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

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

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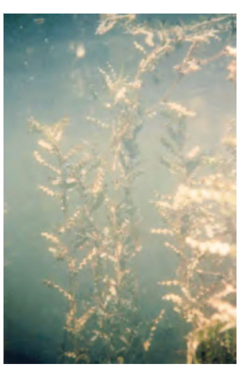
Overview of aquatic invasive species that could impact Lake Tetonka are listed below. As of 2014, curlyleaf pondweed, flowering rush, common carp, and Chinese Mystery snail were the only non-native species known to be present in Lake Tetonka.

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



Curlyleaf Pondweed

Eurasian Watermilfoil

Zebra Mussel

Six Aquatic Invasive Species of Interest

1. Blue-green Algae (Cylindro)

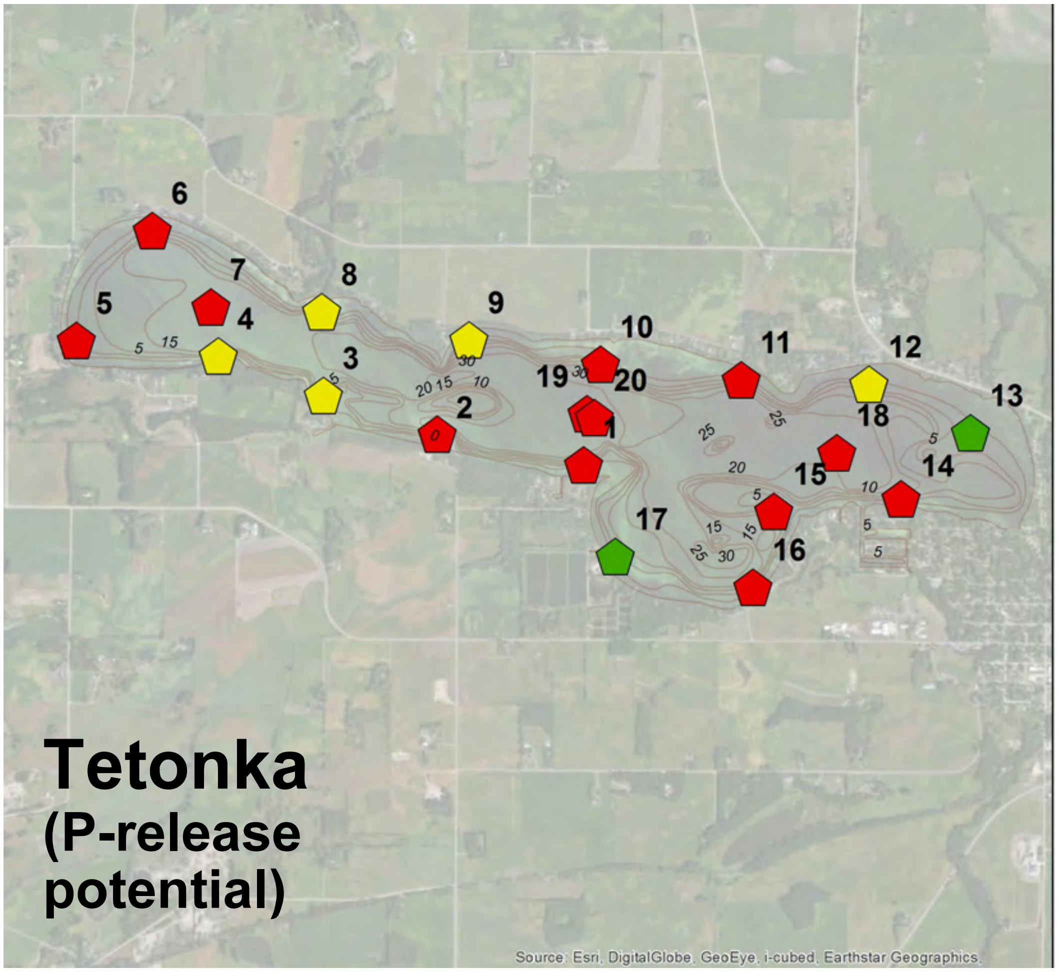


Figure S1. Sediment P-release potential with the possibility to produce excessive phosphorus loading in Lake Tetonka that could produce blue-green algae and Cylindro blooms.
Key: Green = low potential, yellow = moderate potential, and red = high potential.

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

Action Plan: Currently, Lake Tetonka phosphorus concentrations are high and conditions are favorable for Cylindro growth. Two sources of phosphorus to Lake Tetonka 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 Lake Tetonka sediments to release phosphorus. Results of the sediment survey for Lake Tetonka show 13 out of 20 sediment sites (shown with red pentagons) have a low Fe:P ratio and that phosphorus release from lake sediments has the potential to be high (Figure S1). At other sites sediment phosphorus release appears to be light to moderate. 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

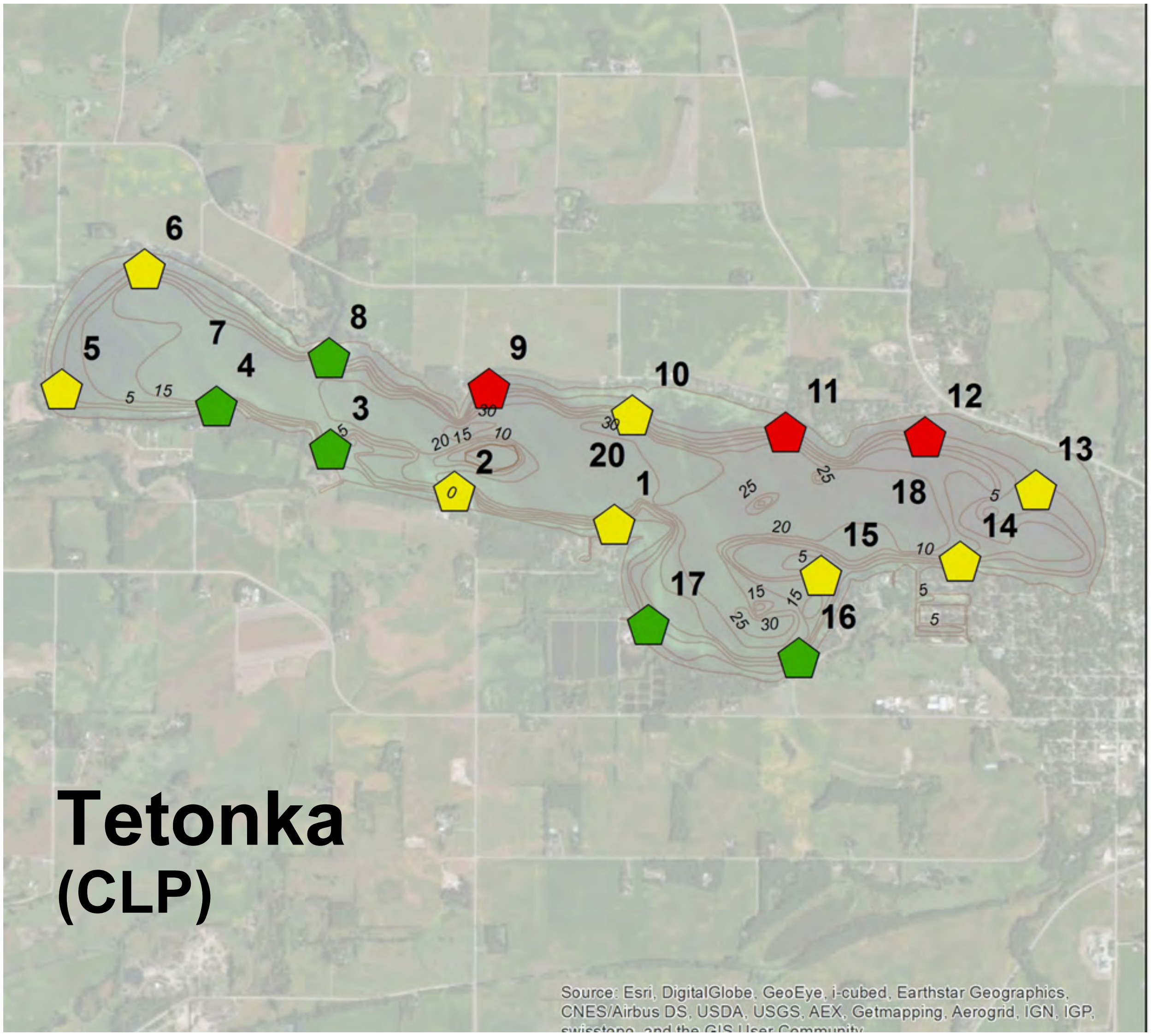


Figure S2. Curlyleaf potential growth based on lake sediment analyses.
Key: Green = light growth, yellow = moderate growth, red = heavy growth.

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

Action Plan: Because curlyleaf pondweed is already established in Lake Tetonka, 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 Lake Tetonka with heavy growth occurring on the northern side of the lake. Areas of heavy growth could be treated either with an endothall herbicide or by harvesting.

3. Eurasian Watermilfoil

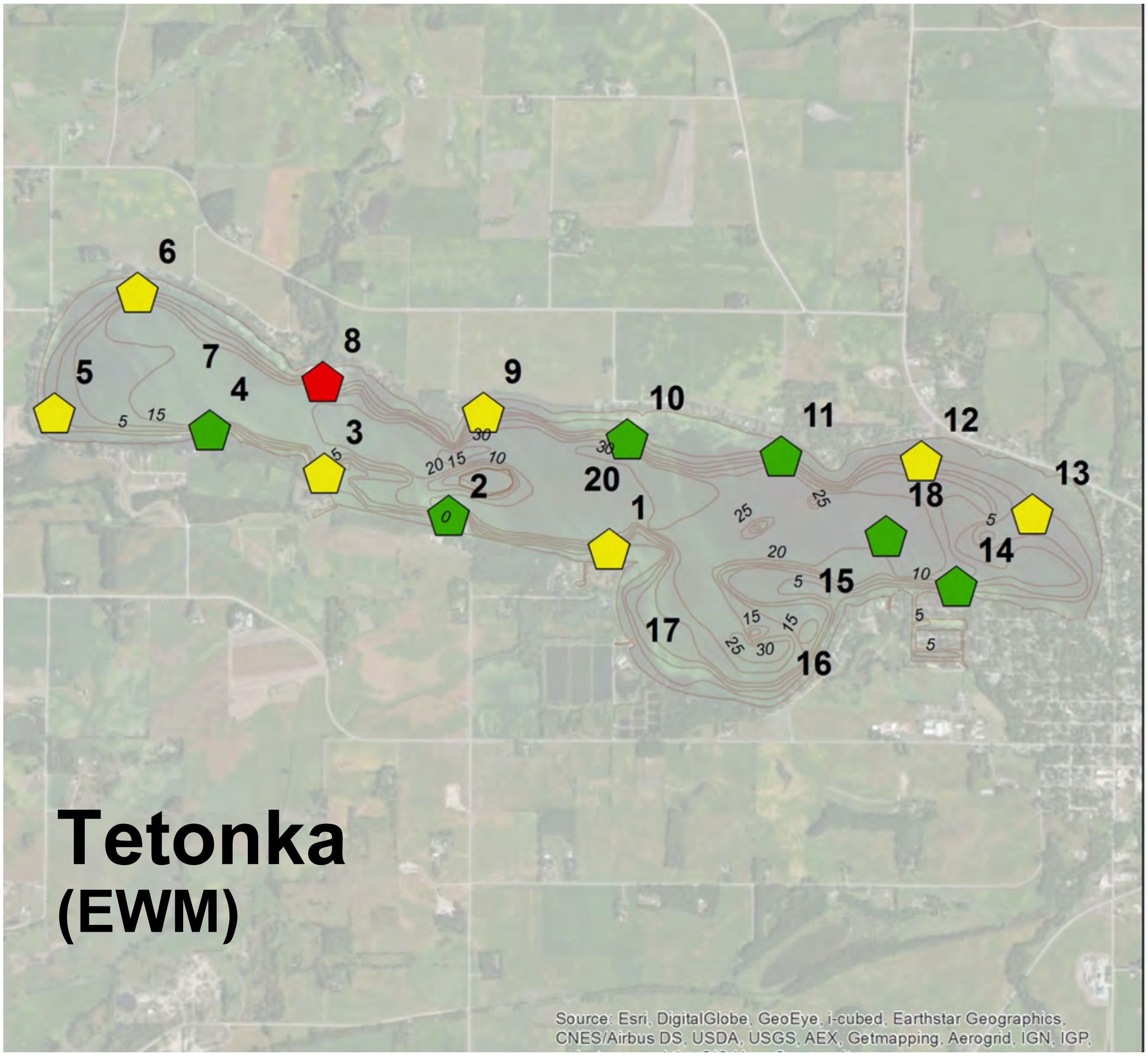


Figure S3. Eurasian watermilfoil potential growth based on lake sediment analyses.
Key: Green = light growth, yellow = moderate growth, red = heavy growth.

Eurasian watermilfoil has not been found in Lake Tetonka as of 2014. The potential for milfoil growth, based on lake sediment sampling predicts mostly light to moderate growth with potential for heavy growth at one site on the west end of Lake Tetonka. Heavy milfoil growth has been correlated with high sediment nitrogen condition and Lake Tetonka has mostly low to moderate nitrogen conditions. For Lake Tetonka, it is estimated the plants have the potential to grow down to at least 10 feet of water depth based on Secchi transparency, resulting in a somewhat restricted distribution.

Action Plan: Eurasian watermilfoil is not present in Lake Tetonka currently. Ongoing annual scouting activities are recommended. Lake sediment analysis indicates the potential for light to moderate milfoil growth over much of the lake. At the present time the low Secchi transparency may restrict growth to water depths of less than 10 feet. However, if water clarity increases, Eurasian watermilfoil could colonize deeper water with potential heavy growth.

4. Flowering Rush

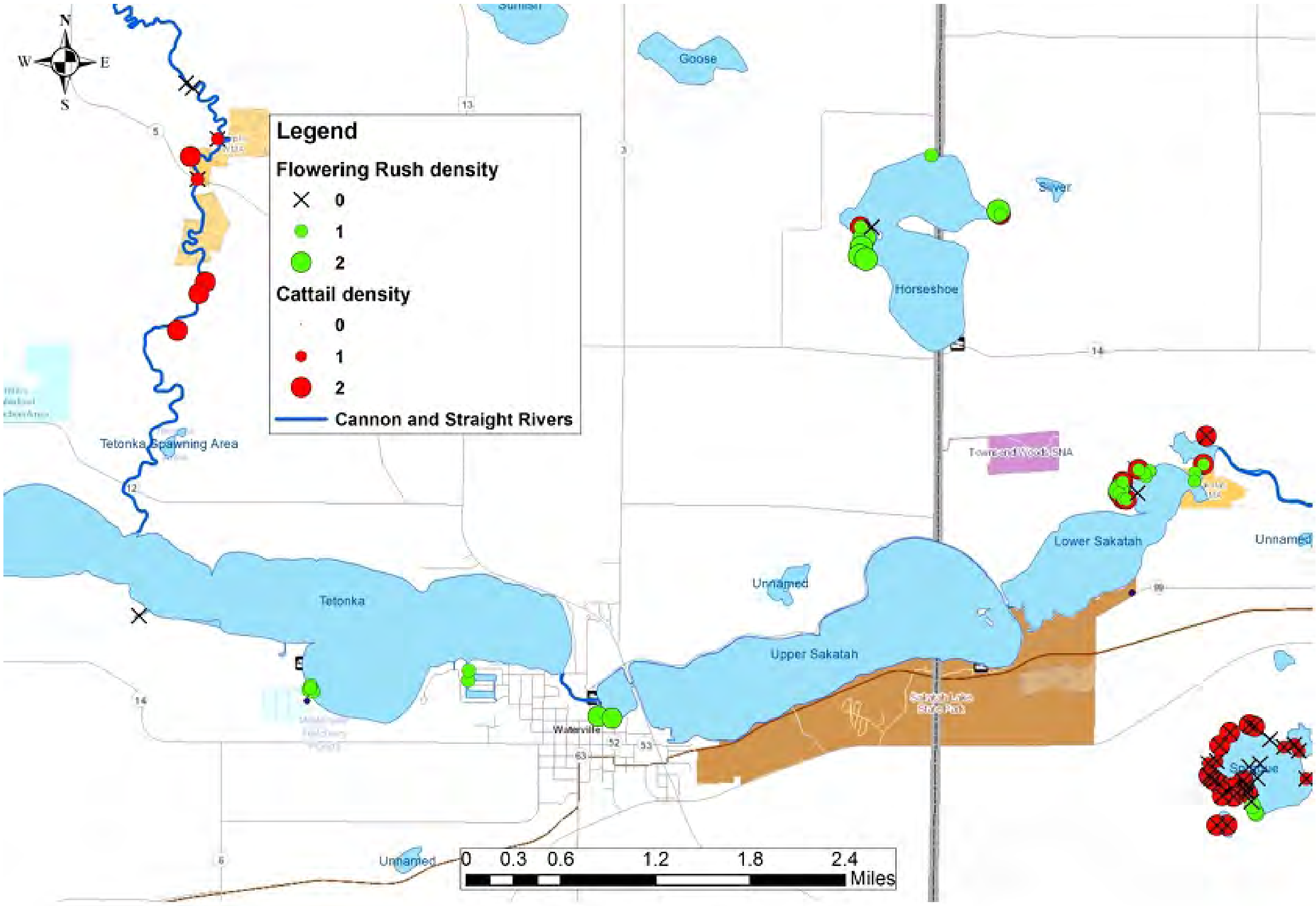


Figure S4. Existing flowering rush distribution and abundance in Lake Tetonka.
Key: Green = locations of flowering rush and red = locations of cattails. The larger the colored dot the denser the growth (source: Gamble 2014).

Flowering rush is present in Lake Tetonka. It is a perennial aquatic plant that grows 1-4' high on an erect stem along shores and 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.

Action Plan: Use lake maps with GPS coordinates to delineate where flowering rush plants are located. For mechanical control, cut emergent plants below the water surface several times per summer and remove cut parts from the water. Cutting stems rather than pulling out the rhizome will help control spreading. Most sites in Lake Tetonka are suitable for mechanical control. If chemical control is used, application of the herbicide diquat (trade name Reward) has been found to be effective. Preliminary testing indicates that a mid-summer application during calm wind conditions may be most effective. Two herbicide applications per year may be needed. Annual treatments are also likely necessary.

5. Zebra Mussel

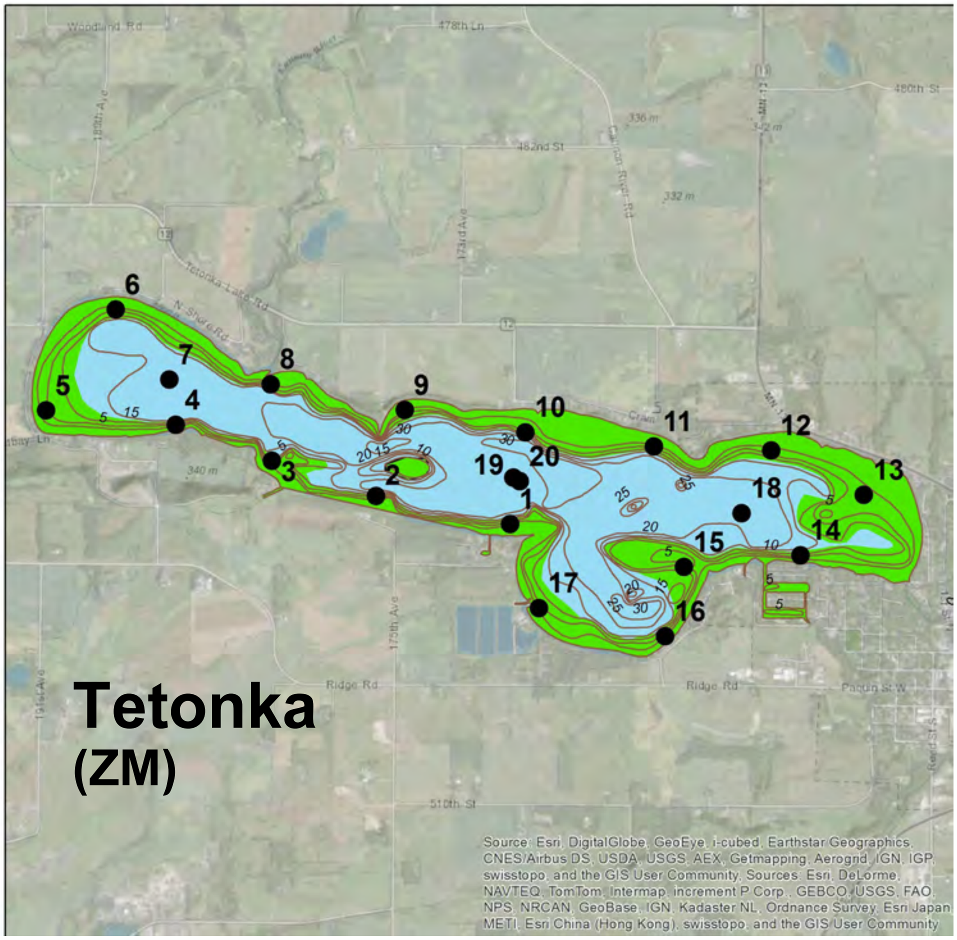


Figure S5. Zebra mussel potential growth based on water column and substrate characteristics. Key: Green = light growth, yellow = moderate growth, blue = no growth.

Zebra mussels have not been found in Lake Tetonka 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 Lake Tetonka 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. However, other conditions are suitable for moderate growth down to water depths of about 12 feet. Below 12 feet of water depth, dissolved oxygen would be limiting for zebra mussel growth. A close cousin to the zebra mussel, the quagga mussel, has similar growth requirements and may actually be able to survive and propagate under more harsh conditions than zebra mussels. No quagga mussels have been reported in Le Sueur County as of 2014.

Action Plan: Zebra mussels have not been found in Lake Tetonka 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 $30,000 if an eradication attempt was considered. Discussions with the MnDNR should be held prior to zebra mussel detection in Lake Tetonka to outline control activities and the need for potential permits.

6. Common Carp

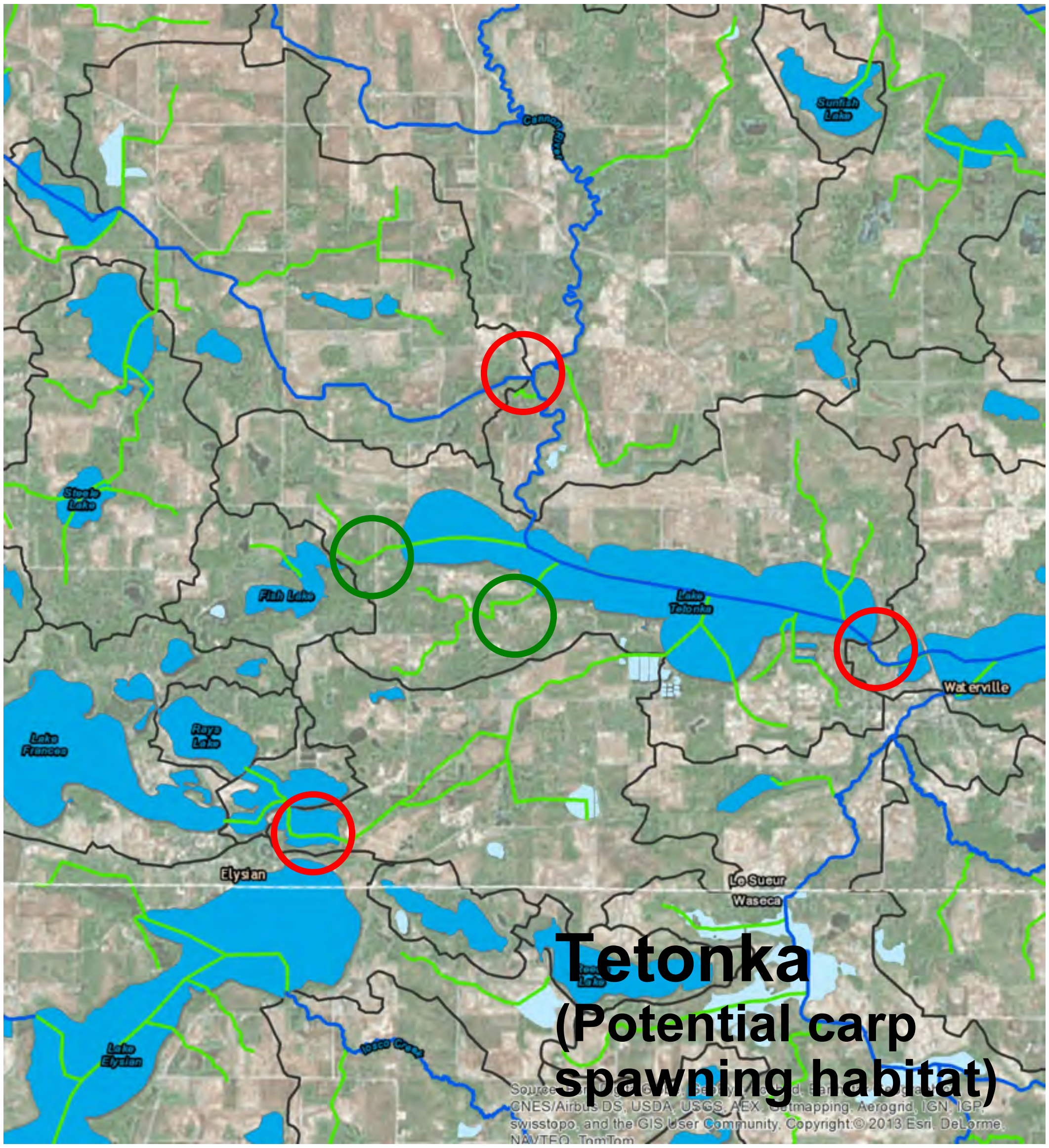


Figure S6. Common carp potential spawning habitat quality. Green circles indicate marginal potential and red circles indicate high potential carp spawning sites in off-lake stream, wetland, and pond habitats.

Common carp are present in Lake Tetonka at a moderate to high density based on the last MnDNR fish survey from 2009. Lake Tetonka habitat suitability for future carp growth is potentially high due to spawning conditions that may be well suited for survival of young fish. Carp spawning success and population expansion is limited when carp are confined to spawning within a lake. Usually predator fish will control the carp eggs and fry. Carp populations do best when there are shallow, off-lake spawning sites where fish predators would be low and thus allow the young carp to grow up to a size where predation is unlikely. It appears that the Lake Tetonka off-lake spawning habitat is favorable to successful carp spawning and immigration by way of the Cannon River and this may sustain the Lake Tetonka carp population.

Action Plan: Carp are present in Lake Tetonka at moderate to high numbers. Carp abundance maybe limiting aquatic plant coverage. Carp management is a project area to consider.

Summary of Environmental Risk Assessments for Six Aquatic Invasive Species for Lake Tetonka, 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 they do become established. The likelihood of introduction and establishment is based on the distance to the nearest AIS population, the activity at the public access, and the suitability of Lake Tetonka 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.

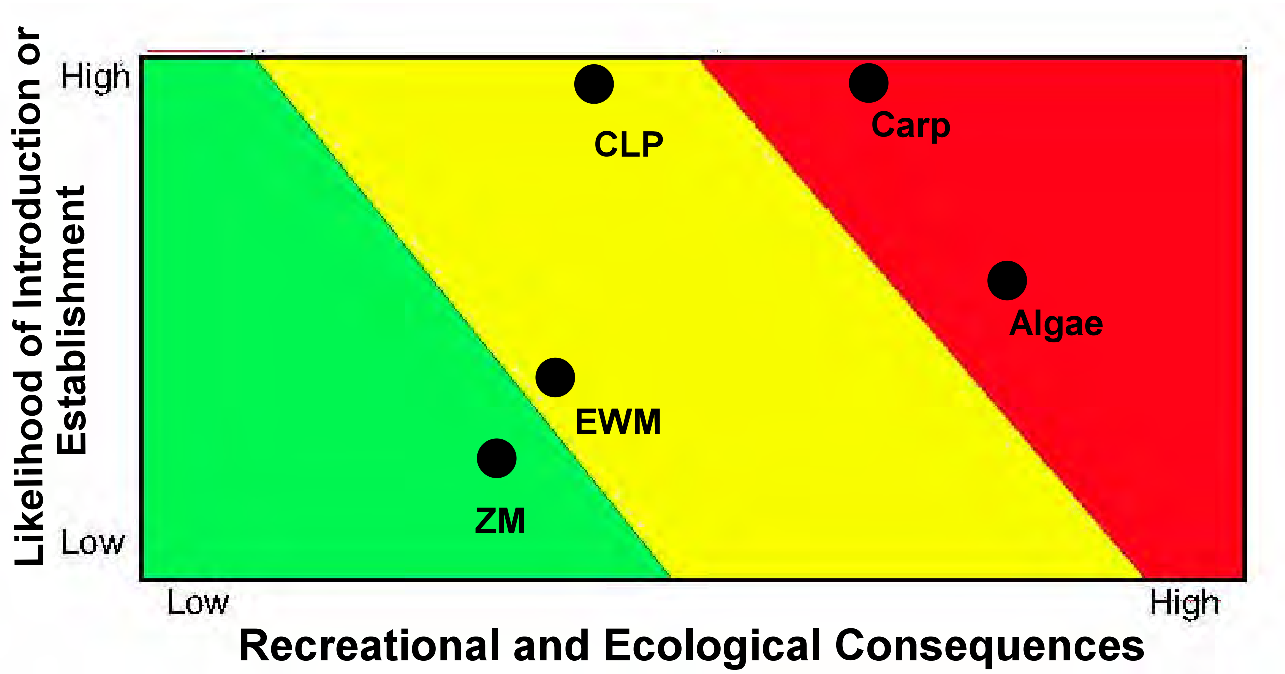


Figure S7. Based on available information, an environmental risk assessment (ERA) chart was prepared for six aquatic invasive species of interest for Lake Tetonka.

Key:

Cylindro: *Cylindrospermopsis*, a blue-green algae species, could reach high densities in Lake Tetonka due to high nutrient conditions. Its introduction is likely by way of the inflowing Cannon River. Consequences could be high.

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

EWM: Public access traffic is brisk and lakes with Eurasian watermilfoil are in the vicinity. Sediments indicate a potential to support mostly moderate growth.

ZM: Zebra mussels are in Prior Lake, Scott County, within 50 miles, and incoming boat traffic is significant. If zebra mussels are introduced, they are predicted to produce mostly light growth due to food limitations.

Carp: Carp are in Lake Tetonka. Conditions appear to be good for producing an abundant carp population. It appears spawning, recruitment, and immigration conditions are favorable.

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

Introduction

Lake Tetonka is a 1,358 acre lake (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 Lake Tetonka associated with non-native aquatic invasive species. The aquatic invasive species evaluated include the following:

Species of Interest:

1. Blue-green algae (*Cylindrospermopsis sp*)(unknown status in Lake Tetonka)
2. Curlyleaf pondweed (present in Lake Tetonka).
3. Eurasian watermilfoil (not present in Lake Tetonka).
4. Flowering rush (present in Lake Tetonka)
5. Zebra mussel (not present in Lake Tetonka).
6. Common carp (present in Lake Tetonka).

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

Plants
- Purple Loosestrife
- Hydrilla

Invertebrates
- Rusty Crayfish
- Chinese and Banded Mystery Snail (may be present in Lake Tetonka)
- 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: Lake Tetonka is located in Le Sueur County (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 ESRI 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 Lake Tetonka, 20 lake sediment samples were collected on October 29, 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.

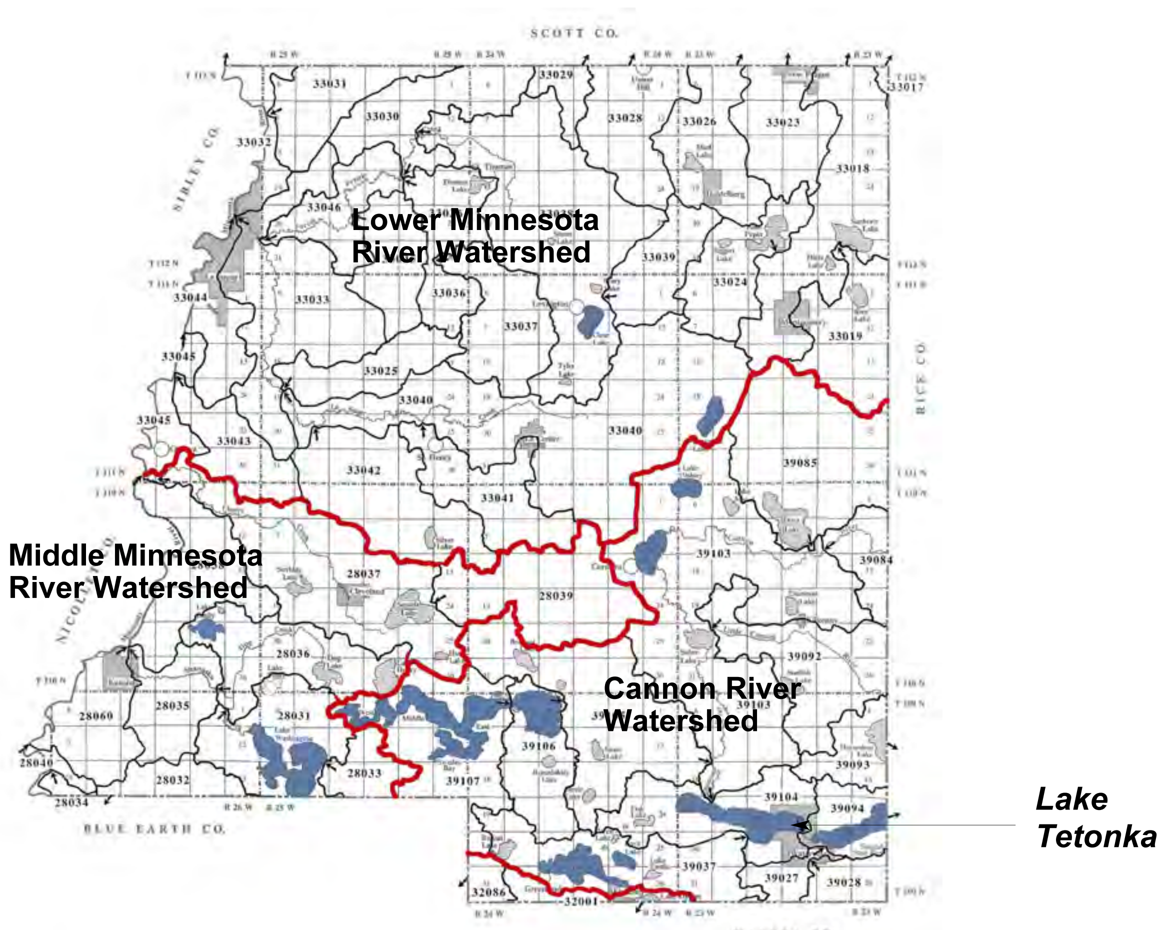


Figure 1. Three major watersheds are located in Le Sueur County. Lake Tetonka is found in the Cannon River Watershed.

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

Lake Tetonka Status: Unknown for Lake Tetonka.

Nearest Occurrence: Lake Nokomis, Minneapolis, MN

Potential for Bloom Conditions in Lake Tetonka: 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, because of high nutrient concentrations, conditions are favorable in Lake Tetonka for blue-green growth including cylindro (Table 1).

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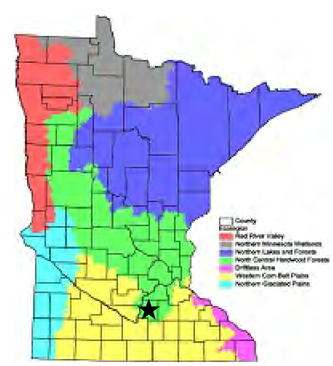
Figure 2. Cylindro is a filamentous blue-green algae.

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

	Deep Lake (MPCA impaired criteria for North Central Hardwood Forest Ecoregion)	Values for Lake Tetonka (MPCA site) (June-Sept) (2007)
Secchi Disc (ft & m) (water clarity)	<4.6 ft (1.4 m)	5.6 ft (1.7 m)
Total Phosphorus (fertilizer nutrient)	>40 ppb	371
Chlorophyll a (measure of algae)	>14 ppb	41



Lake Tetonka 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 contribute to elevated lake phosphorus concentrations could lead to high concentrations of cylindro. A variety of factors contribute to elevated phosphorus levels in lakes and internal loading, including phosphorus release from lake sediments, can be a significant factor. Research by Jensen et al (1992) found when a total iron to total phosphorus ratio was greater than 15 to 1, phosphorus release from lake sediments was minor. The ratio for the soil test results have been used in this report as well. That benchmark of 15:1 has been used to characterize the potential of Lake Tetonka 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 Lake Tetonka show 13 sediment sites (shown with red pentagons) have a low Fe:P ratio which is correlated to high potential phosphorus release from sediments. At other sites sediment phosphorus release appears to be light to moderate (Table 2). Overall p-release may be high in Lake Tetonka.

Table 2. Lake sediment data for iron and phosphorus and the calculated Fe to P ratio. Samples were collected on October 29, 2014.

Sample Number	Depth (ft)	Iron (ppm)	Bray-P (ppm)	Olsen-P (ppm)	Fe/P
Tet 1	5	30.2	6.1	4.9	5.0
Tet 2	6	45.0	6.1	4.9	7.4
Tet 3	6	71.8	3.5	6.9	10.4
Tet 4	6	62.4	7.3	3.7	8.6
Tet 5	9	48.8	1.0	9.3	5.2
Tet 6	8	26.8	1.0	3.9	6.9
Tet 7	24	223.4	0.8	62.5	3.6
Tet 8	6	102.7	3.6	11.9	8.6
Tet 9	8	30.3	0.8	3.4	8.9
Tet 10	5	27.6	11.0	3.7	2.5
Tet 11	7	26.4	6.0	3.6	4.4
Tet 12	5	40.9	2.3	3.5	11.7
Tet 13	7	75.7	2.5	5.0	15.1
Tet 14	8	42.8	9.1	5.2	4.7
Tet 15	10	31.4	7.4	9.8	3.2
Tet 16	6	71.6	2.4	9.5	7.5
Tet 17	8	71.3	1.2	4.6	15.5
Tet 18	27	195.0	0.8	62.0	3.2
Tet 19	29	169.2	0.7	68.2	2.5
Tet 20	29	171.7	0.8	80.8	2.1

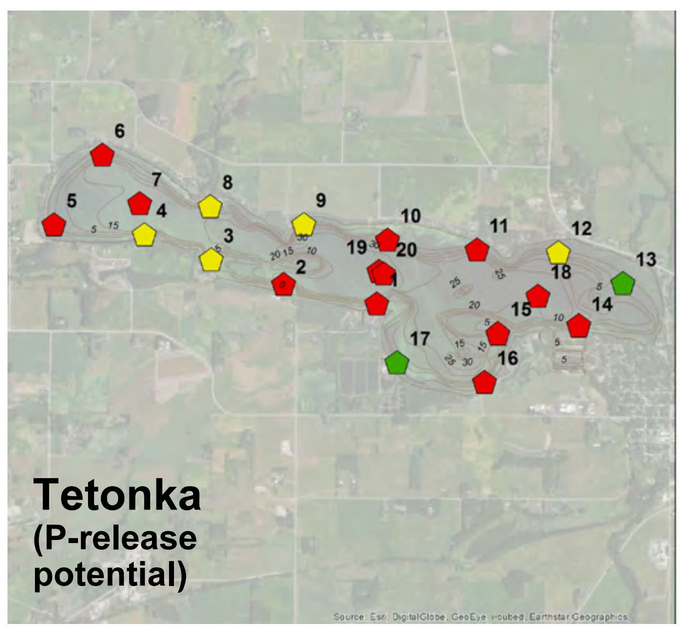


Figure 3. The color indicates the p-release potential of phosphorus in 2014. Key: green = low potential , yellow = moderate potential, and red = high potential.

Management Options for Blue-Green Algae

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

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

Control Options: To reduce excessive algal growth in Lake Tetonka, 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. Lake alum treatments to inactivate lake sediment phosphorus is one approach to reduce lake phosphorus concentrations. At this time, sediment phosphorus release in Lake Tetonka is low. An alum treatment is probably unnecessary.

2. Curlyleaf Pondweed (non-native aquatic plant)

Lake Tetonka Status: Present in Lake Tetonka.

Growth Potential in Lake Tetonka: A broad range from moderate to high growth potential.

Lake sediment sampling results from 2014 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 Lake Tetonka are shown in Table 3 and Figure 7a.

Curlyleaf pondweed growth is predicted to produce nuisance growth (where plants top out in a solid canopy) at a number of sites in Lake Tetonka mostly on the north side of the lake. Otherwise, for other parts of the lake, curlyleaf pondweed is expected to exhibit mostly moderate growth (Figure 7a).

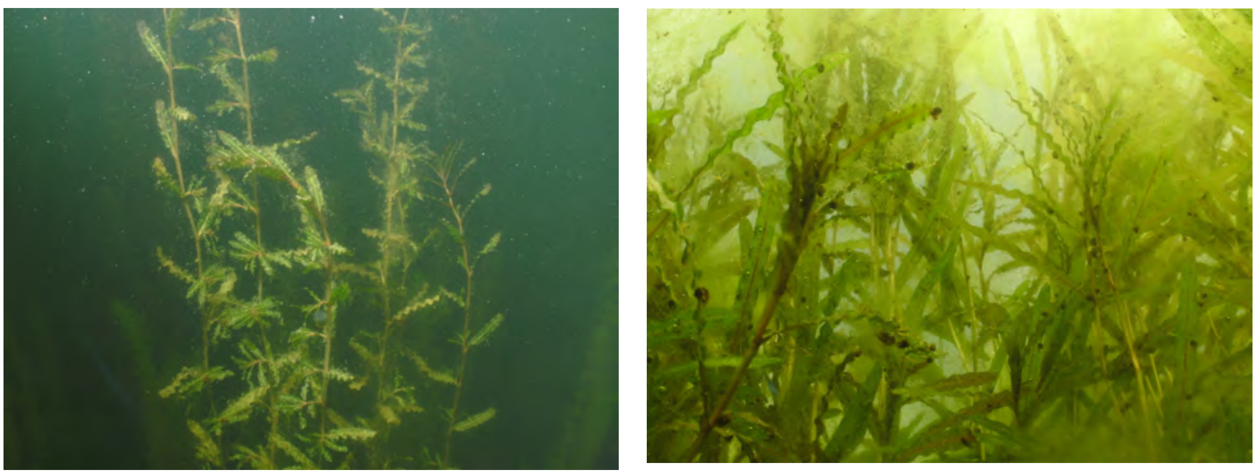


Figure 5. Underwater views of curlyleaf pondweed. Light growth (left) and moderate growth (right).

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 and widespread in Lake Tetonka. Research has found curlyleaf is limited or enhanced based on lake sediment characteristics. Curlyleaf does best in sediments with a high pH and low iron content (McComas, unpublished). Based on lake sediment characteristics, curlyleaf could produce light, moderate, or heavy growth on an annual basis.

In Lake Tetonka it is predicted that curlyleaf will grow in many areas at moderate and heavy densities (Figure 7a and 7b). For future treatments the latest research indicates the use of herbicides produce annual control but long-term control is unlikely.

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

Site	Depth (ft)	pH (su)	Bulk Density (g/cm3 dry)	Organic Matter (%)	Fe:Mn Ratio	Potential for Curlyleaf Pondweed Growth
		<7.4	>1.04	0.1-5	>4.5	Light (green)
		7.4 - 7.7	0.52 - 1.03	6-20	1.6 - 4.5	Moderate (yellow)
		>7.7	<0.51	>20	<1.6	Heavy (red)
Tet 1	5	7.6	1.44	0.3	1.1	Moderate
Tet 2	6	7.8	1.44	0.3	1.4	Moderate
Tet 3	6	7.7	1.36	0.8	1.9	Light
Tet 4	6	7.6	1.44	0.3	3.2	Light
Tet 5	9	7.6	1.22	1.6	1.1	Moderate
Tet 6	8	7.8	1.15	1.2	0.8	Moderate
Tet 7	24	7.4	0.91	10.8	2.4	
Tet 8	6	7.5	1.39	0.8	3.0	Light
Tet 9	8	7.8	0.99	2.2	1.3	Heavy
Tet 10	5	8.0	1.43	0.2	1.5	Moderate
Tet 11	7	7.8	1.42	0.3	1.2	Heavy
Tet 12	5	7.9	1.37	0.9	1.3	Heavy
Tet 13	7	7.6	1.48	0.5	1.7	Moderate
Tet 14	8	7.7	1.53	0.3	2.5	Moderate
Tet 15	10	7.6	1.44	0.5	1.0	Moderate
Tet 16	6	7.6	1.40	0.4	1.9	Light
Tet 17	8	7.5	1.36	0.7	4.3	Light
Tet 18	27	7.4	0.89	11.8	1.8	
Tet 19	29	7.3	0.87	11.5	1.3	
Tet 20	29	7.3	0.91	11.7	1.2	

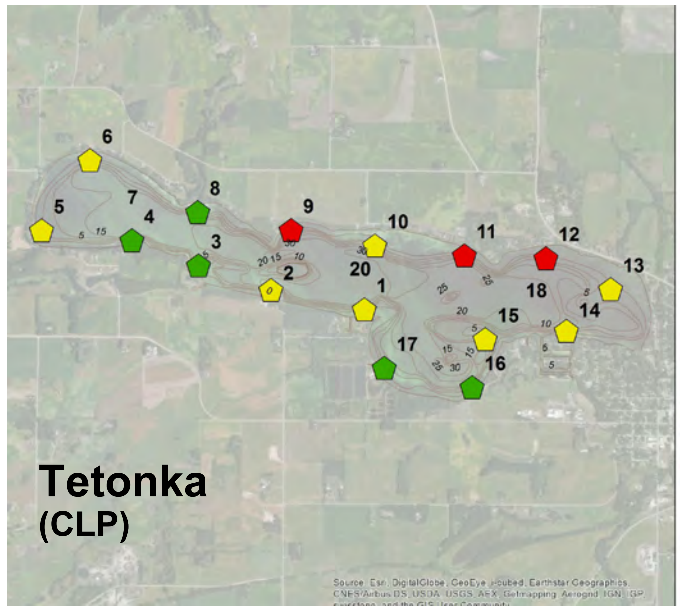


Figure 7a. The color indicates the potential growth of curlyleaf pondweed in 2014. Key: green = light growth, yellow = moderate growth, and red = heavy growth.

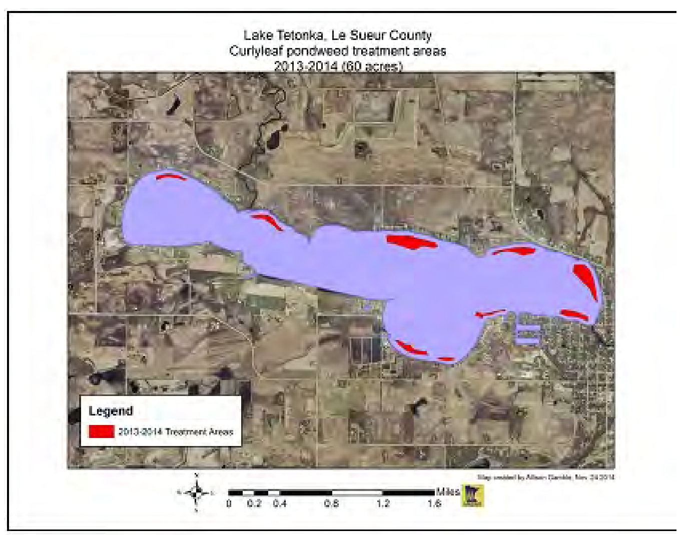


Figure 7b. Red color indicates the 2013-2014 curlyleaf pondweed treatment locations. 60 acres were treated (source: MnDNR).

Management Options for Curlyleaf Pondweed

Scouting Activities: Annual scouting activities can be used to delineate areas where curlyleaf pondweed (CLP) treatment is considered. An example of a CLP delineation is shown in Figure 8. Scouting should be done in April or May. Sediment characteristics, already collected, indicate there is a potential for moderate to heavy growth of CLP in Lake Tetonka. Although scouting should be conducted around the entire lake and all curlyleaf observations should be noted, scouting should be concentrated in areas that are conducive to heavy growth. It is recommended that all aquatic plants (especially the natives) should be recorded within a delineated area containing curlyleaf pondweed when scouting. GPS should be used to outline a treatment area. Areas of light growth do not need to be treated whereas areas of moderate to heavy growth are candidates for treatment.

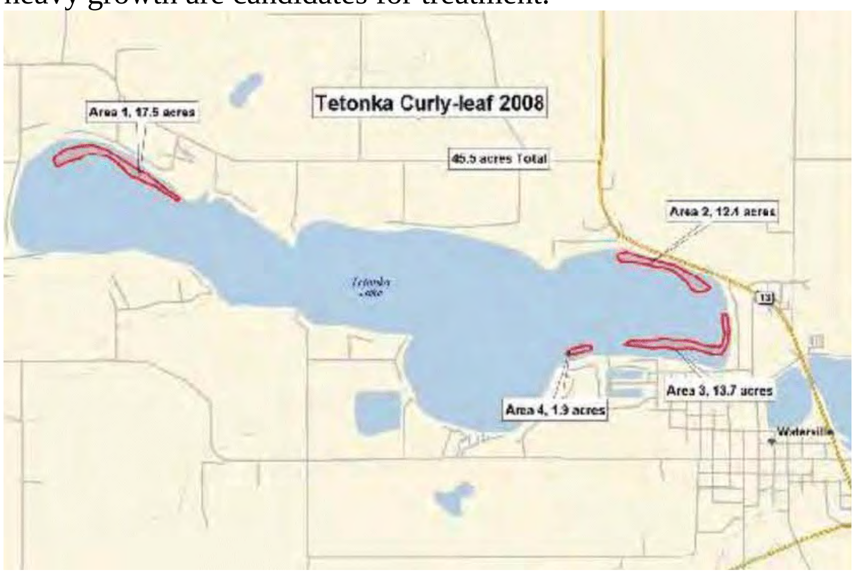


Figure 8. Map shows a historical Lake Tetonka curlyleaf treatment. Acres treated: 45.5 acres in 2007-2009, 36.5 acres in 2010, 39.42 acres in 2011, and 65 acres in 2012 (source: MnDNR).

Control Options: The recommended treatment option at this time is the use of an endothall herbicide. It is estimated that as a worst case situation, curlyleaf would produce up to 150 acres of moderate to heavy growth. 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 Lake Tetonka even in years after treatment. However, heavy growth should be limited by lake sediment conditions. Two common treatment methods are shown below. Herbicide applications have been used for curlyleaf control the last few years.

Herbicide applications

Mechanical harvesters

3. Eurasian Watermilfoil (non-native aquatic plant)

Lake Tetonka Status: Not found in Lake Tetonka.

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

Lake sediment sampling results from 2014 have been used to predict lake areas that have the potential to support various types of Eurasian watermilfoil (EWM) growth. Examples of milfoil growth characteristics are shown in Figures 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 if milfoil becomes established in Lake Tetonka (Table 4 and Figure 11).

In Lake Tetonka a majority of sites had low or moderate nitrogen concentrations and these areas are predicted to produce mostly light or moderate growth on an annual basis.

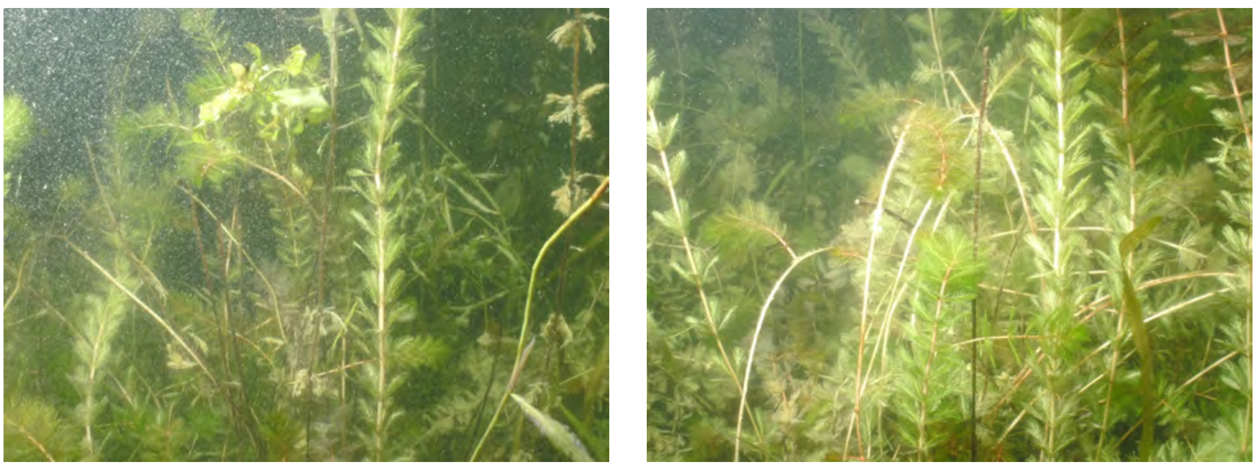


Figure 9. Underwater views of Eurasian watermilfoil

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 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 has not been observed in Lake Tetonka as of 2014. The potential for milfoil growth, based on lake sediment sampling, would be mostly light to moderate growth with potential for heavy growth at Site 8 (Figure 11). Heavy milfoil growth has been correlated with high sediment nitrogen condition and Lake Tetonka has mostly low to moderate nitrogen conditions.

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

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

Site	Depth (ft)	NH_4 Conc (ppm)	Organic Matter (%)	Potential for Eurasian Watermilfoil Growth
		<4	<0.5 and >20	Light (green)
		4 - 10	0.6-2 and 18-20	Moderate (yellow)
		>10	3 - 17	Heavy (red)
Tet 1	5	4.0	0.3	Moderate
Tet 2	6	2.2	0.3	Light
Tet 3	6	5.7	0.8	Moderate
Tet 4	6	3.2	0.3	Light
Tet 5	9	6.3	1.6	Moderate
Tet 6	8	5.5	1.2	Moderate
Tet 7	24	16.1	10.8	
Tet 8	6	10.9	0.8	Heavy
Tet 9	8	4.8	2.2	Moderate
Tet 10	5	1.2	0.2	Light
Tet 11	7	2.8	0.3	Light
Tet 12	5	8.5	0.9	Moderate
Tet 13	7	7.4	0.5	Moderate
Tet 14	8	3.8	0.3	Light
Tet 15	10	3.3	0.5	Light
Tet 16	6	6.8	0.4	Moderate
Tet 17	8	3.4	0.7	Light
Tet 18	27	16.1	11.8	
Tet 19	29	14.7	11.5	
Tet 20	29	15.2	11.7	

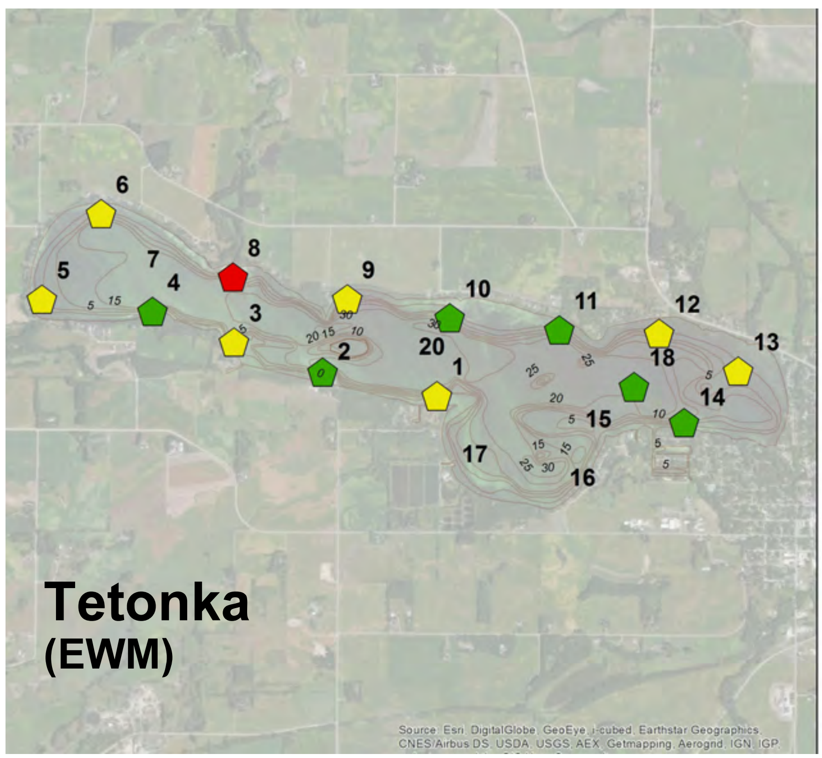


Figure 11. The color indicates the growth potential of Eurasian watermilfoil based on a sediment survey.
Key: green = light growth, yellow = moderate growth, and red = heavy growth.

Management Options for Eurasian Watermilfoil

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

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

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

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

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

Herbicide Applications would use a 2,4-D herbicide

Mechanical harvesting

4. Flowering Rush (non-native aquatic plant)

Lake Tetonka Status: Currently in Lake Tetonka

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

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

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

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

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

Examples of Flowering Rush Growth Characteristics

Figure 12. Light growth (left) refers to sporadic stems and is not a recreational or ecological problem but has the potential to spread. Moderate growth (middle) refers to a sparse density of intermediate sized flowering rush beds. Heavy growth (right) refers to a large area of relatively dense flowering rush.

Management Options for Flowering Rush

Scouting Activities: The current distribution of flowering rush in Lake Tetonka is shown in Figure 13. In the future, flowering rush sites should be delineated before treatment is administered. The emphasis in Lake Tetonka has been to delineate emergent sites of flowering rush. It is possible some areas with submerged patches have not be delineated. Scouting in July or August when plants are in a mature state is a good time to delineate emergent plants and there is still time to treat the beds. GPS waypoints are collected at each flowering rush site along with an estimate of the area of flowering rush colonization at that site.

Control Options: Use lake maps with GPS coordinates to locate where flowering rush plants are found. For mechanical control, cut plants below the water surface several times per summer and remove cut stems from the lake. This method helps to reduce spreading. The current flowering rush distribution is shown in Figure 13. For chemical control, application of the herbicide diquat (trade name Reward) has been found to be effective. Preliminary testing indicates that a mid-summer application during calm wind conditions may be most effective. Two herbicide applications per year may be needed. Annual treatments are also likely necessary.

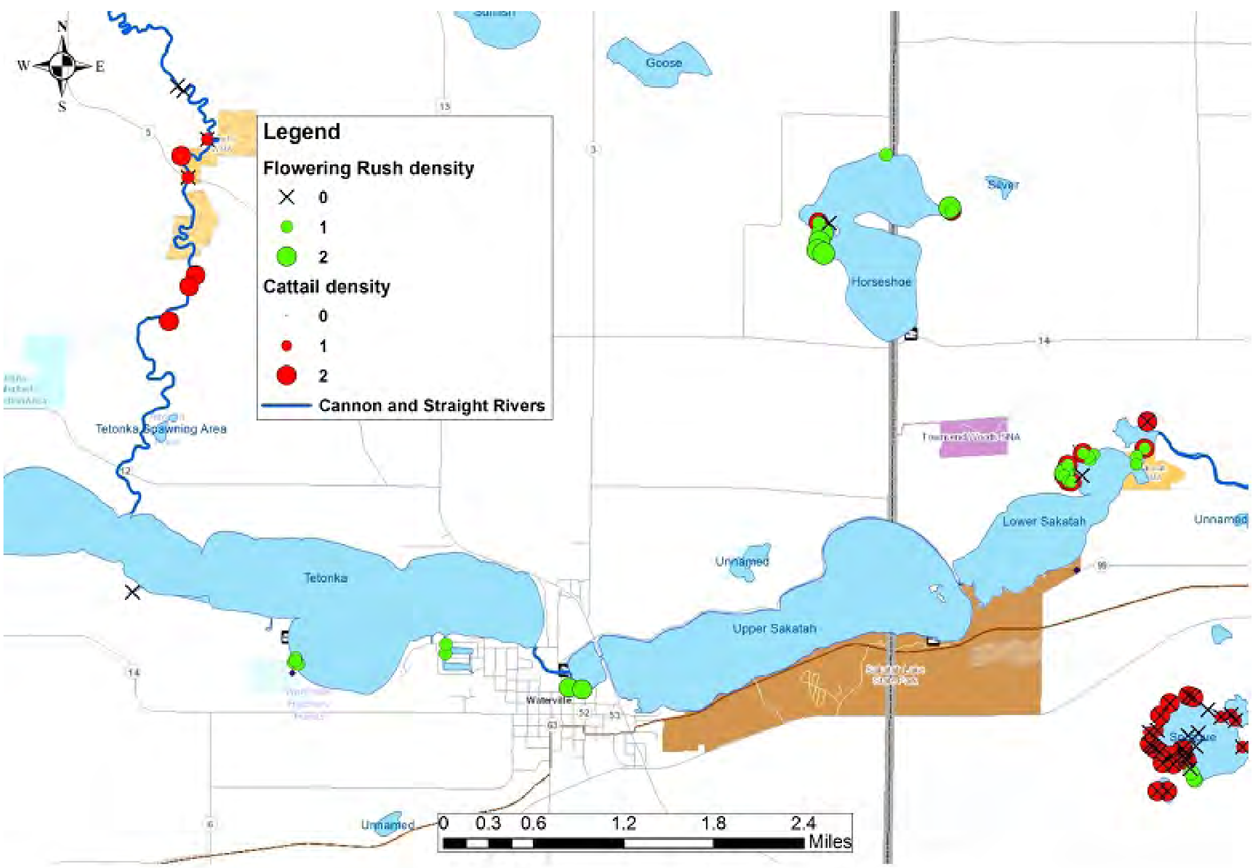


Figure 13. Locations of flowering rush in Lake Tetonka. Green dots = locations of flowering rush and red dots = locations of cattails. The bigger the dot the denser the plant growth is (Gamble 2014).

5. Zebra Mussels (invertebrate)

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

Nearest Occurrence: Prior Lake, Scott County, Minnesota.

Growth Potential in Lake Tetonka: Moderate.

The life cycle of zebra mussels is shown in Figure 14. 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 15. A chart of water column parameters indicates a broad range of potential growth for zebra mussels in Lake Tetonka (Table 5). Although zebra mussels prefer hard substrates for optimal growth, they will grow together forming clumps on sand and silt bottoms. Lake Tetonka has extensive areas of sandy and mucky sediments that would support moderate zebra mussel colonization (Table 5).

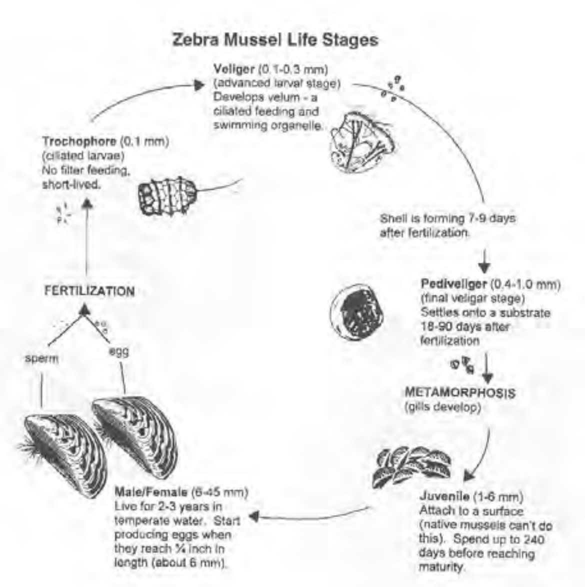


Figure 14. Zebra mussel life stages: Zebra mussels can be detected at the veliger stage using modified zooplankton nets, but this is usually performed by experts. The PVC pipe detection device will pick up mussels starting at the pediveliger stage (Adopted from U.S. Army Corps of Engineers, WES)(from Mccomas, 2003. Lake and pond management guidebook).

Examples of Zebra Mussel Growth Conditions

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

Figure 15. 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 Lake Tetonka as of 2014. A review of water column and substrate characteristics for Lake Tetonka was compared to characteristics suited for zebra mussels. It appears that zebra mussels are likely to be food limited in Lake Tetonka (Table 5). Also substrate conditions would support moderate growth.

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

		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Lake Tetonka				52 (2007)
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Lake Tetonka			8.1 (2007)	
	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)	Lake Tetonka				157 (2007)
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Lake Tetonka				380 (2007)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m)	Lake Tetonka		1.7 m range: 0.7 - 4.3 m (2007)		
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source)	Lake Tetonka	42 range: 3.4 - 187 (2007)			
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l)	Lake Tetonka	371 range: 169 - 597 (2007)			
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35
Substrate Factors					
Dissolved oxygen (mg/l)	Lake Tetonka		0 - 6 m (2007)		
	Mackie and Claudi 2010	<3	3 - 7	7 - 8	>8
Bottom substrate	Lake Tetonka	30%		60%	10%
		Soft muck with no hard objects		Muck, silt, sand	Rock or wood

Zebra Mussel Growth Potential Based on Water Column and Substrate Conditions: Two broad categories combine to produce growing conditions in lakes for zebra mussels. The two categories are water column conditions and lake bottom (also referred to as substrate) conditions. Water column conditions were summarized in Table 5 and indicated that based on chlorophyll data, that blue-green algae could limit zebra mussel growth. Substrate conditions were also inspected at 20 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 Lake Tetonka are sparse. A map that combines the growth potential of water column and substrate characteristics is shown in Figure 16. It appears dissolved oxygen will allow growth to about 12 feet of water depth and zebra mussel production should be light in the shallow water. Zebra mussels will grow on each other in clumps (Figure 17) and begin to become commonly observed two to four years after first being discovered.

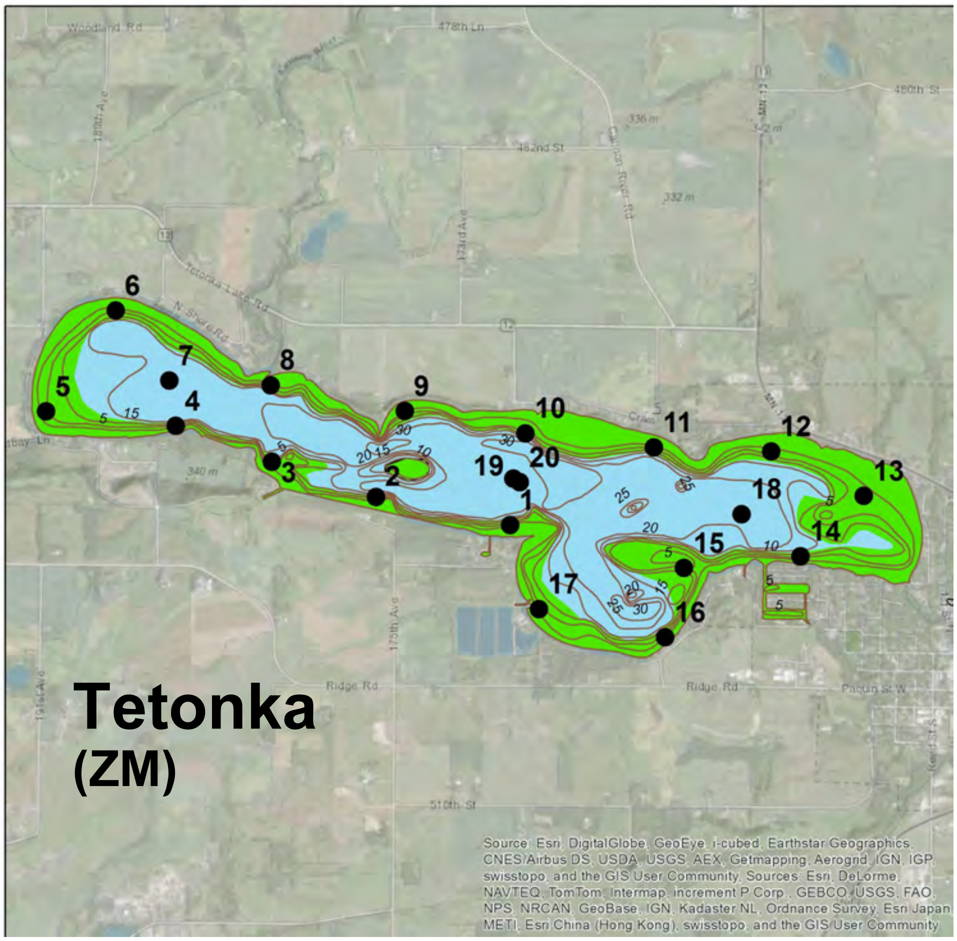


Figure 16. Key for potential growth of zebra mussels: Green = light growth, yellow = moderate growth, and blue = no growth.

Figure 17. Distinctive zebra mussel growth pattern found in areas of sandy and silty sediments. Zebra mussels will grow on each other and form clumps of zebra mussels which sit on top of the sediments.

Management Options for Zebra Mussels

Early Detection: A zebra mussel early detection program should be implemented for Lake Tetonka. 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.

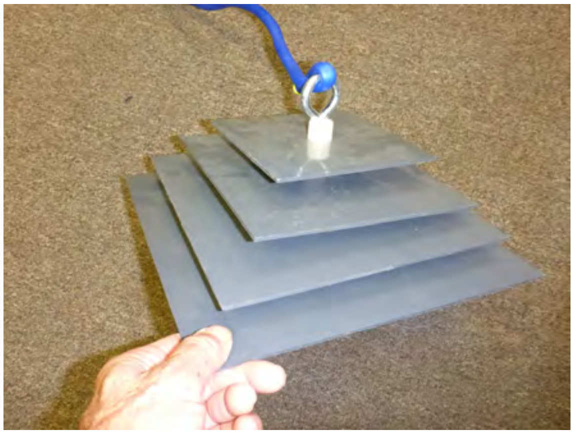


Figure 18. A zebra mussel plate sampler can be made from pvc materials. Ceramic tiles also make for good monitoring surfaces as well as pvc pipes.

Rapid Response Assessment: When zebra mussels are first discovered in Lake Tetonka, 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 Lake Tetonka, a minimum of 20 search hours would be an appropriate search goal.

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

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

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

Figure 19. Small scale control devices maybe considered for removing zebra mussels in a clump form from swimming areas or sandy spawning sites.

6. Common Carp (fish)

Lake Tetonka Status: Present in Lake Tetonka (sampled in the last MnDNR fish survey).

Growth Potential in Lake Tetonka: Moderate to high.

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 20. Common carp were sampled in the last survey in Lake Tetonka, based on the MnDNR fish survey from 2009 (Table 6). Lake Tetonka habitat suitability for future growth is moderate to high due to spawning conditions that may be well suited for survival of young fish (Figure 21). Since the 2009 survey, carp abundance is considered to be above average, probably due to immigration from the Cannon River and poor recruitment of new carp.

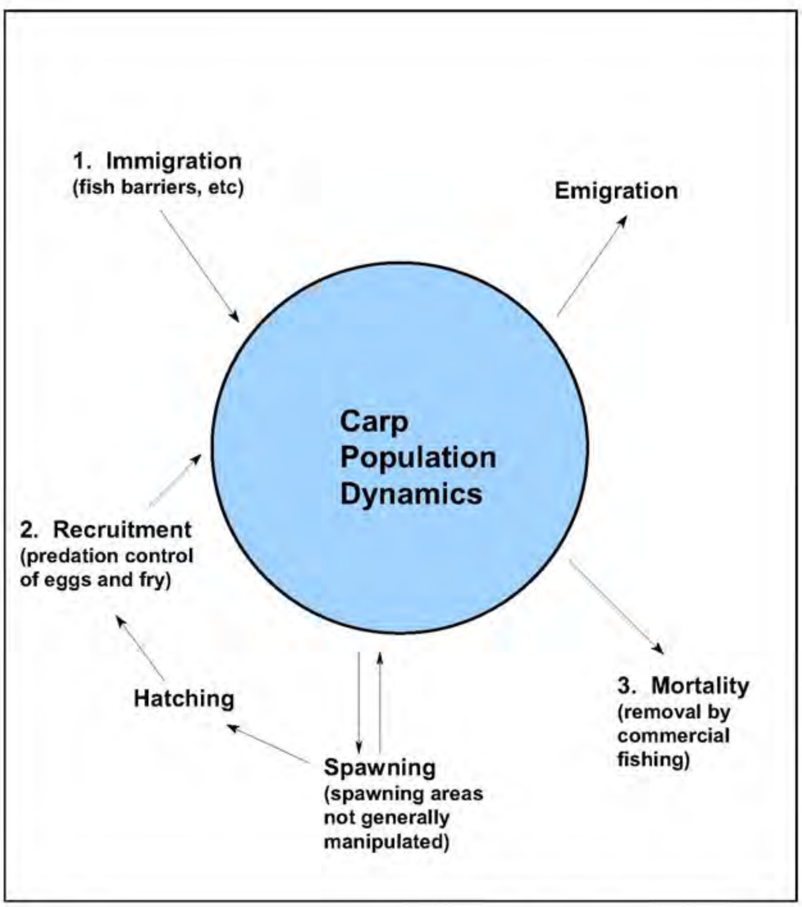


Figure 20. Three factors contribute to carp population dynamics. When carp populations are at a low density in lakes, Factors 1 and 2 generally limit populations.

Table 6. Fish sampled in the Lake Tetonka 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	0.93	0.7 - 25.7	0.86	0.3 - 0.6
	Gill net	1.73	2.5 - 45.0	0.93	0.3 - 0.7
Black Crappie	Trap net	4.8	1.8 - 21.2	0.27	0.2 - 0.3
	Gill net	3.07	2.5 - 16.5	0.44	0.1 - 0.3
Bluegill	Trap net	27.8	7.5 - 62.5	0.17	0.1 - 0.3
	Gill net	1.67	N/A	0.23	N/A
Bowfin (dogfish)	Trap net	1.4	0.4 - 1.3	4.08	2.3 - 4.1
	Gill net	0.2	0.2 - 0.8	6.22	2.4 - 4.2
Channel Catfish	Trap net	0.07	N/A	2.65	N/A
Common Carp	Trap net	1.13	0.4 - 2.0	3.3	2.6 - 6.0
	Gill net	0.33	0.3 - 3.0	5.8	1.9 - 5.2
Freshwater Drum	Trap net	5.87	0.5 - 4.2	1.44	0.4 - 1.2
	Gill net	11.4	4.0 - 32.3	0.76	0.3 - 1.1
Hybrid Sunfish	Trap net	0.13	N/A	0.12	N/A
Longnose Gar	Gill net	0.07	N/A	1.31	N/A
Northern Pike	Trap net	0.33	N/A	2.84	N/A
	Gill net	3.2	1.5 - 7.3	4.82	2.0 - 3.5
Pumpkinseed	Trap net	0.07	0.7 - 4.2	0.2	0.1 - 0.2
Quillback	Gill net	0.13	N/A	1.39	N/A
Smallmouth Bass	Gill net	0.07	0.2 - 2.3	2.2	0.9 - 1.5
Walleye	Trap net	0.33	0.3 - 1.2	1.91	0.8 - 2.8
	Gill net	2.4	1.2 - 6.3	3.01	1.2 - 2.7
White Bass	Trap net	0.27	0.2 - 0.9	1.36	0.5 - 1.5
	Gill net	2.2	0.3 - 3.8	1.22	N/A
White Sucker	Trap net	0.07	0.2 - 1.0	3.66	1.6 - 2.8
	Gill net	0.73	0.4 - 2.2	2.23	1.5 - 2.4
Yellow Bullhead	Trap net	2.33	0.9 - 5.7	0.97	0.5 - 0.8
	Gill net	0.27	0.5 - 7.5	1.21	0.5 - 0.8
Yellow Perch	*Trap net*	*0.73*	*0.3 - 1.7*	*0.27*	*0.1 - 0.2*
	Gill net	*4.33*	*2.0 - 27.9*	*0.33*	*0.1 - 0.2*

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

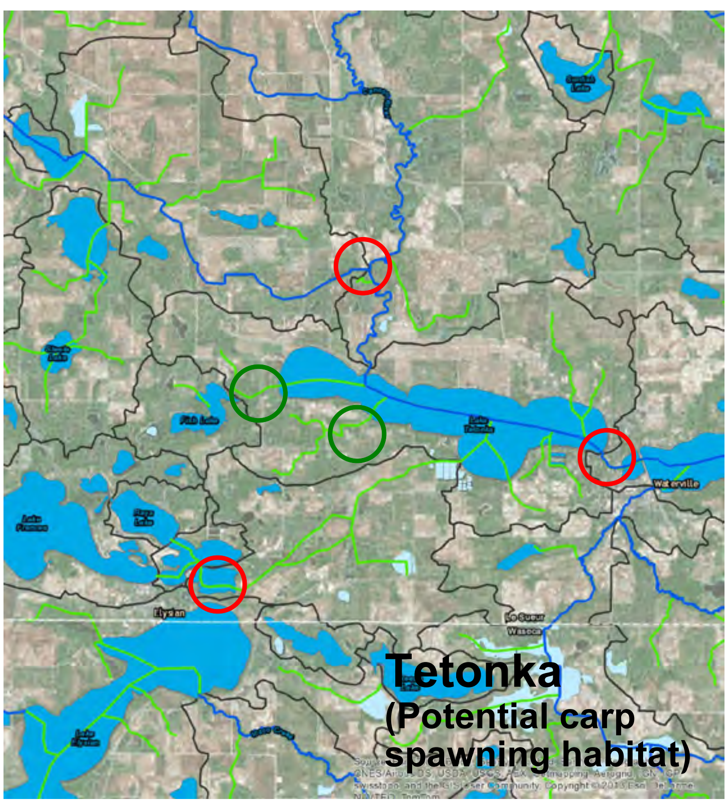


Figure 21. Common carp potential spawning habitat quality. Green circles indicate marginal potential and red circles indicate high potential carp spawning sites in off-lake stream, wetland, and pond habitats.

Management Options for Common Carp

Early Detection: Carp are already present in Lake Tetonka and they have been found in excessive numbers in the past. High carp abundance may impact water clarity they would likely decrease aquatic plant coverage. Carp management is a project area to consider.

Rapid Response Assessment: None needed, carp are already present in the lake. In the future, carp could be assessed to determine their abundance and carp management projects could be implemented.

Rapid Response Action: None at this time.

Control Options: If controlling carp was considered, 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 22). Currently, carp immigration from the Cannon River is likely. The recruitment and mortality areas should also be emphasized for control. The recruitment category centers around the spawning habitat that is found in areas outside of the lake but connected by streams. These areas are present in a couple of places and may be good carp spawning habitat. The third area, mortality, could be implemented by using commercial fishermen if necessary.

1. Immigration
(*High in Lake Tetonka*)

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

3. Mortality
(*Use commercial fishermen*)

Figure 22. Three factors impacting carp population dynamics.

Other Non-native Species to Consider

Purple Loosestrife (aquatic and terrestrial plant)

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

Potential for Nuisance Colonization in Lake Tetonka: 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 Lake Tetonka.

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

Source: MnDNR

Source: MnDNR

Figure 23. [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 Lake Tetonka, 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)

Lake Tetonka Status: Not present in Lake Tetonka (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 Lake Tetonka: 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 Lake Tetonka.

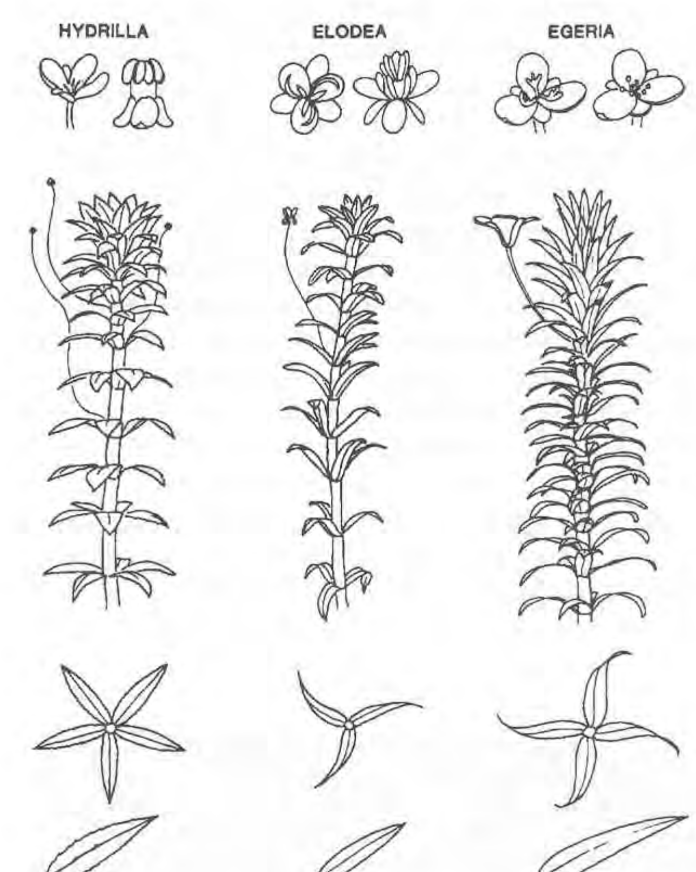


Figure 24.

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

Control Options: If hydrilla was confirmed in Lake Tetonka, 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)

Lake Tetonka Status: Not presently found in Lake Tetonka 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 Lake Tetonka: 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 Lake Tetonka they could reduce the aquatic plants found in the bays. Rusty crayfish would have minimal effect in the main body of Lake Tetonka 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 Lake Tetonka and checked weekly.

Figure 25. [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 Lake Tetonka 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.

Lake Tetonka 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 26. Examples of three types of rusty crayfish traps. The trap on the right is a modified minnow trap.

Figure 27. Big Bearskin Lake, Oneida County, Wisconsin has an active rusty crayfish control program. Volunteers run the rusty crayfish traps. Crayfish are collected and brought to a central site for sorting. Small crayfish are taken into the woods for bear and raccoon food and the large crayfish are taken to a restaurant in Green Bay.

Other Molluscs

Chinese and Banded Mystery Snail (CMS), (BMS):

A larger olive colored snail species, CMS and BMS can form dense aggregations. CMS can transmit human 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.

Faucet Snail:

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

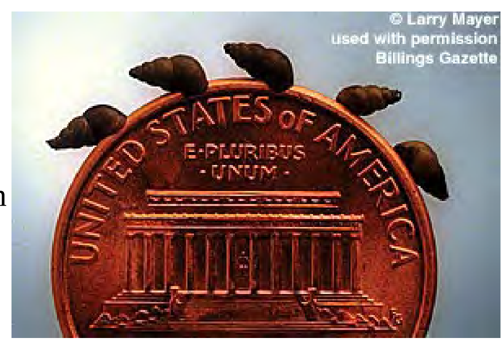
Quagga Mussel:

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


Photo courtesy of USGS

New Zealand Mudsnail:

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



Asian Carp

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

Management Options for Asian Carp

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

Figure 28. Bighead carp, *Hypophthalmichthys nobilis*, and distribution maps (USFWS photo).

Figure 29. Silver carp, *Hypophthalmichthys molitrix*, and distribution map (USFWS photo).

Snakehead

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

Nearest occurrence: East coast.

Potential for Nuisance Colonization in Lake Tetonka: 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 30. Picture of a snakehead (left) and distribution map (right). From the USGS website (Nonindigenous Aquatic Species (NAS) page).

Viral Hemorrhagic Septicemia (VHS)(fish virus)

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

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

Potential for Nuisance Colonization in Lake Tetonka: 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 Lake Tetonka, 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 Lake Tetonka, an intensive information program should be implemented by the Le Sueur County Environmental Services 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 31. Examples of hemorraging in fish with the VHS virus.

References

Christy, M.T., A.A.Y. Adams, G.H. Rodda, J.A. Savidge, and C.L. Tyrrell. 2010. Modelling detection probabilities to evaluate management and control tools for an invasive species. Journal of Applied Ecology 47:106-113.

Gamble, A. 2014. Flowering rush infestation survey of the Cannon River watershed by the invasive species program. Prepared by the Minnesota Department of Natural Resources.

Harvey, C.T., S.A. Qureshi, and H.J. MacIsaac. 2009. Detection of a colonizing, aquatic, non-indigenous species. Diversity and Distributions 15:429–437

Hoffman, J.C., J.R. Kelly, A.S. Trebitz, G.S. Peterson, and C.W.West. 2011. Effort and potential efficiencies for aquatic non-native species early detection. Can. J. Fish. Aqua. Sci 68:2064-2079.

Jensen, H.S., P. Kristensen, E. Jeppesen, and A. Skytthe. 1992. Iron:phosphorus ratio in surface sediment as an indicator of phosphate release from aerobic sediments in shallow lakes. Hydrobiologia 235/236: pp731-743.

Jones, W.W. and S. Sauter. 2005. Distribution and abundance of *Cylindrospermopsis raciborskii* in Indiana lakes and reservoirs. Prepared for Office of Water Quality. Indiana Depart. of Environ. Man. Indianapolis, IN.

Kery, M. 2002. Inferring the absence of a species - a case study of snakes. J. Wildl. Manage. 66:330-338.

Mackie, G.L. and R. Claudi. 2010. Monitoring and control of macrofouling mollusks in fresh water systems. Second Edition. CRC Press, Boca Raton, FL.

McComas, S.R. 2003. Lake and pond management guidebook. CRC Press, Boca Raton, FL.

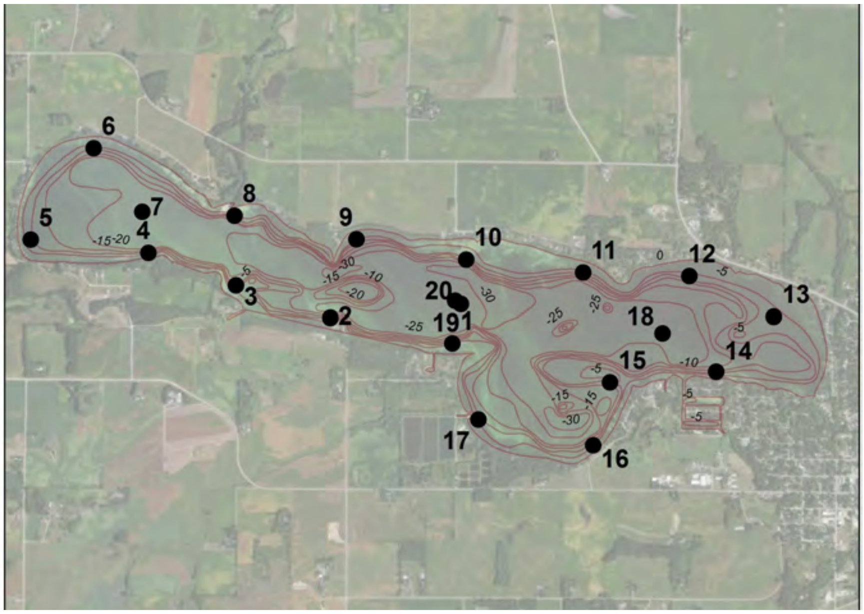
McComas, S.R., Y.E. Christianson, and U. Singh. In press. Effects of curlyleaf pondweed control on water quality and coontail abundance in Gleason Lake, Minnesota. Lake and Reservoir Management.

Nurnberg, G. 1988. Prediction of phosphorus release rates from total and reductant-soluble phosphorus in anoxic lake sediments. Can. J. Fish. Aquatic. Sci. 45:453-462.

Roley, S.S. and R.M. Newman. 2008. Predicting Eurasian watermilfoil invasions in Minnesota. Lake and Reservoir Management 24:361-369.

APPENDIX A

Methods



Lake Soil Survey: A total of 20 samples were collected from depths ranging from 5 to 29 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 (24 - 29 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°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 $\mu g/cm^3$.

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

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

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

APPENDIX B

Samples were collected on October 29, 2014.

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	Hot Water 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	Avg Scoop Wt	Correction Factor	Fe/S	Fe/Mn	Fe/P check P value Olsen was used
Tetonka 1	1.44	6.1	4.9	38	0.3	7.6	0.25	30.2	28.1	0.53	0.57	2224	77	67	4.0	12.22	1.22	0.4	1.1	6.2
Tet 2	1.44	6.1	4.9	34	0.3	7.8	0.25	45.0	32.1	0.52	0.56	2099	93	60	2.2	12.29	1.23	0.7	1.4	9.2
Tet 3	1.36	3.5	6.9	39	0.8	7.7	0.23	71.8	36.2	0.75	0.77	3083	122	94	5.7	11.55	1.15	0.8	2.0	10.4
Tet 4	1.44	7.3	3.7	27	0.3	7.6	0.25	62.4	19.3	0.73	0.87	2176	113	141	3.2	12.23	1.22	0.4	3.2	17.0
Tet 5	1.22	1.0	9.3	28	1.6	7.6	0.35	48.8	45.2	1.66	1.11	3144	162	98	6.3	10.38	1.04	0.5	1.1	5.2
Tet 6	1.15	1.0	3.9	43	1.2	7.8	0.25	26.8	35.7	0.53	0.76	3022	144	37	5.5	9.77	0.98	0.7	0.8	6.9
Tet 7	0.91	0.8	62.5	25	10.8	7.4	0.93	223.4	94.5	3.34	6.82	4058	557	158	16.1	7.71	0.77	1.4	2.4	3.6
Tet 8	1.39	3.6	11.9	47	0.8	7.5	0.37	102.7	33.7	1.81	1.87	3164	167	203	10.9	11.86	1.19	0.5	3.0	8.7
Tet 9	0.99	0.8	3.4	50	2.2	7.8	0.24	30.3	23.5	1.02	1.19	2750	167	35	4.8	8.39	0.84	0.9	1.3	9.0
Tet 10	1.43	11.0	3.7	23	0.2	8.0	0.20	27.6	18.1	0.29	0.37	1444	84	30	1.2	12.19	1.22	0.9	1.5	7.5
Tet 11	1.42	6.0	3.6	22	0.3	7.8	0.25	26.4	21.8	0.75	1.17	2793	118	90	2.8	12.10	1.21	0.3	1.2	7.3
Tet 12	1.37	2.3	3.5	159	0.9	7.9	0.31	40.9	31.2	0.66	1.65	4019	328	56	8.5	11.63	1.16	0.7	1.3	11.7
Tet 13	1.48	2.5	5.0	138	0.5	7.6	0.28	75.7	45.9	0.92	2.43	3350	229	79	7.4	12.58	1.26	1.0	1.7	15.0
Tet 14	1.53	9.1	5.2	23	0.3	7.7	0.27	42.8	17.2	2.17	0.88	2637	109	77	3.8	12.99	1.30	0.6	2.5	8.2
Tet 15	1.44	7.4	9.8	23	0.5	7.6	0.23	31.4	33.2	0.92	0.99	2772	104	100	3.3	12.29	1.23	0.3	0.9	3.2
Tet 16	1.40	2.4	9.5	32	0.4	7.6	0.18	71.6	36.9	0.93	0.77	2950	137	110	6.8	11.91	1.19	0.7	1.9	7.5
Tet 17	1.36	1.2	4.6	27	0.7	7.5	0.26	71.3	16.6	0.58	0.72	3798	154	150	3.4	11.59	1.16	0.5	4.3	15.4
Tet 18	0.89	0.8	62.0	162	11.8	7.4	0.69	195.0	108.0	3.09	7.13	4045	543	126	16.1	7.56	0.76	1.5	1.8	3.1
Tet 19	0.87	0.7	68.2	204	11.5	7.3	0.64	169.2	125.7	2.87	6.45	4311	635	205	14.7	7.41	0.74	0.8	1.3	2.5
Tet 20	0.91	0.8	80.8	191	11.7	7.3	0.82	171.7	141.9	2.99	6.53	4245	602	182	15.2	7.77	0.78	0.9	1.2	2.1

REPORTED FROM THE LAB DATA SET

Sample Name	Bray P (ppm)	Olsen P (ppm)	NH4OAc-K (ppm)	LOI OM (%)	Water pH	Hot Water 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
Tetonka 1	5	4	31	0.3	7.6	0.208	24.726	22.996	0.434	0.464	1820	62.94	55	3.3	12.21	12.17	12.27
Tet 2	5	4	28	0.3	7.8	0.206	36.627	26.086	0.424	0.452	1708	75.94	49	1.8	12.24	12.31	12.33
Tet 3	3	6	34	0.8	7.7	0.195	62.196	31.322	0.650	0.668	2670	105.78	81	4.9	11.60	11.55	11.49
Tet 4	6	3	22	0.3	7.6	0.203	51.042	15.781	0.594	0.714	1780	92.46	115	2.6	12.23	12.21	12.24
Tet 5	1	9	27	1.6	7.6	0.339	47.016	43.529	1.599	1.073	3029	156.31	94	6.1	10.23	10.37	10.54
Tet 6	1	4	44	1.2	7.8	0.252	27.433	36.555	0.546	0.778	3093	147.73	38	5.6	9.87	9.66	9.78
Tet 7	1	81	33	10.8	7.4	1.203	289.72	122.54	4.334	8.846	5264	722.16	204.5	20.9	7.80	7.69	7.64
Tet 8	3	10	40	0.8	7.5	0.311	86.570	28.440	1.524	1.575	2667	140.36	171	9.2	11.91	11.74	11.94
Tet 9	1	4	59.5	2.2	7.8	0.284	36.048	27.943	1.215	1.412	3276	199.10	42	5.7	8.50	8.27	8.41
Tet 10	9	3	19	0.2	8.0	0.165	22.596	14.849	0.241	0.305	1184	68.83	25	1.0	12.20	12.22	12.16
Tet 11	5	3	18	0.3	7.8	0.210	21.806	18.059	0.623	0.964	2309	97.42	74	2.3	11.99	12.07	12.23
Tet 12	2	3	137	0.9	7.9	0.265	35.204	26.871	0.570	1.415	3457	282.47	48	7.3	11.60	11.65	11.63
Tet 13	2	4	110	0.5	7.6	0.222	60.184	36.470	0.732	1.934	2663	182.26	63	5.9	12.45	12.63	12.65
Tet 14	7	4	18	0.3	7.7	0.211	32.925	13.205	1.667	0.677	2030	84.16	59	2.9	12.97	12.93	13.07
Tet 15	6	8	19	0.5	7.6	0.187	25.550	26.994	0.750	0.808	2256	84.72	81	2.7	12.17	12.33	12.36
Tet 16	2	8	27	0.4	7.6	0.151	60.083	30.983	0.781	0.648	2476	114.97	92	5.7	11.76	11.97	12.01
Tet 17	1	4	23	0.7	7.5	0.227	61.476	14.357	0.503	0.618	3277	132.88	129	2.9	11.58	11.55	11.64
Tet 18	1	82	215	11.8	7.4	0.907	257.99	142.93	4.091	9.429	5353	718.58	167	21.3	7.55	7.53	7.59
Tet 19	1	92	275	11.5	7.3	0.860	228.36	169.61	3.871	8.703	5818	856.37	277	19.9	7.32	7.38	7.53
Tet 20	1	104	246	11.7	7.3	1.062	221.09	182.71	3.855	8.413	5465	774.88	234	19.6	7.68	7.87	7.75

APPENDIX C

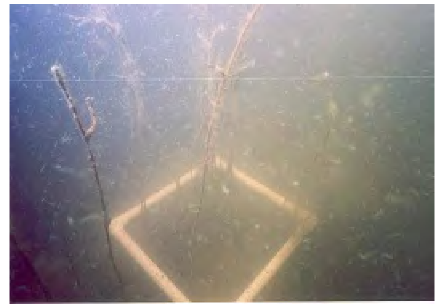
Curlyleaf Pondweed Growth Characteristics
(source: Steve McComas, Blue Water Science, unpublished)

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.

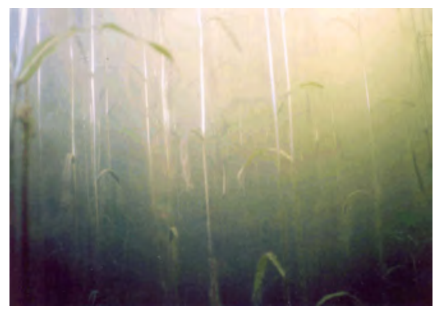
Moderate Growth Conditions

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.

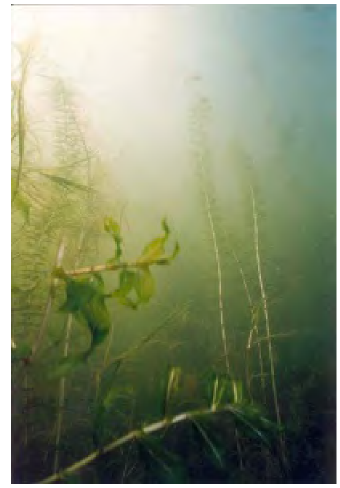
Stem density: 400+ stems/m^2
Biomass: >300 g-dry wt/m^2
Estimated TP loading: >6.7 lbs/ac

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.