Aquatic Plant Community of

Lakes Lucy, Mitchell, Susan, Riley and Staring within the

Riley Purgatory Bluff Creek Watershed:

Annual Report 2015

Melaney A. Dunne
and
Raymond M. Newman

University of Minnesota

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I. Introduction

Lakes Lucy, Riley and Susan are small lakes connected by Riley Creek within the cities of Chanhassen and Eden Prairie, Minnesota in the Riley Creek Subwatershed. Lakes Mitchell and Staring, also in Eden Prairie, are within Purgatory Creek Subwatershed. These lakes are within the Riley-Purgatory Bluff Creek Watershed District and are included in our aquatic vegetation research. Aquatic vegetation surveys were performed on these lakes between May and October during various years from 2009 through 2015. These surveys were conducted to evaluate the response of aquatic plant communities to lake management actions. There are several goals of the project, but the main purpose is to assess the native aquatic plant community response following the removal of common carp (*Cyprinus carpio*) from the lakes. Carp were removed (by the Sorensen lab) from Lake Susan in winter 2009 and its plant community was surveyed in the spring and summers of 2009 through 2015. Carp were removed from Lake Lucy in January 2010 and plants were surveyed in 2010, 2011, 2012 and 2015. Carp were removed from Lake Riley in March 2010 and plant surveys were completed from 2011 through 2015. In Lake Staring, carp removal began in the winter of 2012 and was still ongoing through 2015. In the summer of 2015 the carp population was reduced to approximately 10% of the pre-removal population. Aquatic plants were surveyed in Lake Staring in 2011 through 2015. Continuing these surveys after carp removal allows an assessment of the plant community response compared to the pre-removal surveys.

An additional goal of the project is to promote the recovery of native plants and control aquatic invasive macrophytes. The hypothesis is that removal of carp will lead to a decrease in uprooting of aquatic plants and an increase in water clarity. This will in turn increase the light available to aquatic plants, which will benefit both native and exotic species (Hanson and Butler, 1994). However, invasive species such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curlyleaf pondweed (*Potamogeton crispus*) were already established in the lakes, and due to their natural aggressive recruitment, there was concern the invasive species would expand at a faster rate than native species.

Techniques to reduce the dominance of the invasive species and enhance native plant communities were evaluated. Transplanting native submersed plants took place in Lake Susan in 2009, 2010 and 2011. Early season endothall herbicide treatments were conducted to control curlyleaf pondweed in the spring of 2013 and 2014 in Lake Susan, in 2013, 2014, and 2015 in Lake Riley, and in 2015 in Lake Mitchell. To control Eurasian watermilfoil in Lake Riley a 2, 4-D herbicide treatment was applied in June 2015. To control a sparse population of Eurasian watermilfoil found in Lake Staring in September 2015, a granular form of triclopyr herbicide was used in October 2015.

This annual report presents data and results mainly from 2015 with some data included from 2009 (Newman 2009), 2010 (Newman and Knopik 2011), 2011 (Knopik and Newman 2012), 2012 (JaKa et al. 2013), 2013 (JaKa et al. 2014) and 2014 (JaKa and

Newman 2015). It concludes with recommendations for further management of each of the lakes.

II. Methods

Plant communities were surveyed for species occurrence and diversity (point intercept surveys), biomass, curlyleaf pondweed turion densities, and watermilfoil herbivore abundance to assess response to carp removal and monitor and develop approaches to enhance native plant communities while controlling invasive macrophytes. In 2015, early season, lake-wide, endothall herbicide treatments were employed to control curlyleaf pondweed in Lakes Riley and Mitchell. A lake-wide 2, 4-D herbicide treatment was used on Lake Riley in June to control Eurasian watermilfoil. Localized placement of granular triclopyr (known as Renovate3®) was employed in Lake Staring in October when isolated patches of Eurasian watermilfoil were found. The goal of the herbicide treatments was not only to control the invasive curlyleaf pondweed and Eurasian watermilfoil, but also to determine whether the removal of curlyleaf and Eurasian watermilfoil will enhance the native plant community. Aquatic bathymetry and vegetation sonar data were collected using a Lowrance depth finder and ciBioBase software (by Contour Innovations) to create bathymetry and lake vegetation maps.

Point Intercept Survey:

A point intercept survey approach modeled from the methods described by Madsen (1999) was used to define sampling points to assess the plant community in each lake. Using ArcMap GIS, survey points were generated following a systematic square grid. Grid spacing ranged from 40m to 60m to ensure at least 120 points within the littoral zone (≤4.6m depth) of each lake. The sampling points were loaded into a Garmin GPS 76 and a boat was navigated to each sampling point. A weighted double headed rake (0.3m wide) attached to a rope was then tossed into the lake, allowed to sink and retrieved along the lake bottom for approximately three meters, thus sampling approximately one square meter. The vegetation collected was identified and a semi-quantitative density rating (0 to 5) was visually estimated. Density ratings were given for the total amount of vegetation on the rake in addition to ratings given for each individual species on the rake. Frequency of occurrence was determined for each species within the littoral zone in addition to the overall frequency of native and invasive plants. Mean species richness was determined from the total number of taxa present at each site and total number of species found in each lake was also determined. Samples were taken in depths up to 5.5m to determine the maximum depth of rooted vegetation. ArcMap GIS was used to generate maps to assist in visualizing taxa locations, depth of growth, and richness at sites.

Biomass Sampling:

Plant biomass (g dry/m^2) was sampled using methods described by Johnson and Newman (2011). A subset of at least forty littoral sampling sites were randomly selected from the point intercept survey points on each lake. At each site, all the plants in a $0.09m^2$ area were collected with a long handled garden rake that was lowered to the lake bottom, rotated three times to ensure uprooting of all plants, and pulled to the surface (Johnson and Newman 2011). The samples were placed in plastic bags and taken to a lab where the plants were sorted by species and roots removed. The shoots were spun in a salad spinner to remove excess water and the samples were dried at 105˚C for >48 hr and weighed. Mean dry biomass was calculated for each species based on all samples taken within the littoral zone. Turions were removed from the dried curlyleaf biomass samples, counted and weighed to get an estimate of turion production.

Curlyleaf Pondweed Turion Sampling:

The invasive curlyleaf pondweed is found in many lakes in Minnesota including Lakes Lucy, Mitchell, Riley, Staring and Susan. One of the most common ways curlyleaf pondweed reproduces is by forming over-wintering vegetative propagules called turions (Madsen and Crowell 2002). To better understand the curlyleaf pondweed population dynamics in the lakes, we assessed the turion bank in the sediment of Lakes Mitchell, Riley, Staring and Susan. Turion sampling in Lake Susan began in October of 2010, sampling in Lakes Riley and Staring began in October of 2011, and sampling in Lake Mitchell began in October of 2013. Forty sampling sites in the littoral zone (≤ 4.6m depth) were randomly selected from the littoral zone point intercept sites at each lake. The coordinates were entered into a GPS, and a boat was navigated to each point. At each point a petite ponar (225 cm^2 area, sample depth ~10 cm) was used to take a sediment sample. Sampling depth and substrate type was noted. The sediment sample was then passed through a 1mm mesh sieve to remove fine sediment. The remaining sample was returned to the lab and turions were enumerated. The turions that had sprouted in the field (plants or sprouts collected with turions attached) were discarded. The remaining turions were stored in transparent freezer bags and placed in a dark refrigerator at 5 ˚C. Every 7 days the samples were examined for sprouting, and sprouted turions were counted and removed. After four weeks, the rate of sprouting of cold turions had declined. At this point the samples were placed at room temperature (21 ˚C) under natural spectrum lighting for 12 hours per day. Samples continued to be examined every 7 days for another 4 weeks and sprouted turions were removed and recorded. Turion viability (proportion) was calculated by taking the ratio of the number of sprouted turions per site (including the turions that were sprouted when collected) to the total number of turions collected per site. The total number of turions collected at each site was expressed as number of turions per square meter.

Milfoil Herbivore Abundance:

Surveys were conducted to evaluate the abundance of milfoil herbivores. The milfoil weevil, *Euhrychiopsis lecontei*, is a native weevil found in many lakes in North America. Much of the weevil's life cycle is dependent on the milfoil plant. Evidence suggests the milfoil weevil can be effective in controlling Eurasian watermilfoil (Newman 2004). Surveys were conducted on Lakes Ann, Lucy, Riley and Susan in 2011 and 2012, and continued in Lakes Riley and Susan in 2013, 2014, and 2015 to determine if milfoil weevils were present or abundant. Additionally, Lake Mitchell began to be surveyed in 2015. On Lake Susan, repeated surveys were conducted every four weeks to quantify and monitor the population throughout the summer in 2010 through 2015. Lake Riley was sampled every four weeks in the summers of 2012 through 2015. Lake Mitchell was sampled every four weeks in the summer of 2015. To sample milfoil herbivores, transects perpendicular to the shoreline were predetermined and geographically spread around the lake. Three sampling points were established on each transect, one at a shallow depth (<0.75m), one at an intermediate depth (0.75 to 1.5m), and one at a deeper depth (>1.5m). At each sampling point the top 0.5m of eight stems of Eurasian watermilfoil were collected and placed in a sealable bag with water. In a lab, each sample was examined with a 3x magnifying lens, plant stems and meristems were counted, and all herbivores (lepidopterans and weevils) and weevil life stages (eggs, pupae, larvae, and adults) were counted and preserved in 80% ethanol.

Water Quality:

Several indicators of water quality were measured periodically on all lakes. Water temperature, dissolved oxygen and photosynthetically active radiation (PAR) readings were recorded in 0.5m depth intervals using a YSI ProODO electronic oxygen and temperature meter and a LiCor LI-185 quantum sensor. Secchi depths were recorded to the nearest 0.1m.

Herbicide Treatments

Early season endothall herbicide treatments were conducted in the spring of 2013 and 2014 in Lake Susan and spring of 2013, 2014, and 2015 in Lake Riley and spring of 2015 in Lake Mitchell. It has been shown that endothall can efficiently control curlyleaf pondweed at temperatures between 10-15 ˚C, when native plants should not be actively growing yet (Skogerboe and Getsinger 2002, Poovey et al. 2012). Using this method of timing, we can effectively target curlyleaf pondweed with little collateral damage to the native plant community (Jones et al. 2012). During the early parts of spring when ice came off the study lakes we would begin to closely monitor water temperatures. Once water temperatures approached the treatment temperature threshold we then delineated the densest areas of curlyleaf and provided these areas to the contracted herbicide applicator. We conducted a pretreatment (point intercept and biomass) survey on all treatment lakes just prior to treatments. Post-treatment surveys were conducted at all lakes in June to correspond with typical peak curlyleaf abundance and biomass. Precise survey timing varied with growth each year. A third survey was conducted in August in all lakes corresponding with the timing of peak biomass of native plants. Fall turion surveys were completed in October to monitor the turion densities in the sediments, which is essentially the same as monitoring the seed bank for curlyleaf pondweed. Reducing turions in the sediments is an important management strategy to the reduction of curlyleaf pondweed.

To control Eurasian watermilfoil a 2, 4-D herbicide treatment was conducted on Lake Riley in the summer of 2015. 2, 4-D is a systemic herbicide effective against dicot plants. It has been demonstrated to be effective in controlling Eurasian watermilfoil while having minimal impact on most native species since the majority of native plants are monocots (Parsons *et al.* 2001). Delineation of milfoil occurred in late May and the liquid herbicide was applied to designated areas. A pre-treatment survey occurred in June and an additional survey occurred in August to assess Eurasian watermilfoil and native macrophyte response.

A granular form of triclopyr (known as Renovate3®) was used to control a small population of Eurasian watermilfoil observed in Lake Staring in the fall of 2015. The granules were placed at the locations of occurrence mapped by James Johnson of Freshwater Scientific Services, LLC. Similar to 2, 4-D, triclopyr is selective against Eurasian watermilfoil while having minimal adverse effects on other plant species (Poovey *et al.* 2004). The October 8th treatment was followed by a vegetation survey on October 9th to further assess the macrophyte response to the carp removal and monitor the potential spread of invasive aquatic plants.

Aquatic Bathymetry and Vegetation Mapping

We collected sonar data using a Lowrance HDS 5 Gen 2 Fish finder during all point intercept surveys in 2013, 2014, and 2015. The HDS 5 recorded data onto an SD card while we navigated the boat to survey points. From the lab, we uploaded the sonar data to the ciBioBase servers. After ciBioBase processed the sonar data we then had access to bathymetry and vegetation maps as well as a report generated for each lake containing plant and water data such as average biovolume and percent area covered.

III. Lake Lucy Results

Lake Lucy (DOW ID 10-000700) is the headwaters of the Riley Creek Watershed. Lake Lucy has a surface area of about 36 hectares (87 acres), with about 35 hectares (86 acres) of littoral zone, and a maximum depth of 6.8m (22ft) (MN DNR LakeFinder 2015). The outlet of Lake Lucy goes directly into Lake Ann. In an attempt to improve water quality, common carp were removed from Lake Lucy in January 2010 (Bajer and Sorensen, personal communication). Plant assessments began in summer 2010 to quantify the response of the aquatic plant community to the carp removal and ended in 2012. In 2015, Lake Lucy was surveyed twice in the summer, on July 7th and September 1st, to assess if plants have expanded after the carp removal.

Water Quality:

Water clarity in 2015 was consistent with observations from prior years (Figure 1). Secchi depths did not fall below 1m until August. Dissolved oxygen profiles taken during the summer show an anoxic hypolimnion starting at 2.5 to 3m (Figure 1).

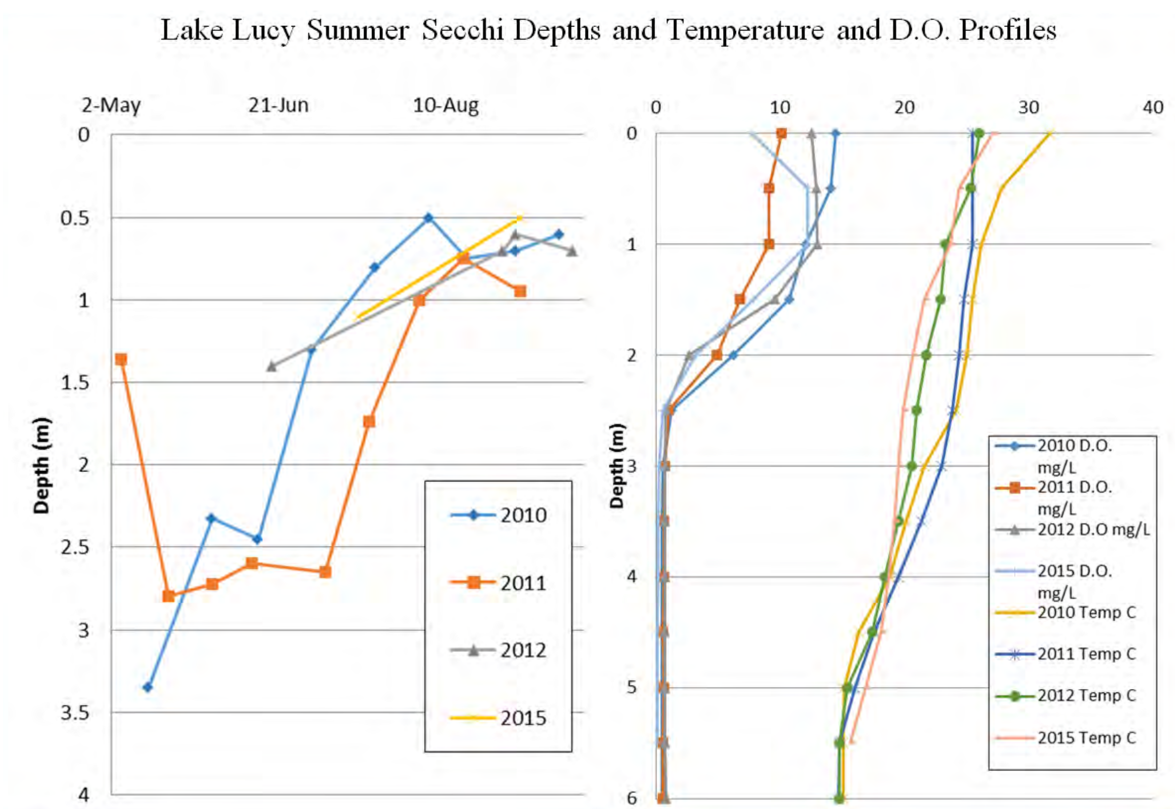


Figure 1. Secchi depths for Lake Lucy 2010 – 2012, 2015 (Bajer and Sorensen unpublished data, personal communication) and dissolved oxygen (mg/L) and temperature (°C) profiles taken on 9 August 2010, 17 August 2011, 27 August 2012, and 1 September 2015.

Aquatic Vegetation Survey:

Point intercept surveys were previously conducted in Lake Lucy in June and August of 2010, 2011, and 2012. Surveys were conducted in July and September of 2015. Overall there was a moderately diverse plant community in Lake Lucy with 18 different aquatic plant species found during the surveys (Table 1). In 2015 only 11 different aquatic plant species were found. The maximum species richness per site in 2015 was 6 species per site in September (Figure 2). The greatest plant coverage was noted in June 2010 when 86% of sites sampled shallower than 4.6m contained plants. In 2015, the greatest plant coverage was only 59% of sites in July. Coontail (*Ceratophyllum demersum*) was the most frequently occurring species in all surveys conducted (Figure 3). Star duckweed (*Lemna trisulca*), white water lily (*Nymphaea odorata*), greater bladderwort (*Utricularia vulgaris*) and curlyleaf pondweed (*Potamogeton crispus*) were also observed at relatively high frequencies.

Coontail, chara (*Chara sp.*) and white water lily had the highest biomass in Lake Lucy during the surveys (Figure 4). Biomass values appeared to be relatively stable throughout survey years of 2010 through 2012. However, in 2015 the biomass of most species showed a slight decline compared to prior August surveys. It may be due to the fact that the survey occurred later in the summer than in previous years.

Overall, exotic species frequency and biomass declined between the 2012 and 2015 survey years. Eurasian watermilfoil was observed at less than 1% of sites during 2011 and 2012 surveys and it was not observed in 2015 (Figure 3). Curlyleaf pondweed was present in over 40% of sites surveyed at 4.6m or shallower in June 2011. In July 2015 curlyleaf pondweed presence declined to less than 10% of sites surveyed in July 2015 (Figure 3 top). Also, curlyleaf pondweed had very little biomass present during all survey years (Figure 4), but the surveys in 2015 were too late to capture peak curlyleaf biomass.

Table 1. Aquatic plants found in surveys conducted in Lake Lucy 2010 through 2012, and 2015.

Common Name	Scientific Name	Abbreviation
Emergent		
Cattail	*Typha spp.*	Typh
Submerged species		
Coontail	*Ceratophyllum demersum*	Cdem
Chara	*Chara spp.*	Char
Canada waterweed	*Elodea canadensis*	Ecan
Eurasian watermilfoil	*Myriophyllum spicatum*	Mspi
Northern watermilfoil	*Myriophyllum sibiricum*	Msib
Curlyleaf pondweed	*Potamogeton crispus*	Pcri
Narrow leaf pondweed	*Potamogeton pusillus*	Ppus
Flat-stem pondweed	*Potamogeton zosteriformis*	Pzos
Sago pondweed	*Stuckenia pectinata*	Spec
Greater bladderwort	*Utricularia vulgaris*	Uvul
Water stargrass	*Zosterella dubia*	Zdub
Floating-leaf Species		
Star duckweed	*Lemna trisulca*	Ltri
Lesser duckweed	*Lemna minor*	Lmin
White water lily	*Nymphaea odorata*	Nodo
Yellow water lily	*Nuphar variegata*	Nvar
Greater duckweed	*Spirodela polyrrhiza*	Spol
Watermeal	*Wolffia columbiana*	Wcol

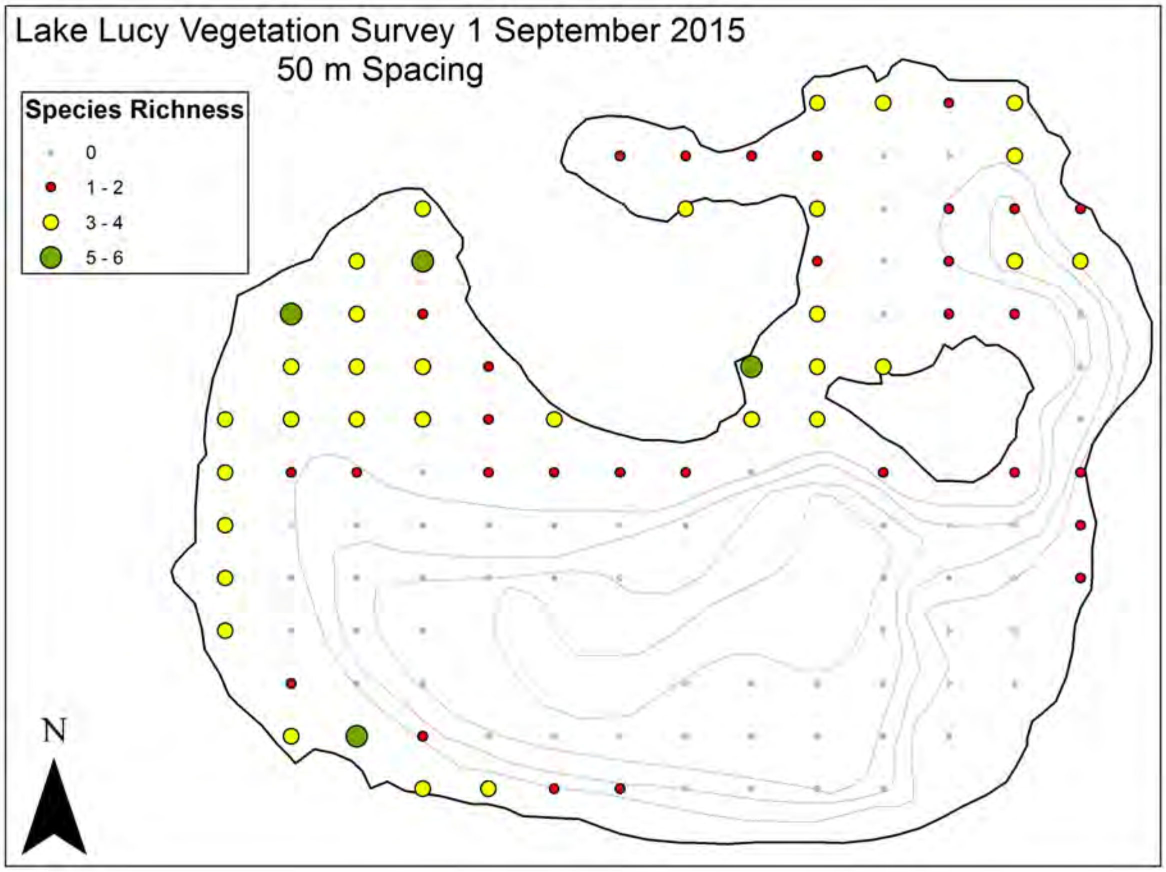


Figure 2. The number of aquatic plant species present at each site surveyed in Lake Lucy, September 2015.

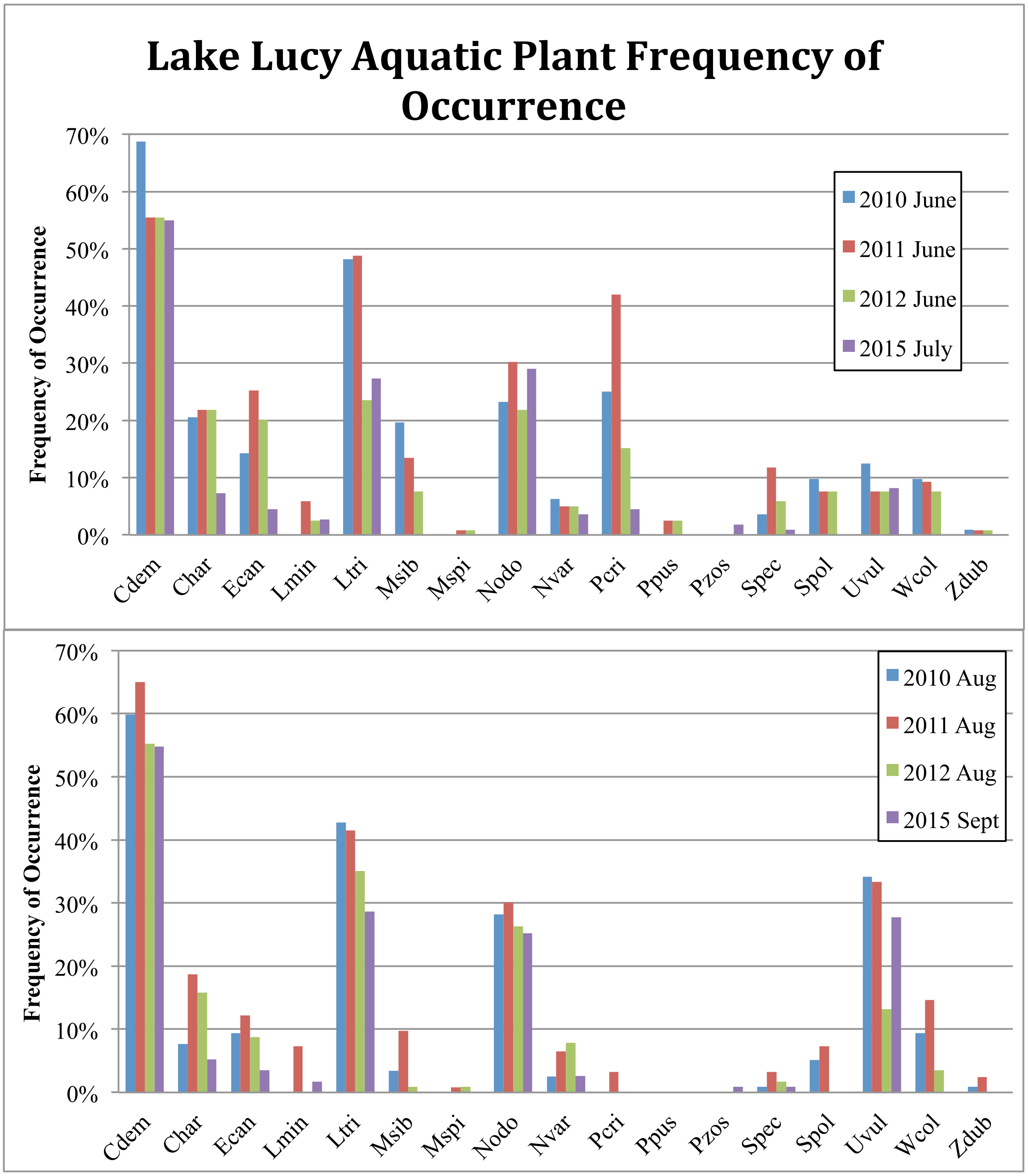


Figure 3. Frequency of occurrence for some of the most commonly occurring species in Lake Lucy found in surveys June 2010 through 2012 and July 2015, and August 2010 through 2012 and September 2015. See Table 6 for abbreviations.

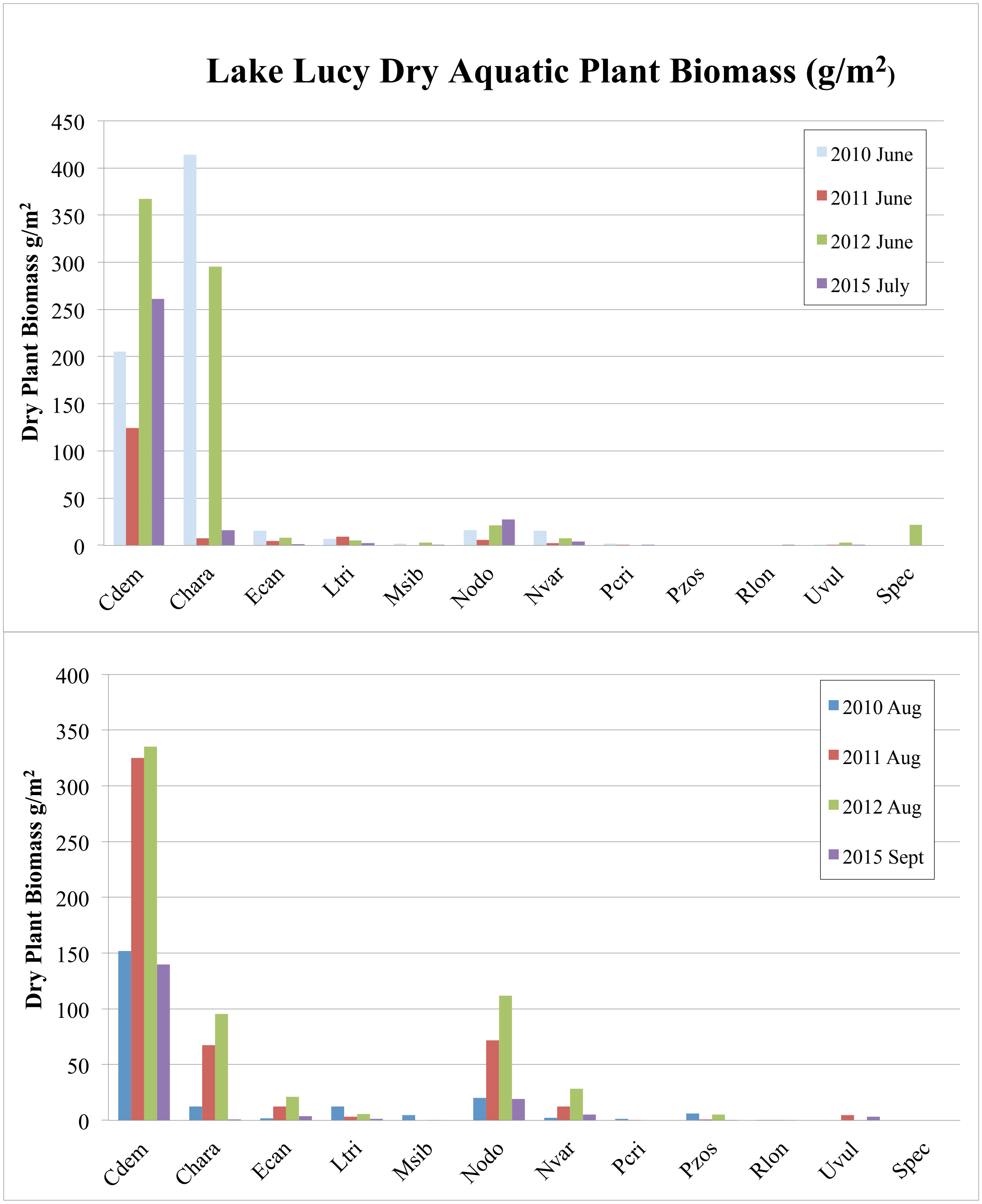


Figure 4. Dry aquatic plant biomass (g dry/m^2) in Lake Lucy from surveys in June 2010 through 2012 and July 2015, and in August 2010 through 2012 and September 2015. See Table 6 for abbreviations.

Recommendations for Lake Lucy:

A slight decrease in the species richness of the aquatic plant community of Lake Lucy appears to have occurred between the 2012 and 2015 sampling period. Declines in the frequency of occurrence and biomass have also been observed in the exotic species Eurasian watermilfoil and curlyleaf pondweed and the plant community is still relatively healthy. Lakeshore homeowners are currently controlling curlyleaf with local herbicide applications so lake-wide treatments are not recommended at this time. If curlyleaf pondweed increases dramatically in the future, Lake Lucy could possibly benefit from a lake-wide early season endothall herbicide treatment.

VI. Mitchell Lake Results

Mitchell Lake (DOW ID 27-007000) is within the city limits of Eden Prairie, Minnesota and is classified as a "Natural Environment Lake" by the Minnesota Department of Natural Resources. Mitchell Lake has a surface area of about 46 hectares (114 acres), with a littoral zone area of about 44 hectares (109 acres), and a maximum depth of about 5.8m (19ft) (MN DNR LakeFinder 2015).

Surveys conducted on Mitchell Lake in 2013 and 2014 were used as a reference for a Master's research project conducted by Jonathan JaKa, a University of Minnesota graduate student. Mitchell Lake was chosen as a reference lake because there were no curlyleaf pondweed treatments planned for 2013 or 2014 and curlyleaf had been present at high frequencies and densities. In 2015, Mitchell Lake was treated with an early season endothall herbicide treatment. Therefore, in 2015 aquatic vegetation surveys and water quality monitoring continued so as to monitor the effects of treatment on the aquatic plant community.

Water Quality:

The Secchi depth in 2015 declined to less than 0.5m by mid-August, approximately a 0.5m decrease compared to previous years (Figure 5). Mid-summer dissolved oxygen and temperature profiles showed some dissolved oxygen to the lake bottom in 2013 but an anoxic hypolimnion beginning at depths of 2.5m to 3m appeared in 2014 and 2015 (Figure 5).

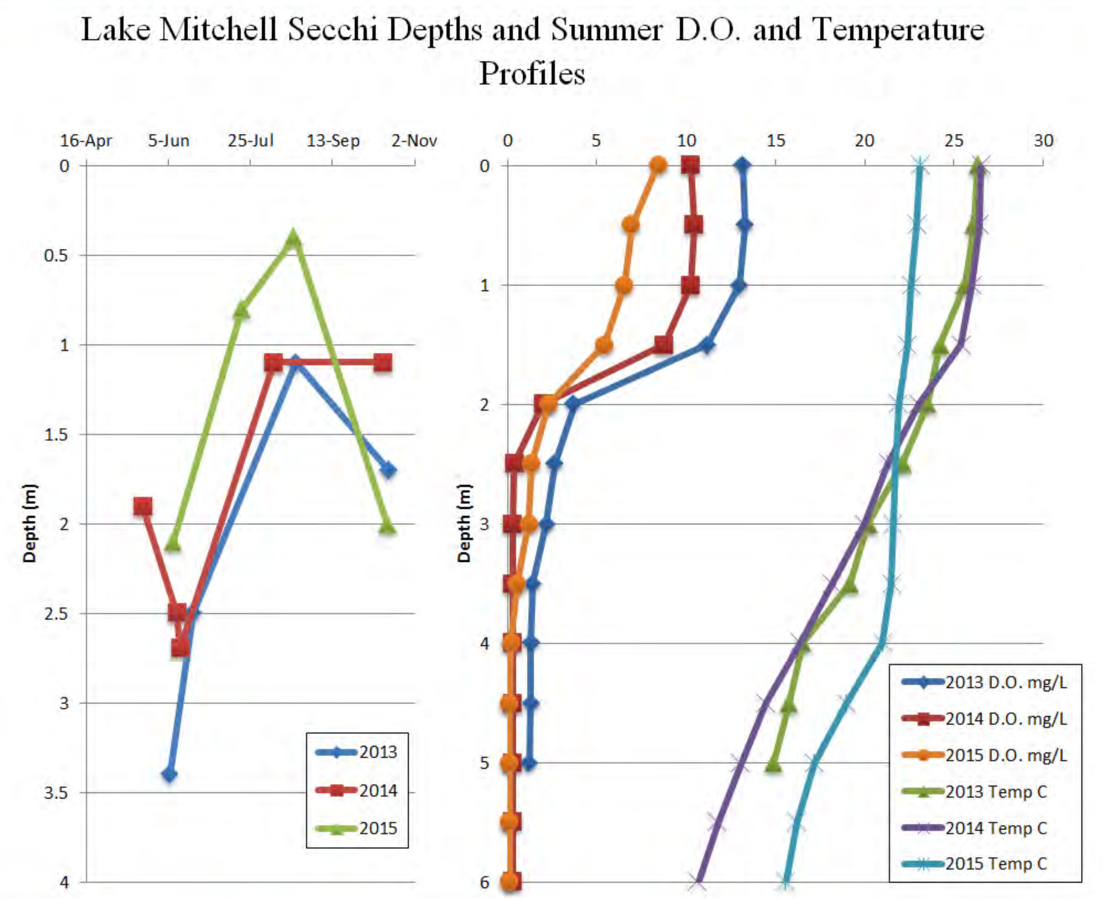


Figure 5. Secchi depths for Mitchell Lake and dissolved oxygen (mg/L) and temperature (°C) profiles taken on 22 August 2013, 8 August 2014, and 21 August 2015.

Aquatic Vegetation Survey:

Aquatic vegetation surveys were conducted in early and late June and once in August of 2013, in May, June and August of 2014, and in late April, June, and August of 2015. Overall there was a fairly diverse aquatic plant community in Mitchell Lake with 21 different species observed over the three survey years (Table 2). In 2015, 16 species were observed throughout the three sampling dates. Species richness per sampling site decreased in 2015 compared to prior years. The highest richness was observed in August 2013 when one site contained 10 species per site and several sites contained between 7 and 9 species. However, in August of 2015 the highest richness obtained at one site decreased to 6 species (Figure 6).

Overall the most dominant species in frequency was coontail (Figure 7). Additionally, curlyleaf pondweed occurred quite frequently in the spring and early summer as well and was the most frequently occurring species in April 2015 (Figure 7). Other commonly occurring species include: star duckweed (*Lemna trisulca*), white water lily (*Nymphaea odorata*), narrow leaf pondweed (*Potamogeton pusillus*), flat-stem pondweed (*Potamogeton zosteriformis*) and northern watermilfoil (*Myriophyllum sibiricum*), all of which were observed in at least 5% of sites surveyed in the littoral zone.

Coontail made up the large majority of the biomass sampled in Mitchell Lake (Figure 8). Curlyleaf pondweed typically had the second highest biomass in the spring and early summer when it reached its peak biomass. Other native plants with higher plant biomass in the summer were northern watermilfoil, star duckweed, narrow leaf pondweed and white water lily (Figure 8). Coontail made up the majority of a significant ($p \leq 0.05$) decline in mean total native plant biomass from August 2013 to August 2014 (Figure 9), but many other species declined as well. In August of 2015 the mean total native plant biomass declined again, however it was not significant (Figure 9).

Eurasian watermilfoil and curlyleaf pondweed were both present in Mitchell Lake. Curlyleaf pondweed has reached nuisance levels in the spring and early summer. In 2015, an early season treatment took place with limited effects on the peak season curlyleaf population (Figures 7 and 10). Eurasian watermilfoil did not appear to be present at high frequencies. However, the taxon we are calling northern watermilfoil (based on leaflet count) may be a hybrid of Eurasian watermilfoil and northern watermilfoil.

Milfoil Weevil Population

Monitoring for the weevil population began this year in Lake Mitchell. No weevils of any life stage were found during the three surveys conducted in June, July and August.

Curlyleaf Pondweed Treatment

An early season endothall treatment was conducted in 2015. The area that was treated was 16 acres (Figure 11). However, the reduction in peak season curlyleaf frequency of occurrence and biomass was less than the reductions seen in the first year of treatment in Lakes Riley and Susan. In 2015, peak season curlyleaf was observed at 35% of sampled sites (Figure 7) and there was no reduction in biomass (Figure 10). However, increases in peak season abundance appear to mainly occur outside of the treated areas, indicating that the treatment was effective, but curlyleaf still persisted in other regions of the littoral zone (Figure 11). Curlyleaf pondweed frequency of occurrence at peak season was 59% in 2013 and 49% in 2014 prior to treatment, and 37% in 2015 after the treatment occurred. The average, peak season littoral-wide biomass in 2013 was 20.2 g dry/m^2, 14.0 g dry/m^2 in 2014, and 14.3 g dry/m^2 in 2015.

There was a significant decrease in turion density between 2014 and 2015. Sediment surveys for curlyleaf pondweed turions were conducted in Mitchell Lake on 17 October 2013, 14 October 2014, and 14 October 2015. Prior to 2015 the turion densities were higher than peak turion densities at both Lakes Riley and Susan, which had lake-wide mean densities of 128 turions/m^2 and 87 turions/m^2 respectively in fall 2012 before spring herbicide treatments. In 2013 the Lake Mitchell turion density was 191 turions/m^2, and 173 turions/m^2 in 2014. After treatment in 2015, the turion density significantly decreased to 14 turions/m^2 (Table 5).

In Lake Mitchell, we saw no decrease in the frequency of occurrence of native plants between untreated and treatment years. Native plant littoral zone frequency of occurrence in August was 85% in 2013 and approximately 60% in 2014 and 2015. We did observe a slight, but insignificant, decrease in native plant biomass between 2014 and 2015 (Figure 9).

Aquatic Bathymetry and Vegetation Maps

Plants at Mitchell Lake were dense in much of the lake to depths of 3m and less (Figure 12). Percent coverage ranged from about 70% to almost 95% of the surveyed area depending on the time year between 2013 and 2014 (Table 4). However, in 2015 the percent area covered dropped to 52% in August compared to previous August coverage values of 70% or greater (Table 4).

Table 2. Aquatic plants found in surveys conducted in Mitchell Lake 2013 through 2015.

Common Name	Scientific Name	Abbreviation
Emergent Species		
Cattail	*Typha spp.*	Typh
Submerged Species		
Coontail	*Ceratophyllum demersum*	Cdem
Muskgrass	*Chara spp.*	Char
Canada waterweed	*Elodea canadensis*	Ecan
Northern watermilfoil	*Myriophyllum sibiricum*	Msib
Eurasian watermilfoil	*Myriophyllum spicatum*	Mspi
Bushy pondweed	*Najas flexilis*	Nfle
Stoneworts	*Nitella spp.*	Nite
Curlyleaf pondweed	*Potamogeton crispus*	Pcri
Illinois pondweed	*Potamogeton illinoensis*	Pill
Leafy pondweed	*Potamogeton foliosus*	Pfol
Narrow leaf pondweed	*Potamogeton pusillus*	Ppus
Flat-stem pondweed	*Potamogeton zosteriformis*	Pzos
White water buttercup	*Ranunculus aquatilis*	Rlon
Sago pondweed	*Stuckenia pectinata*	Spec
Greater bladderwort	*Utricularia vulgaris*	Uvul
Wild celery	*Vallisineria americana*	Vame
Northern wild rice	*Zizania palustris*	Zpal
Water stargrass	*Zosterella dubia*	Zdub
Floating-leaf species		
Lesser duckweed	*Lemna minor*	Lmin
Star duckweed	*Lemna trisulca*	Ltri
American lotus	*Nelumbo lutea*	Nlut
White water lily	*Nymphaea odorata*	Nodo
Yellow water lily	*Nuphar variegata*	Nvar
Great duckweed	*Spriodela polyrrhiza*	Spol

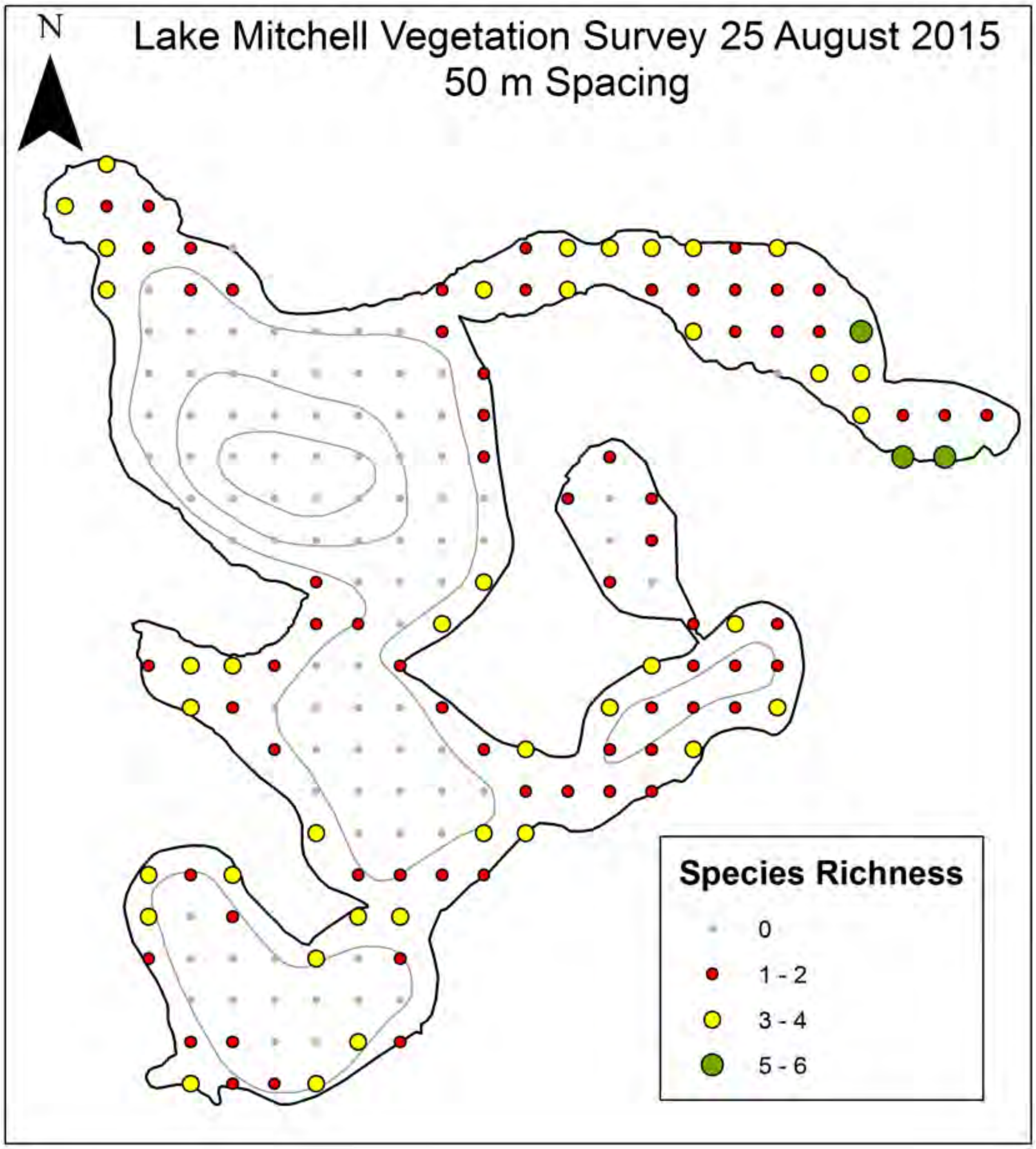


Figure 6. The number of aquatic plant species present at each site surveyed in Mitchell Lake, 25 August 2015.

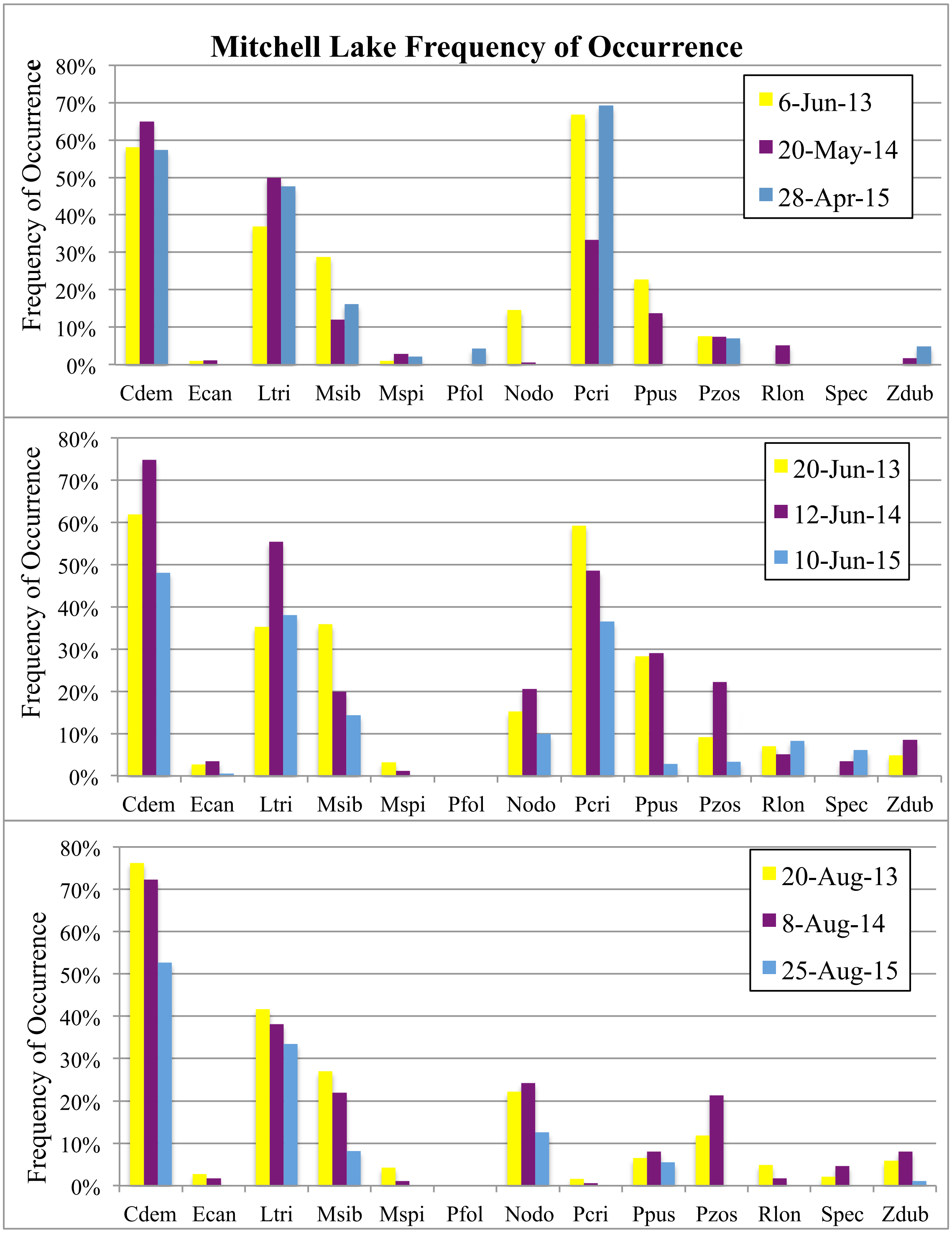


Figure 7. Frequency of occurrence for some of the most commonly occurring species in Mitchell Lake found in surveys from May, June and August 2013, 2014, and 2015. See Table 8 for abbreviations.

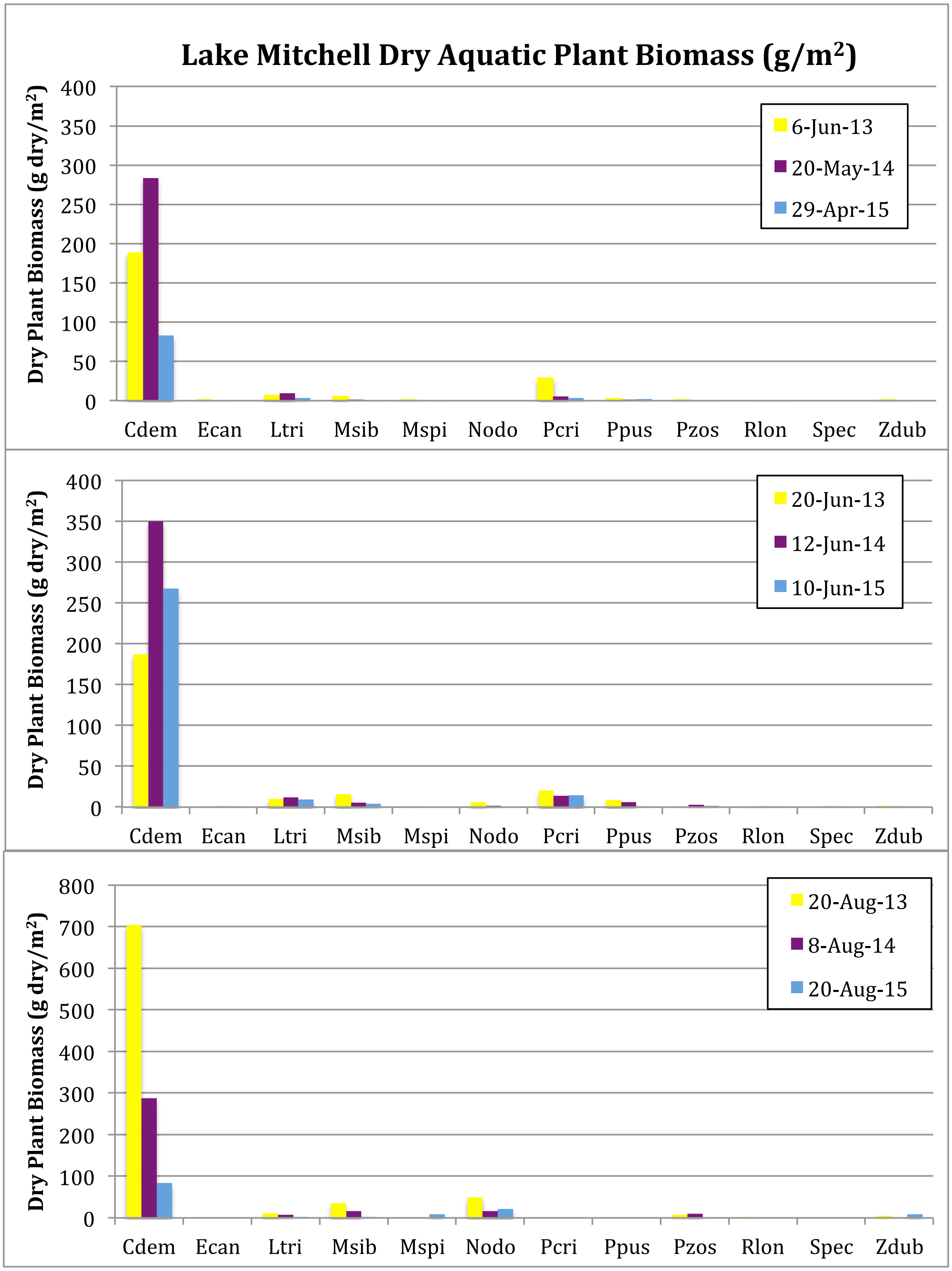


Figure 8. Dry plant biomass (g dry/m^2) for some of the most commonly occurring species in Mitchell Lake found in surveys May, June and August 2013, 2014, and 2015. See Table 8 for abbreviations.

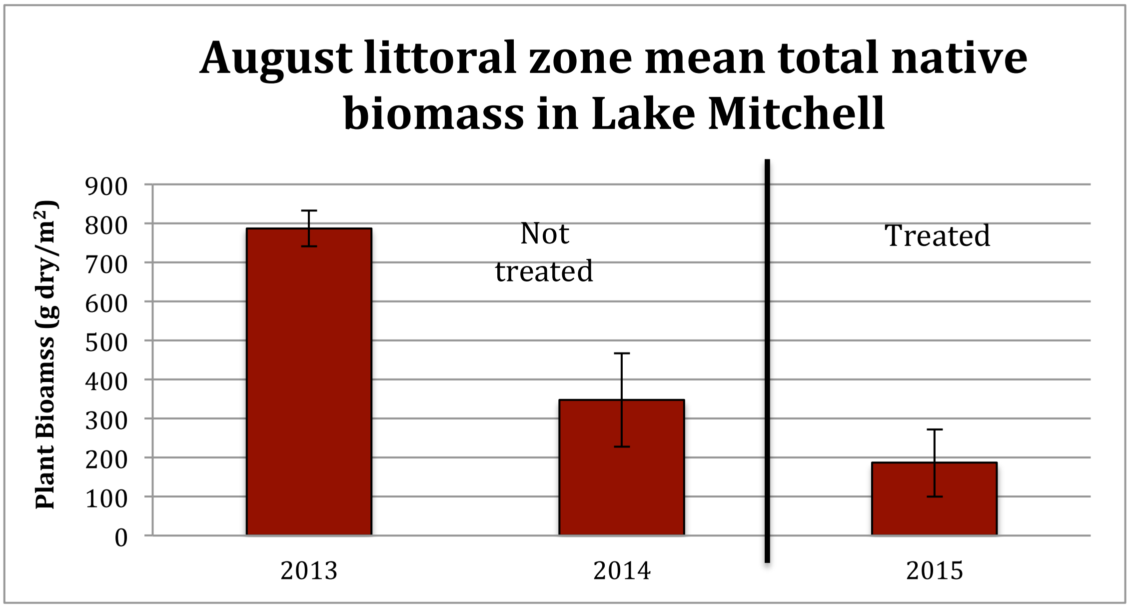


Figure 9. Mean total native aquatic plant biomass in Mitchell Lake August 2013 through 2015. The decline from 2013 to 2014 is significant ($p \leq 0.05$). The vertical line represents the beginning of herbicide treatment and divides pre- and post- treatment years.

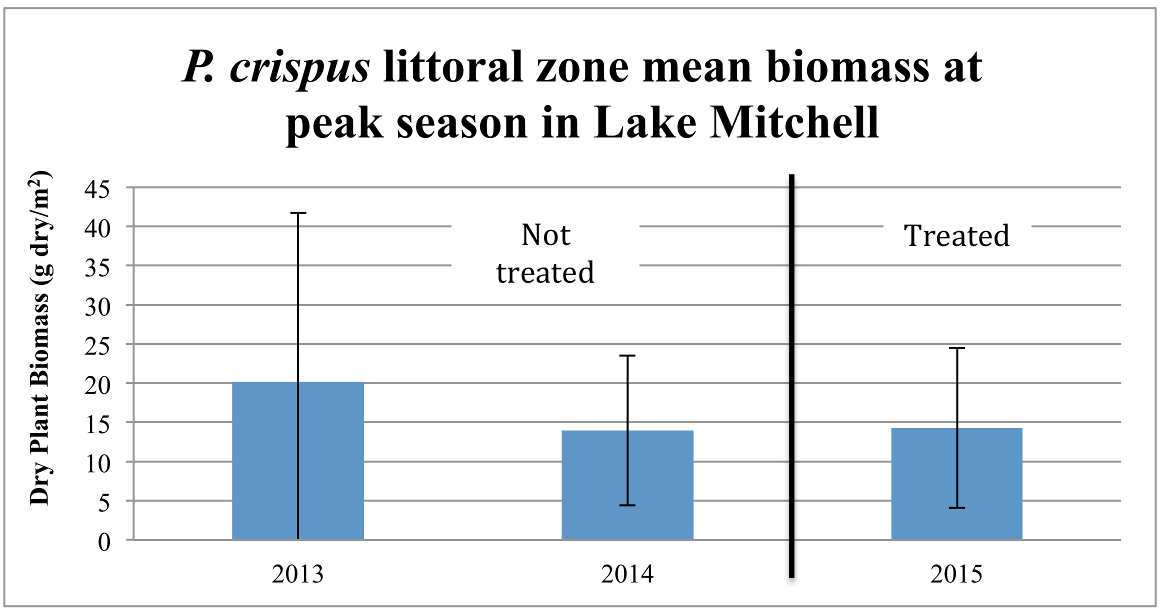


Figure 10. Mean total curlyleaf pondweed plant dry biomass (including turions) in Mitchell Lake from 2013 to 2015. The vertical line represents the beginning of herbicide treatment and divides pre- and post- treatment years.

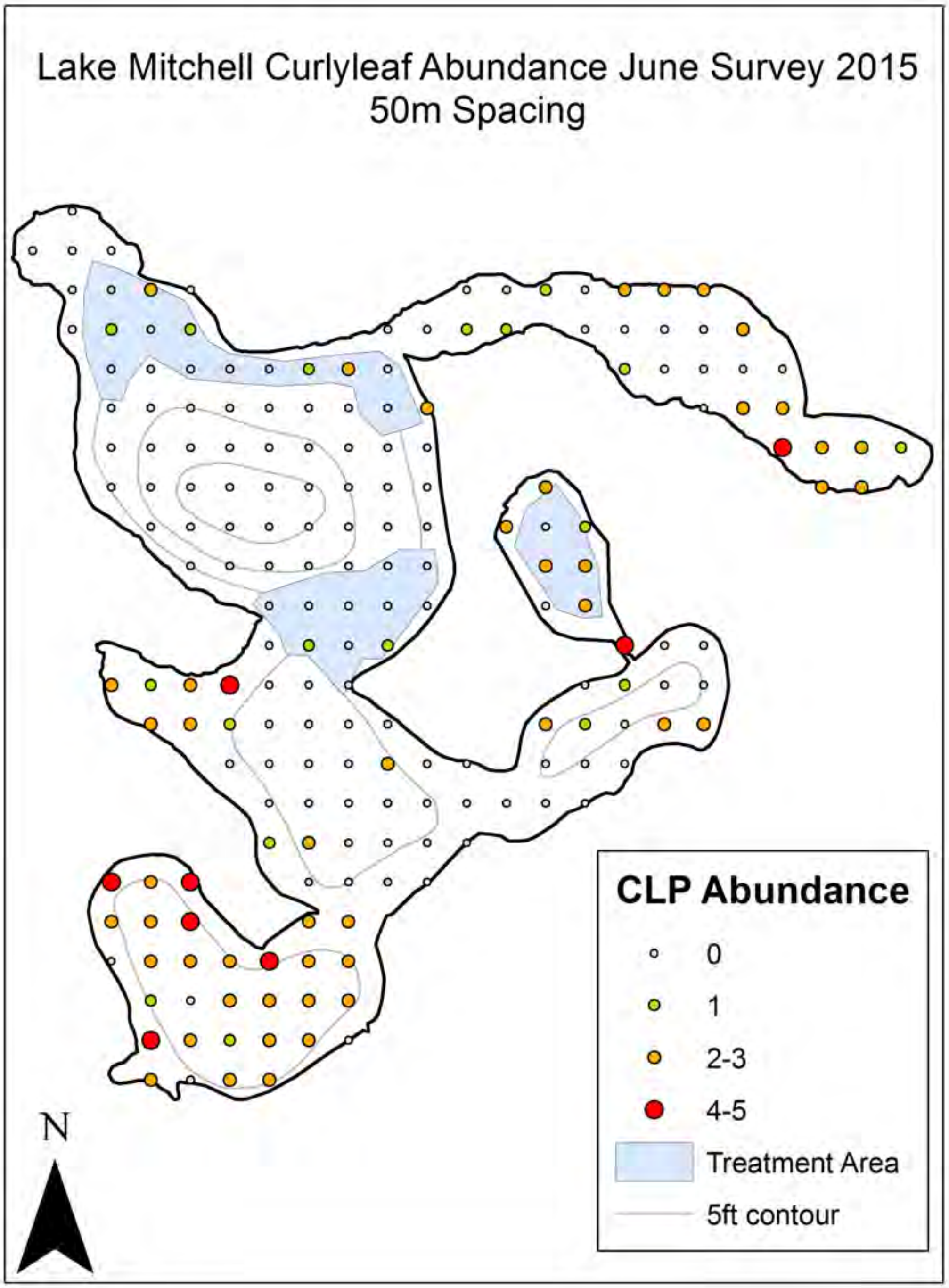


Figure 11. Rake abundance rating for curlyleaf pondweed (*Potamogeton crispus*) during peak growth (after treatment) in 2015 with early season treatment areas shown in green. The treated area is 16 acres.

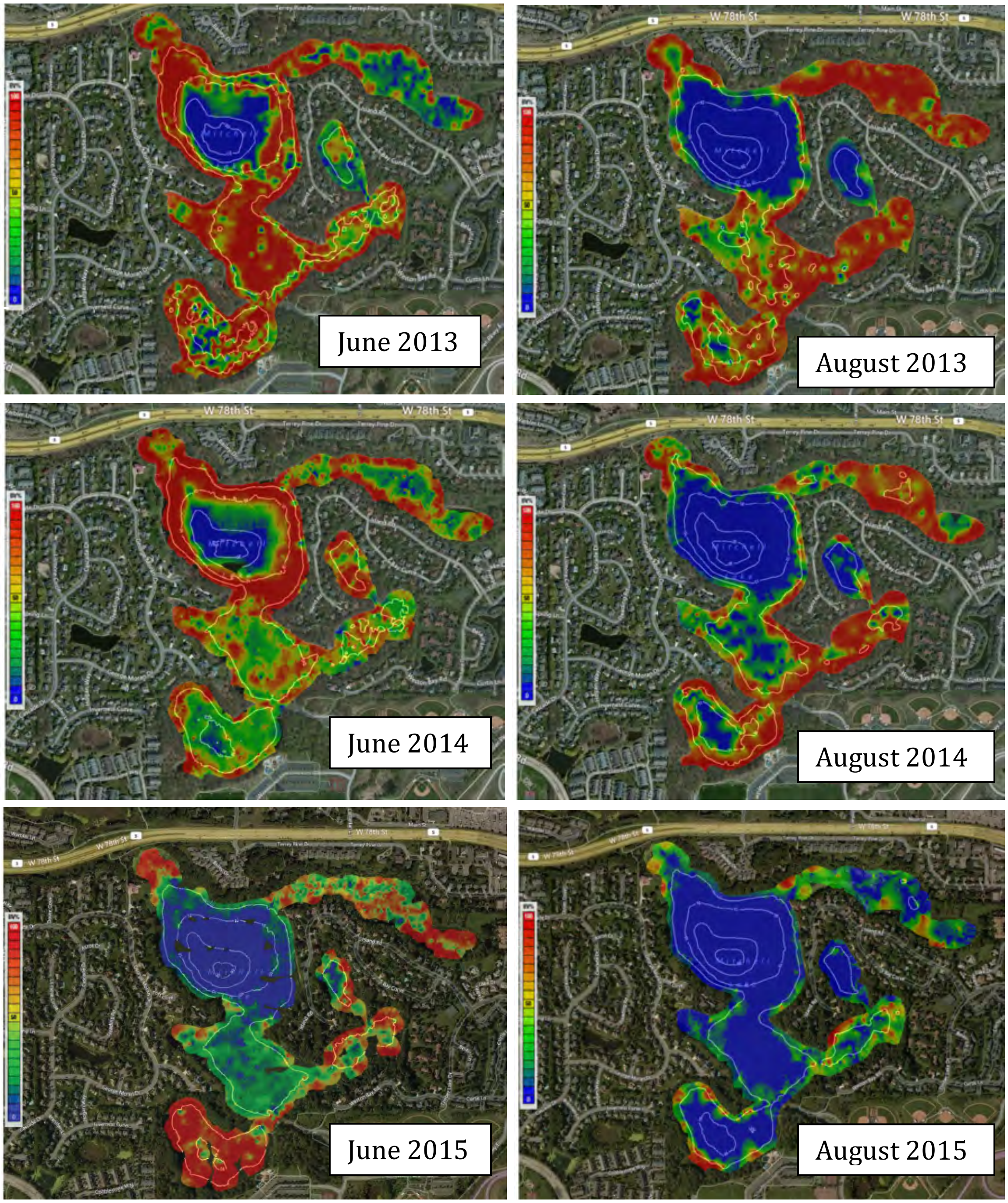


Figure 12. Aquatic bathymetry and vegetation maps of Mitchell Lake. Data collected during point intercept aquatic vegetation surveys on: 13 June 2013, 20 August 2013, 12 June 2014, 8 August 2014, 10 June 2015, and 20 August 2015. Contour lines are 5ft intervals. Color legend represents percent biovolume (refers to the percentage of the water column taken up by vegetation when vegetation exists) with blue representing no vegetation present and red representing 100% of the water column being taken up by vegetation.

Table 3. Lake-wide percent area cover (PAC) and average biovolume (BV) for surveys in June and August 2013 and May, July and August 2014 in Mitchell Lake. Values coincide with maps in Figure 20. PAC refers to the overall surface area that vegetation is growing in the surveyed area. Average BV refers to the percentage of the water column taken up by plants when plants exist; areas that have no plants are not factored into this calculation.

Date	PAC	Average BV
June 2013	89.4%	66.6%
August 2013	75.1%	68.2%
May 2014	79.6%	21.3%
June 2014	94.4%	60.7%
August 2014	70.1%	58.8%
June 2015	82.7%	58.6%
August 2015	52.0%	52.1%

Table 4. Results from sediment turion surveys conducted October 2013 through 2015.

Pcri	Turions/m^2	Viability	Viable turion density
Oct-2013	191	77%	147
Oct-2014	173	45%	78
Oct-2015	14	80%	11

Recommendations for Mitchell Lake:

Mitchell Lake has a fairly diverse aquatic plant community and efforts should focus on maintaining and enhancing the native plant community. The native plant community should continue to be monitored in case of further declines. Another year of early season curlyleaf treatment will be useful to manage the population. However, due to the complex shoreline and limits to application areas, whole-lake reductions in curlyleaf may not be as apparent as in other treated lakes. Furthermore, coontail harvesting is confounding the native plant response and better coordination of timing of management efforts is needed. Although Mitchell Lake is a “Natural Environment Lake”, the Minnesota DNR may grant another variance if early season endothall treatments were likely to maintain or enhance the native plant community. Because Eurasian watermilfoil is relatively low in abundance, Mitchell may benefit from another early season endothall treatment similar to 2015. With coordinated efforts on harvesting, it will allow us to better assess the overall response of plants in the lake.

V. Lake Riley Results

Lake Riley (DOW ID 10-000200) is a eutrophic lake located about 2 km downstream of Lake Susan along the Chanhassen and Eden Prairie city boundary. Rice Lake Marsh lies along the Riley Creek between and Lake Susan and Lake Riley. Lake Riley has a surface area of about 120 hectares (300 acres) with a littoral zone of about 45 hectares (110 acres) and a maximum depth of about 15m (49ft). Carp were removed from Lake Riley in March 2010. A Lake Vegetation Management Plan was developed in winter 2013 and approved by the Riley Lake Association and the Minnesota DNR. To control curlyleaf pondweed, Lake Riley was treated with the herbicide endothall on 10 May 2013, 20 May 2014, and May 2015 after water temperatures rose to between 10-15°C. Curlyleaf was delineated prior to treatment and herbicide was applied to approximately 20 acres in 2013, 32 acres in 2014, and 20.1 acres in 2015. To control for Eurasian watermilfoil a 2, 4-D herbicide treatment occurred on 18 June 2015, it was applied to 35 acres after a delineation took place.

Water Quality:

Lake Riley Secchi depths were typically around 1m by the end of June or beginning of July (Figure 12). Although 2014 had higher water clarity than other years, water clarity was typically low during summer months. Dissolved oxygen and temperature profiles generally show an anoxic hypolimnion below 5m in August (Figure 13).

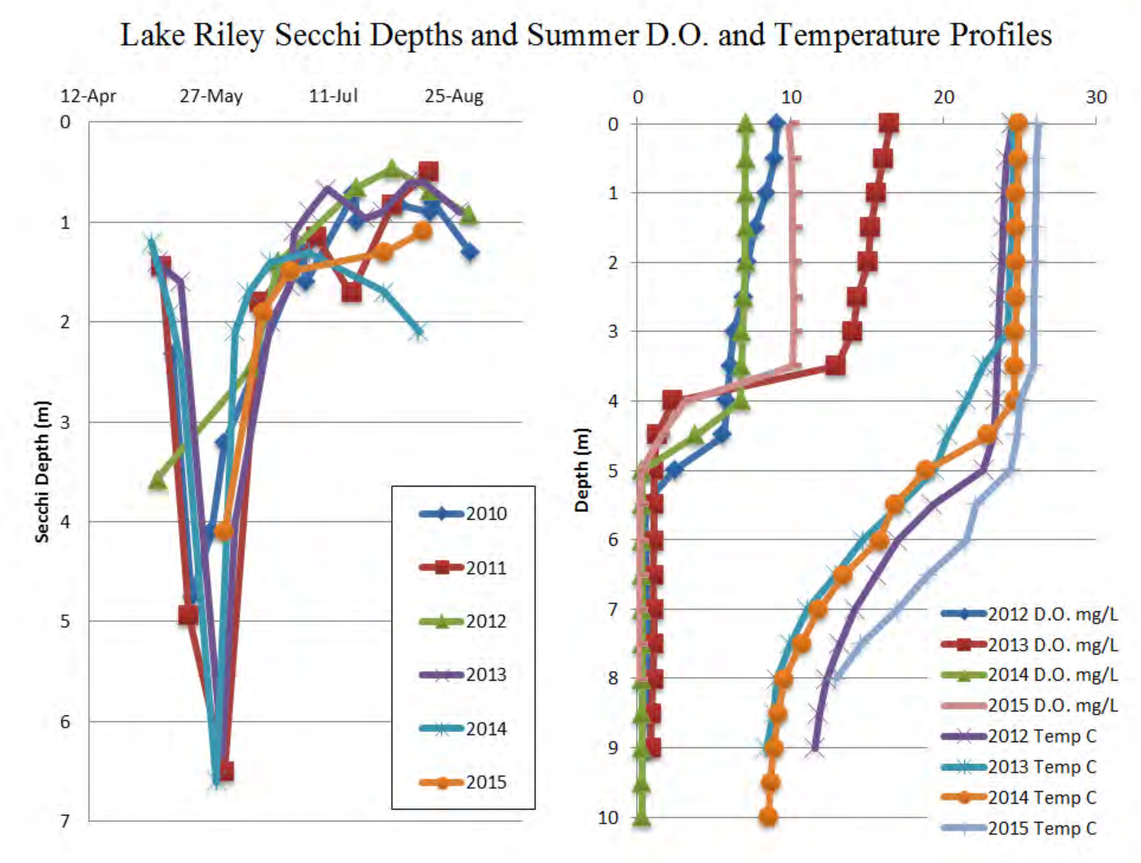


Figure 13. Secchi depths for Lake Riley 2010 through 2015 (Bajer and Sorensen unpublished data, personal communication) and dissolved oxygen (mg/L) and temperature (°C) profiles taken in August 2012 through 2015.

Aquatic Vegetation Survey:

We have conducted point intercept surveys on Lake Riley from 2011 through 2015. Overall there has been low plant diversity in Lake Riley with only 11 species being found during 2011 through 2014. However, 4 additional species were recorded in 2015 bringing the total diversity to 15 species (Table 5). The highest species richness per site was observed in a survey completed in August 2015 with 5 species at one site (Figure 14). Most plants were in water < 2m deep, but in 2015 some plants expanded to 3m. Coontail, curlyleaf pondweed and Eurasian watermilfoil were typically the most frequently occurring species, with the exception of August when curlyleaf was typically not present due to its life cycle (Figure 14). There were slight increases in native plant frequency since curlyleaf pondweed treatments began, but the increases were small likely because of poor water clarity. Chara, Canada waterweed, and bushy pondweed (*Najas flexilis*) were observed in August 2015 at their highest frequencies of occurrence since we began surveying (Figure 16 bottom).

Coontail and Eurasian watermilfoil were also the most dominant species in biomass (Figure 17). Coontail continued to make up the vast majority of the native aquatic plant biomass in Lake Riley, with very little contribution of other native plants to total lake-wide native plant biomass.

Eurasian watermilfoil and curlyleaf pondweed have both been problematic in Lake Riley. Eurasian watermilfoil continues to be a dominant member of the plant community in the lake (Figure 16 and 17). Curlyleaf pondweed has decreased dramatically in both frequency (Figure 16) and biomass (Figure 17) since treatments began in 2013.

Milfoil Herbivore Population:

We began monitoring the milfoil herbivore population in 2011 and the maximum density of weevils was observed on 27 August 2014 at 0.68 weevils per stem (Table 6). The maximum density in 2015 occurred in August at 0.27 weevils per stem (Table 6). It is possible that abundant sunfish may be retarding the weevil population in Lake Riley. The weevil population still does not appear to be persistently abundant enough to control Eurasian watermilfoil.

Curlyleaf Pondweed Herbicide Treatments:

Lake-wide early season endothall treatments took place in Lake Riley in the spring of 2013, 2014, and 2015. The total acreage treated in 2015 was 20 acres. We saw significant declines in curlyleaf frequency (Figure 18), biomass (Figure 19) and turion densities in the sediment (Table 6). Curlyleaf pondweed was observed in over 60% of sites sampled in the littoral zone in 2012 and declined to less than 20% of sties sampled in the littoral zone in all June post-treatment surveys. The reduction of curlyleaf frequency of occurrence was significant ($p \leq 0.05$). At its peak in 2012, we observed a littoral-wide average biomass of about 120 g dry/m^2. Curlyleaf biomass values declined significantly ($p \leq 0.05$) to under 5 g dry/m^2 in 2013 through 2015 (Figure 19). Turion densities in the sediments declined significantly ($p \leq 0.05$) from a peak of 132 turions/m^2 to 14 turions/m^2 in 2015 (Table 7). Native aquatic plants did not increase significantly in biomass or frequency between the years of 2012 to 2014. In 2015, native aquatic plant biomass increased significantly in the August sampling period ($p \leq 0.05$) (Figure 20). Native aquatic plants occurred at 67% of sampled littoral points in August of 2015.

Eurasian Watermilfoil Herbicide Treatment:

On June 18 2015 Lake Riley was treated with 2, 4-D herbicide to control Eurasian watermilfoil. The total acreage treated was 35 acres (Figure 15). The targeted concentration within the treatment areas was 2.0 ppm. Herbicide residuals were collected by University of Minnesota researchers and watershed district staff. Samples were collected four hours after application, a day after application, four days after application, and one week after application. Herbicide residual analysis was completed by Dr. Mike Netherland of the US Army Engineer Research and Development Center in Gainesville, Fl. The results of the herbicide residue monitoring indicated that the desired concentration of herbicide was reached in some of the treatment areas, but not all, leading to a treatment average below the desired concentration of 2.0 ppm. The average residual concentration taken four hours after treatment in each treatment area was 1.085 ppm, and a week later residuals were at near zero levels.

A pre-treatment aquatic vegetation survey took place on June 15th (Figure 15) and the post treatment survey occurred on August 13th. August Eurasian watermilfoil frequency of occurrence (Figure 21) as well as biomass in 2015 decreased compared to the pre-treatment survey. However, August frequency of occurrence has been variable throughout the survey years. Therefore, continued monitoring will allow for better assessment of the effectiveness of the treatment on controlling the Eurasian watermilfoil population.

Aquatic Bathymetry and Vegetation Maps

Abundant plant growth was restricted to areas < 2m deep (Figure 22). In these areas, biovolume can approach 100%, but drops to near zero in deeper areas. Overall plant cover in the littoral was thus not high (usually ≤ 50%) and mean biovolume was 62% or less (Table 13). In 2015, most growth continued at depths of 2m or less but in some regions, such as the southwest bay and east shoreline, abundant growth expanded to 2.5 to 3m (Figure 22).

Table 5. Aquatic plants found in surveys conducted in Lake Riley 2011 through 2015. *indicates new species first found in 2015.

Common Name	Scientific Name	Abbreviation
Submerged species		
Coontail	*Ceratophyllum demersum*	Cdem
Muskgrass	*Chara spp.*	Char
Canada waterweed	*Elodea canadensis*	Ecan
Bushy Pondweed	*Najas flexilis*	Nfle
*Southern Naiad	*Najas guadalupensis*	Ngua
Eurasian watermilfoil	*Myriophyllum spicatum*	Mspi
Curlyleaf pondweed	*Potamogeton crispus*	Pcri
*Leafy pondweed	*Potamogeton foliosus*	Pfol
*Long-leaf pondweed	*Potamogeton nodosus*	Pnod
Narrow leaf pondweed	*Potamogeton pusillus*	Ppus
*Flat-stem pondweed	*Potamogeton zosteriformis*	Pzos
Sago pondweed	*Stuckenia pectinata*	Spec
Horned pondweed	*Zannichellia palustris*	Zpal
Floating-leaf Species		
Common duckweed	*Lemna minor*	Lmin
White lily	*Nymphaea odorata*	Nodo

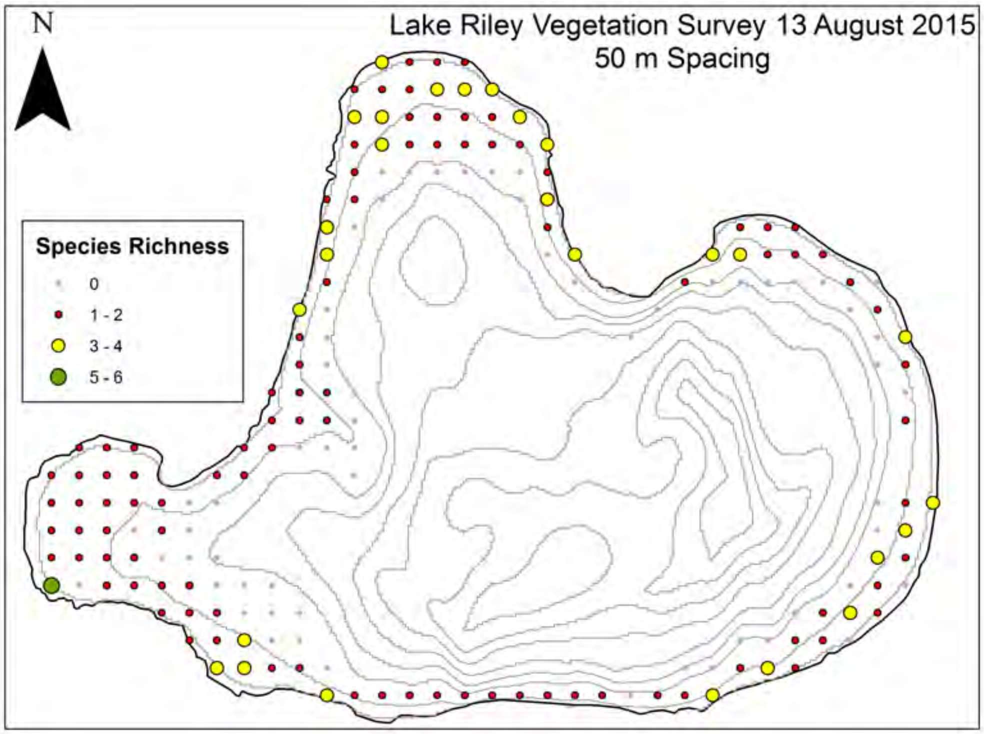


Figure 14. The number of aquatic plant species present at each site surveyed in Lake Riley, 13 August 2015.

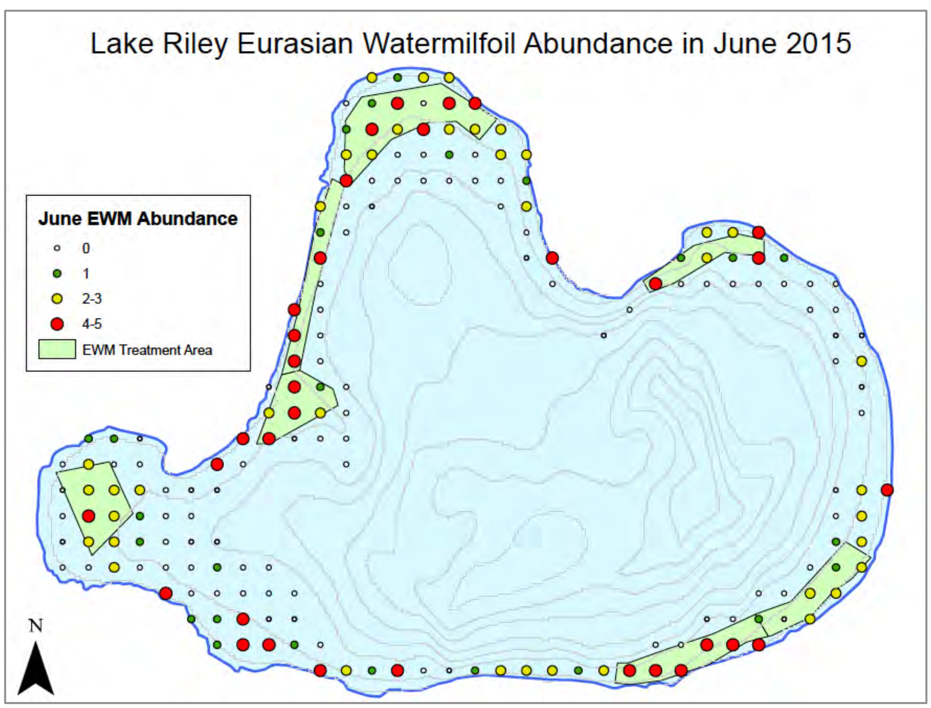


Figure 15. The 2, 4-D treatment areas for Eurasian watermilfoil on Lake Riley in 2015 with EWM rake ratings at each site surveyed on 15 June 2015.

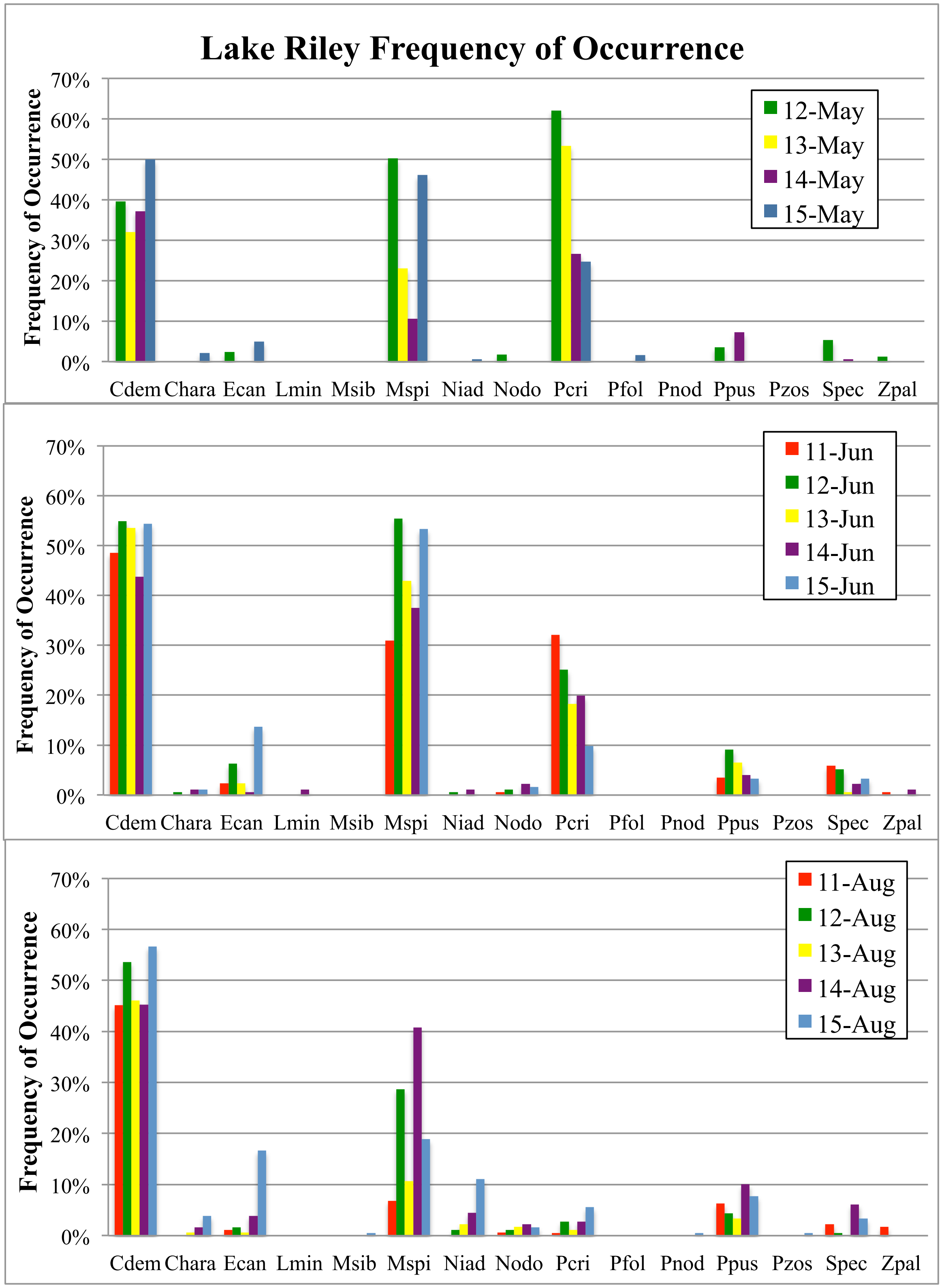


Figure 16. Frequency of occurrence of plants from Lake Riley surveys May, June and August 2011 through 2015. See Table 10 for abbreviations.

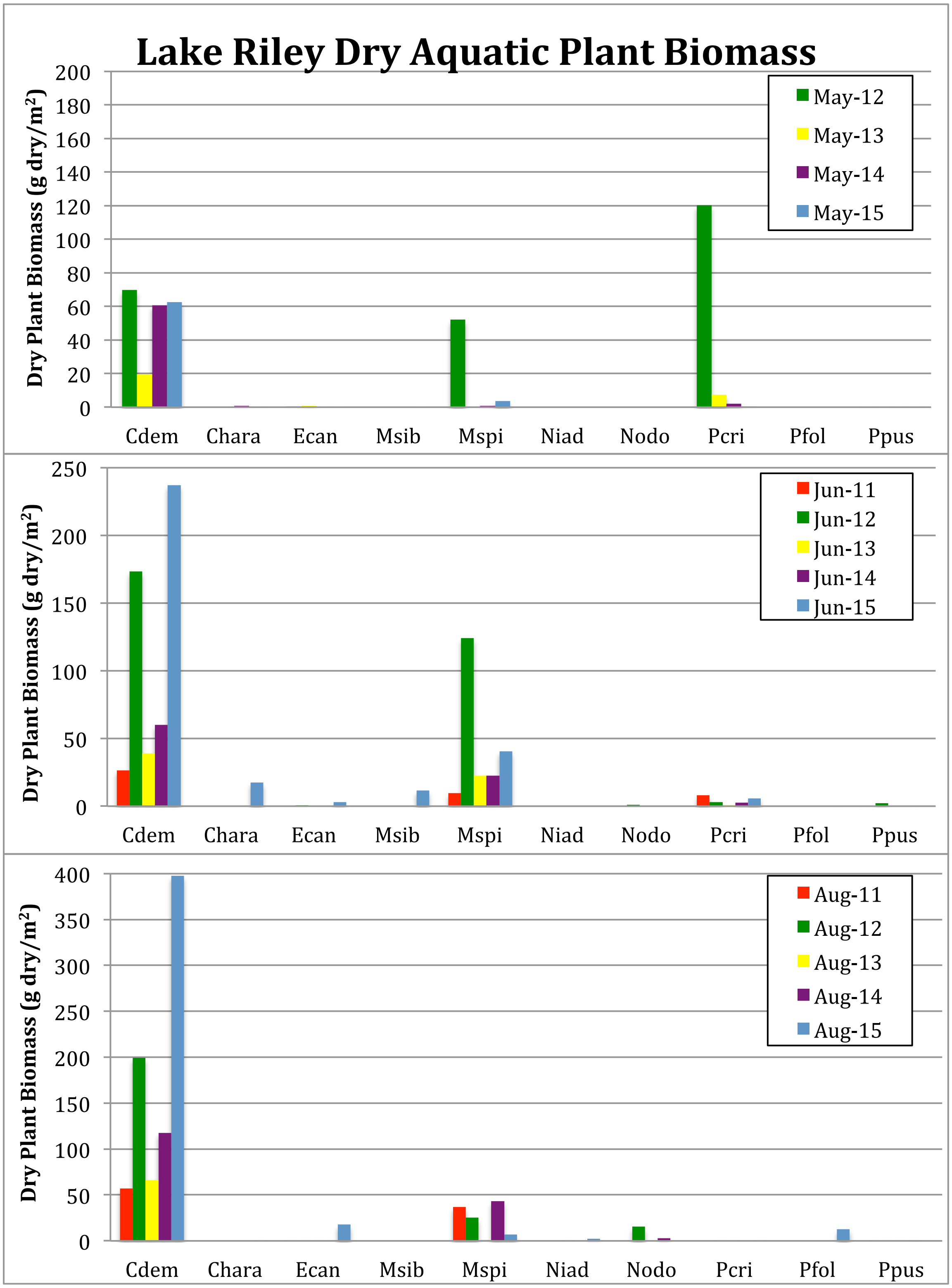


Figure 17. Dry aquatic plant biomass (g dry/m^2) for Lake Riley surveys May, June and August 2011 through 2015. See Table 10 for abbreviations.

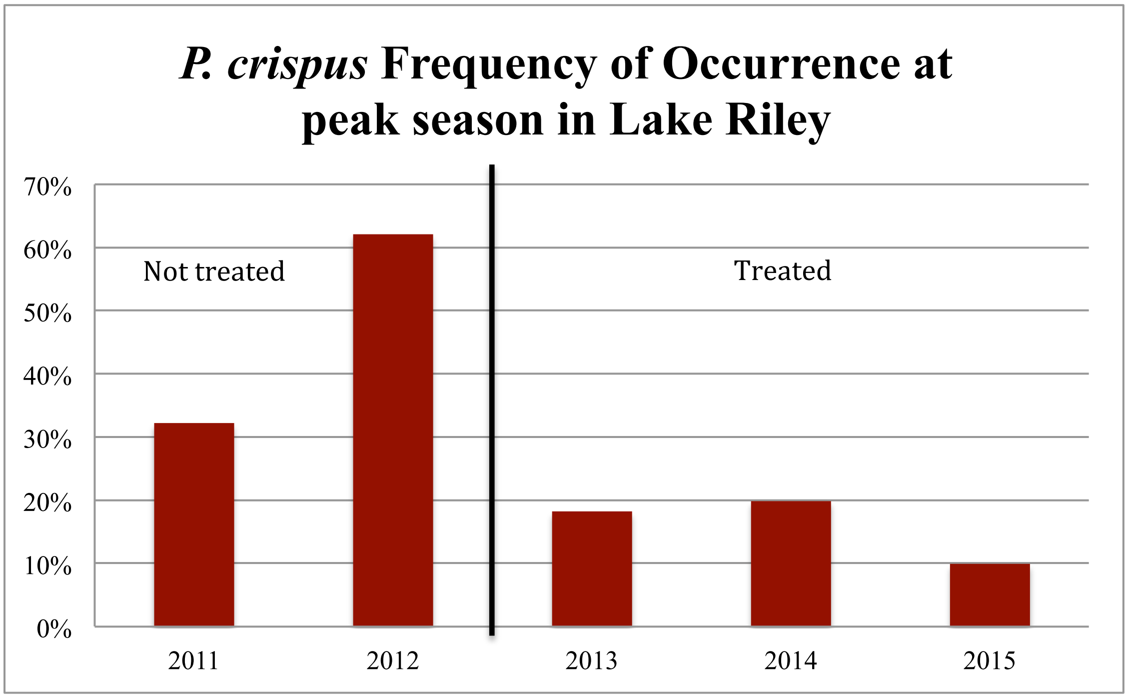


Figure 18. Peak frequency of occurrence of curlyleaf pondweed in Lake Riley. The vertical line represents the beginning of herbicide treatment and divides pre- and post-treatment years. Post-treatment declines are significant ($p \leq 0.05$).

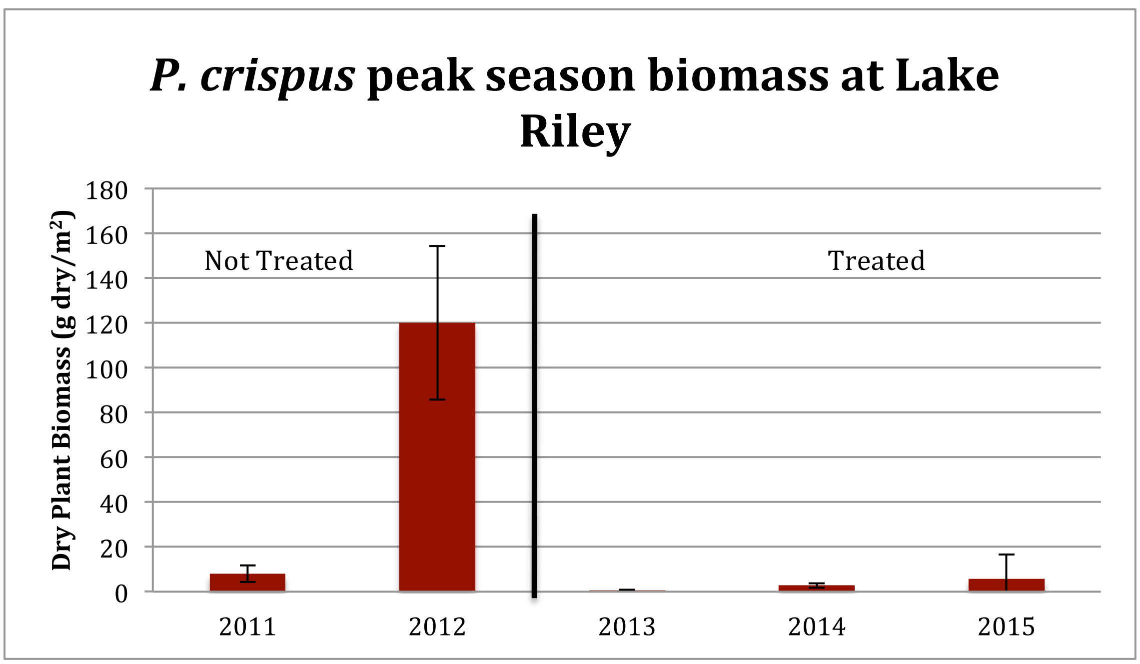


Figure 19. Peak biomass (g dry/m^2) of curlyleaf pondweed in Lake Riley. The vertical line represents the beginning of herbicide treatments and divides pre- and post- treatment years. Post-treatment declines are significant ($p \leq 0.05$).

Table 6. Results of Eurasian watermilfoil herbivore population surveys in Lake Riley 2011 through 2015. Values are lake-wide means for weevil populations expressed as total weevils in all life stages per stem.

Mspi	Weevils/Stem
2011	
19 July	0.20
2012	
18 June	0.02
9 July	0.38
8 August	0.48
2013	
5 June	0.15
27 June	0.08
29 July	0.00
27 August	0.00
2014	
5 June	0.06
2 July	0.04
30 July	0.11
27 August	0.68
2015	
1 June	0.09
29 July	0.12
31 August	0.27

Table 7. Results from sediment turion surveys conducted October 2011 through 2015. Note: Declines from 2012 to 2015 are significant ($p \leq 0.05$).

Pcri	Turions/m^2	Viability	Viable Turion Density
Oct-2011	45	96%	43
Oct-2012	132	99%	131
Oct-2013	56	71%	40
Oct-2014	61	33%	20
Oct-2015	14	44%	6

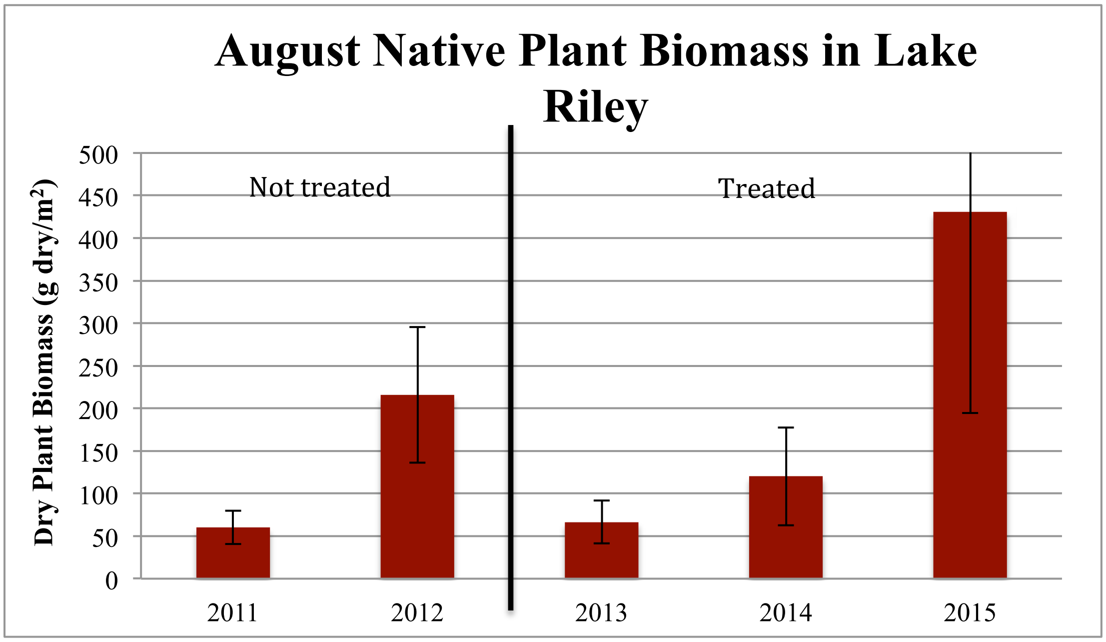


Figure 20. Mean total native plant biomass in the littoral zone in August in Lake Riley 2011 through 2015. The vertical line represents the beginning of herbicide treatments and divides pre- and post-treatment years.

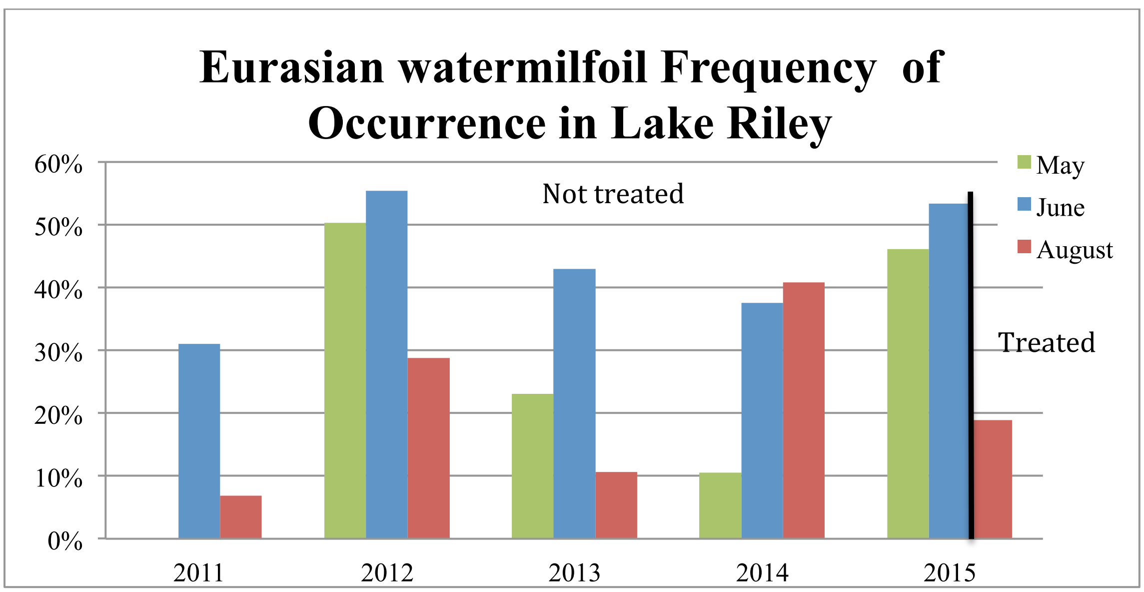


Figure 21. Frequency of occurrence of Eurasian watermilfoil in Lake Riley from 2011 to 2015. The vertical line represents the beginning of herbicide treatments and divides pre- and post-treatment sampling periods.

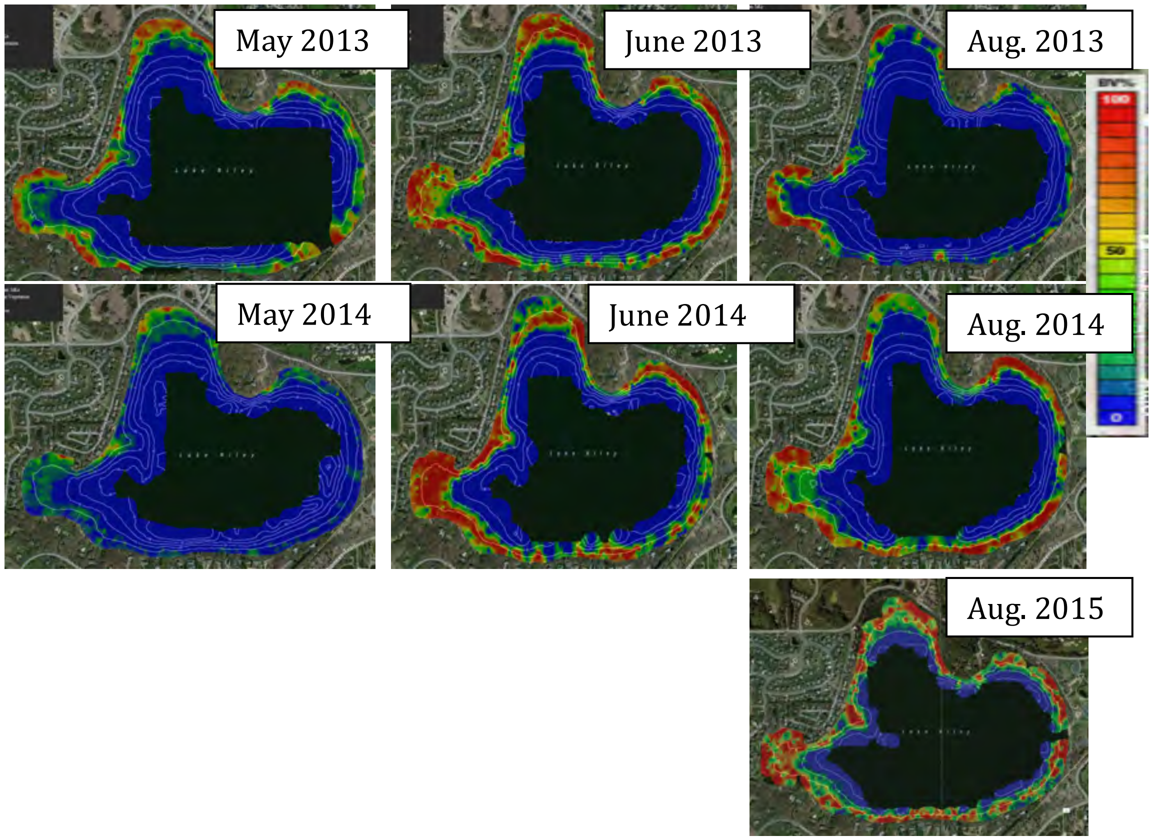


Figure 22. Aquatic bathymetry and vegetation maps of Lake Riley. Data collected during point intercept aquatic vegetation surveys on: 8 May 2013, 18 June 2013, 14 August 2013, 16 May 2014, 18 June 2014 and 12 August 2014, and 13 August 2015. Equipment failure corrupted data in May and June 2015. Contour lines are 5ft intervals. Color legend represents percent biovolume (refers to the percentage of the water column taken up by vegetation when vegetation exists) with blue representing no vegetation present and red representing 100% of the water column being taken up by vegetation.

Table 13. Lake-wide percent area cover (PAC) and average biovolume (BV) for May, June and August 2013 and May, July and August 2014 and August 2015 in Lake Riley. Values coincide with maps in Figure 21. PAC refers to the overall surface area that vegetation is growing in the surveyed area. Average BV refers to the percentage of the water column taken up by plants when plants exist; areas that have no plants are not factored into this calculation.

Date	PAC	Average BV
May 2013	42.9%	36.6%
June 2013	60.2%	53.2%
August 2013	25.6%	38.5%
May 2014	24.6%	15.4%
June 2014	50.3%	55.9%
August 2014	47.6%	47.7%
August 2015	68.3%	62.7%

Recommendations for Lake Riley:

Native plants have appeared to positively respond to combined control of curlyleaf pondweed and Eurasian watermilfoil. Significant increases in both frequency of occurrence and biomass of natives was observed in 2015. However, water clarity continues to be an issue in Lake Riley, inhibiting the recovery of the native plant community and expansion of native plants in water deeper than 2.5m. The proposed alum treatment in 2016 will aid in improving the water clarity and ideally promote the establishment and expansion of native plant populations.

Eurasian watermilfoil has also been present at nuisance levels and the herbicide treatment to control it appeared to reduce the August occurrence and biomass. However, the milfoil biomass is generally reduced by August in most years so it is unknown the extent to which the population was controlled. Spring and summer monitoring in 2016 will provide greater understanding of the extent to which the treatment was effective at reducing the population of Eurasian watermilfoil. With the alum treatment, selective herbicide treatments may be needed to prevent the rapid expansion of exotics. The recommended strategy is to again implement selective control of Eurasian watermilfoil with an auxin mimic on 35 acres before or concurrent with the 2016 alum treatment to prevent it from expanding rapidly with increased clarity.

Curlyleaf pondweed appears greatly reduced from the three consecutive years of treatment based on frequency of occurrence, biomass, as well as turion densities. Treatment of curlyleaf may therefore not be needed due to the current control over the population in Lake Riley. However, both invasives could become abundant and aggressive with increased water clarity if they are not managed in anticipation of improved clarity, so continued monitoring of the curlyleaf population is needed.

Curlyleaf should be assessed after iceout in 2016 and if growth apprears dense an early season endothall treatment should be planned. However, any treatment should be within areas planned for milfoil treatment so as not to reduce the area allowed for 2,4-d treatment of Eurasian watermilfoil (35 acres) later in June. If growth is not dense then no treatment of curlyleaf is advised and the focus shoud be on Eurasian watermilfoil.

If the invasives remain in check, the native plants should have more space and light, and less competition from the invasives and ideally be able to establish and expand with the improved clarity from an alum treatment. If rapid recovery of the native plant community does not occur during the first year of substantially improved water clarity, planting or transplanting should be conducted to jump-start the recovery, along with targeted and selective herbicidal control, in the next year.

VIII. Staring Lake Results

Staring Lake is a eutrophic lake in the Purgatory Creek Watershed. The lake is about 66 hectares (164 acres), with a maximum depth of 4.9m (16ft) (MN DNR LakeFinder 2015). Staring Lake has had a high population of carp (Bajer and Sorensen personal communication) and subsequently has been turbid and algae-dominated with low water clarity. Efforts began in 2012 to reduce the carp population and a substantial, but still only partial, removal occurred in winter 2014 (Bajer and Sorensen, personal communication). In 2015, the carp were further reduced to approximately 10% of the original 2011 population prior to removal (Bajer and Sorensen, personal communication). Increases in native and exotic plant diversity, frequency of occurrence, and biomass occurred in the 2015 surveys in addition to improved water clarity.

Water quality:

The summer Secchi depths have been consistently low, however there was improvement in 2015. The increase in Secchi depth was marginal in the summer of 2015 but the fall Secchi depth greatly improved to 2.5 meters in the beginning of October (Figure 23). Dissolved oxygen profiles show that an anoxic hypolimnion may exist from below 2m to 4m during the summer depending on the year (Figure 23). Three of the five years show some dissolved oxygen throughout the entire water column, likely due to lack of stratification.

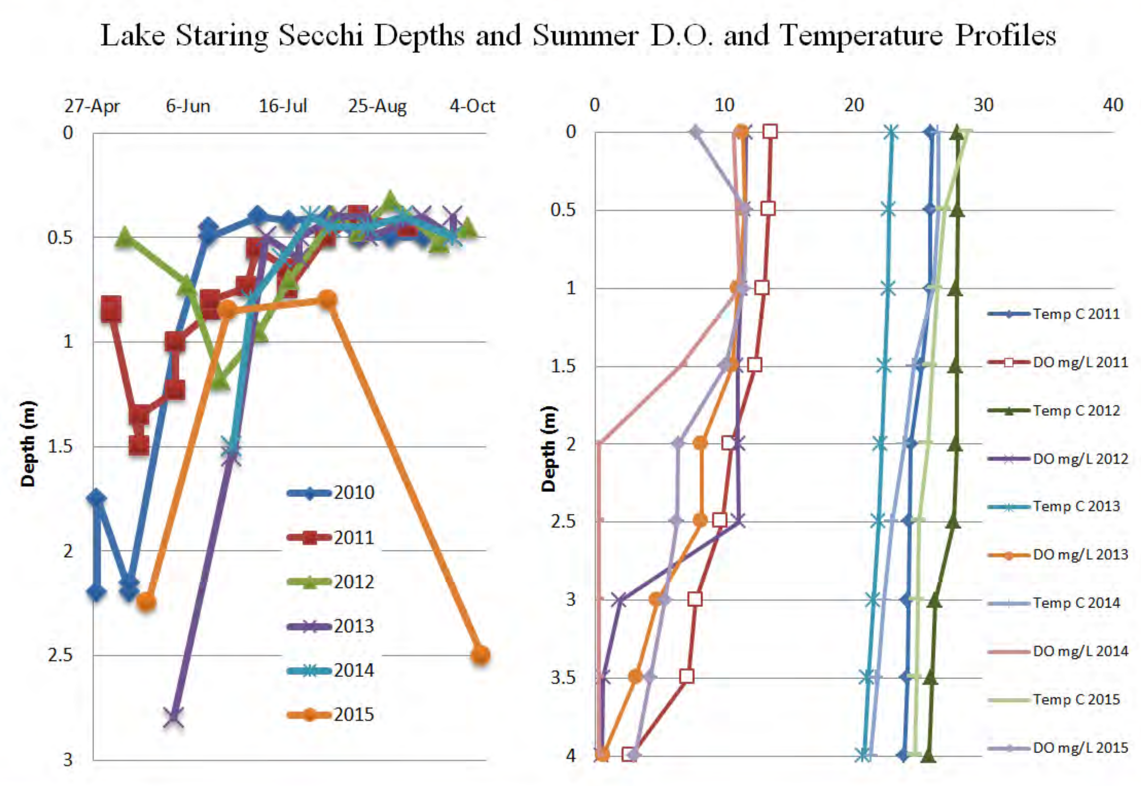


Figure 23. Secchi depths for Staring Lake 2010 through 2015 (Bajer and Sorensen unpublished data, personal communication) and dissolved oxygen (mg/L) and temperature (°C) profiles taken in August 2011 through August 2015.

Aquatic Vegetation Survey:

Point intercept surveys were conducted in Staring Lake in June and August 2011, 2012, 2013 and 2014. In 2015, surveys were conducted in May, June, August, and October. There were increases in frequency and biomass of plants in addition to new species observed in 2015 due to the reduction in carp. Species diversity increased to 19 observed species (Table 14). The maximum species richness per site was observed in the August 2015 survey with one site having 5 species (Figure 24). The species richness per site was typically much lower than 5 in all surveys from 2011 to 2015 on Staring Lake.

In 2015, significant increases in frequency of occurrence were observed. Curlyleaf pondweed was generally the most frequently occurring species in June each year (Figure 25). In 2015, curlyleaf frequency increased to over 35% (Figure 28). White and yellow water lilies were previously two of the most commonly occurring native species in Staring, likely due to that fact that they are floating leaf species and less impacted by poor water clarity. In 2015, Canada waterweed, coontail, chara, naiads, and narrow leaf pondweed all increased in frequency (Figure 25). However, most species of plants, including curlyleaf pondweed, found in Staring Lake continued to exist in low frequencies relative to other lakes described in this report.

Additionally, the biomass of all aquatic plants in Staring Lake (Figure 26) continued to be low relative to other lakes described in this report. In 2015, curlyleaf pondweed had the largest biomass in June. Chara had the second greatest biomass in June (Figure 26). In August, Canada waterweed, coontail, and chara had the greatest biomass. Although, the biomass was lower than other lakes described in the report, the 2015 increases in biomass were significant for several species (Figure 26).

The October vegetation survey was conducted after Eurasian watermilfoil was found in the lake (September) to assess the plant community prior to herbicide treatment as water clarity had increased substantially. Increases in the frequency of occurrence were observed for Canada waterweed, curlyleaf pondweed, and brittle naiad (Figure 27). During the survey brittle naiad (*Najas minor*), an additional exotic aquatic plant, was found. Brittle naiad was found at 16 surveyed littoral points. It is not surprising that this occurred due to the fact that the species was found extensively in Purgatory Creek marsh and recreation area which is located upstream of Lake Staring. The increased water clarity likely improved the colonization potential of the newly observed exotic species.

Eurasian Watermilfoil Herbicide Treatment

In September of 2015, Eurasian watermilfoil was observed in small patches in Lake Staring. In October, efforts by the watershed district with assistance from James Johnson of Freshwater Services, LLC, occurred to manually pull milfoil. Following this treatment an herbicide application consisting of granular Triclopyr (known as Renovate3®) took place to control the remaining plants on October 8th. The October survey which occurred the day after treatment did not find additional milfoil that was not already detected by James Johnson. The mechanism causing the appearance of Eurasian watermilfoil is unknown. Monitoring for the species will continue in the coming field season.

Aquatic Bathymetry and Vegetation Mapping

Plants were generally restricted to depths shallower than 2m (Figure 29), percent area covered was usually <20% and mean biovolume 35% or less before 2015 (Table 15). In 2015, the percent area covered increased in August and October to just under 50% and the mean biovolume was approximately 65% (Table 15).

Curlyleaf pondweed turion surveys:

We conducted fall sediment turion surveys in October of 2011 through 2015. Until 2015, no turions were found in the sediments of Staring Lake in fall despite production of some turions in the spring. With the increase in curlyleaf frequency and abundance in 2015, increased turion production was observed and turions were found in the sediment in fall. The density of turions in 2015 was 30 turions/m^2, with 91% viable.

Table 14. Aquatic plants found in surveys conducted in Staring Lake 2011 through 2015 *indicates new species first found in 2015.

Common Name	Scientific Name	Abbreviation
Submerged species		
Coontail	*Ceratophyllum demersum*	Cdem
Muskgrass	*Chara spp.*	Char
Canada waterweed	*Elodea canadensis*	Ecan
*Eurasian watermilfoil	*Myriophyllum spicatum*	Mspi
Bushy Pondweed	*Najas flexilis*	Nfle
Southern waternymph	*Najas guadalupensis*	Ngua
*Brittle Naiad	*Najas minor*	Nmin
Curlyleaf pondweed	*Potamogeton crispus*	Pcri
Long-leaf pondweed	*Potamogeton nodosus*	Pnod
Narrow leaf pondweed	*Potamogeton pusillus*	Ppus
*Flat-stemmed pondweed	*Potamogeton zosteriformis*	Pzos
Sago pondweed	*Stuckenia pectinata*	Spec
Greater bladderwort	*Utricularia vulgaris*	Uvul
Horned pondweed	*Zannichellia palustris*	Zpal
Water stargrass	*Zosterella dubia*	Zdub
Floating-leaf Species		
Common duckweed	*Lemna minor*	Lmin
Star duckweed	*Lemna trisulca*	Ltri
Yellow water lily	*Nuphar variegata*	Nvar
White water lily	*Nymphaea odorata*	Nodo

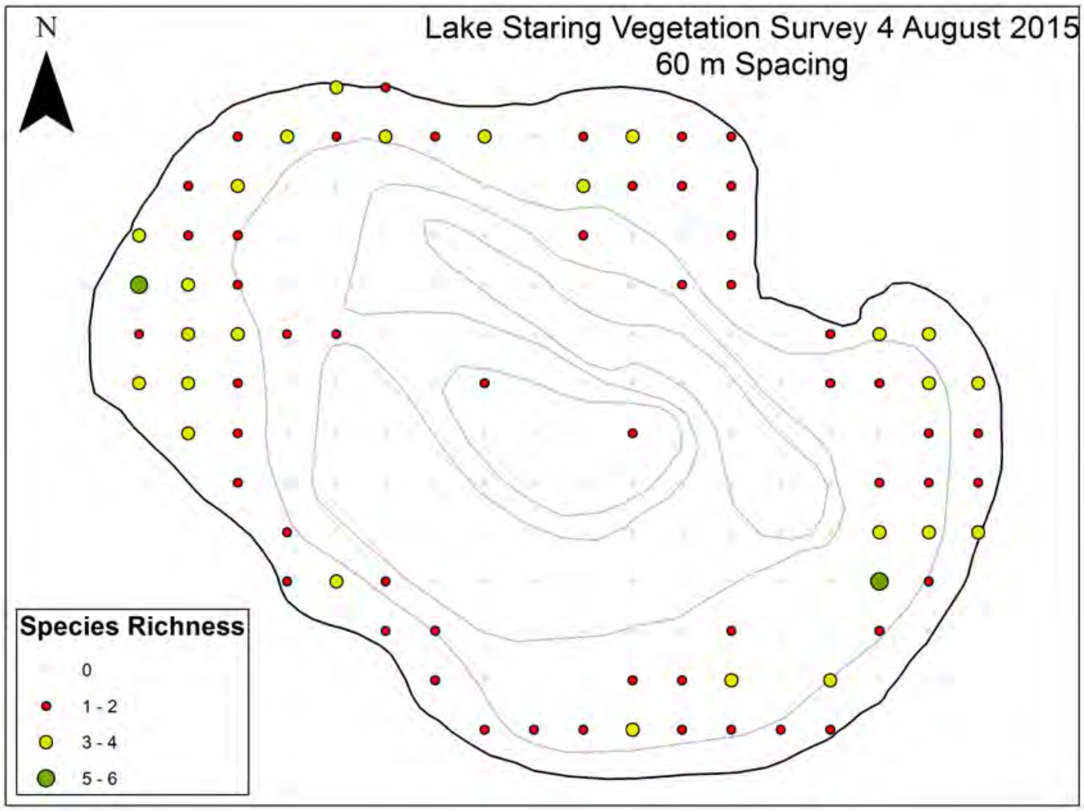


Figure 24. The number of aquatic plant species present at each site surveyed in Staring Lake, August 2015.

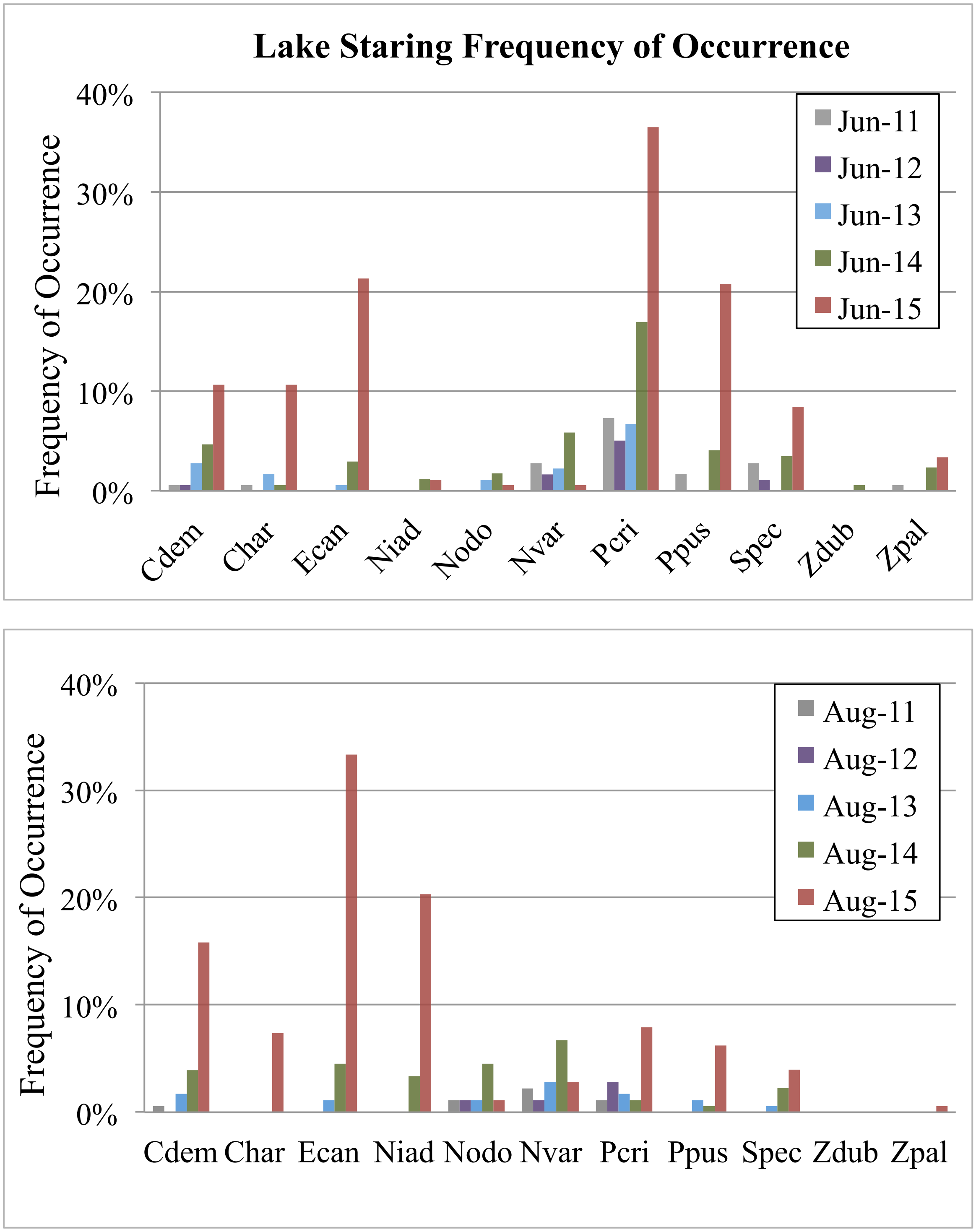
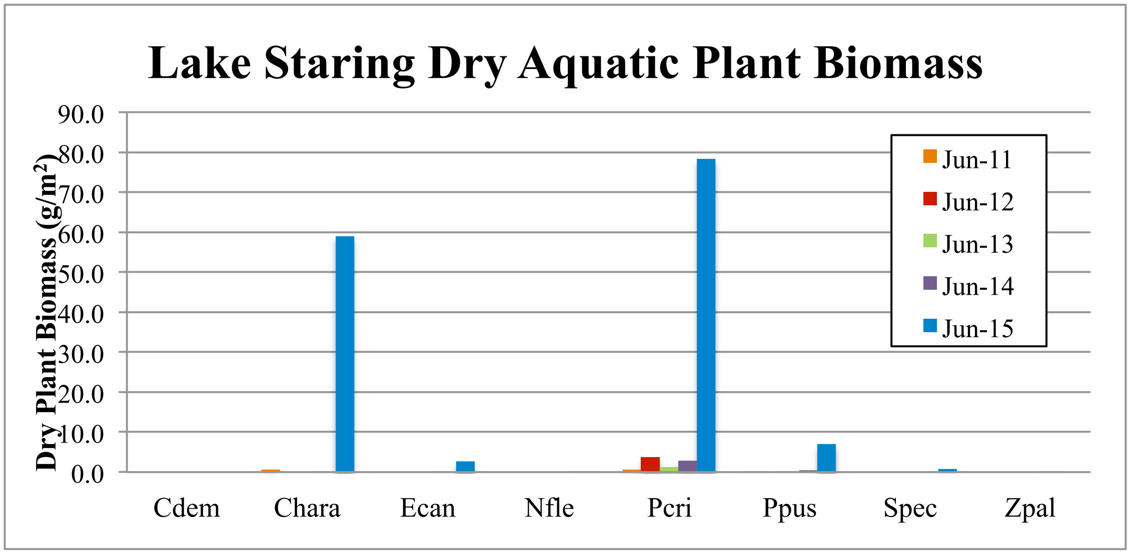


Figure 25. Frequency of occurrence of the most commonly occurring species in Staring Lake surveys in June and August 2011, 2012, 2013, 2014, and 2015. See Table 14 for abbreviations.



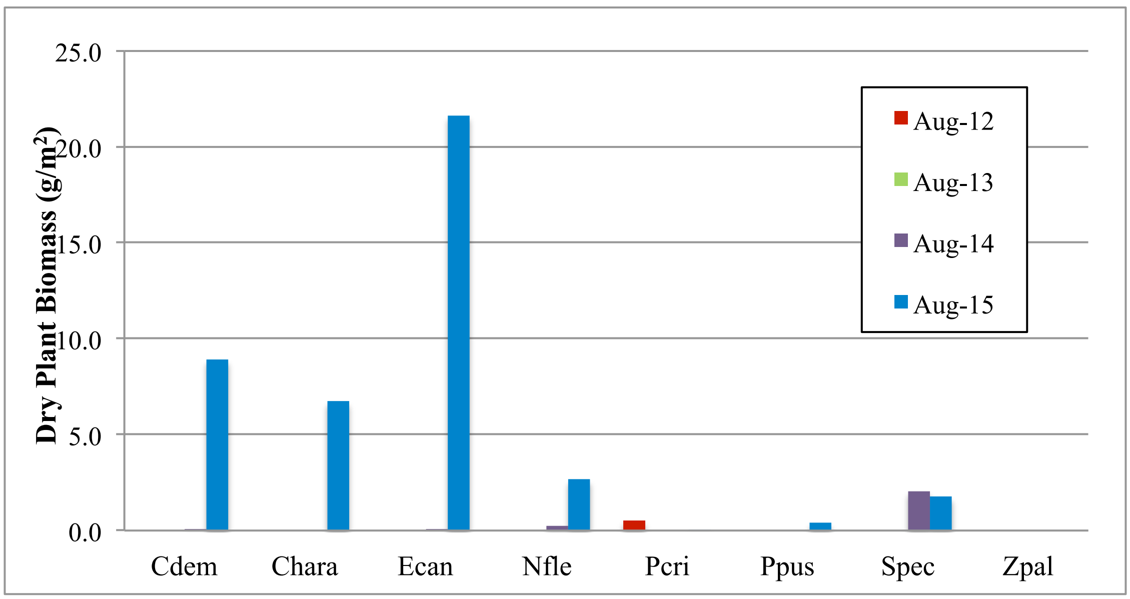


Figure 26. Dry Aquatic Plant Biomass (g dry/m^2) for the most commonly occurring species in Staring Lake surveys June and August 2011, 2012, 2013, 2014 and 2015. See Table 14 for abbreviations. The vertical axis scale is much smaller relative to other lakes described in this report. We attempted to collect biomass in August 2011 and August 2013 and found no plants at any biomass sampling sites.

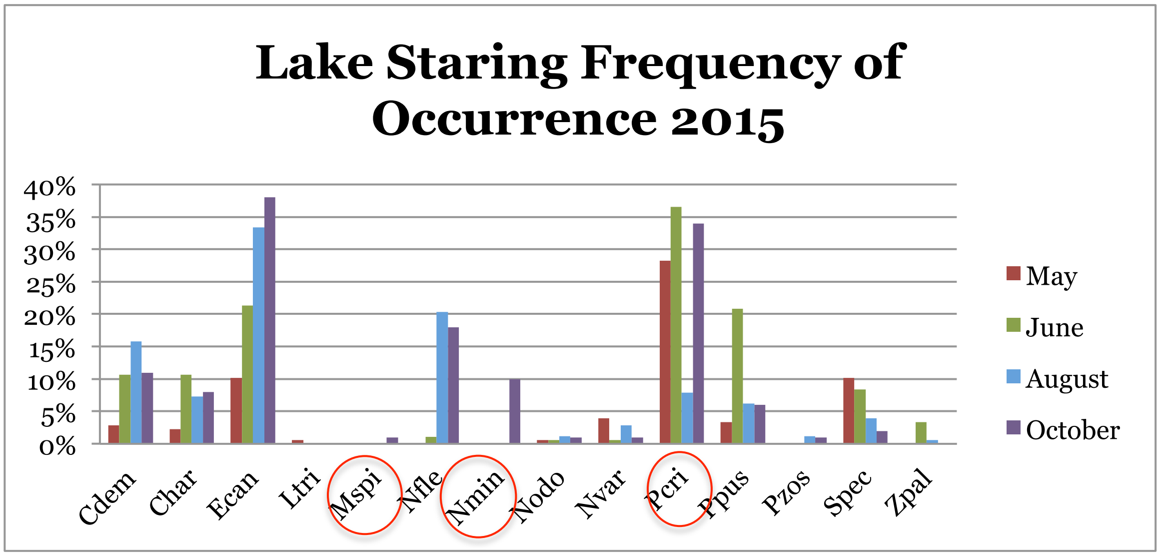


Figure 27. Frequency of occurrence of all observed species in 2015 including the May and October surveys. Exotic species are indicated in red circles.

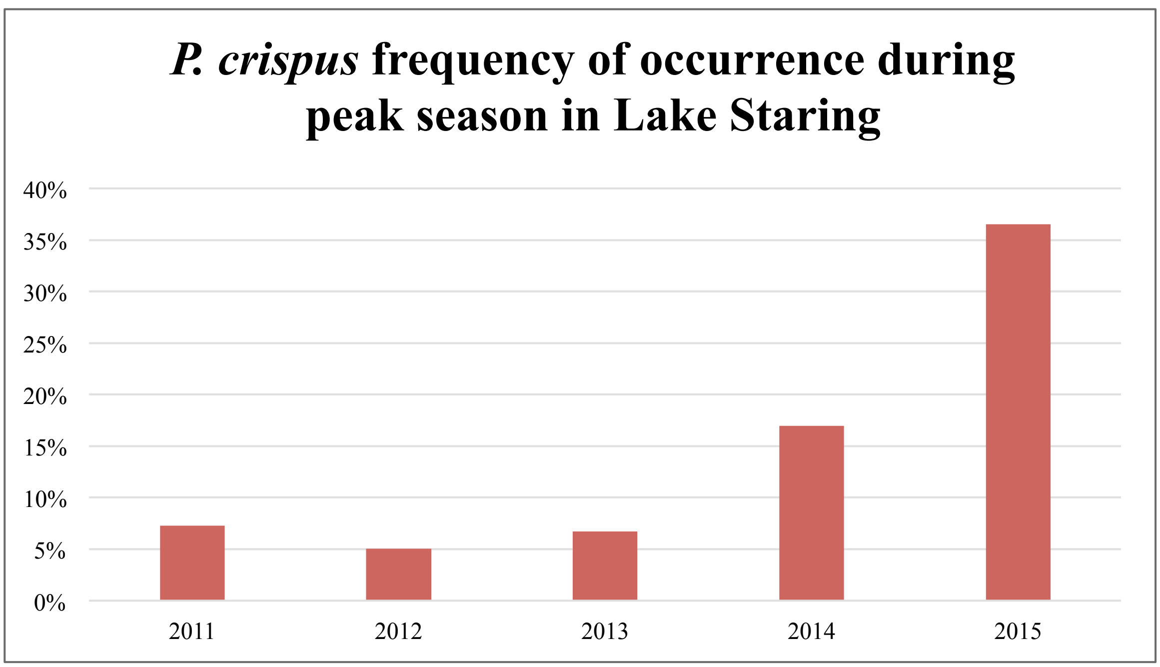


Figure 28. Frequency of occurrence of curlyleaf pondweed in Lake Staring from 2011 through 2015 at June peak season growth.

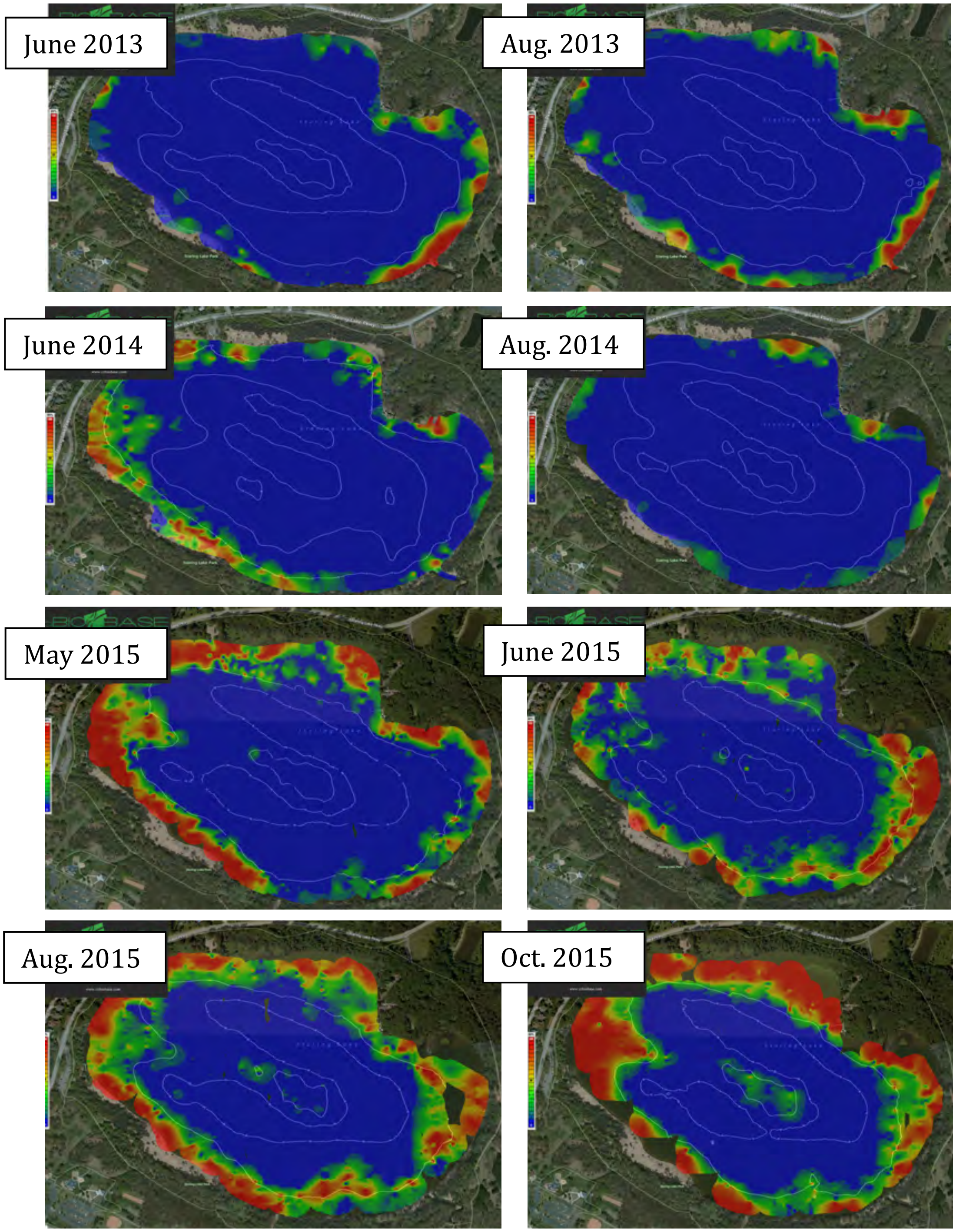


Figure 29. Aquatic bathymetry and vegetation maps of Staring Lake. Sonar data collected during point intercept aquatic vegetation surveys on: 10 June 2013, 5 August 2013, 25 June 2014, 5 August 2014, 21 May 2015, 23 June 2015, 4 August 2015, 9 October 2015. Contour lines are 5ft intervals. Color legend represents percent biovolume (refers to the percentage of the water column taken up by vegetation when vegetation exists) with blue representing no vegetation present and red representing 100% of the water column being taken up by vegetation.

Table 15. Lake-wide percent area cover (PAC) and average biovolume (BV) for data collected in June and August 2013 and July and August 2014 in Staring Lake. Values coincide with maps in Figure 33. PAC refers to the overall surface area that vegetation is growing in the surveyed area. Average BV refers to the percentage of the water column taken up by plants when plants exist; areas that have no plants are not factored into this calculation.

Date	PAC	Average BV
June 2013	12.5%	31.0%
August 2013	15.1%	31.6%
June 2014	23.2%	34.8%
August 2014	9.3%	21.8%
May 2015	21.9%	63.2%
June 2015	36.4%	54.9%
August 2015	47.1%	62.7%
October 2015	49.7%	65.1%

Recommendations for Staring Lake:

In 2015 carp were lowered to a density that allowed for the establishment of macrophytes. Native plant enhancement management strategies should be implemented if natural recovery does not occur in the coming year. Curlyleaf pondweed appears to be becoming problematic in addition to the occurrence of two other exotic species, Eurasian watermilfoil and brittle naiad (*Najas minor*). Curlyleaf pondweed frequency of occurrence doubled from June 2014 to June 2015 warranting consideration of an early season herbicide treatment. Turion densities are still low ($30/m^2$), however, and the native plant community is quite abundant. Therefore, it may be better to not treat for exotic species this year on lake-wide scale so as to monitor the progress of natural revegetation for one more field season. However, if control of curlyleaf is desired, it would be best to do a lake-wide treatment to control the entire population and prevent propagule production. Selective control should allow the native plants to further expand. Current estimates based on last year's coverage suggest 20 to 30 acres be treated, which might require development of a Lake Vegetation Mangement Plan. Spot treatment or focused pulling of Eurasian watermilfoil should be considered. Continued surveys will allow for consistent monitoring of the plant community and to track exotic species expansion.

IX. Lake Susan Results

Lake Susan (DOW ID 10-001300) is a small kettle lake, downstream about two kilometers southeast of Lake Ann, within Chanhassen city limits. Lake Susan covers about 38 hectares (93 acres), with approximately 30 hectares (75 acres) littoral and a maximum depth of about 5.2m (17ft)(MN DNR LakeFinder 2015). Carp removal occurred in the winter of 2009. Following successful carp removal, aquatic plant transplanting experiments began in the summer of 2009 and ended in the summer of 2011. Lake Susan was treated with the herbicide endothall to control curlyleaf in May 2013 and 2014.

Water Quality:

Water clarity has improved in the spring in Lake Susan since carp removal, but usually declined to 1m or less by early summer (Figure 30). Water clarity was typically very low during much of the native aquatic plant growing season. The dissolved oxygen profiles show that by July there was often an anoxic hypolimnion beginning at 3.5m and below (Figure 30).

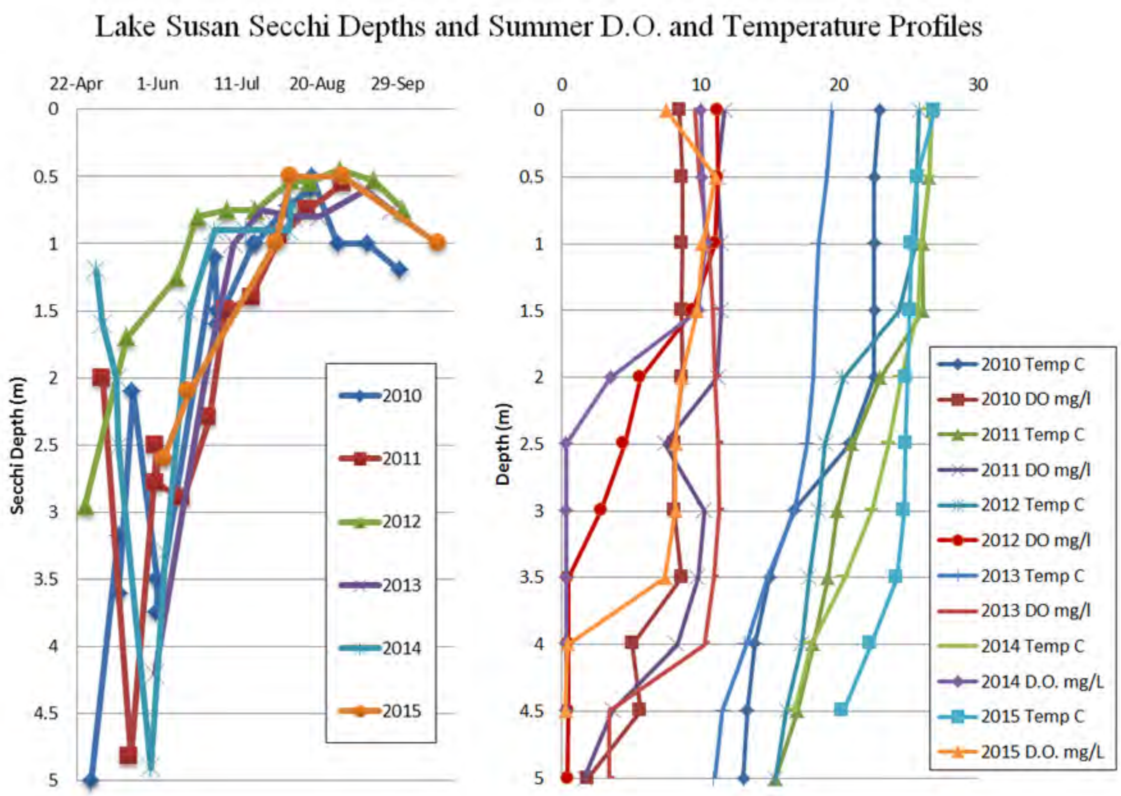


Figure 30. Secchi depths for Lake Susan 2010 through 2014 (Bajer and Sorensen unpublished data, personal communication) and dissolved oxygen (mg/L) and temperature (°C) profiles taken in August 2011 through August 2014.

Aquatic Vegetation Survey:

We have sampled plants in Lake Susan since 2009. We have observed 23 different species (including transplanted species) in Lake Susan from 2009 to 2015 (Table 16). Lake Susan has relatively low to moderate plant diversity, but increased from 9 native taxa in 2009 (Newman 2009) to 15 native taxa found in 2014 (Table 17). The highest species richness per site in 2015 occurred in August with one site containing 4 different species, although most sites had one to two species (Figure 31).

Typically coontail and curlyleaf pondweed were the most frequently occurring species in May (Figure 32). Coontail, curlyleaf pondweed, Canada waterweed, sago pondweed and narrow leaf pondweed were the most frequently occurring species in June (Figure 32). Coontail, Canada waterweed, sago pondweed and narrow leaf pondweed were the most frequently occurring species in August (Figure 32). Transplanted species, such as bushy pondweed, have begun to be observed (in low frequencies) in surveys as some species have expanded. The invasive Eurasian watermilfoil has continued to decline in frequency since 2011.

Total native plant biomass in August has been variable as biomass increased after carp removal from 2009-2011 but then declined in 2012 (Figure 35) when curlyleaf pondweed peaked (Figure 34). This, along with an increasing density of turions in the sediment (Table 18), led to the decision to control the curlyleaf with early season endothall treatments in spring 2013. Native plant biomass in August increased after herbicide treatments in in 2013 and 2014 (Table 19). In 2015, although herbicide treatment did not occur, native plant biomass remained similar to previous levels (Figure 33). Coontail typically had the highest biomass in all months in Lake Susan (Figure 35). Curlyleaf pondweed, Canada waterweed, narrow leaf pondweed and American lotus are some of the higher biomass producing plants in Lake Susan. Eurasian watermilfoil biomass remained at less than 3g dry/m^2 since 2011. Curlyleaf biomass peaked in 2012, but then was low during the treatment years of 2013 and 2014. However, curlyleaf biomass increased in 2015 to 30 g dry/m^2. Despite the increase, this is much lower than native plant biomass (120 g/m^2), much lower than lakes with dense curlyleaf (>300 g/m^2) and well below the peak of 50 g/m^2 in 2012.

Milfoil Herbivore Population:

Eurasian watermilfoil has declined in both frequency of occurrence (Figure 32) and biomass (Figure 35) since we began surveying in Lake Susan. The declines may be partially attributed to relatively high densities of milfoil weevils when milfoil was present in the lake. We began monitoring the milfoil herbivore population in 2010 and the weevil densities were variable but persistent throughout observation years. Weevil populations were lower in 2013 through 2015 (Table 20), but Eurasian watermilfoil was also at very low densities and difficult to find. It is likely the milfoil weevil aided in the control of Eurasian watermilfoil and is perhaps suppressing any resurgence.

Curlyleaf Pondweed Herbicide Treatments:

Lake-wide early season endothall herbicide treatments took place in Lake Susan in the spring of 2013 and 2014. During the herbicide treatment years, curlyleaf pondweed declined significantly ($p \leq 0.05$) in frequency of occurrence (Figure 36), biomass (Figure 34) and turion density in the sediments (Table 18). Curlyleaf pondweed was observed in over 40% of sites sampled in the littoral zone in 2012 and declined to less than 10% of sites sampled in the littoral zone in 2013 and 2014 post-treatment (June).

The low frequency and biomass, along with low turion density in fall of 2014, led to the decision to not treat in 2015. In 2015, without treatment, the peak season frequency of occurrence increased to 25% of sampled littoral points. At its peak in 2012, we observed a littoral-wide average curlyleaf biomass of about 50 g dry/m^2. Curlyleaf biomass values declined to under 5 g dry/m^2 in 2013 and 2014, which was also significant ($p \leq 0.05$). Biomass in 2015 significantly increased to about 30 g dry/m^2, however this is still lower than the peak in 2012 and much less than current native plant biomass and nuisance levels in other lakes. Turion densities in the sediments declined from a peak of 87 turions/m^2 in 2012 to about 8 turions/m^2 in 2014 (Table 18). In 2015, the turion density remained low at 11 turions/m^2. Turion viability increased from 67% in 2014 to 99% in 2015. Mean total native plant biomass increased in 2013 and 2014 compared to previous years, although the increases were not significant (Figure 33). Although curlyleaf frequency increased in 2015 the native plant biomass and frequency remained similar to 2014 observations.

Aquatic Bathymetry and Vegetation Mapping

Plant coverage ranged from 18 to 40% (Table 21) but the highest biovolume was generally in water < 2m deep (Figure 37). Plants were distributed around the lake, but rarely in water deeper than 3m. Mean biovolume ranged from 21% in May 2014 to 26% in August 2013 (Table 21).

Table 16. Aquatic plants found in surveys conducted in Lake Susan 2009 through 2015.
*These species were transplanted in Lake Susan and have been observed in surveys.
**These species were transplanted in Lake Susan and have not been observed in surveys.

Common Name	Scientific Name	Abbreviation
Emergent species		
Cattail	*Typha spp.*	Typh
Hardstem bulrush	*Scirpus acuts*	Sacu
Submerged species		
Coontail	*Ceratophyllum demersum*	Cdem
**Muskgrass	*Chara spp.*	Chara
Canada waterweed	*Elodea canadensis*	Ecan
**Northern watermilfoil	*Myriophyllum sibiricum*	Msib
Eurasian watermilfoil	*Myriophyllum spicatum*	Mspi
*Bushy pondweed	*Najas flexilis*	Nfle
Curlyleaf pondweed	*Potamogeton crispus*	Pcri
Leafy pondweed	*Potamogeton foliosus*	Pfol
Long-leaf pondweed	*Potamogeton nodosus*	Pnod
Narrow leaf pondweed	*Potamogeton pusillus*	Ppus
*Flat-stem pondweed	*Potamogeton zosteriformis*	Pzos
White water buttercup	*Ranunculus longirostris*	Rlon
Sago pondweed	*Stuckenia pectinata*	Spec
*American water celery	*Vallisneria americana*	Vame
Horned pondweed	*Zannichellia palustris*	Zpal
*Water stargrass	*Zosterella dubia*	Zdub
Floating-leaf Species		
Lesser duckweed	*Lemna minor*	Lmin
Star duckweed	*Lemna trisulca*	Ltri
American lotus	*Nelumbo lutea*	Nlut
White lily	*Nymphaea odorata*	Nodo
Yellow lily	*Nuphar variegata*	Nvar

Table 17. Total number of native aquatic plant species found in Lake Susan by year. The number of taxa present column is the total number of native species found in all surveys combined for the given year.

Date	Taxa Present
2009	9
2010	7
2011	10
2012	9
2013	10
2014	15
2015	10

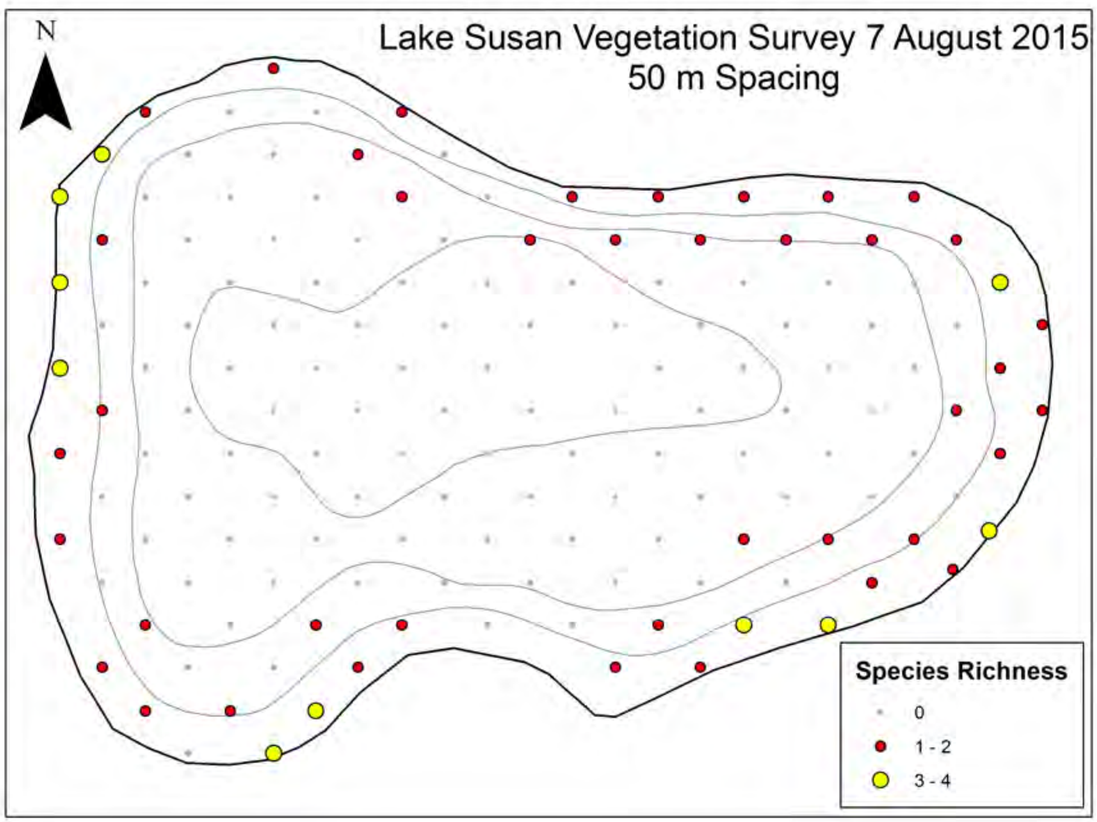


Figure 31. The number of aquatic plant species present at each site surveyed in Lake Susan, August 2015.

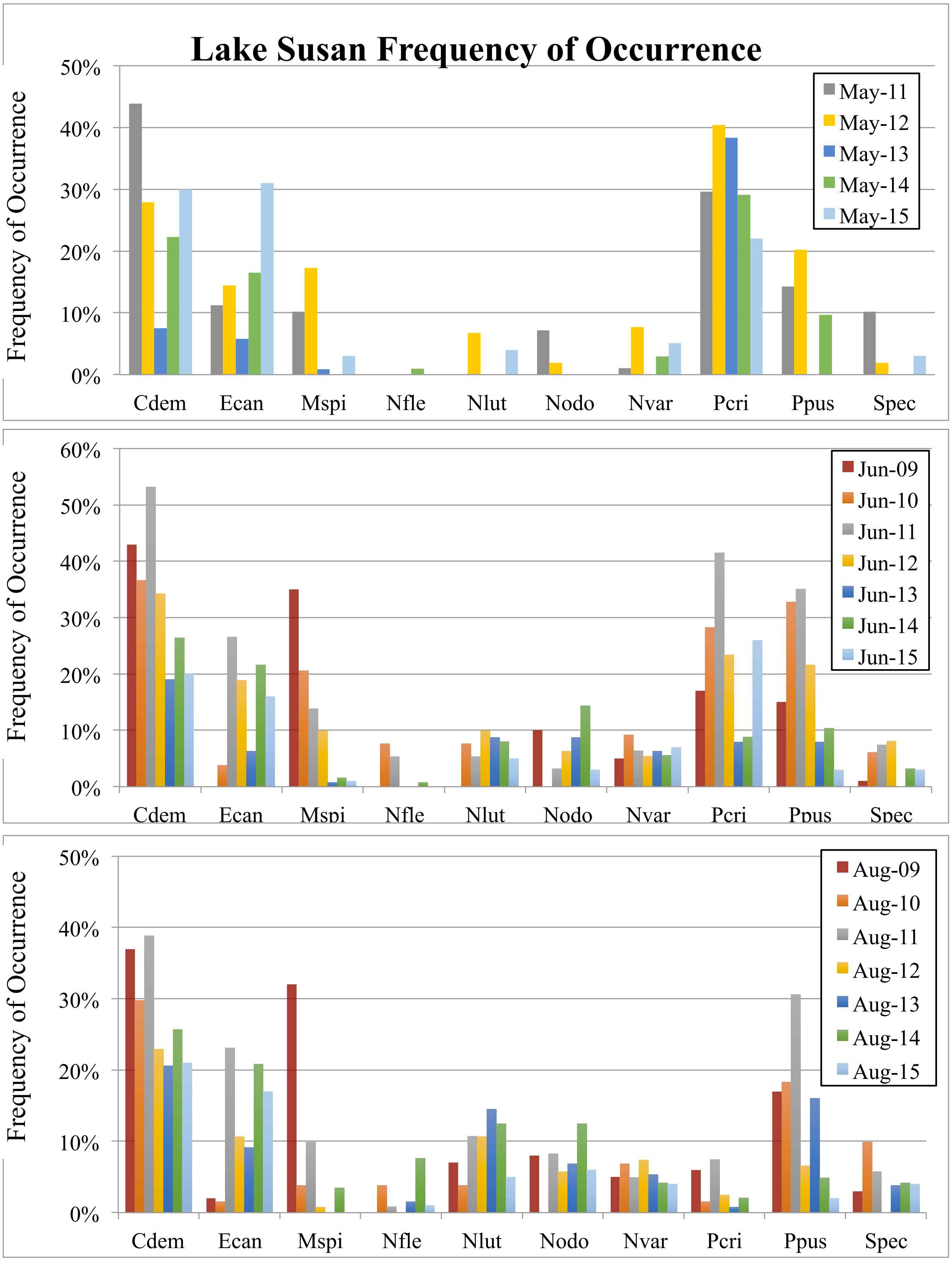


Figure 32. Frequency of occurrence for the most commonly occurring species in Lake Susan surveys May 2011 through 2015 and June and August 2009 through 2015. See Table 16 for abbreviations.

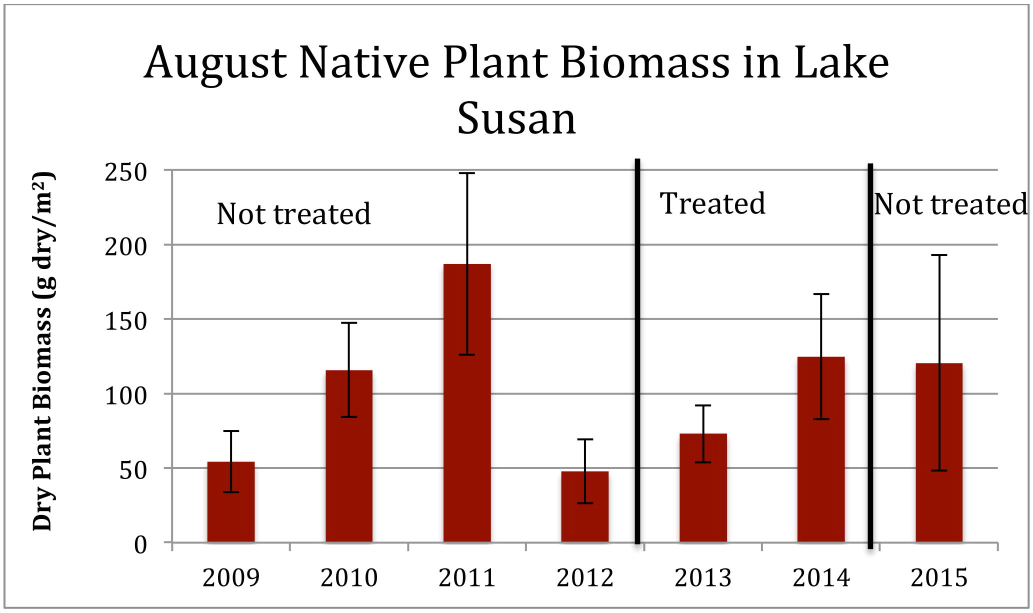


Figure 33. Mean total native plant biomass (g dry /m^2) in the littoral zone (August Surveys) in Lake Susan 2009 through 2015. The vertical lines represent the treatment years of 2013 and 2014.

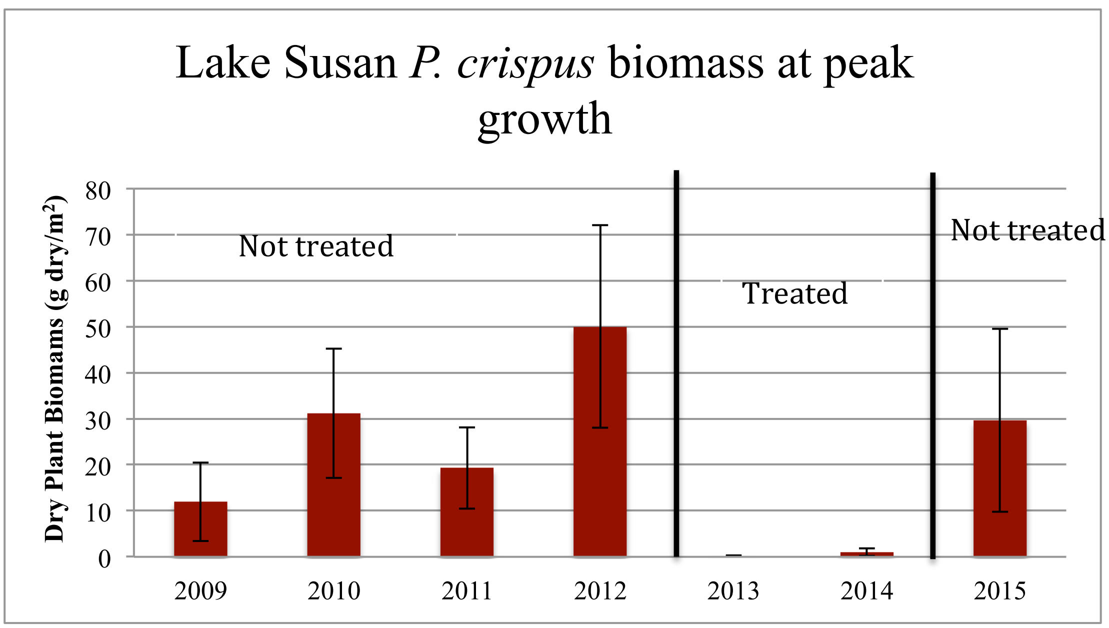


Figure 34. Peak biomass (g dry/m^2) of curlyleaf pondweed in Lake Susan 2009 through 2015. The vertical lines represent the treatment years of 2013 and 2014. Note: Treatment year declines in 2013-2014 are significant ($p \leq 0.05$).

Table 18. Results from turion surveys conducted October 2011 through October 2015 in Lake Susan. Note: Decline from 2012 to 2014 is significant ($p \leq 0.05$).

Pcri	Turions/m^2	Viability	Viable Turion Density
Oct-2010	24	90%	22
Oct-2011	51	98%	50
Oct-2012	87	98%	85
Oct-2013	18	65%	12
Oct-2014	8	67%	5
Oct-2015	11	99%	11

Table 19. Mean dry plant biomass (g dry/m^2) of total native species and total exotic species (curlyleaf pondweed and Eurasian watermilfoil) in Lake Susan.

Date	Native (g dry/m^2)	Exotics (g dry/m^2)
June 2009	6.8	7.4
August 2009	54.3	7.6
June 2010	145.1	36.5
August 2010	115.8	0.7
September 2010	111.4	4.7
May 2011	36.0	5.3
June 2011	85.8	20.3
August 2011	186.9	2.4
May 2012	84.7	51.1
June 2012	73.5	6.9
August 2012	47.9	0.5
May 2013	1.3	6.5
June 2013	3.8	0.2
August 2013	73.0	0.2
May 2014	24.7	1.3
June 2014	47.1	1.0
August 2014	124.8	0.0
May 2015	12.3	1.0
June 2015	30.5	29.7
August 2015	120.3	0.6

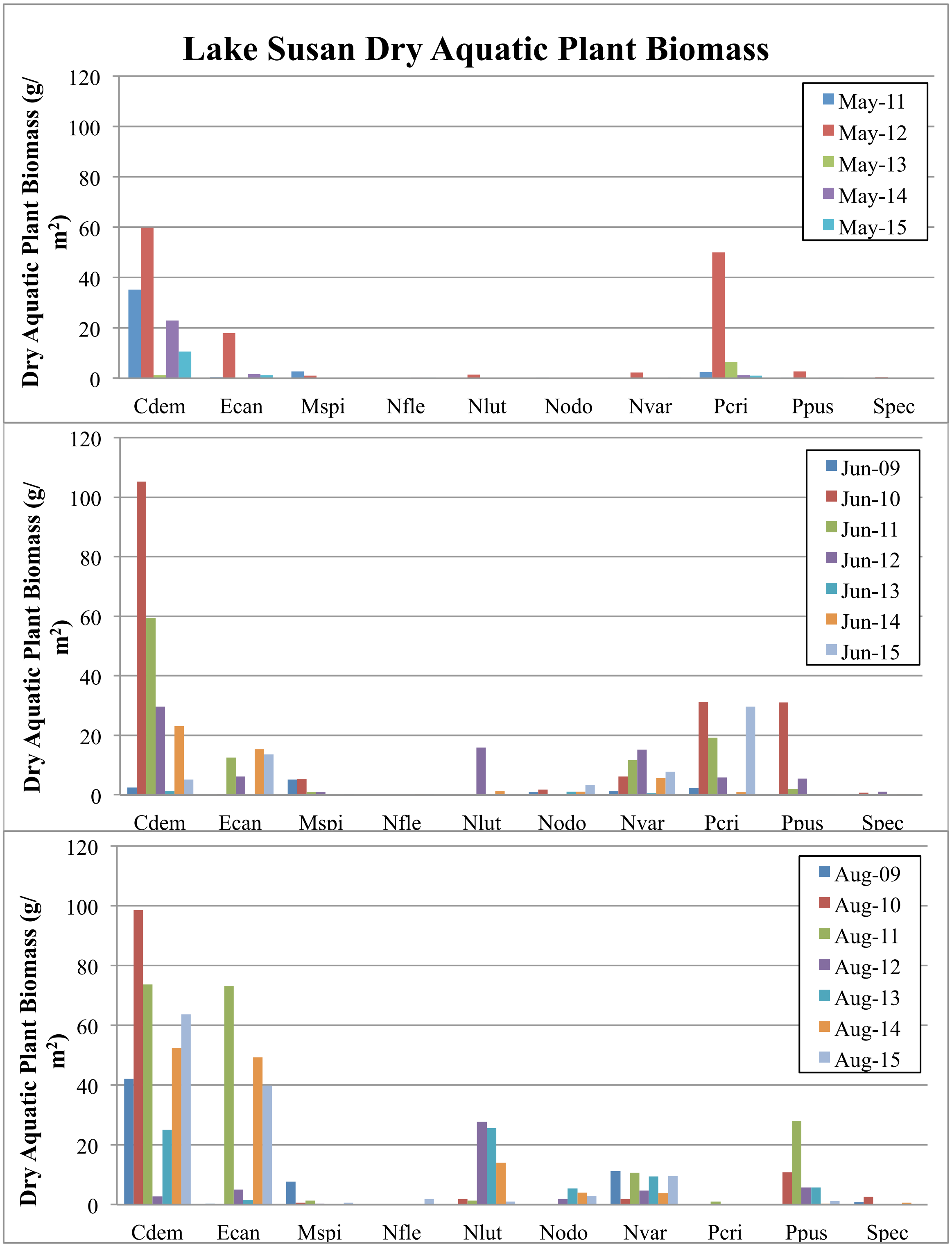


Figure 35. Dry Aquatic Plant Biomass (g dry/m^2) for the most commonly occurring species in Lake Susan surveys May 2011, 2012, 2013, 2014, and 2015 and June and August 2009, 2010, 2011, 2012, 2013, 2014 and 2015. See Table 16 for abbreviations.

Table 20. Results of Eurasian watermilfoil herbivore population surveys in Lake Susan 2010 through 2015. Values are lake-wide means for weevil populations expressed as total weevils in all life stages per stem.

Mspi	Weevils/Stem
2010	
4 June	0.82
17 June	0.87
6 July	0.27
27 July	0.19
17 August	0.04
4 September	0.04
2011	
7 June	0.21
7 July	0.17
3 August	0.15
1 September	0.13
2012	
1 June	0.48
28 June	0.12
8 August	0.09
2013	
3 June	0.13
26 June	0.00
29 July	0.08
27 August	0.00
2014	
5 June	0.00
30 June	0.06
28 July	0.11
26 August	0.04
2015	
1 June	0.01
30 July	0.11
2 September	0.01

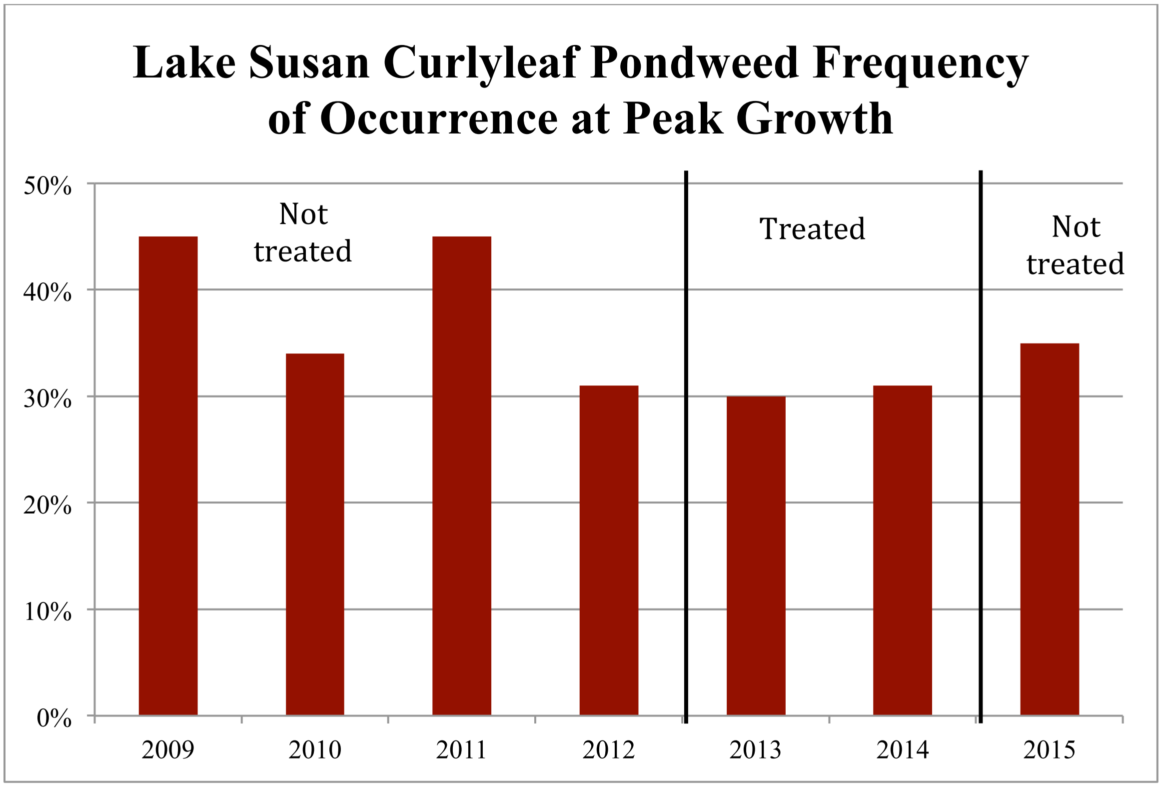


Figure 36. Peak frequency of occurrence for curlyleaf pondweed in Lake Susan 2009 through 2015. The vertical lines represent the treatment years of 2013 and 2014. Note: Post-treatment declines are significant ($p \leq 0.05$).

Table 21. Lake-wide percent area cover (PAC) and average biovolume (BV) for data collected in 2013 through 2015 in Lake Susan. Values coincide with maps in Figure 41. PAC refers to the overall surface area that vegetation is growing in the surveyed area. Average BV refers to the percentage of the water column taken up by plants when plants exist; areas that have no plants are not factored into this calculation.

Date	PAC	Average BV
May 2013	33.7%	46.3%
June 2013	17.9%	35.8%
August 2013	22.5%	56.1%
May 2014	23.6%	20.6%
June 2014	38.6%	47.5%
August 2014	23.8%	37.8%
June 2015	6.6%	68.3%
August 2015	19.0%	55.3%

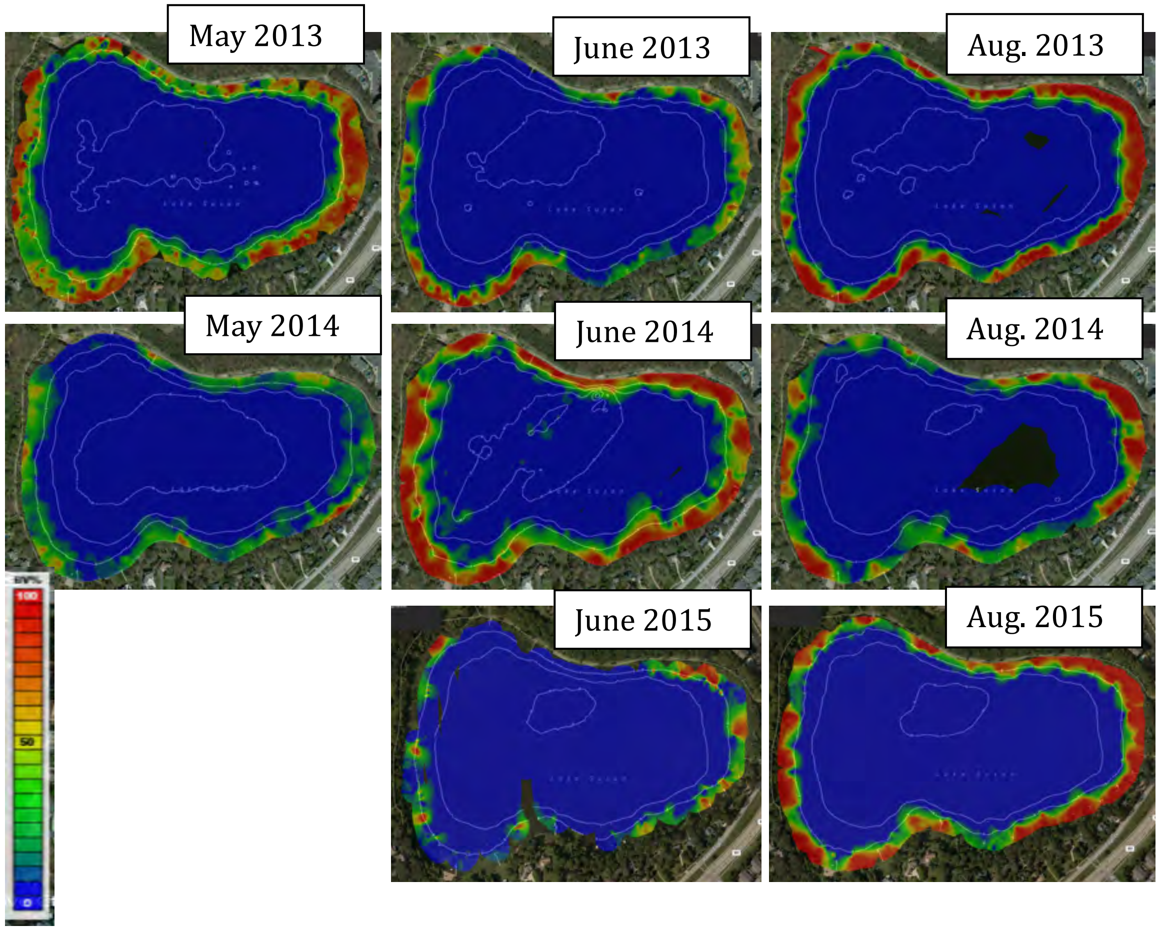


Figure 37. Aquatic bathymetry and vegetation maps of Lake Susan. Data collected during point intercept aquatic vegetation surveys on: 6 May 2013, 7 June 2013, 12 August 2013, 13 May 2014, 17 June 2014, 6 August 2014, June 26 2015, and August 7 2015. Contour lines are 5ft intervals. Color legend represents percent biovolume (the percentage of the water column taken up by vegetation when vegetation exists) with blue representing no vegetation present and red representing 100% of the water column being taken up by vegetation.

Lake Susan Recommendations

The increasing curlyleaf growth in Lake Susan is concerning, however not treating in the coming year may be beneficial to assess the long-term effectiveness of herbicide applications. There is limited information available on how quickly the population will rebound after treatment stops. Turion density in the sediment is still low and native plant biomass appears similar to treatment years.

The currently established native plants may be able to compete with curlyleaf to sustain a diverse and stable plant community. Another option is to treat half or 1/3 of the lake (e.g., East side) with an early season endothall treatment and use the other half of the lake as an untreated reference to determine if not treating would result in a decrease in native plants compared to the treated area. To increase response resolution we would double the number of biomass points from 40 to 80. Under this scenario it will be important to monitor residual herbicide concentrations around the lake and to set up the treatment to minimize lake-wide drift of the herbicide.

Similar to Lake Riley, the expansion of native plants appears to be limited by water clarity. With the limited water clarity Lake Susan will also likely benefit from an alum treatment to bolster clarity and reduce internal nutrient loading. If alum treatments are to occur in the future, herbicide applications will likely be needed to control the spread and expansion of exotic species and additional transplanting into deeper water could be considered.

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