Aquatic Vegetation of Lake Koronis

2015 to 2020

Lake Koronis, Id# 73-0200-02

Stearns County, Minnesota

Emergent and floating-leaf plants in the channel that connects Koronis to Mud Lake

DEPARTMENT OF NATURAL RESOURCES

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A) 2020 point intercept and nearshore plots
B) 2019 point intercept and nearshore plots
C) 2018 point intercept and nearshore plots
D) 2017 point intercept and nearshore plots
E) 2016 point intercept
F) 2015 point intercept
G) 2019 hydroacoustics
H) 2018 hydroacoustics
I) 2017 hydroacoustics
J) 2015 emergent and floating-leaf plant stand mapping

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SUMMARY

In 2015, Lake Koronis became the first Minnesota lake where the non-native submerged plant, starry stonewort (*Nitellopsis obtusa*) was detected. In this report, we use historical data to describe this lake's nearshore and lake-wide plant communities before starry stonewort was found. We then summarize and compare recent quantitative survey results from 2015 to 2020. The results of this study can be informative for other lakes, but specific studies may be needed on lakes with different physical and biological features.

Lake Koronis is a recreational use lake that has been stressed by shoreline development and human-caused eutrophication. A 2017 shore habitat survey found that 80% of the surveyed sites had some level of development. Lake-wide shore habitat rated moderate with a score of 73.7, which is just below the statewide average. Vegetation removal in the shoreland, shoreline and aquatic zones all contributed to this lower rating.

The nearshore zone of Lake Koronis lacks emergent and floating-leaved plants that are important for fish and wildlife habitat and erosion protection. As much as 79% of the nearshore plants that were mapped from aerial extent in 1968 may have been lost. Wild rice (*Zizania palustris*) was last detected in the lake in 1977. In 2015, only three acres of bulrush (*Schoenoplectus* sp.) and cattails (*Typha* sp.) and six acres of waterlilies (*Nuphar variegata* and *Nymphaea odorata*) were delineated.

Submerged plants are common in Lake Koronis. From 2015 through 2020, submerged plants were found to a maximum depth of 19 feet and within the 0 to 20 foot depth zone, plants were detected in at least 70% of the sites in each year with no statistically significant change between years. Plants were most frequent in depths from shore to 10 feet, where 90% of the sites contained at least one submerged taxon.

Historically, a wide diversity of submerged species have been found in the lake. Surveys from 2015 to 2020 indicate that the lake still supports a moderately diverse submerged plant community that would be expected in a central Minnesota hardwater lake. A total of 30 aquatic plant taxa were found including 4 emergent, 3 floating-leaved, 4 free-floating and 19 submerged taxa.

Hydroacoustic surveys were conducted in July 2017, 2018 and 2019 on 26 transects across the lake. The mean plant height varied by depth strata and year. Aquatic plant biovolume was highest in the shallow water zone.

Since its discovery in the lake in 2015, the distribution and abundance of starry stonewort has increased. In 2015, it was already distributed lake wide to a depth of 15 feet, but it was only detected in 17% of the sites and did not dominate the plant community. By 2020, it was the most frequently observed submerged plant, occurring in 44% of the survey sites within the shore to 20 foot depth zone. From 2015 through 2020, it was found most often in depths of 10 feet and less where it often co-occurred with other species.

Changes in the distribution and abundance of some native submerged species were also detected between 2015 and 2020. The most dramatic change detected was with the native macroalgae, muskgrass (*Chara* sp.). From 2015 to 2017, muskgrass was the most common submerged plant and in each year was detected in at least 50% of the sample sites within the shore to 20 feet depth zone. During 2018, 2019 and 2020 muskgrass was found in less than 40% of the survey sites and was no longer the most frequently occurring plant. Wild celery (*Vallisneria americana*) and northern watermilfoil (*Myriophyllum sibiricum*) also decreased in frequency in 2017, 2018, 2019, and 2020.

Multiple factors may influence such declines including declining water clarity and management activities. Management activities aimed at controlling starry stonewort are not selective and because it often grows within and near managed sites, muskgrass may be particularly susceptible to harm. Targeted monitoring is required to assess the effectiveness of those management activities at controlling starry stonewort and to determine if they are causing collateral damage to other species. More detailed information on such monitoring is available from the MNDNR Aquatic Invasive Species Program (Jurek and Hauck Jacobs 2019).

INTRODUCTION

Shoreland and aquatic plants are important to a lake's ecology. They provide sediment stabilization, habitat for fish, frogs and invertebrates, and they help maintain water clarity and purity by filtering nutrients and toxins from the water (Borman et al. 2014). Changes to the plant community can result in changes to the lake clarity and available habitat.

In 2015, Lake Koronis became the first lake in Minnesota where the non-native plant, starry stonewort (*Nitellopsis obtusa*) was detected. In this report, we use historical data to describe the plant communities of Lake Koronis before starry stonewort was introduced. We then summarize and compare recent quantitative survey results from 2015 to 2020. The results of this study can be informative for other lakes, but specific studies may be needed on lakes with different physical and biological features.

Starry stonewort

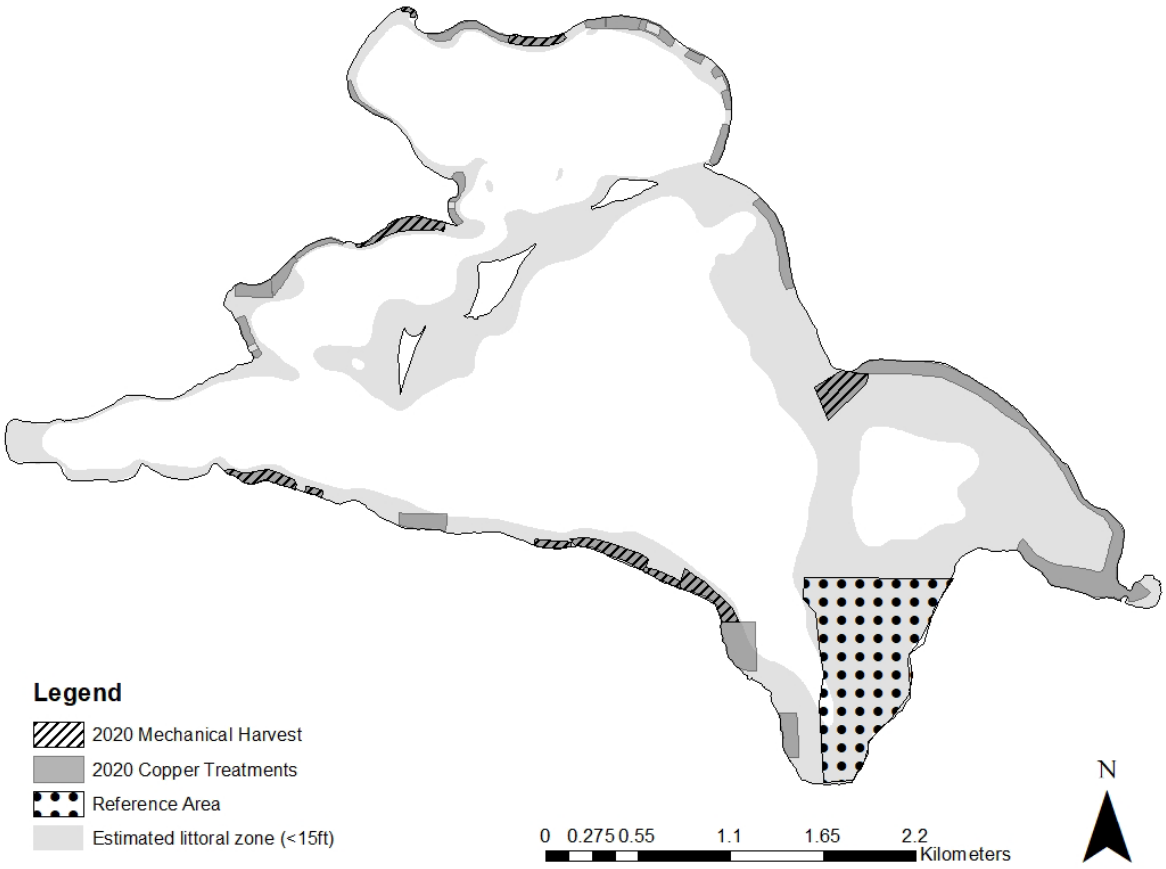
Within its original range in Europe and Asia, starry stonewort is most often found in clearer water lakes with low to moderate fertility. Its distribution within that region has been described as "rare" (Sleith et al. 2015). Much is unknown about how it may grow in North American lakes. Brainard and Schultz (2017) concluded that starry stonewort increased in four New York lakes to the detriment of native plants, but the study was limited to two field seasons.

In Minnesota, there are questions about where starry stonewort may spread and how it might impact the ecology and recreational use of lakes. These are difficult questions because many factors influence the types and amounts of plants in lakes. Growth of native and non-native plants can vary naturally within a lake, between lakes, and between years. Plant growth and abundance is influenced by removal of plant stands, which can change the water quality of the lake. Humans have managed aquatic plants in Lake Koronis for decades. In the last few years mechanical harvesting and herbicide applications have been used in an attempt to control starry stonewort (Table 1 and Figure 1). The surveys used in this report were intended to detect lake wide changes in plant communities; they were not designed to assess site level management activities. Details about the management activities that occurred in Lake Koronis are reported elsewhere (Jurek and Hauck Jacobs 2019).

Table 1. Invasive Plant Management Summary. Characteristics and history of herbicide treatments and mechanical treatments for starry stonewort in Lake Koronis, Stearns County.

Date	Copper Treated (acres)	Mechanical Harvested (acres)	Delineated Beds (acres)
2015	4	N/A	200
2016	18	18	353
2017	15	7	272
2018	224 (2x)	43	376
2019	109 (2x)	41	576
2020	172 (2x)	52	770

Figure 1. 2020 Locations of copper treatments, mechanical harvesting and reference plot *from Lake Koronis (DOW# 73020002), Stearns County, Minnesota.* Map created by AIS staff



Lake Koronis location and characteristics

Lake Koronis is located in north central Minnesota, about one mile south of Paynesville in Stearns County (Figure 2). It occurs in the Eastern Broadleaf Forest region of the state, which is characterized by deciduous forest, woodland and prairie with numerous glacial lakes. Koronis is a drainage lake that is part of a connected chain of lakes in the North Fork of the Crow River Watershed. The main inlet is the Crow River that flows from Rice Lake and Mud Lake into Koronis and then outlets the lake at the southern end and continues southeast to form the Crow River (Figure 2).

With a surface area of about 2,968 acres, Koronis is the 2nd largest lake in Stearns County and the 3rd largest lake in the watershed. The lake has an irregular outline with several islands and a total of 16 miles of shoreline (Figure 3). The shoreline is developed with residential homes, several public boat ramps and public parks.

Lake Koronis has a maximum depth of 132 feet. The lake is a hard water lake and is characterized as eutrophic, based on phosphorus (nutrients), chlorophyll-a (algae concentration) and Secchi depth (transparency) (RMB 2011). The 2019 mean summer water clarity was 6.5 feet which is 2.3 feet higher than the watershed mean (MPCA 2020).

Figure 2. Lake Koronis within the North Fork Crow River watershed

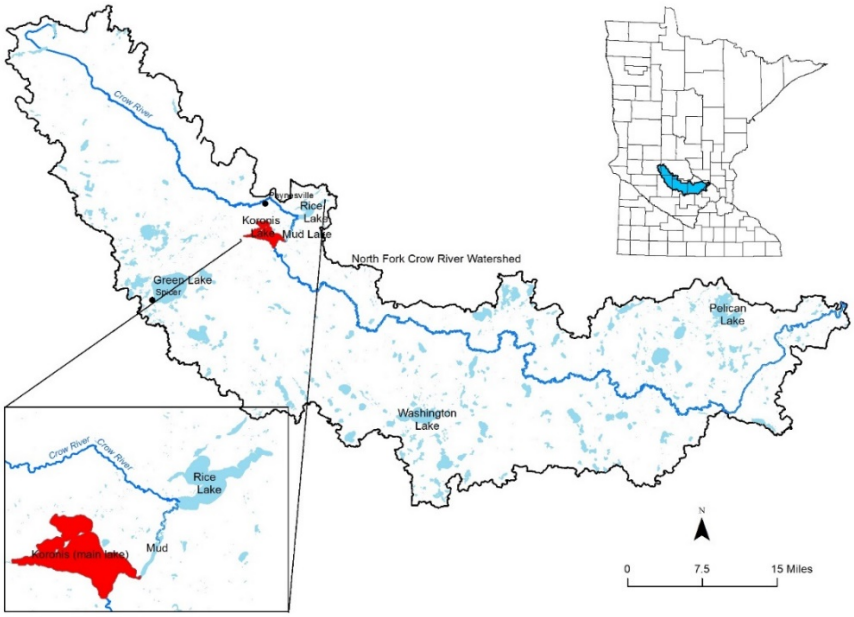
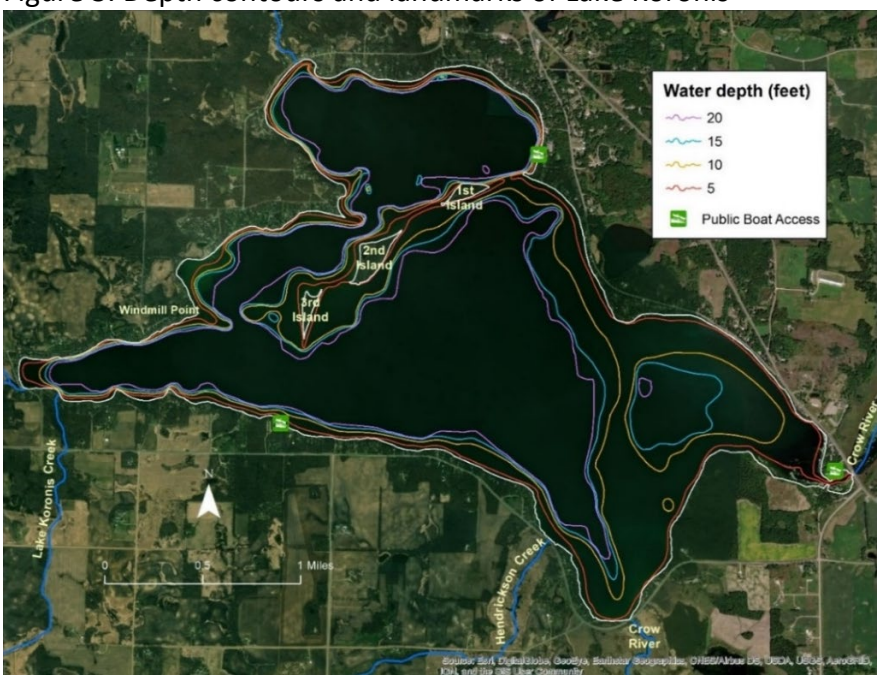


Figure 3. Depth contours and landmarks of Lake Koronis



Existing lake plant information for Lake Koronis

Between 1920 and 2013, eight aquatic plant surveys of Lake Koronis were conducted (MNDNR Fisheries Lake files, Austing 2013). These surveys varied in methods, but all included a list of plant species encountered (Table 2). A total of 26 species have previously been reported in Lake Koronis including emergent, floating-leaved and submerged plants. The number of species identified in any year was influenced by the survey method, the search effort and the botanical knowledge of individual surveyors. If a plant was not reported during a survey, it may have been present but not detected. We can use this long-term dataset to compare Koronis to other lakes in the region and to look at general trends in the plant community.

Water clarity greatly influences the depth at which aquatic plants can grow. In most Minnesota lakes, aquatic plants are restricted to depths of less than 30 feet with the shore to 15 feet depth zone typically considered the zone where light is most available and most plant growth occurs. Other environmental factors that may influence the depth of plant growth include substrate, slope, wind fetch and the types of plants present. About 40% of Lake Koronis is 15 feet or less in depth, creating a broad shallow zone for aquatic plants (Figure 3). Beyond the 15 feet depth the lake depth increases sharply to 30 feet, so even if there is sufficient light at these deeper depths, the available area is limited

In the 1920's, bulrush (*Schoenoplectus* sp.) was noted as a common emergent plant of Lake Koronis, but by the early 1990's, emergent vegetation was estimated to occur in less than one percent of the lake (MNDNR Lake Files). Bulrush stands were noted along the east shore near Hendrickson Creek inlet, in a bay northwest of Windmill Point, and along the west side of

Second Island. Other emergent plants were mostly found in protected bay areas. Wild rice (*Zizania palustris*) was reported as present, but not common, in 1947 and 1977. Similarly, white waterlily (*Nymphaea odorata*) and yellow waterlily (*Nuphar variegata*) have been reported as occurring in the lake, but with limited distribution.

Submerged plants have historically been common in Lake Koronis and a variety of species have been found. In most surveys, the macroalgae, muskgrass (*Chara* sp.) has been described as the most common submerged plant, occurring throughout the shallow zone. Macroalgae do not form true roots, stems or flowers, but because they resemble flowering plants in size and structure, they can provide similar habitat and ecological benefits to the lake. They help maintain water clarity by taking up nutrients and binding substrates, they provide habitat and cover for invertebrates and fish, and may be used as food by a variety of fish and wildlife. Muskgrass is typically found in hardwater lakes that have moderately high water clarity. This plant is often found entirely beneath the water surface where it may form dense “carpets” on the lake bottom. Muskgrass can withstand heavier wave action than taller plants, and is often the first plant to colonize open areas of lake bottom where it can act as a sediment stabilizer. Beds of muskgrass can help maintain higher water clarity and provide important fish spawning and nesting habitat (Crow and Hellquist, 2000; Borman et al., 2014).

A variety of other submerged plants have been reported including wild celery (*Vallisneria americana*), coontail (*Ceratophyllum demersum*), several species of pondweeds (*Potamogeton* spp. and *Stuckenia pectinata*), and northern watermilfoil (*Myriophyllum sibiricum*) (Table 2). These flowering plants vary in height, leaf shape, and density and create a diversity of habitats within the lake.

The historical plant information can be used to assess whether large changes in the plant communities can be detected. The surveys that were conducted in 2015 through 2020 provide a benchmark to monitor future changes. Specific objectives included:

1. Assess the lake-wide shore habitat.
2. Describe the types and general distribution of lake plants present today and compare with historical data.
3. Compare and contrast changes in lake-wide plant community composition and distribution from 2015 through 2020.
4. Collect and contrast nearshore plant communities where vegetation is most likely to impact recreational lake use.
5. Specifically evaluate how the non-native plant, starry stonewort has changed in distribution and occurrence since it was first detected in 2015.

METHODS

Shore habitat assessment (Score the Shore), 2017

The shoreline habitat of Lake Koronis was assessed July 26, 2017 using the "Score the Shore" method (Perleberg et al. 2019). Survey sites were established every 400 meters along the shoreline for a total of 64 sites (Knopik et al. 2019); each individual site extended 100 feet along shore. Surveys were conducted by boat and surveyors visually assessed habitat features in the Shoreland, Shoreline and Aquatic zones including tree cover, shrub cover, natural ground cover, overhanging vegetation, and woody habitat. Sites with a high percent of tree, shrub and natural ground cover and with little or no human disturbance were scored higher than sites where vegetation had been removed.

Mapping of emergent and floating-leaf plant stands, 1968 and 2015

The hand-drawn map of emergent plant stands from 1968 were georectified and the approximate acreage of each stand was calculated.

In August, 2015, surveyors used GPS to map and classify the remaining stands of emergent and floating-leaf plant stands (Perleberg et al. 2019, Knopik et al. 2019). Locations of plant stands mapped in 2015 were compared to stands mapped in 1968.

Lake-wide plant community assessments (point-intercept surveys), 2015-2020

Lake wide quantitative assessments of aquatic plants were conducted annually from 2015 through 2020 using a point-intercept survey method (Madsen 1999, Perleberg et al. 2019). Ideally, Minnesota lake plant surveys should be conducted in July or August when most plants are mature and have reached their annual maximum distribution in the lake. Because starry stonewort was not detected until late August 2015, the 2015 survey was delayed until late September. The survey was repeated in late August 2016, July 2017, July 2018, July 2019, and July 2020.

Surveyors used an existing depth contour map to establish georeferenced sample sites in a grid pattern within the littoral zone (Knopik et al. 2019). Sites were spaced 130 meters apart, which resulted in a total of 340 sites within the shore to 20 feet depth zone (Figure 4). In 2015 and 2016, surveyors sampled all sites within the 0 to 20 foot depth zone and some sites in deeper water. In July 2017, 2018, 2019, and 2020 surveyors extended sampling to include all sites in the 21 to 25 feet zone. Survey effort within each depth zone in each year is provided (Figure 5).

At each site, surveyors recorded water depth and in 2020 surveyors also described the substrate in depths less than 8 feet. Surveyors used a double-headed, weighted garden rake to sample vegetation and recorded all plant taxa found at each sample site. Any additional plant taxa found outside of sample sites were recorded as "present" in the lake, but these data were not used in frequency of occurrence calculations. Plant identification followed Crow and Hellquist (2000) and Flora of North America (1993+) and nomenclature followed MNTaxa (2017).

Frequency of occurrence (percent of sample sites where vegetation was detected) was calculated for the entire vegetated zone (0-20 feet) and data were also separated into five feet increment depth zones for analysis. Frequency estimates were also calculated for individual taxa and selected groups of plants. Confidence intervals (p=.95) were calculated for each estimate of frequency. The confidence intervals (p=.95) were calculated using the high-low charts in Microsoft Excel.

Nearshore plant community assessments (plot surveys), 2017, 2018, 2019, 2020

The point-intercept method may under sample the near-shore plant zone by only surveying 1 meter points, additional surveys were conducted in 2017, 2018, 2019, and 2020 at the shore-water interface (Perleberg et al. 2019). Shoreline vegetation plots were spaced 400 meters apart along the shoreline for a total of 63 sites (Figure 4). Plot area measured approximately 5 meters along the shore and extended 5 meters lakeward. At each site, surveyors recorded all plant taxa observed, mean water depth, and substrate type. Frequency estimates were also calculated for individual taxa and selected groups of plants. Confidence intervals (p=.95) were calculated for each estimate of frequency.

Hydroacoustic surveys, 2017, 2018, 2019

The hydroacoustic survey is designed to assess the distribution of submerged vegetation on a lake-wide or bay-wide scale. A sound signal is emitted from a submerged transducer mounted on a boat and the timing and strength of the signal return can be used to map aquatic plant stands. This survey is designed to, rapidly assess changes in frequency of occurrence and plant height statistics by depth strata. The main metric assessed is “biovolume” which can be generally defined as the percent of the water column occupied by vegetation (Valley and Drake 2007).

Hydroacoustic surveys were completed on 7/12/2017, 7/16/2018, and 7/25/2019 consistent with protocol (Perleberg et al. 2019). Surveys consisted of 26 transects following the point-intercept north-south sampling lines, and the same transects were used for each survey (Figure 4). The 2017 survey produced 30,035 1-second interval records, the 2018 survey produced 32,403 records and the 2019 survey produced 28,150 records. Mean biovolume and plant height per depth strata were computed for each survey, as well as the frequency of plant occurrence by depth for each survey.

Figure 4. Vegetation survey sites, 2015 to 2020.

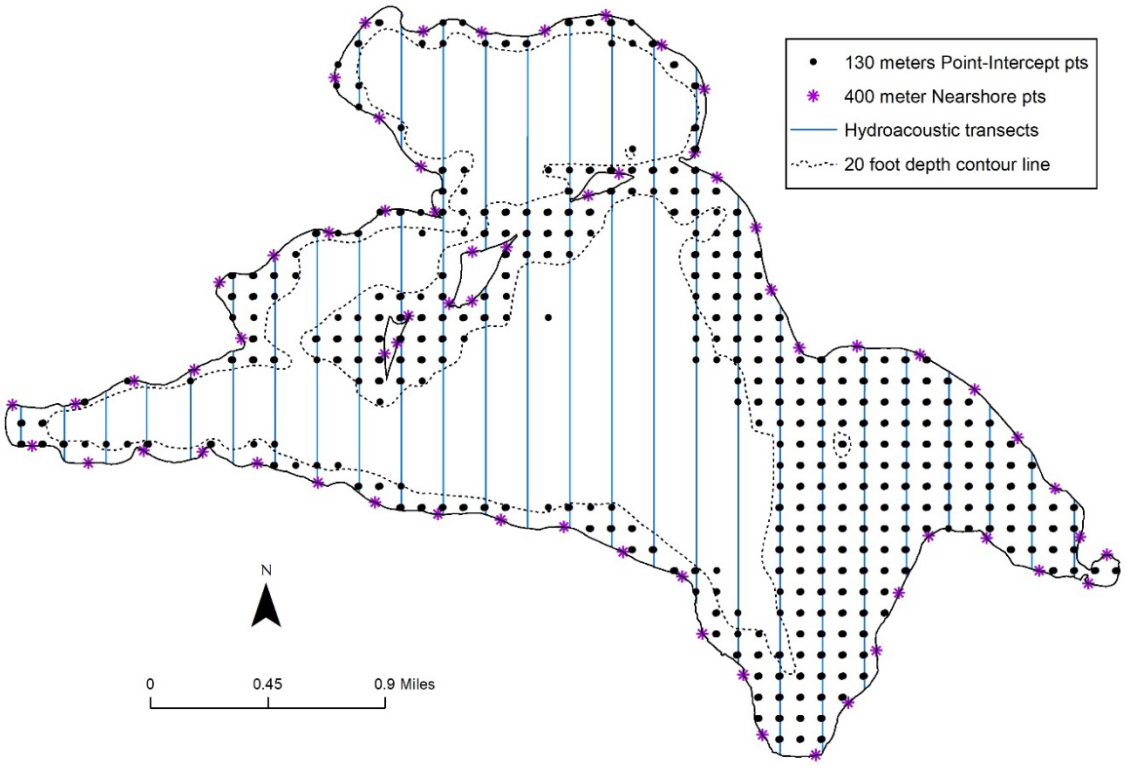
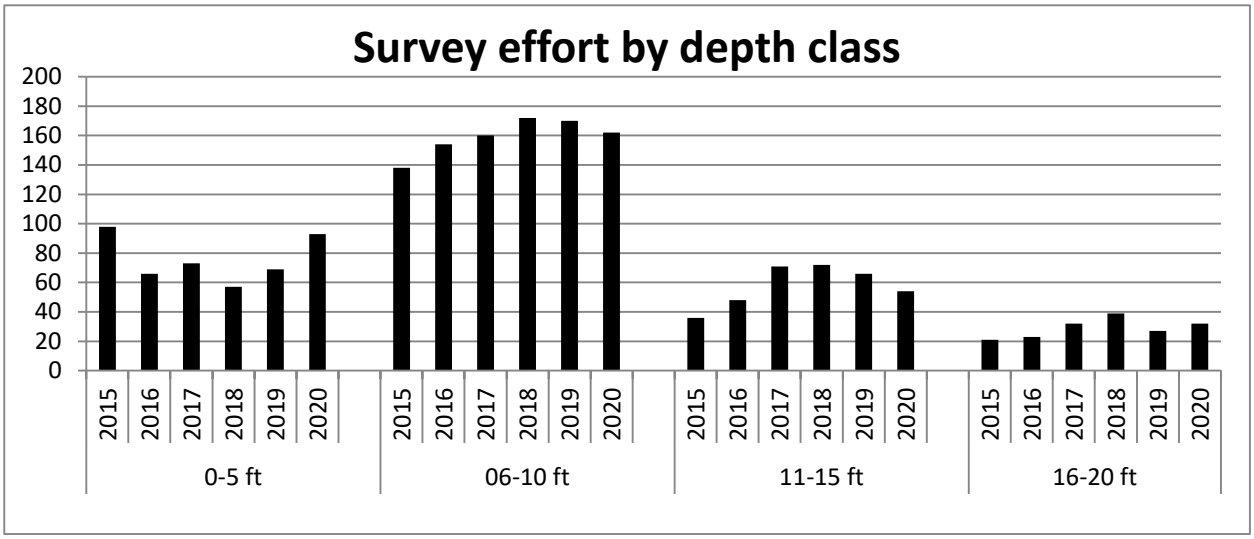


Figure 5. Point intercept survey effort (sample number) by water depth in each year.

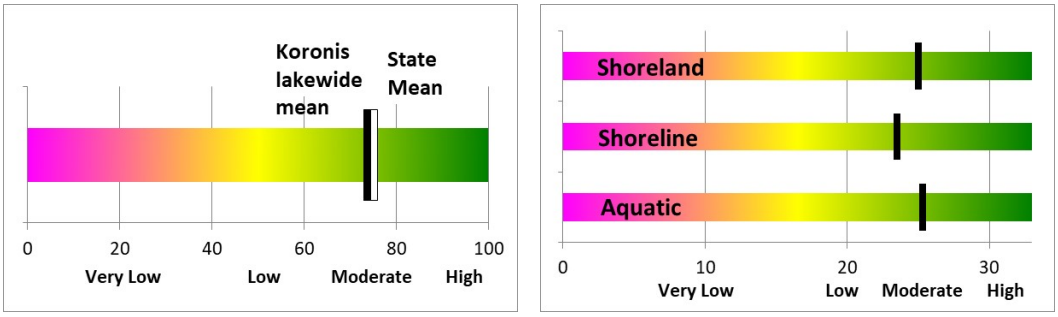


RESULTS

Shore habitat (Score the Shore)

Lake Koronis shore habitat scored 73.7 out of a possible 100 points. This rating is near the statewide mean of 74.4, which was obtained from about 600 lake surveys across the state (Figure 6). On Lake Koronis, 80% of surveyed sites had some level of development. Residential homes were the most common type of development and most sites included more than one home. Other development included a resort, a commercial building, roadway, a public park and a campsite. Developed sites scored lower (mean of 67.5 points) than undeveloped sites (mean of 97.9 points). Habitat removal has occurred in Shoreland, Shoreline and Aquatic Zones with the Shoreline Zone receiving the lowest score.

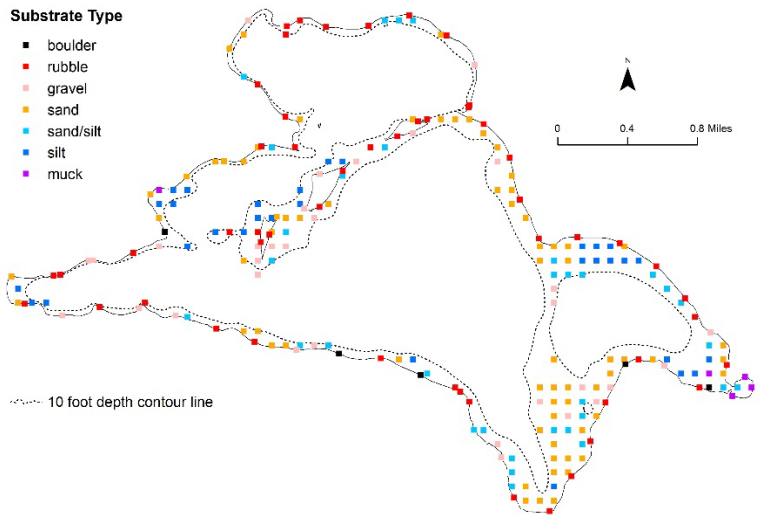
Figure 6. Score the shore lake-wide mean vs state mean.



Substrates

Shallow lake bottom sites observed in 2020 were mainly hard substrates (sand, rubble and boulder) in the main lake and as softer substrates (muck, and silt) in the bays and between the islands (Figure 7).

Figure 7. Nearshore substrates of Lake Koronis, 2020.



Plant types present

Between 2015 and 2020, a total of 30 aquatic plant taxa (types) were recorded in Lake Koronis and included four emergent, three floating-leaved, four free-floating and 19 submerged plants (Table 2). This brings the total taxa ever recorded in the lake to 36. Thirteen species were detected for the first time between 2015 and 2020: two emergent plants, common reed (*Phragmites australis*) and arrowhead (*Sagittaria* sp.), 9 submerged plants: starry stonewort, 2 species of muskgrass (*Chara contraria* and *C. globularis*), native stonewort (*Nitella* sp.), southern naiad (*Najas guadalupensis*), horned pondweed (*Zannichellia palustris*), Fries pondweed (*Potamogeton friesii*), Robbin's pondweed (*Potamogeton robbinsii*), white water buttercup (*Ranunculus aquatilus*); and one free-floating plant: watermeal (*Wolfia* sp.). These 13 species might have historically been present in Lake Koronis but may have been undetected in previous surveys. Six species were detected in earlier surveys but were not found during the 2015 through 2020 surveys; these included three emergent plants: wild rice (*Zizania palustris*), giant burreed (*Sparganium eurycarpum*), and three square bulrush (*Schoenoplectus pungens*), and two submerged plants: large-leaf pondweed (*Potamogeton amplifolius*), and watermoss (not identified to genus).

Plant distribution

Emergent and floating-leaf plant stands

Emergent plant stands mapped in 1968 cover an estimated area of 43 acres and the dominant plant was bulrush (Figure 8). No floating-leaf plant stands were indicated on the 1968 map.

In 2015, only three acres of emergent and six acres of floating-leaf plants were located (Figure 9); this represents a potential total loss of 79% of the nearshore plants that were mapped in 1968. Plant stands remaining in 2015 included cattails, bulrush, white waterlily, yellow waterlily, and floating-leaf pondweed (*Potamogeton natans*). The emergent and floating-leaf plant stands were primarily found adjacent to undeveloped shores. Areas where emergent plant stands were found in 1968 but not in 2015 include the small west bay, the southwest shoreline and the southeast shoreline.

Submerged plant distribution and frequency of occurrence

Lake-wide distribution of submerged plants was similar in all six survey years (2015 to 2020) and the 2020 distribution is shown in Figure 9. The broadest zones of submerged plants occurred on the east side of the lake and around the islands where shallow water extends lakeward for hundreds of meters. Between 2015 and 2020, the maximum depth where vegetation was detected was 19 feet. Within the 0 to 20 foot depth zone vegetation was detected in at least 70% of the sites in each year and there was no significantly detectable change between years (Figure 10).

Figure 8. Change in emergent and floating-leaf plant stands from 1968 to 2015

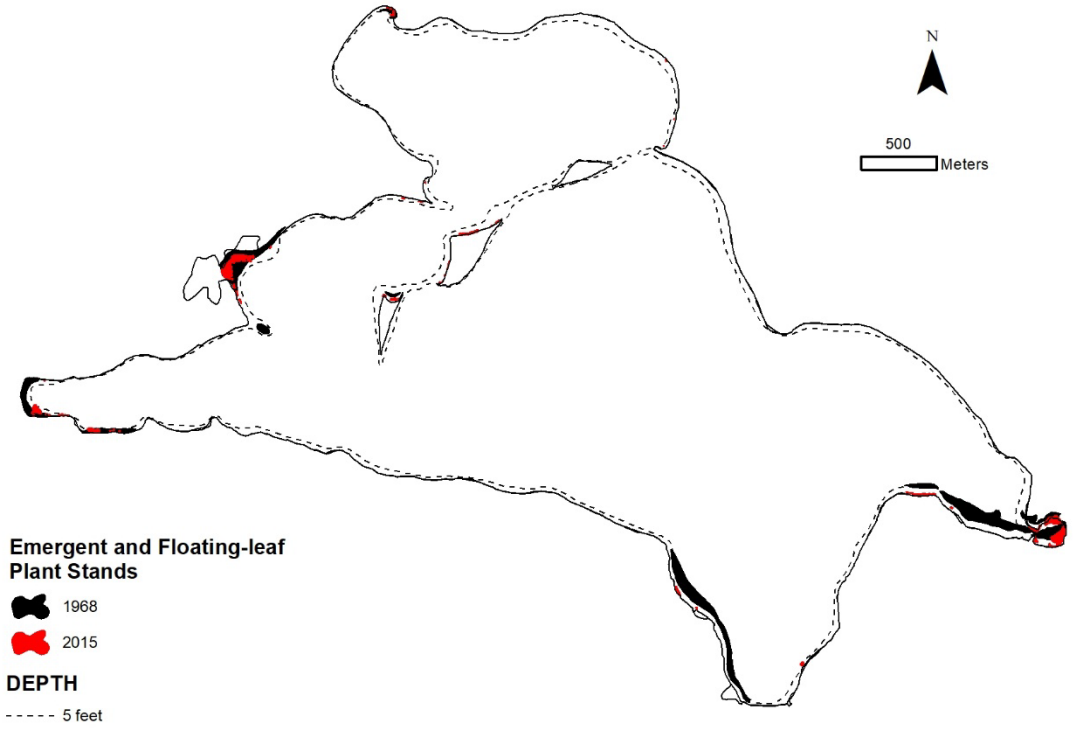


Figure 9. Lake-wide plant distribution.

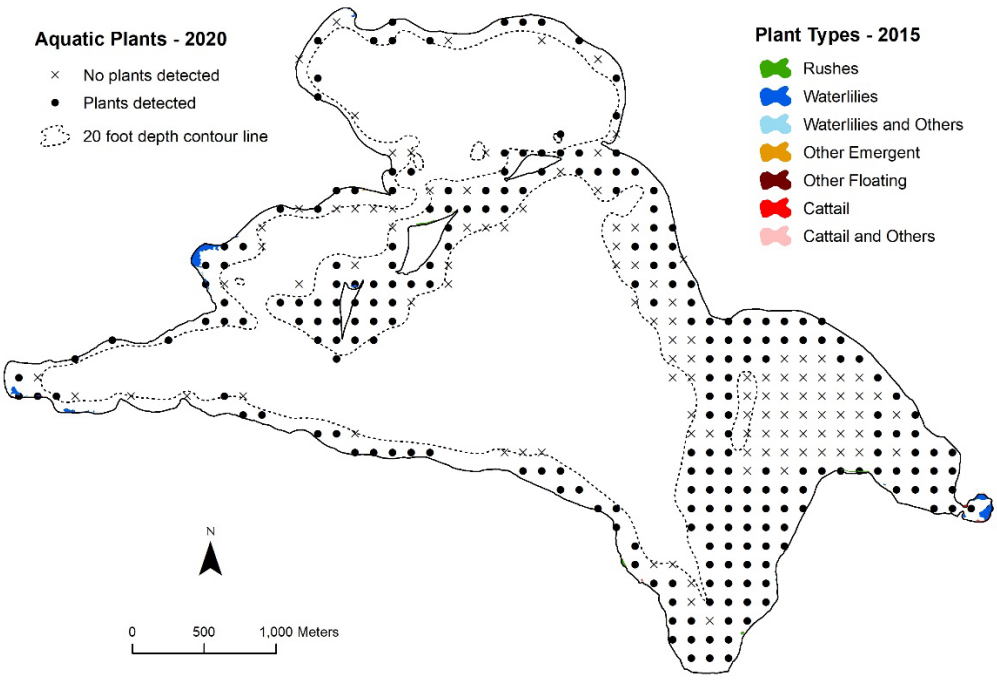
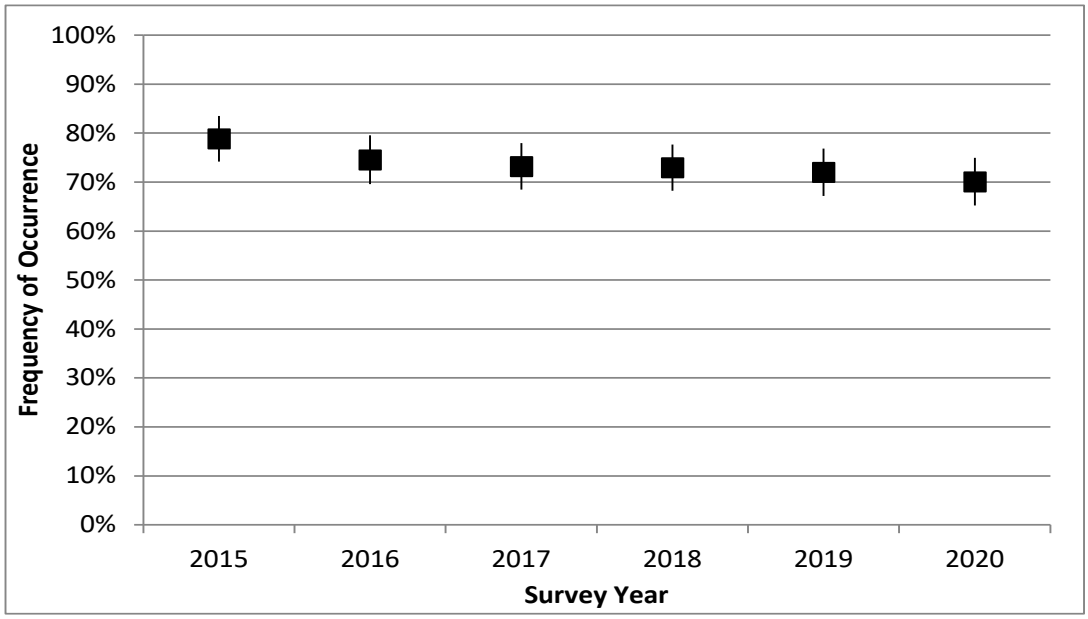


Figure 10. Frequency of vegetation detection in 0-20 feet zone of Koronis, 2015 to 2020.

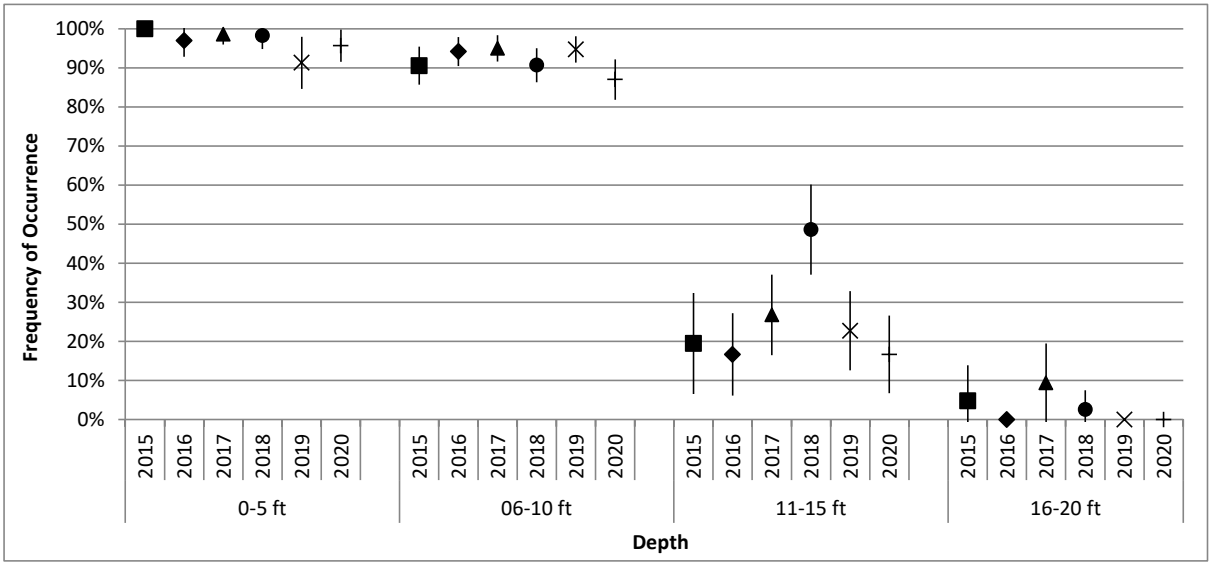
2015 (n=291), 2016 (n=288), 2017 (n=336), 2018 (n=340), 2019 (n=332), 2020 (n=341). (Vertical bars represent 95% confidence limits for frequency estimates)



Detection of plants declined with increasing water depth (Figure 11). In all five survey years, vegetation was most frequent in the shore to 10 feet depth zone, where at least 90% of sites contained plants. Within the 11-15 feet zone, plants were found in less than 50% of the sites annually; and in depths of 16-20 feet, plant detection was less than 10%.

Figure 11.Frequency of vegetation detected by depth zone of Koronis, 2015 to 2020.

(Vertical bars represent 95% confidence limits for frequency estimates)



Commonly occurring submerged plant taxa

Submerged plants that occurred frequently (with a mean frequency of at least 10% in at least one survey year) included muskgrass (*Chara* sp.), starry stonewort, narrow-leaf pondweed (*Potamogeton* spp.), coontail (*Ceratophyllum demersum*), sago pondweed (*Stuckenia pectinata*), wild celery (*Vallisneria americana*), and northern watermilfoil (*Myriophyllum sibiricum*). The frequency of each plant taxa varied between years (Table 2, Figure 12).

Muskgrass was the most frequently detected submerged plant in 2015, 2016 and 2017.It was widely distributed in the lake (Figure 13) and within the vegetated zone (0-20 feet) it was detected in at least 50% of the sites in each year of the first three survey years (Table 2). In 2018, 2019, and 2020 its frequency declined to less than 40% (Table 2) but it remained widespread in distribution.

Starry stonewort was detected in each survey year and showed an increasing trend across the survey period. In 2015 it was already distributed around the entire lake but occurred in only 17% of the sites with a concentration in the eastern bay. By 2020 it was detected in 44% of the sites and was found more evenly distributed around the entire lake (Figure 14).

Of the other commonly occurring taxa, wild celery and northern watermilfoil decreased in frequency in 2017, 2018, 2019 and 2020. Other taxa varied in frequencies between survey years but a trending pattern was not detected (Figure 12).

Figure 12. Occurrence of common submerged plants in 0-20 feet zone, 2015 to 2020.
(Vertical lines represent 95% confidence interval for frequency estimates)

Figure 13. Muskgrass (*Chara* sp.) distribution in Lake Koronis from 2015 to 2020.

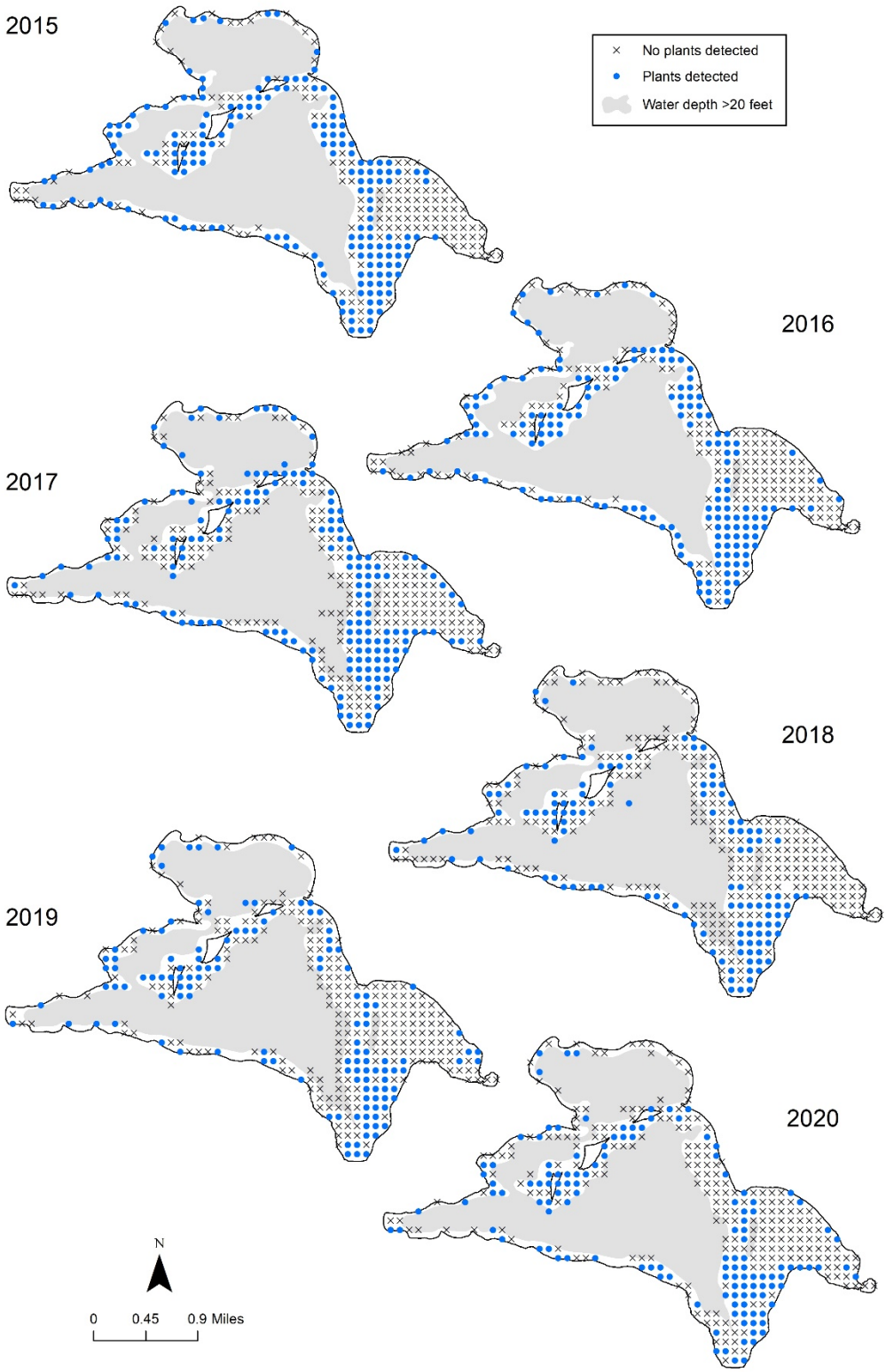
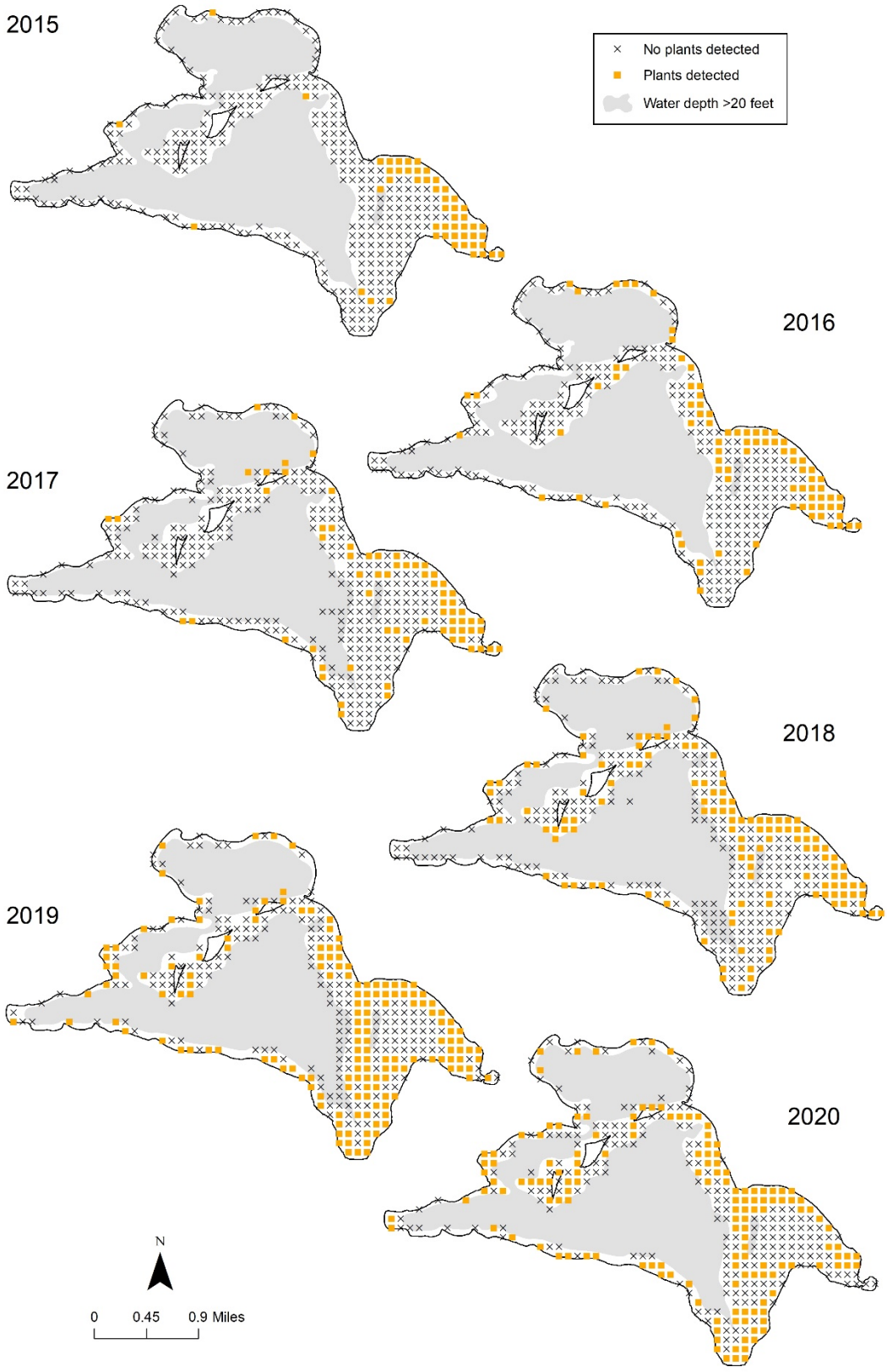


Figure 14. Starry Stonewort distribution in Lake Koronis from 2015 to 2020.



Both macroalgae, muskgrass and starry stonewort, were most frequent in the shore to 10 foot depth (Figure 15, 16). In all years, at most sites where starry stonewort was detected, it often co-occurred with other plants (Figure 17).

Nearshore Survey Plot

The mean depth of the 2017, 2018, 2019 and 2020 nearshore vegetation plots was 2 feet. Plants were detected in more than 95% of the plots in all years. This shallow zone is an area of high plant diversity with a total of 27 taxa identified. Annually, the mean number of submerged taxa per plot ranged from 4 to 6. Nine taxa were commonly found, occurring in at least 25% of the plots in at least one year: starry stonewort, muskgrass, narrowleaf pondweeds (*Potamogeton* spp.), bushy pondweed (*Najas* spp.), sago pondweed, wild celery, water stargrass, horned pondweed and coontail.

Starry stonewort was detected in less than 15% of the plots in 2017 and 2018 but increased to 44% in 2020. In all years, it was found in plots along the eastern, southern and western shores (Figure 18). In nearshore plots, where starry stonewort was detected, native species were also present.

Muskgrass remained the most frequently encountered plant in nearshore plots each year, but changed significantly between years. From 2017 to 2018, it declined from 90% to 52% but then increased to 75% in 2020. A similar pattern of decline followed by increase occurred with curly-leaf pondweed (Table 3). Other species showed a decreasing trend or no discernable pattern in frequency of occurrence between survey years.

Figure 15. Occurrence of muskgrass by depth zone, 2015 to 2020.
(Vertical lines indicate 95% confidence interval for frequency estimates)

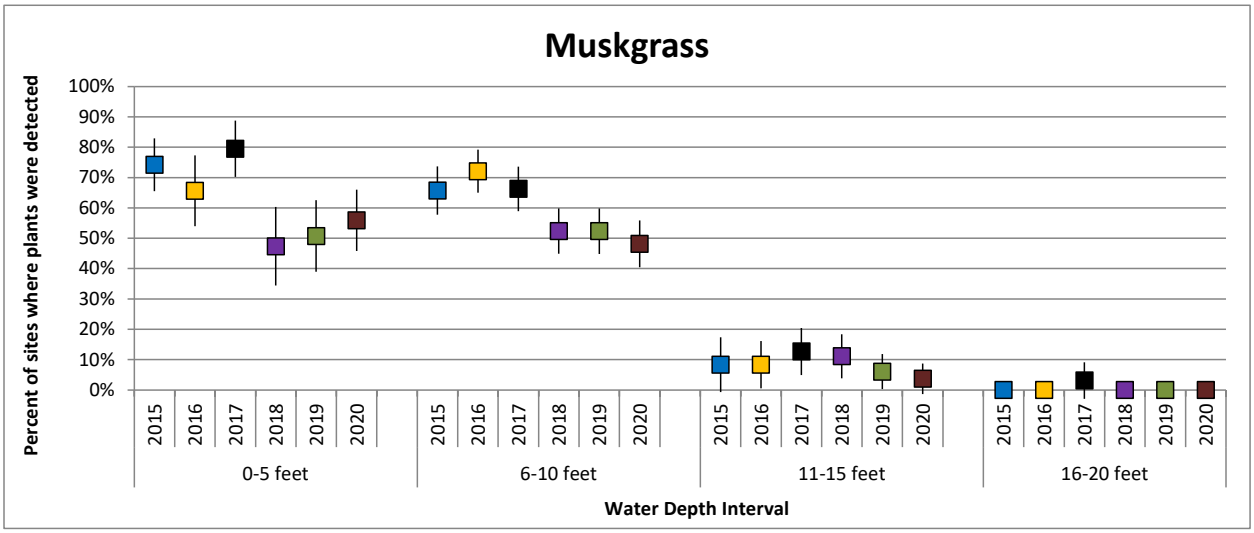


Figure 16. Occurrence of starry stonewort, 2015 to 2020.
(Vertical lines indicate 95% confidence interval for frequency estimate)

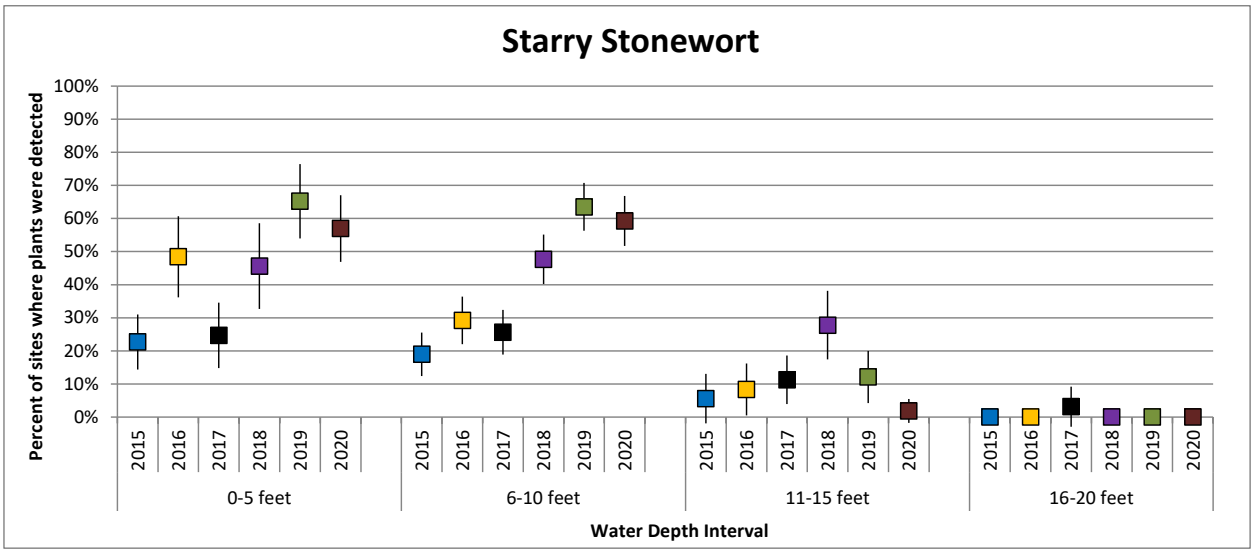


Figure 17. Aquatic vegetation present at sample sites, Lake Koronis, 2015 to 2020.

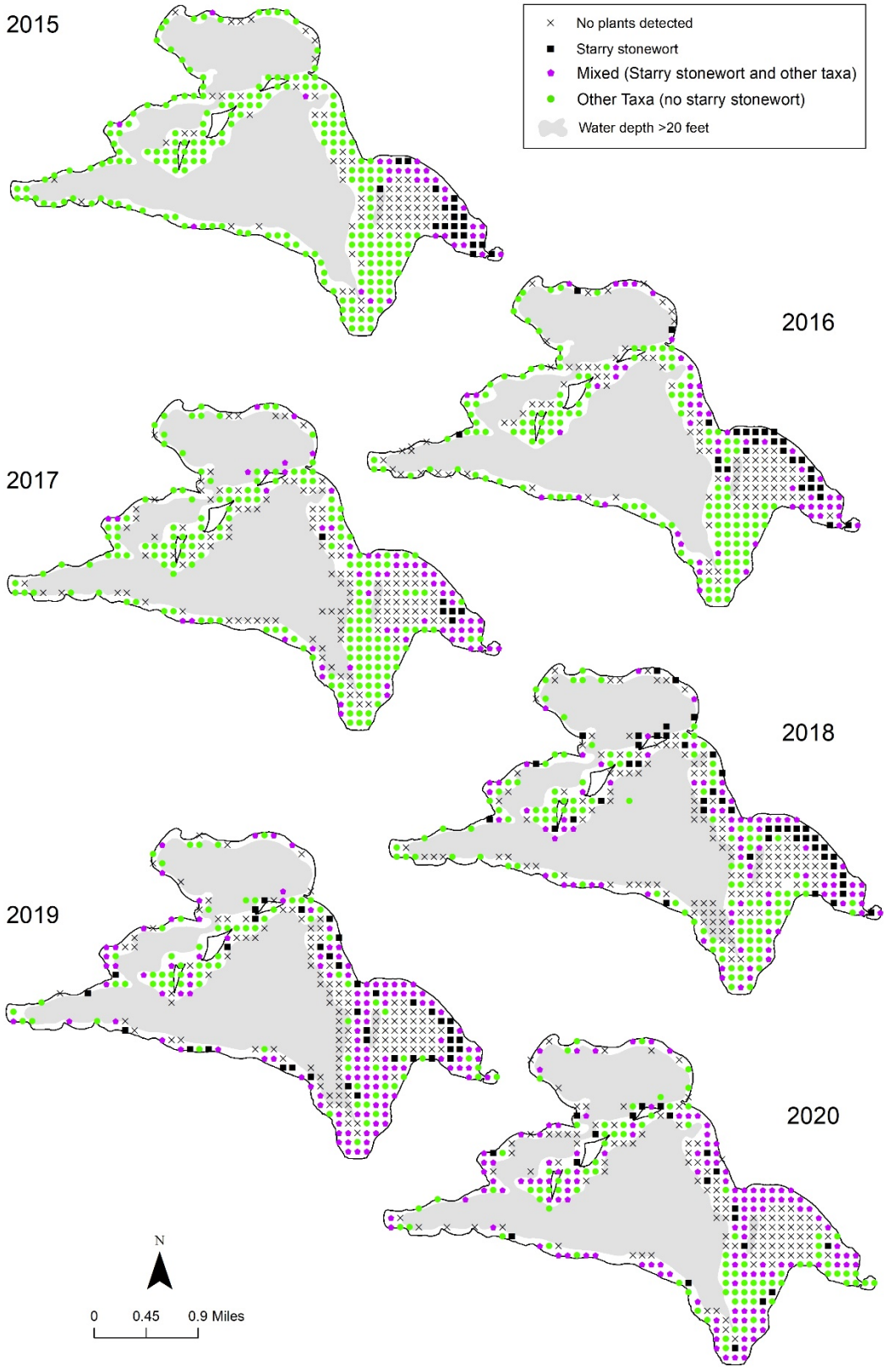
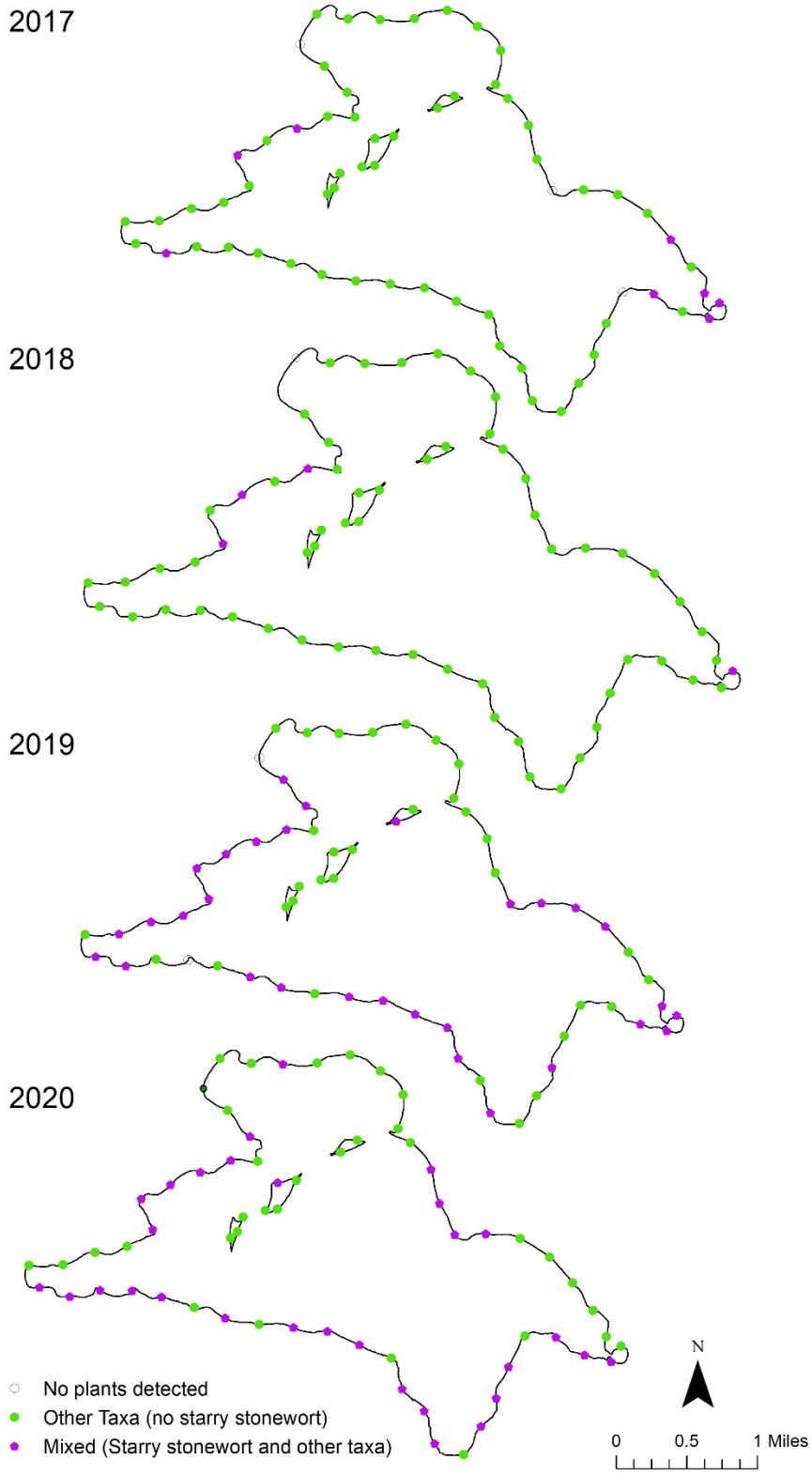


Figure 18. Nearshore aquatic vegetation distribution, Lake Koronis, 2017, 2018, 2019, 2020.



Hydroacoustic Surveys

The mean plant height varied by depth strata and year (Figure 19). The mean biovolume (percentage of the water column occupied by vegetation) was highest in shallow water zone; whereas, at water depth strata greater than 10 feet the mean biovolumes were less than 10% (Figure 20). The frequency of plant detections was highest in 2018 for depths 9 to 14 feet compared to 2017 and 2019 (Figure 21).

Figure 19. Mean plant height by depth zone, 2017, 2018 & 2019.

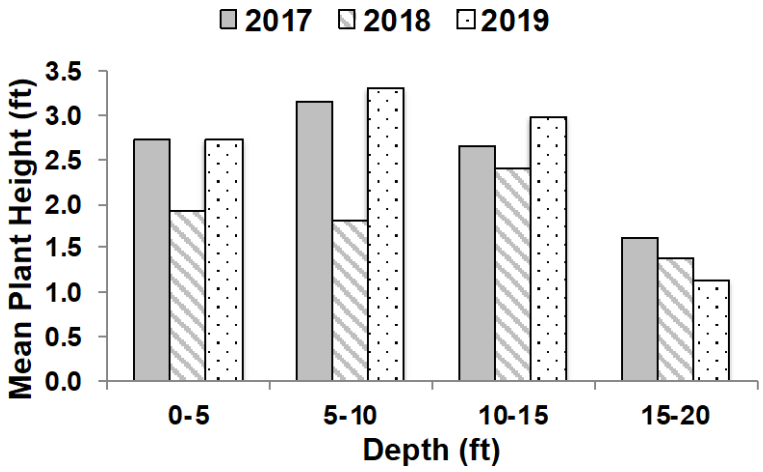


Figure 20. Mean biovolume (frequency) by depth zone, 2017, 2018 & 2019.

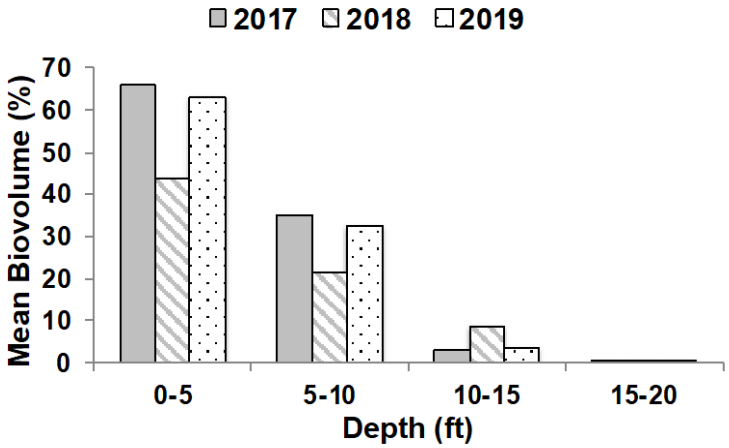
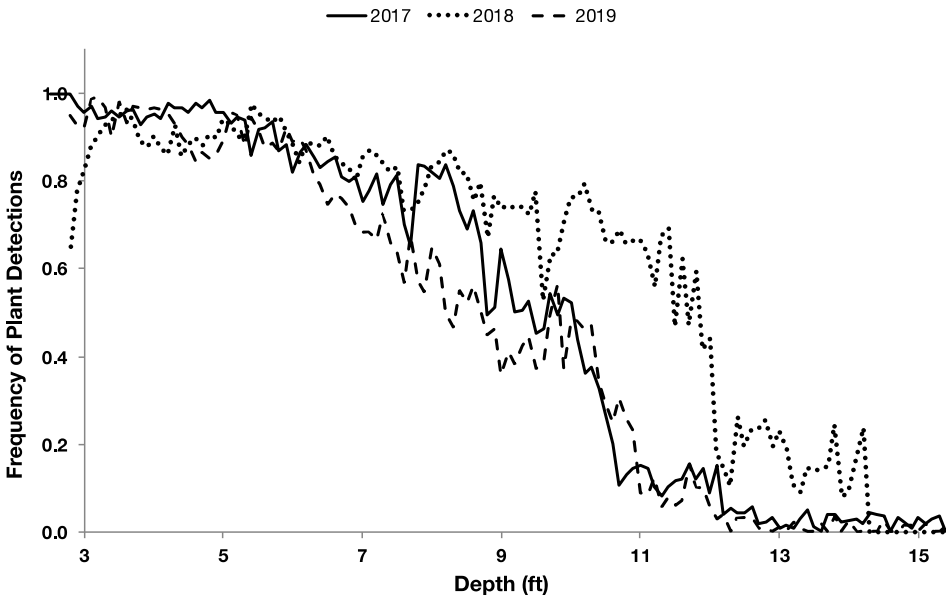


Figure 21. Frequency of plant detection by depth, 2017, 2018 & 2019.



DISCUSSION AND RECOMMENDATIONS

Historically, Lake Koronis has had a robust and diverse aquatic plant community, but development has significantly reduced emergent and floating-leaf plants. Because multiple factors may change (water clarity may decline and a new species may be introduced), it may not be possible to determine the specific cause of the changes.

Today, Lake Koronis supports a moderately diverse submerged plant community that would be expected in a central Minnesota hardwater lake. The different heights and leaf types create a diversity of habitat that are used by fish and other aquatic life. Extensive mat forming plants, like muskgrass, are particularly important in stabilizing sediments and maintaining water clarity. The variety of other submerged plants provides additional habitat structure and diversity.

The data available from 2015 through 2020 indicate several trends in the submerged plant community. Muskgrass and some other native submerged plants appears to be declining, particularly in shallow water, while starry stonewort is increasing in lake-wide distribution and frequency.

Shoreline development of Lake Koronis has resulted in losses to the shoreland and nearshore habitat. As much as 79 percent of the emergent and floating-leaf plant stands that were present in 1968 have been lost. Nearshore vegetation provides critical ecological services including shoreline stabilization, erosion control, shade and cover for wildlife, nutrient uptake, and nesting and feeding habitat. Increasing the amount of these important plants, through habitat restoration, would greatly benefit the lake. The Score the Shore survey and lake-wide emergent and floating-leaf plant stand mapping survey may be repeated to monitor the success

of restoration efforts. We recommend shoreline residents consider restoring portions of their shoreline to vegetation. Creating a “no-mow” strip along the shoreline frontage is a cheap and easy way to begin habitat restoration. DNR also has a simple scoring tool that individual homeowners can use to privately score the habitat along their shoreline.

This shallow zone is the area most impacted by human activity. Management activities aimed at controlling starry stonewort are not selective and have the potential to also negatively impact native species. This is particularly a concern in Lake Koronis because starry stonewort grows in the same depths as other plants and often co-occurs with them, Mechanical harvesting will impact any vegetation within the path of the harvester. Muskgrass may be particularly susceptible to pesticide applications because it is closely related to starry stonewort and often co-occurs with the plant. We recommend continued annual monitoring of these sites as an additional way to track change in the lake. Additional targeted studies are required to evaluate impacts of plant management activities.

LITERATURE CITED

Austing, B. 2013. Aquatic vegetation of Lake Koronis, Stearns County, Minnesota. Unpublished report on July 2013 plant survey. Submitted to Lake Koronis Association.

Borman, S., R. Korth, and J. Temte. 2014. Through the looking glass…A field guide to aquatic plants; second edition. Wisconsin Lakes Partnership, UWEX-CNR, UWSP, Stevens Point, WI 54481. 256 pp.

Brainard, A. and K. L. Schultz. 2017. Impacts of the cryptic macroalgal invader, *Nitellopsis obtusa*, on macrophyte communities. The Society for Freshwater Science. 36(1):55-62

Crow, G.E. and C.B. Hellquist. 2000. Aquatic and wetland plants of Northeastern North America. 2 volumes. The University of Wisconsin Press.

Flora of North America Editorial Committee, eds. 1993+. Flora of North America north of Mexico. 12+ vols. New York and Oxford. Flora of North America

Jurek C. and E. Hauck Jacobs. 2019. Lake Koronis, Stearns County: 2019 MN DNR Aquatic Vegetation Report. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, Invasive Species Program, 1035 South Benton Drive, Sauk Rapids, MN 56379. 41 pp.

Knopik, J., S. Simon, P. Radomski. 2019. GIS Manual for Minnesota Lake Plant Surveys, for use by MNDNR Fisheries Section and EWR Lake Ecology Unit. Minnesota Department of Natural Resources. Ecological and Water Resources Division. Brainerd, MN. 138 pp.

Madsen, J. D. 1999. Point intercept and line intercept methods for aquatic plant management. *APCRP Technical Notes Collection* (TN APCRP-M1-02). U.S. Army Engineer Research and Development Center, Vicksburg, MS. Point intercept and line intercept survey methods

MNDNR Fisheries Lake Files. Minnesota Department of Natural Resources. Division of Fish and Wildlife, Section of Fisheries, Lake Survey Program. 500 Lafayette Rd., St. Paul, MN 55155.

MNTaxa. 2017. Minnesota State checklist of vascular plants. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, St. Paul. Updated May 2013. Available on Internet: MNTaxa

MPCA. 2020. Minnesota Pollution Control Agency. St. Paul, MN. Lake Water Quality Assessment Program. Lake Water Quality Data Search website: MNPCA

Perleberg, D., P. Radomski, S. Simon, K. Carlson, C. Millaway, J. Knopik, and B. Holbrook. 2019. Minnesota Lake Plant Survey Manual, version 3, for use by Fisheries Section, EWR Lake Ecology Unit, and EWR Minnesota Biological Survey Unit. Minnesota Department of Natural Resources. Ecological and Water Resources Division. Brainerd, MN. 150 pages including Appendices A-D.

RMB Environmental Laboratories. 2011. Lake Koronis, 73020000, Stearns County, Lake Water Quality. 21 pp.

Sleith, R., A. J. Havens, R. A. Stewart, K. G. Karol. 2015. Distribution of *Nitellopsis obtusa* (Characeae) in New York, U.S.A. Brittonia 67(2):166-172.

Valley, R. D., and M. T. Drake, 2007. What does resiliency of a clear-water state in lakes mean for the spatial heterogeneity of macrophytes? Aquatic Botany 87: 307–319.

TABLE 2. HISTORICAL AND CURRENT PLANTS OF LAKE KORONIS

Note: For surveys conducted between 1920 and 2015, an "X" indicates surveyors detected the species. Additional comments on the general abundance of the species may be included in the original survey notes.

For the 2015, 2016, 2017, 2018, 2019, 2020 point intercept surveys, the number listed after each species is the percent of sample sites (0-20 feet) in which the species was detected. A point intercept survey was conducted by a private consultant in 2013 but because the original raw data were not available, we did not include the frequency values here.

Emergent plants (0–20 feet)

Common Name	Scientific Name	1920	1947	1950	1972	1977	1987	1990	1991	1992	1997	1999	2007	2013	2015 N= 291	2016 N= 288	2017 N= 336	2018 N= 340	2019 N= 332	2020 N= 341
Common reedgrass	*Phragmites australis*								X						P					
Broadleaf arrowhead	*Sagittaria latifolia*		X			X														
Arrowhead	*Sagittaria* sp.					X		X	X	X					P					
Bulrush	*Schoenoplectus* sp.	X	X			X	X	X	X	X	X		X		P				1	<1
Three-square bulrush	*Schoenoplectus pungens*						X			X										
Giant burreed	*Sparganium eurycarpum*		X																	
Cattail	*Typha* sp.		X			X	X	X	X	X					P	P	P	P		P
Wild rice	*Zizania palustris*		X			X														
Total		1	5	0	0	5	3	3	4	4	1	0	1	0	4	1	1	1	1	1

TABLE 2: HISTORICAL AND CURRENT PLANTS OF LAKE KORONIS (CONTINUED).

Floating-leaved plants (0-20 feet)

Common Name	Scientific Name	1920	1947	1950	1972	1977	1987	1990	1991	1992	1997	1999	2007	2013	2015 N= 291	2016 N= 288	2017 N= 336	2018 N= 340	2019 N= 332	2020 N= 341
White waterlily	*Nymphaea odorata*		X			X	X	X	X	X	X	X	X	X	1	1		1	1	1
Yellow waterlily	*Nuphar variegata*		X			X	X	X	X	X	X	X	X		<1	1	1	1	3	1
Floating-leaf pondweed	*Potamogeton natans*	X	X			X					X				<1					
Total		1	3	0	0	3	2	2	2	2	3	2	2	1	3	2	1	2	2	2

Free-floating (0-20 feet)

Common Name	Scientific Name	1920	1947	1950	1972	1977	1987	1990	1991	1992	1997	1999	2007	2013	2015 N= 291	2016 N= 288	2017 N= 336	2018 N= 340	2019 N= 332	2020 N= 341
Lesser duckweed	*Lemna* sp.		X				X	X	X	X								1	5	1
Star duckweed	*Lemna trisulca*		X															P		
Greater duckweed	*Spirodela polyhriza*		X															P	2	1
Watermeal	*Wolffia* sp.																	P	1	
Total		0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	2

TABLE 2: HISTORICAL AND CURRENT PLANTS OF LAKE KORONIS (CONTINUED)

Submerged plants (0-20 feet)

Common Name	Scientific Name	1920	1947	1950	1972	1977	1987	1990	1991	1992	1997	1999	2007	2013	2015 N= 291	2016 N= 288	2017 N= 336	2018 N= 340	2019 N= 332	2020 N= 341
Native characeae	*Chara/Nitella* spp.[a]	X				X		X	X	X	X	X	X	X	57	55	52	37	39	39
Starry Stonewort (I)	*Nitellopsis obtusa*														17	28	20	38	48	44
Wild celery	*Vallisneria americana*	X		X	X	X	X	X	X	X	X	X	X	X	17	15	6	5	3	4
Sago pondweed	*Stuckenia pectinata*	X	X				X	X	X	X	X	X	X	X	13	9	26	3	20	25
Narrow-leaf pondweeds	*Potamogeton* spp.[c]		X		X		X	X	X		X	X	X	X	3	<1	32	19	14	16
Coontail	*Ceratophyllum demersum*		X	X	X	X	X	X	X	X	X	X	X	X	12	14	7	18	13	10
Northern watermilfoil	*Myriophyllum sibiricum*			X	X	X	X	X	X	X	X	X	X	X	13	4	<1	1	1	1
Bushy pondweeds	*Najas* spp.[b]	X				X		X	X	X	X	X	X		4	2	2	2	<1	3
Water star-grass	*Heteranthera dubia*				X		X								<1		<1	<1	<1	<1
Horned pondweed	*Zannichellia palustris*																3	1	1	3
Clasping-leaf pondweed	*Potamogeton richardsonii*					X	X	X	X	X	X	X	X	X	6	4	2	4	2	2
Curly-leaf pondweed (I)	*Potamogeton crispus*				X		X	X	X	X	X	X	X	X	2		3		2	10
Illinois pondweed	*Potamogeton illinoensis*								X					X	<1	1			<1	1
Large-leaf pondweed	*Potamogeton amplifolius*				X	X								X						
River pondweed	*Potamogeton nodosus*								X	X	X	X	X		P	<1	<1			<1
White-stem pondweed	*Potamogeton praelongus*				X					X			X	X	<1	1	1	<1	1	1
Robbin's pondweed	*Potamogeton robbinsii*														1					
Flat-stem pondweed	*Potamogeton zosteriformis*		X				X	X	X	X	X	X	X	X	1	1	1	1	2	1
Canada waterweed	*Elodea canadensis*				X			X	X	X		X	X	X	1	<1	1	1	<1	<1
Watermoss	not identified to species						X	X	X	X	X	X								
White-water buttercup	*Ranunculus aquatilis*				X															<1
Total		4	4	4	10	5	10	12	14	13	12	13	13	13	17	14	16	14	16	18

TABLE 2: HISTORICAL AND CURRENT PLANTS OF LAKE KORONIS (CONTINUED)

[a] several species of Chara, including *Chara contraria* and *C. globularis*, have recently been verified in the lake. A species of Nitella was confirmed in the lake during the September 2019 and July 2020 survey.

[b] two species of naiad (*Najas flexilis* and *Najas guadalupensis*) have been reported in lake. They are combined in this table because identification can be difficult and voucher specimens were not collected for most surveys.

[c] At least two species of narrow-leaf pondweed have been reported in the lake (*Potamogeton friesii* and *Potamogeton* sp.). They are combined in this table because identification can be difficult and voucher specimens were not collected for most surveys.

I = introduced P = present in lake but not found during the lake-wide survey

1947 (July 10) – MN Dept. of Conservation, Duck Lake Survey Report
1950 (September 5) – MN Dept. of Conservation, Division of Game and Fish, Bureau of Fisheries Research
1972 (June 8) – MNDNR Fisheries
1977 (July 28) – MNDNR Fisheries
1987 (July 21) – MNDNR Fisheries
1990 (July 23) – MNDNR Fisheries
1991 (July 22) – MNDNR Fisheries
1992 (July 20) – MNDNR Fisheries
1997 (July 16) – MNDNR Fisheries
1999 (July 26) – MNDNR Fisheries
2007 (July 25) – MNDNR Fisheries
2013 (July) – B. Austing, St. Cloud State Student
2015 (September 28-29, October 1, 7, 9) – MNDNR EWR Division – Aquatic Invasive Species
2016 (August 16-17) – MNDNR EWR Division – Aquatic Invasive Species
2017 (July 10-13) - MNDNR EWR Division – Lake Ecology Unit
2018 (July 16-17) - MNDNR EWR Division – Lake Ecology Unit and Aquatic Invasive Species
2019 (July 15-16) - MNDNR EWR Division – Lake Ecology Unit and Aquatic Invasive Species
2020 (July 21-23, 30; August 4) - MNDNR EWR Division – Lake Ecology Unit and Aquatic Invasive Species

TABLE 3: AQUATIC PLANTS DETECTED DURING THE 0-5 FEET NEARSHORE SURVEYS 2017, 2018, 2019, AND 2020 (VALUES SHOWN ARE PERCENT FREQUENCY OF OCCURRENCE)

Common Name	Scientific Name	2017 (n=63)	2018 (n=63)	2019 (n=63)	2020 (n=63)
Muskgrass	*Chara* sp.[a]	90	*52	#78	75
Starry Stonewort (I)	*Nitellopsis obtusa*	13	6	#48	48
Narrow-leaf pondweed	*Potamogeton* spp.[b]	78	76	84	*60
Bushy pondweed	*Najas* spp.[c]	62	76	*44	#65
Sago pondweed	*Stuckenia pectinata*	51	*16	#83	*57
Wild celery	*Vallisneria americana*	48	41	57	70
Water star-grass	*Heteranthera dubia*	30	30	*13	30
Horned pondweed	*Zannichellia palustris*	29	19	*0	8
Coontail	*Ceratophyllum demersum*	27	33	40	41
Clasping-leaf pondweed	*Potamogeton richardsonii*	17	17	22	35
Curly-leaf pondweed (I)	*Potamogeton crispus*	16	*3	6	#25
Illinois pondweed	*Potamogeton illinoensis*	5	0	11	17
Northern watermilfoil	*Myriophyllum sibiricum*	3	0	2	10
River pondweed	*Potamogeton nodosus*	2	2	2	2
Flat-stem pondweed	*Potamogeton zosteriformis*	2	2	5	5
Canada waterweed	*Elodea canadensis*	2	0	2	3
White-stem pondweed	*Potamogeton praelongus*	0	2	0	0
Lesser duckweed	*Lemna* sp.	6	13	17	16
Star duckweed	*Lemna trisulca*	0	3	6	0
Greater duckweed	*Spirodela polyhriza*	6	10	16	16
Watermeal	*Wolffia* sp.	3	0	2	10
White waterlily	*Nymphaea odorata*	5	6	6	6
Yellow waterlily	*Nuphar variegata*	5	3	5	5
Arrowhead	*Sagittaria* sp.	2	0	0	0
Bulrush	*Schoenoplectus* sp.	3	5	5	5
Burreed	*Sparganium* sp.	0	0	2	0
Cattail	*Typha* sp.	2	3	2	5
	Total	24	21	24	23

*indicates a statistically significant decline from the previous year, χ^2 (1, N = 63), $p < 0.05$.

# indicates a statistically significant increase from the previous year χ^2 (1, N = 63), $p < 0.05$.