



Minnie, the Lake Monster, Spotted in Lake Nokomis in 2010

Aquatic Invasive Species Action Plan for Rays Lake, Le Sueur County, Minnesota

Prepared for:
Le Sueur County Environmental
Services,
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Summary

Overview of aquatic invasive species that could impact Rays Lake are listed below. As of 2014, curlyleaf pondweed, Eurasian watermilfoil, carp, and purple loosestrife were the only non-native species known to be present in Rays Lake.

Species	Lake Status	Potential for Growth in Rays Lake	Management Action	
			Short Term	Long Term
Species of Interest				
1. Cyllindro (blue-green algae)	Unknown	High	Monitoring	Reduce phosphorus loading
2. Curlyleaf pondweed	Present in Rays	Mostly moderate	Annual delineations or surveys to check curlyleaf growth	Selective treatment for heavy growth conditions
3. Eurasian watermilfoil	Present in Rays	Mostly low	Annual surveys or delineations if detected	Selective treatment for heavy growth conditions
4. Zebra mussels	Not present in Rays, but present in Prior lakes, Scott Co	Low	Mussel monitoring devices for early detection	Small-scale removal techniques if needed
5. Common carp	Present in Rays (based on MnDNR fish surveys)	Moderate to high	Determine where carp are spawning if they are found	Carp management tasks if growth becomes abundant
Species to Watch				
Flowering rush	Present in watershed	Moderate	Annual observations or surveys	Selective treatment
Purple loosestrife	Present in Rays	Fair	Annual surveys or observations	Spot control and use of beetles for large area control
Hydrilla	Not present in Rays	Low to moderate	MnDNR sponsored treatments	Ongoing control
Rusty crayfish	Not present in Rays	Fair to moderate	Crayfish traps for early detection	Use fish to control rusty crayfish
Chinese and Banded Mystery snail	May be present in Rays	Fair	Inform and educate	Small-scale removal techniques, if needed
Spiny waterflea	Not present in Rays	Moderate to high	Inform and educate	Natural fish predation
Faucet snail	Not present in Rays	Moderate to high	Inform and educate	Removal if practical
Asian carp	Not present in Rays	Low	Inform and educate	
Snakehead	Not present in Rays	Moderate	Inform and educate	



Curlyleaf Pondweed



Eurasian Watermilfoil



Zebra Mussel

Five Aquatic Invasive Species of Interest

1. Blue-green Algae (Cylindro)

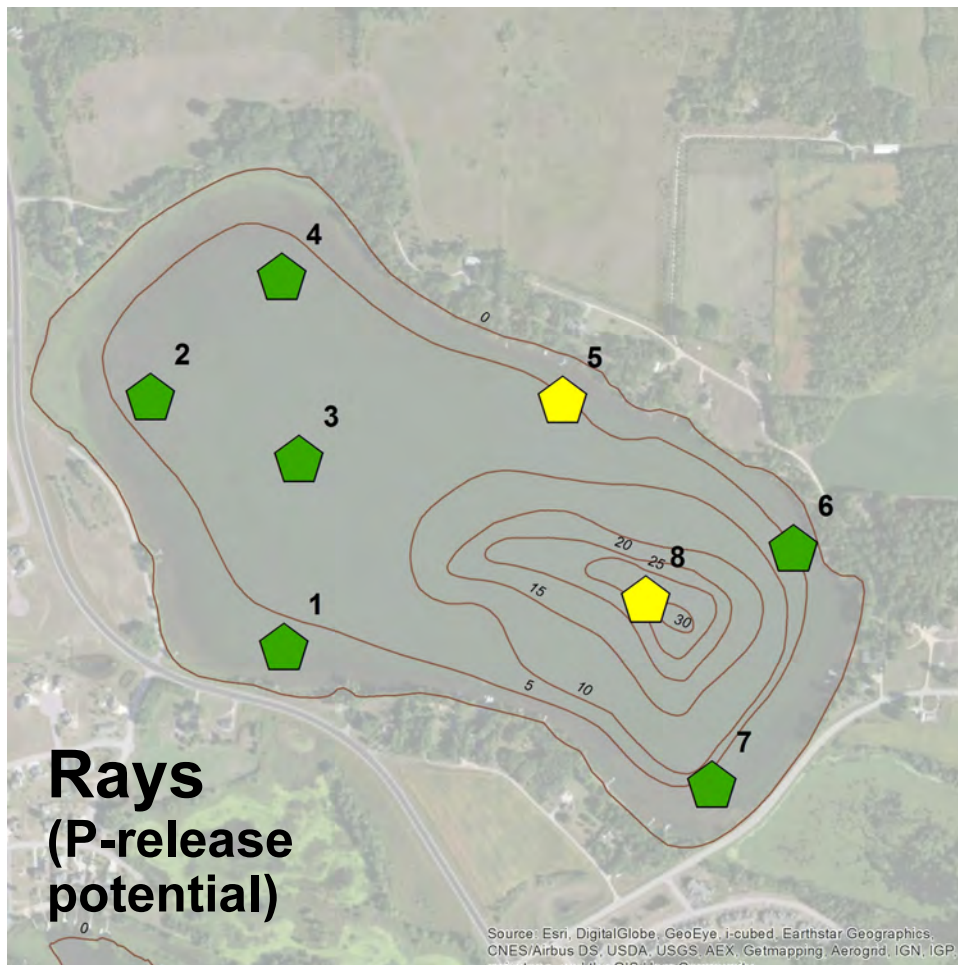


Figure S1. Sediment P-release potential with the possibility to produce excessive phosphorus loading in Rays Lake that could produce blue-green algae and Cylindro blooms. Key: Green = low potential and yellow = moderate potential.

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. Rays Lake currently has these characteristics but Cylindro has not been identified in Rays Lake. Cylindro is known to produce toxins that at high concentrations could be harmful to other aquatic life.

Action Plan: If lake phosphorus concentrations are reduced, conditions will not be favorable to abundant Cylindro growth. Two sources of phosphorus to Rays 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 Rays Lake sediments to release phosphorus. Results of the sediment survey for Rays Lake show sediment sites have a high Fe:P ratio and that phosphorus release from lake sediments to be low to moderate (Figure S1). If watershed phosphorus contributions are reduced, treating the lake sediment phosphorus hot spots with alum could lower lake phosphorus concentrations and reduce algal blooms.

2. Curlyleaf Pondweed

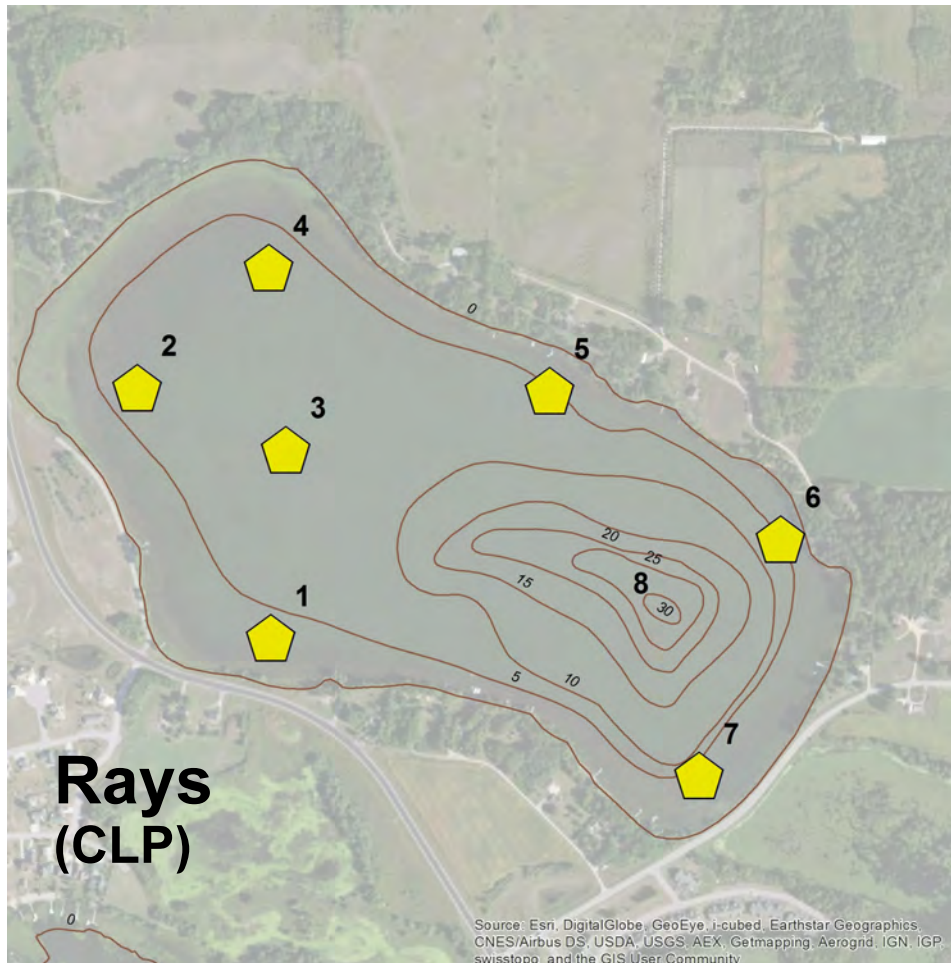


Figure S2. Curlyleaf potential growth based on lake sediment analyses for Rays Lake.
Key for Potential Growth: yellow = moderate growth.

Curlyleaf pondweed is present in Rays Lake. 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 survey results it is predicted curlyleaf will to grow in Rays Lake at mostly moderate abundances. However, some areas may produce heavy growth in some years.

Action Plan: Because curlyleaf pondweed is already established in Rays Lake, it is past the point of eradication. Ongoing activities will concentrate on 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. In press). Therefore annual treatments for curlyleaf control may have to be considered.

Based on lake sediment surveys, it is predicted curlyleaf can grow in a number of areas around Rays Lake although heavy growth will be limited in most years. These areas could be treated either with an endothall herbicide or by harvesting.

3. Eurasian Watermilfoil

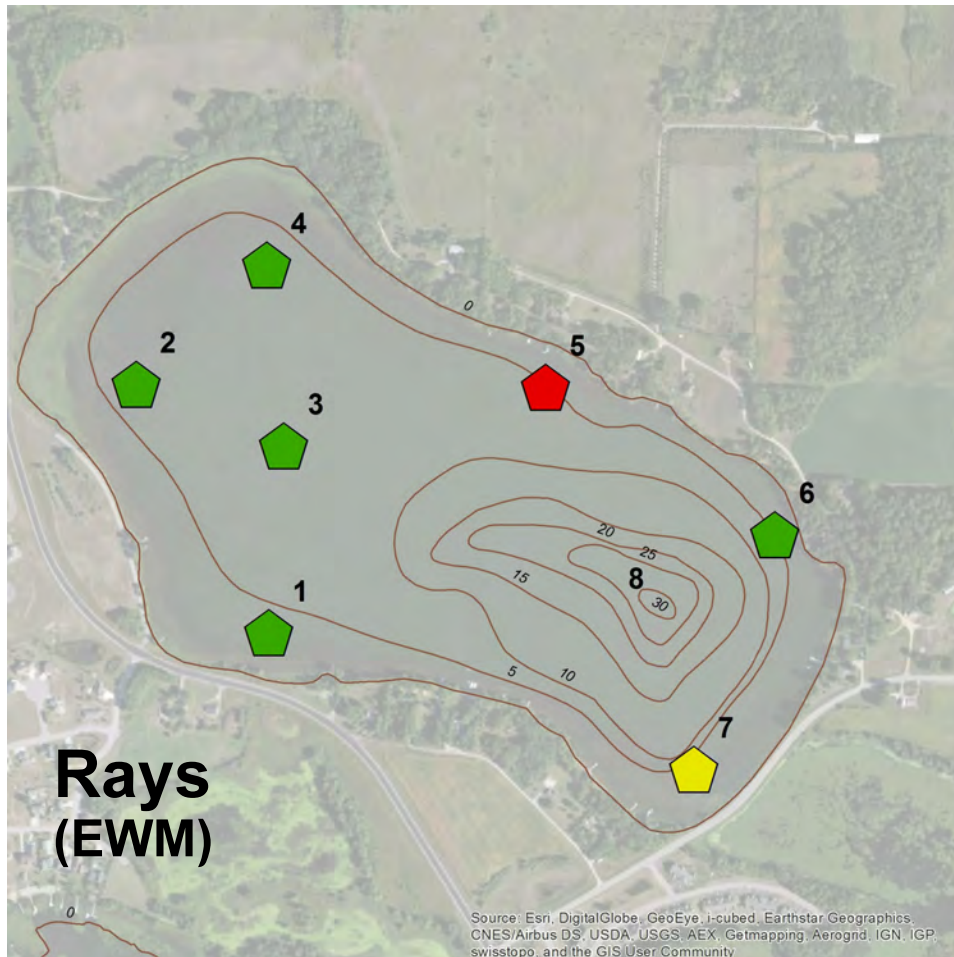


Figure S3. Eurasian watermilfoil potential growth based on lake sediment analyses for Rays Lake.
Key for Potential Growth: Green = light growth, yellow = moderate growth, red = heavy growth.

Eurasian watermilfoil is in Rays Lake. Heavy milfoil growth has been correlated with high sediment nitrogen conditions and Rays Lake has a single site with high lake sediment nitrogen conditions. The potential for future milfoil growth, based on lake sediment sampling, predicts mostly light with some heavy growth in Rays Lake (Figure S3).

For Rays Lake, it is estimated the plants have the potential to grow down to at least 5 feet of water depth based on low Secchi transparencies, restricting milfoil growth to nearshore areas. Results of the sediment survey indicate growth would be a mix of light and heavy growth.

Action Plan: Eurasian watermilfoil is present in Rays Lake currently. Lake sediment analysis indicates the potential for light to heavy milfoil growth over much of the lake. At the present time the low Secchi transparency may restrict growth to water depths of less than 7 feet. However, if water clarity increases, Eurasian watermilfoil could colonize deeper water with potential heavy growth.

4. Zebra Mussel

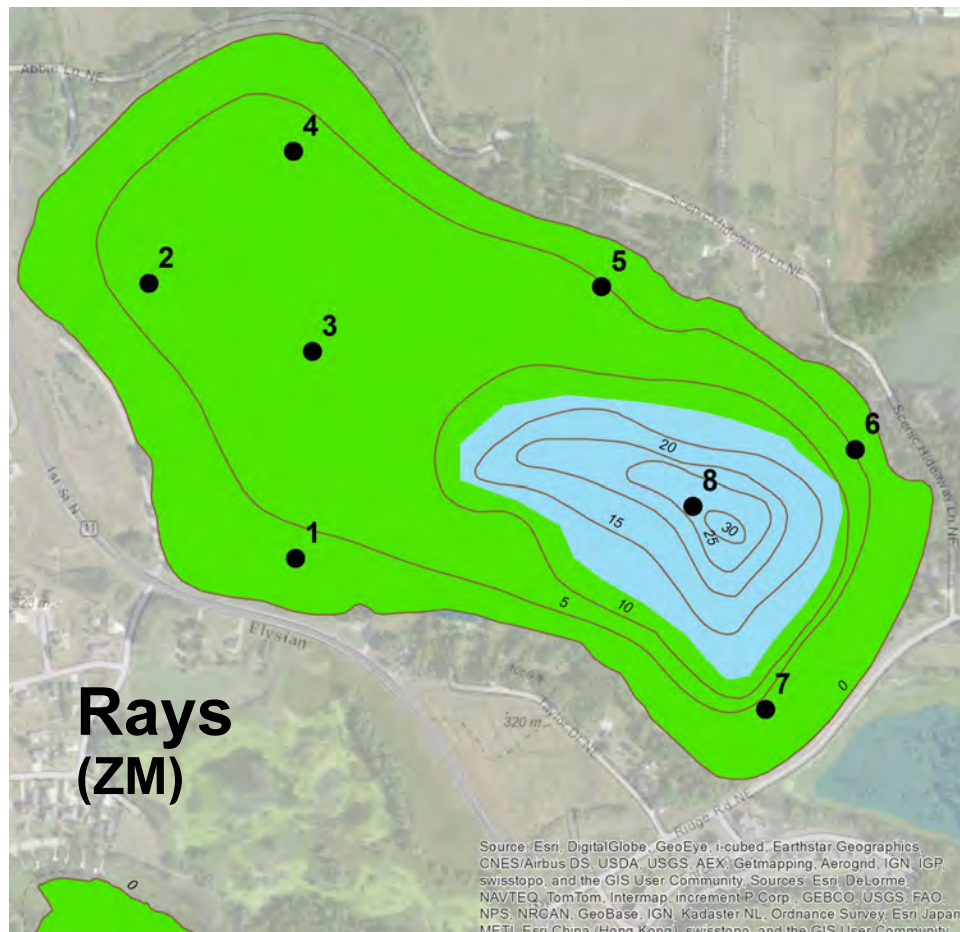


Figure S4. Zebra mussel potential growth based on water column and substrate characteristics.
Key for Potential Growth: Green = light growth and blue = no growth.

Zebra mussels have not been found in Rays Lake as of 2014. 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 Rays Lake due to the high chlorophyll concentration which is indicative of summertime blue-green algae. Colonial blue-green algae are not easily filtered by zebra mussels and limit their growth. Although dissolved oxygen conditions are suitable for optimal to moderate growth down to water depths of about 12 feet and calcium concentrations are optimal for shell production, the blue-green algae would likely limit zebra mussel growth (Figure S4). A close cousin to the zebra mussel, the quagga mussel, has similar growth requirements and may be able to survive and propagate under more harsh conditions than zebra mussels. No quagga mussels have been reported in Le Sueur County as of 2014.

Action Plan: Zebra mussels have not been found in Rays Lake as of 2014. 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 \$50,000 if an eradication attempt was considered. Discussions with the MnDNR should be held prior to zebra mussel detection in Rays Lake to outline control activities and the need for potential permits.

5. Common Carp

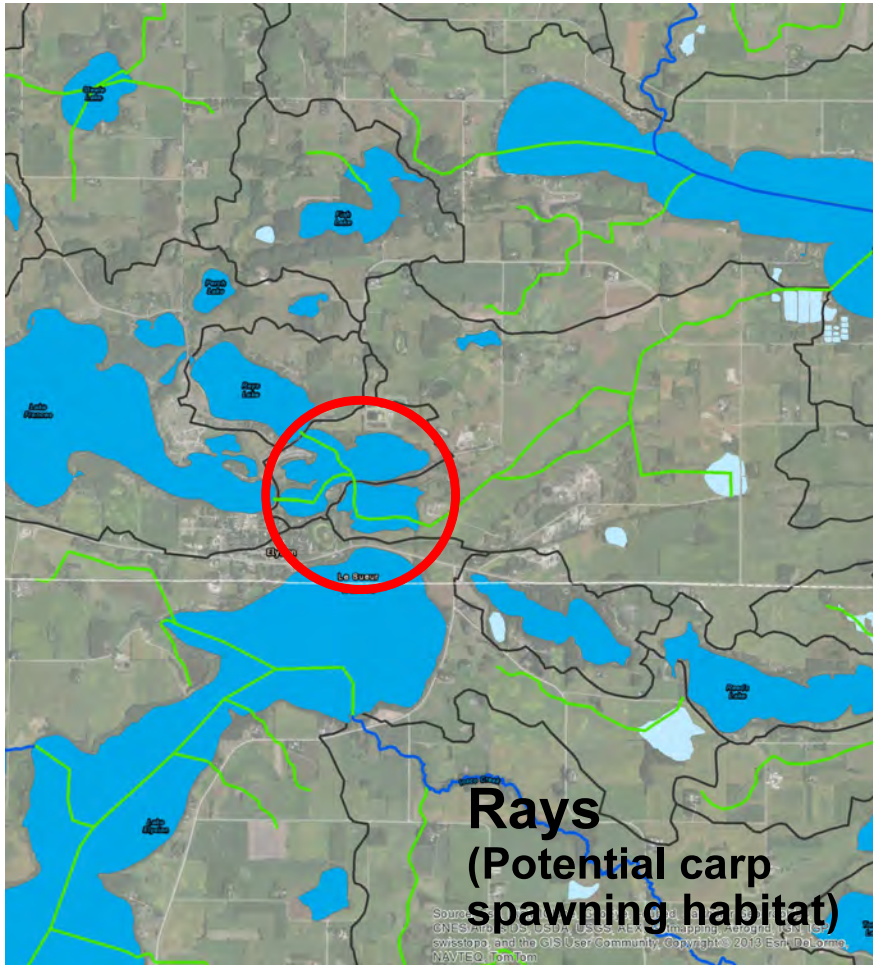


Figure S5. Common carp potential spawning habitat quality. Red circle indicates high potential for carp spawning sites for streams and lakes connected to Rays Lake.

Common carp are present in Rays Lake and the last MnDNR fish survey from 2009 did sample carp. Rays Lake habitat suitability for future carp growth is high due to spawning conditions that are well suited for survival of young fish (Figure S5). Carp spawning success and population growth 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 Rays Lake does have some potential for off-lake spawning habitat and it appears to be favorable to successful carp spawning.

Action Plan: Carp are present in Rays Lake. If carp abundance increases, aquatic plant coverage would likely decrease. As of 2014, no carp management is necessary, rather monitoring should be ongoing.

Summary of Environmental Risk Assessments for Five Aquatic Invasive Species for Rays Lake, Le Sueur 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 it does 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 Rays 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.

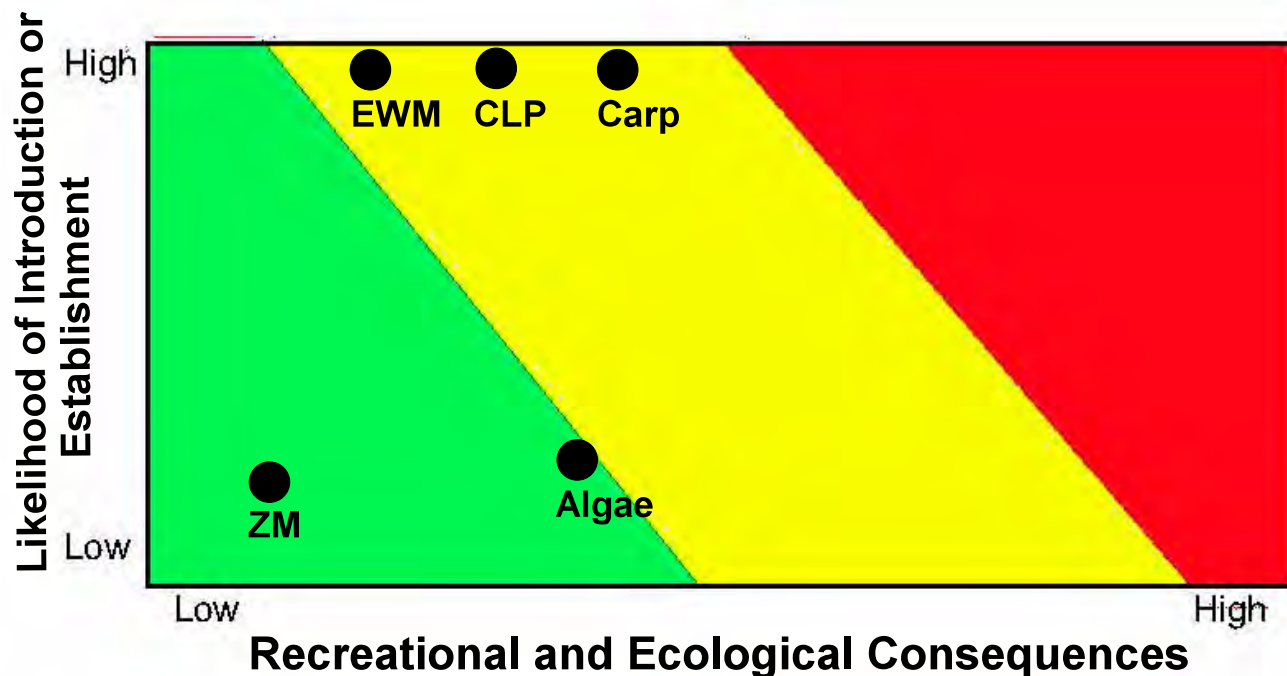


Figure S6. Based on available information, an environmental risk assessment (ERA) chart was prepared for five aquatic invasive species of interest for Rays Lake.

Key:

Algae: *Cylindrospermopsis*, a blue-green algae species, will not do well in Rays Lake under existing conditions. Its introduction may be limited, since there are few tributary inflows. Consequences would be low.

CLP: Curlyleaf pondweed is already in Rays Lake (establishment is 100%). Lake sediment analysis indicates curlyleaf has a light to moderate growth potential resulting in moderate consequences.

EWM: EWM is already in Rays Lake (establishment is 100%). Sediments indicate a potential to support mostly light growth, but it may be limited by low clarity.

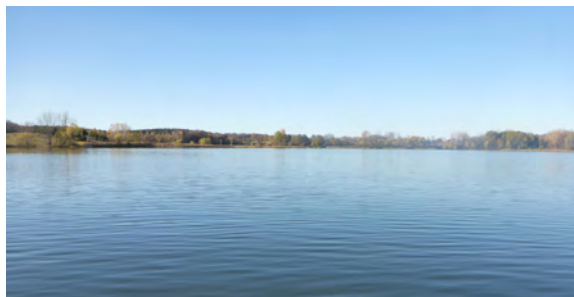
ZM: Zebra mussels are in Scott County, within 50 miles, but incoming boat access is low. If zebra mussels are introduced, they are predicted to produce mostly light growth due to food limitations.

Carp: Carp are in Rays Lake. Conditions are good for establishing an abundant carp population. It appears spawning and recruitment conditions are favorable for carp.

Aquatic Invasive Species Action Plan for Rays Lake, Le Sueur County, Minnesota

Introduction

Rays Lake is a 166 acre lake (139 littoral acres, maximum depth is 32 feet)(source: MnDNR) in Le Sueur County. The objective of this report was to evaluate the potential for ecological and recreational problems that might develop in Rays Lake associated with non-native aquatic invasive species and then list possible management actions. The aquatic invasive species evaluated include the following:



Rays Lake, Le Sueur County, Minnesota

Species of Interest:

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

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

Plants

Purple Loosestrife (present in Rays Lake)
Flowering Rush
Hydrilla

Invertebrates

Rusty Crayfish
Chinese and Banded Mystery Snail (may be present in Rays 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: Rays Lake is located in the Cannon River Watershed (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 Rays Lake, 8 lake sediment samples were collected on October 23, 2014. 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.

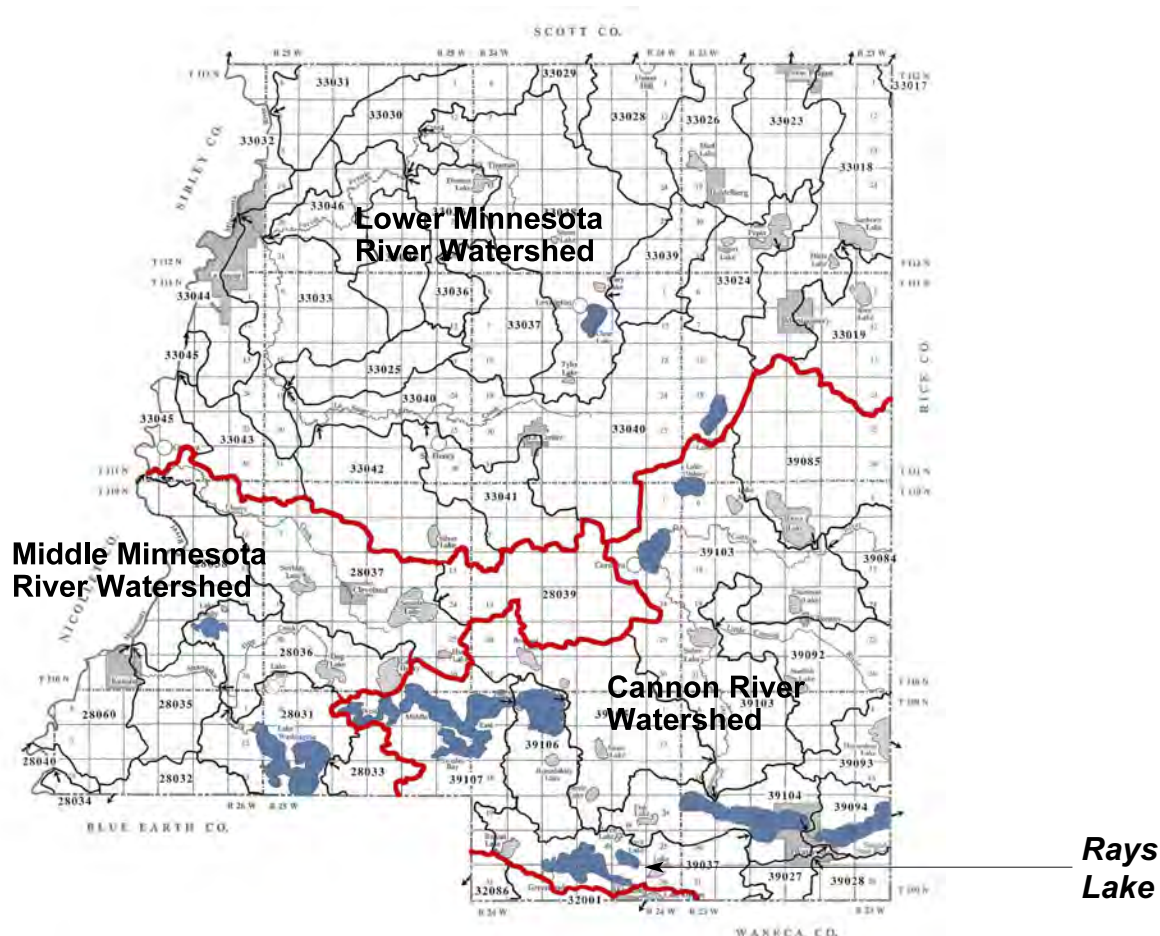


Figure 1. Three major watersheds are located in Le Sueur County. Rays Lake is found in the Cannon River Watershed.

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

Rays Lake Status: Unknown for Rays Lake.

Nearest Occurrence: Lake Nokomis, Minneapolis, MN

Potential for Bloom Conditions in Rays Lake: The potential is high, as long as the nutrient concentrations remain elevated.

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 2014, conditions are somewhat favorable in Rays Lake for blue-green growth including cylindro (Table 1).



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

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

	Shallow Lake (MPCA impaired criteria for North Central Hardwood Forest Ecoregion)	Recent Values for Rays Lake (2007) (Jun-Aug)
Secchi Disc (ft & m) (water clarity)	<3.3 ft (1.0 m)	3.4 ft (1.04m)
Total Phosphorus (fertilizer nutrient)	>60 ppb	55
Chlorophyll a (measure of algae)	>20 ppb	25



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

Cylindro Growth Potential Based on Lake Sediment Nutrient Loading: Factors that will contribute to elevated lake phosphorus concentrations could lead to high cylindro concentrations. 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 Rays 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 Rays Lake show most sediment sites have a high Fe:P ratio which is correlated to low to moderate potential phosphorus release from sediments. Low sediment phosphorus and high Fe both contribute to reduced phosphorus release from sediments (Table 2).

Table 2. Rays Lake sediment data for iron and phosphorus and the calculated Fe to P ratio. Samples were collected on September 17, 2014. The highest sediment phosphorus concentration of a site was used in the Fe/P ratio.

STANDARD SOIL TESTS					
Site	Depth (ft)	Iron (ppm)	Bray-P (ppm)	Olsen-P (ppm)	Fe/P
Ray 1	7	59.4	0.9	0.5	66.0
Ray 2	7	44.8	0.9	0.4	49.8
Ray 3	10	81.7	1.2	0.6	68.1
Ray 4	6	113.1	0.4	2.7	41.9
Ray 5	9	231.8	6.4	19.8	11.7
Ray 6	10	67.1	0.3	1.6	41.9
Ray 7	6	68.1	1.1	2.2	31.0
Ray 8	30	284.0	4.8	29.0	9.8

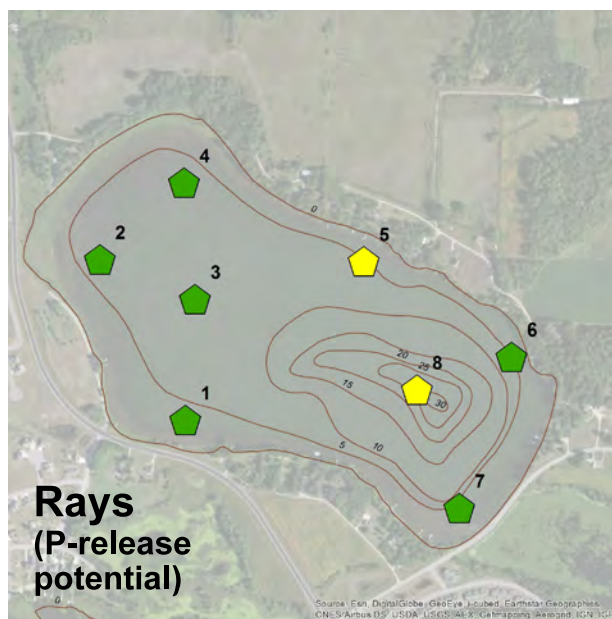


Figure 3. The color indicates the p-release potential of phosphorus in 2014. Key: green = low potential and yellow = moderate potential.

Management Options for Blue-Green Algae

Scouting Activities: Very little information on algal species distribution in Le Sueur County is available. Occasional sampling in Rays 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 reduce phosphorus, which in turn reduce excessive algal growth, is a sound management approach.

Control Options: To reduce excessive algal growth in Rays Lake, phosphorus reduction programs would help. 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. Watershed management practices such as no-till farming (left)(source: USDA - Natural Resources Conservation Service) and lake alum treatments to inactivate lake sediment phosphorus (right) are two approaches that reduce lake phosphorus concentrations.

2. Curlyleaf Pondweed (non-native aquatic plant)

Rays Lake Status: Present in Rays Lake.

Potential for Curlyleaf Pondweed Growth in Rays Lake: Mostly moderate growth potential with scattered areas of light and heavy growth potential.

Lake sediment sampling results from 2014 have been used to predict lake bottom areas that have the potential to support moderate curlyleaf pondweed plant growth. Various types of curlyleaf growth patterns are shown in Figures 5 and 6. Based on the key sediment parameters of pH, sediment bulk density, organic matter, and the Fe:Mn ratio (McComas, unpublished), the predicted growth characteristics of curlyleaf pondweed in Rays Lake are shown in Table 3 and Figure 7.

Curlyleaf pondweed growth is predicted to produce mostly moderate growth (Figure 7).

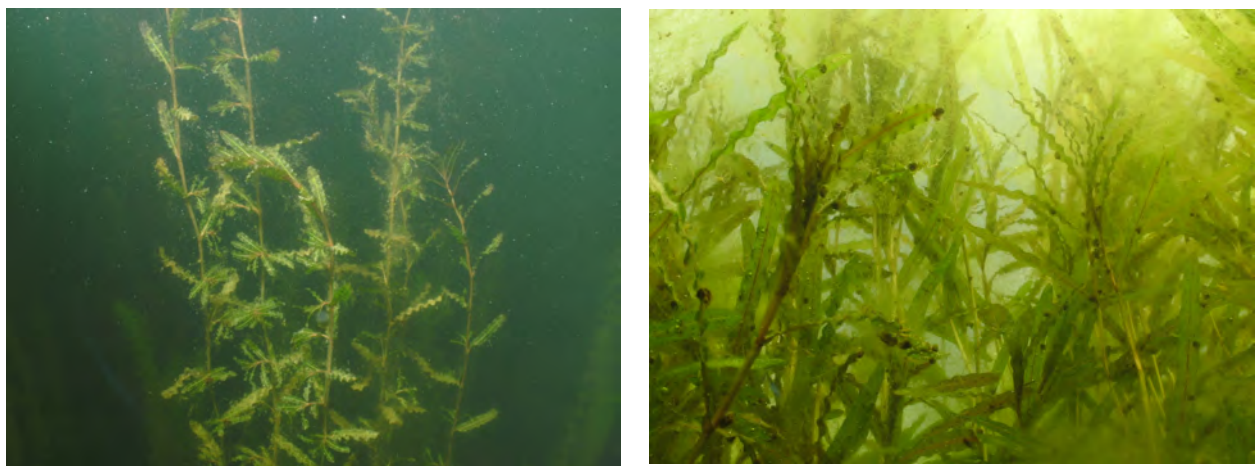


Figure 5. Underwater views of curlyleaf pondweed. Light growth (left) and moderate growth (right).

Examples of Curlyleaf Pondweed Growth Characteristics



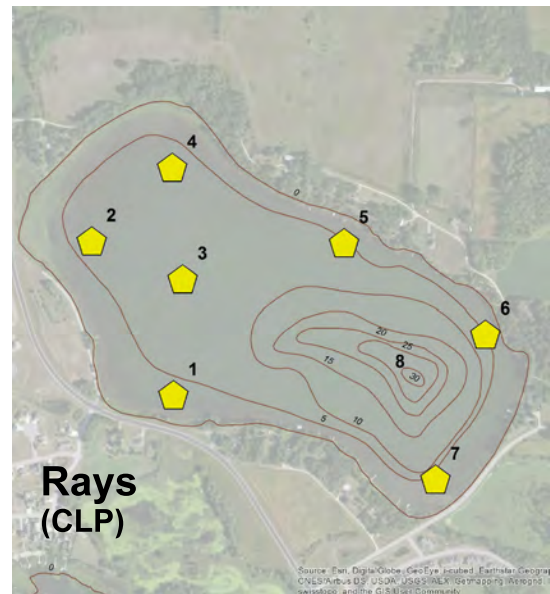
Figure 6. Light growth (left) refers to non-nuisance growth that is mostly below the surface and is not a recreational or ecological problem. Moderate growth (middle) refers to growth that is just below the water surface. Heavy growth (right) refers to nuisance matting curlyleaf pondweed. This is the 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 is present in Rays Lake. Research has found curlyleaf is limited or enhanced based on lake sediment characteristics. Based on lake sediment characteristics, curlyleaf has the potential to produce light, moderate, or heavy growth on an annual basis.

In Rays Lake it is predicted that curlyleaf will grow at mostly moderate densities. Curlyleaf pondweed growth will be mostly enhanced by high organic matter, but pH values may limit growth to moderate conditions.

Table 3. Rays Lake sediment data and ratings for potential growth of curlyleaf pondweed.

Site	Depth (ft)	pH (su)	Bulk Density (g/cm ³ dry)	Organic Matter (%)	Fe:Mn Ratio	Potential for Curlyleaf Pondweed Growth
Light Growth		<7.4	>1.04	0.1-5	>4.5	Light (green)
Moderate Growth		7.4 - 7.7	0.52 - 1.03	6-20	1.6 - 4.5	Moderate (yellow)
Heavy Growth		>7.7	<0.51	>20	<1.6	Heavy (red)
Ray 1	7	7.6	0.27	38.8	11.1	Moderate
Ray 2	7	7.7	0.26	37.9	12.9	Moderate
Ray 3	10	7.5	0.35	43.3	15.7	Moderate
Ray 4	6	7.6	0.45	26.3	7.5	Moderate
Ray 5	9	7.4	0.83	7.8	2.7	Moderate
Ray 6	10	7.6	0.37	29.1	2.6	Moderate
Ray 7	6	8.0	1.27	1.1	3.5	Moderate
Ray 8	30	7.4	0.63	24.5	5.3	



**Figure 7. The color indicates the potential growth of curlyleaf pondweed.
Key: yellow = moderate growth.**

Management Options for Curlyleaf Pondweed

Scouting Activities: Annual scouting activities can be used to delineate areas where curlyleaf pondweed (CLP) treatment is considered. Sediment characteristics, already collected, indicate there is a potential for mostly moderate growth of CLP in Rays Lake. Scouting should be concentrated in areas that are conducive to heavy growth. If a delineation occurs it is recommended that all aquatic plants (including the natives) should be recorded within a delineated area containing curlyleaf pondweed. GPS mapping 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.



Figure 8. Five stems of curlyleaf pondweed are shown on a rakehead sampler in a delineation survey in May. By the end of June this early season density could produce heavy growth.

Rapid Response: Unnecessary, curlyleaf is already present.

Control Options: The recommended treatment option at this time 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. Curlyleaf will continue to grow in Rays Lake even in years after treatment. Two common treatment methods are shown below. In the future, harvesting or cutting could be incorporated into a management program.



Herbicide applications



Mechanical harvesters

3. Eurasian Watermilfoil (non-native aquatic plant)

Rays Lake Status: Present in Rays Lake.

Potential for Eurasian Watermilfoil Growth in Rays Lake: Mostly light to heavy potential.

Lake sediment sampling results from 2014 have been used to predict lake areas that have the potential to support heavy Eurasian watermilfoil growth. Examples of milfoil growth characteristics are shown in Figures 9 and 10. 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 for milfoil in Rays Lake (Table 4 and Figure 11).

In Rays Lake a majority of sites had low to moderate nitrogen and high organic matter and these areas are predicted to have the potential to produce light growth of milfoil on an annual basis. Water clarity will also limit growth to areas less than 7 feet of water depth.



Figure 9. Underwater views of Eurasian watermilfoil.

Examples of Eurasian Watermilfoil Growth Characteristics



Figure 10. 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 (EWM) Growth Potential Based on Lake Sediments: Lake sediment sampling results from 2014 have been used to predict lake bottom areas that have the potential to support heavy EWM growth. Eurasian watermilfoil is present in Rays Lake. The potential for milfoil growth, based on lake sediment sampling, would be light to heavy growth (Figure 11). Heavy milfoil growth has been correlated with high sediment nitrogen condition and Rays Lake has a mix of high and low nitrogen conditions, but organic matter could be limiting.

For Rays Lake, it is estimated the plants have the potential to grow down to about 7 to 8 feet of water depth based on existing water clarity conditions and that could limit EWM distribution.

Table 4. Rays Lake sediment data and ratings for potential growth of Eurasian watermilfoil.

Site	Depth (ft)	NH ₄ Conc (ppm)	Organic Matter (%)	Potential for Eurasian Watermilfoil Growth
Light Growth		<4	<0.5 and >20	Light (green)
Moderate Growth		4 - 10	0.6 - 2 and 18 - 20	Moderate (yellow)
Heavy Growth		>10	3 - 17	Heavy (red)
Ray 1	7	2.7	38.8	Light
Ray 2	7	2.8	37.9	Light
Ray 3	10	3.8	43.3	Light
Ray 4	6	15.8	26.3	Light
Ray 5	9	62.7	7.8	Heavy
Ray 6	10	4.0	29.1	Light
Ray 7	6	4.5	1.1	Moderate
Ray 8	30	70.7	24.5	

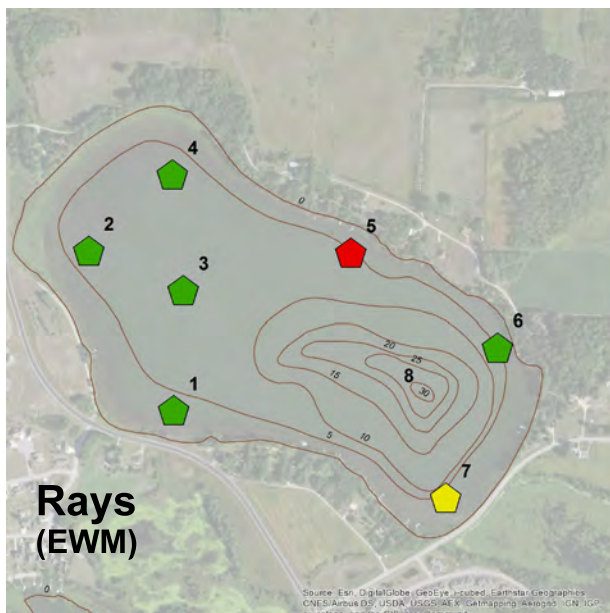


Figure 11. The color indicates the potential growth of Eurasian watermilfoil.
Key: green = light growth, yellow = moderate growth, and red = heavy growth.

Management Options for Eurasian Watermilfoil

Scouting Activities: When observers are on the lake they could be looking for any sign of milfoil growth. This scouting activity can occur at the time of curlyleaf scouting in May and June, but additional monitoring on the lake through the summer sampling season presents additional opportunities for a discovery.

Rapid Response Action: Unnecessary, Eurasian watermilfoil is already present.

Control Options: Even though Eurasian watermilfoil is established in Rays Lake, eradication of Eurasian watermilfoil is not likely to be feasible. Lake sediment analyses indicate the potential for light to heavy growth. However poor water clarity conditions may limit heavy growth of Eurasian watermilfoil or it's hybrid in Rays Lake to water depths of 7 feet or less.

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



Herbicide Applications would use a 2,4-D herbicide



Mechanical harvesting

4. Zebra Mussels (invertebrate)

Rays Lake Status: Not currently found in Rays Lake as of November 2014.

Nearest Occurrence: Prior Lake, Scott County, Minnesota.

Potential for Colonization in Rays Lake: Low.

The life cycle of zebra mussels is shown in Figure 12. 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 13. A chart of water column parameters indicates a broad range of potential growth for zebra mussels in Rays Lake (Table 5).

Although zebra mussels prefer hard substrates for optimal growth, they will grow together forming clumps on sand and silt bottoms. Rays Lake has extensive areas of sandy and mucky sediments that would support moderate zebra mussel colonization (Figure 13). However, blue-green algal dominance would likely restrict zebra mussels to light growth.

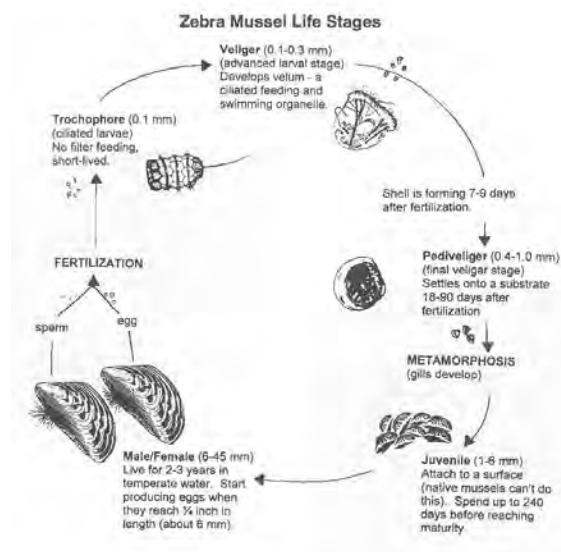


Figure 12. Zebra mussel life stages: Zebra mussels can be detected at the veliger stage using modified zooplankton nets, but this is usually performed by experts (Adopted from U.S. Army Corps of Engineers, WES)(from McComas, 2003. Lake and pond management guidebook).

Examples of Zebra Mussel Growth Conditions



Light Growth



**Moderate Growth
(suboptimal growth)**



**Heavy Growth
(optimal growth)**

Figure 13. 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 Rays Lake as of 2014. A review of water column characteristics for Rays Lake was compared to characteristics suited for zebra mussels. It appears that zebra mussels would be food limited in Rays Lake due to the excessive concentration of blue-green algae which are not easily ingested by zebra mussels (Table 5).

Table 5. Water column zebra mussel suitability criteria and Rays Lake water column conditions.

		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)	Rays Lake			29.4 (Oct 23, 2014)	
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Rays Lake				8.3 (Oct 23, 2014)
	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)	Rays Lake				136 (Oct 23, 2014)
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Rays Lake				280 (Oct 23, 2014)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Chlorophyll a (ug/l) (June-Sept)	Rays Lake		25 8 - 48 (2007)		
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Secchi depth (m) (June-Sept)	Rays Lake		1.04 0.46 - 1.52 (2007)		
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Total phosphorus (ug/l) (June-Sept)	Rays Lake	55 38 - 85 (2007)			
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35
Substrate Factors (Dissolved oxygen and sediment composition)					
Dissolved oxygen (mg/l)	Rays Lake	>12 feet	>12 feet	0 - 12 feet	
	Mackie and Claudi 2010	<3 mg/l	3 - 7 mg/l	7 - 8 mg/l	>8 mg/l
Bottom substrate	Rays Lake	50		48	2
		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 indicate, based on chlorophyll data, blue-green algae could limit zebra mussel growth. Substrate conditions were also inspected at 8 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 Rays Lake are sparse. A map that combines the growth potential of water column and substrate characteristics is shown in Figure 14. It appears dissolved oxygen is adequate to allow growth over nearly all the lake bottom, but zebra mussel production will be mostly light. Zebra mussels will grow on each other in clumps (Figure 15) and begin to become commonly observed two to four years after first being discovered.

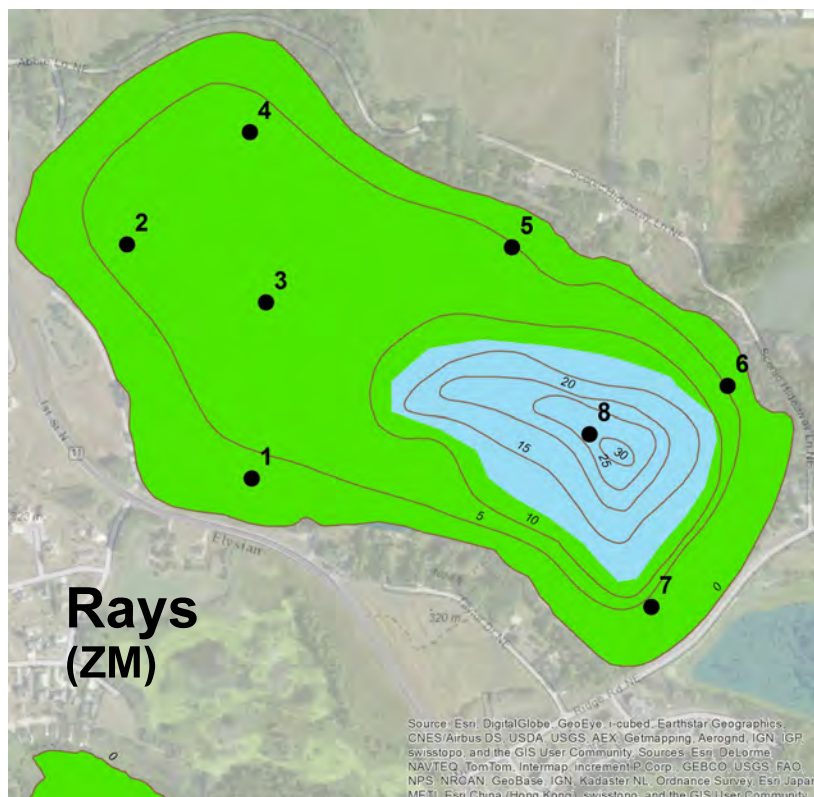


Figure 14. Key for potential growth: Green = light growth and Blue = no growth.



Figure 15. Distinctive zebra mussel growth pattern found in sandy and silty sediments. Zebra mussels will grow on each other and form clumps of zebra mussels.

Management Options for Zebra Mussels

Early Detection: The zebra mussel is an aquatic invasive species that could be scouted in Rays 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 16. 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 Rays 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 Rays Lake, a minimum of 20 search hours would be appropriate.

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 Rays 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 12), 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 Rays Lake, but at predicted low 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 17. 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)

Rays Lake Status: Present in Rays Lake (based on MnDNR fish surveys).

Potential for Excessive Abundance in Rays 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 18. Common carp were sampled at moderate to high abundance in the last survey in Rays Lake, based on the MnDNR fish survey from 2009 (Table 6). Rays Lake habitat suitability for future growth is moderate due to spawning conditions that may be well suited for survival of young fish (Figure 19). Since the 2009 survey, carp abundance has been low, probably due to limited immigration and poor recruitment of new carp.

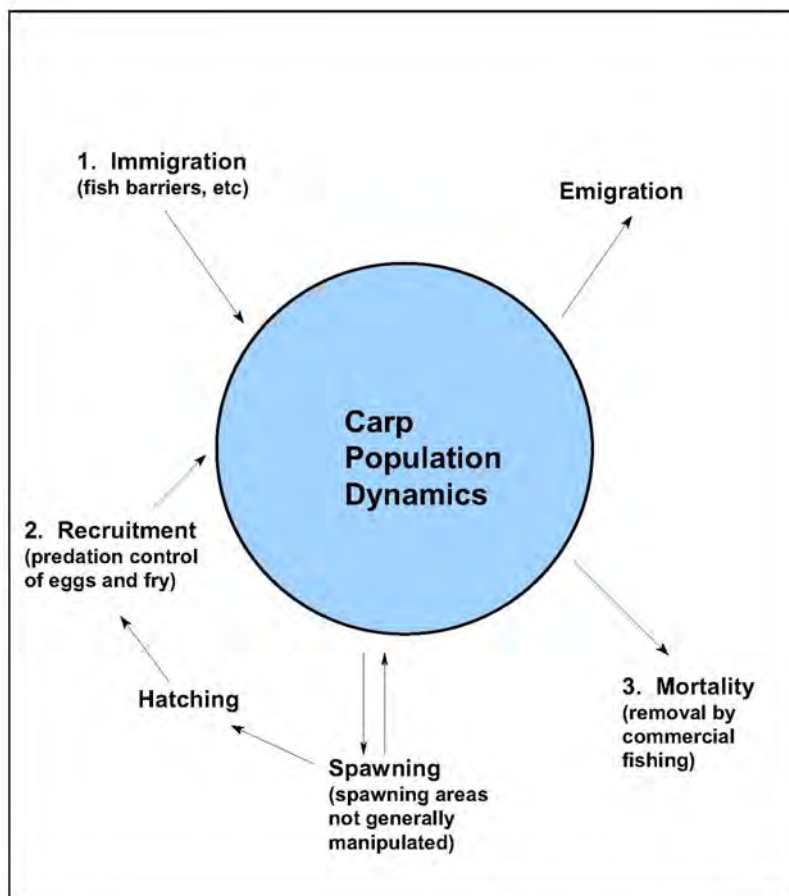


Figure 18. Three factors contribute to carp population dynamics. When carp populations are at a low density in lakes, immigration and recruitment generally limit populations.

Table 6. Fish sampled in the Rays Lake 2009 MnDNR fish survey.

Species	Gear Used	Number of Fish per Net		Average Fish Weight (lbs)	Normal Range (lbs)
		Caught	Normal Range		
Black Bullhead	Trap net	8	1.5 - 58.0	0.48	0.2 - 0.5
	Gill net	18.75	7.7 - 104.7	0.41	0.2 - 0.5
Black Crappie	Trap net	15.89	2.1 - 24.1	0.19	0.2 - 0.4
	Gill net	47.5	1.7 - 17.5	0.14	0.1 - 0.3
Bluegill	Trap net	83.33	3.5 - 57.1	0.16	0.1 - 0.3
	Gill net	6.25	N/A	0.15	N/A
Bowfin (dogfish)	Trap net	0.56	0.3 - 1.3	1.91	2.5 - 4.2
Common Carp	Trap net	0.11	0.4 - 2.4	2.96	1.8 - 5.1
	Gill net	6	0.8 - 4.3	4.52	1.0 - 4.0
Golden Shiner	Trap net	0.89	0.3 - 1.6	0.08	0.1 - 0.1
Hybrid Sunfish	Gill net	0.25	N/A	0.31	N/A
Largemouth Bass	Trap net	0.33	0.2 - 0.8	0.85	0.3 - 1.5
	Gill net	0.5	0.3 - 0.6	0.48	0.5 - 1.5
Northern Pike	Trap net	0.22	N/A	7.19	N/A
	Gill net	1.75	2.0 - 10.8	3.32	1.7 - 3.1
Pumpkinseed	Trap net	0.22	0.7 - 6.5	0.17	0.1 - 0.2
Walleye	Gill net	0.5	0.8 - 3.8	2.65	1.4 - 3.0
White Bass	Gill net	0.25	N/A	1.71	N/A
Yellow Bullhead	Trap net	4	1.0 - 7.1	0.81	0.4 - 0.8
	Gill net	0.5	0.5 - 5.0	0.92	0.4 - 0.8
Yellow Perch	Trap net	0.11	0.4 - 2.8	0.05	0.1 - 0.2

Normal Ranges represent typical catches for lakes with similar physical and chemical characteristics.

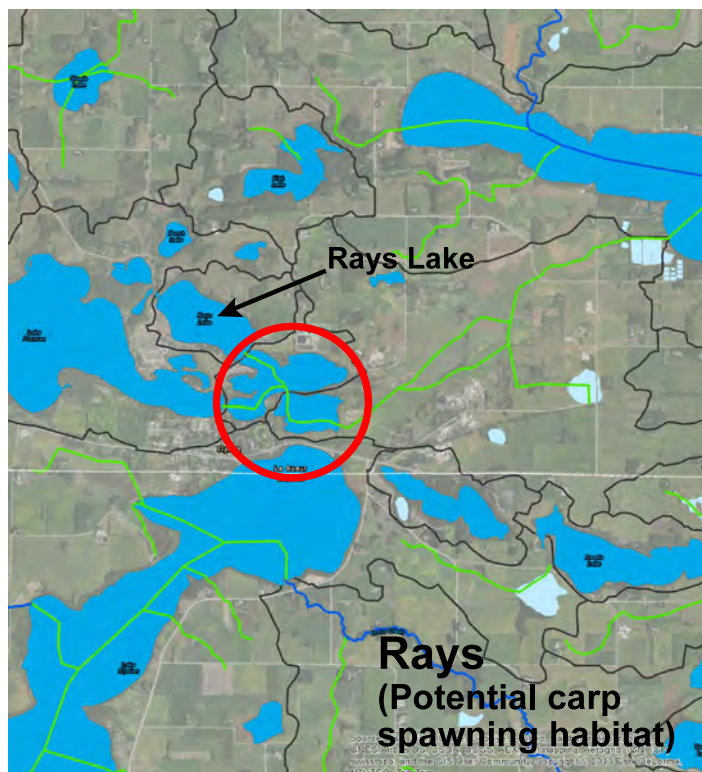


Figure 19. Common carp potential spawning habitat quality. Red circle indicates high potential for carp spawning sites for streams and lakes connected to Rays Lake.

Management Options for Common Carp

Early Detection: Carp are present in Rays Lake, and may be excessive. 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: Unnecessary, rather, use MnDNR fish surveys to track carp numbers.

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 20). 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 found to be good carp spawning habitat. The third area, mortality, could be implemented by using commercial fishermen if necessary.



1. Immigration
(Low in Rays Lake)



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



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

Figure 20. Three factors impacting carp population dynamics.

Other Non-native Species to Consider

Flowering Rush (aquatic plant)

Rays Lake Status: Currently not in Rays Lake

Potential for Colonization in Rays Lake: High. Flowering rush will spread slowly unless it is disturbed.

Background Information:

- Flowering rush is actively expanding in some parts of the country. 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.
- It competes with native shoreland vegetation.
- 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.
- There is documentation from a site in Idaho, between 1956 and 1973, where flowering rush appeared to be out-competing willows and cattails.
- Flowering rush is on the DNR Prohibited invasive species list in Minnesota.

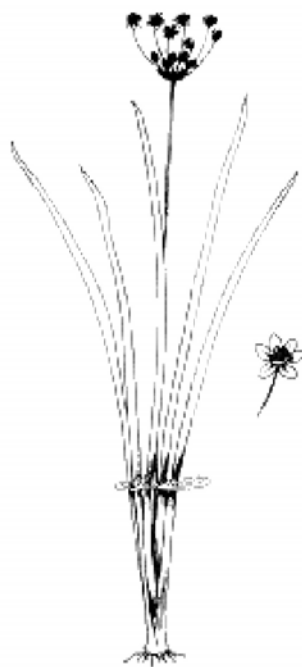


Figure 21. [left] Flowering rush plant and flowering rush flowerhead [right].

Management Options for Flowering Rush

Flowering rush is a perennial aquatic herbaceous plant. It grows 1-4' high on an erect stem along shores in shallow water. In deeper water it grows submerged without producing flowers.

Flowering rush is very difficult to identify when not in flower. It closely resembles many native shoreland plants, such as the common bulrush.

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 buoyant rhizome fragments which may facilitate long distance disposal. Both seeds and bulb-lets are dispersed by water current.

Control Options

Mechanical: Cut below the water surface several times per summer and remove cut parts from water. This will help control spreading. Hand dig isolated plants with care, root fragments can spread and sprout

Chemical: Application of the herbicide diquat (trade name Reward). Preliminary testing indicates that a mid-summer application during calm wind conditions may be most effective.

Purple Loosestrife (aquatic and terrestrial plant)

Rays Lake Status: Purple loosestrife has not been seen around the Rays Lake shoreline in 2014.

Potential for Nuisance Colonization in Rays Lake: Moderate.

Purple loosestrife can colonize a wide range of soil conditions. Because of its 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 Rays Lake.

Purple Loosestrife in Rays Lake: In 2014, Purple Loosestrife was not found in Rays Lake. Purple loosestrife is able to establish and multiply rapidly (Figure 22). If it is found in or around Rays Lake, its recommended that the lake association consider removal of the few individual plants before it can establish a foothold.



Source: MnDNR



Source: MnDNR

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

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 Rays 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)

Rays Lake Status: Not present in Rays 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 Rays 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 than 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 Rays Lake.

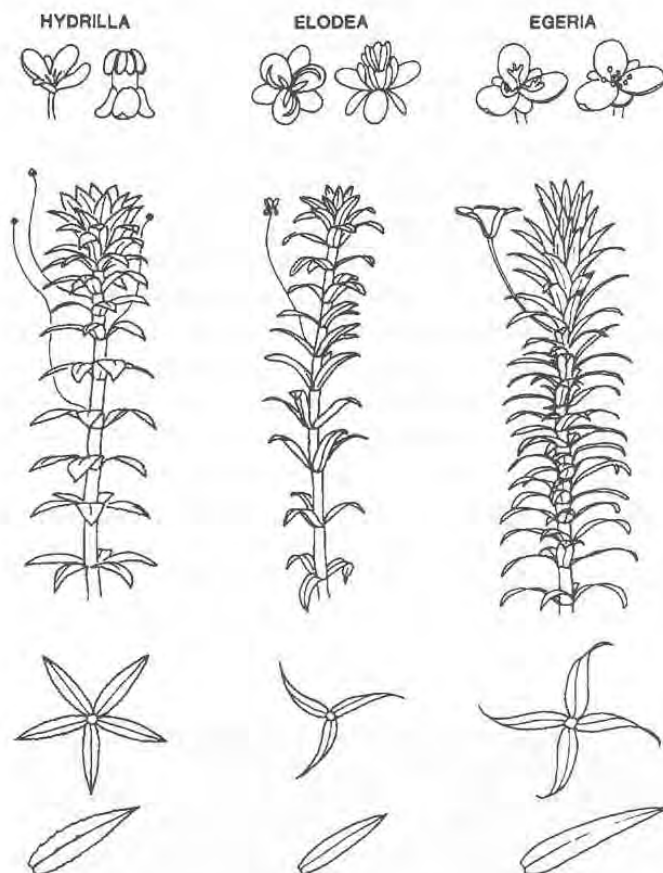


Figure 23.

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 Rays Lake, but observers should be aware of the possibility.

Control Options: If hydrilla was confirmed in Rays 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)

Rays Lake Status: Not presently found in Rays 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 Le Sueur County, but not reported.

Potential for Nuisance Colonization in Rays 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 Rays Lake they could reduce the aquatic plants found in the bays. Rusty crayfish would have minimal effect in the main body of Rays 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 Rays Lake and checked weekly.

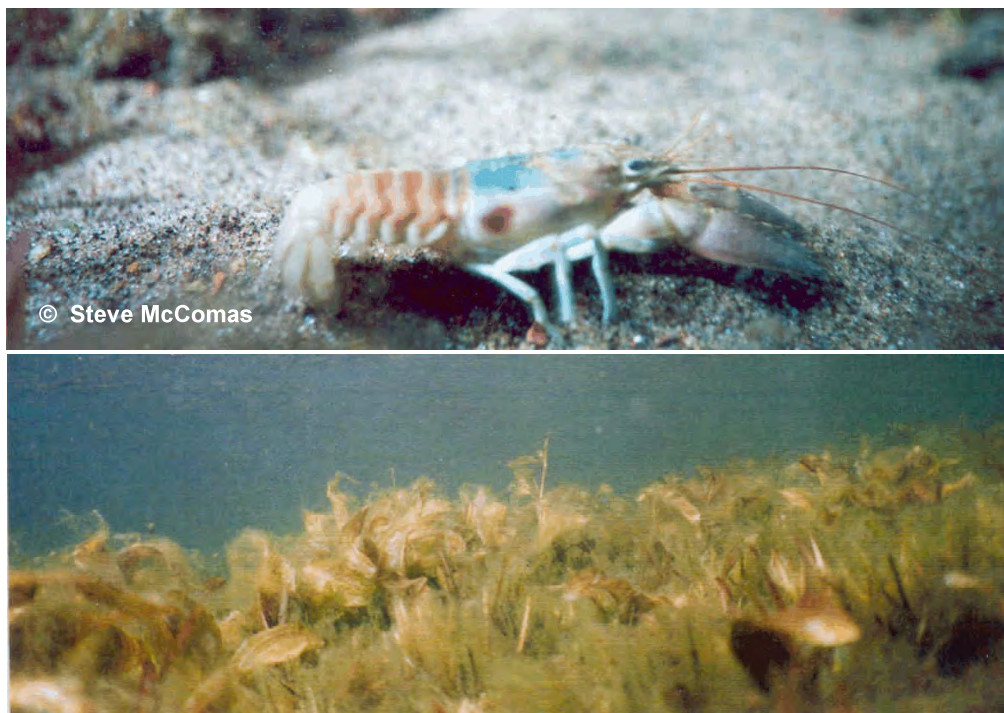


Figure 24. [top] Rusty crayfish in breeding colors (Plum Lake, Wisconsin). They can be identified by a reddish dot on their carapace (side of their body). Native crayfish do not have this marking. [bottom] Rusty crayfish graze down aquatic plant beds and eventually eliminate them.

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 Rays 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.

Rays 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

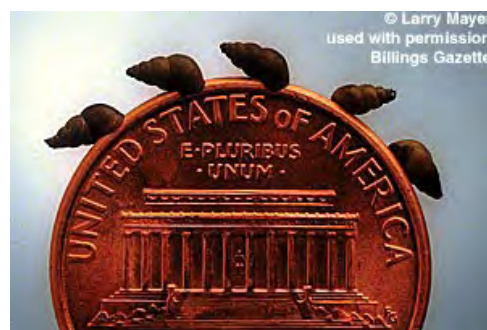
Quagga Mussel: The Quagga mussel can inhabit both hard and soft substrates, including sand and mud, and can colonize to depths with lower dissolved oxygen than zebra mussels can handle but has a hard time colonizing in shallow water. The fan shaped mussel, has several life stages and is about the size 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.



Chinese and Banded Mystery Snail (CMS), (BMS): A larger olive colored snail species, CMS and BMS can form dense aggregations. CMS can transmit human intestinal 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.



New Zealand Mudsnaill: 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 m². 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.



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.



Asian Carp

Rays Lake Status: Not present in Rays 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 Rays 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 Rays Lake watershed.

Management Options for Asian Carp

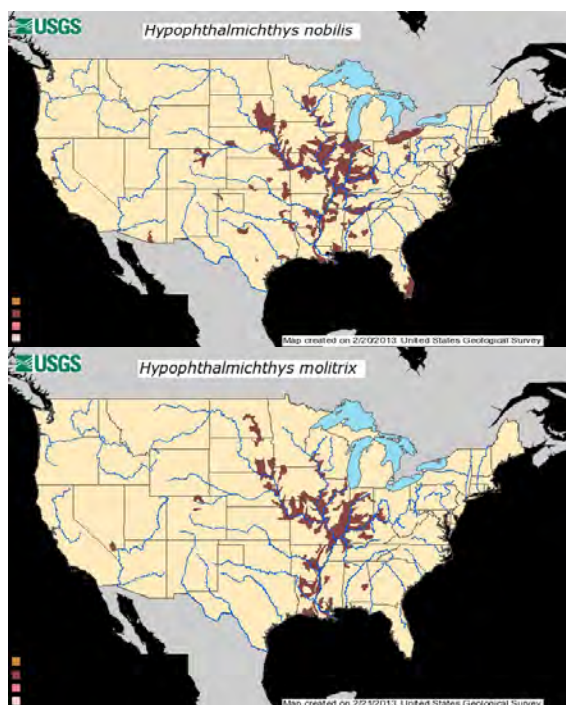
Control Options: Asian carp should not be able to spawn in Rays Lake. Control options include commercial fishing or to let the carp die off naturally.



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



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



Snakehead

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

Nearest occurrence: East coast.

Potential for Nuisance Colonization in Rays 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)

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

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

Potential for Nuisance Colonization in Rays 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 Rays 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 hemorrhaging to the MnDNR. If they have caught a fish with hemorrhaging they should bring the fish to the MnDNR. If a fish kill is observed involving hemorrhaging 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 Rays Lake, an intensive information program should be implemented by the Le Sueur County Environmental staff. 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.



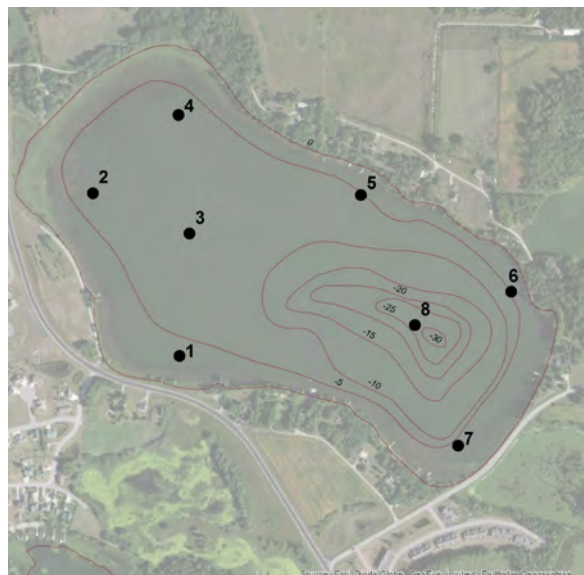
Figure 30. Examples of hemorrhaging in fish with the VHS virus.

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APPENDIX A

Methods



Lake Soil Survey: A total of 8 samples were collected from depths ranging from 6 to 30 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. Samples in deeper water (30 feet) were sampled using a ponar dredge. 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
$\text{NH}_4\text{-N}$	2N KCL
K, Ca, Mg	1N NH_4OAc (ammonium acetate)
Fe, Mn, Zn, Cu	DTPA (diethylenetriamine pentaacetic acid)
B	Hot water
$\text{SO}_4\text{-S}$	$\text{Ca}(\text{H}_2\text{PO}_4)_2$
pH	water
Organic matter	Loss on ignition at 360°C



Figure A2a. Soil auger used to collect lake sediments in water depths to 10 feet.



Figure A2b. Ponar dredge used to collect lake sediments in deeper water.

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 $\mu\text{g}/\text{cm}^3$.

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 $\mu\text{g}/\text{cm}^3$. 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 then 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 $4.00 \text{ g} / 10.00 \text{ g} = 0.40$. If the analytical result was 10 ppm based on 10 grams, then it should be $0.40 \times 10 \text{ ppm} = 4 \text{ ppm}$ based on 4 grams. The results could be written as 4 ppm or 4 $\mu\text{g}/\text{cm}^3$. Likewise, if a 10-gram scoop of lake sediment weighed 12 grams, then the correction factor is $12.00 \text{ g} / 10.00 \text{ g} = 1.20$. If the analytical result was 10 ppm based on a 10 gram scoop, then it should be $1.20 \times 10 \text{ ppm} = 12 \text{ ppm}$ based on 12 grams. The result could be written as 12 ppm or 12 $\mu\text{g}/\text{cm}^3$. 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

2014 sediment data for Rays Lake. Sediments were collected on September 17, 2014.

ADJUSTED DATA SET

Sample Name	Bulk Density (wt/8.51)	Bray P (ppm) <i>adjusted</i>	Olsen P (ppm) <i>adjusted</i>	NH ₄ OAc-K (ppm) <i>adjusted</i>	LOI OM (%)	Water pH	Hot Water Boron (ppm)	Hot Water Boron (ppm) <i>adjusted</i>	DTPA-Fe (ppm) <i>adjusted</i>	DTPA-Mn (ppm) <i>adjusted</i>	DTPA-Zn (ppm) <i>adjusted</i>	DTPA-Cu (ppm) <i>adjusted</i>	NH ₄ OAc-Ca (ppm) <i>adjusted</i>	NH ₄ OAc-Mg (ppm) <i>adjusted</i>	SO ₄ -S (ppm) <i>adjusted</i>	NH ₄ -N (ppm) <i>adjusted</i>	Avg Scoop Wt	Correction Factor	Fe/Mn
Ray 1	0.27	0.9	0.5	11	38.8	7.6	1.067	0.244	59.35	5.336	0.151	0.362	711.5	72.91	2	2.7	2.29	0.23	11.1
Ray 2	0.26	0.9	0.4	11	37.9	7.7	0.920	0.201	44.76	3.463	0.122	0.283	580.5	63.20	3	2.8	2.19	0.22	12.9
Ray 3	0.35	1.2	0.6	25	43.3	7.5	1.130	0.334	81.72	5.208	0.243	0.656	859.4	130.46	3	3.8	2.96	0.30	15.7
Ray 4	0.45	0.4	2.7	36	26.3	7.6	1.095	0.416	113.14	15.122	0.585	0.965	1528.5	144.11	7	15.8	3.80	0.38	7.5
Ray 5	0.83	6.4	19.8	154	7.8	7.4	1.109	0.786	231.80	86.401	1.561	3.652	2550.3	316.75	9	62.7	7.09	0.71	2.7
Ray 6	0.37	0.3	1.6	20	29.1	7.6	0.980	0.312	67.09	25.810	0.304	0.442	1255.1	168.76	10	4.0	3.18	0.32	2.6
Ray 7	1.27	1.1	2.2	47	1.1	8.0	0.212	0.230	68.12	19.647	0.496	0.567	2660.3	163.68	15	4.5	10.83	1.08	3.5
Ray 8	0.63	4.8	29.0	138	24.5	7.4	1.620	0.869	283.97	53.169	1.395	1.713	1850.6	333.14	57	70.7	5.36	0.54	5.3

REPORTED FROM THE LAB DATA SET (UNADJUSTED)

Sample Name	Bray P (ppm)	Olsen P (ppm)	NH ₄ OAc-K (ppm)	LOI OM (%)	Water pH	Hot Water 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)	NH ₄ -N (ppm)	10 gm Scoop Wt	10 gm Scoop Wt	10 gm Scoop Wt
Ray 1	4	2	48	38.8	7.6	1.067	259.55	23.335	0.659	1.585	3111.5	318.85	10	11.9	2.14	2.31	2.41
Ray 2	4	2	51	37.9	7.7	0.920	204.68	15.839	0.557	1.295	2654.9	289.02	12	12.7	2.19	2.22	2.15
Ray 3	4	2	83	43.3	7.5	1.130	276.09	17.595	0.822	2.216	2903.3	440.74	10	12.8	2.93	3.01	2.94
Ray 4	1	7	96	26.3	7.6	1.095	298.01	39.829	1.540	2.542	4025.9	379.57	18	41.7	3.88	3.70	3.81
Ray 5	9	28	218	7.8	7.4	1.109	327.09	121.920	2.203	5.154	3598.7	446.97	13	88.4	7.01	7.13	7.12
Ray 6	1	5	63	29.1	7.6	0.980	210.97	81.162	0.956	1.391	3946.8	530.70	33	12.7	3.26	2.96	3.32
Ray 7	1	2	43	1.1	8.0	0.212	62.902	18.141	0.458	0.524	2456.4	151.14	14	4.1	10.72	10.96	10.81
Ray 8	9	54	258	24.5	7.4	1.620	529.47	99.134	2.601	3.193	3450.4	621.14	107	131.9	5.33	5.29	5.47

APPENDIX C

Curlyleaf Pondweed Growth Characteristics

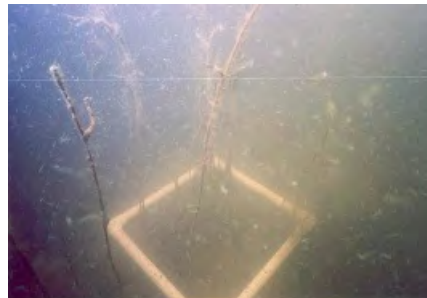
(source: Steve McComas, Blue Water Science, unpublished)

Light Growth Conditions

Plants rarely reach the surface.

Navigation and recreational activities are not generally hindered.

Stem density: 0 - 160 stems/m²
Biomass: 0 - 50 g-dry wt/m²
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/m²
Biomass: 50 - 85 g-dry wt/m²
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/m²
Biomass: >300 g-dry wt/m²
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)

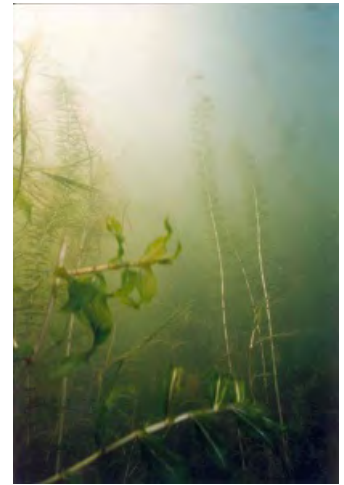
Light Growth Conditions

Plants rarely reach the surface.

Navigation and recreational activities generally are not hindered.

Stem density: 0 - 40 stems/m²

Biomass: 0 - 51 g-dry wt/m²



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

Moderate Growth Conditions

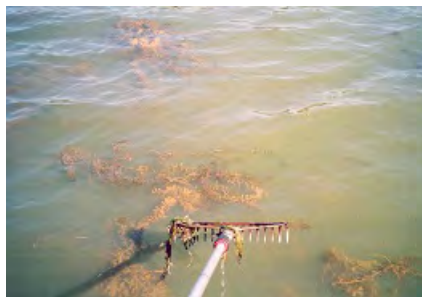
Broken surface canopy conditions. However, stems are usually unbranched.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 35 - 100 stems/m²

Biomass: 30 - 90 g-dry wt/m²



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/m²

Biomass: >285 g-dry wt/m²



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.