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

Aquatic Invasive Species Action Plan for Square Lake, Washington County, Minnesota

Prepared for:
Carnelian-Marine-St. Croix
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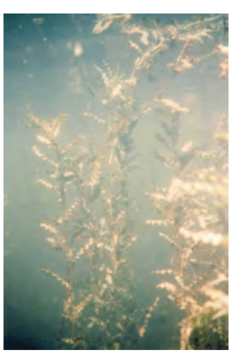
Summary

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

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



Curlyleaf Pondweed

Eurasian Watermilfoil

Zebra Mussel

Five Aquatic Invasive Species of Interest

1. Blue-green Algae (Cylindro)

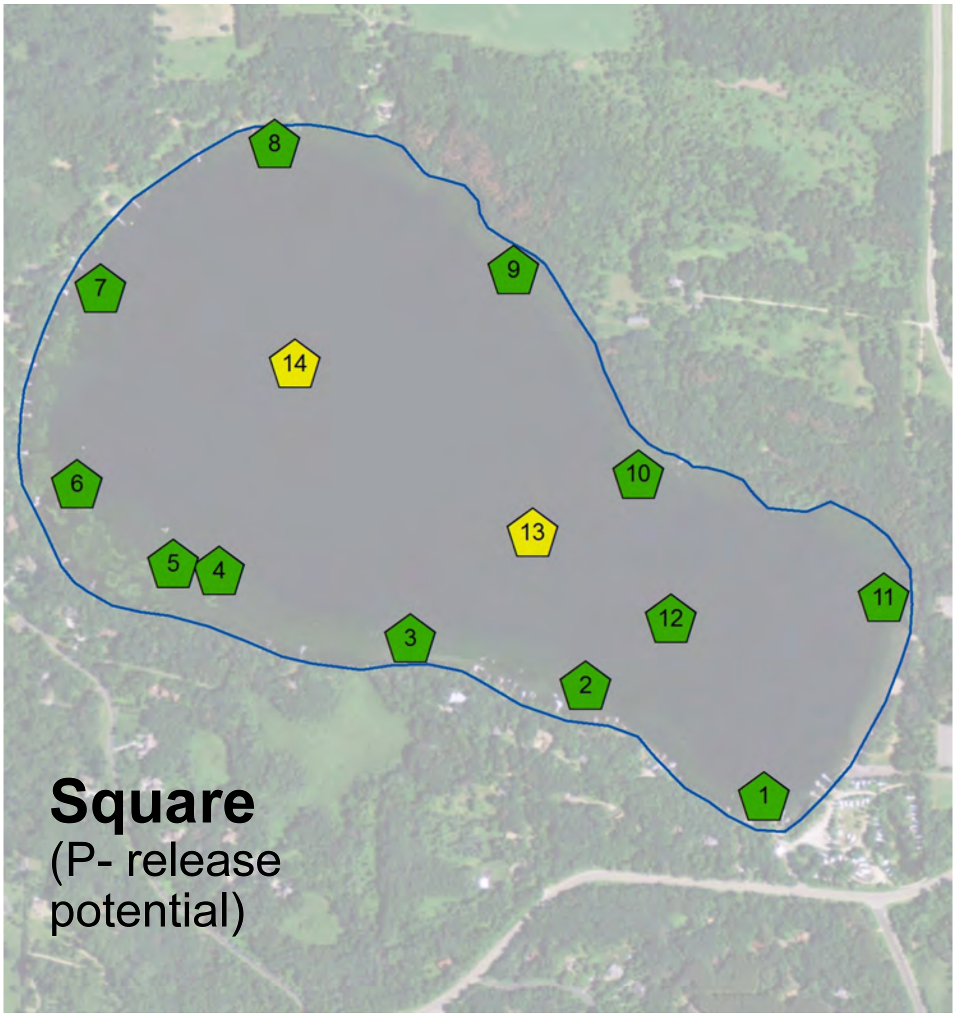


Figure S1. Sediment P-release potential with the possibility to produce excessive phosphorus loading in Square Lake that could produce blue-green algae and Cylindro blooms.
Key: Green = low potential and yellow = moderate potential.

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. Square Lake currently does not have these characteristics. At this time Cylindro has not been identified in Square Lake. Cylindro is known to produce toxins that at high concentrations could be harmful to other aquatic life.

Action Plan: If lake phosphorus concentrations should increase, conditions could be favorable to abundant Cylindro growth. Two sources of phosphorus to Square 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 Square Lake sediments to release phosphorus. Results of the sediment survey for Square Lake show sediment sites have a mostly high Fe:P ratio and that phosphorus release from lake sediments will likely be relatively low at most sites (Figure S1). If watershed phosphorus contributions continue to be low Cylindro should not be a problem in Square Lake.

2. Curlyleaf Pondweed

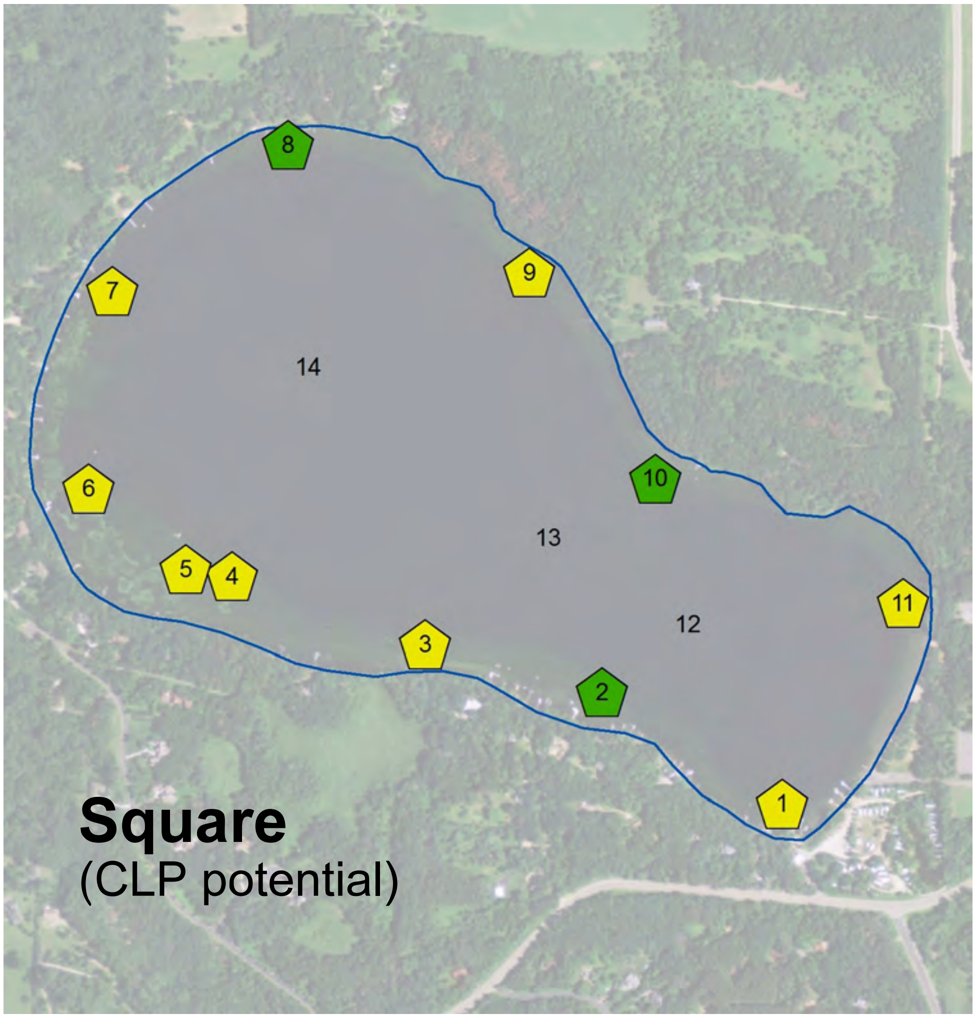


Figure S2. Curlyleaf potential growth based on lake sediment analyses for Square Lake. Key for Potential Growth: Green = light growth and yellow = moderate growth.

Curlyleaf pondweed is present in Square 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 Square Lake at mostly light to moderate abundance. However, some areas may produce heavy growth in some years.

Action Plan: Because curlyleaf pondweed is already established in Square 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 2015). 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 Square Lake to moderate growth and heavy growth will be restricted in most years. These areas could potentially be treated either with an endothall herbicide or by harvesting.

3. Eurasian Watermilfoil

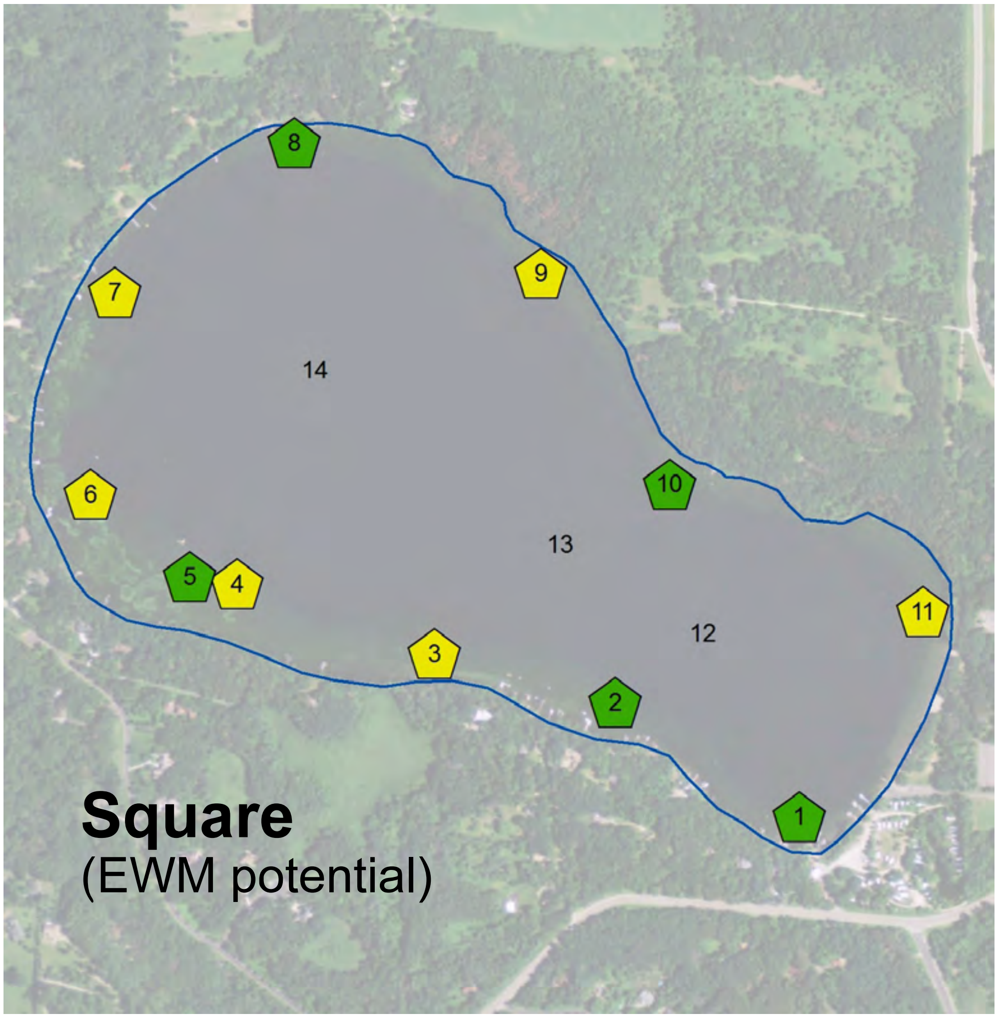


Figure S3. Eurasian watermilfoil potential growth based on lake sediment analyses for Square Lake. Key for Potential Growth: Green = light growth and yellow = moderate growth.

Eurasian watermilfoil has not been observed in Square Lake. Heavy milfoil growth has been correlated with high sediment nitrogen conditions and Square Lake does not have any sites with high sediment nitrogen conditions. The potential for future milfoil growth, based on lake sediment sampling, predicts light to moderate growth (Figure S3).

For Square Lake, it is estimated the plants have the potential to grow down to at least 15 feet of water depth based on Secchi transparencies. Results of the sediment survey indicate growth would be a mix of light to moderate growth.

Action Plan: Eurasian watermilfoil is not present in Square Lake at this time. Ongoing annual scouting activities are recommended. Lake sediment analysis indicates the potential for a range of light to moderate milfoil growth over much of the littoral zone of Square lake

4. Zebra Mussel

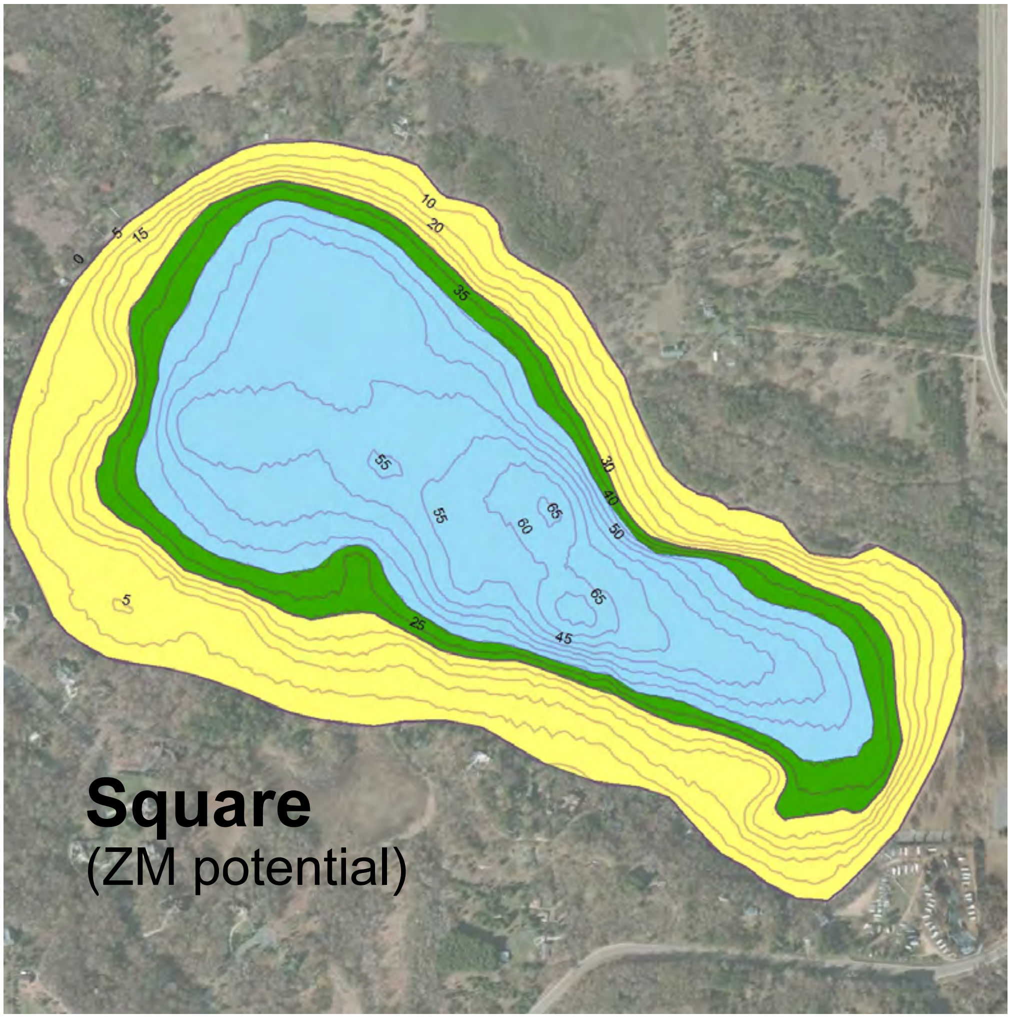


Figure S4. Zebra mussel potential growth based on water column and substrate characteristics. Key for Potential Growth: Green = light growth, yellow = moderate growth, and blue = no growth.

Zebra mussels have not been found in Square 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 is suitable to a depth of 30 feet. Zebra mussel growth would be light to moderate in these areas where it is not limited by dissolved oxygen. Although dissolved oxygen conditions are suitable for optimal to moderate growth down to water depths of about 30 feet and calcium concentrations are optimal for shell production, low existing algae concentration 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 Washington County as of 2015.

Action Plan: Zebra mussels have not been found in Square 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 moderate, a rapid response treatment action should be considered. An action plan includes contact information and procedures that 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 Square Lake to outline control activities and the need for potential permits.

5. Common Carp

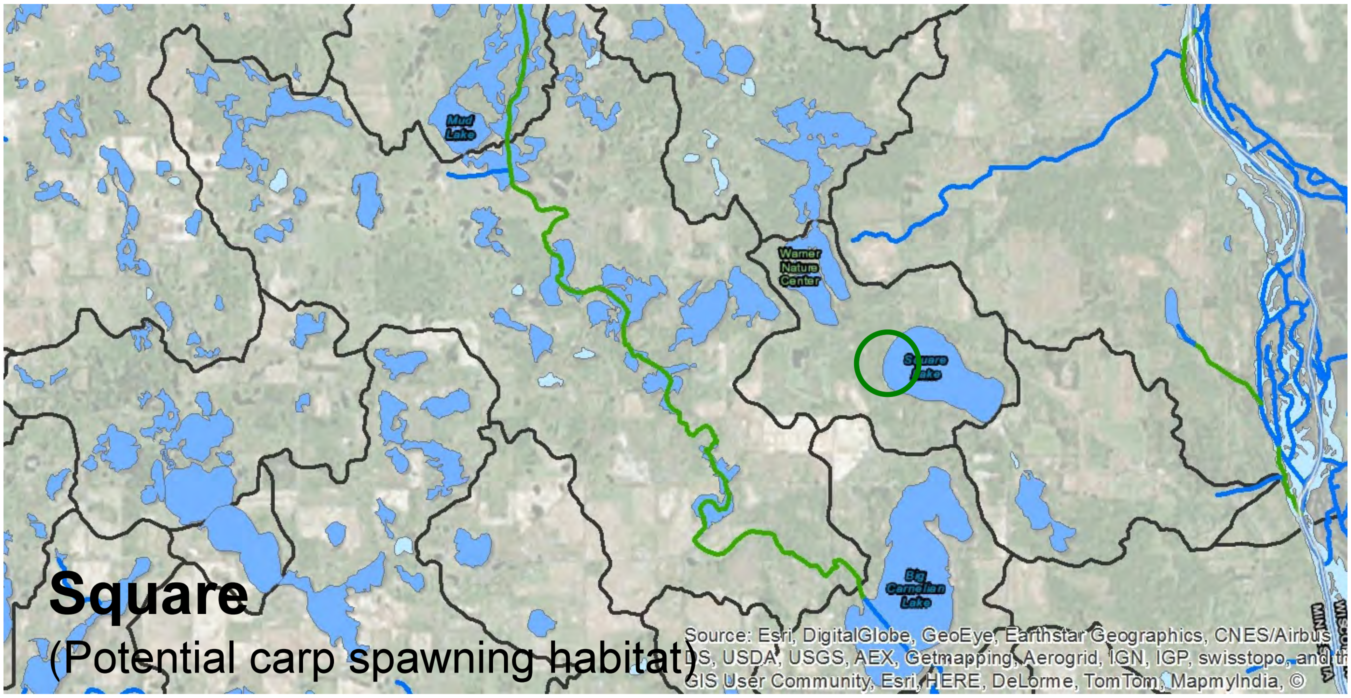


Figure S5. Common carp potential spawning habitat quality. Green circles indicate low potential for carp spawning sites in Square Lake.

Common carp have not been observed in MNDNR fish surveys conducted in 2014 in Square Lake. Square Lake habitat suitability for future carp growth is low due to spawning conditions that may not be 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 Square Lake does not have good off-lake spawning habitat. A lack of off-lake carp spawning may limit the Square Lake carp population.

Action Plan: Carp may be present in Square Lake, but they would be low in numbers. If carp abundance increases, aquatic plant coverage would likely decrease. As of 2015, carp densities do not appear to be detrimental and carp management is not necessary. Monitoring should be ongoing.

Summary of Environmental Risk Assessments for Five Aquatic Invasive Species for Square Lake, Washington 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 Square 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.

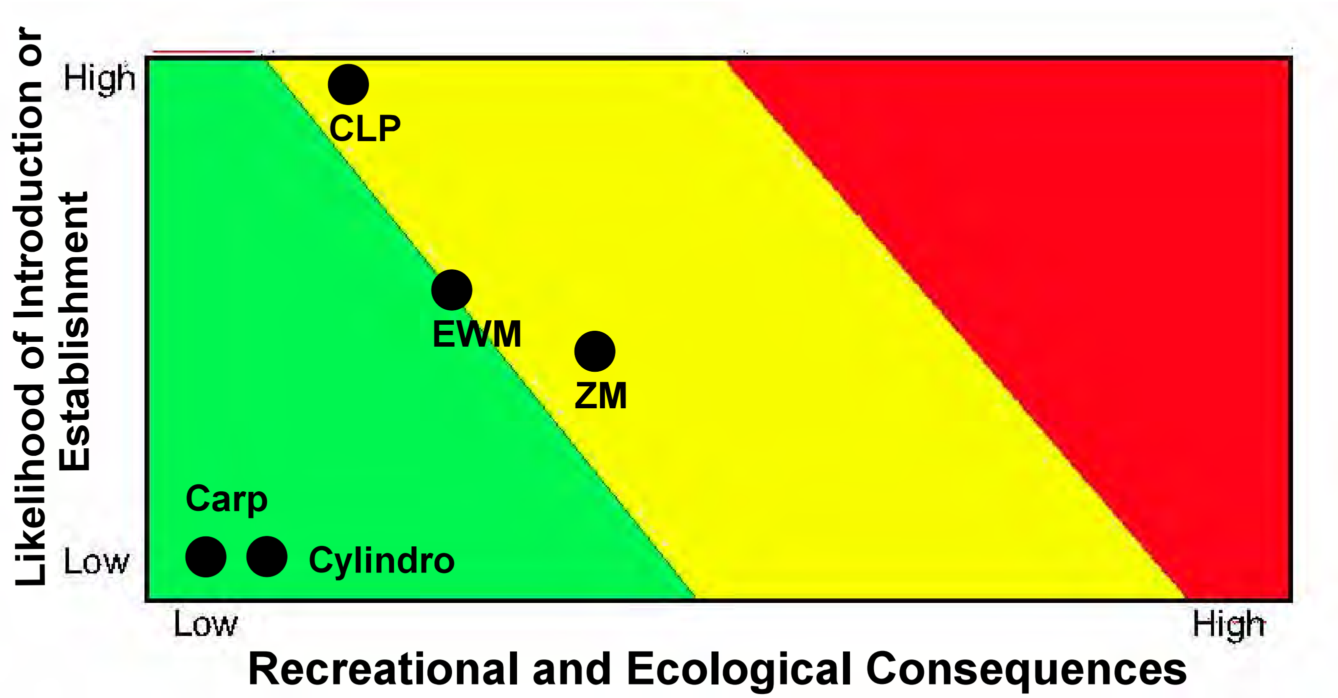


Figure S6. Based on available information, an environmental risk assessment (ERA) chart was prepared for five aquatic invasive species of interest for Square Lake.

Key:

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

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

EWM: Eurasian watermilfoil is not present in Square Lake. Sediments indicate a potential to support low to moderate growth. Consequences are low to moderate.

ZM: Zebra mussels are in Forest lake, Washington County, within 15 miles and incoming boat access is moderate. If zebra mussels are introduced, they are predicted to produce mostly moderate growth due to favorable algal conditions.

Carp: Carp are not found in Square Lake. Conditions do not appear to be optimal 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 Square Lake, Washington County, Minnesota

Introduction

Square Lake is a 203 acre lake (65 littoral acres, maximum depth is 68 feet)(source: MnDNR) in Washington County. The objective of this report was to evaluate the potential for ecological and recreational problems that might develop in Square Lake associated with non-native aquatic invasive species and then list possible management actions. The aquatic invasive species evaluated include the following:

Square Lake, Washington County, Minnesota

Species of Interest:

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

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

Plants
- Purple Loosestrife
- Flowering Rush
- Hydrilla

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

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

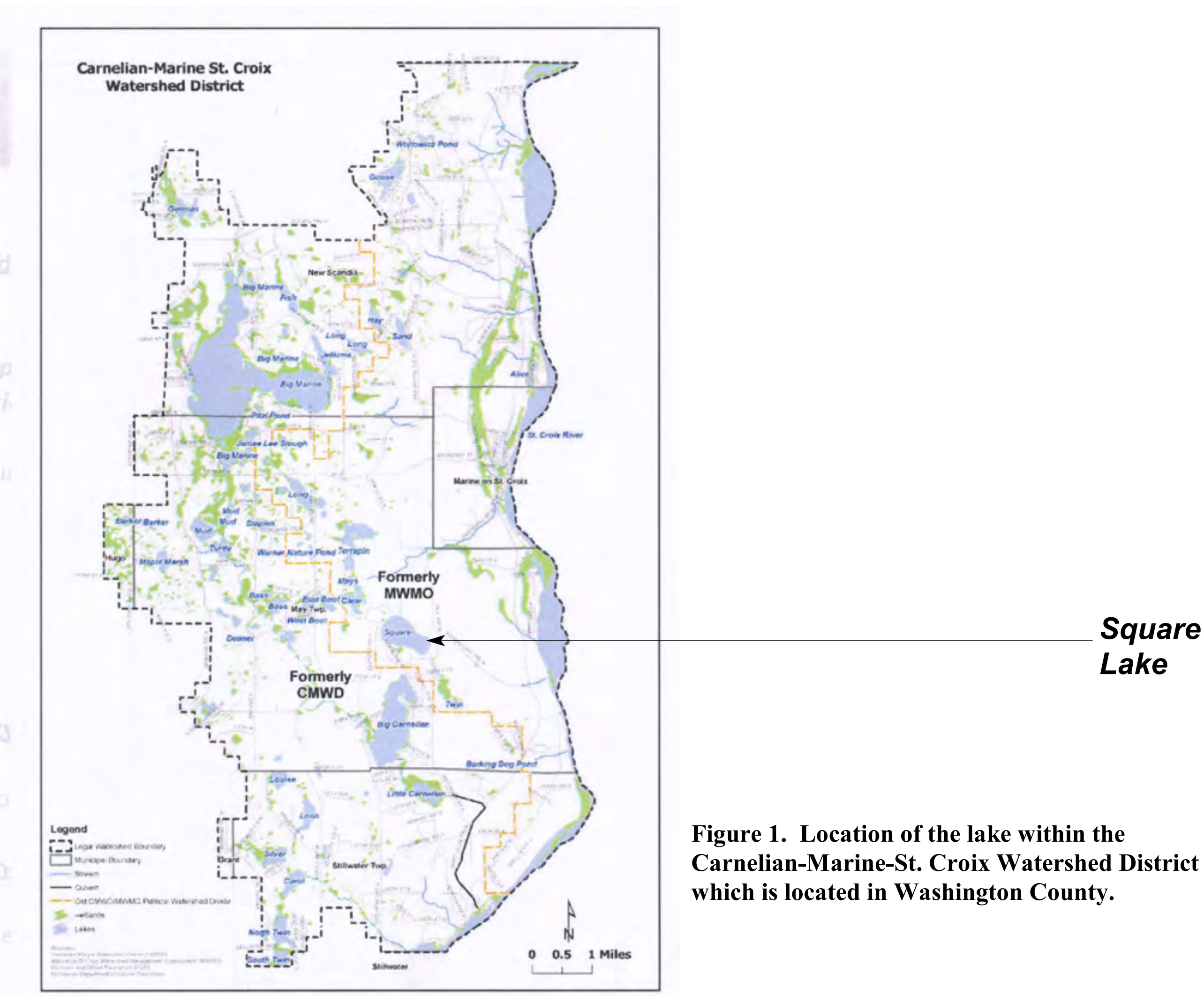
Components that Were Evaluated for Each Species

- 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: Square Lake is located in the Carnelian-Marine-St. Croix Watershed District (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 Square Lake, 14 lake sediment samples were collected on September 11, 2015. 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.



A detailed map of the CMSCWD watershed

Figure 1. Location of the lake within the Carnelian-Marine-St. Croix Watershed District which is located in Washington County.

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

Square Lake Status: Unknown for Square Lake.

Nearest Occurrence: Lake Nokomis, Minneapolis, MN

Potential for Bloom Conditions in Square 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, conditions do not meet those criteria in Square 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 Square Lake.

	Deep Lake (MPCA impaired criteria for North Central Hardwood Forest Ecoregion)	Recent Values for Square Lake (10 year Avg)
Secchi Disc (ft & m) (water clarity)	<4.6 ft (1.4 m)	16.5 ft (5.0 m)
Total Phosphorus (fertilizer nutrient)	>40 ppb	14 ppb
Chlorophyll a (measure of algae)	>14 ppb	3.0 ppb

Square Lake is located in the North Central Hardwood Forest Ecoregion. Unimpaired deep lakes in this ecoregion have water clarity greater than 4.6 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 Square 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). Sediment phosphorus was found to be very low in Square lake, limiting the potential for substantial phosphorus release from the sediments.

Results for Square Lake show two sediment sites (shown with yellow pentagons) that have a moderate Fe:P ratio which is correlated to moderate phosphorus release from sediments. At other sites sediment phosphorus release appears to be light (Table 2).

Table 2. Square Lake sediment data for iron and phosphorus and the calculated Fe to P ratio. Samples were collected on September 11, 2015. 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
1	10	30	0.5	1.9	15.8
2	6	29	1.0	2.1	13.8
3	6	33	0.5	0.9	36.7
4	6	26	0.4	0.9	28.9
5	6	19	0.5	0.5	38.0
6	6	42	0.4	2.6	16.2
7	9	71	0.4	1.6	44.4
8	6	100	0.8	2.4	41.7
9	8	35	0.5	1.4	25.0
10	7	28	1.3	1.3	21.5
11	7	33	0.6	1.1	30.0
12	50	332	2.9	21.7	15.3
13	58	319	0.5	28.5	11.2
14	47	323	2.1	38.0	8.5

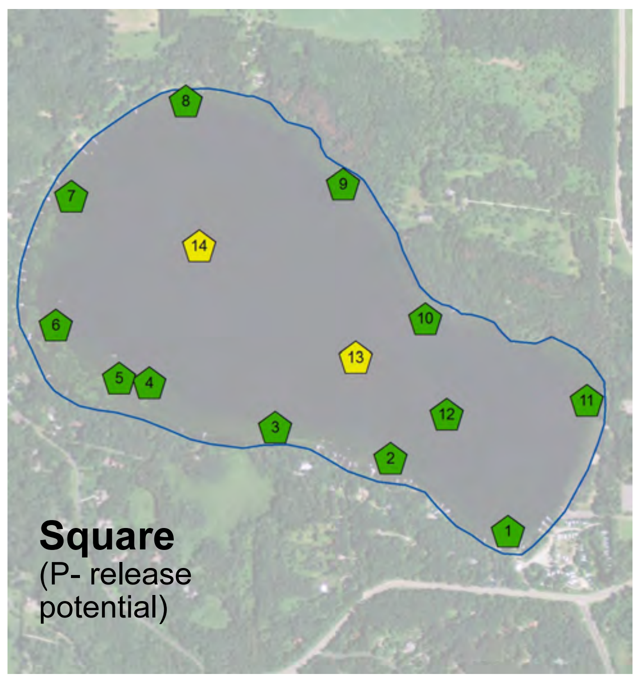


Figure 3. The color indicates the p-release potential of phosphorus in 2015. Key: green = low potential and yellow = moderate potential.

Management Options for Blue-Green Algae

Scouting Activities: Very little information on algal species distribution in Washington County is available. Occasional sampling in Square 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 Square 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)

Square Lake Status: Present in Square Lake.

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

Lake sediment sampling results from 2015 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 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 Square Lake are shown in Table 3 and Figure 7.

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

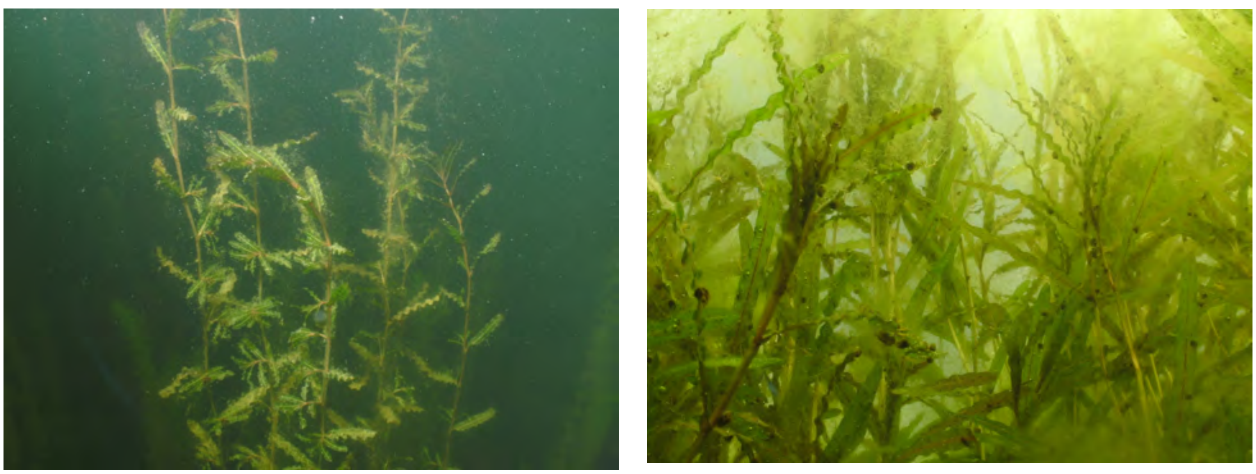


Figure 5. Underwater views of curlyleaf pondweed. Light growth (left) and moderate growth (right).

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 Square 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 moderate growth on an annual basis.

In Square Lake it is predicted that curlyleaf will grow at mostly moderate densities. Although the sediment pH is high, the iron to manganese (Fe:Mn) ratio is moderate. These factors contribute to the moderate growth potential of curlyleaf pondweed in a majority of the sediment sites.

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

Site	Depth (ft)	pH (su)	Bulk Density (g/cm3 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)**
1	10	8.0	0.55	9.2	3.6	Moderate
2	6	8.1	1.21	1.5	3.0	Light
3	6	8.0	0.54	8.9	4.2	Moderate
4	6	7.9	0.52	7.5	3.3	Moderate
5	6	8.0	0.57	5.8	2.8	Moderate
6	6	7.8	0.52	10.4	4.3	Moderate
7	9	7.8	0.48	13.8	15.9	Moderate
8	6	7.6	0.94	3.2	23.2	Light
9	8	8.0	0.54	10.9	4.3	Moderate
10	7	8.2	1.48	0.4	4.1	Light
11	7	8.0	0.67	6.2	4.0	Moderate
12	50	7.2	0.69	19.4	6.7	
13	58	7.2	0.61	17.6	5.6	
14	47	7.1	0.63	19.6	2.6	

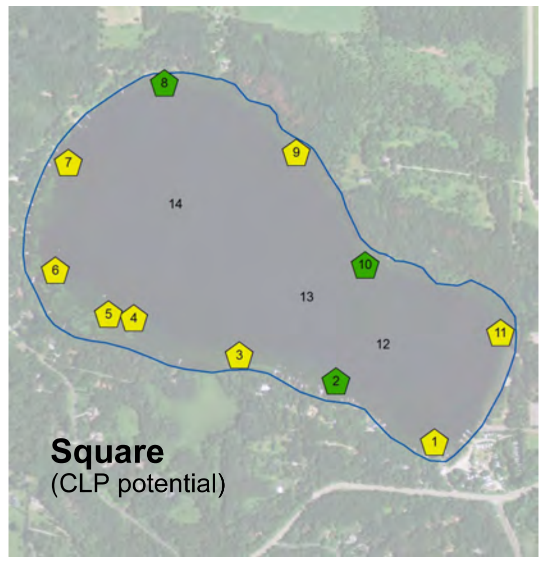


Figure 7. The color indicates the potential growth of curlyleaf pondweed. Key: green = light growth and yellow = moderate growth.

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 indicate there is a potential for mostly light to moderate growth of CLP in Square Lake. 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 Square 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)

Square Lake Status: Not present in Square Lake.

Potential for Eurasian Watermilfoil Growth in Square Lake: Light to moderate potential.

Lake sediment sampling results from 2015 have been used to predict lake areas that have the potential to support light to moderate Eurasian watermilfoil growth. Examples of Eurasian 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 Eurasian milfoil growth could be expected in the future in Square Lake (Table 4 and Figure 11).

In Square Lake sites with low nitrogen are distributed around the lake and will limit Eurasian watermilfoil growth. Eurasian milfoil abundance can vary from year to year depending largely on climatic factors.

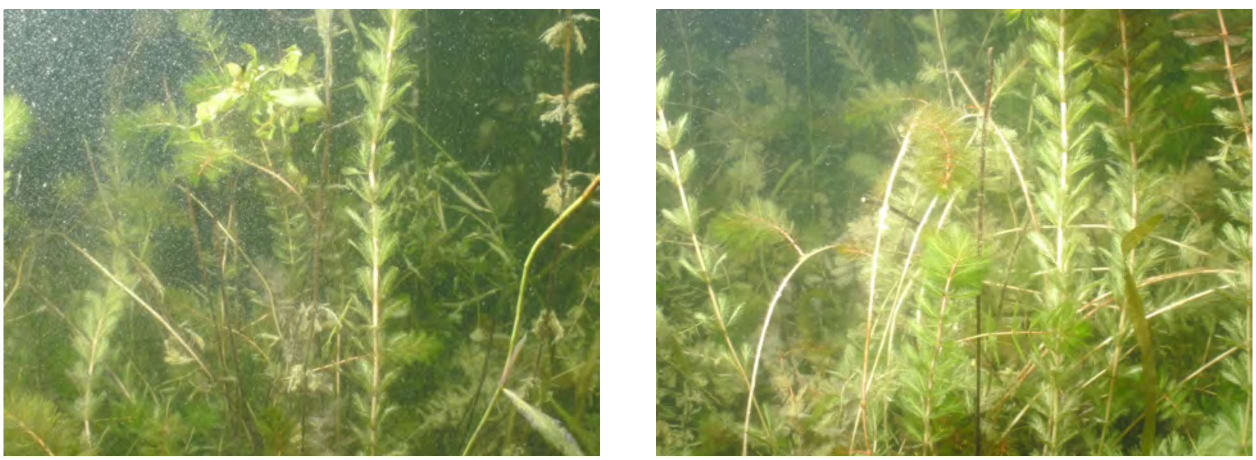


Figure 9. Underwater views of Eurasian watermilfoil.

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 2015 have been used to predict lake bottom areas that have the potential to support heavy EWM growth. The potential for milfoil growth, based on lake sediment sampling, ranges from light to moderate growth (Figure 11). Heavy milfoil growth has been correlated with high sediment nitrogen condition but Square Lake has low nitrogen which will limit heavy growth. Organic matter in the sediments is high enough to support heavy Eurasian milfoil growth but overall Eurasain milfoil will limited by low nitrogen concentrations.

For Square Lake, it is estimated the plants have the potential to grow down to about 30 feet of water depth based on existing water clarity conditions.

Table 4. Square 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)**
1	10	1.0	9.2	Light
2	6	2.3	1.5	Light
3	6	1.5	8.9	Moderate
4	6	1.2	7.5	Moderate
5	6	0.9	5.8	Light
6	6	1.2	10.4	Moderate
7	9	1.6	13.8	Moderate
8	6	3.7	3.2	Light
9	8	1.2	10.9	Moderate
10	7	3.4	0.4	Light
11	7	1.6	6.2	Moderate
12	50	14.7	19.4	
13	58	11.3	17.6	
14	47	13.4	19.6	

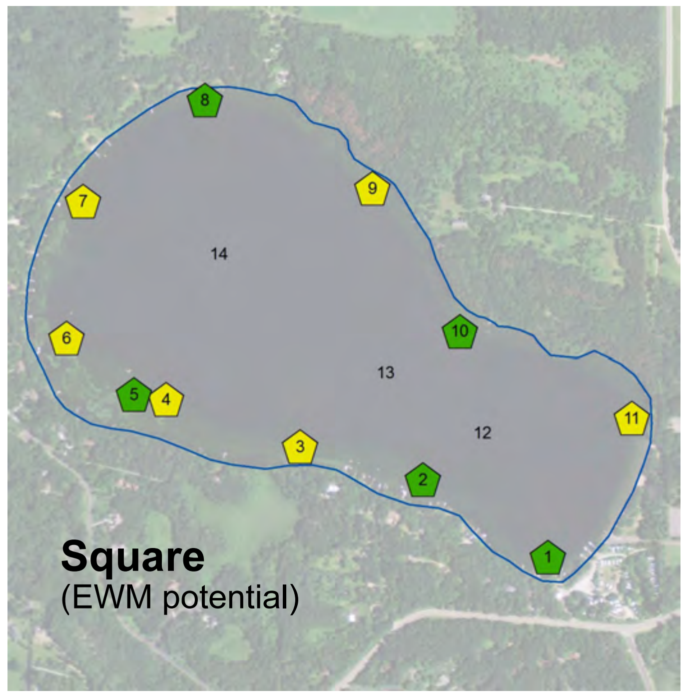


Figure 11. The color indicates the potential growth of Eurasian watermilfoil.
Key: green = light growth and yellow = moderate growth.

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 Assessment: When EWM is first spotted, a rapid response assessment should be conducted. This involves monitoring the nearshore lake perimeter and looking for additional EWM occurrences. Any EWM observations should be marked on a map using GPS coordinates.

Rapid Response Action: A rapid response action will likely be limited. The probability of eradicating EWM through a rapid response is very low. The public access area could be treated, if EWM is present, to minimize possible transport to other lakes. Otherwise future control options should be considered.

Control Options: Even though Eurasian watermilfoil is not established in Square Lake, eradication of Eurasian watermilfoil is not likely to be feasible when it is first observed. Lake sediment analyses indicate the potential for moderate growth

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)

Square Lake Status: Not currently found in Square Lake as of November 2015.

Nearest Occurrence: Forest Lake, Washington County, Minnesota.

Potential for Colonization in Square Lake: Low to moderate.

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 Square Lake (Table 5). Although zebra mussels prefer hard substrates for optimal growth, they will grow together forming clumps on sand and silt bottoms. Square Lake has extensive areas of sandy and mucky sediments that would support moderate zebra mussel colonization (Figure 13). Chlorophyll concentrations indicate that zebra mussels would initially produce heavy growth if they were introduced to Square lake.

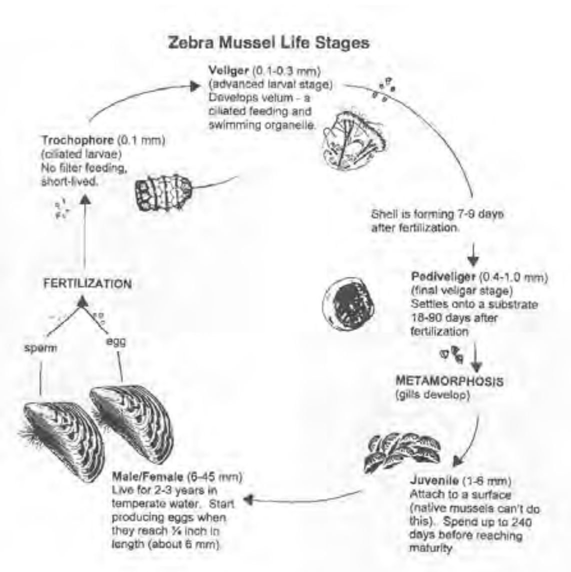


Figure 12. Zebra mussel life stages: Zebra mussels can be detected at the veliger stage using modified zooplankton nets, but this is usually performed by experts (Adopted from U.S. Army Corps of Engineers, WES)(from McComas, 2003. Lake and pond management guidebook).

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 Square Lake as of 2015. A review of water column characteristics for Square Lake was compared to characteristics suited for zebra mussels. It appears that zebra mussels would only be limited in Square Lake due to the lack of dissolved oxygen deeper than 30 feet. However, overtime a dense population could decrease algae and produce limiting conditions (Table 5).

Table 5. Water column zebra mussel suitability criteria and Square 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)	**Square Lake**			**23.0 9/11/15**	
	Mackie and Claudi 2010	*<8*	*8 - 15*	*15 - 30*	*>30*
pH	**Square Lake**				**8.6 9/11/2015**
	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)	**Square Lake**				**105 9/11/2015**
	Mackie and Claudi 2010	*<30*	*30 - 55*	*55 - 100*	*100 - 280*
Conductivity* (umhos)	**Square Lake**				**235 9/11/2015**
	Mackie and Claudi 2010	*<30*	*30 - 60*	*60 - 110*	*>110*
Food Factors					
Chlorophyll a (ug/l) (June-Sept)	**Square Lake**				**2.6 (2012) (range: <1 - 6.4)**
	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)	**Square Lake**			**5.1 (2013) (range: 4.9-5.2)**	
	Mackie and Claudi 2010	*<1 or >8*	*1 - 2 or 6 - 8*	*4 - 6*	*2 - 4*
Total phosphorus (ug/l) (June-Sept)	**Square Lake**			**14 (2012) (range: 6-30)**	
	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)	**Square Lake**	**>11m**	**9-10m**	**7-8m**	**0-5m**
	Mackie and Claudi 2010	*<3 mg/l*	*3 - 7 mg/l*	*7 - 8 mg/l*	*>8 mg/l*
Bottom substrate	**Square Lake**	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, algae would not limit zebra mussel growth. However it is anticipated that zebra mussels would rapidly consume much of the available algae, likely starving themselves, and resulting in significant population crash. Substrate conditions were also inspected at 14 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 Square 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 to at least 30 feet. 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.

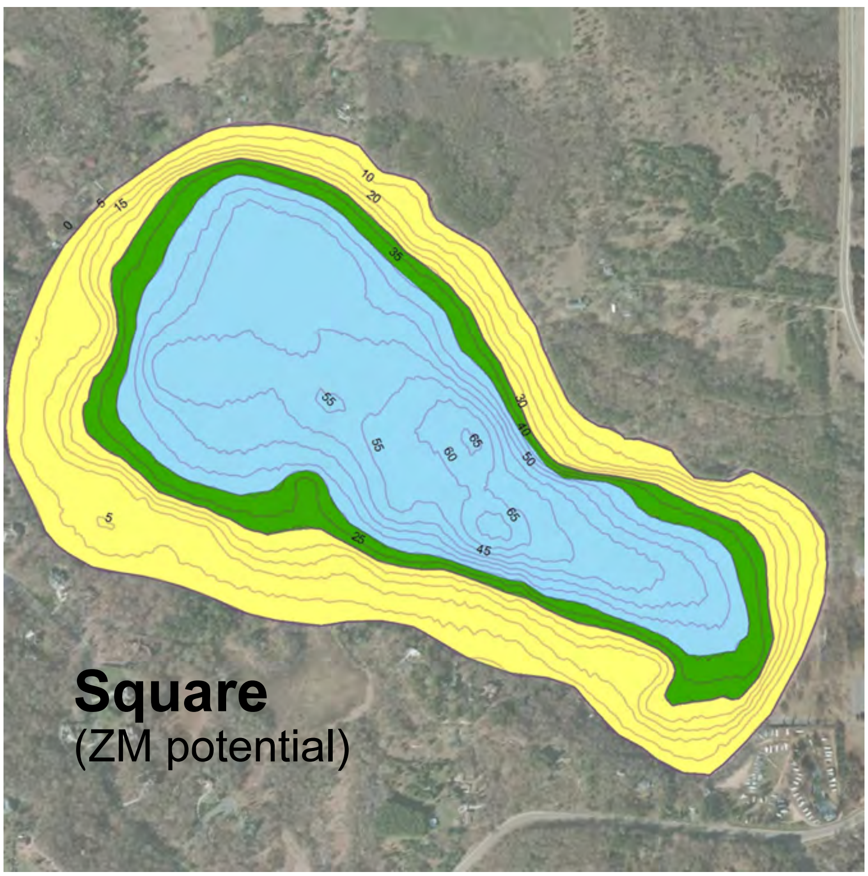


Figure 14. Key for potential growth:
Green = light growth, yellow = moderate growth, and blue = no growth.

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 Square 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.

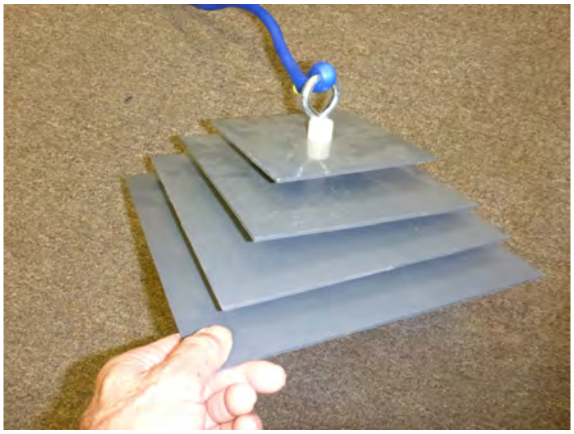


Figure 16. A zebra mussel plate sampler can be made from pvc materials. Ceramic tiles also make for good monitoring surfaces as well as pvc pipes.

Rapid Response Assessment: When zebra mussels are first discovered in Square 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 Square 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 Square 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 Square Lake, but at predicted low densities due to a limiting food source because the available food source would be rapidly depleted.

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)

Square Lake Status: Not present in Square Lake (based on MnDNR fish surveys).

Potential for Excessive Abundance in Square Lake: Low.

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 not sampled in the last survey in Square Lake, based on the MnDNR fish survey from 2014 (Table 6). Square Lake habitat suitability for future growth is low due to spawning conditions that are not be well suited for survival of young fish (Figure 19). Without a adult population present in Square lake future carp abundance will remain low due to limited immigration and poor recruitment of new carp.

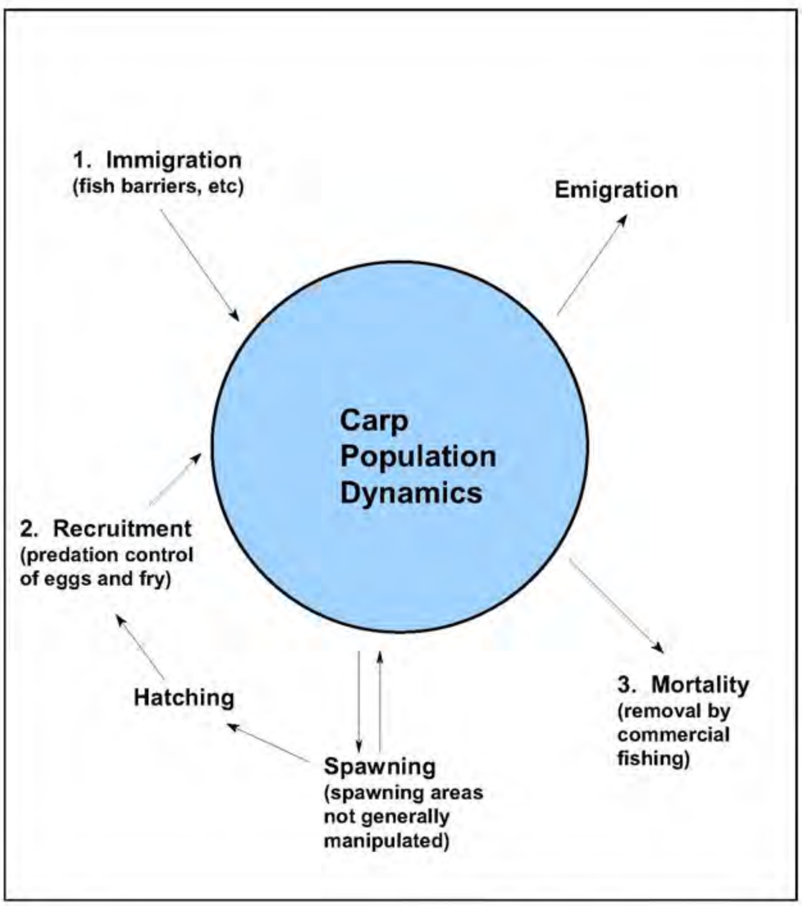


Figure 18. Three factors contribute to carp population dynamics. When carp populations are at a low density in lakes, immigration and recruitment generally limit populations.

Table 6. Fish sampled in the Square Lake 2014 MnDNR fish survey.

Species	Gear Used	Number of Fish per Net		Average Fish Weight (lbs)	Normal Range (lbs)
		Caught	Normal Range		
Black Bullhead	Gill net	4.25	0.3 - 1.9	1.01	0.3 - 0.9
Black Crappie	Trap net	2.33	0.5 - 2.2	0.36	0.3 - 0.5
	Gill net	3.00	0.3 - 1.7	0.32	0.2 - 0.5
Bluegill	Trap net	11.56	7.7 - 43.4	0.23	0.1 - 0.2
	Gill net	4.25	N/A	0.28	N/A
Brown Bullhead	Trap net	0.89	0.3 - 1.0	0.80	0.7 - 1.0
	Gill net	5.25	0.3 - 1.8	0.63	0.5 - 1.1
Green Sunfish	Trap net	0.67	0.6 - 2.0	0.15	0.1 - 0.2
Hybrid Sunfish	Trap net	4.00	N/A	0.31	N/A
	Gill net	0.50	N/A	0.24	N/A
Largemouth Bass	Gill net	0.50	0.5 - 1.7	0.42	0.5 - 1.2
Northern Pike	Trap net	1.22	N/A	0.72	N/A
	Gill net	5.75	2.2 - 8.7	2.34	1.5 - 3.2
Pumpkinseed	Trap net	3.22	1.4 - 5.9	0.21	0.1 - 0.2
	Gill net	1.00	N/A	0.30	N/A
Yellow Bullhead	Trap net	3.44	1.0 - 5.3	0.43	0.5 - 0.9
	Gill net	10.75	1.0 - 6.0	0.40	0.4 - 0.7
Yellow Perch	Trap net	0.11	0.4 - 2.3	0.12	0.1 - 0.2
	Gill net	1.25	1.5 - 13.8	0.42	0.1 - 0.2

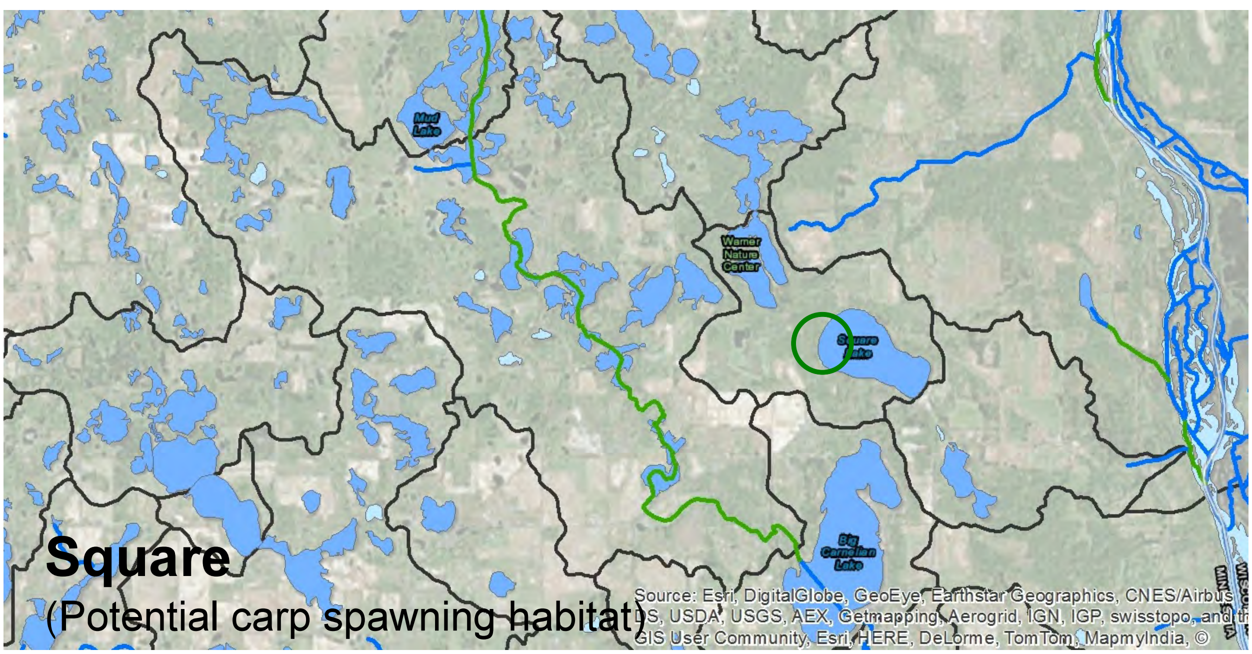


Figure 19. Common carp potential spawning habitat quality. Green circle indicates low potential for carp spawning sites in Square Lake.

Management Options for Common Carp

Early Detection: Carp are not currently present in Square Lake. If carp abundance were to increase, 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 Square 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)

Square Lake Status: Currently not in Square Lake

Potential for Colonization in Square 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)

Square Lake Status: Purple loosestrife has not been seen around the Square Lake shoreline in 2015.

Potential for Nuisance Colonization in Square 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 Square Lake.

Purple Loosestrife in Square Lake: In 2015, Purple Loosestrife was not found in Square Lake. Purple loosestrife is able to establish and multiply rapidly (Figure 22). If it is found in or around Square 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 Square 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)

Square Lake Status: Not present in Square Lake (or in Minnesota) as of 2015.

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 Square 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 Square Lake.

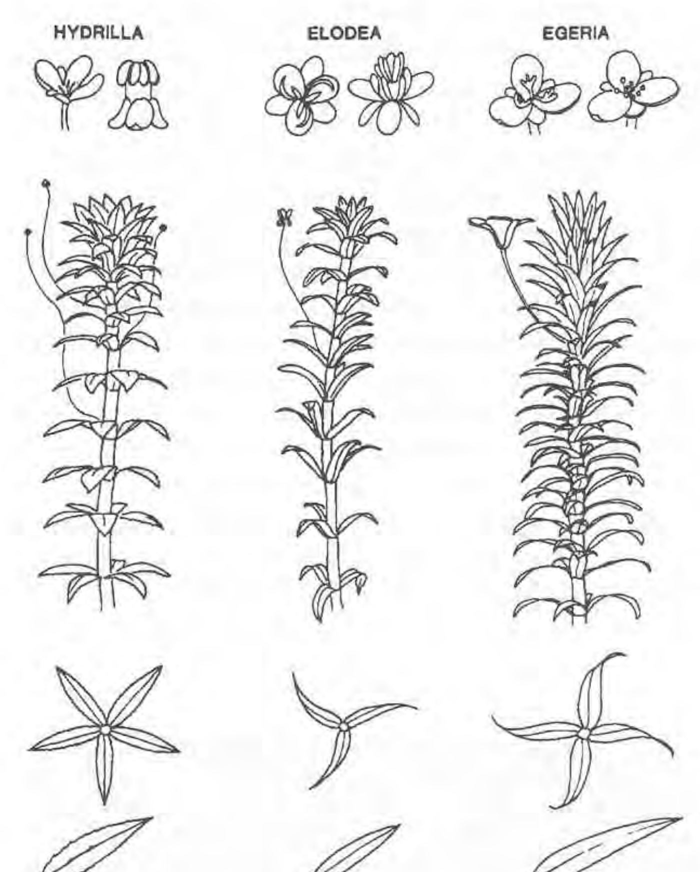


Figure 23.

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

Control Options: If hydrilla was confirmed in Square 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)

Square Lake Status: Not presently found in Square Lake as of 2015.

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

Potential for Nuisance Colonization in Square 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 Square Lake they could reduce the aquatic plants found in the littoral area. Rusty crayfish would have minimal effect in the deeper parts of Square 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 Square 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 Square 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.

Square Lake has several predator fish species that would prey on rusty crayfish. The fish species are northern pike (low numbers), largemouth bass (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.

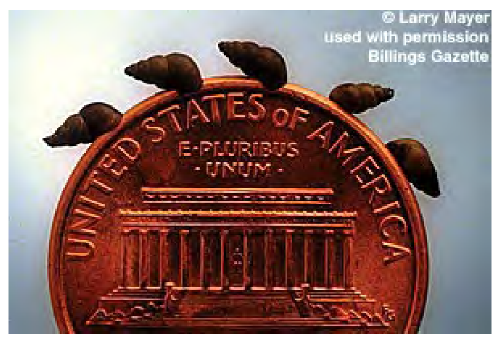
Other Molluscs

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.


Photo courtesy of USGS

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 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.



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

Square Lake Status: Not present in Square Lake as of 2015.

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

Potential for Nuisance Colonization in Square 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 Square Lake watershed.

Management Options for Asian Carp

Control Options: Asian carp should not be able to spawn in Square 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

Square Lake Status: Not present in Square Lake as of 2015.

Nearest occurrence: East coast.

Potential for Nuisance Colonization in Square 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)

Square Lake Status: Not present in Square Lake as of 2015.

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

Potential for Nuisance Colonization in Square 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 Square 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 Square Lake, an intensive information program should be implemented by the Washington 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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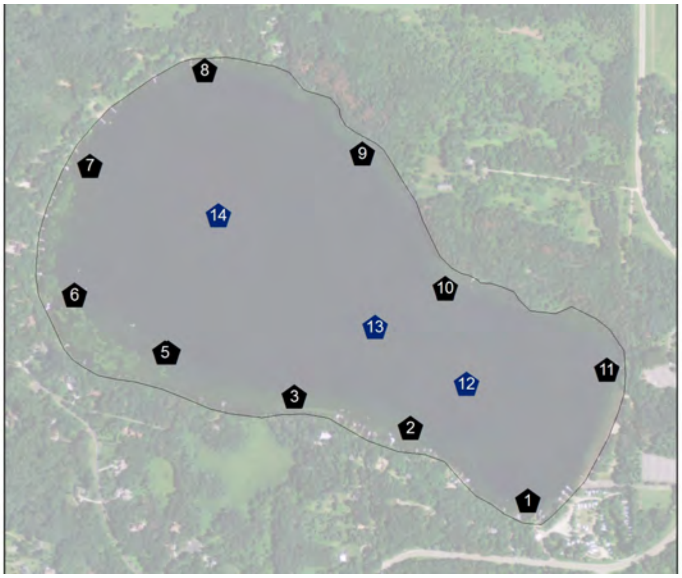
APPENDIX A

Methods



Lake Soil Survey: In Square Lake a total of 14 samples were collected on September 11, 2015 from depths ranging from 6 to 58 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 (47 - 58 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 $NaHCO_3$
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 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 µg/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 µg/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 µg/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 µg/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

2015 sediment data for Square Lake. Sediments were collected on September 11, 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_4OAc-Ca (ppm) *adjusted*	NH_4OAc-Mg (ppm) *adjusted*	SO_4-S (ppm) *adjusted*	NH4-N (ppm) *adjusted*	Average Scoop	Correct factor	Fe/Mn
S 1	0.55	0.5	1.9	12.1	9.2	8.0	0.2	30	8.4	0.4	0.7	1630.0	71	11.2	1.0	4.66	0.47	3.6
S 2	1.21	1.0	2.1	13.4	1.5	8.1	0.2	29	9.9	0.9	1.6	3185.5	136	28.9	2.3	10.31	1.03	3.0
S 3	0.54	0.5	0.9	8.7	8.9	8.0	0.2	33	7.8	0.2	0.6	1611.9	65	7.8	1.5	4.58	0.46	4.2
S 4	0.52	0.4	0.9	12.0	7.5	7.9	0.1	26	8.0	0.4	1.1	1530.8	59	12.5	1.2	4.45	0.44	3.3
S 5	0.57	0.5	0.5	4.9	5.8	8.0	0.1	19	7.0	0.2	0.7	1675.2	56	10.7	0.9	4.88	0.49	2.8
S 6	0.52	0.4	2.6	11.4	10.4	7.8	0.3	42	9.8	0.3	0.9	1546.8	64	24.6	1.2	4.39	0.44	4.3
S 7	0.48	0.4	1.6	5.8	13.8	7.8	0.2	71	4.5	0.3	0.6	1578.2	89	14.0	1.6	4.12	0.41	15.9
S 8	0.94	0.8	2.4	19.2	3.2	7.6	0.2	100	4.3	2.6	11.1	3097.0	189	95.1	3.7	7.99	0.80	23.2
S 9	0.54	0.5	1.4	11.4	10.9	8.0	0.2	35	8.1	0.2	0.5	1652.8	69	8.2	1.2	4.57	0.46	4.3
S 10	1.48	1.3	1.3	23.9	0.4	8.2	0.2	28	6.8	0.5	0.8	3086.6	123	27.7	3.4	12.59	1.26	4.1
S 11	0.67	0.6	1.1	21.7	6.2	8.0	0.2	33	8.2	0.7	2.0	2018.7	82	16.6	1.6	5.72	0.57	4.0
S 12	0.69	2.9	21.7	39.8	19.4	7.2	0.9	332	49.2	3.9	11.8	3010.5	335	300.6	14.7	5.86	0.59	6.7
S 13	0.61	0.5	28.5	25.4	17.6	7.2	0.6	319	57.2	3.1	8.1	2727.8	253	269.2	11.3	5.19	0.52	5.6
S 14	0.63	2.1	38.0	30.5	19.6	7.1	0.2	323	126.6	3.6	11.8	2511.3	271	402.9	13.4	5.35	0.54	2.6

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_4OAc-Ca (ppm)	NH_4OAc-Mg (ppm)	SO_4-S (ppm)	NH4-N (ppm)	10 gm Scoop Wt	10 gm Scoop Wt	10 gm Scoop Wt
S 1	1	4	26	9.2	8.0	0.528	64.547	17.978	0.879	1.480	3495.4	151.84	24	2.1	4.63	4.64	4.72
S 2	1	2	13	1.5	8.1	0.207	28.509	9.627	0.842	1.591	3088.7	132.18	28	2.2	10.48	10.21	10.25
S 3	1	2	19	8.9	8.0	0.515	72.546	17.086	0.519	1.350	3516.9	142.88	17	3.4	4.59	4.61	4.55
S 4	1	2	27	7.5	7.9	0.299	59.032	17.990	0.939	2.383	3442.6	131.89	28	2.6	4.37	4.45	4.52
S 5	1	1	10	5.8	8.0	0.200	39.678	14.262	0.455	1.478	3435.2	115.20	22	1.8	4.83	4.81	4.99
S 6	1	6	26	10.4	7.8	0.583	95.882	22.298	0.787	1.945	3520.8	145.55	56	2.7	4.38	4.33	4.47
S 7	1	4	14	13.8	7.8	0.602	172.97	10.870	0.818	1.456	3827.4	216.26	34	4.0	4.11	4.09	4.17
S 8	1	3	24	3.2	7.6	0.290	125.43	5.411	3.310	13.843	3876.1	236.91	119	4.6	7.97	7.93	8.07
S 9	1	3	25	10.9	8.0	0.401	76.796	17.677	0.477	1.101	3616.6	150.97	18	2.7	4.55	4.56	4.60
S 10	1	1	19	0.4	8.2	0.134	22.105	5.404	0.386	0.612	2451.6	97.886	22	2.7	12.52	12.56	12.69
S 11	1	2	38	6.2	8.0	0.335	57.915	14.348	1.297	3.410	3527.2	143.62	29	2.8	5.75	5.76	5.66
S 12	5	37	68	19.4	7.2	1.527	565.86	84.019	6.570	20.087	5137.3	570.97	513	25.0	5.88	5.85	5.85
S 13	1	55	49	17.6	7.2	1.229	615.46	110.265	6.020	15.599	5259.2	487.80	519	21.7	5.18	5.11	5.27
S 14	4	71	57	19.6	7.1	0.360	604.18	236.57	6.654	22.011	4694.0	506.09	753	25.0	5.35	5.38	5.32

APPENDIX C

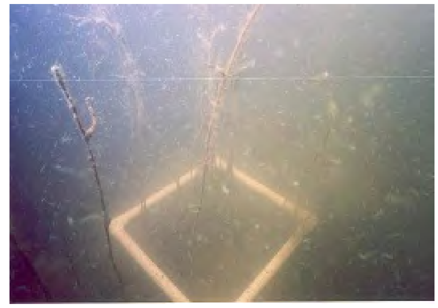
Curlyleaf Pondweed Growth Characteristics
(source: Steve McComas, Blue Water Science, unpublished)

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.

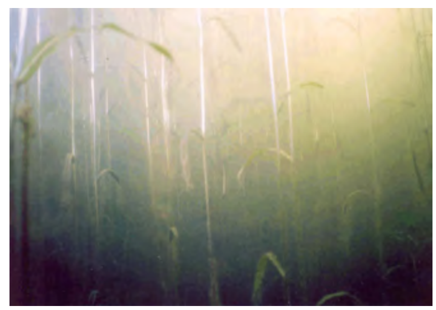
Moderate Growth Conditions

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.

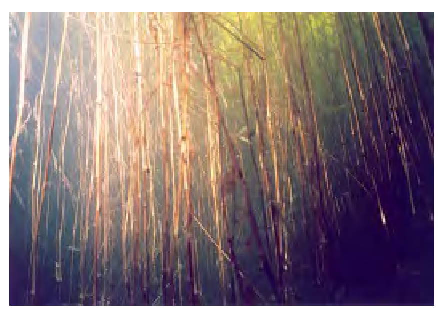
Heavy Growth Conditions

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.

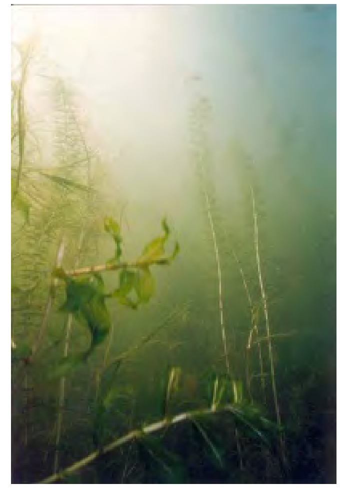
Eurasian Watermilfoil Growth Characteristics
(source: Steve McComas, Blue Water Science, unpublished)

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.