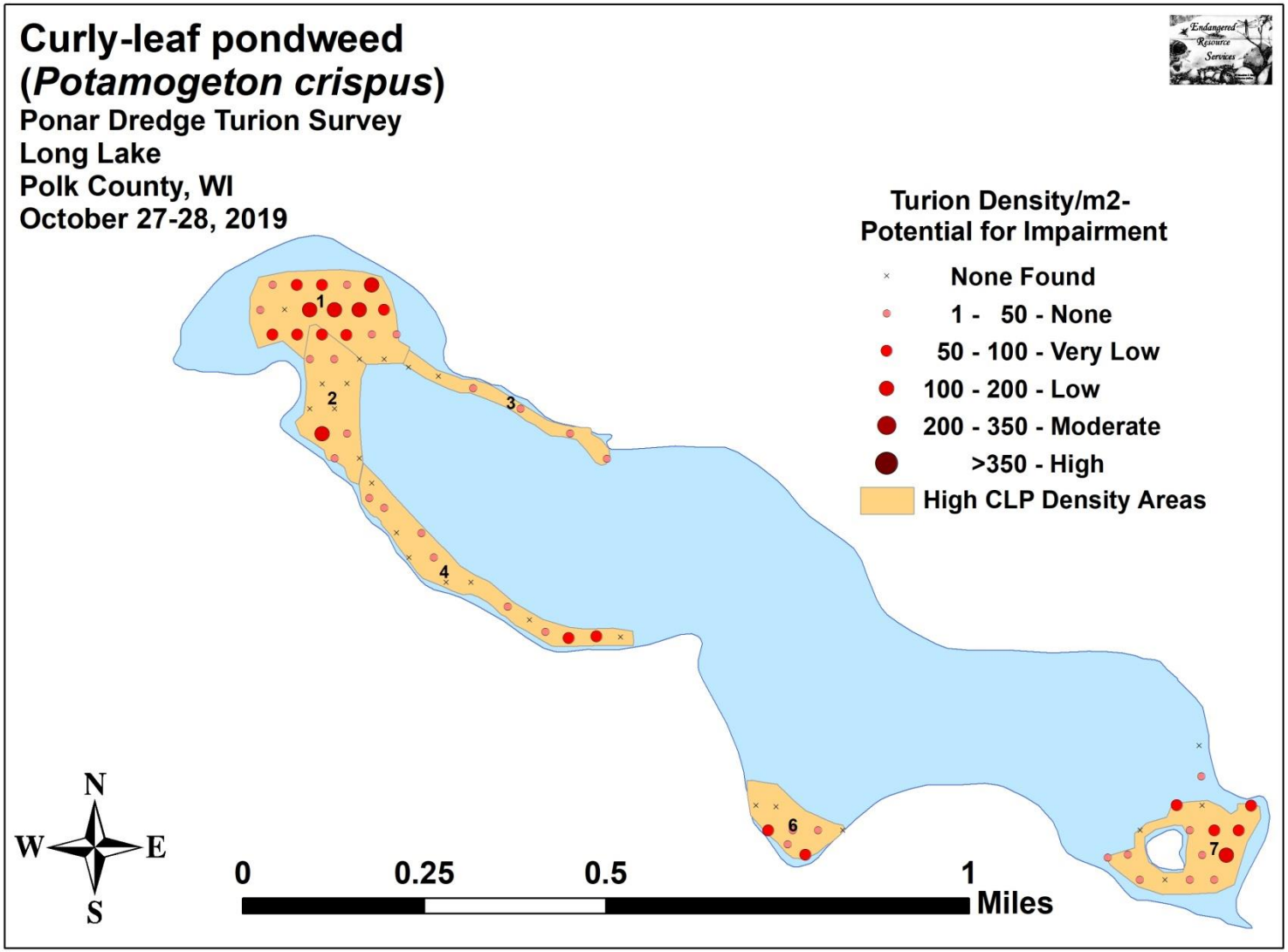
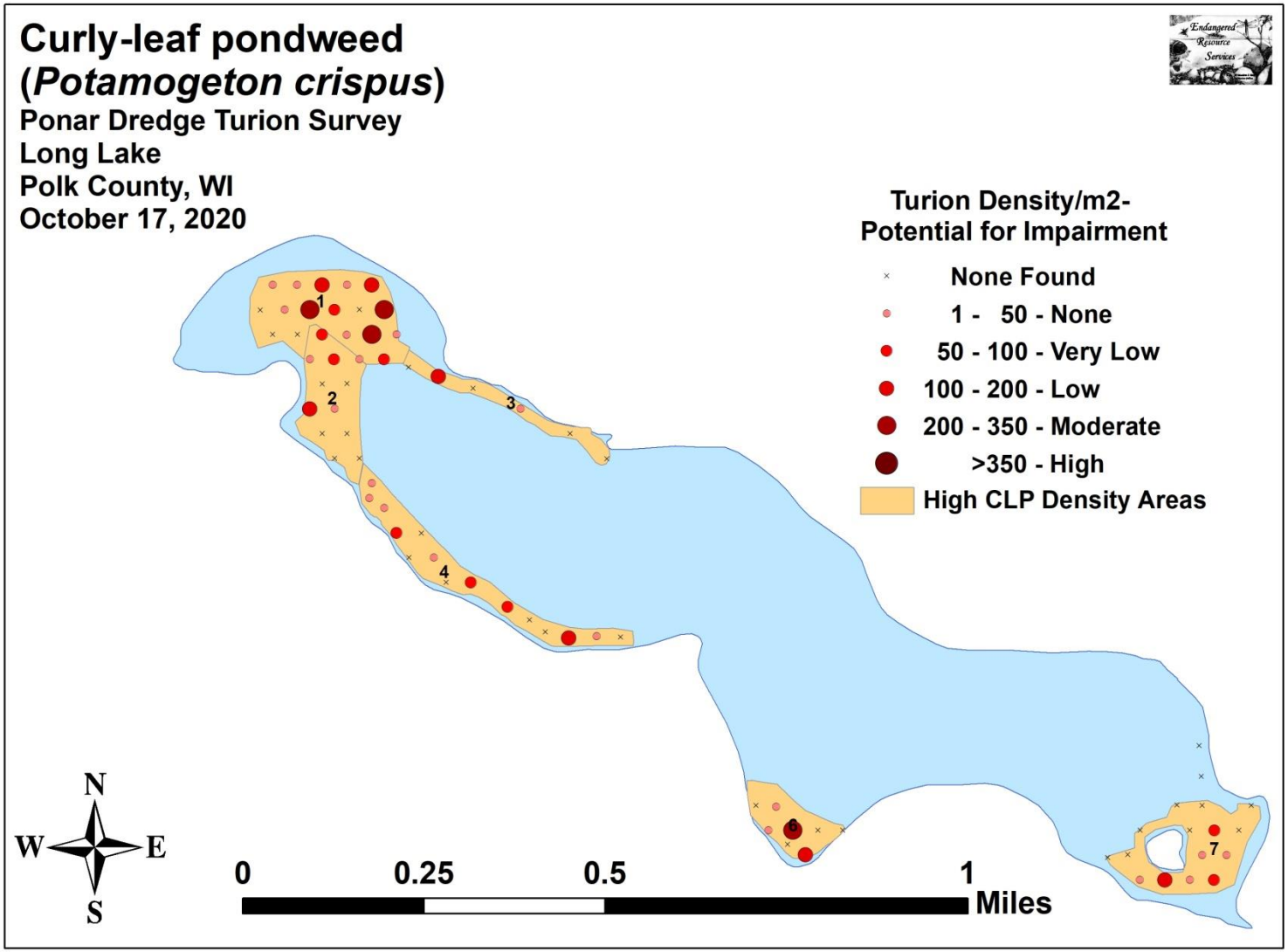
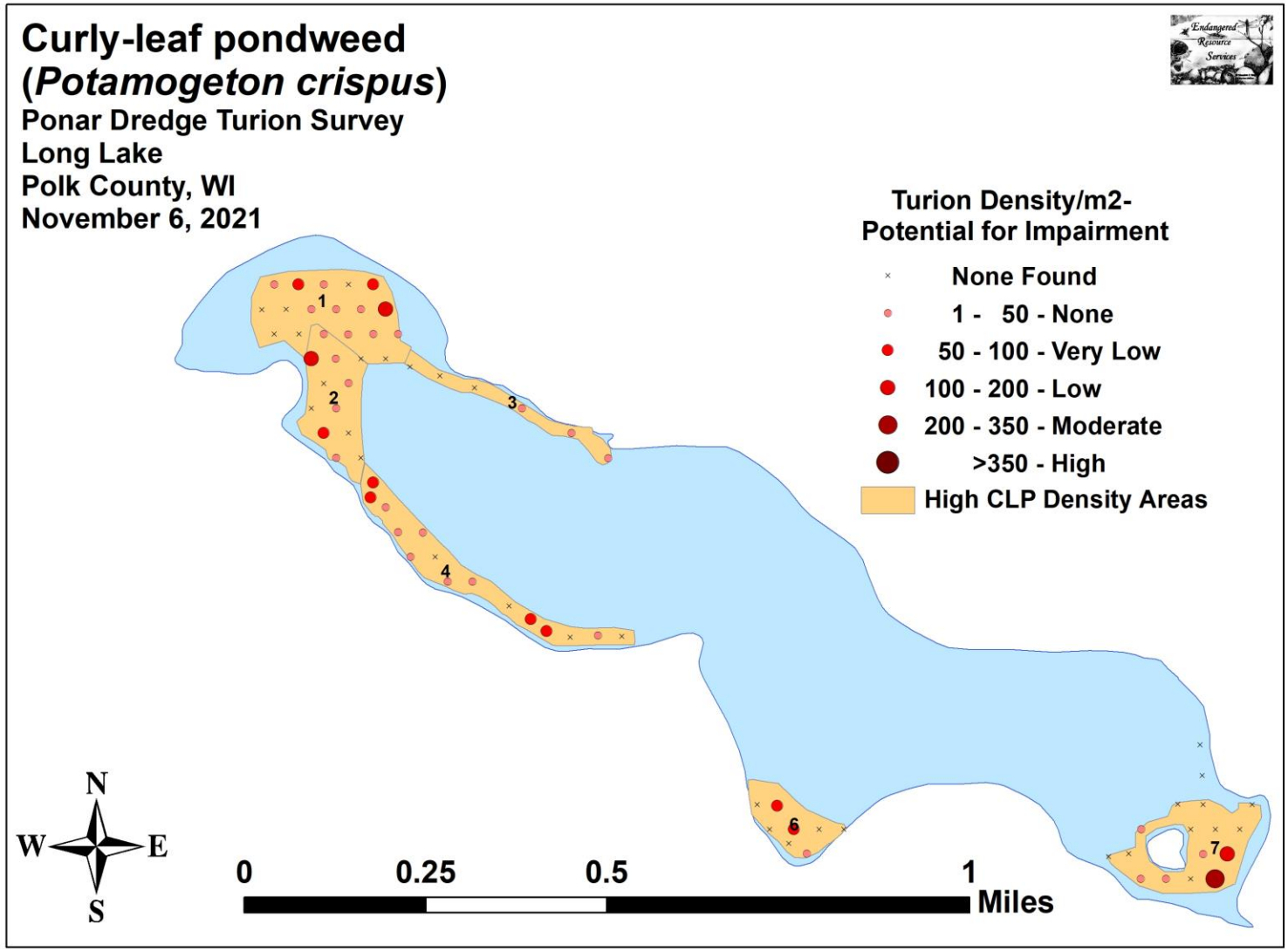
0.25
0.5
1
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
October 27-28, 2019
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
2
3
4
6
7
N
W
E
S
0
0.25
0.5
1
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
October 17, 2020
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
2
3
4
6
7
N
W
E
S
0
0.25
0.5
1
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Ponar Dredge Turion Survey
Long Lake
Polk County, WI
November 6, 2021
Endangered Resource Services
Turion Density/m2-
Potential for Impairment
None Found
1 - 50 - None
50 - 100 - Very Low
100 - 200 - Low
200 - 350 - Moderate
>350 - High
High CLP Density Areas
1
2
3
4
6
7
N
W
E
S
0
0.25
0.5
1
Miles