Invasive Ogopogo in Okanagan Lake, British Columbia, Canada *(source: CBC radio website)*

Aquatic Invasive Species Action Plan for Birch Lake, Ramsey County, Minnesota

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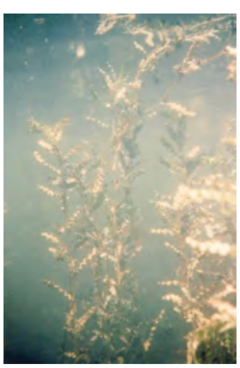
Overview of aquatic invasive species that could impact Birch Lake are listed below. As of 2015, Eurasian watermilfoil was the only non-native species known to be present in Birch Lake.

Species	Lake Status	Potential for Growth in Birch Lake	Management Action	
			Short Term	Long Term
Species of Interest				
1. Cylindro (blue-green algae)	Unknown	Low	Monitoring	Reduce phosphorus loading
2. Curlyleaf pondweed	May be present in Birch	Moderate to high	Annual delineation	Selective treatment for heavy growth
3. Eurasian watermilfoil	Present in Birch	Moderate to high	Annual surveys by consultant or residents	Selective treatment for heavy growth
4. Zebra mussels	Not present in Birch, but present in White Bear Lake, Wash Co	Low	Mussel monitoring devices for early detection	Contingency funds for aggressive rapid response
5. Common carp	Not present in Birch	Low to moderate	Inform and educate	Inform and educate
Species to Watch				
Flowering rush	Not present in Birch	Moderate	Annual surveys	Selective treatment
Purple loosestrife	Not present in Birch	Fair	Annual surveys by residents	Spot control and use beetles for large area control
Hydrilla	Not present in Birch	Low to moderate	MnDNR will take the lead	Ongoing control
Rusty crayfish	Not present in Birch	Fair to moderate	Crayfish traps for early detection	Use fish to control rusty crayfish
Chinese and Banded Mystery snail	May be present in Birch	Low	Inform and educate	Small-scale removal techniques, if needed
Spiny waterflea	Not present in Birch	Moderate to high	Inform and educate	Natural fish predation
Faucet snail	Not present in Birch	Moderate to high	Inform and educate	Removal if practical
Asian carp	Not present in Birch	Low	Inform and educate	
Snakehead	Not present in Birch	Moderate	Inform and educate	



Curlyleaf Pondweed

Eurasian Watermilfoil

Zebra Mussel

Five Aquatic Invasive Species of Interest

1. Blue-green Algae (Cylindro)

Figure S1. Sediment P-release potential with the possibility to produce excessive phosphorus loading in Birch Lake that could produce blue-green algae and Cylindro blooms.
Key: Green = low potential.

An invasive blue-green algae, *Cylindrospermopsis sp*, referred to as Cylindro, is spreading around the United States since it was observed in the early 2000s. Cylindro is typically found in lakes with low Secchi disc transparencies and high phosphorus concentrations. Birch Lake currently does not have these characteristics. Cylindro has not been identified in Birch Lake. Cylindro is known to produce toxins that at high concentrations could be harmful to other aquatic life.

Action Plan: Currently, Birch Lake phosphorus concentrations are moderate and conditions are not be favorable to abundant Cylindro growth. Two sources of phosphorus to Birch Lake come from watershed loading and internal phosphorus loading. A variety of factors contribute to internal phosphorus loading in lakes. Research by Jensen et al (1992) found when a total iron to total phosphorus ratio was greater than 15 to 1, phosphorus release from lake sediments was minor. That benchmark of 15:1 has been used to characterize the potential of Birch Lake sediments to release phosphorus. Results of the sediment survey for Birch Lake show all sediment sites have a high Fe:P ratio and that phosphorus release from lake sediments is predicted to be low. Ongoing watershed management to control excessive phosphorus inputs will prevent lake phosphorus concentrations from increasing (Figure S1).

2. Curlyleaf Pondweed

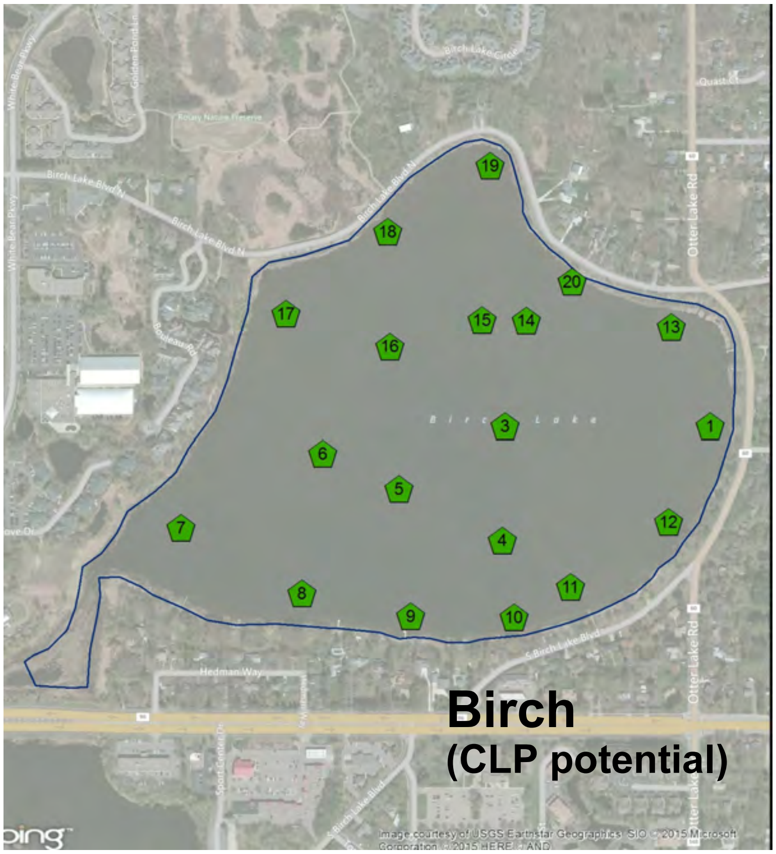


Figure S2. Curlyleaf potential growth based on lake sediment analyses.
Key: Green = light growth.

Curlyleaf pondweed may be present in Birch Lake and if it is, curlyleaf is scarce. Research has found curlyleaf is limited or enhanced based on lake sediment characteristics. Curlyleaf does best in sediments with a high pH and low iron content (McComas, unpublished). If lake sediments are conducive to curlyleaf growth, curlyleaf will continue to grow on an annual basis. It is predicted that curlyleaf could to grow in some areas, but at mostly light densities. If treatment is considered in the future, the latest research indicates the use of herbicides produce annual control but not long-term control.

Action Plan: Ongoing curlyleaf activities would center around plant surveys and potential curlyleaf management. The use of herbicides produce annual control, but long-term control (where treatments could be discontinued in the future) has not been observed (McComas et al. 2015). Therefore annual treatments for curlyleaf control could be considered.

Based on lake sediment surveys, it is predicted curlyleaf can grow in a number of areas around Birch Lake although growth would be limited in most years and treatment would not likely be needed.

3. Eurasian Watermilfoil

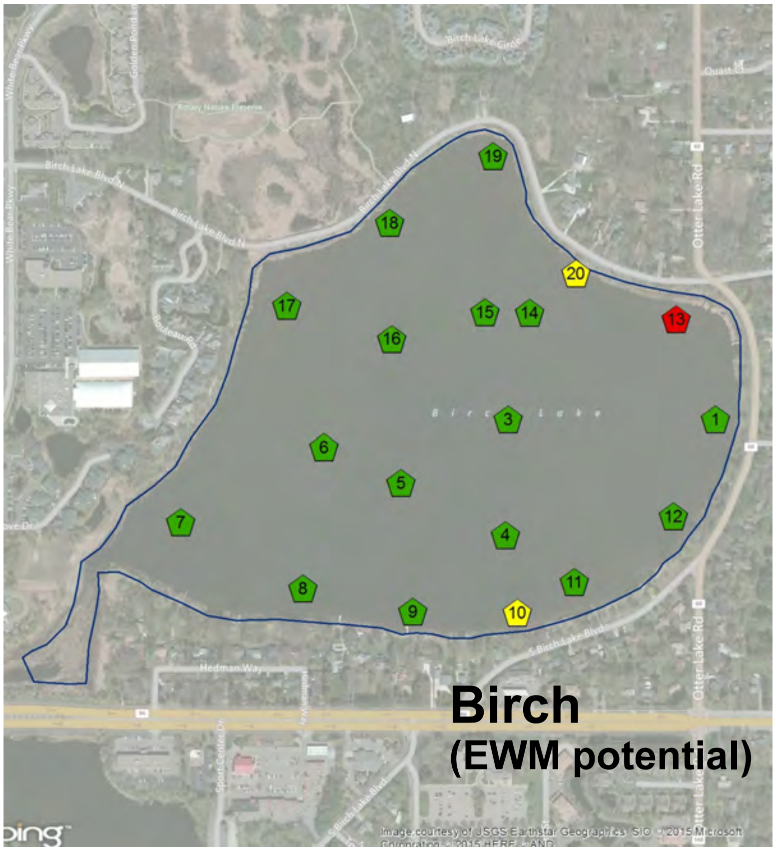


Figure S3. Eurasian watermilfoil potential growth based on lake sediment analyses. Key: Green = light growth, yellow = moderate growth, red = heavy growth.

Eurasian watermilfoil was first found in Birch Lake in 2015. The potential for milfoil growth, based on lake sediment sampling predicts mostly light to moderate growth with potential for heavy growth at Site 13 near the east end of Birch Lake. Heavy milfoil growth has been correlated with high sediment nitrogen condition and Birch Lake has mostly low to moderate nitrogen conditions. For Birch Lake, it is estimated the plants have the potential to grow down to the bottom, resulting in widespread milfoil growth. However, results of the sediment survey indicate that most growth would be light.

Action Plan: Eurasian watermilfoil is present in Birch Lake. Ongoing annual scouting activities are recommended. Lake sediment analysis indicates the potential for mostly light milfoil growth over much of the lake. At the present time the Secchi transparency would allow growth to water depths of 6 feet which is the bottom.

4. Zebra Mussel

Figure S4. Zebra mussel potential growth based on water column and substrate characteristics. Key: Green = light growth, yellow = moderate growth, blue = no growth.

Zebra mussels have not been found in Birch Lake as of 2015. A review of water column and substrate characteristics was used to evaluate the potential for zebra mussel growth. It appears that zebra mussel growth would be limited in Birch Lake due to the low calcium concentration found in the lake. A close cousin to the zebra mussel, the quagga mussel, has similar growth requirements and may actually be able to survive and propagate under more harsh conditions than zebra mussels. No quagga mussels have been reported in Ramsey County as of 2015.

Action Plan: Zebra mussels have not been found in Birch Lake as of 2015. Early detection activities are recommended through the growing season. If zebra mussels are detected, a rapid response plan includes a rapid response assessment. Because zebra mussel growth would likely be light, a rapid response treatment action is not a high priority. However, an action plan should be formulated and procedures should be outlined to prepare for future actions, if needed.

Under the right circumstances and depending on volunteer participation, costs would range from $5,000 to $30,000 if an eradication attempt was considered. Discussions with the MnDNR should be held prior to zebra mussel detection in Birch Lake to outline control activities and the need for potential permits.

5. Common Carp

Figure S5. Common carp potential spawning habitat quality. Green circles indicate marginal carp spawning sites in off-lake stream, wetland, and pond habitats.

Common carp may be present in Birch Lake, but at a low density and have not been observed in fish surveys in 2011 and 2014 by Blue Water Science and sponsored by the Birch Lake Improvement District. Birch Lake habitat suitability for future carp growth is low due to spawning conditions that may not be well suited for survival of young fish. Carp spawning success and population expansion is limited when carp are confined to spawning within a lake. Usually predator fish will control the carp eggs and fry. Carp populations do best when there are shallow, off-lake spawning sites where fish predators would be low and thus allow the young carp to grow up to a size where predation is unlikely. It appears that the Birch Lake off-lake spawning habitat is not favorable to successful carp spawning and this may limit the Birch Lake carp population.

Action Plan: Carp may be present in Birch Lake, but they would be low in numbers. If carp abundance increases, aquatic plant coverage would likely decrease. As of 2015, no carp management is necessary, rather monitoring should be ongoing.

Summary of Environmental Risk Assessments for Five Aquatic Invasive Species for Birch Lake, Ramsey County, Minnesota

Two primary factors are used to define environmental risk assessment for aquatic invasive species: 1) the likelihood of establishment and 2) the consequences if they do become established. The likelihood of introduction and establishment is based on the distance to the nearest AIS population, the activity at the public access, and the suitability of Birch Lake for supporting a new AIS population. The preceding pages outlined the growth potential for five AIS of interest. Typically if an AIS has the potential for heavy growth, the recreational and ecological consequences could be significant.

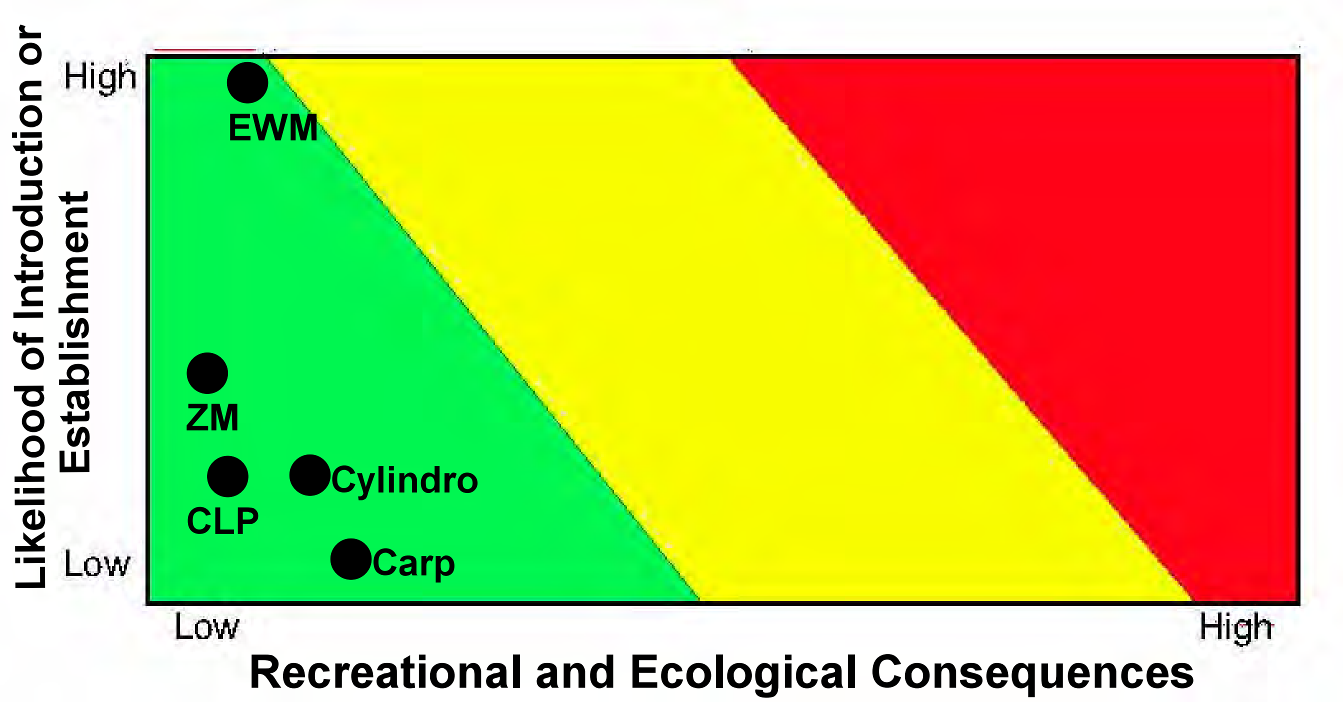


Figure S6. Based on available information, an environmental risk assessment (ERA) chart was prepared for six aquatic invasive species of interest for Birch Lake.

Key:

Cylindro: *Cylindrospermopsis*, a blue-green algae species, will not reach high densities in Birch Lake due to low nutrient conditions. Its introduction may be limited, since there are few tributary inflows. Consequences would be low.

CLP: Curlyleaf pondweed may be in Birch Lake but has not been observed in recent plant surveys. Lake sediment analysis indicates curlyleaf has a light growth potential resulting in moderate to high consequences.

EWM: Eurasian watermilfoil is already established in Birch Lake. Sediments indicate a potential to support mostly light growth.

ZM: Zebra mussels are in White Bear Lake, within 5 miles of Birch Lake. If zebra mussels are introduced, they are predicted to produce mostly light growth due to shell production factors which are based, in part, on calcium. Lake calcium concentrations are low.

Carp: Carp are in Ramsey County and have likely been introduced in Birch Lake in the past. Conditions are not good for establishing an abundant carp population. If conditions were favorable, carp would probably be fairly abundant at this time. It appears spawning and recruitment conditions are not favorable.

Aquatic Invasive Species Action Plan for Birch Lake, Ramsey County, Minnesota

Introduction

Birch Lake is a 123 acre lake (source: MnDNR) in Ramsey County. The objective of this report was to evaluate the potential for ecological and recreational problems that might develop in Birch Lake associated with non-native aquatic invasive species. The aquatic invasive species evaluated include the following:

Species of Interest:

1. Blue-green algae (*Cylindrospermopsis sp*)
2. Curlyleaf pondweed (not present in Birch Lake).
3. Eurasian watermilfoil (present in Birch Lake).
4. Zebra mussel (not present in Birch Lake).
5. Common carp (not present in Birch Lake).

Species to Watch (not present in Birch Lake unless noted):

Plants

Flowering Rush
Purple Loosestrife
Hydrilla

Invertebrates

Rusty Crayfish
Chinese and Banded Mystery Snail (may be present in Birch Lake)
Faucet Snail
Quagga Mussels

Fish

Asian carp (Bighead and Silver Carps)
Viral Hemorrhagic Septicemia (VHS)(fish virus)

Components that Were Evaluated for Each Species

- Status of species in lake: present or absent
- Potential for growth and colonization based on lake conditions and lake sediments
- Management options

Methods Used to Collect Information for AIS Evaluations

Water Quality: Birch Lake is located in the Vadnais Lake Area Water Management Organization (Figure 1). To assist in evaluating the growth potential of various AIS, water quality data were obtained from existing reports or collected in this study. Water quality data was used to evaluate growth potential of algae and zebra mussels. Aerial maps from Google Earth and Bing were used to determine potential carp spawning sites.

Lake Sediments: Lake sediments were collected in this study to evaluate growth potential of various AIS based on sediment characteristics. In Birch Lake, 20 lake sediment samples were collected on March 11, 2008. Sediment samples were analyzed at the University of Minnesota Soil Testing and Research Analytical Laboratory. Additional information on soil testing methods is found in Appendix A. The full soil testing results are found in Appendix B. Specific parameters from the suite of parameters were used to evaluate the growth potential for algae, curlyleaf pondweed, and Eurasian watermilfoil.

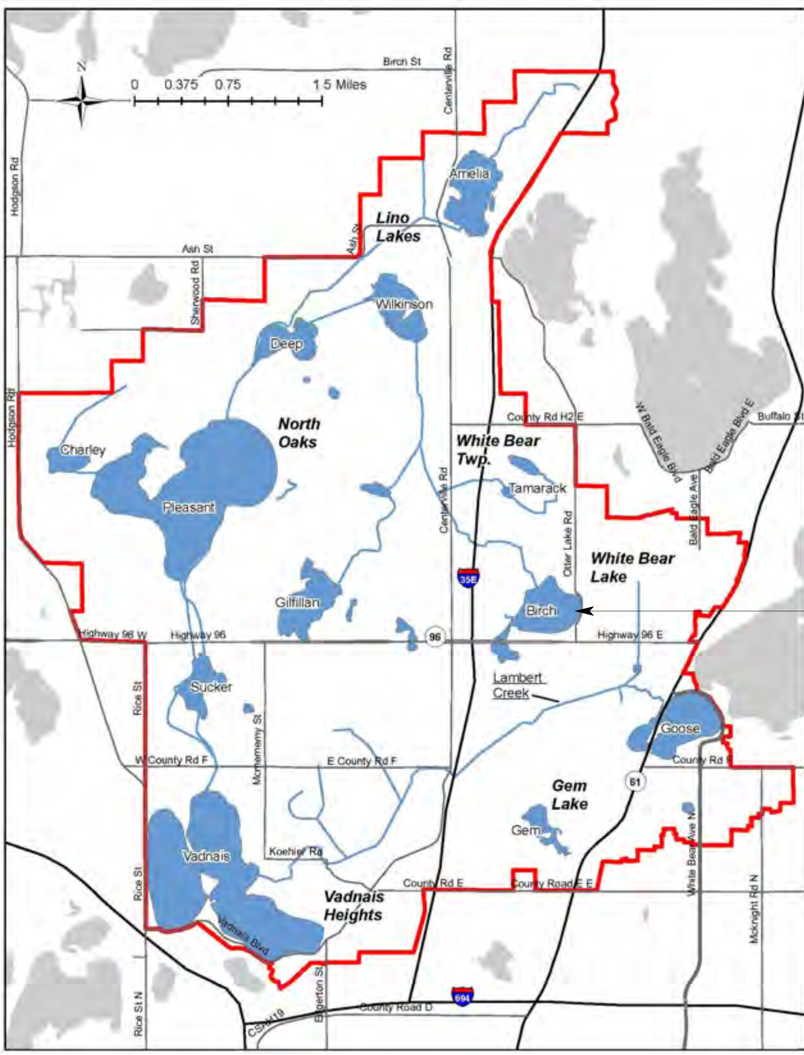


Figure 1. Vadnais Lake Area Water Management Organization located in Ramsey and Anoka Counties.

1. Blue-green Algae (*Cylindrospermopsis sp*)

Birch Lake Status: Unknown for Birch Lake.

Nearest Occurrence: Lake Nokomis, Minneapolis, MN

Potential for Bloom Conditions in Birch Lake: The potential is low, as long as the nutrient concentrations remain low.

Cylindro (*Cylindrospermopsis raciborskii*)(Figure 2) is a relatively new invasive blue-green algae found in Minnesota. Just as other blue-green algal species sometimes produce a toxic strain, some strains of cylindro may produce a toxin called cylindrospermopsin.

When cylindro is a problem it is generally associated with eutrophic conditions. Work in Indiana correlated high densities of cylindro with shallow lakes (maximum depth of 28 feet or less), a low Secchi transparency (average 2.3 feet), and high total phosphorus concentrations averaging 81 ppb (Jones and Sauter 2005). As of 2015, because of moderate nutrient concentrations, conditions are not favorable in Birch Lake for blue-green growth including cylindro (Table 1).

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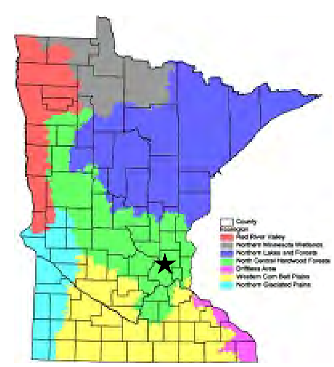
Figure 2. Cylindro is a filamentous blue-green algae.

Table 1. Lake water quality impaired criteria for the North Central Hardwood Birch Ecoregion and recent water quality conditions for Birch Lake.

	Shallow Lake (MPCA impaired criteria for North Central Hardwood Birch Ecoregion)	Values for Birch Lake (MPCA site) (2014)
Secchi Disc (ft & m) (water clarity)	<3.3 ft (1.0 m)	5.6 ft 1.7 m
Total Phosphorus (fertilizer nutrient)	>60 ppb	26 ppb
Chlorophyll a (measure of algae)	>20 ppb	2.6 ppb



Birch Lake is located in the North Central Hardwood Birch Ecoregion. Unimpaired shallow lakes in this ecoergion have water clarity greater than 3.3 feet.

Cylindro Growth Potential Based on Lake Sediment Nutrient Loading: Factors that contribute to elevated lake phosphorus concentrations could lead to high concentrations of cylindro. A variety of factors contribute to elevated phosphorus levels in lakes and internal loading, including phosphorus release from lake sediments, can be a significant factor. Research by Jensen et al (1992) found when a total iron to total phosphorus ratio was greater than 15 to 1, phosphorus release from lake sediments was minor. The ratio for the soil test results have been used in this report as well. That benchmark of 15:1 has been used to characterize the potential of Birch Lake sediments to release phosphorus. If the Fe:P ratio is greater than 15:1, p-release was considered to be low. If the Fe:P ratio was 7.5 to 15, p-release was considered to be moderate and if the Fe:P ratio was less than 7.5, p-release was considered to be high.

A second factor was also considered. If available phosphorus, as determined by Bray-P or Olsen-P, was 3 ppm or less, p-release was considered to be minor, regardless of the Fe:P ratio (derived from Nurnberg 1988).

Results for Birch Lake show all sediment sites have a high Fe:P ratio which is correlated to low potential phosphorus release from sediments (Table 2). Overall p-release should be minor in Birch Lake.

Table 2. Lake sediment data for iron and phosphorus and the calculated Fe to P ratio. Samples were collected on October 19, 2012.

Sample Number	Depth (ft)	Iron (ppm)	Bray-P (ppm)	Olsen-P (ppm)	Fe/P
B1	4	85	2	1	42.5
B3	5	153	4	2	38.3
B4	5	176	1	1	176.0
B5	5	91	3	1	30.3
B6	5	138	4	1	34.5
B7	5	158	3	0	52.7
B8	4.5	149	3	1	49.7
B9	4	33	3	1	11.0
B10	3	76	3	1	25.3
B11	4	88	5	1	17.6
B12	4	126	4	1	31.5
B13	3	153	4	2	38.3
B14	5	208	3	1	69.3
B15	5	151	3	1	50.3
B16	5	129	2	1	64.5
B17	4.5	97	4	1	24.3
B18	4.5	155	3	1	51.7
B19	4	157	4	1	39.3
B20	4	111	4	1	27.8

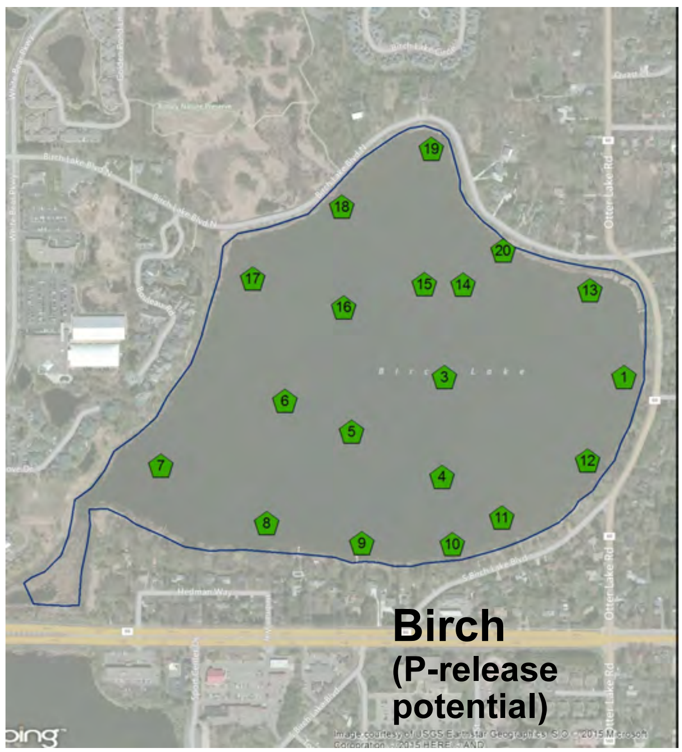


Figure 3. Sediment sample locations are shown with a circle. The color indicates the potential for phosphorus release from the sediments to occur at that site.
Key: green = low potential.

Management Options for Blue-Green Algae

Scouting Activities: Very little information on algal species distribution in Ramsey County is available. Occasional sampling in Birch Lake on a monthly basis from June through September would be one way to evaluate the presence of cylindro as well as other algal species.

Rapid Response: A rapid response plan is not necessary, rather long-term plans to maintain phosphorus at reasonable levels, which in turn reduces excessive algal growth, is a sound management approach.

Control Options: To reduce the potential for excessive algal growth in Birch Lake, phosphorus reduction programs should be maintained. Best management practices in the watershed and in-lake treatments to control phosphorus release from lake sediments would help reduce lake phosphorus concentrations (Figure 4).

Figure 4. Lake alum treatments to inactivate lake sediment phosphorus is one approach to reduce lake phosphorus concentrations. At this time, sediment phosphorus release in Birch Lake is low. An alum treatment is unnecessary at this time.

2. Curlyleaf Pondweed (non-native aquatic plant)

Birch Lake Status: May be present in Birch Lake.

Growth Potential in Birch Lake: Light growth potential is predicted.

Lake sediment sampling results from 2008 have been used to predict lake bottom areas that have the potential to support heavy curlyleaf pondweed plant growth. Various types of curlyleaf growth patterns are shown in Figures 4 and 5. Based on the key sediment parameters of pH, sediment bulk density, organic matter, and the Fe:Mn ratio (McComas, 2015), the predicted growth characteristics of curlyleaf pondweed in Birch Lake are shown in Table 3 and Figure 6.

Curlyleaf pondweed growth is predicted to produce primarily light growth Birch Lake (Figure 6).

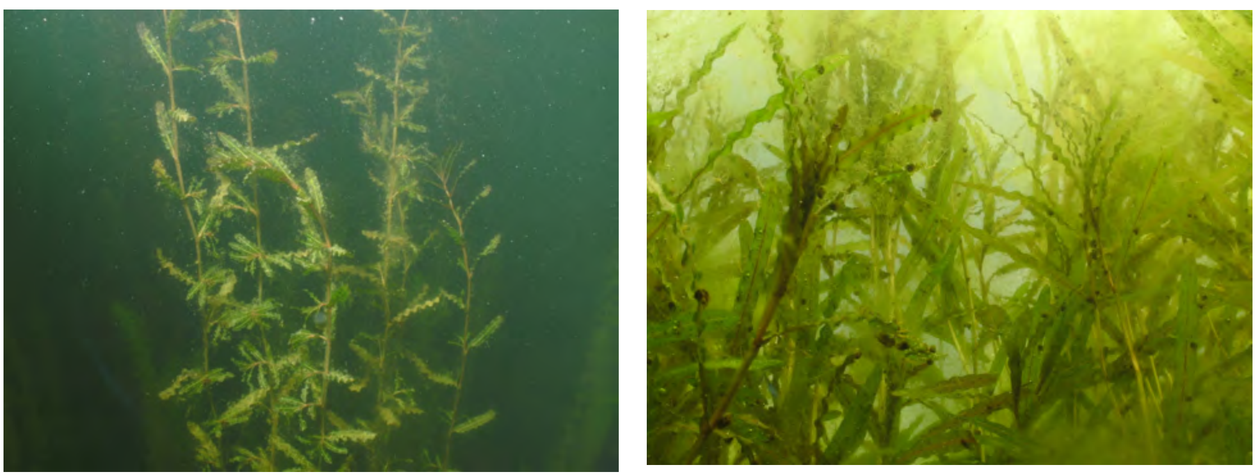


Figure 5. Underwater views of curlyleaf pondweed. Light growth (left) and moderate growth (right).

Examples of Curlyleaf Pondweed Growth Characteristics

Figure 6. Light growth (left) refers to non-nuisance growth that is mostly below the surface and is not a recreational or ecological problem. Moderate growth (middle) refers to growth that is just below the water surface. Heavy growth (right) refers to nuisance matting curlyleaf pondweed. This is the kind of nuisance growth predicted by high sediment pH and a sediment bulk density less than 0.51.

Curlyleaf Pondweed Growth Potential Based on Lake Sediments: Curlyleaf pondweed has not been observed in recent aquatic plant surveys. Research has found curlyleaf is limited or enhanced based on lake sediment characteristics. Curlyleaf does best in sediments with a high pH and low iron content (McComas, unpublished). Based on lake sediment characteristics, curlyleaf could produce light, moderate, or heavy growth on an annual basis.

In Birch Lake it is predicted that curlyleaf growth would be light in Birch Lake (Table 3 and Figure 7).

Table 3. Birch Lake sediment data and ratings for potential nuisance curlyleaf pondweed growth.

Site	pH (su)	Bulk Density (g/cm^3 dry)	Organic Matter (%)	Fe:Mn Ratio	Potential for Nuisance Curlyleaf Pondweed Growth
Light Growth	**6.8**	**1.04**	**5**	**4.6**	**Low (green)**
Moderate Growth	**6.2**	**0.94**	**11**	**5.9**	**Medium (yellow)**
Heavy Growth	**>7.7**	**<0.51**	**>20**	**<1.6**	**High (red)**
1	5.9	0.445	41.4	7.5	Low
3	5.7	0.767	54.3	12.4	low
4	5.7	0.720	66.6	12.6	low
5	5.8	0.770	52.3	8.1	low
6	5.8	0.794	56.9	10.7	low
7	5.9	0.553	48.6	16.0	low
8	5.8	0.799	49.8	6.1	low
9	5.7	1.342	1.0	18.3	low
10	6.1	1.071	6.4	11.8	low
11	6.0	0.774	20.3	5.4	low
12	5.8	0.615	33.2	10.6	low
13	5.9	0.775	16.4	14.8	low
14	5.8	0.748	52.3	21.5	low
15	5.9	0.790	52.2	16.5	low
16	5.9	0.585	55.7	16.4	low
17	6.0	0.539	40.9	6.0	low
18	6.0	0.684	36.7	17.2	low
19	6.0	0.638	38.4	11.1	low
20	6.1	0.867	12.5	8.5	low

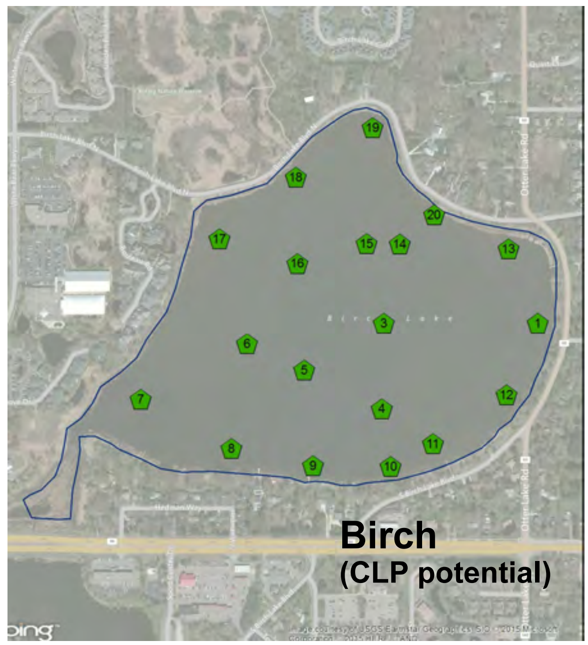


Figure 7. Sediment sample locations are shown with a circle. The circle color indicates the potential for nuisance curlyleaf pondweed to occur at that site. Key: green = low; yellow = medium; red = high potential.

Management Options for Curlyleaf Pondweed

Scouting Activities: Annual scouting activities can be used to delineate areas where curlyleaf pondweed (CLP) treatment is considered. Scouting should be done in April or May. Sediment characteristics, already collected, indicate there is a potential for light growth of CLP in Birch Lake. Although scouting should be conducted around the entire lake and all curlyleaf observations should be noted, scouting should be concentrated in areas that are conducive to heavy growth. It is recommended that all aquatic plants (especially the natives) should be recorded within a delineated area containing curlyleaf pondweed when scouting. GPS should be used to outline a treatment area. Areas of light growth do not need to be treated whereas areas of moderate to heavy growth are candidates for treatment.

Control Options: The recommended treatment option, if needed, is the use of an endothall herbicide. Cost of herbicide applications range from about $300 to $500 per acre. Not all curlyleaf areas have to be treated. The areas to consider are areas with moderate to heavy growth. However, heavy growth should be limited by lake sediment conditions. Two common treatment methods are shown below.

Herbicide applications

Mechanical harvesters

3. Eurasian Watermilfoil (non-native aquatic plant)

Birch Lake Status: Present in Birch Lake since 2005.

Growth Potential in Birch Lake: Mostly light to moderate growth potential.

Lake sediment sampling results from 2008 have been used to predict lake areas that have the potential to support various types of Eurasian watermilfoil (EWM) growth. Examples of milfoil growth characteristics are shown in Figures 8 and 9. Based on the key sediment parameters of NH_4 and organic matter (McComas, unpublished), a table and map were prepared that predict the type of growth that could be expected in the future if milfoil becomes established in Birch Lake (Table 2 and Figure 10).

In Birch Lake a majority of sites had high organic matter and/or low nitrogen and these areas are not predicted to produce nuisance milfoil conditions on an annual basis. It is estimated that less than 10 acres of heavy growth on an annual basis is expected in Birch Lake.

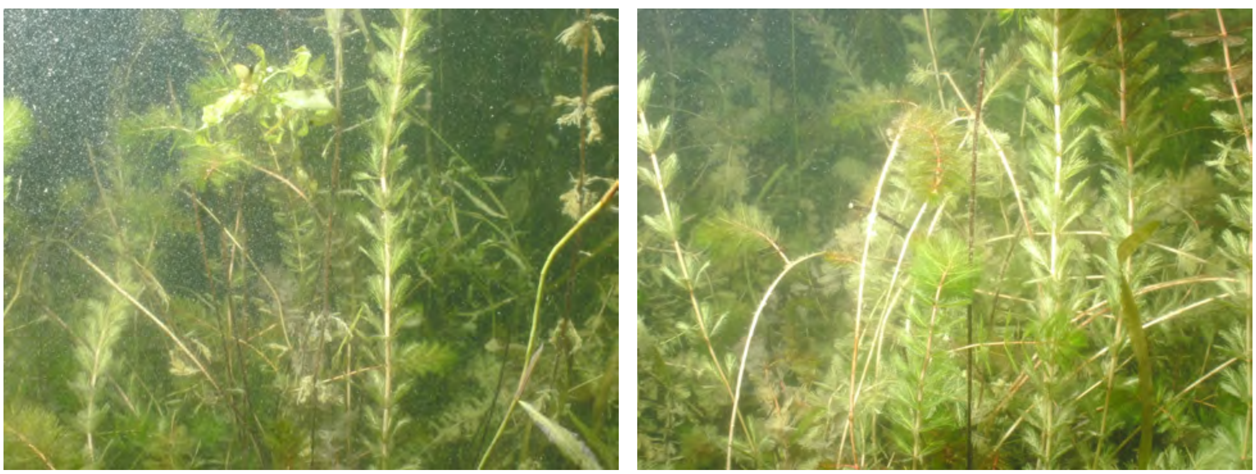


Figure 8. Underwater views of Eurasian watermilfoil.

Examples of Eurasian Watermilfoil Growth Characteristics

Figure 9. Light growth (left) refers to non-nuisance growth that is mostly below the surface and is not a recreational or ecological problem. Heavy growth (right) refers to nuisance matting Eurasian watermilfoil. This is the kind of nuisance growth predicted by high sediment nitrogen values and a sediment organic matter content less than 20%.

Eurasian Watermilfoil Growth Potential Based on Lake Sediments: Lake sediment sampling results from 2012 have been used to predict lake bottom areas that have the potential to support heavy EWM growth. Eurasian watermilfoil has not been observed in Birch Lake as of 2014. The potential for milfoil growth, based on lake sediment sampling, would be light to moderate growth with potential for heavy growth at a couple of sites in the north basin (Figure 10). Heavy milfoil growth has been correlated with high sediment nitrogen condition and Birch Lake has mostly low to moderate nitrogen conditions.

For Birch Lake, it is estimated the plants have the potential to grow down to at least 10 feet of water depth, resulting in widespread milfoil growth. However, results of the sediment survey indicate that only a fraction of the sites are conducive to heavy milfoil growth. In 2014, milfoil was not observed in the aquatic plant assessments.

Table 4. Birch Lake sediment data and ratings for potential nuisance EWM growth.

Site	NH_4 Conc (ppm)	Organic Matter (%)	Potential for Nuisance EWM Growth
Light Growth or Moderate Growth	<10	>20	Low (green) to Medium (yellow)
Heavy Growth	>10	<20	High (red)
1	8	41.4	low
3	10	54.3	low
4	40	66.6	low
5	18	52.3	low
6	15	56.9	low
7	13	48.6	low
8	15	49.8	low
9	4	1.0	low
10	8	6.4	medium
11	8	20.3	low
12	9	33.2	low
13	10	16.4	high
14	16	52.3	low
15	19	52.2	low
16	17	55.7	low
17	13	40.9	low
18	14	36.7	low
19	27	38.4	low
20	8	12.5	medium

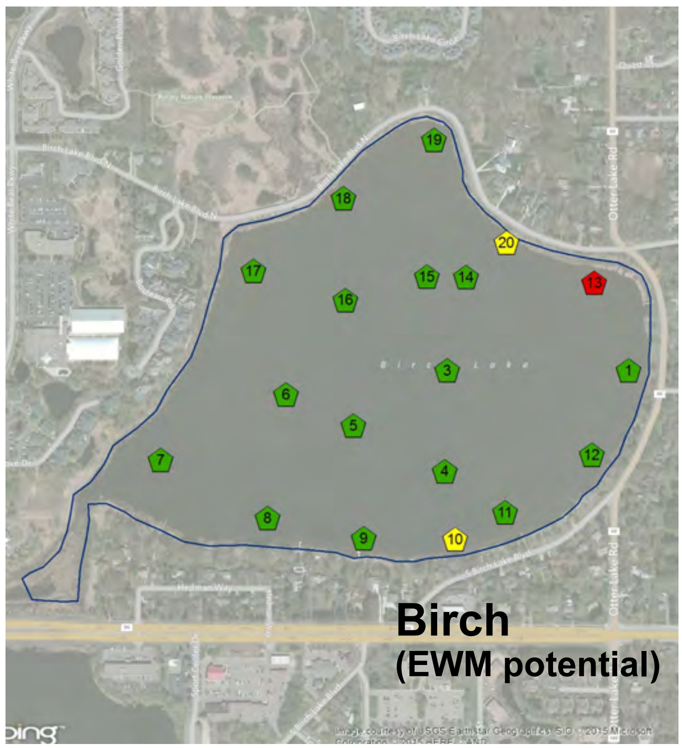


Figure 10. The color indicates the growth potential of Eurasian watermilfoil based on a sediment survey.
Key: green = light growth, yellow = moderate growth, and red = heavy growth.

Management Options for Eurasian Watermilfoil

Early Detection: Observers should continue lake milfoil evaluations to look for areas of any milfoil growth. This scouting activity can occur at the time of curlyleaf scouting in May and June, but additional monitoring is recommended in July. If milfoil is located, a rapid response assessment should be considered.

Rapid Response Assessment: When EWM is first observed a nearshore survey should be conducted to delineate areas of EWM colonization throughout the whole lake. All areas should be identified with GPS coordinates. A map of EWM locations and area colonized should be prepared.

Rapid Response Action: Based on the rapid response assessment, an EWM treatment strategy should be prepared, followed by a herbicide treatment. Eradication of EWM has rarely been successful in a lake. A small, pioneer area should be treated. If EWM is found at a number of locations, treatment for areas of heavy growth is appropriate, treatment in areas of light growth is unnecessary.

Control Options: Eurasian watermilfoil is not established in Birch Lake as of 2014. Lake sediment analyses indicate mostly light to moderate sediment conditions for milfoil growth are predicted in Birch Lake. Lake sediments are moderate in nitrogen and moderate to high in organic matter. These conditions may limit heavy growth of Eurasian watermilfoil or it's hybrid in Birch Lake.

If treatment is to be conducted, two treatment options include herbicides and harvesting. Herbicide applications would be the preferred option for areas greater than 1 acre.

Herbicide Applications would use a 2,4-D herbicide

Mechanical harvesting

4. Zebra Mussels (invertebrate)

Birch Lake Status: Not currently found in Birch Lake as of December 2014.

Nearest Occurrence: White Bear Lake, Ramsey County, Minnesota.

Growth Potential in Birch Lake: Moderate.

The life cycle of zebra mussels is shown in Figure 11. Zebra mussels can change the water quality in a lake. A dense population filters large volumes of lake water and zebra mussels use the filtered algae for food. Eventually the build-up of excreted fecal material will fertilize the lake bottom and in some cases, generate nuisance growth of filamentous algae. However, zebra mussels do not take over every lake. Factors can limit their growth and three types of growth conditions are shown in Figure 12. A chart of water column parameters indicates a broad range of potential growth for zebra mussels in Birch Lake (Table 5). Although zebra mussels prefer hard substrates for optimal growth, they will grow together forming clumps on sand and silt bottoms. Birch Lake has extensive areas of sandy and mucky sediments that would support moderate zebra mussel colonization (Table 5).

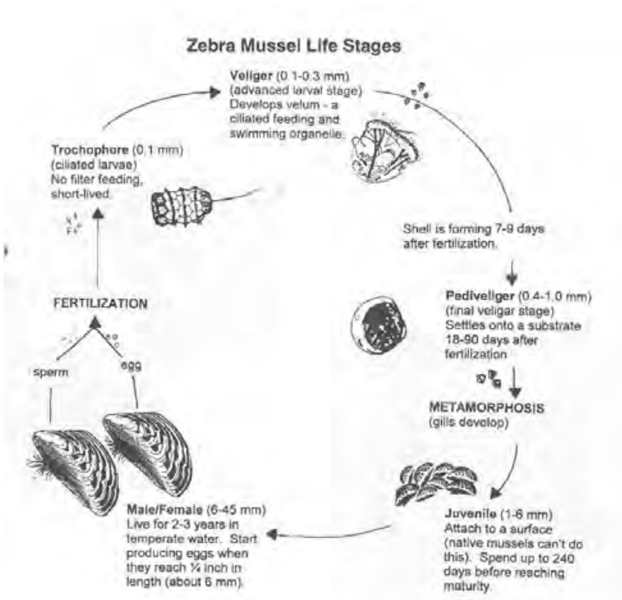


Figure 11. Zebra mussel life stages: Zebra mussels can be detected at the veliger stage using modified zooplankton nets, but this is usually performed by experts (Adopted from U.S. Army Corps of Engineers, WES)(from McComas, 2003. Lake and pond management guidebook).

Examples of Zebra Mussel Growth Conditions

Light Growth | **Moderate Growth (*suboptimal growth*)** | **Heavy Growth (*optimal growth*)**

Figure 12. Light growth (left). Small mussels can colonize on plants or hard substrates but sometimes conditions will limit growth to a single season followed by a zebra mussel die-off at the end of the year. Moderate growth (middle) can be found on soft sediments, in clumps, with zebra mussels attached to each other. Zebra mussels can colonize aquatic plants as well. Heavy growth (right) is found where there are hard surfaces such as rocks, woody structures, or docks and where water column conditions are suitable.

Zebra Mussels have not been found in Birch Lake as of 2014. A review of water column and substrate characteristics for Birch Lake was compared to characteristics suited for zebra mussels. It appears that zebra mussels are close to being food limited in Birch Lake (Table 5). Also substrate conditions would support moderate growth.

Table 5. Water column and substrate zebra mussel suitability criteria and Birch Lake conditions. Conditions for moderate growth seem to dominate.

		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Birch Lake	7.5 (9.11.15)			
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Birch Lake				8.5 (9.11.15)
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Birch Lake	23 (9.11.15)			
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Birch Lake				350 (9.11.15)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m)	Birch Lake		1.7		
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source)	Birch Lake				4.2
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l)	Birch Lake				26
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35
Substrate Factors					
Dissolved oxygen (mg/l)	Birch Lake		5-6 feet		0-5 feet
	Mackie and Claudi 2010	<3	3 - 7	7 - 8	>8
Bottom substrate	Birch Lake	19%		80%	1%
		Soft muck with no hard objects		Muck, silt, sand	Rock or wood

Zebra Mussel Growth Potential Based on Water Column and Substrate Conditions: Two broad categories combine to produce growing conditions in lakes for zebra mussels. The two categories are water column conditions and lake bottom (also referred to as substrate) conditions. Water column conditions were summarized in Table 5 and indicated that based on chlorophyll data, that blue-green algae could limit zebra mussel growth. Substrate conditions were also inspected at 40 sites where lake sediments were collected. The sediments were dominated by sand and silty-sand conditions. Zebra mussels will grow on these bottom sediments, but it is not the optimal substrate. A hard substrate of rocks and boulders is the optimal substrate and rocky areas in Birch Lake are sparse. A map that combines the growth potential of water column and substrate characteristics is shown in Figure 13. It appears where dissolved oxygen will allow growth, zebra mussel production will be light to moderate. Zebra mussels will grow on each other in clumps (Figure 14) and begin to become commonly observed two to four years after first being discovered.

Figure 13. Key for potential growth of zebra mussels: Green = light growth.

Figure 14. Distinctive zebra mussel growth pattern found in areas of sandy and silty sediments. Zebra mussels will grow on each other and form clumps of zebra mussels which sit on top of the sediments.

Management Options for Zebra Mussels

Early Detection: A zebra mussel early detection program should be implemented for Birch Lake. An active scouting program consists of volunteers using a plate sampler, pvc pipe, or ceramic tiles hung from docks to monitor the appearance of juveniles. Samplers should be checked monthly over the summer months. Also docks and boats lifts should be inspected as they are removed at the end of each summer.

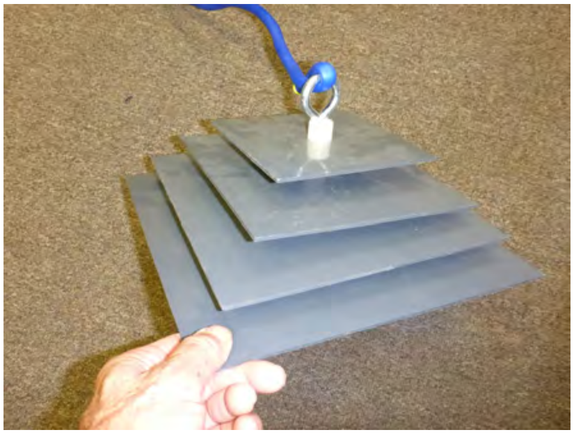


Figure 15. A zebra mussel plate sampler can be made from pvc materials. Ceramic tiles also make for good monitoring surfaces as well as pvc pipes.

Rapid Response Assessment: When zebra mussels are first discovered in Birch Lake, a rapid response assessment should be conducted. Because search time will likely be limited, high quality target areas should be searched first. High quality areas include public access ramps and rocky shores. For Birch Lake, a minimum of 20 search hours would be an appropriate search goal.

Rapid Response Action: One approach for eradicating an early zebra mussel introduction is to surround the area of all known zebra mussels with a floating silt curtain and treat within the site with a copper sulfate compound or potassium chloride. Special permits from the MnDNR would be needed for efforts like these. An intense assessment is necessary in order to locate all zebra mussel colonies in a lake if an eradication attempt is planned. It should be noted that there has been only one documented eradication of zebra mussels from a lake once they were discovered. The cost for an eradication attempt in Birch Lake could cost up to $30,000.

Control Options: Because it takes male and female gametes combining to make trochophore (larvae) which turn into veligers and then into adults (Figure 14), it takes a critical number of mussels to establish a thriving colony. However efforts to control the mussels from reaching a threshold number have not been effective. Therefore zebra mussels will likely colonize around Birch Lake, but at predicted low to moderate densities due to a limiting food source because blue-green algae dominate.

Use of small-scale controls that pick-up and remove zebra mussel clumps from the lake bottom could be considered. Modified clam rakes are an example of a small-scale zebra mussel removal tool that would be appropriate for a swimming beach or a boat landing area.

Figure 16. Small scale control devices maybe considered for removing zebra mussels in a clump form from swimming areas or sandy spawning sites.

5. Common Carp (fish)

Birch Lake Status: Present in Birch Lake (although not sampled in the last MnDNR fish survey).

Growth Potential in Birch Lake: Low to moderate.

Under the right conditions, common carp can become abundant in lakes and produce poor water quality. Three factors that influence carp population are shown in Figure 17. Common carp were not sampled in the last survey in Birch Lake, based on the MnDNR fish survey from 2009 (Table 6). Birch Lake habitat suitability for future growth is low to moderate due to spawning conditions that may not be well suited for survival of young fish (Figure 18). Since the 2009 survey, carp abundance remains low, probably due to limited immigration and poor recruitment of new carp.

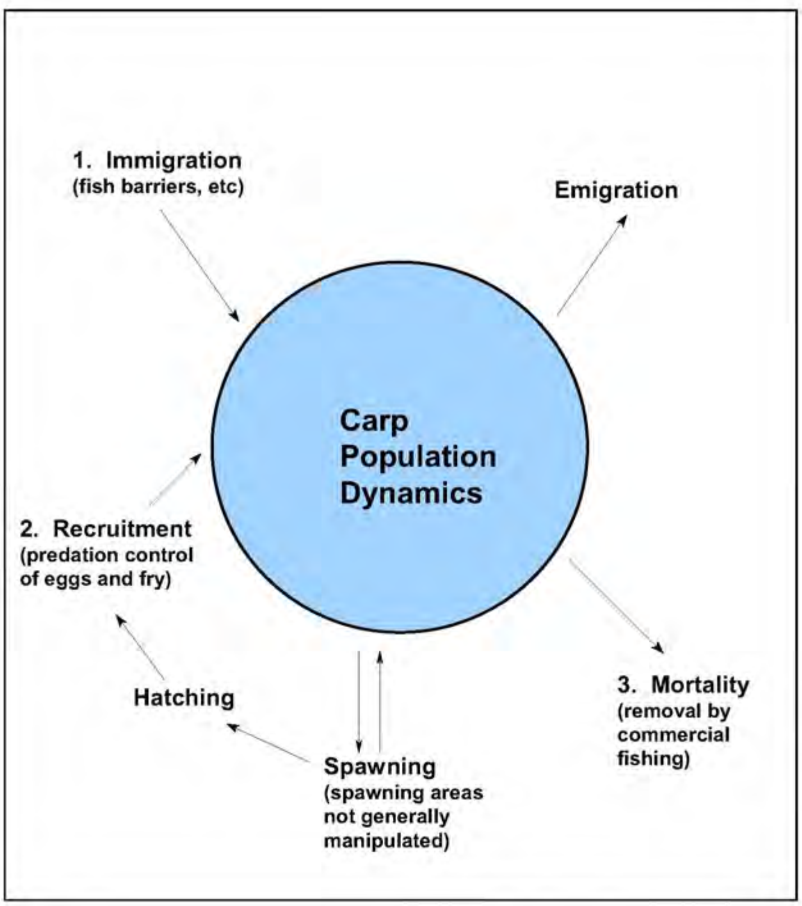


Figure 17. Three factors contribute to carp population dynamics. When carp populations are at a low density in lakes, Factors 1 and 2 generally limit populations.

Table 6. Birch Lake trapnet results for the fish survey conducted in 2011 and in 2014 by Blue Water Science. Fish data are shown as fish/trapnet.

	2011 August 23-24 (12 nets)	2014 Sept 5-6 (12 nets)	DNR Range (fish/net)
Black Bullhead	0.6	1.4	2 - 61
Black Crappie	0.6	4.3	2 - 18
Bluegill	15	19	6 - 60
Green Sunfish	--	0.3	0.3 - 2.8
Hybrid Sunfish	--	0.3	NA
Largemouth Bass	1.0	--	0.3 - 1
Northern Pike	1.3	1.2	NA
Pumpkinseed	3.4	4.6	1 - 8
Yellow Perch	--	0.1	0.3 - 1.5

Figure 18. Common carp potential spawning habitat quality. Green circles indicate marginal carp spawning sites in off-lake stream, wetland, and pond habitats.

Management Options for Common Carp

Early Detection: If carp are present in Birch Lake, they are not found in excessive numbers. If carp abundance increases, water clarity would likely decrease along with aquatic plant coverage. At this time, no carp management is necessary, rather, water quality and aquatic plant monitoring should be ongoing.

Rapid Response Assessment: None needed. Some carp present in a lake are not always detrimental. If water quality starts to decline in the future, carp could be assessed to determine if they are impacting water quality.

Rapid Response Action: None at this time.

Control Options: If controlling carp was necessary, there are three areas to address to implement a successful program. The three areas to address are 1) Immigration, 2) Recruitment, and 3) Mortality (Figure 19). Currently, there is no known carp immigration from other systems. Therefore the recruitment and mortality areas would be emphasized if control was needed. The recruitment category centers around the spawning habitat that is found in areas outside of the lake but connected by small streams. These areas are present in a couple of places, but are not considered to be good carp spawning habitat. The third area, mortality, could be implemented by using commercial fishermen if necessary.

1. Immigration
(*Low in Birch Lake*)

2. Recruitment
(*Low with some possible wetland spawning that could be a factor*)

3. Mortality
(*Only necessary if carp become too abundant*)

Figure 19. Three factors impacting carp population dynamics.

Other Non-native Species to Consider

Flowering Rush (non-native aquatic plant)

Birch Lake Status: Currently in Birch Lake

Growth Potential in Birch Lake: High. Flowering rush will spread slowly, but if disturbed, it will spread rapidly.

Flowering rush is actively expanding in the United States. It has spread from a limited area around the Great Lakes and the St. Lawrence river to sporadic appearances in the northern U.S. and southern Canada. Populations in the eastern U.S. produce seeds. Only one Minnesota population (Forest Lake, Washington County) produces viable seeds. Flowering rush reproduces by vegetative spread from its rootstock in form of bulb-lets. Both seeds and bulb-lets are dispersed by water current.

Flowering rush competes with native shoreland vegetation. There is documentation from a site in Idaho, between 1956 and 1973, where flowering rush appeared to be out-competing willows and cattails.

It is a Eurasian plant that is sold commercially for use in garden pools. It is now illegal to buy, sell or possess the plant.

Flowering rush is on the DNR prohibited invasive species list in Minnesota.

Examples of Flowering Rush Growth Characteristics

Figure 20. Light growth (left) refers to sporadic stems and is not a recreational or ecological problem but has the potential to spread. Moderate growth (middle) refers to a sparse density of intermediate sized flowering rush beds. Heavy growth (right) refers to a large area of relatively dense flowering rush.

Management Options for Flowering Rush

Scouting Activities: All flowering rush sites should be delineated before treatment is administered. The emphasis in Birch Lake has been to delineate emergent sites of flowering rush. Some areas with submerged patches have not be delineated. Scouting in July or August when plants are in a mature state is a good time to delineate emergent plants and there is still time to treat the beds. GPS waypoints are collected at each flowering rush site along with an estimate of the area of flowering rush colonization at that site.

Control Options: Use lake maps with GPS coordinates to locate where flowering rush plants are found. For mechanical control, cut plants below the water surface several times per summer and remove cut stems from the lake. This method helps to reduce spreading. For chemical control, application of the herbicide diquat (trade name Reward) has been found to be effective. Preliminary testing indicates that a mid-summer application during calm wind conditions may be most effective. Two herbicide applications per year may be needed.

Figure 21. Flowering rush has a distinctive flowerhead.

Purple Loosestrife (aquatic and terrestrial plant)

Birch Lake Status: Purple loosestrife is present in the Birch Lake watershed.

Potential for Nuisance Colonization in Birch Lake: Moderate.

Purple loosestrife can colonize a wide range of soil conditions. Because of it's high seed production it has a high potential to spread. It has moderate potential to produce nuisance growth conditions on individual lake lots because residents can control small infestations. It has a higher potential to produce moderate to heavy growth in undeveloped areas around Birch Lake.

Purple Loosestrife in Birch Lake: Purple Loosestrife is found in the watershed but locations have not been delineated in Birch Lake. Purple loosestrife is able to multiply rapidly under good growing conditions. Its recommended that the BLID or the lake association consider removal of the few individual plants before it can establish a foothold.

Figure 22. [left] Purple loosestrife flowerhead and a purple loosestrife plant [right].

Source: MnDNR

Management Options for Purple Loosestrife

Scouting Activities: Using lake maps lake observers should make notes of where shoreland purple loosestrife plants are observed. The next step would be to notify lake residents that purple loosestrife is present on their property and that removal is encouraged.

Control Options: Information and education materials are abundant from the MnDNR and other sources that describe how to control purple loosestrife found in small or large patches. For small area control, like what would be found along a shoreline area, hand pulling or treatment with a herbicide such as Rodeo is recommended. Rodeo is a broad spectrum herbicide and will kill all plants it comes in contact with. Therefore applications should target individual plants. If chemical treatment occurs within the ordinary high water mark on Birch Lake, a MnDNR aquatic nuisance control permit may be needed. There is no charge.

For large-scale control efforts encompassing an acre or more, biological control using flower-eating weevils and leaf-eating beetles could be considered. The MnDNR at the Brainerd office has information on the steps needed to implement a control program using weevils or beetles.

Hydrilla (aquatic plant)

Birch Lake Status: Not present in Birch Lake (or in Minnesota) as of 2014.

Nearest occurrence: Arkansas to the south and Maryland to the east. Hydrilla was reported in a pond in Wisconsin and a lake in Indiana. Both infestations were considered to be eradicated.

Potential for Nuisance Colonization in Birch Lake: Low to moderate.

Hydrilla is an aquatic plant in the same family as Elodea, a native aquatic plant. Based on the ecology of hydrilla, studies have found it could survive in Minnesota. In the right settings hydrilla has the potential to produce more significant nuisance growth then curlyleaf pondweed or Eurasian watermilfoil. However, the correlation of hydrilla growth characteristics to sediment characteristics is not as well established compared to what is known for curlyleaf pondweed and Eurasian watermilfoil so it is difficult to predict what it would do in Birch Lake.

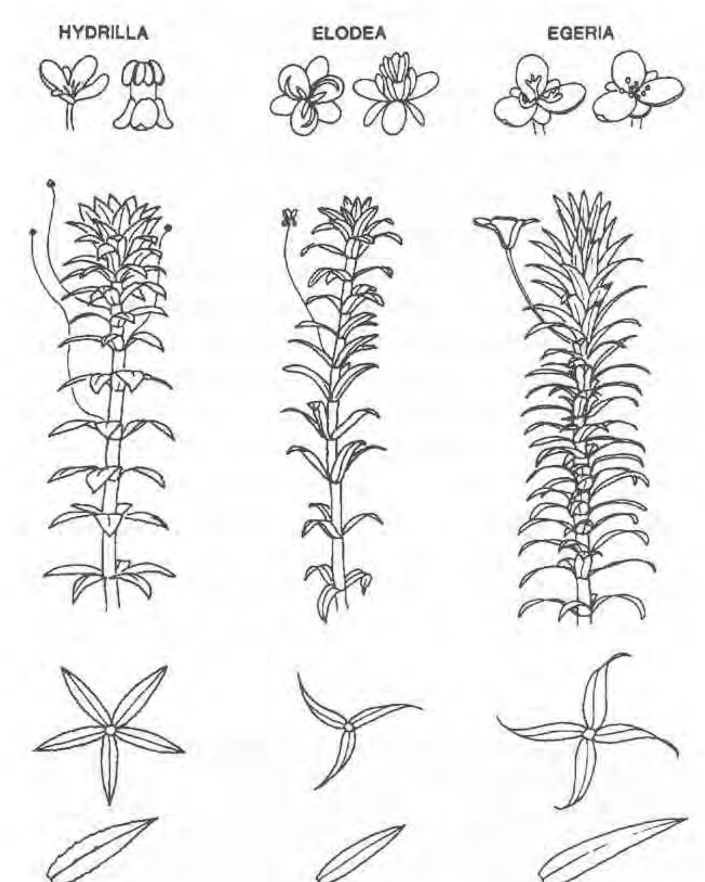


Figure 23.

Hydrilla is closely related to Egeria (an exotic plant in the U.S.) and elodea (a native). All three can produce nuisance growth conditions, but hydrilla takes the prize. (Line drawings from University of Florida, IFAS, Center for Aquatic Plants, Gainesville. With permission.)

From McComas 2003. Lake and Pond Management Guidebook.

Management Options for Hydrilla

Scouting Activities: The picture of hydrilla should be copied and laminated and taken along with observers when they are scouting for curlyleaf pondweed and Eurasian watermilfoil. Any suspicious looking plant should be bagged and brought into the MnDNR for an identification confirmation. The probability is low that the first sighting of hydrilla in Minnesota would occur in Birch Lake, but observers should be aware of the possibility.

Control Options: If hydrilla was confirmed in Birch Lake, the MnDNR would more than likely handle the initial control or eradication tasks. Because hydrilla has the potential to be worse than curlyleaf pondweed or milfoil in the State of Minnesota, aggressive eradication efforts should be taken. Herbicides would be used immediately with follow-up inspections and treatments continuing for a year or more.

Rusty Crayfish (invertebrate)

Birch Lake Status: Not presently found in Birch Lake as of 2014.

Nearest Occurrence: They are found in Cass County in Leech Lake as well as several other lakes. Rusty crayfish may be in Ramsey County, but not reported.

Potential for Nuisance Colonization in Birch Lake: Low to moderate.

Rusty crayfish are regional non-native species. They are native to the Ohio River drainage, but once they get into a new area, rusty crayfish population controls are not in place and their population can increase dramatically. They feed heavily on vegetation and can devastate aquatic plant beds. If rusty crayfish invade Birch Lake they could reduce the aquatic plants found in the bays. Rusty crayfish would have minimal effect in the main body of Birch Lake since submerged aquatic plants are rare there.

Management Options for Rusty Crayfish

Scouting Activities: Over the course of the summer, modified minnow traps can be set to check for the presence of rusty crayfish. Several traps should be set around the Birch Lake and checked weekly.

Figure 24. [top] Rusty crayfish in breeding colors (Plum Lake, Wisconsin). They can be identified by a reddish dot on their carapace (side of their body). Native crayfish do not have this marking.
[bottom] Rusty crayfish graze down aquatic plant beds and eventually eliminate them.

Rusty crayfish traps are basically standard minnows trap with a slightly enlarged opening to allow crayfish entry. It is often baited with fish parts. A goal for Birch Lake is to deploy 5 to 10 rusty crayfish traps and monitor them over the summer for the presence of rusty crayfish, although any native crayfish appearances should be noted as well.

Control Options: Once in a lake, rusty crayfish are difficult to get under control and even more difficult to eradicate. Control efforts are two-pronged. Lake groups implement a trapping program to remove large crayfish and then rely on fish predation to control the smaller crayfish. Crayfish trapping would be concentrated in the bays that have aquatic plants. A total of 30 to 50 traps would be set in an initial control effort. If crayfish abundance was high, trapping would probably occur for 5 to 10 years. If crayfish abundance is low, trapping could be discontinued after a year or two and natural fish predation would be the main control.

Birch Lake has several predator fish species that would prey on rusty crayfish. The fish species are dogfish (low numbers), largemouth bass (low numbers), walleye (low numbers), and yellow perch (low numbers). Because rusty crayfish are more aggressive defenders than native crayfish, it takes several years for the predator fish to “learn” how to capture rusty crayfish. Once this behavior is learned, it seems fish could be a long-term control.

Figure 25. Examples of three types of rusty crayfish traps. The trap on the right is a modified minnow trap.

Figure 26. Big Bearskin Lake, Oneida County, Wisconsin has an active rusty crayfish control program. Volunteers run the rusty crayfish traps. Crayfish are collected and brought to a central site for sorting. Small crayfish are taken into the woods for bear and raccoon food and the large crayfish are taken to a restaurant in Green Bay.

Other Molluscs

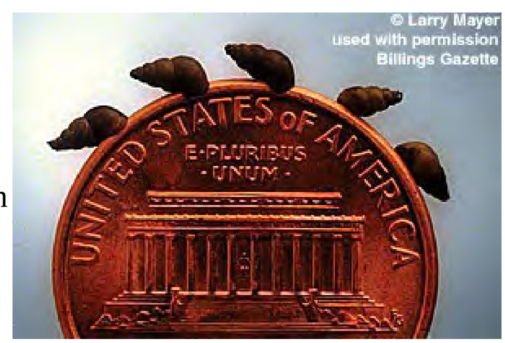
Chinese and Banded Mystery Snail (CMS), (BMS): A larger olive colored snail species, CMS and BMS can form dense aggregations. CMS can transmit human intestional flukes, not documented in the US. Also a carrier of trematode parasites found in native mussels. CMS occur in over 80 waters and BMS are present in about 50 waters. The name “mystery” snail comes from their odd reproduction, where offspring appear, suddenly, fully developed. After a fourth year of reproduction, the snails die and the shells wash to shore. The snail was introduced as an aquarium organism that may have been dumped into a water body.

Faucet Snail: Introduced in the great lakes in the 1870’s the faucet snail has become fairly well established in Minnesota especially along the Mississippi River corridor. The snail acts as an intermediate host for 3 different hosts that can be fatal to ducks and coots, causing internal hemorrhaging and lesions. The parasites have a complex life cycle, requiring 2 intermediate hosts.

Quagga Mussel: The Quagga mussel can inhabit both hard and soft substrates, including sand and mud, and can colonize to depths with lower dissolved oxygen than zebra mussels can handle but has a hard time colonizing in shallow water. The fan shaped mussel, has several life stages and is about the size of an adult’s thumbnail. The quagga, like zebra mussels, is a filter feeder that can hurt fisheries by eating the zooplankton that native fish need to survive. It has also been noted to accumulate pollutants and pass them up the food chain.


Photo courtesy of USGS

New Zealand Mudsnail: A small snail introduced with fish stocking and ballast waters in the 1980’s. They reproduce asexually and their numbers can reach high densities, 100,000-700,000 per m^2. They are typically able to outcompete native snails that are important forage for fish. Found in Lake Superior in 2001, they have been slowly spreading inland since. The New Zealand mudsnail can attach to gear placed in the water or on hard surfaces.



Asian Carp

Birch Lake Status: Not present in Birch Lake as of 2014.

Nearest occurrence: St. Croix and Mississippi Rivers eDNA found. Live fish caught March 2012 on the Mississippi River.

Potential for Nuisance Colonization in Birch Lake: Low.

Asian carp are filter feeders that can consume large amounts of plankton. They are voracious feeders, reaching over a hundred pounds for bighead and 60 lbs for silver carp. The worry is they will outcompete native fishes and young of the year for the plankton, thereby reducing sport fish abundance. The river fish have been spreading up from Illinois where ideal conditions have allowed them to establish. In Minnesota, individual carps have been netted but no established populations have been found.

The spawning requirements for Asian carp require a river flow of 2 to 8 feet per second and 50 miles long. There are no rivers with that flow in the Birch Lake watershed.

Management Options for Asian Carp

Control Options: Asian carp should not be able to spawn in Birch Lake. Control options include commercial fishing or to let the carp die off naturally.

Figure 27. Bighead carp, *Hypophthalmichthys nobilis*, and distribution maps (USFWS photo).

Figure 28. Silver carp, *Hypophthalmichthys molitrix*, and distribution map (USFWS photo).

Snakehead

Birch Lake Status: Not present in Birch Lake as of 2014.

Nearest occurrence: East coast.

Potential for Nuisance Colonization in Birch Lake: Moderate to high.

The northern snakehead is native to eastern Asia. In the United States, it has few predators, and could disrupt ecosystems and native fish assemblages. Snakeheads are very hardy, adaptive, and can even live and travel out of water. The snakehead is extremely aggressive and territorial, typically feeding on other fish species. Adult snakeheads have been shown to have a diet overlap with largemouth bass in the Potomac River where they are established.

The northern snakehead has a range that extends north of the great lakes region.

Management Options for Snakehead

Control Options: Preventative measures will be the most effective. Once established, rotenone can be used for eradication, however all fish species will be killed. A dissolved oxygen content of less than 3 parts per million should be achieved throughout the waterbody to ensure sufficient dosage.

Figure 29. Picture of a snakehead (left) and distribution map (right). From the USGS website (Nonindigenous Aquatic Species (NAS) page).

Viral Hemorrhagic Septicemia (VHS)(fish virus)

Birch Lake Status: Not present in Birch Lake as of 201.

Nearest occurrence: Several inland lakes in Wisconsin and all the Great Lakes.

Potential for Nuisance Colonization in Birch Lake: Moderate to high.
Prevention is the key to minimize the impact of VHS. This fish virus will kill a variety of fish species, but does not eliminate the entire fish population in a lake. If it were to be introduced to Birch Lake, it has a high probability of becoming established.

Management Options for VHS

Scouting Activities: The basic strategy is to make anglers aware that they should report any fish with signs of hemorraging to the MnDNR. If they have caught a fish with hemorraging they should bring the fish to the MnDNR. If a fish kill is observed involving hemorraging fish don't collect the fish, but call the MnDNR immediately.

Control Options: At the present time, there is no known way to reduce or inactivate the virus in the open water. The best approach is to remove infected fish as soon as feasible. The virus can be passed from one infected fish to another. If VHS is discovered in Birch Lake, an intensive information program should be implemented by the BLID. Staffing public access landings could be considered to prevent the spread of VHS by way of livewell and bilge water transport to other lakes. Costs for these actions could be partly covered by grants.

Figure 30. Examples of hemorraging in fish with the VHS virus.

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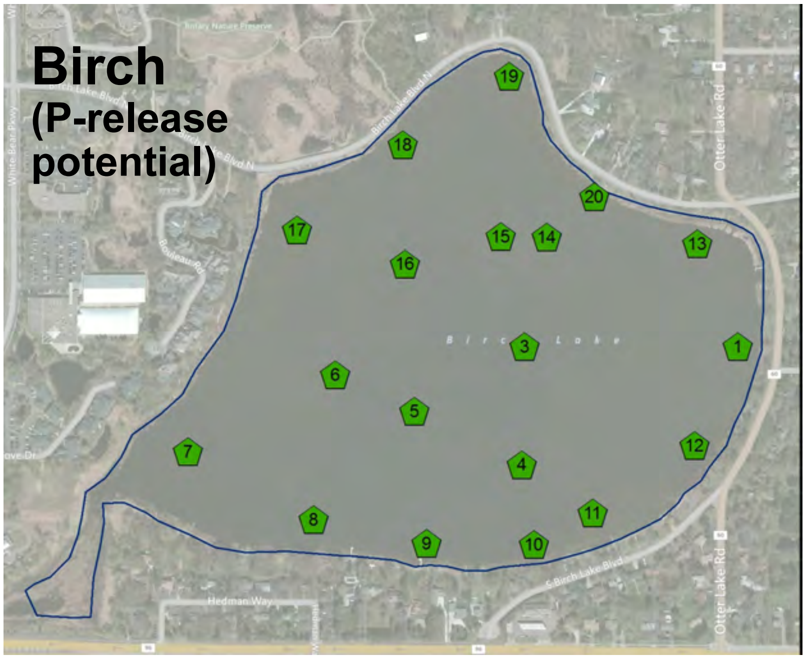
APPENDIX A

Methods



Lake Soil Survey: A total of 20 samples were collected on March 11, 2008 from depths ranging from 4 to 5 feet. Location of sample sites is shown in Figure A1. Samples in shallow water were collected using a modified soil auger, 5.2 inches in diameter. Soils were sampled to a sediment depth of 6 inches. The lake soil from the sampler was transferred to 1-gallon zip-lock bags and sent to the University of Minnesota Soil Testing and Research Analytical Laboratory.

Figure A1. Location map of the lake sediment collection sites.

Lake Soil Analysis Using Standard Soil Tests: At the lab, sediment samples were air dried at room temperature, crushed and sieved through a 2 mm mesh sieve. Sediment samples were analyzed using standard agricultural soil testing methods. Fifteen parameters were tested for each soil sample. A summary of extractants and procedures is shown in Table A1. Routine soil test results are given on a weight per volume basis.

Table A1. Soil testing extractants used by University of Minnesota Soil Testing and Research Analytical Laboratory. These are standard extractants used for routine soil tests by most Midwestern soil testing laboratories (reference: Western States Laboratory Proficiency Testing Program: Soil and Plant Analytical Methods, 1996-Version 3).

Parameter	Extractant
P-Bray	0.025M HCL in 0.03M NH_4F
P-Olsen	0.5M $NaHCO_3$
NH_4-N	2N KCL
K, Ca, Mg	1N NH_4OA_c (ammonium acetate)
Fe, Mn, Zn, Cu	DTPA (diethylenetriamine pentaacetic acid)
B	Hot water
SO_4-S	$Ca(H_2PO_4)_2$
pH	water
Organic matter	Loss on ignition at 360^{o}C

Figure A2. Soil auger used to collect lake sediments in water depths to 5 feet.

The Adjustment Factor for Reporting Results as Volume/Weight: There has been discussion for a long time on how to express analytical results from soil sampling. Lake sediment research results are often expressed as grams of a substance per kilogram of lake sediment, commonly referred to as a weight basis (mg/kg). However, in the terrestrial sector, to relate plant production and potential fertilizer applications to better crop yields, soil results typically are expressed as grams of a substance per cubic foot of soil, commonly referred to as a weight per volume basis. Because plants grow in a volume of soil and not a weight of soil, farmers and producers typically work with results on a weight per volume basis.

That is the approach used here for lake sediment results: they are reported on a weight per volume basis or $\mu g/cm^3$.

A bulk density adjustment was applied to lake sediment results as well. For agricultural purposes, in order to standardize soil test results throughout the Midwest, a standard scoop volume of soil has been used. The standard scoop is approximately a 10-gram soil sample. Assuming an average bulk density for an agricultural soil, a standard volume of a scoop has been a quick way to prepare soils for analysis, which is convenient when a farmer is waiting for results to prepare for a fertilizer program. It is assumed a typical silt loam and clay texture soil has a bulk density of 1.18 grams per cm^3. Therefore a scoop size of 8.51 cm^3 has been used to generate a 10-gram sample. It is assumed a sandy soil has a bulk density of 1.25 grams per cm^3 and therefore a 8.00 cm^3 scoop has been used to generate a 10-gram sample. Using this type of standard weight-volume measurement, the lab can use standard volumes of extractants and results are reported in ppm which is close to $\mu g/cm^3$. For all sediment results reported here, a scoop volume of 8.51 cm^3 was used.

Although lake sediment bulk density has wide variations, a scoop volume of 8.51 cm^3 was used for all lake sediment samples in this report. This would not necessarily produce a consistent 10-gram sample. Therefore, for our reporting, we have used adjusted weight-volume measurements and results have been adjusted based on the actual dry lake sediment bulk density. We used a standard scoop volume of 8.51 cm^3, but sediment samples were weighed. Because test results are based on the premise of a 10 gram sample, if our sediment sample was less than 10 grams, then the reported concentrations were adjusted down to account for the less dense bulk density. If a scoop volume weighed greater than 10.0 grams than the reported concentrations were adjusted up. For example, if a 10-gram scoop of lake sediment weighed 4.0 grams, then the correction factor is 4.00 g/ 10.00 g = 0.40. If the analytical result was 10 ppm based on 10 grams, then it should be 0.40 x 10 ppm = 4 ppm based on 4 grams. The results could be written as 4 ppm or 4 $\mu g/cm^3$. Likewise, if a 10-gram scoop of lake sediment weighed 12 grams, then the correction factor is 12.00 g / 10.00 g = 1.20. If the analytical result was 10 ppm based on a 10 gram scoop, then it should be 1.20 x 10 ppm = 12 ppm based on 12 grams. The result could be written as 12 ppm or 12 $\mu g/cm^3$. These are all dry weight determinations.

This adjustment factor is important for evaluating the ammonium-nitrogen raw data. There appears to be a threshold nitrogen concentration at 10 ppm. If nitrogen is greater than 10 ppm, heavy milfoil growth can occur. If the adjustment factor is not applied, light, fluffy sediments may produce a high nitrogen reading based on a weight basis, but would not support heavy milfoil growth. When the adjustment factor is applied, and if the nitrogen concentration falls below 10 ppm, light or moderate growth of milfoil is predicted rather than heavy growth.

APPENDIX B

Birch Lake soil data. Sample were collected on March 11, 2008. Soil chemistry results are reported as µg/cm^3-dry which is equivalent to ppm except for organic matter (%) and pH (standard units).

Sample Number	Depth (ft)	Bulk Density (g/cm3)	O.M. (%) by L.O.I.	pH	Bray-P (ppm) (corr)	Olsen-P (ppm) (corr)	K (ppm) (corr)	Ca (ppm) (corr)	Mg (ppm) (corr)	Boron (ppm) (corr)	NH4-N (ppm) (corr)	Fe (ppm) (corr)	Cu (ppm) (corr)	Mn (ppm) (corr)	Zn (ppm) (corr)	SO4-S (ppm) (corr)
B1	4	0.445	42.2 /40.5	5.8 / 6.0	2	1	22	710	86	0	8	85	1	11	5	16
B3	5	0.767	54.3	5.7	4	2	60	1401	214	1	10	153	3	13	6	49
B4	5	0.720	66.6	5.7	1	1	46	954	160	1	40	176	1	14	2	15
B5	5	0.770	52.3	5.8	3	1	74	1022	172	2	18	91	2	11	3	43
B6	5	0.794	56.9	5.8	4	1	63	1637	266	2	15	138	3	13	5	47
B7	5	0.553	48.6	5.9	3	0	46	928	143	1	13	158	1	10	1	12
B8	4.5	0.799	49.8	5.8	3	1	57	1757	207	1	15	149	2	24	3	31
B9	4	1.342	1.0	5.7	3	1	62	368	42	0	4	33	1	2	1	37
B10	3	1.071	6.4	6.1	3	1	26	813	90	0	8	76	1	6	1	16
B11	4	0.774	20.3	6.0	5	1	30	1035	118	1	8	88	1	16	3	13
B12	4	0.615	33.2	5.8	4	1	38	1068	134	1	9	126	1	12	4	21
B13	3	0.775	16.4	5.9	4	2	33	1379	107	1	10	153	3	10	10	79
B14	5	0.748	52.3	5.8	3	1	73	1765	282	1	16	208	2	10	2	19
B15	5	0.790	52.2	5.9	3	1	54	1110	183	1	19	151	2	9	5	37
B16	5	0.585	55.7	5.9	2	1	40	895	146	1	17	129	1	8	4	20
B17	4.5	0.539	40.9	6.0	4	1	30	1008	116	0	13	97	1	16	4	21
B18	4.5	0.684	36.7	6.0	3	1	61	1030	166	1	14	155	1	9	2	12
B19	4	0.638	38.4	6.0	4	1	51	1280	181	1	27	157	2	14	5	22
B20	4	0.867	12.5	6.1	4	1	41	1297	125	0	8	111	1	13	4	21

2015 - ADJUSTED DATA SET

Sample Name	Bulk Density (wt/8.51)	Bray P (ppm) *adjusted*	Olsen P (ppm) *adjusted*	NH4OAc-K (ppm) *adjusted*	LOI OM (%)	Water pH	Boron (ppm) *adjusted*	DTPA-Fe (ppm) *adjusted*	DTPA-Mn (ppm) *adjusted*	DTPA-Zn (ppm) *adjusted*	DTPA-Cu (ppm) *adjusted*	NH$_4$OAc-Ca (ppm) *adjusted*	NH$_4$OAc-Mg (ppm) *adjusted*	SO$_4$-S (ppm) *adjusted*	NH4-N (ppm) *adjusted*	Average Scoop	Correct factor	Fe/Mn
BIR 3	0.49	4.2	1.3	34.5	66.7	6.0	0.8	64	5.8	13.8	0.7	823.4	150	42.0	3.7	4.20	0.42	11.0
BIR 10	1.13	2.9	1.0	39.4	6.3	6.8	0.2	53	5.4	2.0	0.6	936.0	85	31.7	3.6	9.62	0.96	9.9
BIR 19	0.59	1.5	1.0	69.7	43.9	5.9	0.6	133	7.7	2.2	1.1	1279.7	197	64.6	6.3	5.05	0.51	17.3

2015 - REPORTED FROM THE LAB DATA SET (UNADJUSTED)

Sample Name	Bray P (ppm)	Olsen P (ppm)	NH4OAc-K (ppm)	LOI OM (%)	Water pH	Boron (ppm)	DTPA-Fe (ppm)	DTPA-Mn (ppm)	DTPA-Zn (ppm)	DTPA-Cu (ppm)	NH$_4$OAc-Ca (ppm)	NH$_4$OAc-Mg (ppm)	SO$_4$-S (ppm)	NH4-N (ppm)	10 gm Scoop Wt	10 gm Scoop Wt	10 gm Scoop Wt
BIR 3	10	3	82	66.7	6.0	1.918	151.39	13.733	32.926	1.739	1959.0	357.56	100	8.7	4.29	4.23	4.09
BIR 10	3	1	41	6.3	6.8	0.234	55.02	5.570	2.116	0.658	973.0	88.38	33	3.7	9.83	9.47	9.56
BIR 19	3	2	138	43.9	5.9	1.151	262.42	15.153	4.306	2.152	2534.0	390.33	128	12.5	5.02	5.02	5.11

In 2015, three Birch Lake sediment samples were collected from the same sites sampled in 2008. Phosphorus and organic matter were similar from 2008 and 2015 sites. For other parameters, most of the concentrations between the years were comparable. It appears the lake sediments sampled in 2008 are relatively stable and results can still be predictive for at least 7 years after they were collected.

2008 and 2015 - ADJUSTED DATA FOR THREE BIRCH LAKE SITES

Sample Name	Bulk Density (wt/8.51)	Bray P (ppm) *adjusted*	Olsen P (ppm) *adjusted*	NH4OAc-K (ppm) *adjusted*	LOI OM (%)	Water pH	Boron (ppm) *adjusted*	DTPA-Fe (ppm) *adjusted*	DTPA-Mn (ppm) *adjusted*	DTPA-Zn (ppm) *adjusted*	DTPA-Cu (ppm) *adjusted*	NH$_4$OAc-Ca (ppm) *adjusted*	NH$_4$OAc-Mg (ppm) *adjusted*	SO$_4$-S (ppm) *adjusted*	NH4-N (ppm) *adjusted*	Fe/TP	Fe/MN
Site 3																	
2008	0.767	4	2	60	54.3	5.7	1	153	13	6	3	1401	214	49	10	38.2	11.8
2015	0.49	4.2	1.3	34.5	66.7	6.0	0.8	64	5.8	13.8	0.7	823.4	150	42.0	3.7	15.2	11.0
Site 10																	
2008	1.071	3	1	26	6.4	6.1	0	76	6	1	1	813	90	16	8	25.3	12.7
2015	1.13	2.9	1.0	39.4	6.3	6.8	0.2	53	5.4	2.0	0.6	936.0	85	31.7	3.6	18.3	9.9
Site 19																	
2008	0.638	4	1	51	38.4	6.0	1	157	14	5	2	1280	181	22	27	39.3	11.2
2015	0.59	1.5	1.0	69.7	43.9	5.9	0.6	133	7.7	2.2	1.1	1279.7	197	64.6	6.3	88.7	17.3

APPENDIX C

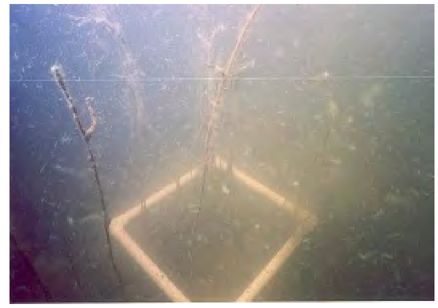
Curlyleaf Pondweed Growth Characteristics
(source: Steve McComas, Blue Water Science, unpublished)

Light Growth Conditions

Plants rarely reach the surface.

Navigation and recreational activities are not generally hindered.

Stem density: 0 - 160 stems/m^2
Biomass: 0 - 50 g-dry wt/m^2
Estimated TP loading: <1.7 lbs/ac



MnDNR rake sample density equivalent for light growth conditions: 1, 2, or 3.

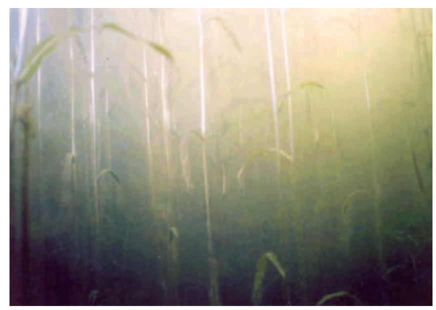
Moderate Growth Conditions

Broken surface canopy conditions.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 100 - 280 stems/m^2
Biomass: 50 - 85 g-dry wt/m^2
Estimated TP loading: 2.2 - 3.8 lbs/ac



MnDNR rake sample density equivalent for moderate growth conditions: 2, 3 or sometimes, 4.

Heavy Growth Conditions

Solid or near solid surface canopy conditions.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

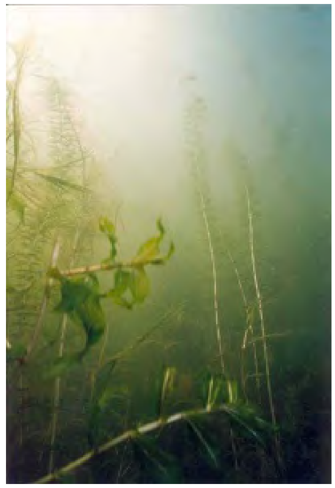
Stem density: 400+ stems/m^2
Biomass: >300 g-dry wt/m^2
Estimated TP loading: >6.7 lbs/ac

MnDNR rake sample density has a scale from 1 to 4. For certain growth conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy. Heavy growth conditions have rake densities of a 4 (early to mid-season with the potential to reach the surface), 4.5, or 5.

Eurasian Watermilfoil Growth Characteristics

(source: Steve McComas, Blue Water Science, unpublished)

Light Growth Conditions



Plants rarely reach the surface.

Navigation and recreational activities generally are not hindered.

Stem density: 0 - 40 stems/m^2
Biomass: 0 - 51 g-dry wt/m^2

MnDNR rake sample density equivalent for light growth conditions: 1, 2, or 3.

Moderate Growth Conditions

Broken surface canopy conditions. However, stems are usually unbranched.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 35 - 100 stems/m^2
Biomass: 30 - 90 g-dry wt/m^2

MnDNR rake sample density equivalent for moderate growth conditions: 3 or 4.

Heavy Growth Conditions

Solid or near solid surface canopy conditions. Stems typically are branched near the surface.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

Stem density: 250+ stems/m^2
Biomass: >285 g-dry wt/m^2

MnDNR rake sample density has a scale from 1 to 4. For heavy growth conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy.