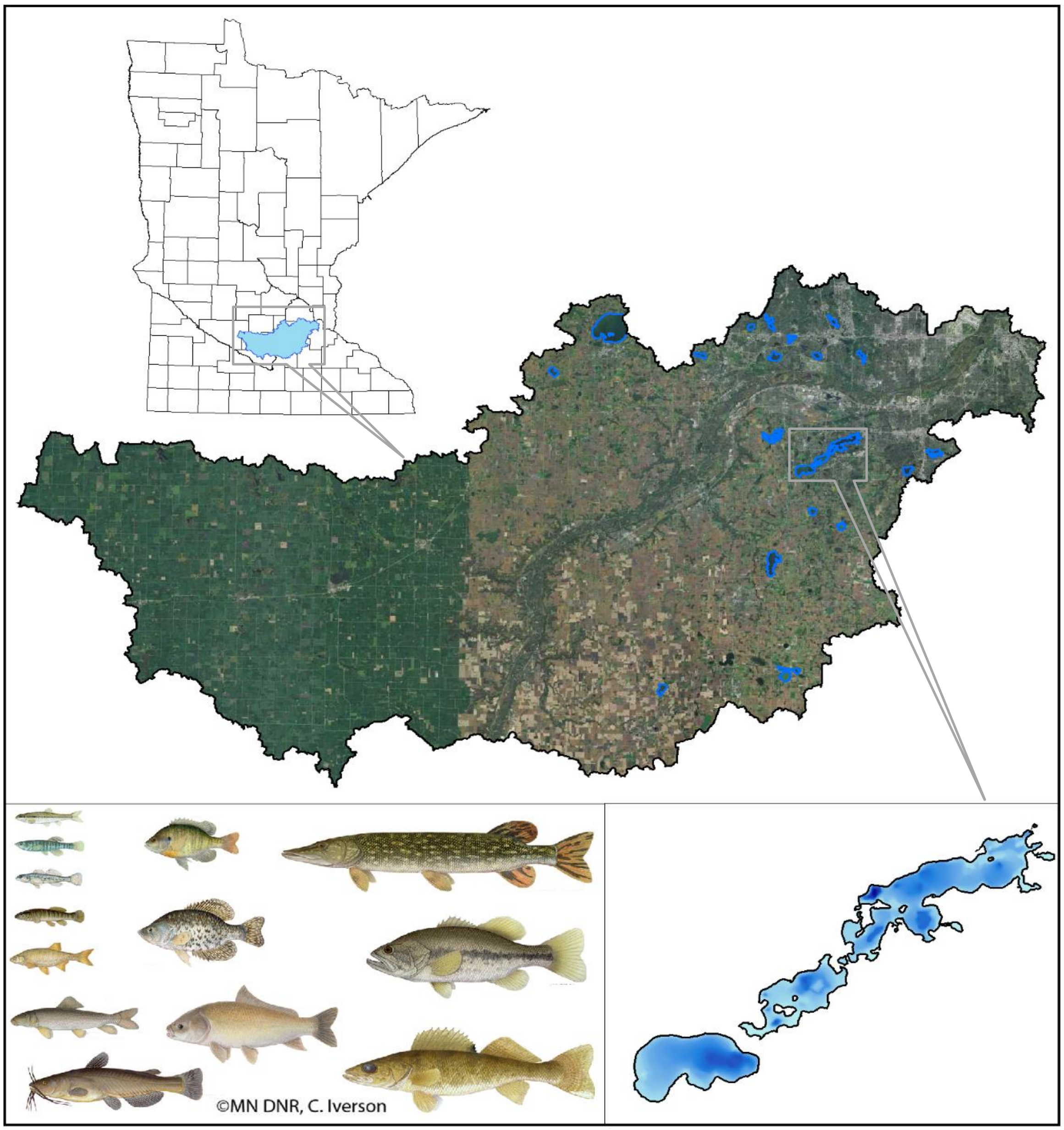
Lower Minnesota River Watershed Lakes Stressor Identification Report

A study of local stressors limiting the biotic communities in lakes in the Lower Minnesota River Watershed.



DEPARTMENT OF NATURAL RESOURCES

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Key Terms & Abbreviations

APM	Aquatic Plant Management
DOW	Division of Waters
FIBI	Fish-based Index of Biological Integrity
IBI	Index of Biological Integrity
LMRW	Lower Minnesota River Watershed
MDA	Minnesota Department of Agriculture
MnDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
STS	Score the Shore

Executive Summary

In recent years, the Minnesota Pollution Control Agency (MPCA) has incorporated the use of biological monitoring and assessment as a means to determine and report the condition of the state's surface waters. The Minnesota Department of Natural Resources (MnDNR) has developed tools to assess the condition of a broad range of game fish lakes in coordination with the MPCA watershed assessment framework. The basic approach is to collect data from fish communities and related habitats at multiple lakes throughout a major watershed. From these data, an Index of Biological Integrity (IBI) score can be developed, which provides a measure of overall community health. If biological impairments are found, stressors to the aquatic community must be identified.

Stressor identification is the process of identifying the major factors causing the biological impairment of the aquatic ecosystem. It is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act.

The Lower Minnesota River Watershed (LMRW) covers an area of 1,760 square miles and includes Sibley and Scott counties, and portions of Le Sueur, Carver, Hennepin, Dakota, Rice, Nicollet, Renville and McLeod counties. There are several local government units, watershed districts, and other watershed management organizations that share the responsibility for maintaining healthy aquatic communities.

This report summarizes stressor identification work for biological impairments to lake fish communities in the LMRW. It provides a summary of possible stressors to lake fish communities. In addition, the report identifies the stressors most likely responsible for the impairments in the watershed and evaluates the available information for each lake. Information from this document can be used by local planning organizations to help establish goals for protection and prioritize restoration efforts.

After examining many candidate causes for the biological impairments, the following stressors were identified as probable causes of stress to aquatic life:

- Excess Nutrients
- Non-Native Aquatic Species
- Riparian Lakeshore Development

1. FIBI Summary

The current suite of Fish-based IBI (FIBI) tools was developed by MnDNR to assess aquatic life use in a broad range of gamefish lakes in Minnesota. (For more information go to: Minnesota DNR Lake IBI webpage). Each tool uses multiple metrics known to be correlated to stressors of the fish community and tool selection is based on the physical characteristics of the lake to be assessed (Table 1.1). All metrics for each tool are calculated and combined together to produce a single composite FIBI score for a lake. These scores are compared against an impairment threshold established for each of the four current FIBI tools to come to an assessment decision.

Table 1.1 Summary of lake characteristics and metrics for current FIBI tools.

Lake Characteristics	Tool 2	Tool 4	Tool 5	Tool 7
Generally deep (many areas greater than 15' deep)	X	X		
Generally shallow (most areas less than 15' deep)			X	X
Well vegetated (aquatic plants occur in many areas)		X	X	
Generally with complex shape (with bays, points, islands)	X			
Simple shape (generally round)		X	X	
Species Richness Metrics	**Tool 2**	**Tool 4**	**Tool 5**	**Tool 7**
Number of native species captured in all gear	X			
Number of intolerant species captured in all gear	X	X	X	
Number of tolerant species captured in all gear	X	X	X	X
Number of insectivore species captured in all gear	X			X
Number of omnivore species captured in all gear	X	X	X	
Number of cyprinid species captured in all gear	X			
Number of small benthic dwelling species captured in all gear	X	X		X
Number of vegetative dwelling species captured in all gear	X	X		X
Community Composition Metrics	**Tool 2**	**Tool 4**	**Tool 5**	**Tool 7**
Relative abundance of intolerant species in nearshore sampling	X		X	
Relative abundance of small benthic dwelling species in nearshore sampling	X	X		
Relative abundance of vegetative dwelling species in nearshore sampling				X
Proportion of biomass in trap nets from insectivore species	X	X	X	X
Proportion of biomass in trap nets from omnivore species	X	X	X	
Proportion of biomass in trap nets from tolerant species	X	X	X	X
Proportion of biomass in gill nets from top carnivore species	X	X	X	X
Presence/Absence of Intolerant species captured in gill nets	X	X		
Total number of metrics used to calculate FIBI	15	11	8	8
Number of Lakes Assessed in the LMRW	8	3	2	6

Data from surveys of the gamefish community and the nearshore fish community are combined to provide information used to calculate an FIBI score. Lakes were limited to those greater than 100 acres and sampled by MnDNR Fisheries using standard sampling protocols for gamefish and nearshore fish communities. Fish community data was available for 19 lakes that met these criteria in the Lower Minnesota River Watershed (LMRW) to assess aquatic life use with FIBI tools (Figure 1.1). A review of data determined six lakes fully supported the expected fish community while eight lakes had impaired fish communities based on the FIBI tool used, and insufficient information existed to assess aquatic life use on five lakes due to issues with sampling effort or uncertainty regarding tool selection. Fish data was collected on four additional lakes; however, the current FIBI tools were not appropriate to assess these lakes due to the impact of regular winterkill events on the fish community.

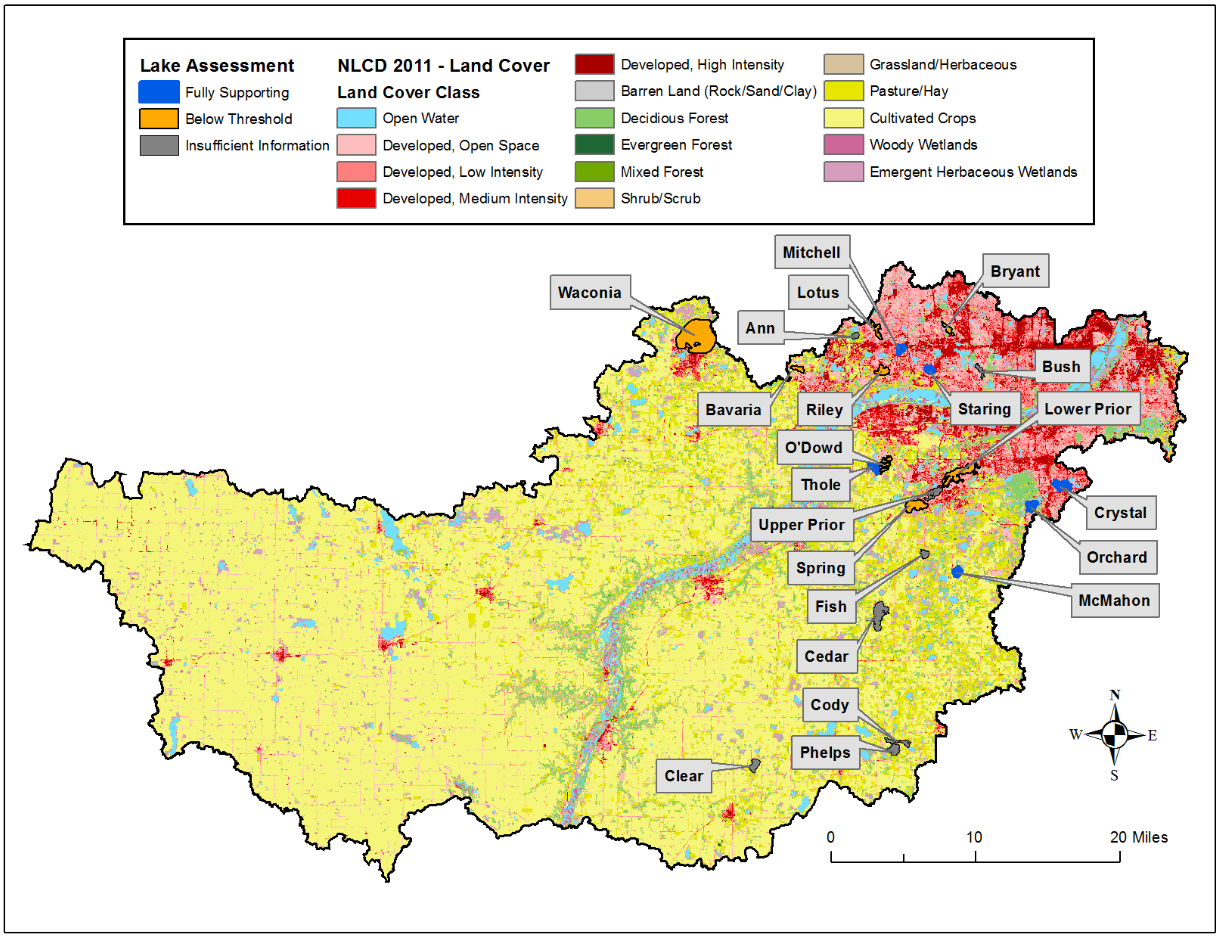

Figure 1.1 Summary of lakes within the LMRW with aquatic life use assessments using the FIBI.

2. FIBI Assessments

FIBI Tool 2 is used to assess lakes that are generally deep, have complex shorelines, and high species diversity. It was used to assess aquatic life use on eight lakes, none of which were found to fully support the expected fish community (Table 2.1). Insufficient information was available to assess Lake Ann due to sampling difficulties and the remaining seven lakes were all found to be impaired for aquatic life use based on the FIBI. The scores for Bryant Lake calculated from surveys conducted in 2012 (42) and 2016 (43) were below the impairment threshold but within the 90% confidence interval (36-54) of the threshold of FIBI Tool 2. All other lakes assessed with this tool had scores that were well below the established impairment threshold (Table 2.1). Low species richness had the greatest impact on the scores assessed with this tool, as these lakes are expected to have more diversity because they are generally larger and have more complex shoreline habitat than lakes assessed with other tools.

FIBI Tool 4 is used to assess lakes that are generally deep and round, are well vegetated, and have moderate species diversity. It was used to assess aquatic life use on three lakes, although assessment decisions were not made on two lakes because of insufficient information. Bush Lake was not assessed because of sampling difficulty and Fish Lake was not assessed because of uncertainty regarding appropriate tool selection (Table 1.2). The score for Orchard Lake calculated from a survey conducted in 2015 (46) was above the impairment threshold (38) and equal to the upper limit of the 90% confidence interval (30-46) for FIBI Tool 4. Species diversity was generally lower than expected but community composition was favorable. A high proportion of insectivores (mainly Bluegill) caught in trap nets and high proportion of top predators (mainly Northern Pike) in gill nets were community composition metrics that contributed positive metric values.

FIBI Tool 5 is used to assess lakes that are generally shallow and round, well vegetated, and have low species diversity relative to lakes assessed with the other tools. It was used to assess aquatic life use on two lakes although insufficient information was available to make assessment decisions on Clear Lake due to uncertainty regarding appropriate tool selection (Table 2.1). The score for Crystal Lake calculated from a survey conducted in 2015 (41) was above the impairment threshold (24) and above the 90% confidence interval (9-39) for FIBI Tool 5. Metrics had a mix of positive and negative values but a high proportion of insectivores (mainly Bluegill) caught in trap nets contributed the greatest positive metric value to the score.

FIBI Tool 7 is used to assess lakes that are shallow, with most areas less than 15 feet deep. It was used to assess aquatic life use on six lakes although insufficient information was available to make an assessment decision on Upper Prior Lake due to multiple surveys that resulted in FIBI scores that suggest conflicting results. Assessments determined that four lakes fully supported the expected fish community and one lake was impaired for aquatic life use based on the FIBI. The scores for O'Dowd Lake calculated from two surveys conducted in 2013 (32 and 31) were below the impairment threshold (36) but within the 90% confidence interval (27-45) for FIBI Tool 7. Low diversity resulted in negative species richness metric values that contributed to the poor FIBI score. Bluegill were the most common species from trap net and nearshore sampling.

Table 2.1 **Summary of assessments for lakes in the LMRW using FIBI tools.**

DOW Number	Lake Name	FIBI Tool (Threshold)	FIBI Score(s)	Survey Year(s)	Assessment Decision
10000200	**Riley**	**2 (45)**	**13.2**	**2015**	**Non supporting (Impaired)**
10000600	**Lotus**	**2 (45)**	**28.6**	**2015**	**Non supporting (Impaired)**
10001200	*Ann*	*2 (45)*	*37.6*	*2015*	*Insufficient Information*
10001900	**Bavaria**	**2 (45)**	**14.8**	**2013**	**Non supporting (Impaired)**
10005900	**Waconia**	**2 (45)**	**12.8**	**2014**	**Non supporting (Impaired)**
27006700	**Bryant**	**2 (45)**	**41.7, 42.7**	**2012, 2016**	**Non supporting (Impaired)**
70002600	**Lower Prior**	**2 (45)**	**19.8,7.7**	**2012, 2015**	**Non supporting (Impaired)**
70005400	**Spring**	**2 (45)**	**7.8,20.1,24.3**	**2012, 2015 (2)**	**Non supporting (Impaired)**
19003100	Orchard	4 (38)	45.9	2015	Full Support - Vulnerable
27004700	*Bush*	*4 (38)*	*25.6, 20.3*	*2013, 2015*	*Insufficient Information*
70006900	*Fish*	*4 (38)*	*41.7*	*2014*	*Insufficient Information - Vulnerable*
19002700	Crystal	5 (24)	40.8	2015	Full Support - Vulnerable
40007900	*Clear*	*5 (24)*	*23.7*	*2013*	*Insufficient Information*
27007000	Mitchell	7 (36)	45	2015	Full Support
27007800	Staring	7 (36)	46.6	2015	Full Support
70005000	McMahon	7 (36)	44	2015	Full support
70007200	*Upper Prior*	*7 (36)*	*21.7, 37.9*	*2012, 2015*	*Insufficient Information - Vulnerable*
70009500	**O'Dowd**	**7 (36)**	**31.6, 30.8**	**2013 (2)**	**Non supporting (Impaired)**
70012001	Thole	7 (36)	38.8	2013	Full support

A review of available data from "Fishes of Minnesota Mapper" (MnDNR 2016) found 75 fish species recorded from within the LMRW overall and 42 species from the lakes assessed with the FIBI. Species recorded within the watershed from this data but absent from the lakes assessed with the current FIBI were predominantly riverine species. Lake fish species considered intolerant of disturbance with past records in the watershed included six species with vouchered specimens (Banded Killifish, Blackchin Shiner, Burbot, Iowa Darter, Logperch, and Pugnose Shiner) and three additional species that lack voucher specimens (Blacknose Shiner, Muskellunge, and Rock Bass). Data used to assess lakes with the FIBI included only three intolerant species (Banded Killifish, Iowa Darter, and Muskellunge) suggesting at least the potential that some intolerant species have been lost in lakes within the watershed.

It is important to understand the limitations of the available data, which includes information collected over a long time period, by many organizations using a variety of methods, and for different purposes. The completeness and accuracy of the available data cannot be confirmed with certainty to say that any species has been lost. Current sampling protocol for FIBI data is intended to collect a representative sample of the fish community and 90% or more of the warm-water species in the lake.

3. Possible Stressors to Fish Communities

Several human induced changes have been shown to impact the community of fish inhabiting a lake. (A comprehensive list of stressors that can potentially cause biological impairment can be found at the US EPA Causal Analysis/Diagnosis Decision Information System (CADDIS) website: Stressors that Can Potentially Cause Biological Impairment) A list of possible stressors was selected for consideration for the LMRW and includes:

- Gamefish Management
- Habitat Alteration
    - Aquatic Plant Removal
    - Riparian Lakeshore Development
    - Sedimentation/Change in Substrate
    - Water Level Management
- Non-Native Aquatic Species
- Toxic Chemicals
- Watershed Alteration
    - Excess Nutrients
    - Loss of Connectivity

3.1. Inconclusive Causes

3.1.1. Toxic Chemicals

A number of toxic chemicals exist that impact aquatic life and can enter the aquatic environment through a variety of pathways. Impacts to fish communities range from direct lethal effects on individuals, altered food web from impacts to forage organisms, and reduced fitness from chronic exposure.

Hazardous chemicals such as herbicides, pesticides, fertilizers, and petroleum-based products typically enter the aquatic environment as a result of an unintentional discharge or spill. A desktop review of Minnesota Department of Agriculture (MDA) incident reports indicated no agricultural chemical contamination in the quantity and proximity to any lake assessed to impact the fish communities present (MDA 2016). MDA also conducts sampling to monitor surface waters for pesticides. A summary of monitoring data from the 2012 National Lakes Assessment concluded that pesticide levels detected in Minnesota lakes were well below applicable water quality standards and reference values (MDA 2014). A review of publicly accessible Minnesota Pollution Control Agency (MPCA) data also indicated hazardous chemicals were uncommon near lakes in the LMRW (MPCA 2016a). The impact of chronic exposure to lower concentrations of these chemicals on the fish community and FIBI score is not well understood at this time. Based on the information presented, hazardous chemicals are an inconclusive candidate cause for the impairments in the LMRW. Direct application of chemicals to lakes for management purposes will be discussed in following sections.

Chloride is a naturally occurring chemical, which at high concentration, can be toxic to fish and aquatic plant life. MPCA has adopted a chronic standard for chloride to protect aquatic life use in lakes. Of the eleven lakes assessed with the current FIBI Tools that also had chloride data, none were found to exceed this standard. However, some other small lakes within the watershed have been listed as not supporting aquatic life based on chloride levels. A Chloride Management Plan has been drafted by MPCA and local partners to address these specific impairments as well as provide a plan for protecting lakes from future impairment to aquatic life from chloride (MPCA 2016b). Based on available information chloride is not a likely candidate cause for any of the impaired fish communities in the LMRW, but could not be ruled out.

Mercury is another naturally occurring chemical that can be toxic to fish and other aquatic life. Currently, mercury levels in fish tissue are used to assess lakes for aquatic consumption use. The LMRW has several lakes that have been identified as impaired based on mercury levels, including 17 of the 19 lakes assessed with the FIBI. MPCA and local partners have developed a statewide mercury reduction plan approved by EPA to address these impairments (MPCA 2007). Mercury concentrations that are toxic to fish and other aquatic organisms would need to far exceed the current aquatic consumption standards. The impact of chronic exposure to lower concentrations on the fish community and FIBI score is not well understood at this time. Based on the information presented, mercury is an inconclusive candidate cause for the impairments in the LMRW.

3.1.2. Sedimentation

Diverse quality habitats are required to sustain healthy, robust fish communities in lakes. Sedimentation can be caused by a variety of activities. Human development along lakeshores can result in significant changes to the sediment characteristics in a lake (Francis et al 2007). Destruction of nearshore aquatic vegetation and removal of woody material that helps to stabilize substrates can lead to resuspension and redistribution of sediments. Non-native Common Carp also contribute to the loss of aquatic vegetation by dislodging plants which leads to the resuspension of bottom sediments (Breukelaar et al 1994). A further discussion of the impacts of Common Carp to the fish community will follow in subsequent sections.

Minimal quantitative data were collected historically to document the condition of lake substrates in Minnesota, although some MnDNR Fisheries surveys do include a qualitative evaluation. MnDNR Fisheries researchers are currently investigating the spatial relationship between a variety of habitat measurements and their associated fish communities. Completion of this study is pending and may provide a more clear understanding of the importance of different habitats to the overall fish community living in a lake.

Although sedimentation may possibly be contributing to the impaired fish community in some lakes, there is a lack of high quality quantitative data and scientific research evaluating the relationship to the current FIBI tools. Therefore, sedimentation is considered an inconclusive candidate cause for the impairments in the LMRW.

3.1.3. Water Level Management

Historically managing water levels in lakes has been undertaken in response to perceived problems that humans have with the quantity of water within a lake basin at a given time. Lake outlet structures were often built with the goal of maintaining more consistent water levels through spring, summer, and fall. Little or no consideration was given to the impact of these water level manipulations on the quantity and quality of the aquatic habitat for fish.

However, research has shown that water level fluctuations are important for structuring aquatic habitats that benefit several organisms (White et al 2008). Most studies focus on the impact to aquatic plant communities while few studies evaluate the impact to fish communities directly (Leira and Cantonati 2008). Natural water level fluctuations promote more structurally diverse plant communities, which provide better fish habitat than lakes with regulated water levels (Wilcox and Meeker 1991). As well as providing physical habitat, aquatic plants perform secondary functions that benefit fish such as stabilizing lake sediments or harboring organisms used by fish as forage.

In addition to direct manipulation using control structures, the timing and amount of water entering the lake basin are affected by land use in the immediate and contributing watershed. Human activities such as draining wetlands and increasing impervious surface coverage impact how quickly lake levels rise after a rainfall and how high peak levels reach. Sophisticated and time-consuming modeling would be needed to quantify the impact of this change to the quality of the existing aquatic habitat. Also, limited research is available to suggest the appropriate range of lake level fluctuations for optimum fish habitat.

Minimal quantitative data is available describing fish habitat conditions prior to engaging in long-term water level management on lakes within the watershed. Therefore, water level management is not considered further as a candidate cause for impairments in the LMRW.

3.1.4. Aquatic Plant Removal

Healthy aquatic plant communities provide important benefits to fish communities including spawning habitat for some species, protection or refuge areas for juvenile fish, and foraging opportunities. Because aquatic plants growing in public waters in Minnesota are owned by the state, control activities are regulated by the MnDNR Fisheries, Aquatic Plant Management (APM) program.

APM program rules limit the amount of lake area that can be controlled based on the type of plant and control method in order to protect fish habitat and allow lakeshore owners reasonable access. Activities that have the potential to harm fish (e.g., herbicide applications) or important fish habitat (e.g., removal of emergent vegetation) require an APM permit. Other activities, such as the mechanical removal of some submerged or a small amount of floating-leaf vegetation by lakeshore property owners, are not likely to significantly alter fish habitat on a lakewide scale. Therefore, these activities do not require a permit but are covered under program rules. Current APM rules that limit total lakewide removal of vegetation are designed to prevent negative impacts to the fish community, but lower amounts of removal still constitute a loss of habitat (Valley et al 2004; Radomski and Goeman 2001).

In addition to regulated control activities, aquatic plants are sometimes destroyed through illegal activities, which can be difficult to detect as they occur. The cumulative impact of illegal activities is also difficult to quantify since incremental habitat loss can occur over a long period of time. High quality aquatic plant survey data, which would provide a baseline for comparison to quantify the amount of habitat loss, is often limited or completely absent. Lack of this type of data is a problem for statewide analysis although some organizations do have quantitative data in various formats.

Aquatic plant control activities are not likely a candidate cause for the impairments in the LMRW, but they could not be eliminated due to a lack of understanding of levels that negatively impact the fish community.

3.1.5. Loss of Connectivity

The ability of fish to move upstream and downstream is important to the natural population and community dynamics of some fish species. The impact of connectivity is more widely studied in flowing water systems although there has been increased interest in understanding the importance of connectedness to lake fish diversity. Aquatic connectivity can be an important factor in explaining some of the natural variability of species richness in some gamefish lakes (Tonn and Magnuson 1982), but other geologic and hydrologic variables best explain variation in species richness (Hrabik et al 2005).

Connectivity influences the number of species available to inhabit lakes and can impact the abundance of certain species (Bouvier et al 2009). Connectivity can also influence species diversity differently over different temporal scales. Connection to other surface waters may be important to determine the number of species available to inhabit a given lake, but once established these species should persist if the lake has enough appropriate habitat. Therefore, the loss of connectivity is not likely the mechanism for loss of species in lakes but may limit the potential for recolonization once a species is lost.

3.1.6. Gamefish Management

Gamefish management includes a wide range of activities such as protecting fish habitat, regulating harvest of species to improve quality, stocking fish to provide additional opportunities, removing fish to restructure the community, and many others. Some of these activities have potential to be a stressor to the fish community in a lake and be reflected in the FIBI score.

In Minnesota, regulating fish harvest is typically pursued to preserve or enhance the quality of predator fish populations such as Largemouth Bass, Northern Pike, or Walleye. It is generally regarded that regulations do not significantly impact biological integrity although no research has been completed in Minnesota to evaluate the impact of fish regulations on the FIBI score. Predator size may influence the relative abundance of different forage species in a lake but is not likely to result in a loss of species richness. Since the fish community inhabiting a lake is determined over a long time and by many forces, lake fish communities have a natural adaptive capacity or resilience.

Fish stocking is another common technique managers use to preserve or enhance opportunities for anglers. Historically, stocking may have added new predator species to lakes where otherwise not naturally present. Introduced predators can impact the community by replacing naturally occurring predators or by adding to total predator density. Therefore, stocking has more potential to impact the fish community and be reflected in the FIBI score for a lake than regulating harvest. Stocking predator fish into lakes that previously had none can dramatically alter the community. However, fish community structure is more strongly influenced by location and lake characteristics that define available habitat than by introduction of a predator species (Trumpickas et al 2011).

Specific case studies demonstrate the potential for negative consequences of fish stocking in the United States. Examples include the introduction of Lake Trout to the Greater Yellowstone Ecosystem or Northern Pike to river systems in California, which have changed these systems dramatically. In addition, current stocking practices typically involve ongoing effort at regular intervals to maintain the target species above naturally occurring levels. This higher predator density can impact the composition of the community but is not thought to impact the overall richness of species. Stocking often results in changes to the flow of nutrients and energy through the food web directly by competition and indirectly by impacting forage fish or zooplankton density and composition (Eby et al 2006).

Predator stocking remains a commonly used tool for fish managers in Minnesota. Limited research in the region has focused on the impact of predator stocking to other gamefish populations (Fayram et al 2005; Knapp et al 2008). Studies have shown a negative relationship between predator stocking and yellow perch abundance, an important forage fish in many Minnesota lakes (Anderson and Schupp 1986; Pierce et al 2006). Strong yellow perch year-classes are thought to buffer the impact of walleye predation on small-bodied fishes like minnows and darters (Forney 1974; Lyons 1987). Statewide analysis found a significant negative trend in yellow perch catches in Minnesota from 1970 to 2013 (Bethke and Staples 2015), which may result in small-bodied fish populations in lakes being less resilient to increased stress from human disturbance.

Current protocols for collecting data used to assess aquatic life use in lakes based on the FIBI were adopted in 2013, which make historic comparisons impossible. The goal of the protocols are to capture a representative sample of the fish community and not necessarily to sample every species in a lake. Availability of complete historic species lists is also limited and makes substantiating claims of loss of species in an individual lake difficult. The data used during this assessment will allow for comparison over time going forward.

While some gamefish management activities can result in significant changes to the fish community of a lake, there is an overall lack of conclusive evidence linking these changes to the FIBI score. Therefore, gamefish management activities are not considered further as a candidate cause for the impairments in the LMRW.

3.2. Candidate Causes

3.2.1. Candidate Cause: Excess Nutrients

The addition of excess nutrients, primarily phosphorus, is the cause of eutrophication in lakes and accounts for about a third of the impairment listings for lakes in Minnesota (Draft 2016 Inventory of All Impaired Waters). Research has shown that elevated phosphorus levels significantly affect fish community structure and function in Minnesota lakes (Schupp and Wilson 1993; Heiskary and Wilson 2008). Negative effects of eutrophication include shifts in phytoplankton and zooplankton composition, and decreases in water transparency that lead to changes in the fish community. MnDNR Fisheries research has found that individual FIBI metrics respond to stress differently but the overall FIBI score was most highly correlated with trophic state (Drake and Valley 2005). The current suite of FIBI tools were developed based on these relationships.

Several mechanisms exist by which eutrophication contributes to impaired fish communities. Excess nutrients impact plankton communities that make up the foundation of aquatic food webs. Increased primary production leads to more phytoplankton, reduced light penetration, and fewer rooted aquatic macrophytes. Loss of aquatic plants represents a physical alteration to available habitat, which can alter fish community composition over time. Reduced plant cover can impact the success of vegetation dwelling species from a variety of feeding guilds. Decreased light penetration can also reduce the efficiency of sight-feeding predators like Largemouth Bass and Northern Pike, which results in lower biomass of top carnivores in the community.

Increased phytoplankton can also lead to an unbalanced community with few large bodied zooplankton that are preferred food for forage fish and important to the diet of many young game fish. These conditions favor undesirable plankton eating fish species over predatory game fish, which alter the composition of the community over time. In turn, some fish like Common Carp increase internal loading of nutrients in shallow lakes through feeding behaviors. Impacts of non-native aquatic species will be discussed as a separate potential stressor.

Because of the potential impact of eutrophication to aquatic environments, MPCA has developed water quality standards to assess nutrient impairment for lakes using measurements of total phosphorus, chlorophyll-a, and transparency. Data for total phosphorus and either of the two response variables is needed to determine whether a lake meets the standard. Some of the lakes assessed as having impaired fish communities based on the FIBI also are listed as impaired for nutrients. This indicates that the ecological changes resulting from eutrophication are a likely stressor contributing to the impairment of aquatic life in some lakes in the LMRW. Available data will be evaluated later in this report.

3.2.2. Candidate Cause: Non-Native Aquatic Species

Fish communities may experience stress caused by direct competition from newly arrived organisms, or non-native species. A few examples of newly arrived organisms that directly compete with native fish species for resources are Rainbow Smelt and Alewife. These species have led to changes in the forage base of the Great Lakes including Lake Superior. More often, new species arrivals indirectly alter fish habitat and food web dynamics due to specific life history and behavioral processes.

Some non-native species have multiple mechanisms for impacting the aquatic environment. Common Carp, for example, compete with native fish species for resources and reduce aquatic plant habitat through their feeding behavior. Invertebrate species such as Spiny Waterflea, Zebra Mussels, and Faucet Snails are examples of non-native species that alter lake ecology by changing the food web that structures the fish community. Non-native aquatic plants may compete with native species, which can alter the aquatic plant community and change the character and quality of fish habitat.

Biotic and abiotic characteristics can also impact the extent to which a newly arrived species will ultimately impact each lake. Lake morphology may limit the potential impacts of certain species and favor others based on the amount of available resources in each lake. Regardless of abiotic factors, lakes that maintain high biological diversity are generally more resilient to changes caused by non-native species. Research continues to develop and improve techniques to quantify the impact of non-native species to aquatic ecosystem function. Because several non-native species are known to occur in lakes within the LMRW, their potential as a candidate stressor will be discussed later in this report.

3.2.3. Candidate Cause: Riparian Lakeshore Development

Residential development adjacent to lakes is known to negatively affect riparian habitat (Jennings et al 2003) and result in changes to fish community composition (Jennings 1999, Radomski and Goeman 2001). Human development of lakeshores results in removal of riparian vegetation for lawns and views, addition of sand blankets for swimming beaches or rip-rap for erosion control, and destruction of aquatic vegetation and placement of docks for recreation. An analysis of lakeshore development found that up to half of the shoreline and 14% of the littoral zone habitat may be lost in some Minnesota lakes with full build out based on current shoreland development standards (Radomski et al 2010).

Lakeshore development activities impact fish communities through a variety of indirect pathways and to different extents. For example, destruction of aquatic vegetation reduces available fish habitat that influences the reproduction, survival, and abundance of some species. Likewise, clearing riparian vegetation can increase sedimentation and nutrient inputs that impact the physical condition of nearshore habitat and alter ecological processes at the base of the food web. Clearing living or dead trees from the shoreline can also reduce habitat complexity, which is important for supporting a biologically diverse and resilient aquatic ecosystem.

Fish communities are influenced by the cumulative effects of modifications to several components of riparian habitat that occur incrementally over many years, therefore separating the impacts of individual components is difficult (Jennings 1999). In addition, a lag time exists between the loss of habitat and community response, which occurs over several generations of fish. Therefore, the status of the current fish community is a reflection of the impact of the collective activities that have resulted in the loss of riparian habitat over several decades.

Attempts to assess the extent of riparian habitat loss have ranged from direct measurement of physical conditions to indirect indices that quantify human structures associated with alteration of habitat. Direct measurements of physical habitat are expensive, require large amounts of time, and have lacked professionally accepted standard protocols. To address some of these limitations, MnDNR Ecological and Water Resources (EWR) developed “Score the Shore” (STS) survey protocols (Perleberg et al 2015) in 2013 to assess riparian lake habitat. These protocols have subsequently been adopted for use by MnDNR Fisheries beginning with the 2015 field season. A review of surveys completed on lakes within the LMRW indicate that the condition of riparian habitat may be a stressor to the fish community. Similarly, an inventory of residential docks has been used as a surrogate to measure the impact of human development to riparian areas (Radomski et al 2010). Riparian lakeshore development on some of the lakes within the LMRW is above levels generally believed to indicate that loss of riparian habitat is a stressor to the fish community. Based on available data, the alteration of fish habitat caused by riparian lakeshore development may be contributing to the impairment of aquatic life in lakes in the LMRW and will be discussed further.

4. Evaluation of Candidate Causes

Excess nutrients, non-native aquatic species, and riparian lakeshore development have been identified as likely stressors to aquatic life use in LMRW lakes and will be evaluated further. A description of available data and current understanding of levels that impact the fish communities will be discussed for each candidate.

4.1. Excess Nutrients

MPCA has developed water quality standards to assess nutrient impairment for lakes using measurements of total phosphorus, chlorophyll-a, and transparency. Data for total phosphorus and at least one other variable is needed to determine whether a lake meets the standard. Assessments are based on mean values collected from the lake surface during summer months (June to September). A summary of nutrient impairments for lakes in the LMRW are presented in Table 4.1.

Lakes assessed as not supporting for aquatic life use based on the FIBI and not supporting for aquatic recreation due to excess nutrients were Lotus, Riley, and Spring. The likelihood that impacts of excess nutrients are a stressor to the aquatic life in these lakes is “High” based on these standards (Table 4.1). Conversely, Bavaria and Lower Prior lakes, which were assessed as not supporting for aquatic life use based on the FIBI but fully supporting for aquatic recreation based on water quality standards, are considered to have a “Low” likelihood that impacts from excess nutrients are a stressor to the fish community (Table 4.1).

Bryant Lake was previously assessed as not supporting aquatic recreation use based on nutrient criteria but is currently being considered for delisting after implementation of extensive restoration efforts. However, there is a lag time between the reduction of nutrients and recovery of fish communities due to the multiple mechanisms that caused the stresses described in the previous section. Excess nutrients were likely a stressor that structured the fish community in the past but current nutrient levels are associated with lakes that fully support aquatic life use based on the FIBI. However, because fish populations can take generations to recover after restoration there is still a “Moderate” likelihood that excess nutrients are a stressor to the fish community in Bryant Lake (Table 4.1).

Similar potential for stress caused by excess nutrients can also be seen with O’Dowd Lake. A 2007 assessment using the standards for deep lakes within the North Central Hardwood Forest ecoregion found the lake to be impaired due to excess nutrients. Further evaluation by MPCA and local partners determined the shallow lake standard for the ecoregion is more appropriate for O’Dowd Lake. During the current assessment, only one of the criteria used to evaluate the lake with this standard is exceeded. The remaining criteria show a trend of improving conditions since the last assessment suggesting some reduction in nutrients, possibly a result of local water planning activities. Based on this information there is a “Moderate” likelihood that excess nutrients are a stressor to the fish community in O’Dowd Lake (Table 4.1).

Table 4.1 Summary of eutrophication information and likelihood that excess nutrients are a stressor to the fish community.

DOW Number	Lake Name	FIBI Aquatic Life Use Assessment	Aquatic Recreation Assessment	Total Phosphorus Standard	Chlorophyll-a Standard	Transparency Standard	Fish Community Stressor Likelihood
10000200	Riley	NS	NS	EX	EX	MTS	**High**
10000600	Lotus	NS	NS	EX	EX	MTS	**High**
10001900	Bavaria	NS	FS	MTS	MTS	MTS	Low
10005900	Waconia	NS	IF	IF	EX	MTS	*Moderate*
27006700	Bryant	NS	NS(DL)	MTS	EX	MTS	*Moderate*
70002600	Lower Prior	NS	FS	MTS	MTS	MTS	Low
70005400	Spring	NS	NS	EX	EX	EX	**High**
70009500	O'Dowd	NS	IF	MTS	EX	MTS	*Moderate*

NS = Not Supporting, FS = Full Support, IF = Insufficient Information, EX = exceeds standard parameter threshold, NS(DL) = previously impaired but delisting requested, MTS = meets standard parameter threshold, **High** = likely stressor; nutrient impaired with not supporting aquatic life use assessment, Moderate = possible stress from excess nutrients; previously listed as nutrient impaired or insufficient assessment information, Low = no nutrient impairment or no impaired fish community

4.2. Non-Native Aquatic Species

A number of non-native species that may compete with native species or alter fish habitat are known to occur in lakes assessed as impaired for aquatic life use based on the FIBI in the LMRW with initial colonization documented at various times in the past (Table 4.2).

Curlyleaf Pondweed, Eurasian Watermilfoil, and Purple Loosestrife may displace native vegetation, reduce habitat complexity, and alter nutrient cycling. Curlyleaf Pondweed was first observed in Minnesota in about 1910 and is currently known to be in about 750 lakes statewide. Eurasian Watermilfoil was first discovered in Minnesota in 1987 and currently occurs in 342 waterbodies. In some instances, these species provide fish habitat where little would naturally occur due to poor water clarity. Destruction of native plant beds creates a disturbance that allows opportunities for non-native species to colonize lakes. The impact of both native and non-native plant species is unique to each lake based on physical characteristics such as lake depth, bottom substrates, and water clarity. The potential impact to the fish community includes indirect influence to the composition of other aquatic organisms or direct influence to the survival of certain fish species. Lakes with a variety of non-native aquatic plant densities were included in the FIBI too development, however because the impact of these species is very lake-specific there has been no attempt to evaluate their relationship to the FIBI independently. It is also difficult to determine if plant densities drive the change in habitat or are an indicator of a systemic problem such as excess nutrients. Based on this information non-native submerged aquatic plants alone are considered to have a “Low” likelihood as a stressor to the fish community although their impacts are additive with other stressors.

Common Carp and Zebra Mussels are examples of non-native aquatic animals that have been documented in several lakes in the LMRW. Common Carp stress fish communities directly by competing with native fish species for resources and indirectly by altering aquatic plant habitat, reducing water clarity, and increasing internal nutrient loading. They were intentionally introduced into the United States in the 1880’s from Europe and Asia as a game fish and are now established in 48 states. Common Carp alter the ecology of lakes more than any other non-native fish in the United States due to their wide distribution and impact to shallow lakes and wetlands. In Minnesota, they occur in hundreds of lakes in the southern two-thirds and only a few waters in the northern third of the state. The overall impact to the fish community is structured by the amount and quality of the littoral habitat. Lakes assessed with FIBI Tool 2 are generally deep with complex shoreline habitat and healthy aquatic plant communities that are less likely to be impacted by Common Carp compared to shallow round lakes with simple plant communities. Many lakes have had Common Carp present as part of the fish community for several decades, but their population has never reached a density that alter aquatic habitat significantly. Although these types of lakes may be important to some populations seasonally.

Lakes assessed with FIBI Tool 7 are the most likely to be impacted by Common Carp due to their aquatic plant communities and generally shallow depth. However, in lakes assessed as impaired for aquatic life use with FIBI Tool 7, Common Carp have never been sampled in O'Dowd Lake and have persisted at low levels in Lower Prior Lake. Based on this information the presence of Common Carp alone are considered to have a "Low" likelihood as a stressor to the fish community although their impacts are additive with other stressors.

Table 4.2 Summary of non-native aquatic species that may alter fish habitat found in lakes assessed as impaired for aquatic life use based on the FIBI within LMRW with a likelihood ranking as a potential stressor to the fish community.

Lake	Curlyleaf Pondweed	Eurasian Watermilfoil	Purple Loosestrife	Common Carp	Zebra Mussel	Stressor Likelihood Ranking
Bavaria	X	1989	1988	X		*Moderate*
Bryant	X	1991	1947	X	2015	*Moderate*
Lotus		1991	1987	X		*Moderate*
Lower Prior	X	1991	1987	X	2009	**High**
O'Dowd	X	2001				Low
Riley	X	1990		X		*Moderate*
Spring	X			X		Low
Waconia		1989	1987	X	2014	**High**

Zebra Mussels were first discovered in the Duluth harbor of Lake Superior in 1989 and began to appear in inland lakes in Minnesota in the early 2000's. They cause numerous recreational problems in addition to the environmental impact they have on ecosystem function. While the overall environmental impact to a particular system is not fully understood, Zebra Mussel populations do cause a change in energy cycling from the lowest trophic levels. As a result of their capacity to filter feed they can influence zooplankton community composition. Changes to the plankton community then result in cascading trophic interactions that can impact many organisms at different levels of the food web. Based on this information Zebra Mussels are considered to have a "Moderate" likelihood as a stressor to the fish community and their impacts are additive with other stressors.

4.3. Riparian Lakeshore Development

Several methods have been developed to quantify the status of riparian lakeshore habitat and to index the amount of human development in these areas. A count of dock structures has been used as an index for estimating the impacts from human development to riparian shoreland habitat (Radomski et al 2010). Dock placement is often associated with clearing of aquatic vegetation to facilitate recreational activities such as swimming and boating that lead to resuspension of sediments, loss of woody structure, and reduced habitat complexity. Ongoing research projects by MnDNR Fisheries suggest that 10 to 20 docks per kilometer of shoreline has been the consistent breakpoint where noticeable impacts to some fish species are observed.

Dock density can be obtained easily from aerial photography (Radomski et al 2010) and computer analysis can be applied to quantify docks in many lakes quickly (Beck et al 2013). The dock density index can also be used as a surrogate for the measurement of physical habitat such as the amount of tree cover near the lake, the amount of overhanging woody cover at the shoreline, or presence of emergent or floating-leaf vegetation.

STS survey protocols were developed by MnDNR EWR in 2013 as a rapid assessment of riparian lake habitat (Perleberg et al 2015) and adopted for use by MnDNR Fisheries beginning in 2015. Aquatic, upland (Shoreland), and transition zone (Shoreline) habitats are assessed using this technique. A lakewide score (ranging for 0 to 100) is determined as the sum of three habitat scores, which are equally weighted. STS surveys provide a lakewide lakeshore habitat score that can be used to monitor changes in a lake over time and to compare lakes within and between watersheds. As of the end of 2016, a total of 345 surveys completed statewide had an average lakewide score of 73.6.

Dock density and available STS scores for lakes assessed for aquatic life use with the FIBI within the LMRW are summarized in Table 4.3. Riparian lakeshore development is considered to have a high likelihood as a stressor to the fish community if dock density is greater than 20 docks per kilometer and a lakewide STS score below 60. “Moderate” likelihood is associated with lakes with between 10 and 20 docks per kilometer or a lakewide STS score below 75. Stress from riparian lakeshore development is considered “Low” for lakes with fewer than 10 docks per kilometer and a lakewide STS score greater than 75.

Table 4.3 Summary of riparian lakeshore development variables and likelihood as a stressor for lakes assessed for aquatic life use with the FIBI in the LMRW.

Lake Name	Aquatic Life Use Assessment Decision	Docks/km*	Lakewide STS Score	STS-Shoreland Zone	STS-Shoreline Zone	STS-Aquatic Zone	Stressor Likelihood Ranking
Riley	Impaired	*11.3*	*68*	21	21	26	*Moderate*
Lotus	Impaired	*11.6*	74	26	25	23	*Moderate*
Bavaria	Impaired	9.7	72	27	21	24	*Moderate*
Waconia	Impaired	*11.7*	72	22	23	27	*Moderate*
Crystal	Full Support	9.4	*63*	21	17	25	*Moderate*
Orchard	Full Support	9.9	*62*	21	17	24	*Moderate*
Bryant	Impaired	6.8	*63*	26	16	21	*Moderate*
Mitchell	Full Support	3.2	79	29	26	26	Low
Staring	Full Support	0	N/A				Low
Lower Prior	Impaired	28.2	46	14	9	22	**High**
McMahon	Full support	0.9	86	26	28	32	Low
Spring	Impaired	24.5	50	19	11	20	**High**
O'Dowd	Impaired	2.8	77	28	24	25	Low
Thole	Full support	1.0	N/A				Low
LMRW Lakes Average		**9.4**	**68**	**23**	**20**	**25**	
Statewide Average to Date (345 Lakes)		N/A	74	24	24	25	

* = Dock density from Beck et al 2013

5. Candidate Stressor by Lake

A summary of rankings of the likelihood for the three candidate stressors identified as potentially impacting the fish communities in lakes in the LMRW are given in Table 5.1. It is important to note that the rankings for each stressor are independent of each other and represent the relative likelihood that a particular stressor is impacting the fish community in a given lake.

Inconclusive stressors were also evaluated for the potential they are impacting the fish community. Although the level of disturbance required for inconclusive stressors to be significant is unclear, or data is lacking to quantify their status, it is important to acknowledge they may be contributing factors for some impairments.

Table 5.1 Summary of candidate stressors in the LMRW with.

		Stressor Likelihood Ranking		
DOW Number	**Lake Name**	**Excess Nutrients**	**Non-native Aquatic Species**	**Riparian Lakeshore Development**
10000200	Riley	**High** (1)	*Moderate* (3)	*Moderate* (2)
10000600	Lotus	**High** (1)	*Moderate* (3)	*Moderate* (2)
10001900	Bavaria	Low (3)	*Moderate* (2)	*Moderate* (1)
10005900	Waconia	*Moderate* (1)	*Moderate* (3)	*Moderate* (2)
27006700	Bryant	*Moderate* (1)	*Moderate* (3)	*Moderate* (2)
70002600	Lower Prior	Low (3)	**High** (2)	**High** (1)
70005400	Spring	**High** (1)	Low (3)	**High** (2)
70009500	O'Dowd	*Moderate* (1)	Low (3)	Low (2)

5.1. Riley (10-0002-00)

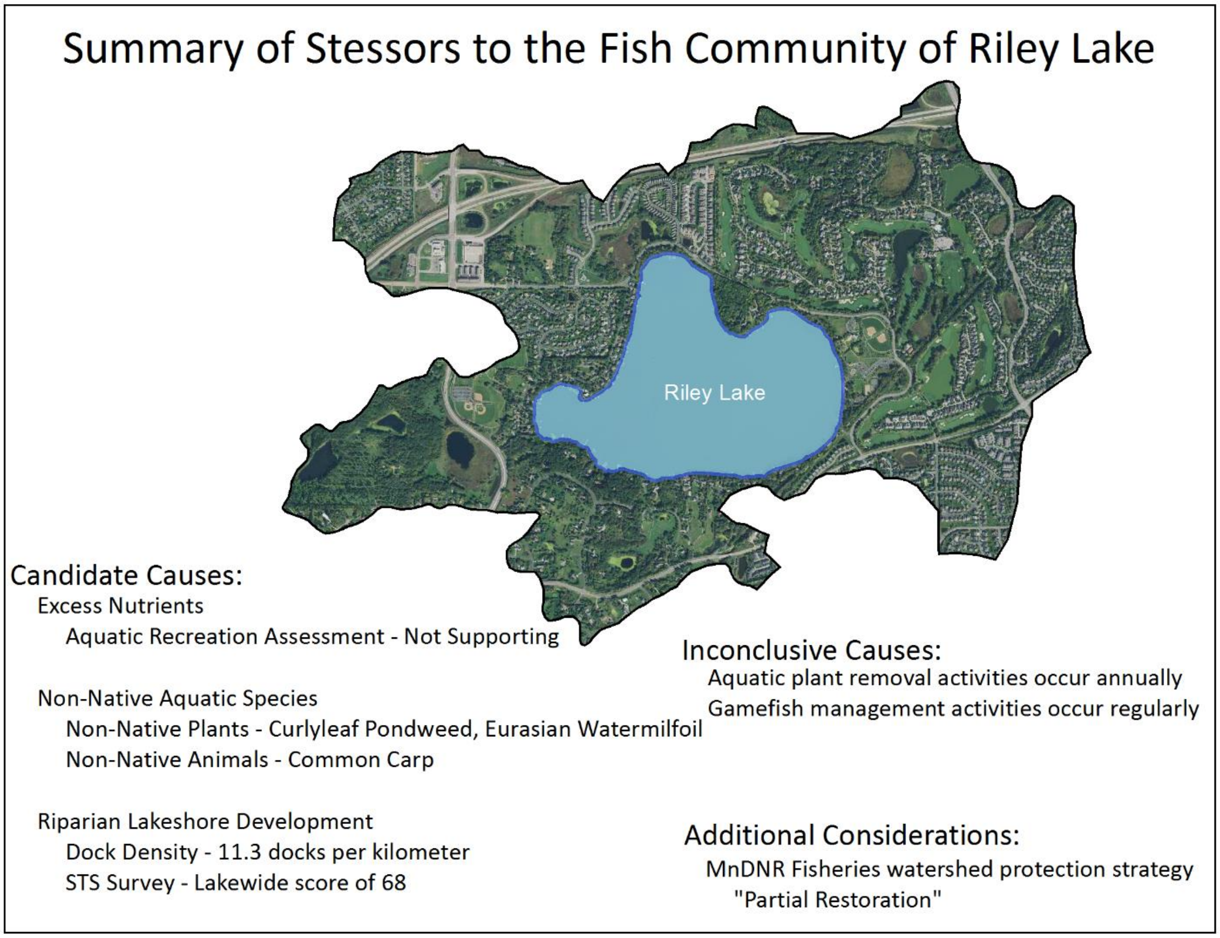

Figure 5.1.1 Summary of potential stressors to the fish community of Riley Lake.

A summary of stressors to the fish community of Riley Lake is presented in Figure 5.1.1. Excess nutrients was the stressor assigned the highest priority (Table 5.2). A 2007 assessment determined Riley Lake was impaired for aquatic recreation use due to excess nutrients based on water quality standards. As a result, substantial investments have been made to reduce nutrients entering the lake from a variety of sources. Future projects that expand or enhance these efforts will benefit human (aquatic recreation use) and the aquatic ecosystem (aquatic life use) health. It is important to note though that a full response of lake ecology may take decades after external nutrient loads are reduced (Schindler 2006).

Riparian lakeshore development was given the second priority because both of the variables measured had levels near those believed to cause stress to fish communities. Dock density was estimated to be 11.3 docks per kilometer of shoreline, which equals an average of one dock every 290 feet. A 2015 STS survey resulted in a lakewide score of 68 compared to the statewide average of 74. The shoreline component score, which assesses the land immediately above the waterline, was the furthest from the statewide average. Most survey sites (31 of 34) had some sign of human development, but undeveloped sites did have scores of 100 out of 100. Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted. Lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to restore the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Removal of woody habitat from the lake should be discouraged because natural woody structures add to the nearshore habitat complexity important to a variety of organisms including fish. Trees that provide habitat for wildlife while living can provide habitat in aquatic environments for a much greater period of time because submerged wood decomposes slowly. Removing dead trees from the water has the effect of reducing overall aquatic habitat in a lake for decades or longer.

Non-native aquatic species impacts were ranked third in likelihood as a candidate stressor. Common Carp, Curlyleaf Pondweed, and Eurasian Watermilfoil are found in Riley Lake and have been present for several decades. Each species competes directly with native species for resources and also impacts aquatic ecosystems through secondary mechanisms such as altering nutrient cycling when their populations reach high densities. There is limited statewide data available on non-native aquatic plant densities to evaluate the relationship to the current FIBI tools. Curlyleaf Pondweed and Eurasian Watermilfoil can reach densities that reduce native plant diversity in some areas of a lake. However, there is no known threshold level of density where aquatic invasive plants cause quantifiable impacts to fish communities that can be detected by the FIBI.

Recent research has suggested potential threshold levels where aquatic ecosystems are significantly impacted by Common Carp in Minnesota (Bajer et al 2016). These impacts are structured by lake specific factors such as size, depth, productivity, and connectivity. Effective restoration may require removal of Common Carp to reduce their abundance below threshold levels to improve water quality and increase the abundance of native fishes in some lakes (Weber and Brown 2011). Intensive management efforts to control Common Carp in Riley Lake and connected waters were initiated in 2009 and monitoring of results continues. Fisheries assessments dating back to 1954 indicate Common Carp densities have fluctuated some over time. Three assessments performed between 2005 and 2015 had Common Carp densities ranging from 0 to 0.11 fish per trap net while the three prior assessments between 1990 and 1999 ranged from 0.5 to 3.8 fish per trap net.

Aquatic plant removal and gamefish management activities may also be contributing to the impairment to aquatic life use based on the FIBI. Although the significance of these stressors is inconclusive at this time, both types of management activities occur regularly in Riley Lake. A review of APM permits found that permitted aquatic plant removal activities not targeting non-native aquatic plants have impacted an area ranging from 3-5% of the littoral area (about 3-6 acres) annually in recent years. Walleye fingerlings have been purchased by the lake association and stocked into the lake several times over the last decade. An evaluation of FIBI Tool 2 has shown no difference in overall FIBI score between non-stocked and stocked walleye lakes; stocking density was not correlated to FIBI score, it was correlated to the number of tolerant species (with a higher number of tolerant species sampled in non-stocked lakes) (Bacigalupi 2015, personal communication).

Based on available information, the three candidate stressors ranked by likelihood were excess nutrients, riparian lakeshore development, and non-native aquatic species. Efforts that focus on reducing these stressors are most likely to have a positive effect on the restoration of aquatic life use in this lake. If aquatic plant removal or gamefish management activities intensify in the future, managers should consider the possible negative impacts to the lake ecosystem prior to implementing additional activities. MnDNR Fisheries analysis (MnDNR 2013) has set a goal of "partial restoration" for the immediate watershed around Riley Lake. See "Recommendations" for additional information.

5.2. Lotus (10-0006-00)

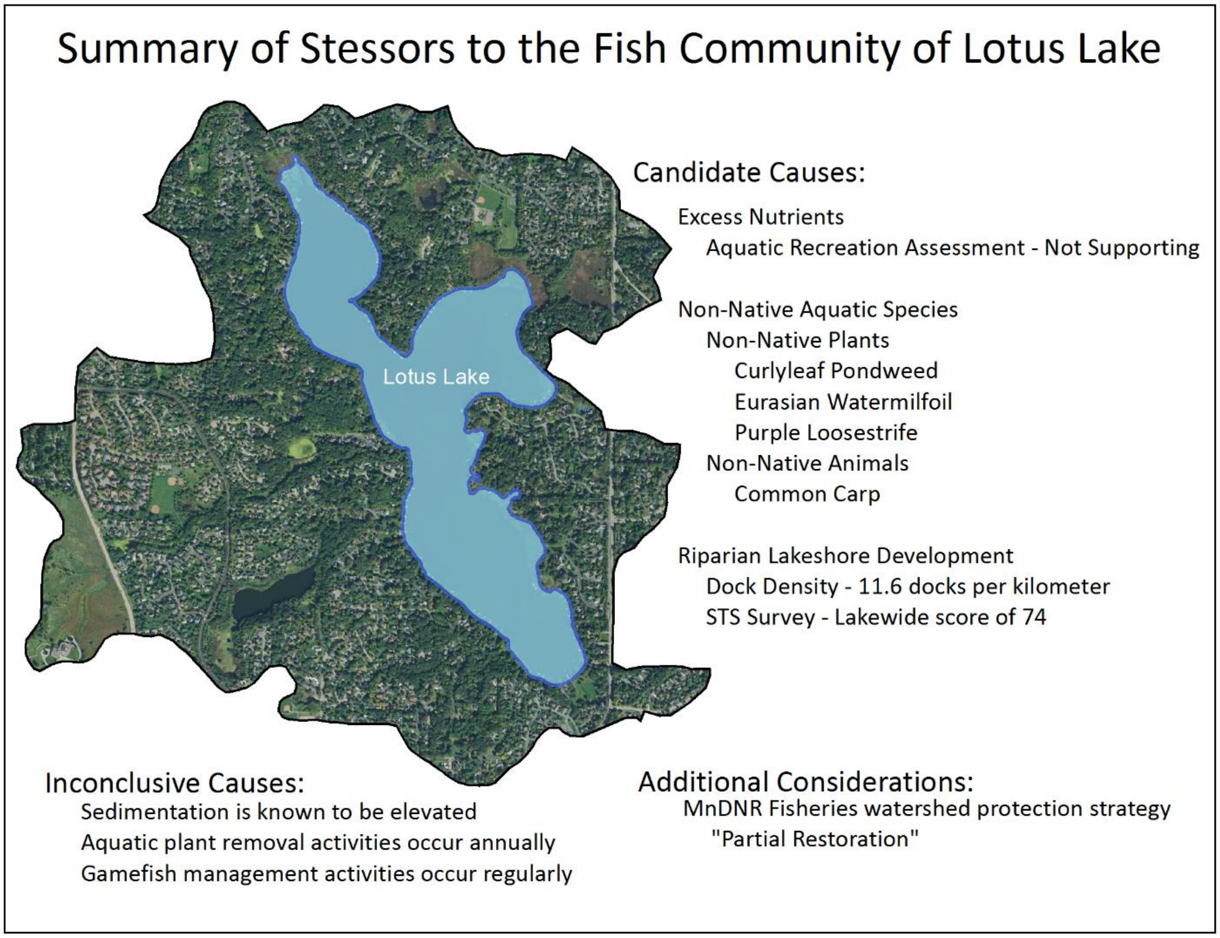

Figure 5.2.1 Summary of potential stressors to the fish community of Lotus Lake.

A summary of stressors to the fish community of Lotus Lake is presented in Figure 5.2.1. Excess nutrients was the stressor assigned the highest priority (Table 5.2). A 2007 assessment determined Lotus Lake was impaired for aquatic recreation use due to excess nutrients based on water quality standards. As a result, substantial investments have been made to reduce nutrients entering the lake from a variety of sources. Future projects that expand or enhance these efforts will benefit human (aquatic recreation use) and the aquatic ecosystem (aquatic life use) health. It is important to note though that a full response of lake ecology may take decades after external nutrient loads are reduced (Schindler 2006).

Riparian lakeshore development was given the second priority because both of the variables measured had levels near those believed to cause stress to fish communities. Dock density was estimated to be 11.6 docks per kilometer of shoreline, which equals an average of one dock every 283 feet. A 2015 STS survey resulted in a lakewide score of 74 compared to the statewide average of 74. Most survey sites (33 of 38) had some sign of human development, but undeveloped sites did have and average score of 93 out of 100. Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted. Lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to restore the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Removal of woody habitat from the lake should be discouraged because natural woody structures add to the nearshore habitat complexity important to a variety of organisms including fish. Trees that provide habitat for wildlife while living can provide habitat in aquatic environments for a much greater period of time because submerged wood decomposes slowly. Removing dead trees from the water has the effect of reducing overall aquatic habitat in a lake for decades or longer.

Non-native aquatic species impacts were assigned the third priority as a candidate stressor. Common Carp, Curlyleaf Pondweed, Eurasian Watermilfoil, and Purple Loosestrife are found in Lotus Lake and have been present for several decades. No management activities have occurred for any of these species which suggests that their densities have persisted a low levels. Therefore not likely a significant stressor to the fish community in the lake. Populations may be limited by the physical characteristics of the lake, which are generally not favorable for these species. Monitoring the status of these aquatic invasive species populations should continue to ensure their impacts to the lake are minimized. Brittle Naiad (Najas minor) was also confirmed in the lake while drafting this report in 2017. The impact of this species on the fish community is not well understood.

Sedimentation, aquatic plant removal, and gamefish management activities may also be contributing to the impairment to aquatic life use based on the FIBI. Although the significance of these stressors is inconclusive at this time, each possible stressor currently occurs in Lotus Lake regularly. An investigation of historic conditions found peaks in sedimentation occurred in 1966 and 1993 and current rates are slightly elevated compared to pre-European settlement (Ramstack and Edlund 2011). A review of APM permits found that approximately 11 acres (6% of the littoral area) of vegetation are controlled annually by individuals for access and recreation. Walleye have been stocked regularly at various rates and sizes since the 1960’s and currently fingerling stocking occurs in odd numbered years. An evaluation of FIBI Tool 2 has shown no difference in overall FIBI score between non-stocked and stocked walleye lakes; stocking density was not correlated to FIBI score, it was correlated to the number of tolerant species (with a higher number of tolerant species sampled in non-stocked lakes) (Bacigalupi 2015, personal communication).

Based on available information, the candidate stressors ranked by likelihood were excess nutrients, riparian lakeshore development, and non-native aquatic species. Efforts that focus on reducing excess nutrients and reducing the impact of riparian lakeshore development are most likely to have a positive effect on the restoration of aquatic life use in this lake. Projects that investigate how elevated sedimentation rates impact fish communities should be supported. Although ranked third in priority due to their abundance at this time, non-native aquatic species should continue to be monitored to limit their impact to the lake. If aquatic plant removal or gamefish management activities intensify in the future managers should consider the possible negative impacts to the lake ecosystem prior to implementing additional activities. MnDNR Fisheries analysis has set a goal of “partial restoration” for the immediate watershed around Lotus Lake. See “Recommendations” for additional information.

5.3. Bavaria (10-0019-00)

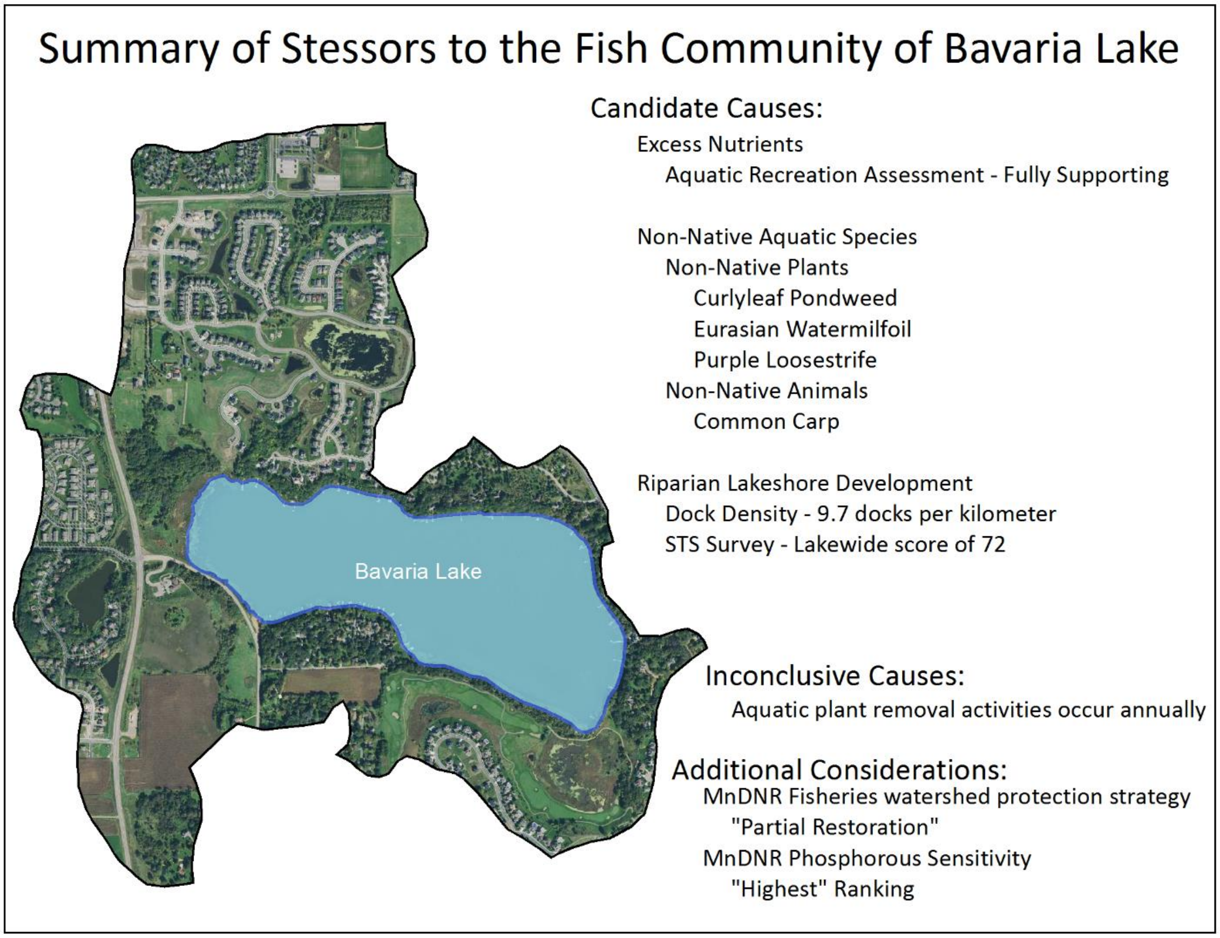

Figure 5.3.1 Summary of potential stressors to the fish community of Bavaria Lake.

A summary of stressors to the fish community of Bavaria Lake is presented in Figure 5.3.1 and summarized in Figure 5.3.1. Riparian lakeshore development was assigned the highest priority because both the number of residential docks (9.7 per km) and STS score (72) are near levels believed to impact aquatic ecosystems. The 2015 STS survey determined that developed sites (18 of 26) had an average score of 61 while undeveloped sites had an average score of 97 out of 100. Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted. Lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to restore the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Removal of woody habitat from the lake should be discouraged because natural woody structures add to the nearshore habitat complexity important to a variety of organisms including fish. Trees that provide habitat for wildlife while living can provide habitat in aquatic environments for a much greater period of time because submerged wood decomposes slowly. Removing dead trees from the water has the effect of reducing overall aquatic habitat in a lake for decades or longer.

Aquatic invasive species impacts were ranked as the second priority for candidate stressors. Common Carp, Curlyleaf Pondweed, Eurasian Watermilfoil, and Purple Loosestrife are found in and around Bavaria Lake and have been present for several decades. Aquatic invasive plants can reach densities that reduce native plant diversity in some areas of lakes. A small amount (2.7 to 3.5 acres) of Eurasian Watermilfoil has been treated with a selective herbicide annually in recent years to reduce nuisance conditions. However, there is no known threshold level of density where aquatic invasive plants cause quantifiable impacts to fish communities that can be detected by the FIBI. Recent research has suggested potential threshold levels where aquatic ecosystems are significantly impacted by Common Carp in Minnesota (Bajer et al 2016). These impacts are structured by lake specific factors such as size, depth, productivity, and connectivity. Fisheries assessments dating back to 1949 indicate Common Carp densities have remained low and below levels that alter lake ecology.

Excess nutrient impacts were ranked as the third priority for candidate stressors. Lake Bavaria is currently not listed as impaired for aquatic recreation use due to excess nutrients based on water quality standards. It is possible that nutrient levels are elevated but not to levels that cause an impairment to recreational use. The current assessment did note a possible trend of decreased water clarity as well as individual summer nutrient measurements that have exceed the standard. Watershed disturbance variables exceeded threshold levels that indicate excess nutrients are likely to enter lakes. Overall watershed disturbance was a mix of urban (41%) and agricultural (28%) development, which can each impact aquatic ecosystems uniquely. Best Management Practices (BMP) that reduce external nutrient loading into the lake should be promoted to ensure stress to the fish community is minimized.

Aquatic plant removal activities may also be contributing to the impairment to aquatic life use based on the FIBI. Although the likelihood as a stressor is inconclusive at this time, management activities occur annually in Lake Bavaria. Current statewide rules limit the amount of submerged vegetation treated with herbicides to 15% of the littoral area of a lake to limit the potential impact of control activities to fish habitat. A review of recent aquatic plant removal permits (2010-2016) found that control intended for individual access and recreation combined with control targeting non-native aquatic species approaches this limit annually.

Based on available information, the candidate stressors ranked by likelihood were riparian lakeshore development, non-native aquatic species, and excess nutrients. Efforts that focus on reducing the impact of these stressors are most likely to have a positive effect on the restoration of aquatic life use in Lake Bavaria. In addition, aquatic plant removal activities should receive additional scrutiny to reduce potential negative impacts to the lake ecosystem that are not well understood at this time. MnDNR Fisheries analysis has set a goal of “partial restoration” for the immediate watershed around Bavaria Lake. In addition, MnDNR modeling has placed the lake within the highest priority ranking for sensitivity to increased phosphorus loading (MnDNR 2015). See “Recommendations” for additional information.

5.4. Waconia (10-0059-00)

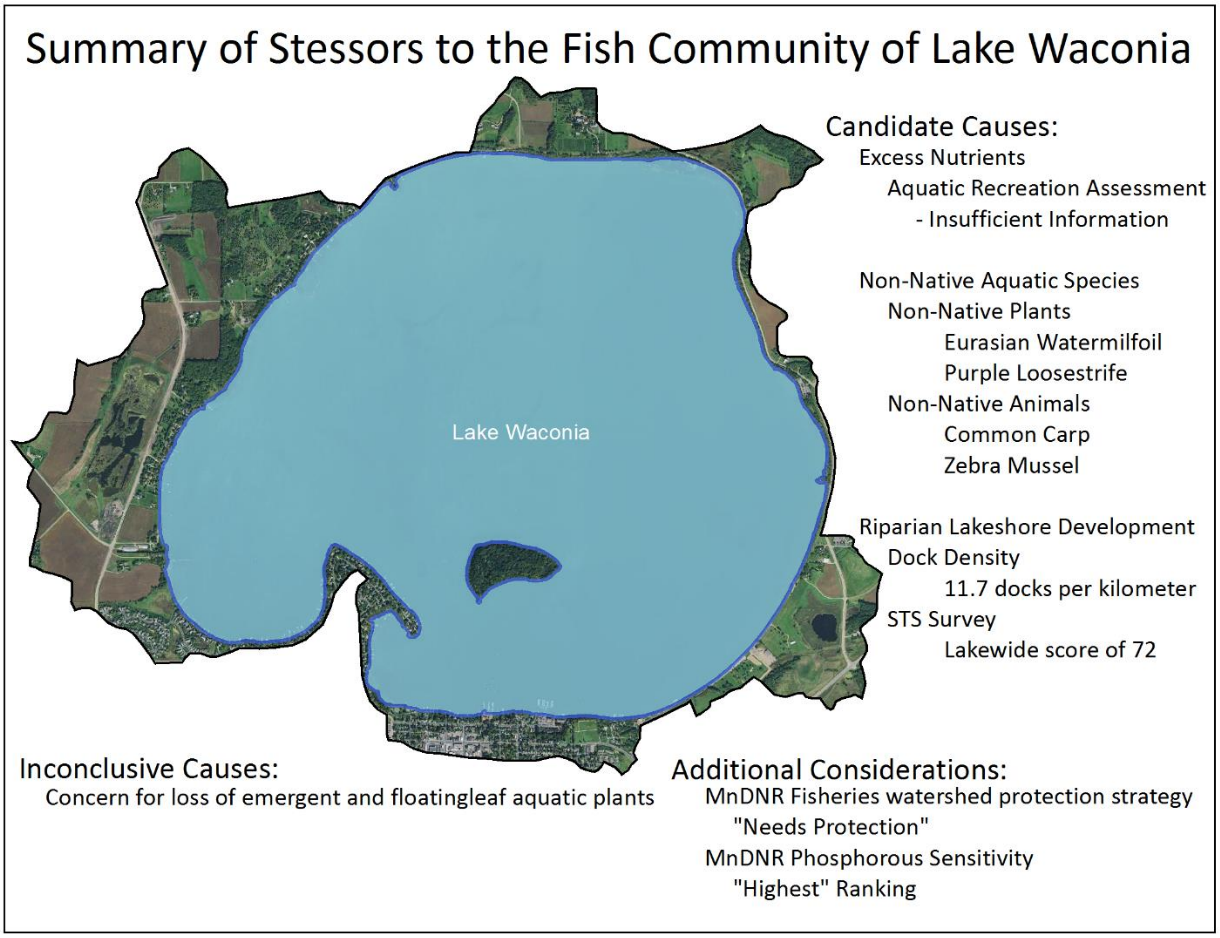

Figure 5.4.1 Summary of potential stressors to the fish community of Lake Waconia.

Each of the three candidate causes was assigned a moderate likelihood ranking as possible stressors to aquatic life use based on the FIBI in Lake Waconia (Table 5.1). A summary of stressors is presented in Figure 5.4.1. Excess nutrients was the stressor assigned the highest priority (Table 5.2). There was insufficient information to assess nutrient levels for aquatic recreation, although data did suggest an increase in nutrients in the lake over the last decade. BMPs to reduce nutrient loading into lakes should be promoted because these efforts will benefit human (aquatic recreation use) and aquatic ecosystem (aquatic life use) health. It is important to note though that a full response of lake ecology may take decades after external nutrient loads are reduced (Schindler 2006).

Riparian lakeshore development was given the second priority because both of the variables measured had levels near those believed to cause stress to fish communities. Dock density was estimated to be 11.7 docks per kilometer of shoreline, which equals an average of one dock every 280 feet. A 2015 STS survey resulted in a lakewide score of 72 compared to the statewide average of 74. Most survey sites (74 of 87) had some sign of human development, but undeveloped sites did have an average score of 99 out of 100. Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted. Lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to restore the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Removal of woody habitat from the lake should be discouraged because natural woody structures add to the nearshore habitat complexity important to a variety of organisms including fish. Trees that provide habitat for wildlife while living can provide habitat in aquatic environments for a much greater period of time because submerged wood decomposes slowly. Removing dead trees from the water has the effect of reducing overall aquatic habitat in a lake for decades or longer.

Non-native aquatic species impacts were ranked as the third priority for candidate stressors. Despite being assigned a high likelihood due to the number of species present, the overall impact of non-native aquatic species was prioritized lower than excess nutrients and riparian lakeshore development for Lake Waconia. Common Carp, Eurasian Watermilfoil, and Purple Loosestrife are found in the lake and have been present for several decades. No management activities have occurred for any of these species which suggests that their densities have persisted a low levels. Therefore not likely a significant stressor to the fish community in the lake. Populations may be limited by the physical characteristics of the lake, which are generally not favorable for these species. Zebra Mussels were discovered in the lake in 2014, the same year fish data was collected to use in the assessment. Because the ecological alterations caused by Zebra Mussels may take several years, the impact of Zebra Mussels was not likely expressed in fish data used to make the assessment decision. Monitoring the status of non-native aquatic species populations should continue to ensure their impacts to the lake are minimized.

Aquatic plant removal activities may also be contributing to the impairment to aquatic life use based on the FIBI. Although the significance of this stressor is inconclusive at this time, a small amount of control does occur annually. There is some concern that a loss of emergent and floating-leaf vegetation has occurred in the lake through non-permitted, illegal activities. These plant beds were mapped in 2015 to document the status of these important habitats and provide data to compare future monitoring efforts.

Based on available information, the candidate stressors ranked by likely significance were excess nutrients, riparian lakeshore development, and non-native aquatic species. Efforts that focus on reducing the impact of these stressors are most likely to have a positive effect on the restoration of aquatic life use in Lake Waconia. MnDNR Fisheries analysis has set a goal of “needs protection” for the immediate watershed around Lake Waconia. In addition, MnDNR modeling has placed the lake within the highest priority ranking for sensitivity to increased phosphorus loading. See “Recommendations” for additional information.

5.5. Bryant (27-0067-00)

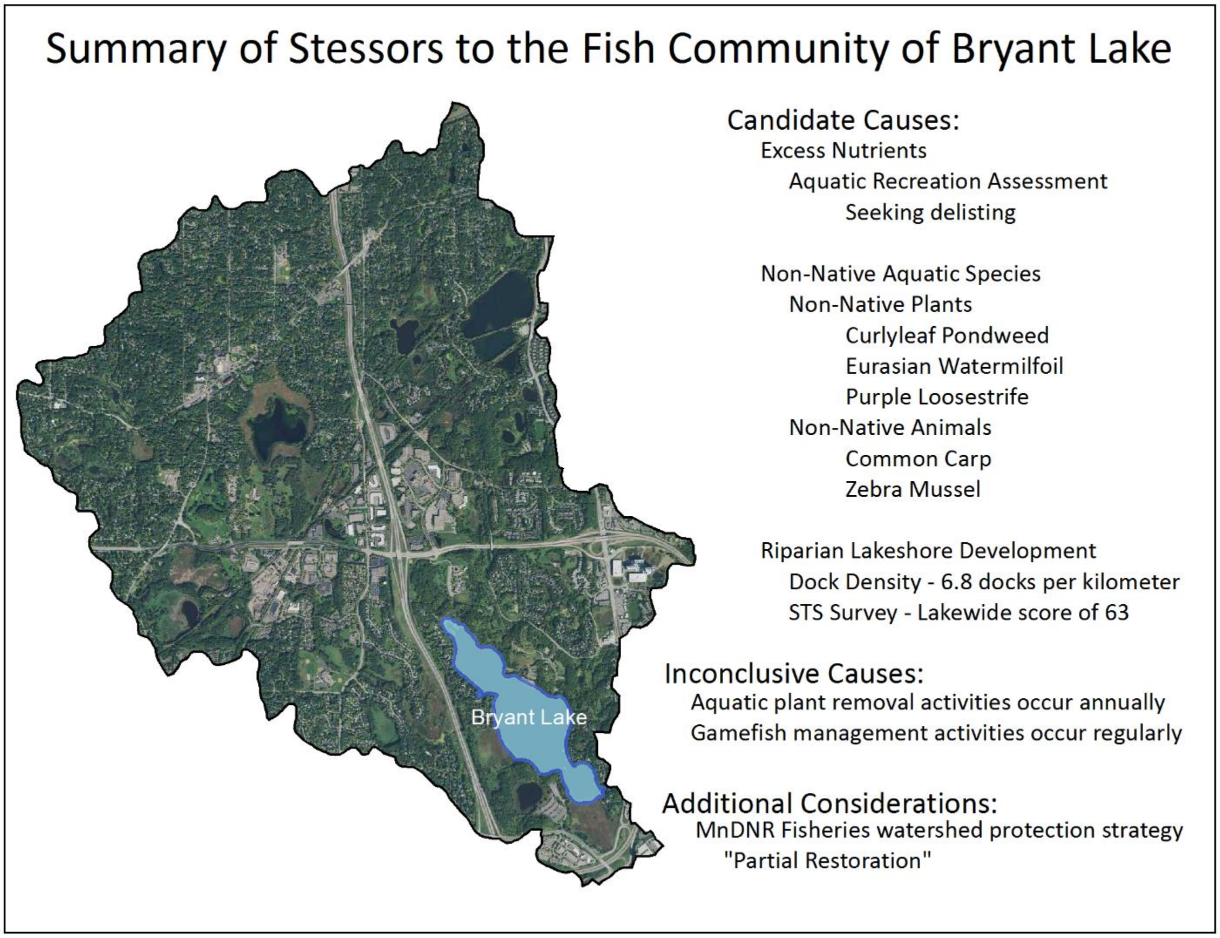

Figure 5.5.1 Summary of potential stressors to the fish community of Bryant Lake.

Available data indicates a moderate likelihood that non-native aquatic species, riparian lakeshore development, and excess nutrients are significant stressors impacting the fish community in Bryant Lake (Table 5.1). A summary of stressors are presented in Figure 5.5.1. Excess nutrient impacts were ranked first as a candidate stressor. A 2009 assessment determined Bryant Lake was impaired for aquatic recreation use due to excess nutrients based on water quality standards. As a result, substantial efforts have been made to reduce nutrients entering the lake and internal loading within the lake. Bryant Lake is currently proposed for delisting as impaired for aquatic recreation use due to excess nutrients based on water quality standards. It is important to note though that a full response of lake ecology may take decades after external nutrient loads are reduced (Schindler 2006). Future projects that expand or enhance these efforts will benefit human (aquatic recreation use) and aquatic ecosystem (aquatic life use) health.

Riparian lakeshore development was given the second priority. Although both of the variables measured had levels near those believed to cause stress to fish communities, approximately 25% of the lakeshore is in public ownership and these areas are not likely to experience additional deterioration of riparian habitat. Wide wetland fringes also help to protect approximately 15% of the lakeshore from stress caused by riparian development. Dock density was estimated to be 6.8 docks per kilometer of shoreline, which equals an average of one dock every 482 feet. A 2015 STS survey resulted in a lakewide score of

63 compared to the statewide average of 74. Developed sites (18 of 27) had an average score of 51 while undeveloped sites did had an average score of 86 out of 100. Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted. Lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to restore the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Removal of woody habitat from the lake should be discouraged because natural woody structures add to the nearshore habitat complexity important to a variety of organisms including fish. Trees that provide habitat for wildlife while living can provide habitat in aquatic environments for a much greater period of time because submerged wood decomposes slowly. Removing dead trees from the water has the effect of reducing overall aquatic habitat in a lake for decades or longer.

Impact from non-native aquatic species was the stressor assigned the third highest priority (Table 5.2) because of the number of non-native plant and animal species known to occur in the lake. Common Carp, Curlyleaf Pondweed, Eurasian Watermilfoil, and Purple Loosestrife are found in and around Bryant Lake and have been present for several decades. Zebra Mussels were discovered in 2015 and are not responsible for the impaired fish community that was sampled in 2012, but may exert additional stress on the system into the future. Monitoring the status of non-native aquatic species populations should continue to ensure their impacts to the lake are minimized.

Aquatic plant removal and gamefish management activities may also be contributing to the impairment to aquatic life use based on the FIBI. Although the significance of these stressors is inconclusive, at this time both types of management activities occur regularly in Bryant Lake. Permitted aquatic plant removal activities not targeting aquatic invasive plants have impacted about 6-9% of the littoral area (4-6 acres) annually in recent years. Walleye and tiger muskellunge fingerling have been stocked into the lake regularly over the last decade. An evaluation of FIBI Tool 2 has shown no difference in overall FIBI score between non-stocked and stocked walleye lakes; stocking density was not correlated to FIBI score, it was correlated to the number of tolerant species (with a higher number of tolerant species sampled in non-stocked lakes) (Bacigalupi 2015, personal communication). The impact of stocking multiple top predators into a lake on the FIBI has not been evaluated for the current tools.

Based on available information, the three candidate stressors ranked by likelihood were excess nutrients, riparian lakeshore development, and non-native aquatic species. Efforts that focus on reducing these stressors are most likely to have a positive effect on the restoration of aquatic life use in this lake. If aquatic plant removal or gamefish management activities intensify in the future managers should consider the possible negative impacts to the lake ecosystem prior to implementing additional activities. MnDNR Fisheries analysis has set a goal of “partial restoration” for the immediate watershed around Bryant Lake. See “Recommendations” for additional information.

5.6. Lower Prior (70-0026-00)

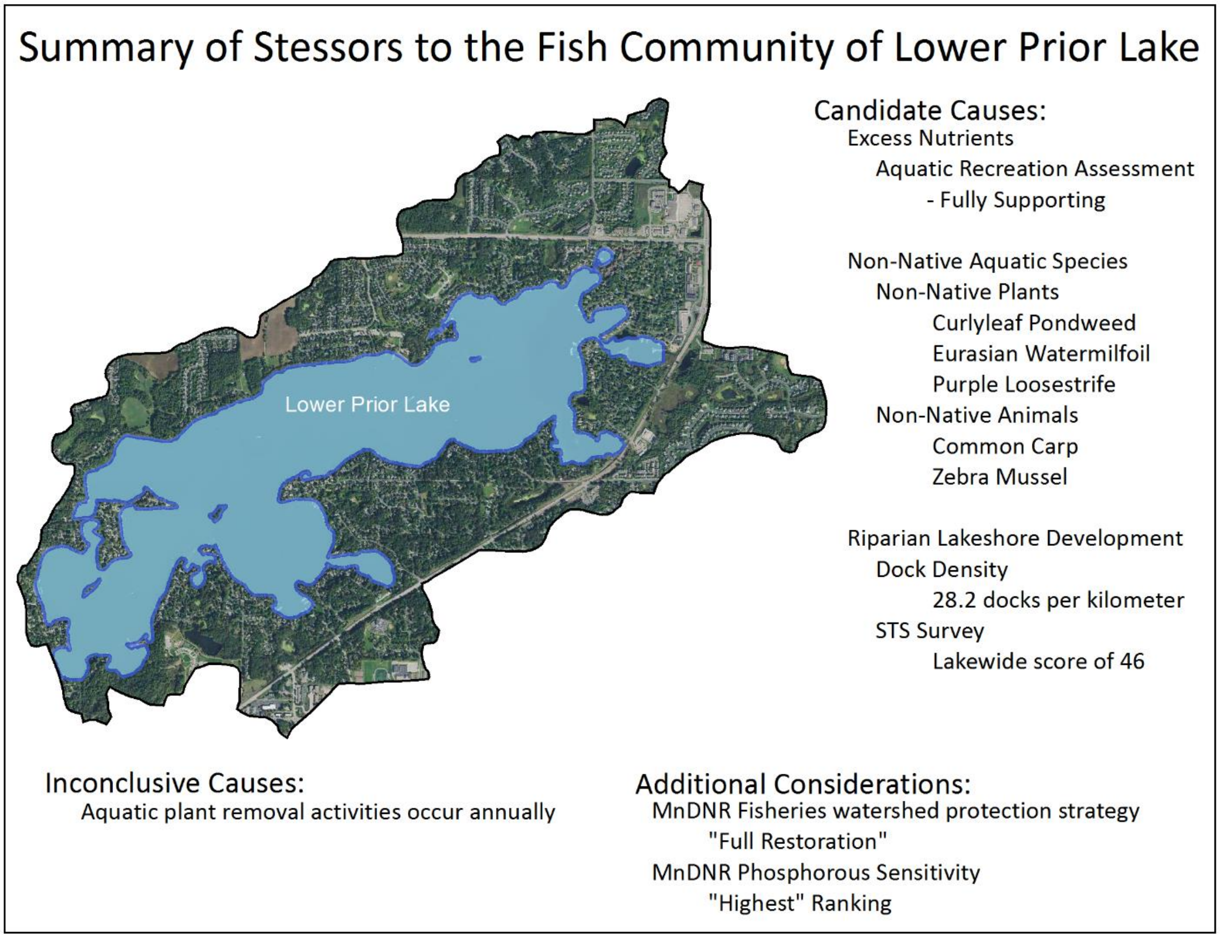

Figure 5.6.1 Summary of potential stressors to the fish community of Lower Prior Lake.

Available data indicates a high likelihood that riparian lakeshore development and non-native aquatic species are impacting the fish community in Lower Prior Lake and a low likelihood that excess nutrients are a stressor (Table 5.1). A summary of stressors are presented in Figure 5.6.1. Riparian lakeshore development was assigned the highest priority (Table 5.2) because both the number of residential docks (28.2 per km) and STS score (46) are at levels believed to impact aquatic ecosystems and among the most impactful levels in the state. Dock density was estimated to be 28.2 docks per kilometer of shoreline, which equals an average of one dock every 116 feet. A 2015 STS survey resulted in a lakewide score of 46 compared to the statewide average of 74. The shoreline and shoreland component scores were well below the statewide average. Most survey sites (107 of 119) had some sign of human development and had an average score of 40, but undeveloped sites did average a score of 88 out of 100.

Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted. Existing undeveloped shoreline should be protected to maintain the ecological functions they provide. In addition, lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to reestablish the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Although the land around the lake is already heavily developed, small incremental changes that restore some of the natural complexity can have a meaningful impact long term.

Aquatic invasive species impacts were ranked as the second priority for candidate stressors. Common Carp, Curlyleaf Pondweed, Eurasian Watermilfoil, and Purple Loosestrife are found in and around Lower Prior Lake and have been present for several decades. Zebra Mussels were discovered in 2009 and the ultimate impact to the fish community is still unknown. Aquatic invasive plants can reach densities that reduce native plant diversity in some areas of lakes. Curlyleaf Pondweed and Eurasian Watermilfoil have been treated with a selective herbicide annually in recent years to reduce nuisance conditions. However, there is no known level of density where aquatic invasive plants cause quantifiable impacts to fish communities that can be detected by the FIBI. Conversely, recent research has suggested potential threshold levels where aquatic ecosystems are significantly impacted by Common Carp in Minnesota (Bajer et al 2016). Fisheries assessments dating back to 1948 indicate Common Carp densities have remained low in gill net catches. Seven standardized MnDNR surveys performed between 2000 and 2015 had Common Carp densities ranging from 0 to 0.18 fish per trap net with Common Carp absent from four surveys. Despite not having a large catch rate in standard gamefish surveys the lake may be important to the Common Carp population inhabiting connected lakes. Monitoring the status of non-native aquatic species populations should continue to ensure their impacts to the lake are minimized.

Excess nutrient impacts were ranked as the third priority for candidate stressors. Lower Prior Lake is currently not listed as impaired for aquatic recreation use due to excess nutrients based on water quality standards. It is possible that nutrient levels are elevated, but not above levels that cause an impairment to recreational use. Substantial investments have been made by local partners to reduce nutrients entering lakes in the area including leveraging local resources to secure grant funding for larger projects. BMPs that reduce external nutrient loading into the lake should continue to be promoted to ensure stress to the fish community is minimized.

Aquatic plant removal activities may also be contributing to the impairment to aquatic life use based on the FIBI. Although the significance of this stressor is inconclusive at this time, management activities occur annually in Lower Prior Lake. Current statewide rules limit the amount of submerged vegetation treated with herbicides to 15% of the littoral area of a lake to limit the potential impact of control activities to fish habitat. A review of recent aquatic plant removal permits (2010-2016) found that control intended for individual access and recreation combined with control targeting non-native aquatic species approaches this limit annually.

Based on available information, the three candidate stressors ranked by likelihood were riparian lakeshore development, non-native aquatic species, and excess nutrients. Efforts that focus on reducing these stressors are most likely to have a positive effect on the restoration of aquatic life use in this lake. If aquatic plant removal activities intensify in the future managers should consider the possible negative impacts to the lake ecosystem prior to implementing additional activities. MnDNR Fisheries analysis has set a goal of “full restoration” for the immediate watershed around Lower Prior Lake. In addition, MnDNR modeling has placed the lake within the highest priority ranking for sensitivity to increased phosphorus loading. See “Recommendations” for additional information.

5.7. Spring (70-0054-00)

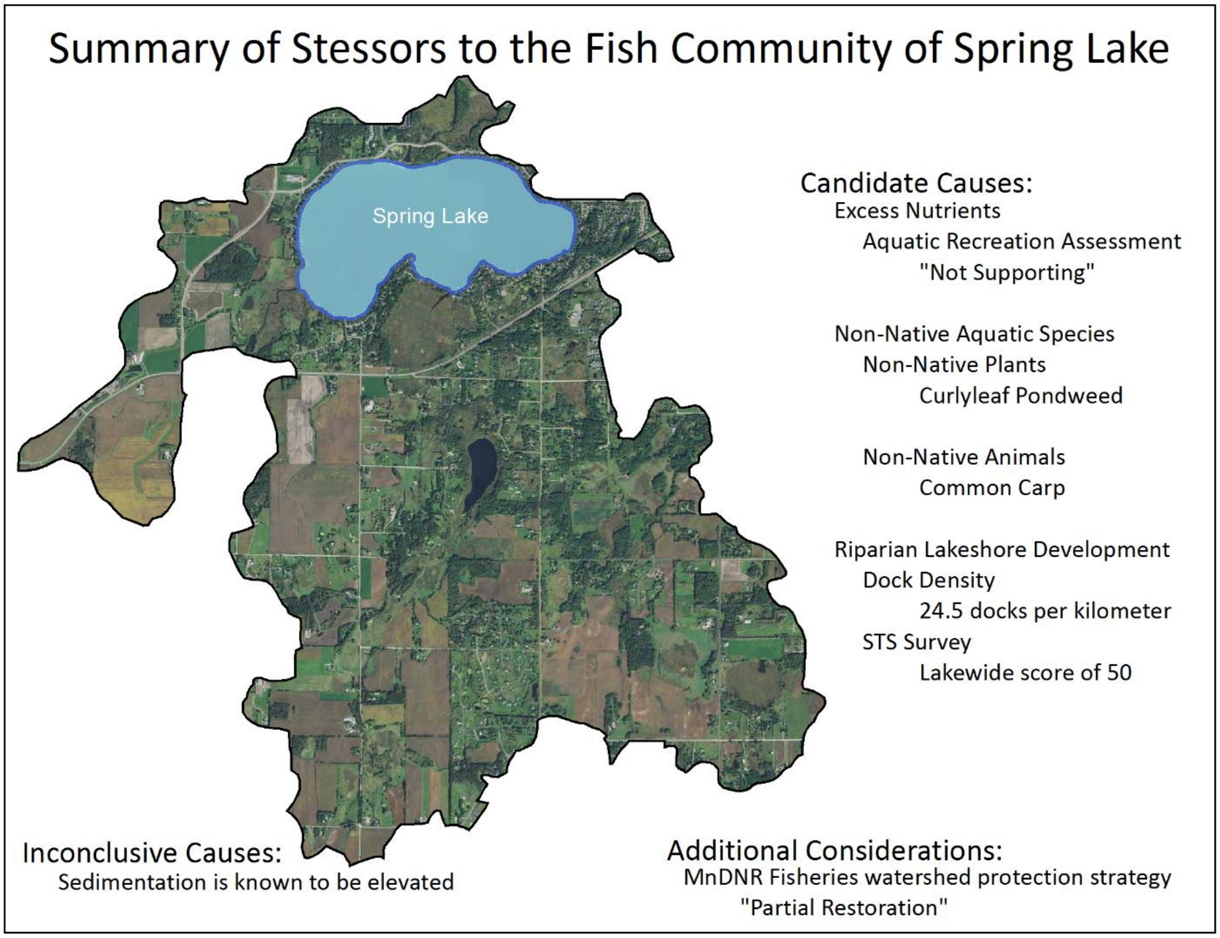

Figure 5.7.1 Summary of potential stressors to the fish community of Spring Lake.

Available data indicates a high likelihood that excess nutrients and riparian lakeshore development are impacting the fish community in Spring Lake and a low likelihood that non-native aquatic species are a stressor (Table 5.1). A summary of stressors is presented in Figure 5.7.1. Excess nutrients was the stressor assigned the highest priority (Table 5.2). Spring Lake has been identified for impairment of aquatic recreation (swimming) due to excess nutrients (phosphorus) and has been on Minnesota's 303(d) list of impaired waters since 2002. As a result, substantial efforts have been made to reduce nutrients entering the lake from a number of sources. (See the Spring Lake – Upper Prior Lake Nutrient TMDL and Implementation Plan for more information) Future projects that expand or enhance these efforts will benefit human (aquatic recreation use) and aquatic ecosystem (aquatic life use) health. It is important to note though that a full response of lake ecology may take decades after external nutrient loads are reduced (Schindler 2006). Even as internal loads return to expected conditions fish population require several generation to achieve a new equilibrium based on the quality of their habitat.

Riparian lakeshore development was given the second priority because both the number of residential docks and STS score are at levels believed to impact aquatic ecosystems and among the most highly developed levels in the state. Dock density was estimated to be 24.5 docks per kilometer of shoreline, which equals an average of one dock every 134 feet. A 2015 STS survey resulted in a lakewide score of 50 compared to the statewide average of 74. The shoreline and shoreland component scores were well below the statewide average. Most survey sites (32 of 36) had some sign of human development and had an average score of 45, but undeveloped sites did average a score of 92 out of 100. Existing undeveloped shoreline should be protected to maintain the ecological functions they provide. In addition, lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to reestablish the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Although the land around the lake is already heavily developed, small incremental changes that restore some of the natural complexity can have a meaningful impact long term.

Non-native aquatic species impacts were ranked as the third priority for candidate stressors. Common Carp and Curlyleaf Pondweed are found in Spring Lake and have been present for several decades. Non-native aquatic plants can reach densities that reduce native plant diversity in some areas of the lake. Curlyleaf Pondweed has been mechanically harvested and treated with a selective herbicide in the past to reduce nuisance conditions and attempt to achieve long-term control. However, there is no known threshold level of density where non-native aquatic plants cause quantifiable impacts to fish communities that can be detected by the FIBI. Conversely, recent research has suggested potential threshold levels where aquatic ecosystems are significantly impacted by Common Carp in Minnesota (Bajer et al 2016). The impacts from non-native aquatic species are structured by lake specific factors such as size, depth, productivity, and connectivity. Despite not having a large catch rate in standard gamefish surveys the lake may be important to the Common Carp population inhabiting connected lakes. Monitoring the status of non-native aquatic species populations should continue to ensure their impacts to the lake are minimized.

Sedimentation may also be contributing to the impairment to aquatic life use based on the FIBI although the significance of this stressor is inconclusive at this time. An investigation of historic conditions found peak sedimentation rates occurred around 1980 with recent rates several times higher than pre-European settlement (Hobbs 2013). The report concluded that the major driver for increased sedimentation was excess nutrients, which resulted in changes to the plankton community structure and density. Actions that reduce nutrient loading will have the added benefit of reducing sedimentation that may be altering the aquatic habitat for fish.

Based on available information, the three candidate stressors ranked by likelihood were excess nutrients, riparian lakeshore development, and non-native aquatic species. Efforts that focus on reducing these stressors are most likely to have a positive effect on the restoration of aquatic life use in this lake. MnDNR Fisheries analysis has set a goal of “partial restoration” for the immediate watershed around Spring Lake. See “Recommendations” for additional information.

5.8. O’Dowd (70-0095-00)

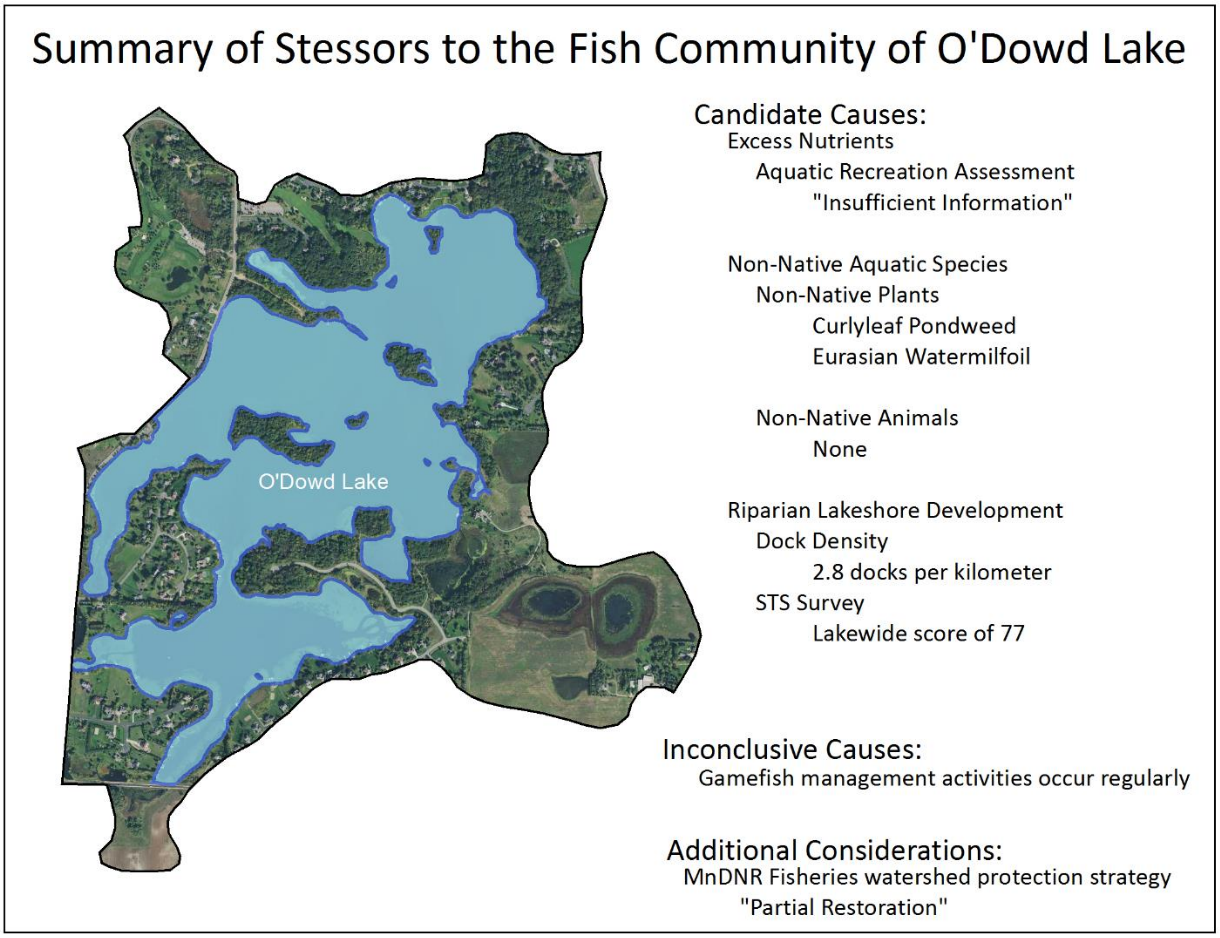

Figure 5.8.1 Summary of potential stressors to the fish community of O’Dowd Lake.

Available data indicates a moderate likelihood that excess nutrients are impacting the fish community in O’Dowd Lake and a low likelihood that riparian lakeshore development and non-native aquatic species are stressors (Table 5.1). A summary of stressors is presented in Figure 5.8.1. Excess nutrients was the stressor assigned the highest priority (Table 5.2). Although the current assessment found insufficient information to determine if the lake meets water quality standards, it is possible that nutrient levels are elevated but not to levels that cause an impairment to recreational use. BMPs that reduce external nutrient loading into the lake should be promoted to ensure stress to the fish community is minimized.

Riparian lakeshore development were ranked as the second priority for candidate stressors although the significance of this stressor was classified as low based on the current number of docks and a recent STS survey. A review of aerial photography indicates a substantial amount of residential development on the lake has occurred over the last 25 years. These activities may not yet be expressed in the fish community which may require several generations to realize the full impact. Much of the undeveloped lakeshore is privately owned and has the potential to be developed in the future. Policies that protect riparian lakeshore habitat complexity should be promoted.

Non-native aquatic species impacts were ranked as the third priority for candidate stressors. Curlyleaf Pondweed and Eurasian Watermilfoil are found in O’Dowd Lake and have been present since at least 2001. Non-native aquatic plants can reach densities that reduce native plant diversity in some areas of the lake. Curlyleaf Pondweed has been treated with a selective herbicide annually in recent years to reduce nuisance conditions and attempt to achieve long-term control. Treatment areas approach the current statewide limit (15% of the littoral area of a lake), which is intended to protect fish habitat and restrict the amount of submerged vegetation treated with herbicides.

Gamefish management activities may also be contributing to the impairment to aquatic life use based on the FIBI. Although the significance of this stressor is inconclusive at this time, predator stocking, commercial harvest, and winter aeration occur regularly in O'Dowd Lake. The impacts of these activities to the fish community as measured by the FIBI are not well understood. Commercial harvesters target tolerant, omnivorous species, which should generally have a positive influence on community composition metrics. Walleye stocking and winter aeration have a greater potential to alter the fish community because they are intended to increase predator density and survival.

Based on available information, the three candidate stressors ranked by likelihood were excess nutrients, riparian lakeshore development, and non-native aquatic species. Efforts that focus on reducing these stressors are most likely to have a positive effect on the restoration of aquatic life use in this lake. MnDNR Fisheries analysis has set a goal of "full restoration" for the immediate watershed around O'Dowd Lake. In addition, MnDNR modeling has placed the lake within the highest priority ranking for sensitivity to increased phosphorus loading. See "Recommendations" for additional information.

6. Summary of Vulnerable Lakes

In addition to lakes assessed as impaired for aquatic life use based on the FIBI, four other lakes were identified as "Vulnerable" to future impairment based on current conditions. Assessments of Crystal Lake and Orchard Lake determined both lakes fully supported the expected fish community as measured by the FIBI Tools. Insufficient information was available to assess Fish Lake due to uncertainty regarding the appropriate tool to use and Upper Prior Lake due to conflicting results from multiple surveys. Each of the candidate stressors presented in this report are known to impact these lakes to varying degrees. Some of the variables that measure these stressors exceed levels considered to impact the fish community (Table 6.1).

Table 6.1 Summary of potential stressor to the fish community of lakes in the LMRW identified as vulnerable to future impairment.

		Excess Nutrient	Riparian Lakeshore Development		Non-Native Aquatic Species	
Lake Name	Aquatic Life Use Assessment	Aquatic Recreation Assessment	STS	Docks/km *	Plant	Animal
Crystal	FS - Vulnerable	**NS(DL)**	63	**9.4**	Yes	**No**
Orchard	FS - Vulnerable	**FS**	62	9.9	Yes	Yes
Fish	IF - Vulnerable	NS	**80**	**8.4**	Yes	**No**
Upper Prior	IF - Vulnerable	NS	50	31.8	Yes	Yes

* = Dock density from Beck et al 2013

6.1. Crystal Lake

Crystal Lake was previously listed as impaired for aquatic recreation use due to excess nutrients based on water quality standards. Substantial investments have been made to reduce nutrients entering the lake, which has resulted in MPCA seeking delisting during the current assessment. These efforts reduce the impact of watershed disturbance, the other variable used to measure potential for excess nutrients to be impacting a fish community. The lake is also moderately developed, with a 2015 lakewide STS score of 63 and a dock density of 9.4 residential docks per kilometer. Consequently, riparian lakeshore development has a moderate likelihood of impacting the fish community. The presence of Curlyleaf Pondweed and Purple Loosestrife indicate that non-native aquatic species may also be contributing as a potential stressor. Based on these factors Crystal Lake is considered vulnerable to future impairment of aquatic life use based on FIBI tools. Policies and projects related to these stressors should consider their impact to aquatic life use in this lake. MnDNR Fisheries analysis has set a goal of "partial restoration" for the immediate watershed around Crystal Lake.

6.2. Orchard Lake

Orchard Lake has some residential development, with a 2015 lakewide STS score of 62 and a dock density of 9.9 residential docks per kilometer. Consequently, riparian lakeshore development has a moderate likelihood of impacting the fish community. The level of watershed disturbance exceeds the level shown by MnDNR research to impact fish communities although assessments of aquatic recreation use based on nutrient criteria are fully supporting. Non-native aquatic species present include Common Carp, Curlyleaf Pondweed, and Eurasian Watermilfoil, which can all impact aquatic ecosystems individually and collectively. Based on these factors Orchard Lake is considered vulnerable to future impairment of aquatic life use based on FIBI tools. Policies and projects related to these stressors should consider their impact to aquatic life use in this lake. MnDNR Fisheries analysis has set a goal of "partial restoration" for the immediate watershed around Orchard Lake. In addition, MnDNR modeling has placed the lake within the highest priority ranking for sensitivity to increased phosphorus loading.

6.3. Fish Lake

Fish Lake was listed as impaired for aquatic recreation use in 2007 due to excess nutrients based on water quality criteria, indicating excess nutrients are likely a significant stressor to the fish community. The level of watershed disturbance exceeds the level shown by MnDNR research to impact fish communities. Non-native aquatic species present include Common Carp and Curlyleaf Pondweed, which can each impact aquatic ecosystems individually and collectively. The lake has a dock density of 8.4 residential docks per kilometer and a 2015 lakewide STS score of 80. These measures indicate that riparian lakeshore development has a low likelihood of impacting the fish community, although there is concern for additional development in the future. Based on these factors, Fish Lake is considered vulnerable to future impairment of aquatic life use based on FIBI tools. Policies and projects related to these stressors should consider their impact to aquatic life use in this lake. MnDNR Fisheries analysis has set a goal of "partial restoration" for the immediate watershed around Fish Lake.

6.4. Upper Prior Lake

The lake is currently listed as impaired for aquatic recreation use due to excess nutrients based on water quality standards. Substantial investments have been made to reduce nutrients entering the lake. (See the Spring Lake – Upper Prior Lake Nutrient TMDL for more information). These efforts reduce the impact of watershed disturbance, the other variable used to measure potential for excess nutrients to be impacting the fish communities. The lake has a dock density of 31.8 residential docks per kilometer and a 2015 lakewide STS score of 50. These measures indicate that riparian lakeshore development has a high likelihood of impacting the fish community. Non-native aquatic species present include Common Carp, Curlyleaf Pondweed, Eurasian Watermilfoil, and Zebra Mussels, which can all impact aquatic ecosystems individually and collectively. Based on these factors, Upper Prior Lake is considered vulnerable to future impairment of aquatic life use based on FIBI tools. Policies and projects related to these stressors should consider their impact to aquatic life use in this lake. MnDNR Fisheries analysis has set a goal of "full restoration" for the immediate watershed around Upper Prior Lake.

7. Conclusions and Recommendations

7.1. Conclusions

This report has presented information summarizing the potential stressors responsible for impairments to aquatic life use based on the FIBI in lakes within the LMRW. Excess nutrients are the most significant candidate stressor for five of the impaired lakes in the watershed (see Table 5.1). Substantial efforts have been expended to reduce nutrient loading into lakes impaired for aquatic recreation based on water quality standards. Future projects that expand or enhance these efforts will benefit human (aquatic recreation use) and aquatic ecosystem (aquatic life use) health. It is important to note that impacts to aquatic life use may occur at lower nutrient inputs than required to impact aquatic recreation use. It is also important to note though that a full response of lake ecology may take decades after external nutrient loads are reduced (Schindler 2006) and that in many instances there is no avenue for some species to recolonize lakes. The benefits of recent work may not be reflected in the fish community at this time but future assessments will be able to detect changes that occur.

Riparian lakeshore development was identified as the most significant candidate stressor for Lake Bavaria and Lower Prior Lake and the second most significant stressor for the remaining lakes. Previous activities in the riparian lakeshore areas have focused on minimizing nutrient loading caused by riparian development but few attempts have been made to preserve the natural complexity of these areas for aquatic life use. Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted.

Non-native aquatic species impacts were identified as the second most significant candidate stressor for Lake Bavaria, Bryant Lake, and Lower Prior Lake. Several non-native aquatic species occur within the LMRW and each is associated with a potential risk to the aquatic ecosystem and cost of control. While there is a lack of research on direct effects of different non-native aquatic species to the FIBI score, each species has displayed the potential to alter the ecology of a lake. Specific impacts caused by each non-native aquatic species are structured by lake specific factors such as size, depth, productivity, and connectivity.

In addition to the three candidate causes identified, a variety of other possible stressors to fish communities were presented. These stressors were considered inconclusive due to a lack of quality data or a lack of understanding of how their impacts may be expressed in the FIBI tools. Sedimentation and aquatic plant removal are examples of stressors that generally lack sufficient data to quantify the impact of these stressors to the fish community. Water level management, loss of connectivity, and gamefish management are examples of potential stressors with impact to lake ecosystems that are not well understood at this time. Activities related to these stressors should consider the potential positive and negative impacts to the aquatic life use of lakes in the watershed.

7.2. Recommendations

The status of lakes assessed for aquatic life use with the FIBI varied within the LMRW. Excess nutrients are likely contributing significantly to many of the impairments identified in the watershed. Several lakes impaired for aquatic life use had previously been identified as impaired for aquatic recreation based on nutrient criteria. Multiple agencies have been working together to reduce nutrient loading to enhance the health of aquatic life and increase the recreational potential of Minnesota waters for many years. TMDL projects have been completed for several lakes and streams within the LMRW that identify target conditions and prioritize management activities. Information presented in this report provides support for continuing efforts to reduce excess nutrients entering lakes in the watershed.

Riparian lakeshore development was also identified as an important source of stress to the fish communities in the LMRW. The current status of riparian lakeshore habitat is a legacy of lakeshore management practices over many decades. Residential development of some lakes in the watershed occurred during the first half of the 20th century while others have been developed more recently. Statewide shoreland management standards were first adopted in 1970 and were last updated in 1989 (MnDNR 2008). Another attempt to update these standards began in 2004 and resulted in “Minnesota’s Alternative Shoreland Management Standards” (MnDNR 2005). These standards were developed as a set of additional tools for voluntary use by local governments to adopt stricter rules to protect water quality and lakeshore habitat. Organizations responsible for administering shoreland zoning rules should incorporate portions of these alternative standards as rules are updated. In addition, a new model shoreland ordinance has been developed for use by local organizations (see 2017 model shoreland ordinance here). Consideration should be given to standards intended to preserve or enhance the natural ecological function of lakeshore habitats.

Lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to restore the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Removal of woody habitat from the lake should be discouraged because natural woody structures add to the nearshore habitat complexity important to a variety of organisms including fish. Trees that provide habitat for wildlife and benefits to humans while living can provide habitat in aquatic environments for a much greater period of time because submerged wood decomposes slowly. Removing dead trees from the water has the effect of reducing overall aquatic habitat in a lake for decades or longer.

Advances to the understanding of non-native aquatic species impacts to aquatic ecosystems and effective control techniques have also been made in recent years by a variety of partners. Because each species has a different potential to impact fish communities based on unique lake characteristics, it is not possible to prioritize management of these organisms at the watershed scale. Although the MnDNR Invasive Species Program administers statewide rules related to non-native species, management efforts targeting these species are initiated by individuals, lake associations, watershed districts, or other stakeholders. Management activities should have well defined goals and acknowledge the difference between efforts to reduce recreational nuisances and efforts to restore aquatic life use.

Non-native aquatic plants alter the quality of vegetated habitat important for a variety of fish at certain times in their life cycle. There is no known level of density where aquatic invasive plants cause quantifiable impacts to fish communities that can be detected by the FIBI. Currently no single method for the selective control of non-native aquatic plants has been effective at achieving tong-term control although management techniques continue to be improved as information becomes available. Management efforts intended to restore aquatic life use should have a goal of restoring aquatic plant community abundance, diversity, and composition that provide habitat for a healthy fish community.

Recent research has suggested potential levels where aquatic ecosystems are significantly impacted by Common Carp in Minnesota (Bajer et al 2016). Control efforts with the goal of reducing density to minimize impact to the aquatic life inhabiting the lake should be supported. The ultimate impact of Zebra Mussel infestations on fish community richness and composition are currently being evaluated but may take several years to fully materialize in FIBI sampling. Monitoring the status of non-native aquatic species populations should continue to ensure their impacts to lakes are minimized.

Protection and restoration efforts that reduce the impact of any of the candidate stressors presented in this report will have a positive influence on the fish community. Actions initiated to restore the aquatic life use of a particular lake should focus on the priorities presented in this report.

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