Lundgren Lake

Rapid Response Grant Final Report
&
Aquatic Invasive Species Management Plan

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Lundgren Lake Overview

Lundgren Lake is a 29-acre seepage lake located in the Town of Pembine (T36N, R20E, S6) in Marinette County, Wisconsin. The lake has a maximum depth of 62 feet and 85% of the lake is more than 20 feet deep (figure 1). While water chemistry data is limited, Secchi disk readings during the project period typically exceeded 20 feet, pointing to very low nutrient levels (oligotrophic conditions) and excellent water quality.

There are 19 residences and 1 private youth camp located on Lundgren Lake. The Town of Pembine provides a public boat landing. Parking is limited to two small vehicle/trailer units at the landing and roadside parking on Monson Lake Road or nearby side roads. Lundgren is a slow-no-wake lake and motor size is limited to 15 hp. by Town ordinance.

History of Aquatic Invasive Species on Lundgren Lake

The Wisconsin Department of Natural Resources (WDNR) discovered Eurasian watermilfoil (*Myriophyllum spicatum*) growing in Lundgren Lake in the summer of 2014. The Marinette County Land & Water Conservation Division (LWCD) conducted EWM reconnaissance in 2014 and followed up with a point/intercept survey of the aquatic plant community in 2015.

The initial aquatic plant survey found EWM at 42% of sites within the littoral zone. The littoral zone is the area of the lake where the amount of light reaching the lakebed is sufficient to allow for plant growth, which is approximately 17 feet in Lundgren Lake. EWM was scattered throughout the lake with the maximum density near the public boat landing (figure 1). While it is not known when EWM was introduced to the lake, the pattern of spread and plant density suggest it's a recent introduction, likely originating near the public boat landing. Many lake residents recalled that EWM was originally limited to the shallow bay near the landing but had been expanding its range in recent years.

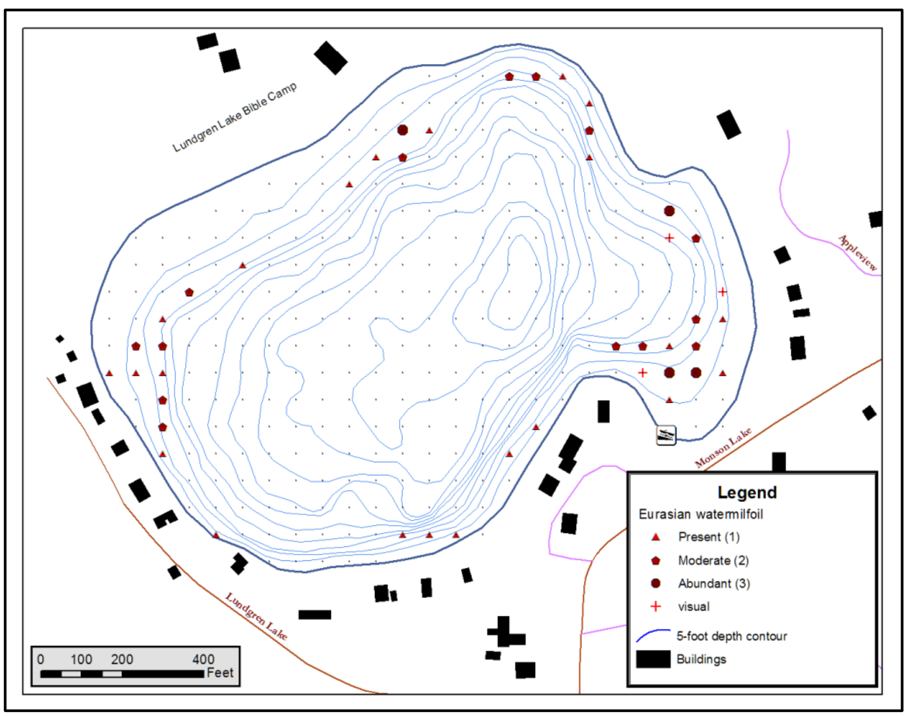


Figure 1. 2015 Eurasian watermilfoil density.

Rapid Response Grant
In the fall of 2015, the Marinette County LWCD began working with landowners on Lundgren Lake to gain support for controlling EWM and preventing its spread to nearby lakes, which remain EWM-free. After receiving nearly unanimous support from lakefront property owners and the Town of

Pembine, the LWCD applied for an Aquatic Invasive Species Rapid Response Grant to jump-start EWM control efforts and develop a plan for the long-term management of the aquatic invader.

The purpose of this report is to document and evaluate EWM control measures undertaken with AIS grant funding, and to lay out a plan for managing Eurasian watermilfoil in Lundgren Lake. This document also provides a plan for preventing the spread of EWM and other aquatic invasive species between and among area lakes and flowages.

Lundgren Lake Association

The Lundgren Lake Association was formed in 2016 in response to the discovery of EWM. Since its formation, the lake association has been actively managing EWM, educating members about the dangers of aquatic invasive species, and working to prevent their spread to Lundgren and neighboring lakes.

Lundgren Lake
Aquatic Plant Community

The aquatic plant community of Lundgren Lake has been studied extensively since the discovery of EWM. As part of the initial rapid response efforts, EWM reconnaissance was completed in the fall of 2014 to assess the extent of the EWM invasion. In the summer of 2015, an initial point/intercept aquatic plant survey was conducted to describe baseline conditions and evaluate the potential for management and/or eradication efforts. Follow-up plant surveys were completed in 2016, 2017, and 2019 to evaluate EWM control efforts and document their effects on the aquatic plant community. All aquatic plant surveys were conducted according to Wisconsin WDNR aquatic plant survey monitoring protocols for point-intercept plant surveys. Aquatic plant survey data can be found in Appendix A.

While nutrient monitoring was not conducted in Lundgren Lake, water quality appears to be excellent. During the summer of 2016 the average Secchi depth in Lundgren Lake was 24 feet and the maximum Secchi depth was 37.5 feet! Secchi depth is the depth at which a special 8" diameter black and white disk (the Secchi disk) can be seen. The excellent water clarity is reflected in the maximum rooting depth for aquatic plants, which averaged 17.3 feet during the study period. In 2017 the maximum rooting depth was 19 feet.

The Floristic Quality Index (FQI) is a rough measure of the "health" or amount of disturbance in the aquatic plant community. The FQI is based on the number of native species and their relative sensitivity to environmental stressors. Each species of plant found in Wisconsin lakes has been assigned a "coefficient of conservatism" which represents how typical the plant is in pristine conditions. The FQI is based solely on the presence of a plant, not its abundance or dominance. Statewide, the average FQI for lakes is 22.2. In Lundgren Lake, the FQI ranged from 24.0 to 28.5 with a five year average of 26.4. During the study period, 26 native species were identified. Eurasian watermilfoil was the only non-native species identified during the study period.

Despite the presence of EWM, the plant community of Lundgren Lake is healthy. Plant diversity is somewhat limited and plants that are adapted to low nutrient conditions dominate the plant community. This is typical for deep oligotrophic (nutrient poor) lakes.

EWM Management Efforts

During the grant application process, the LWCD worked closely with the WDNR to develop a plan to manage EWM. Lundgren is a small lake with a narrow littoral zone, excellent water clarity and a plant population dominated by low-growing species. These factors favor manual removal of EWM as a long-term management strategy. Marinette County also operates a diver assisted suction harvester (DASH) which greatly aids in manual plant removal, particularly in deep water. With this in mind, the LWCD, in consultation with landowners and the WDNR, adopted an aggressive plan to reduce the EWM population with herbicides followed by two years of DASH harvesting to remove the "survivors". If successful, it was hoped that careful EWM reconnaissance and manual harvesting could be employed by lake residents to eradicate EWM from Lundgren Lake.

Whole-Lake 2,4-D Treatment

At the time of the grant application the WDNR was conducting a study of large-scale low-concentration 2,4-D treatments to control EWM. Several of the test cases showed excellent EWM control with minimal impact on native plant communities. It was decided to include Lundgren Lake in the study, which called for post-treatment herbicide residual monitoring to evaluate concentration exposure times (CET). Follow-up aquatic plant surveys were conducted to evaluate the effect on EWM and non-target species.

Based on previous experience it was decided to treat the entire lake with 2,4-D with the goal of maintaining a concentration of 300 ppb for seven days. Since Lundgren Lake stratifies, it was necessary to calculate the volume to be treated based on the depth of the thermocline. The only existing temperature profiles of the lake showed the thermocline set up at 15 to 18 feet so the volume for treatment was assumed to be the upper 18 feet of the water column. Using a hydrographic map created from depth and location data gathered during the 2015 aquatic plant survey (figure 2), the volume above the thermocline (the epilimnion) was calculated to be approximately 470 acre feet of water.

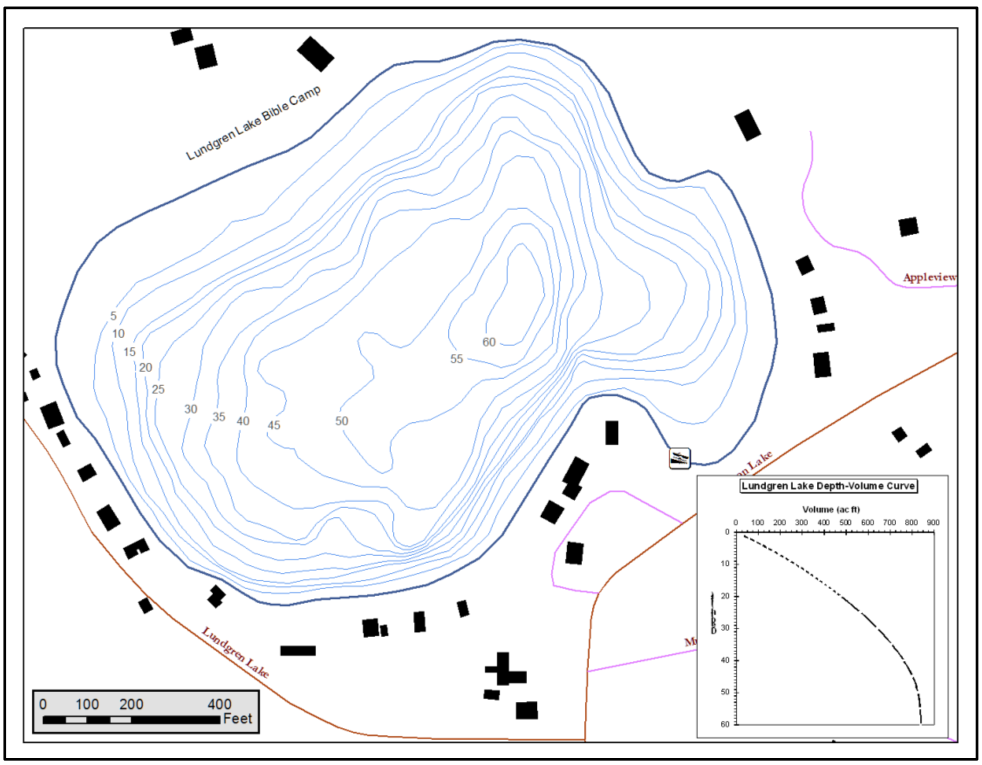


Figure 2. Depth-Volume curve for Lundgren Lake

A whole-lake treatment of Lundgren Lake was carried out on May 3, 2016 using 101 gallons of DMA IV Liquid 2,4-D. Schmidt's Aquatic out of Weyauwega, WI applied the herbicide to the entire littoral zone of the lake (waters less than 18 feet deep). Initial Treatment Results were excellent. By mid-June, EWM throughout the lake showed noticeable deterioration. By mid-July, dense EWM beds near the boat landing had collapsed to the bottom and turned black with no evidence of re-growth.

2,4-D Herbicide Residual Monitoring

The herbicide residual monitoring program was designed according to the Draft Fact Sheet: Design of Herbicide Concentration Monitoring Plans for Whole Lake Treatments, a WDNR draft guidance document. Lundgren Lake is a relatively simple bowl-shaped seepage lake so sample sites were limited to two littoral zone sites and one mid-lake, deep-water site (figure 3). The initial sampling interval was 1, 3, 6, 8, 14, 20, 29, 36, and 49 days after treatment (DAT). After initial laboratory results indicated slow herbicide degradation, additional samples were collected at 71, 96, and 145 DAT.

During each monitoring event, a 1-meter surface-integrated sample was collected at each site (LE, LW, LD). At the deep water site (LD) a water temperature profile was measured and samples were collected using a Van Dorn-type horizontal sampler one meter above the thermocline and one meter below the thermocline. All samples were acidified and refrigerated until the end of the monitoring period and analyzed for 2,4-D concentration at the Wisconsin State Lab of Hygiene.

Herbicide Dissipation and Degradation

Initial herbicide residual monitoring results were reported in mid-July, nearly 2.5 months after the herbicide application. Laboratory results showed rapid dissipation of the herbicide from the littoral zone to the center of the lake, which agrees with other study lakes. Monitoring also revealed that the treatment significantly overshot the target concentration of 300 ppb 2,4-D. Integrated samples collected during the first six days after treatment ranged from a low of 470 ppb to a high of 600 ppb with an average surface integrated concentration of 530 ppb.

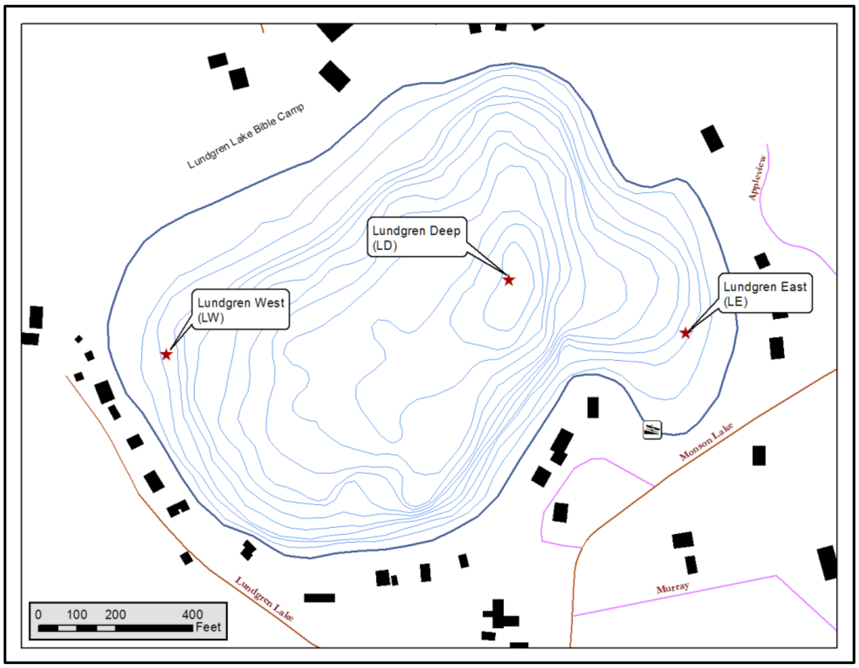


Figure 3. Herbicide residual monitoring stations.

The initial elevated herbicide concentration is a result of incorrectly predicting the thermocline depth. Studies show that vertical mixing of chemicals is impeded in thermally stratified lakes (Nault, 2018) and accurately measuring the volume of water above the thermocline is important when calculating herbicide application rates. On April 29, 2016 (6 days before the treatment) the lake was just beginning to warm and a weak thermocline was starting to set-up around 10 feet. Based on the limited information from previous temperature profiles it was thought warming would continue to push the thermocline deeper. Instead, there was considerable warming at depth and a rather wide metalimnion (that area between

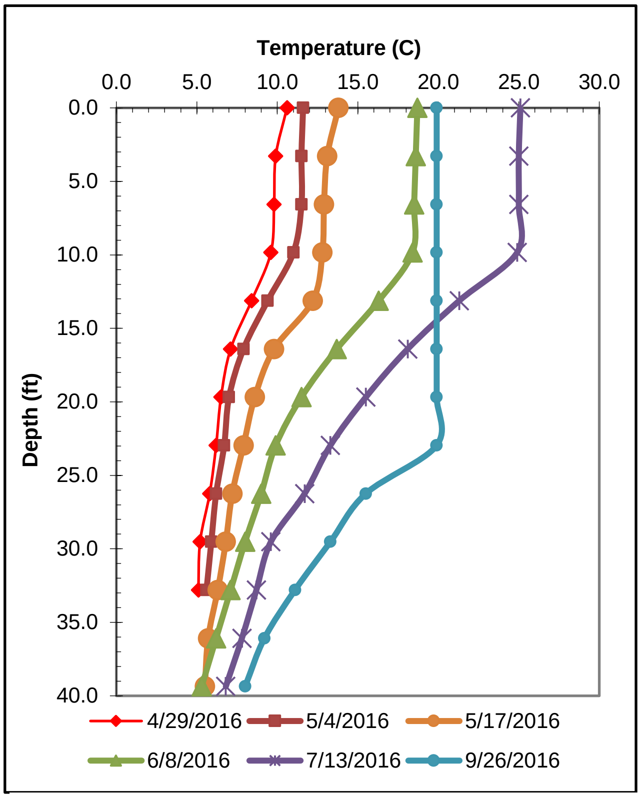


Figure 4. Ludgren Lake temperature profiles during the treatment period.

the warm upper water and cold deep water) formed, but the top of the thermocline remained at ten feet until sometime in September (figure 4).

The upper 18 feet of Lundgren Lake has a volume of 470 acre feet, requiring the application of 101 gallons of DMA IV- 2,4-D to reach an initial herbicide concentration of 300 ppb. That same herbicide volume applied to 270 acre feet, which is the volume of the lake to a depth of 10 feet, results in an herbicide concentration of 531 ppb, which agrees well with the actual concentration measured during the first 14 DAT.

Herbicide degradation was also very slow. While the goal was to maintain the target herbicide concentration for 7 days, the average surface integrated 2,4-D concentration remained above 500 ppb for approximately 18 DAT and did not fall below 300 ppb for nearly 62 DAT (figure 5). The calculated 2,4-D half-life was 76 days. Much higher than the WDNR large-scale treatment study average (30 days). Slow herbicide degradation was also recorded in other oligotrophic study lakes (Nault, 2018) and may result from decreased microbial degradation of the chemical. Full residual monitoring results are found in Appendix B.

Aquatic Plants & Plant Community Response

Like any plant community, differences in growing conditions and plant interactions will result in some year-to-year variability in the frequency and density of aquatic plants. Prior to the herbicide treatment, the expansion of EWM had likely reduced the abundance of some native species. The success of EWM control efforts would provide opportunities for native species to expand. Also, while the whole-lake treatment was designed to reduce damage to native species, the actual 2,4-D concentration was significantly

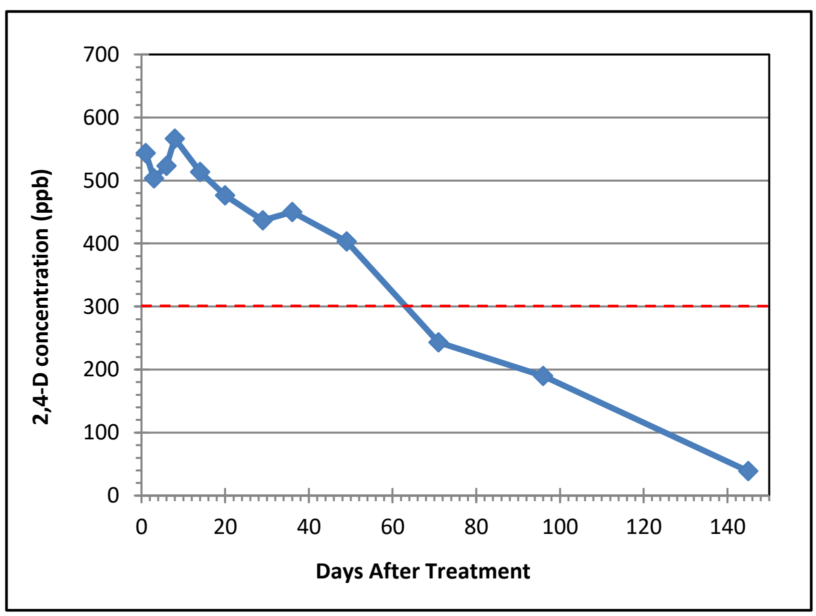


Figure 5. Post-treatment herbicide concentration.

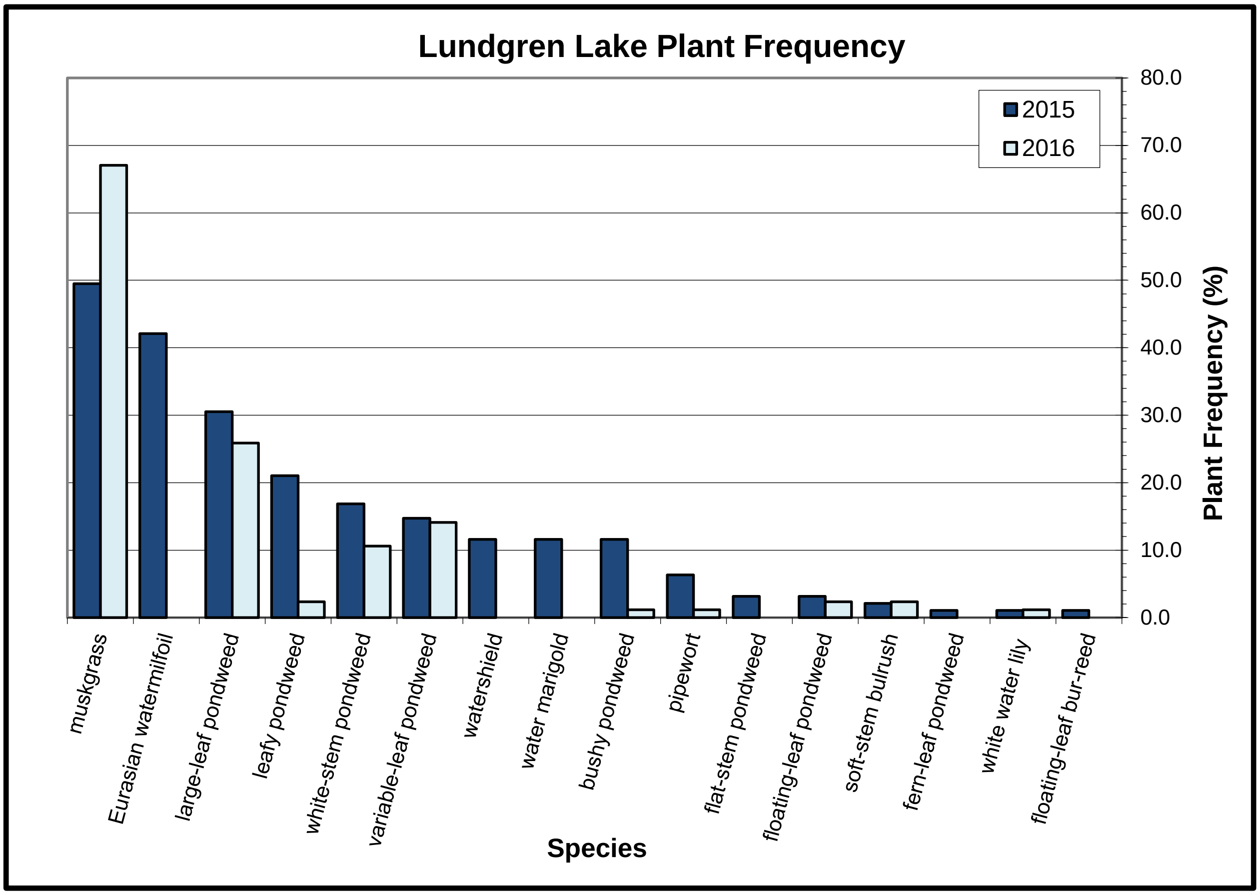


Figure 6. Pre-treatment versus post-treatment aquatic plant frequency in Lundgren Lake.

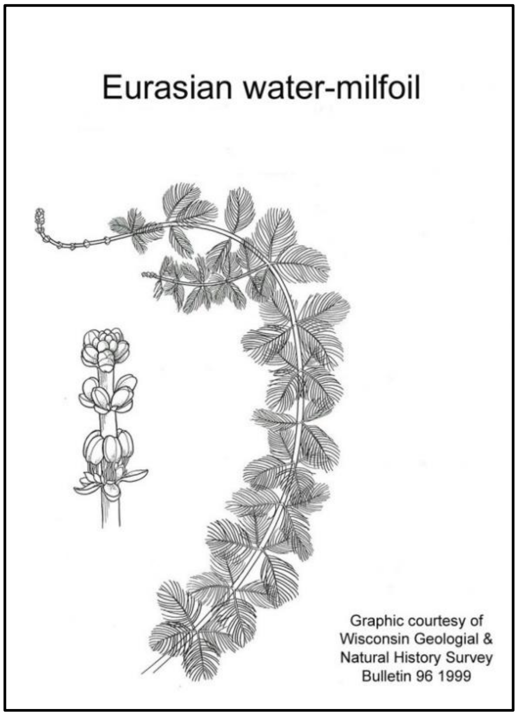
higher than planned. More importantly, the duration of herbicide exposure lasted well into the summer when all of the native plants are actively growing. These factors resulted in significant declines in some native species in Lundgren Lake (figure 6).

The following discussions focus on individual plant species, their role in the lake ecosystem, and their response to the 2016 whole-lake herbicide treatment. Plant descriptions and drawings are from "Through the Looking Glass… A Field Guide to Aquatic Plants" (Borman 1997) and "Distribution and habitat descriptions of Wisconsin lake plants" (Nichols 1999). Plant frequency is calculated using only those points shallower than the maximum depth of plant growth.

Eurasian Watermilfoil (EWM)

Eurasian watermilfoil (*Myriophyllum spicatum)* is an invasive exotic species with soft feather-like leaves arranged in groups of four along a long thin stem. Each leaf has 14-20 pairs of leaflets and the stems and tip of the plant often appear reddish in summer. Depending on water clarity, the plant can grow as tall as 15 feet. In shallow water, EWM often reach the surface where it branches profusely and spreads out to form a canopy that shades the water beneath. Eurasian watermilfoil is considered invasive since it has a habit of spreading rapidly and suppressing or displacing native aquatic plants.

EWM can overwinter green or survive as sprouts on the rootstock. The plant begins rapid growth early in the spring while the water is still cold and quickly reaches the surface. EWM spreads primarily by fragmentation, a process where the outer branches of the plant weaken and separate



from the main plant by minor disturbances or wave action. Fragments drift to a new place then take root and form a new plant. The rapid growth, ease of spread, and its canopy forming habit, allows EWM to out compete many of the slower growing native plants. While Eurasian watermilfoil provides some fish and wildlife habitat, studies show that native pondweeds typically have more diversity and support greater numbers of insects (Engel 1990).

In Lundgren Lake, EWM shows a preference for water greater than four feet deep and was found growing in water up to 17 feet deep. EWM shows a preference for muck sediment, which may explain the low frequency of EWM in shallow water where sand is dominant. In 2015, EWM was found at 42% of sample points shallower than the maximum depth of plant growth. While it was found throughout the lake, EWM density was greatest near the boat landing.

Following the 2016 herbicide treatment EWM quickly deteriorated and collapsed to the lakebed. EWM reconnaissance was conducted in early July 2016 from the surface and by snorkel diver. In August, an aquatic plant survey was completed and EWM reconnaissance was conducted by a SCUBA diver in areas where EWM had been found rooted below the thermocline. No EWM was located in 2016. In the summer of 2017, an aquatic plant survey and EWM reconnaissance by boat, SCUBA, and snorkel gear again failed to locate EWM in Lundgren Lake.

In 2018, no aquatic plant survey was completed but EWM reconnaissance found approximately ten plants along the south shore of the lake. The plants were growing in one to three feet of water in an area where flowering EWM was identified in 2015. A snorkeling diver manually removed all plants and roots but they were already weak and fragmenting. In August of 2019, several dozen plants were located along the south shore in the same vicinity and three plants were found near the boat landing (figure 7). A diver using SCUBA manually removed all of the plants. The total amount of plants and fragments nearly filled a 3-gallon pail.

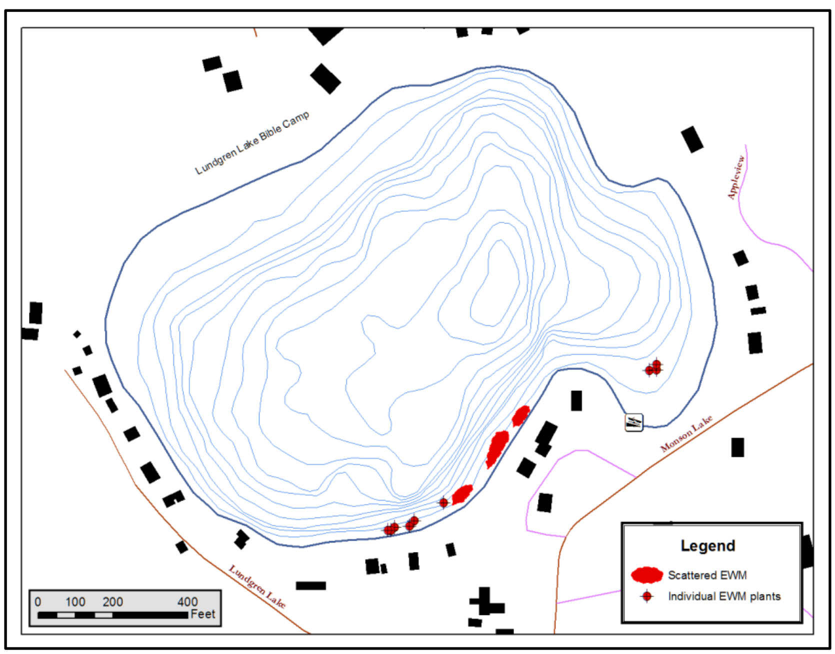
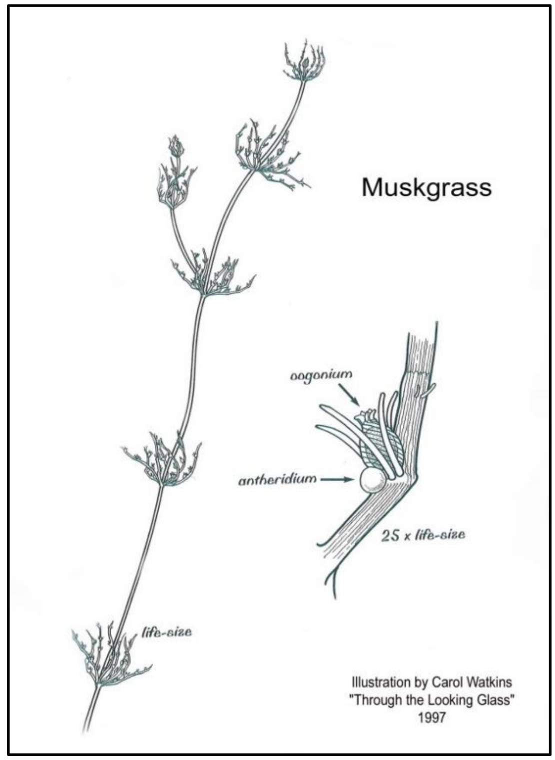


Figure 7. 2019 EWM reconnaissance results.

Muskgrass

While outwardly appearing like many other aquatic plants, muskgrass (*Char sp.*) is actually a type of colonial algae. Each "stem" and "leaf segment" is actually a separate algae cell. Muskgrass has branching slender "stems" with whorls of "leaves" at each joint. The main branches have ridges and the entire plant is often encrusted with calcium carbonate, giving the plant a gritty or crusty feel. Muskgrass is easily identified by its smell. When crushed the plant smells like skunk! Muskgrass is one of the more opportunistic aquatic plants and is often the first plant to colonize new ponds. The plant overwinters by rhizoids (root like structures), plant fragments, and seed-like structures called oogonia.



In Lundgren Lake, muskgrass shows no real sediment preference and was found growing in water from one to 14 feet deep. Muskgrass tends to hug the bottom and rarely grows more than two feet tall so it is seldom viewed as a nuisance species. However, because it is poorly "rooted", dense mats of muskgrass can break loose from the bottom in mucky areas and float to the surface. These floating mats are often mixed with watershield, water lilies, and their large roots.

Muskgrass is a favorite food of waterfowl and provides excellent fish habitat. In shallow sandy areas used by newly hatched fry (juvenile fish), muskgrass and bushy pondweed are often the only plants available for cover.

Throughout the study period, muskgrass was the most common plant in Lundgren Lake. In 2015, it was found at 49.5% of sample points. After the herbicide treatment, muskgrass frequency increased considerably and it was found at 77% of the sites by 2019. Muskgrass is an opportunistic plant that quickly colonizes new habitats. The increase in frequency may be due to muskgrass expanding into areas previously dominated by EWM.

Large-leaf Pondweed

Large-leaf pondweed (*Potamogeton amplifolius*) is one of the largest submersed aquatic plants. It can be identified by its wide (1-2 in) arching leaves and by its thick seed stalk that is held above the surface. Like many pondweeds it produces oval shaped floating leaves that help support the flower stalk.

Collectively, large-leaf and a few other large pondweeds are known by anglers as "musky-weed" or "cabbage" which points to its importance as deep-water shelter for fish and as ambush cover for predators. Waterfowl prize the abundant seeds.

In 2015, Large-leaf pondweed was found growing at 30% of the sample sites. It was most abundant in four to nine feet of water but could be found growing up to twelve feet deep. It shows a strong preference for muck sediment.

One year after the herbicide treatment large-leaf pondweed frequency had decreased to 26%. By 2017, it had fallen to 3.4% and only rebounded to 8% by 2019. Although delayed by a year, the sharp decline might be due to the herbicide treatment.

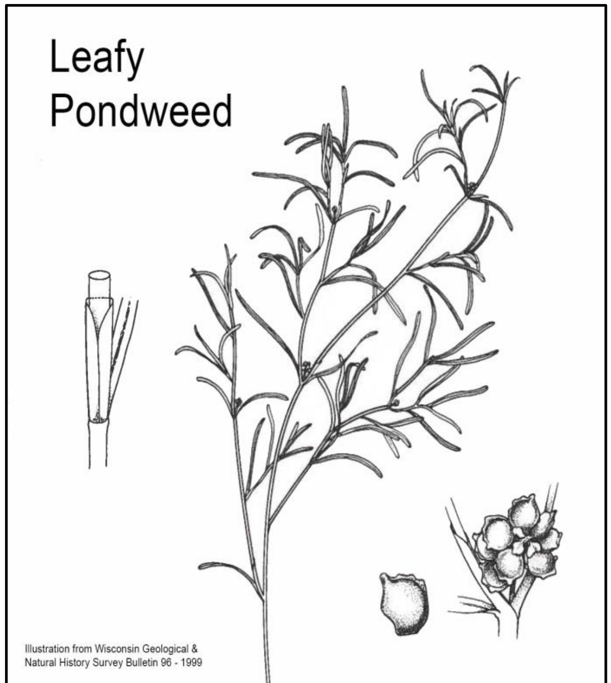
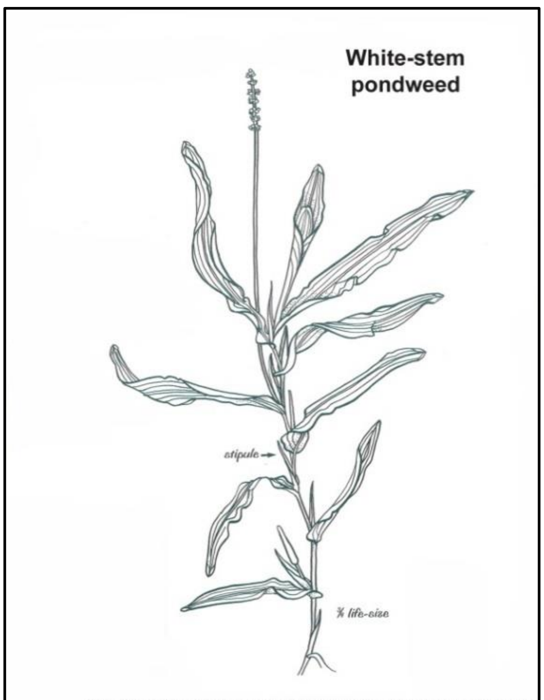


Illustration from Wisconsin Geological & Natural History Survey Bulletin 96 - 1999

Leafy Pondweed
Leafy pondweed (*Potamogeton foliosus*) is one of several small narrow-leaved pondweeds that are most easily identified by their fruit. Leafy pondweed has freely branching stems and narrow (1/16th inches or less) leaves that are typically 3/4 to 2-1/2 inches long. No floating leaves are produced and fruits are produced on short stalks in the leaf axils.

In Lundgren Lake, leafy pondweed was found at depths from four to 15 feet where it showed a preference for muck sediment. Ducks and geese eat the fruits of leafy pondweed and it provides important fish habitat.



Graphic courtesy of Through the Looking Glass Carol Watkins Illustrator

Leafy pondweed is known to be susceptible to 2,4-D. In 2015, it was found at 21% of the sample points. After the herbicide treatment, frequency of occurrence fell to 2%. By 2019, leafy pondweed frequency had rebounded to 13%.

White-stem Pondweed
White-stem pondweed (*Potamogeton praelongus*) is a frequent inhabitant of Lundgren Lake. Its thick white zigzag stems are a strong identifying characteristic. It has large lance shaped leaves measuring ½-1 ½ inches wide and 3- 10 inches long. No floating leaves are produced.

White-stem pondweed is often found in very clear lakes and it’s often seen as an indicator of good water quality. In Lundgren Lake, white-stem pondweed is typically found growing in water more than ten feet deep. On the west end of the lake it is often seen growing to the surface in water as deep as 16 feet!

Graphic courtesy of WI Geological & Natural History Survey - Bulletin 96 - 1999

White-stem pondweed is often grouped together with other large pondweeds as "musky weed" or "cabbage". It provides important cover for forage species and feeding sites for large predatory fish. In 2015, white-stem pondweed had a frequency of 17%. The frequency of occurrence has declined in each year since the herbicide treatment, to a low of 8% in 2019. There were no steep declines to point to the herbicide treatment as being the cause.

Variable-leaf Pondweed

Variable-leaf pondweed (*Potamogeton gramineus*), as the name implies, varies greatly in growth form depending on depth and sediment type. It typically has lance shaped leaves 1-3 inches long and 1/8" - 3/8" wide. In shallow water, the leaves tend to be on the small side of the range and the plant branches repeatedly so it appears very bushy. In deep water, variable-leaf pondweed leaves tend toward the upper end of the size range and the entire plant is less bushy and may be several feet tall. When variable-leaf pondweed is flowering it forms small floating leaves that are wider and more ellipse-shaped than the submerged leaves.

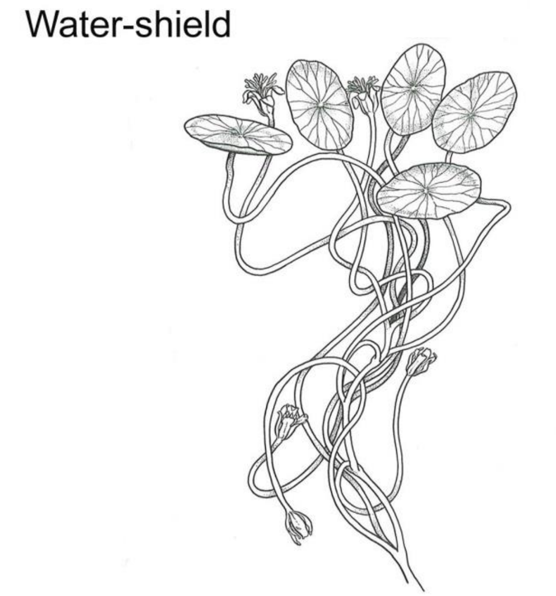
Like all of the true pondweeds (*Potamogeton sp*.), variable-leaf is a perennial plant that dies back in the fall and re-grows from the rootstock. It spreads by seeds produced on stalks held above the water surface and by winter buds. In Lundgren Lake, variable-leaf pondweed shows a slight preference for muck sediment. It is most common in water less than ten feet deep. Waterfowl eat the seeds and tubers of variable-leaf pondweed and the plant provides excellent shallow-water habitat for juvenile fish.

Variable-leaf pondweed showed no decline following the 2,4-D treatment. In 2015, it was found at 15% of the sites. Frequency was nearly the same in 2016 (14%) followed by a decline to 7% in 2017. In 2019, the frequency of variable-leaf pondweed had increased to 32%.

Bushy Pondweed

Bushy pondweed (*Najas flexilis*) is a common aquatic plant that, like variable-leaf pondweed, can look very different depending on the depth and sediment type where it's found. The needle-like leaves are ½"- 1" long and very narrow (1/16") with toothed edges. The leaves are broad at the base with sloping shoulders where they clasp the stem. In shallow water, the stems are heavily branched and the leaves are crowded on the stems giving the plant its "bushy" appearance. In deep

Graphic courtesy of WI Geological & Natural History Survey - Bulletin 96 - 1999 water, the stems can be up to three feet long with less branching and greater spacing between the leaves. In deep water, the plant often forms dense mats of intertwining stems on the lakebed.



Graphic courtesy of WI Geological and Natural History Survey - Bulletin 96 1999

Most aquatic plants are long-lived perennials. Bushy pondweed is unique because it's one of the few annual aquatic plants. Mature plants die each winter but produce abundant seeds to fuel next year's growth. The plants and seeds are both important food for waterfowl. Bushy pondweed also provides shelter for fish, particularly in very shallow sandy areas where it's often the only cover available for minnows and juvenile fish.

In Lundgren Lake bushy pondweed is a generalist where it grows equally well in sand or firm muck. In 2015, bushy pondweed was found growing in water from two to eight feet deep. In 2019, it was found in water up to 12 feet deep.

In the WDNR large-scale, low-concentration 2,4-D treatment study bushy pondweed experienced significant declines in almost every test case. In Lundgren Lake, bushy pondweed frequency fell from 12% in 2015 to 1% in 2016 after the herbicide application. Since bushy pondweed produces abundant seeds, many of which lay dormant for years in the sediment, it is able to recover quickly. Bushy pondweed frequency was 6% in 2017 and 18% in 2019.

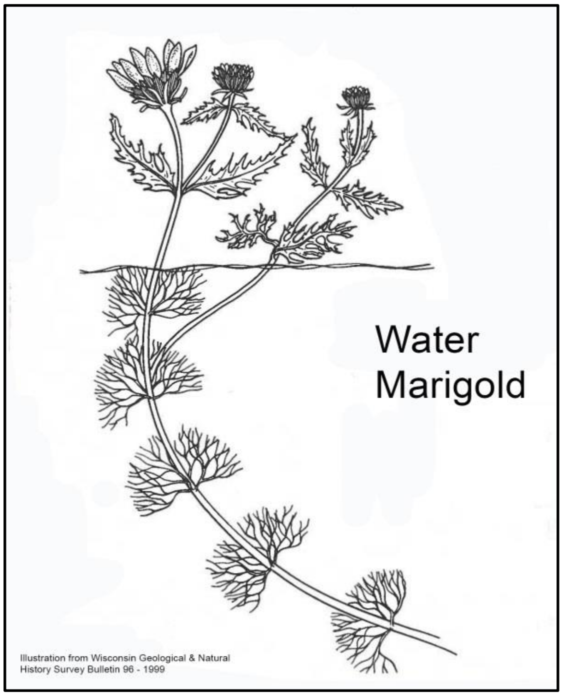
Watershield

Watershield (*Brasenia schreberi*) is a floating leaf plant that many people confuse with water lilies. It has small (3"- 5" long) football-shaped floating leaves with wiry reddish stalks attached at the center. The floating leaves are dark green on top and reddish purple on the underside. The stems and underside of the leaves are typically covered with a thick, gelatinous coating.

Waterfowl consume the seeds, flower buds, and leaves of watershield and the floating leaves provide shade and shelter for fish. Watershield is often found growing in mixed colonies with white and yellow water lilies.

Watershield prefers soft organic sediment but can grow in firm muck or sand. A long-lived perennial, watershield emerges from thick, starchy rhizomes buried in the sediment. In Lundgren Lake, watershield was found growing in water up to seven feet deep but is most abundant in water from two to five feet deep.

Experience with other EWM control projects show that watershield is very susceptible to 2,4-D. In Lundgren Lake, the pre-treatment frequency of occurrence was 12%. One year after the herbicide application watershield had disappeared from the lake. Experience also shows that watershield recovery is often slow. In Lundgren, the frequency of occurrence was 1% in 2017, increasing to 5% by 2019.



Water Marigold

Water marigold (*Megalodanta beckii*) is an interesting plant. Below the water, the leaves are arranged in bushy whorls on the stem that might reach 2" in diameter. The whorls are typically spaced a few inches apart and the individual leaves are repeatedly branched. In shallow water, if the plant reaches the surface the leaves above the water will be lance shaped with a deeply toothed margin. When the plant does break the surface, it may produce 1" wide yellow daisy-like flowers.

Water marigold is often seen as an indicator of good water quality. In Lundgren Lake, it was most often found in areas with muck sediment in water from three to nine feet deep.

In 2015 water marigold had a frequency of 12%. Since the 2016 herbicide treatment, it has not been found in Lundgren Lake. Similar effects were seen on other WDNR study lakes. Since it is very difficult to eradicate a plant from a lake there is hope that water marigold will yet make a recovery.

Infrequent Aquatic Plants

The following aquatic plants occurred at fewer than 10% of the Lundgren Lake survey points. This does not necessarily mean they are rare. The survey methodology tends to under sample some plants due to their location or their growth form, and some plants rarely constitute a large part of the plant community. As before, descriptions are from "Through the Looking Glass… a Field Guide to Aquatic Plants" (Borman, 1997).

Fine-leaved Pondweeds

In addition to leafy pondweed (*Potamogeton foliosus*) there were two other fine-leaved pondweeds found in Lundgren Lake, small pondweed (*P. pusillus*) and Fries' pondweed (*P. fresii*). Both have fine leaves, prefer moderate depths, and muck sediment. The shape of the winter buds, glands, and leaf sheaths help differentiate these and several other fine-leaved species. Both are susceptible to 2,4-D

Large Pondweeds

Several common large pondweeds were found in Lundgren Lake. Flat stem pondweed (*P. zosteriformis*) is a common pondweed that shows a strong preference for deep water. Ribbon-leaf pondweed (*P. epihydrus*) and fern-leaf pondweed (*P. robbinsii*) are both high quality species that provide excellent fish habitat. Floating-leaf pondweed (*P. natans*) is typically found in shallow water where it is often confused with lilies and other floating-leaf plants since it has no obvious underwater leaves. Most of the large pondweeds share the same depth and sediment preferences as EWM. As a result, most compete directly with EWM for space in the lake.

Native milfoil
Northern watermilfoil (*Myriophyllum sibericum*) was found at one sample point in 2016. Northern watermilfoil differs from EWM by the number of leaflets in each leaf. Northern has 5-12 pairs while EWM has 14-20 pairs. Northern watermilfoil develops winter buds and is stiffer when removed from the water. In some lakes, northern watermilfoil hybridizes with EWM. The resulting plant shares physical characteristics of both and the same invasive tendencies of EWM. In many lakes the hybrid milfoil also shows some resistance to 2,4-D and faster recovery times after treatment.

Other Submersed Aquatic Plants
Several other submersed aquatic plants were identified in Lundgren Lake. Common waterweed (*Elodea canadensis*) is a dominant plant in many lakes, where it often grows in deep water, but is relatively infrequent in Lundgren. It provides important habitat because it overwinters green and grows in colder water than most other native plants. Floating-leaf bur-reed (*Sparganium fluctuans*) is a shallow-water plant with long flowing grass-like leaves. Stonewort (*Nitella sp*.) is a macro-alga similar to muskgrass. It typically grows in very deep water or under low-light conditions. Stonewort looks similar to muskgrass but has bright green translucent "stems" and "leaves" and lacks the skunky odor.

Pipewort (*Eriocaulon aquaticum*) and needle spikerush (*Eleocharis accicularis*) are short grass-like plants that grow in clumps with a basal rosette. Both are adapted to growing in low-nutrient environments.

Other Floating-Leaf Plants
Floating-leaf plants include those with underwater stems, and leaves that float on the surface. While many pondweeds also produce floating leaves when they flower, their primary leaves are under water. In Lundgren Lake, white water lily (*Nymphaea odorata)* grows in mixed communities with watersheield, which is the dominant floating-leaf plant in the lake. Both are limited by growth form to water less than 7 feet deep.

All of the floating leaf plants have large fleshy rhizomes (roots) to anchor the plant and store nutrients that allow new plant growth to reach the surface in the spring. In areas with very flocculent muck these rhizomes, which are filled with air, can break loose and float to the surface where they decay and become rather unsightly.

Emergent Vegetation
Plants such as cattails, bulrushes and others that reach above the surface of the lake are known as emergent vegetation. Many of these plants grow in very shallow water or on saturated soil at the shoreline. Most are adapted to fluctuating water levels and are unharmed, or actually stimulated, by low water periods. Some emergent species form large colonies in shallow water.

Due to their location on the shoreline emergent plants are under-sampled in grid surveys. Those found on the lake include soft-stem bulrush (*Scirpus validus*), three-way sedge (*Dulichium arundinaceum*), and one unknown rush (*Eleocharis sp.*) A more intensive survey of shoreline vegetation would certainly show even more species including sedges and other wetland vegetation.

In general, the emergent plant community on Lundgren Lake is healthy. Around most of the lake, emergent plants occupy a very narrow fringe at the water's edge. West of the Bible Camp, on the north shore of the lake, a large emergent plant bed extends as much as 75 feet from the shoreline.

Emergent plants are important in the lake ecosystem because of the habitat they provide for fish and amphibians that spawn on and amongst their underwater stems. Invertebrates (insects) and amphibians living at the shoreline fringe are also an important part of the aquatic food web and are vital for a healthy lake.

Research on the effects of 2,4-D on emergent vegetation in lakes is limited. Since there is no reliable frequency data for emergent species on Lundgren Lake, it's impossible to say if the community was harmed by the herbicide application. However, there was no notable dieback of the large emergent plant bed along the north shore.

Lundgren Lake Association
EWM Education & AIS Prevention Efforts

Following the discovery of EWM in the summer of 2015, the Marinette County LWCD contacted all riparian landowners on Lundgren Lake to gauge interest in pursuing a Rapid Response Grant and forming a lake group to guide EWM and AIS management efforts after the grant period. Within a week, more than 80% of lake residents responded favorably.

An initial organizational meeting was held in May 2016 at the Lundgren Lake Bible Camp. The Lundgren Lake Association was officially incorporated as a 501C-3 nonprofit organization in 2018. Annual meetings are held on Labor Day weekend. Since its formation, the lake association has been active in managing EWM, educating members about the dangers of aquatic invasive species, and preventing their spread to neighboring lakes.

AIS Education and Citizen Monitoring Efforts
The LWCD has been working with riparian property owners and the Lundgren Lake Association to educate owners about the dangers of aquatic invasive species in general, how to prevent their spread, and how to identify the more common aquatic invasive species. The LWCD conducted AIS training as part of the 2017 annual meeting. The training included viewing and handling live specimens of the common aquatic plants found in Lundgren Lake, including EWM, and exotic species not found in the lake (curly-leaf pondweed) so residents could help with AIS reconnaissance efforts. This effort has paid dividends as a resident alerted the LWCD to the re-emergence of EWM along the south shore of the lake in 2018.

The LWCD has presented project updates and ongoing AIS updates at each annual meeting of the Lundgren Lake association. The LWCD will continue to work with the Lake Association beyond the grant period as needed to manage EWM on Lundgren Lake.

Signage and CBCW AIS Control Efforts
The Lundgren Lake boat landing is steep, narrow, and has limited parking. The Town of Pembine also has a 15hp limit on gasoline motors on Lundgren Lake. As a result, off-lake motor boat use is rather infrequent and traditional CBCW watercraft inspections would be a poor use of lake residents' time.

The grant application included updated EWM signage at the Lundgren Lake boat landing and alternative AIS prevention measures for low-use boat landings. The plan was to install a small informational kiosk at the landing with 3-gallon "AIS buckets". The buckets will be stenciled with a graphic of EWM and instructions for anglers to collect all plants from anchors and lures for disposal back at the landing.

The initial herbicide treatment and follow-up harvesting has been so successful that EWM has been difficult, if not impossible to find on Lundgren Lake. As a result, the informational kiosk has been constructed but not installed. The educational kiosk and AIS buckets will be installed at the landing in the spring of 2020.

Lundgren Lake AIS Management Plan

The most pressing issue confronting Lundgren Lake is the recent EWM invasion. There are four lakes within a mile of Lundgren including two with public access and one with a popular park and swimming beach. As of 2019, all remain EWM-free. Of the 38 lakes within five miles of Lundgren Lake, only Beecher Lake is known to support EWM.

As a deep oligotrophic lake, Lundgren supports a locally unique aquatic plant community. Allowed to grow unchecked, EWM would likely replace many of the native plants that share similar depth and sediment preferences. These include most of the large pondweeds that currently provide critical habitat for fish and other aquatic life in this exceptionally clear lake. Given its preference for muck bottom and water depths between four and 16 feet, EWM could potentially thrive in more than 8.6 acres of the lake as shown in figure 8.

While initial control efforts in Lundgren Lake have been successful, the history of EWM management in similar Marinette Count Lakes illustrates the difficulty of eradicating this invasive plant. Like Lundgren, Little Newton Lake is deep and clear with a sandy substrate. EWM was discovered in 2008, leading to several years of herbicide treatments and routing DASH harvesting. After eleven years, despite early success and annual harvesting, EWM eradication on Little Newton Lake remains an elusive goal. Statewide, since its discovery in the early 1960's, EWM has expanded to more than 400 lakes without a single verified case of eradication.

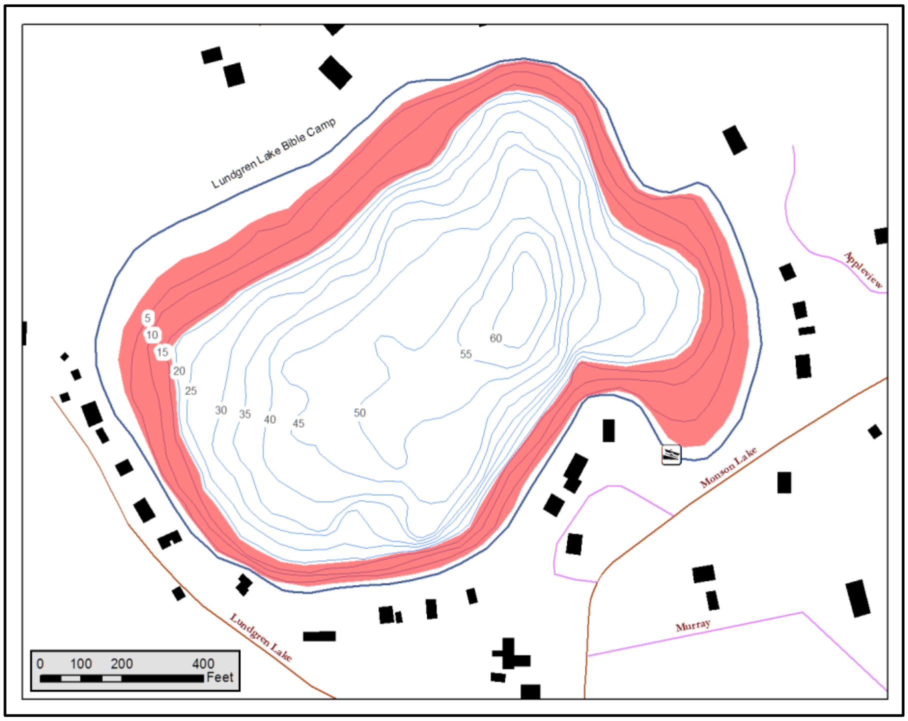


Figure 8. Areas of Lundgren Lake that could potentially support EWM.

Aquatic Invasive Species Management Goals & Objectives

The goals of the Lundgren Lake Association are to; <u>aggressively manage EWM in Lundgren Lake to eradicate the invasive species, prevent new AIS infestations, and prevent the spread of EWM to neighboring Lakes</u>. Specific management objectives have been identified to achieve these goals and targets have been set to gauge success and guide selection of management options.

Goal: <u>Aggressively manage EWM in Lundgren Lake to eradicate the invasive species.</u>

While there is no verified instance of EWM eradication in Wisconsin, it remains a realistic goal for Lundgren Lake. The limited littoral zone, relatively sparse native plant population, and exceptional water clarity make EWM reconnaissance relatively easy. Given the early success and a full complement of tools for managing low-density populations, it makes sense to target EWM aggressively with the goal of eradicating the species. This will require persistence in searching out EWM in the lake, using all available options to target EWM, and preserving a strong native plant community. With the assistance of lake residents, it will be possible to eradicate EWM from Lundgren Lake.

Objective: Remain vigilant in searching out EWM in Lundgren Lake.

While very successful, the 2016 herbicide application did not eradicate EWM from Lundgren Lake. Scattered EWM plants were removed from the lake in the summer of 2018 and again in the summer of 2019. The likely source of these new plants is EWM seeds lying dormant in the sediment. In this case, EWM may continue to "pop up" throughout the lake for several years. To have a real chance at eradicating EWM, lake residents need to adopt a strategy to actively search for EWM and promptly remove all plants from the lake.

<u>Target</u> – Form an invasive species committee to search for EWM and work with local resource agencies to coordinate eradication efforts.

<u>Target</u> – Conduct routine EWM reconnaissance on Lundgren Lake and remove scattered EWM plants when found.

EWM reconnaissance should be conducted at least twice each year, in late May and again in late August. Ideally, trained volunteers should be on the lookout for EWM whenever they are on the water. When EWM is discovered residents need to have a plan in place to remove the plants. The appropriate action depends primarily on the size of the new EWM growth, water depth, and time of year the discovery is made.

Objective: Have a plan in place to contact the appropriate people and implement controls based on the size and location of the EWM discovery.

A plan for dealing with new EWM discoveries should include whom to contact, a designated person to coordinate EWM eradication efforts, a list of people who can assist with eradication efforts, and list of state and local resource agencies to contact for assistance.

<u>Target</u> – Set up a procedure for whom to notify when EWM is found.

<u>Target</u> – Develop a procedure to respond to EWM discoveries based on the number of plants and location.

Objective: Preserve a strong native plant community in Lundgren Lake.

It is much more difficult for an invasive species to establish a foothold in areas with a healthy native plant community. EWM and many other invasive species are very good at exploiting disturbed areas and rapidly filling in where native plants have been removed.

> Target – Limit disturbance to the native plant community.
>
> Target – Chose management techniques that selectively control EWM while preserving native plants.
>
> **Objective: Educate lake residents and visitors and enlist their assistance in EWM eradication efforts.**

Implementing an aggressive EWM eradication effort that will be sustainable for several years will require effective communication. The Association should use every avenue at its disposal to communicate information, goals and outcomes to its members. The EWM eradication plan should include a strong educational component to provide information to lake residents and visitors.

> Target – Provide EWM educational materials to members including who to contact when EWM is found, how to prevent the spread of EWM, and how to properly hand-harvest EWM.
>
> Target – Provide EWM educational materials to visitors to Lundgren Lake including how they can prevent the spread of AIS by collecting plant fragments for proper disposal.

Goal: Prevent the spread of EWM and other invasive species into Lundgren Lake.

Protecting Lundgren Lake from new aquatic invasive species and successfully responding to new invaders will require the Association to educate the public and lake residents, be on the lookout for invasive species, and have a plan in place to deal with new invasions.

> **Objective: Develop a plan to prevent new aquatic invasions, monitor for the presence of aquatic invasive species, and respond to new invasions should they occur.**

Any plan for the prevention of aquatic invasive species will require an educational component, a plan to monitor the lake on a routine basis, and a plan to respond quickly when new invasive species are discovered.

> Target – Develop an information and education program to target residents and visitors who bring watercraft to Lundgren Lake from other water bodies.
>
> Target – Develop a plan to have volunteers survey the lake for aquatic invasive species on a routine basis.
>
> Target – Work with local resource agencies to develop a plan for responding to new AIS invasions.

Aquatic Invasive Species Management Alternatives

A successful aquatic invasive species management strategy will be tailored to the lake and species in question and will typically utilize multiple control methods as appropriate. A comprehensive review of AIS management alternatives follows. While each of the alternatives may be beneficial in certain situations, not all are currently applicable to managing EWM in Lundgren Lake.

Do Nothing

Doing nothing is inexpensive, easy to do, and relatively uncontroversial. However, it is rarely effective. Lakes are complicated ecosystems and aquatic plant populations fluctuate within them due to a variety of factors such as large-scale climactic conditions, local weather cycles, changing water levels, and nutrient enrichment. Aquatic invasive species are "invasive" because they grow quickly, are more adaptable, and have developed strategies to suppress native plants. Left to its own devices EWM will likely come to dominate the aquatic plant community of Lundgren Lake.

While the EWM dominance is thought to be permanent, the history of EWM in Wisconsin shows this is not always the case. Carpenter (1980) reported that the duration of peak abundance in some lakes is approximately 10 years after which EWM may experience a significant decline. While the reason for these "natural" EWM declines is poorly understood, some attribute it to the native milfoil weevil (*Euhrychiopsis lecontei*). Unfortunately, this natural decline reduces EWM dominance but seldom results in noticeable improvements in nuisance plant levels. In Lundgren Lake, doing nothing will likely lead to a dramatic increase in EWM abundance to the point where it negatively affects native plants and becomes a nuisance for boaters, anglers, and swimmers.

Chemical Control

There are several herbicides approved for aquatic use in Wisconsin, each differs in its mode of action and in the species it controls. Contact herbicides kill exposed plant material but can leave the root system intact, allowing for rapid recovery and plant growth. Systemic herbicides are transported to the roots and kill the entire plant. For this reason, systemic herbicides provide long-term control but may act slower than contact herbicides.

Herbicides can also be "broad-spectrum" or "selective". Broad-spectrum herbicides control a relatively broad range of plants. Selective herbicides, as the name implies, are more-or-less selective and control fewer species while leaving many others unharmed. Often selectivity is a function of timing of the application or herbicide concentration.

Eurasian watermilfoil (EWM) is susceptible to several common aquatic herbicides. The plant is especially susceptible to formulations of 2,4-D, a systemic herbicide. Since many pondweeds and other native aquatic plants are less susceptible to 2,4-D it is often used to selectively control milfoil (Parsons, 2001). Selective control of EWM with 2,4-D requires careful consideration of the concentration and exposure time (CET). Controlling EWM while minimizing damage to native species requires a relatively low herbicide concentration maintained over a relatively long exposure time (Nault, 2018). Experience shows that this is difficult to do when treating small areas of a lake. These "spot treatments" using 2,4-D are notoriously unreliable due to rapid dispersion of the herbicide from the treatment area, resulting in inadequate CET's. Treating the entire lake with 2,4-D allows for more accurate herbicide concentrations but local water quality conditions still effect herbicide degradation rates and resulting herbicide exposure times (Nault, 2018). The 2016 whole-lake treatment of Lundgren Lake shows the importance of accurately calculating the water volume to be treated and illustrates the difficulty of predicting herbicide degradation rates.

Low-dose fluridone treatments have also shown promise in treating EWM. Fluridone is a newer systemic herbicide that acts slowly to kill target plants. Since the chemical concentration must be maintained for 60 to 90 days, fluridone is only appropriate for whole-lake treatments. Post-treatment concentration monitoring is also required for fluridone treatments and follow-up applications may be necessary to maintain chemical concentrations. While many native species are not susceptible to low doses of Fluridone, studies in Wisconsin lakes found that common waterweed and bushy pondweed are both susceptible at concentrations required to treat EWM (Wagner, 2007). Since bushy pondweed is one of the dominant species in Lundgren Lake Fluridone may not be the best chemical for EWM control.

When used in a selective manner it is possible to get multi-year control from herbicides. This is most likely when the native plant community is relatively vigorous and can resist EWM reestablishment. If other methods of control are not used EWM will eventually return so even selective herbicide management may have to be repeated on a regular basis.

Improper or excessive use of aquatic herbicides can have unintended consequences. Widespread use of broad-spectrum herbicides can decimate aquatic plant communities, leaving large areas of suitable habitat open for colonization. The plants best suited to take advantage of these newly exposed habitats are the fast-growing aquatic invasive species! The decomposition of tons of aquatic plants also releases large amounts of nutrients to the water column. These nutrients can trigger algae blooms and fuel additional aquatic plant growth

Chemical treatment cost depends on the chemical formulation, application rate, the distance a certified applicator has to travel, and the time and equipment involved. In some instances, the State of Wisconsin can provide funding for chemical treatment of Eurasian watermilfoil or other lake restoration activities recommended in a lake management plan approved by the WDNR.

Chemical treatment of aquatic plants in Wisconsin always requires a permit from the Wisconsin WDNR. This is to ensure that the proposed treatment will use appropriate chemical(s), at the correct concentration and at the proper time of year. In almost all situations, the chemical applicator must be licensed by the Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP).

Herbicide Enclosures

The Marinette County LWCD has recently developed a relatively inexpensive process to create and deploy barriers to cordon off small sections of a lake to reduce herbicide dissipation and improve CET's. Early results are promising. The use of these herbicide treatment barriers provides a new tool for improving the reliability of EWM spot-treatments.

Benthic Barriers

Benthic barriers cover the sediment and prevent the growth of aquatic plants. The barriers work by physically disrupting plant growth or eliminating light at the sediment surface. When installed properly benthic barriers are very effective at eliminating all plant growth. However, the difficulty of installing and maintaining these barriers prevent their widespread use.

Benthic barriers can be made of naturally occurring materials (sand and gravel) or artificial (synthetic plastic sheeting). Sand or pea gravel is commonly used to create weed free swim areas but longevity is not good. If deposited on soft sediment the barrier sinks and mixes with native sediment, and over time, new sediment is deposited on top of the barrier. In every case, aquatic plants will soon colonize sand or pea gravel barriers.

Artificial barriers typically consist of sheets of polypropylene, polyethylene, fiberglass or nylon (Wagner 2004). All must be weighted to hold them in place against water currents, waves, and boat wake. If constructed of non-porous material, benthic barriers will be subject to billowing and may float free of the sediment as gasses from decomposition build up beneath them. Porous barriers are less subject to billowing but plant fragments that settle on top are better able to root through them. Both types of barriers must be removed annually to eliminate accumulated sediment. If sediment is allowed to accumulate on top of the barriers, it will support new aquatic plant growth.

Artificial benthic barriers are relatively expensive and difficult to install and maintain. The use of any type of benthic barrier requires a WDNR permit.

Dyes and Floating Covers

Dyes are liquid chemicals applied to change the color and transparency of the water. Covers physically cover the water surface. Both control aquatic plants by reducing the amount of light reaching the sediment.

Dyes typically color the water a deep blue or even black. For small ponds they are relatively inexpensive, long lasting, and effective. Effectiveness is limited in shallow water (2 feet or less) where the light reduction is seldom enough to prevent plant growth. Dyes must stay in the water throughout much of the growing season. Because of their dark color, dyes increase light absorption and can result in higher water temperatures. The increased water temperatures can result in stronger stratification, lower dissolved oxygen and widespread changes in the aquatic community (Wagner 2004). Dyes also favor the growth of blue-green algae, especially species that float at the surface. Dyes are not an option in larger water bodies (most lakes) and those with significant outflow.

Floating covers also disrupt plant growth by reducing light levels at the sediment surface. However, unlike dyes the floating covers prevent virtually all water use while they are in place. Floating covers can be difficult to install and effectively anchor.

Both dyes and floating covers require WDNR permits. The main permitting issue with floating covers is the disruption of public water rights (fishing and navigation) that they cause while installed.

Manual Plant Removal

Divers or snorkelers can manually remove small EWM colonies or individual plants from the lake. Manual removal is typically only feasible as a “mop-up” operation where EWM growth is widely scattered and/or very limited in density. Typically, EWM plants and colonies are marked with buoys from the surface while a team of divers removes the offending plants. For hand pulling, a good technique is for the diver to wrap larger plants around his or her forearm then reach into the sediment to pull as many roots as possible. Plants and roots are placed in a mesh bag. Mesh laundry bags work well. Adding a stiff wire to the rim so the bags stay open underwater helps considerably.

Diver Assisted Suction Harvesting (DASH) can significantly improve manual harvesting efficiency. Suction harvesting utilizes a small hydraulic dredge to create suction in a hose controlled by a diver. The diver pulls target plants by the roots and feeds them into the hose for transport to a boat at the surface. On the boat, plants and water is discharged onto a screen. Plants are bagged for disposal and suction water is returned to the lake. The LWCD owns and operates a DASH boat for use on Marinette County Lakes.

Manual EWM removal and DASH harvesting work best where water clarity is good and EWM can be easily distinguished from other plants in the lake. In these respects, Lundgren Lake is an ideal lake for manual EWM removal. The water clarity in Lundgren Lake is typically excellent and the dominant native plants are generally low growing. As a result, EWM in Lundgren tends to stand out and be readily identifiable.

A WDNR permit is required for DASH harvesting but not for hand pulling of EWM.

Mechanical Plant Removal (Harvesting)

Aquatic plant harvesting is a widely accepted aquatic plant management alternative that can be effective on a large or small scale. Individual landowners' often manually clear small areas around their dock or swim area using one of several specially designed aquatic plant rakes and/or hand-held cutting implements. Under current Wisconsin Law landowners can manually harvest plants without a permit if the plant removal is not in a WDNR designated sensitive area and is limited to a 30-foot wide area (measured parallel to shore). There is no limit on how far out into the lake a landowner can harvest by hand if they stay within the 30-foot wide corridor. The control area must be around existing piers, boatlifts, and swim rafts. The WDNR requires that cut plants be removed from the water.

Large-scale harvesting is done using specially designed aquatic plant harvesters that cut and collect aquatic plants in one operation. The size and capacity of these harvesters varies greatly but the largest can cut a 10-foot wide swath up to 6 feet deep and hold more than 16,000 lbs. of cut plants. Large-scale mechanical harvesting requires a permit from the Wisconsin WDNR and a DNR approved aquatic plant management plan.

Like most aquatic plant management alternatives, harvesting seldom eliminates plants. Much like cutting your lawn, harvesting leaves the root system intact and plants will re-grow. In some cases, repeated harvesting close to the sediment surface can stress plants enough to cause mortality. Species that depend on seed production for their spread may be partially controlled by harvesting if seeds are repeatedly removed.

Plants that spread by fragmentation such as EWM can actually be spread through harvesting when cut fragments escape the harvester and drift to other areas of the lake. For this reason, harvesting should only be used as a tool for managing EWM if the plant has already taken over a lake. With early infestations, harvesting will likely speed the spread of EWM within the lake.

Biological Plant Control

Biological control (biocontrol) typically utilizes bacteria, fungi, or insects to control an unwanted plant. Biocontrol of exotic species often involves finding the natural control mechanism in the exotic plants country of origin and importing it to the US. Since there is always a risk that

introducing a new organism may lead to unintended impacts to non-target species, a lot of study is required to approve the use of new biocontrol agents.
In a rather unusual twist, one of the most promising biocontrol agents for Eurasian watermilfoil is a native weevil (*Euhrychiopsis lecontei*). The milfoil weevil normally feeds on our native northern water milfoil. The adult weevil lays its eggs on the growing tips of milfoil where the larvae feed and weaken the plant. Older larvae also burrow into the stems, often causing enough damage to make the plant loose buoyancy and sink. The stout stems and shoots of northern water milfoil typically show little damage from this feeding activity. Eurasian water milfoil however has relatively weak stems that are readily damaged by the insects. Studies have shown that milfoil weevils actually prefer EWM and increase in population when EWM is the dominant food source (Lillie, 1997). The native milfoil weevil is widespread in Wisconsin (Jester, 1998) and thought to be the cause of natural EWM decline in some lakes.

Since its discovery as a control agent "stocking" milfoil weevils to control Eurasian watermilfoil has been used with mixed results. In a study conducted on twelve Wisconsin lakes, Jester (1999) found a significant decline in EWM biomass and density in 50% of the lakes, however the author reported that most of the changes were localized, and the changes were "certainly nothing the public would consider a decline and successful milfoil control". The study found that weevil density was positively correlated with increasing water temperature, distance of plant beds from shore (closer was better), and the percent of natural shoreline. The amount of natural shoreline is important because adult weevils migrate to shore and over winter in leaf litter on the forest floor within several yards of the water.

Where successful, biocontrol can reduce the abundance of EWM and allow the native species to compete. However, the expense ($1.00 per weevil) and highly variable results make it hard to recommend weevil stocking as a control measure. Also, even in lakes were biocontrol has been effective, the decline in EWM biomass is often temporary. This may be due to natural cycles in weevil abundance and fish predation. Newman, (2004) and Ward (2006) found that sunfish species (bluegill, pumpkinseed etc.) are very efficient predators of milfoil weevils and play a major role in reducing their effectiveness.

Exotic Species Monitoring and Prevention
As is often the case, an ounce of prevention is worth a pound of cure. With exotic species, this is doubly true. In most lakes, and for most exotic species, the primary mode of introduction is by boat, boat trailer, or bait bucket. While public access points are particularly susceptible, many exotic species have been introduced to lakes without any public access.

Once established in a water body it is extremely difficult to eradicate an exotic species. In the few cases where eradication has been successful, the introduction was detected early. For this reason, routine monitoring to detect new invasive species is an important step in any aquatic plant management effort. The Wisconsin DNR and University of Wisconsin Extension have many good publications and websites to help the layperson identify exotic species. Periodically these agencies also offer exotic species identification and control training to landowners.

EWM Management Recommendations

Since the EWM invasion of Lundgren Lake is still in an early stage and the native plant community is still in relatively good condition, it makes sense to attack the EWM with the goal of eradication. At the same time, the Association needs to explore all available options for the long-term control of EWM should eradication efforts fail.

Recommendation #1 – Form an invasive plant committee to coordinate EWM eradication efforts.

The committee should oversee efforts to find and eradicate EWM from Lundgren Lake, keep accurate records of EWM control/removal, and coordinate AIS information and education efforts.

Recommendation #2 – **Conduct routine EWM reconnaissance on Lundgren Lake**.

Despite early success, EWM has not been eradicated from the lake and it will likely persist for many years. The Association should survey the lake for EWM at least twice per year (late May and late August). The location of EWM plants should be marked for removal and their location recorded using a handheld GPS.

Recommendation #3 – Hand pull isolated EWM plants and colonies as soon as possible after discovery.

Snorkeling or SCUBA divers can pull plants by the roots and collect them in a mesh bag. It is best to have a partner on the surface in a kayak to keep empty bags and collect the inevitable "floaters" dislodged by the diver. Be sure to collect all plant fragments. Where EWM is dense or in water too deep for snorkelers, work with the LWCD to utilize the Counties DASH boat for suction harvesting.

Recommendation #4 – Mark larger EWM colonies and contact the Marinette County LWCD and/or WDNR for assistance with DASH harvesting or chemical control.

The LWCD can assist with accurate GPS mapping and spot treatments using herbicide enclosure curtains.

Recommendation #6 – Conduct whole-lake herbicide treatment if necessary.

If manual harvesting and herbicide enclosure treatments fail and EWM becomes reestablished throughout the lake, consult with the LWCD and WDNR about conducting another whole-lake herbicide treatment.

Information & Education Plan

A strong information & education program will help considerably in the EWM eradication effort and is the most important part of any AIS prevention program. The information and education plan should target lake residents and visitors alike.

Recommendation #1 – **Publish a regular newsletter, provide educational materials, and update lake residents about AIS management efforts**.

The Association should publish a regular newsletter as a way of distributing educational materials and keeping members abreast of the EWM eradication project and other lake management issues. E-newsletters can be a cost effective alternative or supplement. The Association should also sign members up to receive the Lake Tides Newsletter, a free quarterly publication by the Wisconsin Lakes Partnership.

Recommendation #2 – **Maintain signage at the boat landing and provide educational materials to visitors to Lundgren Lake.**

Signage should inform visitors to Lundgren Lake about the EWM eradication efforts and efforts to prevent its spread. Signage and educational materials can be obtained online at Wisconsin Lakes Partnership or UW Extension Lakes Program websites.

Recommendation #3 – **Become a member of Wisconsin Lakes (formerly Wisconsin Association of Lakes) and take advantage of their resources**.

Wisconsin Lakes is a statewide lake organization that promotes sound lake policy and provides training opportunities for lake groups throughout the state. The Association should send a few members each year to the annul lakes convention, a three day event featuring numerous speakers, workshops and presentations concerning lake management, operating effective lake organizations, and other current issues affecting Wisconsin Lakes. The annual convention is typically held in Stevens Point in late May.

Lundgren Lake
AIS Prevention, Monitoring & Rapid Response Plan

Unfortunately, Eurasian watermilfoil is not the only aquatic invasive species threatening our lakes. South of Marinette County curly-leaf pondweed (*Potamogeton crispus*) is an emerging problem. Other species including Hydrilla (*Hydrilla verticillata*), Brazilian waterweed (*Egaria densa*) and yellow floating heart (*Nymphoides peltata*) have been spreading north and may threaten our lakes in the future. Beyond the plant world, we have Zebras mussels (*Drissena polymorpha*), Quagga mussels (*Drissena rostriformis*), Rusty crayfish (*Orconenctes rusticus*), exotic zooplankton, and fish diseases such as VHS to worry about. The best way to deal with these invaders is to be proactive and prevent their introduction. The Lundgren Lake Association should adopt an exotic species prevention plan to reduce the likelihood of new invasions, a monitoring plan to detect early invasions, and a rapid response plan to deal with new invasive species when found.

Prevention

An effective AIS prevention plan should focus on the most common routes of AIS invasion, boats, and water gardens. Boats traveling between lakes can carry plant fragments or zebras mussels attached to the boat or trailer. Water in the boat or bait buckets can carry plants, mussels, zooplankton, algae, and disease causing organisms.

Recommendation #1 – The Association should maintain signage at the public boat landing stressing the importance of inspecting boats, removing plants, and draining water to prevent the movement of aquatic invasive species. AIS publications are available through the WDNR at https://WDNR.wi.gov/topic/Invasives/publications.html .

Recommendation #2 –The Association should provide "weed buckets" at the landing for anglers. Signage should instruct anglers how they can help prevent the spread of AIS by keeping all plant fragments caught on lures and anchors and disposing of them on shore.

Recommendation #3 – Education efforts should focus on the dangers of water gardening and the unintentional releases associated with the hobby. Mail order water garden plants are believed to be the likely source of hydrilla, an invasive exotic that was recently found growing in a Marinette County pond. For many years, scientists believed hydrilla could not survive in Northern Wisconsin, but the plant was well established and expanding in the pond when discovered. On a positive note, the hydrilla was aggressively attacked and it appears to have been eliminated. Yellow floating heart has also been found growing in outdoor garden ponds in the county. A recent investigation of the water garden industry found that plants known to be invasive are available and routinely shipped around the country. Contamination of orders with other species, including invasive species, is also rampant (Maki, 2004).

Monitoring

Effective management of AIS is much easier when the invader is detected before it is well established in the lake. Early detection also improves the odds of eradication.

Recommendation #1 – The Association should join the Citizen Lake Monitoring Network and train several members in AIS monitoring procedures. While the information & education program should equip all Association members with a basic knowledge of invasive species, several should be trained specifically for AIS monitoring. The Citizen Lake Monitoring Network holds training workshops to train volunteers in AIS monitoring protocol. They also provide a monitoring manual and laminated AIS identification sheets along with reconnaissance and reporting forms. The County LWCD can assist in AIS training, identification and monitoring.

Recommendation #2 – Volunteer AIS monitors should conduct annual AIS surveys of the lakes. Aquatic plant surveys, although beneficial, are not designed to find many types of aquatic invaders and may even miss pioneer plant invasions. A better method is to look specifically for different invasive species at the optimal time and in the most likely habitats. The ideal monitoring time varies by species, but can typically be covered with one early and one late summer survey.

Trained volunteers should conduct annual invasive species surveys. Findings should be reported to the Association and the Citizen Lake Monitoring Network.

Recommendation #3 – Report any suspected aquatic invasive species to the Peshtigo DNR office or the Marinette County LWCD. Keep samples of any suspected exotic species refrigerated in a zip-lock bag until it can be positively identified.

Rapid Response

When a new aquatic invasive species is identified, the District needs to act quickly. Depending on the species found, length of time since invasion, and where the pioneer colony is found, there may be a possibility for eradication. The following steps should be followed:

Step #1 – Notify the Lake Association Board and local resource agencies and explore grant funding opportunities. The Lake Association Board should meet with the Wisconsin DNR and LWCD to explore control measures, and determine if an AIS Rapid Response Grant is advisable. AIS Rapid Response Grants bypass most of the normal grant application process so funds are available for quick action in hopes of eradication.

Step #2 – Notify membership of the discovery and what the Board plans to do about it. Educate members about measures they can take to prevent its further spread within the lake or to other waters.

Step #3 – Conduct a thorough survey of the lake to determine the extent of the AIS infestation. Working with County or WDNR staff, conduct a thorough survey of the lake. For invasive plants, map the location, plant density, and other physical data that may be important such as water depth, sediment type etc.

Step #4 – Work with local resource agencies and outside experts where necessary to determine if eradication is possible. Where eradication is not feasible, begin developing a management plan to deal with the new species.

Step #5 - Develop an action plan based on species and extent of invasion. Work closely with the experts to develop a customized plan aimed at eradication or control. If outside consultants are needed for things like herbicide treatment or scuba diving bring them into the process early. Many consultants can also help with things like mapping and planning.

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Lundgren Lake

Rapid Response Grant Final Report
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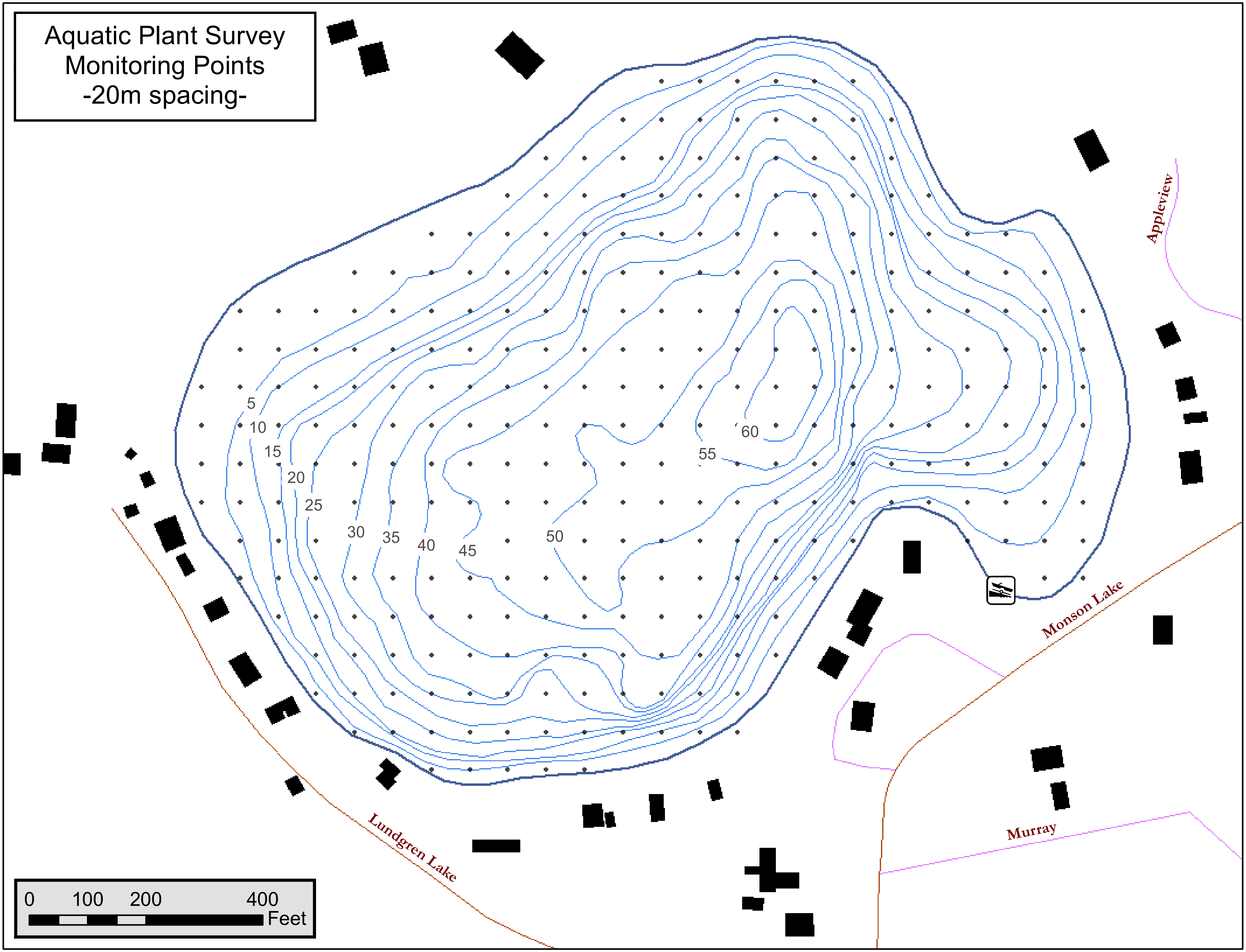
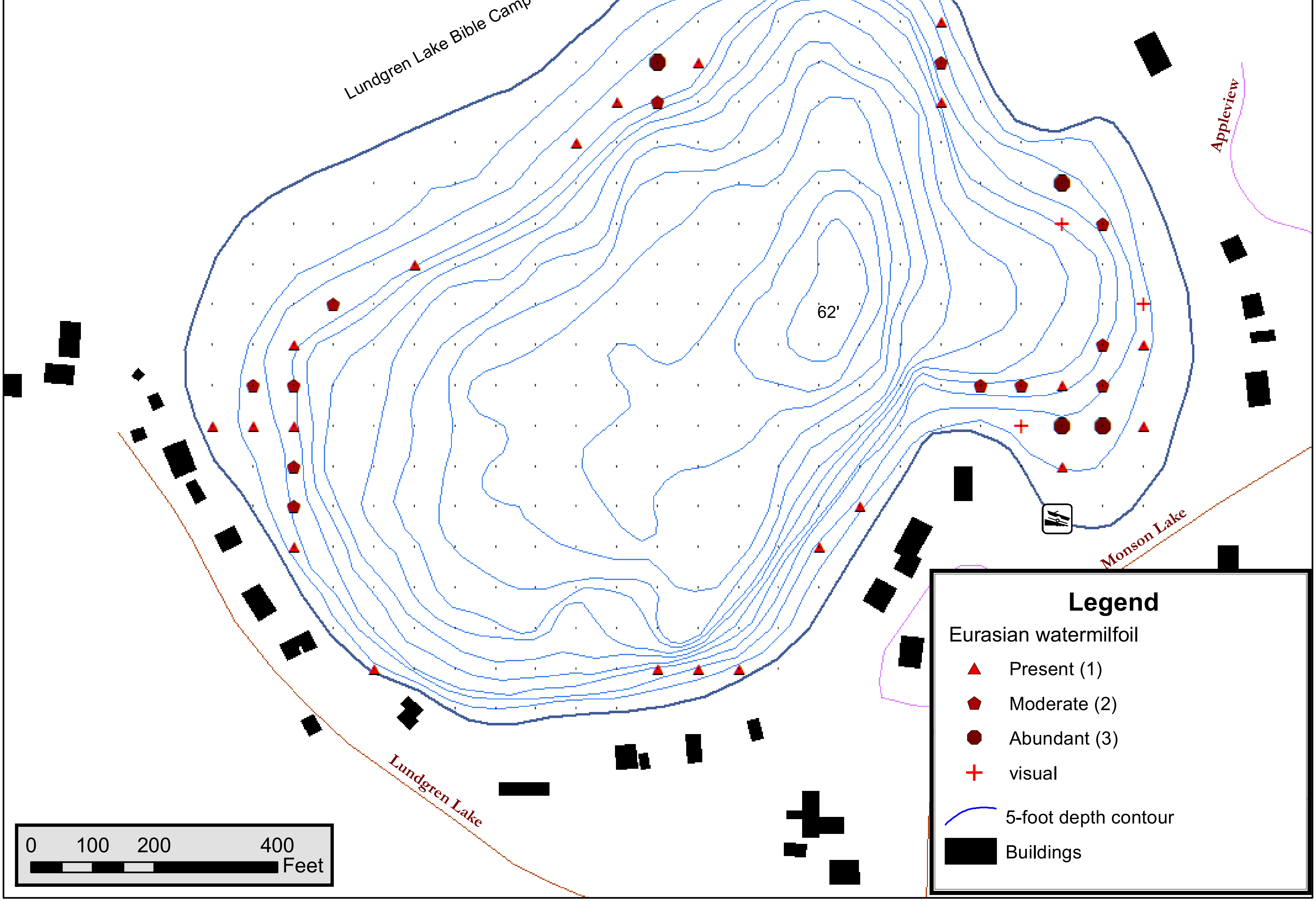
Appendix A

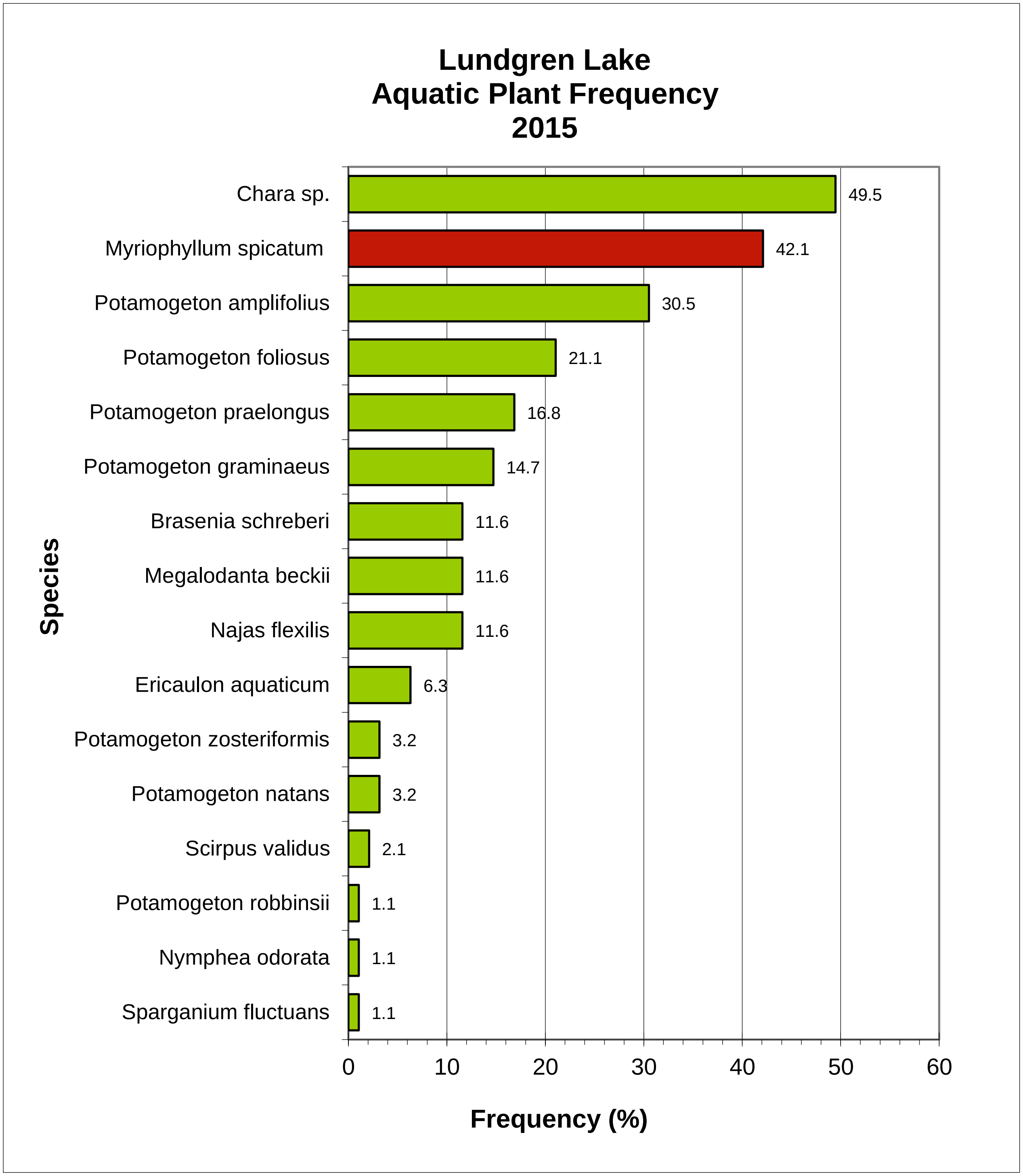
Aquatic Plant Survey Data
&
Graphs

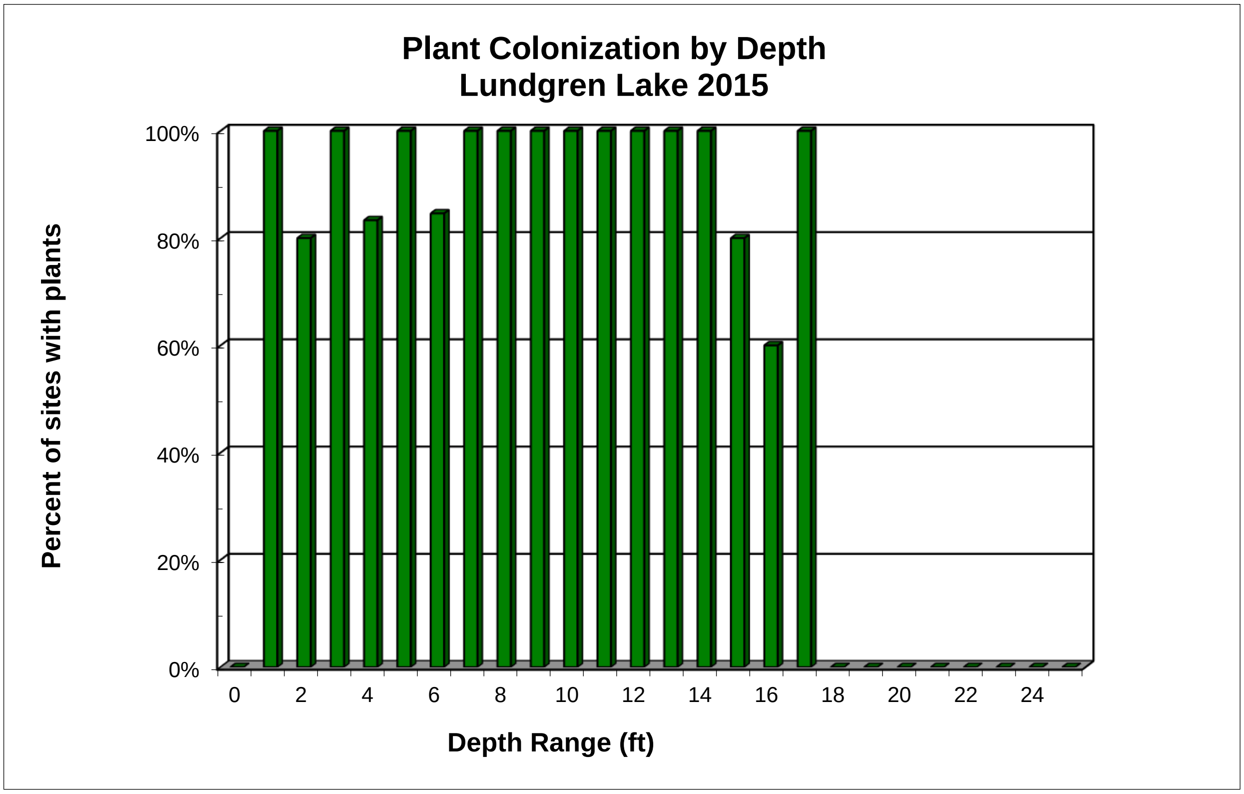
Aquatic Plant Survey Monitoring Points -20m spacing-

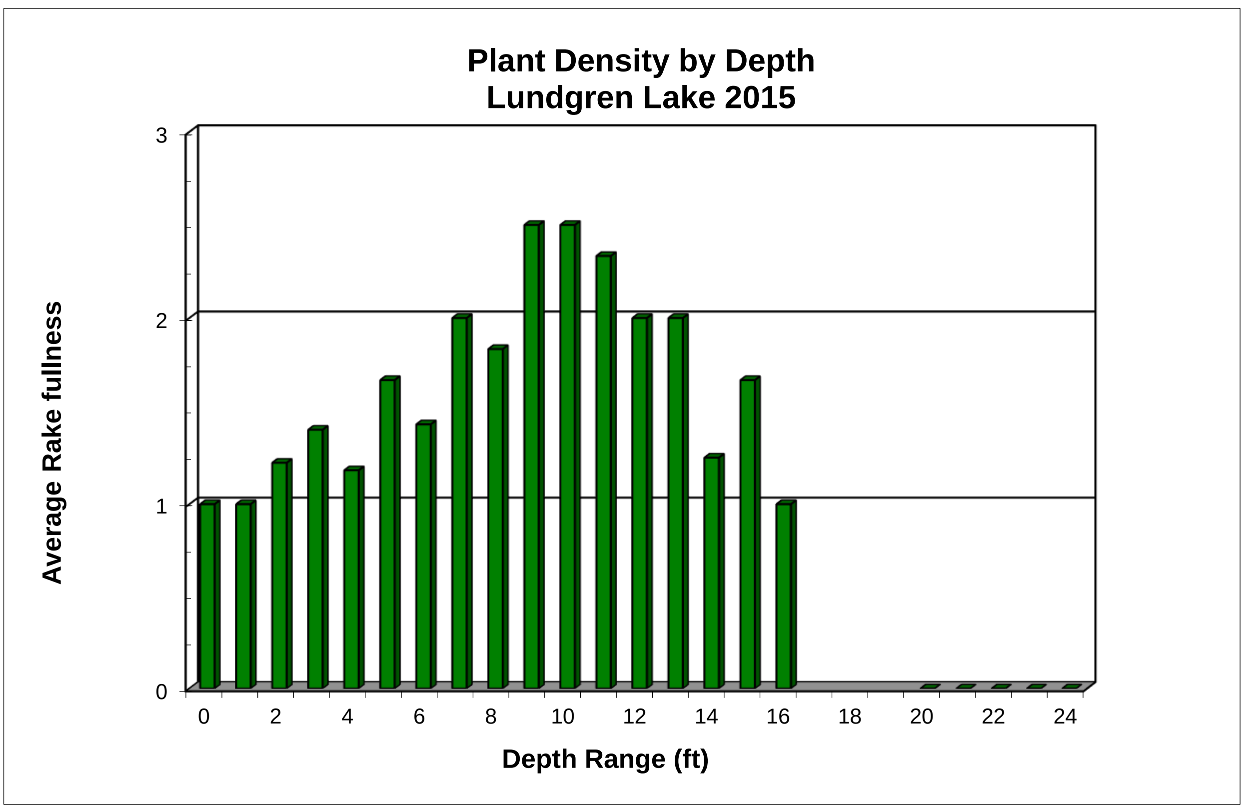


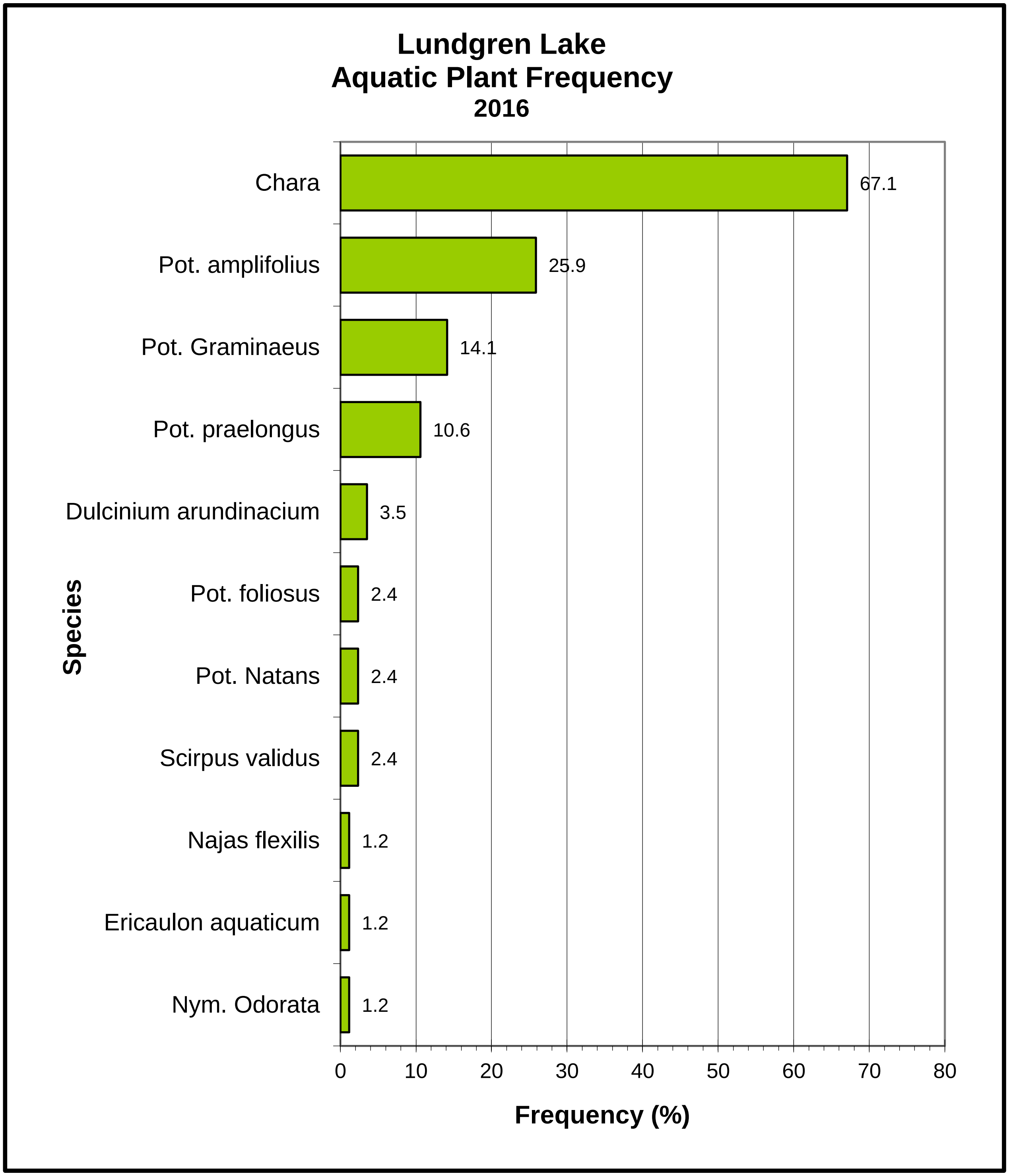
Lundgren Lake - 2015
Pre-Treatment EWM

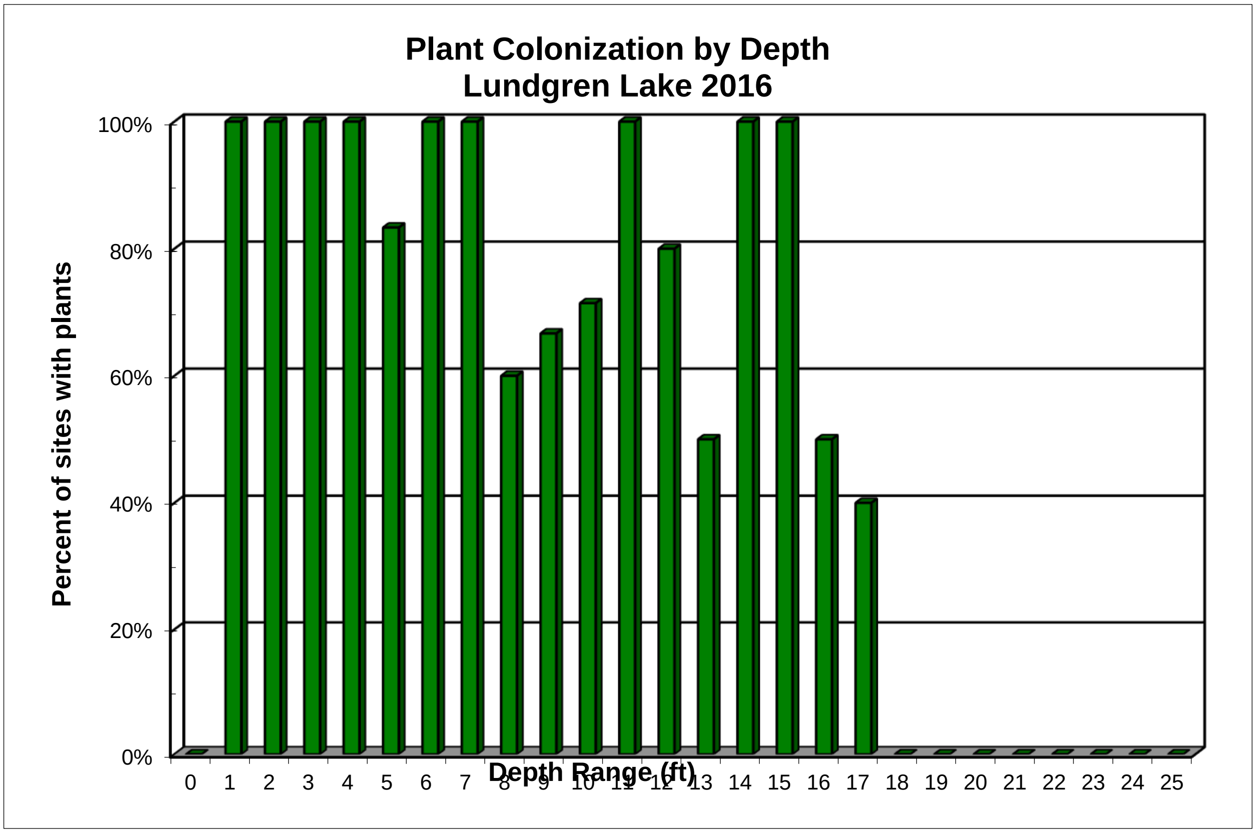


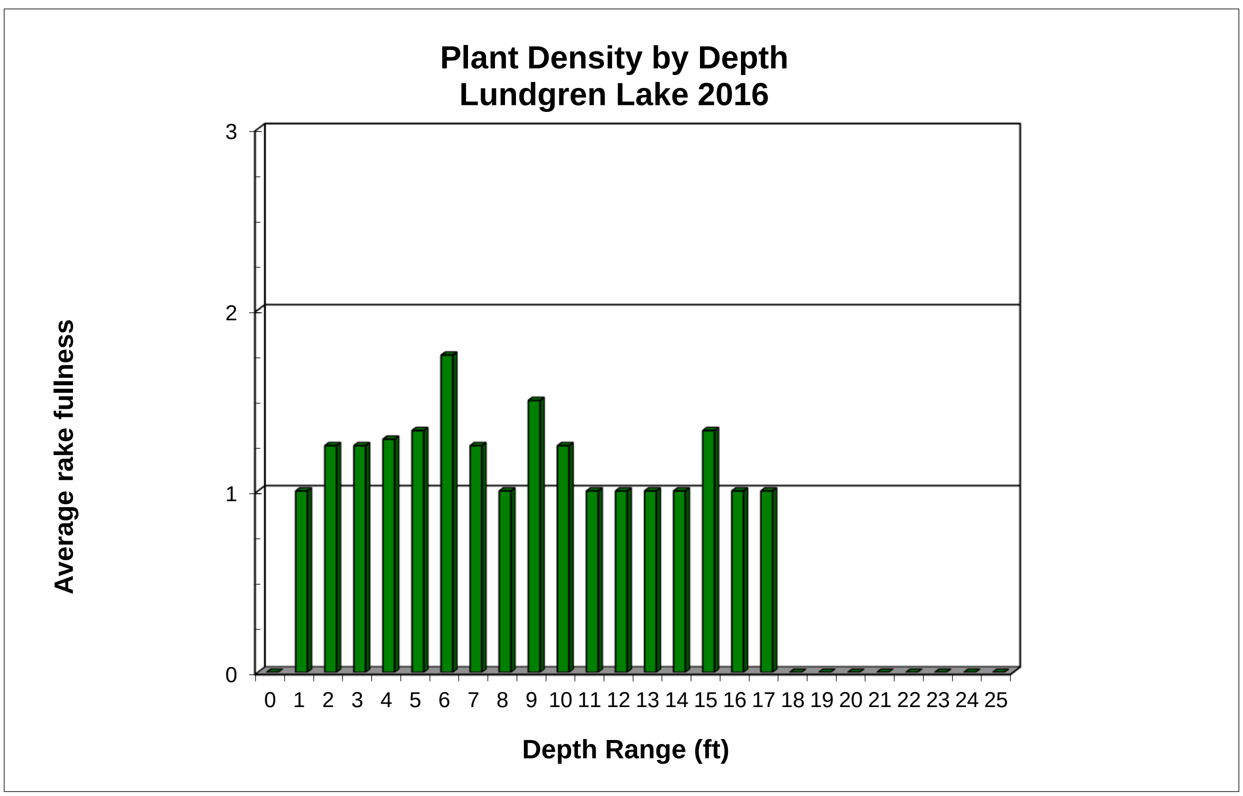

Lundgren Lake
Aquatic Plant Frequency
2015
Species
Chara sp.
49.5
Myriophyllum spicatum
42.1
Potamogeton amplifolius
30.5
Potamogeton foliosus
21.1
Potamogeton praelongus
16.8
Potamogeton graminaeus
14.7
Brasenia schreberi
11.6
Megalodanta beckii
11.6
Najas flexilis
11.6
Ericaulon aquaticum
6.3
Potamogeton zosteriformis
3.2
Potamogeton natans
3.2
Scirpus validus
2.1
Potamogeton robbinsii
1.1
Nymphea odorata
1.1
Sparganium fluctuans
1.1
0
10
20
30
40
50
60
Frequency (%)

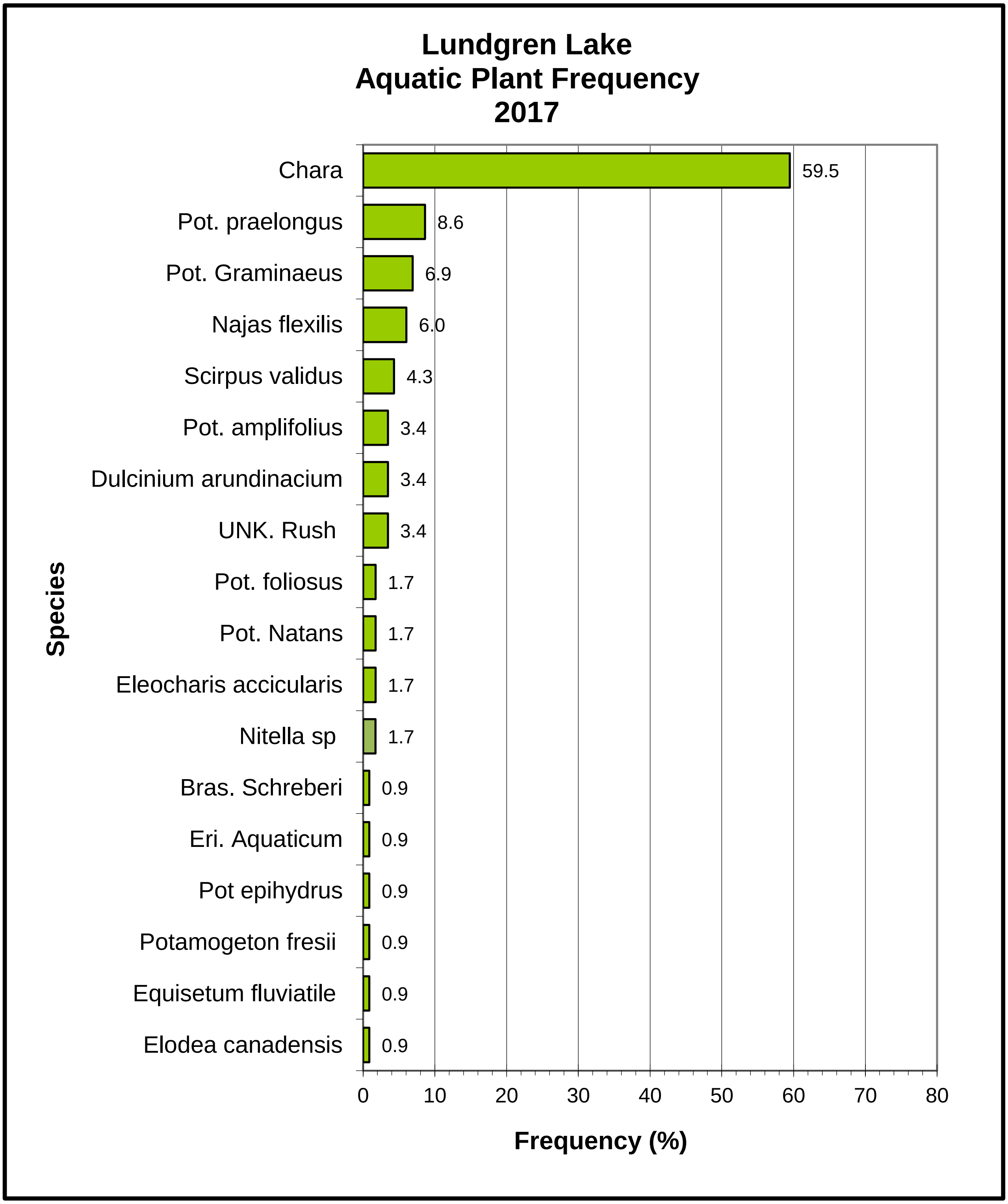

Plant Colonization by Depth
Lundgren Lake 2015
Percent of sites with plants
100%
80%
60%
40%
20%
0%
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth Range (ft)

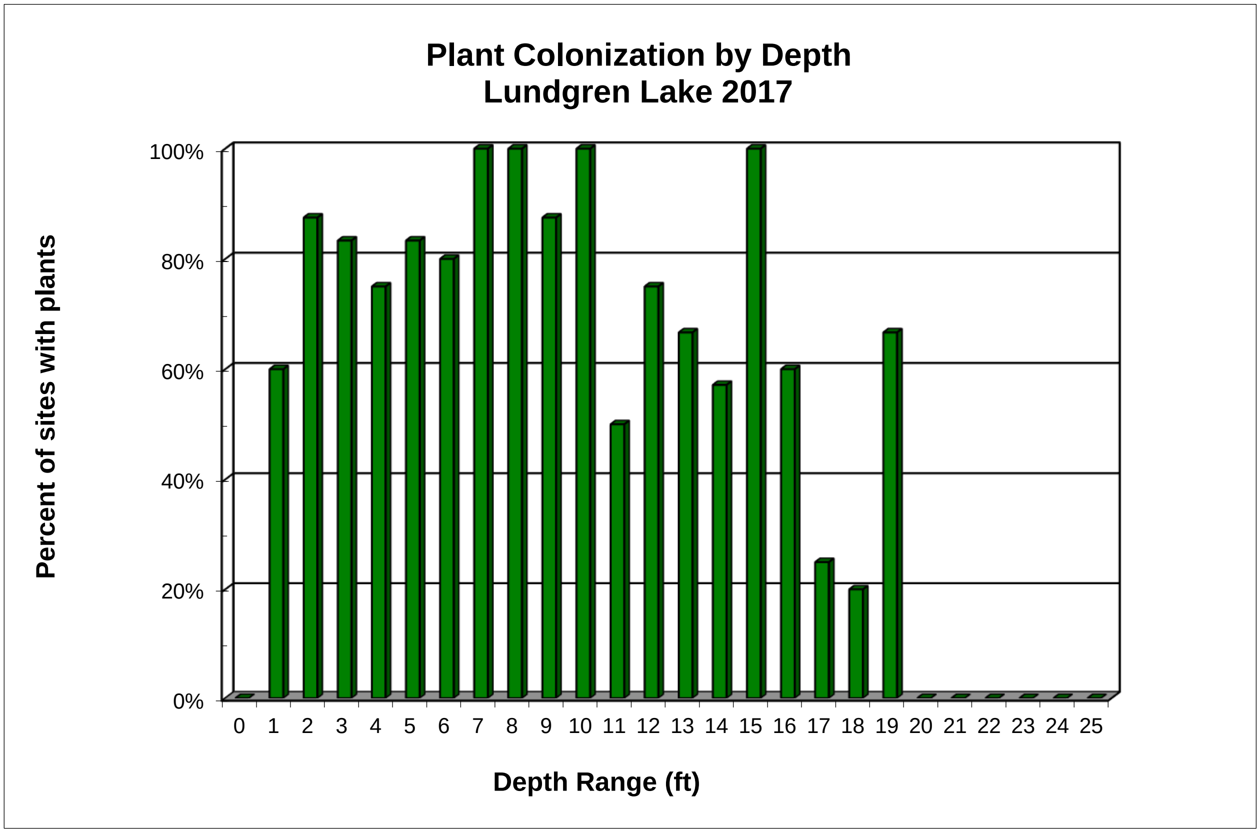

Plant Density by Depth
Lundgren Lake 2015
Average Rake fullness
3
2
1
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth Range (ft)

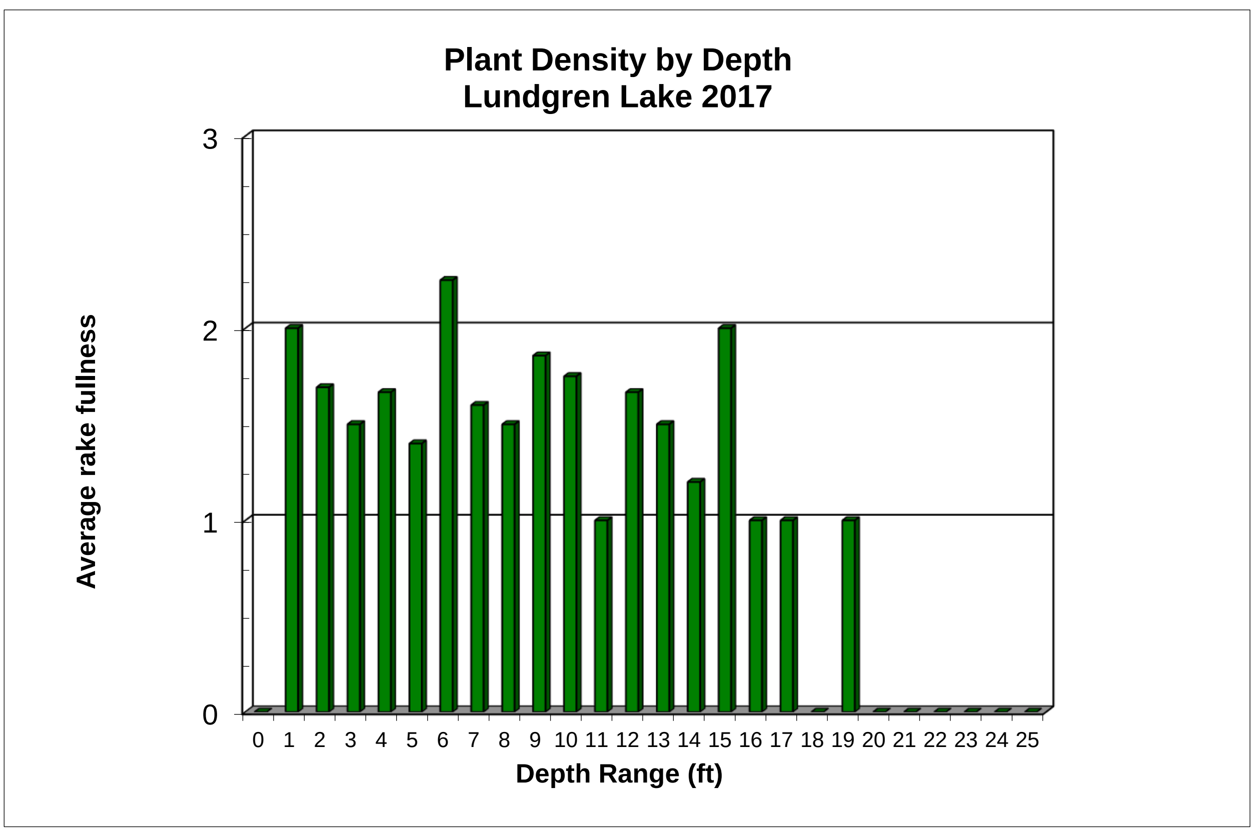

Lundgren Lake
Aquatic Plant Frequency
2016
Species
Chara
Pot. amplifolius
Pot. Graminaeus
Pot. praelongus
Dulcinium arundinacium
Pot. foliosus
Pot. Natans
Scirpus validus
Najas flexilis
Ericaulon aquaticum
Nym. Odorata
67.1
25.9
14.1
10.6
3.5
2.4
2.4
2.4
1.2
1.2
1.2
0
10
20
30
40
50
60
70
80
Frequency (%)

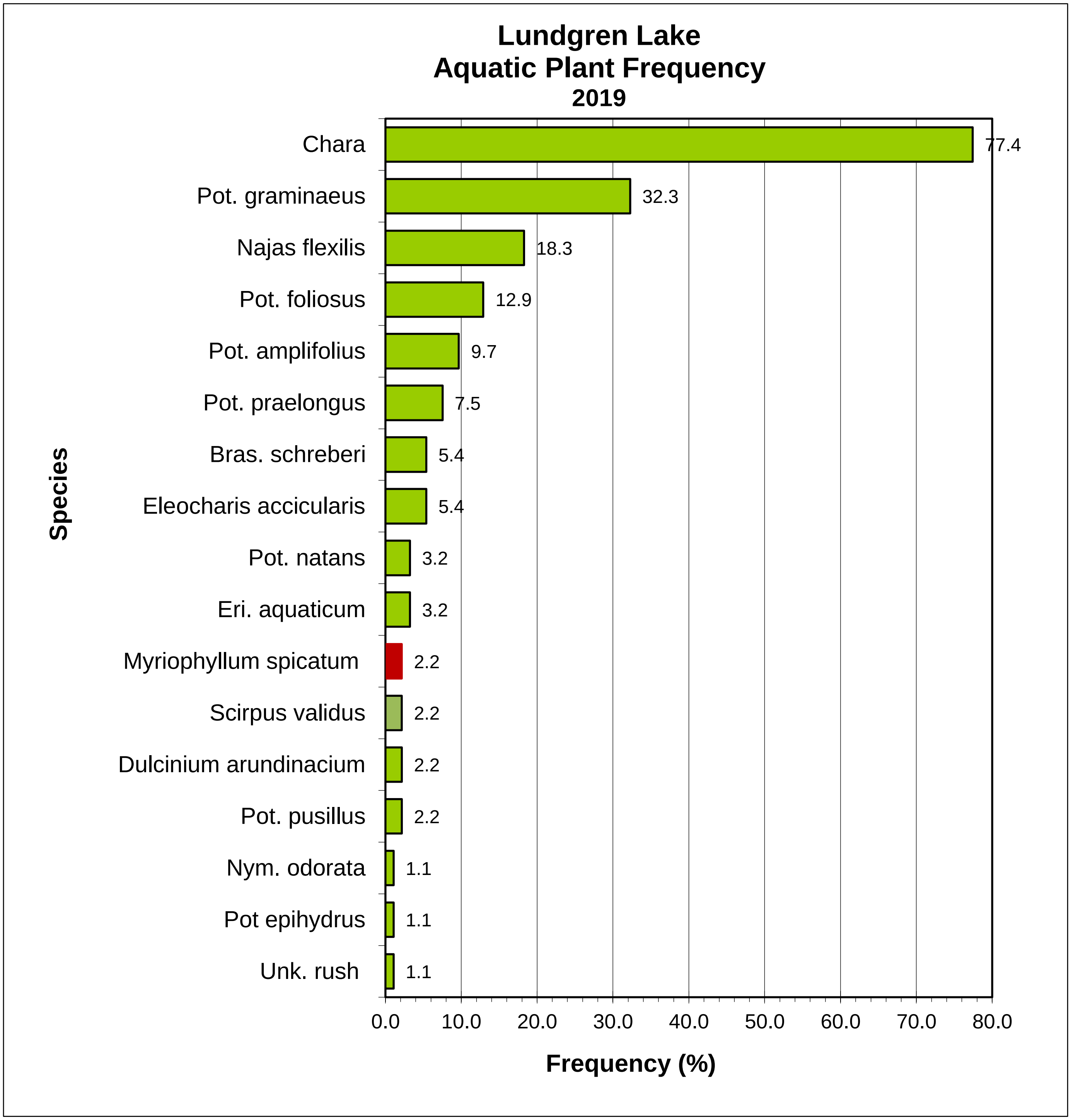

Plant Colonization by Depth
Lundgren Lake 2016
Percent of sites with plants
100%
80%
60%
40%
20%
0%
Depth Range (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

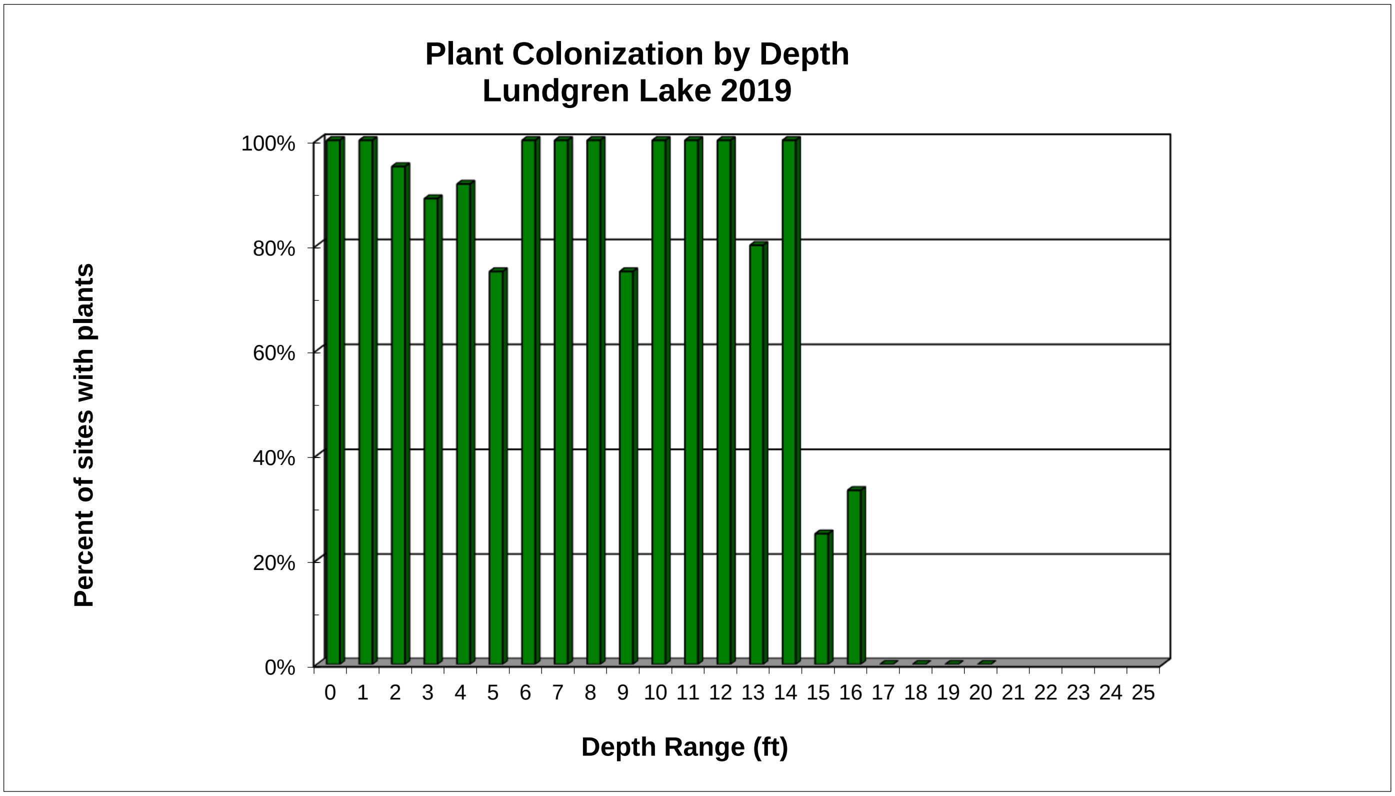

Plant Density by Depth
Lundgren Lake 2016
Average rake fullness
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Depth Range (ft)

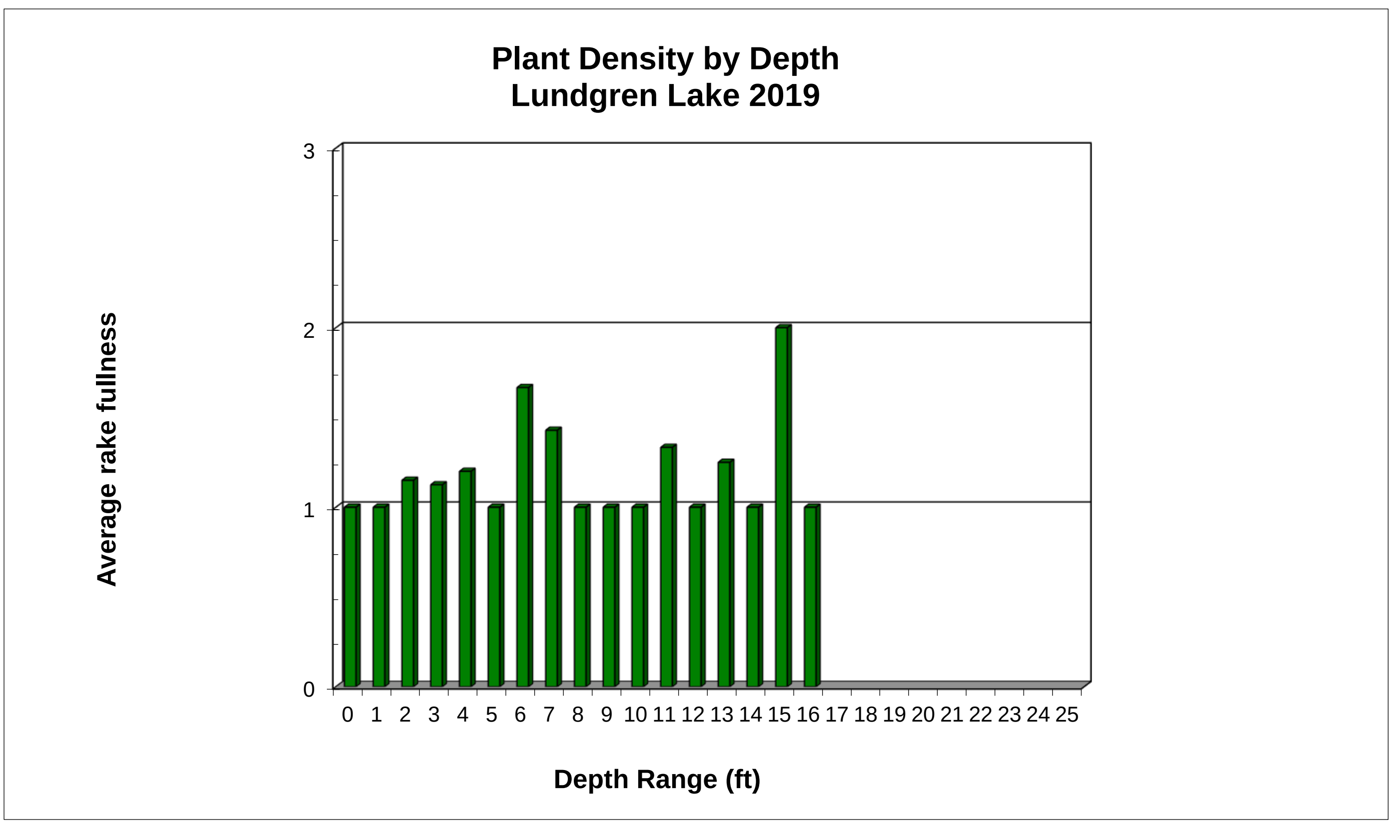

Lundgren Lake
Aquatic Plant Frequency
2017
Species
Chara 59.5
Pot. praelongus 8.6
Pot. Graminaeus 6.9
Najas flexilis 6.0
Scirpus validus 4.3
Pot. amplifolius 3.4
Dulcinium arundinacium 3.4
UNK. Rush 3.4
Pot. foliosus 1.7
Pot. Natans 1.7
Eleocharis accicularis 1.7
Nitella sp 1.7
Bras. Schreberi 0.9
Eri. Aquaticum 0.9
Pot epihydrus 0.9
Potamogeton fresii 0.9
Equisetum fluviatile 0.9
Elodea canadensis 0.9
0 10 20 30 40 50 60 70 80
Frequency (%)


Plant Colonization by Depth
Lundgren Lake 2017
Percent of sites with plants
100%
80%
60%
40%
20%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Depth Range (ft)

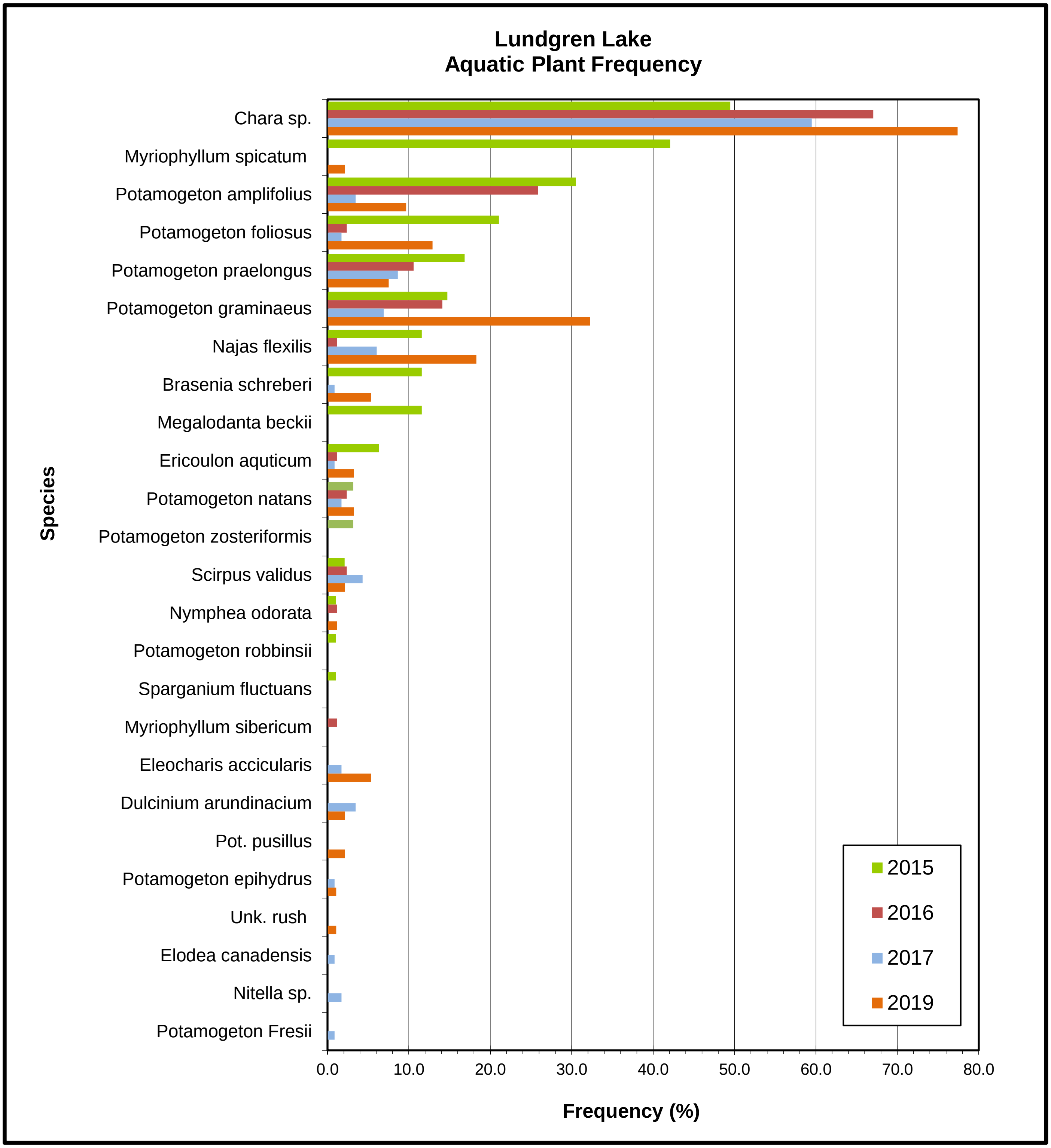

Plant Density by Depth
Lundgren Lake 2017
Average rake fullness
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Depth Range (ft)


Lundgren Lake
Aquatic Plant Frequency
2019
Species
Chara
Pot. graminaeus
Najas flexilis
Pot. foliosus
Pot. amplifolius
Pot. praelongus
Bras. schreberi
Eleocharis accicularis
Pot. natans
Eri. aquaticum
Myriophyllum spicatum
Scirpus validus
Dulcinium arundinacium
Pot. pusillus
Nym. odorata
Pot epihydrus
Unk. rush
77.4
32.3
18.3
12.9
9.7
7.5
5.4
5.4
3.2
3.2
2.2
2.2
2.2
2.2
1.1
1.1
1.1
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Frequency (%)


Plant Colonization by Depth
Lundgren Lake 2019
Percent of sites with plants
100%
80%
60%
40%
20%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Depth Range (ft)


Plant Density by Depth
Lundgren Lake 2019
Average rake fullness
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Depth Range (ft)

		2015	2016	2017	2019
	Sites less than max rooting depth (n) =	95	85	110	93
	Max rooting depth (ft) =	17	17	19	16
	FQI =	26.9	24.0	28.5	26.1
Scientific Name	**Common Name**	**Frequency**	**Frequency**	**Frequency**	**Frequency**
Chara sp.	muskgrass	49.5	67.1	59.5	77.4
Myriophyllum spicatum	Eurasian watermilfoil	42.1			2.2
Potamogeton amplifolius	large-leaf pondweed	30.5	25.9	3.4	9.7
Potamogeton foliosus	leafy pondweed	21.1	2.4	1.7	12.9
Potamogeton praelongus	white-stem pondweed	16.8	10.6	8.6	7.5
Potamogeton graminaeus	variable-leaf pondweed	14.7	14.1	6.9	32.3
Najas flexilis	bushy pondweed	11.6	1.2	6.0	18.3
Brasenia schreberi	watershield	11.6		0.9	5.4
Megalodanta beckii	water marigold	11.6			
Ericoulon aquticum	pipewort	6.3	1.2	0.9	3.2
Potamogeton natans	floating-leaf pondweed	3.2	2.4	1.7	3.2
Potamogeton zosteriformis	flat-stem pondweed	3.2			
Scirpus validus	soft-stem bulrush	2.1	2.4	4.3	2.2
Nymphea odorata	white water lily	1.1	1.2		1.2
Potamogeton robbinsii	fern-leaf pondweed	1.1			
Sparganium fluctuans	floating-leaf bur-reed	1.1			
Myriophyllum sibericum	Northern watermilfoil	0.0	1.2		
Eleocharis accicularis	needle spikerush			1.7	5.4
Dulcinium arundinacium	three way sedge			3.4	2.2
Pot. pusillus	Small pondweed				2.2
Potamogeton epihydrus	ribbon leaf pondweed			0.9	1.1
Unk. rush	unk. Rush				1.1
Elodea canadensis	common Waterweed			0.9	
Nitella sp.	stoneworts			1.7	
Potamogeton Fresii	fries pondweed			0.9	



Lundgren Lake
Aquatic Plant Frequency
Species
Chara sp.
Myriophyllum spicatum
Potamogeton amplifolius
Potamogeton foliosus
Potamogeton praelongus
Potamogeton graminaeus
Najas flexilis
Brasenia schreberi
Megalodanta beckii
Ericoulon aqutcum
Potamogeton natans
Potamogeton zosteriformis
Scirpus validus
Nymphea odorata
Potamogeton robbinsii
Sparganium fluctuans
Myriophyllum sibericum
Eleocharis accicularis
Dulcinium arundinacium
Pot. pusillus
Potamogeton epihydrus
Unk. rush
Elodea canadensis
Nitella sp.
Potamogeton Fresii
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Frequency (%)
2015
2016
2017
2019

Lundgren Lake

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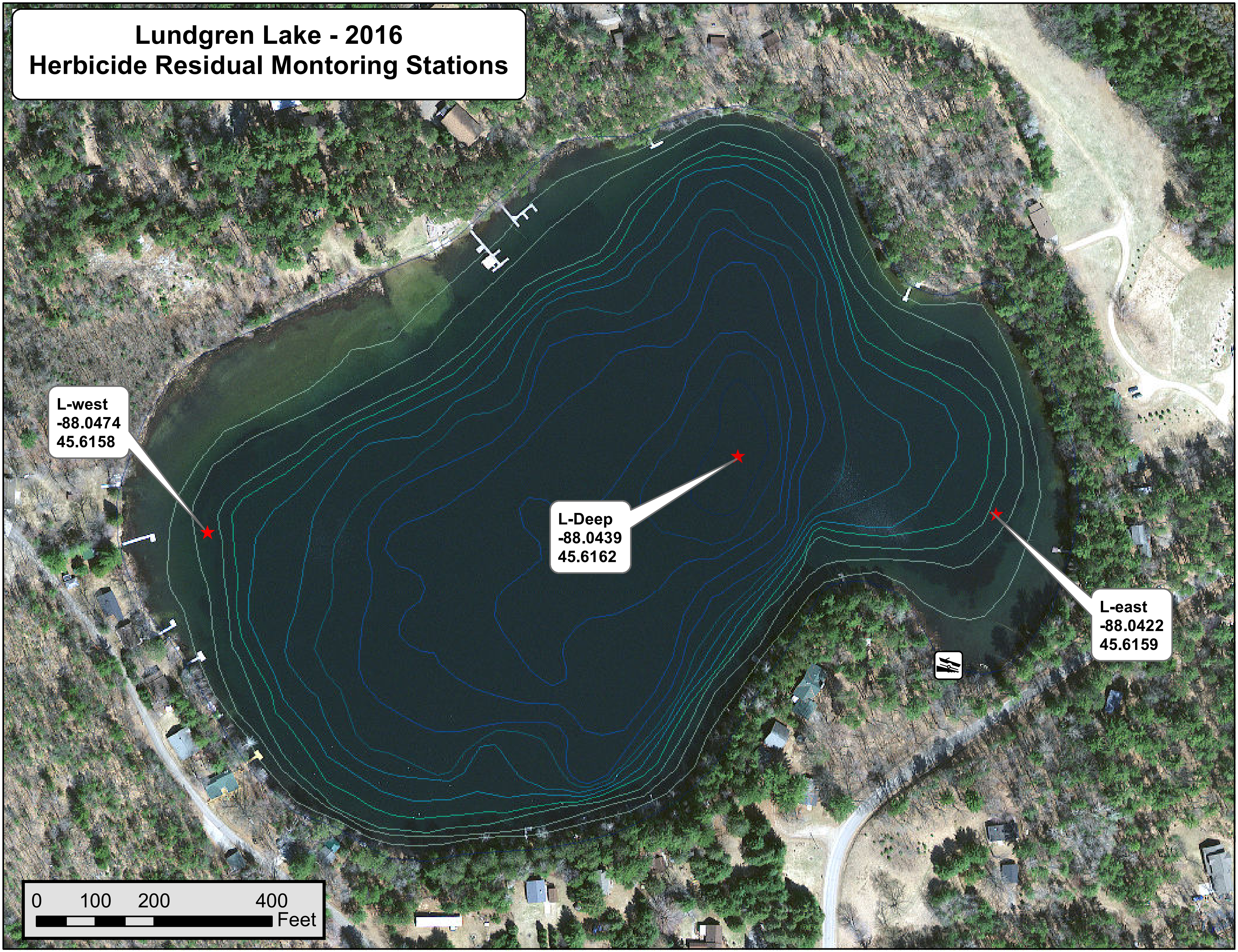
Appendix B

Herbicide Residual Monitoring Data
&
Graphs

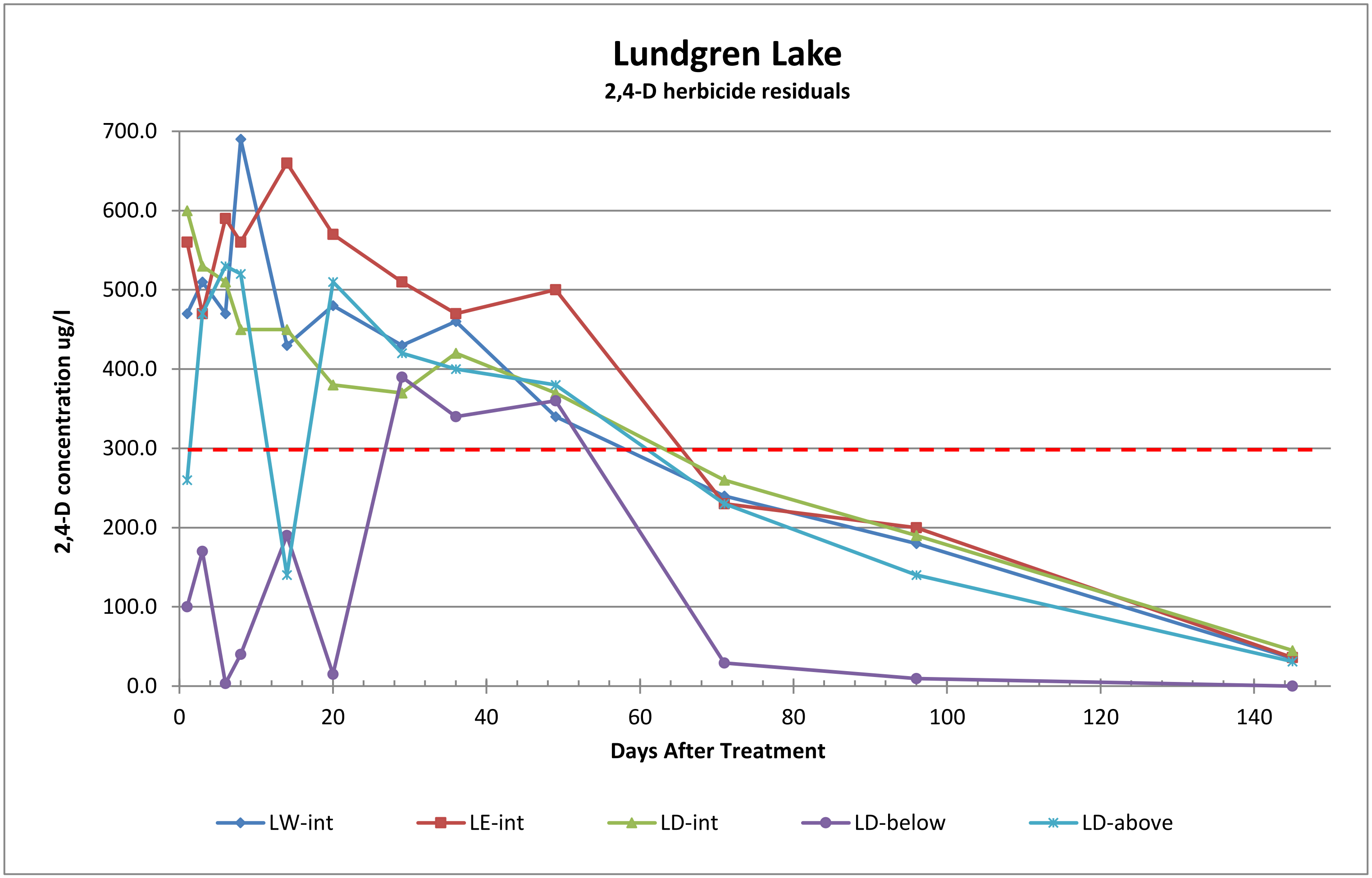


Lundgren Lake - 2016
Herbicide Residual Montoring Stations
L-west
-88.0474
45.6158
L-Deep
-88.0439
45.6162
L-east
-88.0422
45.6159
0
100
200
400
Feet

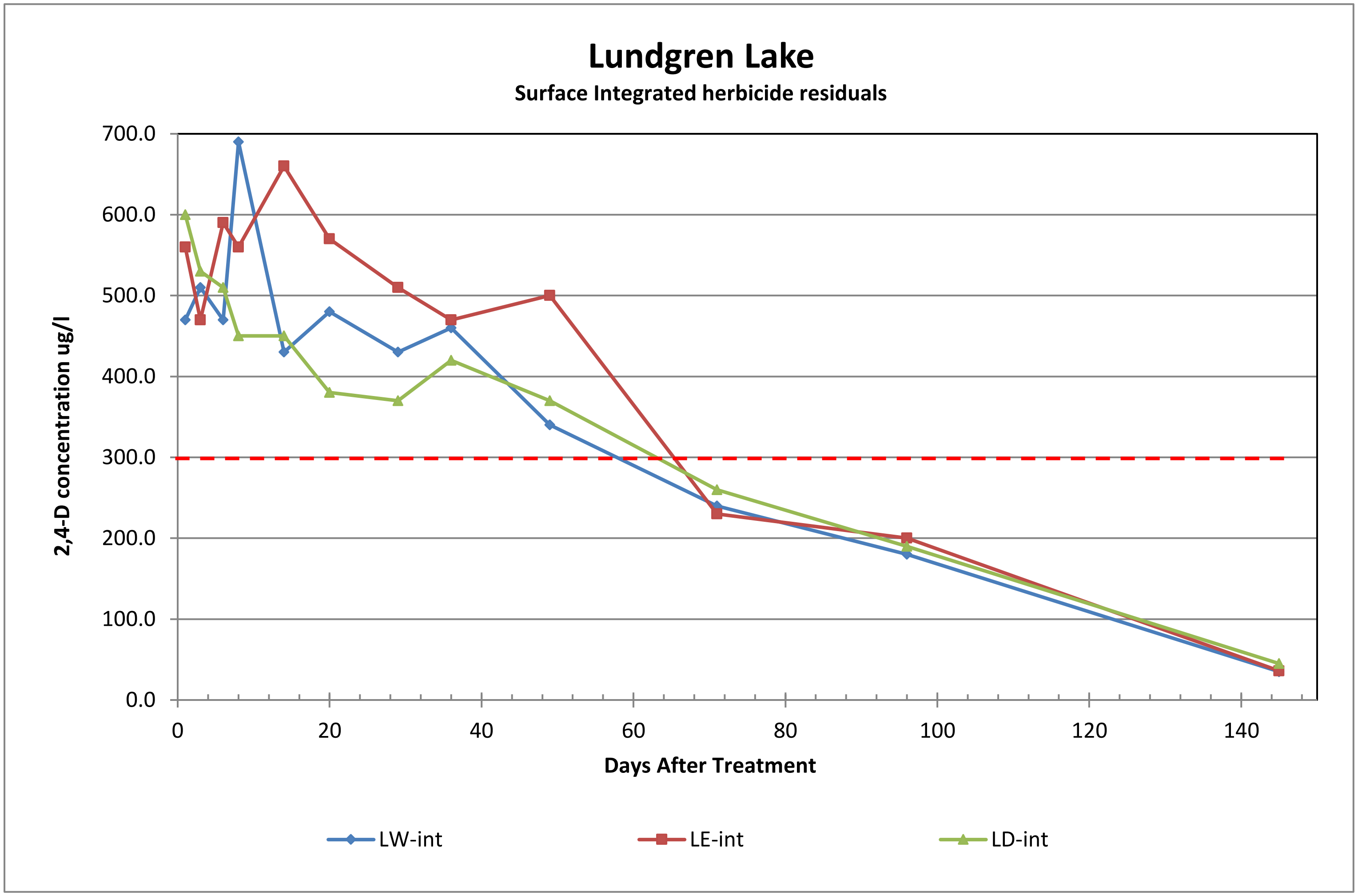
Lundgren Lake Herbicide Residuals 2016

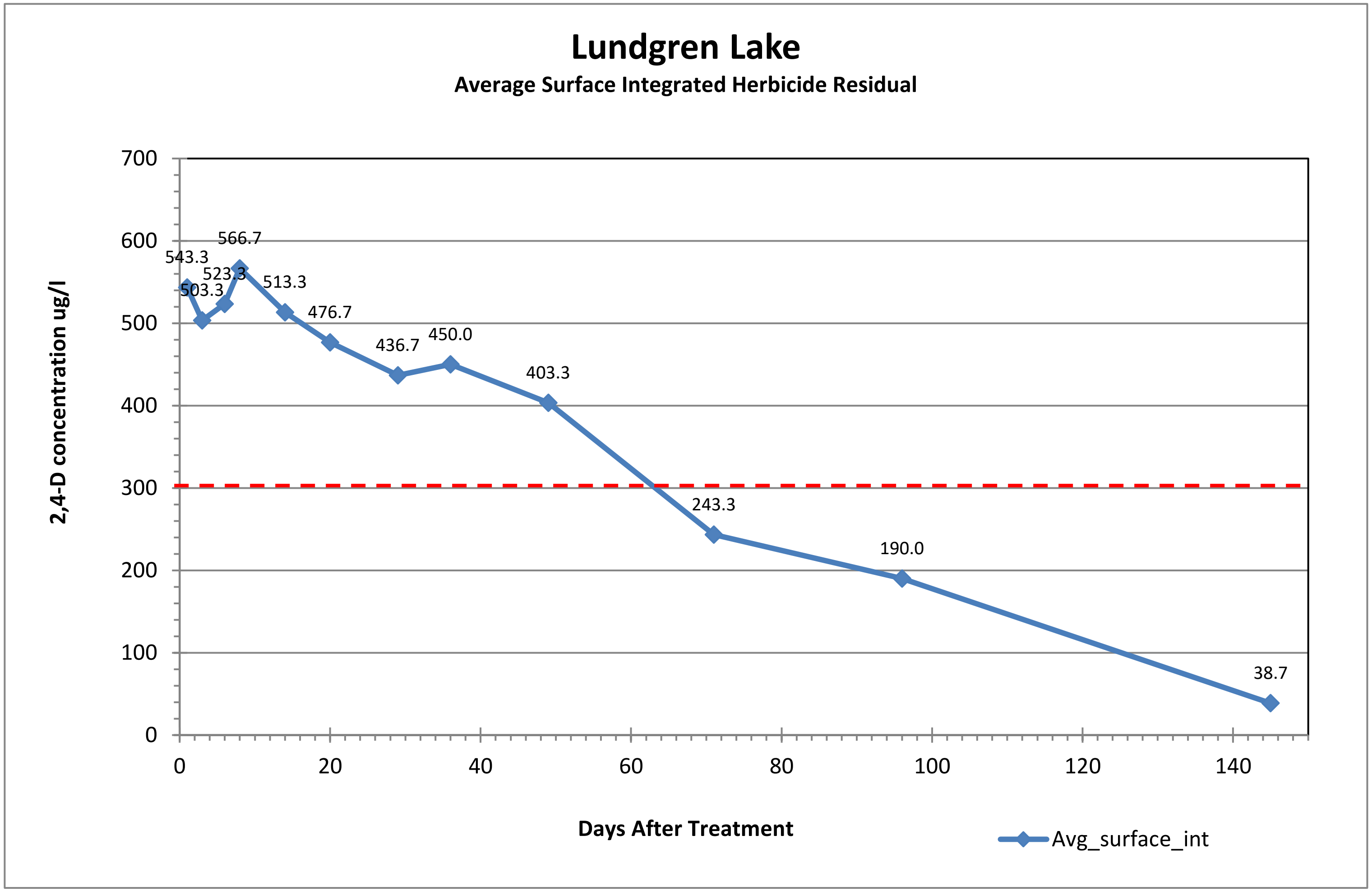
Ug/l 2,4-D

Date	DAT	LW-int	LE-int	LD-int	LD-above	LD-below	Avg_surface_int
5/4/2016	1	470.0	560.0	600.0	260.0	100.0	543.3
5/6/2016	3	510.0	470.0	530.0	470.0	170.0	503.3
5/9/2016	6	470.0	590.0	510.0	530.0	3.3	523.3
5/11/2016	8	690.0	560.0	450.0	520.0	40.0	566.7
5/17/2016	14	430.0	660.0	450.0	140.0	190.0	513.3
5/23/2016	20	480.0	570.0	380.0	510.0	15.0	476.7
6/1/2016	29	430.0	510.0	370.0	420.0	390.0	436.7
6/8/2016	36	460.0	470.0	420.0	400.0	340.0	450.0
6/21/2016	49	340.0	500.0	370.0	380.0	360.0	403.3
7/13/2016	71	240.0	230.0	260.0	230.0	29.0	243.3
8/8/2016	96	180.0	200.0	190.0	140.0	9.6	190.0
9/26/2016	145	35.0	36.0	45.0	31.0	ND	38.7



Lundgren Lake
2,4-D herbicide residuals
2,4-D concentration ug/l
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0
20
40
60
80
100
120
140
Days After Treatment
LW-int
LE-int
LD-int
LD-below
LD-above


Lundgren Lake
Surface Integrated herbicide residuals
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
2,4-D concentration ug/l
0
20
40
60
80
100
120
140
Days After Treatment
LW-int
LE-int
LD-int



Lundgren Lake
Average Surface Integrated Herbicide Residual
2,4-D concentration ug/l
Days After Treatment
Avg_surface_int
543.3
503.3
523.3
566.7
513.3
476.7
436.7
450.0
403.3
243.3
190.0
38.7
0
100
200
300
400
500
600
700
0
20
40
60
80
100
120
140