Diamond Lake (DOW 34-00-4400)
Kandiyohi County, Minnesota

June 2019

Aquatic Plant Survey

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Early spring aquatic vegetation survey of Diamond Lake with focus on curlyleaf pondweed

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Executive Summary

A point intercept (n = 635) aquatic vegetation survey of Diamond Lake, Kandiyohi County, Minnesota was conducted over seven days between June 11-28 for the primary purpose of mapping curlyleaf pondweed. Secondarily, we describe here the early spring plant community. We found curlyleaf pondweed to cover 44% (or 282 acres) of the littoral zone. At present curlyleaf pondweed is distributed randomly around the entire lake with a few high density areas, particularly at the southern lobe of the lake. Aquatic plants, in general, covered 95% of all points sampled. Plants could be detected at the deepest sampled depth of approximately 19 feet. The community consisted of 21 species, and included, in order of abundance curlyleaf pondweed (*Potamogeton crispus*), muskgrass (*Chara* spp.), flatstem pondweed (*Potamogeton zosteriformis*), coontail (*Ceratophyllum demersum*), northern watermilfoil (*Myriophyllum sibericum*), star duckweed (*Lemna trisulca*), eelgrass (*Vallisneria americana*), clasping-leaf pondweed (*Potamogeton richardsonii*), Canadian waterweed (*Elodea canadensis*), bulrush (*Scripus* spp), water stargrass (*Heteranthera dubia*), Illinois pondweed (*Potamogeton illinoensis*), sago (*Stuckenia pectinata*), cattail (*Typha* spp.), yellow waterlily (*Nuphar variegata*), yellow iris (*Iris pseudacorus*), whitestem pondweed (*Potamogeton praelongus*), water crowsfoot (*Ranunculus aquatilis*), slender naiad (*Najas flexilis*), Nitella (*Nitella* spp.), and floating-leaf pondweed (*Potamogeton natans*). While early spring is the best time to survey for curlyleaf pondweed, it is not a good time to get an accurate view of the true plant community as most native species and some invasives such as Eurasian watermilfoil or starry stonewort, will not have started to grow. Subsequently, the community description here should be considered preliminary. Current goals would be to manage curlyleaf pondweed with chemical in targeted areas where lake users are either likely to continue to spread the plant or where it is a nuisance. Repeat mapping of curlyleaf is recommended every 2-3 years to check treatment effectiveness and further spreading. We recommend annual searches at boat launches for detection of pioneering populations of Eurasian watermilfoil and starry stonewort and late season (August 1 - September 30) full lake surveys or meandering surveys repeated every 2-3 years to search for them throughout the lake.

INTRODUCTION

This report describes an early spring, aquatic plant, point intercept survey performed by Limnopro Aquatic Science, Inc., for Diamond Lake (DOW 34-00-4400) in Kandiyohi County during the summer of 2019 on June 11-13, 17, 26, and 28.

On 6/6/2018 Harlan Meints, president of the *Diamond Lake Area Recreational Association* (DLARA), contacted *Limnopro Aquatic Science, Inc.* (Limnopro) to inquire about aquatic invasive species management services. On August 18, 2018, Dan McEwen of Limnopro met with the DLARA board to discuss a partnership. As a consequence of that meeting, DLARA hired Limnopro to (1) perform an AIS Early Detection Survey in 2018, primarily to rule out presence of zebra mussels, Eurasian watermilfoil (EWM) and starry stonewort (SSW) and (2) perform a full lake aquatic plant intercept survey during the first two weeks of June 2019 to map curlyleaf pondweed (hereafter CLP) for treatments to begin in 2020.

Because management of CLP can depend on the other plants it shares space with in the lake, the report will also provide information on whole lake aquatic plant community in the early spring. We note, however, that because CLP and other plants have different growth schedules, this survey will not get a clear picture of the entire aquatic plant community and should be thought of as incomplete in that respect.

The only known prior aquatic plant survey was done on June 26, 2012 on Diamond Lake as reported on in a working document by *Wenck Associates, Inc.*, dated May 2015 produced for the *Middle Fork Crow Watershed District* entitled "Diamond Lake Aquatic Management Plan." That report identified nine plant species, including CLP, which was found at 18% of the sites sampled.

Diamond Lake has a reported surface area of 1610 acres with 635 acres classified as littoral zone (Fig. 1). The littoral zone is the area of the lake that is shallow enough for sunlight to penetrate deep enough to allow rooted plants to grow. While this depth is different for every lake and depends on water clarity and other environmental factors, the MN DNR uses all the lake bottom that is less than 15 feet as a standardized littoral zone. Based on an average Secchi depth for Diamond Lake of 8.8 feet, statistical models suggest plants should grow to a depth between 10-13 feet in the lake with maximum growth occurring at 4.5 feet.

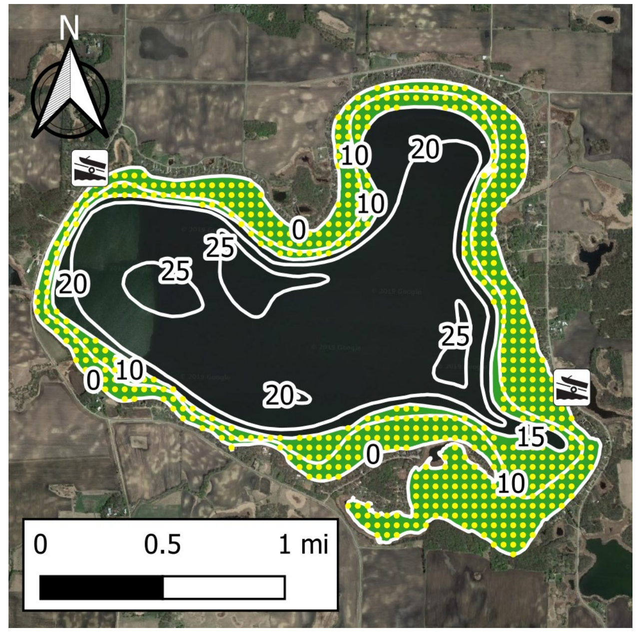


Fig. 1. Diamond Lake in Kandiyohi County, Minnesota. The green area of the lake is the DNR determined littoral zone (< 15 ft depth) where aquatic plants are expected to grow. Yellow points are the 635 points where samples were collected.

There are two public access points to the lake, one occurring on the northwest lobe of the lake and the other approximately 3/4 the length of the shoreline along the eastern shore.

METHODS

On June 11-13, 17, 20-21, and 28, 635 pre-loaded GPS coordinates (i.e., 1 point per littoral acre) equally spaced 64 meters apart, were loaded to an onboard GPS/sonar unit. After navigating the boat to each point a double-sided rake attached to a rope was tossed off the port side of the boat and dragged with four distinct pulling motions over an area of approximately three-meters (10 ft) length so that each sample represented approximately one square

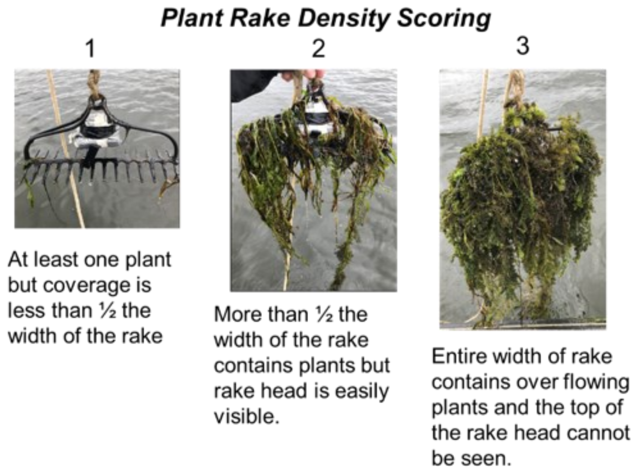


Fig. 2. Aquatic point intercept rake method density scoring. Additional scoring is "v" if plants are visually observed but not collected by the rake and a "4" if the plant is matting at the surface.

meter of the bottom. All plants brought to the surface were identified to species and ranked on a density scale from 1 to 3 (Fig. 2). Data were tabulated and analyzed within a Geographic Information System to generate point density maps and a variety of other analyses.

Conditions at the time of the survey showed water temperatures ranging from 66 to 69 °F over the duration of the study. CLP looked to be at or near peak growth for the year.

RESULTS

Two invasive plant species were detected, including CLP and yellow iris. CLP was found in 282/635 (44%) of the sites surveyed while yellow iris was visually identified near 2/635 sites (< 1%) (Fig. 3A). A total of 20 different native species covered (559/635) 88% of all sites surveyed (Fig. 3B). Combining both invasives and natives, we found 603/635 (95%) having some plants. In other words, 5% of the bottom had no plants even though shallow enough in theory to provide habitat for them. Likely a survey later in the year would show even higher coverage.

Which technically not a plant, there was also an abundance (356/635 = 56% of sites) of filamentous algae in the lake, either floating in the water column or wrapped around plants (Fig. 4). The type of filamentous algae visually detected most often are various species of the *Cladophora* genus. *Cladophora* is common in lakes of the region. It begins growing on bottom surfaces following ice out and then at some period during the year releases and becomes a floating mass. We recorded both surface and bottom attached filamentous algae but did not include it in analysis because its location does not relate to site specific environmental characteristics. For unknown reasons, filamentous algae was particularly abundant regionally in lakes during 2019.

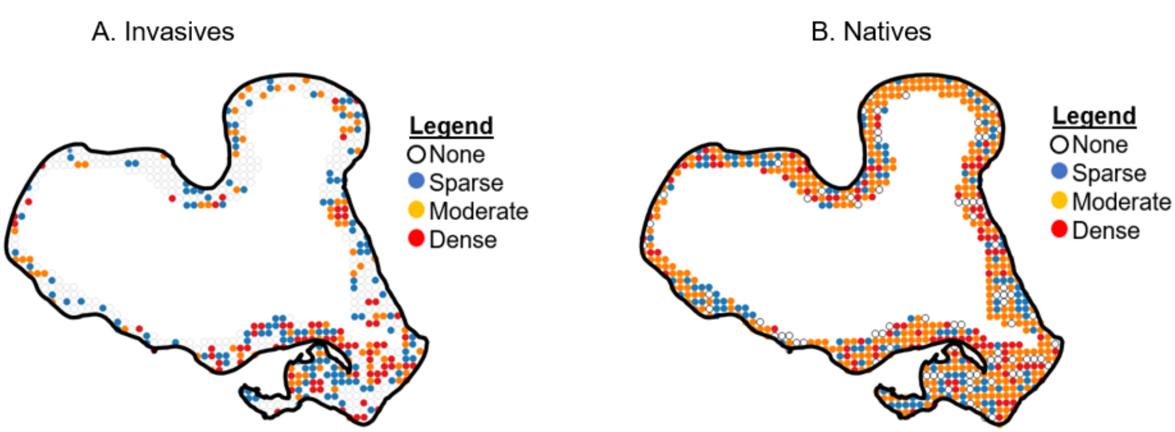


Fig. 3. Diamond Lake aquatic plant densities, showing invasive plants (A) and native plants (B). Invasive plants are primarily showing curlyleaf pondweed. The additional invasive is yellow iris present at only two sites.

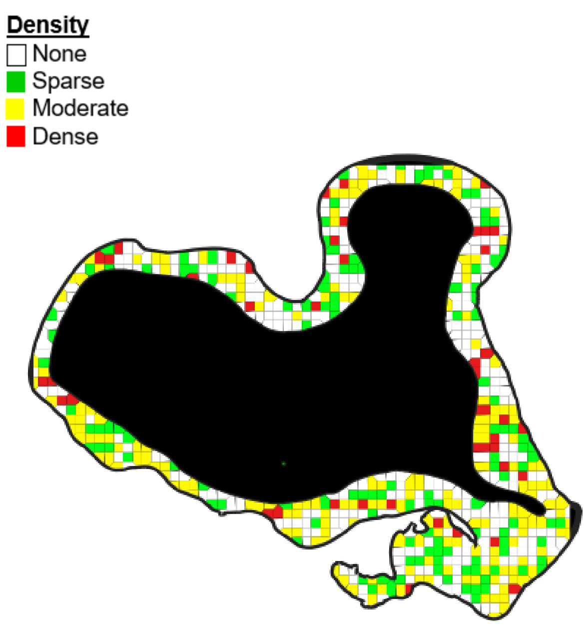


Fig. 4. Coverage of filamentous algae.

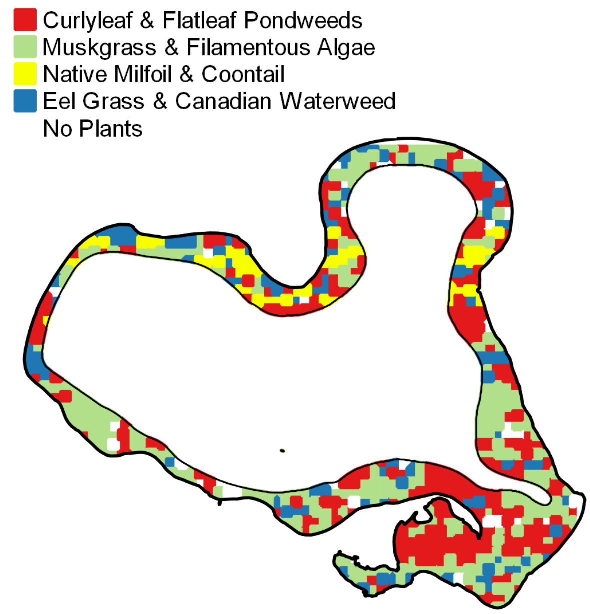


Fig. 6. Plant communities by dominant species

At any given site, there was a range between 0 and 8 different plant species. The majority of sites had 2-4 species present (Fig. 5) Higher numbers of species at a given site (i.e., diversity) are preferable to lower numbers because of additional ecosystem services a variety of types of plants living together can perform. High diversity also likely indicates areas that are not commonly exposed to human disturbance.

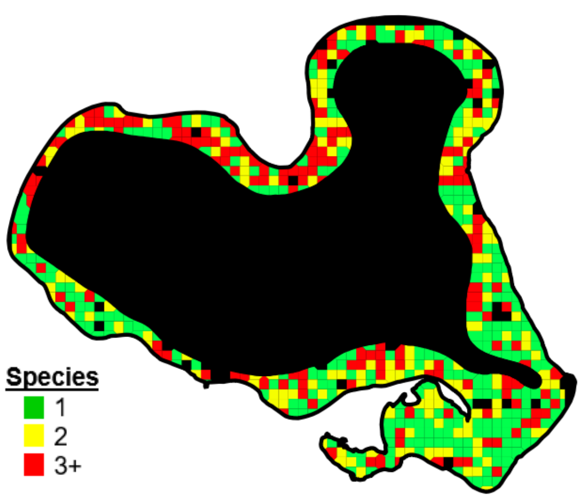


Fig. 5. Diversity of species at each sampled location. Red color indicates more species or highest diversity and green indicates monoculture (i.e., a single species occupying the space).

Based on a statistical method called an "*Indicator Species Analysis*" at each site, we assigned each area of the lake to predominant community types (Fig. 6). The analysis indicated all sites could be assigned to one of four main communities based on criteria including density, frequency of occurrences, and degree of uniqueness to an area. In general, the most important defining species for each of the four communities included CLP, muskgrass, northern milfoil, and eel grass, respectively.

As is usual, there is a clear relationship between the number of sites having plants and depth (Fig. 7). Plants were found to depth of 19 feet, which was the deepest depth surveyed. Nearly 100% of all sites to a depth of 12 feet had plants. From 12-18 feet there was a decline in proportion of sites with plants but never to 0%. For CLP only, there was a clear peak at depths of 10-12 feet.

CLP was the most common and abundant early spring plant. Other common plants included muskgrass, flatstem pondweed, coontail, and northern milfoil. Together with CLP, those four species accounted for 84% of all plants identified. A total of 13 species were detected but considered rare be-

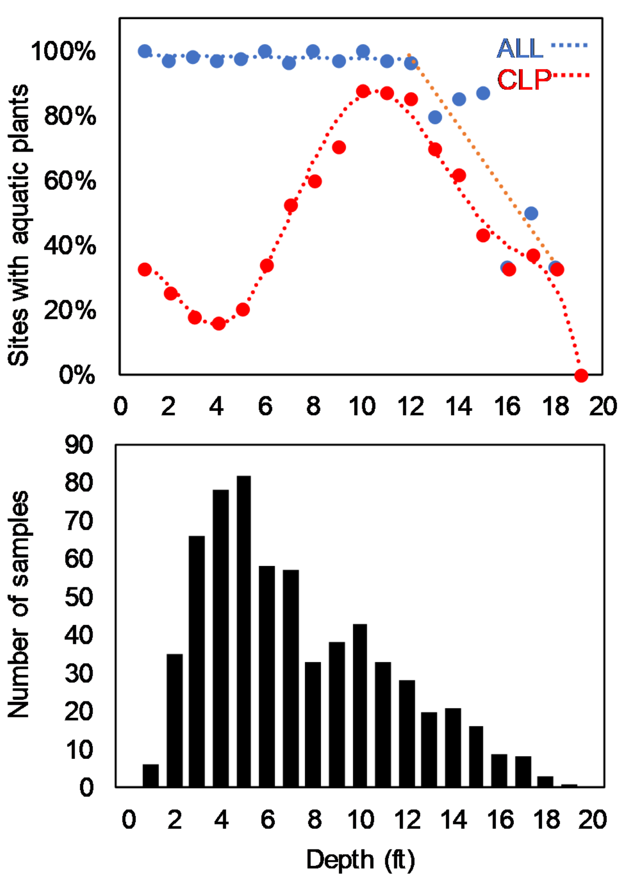


Fig. 7. Plant occurrence by depth in Diamond Lake. Top plot indicates the proportion of sites surveyed at a given depth where at least one species of plant exists (i.e., ALL) and separately where only curlyleaf pondweed (i.e., CLP) exists. The bottom plot shows the actual depths sampled out of 635. For example, 35 sites out of 635 were at 2 feet of depth. At 2 feet depth, 97% of sites (617/635) had at least one plant and 26% of sites (163/635) had curlyleaf pondweed.

cause they occupied less than 5% of the total areas sampled. These rare species included Canadian waterweed, bulrush, water stargrass, Illinois pondweed, sago, cattail, yellow waterlily, yellow iris, whitestem pondweed, water crowsfoot, slender naiad, *Nitella*, and floatingleaf pondweed. Three other species of intermediate occurrence included star duckweed, eelgrass, and clasping-leaf pondweed.

Aquatic plants can be scored using a Conservation Coefficient (CC), which is an index of how well a species can exist in the face of disturbance. CC's range from 0 (most able to withstand disturbance) to 10 (least able to withstand disturbance). CC's allow lake users to make some judgements about the "value" of certain plants over others as information about the ecological integrity of areas or whole lakes (i.e., lakes with many high CC plants are valued as "good").

The three plant species found in the spring with the highest CC's include northern watermilfoil, whitestem pondweed, and water crowsfoot, all with CC's=7. The higher CC values indicate they can only exist where habitats are relatively undisturbed. Compare this, for example, with CLP, which has a CC's of zero, meaning it can survive in lakes with high levels of disturbance.

The weighted average value Diamond Lake spring plant community is 3.47. Literature values suggest cutoff values for $C < 3$ to indicate stressed lakes and $C > 7$ to indicate unstressed lakes. By this measure, the spring community indicates a lake that is within an average range but trending toward a stressed classification.

A full list summary of plant species identified in Diamond Lake along with their CC's, occurrences and densities are given in Table 1. Finally, spatial density plots for all species, a pictorial atlas of species found, and raw data are all provided as report Appendices.

DISCUSSION AND RECOMMENDATIONS

CLP occupies 44% of Diamond Lake, which is a 26% increase since the last report on Diamond Lake that indicated it covered 18% of the littoral zone in 2012. This equates to an increase of approximately four acres per year of newly infested areas in the lake.

Current Minnesota statute allows for mechanical removal of up to 50% of CLP and/or herbicide treatment up to 15% of CLP. A combined area of mechanical or herbicide treatment may not exceed 50% of the littoral zone total except in special circumstances. A variance can be applied for in concert with a Lake Vegetation Management Plan (LVMP), which is a MN statutory document used to provide justification for any requested activities that fall outside of currently allowed control of either invasive or native plants in a lake.

Table 1. Summary of plant species identified during June 2019 during an aquatic plant survey at Diamond Lake. Conservation Coefficients (CC) range from 0 (can survive disturbed conditions) to 10 (cannot survive disturbed conditions). Occurrence is a measure of the percentage of sites that a given species was found at out of 635 sampled. Occupancy from a previous study conducted by the MN DNR in 2012 are also shown for comparison. Density is a measure of the total proportion of plant biomass collected during the survey estimated by rake density scores. Cumulative density adds density from most to least dense plants. For example, 25% of all plants collected were curlyleaf pondweed while 20% of all plants collected were coontail. Their cumulative density is 45%, meaning 45% of all plants collected were either curlyleaf pondweed or coontail.

Conservation Coefficient	Common Name	Scientific Name	2012 Occupancy	2019 Occupancy	Change (2012-2019)	2019 Density	2019 Cumulative Density
0	Curlyleaf pondweed	*Potamogeton crispus*	18%	44%	26%	25%	25%
NA	Muskgrass	Chara spp.	40%	39%	-1%	20%	45%
6	Flatstem pondweed	*Potamogeton zosteriformis*	34%	42%	8%	20%	65%
2	Coontail	*Ceratophyllum demersum*	13%	26%	13%	12%	76%
7	Northern milfoil	*Myriophyllum sibiricum*	8%	14%	6%	8%	84%
5	Star duckweed	*Lemna trisulca*		11%		4%	88%
6	Eelgrass	*Vallisneria americana*	6%	11%	5%	4%	92%
5	Claspingleaf pondweed	*Potamogeton richardsonii*	3%	6%	3%	2%	94%
4	Canadian waterweed	*Elodea canadensis*	5%	3%	-2%	1%	95%
NA	Bullrush	*Scirpus* spp.		3%		1%	96%
6	Water stargrass	*Heteranthera dubia*		3%		1%	97%
6	Illinois pondweed	*Potamogeton illinoensis*		2%		1%	98%
3	Sago	*Stuckenia pectinata*	5%	2%	-3%	1%	99%
NA	Cattail	*Typha* spp.		2%		1%	99%
6	Yellow waterlily	*Nuphar variegata*		1%		0.32%	100%
0	Yellow iris	*Iris pseudacorus*		0.3%		0.09%	100%
7	Whitestem pondweed	*Potamogeton praelongus*		0.3%		0.09%	100%
7	Water crowsfoot	*Ranunculus aquatilis*		0.3%		0.09%	100%
5	Slender naiad	*Najas flexilis*		0.2%		0.05%	100%
NA	Nitella	*Nitella* spp.		0.2%		0.05%	100%
5	Floatingleaf pondweed	*Potamogeton natans*		0.2%		0.05%	100%

Given a 635 acre littoral zone, the lake association could potentially treat up to 95 acres (i.e., 15%) chemically. If the total of 15% (i.e., 95 acres) were chemically treated that would leave 184 acres for mechanical treatment. Because CLP spread through fragmentation and because reducing only the tops of plant canopies can increase light and nutrient availability allowing for greater growth in remaining plants, we do not generally recommend mechanical treatment of CLP. In fact, mechanical treatment may actually increase coverage.

Costs for either mechanical or chemical treatment are highly variable and depend on the depth of the area to be treated and/or the equipment to be used during a mechanical treatment. Typical costs can range from $600 per acre to upwards of $1,200 per acre. Generally, the deeper the area to be treated, the greater the expense. Chemical costs are based on volume (i.e., acre-ft) treated and estimates of such are provided in the Appendix.

We provide two separate approaches to delineate areas for consideration of treatment (Fig. 8). Given the total area of curlyleaf infestation is less than 50% (i.e., 44%) in theory all of it could be treated. The entire area along with depths and volumes for each area with curlyleaf on the lake are provided in the appendix. These areas were produced by assuming the point at the middle of a littoral acre represents the entire littoral acre to which it belongs. The geographical products resulting from this type of mapping is called a set of Voronoi polygon (Fig. 8B).

Likely, not all of these areas will be treated. The lake association can use the plotted areas to choose a subset to treat. There is no scientific way to determine the "right" areas to select as it depends on an estimation of how users see the lake in terms of

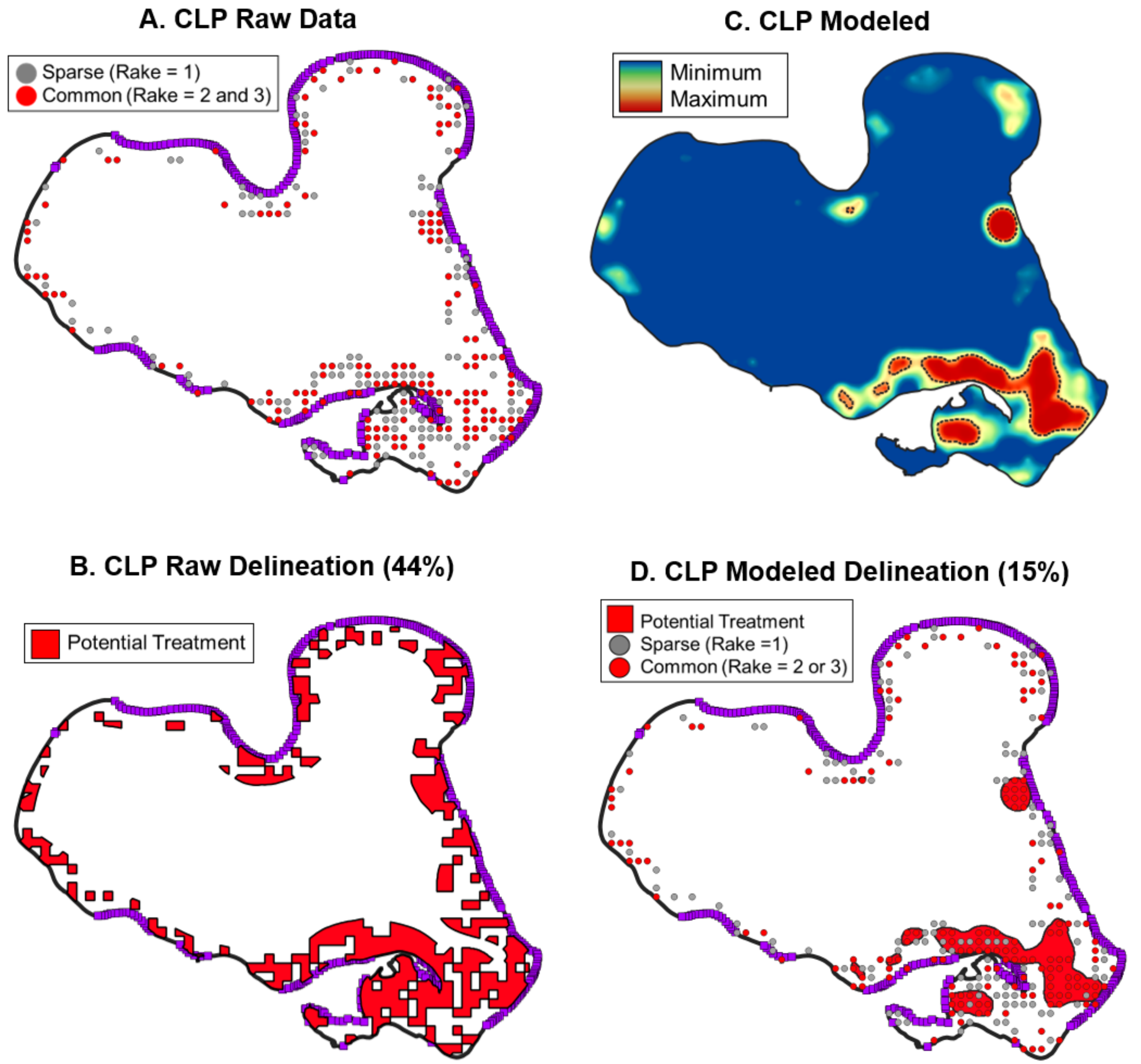


Fig. 8. Curlyleaf pondweed (CLP) results and delineation of potential areas for treatment. Clockwise, starting in the upper left-hand corner shows (A) the location of sampled points where CLP was found and its approximate density, (B) a delineation map based on dissolved Voronoi polygons, which indicates all areas in the lake where a particular area of the lake is closer to a point that was sampled with CLP versus having no CLP, (C) krige-modelled CLP based on densities at each point , and (D) the modeled highest 15% of the littoral zone with CLP for chemical treatment consideration. Purple squares on A, B, and D show parcel locations with properties as digitized from satellite images.

which particular areas of infestation are more problematic than others.

We can offer some general suggestions that seem to provide a reasonable approach.

1. Public access sites. If CLP exist near a boat launch it provides an area of contact with boats moving in and out of the lake. If moving into the lake and CLP becomes attached to boat motors at the boat launch it may be distributed to new areas (e.g., Appendix, Fig. 13, area 43).

2. Channel leading from the public access to open

water. If there is a typical path boaters take in and out from the boat launch and CLP is at or near the surface, it can potentially be moved to new areas within the lake (e.g., Appendix, Fig. 13, area 43).

3. Highly developed shorelines with high densities of docks or homes. If lake home owners recreate off of their shorelines, the greater the density the more individuals in the lake that would be served by treatment (e.g., Appendix, Fig. 13, area 48)

4. Shallow areas. CLP in shallow areas is most likely to cause a nuisance given it will likely reach the lake's surface. For a given acreage, shallower areas are less expensive to treat than deeper areas. Shallow areas are also more prone to anoxic conditions developing as CLP grows given shallower areas warm faster. This may be particularly important in shallow areas that serve as spawning areas for fish (e.g., Appendix, Fig. 13, area 31).

5. Highest density areas. These are the areas with the most dense beds of CLP. These areas, particularly in more shallow regions of the lake, produce an obvious nuisance. High density areas also can provide a source of turions for new growth (e.g., Appendix, Fig. 13, area 26).

Because high density (Suggestion #5) is a common way to delineate treatment areas, we have provided a geostatistical model of the 15% highest density areas of CLP in the lake (Fig. 8C-D). A geostatistical model uses mathematical relationships between points where plants were surveyed to predict the amount of CLP in areas where samples were not taken.

Finally, timing of chemical treatment for CLP is an important consideration. CLP is one of the first plants to grow in the spring after ice-out before most native plants have grown (Fig. 9). Because CLP grows so early, it can shade out native plants, which require early season sunlight begin their annual growth. This can, and often does, lead to CLP becoming a dominant plant in lakes it infests.

CLP becomes a detriment to lakes when it surface mats and interferes with recreation, and when it dies and senesces beginning in July. As it dies, it releases nutrients, which can stimulate algae growth to

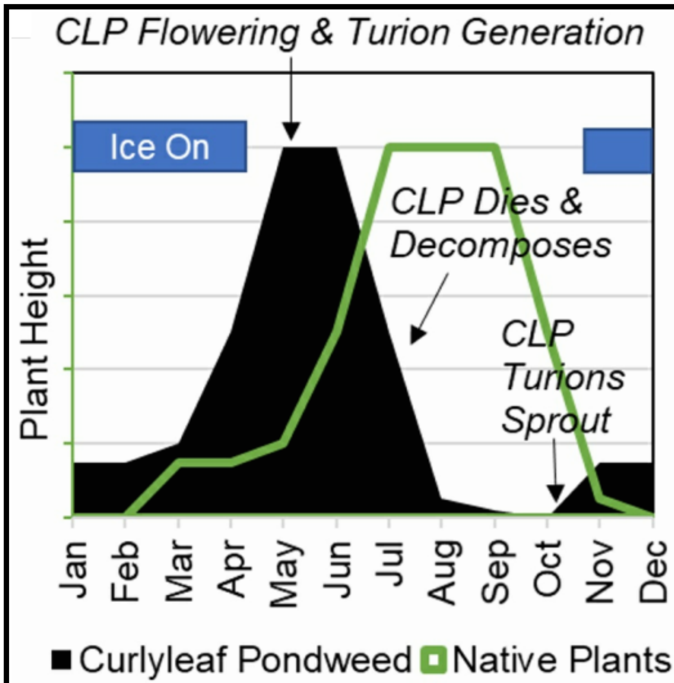


Fig. 9. Curlyleaf pondweed idealized life cycle (black solid area) compared with most native plants life cycle (green line)

make the water turbid or cloudy. Bacteria that decompose the dead plant use oxygen in the water in that process, which can lead to localized suffocation of fish and other organisms.

Averaged monitoring data between 2012-2018 indicate this may be occurring in Diamond Lake. There tends to be a deterioration in water clarity that coincides with increases in nutrients and algae after die off in July of CLP (Fig. 10).

Any treatment or removal of plants from the lake requires the approval of the MN DNR. Two separate departments within the MN DNR work to regulate permitting for aquatic plant control. One of those processes is treatment under an Invasive Aquatic Management Permit (IAMP) applied for by a lake association or some other local government unit and regulated by the area Aquatic Invasive Species Specialist and the other process is for individual property owners to obtain an Aquatic Management Permit (APM), which is regulated by the local MN DNR Fisheries department.

The general process to obtain an IAMP is to have a delineation mapping and survey of the area to be treated, applying for the permit through MN DNR

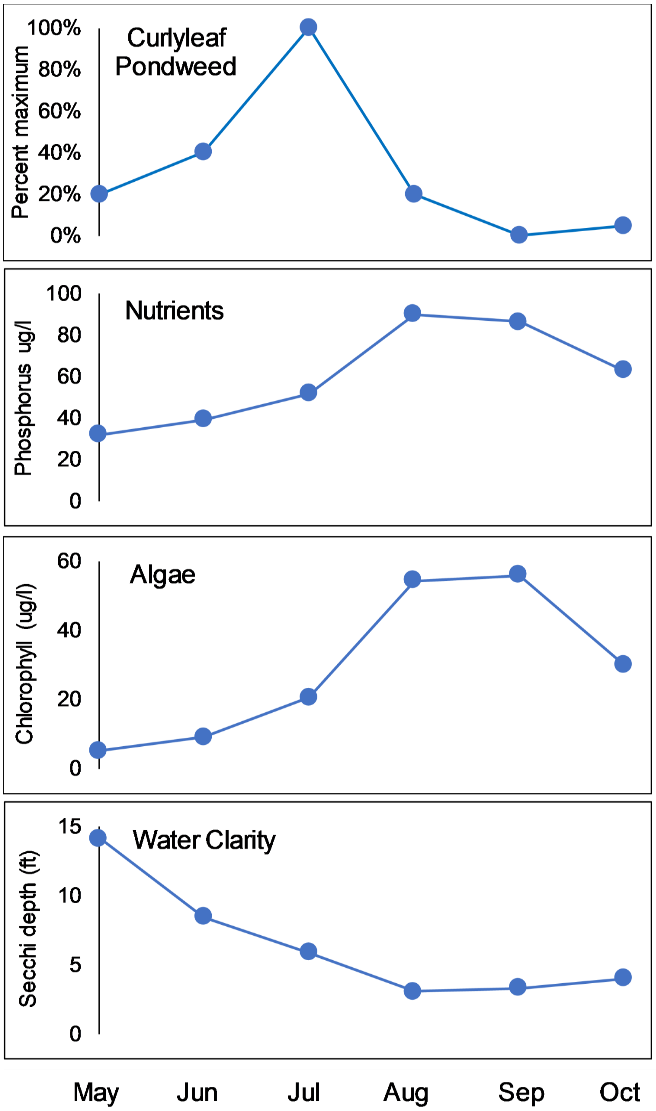


Fig. 10. Monthly averaged trophic measurements for Diamond Lake over the period of 2012-2018. Curlyleaf pondweed plot is not based on data but on general knowledge of growth pattern in Minnesota.

Permitting and Reporting System (MPARS; dnr.state.mn.us/mpars) at which time, generally, the MN DNR will validate maps and make a ruling on areas that can or cannot be treated. At that time, a permit is issued and an approved lake management IAMP are typically issued for larger areas of treatment and are applied for directly by the lake association. As of the writing of this report, Kandiyohi County falls under the Southern Region as it pertains to AIS management, and the MN DNR AIS Specialist is Eric Katzenmeyer who can be reached at 320-234-2550 or eric.katzenmeyer@state.mn.us by email.

This current survey should suffice for that for the next 2-3 years or more. The AIS Specialist will request electronic GPS/GIS Shapefiles which are being provided to you and will also be kept on file at Limnopro Aquatic Science, Inc. for up to 5 years. Once he receives these, in the spring he may come out to the lake to physically verify that there is still CLP to be treated prior to issuing a permit.

The only MN DNR approved chemical that can be used to treat CLP under an IAMP is the contact herbicide endothall. Unlike systematic herbicides, contact herbicides only destroy parts of the plant the chemical touches. In a sense, it is like a chemical lawnmower. For that reason, strategies for long term control of CLP focus on treating the plant prior to it's production of turions.

Studies indicate that small areas, generally defined as areas less than 5 acres, require higher concentration of chemical than larger areas. Minimum and maximum labeled rate for application of endothall is 1 ppm and 5 ppm active ingredient respectively. Our recommendation would be to use these as guidelines for applying to areas in the lake. Consequently, it will take less chemical (1/5) to treat larger rather than smaller areas on a per acre basis and as such there is economical benefit of treating larger areas.

While the plant reproduces both sexually (flower stalks protrude from the water surface to produce seeds), its primary mode of spread is thought to be vegetative spread via turions (Fig. 11). Turions looks like miniature pine cones, can last for many seasons, and are very hardy against extreme conditions, including herbicide and mechanical treatments.

We recommend choosing the same areas for treatment over a period of 2-3 years before a new CLP survey is conducted and new plots are make for further treatment.

In addition to or in the place of an IAMP treatments can also be granted on a property by property basis with an Aquatic Plant Management (APM) permit. These permits are regulated by the MN DNR Fisheries Office. The New Ulm Office currently over-

Fig. 11. Curlyleaf pondweed reproductive structures with flowers (left) that break the water surface to be pollinated and turions (right) that are produced vegetatively and break off of existing plants in June or July to sprout and begin to grow in September.

sees these permit applications for Kandiyohi County. They can be reached at 507-233-1218 with questions. These permits allow up to two seasonal chemical and/or mechanical removal of aquatic plants along property owner shorelines if aquatic plants impede the ability of the property owner to use the lake. Generally, the MN DNR will allow you to treat a width of half of the shoreline property you own out to 100 or 150 feet lakeward. They will also allow you to carve out a 15-foot width channel to reach the main lake if given permissions. An additional benefit of AMP over IAMPs is that there are fewer restrictions in chemicals that can be used and in the allowed timing for their application. While IAMPs are restricted to treatment of invasive species, AMPs can be applied for to control any plant, including natives that may impede with property owners to use waters adjacent to their properties.

Recognize that individual property owners, not a lake association, would apply for these permits. Typical costs for individual property shoreline treatments are less variable and tend to be around the $300 per treatment cost. Because these treatments can benefit the entire lake, it is not uncommon for lake associations to offer some level of cost sharing for property owner treatments.

Aside from CLP, separate efforts to monitor for early detection of Eurasian watermilfoil and starry stonewort should also be a priority. At the very least, intense searches at and around boat launch areas would provide opportunity for detection and control before these get spread throughout the lake. The best time for looking for these other invasive plants would be between August 15 and September 30.

In conclusion, continued monitoring will be important in keeping CLP localized and under control

Appendix

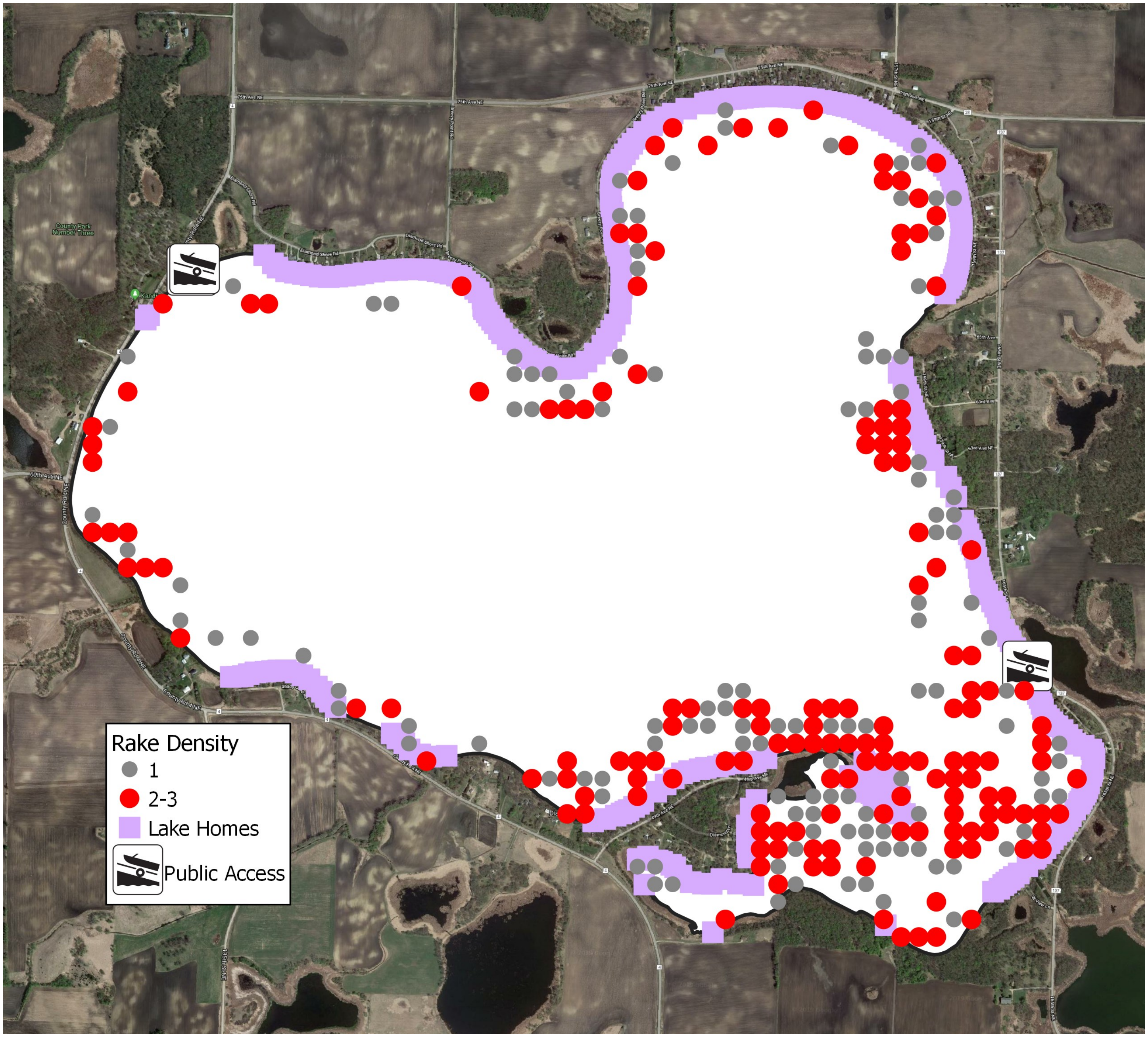
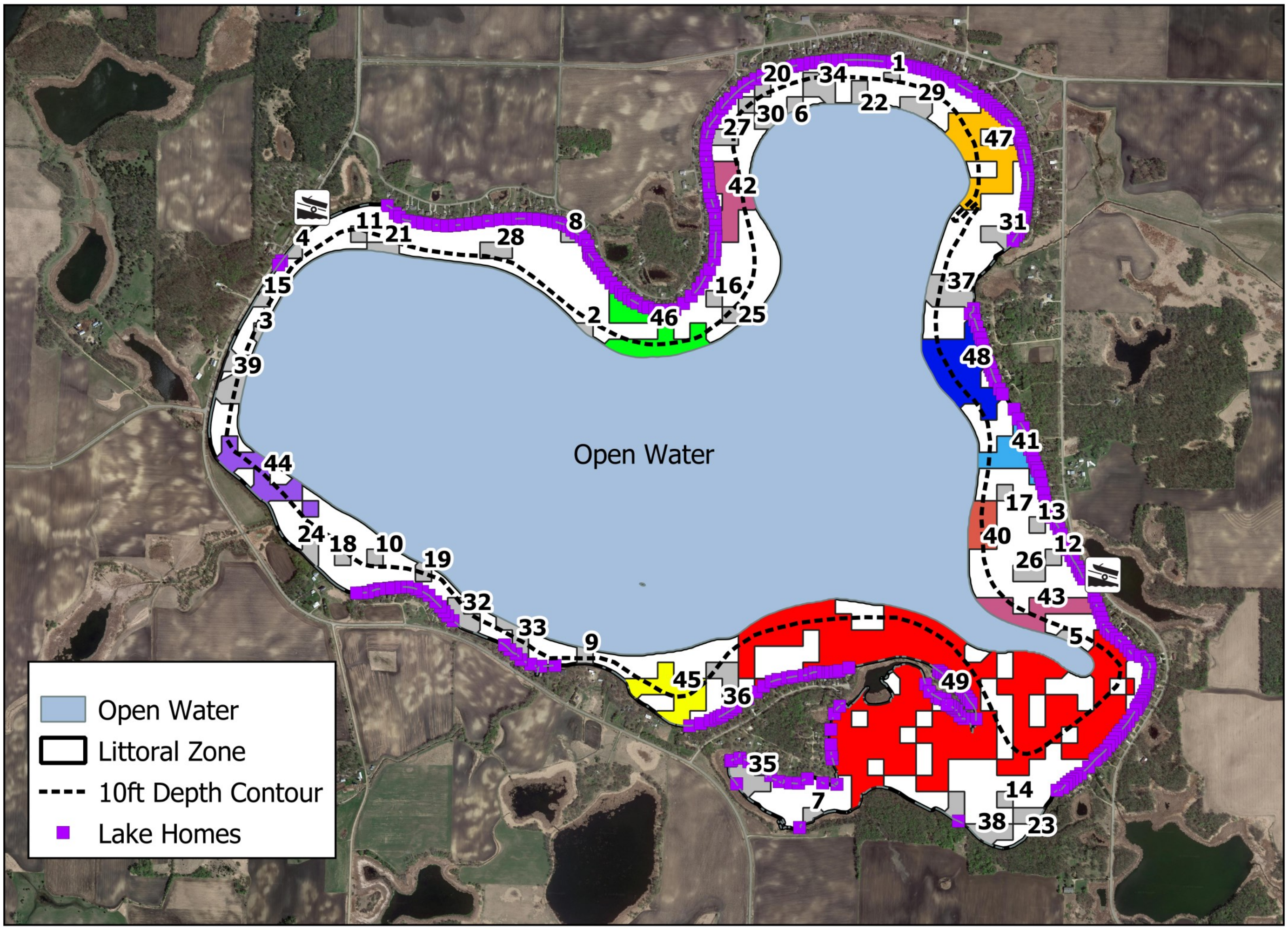


Fig. 12. Point intercept results for curlyleaf pondweed. Rake densities have been divided into two categories indicating sparse or rare (rake density = 1) or common (rake density = 2-3).

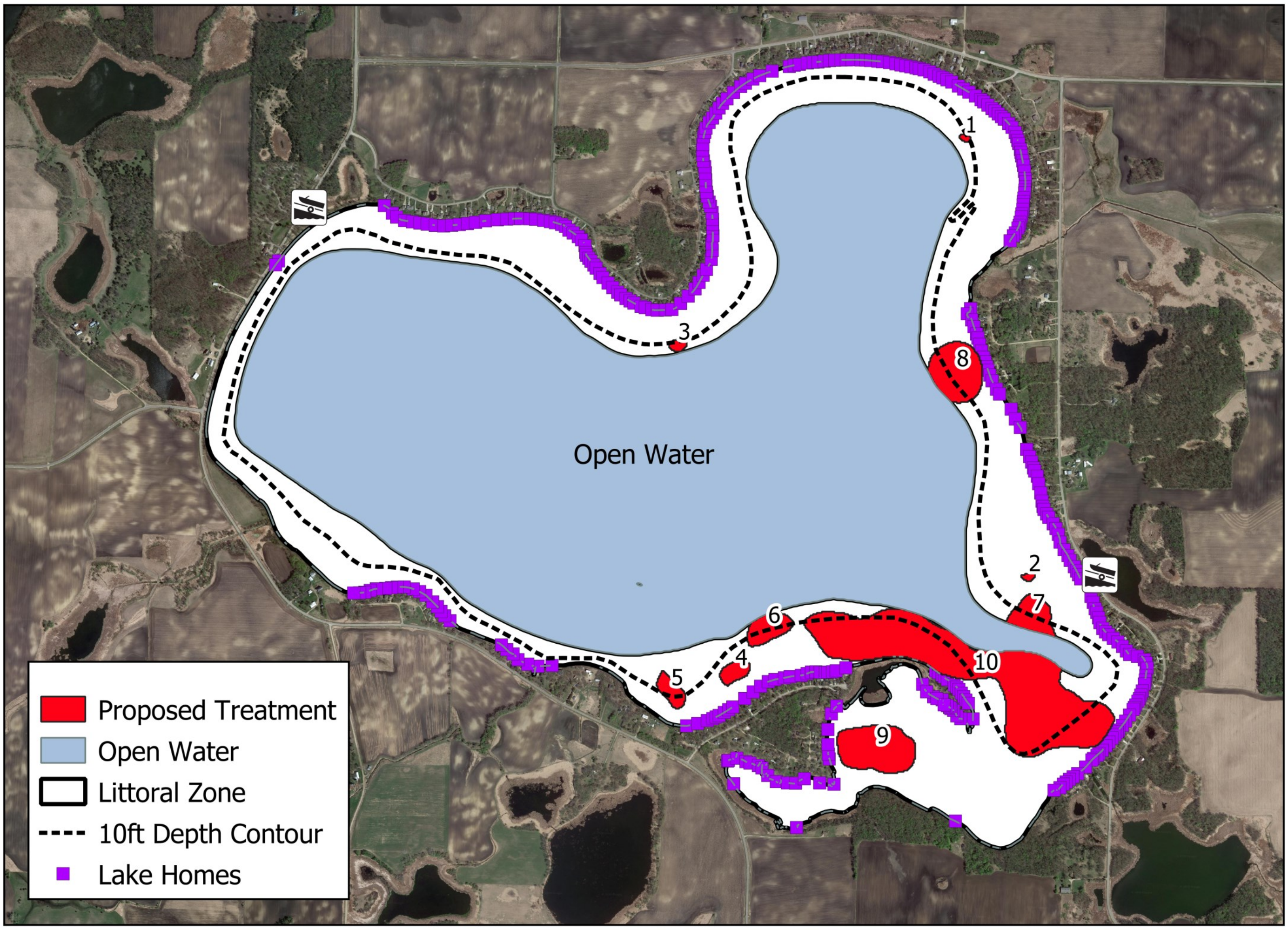


ID	Acres	Depth (ft)	Acre-ft	Density
1	0.5	7.7	3.9	0%
2	0.6	13.4	8.0	75%
3	0.7	12.4	8.7	100%
4	0.8	3.5	2.8	75%
5	0.9	12.8	11.5	25%
6	0.9	13.7	12.3	50%
7	0.9	2.5	2.3	75%
8	1.0	0.8	0.8	50%
9	1.0	10.2	10.2	25%
10	1.0	10.5	10.5	25%
11	1.0	10.9	10.9	25%
12	1.0	2.0	2.0	25%
13	1.0	2.3	2.3	25%
14	1.0	3.4	3.4	75%
15	1.0	4.3	4.3	25%
16	1.0	4.8	4.8	25%
17	1.0	6.5	6.5	50%

ID	Acres	Depth (ft)	Acre-ft	Density
18	1.0	7.9	7.9	25%
19	1.1	10.3	11.3	25%
20	1.2	5.7	6.8	50%
21	1.3	13.0	16.9	50%
22	1.5	12.8	19.2	50%
23	1.7	0.8	1.4	50%
24	1.8	3.5	6.3	38%
25	1.9	12.0	22.8	38%
26	2.0	5.6	11.2	100%
27	2.0	5.9	11.8	38%
28	2.0	7.9	15.8	25%
29	2.2	13.3	29.3	38%
30	2.3	11.3	26.0	38%
31	2.5	2.9	7.3	38%
32	2.7	5.5	14.9	33%
33	2.9	8.3	24.1	56%
34	2.9	11.7	33.9	38%

ID	Acres	Depth (ft)	Acre-ft	Density
35	3.8	2.5	9.5	25%
36	4.1	5.8	23.8	63%
37	4.3	8.0	34.4	25%
38	4.6	0.1	0.5	65%
39	4.7	7.6	35.7	56%
40	5.2	10.6	55.1	33%
41	6.8	4.7	32.0	32%
42	8.6	5.4	46.4	38%
43	8.6	9.3	80.0	56%
44	9.4	8.8	82.7	42%
45	9.5	7.8	74.1	53%
46	12.1	8.1	98.0	42%
47	15.5	7.3	113.2	45%
48	15.9	7.6	120.8	52%
49	126.1	5.6	706.2	51%

Fig. 13. Estimated areas of curlyleaf pondweed based on measured amounts at points. Density indicates the average density of curlyleaf pondweed where 100% is highest amount found at a point. Colored polygons indicate proposed treatment areas. Colors are randomly assigned except for areas that are less than 5 acres total, which are colored grey. These areas would require higher concentrations of chemical to get control.



ID	Acres	Depth (ft)	Acre-ft	Density
1	0.2	10.8	2.2	54%
2	0.3	5.7	1.7	54%
3	0.7	11.5	8.1	55%
4	2.1	5.9	12.4	55%
5	2.3	10.1	23.2	55%
6	4.0	10.8	43.3	57%
7	4.9	10.8	52.9	60%
8	9.8	8.2	80.2	65%
9	12.0	5.0	60.0	59%
10	61.1	9.2	561.3	61%

Fig. 14. Estimated areas of curlyleaf pondweed based on modeled amounts at points. Density indicates the average density of curlyleaf pondweed where 100% is highest amount found at a point. Total area represented in 15% of the littoral zone, which is the maximum amount the MN DNR allows for chemical treatment.

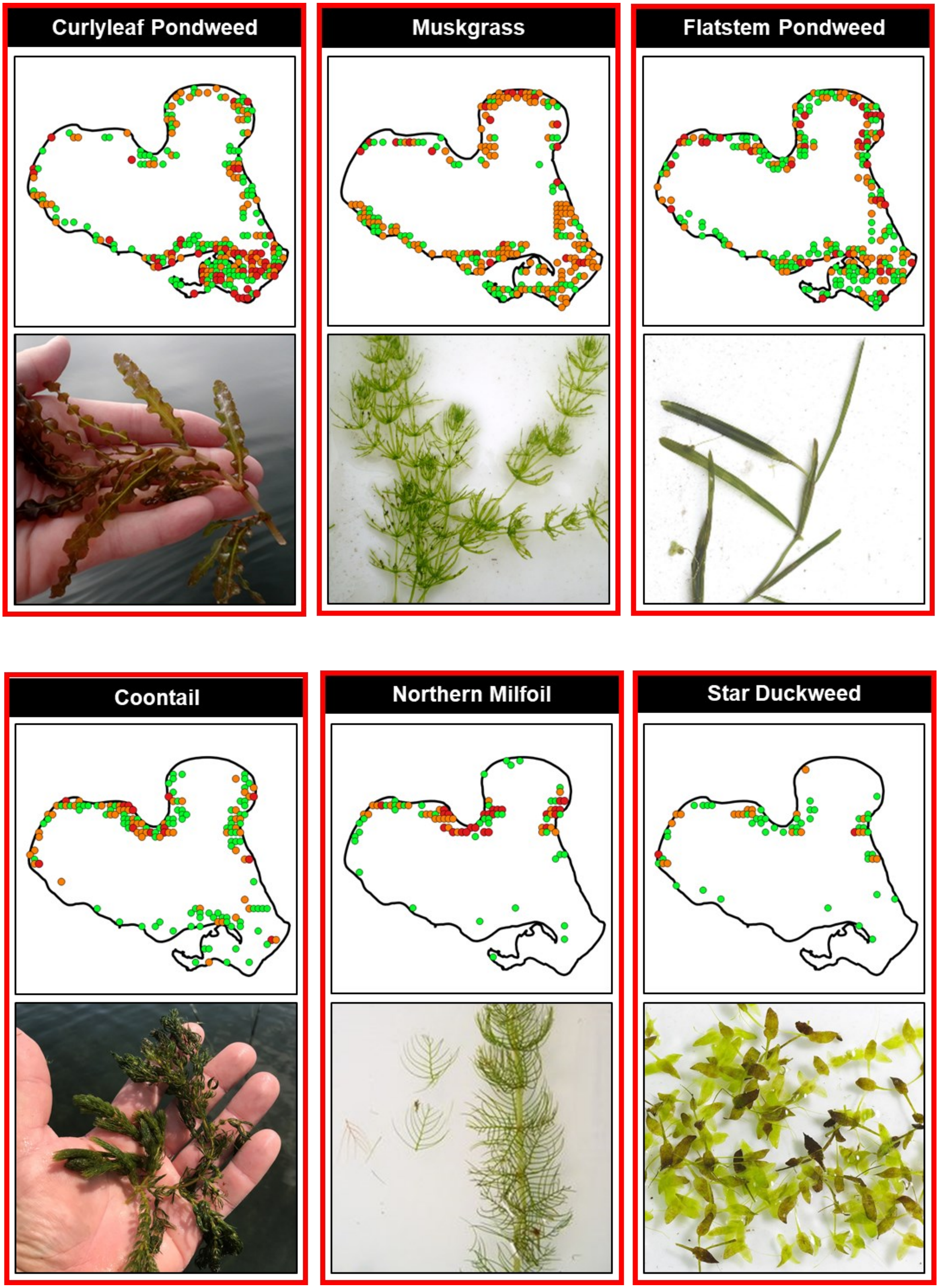


Fig. 15. Photographic atlas of plants identified in Diamond Lake during the 2019 plant survey

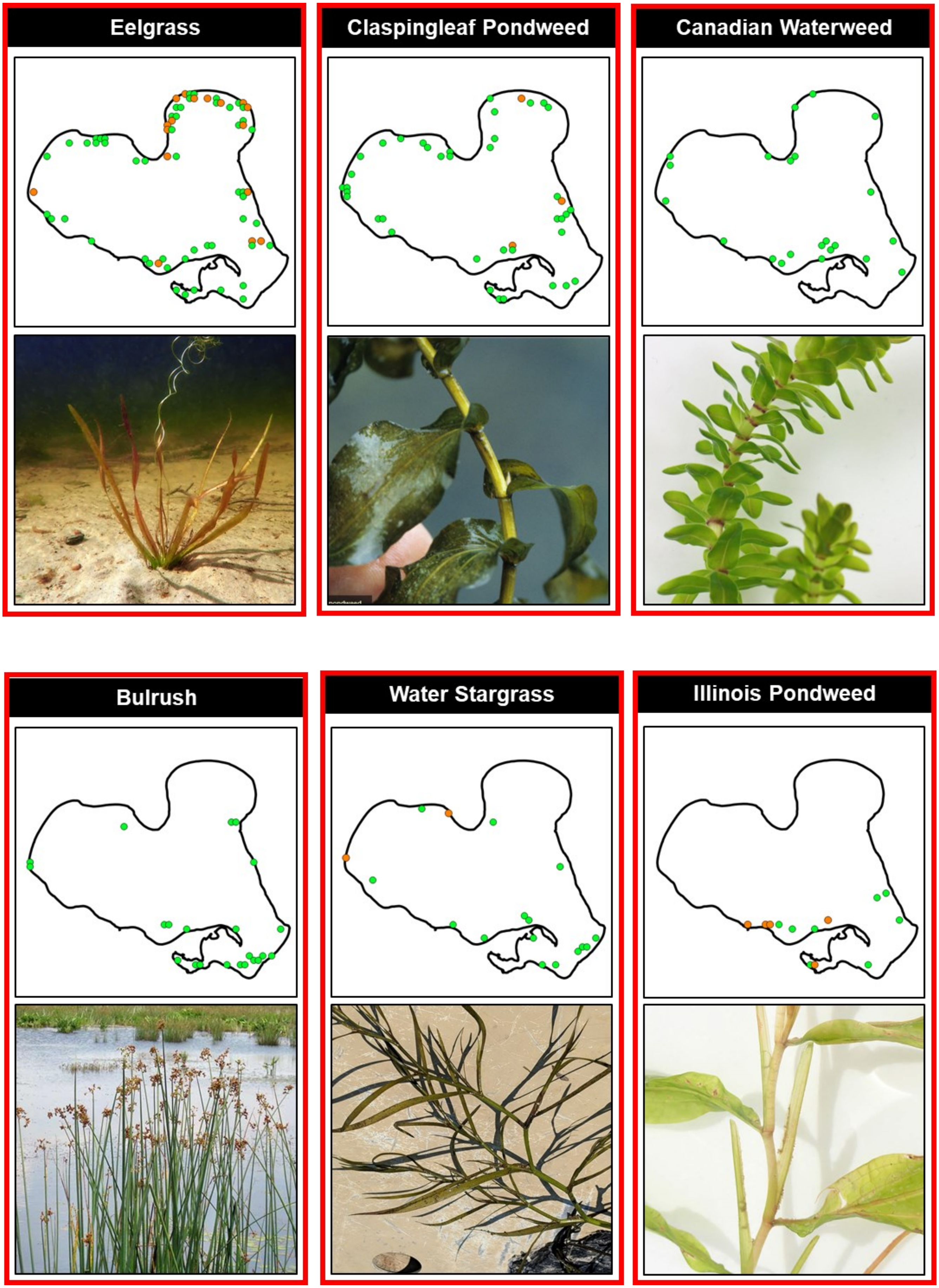


Fig. 15. Photographic atlas of plants identified in Diamond Lake during the 2019 plant survey

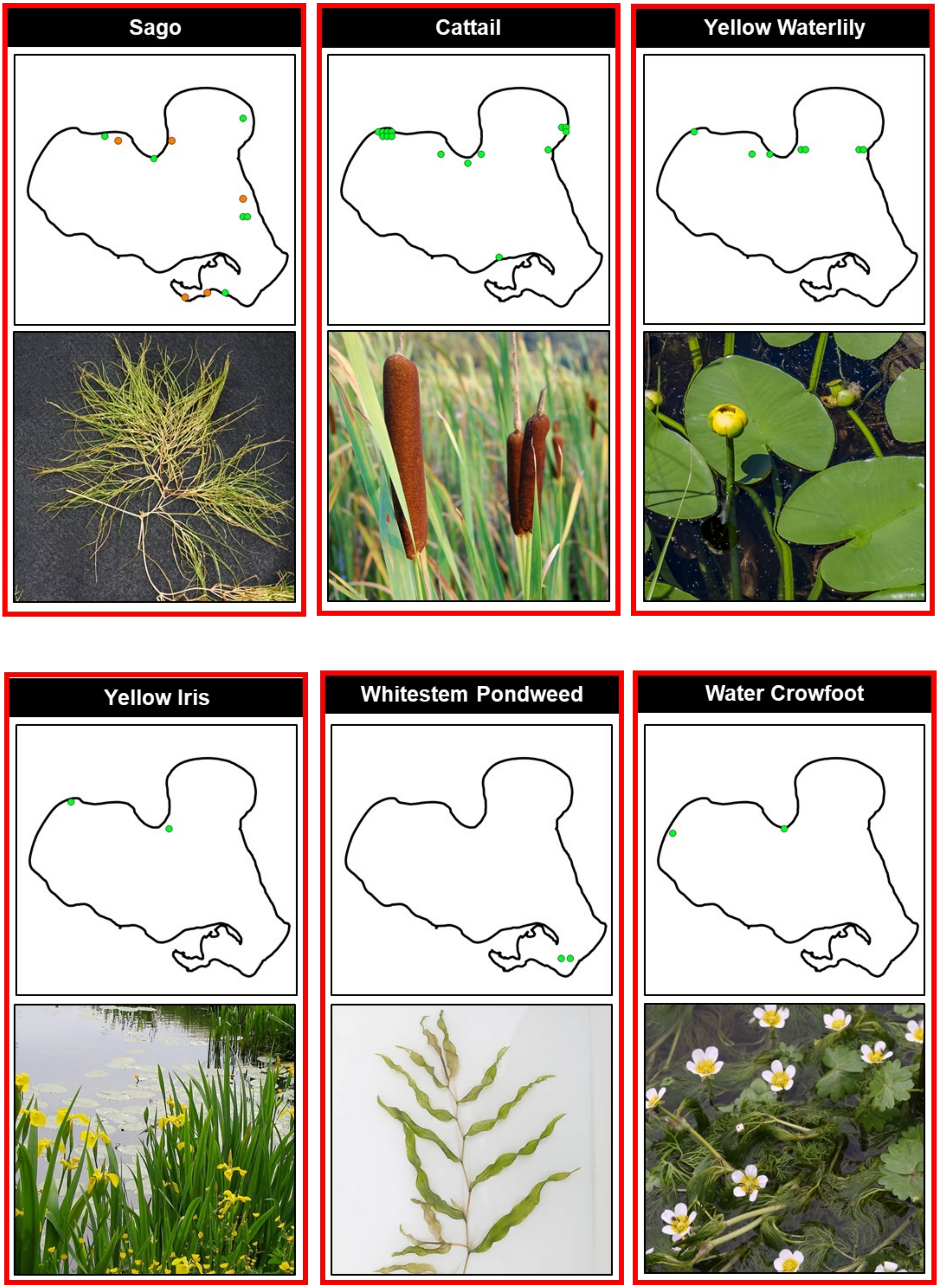


Fig. 15. Photographic atlas of plants identified in Diamond Lake during the 2019 plant survey

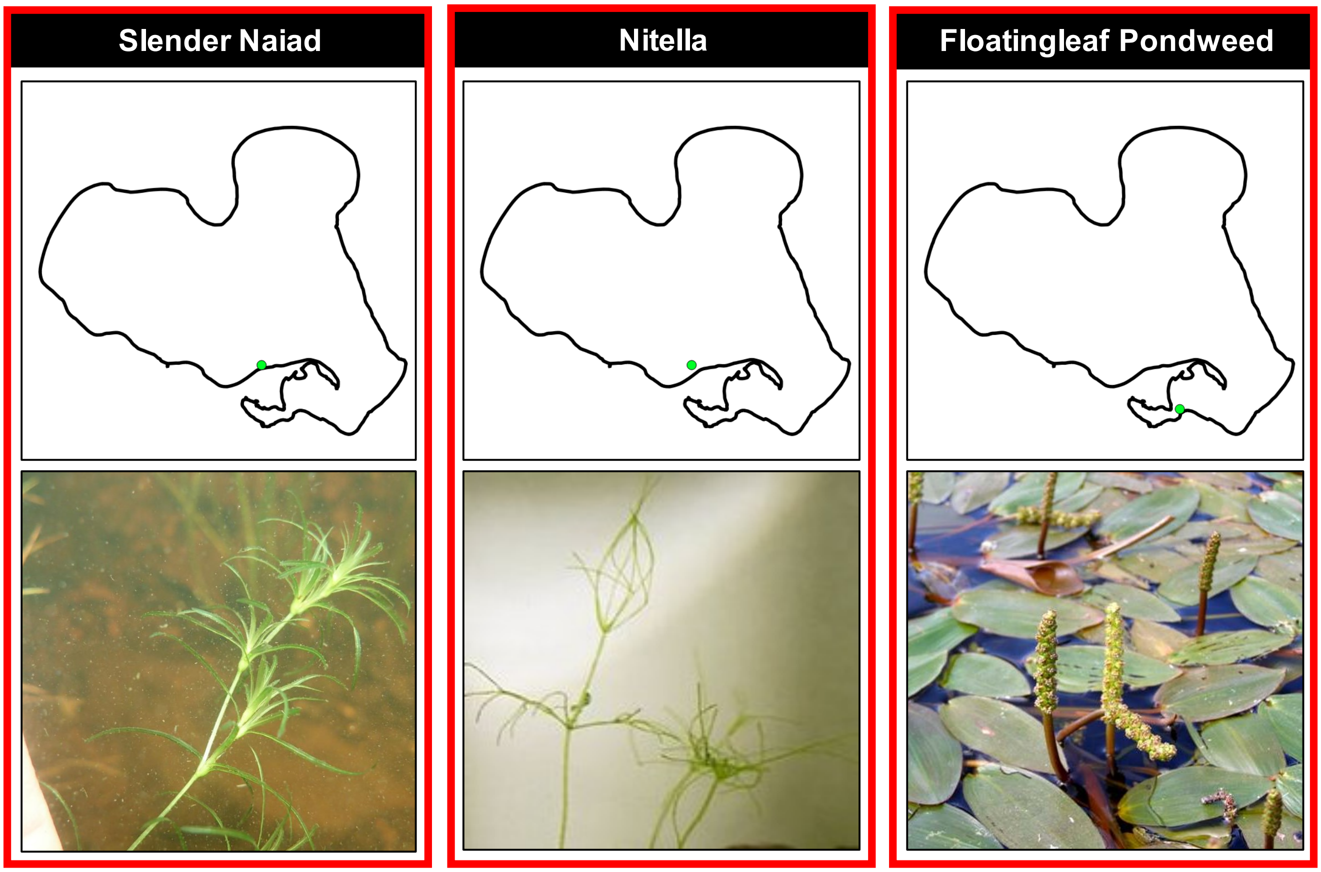


Fig. 15. Photographic atlas of plants identified in Diamond Lake during the 2019 plant survey