2021 Aquatic Vegetation Survey Results

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2021 AQUATIC VEGETATION SURVEY RESULTS
October 2021

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EXECUTIVE SUMMARY

Stantec Consulting Services (Stantec) surveyed the aquatic plant communities of eight lakes within the South Washington Watershed District (Washington Co., MN) in June and August 2021. Each lake was surveyed twice, once in June for an early season survey and again in August for a late season survey, except for Armstrong Lake which could not be sampled in August due to low water levels. Lake vegetation was sampled according to the methods outlined in Madsen (1999) and according to Minnesota Department of Natural Resources (DNR) protocols. In addition to aquatic plant community surveys, curly-leaf pondweed (CLP) was delineated in Ravine Lake and Eurasian watermilfoil (EWM) beds were delineated in Colby and Powers Lakes in June 2021. Delineations were done using rake throws and visually using DNR guidance.

Many of the District lakes were highly vegetated, with most littoral (<15 feet deep) points vegetated. The aquatic invasive species (AIS) curly-leaf pondweed and Eurasian watermilfoil are present in District lakes, and all lakes sampled had one or both species present. Armstrong Lake had the highest observed species richness (14) and Wilmes had the lowest (6). Spiny hornwort was the only rare species observed during the surveys; it was observed in La Lake during both the early and late season survey. AIS delineations showed large areas of EWM infestation in Colby and CLP in Ravine. Powers Lake had minimal areas of EWM growth and low frequency of occurrence of EWM during the 2021 point-intercept surveys.

1.0 METHODS

1.1 POINT-INTERCEPT SURVEYS

Stantec surveyed the aquatic plant communities in eight District lakes in June and August 2021. Each lake was surveyed using the point-intercept methods described in Madsen (1999) and survey points were determined from previous surveys conducted by Freshwater Scientific Services, LLC (2015 and 2018).

To assess the presence, abundance, and health of the lake's aquatic vegetation community, two point-intercept surveys were conducted: an early season (June) and a late season survey (August). During each point-intercept survey, all submerged, floating leaf, and emergent species were identified at each survey point. Early season surveys are primarily conducted to understand the presence and distribution of *Potamogeton crispus* (curly-leaf pondweed, CLP), an aquatic invasive species (AIS) with high spring growth and early senescence. Late season surveys target the greatest assessment of SAV (submerged aquatic vegetation) community, abundance, and spatial distribution because the community is ideally at peak diversity. Photos of field work are included in Appendix A.

GIS files of the point-intercept survey points used in the previous surveys performed by Freshwater Scientific Services were supplied by the District and served as predetermined sampling locations for each lake. These points were originally developed by overlaying a grid across the entire lake according to the point-intercept methods mentioned previously (Madsen 1999). Thus, the sampling protocol and reporting of each lake is similar and allows comparisons to be made across systems and between years.

At each survey location a double-sided, weighted 14-tine rake was thrown from the boat, allowed to sink, and pulled across the lake bottom to represent approximately 1 square meter of lake area. We refer to this process as a rake toss. For each rake toss, vegetation is removed from the rake, identified to the species level, placed in a perforated bucket, weighed, and assigned a proportion of the total biomass based on visual approximation (i.e., 80% of total weight was CLP and 20% of total weight was coontail). All biomass values are reported in wet weights (kg). Emergent plant species, lily species, duckweed species, and filamentous algae are not included in any biomass measurements due to difficulty in collecting a representative sample with the sample rake, however, their presence (P) and location are still recorded.

Continuous sonar readings were also collected during each survey trip using a Lowrance Elite 7 Sonar/GPS unit. This data was processed using CiBioBase (BioBase) software (https://www.cibiobase.com/) that allows for mapping water depth, bottom hardness, and plant biovolume. Biovolume differs from biomass in that it provides context to vegetation water column saturation. The higher the biovolume the more saturated the water column is with vegetation. Sonar readings in depths <2 feet are subject to extreme 'sonar noise' and therefore are not always accurate. Sonar readings do not detect surface floating vegetation (i.e., pad of Lily species, duckweed). BioBase interpolates sonar readings between boat tracks to estimate biovolume. Variation in boat tracks during surveys sometimes

results in areas where biovolume cannot be estimated because boat tracks were not dense enough. There are a few cases of missing biovolume estimates in this report described in the results.

Table 1-1. An early-season and late-season point-intercept survey was done on each lake on the following dates:

Lake	Early-season survey	Late-season survey
Armstrong[1]	6/10/2021	--
Bailey	6/8/2021	8/4/2021
Colby	6/22/2021	8/9/2021
La	6/9/2021	8/5/2021
Markgrafs	6/3/2021	8/2/2021
Powers	6/7/2021	8/2/2021
Ravine	6/4/2021	8/3/2021
Wilmes	6/7/2021	8/3/2021

[1]Armstrong Lake was not surveyed in August due to issues accessing the lake and low or no water present across much of the basin.

1.1.1 SAV Community Indices

Point-intercept survey data can be used to calculate various survey metrics and indices to assess the health of the SAV community and easily compare across survey years and lakes. The metrics total point sampled during the survey, total littoral (<15 feet deep) points sampled, percent of littoral points with vegetation, maximum depth of plant growth, and species richness (i.e., the number of species observed) were calculated for each lake. In addition, the key indices used to assess the SAV survey results in this study and previous studies were Floristic Quality Index (FQI), biomass estimates, Simpson's Diversity Index (Simpson's *D*), and Aquatic Macrophyte Community Index (AMCI).

Floristic Quality Index (FQI)

The FQI is an assessment tool used to determine the biological health of the SAV community. The FQI uses species richness and the habitat specificity (C-score) of each species identified to score community health (Equation 1). C-score is an index of how desirable a particular species is and how tolerant it is to stressors. Minnesota Department of Natural Resources (DNR) standard C-scores range from 1 to 10 with 1 being the least desirable and most tolerant to stressors, and 10 being the most desirable and least tolerant to stressors.

Equation 1. Definition of the DNR's Floristic Quality Index (FQI).

$$FQI = \overline{C_{Score}} * \sqrt{No.of\ Species}$$

Lakes with higher FQI scores and taxa richness are typically comprised of diverse, native communities with abundant plant growth across the entire littoral area. As stressors to the SAV community increase, we typically see reduced species diversity, introduction of invasive species, more monodominant stands of vegetation, and decreased late-season SAV abundance and density within the littoral area. Extremely degraded lakes become void of plant growth and become dominated by algae, which can sometimes be harmful during blooms.

The DNR developed thresholds for FQI and species richness to assess the health of lake vegetation communities and compare communities across lakes (Radomski and Perleberg 2012). Thresholds for deep and shallow lakes in the Central Hardwood Forest and Western Corn Belt Plains ecoregions are presented in Table 1-2. All surveyed lakes are in the Central Hardwood Forest ecoregion, except for Ravine Lake which is in the Western Corn Belt Plains ecoregion.

Table 1-2. FQI and species richness thresholds for deep and shallow lakes in the Central Hardwood Forest ecoregion.

		FQI threshold	Species Richness Threshold
North Central Hardwood Forest	Deep lakes	18.6	12
	Shallow lakes	17.8	11
Western Corn Belt Plains	Deep lakes	8.0	5
	Shallow lakes	7.7	4

Vegetation Biomass

We developed a model to estimate the total SAV biomass within the lake. Depth was stratified into four intervals (0-5, 5-10, 10-15, >15 feet) to more accurately account for spatial variation in vegetation growth and improve model accuracy. For each species we calculate a depth interval specific FQI, an average rake toss biomass, and a depth interval lake area. Multiplying these three parameters results in a species-specific total biomass/depth interval. All species-specific depth interval biomasses are then summed within each depth interval to calculate depth-specific biomasses and all depth intervals are summed to calculate a total lake biomass (Equation 2). The total lake biomass estimation uses the individual surveyed data point information to extrapolate coverage estimates across the entire basin. This is not meant to serve as an exact biomass calculation, rather, this estimate is useful to 1) make relative comparisons to other observed species, 2) be used to compare to future sampling efforts, and 3) provide general information to assist aquatic vegetation management planning.

Equation 2. Definition of total in-lake submersed aquatic vegetation biomass.

$$Total\ Lake\ Biomass = \sum ([Depth\ Interval]\ (Species\ Biomass * Species\ \%\ Occurence * Basin\ Area))$$

Biomass data were collected for this study; however, the data are not presented in this report. Biomass data will be kept for use with future management efforts.

Simpson's Diversity Index

Data collected during the point-intercept surveys was used to calculate the Simpson's Diversity Index (Simpson's D) (Simpson 1949). Simpson's D is a measure of community diversity that accounts for the relative abundance of each species rather than just the community composition. This index is useful in assessing communities that have a high abundance of only a few species and low abundance of other species, giving more weight to more abundant species. The index ranges from 0–100 with 100 representing high diversity and even abundance across species and 0 representing low diversity and disproportionate abundance.

Equation 3. Simpson's Diversity index.

$$D = 1 - \left(\frac{\sum n\,(n-1)}{N\,(N-1)}\right) * 100$$

n = the total number of organisms of a particular species

N = the total number of organisms of all species

Aquatic Macrophyte Community Index (AMCI)

The Aquatic Macrophyte Community Index (AMCI) is a metric used to assess the biological quality of lake aquatic plant communities (Nichols et al. 2000). The AMCI combines maximum depth of plant growth, percent of littoral zone vegetated, Simpson's D, the relative frequencies of submersed, sensitive, and exotic species, and taxa number. AMCI ranges from 0-70, with higher values representing higher quality plant communities. The AMCI was calculated for each point-intercept survey using the methods described by Nichols et al. (2000).

1.2 INVASIVE SPECIES DELINEATIONS

Stantec completed delineations of Eurasian watermilfoil (EWM) on Colby and Powers and CLP on Ravine following standard DNR methods. Delineations were conducted by running boat transects in the littoral zones of the lake. Both visual observations and periodic rake throws were conducted to determine the presence or absence or the targeted AIS species. When AIS species are detected, additional visual observations and rake throws are deployed in the area of infestation to determine density of AIS and extent of boundary. Once a boundary is determined a polygon is traced around the border of the infested area and mapped in GIS. The delineated areas of infestation are not presented as recommended treatment areas as they do not follow the DNR's guidance for maximum allowed treatment area (15% of the littoral area), thus if full treatment of these areas was pursued a Lake Vegetation Management Plan approved by the DNR would be required.

1.3 EURASIAN WATERMILFOIL GENETIC SAMPLING

EWM has the ability to hybridize with the native northern watermilfoil (5-10 pairs of leaflets). Hybrids (8-18 pairs of leaflets) are difficult to distinguish from EWM (12-20 pairs of leaflets), and as a result, lakes that are infested with EWM may be composed of "pure" EWM, hybrids, or both (Newman and Thum 2019). Recent studies show that some genotypes of hybrid are resistant to specific herbicides, and some may be more invasive. Stantec collected watermilfoil samples from Colby and Powers Lake to assess the magnitude and extent of EWM and northern watermilfoil hybridization. Fifty-two samples were collected from Colby Lake and 23 samples were collected from Powers Lake on June 23rd, 2021. Samples were collected using a double-sided, weighted 14-tine rake or by hand where milfoil was growing to the surface.

Upon obtaining each EWM specimen, the sample was thoroughly inspected by Stantec staff for meristems and those with no visible meristems were discarded. Each sample was then further processed by cutting 5–6-inch apical sections from the plant that included meristem tissue. Algae and other debris were removed from the sample by gently agitating the sample under water. Each sample was then gently dried using a paper towel and placed in a 3.125-inch by 5.5-inch paper envelope. Each envelope was sealed, labeled, and placed in a labeled 1-quart heavy duty zipper freezer bag. Approximately 30 grams of silica beads were added to each freezer bag and excess air was removed before each bag was sealed. The freezer bags containing the samples were stored in a 12-gallon watertight cooler with approximately one inch of silica beads covering the bottom. The cooler was shipped via FedEx to the Thum Lab at Montana State University in Bozeman, Montana.

At the Thum Lab, the samples were genotyped via eight microsatellite loci developed by Wu et al. (2013) (Myrsp 1, Myrsp 5, Myrsp 9, Myrsp 12, Myrsp 13, Myrsp 14, Myrsp 15, and Myrsp 16). Distinct genotypes were delineated using genetic distance calculations appropriate for polyploids (EWM and northern watermilfoil are hexaploids). Each genotype identified in this study was cross-referenced with those identified in other studies.

Laboratory results of the milfoil genetic sampling are presented in Appendix B.

2.0 SURVEY RESULTS

2.1 ARMSTRONG LAKE

Armstrong Lake (Public Water No. 82-0116-00) is 29-acre shallow lake (maximum observed depth of 3.8 feet during June 2021 survey) within the cities of Lake Elmo and Oakdale, MN. Armstrong acts as the headwaters of a multi-lake system; it outlets to multiple small wetlands and eventually to North Wilmes Lake. Armstrong Lake's watershed is 563 acres, with 191 acres of impervious surface from residential and commercial land use.

Average total phosphorus (TP) concentration in Armstrong is 70 ug/L, exceeding the shallow lake standard for the North Central Hardwood Forest ecoregion (60 ug/L). Average Secchi depth is 0.7 meters, below the State standard of 1.0 meter.

Below are two tables outlining species observed during 2015, 2018, and 2021 surveys, and metrics and indices for each survey. The shallowness of the lake prevented accurate BioBase sonar readings and biovolume estimates. The BioBase map is not included for Armstrong Lake. Nearly the entirety of the lake edge is covered with dense cattail stands followed by a dense mix of both white and yellow water lilies. During the spring survey when lake water levels were accessible the entire lake surface was covered in coontail and other submerged vegetation, making lake navigation difficult. The shallowness of the lake and dropping lake levels due to the summer drought made the lake inaccessible for a late season August survey, thus only 2015, 2018, and June 2021 surveys are reported. A map showing the number of taxa observed at each survey point (**Figure 2-1**) and a map of locations and density of CLP (**Figure 2-2**) are provided. CLP is the only AIS observed in Armstrong Lake. Coontail, a native, but sometimes nuisance aquatic plant has been abundant in the lake during all surveys.

Table 2-1. Armstrong Lake plant taxa and littoral frequency of occurrence from 2015, 2018, and 2021 surveys.

Taxa	Common Name	August 3rd, 2015 (Freshwater Scientific)	August 3rd, 2018 (Freshwater Scientific)	June 10th, 2021 (Stantec)[1]
SUBMERSED TAXA				
Ceratophyllum demersum	Coontail	100	98	94
Potamogeton zosteriformis	Flat-stem pondweed	52	71	42
Najas flexilis	Slender naiad	16	14	2
Potamogeton pusillus	Small pondweed	12	--	--
Elodea canadensis	Canadian waterweed	10	12	6
Potamogeton friesii	Fries' pondweed	2	12	
Stuckenia pectinata	Sago pondweed	2	4	--
Potamogeton crispus	Curly-leaf pondweed	--	--	6

Taxa	Common Name	August 3rd, 2015 (Freshwater Scientific)	August 3rd, 2018 (Freshwater Scientific)	June 10th, 2021 (Stantec)[1]
Potamogeton strictfolius	Straight-leaved pondweed	--	6	68
FLOATING TAXA				
Lemna trisulca	Star duckweed	66	88	84
Nymphaea odorata	White waterlily	44	63	56
Lemna minor	Small duckweed	38	57	90
Spirodela polyrhiza	Large duckweed	26	43	86
Wolffia columbiana	Common watermeal	16	18	18
Nuphar variegata	Spatterdock	8	8	18
Riccia sp.	Riccia	2	--	--
Polygonum amphibium	Water smartweed	P	--	--
Riccia fluitans	Crystalwort	--	18	--
EMERGENT TAXA				
Typha sp.	Cattail	6	31	P
Sagittaria sp.	Arrowhead	2	--	--
Lythrum salicaria	Purple loosestrife	P	P	P
Schoenoplectus acutus	Hardstem bulrush	P	--	--
Schoenoplectus fluviatilis	River bulrush	P	--	--
Sagittaria latifolia	Common arrowhead	--	2	--

[1]No late summer point-intercept survey was completed for Armstrong Lake due to shallow lake levels

Table 2-2. Armstrong Lake SAV metrics and indices.

	August 3rd, 2015 (Freshwater Scientific)	August 3rd, 2018 (Freshwater Scientific)	June 10th, 2021 (Stantec)[1]
LAKEWIDE METRICS			
Total Points Sampled	50	50	50
Total Littoral Points Sampled	50	50	50
% Littoral with Veg	100	100	100
Max depth of plant growth (ft)	4.3	4.3	3.8
Shallow Lake Species Richness Threshold	11		
Species Richness	20	17	14
COMMUNITY INDICES			
Shallow Lake FQI Threshold	*17.8*		
Floristic Quality Index (FQI)	20.8	17.7	18.2

	August 3rd, 2015 (Freshwater Scientific)	**August 3rd, 2018 (Freshwater Scientific)**	**June 10th, 2021 (Stantec)[1]**
Simpson's Diversity Index	86.0	88.7	87.5
Aquatic Macrophyte Community Index (AMCI)	48	41	40

[1] No late summer point-intercept survey was completed for Armstrong Lake due to shallow lake levels

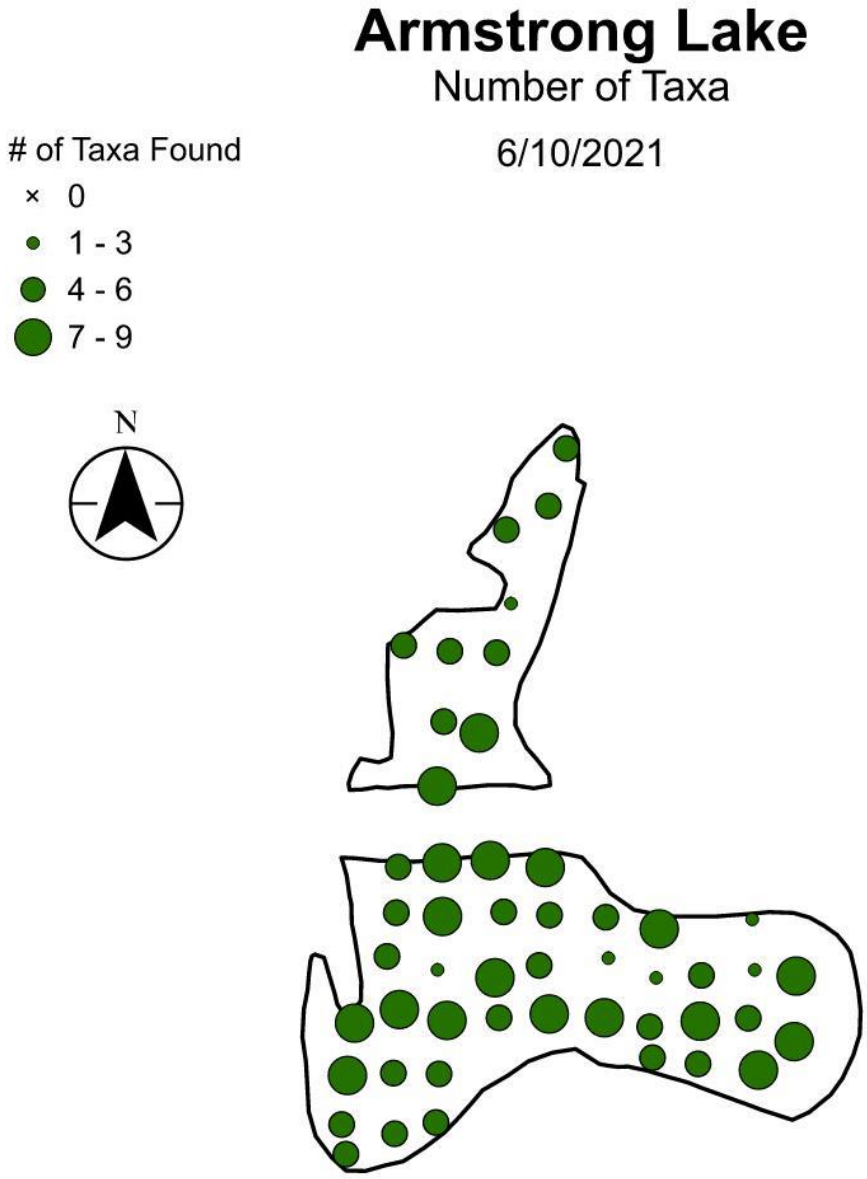

Figure 2-1: Map of the number of taxa found in Armstrong Lake.

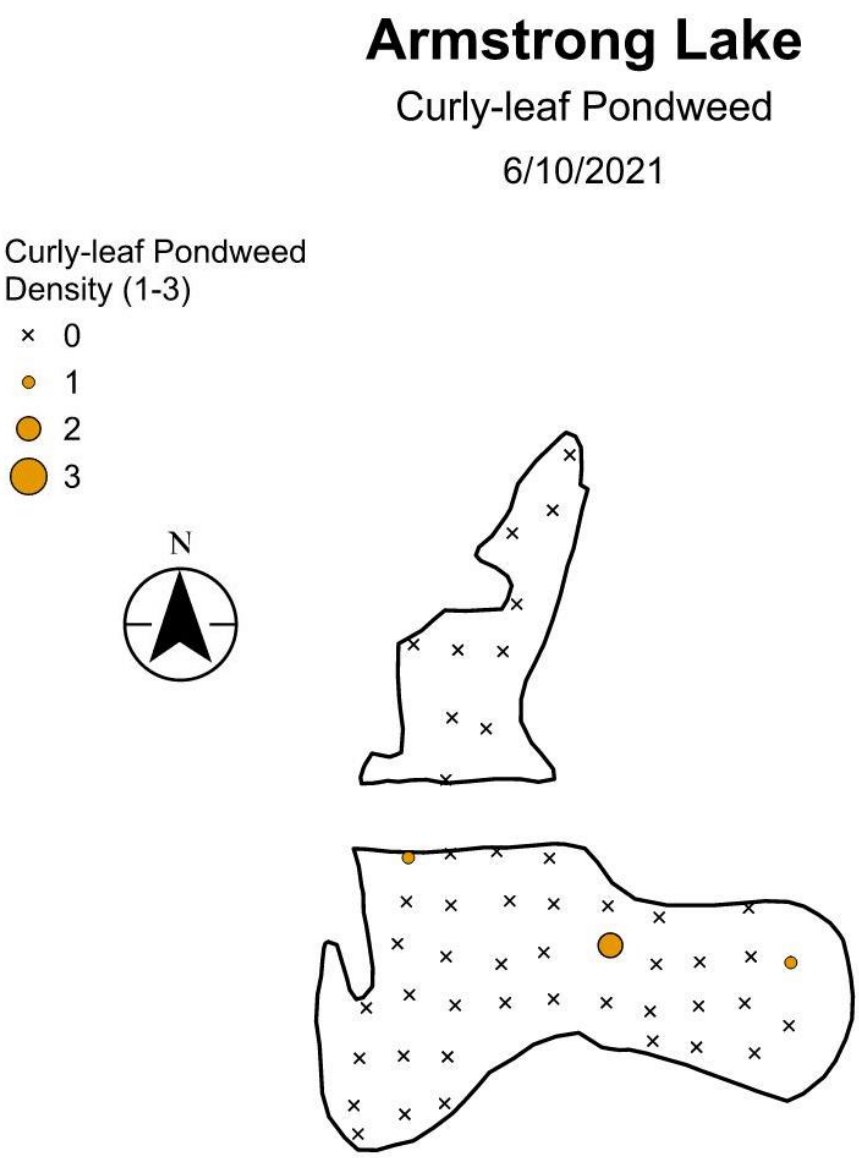

Figure 2-2: Map of the location and density of Curly-leaf Pondweed in Armstrong Lake.

2.2 BAILEY LAKE

Bailey Lake (Public Water No. 82-0456-00) is a 61-acre lake near Woodbury, MN. Bailey drains approximately 18,430 acres. Bailey Lake is a shallow lake with a maximum observed depth of 19 feet during the 2021 surveys.

Bailey Lake was not previously surveyed by Freshwater Scientific Services in 2015 or 2018, thus only 2021 survey data are included for Bailey in this report. Below are two tables outlining survey results and associated metrics and indices. Maps include early and late-season BioBase maps of vegetation biovolume (**Figure 2-3: Early and late-season BioBase maps of vegetation biovolume in Bailey Lake.Figure 2-3**), number of taxa (**Figure 2-4**), CLP location and density (**Figure 2-5**), and EWM location and density maps (**Figure 2-6**). CLP and EWM are both present in the lake.

Table 2-3. Bailey Lake plant taxa and littoral frequency of occurrence from 2021 surveys. No surveys previous to 2021 have been conducted.

Taxa	Common Name	June 8th, 2021 (Stantec)	August 4th, 2021 (Stantec)
SUBMERSED TAXA			
Potamogeton crispus	Curly-leaf pondweed	70	11
Ceratophyllum demersum	Coontail	40	64
Potamogeton pusillus	Small pondweed	28	14
Stuckenia pectinata	Sago pondweed	21	7
Elodea canadensis	Canadian waterweed	14	21
Myriophyllum spicatum	Eurasian watermilfoil	7	11
Chara sp.	Muskgrass	2	9
Potamogeton zosteriformis	Flat-stem pondweed	--	2
Najas flexilis	Slender naiad	--	--
FLOATING TAXA			
Lemna minor	Small duckweed	9	7
Spirodela polyrhiza	Large duckweed	4	5
EMERGENT TAXA			
Phragmites australis	Reed grass (common)	2	2
Shoenoplectus tabernaemontani	Soft-stem bulrush	2	2
Typha sp.	Cattail	P	P

Table 2-4. Bailey Lake SAV metrics.

	June 8th, 2021 (Stantec)	August 4th, 2021 (Stantec)
LAKEWIDE METRICS		
Total Points Sampled	62	60
Total Littoral Points Sampled	57	56
% Littoral with Veg	84.2	67.9
Max depth of plant growth (ft)	11.8	7.2
Shallow Lake Species Richness Threshold	*11*	
Species Richness	12	12
COMMUNITY INDICES		
Shallow Lake Floristic Quality Index (FQI) Threshold	*17.8*	
FQI	13.3	14.4
Simpson's Diversity Index	80.0	79.2
Aquatic Macrophyte Community Index (AMCI)	38	39

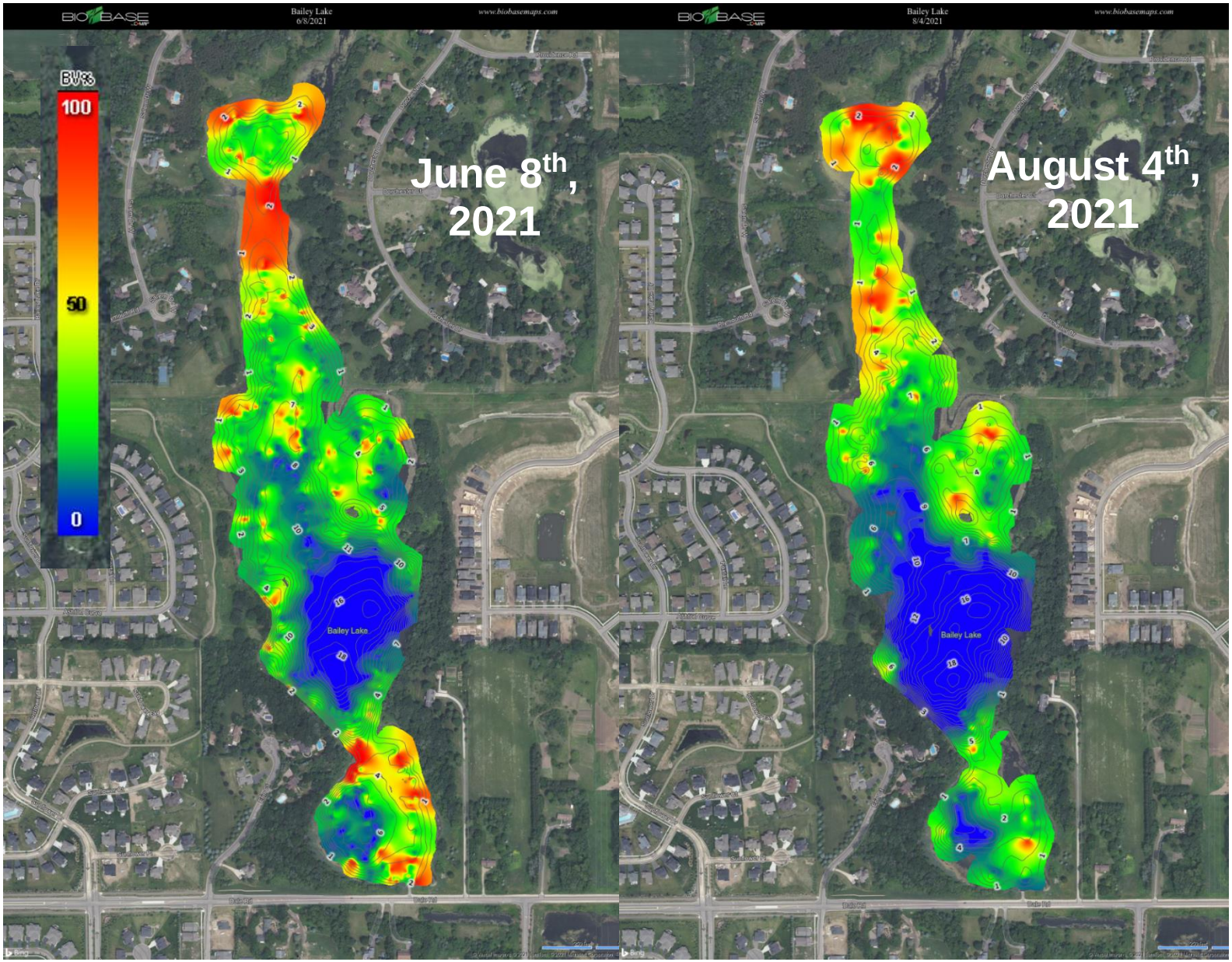

Figure 2-3: Early and late-season BioBase maps of vegetation biovolume in Bailey Lake.

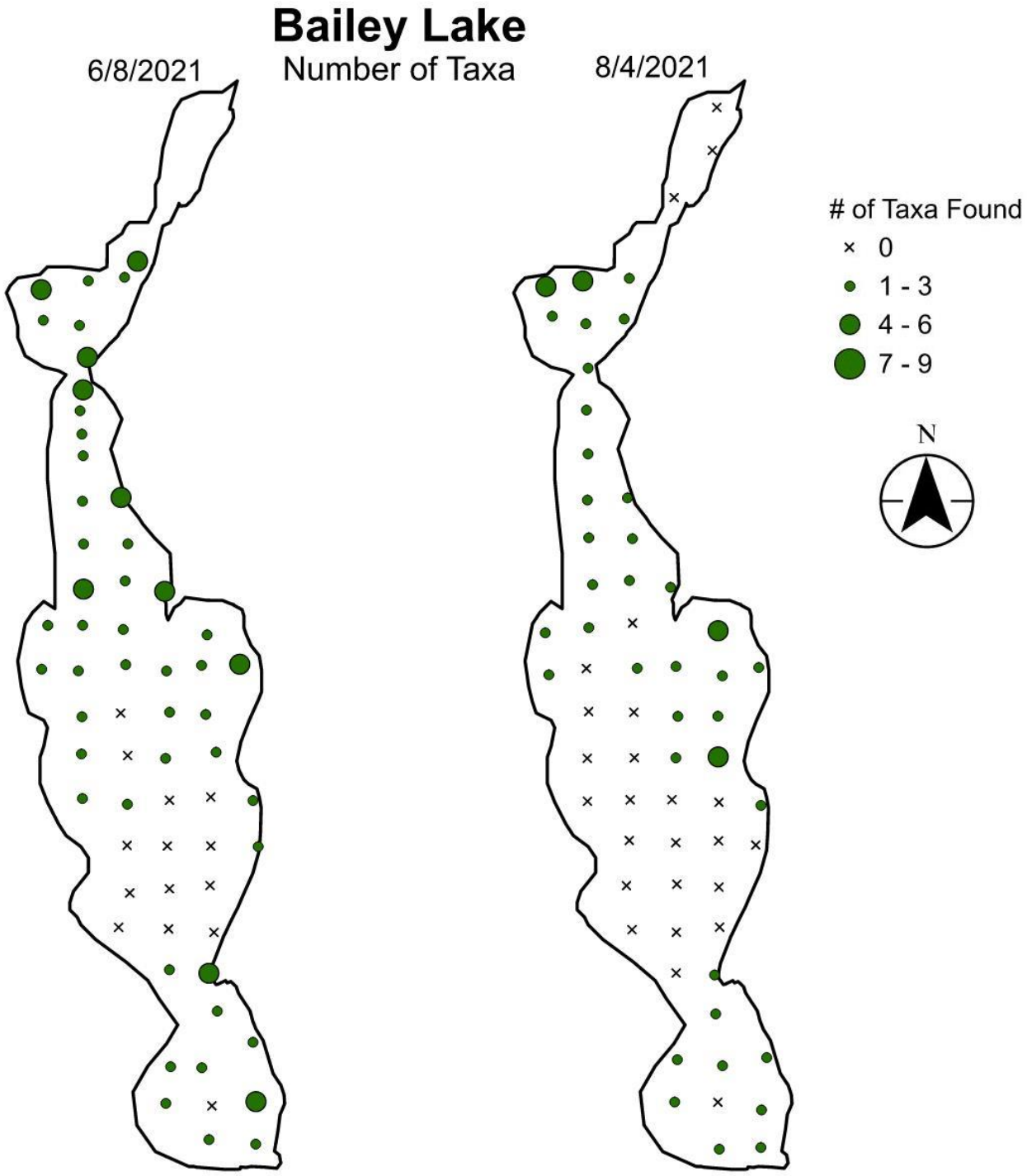

Figure 2-4: Map of the number of taxa found in Bailey Lake.

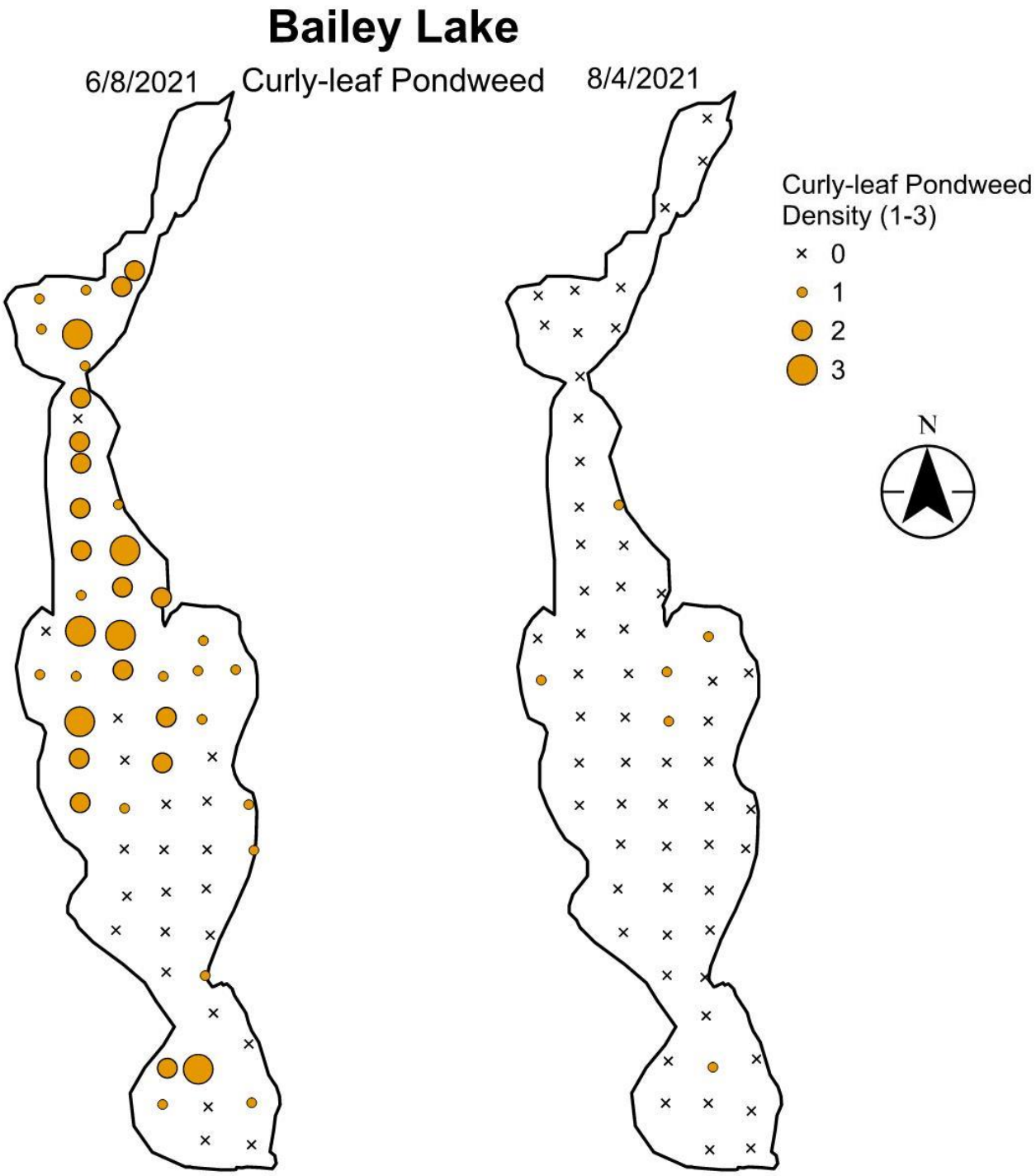

Figure 2-5: Map of the location and density of Curly-leaf Pondweed in Bailey Lake.

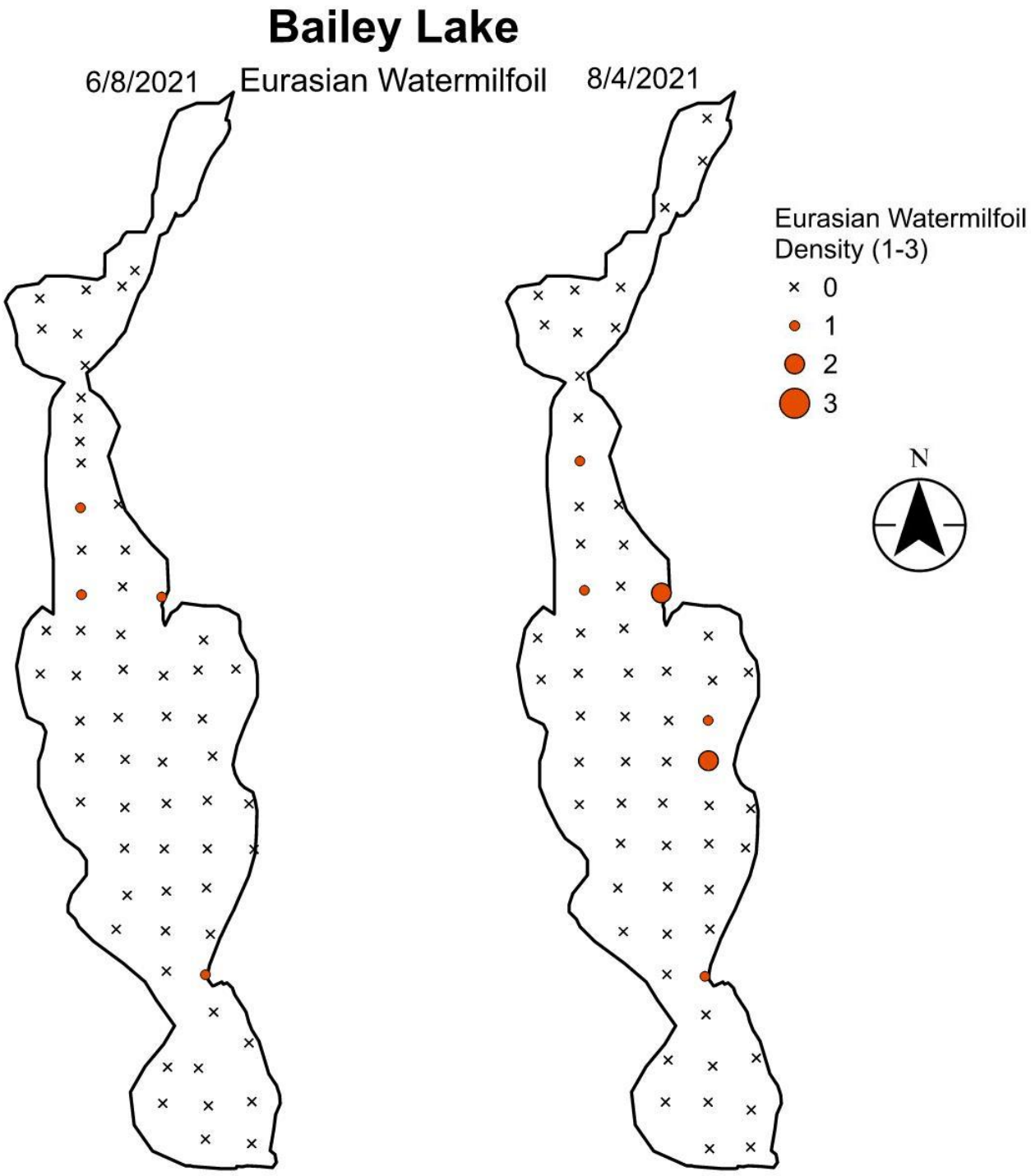

Figure 2-6: Map of the location and density of Eurasian Watermilfoil in Bailey Lake.

2.3 COLBY LAKE

Colby Lake (Public Water No. 82-0094-00) is a 69-acre, shallow lake with a max depth of 9 feet. Colby receives contributions from South Wilmes and its 2,924 direct drainage area, of which 1,075 acres are impervious. During the early season surveys multiple dense mats of CLP were present throughout the central and southern portion of the lake limiting lake navigability and recreational opportunities.

Average TP concentration in Colby is 156 ug/L, exceeding the shallow lake standard for the North Central Hardwood Forest ecoregion (60 ug/L). Average Secchi depth is 0.6 meters, below the State standard of 1.0 meter.

Below are two tables outlining survey results and associated metrics and indices, as well as vegetation biovolume, taxa, CLP density, and EWM density maps for both the early and late-season surveys (Figure 2-7,Figure **2-8**,Figure **2-9**, Figure 2-10, respectively). Boat tracks during the June 22nd survey prevented BioBase from calculating biovolume for a section in the middle of Colby Lake (Figure 2-7). CLP and EWM are both present in the lake. See Section 3 for the EWM delineation areas.

Table 2-5. Colby Lake plant taxa and littoral frequency of occurrence from 2015, 2018, and 2021 surveys.

Taxa	Common Name	August 5th, 2015 (Freshwater Scientific)	August 6th, 2018 (Freshwater Scientific)	June 22nd, 2021 (Stantec)	August 9th, 2021 (Stantec)
SUBMERSED TAXA					
Elodea canadensis	Canadian waterweed	88	19	13	10
Potamogeton zosteriformis	Flat-stem pondweed	44	--	--	--
Ceratophyllum demersum	Coontail	31	56	66	82
Potamogeton foliosis	Leafy pondweed	5	--	--	--
Potamogeton nodosus	Long-leaf pondweed	5	1	--	--
Potamogeton pusillus	Small pondweed	5	4	--	--
Najas flexilis	Slender naiad	1	3	1	
Myriophyllum spicatum	Eurasian watermilfoil	P	24	40	29
Potamogeton crispus	Curly-leaf pondweed	P	6	89	P
Potamogeton zosteriformis	Flat-stem pondweed	--	6	1	1
Potamogeton sp.	Narrowleaf species	--	--	4	--
FLOATING TAXA					
Lemna minor	Small duckweed	20	11	25	42
Wolffia sp.	Watermeal	15	5	5	45
Polygonum amphibium	Water smartweed	8	--	--	P
Spirodela polyrhiza	Large duckweed	1	8	28	44
	Filamentous algae	--	--	P	P

Taxa	Common Name	August 5th, 2015 (Freshwater Scientific)	August 6th, 2018 (Freshwater Scientific)	June 22nd, 2021 (Stantec)	August 9th, 2021 (Stantec)
EMERGENT TAXA					
Typha sp.	Cattail	1	P	P	P
Sagittaria sp.	Arrowhead	P	P	--	--
Schoenoplectus acutus	Hardstem bulrush	P	P	--	--

Table 2-6. Colby Lake SAV metrics

	August 5th, 2015 (Freshwater Scientific)	August 6th, 2018 (Freshwater Scientific)	June 22nd, 2021 (Stantec)	August 9th, 2021 (Stantec)
LAKEWIDE METRICS				
Total Points Sampled	82	82	80	82
Total Littoral Points Sampled	80	80	80	82
% Littoral with Veg	100	86	99	82
Max depth of plant growth (ft)	7.9	7.2	9.2	9.9
Shallow Lake Species Richness Threshold	*11*			
Species Richness	16	14	10	9
COMMUNITY INDICES				
Shallow Lake Floristic Quality Index (FQI) Threshold	17.8			
FQI	17.0	13.9	15.2	13.3
Simpson's Diversity Index	77.0	78.0	78.6	74.8
Aquatic Macrophyte Community Index (AMCI)	47	34	38	33

Figure 2-7: Early and late-season BioBase maps of vegetation biovolume in Colby Lake.

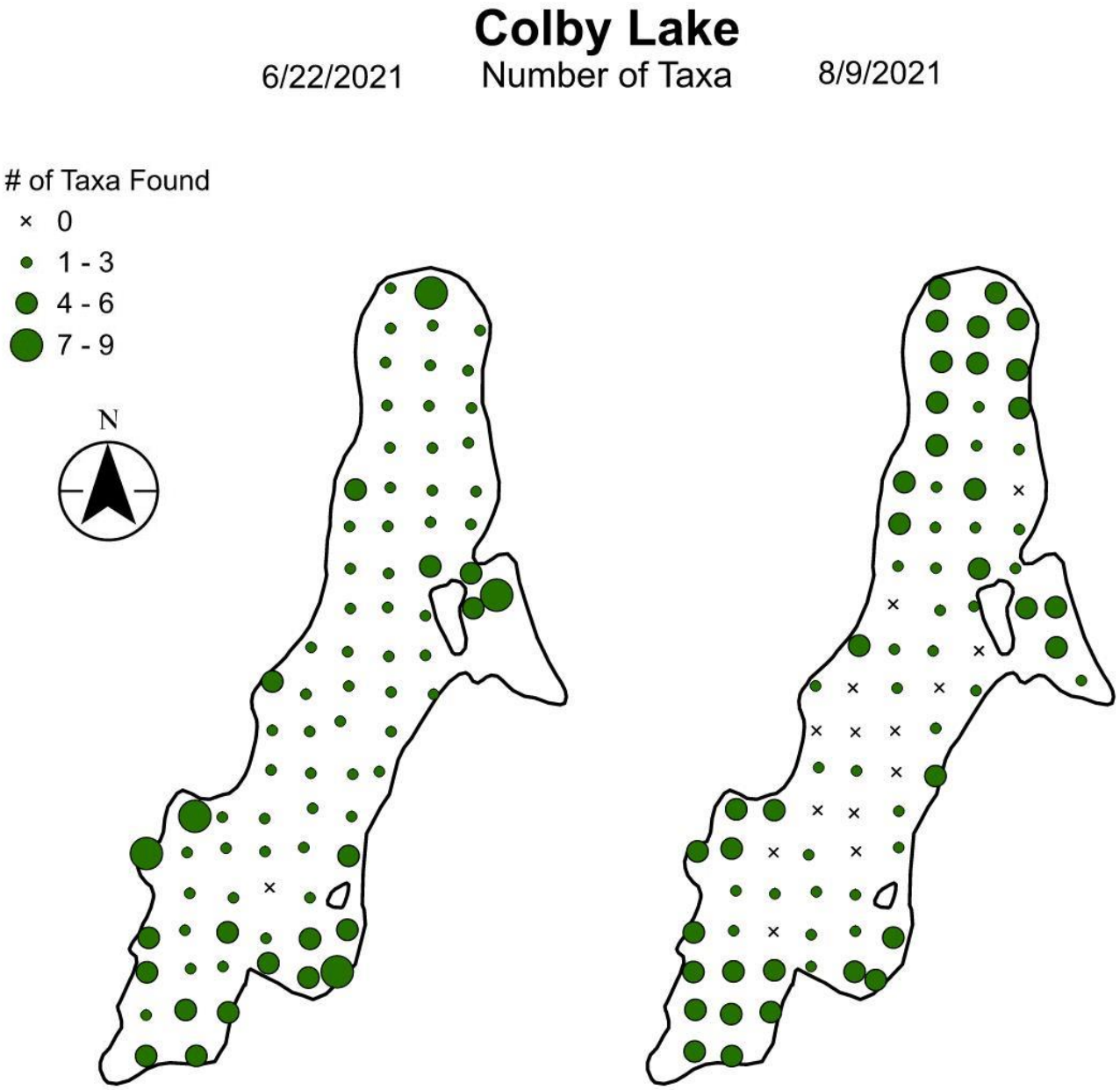

Figure 2-8: Map of the number of taxa found in Colby Lake.

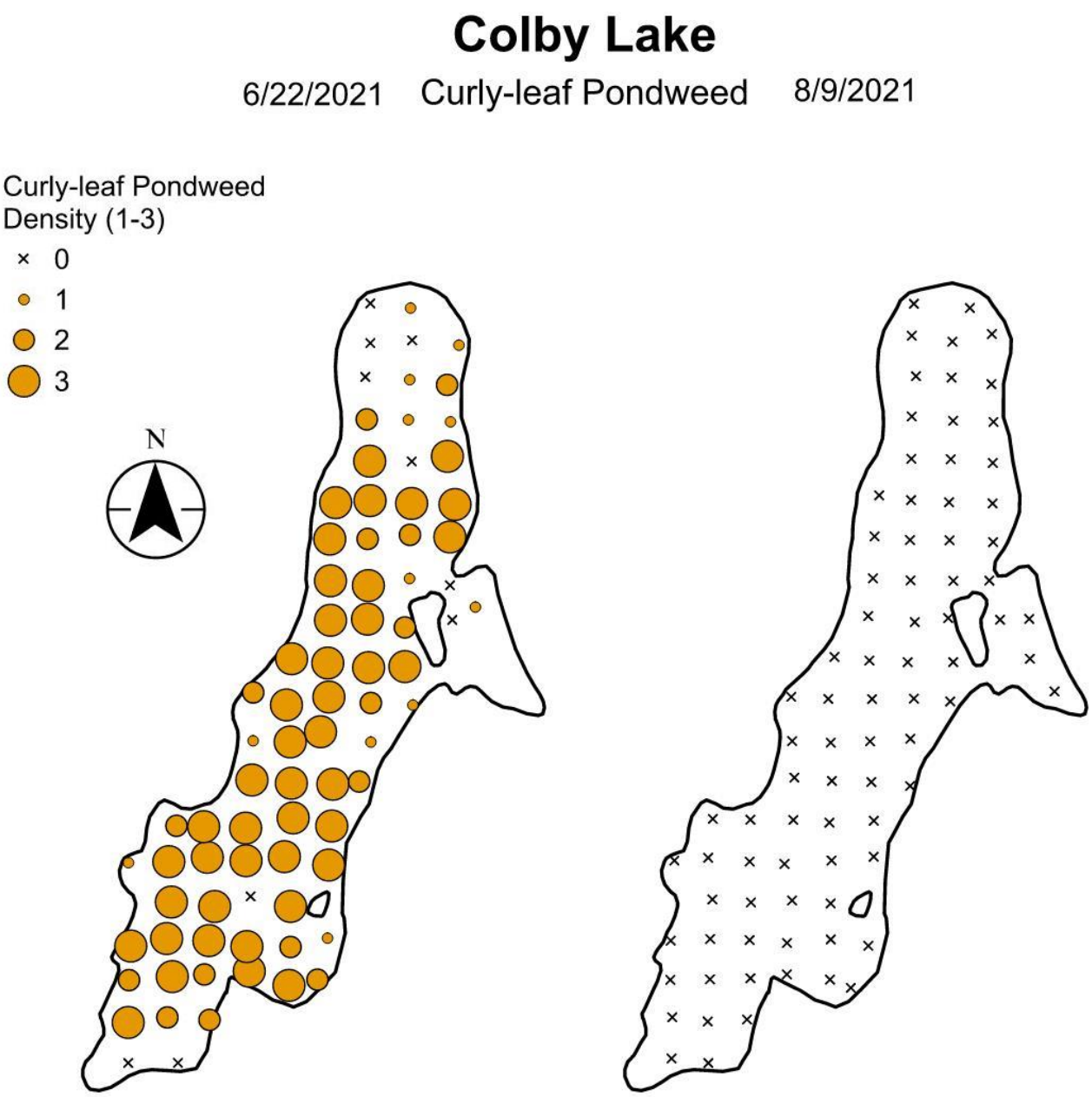

Figure 2-9: Map of the location and density of Curly-leaf Pondweed in Colby Lake.

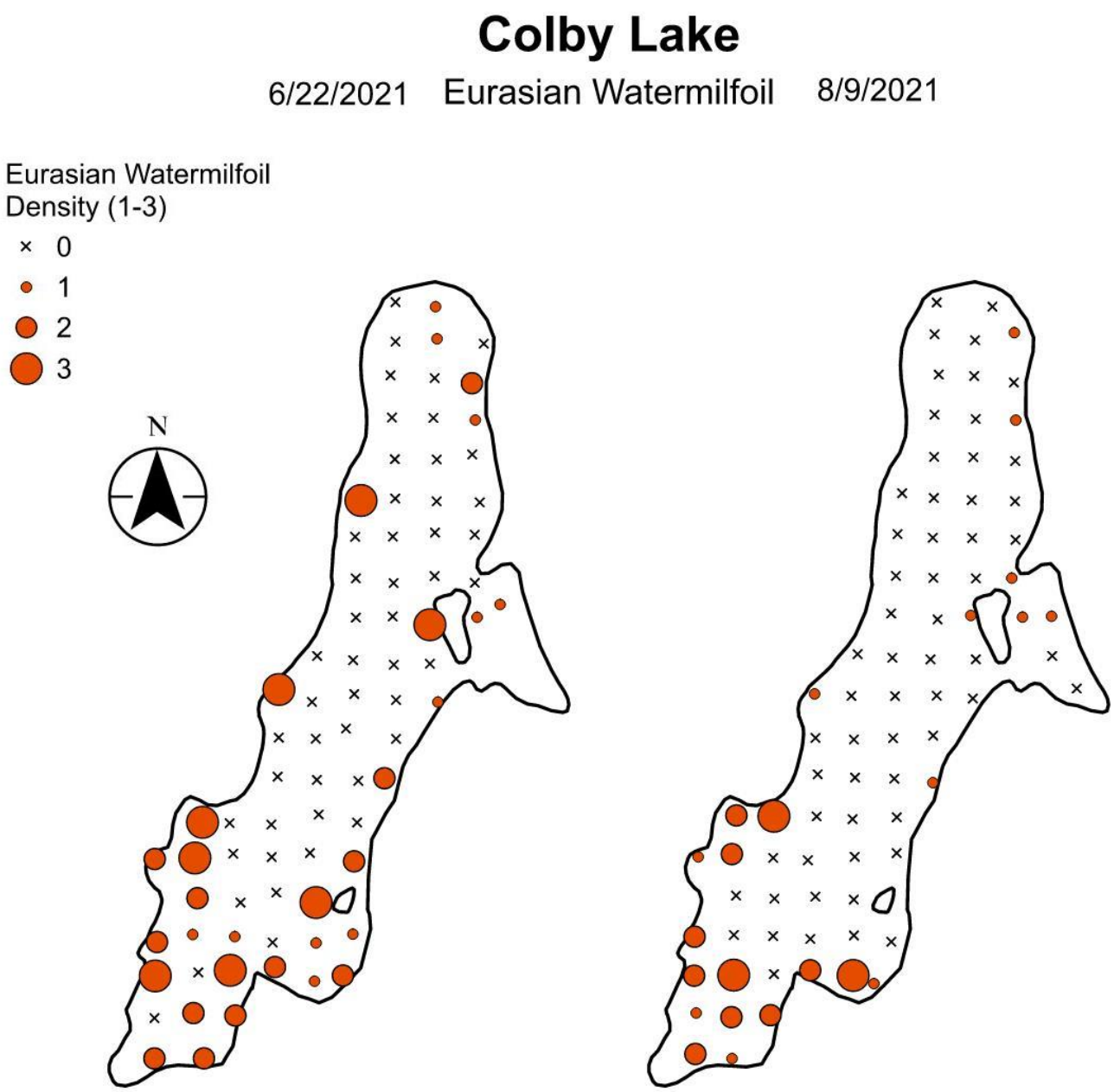

Figure 2-10: Map of the location and density of Eurasian Watermilfoil in Colby Lake.

2.4 LA LAKE

La Lake (Public Water No. 82-0097-00) is a 52-acre, shallow lake in Woodbury, MN. The lake has a max depth of 8 feet. La receives contributions from a small watershed of 64 acres, 3.5 acres of which are impervious.

Average TP concentration in La Lake is 68 ug/L, just exceeding the shallow lake standard for the North Central Hardwood Forest ecoregion (60 ug/L). Average Secchi depth is 1.4 meters and meets the State standard of 1.0 meter.

Below are two tables outlining survey results and associated metrics and indices, as well as vegetation biovolume, taxa, and CLP density maps for both the early and late-season surveys (Figure 2-11,Figure **2-12**,Figure 2-13, respectively). CLP is the only AIS present in the lake. Spiny Hornwort, a rare aquatic plant in Minnesota was observed in the lake during both early and late season surveys. Canadian waterweed, a native species, is the most abundant in the lake.

Table 2-7. La Lake plant taxa and littoral frequency of occurrence from 2015, 2018, and 2021 surveys.

Taxa	Common Name	August 3rd, 2015 (Freshwater Scientific)	August 2nd, 2018 (Freshwater Scientific)	June 9th, 2021 (Stantec)	August 5th, 2021 (Stantec)
SUBMERSED TAXA					
Potamogeton robbinsii	Fern-leaf pondweed	64	63	2	--
Elodea canadensis	Canadian waterweed	45	65	89	83
Potamogeton amplifolius	Large-leaf pondweed	23	31	39	32
Ceratophyllum echinatum	Spiny hornwort	21	92	56	47
Nitella sp.	Nitella	2	--	--	--
Potamogeton foliosus	Leafy pondweed	2	--	--	--
Potamogeton zosteriformis	Flat-stem pondweed	2	21	21	17
Utricularia vulgaris	Common bladderwort	2	P	--	--
Ceratophyllum demersum	Coontail	--	--	12	21
Potamogeton crispus	Curly-leaf pondweed	--	--	29	--
FLOATING TAXA					

Taxa	Common Name	August 3rd, 2015 (Freshwater Scientific)	August 2nd, 2018 (Freshwater Scientific)	June 9th, 2021 (Stantec)	August 5th, 2021 (Stantec)
Lemna minor	Small duckweed	4	--	6	--
Spirodela polyrhiza	Large duckweed	2	8	6	2
Wolffia columbiana	Common watermeal	2	--	--	--
Polygonum amphibium	Water smartweed	--	P	2	2
Riccia fluitans	Crystalwort	--	P	--	--
EMERGENT TAXA					
Sagittaria sp.	Arrowhead	9	P	2	2
Schoenoplectus acutus	Hardstem bulrush	2	P	--	--
Typha sp.	Cattail	2	P	P	P
Lythrum salicaria	Purple loosestrife	P	P	--	P
Schoenoplectus fluviatilis	River bulrush	P	--	--	--

Table 2-8. La Lake SAV metrics

	August 3rd, 2015 (Freshwater Scientific)	August 2nd, 2018 (Freshwater Scientific)	June 9th, 2021 (Stantec)	August 5th, 2021 (Stantec)
LAKEWIDE METRICS				
Total Points Sampled	53	52	52	53
Total Littoral Points Sampled	53	52	52	53
% Littoral with Veg	81	100	100	100
Max depth of plant growth (ft)	8.4	10.2	10.0	98.1
Shallow Lake Species Richness Threshold	*11*			
Species Richness	14	13	12	10
COMMUNITY INDICES				
Shallow Lake Floristic Quality Index (FQI) Threshold	*17.8*			
FQI	19.8	18.9	18.7	16.0
Simpson's Diversity Index	78.0	77.0	80.2	75.0
Aquatic Macrophyte Community Index (AMCI)	49	42	46	45

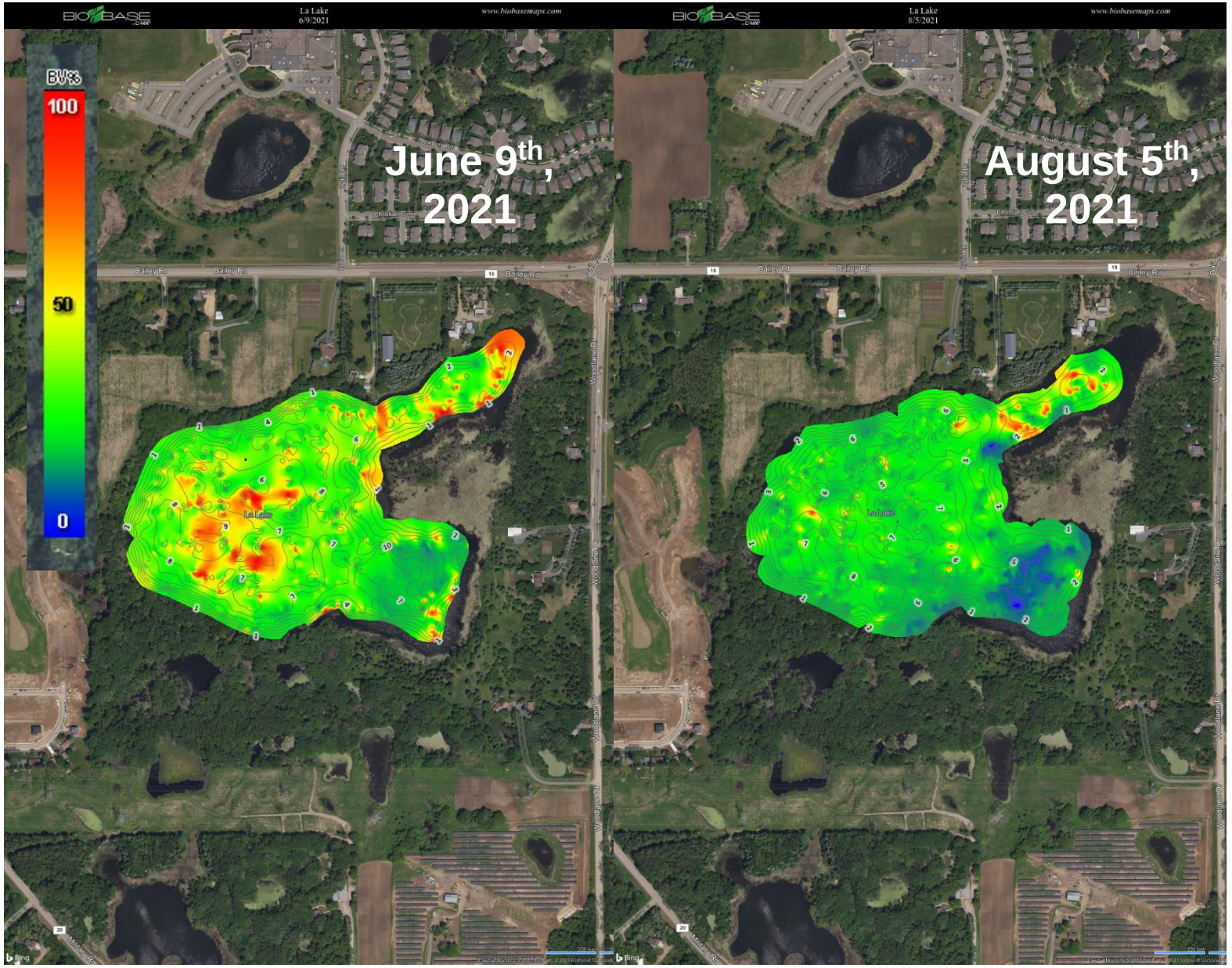

Figure 2-11: Early and late-season BioBase maps of vegetation biovolume in La Lake.

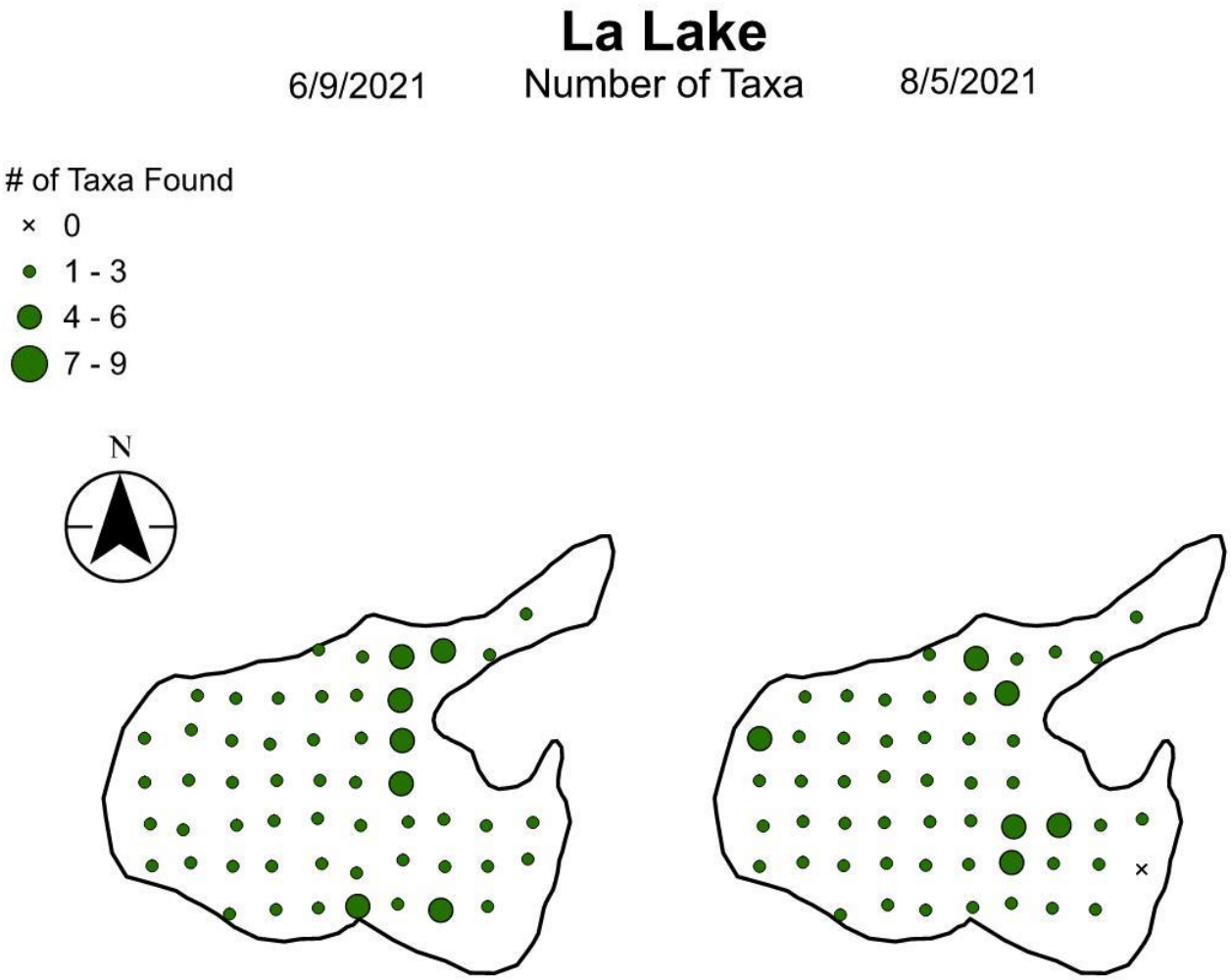

Figure 2-12: Map of the number of taxa found in La Lake.

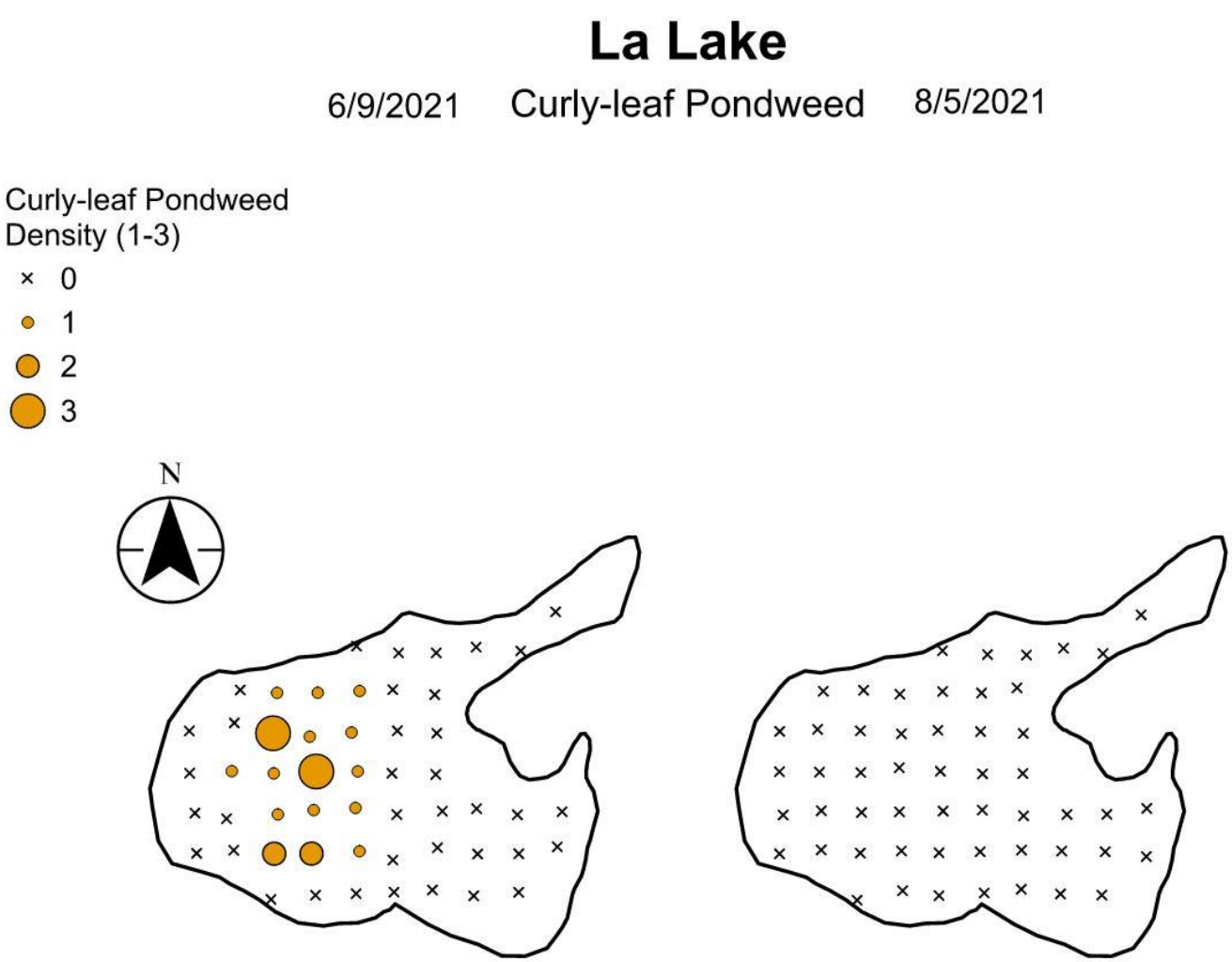

Figure 2-13: Map of the location and density of Curly-leaf Pondweed in La Lake.

2.5 MARKGRAFS LAKE

Markgrafs Lake (Public Water No. 82-0089-00) is 46-acre, shallow lake in Woodbury, MN. Markgrafs Lake had a maximum observed depth of 7.4 feet during the 2021 surveys. The lake's watershed is 436 acres.

Average TP concentration in Markgrafs is 125 ug/L, exceeding the shallow lake standard for the North Central Hardwood Forest ecoregion (60 ug/L). Average Secchi depth is 0.5 meters, below the State standard of 1.0 meter.

Below are two tables outlining survey results and associated metrics and indices, as well as vegetation biovolume, taxa, and CLP density maps for both the early and late-season surveys (Figure 2-14,Figure **2-15**, andFigure **2-16**, respectively). The late season BioBase map did not capture biovolume on two distinct areas in the lake due to shallow water levels (Figure 2-14). BioBase sonar readings are subject to extreme noise in water <1 foot deep. CLP is the only AIS present in the lake. Coontail and Canadian waterweed were the most abundant species during the 2021 surveys.

Table 2-9. Markgrafs Lake plant taxa and littoral frequency of occurrence from 2015, 2018, and 2021 surveys.

Taxa	Common Name	August 4th, 2015 (Freshwater Scientific)	August 3rd, 2018 (Freshwater Scientific)	June 3rd, 2021 (Stantec)	August 2nd, 2021 (Stantec)
SUBMERSED TAXA					
Elodea canadensis	Canadian waterweed	58	78	84	57
Nitella sp.	Nitella	18	--	--	--
Potamogeton pusillus	Small pondweed	16	2	8	6
Ceratophyllum demersum	Coontail	12	8	66	67
Potamogeton foliosis	Leafy pondweed	8	--	--	--
Najas flexilis	Slender naiad	4	2	--	2
	Aquatic moss	2	--	--	--
Potamogeton crispus	Curly-leaf pondweed	P	4	10	2
Potamogeton nodosus	Long-leaf pondweed	P	--	--	--
Chara sp.	Muskgrass	--	2	--	--
Heteranthera dubia	Water stargrass	--	--	--	2
Potamogeton robbinsii	Robbins' pondweed	--	--	--	P

Taxa	Common Name	August 4th, 2015 (Freshwater Scientific)	August 3rd, 2018 (Freshwater Scientific)	June 3rd, 2021 (Stantec)	August 2nd, 2021 (Stantec)
Potamogeton zosteriformis	Flat-stemmed pondweed	--	--	--	2
FLOATING TAXA					
Polygonum amphibium	Water smartweed	P	--	--	--
Lemna minor	Small duckweed	--	8	2	2
Spirodela polyrhiza	Large duckweed	--	4	--	--
Wolffia sp.	Watermeal	--	--	2	--
EMERGENT TAXA					
Sagittaria sp.	Arrowhead	4	--	2	--
Schoenoplectus acutus	Hardstem bulrush	P	P	--	--
Shoenoplectus fluviatilis	River bulrush	P	--	--	--
Typha sp.	Cattail	P	P	--	--
Sagittaria graminea	Grass-leaved arrowhead	--	2	--	--
Sagittaria latifola	Common arrowhead	--	P	--	P

Table 2-10. Markgrafs Lake SAV metrics.

	August 4th, 2015 (Freshwater Scientific)	August 3rd, 2018 (Freshwater Scientific)	June 3rd, 2021 (Stantec)	August 2nd, 2021 (Stantec)
LAKEWIDE METRICS				
Total Points Sampled	50	50	50	51
Total Littoral Points Sampled	50	50	50	51
% Littoral with Veg	62	78	94	72.5
Max depth of plant growth (ft)	6.8	6.2	7.4	6.7
Shallow Lake Species Richness Threshold	*11*			
Species Richness	14	12	7	10
COMMUNITY INDICES				
Shallow Lake Floristic Quality Index (FQI) Threshold	*17.8*			

	August 4th, 2015 (Freshwater Scientific)	**August 3rd, 2018 (Freshwater Scientific)**	**June 3rd, 2021 (Stantec)**	**August 2nd, 2021 (Stantec)**
FQI	15.0	13.6	11.9	15.4
Simpson's Diversity Index	72	48.3	61.6	63.1
Aquatic Macrophyte Community Index (AMCI)	42	27	35	40

Figure 2-14: Early and late-season BioBase maps of vegetation biovolume in Markgrafs Lake.

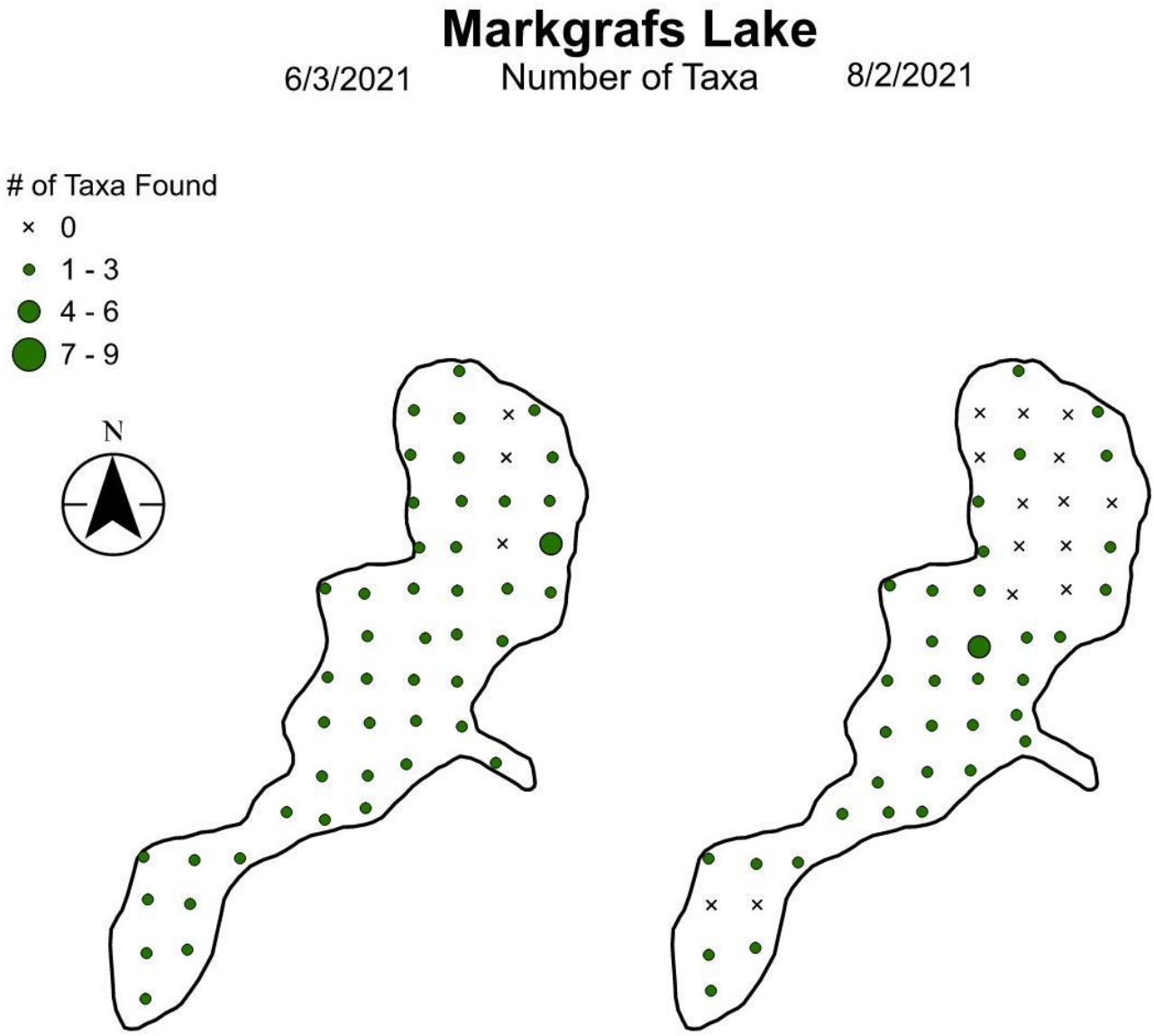

Figure 2-15: Map of the number of taxa found in Markgrafs Lake.

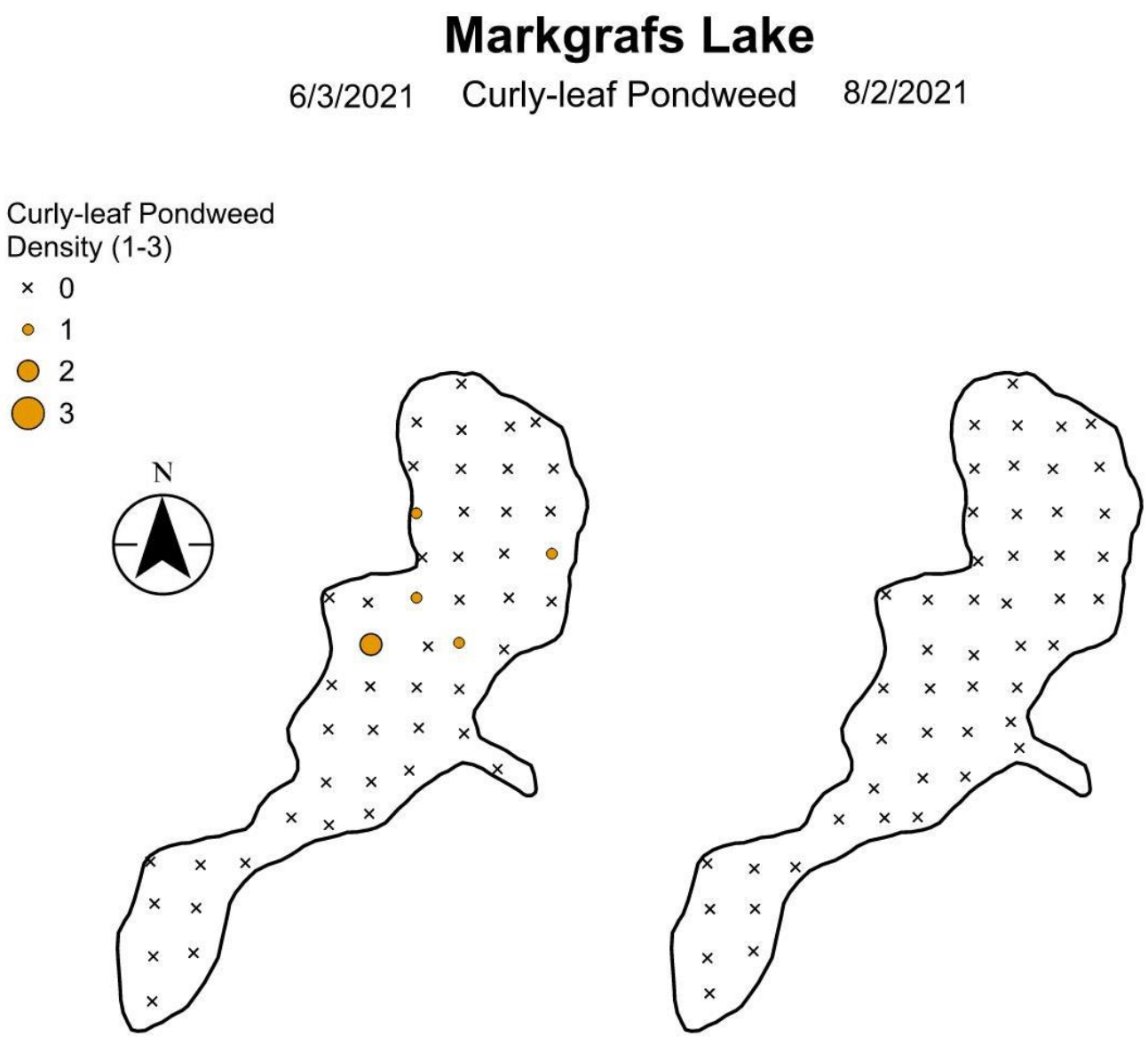

Figure 2-16: Map of the location and density of Curly-leaf Pondweed in Markgrafs Lake.

2.6 POWERS LAKE

Powers Lake (Public Water No. 82-0092-00) is a 62-acre, deep lake in Woodbury, MN. Powers Lake has a max depth of 40 feet. Powers receives contributions from 1,257 acres, 484 acres of which are impervious. In addition to both early and late season SAV surveys an EWM delineation occurred on Powers Lake to map the extent of EWM growth.

Average TP concentration in Powers is 28 ug/L, meeting the deep lake standard for the North Central Hardwood Forest ecoregion (40 ug/L). Average Secchi depth is 3.0 meters, meeting the State standard of 1.2 meters.

CLP and EWM are both present in the lake, though in low abundance. Below are two tables outlining survey results and associated metrics and indices, as well as maps of vegetation biovolume, taxa, CLP density, and EWM density for both the early and late-season surveys (Figure 2-17,Figure **2-18**,Figure **2-19**, and Figure **2-20**, respectively). Both the early and late season BioBase maps did not capture biovolume in distinct areas in the lake due to the survey boat tracks (Figure 2-17). The deepest points in Powers Lake where vegetation is not expected to grow were not sampled during the surveys, inhibiting BioBase's ability to make biovolume estimates in those areas. See Section 3.2 for the EWM delineation on Powers Lake.

Table 2-11. Powers Lake plant taxa and littoral frequency of occurrence from 2015, 2018, and 2021 surveys.

Taxa	Common Name	August 4th, 2015 (Freshwater Scientific)	August 6th, 2018 (Freshwater Scientific)	June 7th, 2021 (Stantec)	August 2nd, 2021 (Stantec)
SUBMERSED TAXA					
Ceratophyllum demersum	Coontail	95	34	20	44
Nitella sp.	Nitella	38	--	--	--
Myriophyllum spicatum	Eurasian watermilfoil	35	53	3	9
Najas flexilis	Slender naiad	30	26	--	9
Potamogeton crispus	Curly-leaf pondweed	30	18	46	18
Elodea canadensis	Canadian waterweed	16	P	3	--
Potamogeton pusillus	Small pondweed	14	26	17	62
Potamogeton foliosus	Leafy pondweed	11	--	--	--
Eleocharis acicularis	Needle spikerush	P	5	--	--
Potamogeton nodosus	Long-leaf pondweed	P	P	3	3

Taxa	Common Name	August 4th, 2015 (Freshwater Scientific)	August 6th, 2018 (Freshwater Scientific)	June 7th, 2021 (Stantec)	August 2nd, 2021 (Stantec)
Heteranthera dubia	Water stargrass	35	42	37	53
Chara sp.	Muskgrass	--	24	3	6
Potamogeton zosteriformis	Flat-stem pondweed	--	5	14	29
Potamogeton amplifolius	Large-leaf pondweed	--	3	6	6
Stuckenia pectinate	Sago pondweed	--	P	--	3
Elatine minima	Waterwort	--	P	--	--
Potamogeton robbinsii	Robbins' pondweed	--	--	--	3
FLOATING TAXA					
Persicaria amphibia	Water smartweed	19	P	3	3
Wolffia columbiana	Common watermeal	--	5	--	--
Lemna minor	Small duckweed	--	3	3	--
Potamogeton natans	Floating-leaf pondweed	--	P	--	--
EMERGENT TAXA					
Lythrum salicaria	Purple loosestrife	5	P	P	P
Sagittaria sp.	Arrowhead	--	P	--	--
Schoenoplectus acutus	Hardstem bulrush	--	P	--	--
Typha sp.	Cattail	--	P	--	--
Eleocharis acicularis	Needlerush (least spikerush)	--	--	6	--

Table 2-12. Powers Lake SAV metrics.

	August 3rd, 2015 (Freshwater Scientific)	August 3rd, 2018 (Freshwater Scientific)	June 7th, 2021 (Stantec)	August 2nd, 2021 (Stantec)
LAKEWIDE METRICS				
Total Points Sampled	65	67	68	66
Total Littoral Points Sampled	37	38	35	34
% Littoral with Veg	100	84	86	85

	August 3rd, 2015 (Freshwater Scientific)	**August 3rd, 2018 (Freshwater Scientific)**	**June 7th, 2021 (Stantec)**	**August 2nd, 2021 (Stantec)**
Max depth of plant growth (ft)	20.0	18.0	13.1	15.8
Deep Lake Species Richness Threshold	*12*			
Species Richness	12	12	10	13
COMMUNITY INDICES				
Deep Lake Floristic Quality Index (FQI) Threshold	*18.6*			
FQI	13.9	20.9	16.3	19.2
Simpson's Diversity Index	85	86.6	84.6	84.6
Aquatic Macrophyte Community Index (AMCI)	43	47	44	46

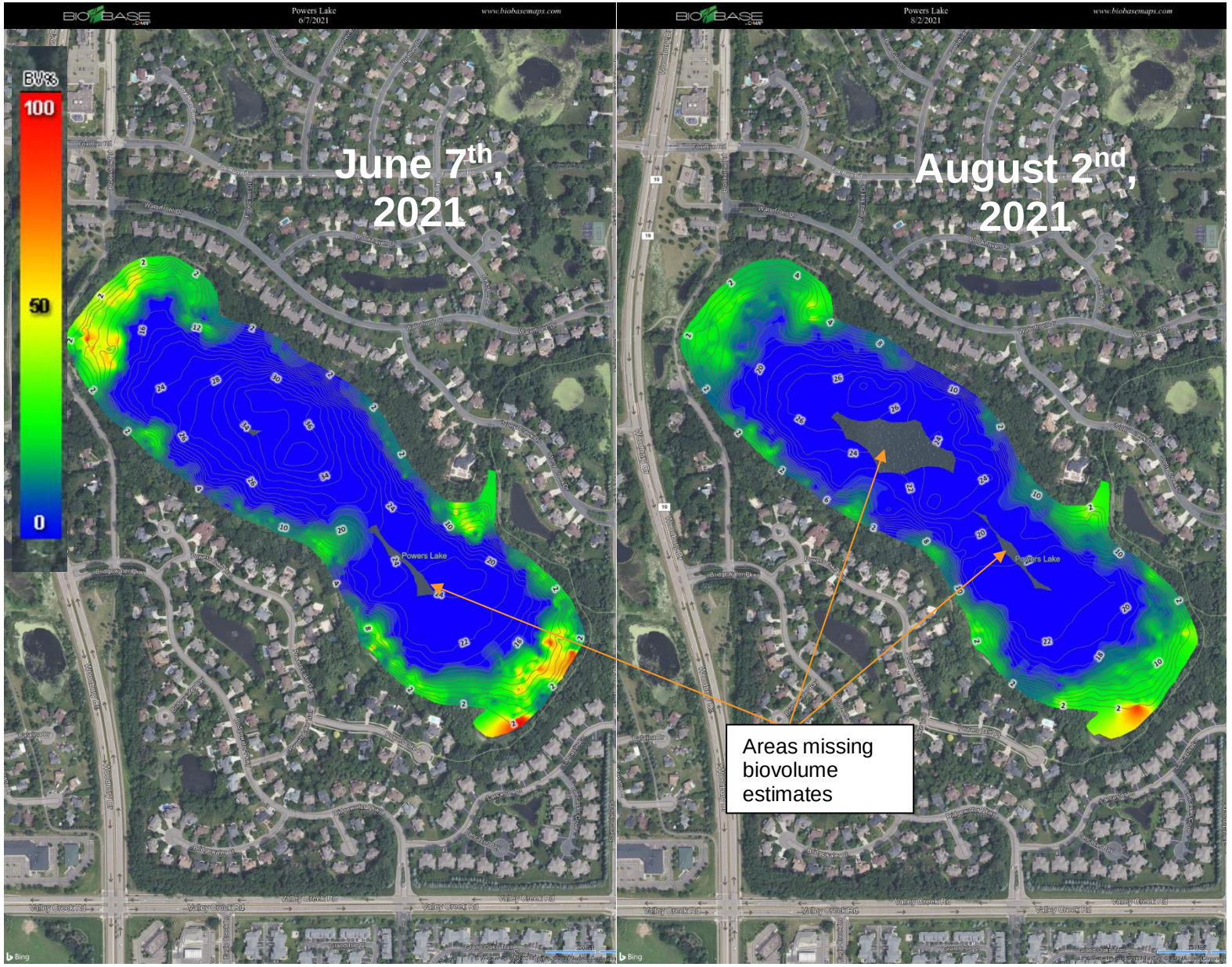

Figure 2-17: Early and late-season BioBase maps of vegetation biovolume in Powers Lake.

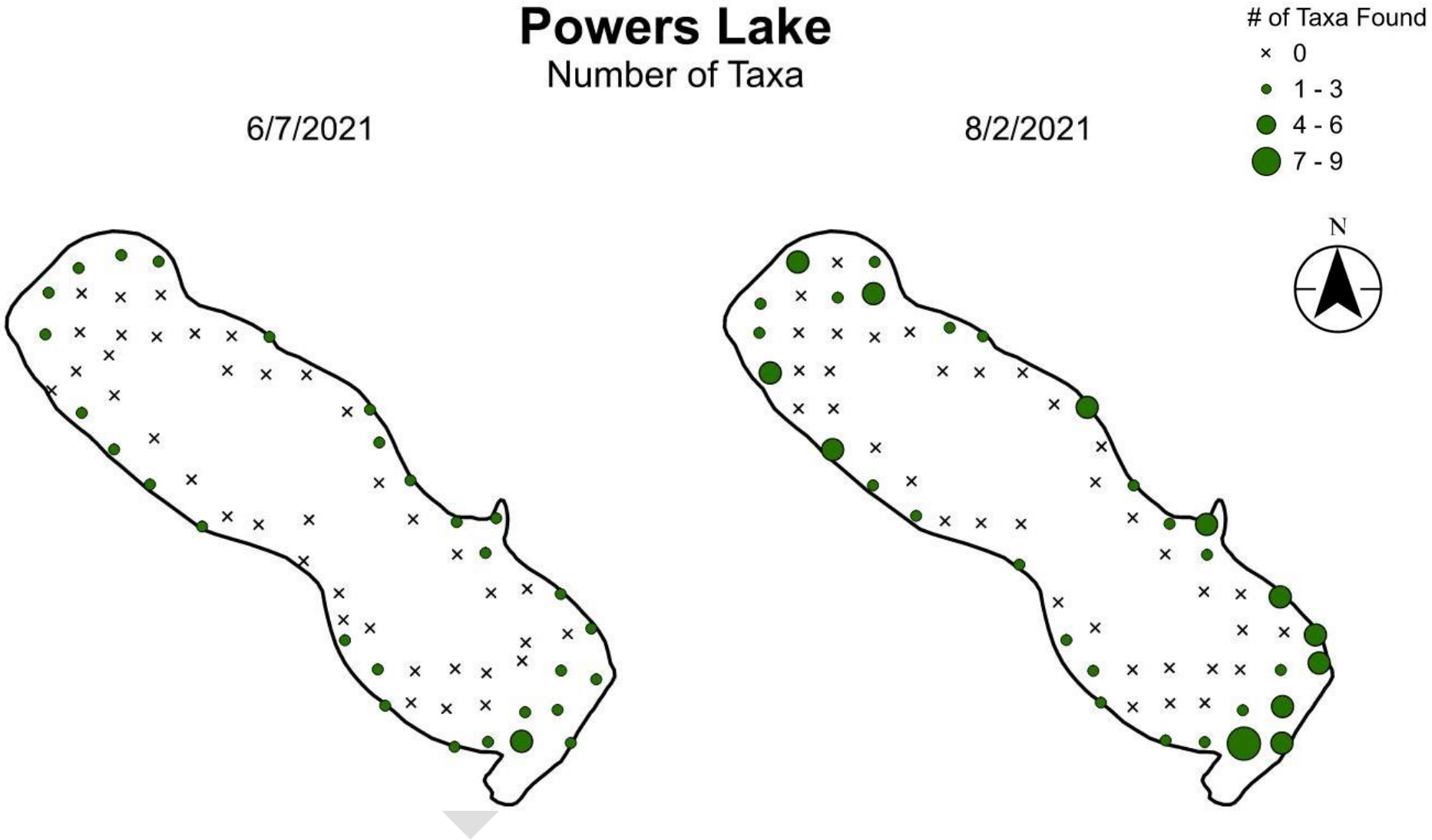

Figure 2-18: Map of the number of taxa found in Powers Lake.

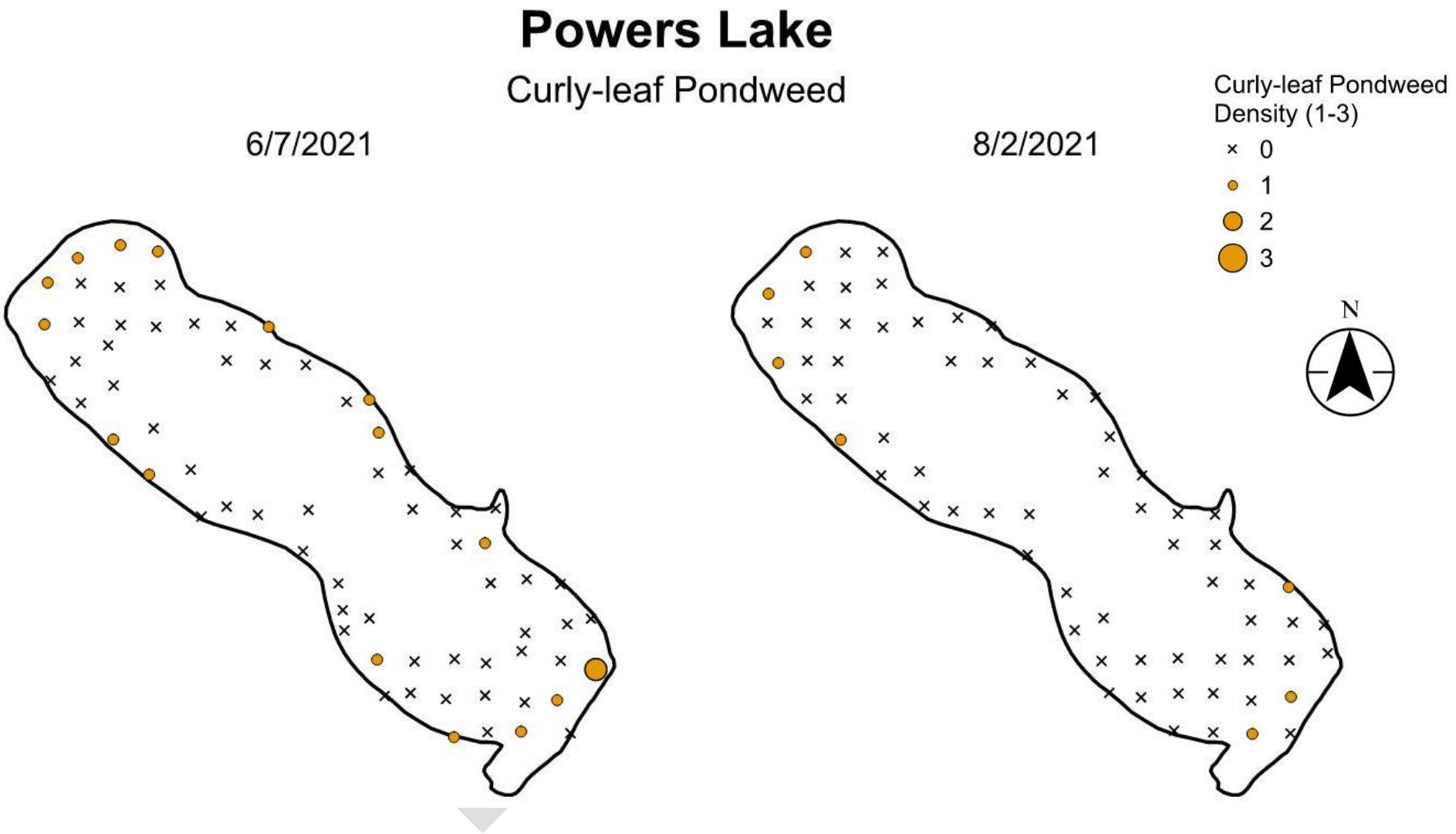

Figure 2-19: Map of the location and density of Curly-leaf Pondweed in Powers Lake.

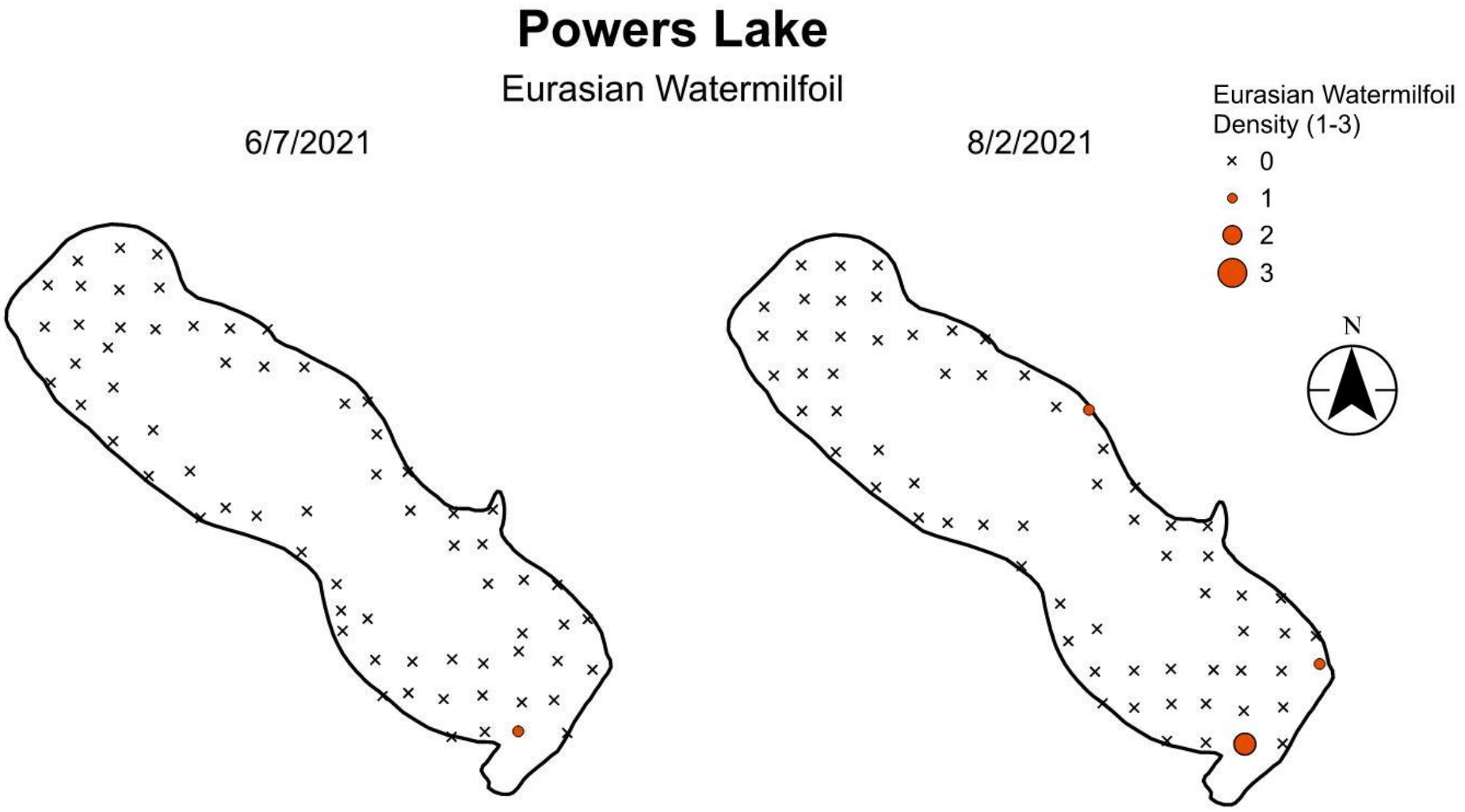

Figure 2-20: Map of the location and density of Eurasian Watermilfoil in Powers Lake.

2.7 RAVINE LAKE

Ravine Lake (Public Water No. 82-0087-00) is a 27-acre, shallow lake in Cottage Grove, MN. The lake has a max depth of 16 feet. Ravine's drainage area is approximately 2,191 acres, of which approximately 665 acres are impervious. During the early season surveys multiple dense mats of CLP were present throughout the entirety of the lake limiting lake navigability and recreational opportunities.

Average TP concentration in Ravine is 76 ug/L, under the shallow lake standard for the Western Corn Belt Plains ecoregion (90 ug/L). Average Secchi depth is 1.7 meters, meeting the State standard of 0.7 meters for its ecoregion.

Below are two tables outlining survey results and associated metrics and indices, as well as vegetation biovolume, taxa, and CLP density maps for both the early and late-season surveys (Figure 2-21,Figure **2-22**, andFigure **2-23**, respectively). CLP is the only AIS present in the lake. See Section 3 for the CLP delineation on Ravine Lake. Coontail is the most abundant plant in the lake, and though it is native, can reach nuisance levels.

Table 2-13. Ravine Lake plant taxa and littoral frequency of occurrence from 2015, 2018, and 2021 surveys.

Taxa	Common Name	August 4th, 2015 (Freshwater Scientific)	August 8th, 2018 (Freshwater Scientific)	June 4th, 2021 (Stantec)	August 3rd, 2021 (Stantec)
SUBMERSED TAXA					
Ceratophyllum demersum	Coontail	96	96	67	88
Stuckenia pectinata	Sago pondweed	39	20	12	10
Ranunculus aquatilis	Stiff water crowfoot	35	2	8	--
Potamogeton zosteriformis	Flat-stem pondweed	15	--	--	--
Potamogeton pusillus	Small pondweed	9	--	--	--
Chara sp.	Muskgrass	4	4	2	--
Potamogeton foliosus	Leafy pondweed	2	2	8	--
Potamogeton crispus	Curly-leaf pondweed	P	52	86	27
Heteranthera dubia	Water stargrass	7	P	--	P
FLOATING TAXA					
Lemna minor	Small duckweed	30	38	49	35
Spirodela polyrhiza	Large duckweed	--	4	39	27

Taxa	Common Name	August 4th, 2015 (Freshwater Scientific)	August 8th, 2018 (Freshwater Scientific)	June 4th, 2021 (Stantec)	August 3rd, 2021 (Stantec)
Wolffia sp.	Watermeal	30	38	55	69
EMERGENT TAXA					
Eleocharis palustris	Creeping spikerush	P	--	--	--
Schoenoplectus acutus	Hardstem bulrush	P	2	--	--
Typha sp.	Cattail	P	P	P	P
Shoenoplectus tabernaemontani	Softstem bulrush	--	P	2	P

Table 2-14. Ravine Lake SAV metrics.

	August 4th, 2015 (Freshwater Scientific)	August 8th, 2018 (Freshwater Scientific)	June 4th, 2021 (Stantec)	August 3rd, 2021 (Stantec)
LAKEWIDE METRICS				
Total Points Sampled	51	53	53	53
Total Littoral Points Sampled	46	50	51	49
% Littoral with Veg	96	96	90	88
Max depth of plant growth (ft)	15.7	14.1	15.7	9.9
Shallow Lake Species Richness Threshold[1]	*4*			
Species Richness	14	13	11	9
COMMUNITY INDICES				
Shallow Lake Floristic Quality Index (FQI)Threshold[1]	*7.7*			
FQI	17.1	14.1	15.5	11.7
Simpson's Diversity Index	80	77.1	78.9	71.2
Aquatic Macrophyte Community Index (AMCI)	46	36	36	32

[1]Note that Ravine Lake is the only lake in this study that falls in the Western Corn Belt Plains ecoregion, and thus is compared to a different species richness and FQI threshold.

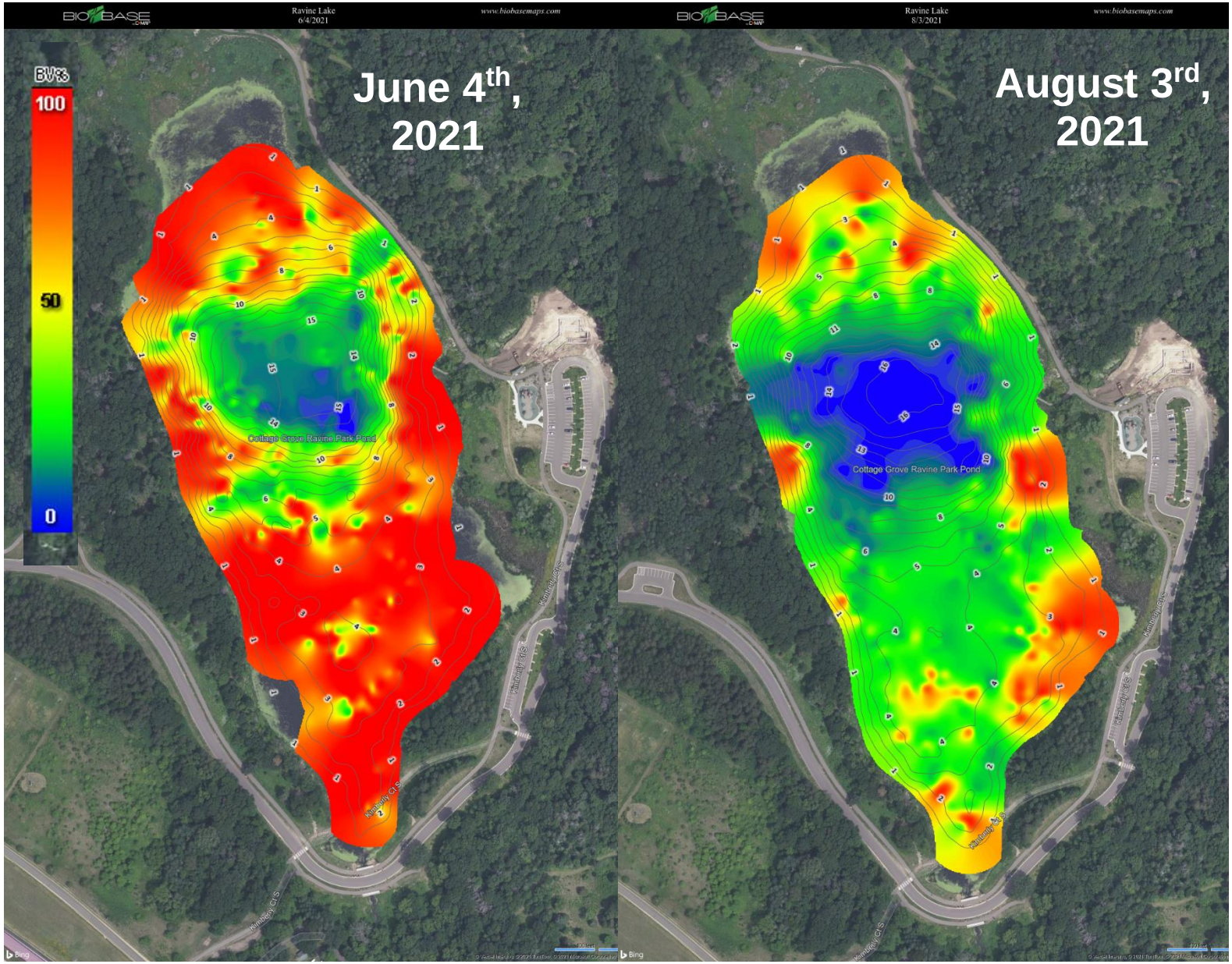

Figure 2-21: Early and late-season BioBase maps of vegetation biovolume in Ravine Lake.

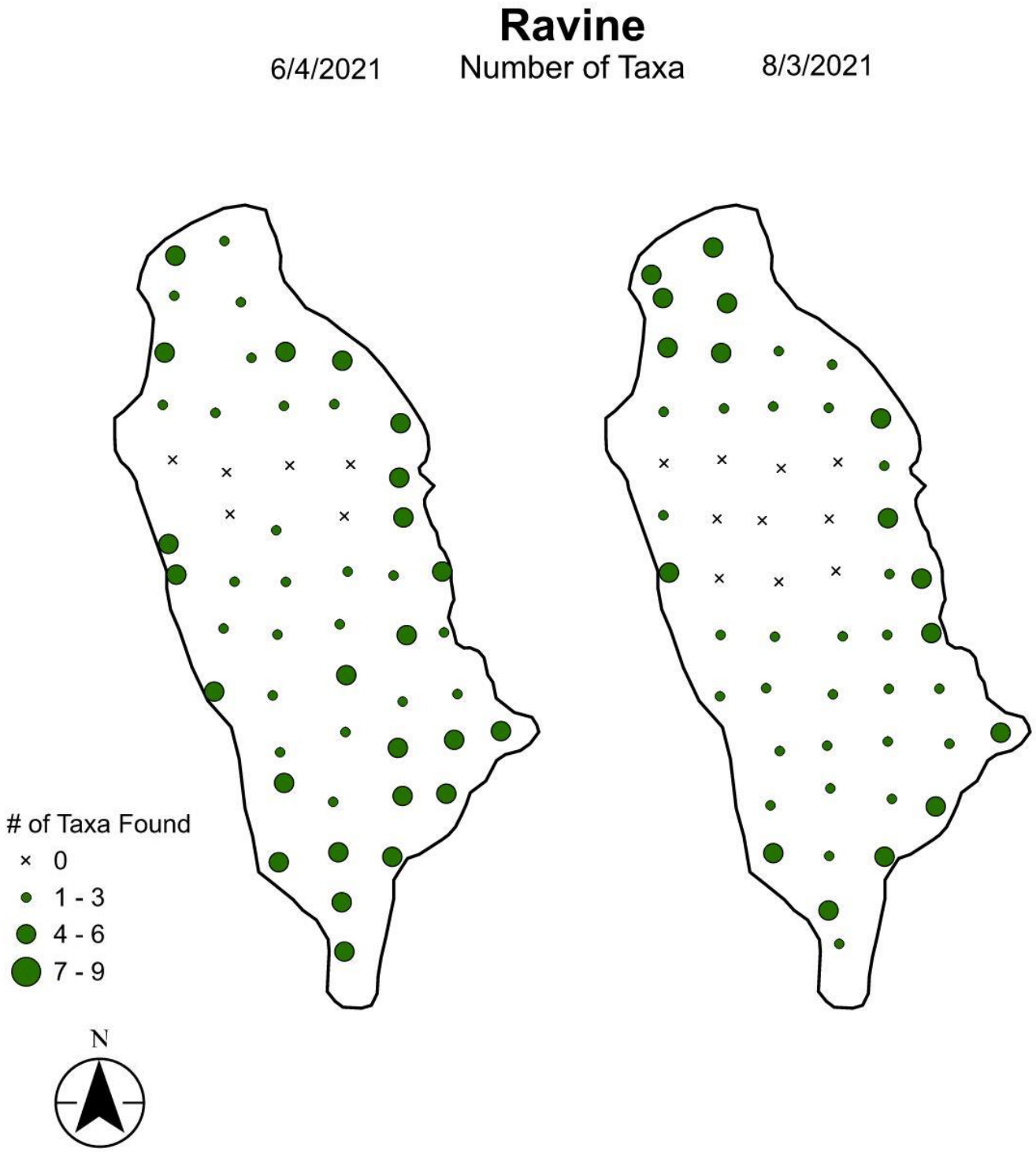

Figure 2-22: Map of the number of taxa found in Ravine Lake.

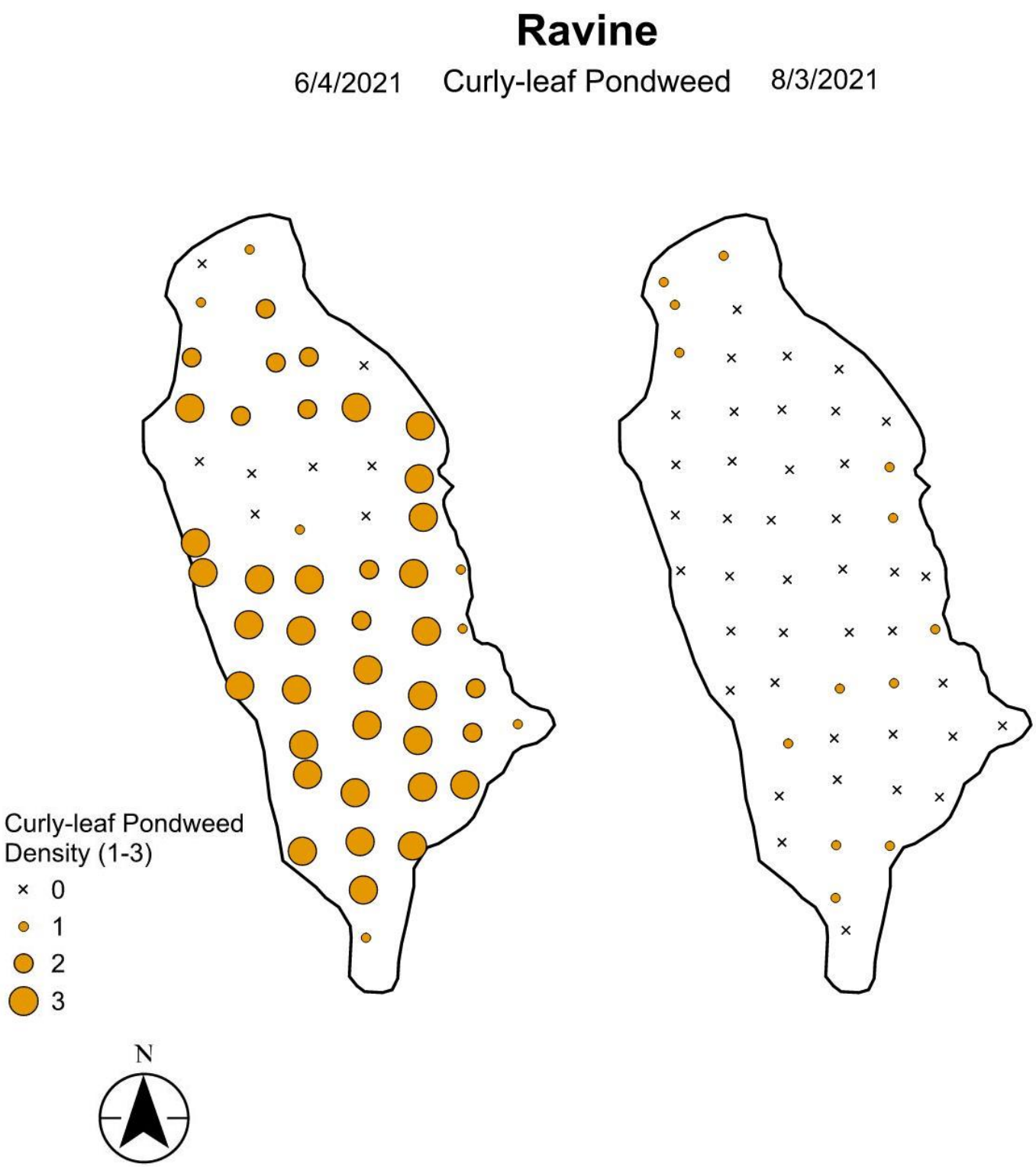

Figure 2-23: Map of the location and density of Curly-leaf Pondweed in Ravine Lake.

2.8 WILMES LAKE

Wilmes Lake (Public Water No. 82-0090-00) is a shallow lake with a maximum observed depth of 20 feet during the 2021 surveys. The lake is located in Woodbury, MN. Wilmes Lake has both a north and a south basin that were combined for analysis in both vegetation surveys. Wilmes Lake had the most drastic difference in observed lake water level between the early and late season surveys. Five points that were surveyable in the early season surveys were dry land during the fall surveys. It appears that the lake level dropped between two to six feet between the two surveys (see BioBase figure below).

Average TP concentration in North and South Wilmes is 75 and 73 ug/L, respectively, exceeding the shallow lake standard for the North Central Hardwood Forest ecoregion (60 ug/L). Average Secchi depth is 1.2 and 0.8 meters, respectively, compared to the State standard of 1.0 meter.

Below are two tables outlining survey results and associated metrics and indices, as well as vegetation biovolume, taxa, and EWM density maps for both the early and late-season surveys (Figure 2-24,Figure **2-25**Figure 2-26Figure 2-27Figure 2-28, respectively). Both the early and late season BioBase maps did not capture biovolume in distinct areas in the lake due to the survey boat tracks (Figure 2-24 and 2-25). EWM is the only AIS present in the lake. Coontail is the most abundant plant in the lake, and though it is native, can reach nuisance levels.

Table 2-15. Wilmes Lake plant taxa and littoral frequency of occurrence from 2015, 2018, and 2021 surveys.

Taxa	Common Name	August 5th, 2015 (Freshwater Scientific)	August 8th, 2018 (Freshwater Scientific)	June 7th, 2021 (Stantec)	August 3rd, 2021 (Stantec)
SUBMERSED TAXA					
Potamogeton zosteriformis	Flat-stem pondweed	53	54	50	55
Elodea canadensis	Canadian waterweed	27	59	36	33
Ceratophyllum demersum	Coontail	13	67	66	79
Najas flexilis	Slender naiad	11	15	--	--
Potamogeton pusillus	Small pondweed	7	--	14	--
Potamogeton foliosus	Leafy pondweed	2	17	--	--
Myriophyllum spicatum	Eurasian watermilfoil	--	7	27	12
Potamogeton crispus	Curly-leaf pondweed	--	2	23	--
Stuckenia pectinata	Sago pondweed	--	--	2	--

Taxa	Common Name	August 5th, 2015 (Freshwater Scientific)	August 8th, 2018 (Freshwater Scientific)	June 7th, 2021 (Stantec)	August 3rd, 2021 (Stantec)
FLOATING TAXA					
Lemna minor	Small duckweed	33	22	25	21
Polygonum amphibium	Water smartweed	13	--	--	--
Lemna trisulca	Star duckweed	9	P	5	--
Spirodela polyrhiza	Large duckweed	9	17	25	29
Wolffia columbiana	Common watermeal	--	4	--	--
EMERGENT TAXA					
Schoenoplectus acutus	Hardstem bulrush	P	P	--	--
Typha sp.	Cattail	--	P	--	--

Table 2-16. Wilmes Lake SAV metrics.

	August 4th, 2015 (Freshwater Scientific)	August 8th, 2018 (Freshwater Scientific)	June 7th, 2021 (Stantec)	August 3rd, 2021 (Stantec)
LAKEWIDE METRICS				
Total Points Sampled	50	50	51	46
Total Littoral Points Sampled	45	46	33	42
% Littoral with Veg	69	74	75	79
Max depth of plant growth (ft)	10.8	11.2	9.2	10.8
Shallow Lake Species Richness Threshold	*11*			
Species Richness	11	14	10	6
COMMUNITY INDICES				
Shallow Lake Floristic Quality Index (FQI) Threshold	*17.8*			
FQI	17.5	13.6	13.9	10.2
Simpson's Diversity Index	83	82.5	86.1	78.4
Aquatic Macrophyte Community Index (AMCI)	51	43	41	46

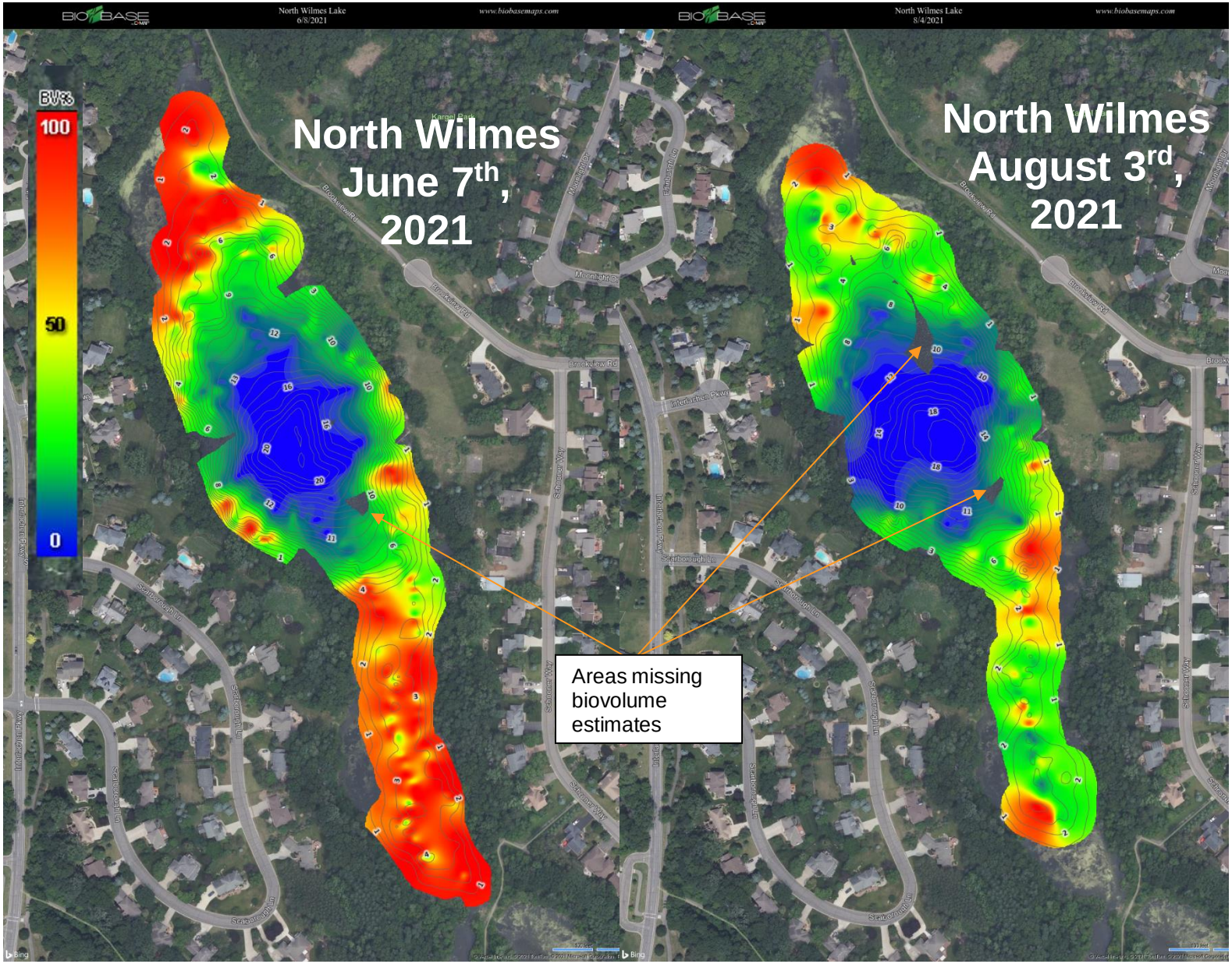

Figure 2-24: Early and late-season BioBase maps of vegetation biovolume in North Wilmes Lake.

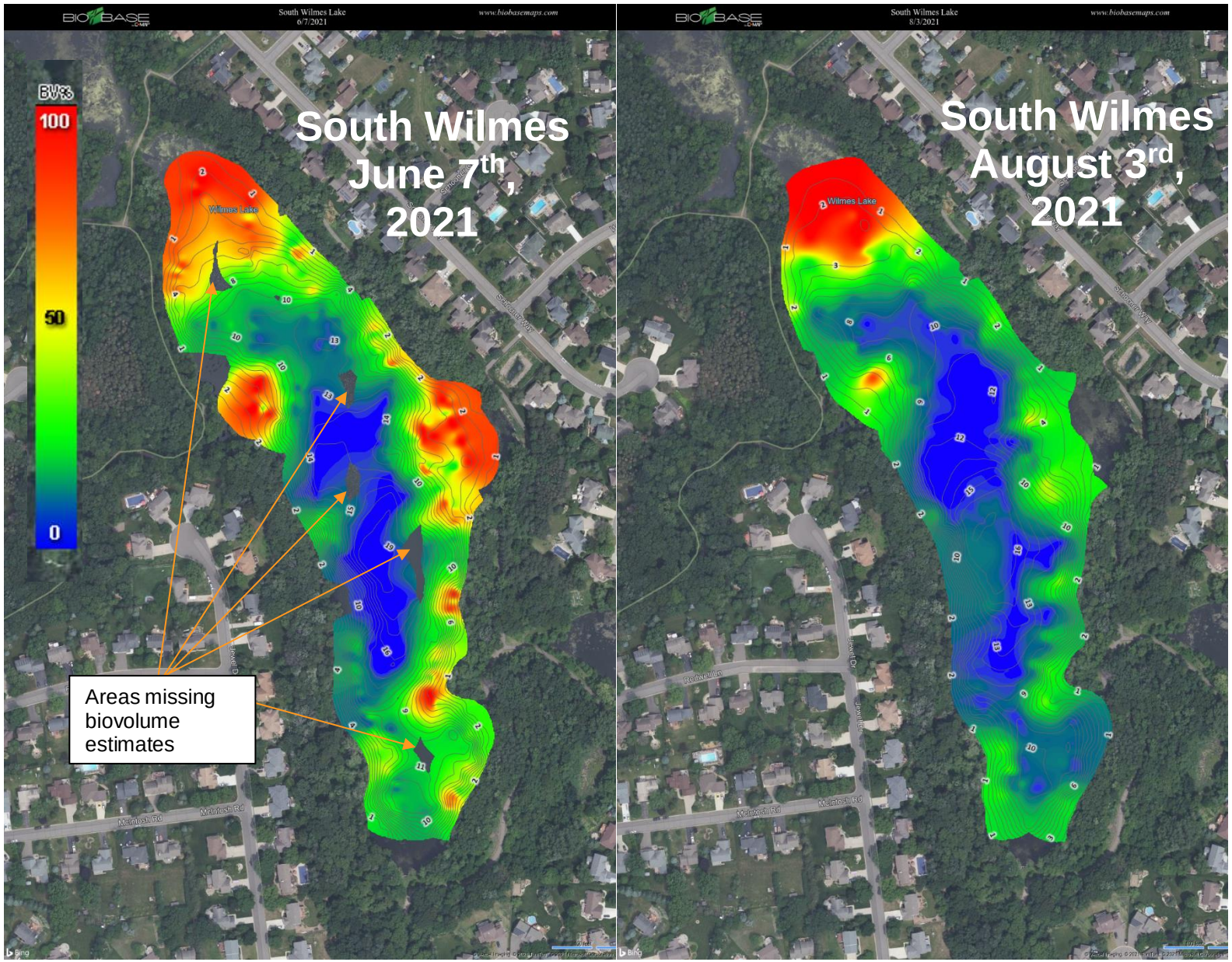

Figure 2-25: Early and late-season BioBase maps of vegetation biovolume in South Wilmes Lake.

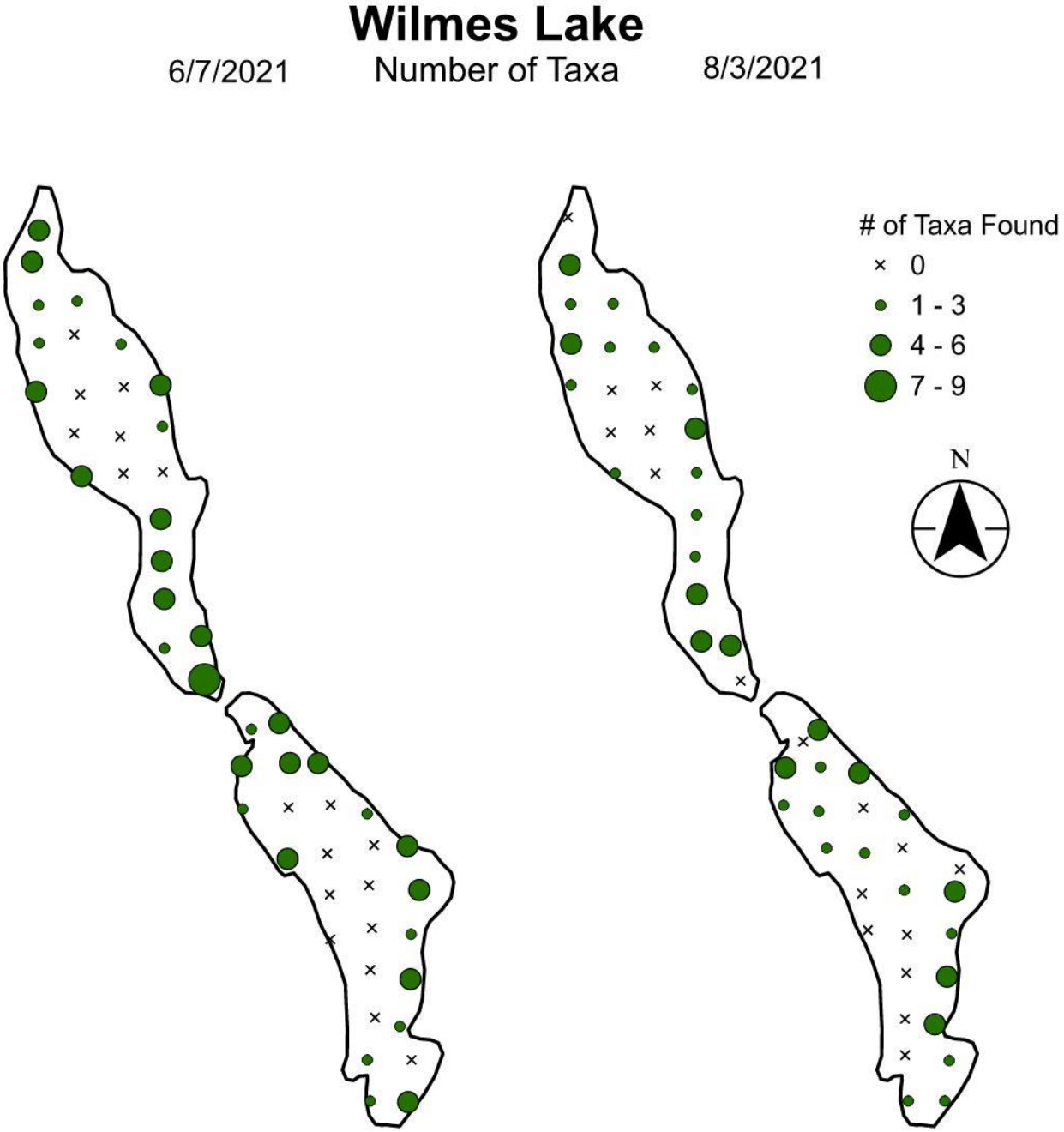

Figure 2-26: Map of the number of taxa found in Wilmes Lake.

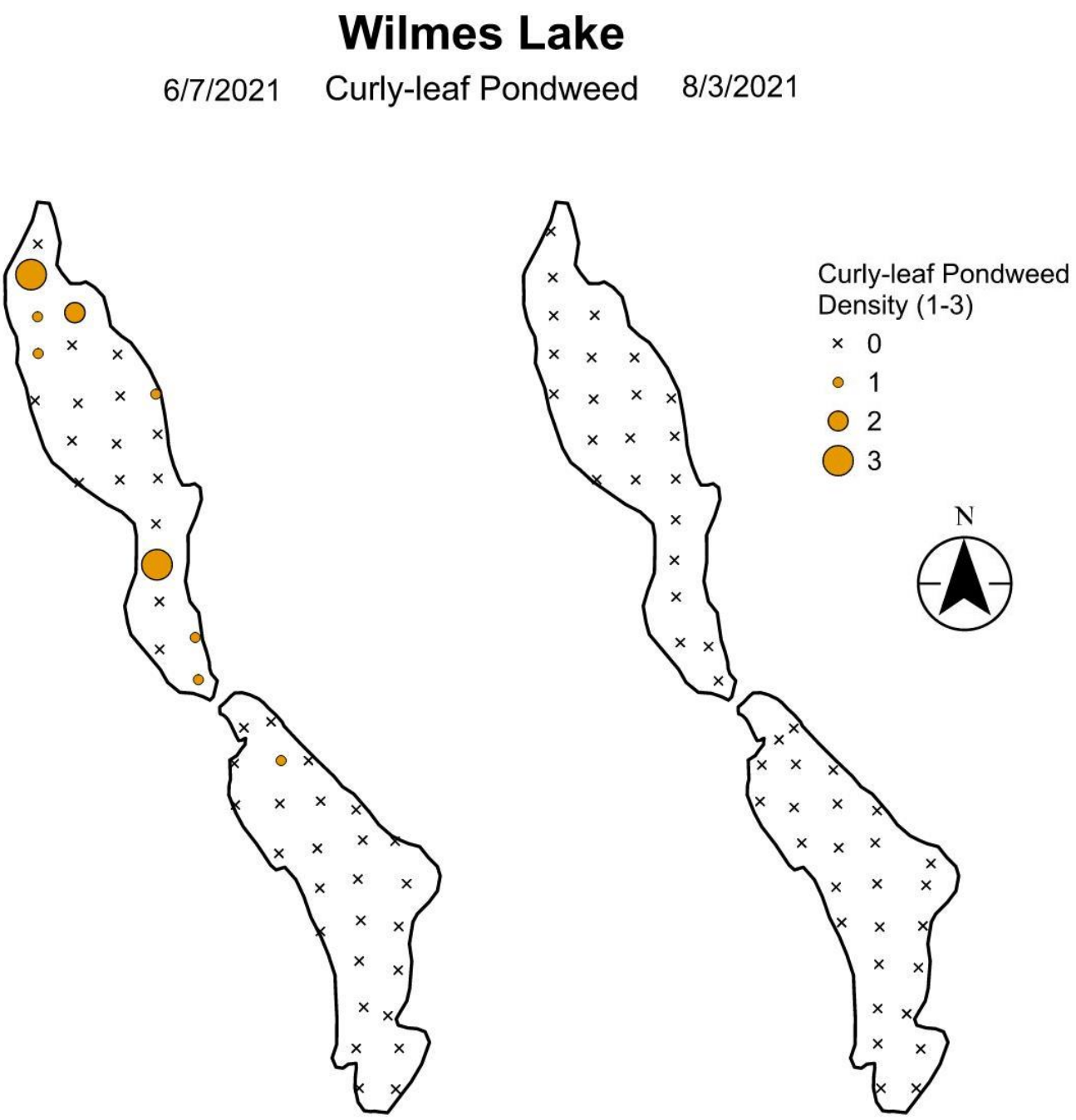

Figure 2-27: Map of the location and density of Curly-leaf Pondweed in Wilmes Lake.

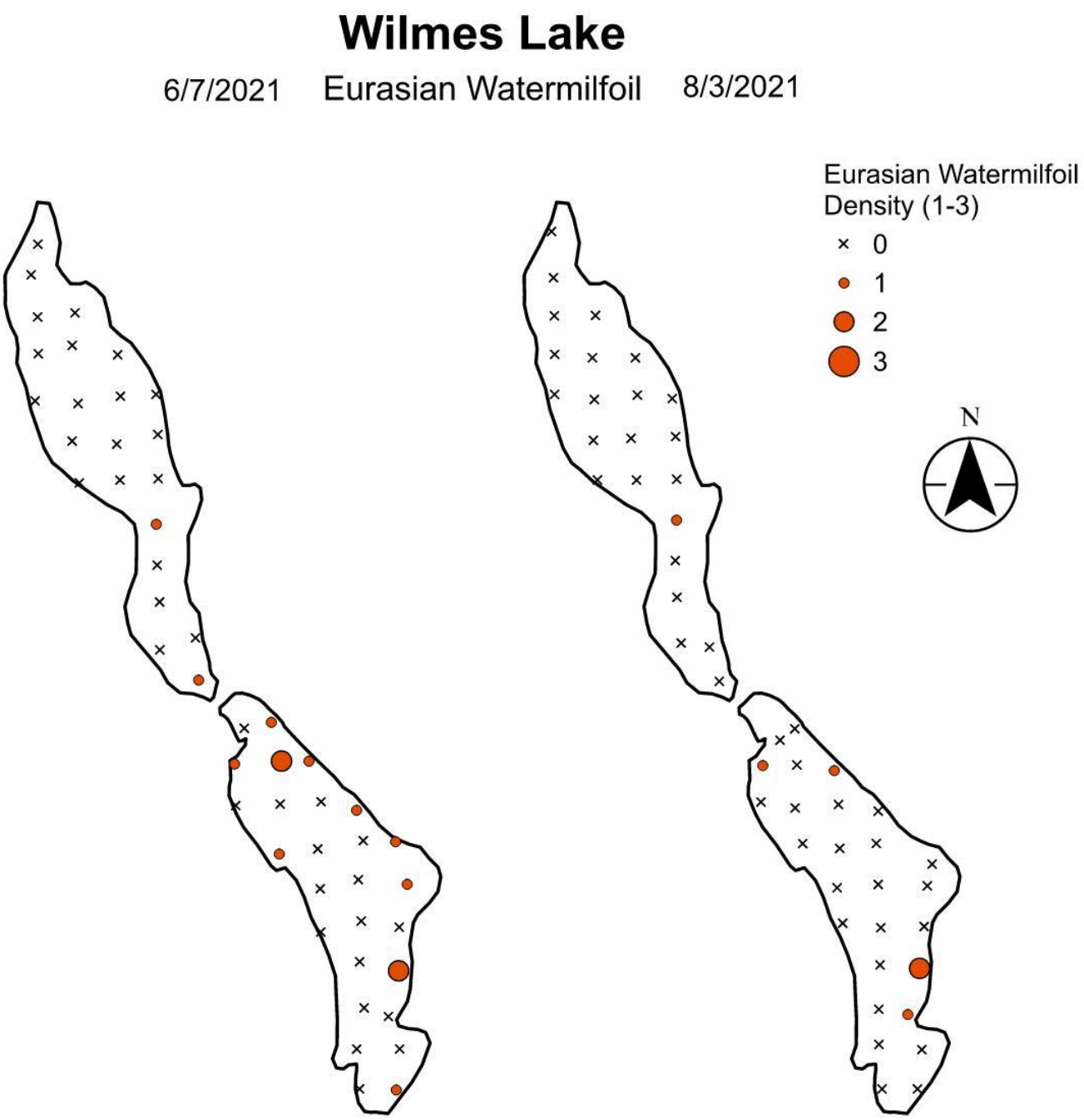

Figure 2-28: Map of the location and density of Eurasian Watermilfoil in Wilmes Lake.

3.0 AIS DELINEATIONS

EWM delineations were completed on Colby and Powers Lakes on June 23rd, 2021. A CLP delineation was done on Ravine Lake on June 4th, 2021. The maps below present boat tracks and EWM or CLP density during each delineation, and areas of infestation for each lake. Areas of 20.7 acres (~30% of the lake) were delineated on Colby (EWM), 0.25 acres (<1% of the lake) on Powers (EWM), and 16.2 acres (~60% of the lake) on Ravine (CLP) for specific invasive species infestations. Although CLP was not formally delineated in Colby Lake, the early season point-intercept survey results indicate widespread infestation covering approximately 54 acres (~80%) of the lake surface area.

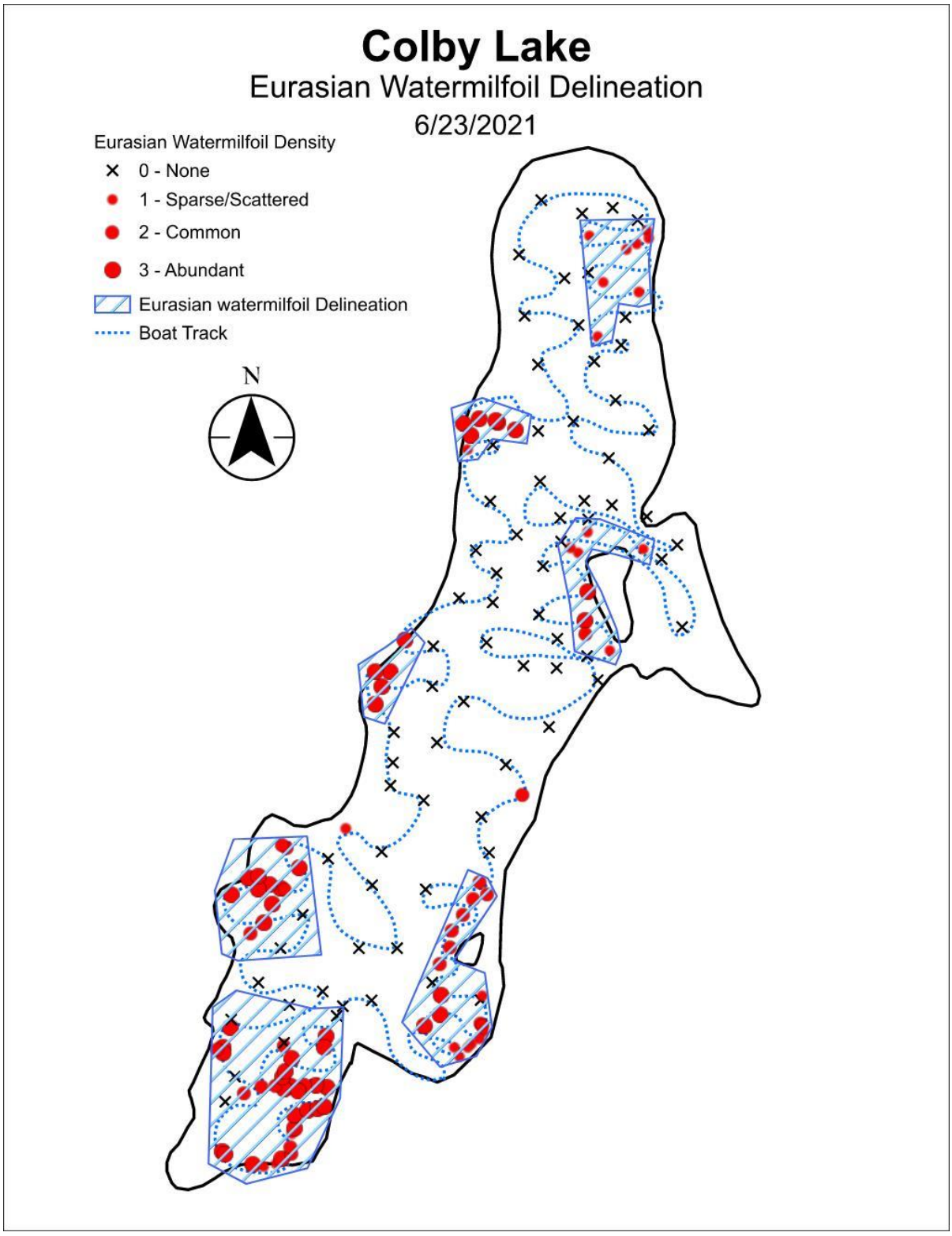

Figure 3-1: Map of boat track and EWM density during delineation and areas of infestation for Colby Lake.

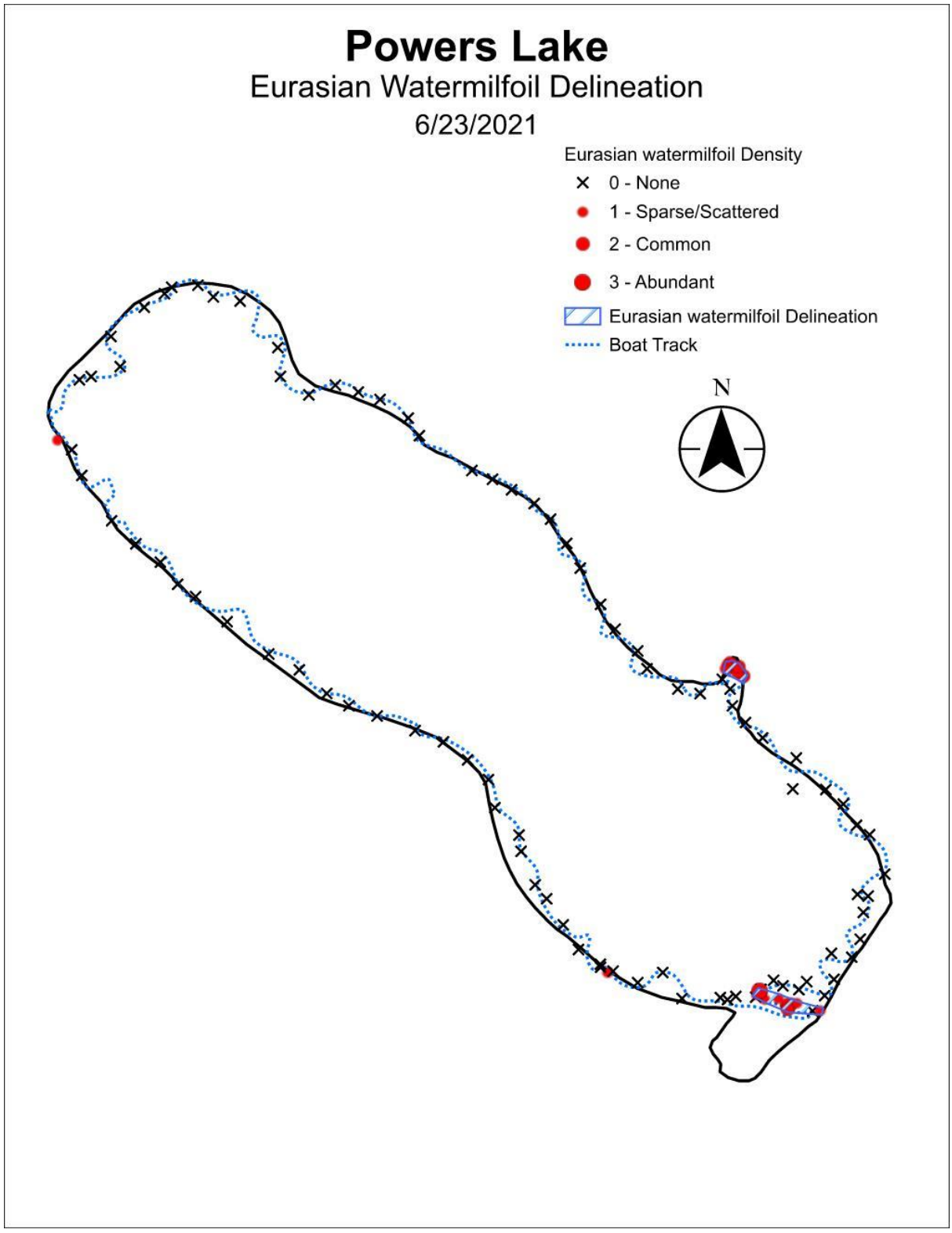

Figure 3-2: Map of boat track and EWM density during delineation and areas of infestation for Powers Lake.

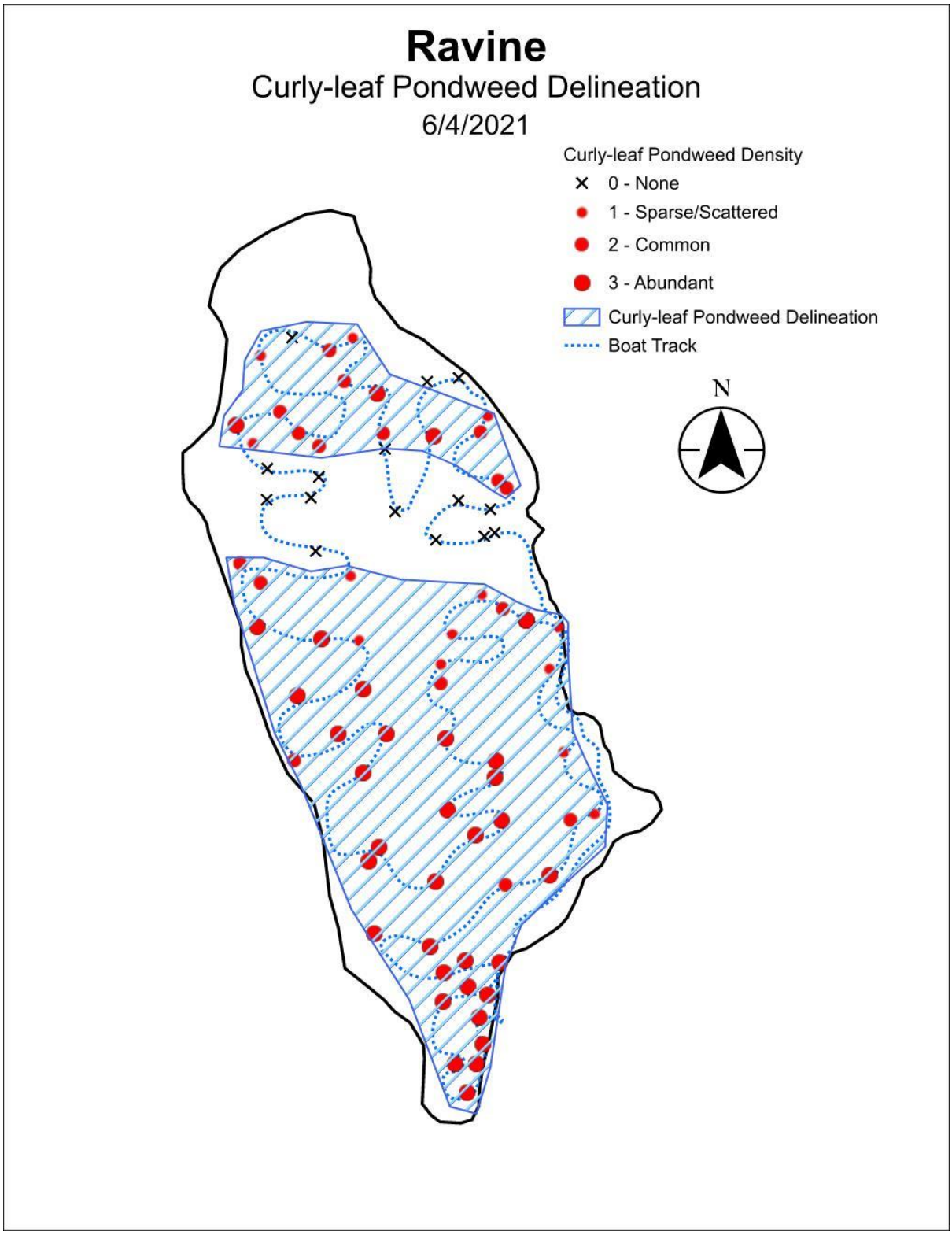

Figure 3-3: Map of boat track and CLP density during delineation and areas of infestation for Ravine Lake.

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APPENDIX A

Field Work Photos

APPENDIX B

EWM Genetic Sampling Results