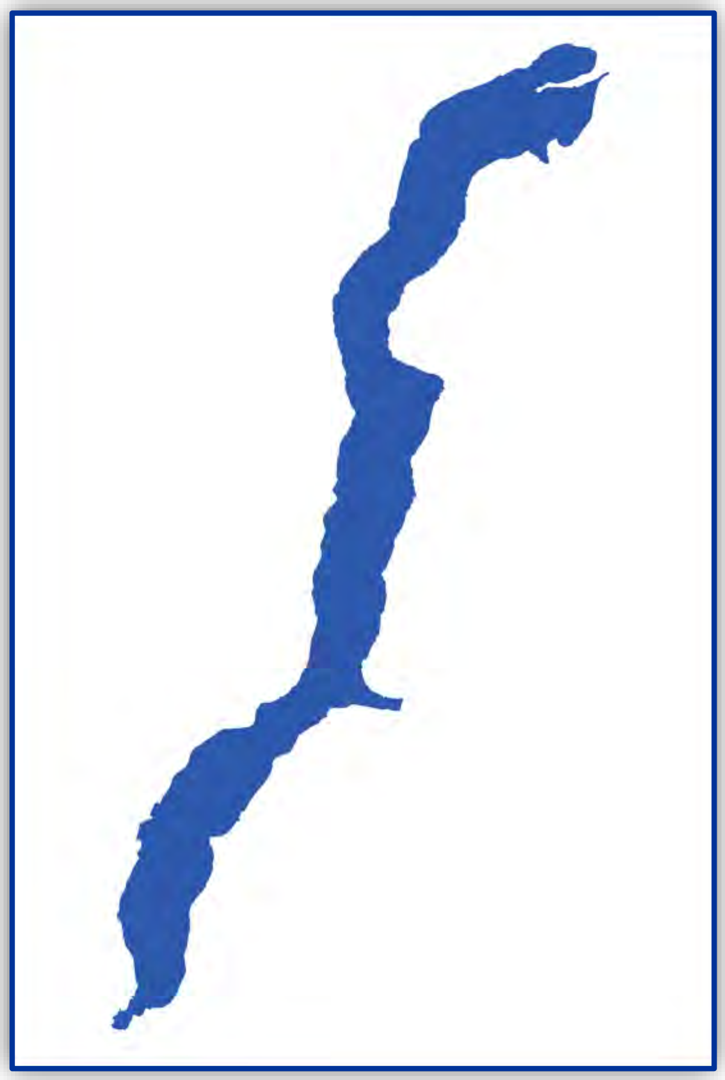
# CROSS LAKE
# PINE COUNTY
# MINNESOTA



# LAKE MANAGEMENT PLAN

2024

**Cross Lake**
**Lake Management Plan**

2024

**Prepared by**

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## EXECUTIVE SUMMARY

This lake management plan synthesizes publicly available data from a variety of sources to make diagnostic conclusions and recommend management activities. Data availability on the lake is extraordinary poor compared to many other lakes of similar size and accessibility in the state of Minnesota. There are no recent regularly collected Secchi depth, chlorophyll *a* or total phosphorus to provide a generalized baseline of conditions and as such conclusions are based on infrequently collected samples that are 10 or more years old. We suggest that the most urgent management activity is to train a volunteer to collect water samples for incorporation to the Minnesota Citizen Lake Monitoring Program, which has water samples analyzed for Secchi depth, chlorophyll *a*, and total phosphorus, on a monthly basis through the open water season, at a minimum. Cross Lake has been listed since 2003 by the state of Minnesota as an impaired water body, having records indicating poor water quality as measured by high concentrations of nutrients, particularly phosphorus, algae, and low water clarity. The poor water quality limits light to an extent that plant coverage is minimal, and those plants that do exist are species that tend to grow near to or at the surface, and often present nuisance for recreators. Nuisance plants on Cross Lake currently include two invasive species: curlyleaf pondweed and Eurasian watermilfoil. The combination of poor water quality and low aquatic plant coverage and diversity likely are influencing low densities of gamefish compared to other lakes in the region. Causally, the most important contributor to current poor conditions are high concentrations of phosphorus recycled from lake sediments through the summer. Based on availability of data, our preliminary estimation is that the most meaningful management activity that would provide the highest amount of positive change in the lake would be an alum treatment to lock up available phosphorus in the lake sediment. This would be expected to reduce algae concentrations, increase water clarity, increase coverage and diversity of aquatic plants, which would provide refuge for fish that may improve their fish population densities. Positive impacts for alum treatments can last 20 years or more if properly done. A total of 25 additional management objectives listed throughout this report. Certainly one of the challenges for managing lakes for residents is both funding and making sure local professionals follow through with generated workplans for which they are responsible. Some ways to help with funding would include applying for grants, increasing due paying members, establishment of a Lake Improvement District, and/or establishing a relationship with local business partner to take advantage of gambling revenues as allowed by the state for non-profits. Primary contacts of local professional groups with responsibilities for watershed management and by extension Cross Lake includes Snake River Watershed Management Board and Pine County Soil and Water Conservation District. As part of this process of writing a lake management plan, a Lake User Opinion Survey was administered in 2023 and is included in whole in the appendix.

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# *CHAPTER 1*

## INTRODUCTION

### Overview

This document describes what is currently (as of 2024) known of the condition of and potential for management of Cross Lake of Pine County to support lake health.

The primary resources used to put the lake management plan together included materials provided by The Cross Lake/Snake River Association (CLSRA) along with publicly available data accessed through the internet from the following government entities:

1. Minnesota Department of Natural Resources (MN DNR) Lake Finder (www.dnr.state.mn.us/lakefind)
2. Minnesota Geospatial Commons (gisdata.mn.gov)
3. Natural Resources Conservation Service (NRCS) Web Soil Survey (websoilsurvey.sc.egov.usda.gov)
4. Minnesota Pollution Control Agency (MPCA) (www.pca.state.mn.us/watershed-information/snake-river-st-croix-basin) series of documents including TMDL and WRAPS.
5. Wenck (2013) Snake River Watershed TMDL prepared for MPCA (https://www.pca.state.mn.us/sites/default/files/wq-iw6-11e.pdf)
6. Wenck (2017) Pine County Aquatic Vegetation Management Plan: Pokegame, Cross, Sand, and Sturgeon Lakes prepared for Pine County Planning and Zoning.
7. Limnopro Aquatic Science (2021) Aquatic Plant Survey.

Additional documents have been used and are referred through the document where appropriate.

While the primary audience for this document is members of Cross Lake/ Snake River Association, portions may be beyond the interest of some readers; however, in-depth descriptions and analyses occur for educational purposes and to provide information to technical workers who may perform projects on the lake in the future.

Governmental and nonprofit partners who are on record as having some responsibility for health of Cross Lake according to the 2014 Snake River Watershed (St Croix) Watershed Restoration and Protection Strategy Report include The Snake River Watershed Management Board, Pine County Soi land Water Conservation District, Pine County Soil and Water, Pine City, Natural Resources Conservation Science—USDA, Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, and Nature Conservancy.

A major objective of this report was to pull together information from disparate sources about Cross Lake into a single document and then to provide some synthesis of the information and identify data gaps where appropriate.

**Why Manage Lakes?**

There are two main reasons lake stakeholders want to manage lakes: (1) improve opportunities for recreation and (2) improve or maintain their investment in properties along the lake.

By recreation, we mean the ability to boat, swim, waterski, fish, and in any other way enjoy lake life. Lakes that are green with algal blooms are not desirable to swim in, and in fact, depending on what sort of algae is blooming, may pose health risks. Lakes that are full of dense plant growth can be hard to navigate around or cast into when fishing. Lakes with deteriorating fishing opportunities are less enjoyable to fish on than those with good fisheries. Most users desire lakes that are relatively clear with moderate plant growth and good fishing.

People purchase lake properties to take advantage of all that lakes provide in terms of recreational opportunities, so having lakes in optimal shape to enjoy them is a desirable goal.

While it is probably intuitive that property values on lakes are tied to the condition of the lake, there is scientific research that supports such claims (e.g., Caleron-Arrieta et al., 2019, Nicholls and Crompton, 2018, Liao, et al. 2016).

For example, Kristen Swedberg and colleagues (2021) from Virginia Tech summarized research showing water clarity impacts lakefront homes. In particular, in Minnesota, her research group found that for a three feet increase in Secchi depth, there is an associated increase in $13,000 to $45,000 in what people are willing to pay for a home on a lake depending on where in Minnesota homes would be purchased.

Stephen Polasky, a researcher in the Department of Applied Economics at the University of Minnesota, summarized research around the country that showed people were willing to pay upwards of near 20% more for properties on lakes without nuisance plant growth compared to similar homes on lakes with nuisance plant growth (Polasky and Hansen, 2021). In Minnesota, he showed a difference in the range of 4 - 7%, which equated to a loss in value of $13,000 - $19,000 per home for an average price home studied on lakes with nuisance plant growth.

There is real dollar value in improving the condition of the lake with respect to both water quality and plant conditions.

In concert with this lake management plan, Limnopro created, and Cross Lake/Snake River Association administered, a lake opinion survey (hereafter the “Lake User Opinion Survey”), which was responded to by 135 respondents during 2023.

This survey indicated that 91% of respondents had at least some concern about impacts of lake condition on their property value.

This lake management plan will provide a beginning framework for man-

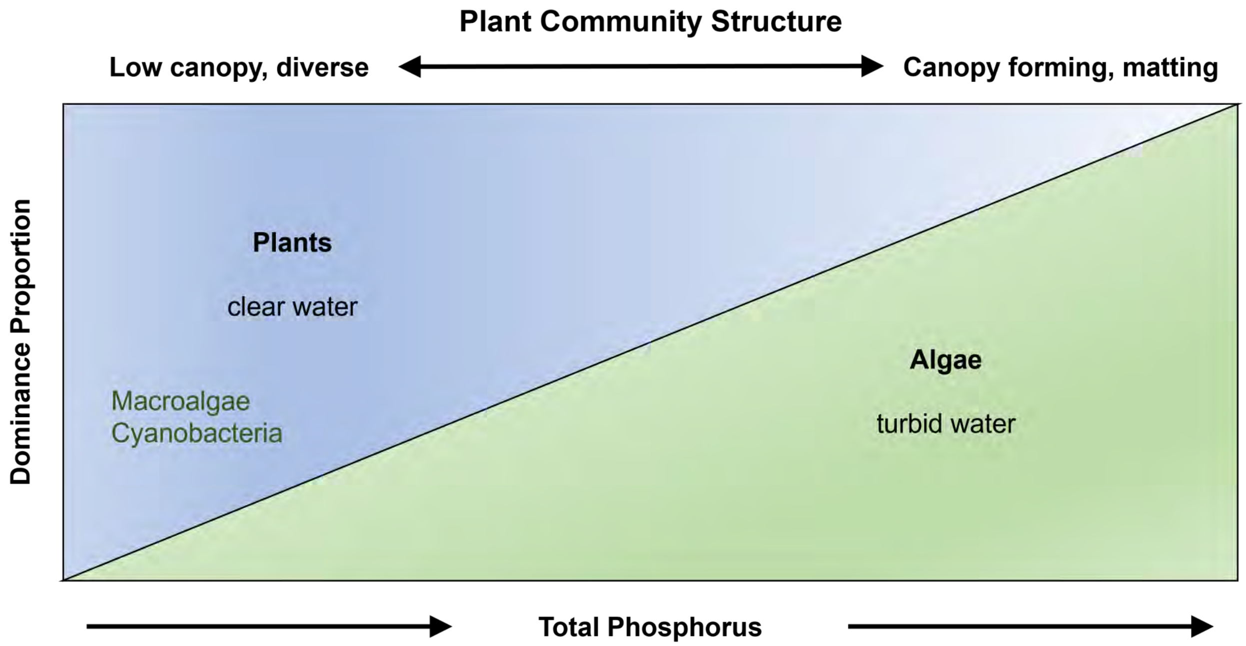


*Fig. 1. Illustration of how in lakes community structure can change with water quality. Clear lakes often have high plant coverage with high diversity. Turbid lakes often have low plant cover, or high coverage of plants that grow to the surface.*

aging Cross Lake in an attempt to optimize water quality, plant growth, and fishing conditions for recreation and to preserve property values.

As lake management really focuses on plants, water quality and fisheries, it is important to recognize at the outset that there are tradeoffs to optimizing water quality, plant growth and fishing. Good water quality means clear water, which means high plant growth, including some nuisance growth. Poor water quality means turbid water, which means few plants with little plant growth. Fish can both impact water quality and plant growth and in turn be impacted by both. Lake users need to understand that crystal clear water with low plant coverage and great fishing is not ecologically realistic. In lake management, average conditions are often a goal that produces moderately clear water with moderate plant growth. Such average conditions often produce the best fisheries (Fig. 1).

### The Natural Life of a Lake

Before reviewing conditions and potential management activities some background on the origin and development of lakes should be helpful to provide some context of what is to follow.

All natural lakes in Minnesota were formed by the last glaciers. A long time ago, the state was covered with ice. As climate warmed and the glaciers began to melt, pieces of ice broke off, sunk into the ground to create a de-

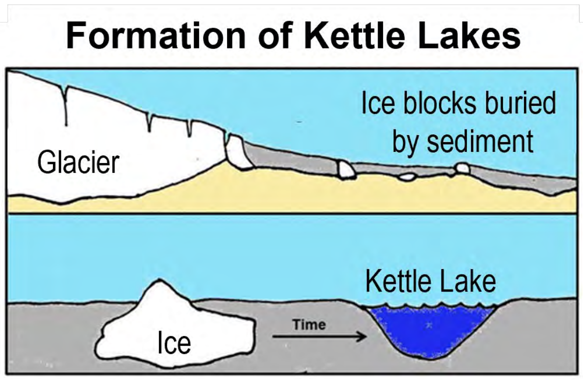


*Fig. 2. Illustration of how lakes in Minnesota were formed as glacier's melted and retreated on the landscape. Minnesota's natural lakes are mostly "kettle" lakes that form from melted buried ice chunks. Image source: Lotus Arise, UPSC.*

pression, and then when the ice finally melted, the melted water became a lake (Fig. 2). Such events over the landscape led to the "birth" of our 10,000 lakes.

In time, all lakes will progress through a natural process of filling with sediment to become land (Fig. 3). This aging process is called "eutrophication" (i.e., "eu" = *many* and "trophic" = *nutrients*, so "many nutrients"). Sediment is carried from land during spring snowmelt and rain events that carries nutrients from land to water. Devoid of humans, the aging of a lake from formation to filling in would take thousands of years.

Likely, human intervention on the landscape has sped up this aging process, principally by developing the land that surrounds a lake, which increases sedimentation rates. This acknowledgement of a quickened pace of lake development has led to a separation of "natural" and "cultural" (or human caused) eutrophication (Fig. 4)

Eutrophication is important to under-

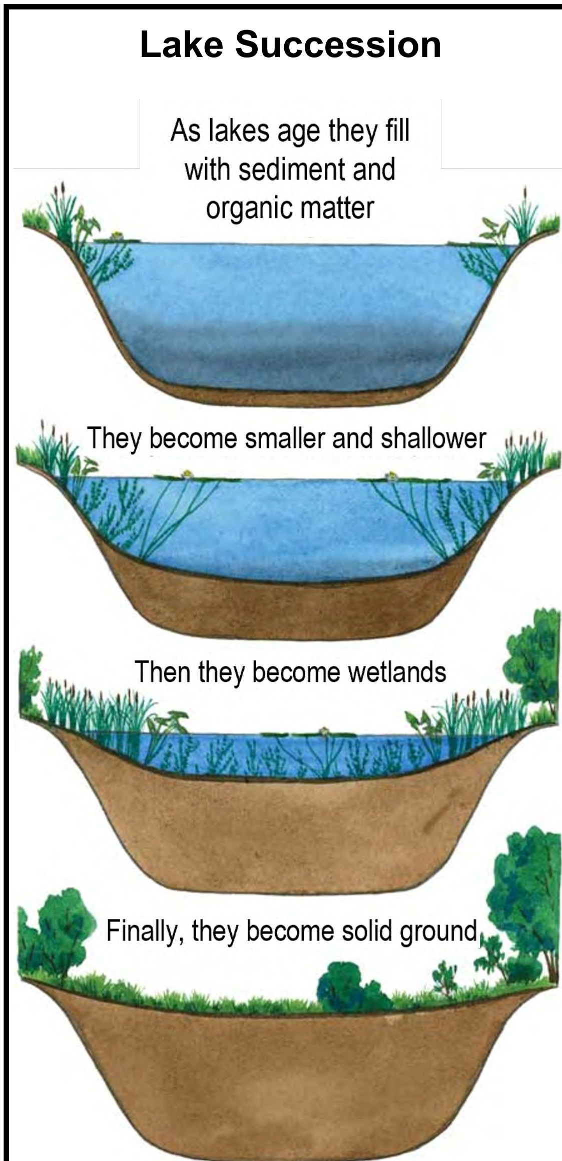


*Fig. 3. Natural lake aging, also known as succession or eutrophication. The natural life for any lake is to fill in to become solid ground over periods measured in centuries. Image source: Missouri DOC.*

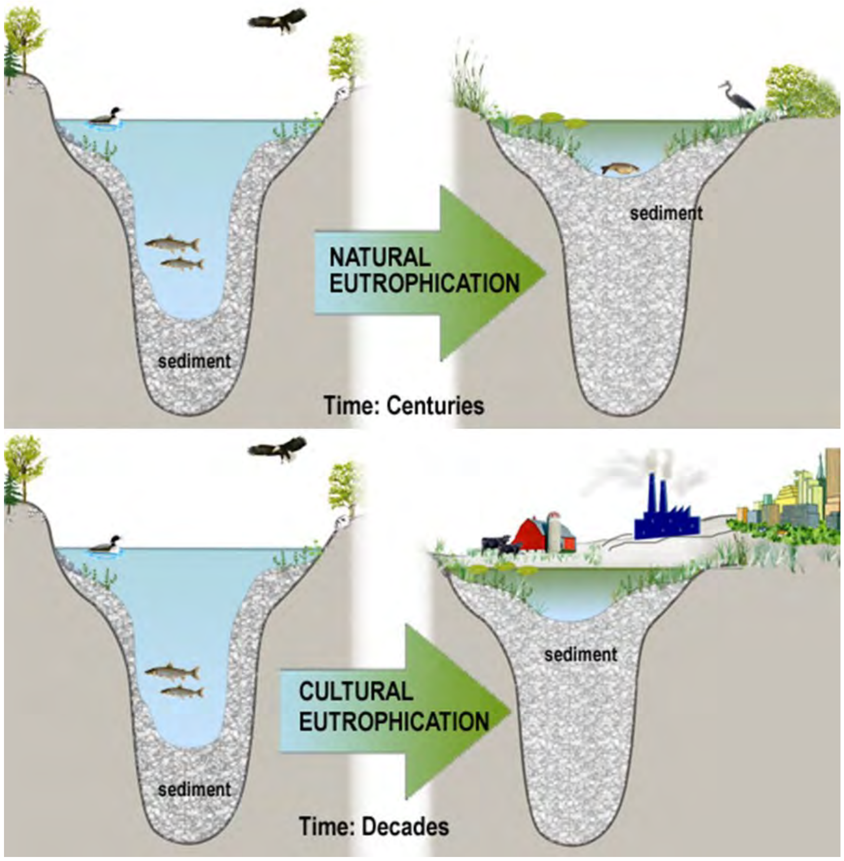


*Fig. 4. Differences between "natural" and "cultural" eutrophication have to do with both the time it takes to occur and the cause. Natural eutrophication takes much longer, mostly because of intact soils on the watershed and natural nutrient recycling. Cultural eutrophication is faster because humans create landscape where erosion occurs fast and nutrients are added to the landscape at a rate that is faster than they can be recycled on the landscape so they end up in the water. Image Source: RMBEL.*

stand for lake management because it is related to the age of a lake, and management needs to take into account just what is possible and what is not possible for a lake of a given age. In other words, it is important to manage expectations and reach for realistic goals.

Because climate in the southern part of the state warmed faster than in the north, glaciers melted or retreated in order from the south to the north. The result of this is that lakes in the southern part of the state are "older" than those in the north (Fig. 5). Some of the oldest lakes in Minnesota, now have hundreds of feet of sediment that has been carried in and deposited to the bottom. Cross Lake occurs in the part of the state where they might be considered late middle-aged.

From the perspective of humans, old lakes are less appealing than younger lakes. This is because older lakes are greener from algal and plant growth,

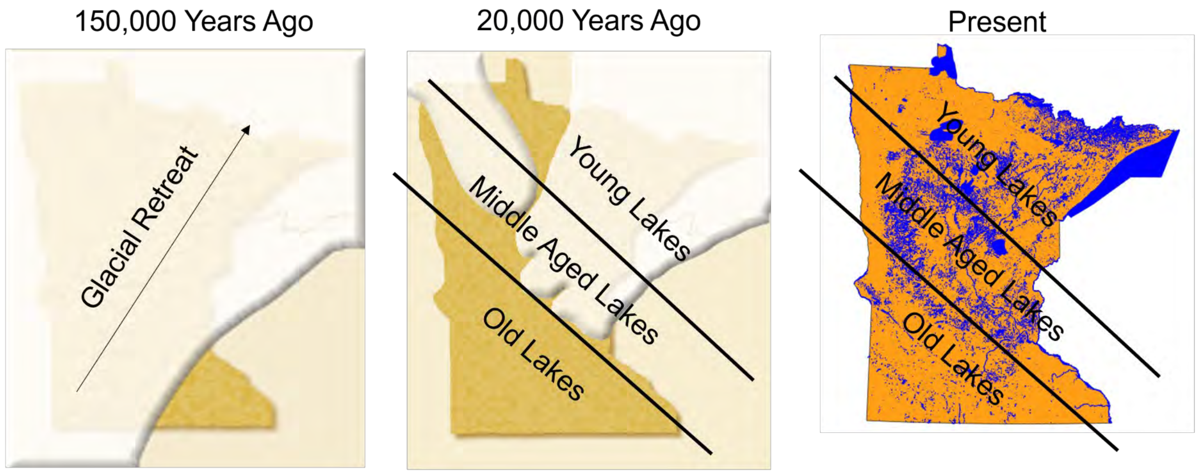


*Fig. 5. Aging of lakes in Minnesota relative to the retreating of glaciers thousands of years ago. Lines delineating lake groups are for illustration only and do not imply a quantitative measurement.*

which are both consequences of nutrients delivered to lakes from sediment. Both algae and plants can become a nuisance and create unappealing conditions.

One measure the MPCA uses to determine the health of the lake for its age is its "trophic state index", which uses a formula to combine water clarity, algae concentrations, and nutrients to a standardized value. Lakes that have higher values of these measurements than might be expected for a lake of its kind, at its location in the state, are deemed to be impaired. In Minnesota, "water quality" is measured by trophic state index, so monitoring total phosphorus, chlorophyll a and Secchi depth is important to gain perspective about the health of the lake.

Currently, Cross Lake is considered to be impaired for recreational proposes by the State of Minnesota, meaning it is considered to have nutrients (i.e., phosphorus) in excess for its age (Fig. 6). One disadvantage of the trophic state index is that it does not account for nuisance plant growth or impacts of

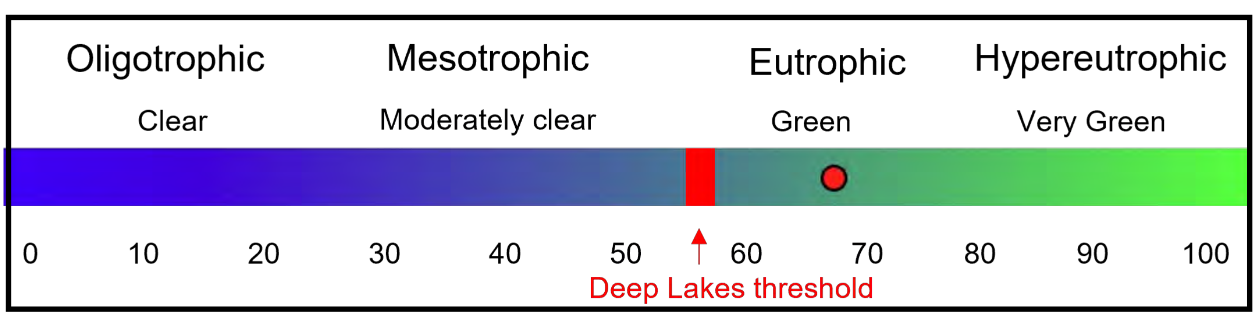


*Fig. 6. MPCA trophic state index scores for Cross Lake (67). Impaired waters thresholds for comparable lakes is 57 for deep lakes in the region. The lake is listed as impaired.*

aquatic invasive species, two factors that are impacting conditions on the lake.

With this information as a background, this report will provide a diagnostic of present conditions of these lakes and management guidance toward helping the lakes to become more healthy relative to its current condition. First, some history on the lake will be outlined.

# *CHAPTER 2*
## MANAGERS AND MONEY

### Overview

An historical recollection of some significant events from the past in Cross Lake are summarized below.

**1837—**Logging began in the areas around Cross Lake. The Snake River and Cross Lake were both used as staging and transport for logging operations.

**1849—**A dam was constructed on the Snake River to increase water levels on Cross Lake and serve as a sluiceway for logs.

**1897—**As the logging industry died, the recreational use of waterbodies in the area increased. Cross Lake was a popular fishing and camping getaway.

**1964—**The dam as it stands today was formed from modifications to a previous dam.

**1981**—Curlyleaf pondweed, an aquatic invasive species, is known to be growing in Cross Lake.

**2003**—Cross Lake is listed as an impaired water body due to excessive nutrients and algae concentrations.

**2004**—Eurasian watermilfoil, an aquatic invasive species, is first recognized in Cross Lake.

**2014**—The Snake River watershed TMDL received EPA approval, which provided goals for nutrient reductions to improve water quality in Cross Lake.

**2017—**An erosion control project was completed on the northern bank of Cross Lake.

**2018—**Wenck completed an aquatic vegetation management plan which included Cross Lake.

**2021—** Limnopro conducted an aquatic vegetation survey on Cross Lake.

**2022—**Carp Solutions completed a report on carp populations in Cross Lake.

**2023—** Limnopro begins the creation of a lake management plan to address water quality, plant, aquatic invasive species, and fisheries health.

Today Cross Lake residents work closely with the community and local groups as well as being a member of the MN Coalition of Lake Associations.

### Cross Lake/Snake River Association

The Cross Lake/Snake River Association is a registered 501 (3)(C) organization with the IRS and subsequently contributions to it are tax deductible.

The Cross Lake/Snake River Association reports 220 dues-paying members out of a possible 475 for a membership proportion of 40%. We suggest setting a minimal goal for increasing membership annually. Even increasing by as few as 1-5 new membership while maintaining current number keeps membership numbers heading the right direction. At the very least purposefully getting accurate number and reporting these annually can keep the board abreast of changes.

Higher membership of lake residents will bring in both an awareness of lake issues and a diversity of talents that will be useful for carrying through with management objectives, particularly when they rely on volunteer efforts. Furthermore, many grant monies that Cross Lake/Snake River Association might apply for in support of lake health will require matching funds, which can take the form of either cash contributions or volunteer hours.

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**MANAGEMENT OBJECTIVE #1**

SET A GOAL TO INCREASE ACTIVE AND DUE-PAYING MEMBERSHIP TO THE LAKE ASSOCIATION BY A REASONABLE NUMBER ANNUALLY.

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### Funding and Lake Management

One of the major challenges for lake association groups in providing a useful program for monitoring and management is coming up with enough money to budget meaningful work. Most lake associations in the state operate principally on voluntary annual membership dues coupled with available grant monies that can require some cost sharing.

The most common source of funding for lake associations currently is an annual grant program run by the MN DNR to provides some funding for help in controlling aquatic invasive species, and access to county funds earmarked specifically for managing aquatic invasive species as part of "Local Aquatic Invasive Species Prevention Aid".

The MN DNR grant money comes via a program called the "Invasive Aquatic Plant Management Grant Program". It provides some funds for both surveying and treating aquatic invasive plant species. Specific information and application packets can be found on the MN DNR webpage at www.dnr.state.mn.us/grants/aquatic_invasive/control-projects.html. Funds provided to lake groups most often are limited to a total of $1500 but see application materials for exceptions.

The county level Local Aquatic Invasive Prevention Aid dollars tend to be the larger pot of money as they access an approximate 10 million dollars that are annually doled out by the state to counties based on public lake densities. Counties have a lot of latitude on how those funds are spent. For Pine County, the latest primary contact for more information on these dollars is Erin Hoxsie (erin.hoxsie@co.pine.mn.us, 320-216-4220) and Mike Gainor (mike.gainor@co.pine.mn.us, 320-591-1657). Making contact with these individuals to determine what funds are available and what processes are in place for acquiring such funds is recommended.

A third source of dollars available to lake associations for projects comes that can provide hundreds of thousands of dollars for larger projects but is highly competitive comes from the Clean Water Fund Grants administered through the MN Board of Water and Soil Resources. These dollars go toward watershed projects mostly. They do fund some in-lake projects, including alum treatments and carp management. Information on these funds can be learned on BWSR webpage at https://bwsr.state.mn.us/clean-water-fund-grant-recipients.

Beyond these three sources of grant monies (i.e., MN DNR AIS Control Grants, Local AIS Prevention Aid, and BWSR Cleanwater Fund) occasional programs may be offered by different agencies.

**MANAGEMENT OBJECTIVE #2**
EXPLORE GRANT OPPORUNITIES FOR AIS WORK AND WATERSHED PROJECTS AS APPROPRIATE FROM DNR, COUNTY, AND/OR BWSR

There are a couple of different ways that some lake associations have been successful in generating additional funds beyond those provided through volunteer due contribution, including partnering with local businesses to acquire dollars from gambling proceeds and/or the establishment of a Lake Improvement District. Gambling proceeds may be available with a nonprofit status. A Lake Improvement District is a tax and spend authority granted by Minnesota Statutes 103B.501-103B.581. If a LID is petitioned for and granted, a governing body can collect funds from all shoreline residents and at a higher rate than generally can be collected through volunteer contributions. The MN DNR can help guide through the process and has a webpage landing space with additional information at https://www.dnr.state.mn.us/waters/watermgmt_section/shoreland/lake-improvement-districts.html.

Exploring creative ways to generate funds for lake management will be important to generate real change as budget limitations often restrict meaningful work from being accomplished.

**MANAGEMENT OBJECTIVE #3**
EXPLORE PARTNERING WITH LOCAL BUSINESSES FOR GAMBLING PROCEEDS AND/OR ESTABLISHMENT OF A LAKE IMPROVEMENT DISTRICT

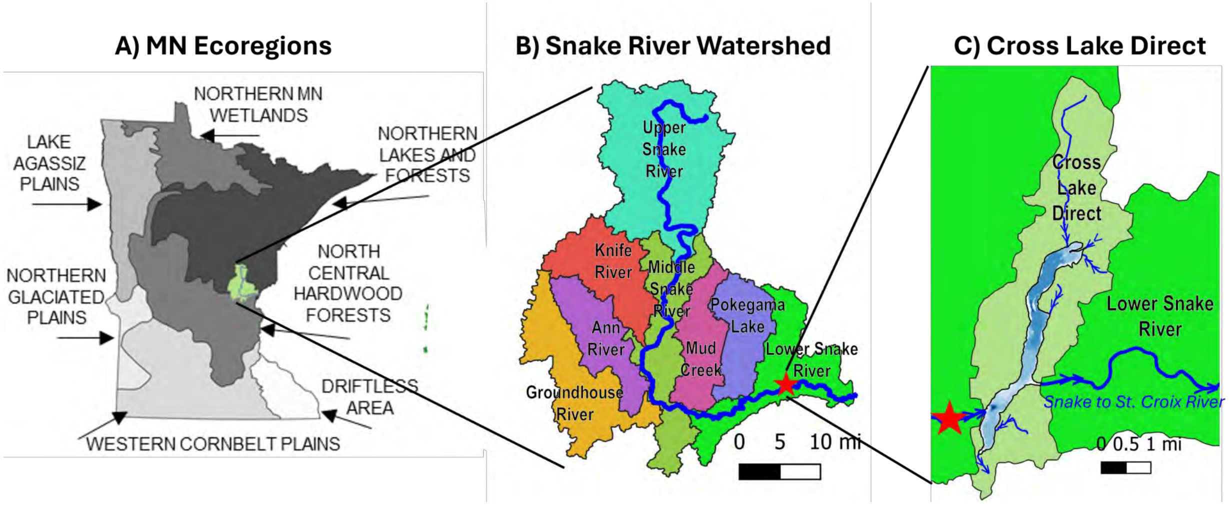



*Fig. 7. Cross Lake location within the (A) North Central Hardwood Forests, (B), the Snake River major watershed, and (C) Cross Lake direct lakeshed*

### Local Partners

There are several local governmental organizations that can help provide professional services often at no cost or access to funding. Potential partners for work on the watershed include the Snake River Watershed Management Board, Pine County SWCD, and Pine County Planning and Zoning. Partners that focus more on the lake directly include the Minnesota Department of Natural Resources who generally oversee biology of lakes (e.g., fish and plants) and the Minnesota Pollution Control Agency (MPCA) who oversees nonbiological aspects of lake conditions such as phosphorus loadings, toxins, and chemicals. A number of commercial lake management companies exist that can do surveys, monitoring, or treatments, including Limnopro Aquatic Sciences, Inc. Developing relationships with individuals within these organizations as partners to improve conditions on the lake is certainly worthwhile.

The next two chapters will describe both the watershed and lake morphology (shape) to provide additional context for a management view of water quality, aquatic plants and fish.

## CHAPTER 3
## WATERSHED

### Overview

A watershed is a geographic region where all precipitation that falls within it reaches the main river that flows through it. Cross Lake occurs within the Snake River Watershed, which is 1 of 80 "*Major*" Watersheds as defined by the state of Minnesota.

The watershed itself is within Minnesota's North Central Hardwood Forests (NCHF) Ecoregion (Fig. 7). The NCHF is between agricultural rich landscape south and the forest-rich landscape north, so has some characteristics of both. Minnesota compares all lakes within a given Ecoregion together to determine whether it has unusual water quality, so the ecoregion designation is important.

As Cross Lake is situated near the bottom of the watershed along the Snake River, most of the water that falls or drains into the watershed eventually makes its way into the lake, and eventually the St. Croix River which dumps into the Mississippi River. As such, Cross Lake acts as a receiving basin for a large area of land.

Cross Lake receives flow from 1,665 permanent or semi-permanent lakes, ponds or wetlands ranging in size from 0.1 acres to 1,521 acres. Lakes that provide flow to Cross Lake that are over 100 acres in size from smallest to largest include Bear, Pennington, Upper Rice, Rice, Quamba, Pomroy, Fish, Ann, Knife, and Pokegama.

The total area of land that contributes to a lake (i.e., the lakeshed) relative to the size of the lake is an important measure for lake managers. It gives some indication of the expectation for the influence of runoff based nutrient additions to a lake. For Cross Lake, the size of the lakeshed is 620,215 acres with a lake surface area of 925 acres. This gives a ratio of 620,215:925 = 670. The watershed is large and likely has an impact on the lakes internal chemistry.

Lakes like Cross with large lake sheds accumulate more sediment from precipitation washing over larger areas. In general, lakes with small lakeshed ratios (<< 10) tend to have better water quality as measured by nutrient pollution, algae blooms, and water clarity than those with large watersheds. Lakes with small lakeshed-to-surface area ratios lakes tend to have water budgets mostly featuring groundwater flow with long nutrient retention times (i.e., once nutrients are flushed into the lake, they stay put for a long time).

The Cross Lake watershed can be divided into nine separate subsheds. This final delineation into lakesheds is the most relevant for managing lakes because they directly impact what happens to the lakes that we are interested in given these are the areas flowing into, and thus impacting, the lake.

Understanding the characteristics of the land surrounding the lake is important because the lake interacts with the land in such a way that the land supplies the lake with sediment and nutrients, both impacting water clarity, nutrients, algae concentrations and nearly every other important measure of water quality. In particular, outside of the ratio of the size of the lake to the surrounding land, the type of predominant soils in the watershed and how the land is used can determine what sort of load of sediment ends up in the lake.

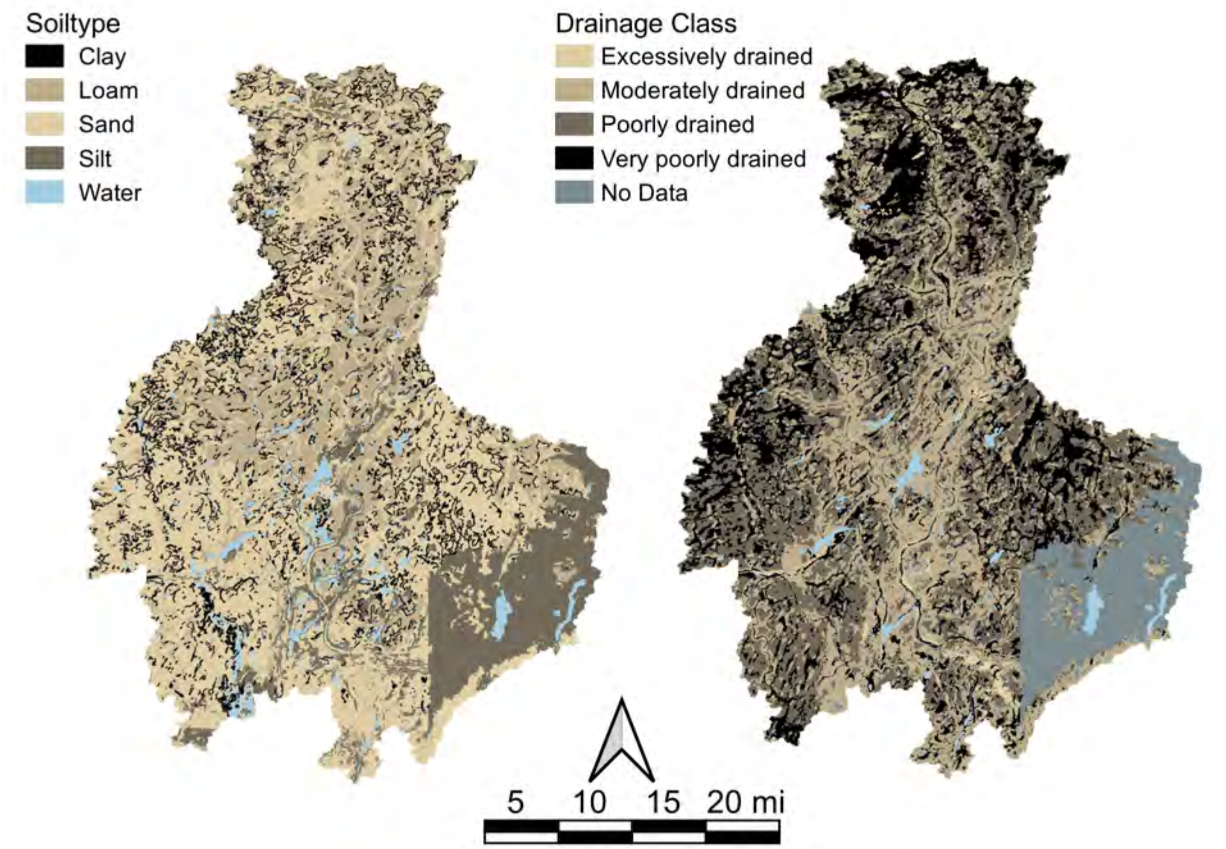



*Fig. 8. Lakeshed soil characteristics based on NCRS soil data.*

**Watershed Soil Characteristics**

Cross Lake sits on glacially sourced sediments left over from advancing and retreating ice-sheets from thousands of years ago. The types of sediments left behind is important in thinking about how water moves over the landscape and into Cross Lake.

Both particle size and elevation/slope of the contributing lakeshed impact the ability of soils to drain precipitation to keep it from lakes. Areas in the lakeshed with poorly drained soils will contribute more nutrients to the lake than areas that are well drained, which is important for thinking about where to implement management strategies to help keep nutrients dissolved in runoff from rain events out of the lake.

In general, soils can be classified based on particle size with the largest particles classified as "sand" and smallest as "clay with "silt" for particles intermediate in size between sand and clay.

The majority of the lakeshed for Cross Lake would best be classified as "sand" (Fig. 8). There are few isolated veins of clay and silt deposits occurring largely in wet areas with a large silt deposit at the bottom of the watershed surrounding Cross Lake. Sandy soils allow for easy infiltration of precipita-

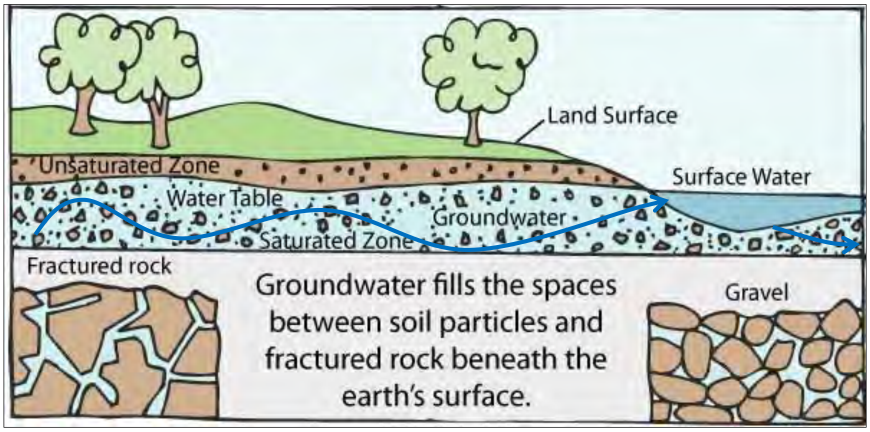



*Fig. 9. An illustration of groundwater flow over the landscape. While generally not observable, there is a continual flow of groundwater through the lake. Image Source: groundwater.org.*

tion to groundwater reservoir.

Groundwater is the water that flows unseen beneath the ground (Fig. 9). Groundwater flow is constrained within divides much like watersheds, the shape of which differs from surface watersheds. All lakes have their water budgets to some degree dependent upon groundwater flow.

Existing groundwater data for the region suggest a water table depth of 3.5 feet or less on average.

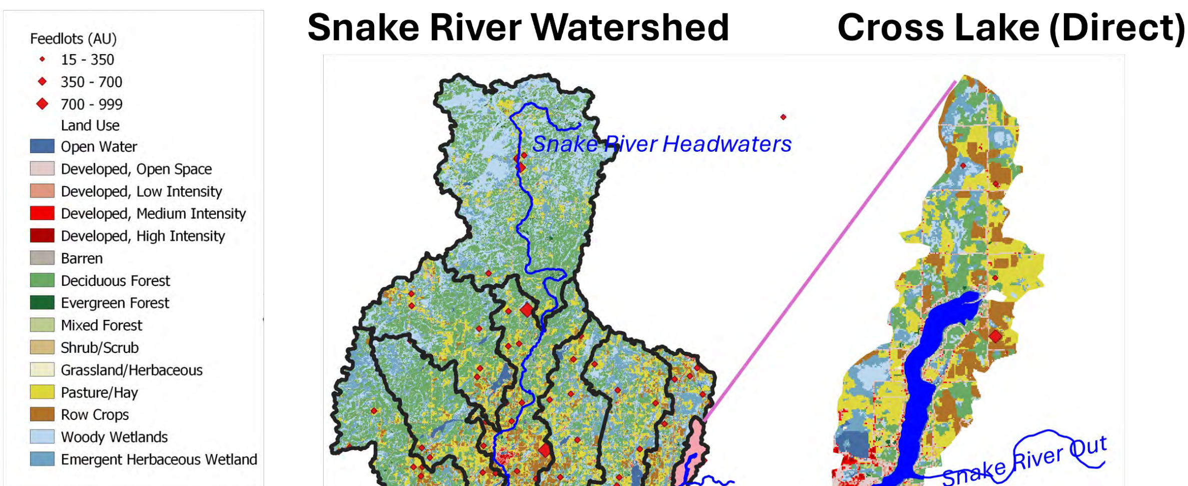
**Watershed Land Use**

Land use is often important in determining how nutrients carried by run off are contributed to a lake. The most common land types in the lakeshed are forest and wetlands, each representing 35% of the land cover for a combined 70%. This is followed by agriculture which accounts for 25% of the lakeshed area (Fig 10).

High concentrations of agriculture in a lakeshed can impact lakes more so than landscapes left as native forests, grasslands or wetlands. This is because many producers use fertilizers on their fields to feed their plants. Fertilizers are nutrients that can be washed off the fields to eventually end up in the lake. Because farming turns over or loosens soil most fields have little natural cover and crop plants tend to have relatively shallow roots to consolidate sediments, which means precipitation or irrigation events may easily move top soils as runoff to the lake.

Even so, its important to recognize that producers will do what they can to conserve soil and fertilizers placed on fields to keep them from running off. It does not help a producers financial bottom line to waste either. Still, inevitably, there is some that will end up in lakes.

Most of the agriculture is concentrated in the bottom or southern portions of




| Land Use | Watershed | Direct |
|---|---|---|
| Forest | 35% | 23% |
| Wetlands | 35% | 18% |
| Pasture | 16% | 26% |
| Crops | 9% | 19% |
| Developed | 4% | 14% |

**summarized by major group*

*Fig. 10. Percentages are reported for each land class as a part of the total lakeshed (NLCD 2019). An overlay of feedlots within the lakeshed.*

the lakeshed with isolated areas in the northern portion.

There are 153 active feedlots operations with 84 required to be registered in the lakeshed. A feedlot is required to be registered if it has 50 or more animal units (AUs) or has 10 or more AUs and is located within shoreland. Of those with registration requirements, they are primarily for either beef or dairy cattle, with some dedicated to swine. In order to determine potential impacts to ecosystems, animals are standardized to "Animal Units" or AUs. The number of AUs in the lakeshed ranges from 14 to 999. The mean and median animal unit values are 195 and 138 respectively.

Feedlots can produce nutrient rich waste from animals that may end up in lakes; however, feedlots are heavily regulated and there are a number of tools at their disposal to help with waste management, and waste may likely be well contained (Fig. 11). If a concern exists that animal waste is getting into the lake from the feedlots, a test for fecal coliform can be done.

Fecal coliform is a collection of common bacteria that is found in the intestines of animals, including humans. The vast majority of fecal coliform are harmless (see exception for some strains of *E. coli* below), but if they are detected, it indicates other sorts of bacteria, including pathogenic (i.e., types that can make a person sick) forms that cannot be tested for, may also be getting into the water.

*Fig. 11. Cattle standing in Pomme de Terre River. Pomme de Terre River is in Minnesota but does not occur in Cross Lake lakeshed. This is only an example of how animal waste can end up on water ways. Image source: pca.state.mn.us/water/bacteria.*

High levels of fecal coliform also may indicate that animal waste is a contributor of excess nutrient pollution to the lake. As such, fecal coliform tests are done as an indicator of animal waste getting into the lake.

**MANAGEMENT OBJECTIVE #4**

COLLECT WATER SAMPLES TO ASSESS POTENTIAL IMPACTS TO LAKE FROM FEEDLOT FECAL COLIFORM

One type of fecal coliform that can potentially make a person sick is *E. coli*. While most strains of *E. coli* are harmless, a few may lead to stomach cramping, diarrhea, vomiting, and/or general nausea.

The MPCA has set water quality standards for both fecal coliform and for E. *coli* separately. In order to compare lake water to standards, a minimum of five samples per month is required over at least three months of the open water season. Provided that frequent enough samples are collected, impairment can be determine in one of two ways: (1) waters with a geometric mean of 200 colony forming units (CFU) per 100 ml and/or 126 CFU per 100 ml for E. coli would be cause for concern; or (2) not more than 10% of samples should contain more than 1000 fecal coliform CFU per 100 ml and/or 1260 *E. coli* CFU per 100 ml.

Given the number of feedlots in the lakeshed doing a solid year of fecal coliform and *E. coli* testing can help to as-

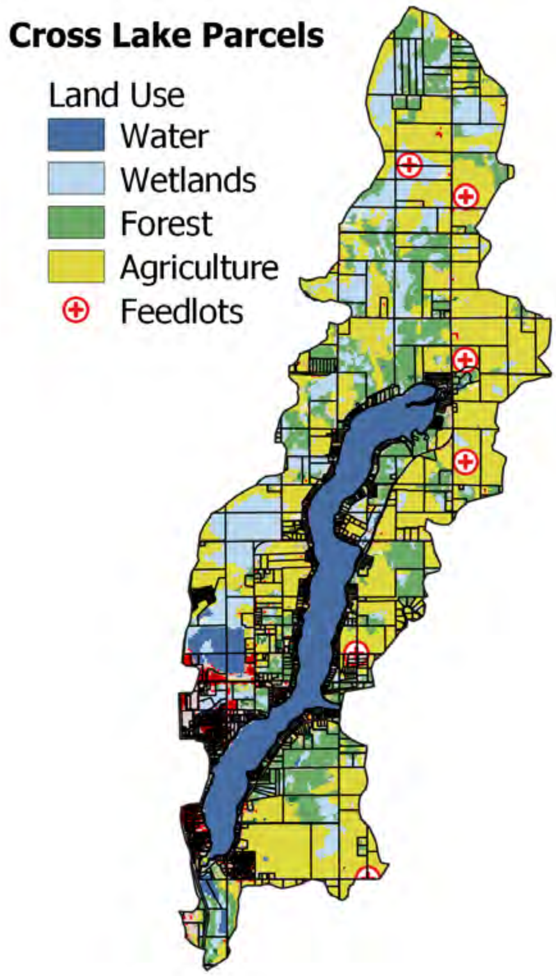



*Fig. 12. Parcel boundaries in the directly contributing lakeshed for Cross Lake. Overlaid on land use.*

sess the potential impacts those feedlots are having on the lake. Areas for assessment would be points of inflow to the lake, and any area where people spend a large amount of time in contact with the water (e.g., beaches).

Impervious surfaces of developed regions impact water quality by carrying increased quantities of water and nutrients to surface waters due to little being absorbed by soil or vegetation. These areas are primarily cities but include industrial parks, residential neighborhoods, and roadways. Total land cover for developed land is 4% in the lakeshed and consisting primarily of roads and cities. The largest cities are Pine City and Mora, with the former being in direct proximity to Cross Lake.

**Lakeshed Property Owners**

The direct watershed to Cross Lake is composed of 1,621 taxable parcels owned by 1,199 different entities. The majority of the parcels (61%) are less than 1 acre in size. Less than 60 owners claim 50% of the taxable land (Fig. 12).

Many larger parcels appear to be used agriculturally. These parcels and their owners may be good candidates for partnering with the Minnesota Department of Agriculture (MDA) in the Minnesota Agricultural Water Quality Certification Program.

The MAWQCP is a program where agricultural producers work with the MDA and agree to implement certain management practices to improve the quality of water leaving farmland toward lakes. Certain incentives are offered to producers in exchange for compliance with the goal of delivering fewer nutrients to local waterbodies. The program manager is Brad Redlin (brad.redlin@state.mn.us or 651-201-6489) and lake associations interested in working with the MDA to reach out

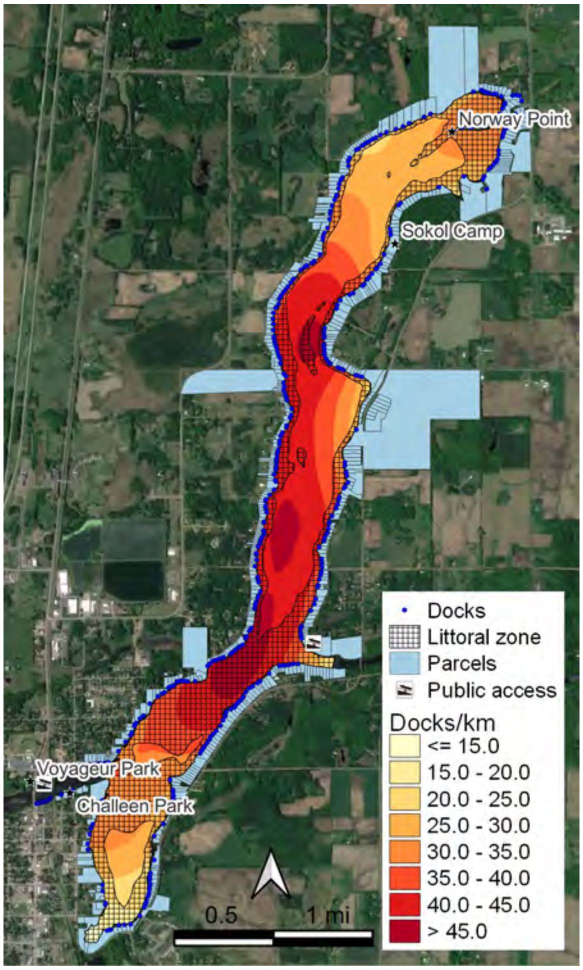



*Fig. 13. Estimate for usage density and locations of interest. Gradient of color on the map is expected least used (yellow) to most used (red) portion of the lake based on dock densities. The 15 ft depth contour is shown to provide some insight to where plants may be growing (i.e., < 15 ft).*

to local producers are encouraged to contact him.

**MANAGEMENT OBJECTIVE #5**

CONNECT LOCAL FARMERS TO MDA MAWQCP PROGRAM

Of the 1,621 parcels in the lakeshed, 544 (~34%) of them have shoreline dwellings on the Lake. Currently, residential development is along the majority of the shoreline.

The lakeshore has several other points of interest, including two public access points, one on the eastern side by the outlet and a second on the Snake River by the inlet. There are multiple parks along the lakes that offer fishing piers and carry-in opportunities. There are also a series of docks open to the public called the "5th Street Docks" that offer free boat parking for users to get into town or delivery options. A summer camp, Sokol Camp, exists on the northwestern side.

Often management decisions are done to provide the greatest benefit to the most users when finite resources are used to address problems. Where to implement management activities such as plant control often has a spatial component to it. We provide a mapping of potential intensity of lake usage by creating a heat map of lake usage based on digitized docks from satellite photography. The heatmap provides the number of docks within 1 kilometer. We also provide estimated navigational channels based on probable paths through lake. While none of this is exact and admittedly based on some subjectivity, it does provide some information about possible lake usage intensity (Fig. 13).

There is also a fair amount of public lands within the watershed. There are

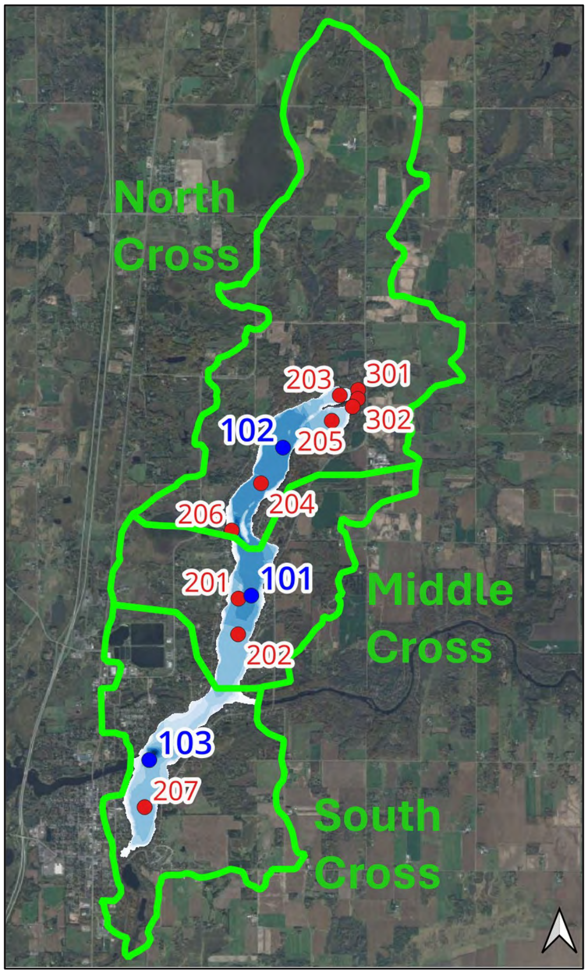



*Fig. 14. Cross Lake basins with historical MPCA sampling sites. Site points colored in blue are recommended for annual monitoring going forward as representative of the deep portion for each basin.*

three state forests with portions either entirely within or with portions within the lakeshed. The Solana State Forest has 41,708 acres within the lakeshed while the Rum River State Forest totals 19,216 acres within the lakeshed. The Snake River State Forest is entirely within the lakeshed totaling 9,463 acres. Additionally, there are 40,718 acres of state managed Wildlife Management Areas (WMA) and 204 acres on Aquatic Management Areas (AMA) in the Lakeshed with 16 acres directly bordering Cross Lake. WMA's are state managed lands or waters that are open to the public for hunting, trapping, fishing and various other recreational activities. AMA's are also state managed areas along the shoreline that are open for public use, primarily for fishing. They typically are for the purpose of preserving shoreline habitat as well as providing access for anglers along shore.

## *CHAPTER 4*
## LAKE MORPHOLOGY

### Overview

By "lake morphology" we mean the shape of the lake. A number of different characteristics of the shape of a lake can impact water quality, fish habitat, and plant densities both directly (i.e., the actual shape of the lake) and indirectly through the influence of the shape of the lakes on how they hold temperature and oxygen.

Wenck (2014) indicated that Cross Lake has three separate basins that behave very differently from one another . The south portion of the lake acts more like a flow-through than an actual lake and may be better considered a swelling of the snake river (Fig. 14). Water moves quickly through the southern portion as it enters from Snake River inlet and exists at the outlet. Water generally flows from the north basin to a middle basin to the south and out.

*Table 1. Cross Lake basin bathymetry.*

| Parameter | Cross - All | South Cross | Middle Cross | North Cross |
|---|---|---|---|---|
| Surface area (acres) | 924 | 311 | 269 | 344 |
| Average depth (ft) | 13.8 | 10.4 | 15.5 | 15.7 |
| Maximum depth (ft) | 30 | 30 | 22 | 27 |
| Volume (ac-ft) | 12,807 | 3,238 | 4,171 | 5,398 |
| Residence time (years) | 0.02 | 0.01 | 0.8 | 1.45 |
| Littoral area (acres) | 472 | 57 | 198 | 217 |
| Littoral area (%) | 51% | 18% | 73% | 63% |
| Watershed (acres) | 618,806 | 613,563 | 1,470 | 3,773 |

Based on these different basin morphometries, for the remainder of the report the three different basins will be described as North Cross, Middle Cross, and South Cross Basins, respectively. As described below the differences in the morphometries of each have impacts on a variety of lake characteristics including water quality.

**Bathymetry**

"Bathymetry" is a term used in lake science to describe features of the lake bottom. Generally the term is synonymous with measurements of depth. Depth maps were produced by the MN DNR in 1986. The MN DNR estimated a mean depth of 13.8 feet with a maximum depth of 30 feet. The mapping effort estimated 924 acres with 472 acres (51%) classified as littoral (Table 1).

The littoral zone is the area of the lake over which light penetration is expected to be deep enough to allow for rooted plant growth. While the actual maximum depth for plant growth is a function of water clarity, for purposes of standardization, the MN DNR uses a 15 foot cutoff. A 2017 survey by Wenck and a 2021 survey by Limnopro indicate that plant growth is limited to less than 10 feet. This dept is less than expected but consistent for lakes with poor water quality.

**Lake Stratification**

Lake morphology, including maximum depth, has an impact on stratification of vertical water columns through the year, which directly influences nutrient availability and subsequently algae concentrations through the year.

Cold water becomes increasingly heavier than warm water until it reaches 39 $^{o}$F at which point it starts to lighten up until ice is formed at 32 $^{o}$F (Fig. 15) This water-temperature relationship has important impacts to the lake environment over a given year and is the cause of a phenomenon known as "stratification" that is common in lakes.

This leads to seasonal cycles with isothermal (same temperature from top to

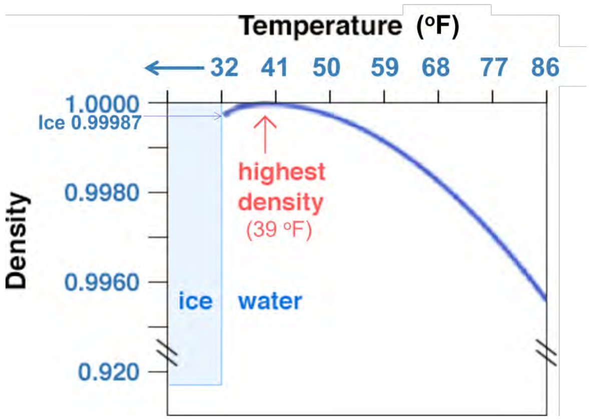



*Fig. 15. Density of water relative to temperature. Density is the weight of a fixed volume of water (e.g., 1 liter) and here scaled to maximum equal to 1. Once froze the density of water does not change no matter hold cold it gets.*

bottom) for a brief period at ice-out, to summer stratification (i.e., warm water develops on top of cold water, to fall turnover when the lake becomes isothermal again late in the year, to winter stratification (i.e., colder water sits on top of cold water).

During periods of stratification, layers or "strata" of water are divided by a thermocline (i.e., a small area of rapid temperature decrease). The upper layer is called the "epilimnion" and the lower layer is called the "hypolimnion". The area between the epilimnion and hypolimnion with a thermocline is called the "metalimnion" which means "between the layers".

During summer stratification, wind mixes oxygen into the epilimnion but deeper areas of the lake are not affected by physical impacts of wind turbulence. As such, oxygen does not get mixed in the lower layer hypolimnion. Additionally, the thermocline creates a density barrier that keeps oxygen from mixing top to the bottom (Fig. 16).

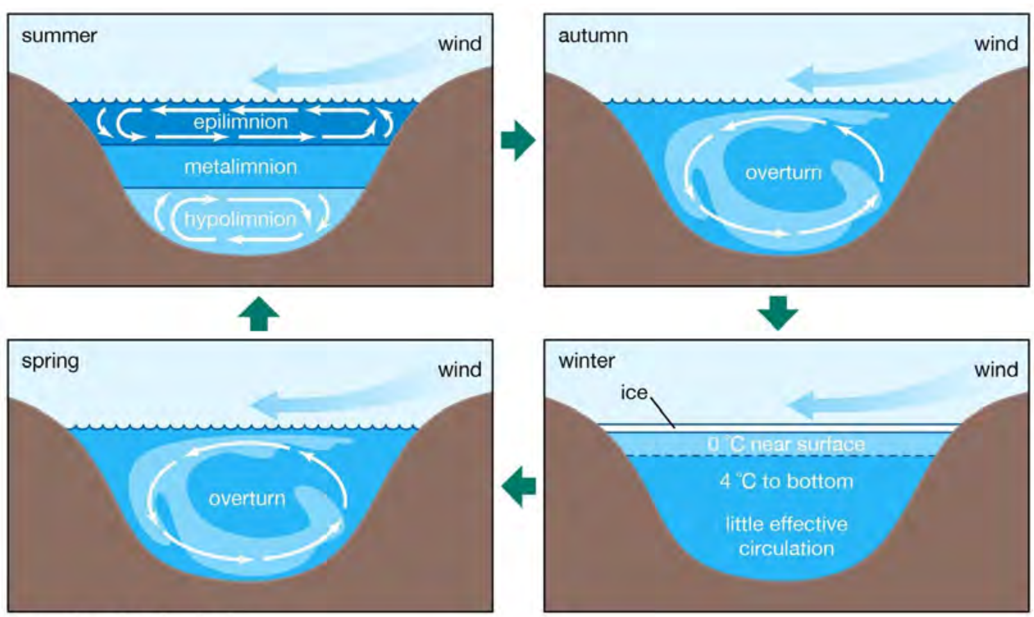





*Fig. 16. Illustration on how differences in temperature in lake layers leads to stratification events. Of importance is that during stratification, epilimnion becomes separated from the hypolimnion preventing the circulation of oxygen to lower water layers.*

While the supply of oxygen to the hypolimnion is cut off, the demand for oxygen remains high, and in fact increases over the summer. As algae, zooplankton, and fish die during the summer, they sink into the hypolimnion where bacteria break them down, using oxygen while they do so. The result is a buildup of available nutrients and low to no oxygen near the bottom.

This general process can also occur during Because ice covers the lake, there is no chance for oxygen from the air to get into the lake to replace the used up oxygen. During years with little snow cover and good clear ice, plants and algae will photosynthesize and in the process introduce oxygen (i.e., oxygen is a byproduct of photosynthesis). Photosynthesis requires light getting into the water, so during years with much snow covering the ice, little gets introduced that way. This can sometimes lead to low enough oxygen where there are fish kills.

Lake scientists call these mixing events "mixis" and classify lakes, in part, based on how many times mixing occurs during a year.

Deeper lakes in Minnesota mix twice in a year, once at ice out and again during lake fall when temperatures drop in the lake. These lakes are said to be "dimictic" or twice mixed. An important characteristic of dimictic lakes is that they stratify once during the open water season and stay stratified through the summer. Both during spring and fall turnover, built up concentrations of nutrients get mixed throughout the lakes, which can feed algae growth for prolonged periods of time.

Shallower lakes behave a little differently. Because wind is generally able to generate enough force deep enough to keep the lake mixed during the summer, what will happen is there will be temporary stratification events that happen many times over the year, particularly during periods of calm, warm weather. Anyone that spends time swimming in lakes feels the cold deeper water deep compared to the top layer of water. Lakes that setup to stratify many times during the year and then get mixed are called "polymictic", or "many mixing events". Even in deep lakes, shallower areas can be polymictic even when deeper areas act dimictically.

Depth profiles for oxygen and temperature data are published with MPCA at varying locations for multiple years; 1994, 2006, 2007, 2008, 2009, 2010, and 2018. For reasons discussed below, having good temperature and oxygen profile data are important for making some management decisions (Fig. 17).

Using the depth profile data, we estimated the area and location of the lake that may be subject to periods of anoxia during the summer (Fig. 18). Anoxic

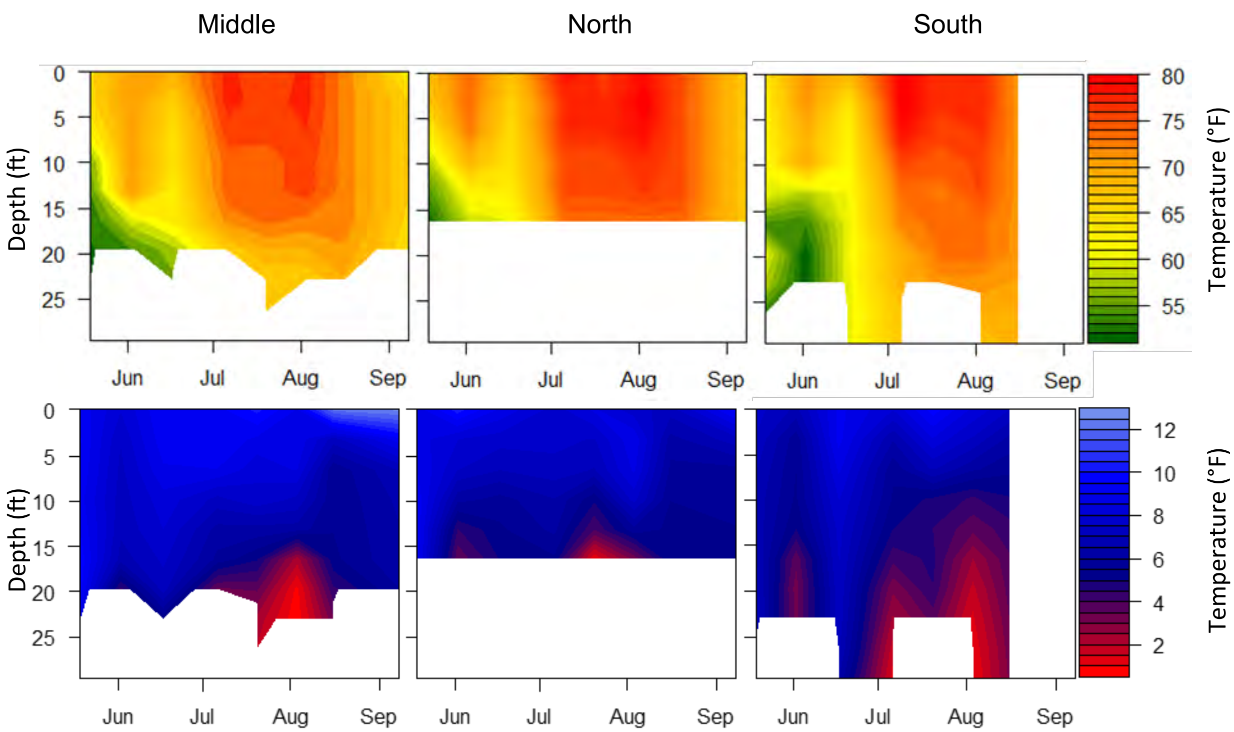



*Fig. 17. Oxygen and temperature profiles during open water season (i.e., June through September) from 2010 at three separate locations in Cross Lake. Oxygen stress generally begins to occur around 2 mg/l. White areas on the bottom of the graphs indicate no data.*

lake sediments release phosphorus, which stimulates algae growth (see below). Low oxygen (< 3.5 mg/L) near the bottom of the lake also restricts fish from those areas.

We determined the average depth of anoxia based on existing data to occur at roughly 20 feet. The zone of potential anoxia then was estimated using a depth map and using the 20 foot contour line where we found 218 acres where there may be anoxia on any given year. Given all data, bottom hypoxia is fully set up by 18 July and persists through August 3 for a period of 17 days.

Given the majority of this data is rela-

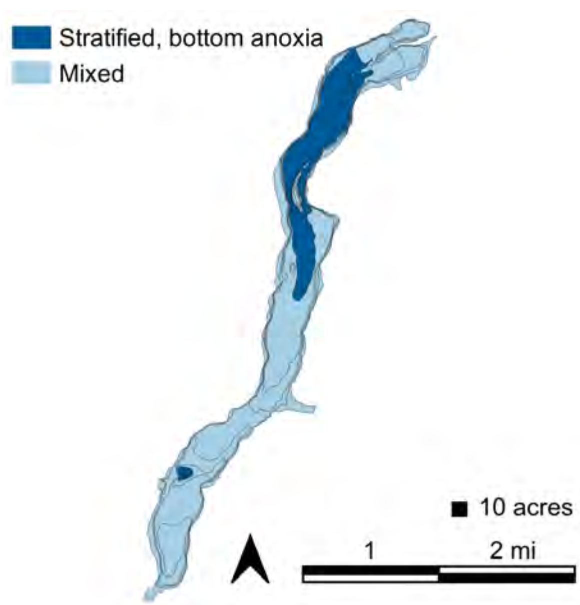



*Fig. 18. Estimation of areas on Cross Lake that seasonally stratify and might be classified as dimictic. Areas marked "mixed" likely act as polymictic zones.*

tively dated, additional monitoring should occur to improve estimates of internal loading. The association might purchase a dissolved oxygen meter and take regular readings through the open water season. A quality dissolved oxygen meter can be purchased for between $1,500-$2,000 and volunteers can easily be trained to collect data. An industry standard and unit we use is the YSI Pro20 Dissolved Oxygen meter with galvanic probe although there are other high quality instruments. A cable will be need to be purchased that can reach the bottom at the deepest depth. For Cross Lake, a 10 meter (~32.8 feet) cable should be sufficient.

Our recommendation would be to collect dissolved oxygen and temperature profiles at 1 meter increments at each of the deep points in the three separate basins between May and October each year. This tool could also help with fish management as it can be used to monitor under ice conditions in the winter that may indicate fish kills (see below).

**MANAGEMENT OBJECTIVE #6**

COLLECT MONTHLY DISSOLVED OXYGEN/TEMPERATURE PROFILES ANNUALLY TO SUPPORT NUTRIENT MANGEMENT GOALS

The discussion of mixis is not merely academic as it directly influences water quality due to its impact on oxygen dynamics and internal loading of nutrients, which according to Wenck (2014) TMDL is the major source of phosphorus and thus contributor to poor water quality it the lake.

**Lake Levels**

Cross Lake has its water levels maintained by a dam in the outlet structure along the Snake River. The snake River serves as the main inflow into Cross Lake, which could be thought of as a wide spot in the river.

Water level measurements exist sparingly in various years from 1962 to 2004. In years where measurements do exist they range from daily to monthly. Good water level data are important for constructing water and nutrient budgets.

Based on the limited data available, the single lowest readings reading occurred on 7/23/1963 at 931.16 feet above sea level (fasl) and the highest single reading occurred on 4/19/1965 at 939.08 fasl. Many of the highest readings are from 1965, when major flooding was present in Minnesota. The 19 lowest recorded levels are all from 1963 prior to the dam modification.

In 2019, we had the highest precipitation ever recorded in Minnesota for a year going back to the late 1800’s. Starting in 2020 and into 2021 and 2022 water levels were lower and normal to below normal. This has caused reductions in water levels across the state which can lead to increased nutrient concentrations. While we do not have direct monitoring data likely Cross Lake levels have been lower than normal.

Seasonal patterns (i.e., within year) for most Minnesota lakes during most years, have water-levels hit a maximum during April following spring thaw before gradually drawing down for the rest of the open water season as evaporation rates are greater than precipitation. As temperatures cool into autumn, water levels will rise again as precipitation rates become higher than evaporation rates.

Water levels are not only important from the perspective of land owners who seek not to be flooded yet have enough water to provide access to the lake, but water levels directly have an impact on both water quality and plant growth. High water levels dilute nutrient concentrations so that water quality tends to be improved when high water persists and generally fewer plants grow because the distance light must travel through the water to the bottom increases. The converse is true under conditions of lower water. Nutrients are concentrated, so water quality decreases and more plants grow as light has shorter distance to travel to the bottom.

We recommend purchasing a water level logger that can autonomously record data once per day or even more frequently. We use HOBO U20 loggers sold by Onset at a cost of approximately $400. Limnopro can do data management or the association could purchase an entire kit (KIT-S-U20-01) with shuttle and necessary software for approximate $800.

**MANAGEMENT OBJECTIVE #7**

PURCHASE AND IMPLEMENT A WATERLEVEL LOGGER FOR ESTIMATING RESERVIOR VOLUME IN SUPPORT OF NUTRIENT MANAGEMENT

## *CHAPTER 5*

## WATER QUALITY

### Overview

The term "water quality" can be ambiguous because quality is a subjective measure; however, by "water quality" most people mean to judge how clear the lake is at any given time.

### Secchi Depth Water Clarity

The clarity of water can be measured inexpensively using a Secchi disk, a black and white disk of a standard size that is used to judge transparency (Fig. 19). The deeper in the water the Secchi disk can be seen, the higher the quality of the water is determined to be.

Impairment for aquatic recreation essentially says that the MPCA has deemed the lake to not be suitable for swimming, although the MPCA also includes "other recreational uses" as a

*Table 2 Minnesota impaired water's thresholds by Ecoregion. Red asterisk indicates the classification given to Cross Lake by the MPCA, which is a Class 2B NCHF lake.*

| Ecoregion | Resource | TP (ug/l) | Chl a (ug/l) | Secchi (feet) |
|---|---|---|---|---|
| Northern Lakes and Forests | Lake Trout Lakes, Class 2A | 12 | 3 | 15.7 |
| | Trout Lakes (non-Lake Trout), Class 2A | 20 | 6 | 8.2 |
| | Aquatic Life and Recreation, Class 2B | 30 | 9 | 6.6 |
| North Central Hardwood Forests | Trout Lakes (non-Lake Trout), Class 2A | 20 | 6 | 8.2 |
| | Aquatic Life and Recreation, Class 2B * | 40 | 14 | 4.6 |
| | Aquatic Life and Recreation, Shallow Lakes, Class 2B | 60 | 20 | 3.3 |
| Western Corn Belt Plans & Northern Glaciated Plains | Aquatic Life and Recreation, Class 2B | 65 | 22 | 3.0 |
| | Aquatic Life and Recreation, Shallow Lakes, Class 2B | 90 | 30 | 2.3 |

criteria. For lakes that share the same ecoregion as Cross Lake (i.e., North Central Hardwood Forest Ecoregion), the Secchi depth threshold is 4.6 feet (Table 2). In other words, if the lake consistently shows Secchi depth measurements less than 4.6 feet, it has poorer water quality than expected. The MPCA has determined that it can be better.

*Fig. 19. Secchi disk (top) is used to judge water clarity through Secchi depth readings (bottom) off the side of the boat. Lakes with high water quality are transparent and as such have deep Secchi depth readings. Image source: Carleton University.*

**MANAGEMENT OBJECTIVE #8**

IMPROVE WATER CLARITY TO INCRASE ABOVE THE MPCA IMPAIRED THRESHOLD OF 4.6 FT

Cross Lake does not have many measurements within the last 10 years, but for measurements since 2006 the average June through September Secchi depth is 3.6 feet and has not met the standard during any year (Fig. 20).

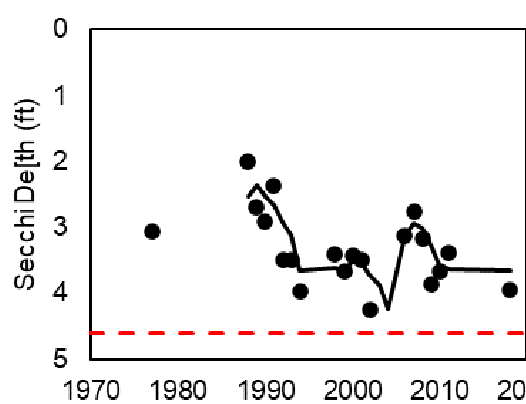



*Fig. 20. Cross Lake Secchi depth record. Black points indicate average values during the summer months (June-Sept). Solid lines are the 3-year average. Dashed red line is the impaired waters threshold at 4.6 feet.*

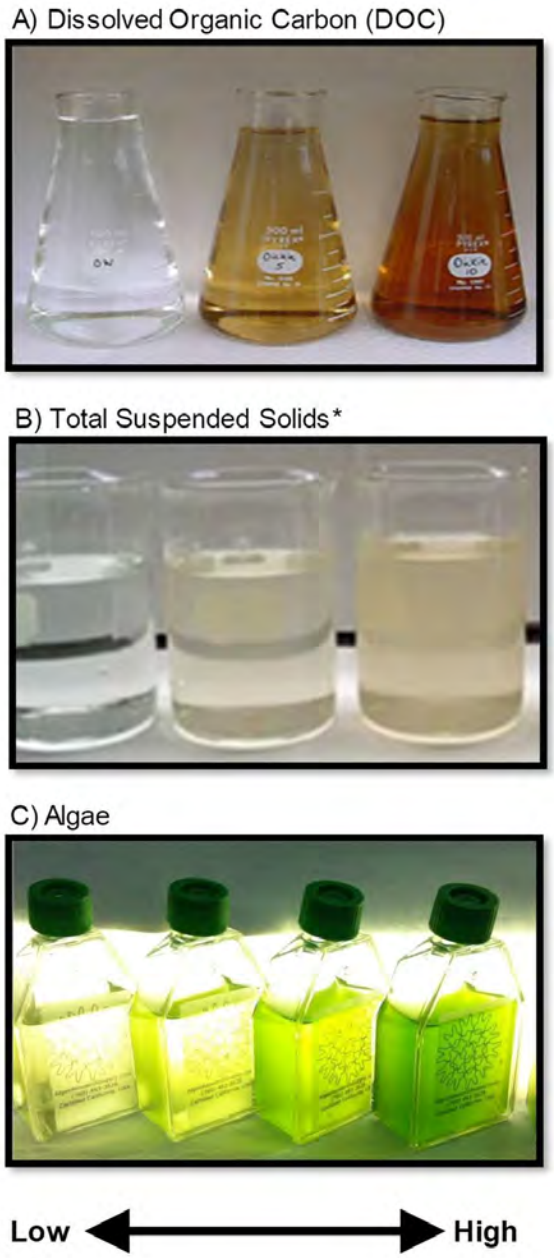



*Fig. 21. Contributing factors to decreased water clarity as measured by Secchi depth. TSS includes algae and all other particulate matter such as sand, silt, and clay.*

As part of the MPCA's Citizen Volunteer Lakes Program, of which Cross Lake has contributed to infrequently over the years, users judge the water subjectively during times the take Secchi depth readings. According to these data, users on Cross Lake perceive water quality as "Good" when Secchi depths are above four feet (Table 3).

Based on the 2023 Lake User Opinion Survey, the majority of users indicated that water clarity has remained relatively constant (33%) or only declining slightly (36%) in recent years.

Water clarity reflects the color and concentration of particles in the water. Lakes lose clarity when they gain dissolved organic carbon (DOC), suspended sediments, and algae (Fig. 21). As any of these increases, water becomes less clear, or more turbid.

DOC stains water brownish, which follows mainly from color releasing from decaying plant material in much the same way that color is introduced to brewed tea. DOC is an important contributor to water clarity in northern Minnesota lakes but likely less so in the central Minnesota lakes area. DOC is a chemical that can be analyzed from water samples if lake groups suspected it

*Table 3. Cross Lake user perception survey of water quality based on Secchi depth from the MPCA Citizen Volunteer Monitoring Program.*

| Rank | Rating | Secchi (ft) |
|---|---|---|
| 1 | Very Good | 6.9 |
| 2 | Good | 4.0 |
| 3 | Fair | 3.5 |
| 4 | Poor | 2.6 |
| 5 | Very Poor | 2.3 |

*Fig. 22. Typical algae collected from lake water magnified under a microscope by 200 times.*

was an important contributor to deteriorated water quality. Even though there is not much to be done with high DOC, if it is the primary reason for poor water quality, strategies for nutrient reductions (see below) likely will provide little relief. So, in that sense it may be good to rule out as a cause of low water clarity.

There are no DOC data available through the MPCA but it can be inferred with true color measurements taken. True color measurements from 1994 would indicate that Cross Lake is dark in color due to organic material.

Suspended sediments are particles and debris that clouds water. They are the clay, sand, silt, mud and even dead or decaying parts of organisms that get disturbed from the lake bottom. Water samples can be analyzed for "total suspended sediments" (TSS) and "volatile suspended sediments" (VSS) and/or by difference "nonvolatile suspended sediments" (TSS - VSS = NVSS). VSS represents the organic portion (i.e., algae, zooplankton and bacteria – live or dead). The proportion of TSS truly inorganic (i.e., sediments) is the NVSS.

There are also not enough data on suspended solids to make any conclusions about it, though the data that does exist suggests a strong relationship. Given that there is a major river that directly flows into Cross Lake, suspended sediments could be a contributor to low clarity and it may be worthwhile to collect water samples. Unlike DOC, however, suspended sediments can be managed against with a variety of watershed BMP's.

We do note that is no impairment for TSS reported for in the Wenck 2014 TMDL, but the MPCA has noted that suspended solids can elevate quickly for brief periods during rain events.

Speculation would lead us to consider that the primary cause of a period of low clarity would be chlorophyll as this is the case for most MN lakes. As such, for managing water quality, in general there is more focus placed on reducing algae chronically and frequency of algal blooms over a given year.

### Algae and Chlorophyll *a*

Algae are microscopic photosynthetic organisms that are a primary cause of water turning greenish (Fig. 22). The green coloring comes from a pigment

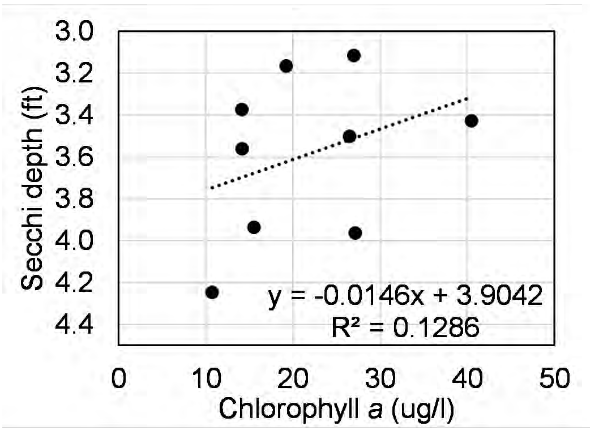



*Fig. 23. The relationship between algae as measured by chlorophyll a and Secchi depth as a measure of water clarity for Cross Lake.*

within the algae cells called chlorophyll *a*. There is a direct relationship between the amount of chlorophyll *a* and algae in water.

Chlorophyll *a* is relatively simple to analyze using standard water chemistry techniques while algae counts and biomass measurements are laborious and time consuming. Subsequently, chlorophyll *a* becomes a substitute for measuring the amount of algae in a lake.

For times when both chlorophyll *a* and Secchi depth are measured we find that water clarity at any given time is related to how much algae is growing in a predictable way but the relationship is weak and there is more variability than we might expect but data are poor (Fig. 23). The variability could also be explained by the characteristic differences between the north and south basins on Cross Lake. For example, the southern basin has a much shorter residence time due to the flow through of the Snake River and there is little to no relationship between chlorophyll and Secchi depth in the deep basin. For sample sites in the northern portion with longer residence times the relationship is stronger. The variability is likely a factor of both sediment and residence time influences of the Snake River.

The relationship between chlorophyll *a* and Secchi depth being weak suggests that suspended solids in the water may also be contributing to water clarity, but more data are required to gain confidence in that statement.

Cross Lake's summer average chlorophyll concentration since 2006 is 20 ug/l, which is higher than the NCHF ecoregion relevant standard for Cross Lake, which is 14 ug/l (Fig. 24). There are no recent data exist to determine whether the lake is impaired by algae.

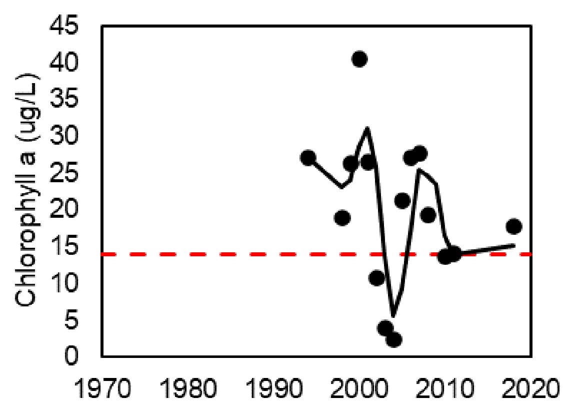



*Fig. 24. Cross Lake chlorophyll a record. Black points indicate average values during the summer months (June-Sept). Solid lines indicate the 3-year moving average. Dashed red line is the impaired waters threshold for NCHF Ecoregion at 14 ug/L.*

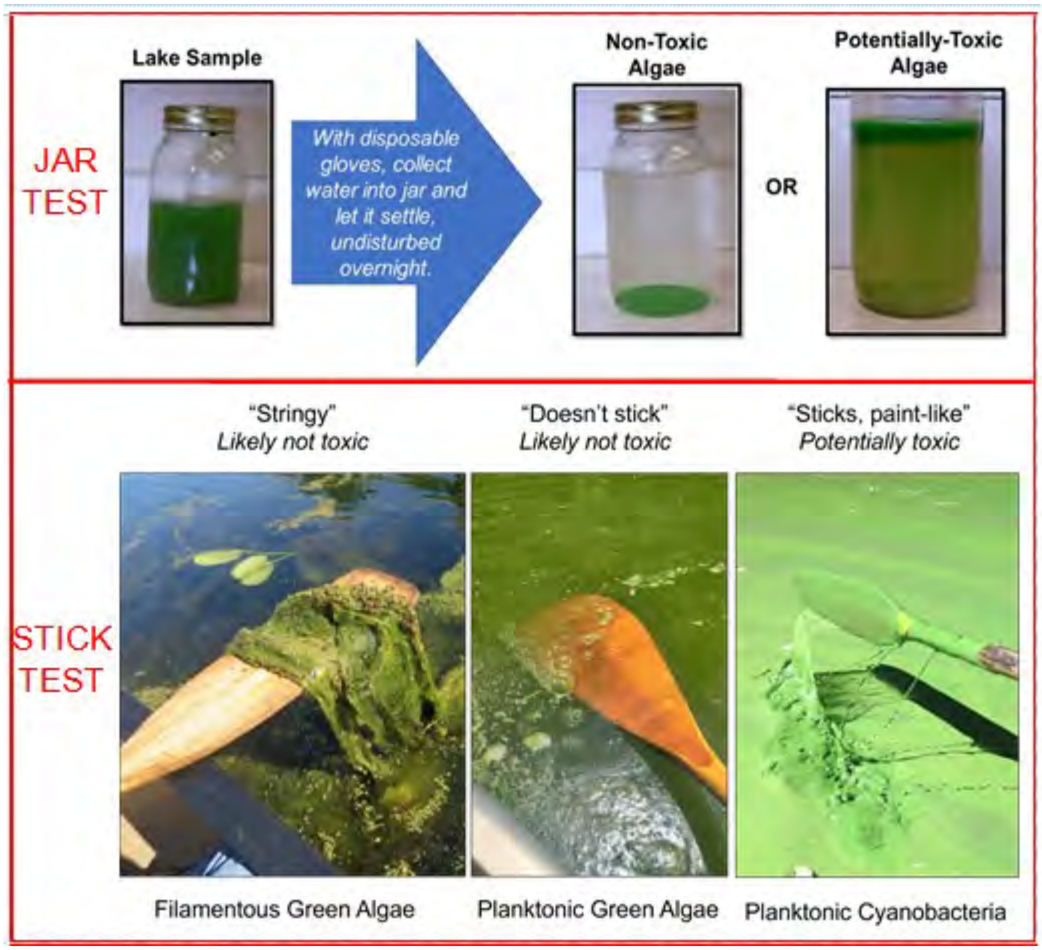



*Fig. 25. The "jar test" (top) to determine likelihood that an algal bloom is potentially toxic. Collect a sample of the bloom, being sure to wear disposable gloves and place in a refrigerator overnight. If when checking the jar after 24 hours, there is a clear layering at the bottom, it islikely not toxic. If the layer floats to the top, it is potentially toxic. If the lake sample does not produce layering, transfer a small amount of the water to a new jar and fill with regular waterto dilute it. Repeat until you see layering. The "stick (or paddle) test" (bottom) to determined whether a surface scum of algae is potentially toxic. If the algae pulled up stays on the stick and hangs off, it is likely non-toxic. If the stick moves through the scum and you pull it out and no algae sticks to the stick, it is likely nontoxic. If you pull it through the water and it appears to be covered like a paint, it may be toxic.*

**MANAGEMENT OBJECTIVE #9**

REDUCE CHLOROPHYLL A MEASURE LESS THAN THE MPCA IMPAIRED THRESHOLD OF 14 PPB ON AVERAGE OVER THE SUMMER.

According to the administered 2023 Lake User Opinion Survey 62% say that high or severe algae levels were impacting their perception of water quality and 82% experienced problems with algae blooms.

The generally accepted threshold of 30 ug/l chlorophyll *a* identifies what is considered an "algae bloom". All data available indicate that the lake reaches this threshold roughly 25% of the summer and primarily in the later portions during August or September.

Algae blooms may be not only unpleasing to look at but toxic and dangerous if persons (or pets) come into direct contact with the water such as occurs during water skiing, jet skiing, tubing, and etc. These types of algae are referred to as harmful algae blooms (HABs), and are a current point of interest for the MPCA and lake management science. Visual evidence of algae blooms at any point during the year should prompt caution about contacting water in Cross Lake. While microscopic assessment by trained workers is required to determine whether a particular alga is capable to producing toxins, lake volunteers can perform simple tests to determine whether certain blooms of algae are toxic forming groups by using the "jar" test and the "stick" test (Fig. 25). This works because HABs are actually photosynthetic bacteria and have a different structure than "regular" non-toxic green algae.

The amount of algae that can grow is determined by nutrients, primarily the availability of phosphorus in the water. Phosphorus drives algae growth, which drives water clarity.

Algae are produced when solar energy is used to put together nutrients in the water to build cells. While there are dozens of nutrients that are required to construct algae cells, phosphorus is considered a "limiting" nutrient. This means that the amount of algae (and subsequently chlorophyll *a*) is most often directly regulated by the amount of phosphorus in a lake.

One other contender for that role is nitrogen. These two nutrients are generally in shortest supply in the environment relative to demand for growing algae; however, it is phosphorus that we typically focus on unless there is strong evidence to the contrary for other causes.

Both nitrogen and phosphorus are used in agricultural fertilizers, but whereas nitrogen easily dissolves in water and is carried to the lake through run-off, phosphorus is sticky to the dirt. This means that less of it dissolves in water and reaches the lake so that lakes in general are phosphorus starved relative to other nutrients, including nitrogen.

**Phosphorus as a Limiting Nutrient**

Overall, based on available data, water quality as measured by Secchi depth, chlorophyll *a*, and total phosphorus would be considered poor by most objective measures on Cross Lake. This can be a consequence of multiple factors related to phosphorus inputs. The lake drains a large area and receives flow from multiple impaired waterbodies.

The impaired threshold for phosphorus in lakes of the NCHF ecoregion is 40 ug/l. The summer average since 2006

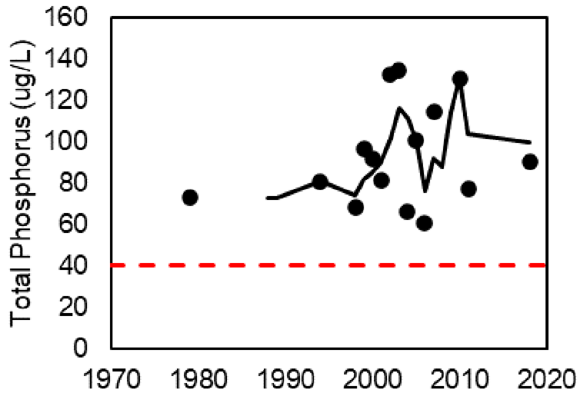



*Fig. 26. Cross Lake total phosphorus record. Black points indicate average values during the summer months (June-Sept). Solid lines indicate the 3-year moving average. Dashed red line is the impaired waters threshold 40 ug/l.*

has been 95 ug/l, and there is not a sampled year where the average is below the standard, but again recent data are scarce (Fig. 26).

**MANAGEMENT OBJECTIVE #10**

REDUCE TOTAL PHOSPHORUS SUCH THAT LEVELS MEASURE LESS THAN THE MPCA IMPAIRED THRESHOLD OF 40 PPB ON AVERAGE OVER THE SUMMER.

Given the central role of phosphorus in driving water quality conditions, one of the most important pieces of baseline data for evaluating for methods of remediation on a lake is a "phosphorus budget".

The MPCA attempts to construct phosphorus budgets for some of Minnesota's 10,000 lakes as part of larger watershed TMDLs. A Total Maximum Daily Load (TMDL) is a regulatory concept associated with the US Clean Water Act that aims to determine the maximum amount of phosphorus that can enter impaired waters such that the waterbody can still meet water quality standards.

While these provide some initial indication of phosphorus budget, the resolution and data used to determine these TMDLs might not have the sort of information that allows specific management activities for lakes, and as such specific lake phosphorus budgets are still useful. The MPCA aims to have TMDLs done for each of Minnesota's watersheds once every ten years. The MPCA awards the construction of TMDLs to engineering companies, and in the case of Snake River Watershed this was done by Wenck. The last approved TMDL for Snake River Watershed, which includes Cross Lake was in 2014. The next scheduled one is targeted to begin 2028.

A phosphorus budget identifies sources and sinks of the nutrient. In general, we divide phosphorus contributions to the lake into *external* and *internal* sources (Fig. 27). External sources of phosphorus to the lake includes amounts delivered by streams flowing into the lake, sheetflow runoff from the surround landscape, septic inputs,

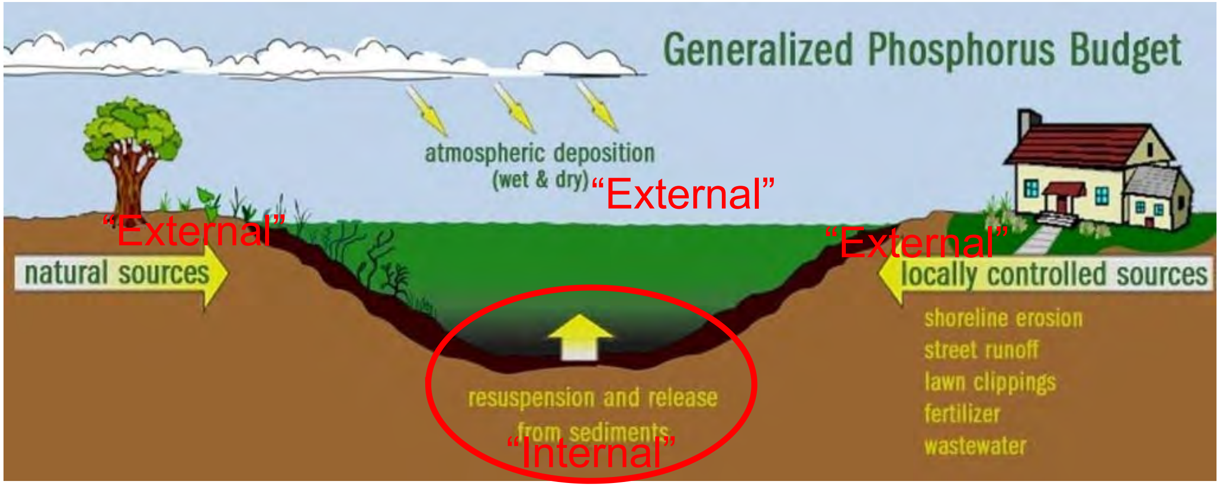



*Fig. 27. A generalized phosphorus budget for a lake showing differences between external and internal loadings. Image source: water on the web.*

groundwater flows, and nutrients delivered via precipitation and dryfall directly to the lake. Internal sources includes recycling of phosphorus into the water column from the lake sediment by chemical conditions, wind, pumping from rooted plants, release of from plants, particularly curlyleaf pondweed, and bottom stirring fish like carp and bullhead if they exist in the lake.

*External Phosphorus Sources*. During snow melt and precipitation events, some water will flow over the land in the watershed and move sediments that contain phosphorus, from the land, to the lakes. How much nutrients gets moved from land to the lakes depends on annual rainfall and land use types.

Forests and wetlands tend to absorb phosphorus in sediments, reducing the amount that flows to lakes. Agricultural and urban areas tend to allow more phosphorus to lakes.

Some phosphorus exists naturally in soils but it is a fertilizer that is often used in agricultural areas to improve crop production. The majority of runoff over land gets into lakes through stream inflows or sheetflow (i.e., water that moves across the landscape and dumps into the lake without first intercepting a stream). Tile line inputs might be considered additional sources but there is difficulty in knowing where precisely water collected to tile lines is coming from.

Finally, external sources of phosphorus also includes direct inputs to the lake from precipitation, dry deposition (e.g., insects or leaves blowing into the lake) and phosphorus from groundwater supplies. Generally all of these sources are dilute compared to what gets washed into the lake from stream inflow or surface sheet flow to the lake during precipitation events.

Wenke (2014) TMDL estimated external contributions of phosphorus to the

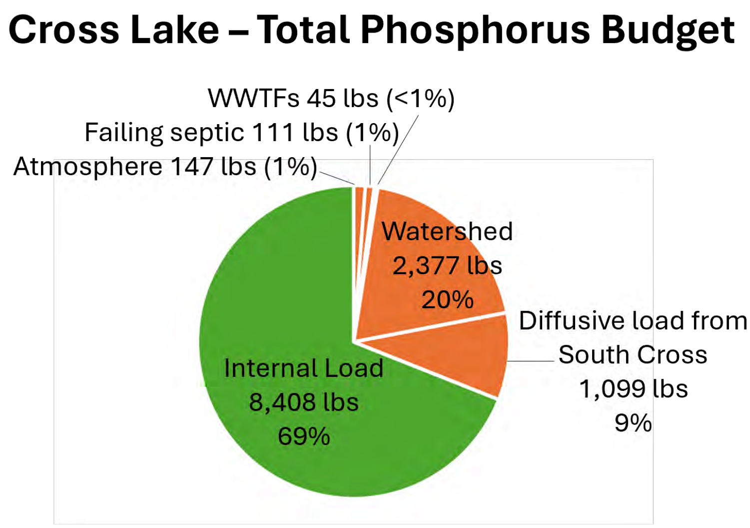



*Fig. 28. Annual loads of phosphorus to Cross Lake as determined in Wenck TMDL (2014). Loads are associated for North and Middle Cross Lake only. WWTF are loads for waste water treatment facilities. Diffusive load from South Cross can generally be thought of as contribution from Snake River. Orange slices are interpreted as "external" and green as "internal" sources.*

lake as being approximately 30%. Of note, they only budgeted for North and Middle Cross as a single unit with South Cross considered as a river expansion. Their model predicted approximately 20% of phosphorus getting into the lake over a year come directly from the watershed and another 9% coming into the two basins as diffusive flow from South Cross (Fig. 28).

Management efforts to control phosphorus from reaching the lake are generally referred to as *Best Management Practices*, or BMP's. There is an overwhelming literature that exists on BMP methods but most fall into one of two categories: methods to intercept and detain water or methods to filter water prior to it reaching the lake.

BMP's that detain water will hold it for a period of time to let sediment settle out prior to the "cleaned" water slowly making its way to the lake. Most common ways detention is done is through the construction or restoration of wetlands. Historically, wetlands have been drained in order to make land more amenable to agriculture.

Filtration methods have water flow through some medium that can potentially strip out nutrients prior to water reaching the lake. These are typically iron or lime filtration systems. Both effectively strip phosphorus out of oxygenated water as it flows through.

Given the obvious impact that the Snake River would have as an inflow to the system, consideration of filtering water prior to it dumping into South Cross Lake would be worthwhile as a

*Table 4. Summary of common best management practices (BMPs) for reducing external phosphorus to lakes. Source: Minnesota Stormwater Manual (2022).*

| BMP group | Ease of maintenance[a] | Construction cost | Nuisances |
|---|---|---|---|
| Bioretention | Medium | Medium | Mosquitoes<br>Overgrown vegetation |
| Filtration - media | Difficult | High | Filter media replacement<br>Underground practices not seen and maintained |
| Filtration - vegetative | Medium | High | Filter media replacement<br>Underground practices not seen and maintained |
| Infiltration trench | Difficult | High | Susceptible to failure if poorly installed or maintained |
| Infiltration basin | Medium | Medium | Susceptible to failure if poorly installed or maintained |
| Stormwater ponds | Easy to medium | Low | Geese<br>odors<br>Mosquitoes<br>Floatables |
| Constructed wetlands | Medium | Medium | Overgrown vegetation<br>Mosquitoes |
| Hydrodynamic devices | Medium | High | Underground practices not seen or maintained |
| Filtration devices | Difficult (expensive) | High | Underground practices not seen or maintained |

means to reduce external loading of phosphorus to the lake. Iron-sand filters are a common way to strip phosphorus from entering waters. Inputs from engineers will be required to determine whether this is feasible for the snake river inflow, even if upstream some distance.

**MANAGEMENT OBJECTIVE #11**

CONSIDER METHODS FOR INTERCEPTING PHOSPHORUS ENTERING CROSS LAKE FROM SNAKE RIVER INFLOW

The MPCA has created some excellent guidance on BMPs published in their Minnesota Stormwater Manual and available to the public at stormwater.pca.state.mn.us/index.php/Process_for_selecting_Best_Management_Practices (Table 4).

Regarding agricultural loads to the lake, it is important to recognize that while agricultural practices historically may have contributed a lot of nutrients as runoff to lakes, practices in agriculture have improved greatly and developments have led to more nutrients being kept from lakes.

*Internal Phosphorus Sources*. Internal sources of phosphorus are those that do not come directly from rain or stream flow but that have accumulated over time in lake sediments and get recycled in the lake. Lakes act as a net sink for phosphorus, meaning there are more nutrients that flow in externally than flows out of the lake.

Phosphorus that is stored in the lake's sediments can be recycled to the water column either directly through sedi-

*Table 5. Sediment chemistry as reported in Wenck (2014) TMDL for Cross Lake.*

| Parameter | South Cross | Middle Cross | North Cross |
|---|---|---|---|
| Oxic Release (mg/m$^2$/day) | NA | 1.8 | 0.5 |
| Anoxic Release (mg/m$^2$/day | 18.8 | 31.1 | 17.8 |
| Anoxic Factor (days) | 56 | 51 | 50 |
| Internal Load (lbs/day) | 3,612 | 5,196 | 3,212 |

ment loading or by being taken up into plants and then released when the plants die off for the year. Lakes with significant amounts of curlyleaf pondweed can also pump phosphorus from sediment to the water column as they grow and then die and decompose in early summer. Large populations of carp can also redistribute phosphorus from the bottom of the lake to the water column as they root around in the mud to feed. Following is a brief discussion of each of these three internal sources.

*Sediment Loading*. When there is abundant oxygen near the bottom sediments in the lake, the iron in the sediment holds on to phosphorus. This effectively removes it from being available in the water column to promote algae growth. During periods of the year, due to either temporary or permanent summer/winter stratification, when bottom of the lake loses its oxygen, a chemical reaction occurs where iron will release phosphorus back into the water column where it can be used by growing algae.

The cycle in the lake of having oxygen available sometimes but not others can act as a sort of pump that introduces additional phosphorus into the lake over and above that which enters externally. Even if all external pathways were shut down, many lakes would still struggle with poor water quality because of this pumping or "internal loading."

An important step in estimating the contribution of sediment loading to lakes is collecting lake bottom mud from the deepest areas of the lake to have them assessed for their ability to release phosphorus under anoxic conditions.

As part of the 2014 TMDL, Wenke had sediment cores collected and analyzed in each of the three basins of the lake, finding extraordinary high rates of anoxic release rates (Table 5). These are some of the highest rates, we have seen and likely indicate that internal loading is a significant problem for adding nutrients to the lake. The 2014 TMDL estimated that approximately 70% of the phosphorus in the lake that fuels algae growth comes from anoxic internal loading.

Lakes with notable internal loading

problems are sometimes managed with aluminum sulfate, or "alum", which works the same way as iron does except that its binding ability to phosphorus does not depend on how much oxygen is in the water.

Using alum to curb internal phosphorus loading is a well-tested but expensive management tool to implement, costing in the range of $2,000 - $3,000 per acre for whole lake treatments; however, in stratifying lakes like Cross, it is often not necessary to dose the entire lake but rather target areas of known anoxia, which requires knowing the size and location anoxic areas in the lakes.

*Aquatic Plant (Curlyleaf Pondweed) Contributions.* Aquatic plants are not limited by water nutrients but rather light. They get their nutrients from the sediment where they are plentiful.

While most plants will die and decompose during the later part of the year, releasing phosphorus when it is too cold to be well utilized for algal growth, the invasive curlyleaf pondweed is different. It can be a particularly high contributor to phosphorus because it dies off during the part of the year when it matters most around the first part of July at a time when water temperatures are optimal for algae growth.

Previous aquatic plant surveys indicate that curly leaf pondweed is in Cross Lake, but not dense or particularly abundant.

Efforts to control curlyleaf pondweed can have the potential impact of improving water quality. Methods for doing so are provided later in the chapter on aquatic plants.

*Carp Contributions.* Cross Lake has had carp since at least 1981. Carp are invasive fish species that are known to cause water quality problems due to their feeding behaviors. Carp eat aquatic plants and root around in the lake bottom for insects and other invertebrates. By destroying plants, roots are lost that would otherwise hold together sediments and keep phosphorus in the mud. As carp dig around in the mud for food, they also suspend sediments, add oxygen, and release some of the phosphorus from the lake.

Bajer et al. (2016) was able to make an estimate of a threshold of when a certain amount of carp in the lake may be a significant contributor to poor water quality. According to their research, the threshold is 89 lbs/acre. Some of their other research indicates that ideally carp should be controlled to be at less than 45 lbs/acre, and at 178 lbs/acre, most lakes cannot support the growth of any plants (Bajer 2017).

During 2022, the Cross Lake/Snake River Association hired Carp Solutions, a company that specializes in estimating carp populations in lake to determine the current conditions of the lake after observations were made by Limnopro during a routine aquatic plant survey that carp may be problematic.

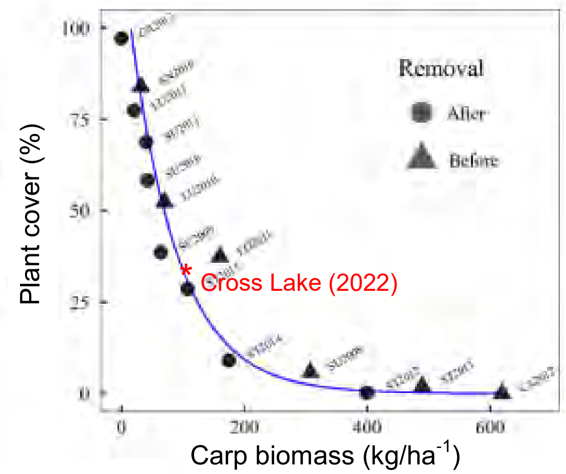



*Fig. 29. Relationship between carp biomass and plant cover in lakes as published by Bajer et al. (2016). Asterisk added shows position of Cross Lake for both plant coverage and carp biomass (101 lbs/acre = 113 kg/ha).*

They estimated Cross Lake carp biomass at 101 lbs/acre, which is between the thresholds of concern.

While Carp Solutions advised biomass was probably not high enough to warrant control, you might consider that given biomass is so close to the threshold, attempts to control now relative to waiting for biomass to increase would be easier. We would also make the point that given the nonlinearity of the relationship in Bajer et al. (2016) reducing biomass near the threshold had a larger impact on plant coverage and presumably water quality than controlling at the tails of the curve (Fig. 29).

It is worth noting that Cross Lake is a highly connected waterbody to other potential sources of carp, and any management strategy for carp would have to take into account the potential for populations from other lakes to migrate to available space in Cross Lake.

If management of carp is desired, the first effort should be to find spawning areas. Carp spawn in shallow wetland areas in the spring. Newly hatched fish will often remain in these wetland areas for their first couple years before migrating to the main lake body. Trap nets can be set in suspected areas to determine where reproduction might be occurring. Once spawning areas are found, methods can be designed to reduce recruitment, whether that includes barriers, drawdown, or other physical means of removal.

Carp Solutions estimates that no serious production of young has happened in awhile on Cross Lake and spawning likely happens elsewhere.

Bluegills are known predators to carp eggs and either stocking those or aerating wetlands so that bluegills can survive and may assist in controlling carp populations (e.g., Silbernagal and Sorensen 2013). In fact, lakes with healthy bluegill populations tend to have fewer problems overall with carp (Bajer 2017). Cross Lake has bluegill populations within the normal range.

Carp removal typical involves commercial fishers taking carp during the winter through the ice as carp are known to aggregate during that time. Alternatively, removing carp can be done with bait traps during the summer. In either case, it is important to target removal of

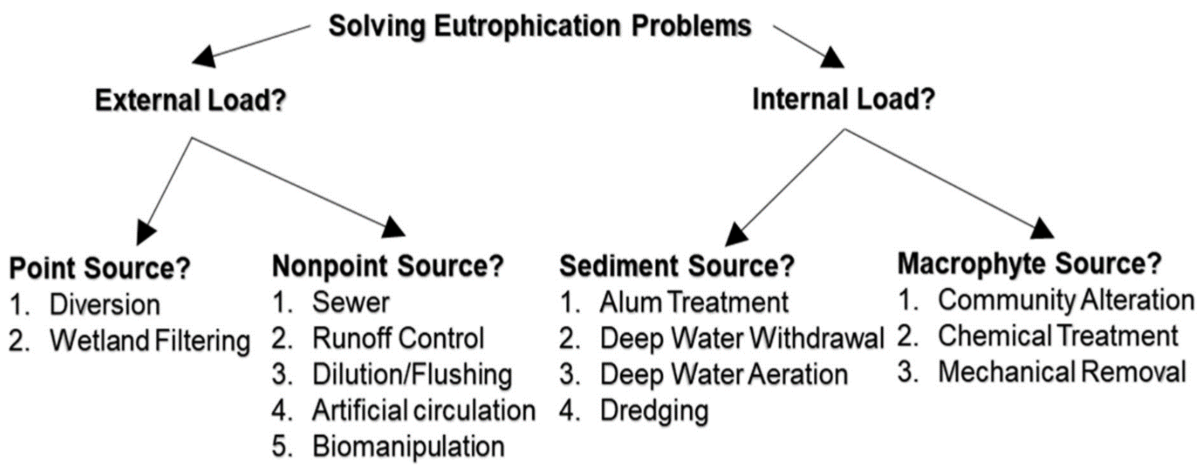



*Fig. 30. Common methods for lake restoration from eutrophication (modified from Cooke et al. 1993. Restoration and Management of Lakes and Reservoirs. Boca Raton: CRC Press,Inc.*

enough biomass to reduce populations below the threshold; otherwise, carp can quickly replace themselves through reproductive efforts.

A well done carp management program can be quite labor intensive and expensive, but the State of Minnesota provides some grant help with carp management through offerings of the Clean Water Fund monies administered by the Board of Water and Soil Resources (BWSR).

**MANAGEMENT OBJECTIVE #12**

REDUCE/ELIMINATE CARP IN CROSS LAKE

There are a number of different ways that phosphorus control can occur (Fig. 30). One of the important points for potential management of phosphorus in lakes is that overwhelmingly prioritizing internal management over external management will likely provide a more immediate lake response. This is because even if all external loading was cut off there can still be a lot of phosphorus already in the lake from runoff events over the last hundreds of years.

A number of research papers have discussed this point. For example, Osgood (2017) did a review of hundreds of lakes and phosphorus control activities and concluded that while most external reductions reduce phosphorus loads to the lake by less than 25%, over 80% load reductions are reduced to show a difference in lakes. He discusses how an 80% reduction in external loads is virtually impossible. At the same time, a number of studies indicate internal load reductions, principally using alum, can reduce water column loads by 80-95%.

*Table 6. Summary of common methods for reducing internal phosphorus to lakes. Source: MPCA State and Regional Gov Review of Internal Phosphorus Load Control (2020).*

| Type | Treatment | Lake morphology | Considerations |
|---|---|---|---|
| Chemical | Aluminum sulfate (alum) | shallow/deep | Whole lake treatments generally limited to smaller lakes (<500 acres). Larger lakes might require targeting of higher loading areas in the lake. Can also be added to tributary inflows. |
| | Lanthanum | shallow | Works well under anoxic conditions. Turbidity increases immediately after application - turbidity decreases after settling. Trade name is Phoslock. |
| Physical | Dredging | shallow | Goal to remove high phosphorus sediments. High cost and placement of dredged materials. Potentially toxic materials such as trace elments and organic pesticides need to be disposed. Can also be used to increase depth for recreation. |
| | Drawdown | shallow | Disposal of water from drawdown. Expensive, engineering costs. Manually removal accumulations of dead fish as basins are dewatered. Vegetation maintenance. |
| | Oxygen injection | deep | Costs for initial setup; sizing system to lake for desired effect. Maintenance and operation costs annually. Can create thin ice areas during winter. |
| | Hypolimnetic withdrawal | deep | Multiple options: withdrawal and return, withdrawal and discharge, withdrawal and treatment aned return; winter aeration causes ice instability. |
| | Hypolimnetic aeration | deep | Goal to eliminate the loss of oxygen, either by injecting oxygen or increasing mixing of water column. Can create thin ice areas in winter months. |
| | Circulation and aeration | shallow/deep | Can create tink ice conditions in winter months; used to prevent winterkill. |
| Biological | Carp control | shallow/deep | Phyisical fish capture and disposal are the primary cost drivers. Creative alternatives to the capture and disposal of carp will reduce costs. Requires consideration of barrier installation to prevent reintroduction. Reinstroduction of appropfirate fish and othe rrelated aquatic species should be considered when whole community removal is attempted. |
| | Mechanical aquatic plant removal | shallow/deep | A relatively short-term solution and targets invasive aquatic plants. Risk in spreading invasives plants by framentation or seeds. Harvesting programs are typically developed for recreational purposes; increase lake access. Limited phosphorus removal relative to the whole internal load. |

The MPCA recently came out with some guidance to manage internal loads of phosphorus to lakes. It contains a summary of the most common methods and their application (Table 6).

As foundational as phosphorus is to the behavior of the lake, and given the absence of lake specific nutrient budget, we recommend as a priority of 1-3 year lake specific phosphorus budget to be completed for the lake.

**MANAGEMENT OBJECTIVE #13**

COMPLETE AN UP-TO-DATE DETAILED PHOSPHORUS BUDGET

Completed alongside Wenck (2014) TMDL for the Snake River Watershed including Cross Lake was a regulatory document with the acronym “WRAPS”, which stands for “Watershed Restoration and Protection Strategy”. Watershed WRAPS and TMDLs are scheduled on a rotating basis on a targeted 10 year rotation. The TMDL and WRAPs were both approved by the MPCA in 2014, which means this year (2024) is the 10 year mark. Most recent schedules indicate that the Snake River is not scheduled for new TMDLs or WRAPS until 2028.

The WRAPS report provides specific goals and activities that are meant to reduce nutrient loads to lakes. We have reproduced portions of the WRAPS from 2014 that directly address nutrient reduction for Cross Lake (Table 7). Some of these goals have the Cross Lake/Snake River Association as an entity that is primarily responsible for, and of note, those activities are focused on “internal loading” piece of nutrient reduction, principally in managing sediment release of phosphorus to the lake and management of curlyleaf pondweed.

The primary responsibilities for managing watershed and external contributions of phosphorus to the lake are the Snake River Watershed Management Board (SRWMB) and the Soil of Water and Conservation District (SWCD). The WRAPS report has 10 year interim goals, which should be due this year (2024). We would recommend identifying responsible individuals at both SRWMB and SWCD to discuss progress on the goals. Without membership of Cross Lake/Snake River Association requiring some accountability for goals in the WRAPS plan, it is possible that all of the monitoring objectives and goals published in that document have made and will continue to make little progress toward completion. These reports and goal setting activities based on monitoring cost the state a lot of money and there is always a concern that the creation of planning documents stop at the planning process. We would recommend a lake association volunteer that can be a liaison between the lake association and the appropriate representatives of SRWMB and SWCD to ensure progress is being made on the WRAPS goals.

**MANAGEMENT OBJECTIVE #14**

APPOINT A LIASON TO SRWMB AND SWCD TO ENCOURAGE THEM TO WORK TOWARD WRAPS GOALS

### Water Quality Seasonally

Up to this point, we have focused on annual average conditions. Briefly we discuss how Secchi depth, chlorophyll *a*, and phosphorus dynamics occur over a typical open water season in Cross Lake (Fig. 31).

*Table 7. Strategies to work toward getting Cross Lake off of the impaired waters list. Target data for completion of activities is 2035 with 2024 interim goals. Table is reproduced from Snake River Watershed WRAPs (2014).*

| Strategies | Estimated Scale of Adoption Needed | SRWMB | SWCDs | County | City | NRCS | MPCA | DNR | Lake Association | Interim 10-yr (2024) Milestones |
|---|---|---|---|---|---|---|---|---|---|---|
| Livestock/pasture/feed lot management | Establish 3-6 livestock managed access control areas near streams | • | • | | | • | | | | Establish at least 3 access control areas |
| | Implement 2-4 pastureland runoff controls, and 2-4 buffers near streams | • | • | | | • | | | | Implement at least 2 pasture runoff controls or stream buffers |
| | Programs/funding for 2-4 feedlot runoff treatment, control and storage BMPs | • | • | | | • | | | | Implement at least 2 feedlot projects |
| Cropland and manure management | Promote/educate agronomic rates and chemical addition of manure. Work with 5-10 landowners on nutrient management and hold 2-4 workshops | • | • | | | • | | | | Work with 5 landowners on nutrient management and hold 2 nutrient management workshops |
| | Provide resources/education for soil nutrient testing and spreading in sensitive areas. Work with 5-10 on P spreading and send out at least 2-4 nutrient management mailings | • | • | | | • | | | | Work with at least 5 landowners on soil P and spreading. Send out at least 2 nutrient management mailings. |
| | Promote/educate conservation and reduced tillage methods. Conduct 2-4 reduced tillage workshops and work with at least 20 landowners | • | • | | | | | | | Conduct 2 reduced tillage workshops and work with at least 10 landowners |
| Septic system upgrades | ID and upgrade all ITPHS threat systems | • | • | • | | | | | | Identify and upgrade 40% of ITPHS systems in shoreland areas within 10 years |
| | ID and upgrade all non-conforming systems near streams/waterways | • | • | • | | | | | | Identify and upgrade 40% of failing systems near streams/water |
| In-lake sediment P release | In-lake sediment inactivation feasibility study and treatment for Cross Lake | • | • | | | | | | • | Complete feasibility study |
| Lake vegetation management | Adopt management plan for Cross Lake curlyleaf pondweed treatments | | | | | | | • | • | Adopt and implement curlyleaf pondweed plan as soon as possible |
| Shoreline protection | Promote, educate and install 40 shoreline plantings/buffers/setbacks | • | • | | | | | • | • | Install shoreline buffers |
| | Continue to educate through mailings, presentations and demonstration site at public access | • | • | | | | | • | • | Ongoing |
| Wetland restorations | Identify degraded and impacted wetlands that may be contributing phosphorus and implement wetland restorations | • | • | | | | | • | • | Identify all degraded wetlands in the watershed and begin restoration |
| Roadside erosion control at stream crossings | 80% of road crossings (particularly gravel roads with culverts) over tributaries will be protected by implementing flow and erosion control measures at/near culvert inlets and outlets | • | • | | | | | | | Identify and protect 40% of road crossing in watershed |
| Dam/culvert inventory/upgrades | Inventory of all dams and culverts to assess problem sites that need replacement/improvement. Begin upgrades/improvements. | • | • | • | | | | • | | Inventory and identify all dams and culverts |
| Septic pumping regulation | Regulate, supervise and monitor all land application of septic waste throughout the watershed (i.e., Bear Creek) | | | • | | | • | | | Ongoing |
| City stormwater management | Continue incorporating low impact development practices into construction/reconstruction projects throughout city. Install 10-20 CMPs through street reconstruction, rain gardens, or other infiltration practices | • | • | | • | | | | | Install up to 10 BMPs within 10 years |

On average, the lake's water quality is best in spring, deteriorates slightly beginning in June and remains impaired through the year with the lowest water clarity occurring in August and September.

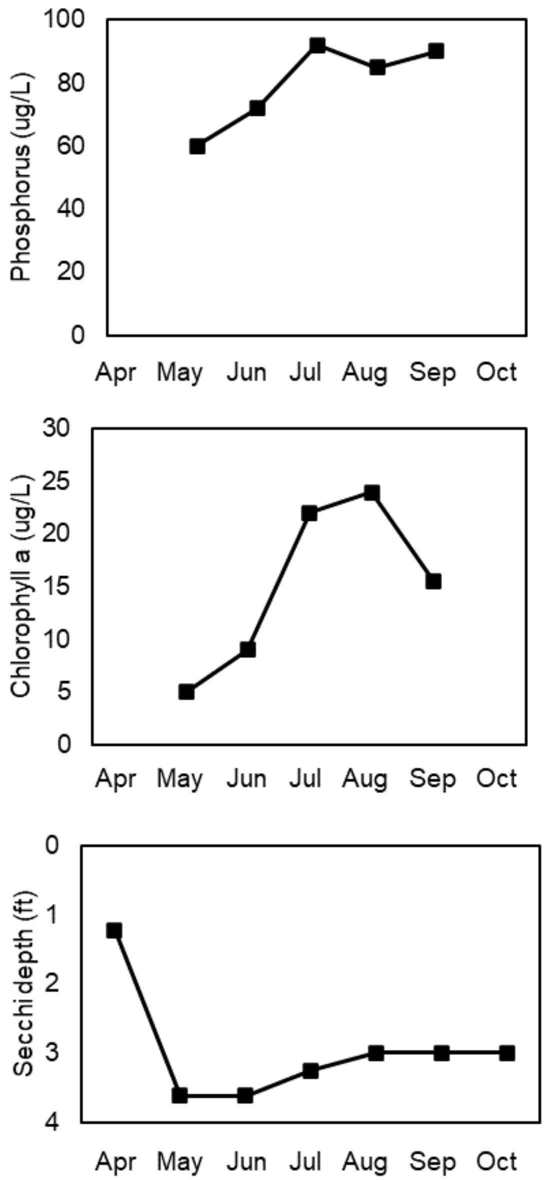



*Fig. 31. Cross Lake average seasonal pattern shown as medians for all data stored at MPCA.*

Following ice-out in the spring, colder temperatures keep algae growth rates low, which can provide clear waters. Algae tends to be at low concentrations during May and June and then increases for the remaining year.

In lakes with curlyleaf pondweed, the plants stabilize lake sediments in the spring, keeping them from mixing into the water column to introduce nutrients for algae growth. This keeps the lake clear during spring. Once the curlyleaf pondweed dies back around the beginning of July, it can release additional nutrients to the water column and no longer is as effective in keeping sediments tied down to the bottom.

A few water chemistry labs in Minnesota offer a "Lake's Package" that offers chlorophyll *a* and total phosphorus chemistry on submitted samples at a reduced cost (~$250-300 annually) to Lake Associations. These data are used for long term monitoring in thousands of lakes in the state through the MPCA with their Citizen Lake Monitoring Program (CLMP).

The MPCA has several long term stations that have been established for the past few decades. We recommend seasonal sampling between June and September at their stations 102 (North Cross), 103 (South Cross) and 202 (Middle Cross). This is one of the most important longer term efforts that can be made for work on the lake as it provides the best perspective through time of any unusual changes as well as provides a basis for obtaining funding for lake important projects.

Two of the most used chemistry labs that directly work with supplying data to the MPCA include AW Research Laboratories in Brainard, MN and RMB Environmental labs in Detroit Lakes, MN. Both have a lakes package and use SpeeDee Delivery as a courier. These water quality records are important tools for monitoring and provide a baseline for detecting unusual changes fast provided they are collected on a regular basis. It should be noted that these data have been regularly collected by either the lake association or government entity.

**MANAGEMENT OBJECTIVE #15**
REGULAR WATER MONITORING FOR SECCHI DEPTH, CHLOROPHYLL A, AND PHOSPHORUS MONTHLY AS PART OF THE MPCA CITIZEN LAKE MONITORING PROGRAM

Below for completeness, we report and briefly describe a number of other chemistry variables that have historically been measured on Cross Lake and compare these to similar lakes in the region. None of the other parameters look to be outside the expected range or anything to be concerned about. significance that may have.

### Other Chemistry

The MPCA has stored records of additional chemistry that was collected at Cross Lake. We summarized these data and compared them to the average range of values for all lakes in the Snake River Watershed (Table 8). Data from the last 10 years was used unless none exists, then data from the entire monitoring period was used.

Other chemistry data include information on nutrients and ionic chemistry. These data were collected historically but it is unclear what they were collected for and as such are of limited.

<u>*True Color (PTU)*</u> – A measure of the color of the lake attributable to dissolving humic substances that can sometimes give water a “tea-stained” appearance. This color is separate from either algae or suspended in organic matter and can provide shading to the water, reducing light penetration of subsequently of algae growth. Color in Minnesota < 20 PCU is considered clear, devoid of humic substances; 20-50 PCU has moderate and > 50 PCU dark coloration. Data from a single year in 1994 indicated average PCU of 92, suggesting significant coloration.

<u>*Total Suspended Solids (TSS)*</u> – A measure of suspended solid particles stirred up in the water column. These suspended particles can be either organic or inorganic. Organic TSS include live/dead algae, live/dead zooplankton, dead fish tissues, or other very small living or recently living things. Inorganic TSS includes all the particles suspended in the lake that have a nonliving origin (e.g., clay, sand, silt). Data from

*Table 8. Select water chemistry from MPCA comparing Cross Lake to the 17 lakes in the Snake River Watershed for which data exist. Watershed data are reported as Lower and Upper expected range as mean plus/minus one standard deviation respectively. Column labeled "N" is the number of lakes for which the parameter was measured. Comparisons were made for average value per lake over past 10 years (2013-2023). ND = no data. Parameters with an " * " did not have any measurement from within the last 10 years and the entire data range was used.*

| | | Snake River | | | |
|---|---|---|---|---|---|
| **Parameter** | **Cross Lake** | **Lower** | **Average** | **Upper** | **N** |
| Lake physical appearance | 2.60 | 1.75 | 2.60 | 3.45 | 12 |
| Lake recreational suitability | 2.40 | 1.58 | 2.43 | 3.28 | 12 |
| Organic carbon (mg/L) | ND | | *7.36 | | 1 |
| True color (PCU) | *92 | 47.12 | *76.48 | 105.85 | 5 |
| Total suspended solids (mg/L) | *6.36 | 0.00 | *27.29 | 141.21 | 6 |
| Volatile suspended solids (mg/L) | *3.52 | 0.00 | *25.83 | 159.28 | 6 |
| Alkalinity (mg/L) | 74 | 32.50 | 54.57 | 76.65 | 7 |
| Calcium (mg/L) | ND | 0.00 | *11.64 | 25.99 | 10 |
| Chloride (mg/L) | 2.95 | 0.00 | 5.48 | 11.96 | 11 |
| Hardness (mg/L) | 81 | 31.69 | 71.53 | 111.38 | 11 |
| Magnesium (mg/L) | ND | 0.00 | *6.56 | 13.69 | 10 |
| (ORP) | ND | 289.99 | *368.9 | 447.81 | 2 |
| pH | 7.37 | 7.21 | 7.87 | 8.52 | 7 |
| Specific conductance (uS/cm) | 138.78 | 65.19 | 113.97 | 162.75 | 8 |
| Sulfate (mg/L) | ND | 2.80 | 3.02 | 3.25 | 4 |
| Chlorophyll a (ug/L) | 17.70 | 0.00 | 24.51 | 52.90 | 11 |
| Orthophosphate (mg/L) | *0.04 | 0.00 | 0.03 | 0.07 | 3 |
| Pheophytin a (mg/L) | 6.05 | 1.25 | 7.99 | 14.74 | 9 |
| Secchi Depth (m) | 1.22 | 0.37 | 1.21 | 2.06 | 12 |
| TKN (mg/L) | *1.16 | 0.47 | 0.99 | 1.51 | 3 |
| TP (mg/L) | 0.09 | 0.01 | 0.07 | 0.14 | 12 |

1994 exists for this parameter, which gives an average of 6.4 mg/l, which is less than the established level of concern statement from the MPCA of 10.0 mg/l. It is also lower than lakes in the watershed

Volatile Suspended Solids (VSS) – A measure of organic TSS (see above) that can easily be determined and used to estimate the inorganic fraction of the TSS. Inorganic TSS can be determined as the difference between TSS and VSS such that nonvolatile suspended solids (NVSS= inorganic TSS) is NVSS=TSS -VSS. Data from 1994 exists for this parameter, which givens value of 3.52 mg/l, indicating that most of the TSS (55%) in 1994 was organic and 45%

was inorganic. The values are low and not of great concern.

Alkalinity ($CaCO_3$) – Alkalinity is a measure of (1) the ability of the water to neutralize acids and how well the lake responds to rapid changes in pH and (2) the availability of inorganic carbon as a food source to algae. Alkalinity gives an indication of how sensitive a lake would be to acid rain or to acid mine drainage. Cross Lake has high alkalinity (74 mg/L $CaCO_3$) than other lakes in the watershed but within range.

Alkalinity should be higher than 20 ppm for the protection of aquatic life living in the lake. Alkalinity is also related to hardness, which is a measure of calcium and magnesium ions. MN and EPA based thresholds identify lakes with < 50 ppm as soft, 50-150 ppm as medium, and >150 ppm as hard. Data used from 1994 and a single measurement from 2018 showed an average of 85 ppm. Using that, the lake is classified a medium alkaline lake.

Calcium – In Minnesota, calcium-poor lakes are those with < 10 ppm and calcium rich waters are defined as those with > 20 ppm calcium. Calcium is thought to be an important limiting factor to zebra mussel survival. Studies indicate that lakes with less than 10 mg/l of calcium cannot support zebra mussels while those between 10-12 ppm have very low risk, 12-20 ppm low risk, 20-28 ppm moderate risk, and > 28 ppm high risk. There are no data on calcium concentrations within Cross Lake, but other lakes in the watershed are considered to have low to moderate concentrations of calcium. An estimate of calcium may be useful to gauge potentially suitability for zebra mussels.

Chloride – High chloride levels can occur in Minnesota with runoff from salt that is used on winter roads or water treatment plants and sometimes from water softeners. The MPCA warns for chloride levels that have reached 230 mg/l. It is an ion that is not used by fish or plants and thus once it gets into the lake it remains there in the form it arrived. Chloride levels in Cross Lake were 4.1 mg/l, which is very low when averaging 1994 samples with a single 2018 sample.

pH – Pure water has a pH of 7 and lakes that have pH < 7 are said to be "acidic" while those pH > 7 are said to be "basic". Aquatic organisms are happiest at a pH between 6.5 and 8.5. Cross Lake has a pH of 7.37, which is ideal and similar to other lakes in the watershed.

Specific Conductance – A measure of electrical conduction in the lake, which indicates overall concentration of charged particles without interest in their particularly speciation. The major positively charged ions in a lake are calcium, magnesium, sodium, and potassium and the major negatively charged ions are bicarbonate, sulfate, and chloride. Ions are charged molecules required by algae to grow. Many ions correlate well to high nutrients and productivity. Specific conductance is easily and often measured with a field meter. It does not require special laboratory methods and can be read directly in the field inexpensively. Cross Lake has a relatively rich record of data back to 2006, indicating an average of 193 uS/cm. The only limit set by the state of Minnesota is for agricultural irrigation to use water with < 1,000 uS/cm. Based on that Cross Lake is well below any levels of concern.

Sulfate – Sulfate is known to be a limiting factor to the growth of wild rice in Minnesota lakes. MN studies show wild rice will not grow in lakes with < 10 ppm, which is a threshold set for lakes known to historically produce wild rice. There is no measurement of sulfate concentrations in Cross lake, but other lakes in the watershed have low concentrations.

Also included in Table 8 are standard nutrient measurements for Secchi depth, chlorophyll a, total phosphorus, organic carbon, and nitrogen. For nitrogen, the total nitrogen is separated into Total Kjeldahl Nitrogen (TKN) (i.e., organic) and inorganic nitrogen. Chemistry methods to get these parts differ so that they are often reported this way. TKN, the organic form of nitrogen, generally dominates in form. Often TKN will be a good surrogate for total nitrogen.

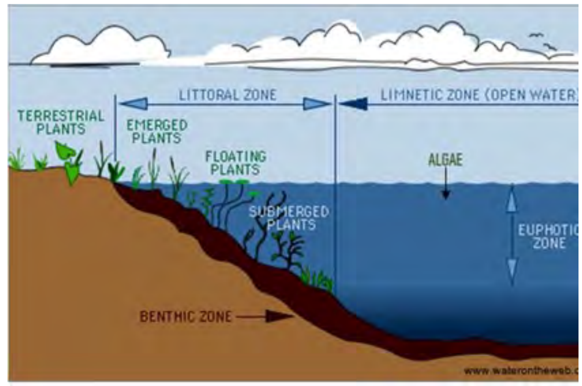



*Fig. 32. Different types of vegetation found in a typical lake including emergent, floating leaved, and submergent plants. Microscopic algae also exist in the water column and are plant-like but not true plants. A lake's "littoral zone" is the area from the shore out to the middle of the lake where light gets deep enough to allow plants to grow.*

## CHAPTER 6

### AQUATIC PLANT MANAGEMENT

**Overview**

Lake scientists categorize plants into four convenient groups, which include emergent, submergent, rooted plants with floating leaves, and non-rooted plants with floating leaves (Fig. 32).

While algae do photosynthesize like plants, they do not possess roots, stems, or leaves and subsequently are not true plants. Most algae are microscopic, but a few species are multi-celled plant-like organisms that include the likes of filamentous algae, muskgrass or starry stonewort (Fig. 33). Even though these species are not truly plants, given their similarity to plants they are surveyed along with them.

**Macroalgae**

Chara Starry Stonewort Filamentous Algae

*Fig. 33. Some typical macroalgae that look like plants. Algae have different biology than plants and as such require different methods for management.*

The general composition of a lake's native plant community can indicate how healthy a lake is because some species of plants are more tolerant to poor water quality and disturbance than others. For example, lakes with poor water clarity will favor species that grow to the surface where it is easier for them to intercept sunlight. This condition is usually not preferable to lake users because plants growing to the surface can cause nuisance. Historical plant surveys for Cross Lake indicate sparse coverage of plants with common species that are of this type (see below).

According to the Lake User Opinion Survey of 2023 for Cross Lake, 71% of respondents indicated that they experienced problems with aquatic plants with 51% indicating an increase in plant coverage and densities relative to what they remember.

One of the principal, but not only, culprits in creating nuisance plant conditions on a lake are invasive plant species. As such, quite a bit of effort by lake associations is put forth in surveying and treating invasive plant species.

Invasive plant species are species that originate from other continents that, because of their life history characteristics, outcompete native plants for sunlight and nutrients. When these species are introduced to a lake they have not previously been found in, they cause problems that reduce the recreational value of a lake because they often grow densely and close to the surface. When this type of growth occurs, they shade out the water column and reduce native plant diversity. Cross Lake is known to have populations of two invasive plant species: curlyleaf pondweed and Eurasian watermilfoil (see below).

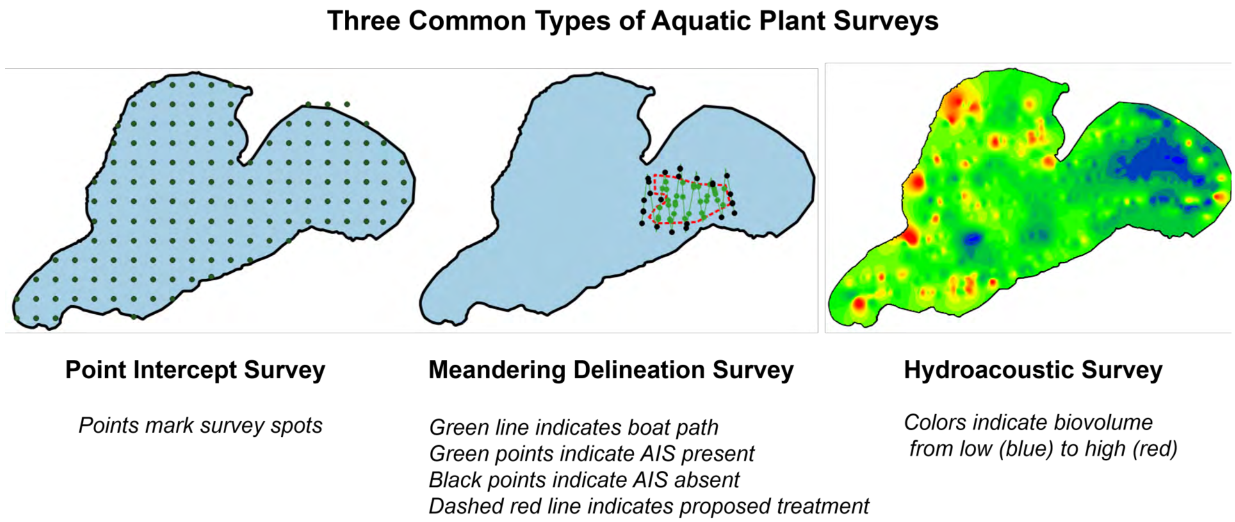



*Fig. 34. Example of three types of aquatic plant surveys commonly done in Minnesota for a fictious lake.*

## Aquatic Plant Survey Types

There are a few different ways that aquatic plants in lakes are surveyed, and each has different goals and methods. These are point intercept surveys, meandering delineation surveys, and hydroacoustic surveys (Fig. 34).

Point intercept surveys are the most complete and are best for knowing where in the lake different species of plants exist as well as the relative densities of each species. These are also really good for finding new invasive species, not previously known to exist in a lake. Standard point intercept surveys are conducted a spatial resolution of 1 point per littoral acre but surveys at the finer resolution of 1 point per half acre.

Meandering surveys are an invention of the MN DNR and are their preferred method of having boundaries of invasive species mapped prior to chemical or mechanical treatments. These are not full lake surveys but typically use previous information or knowledge about where an invasive species is on the lake to reconfirm their presence and extent.

Hydroacoustic surveys cover the entire lake and give an unbiased estimate of both coverage and density of plants, but unlike point intercept surveys, they do not tell you what kind of plants are being recorded. Some of the output from these surveys is spatial information describing “biovolume percent” (BV%) and depth to top of the plant canopy. BV% is a measure of the percentage of the water column depth occupied by plants. The depth to plant canopy is the distance between the surface of the water and the top of the plants in a given area. More information on BioBase processing and data output can be learned at www.biobasemaps.com.

Because aquatic plants play such an important role in water quality, fisheries habitat and people's ability to recreate on the lake, regular efforts to survey the plant community are highly recommended as budget allows. At a minimum, point intercept surveys should be repeated every three years.

**MANAGEMENT OBJECTIVE #16**
COMPLETE REGULAR POINT INTERCET SURVEY AT A MINIMUM OF ONCE PER THREE YEARS SPLIT BETWEEN JUNE/AUGUST EVENTS

**Past Survey Results**

The MN DNR had done aquatic plant surveys on Cross Lake in 1955, 1971, 1981, 1990, 1998, 2000, 2007, and 2014. Wenck Engineering conducted an aquatic point intercept survey on May 31, 2017 over the entire lake. Limnopro did a whole lake point intercept survey divided into down bouts in 2021, one done in June and the other in August.

The MN DNR rarely does who lake surveys and often are determining only presence and absence over parts of the lake. Wenck's (2017) survey was done during late spring, principally to determine curlyleaf pondweed coverage. Subsequently, their survey would not have described well the plant community during middle summer. Limnopro's (2021) survey was decided into two sessions, one for late spring and the other mid-summer and as such likely provides the most complete assessment of the plant community up to that date.

A more thorough treatment of plant community results can be found in Wenck (2017) and Limnopro (2021). For the purposes of this plan, summary information only is provided.

The highest number of plant species found during any single event was 28 (Table 9). In most of the surveys on record, water celery, waterlilies, filamentous algae and coontail were the most frequently encountered species. All of these tend to be favored in lakes with poor water quality and can grow near to the surface and cause nuisance. Total coverage for plants in the littoral zone for the most recent survey was 34%, which is low, and plants were mostly restricted to depths of less than 10 ft (Fig. 35). In lakes with better water clarity, plants tend to be found routinely to 15 ft. This 10 ft weed line depth result was similar to what Wenck found in 2017.

Curlyleaf pondweed was found covering an estimated 23 acres (~3%) of sites sampled and Eurasian watermilfoil was estimated to be covering 19 acres (~3%) (Fig. 36). Notably, Wenck (2017) recorded higher coverage of both curlyleaf pondweed (~20%) and

*Table 9. Summary of plant surveys on record as reported by Wenck (2017) and Limnopro (2021). Column headers show year of survey. Surveys from 1955-2007 only indicate presence (P) of species. Surveys from 2014-2021 are frequency of occurrence (i.e., percent of sites sampled with at least one individual). Surveys from 1955-2014 were done by MN DNR, 2017 done by Wenck, and 2021 by Limnopro. Species are sorted by highest to lowest occupancy based on Limnopro's latest survey.*

| Common Name | Scientific Name | 1955 | 1971 | 1981 | 1990 | 2000 | 2007 | 2014 | 2017 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|
| Water celery | *Vallisneria americana* | P | P | | P | P | P | 60% | 4% | 19% |
| White waterlily | *Nymphaea odorata* | P | P | P | P | P | P | 12% | 5% | 17% |
| Filamentous algae | *Various* | | | | | | | | | 15% |
| Coontail | *Ceratophyllum demersum* | P | P | P | P | P | P | 49% | 27% | 13% |
| Small pondweed | *Potamogeton pusillus* | | | | | P | | | | 10% |
| Canadian waterweed | *Elodea canadensis* | | | | P | P | | | 5% | 8% |
| Curlyleaf pondweed | *Potamogeton crispus* | | | P | P | P | P | 5% | 20% | 3% |
| Eurasian watermilfoil | *Myriophyllum spicatum* | | | | | | | | 7% | 3% |
| Water stargrass | *Heteranthera dubia* | | | | | P | | 1% | | 2% |
| Claspingleaf pondweed | *Potamogeton richardsonii* | | P | | P | P | | | 2% | 2% |
| Flat-stemmed pondweed | *Potamogeton zosteriformis* | | | | | P | P | 1% | 9% | 2% |
| Fries' pondweed | *Potamogeton friesii* | P | P | P | | | | | | 1% |
| Cattail | *Typha* spp. | | | | | | | | | 1% |
| Leafy pondweed | *Potamogeton foliosus* | | | | | | | | | 1% |
| Humped bladderwort | *Utricularia gibba* | | | | | | | | | 1% |
| Flexuous naiad | *Najas flexilis* | P | | | | P | | 1% | | 1% |
| Greater duckweed | *Spirodela polyrrhiza* | | | | | P | | 2% | | 1% |
| Thread-leaved pondweed | *Stuckenia filiformis* | | | | | | | | | 1% |
| Yellow waterlily | *Nuphar variegata* | | P | P | | | P | 1% | | 1% |
| Duckweed | *Lemna* spp. | | P | P | P | P | | 10% | 1% | 0.5% |
| Water moss | *Various* | | | | | P | | | | 0.5% |
| White waterscrowfoot | *Ranunculus aquatilis* | | | | | | | | 1% | 0.2% |
| Northern watermilfoil | *Myriophyllum sibiricum* | P | | | | P | P | | | 0.2% |
| Sago | *Stuckenia pectinata* | | | | | P | | | | 0.2% |
| Little yellow waterlily | *Nuphar microphyllum* | | | | | | | 8% | | 0.0% |
| Watermeal | *Wolffia spp.* | | | | | P | | 5% | | 0.0% |
| Narrowleaf pondweed | *Potamogeton spp.* | | | | | | P | 3% | | 0.0% |
| Whitestem pondweed | *Potamogeton praelongus* | | | | | | | 1% | 1% | 0.0% |
| Nitella | *Nitella spp.* | | | | | P | | | | 0% |
| Berchtold's pondweed | *Potamogeton berchtoldii* | | | | P | P | | | | 0% |
| River pondweed | *Potamogeton nodosus* | | | | P | P | | | | 0% |
| Spotted watermeal | *Wolffia borealis* | | | | | | | | | 0% |
| Wild rice | *Zizania palustris* | | | | | | | | | 0% |
| Muskgrass | *Chara* spp. | | | | | | | | | 0% |
| Nuttall's elodea | *Elodea nuttallii* | | | | | | | | | 0% |
| Robbin's pondweed | *Potamogeton robbinsii* | | | | | | P | | | 0% |
| Arum-leaved arrowhead | *Sagittaria cuneata* | | | | | | | | | 0% |
| | **Species Detected** | **6** | **7** | **6** | **9** | **19** | **9** | **14** | **11** | **28** |

Eurasian watermilfoil (~7%). No other aquatic invasive plants were found during any existing plant survey.

Management of curlyleaf pondweed has occurred since 2014 and Eurasian watermilfoil since 2016. The first rec-

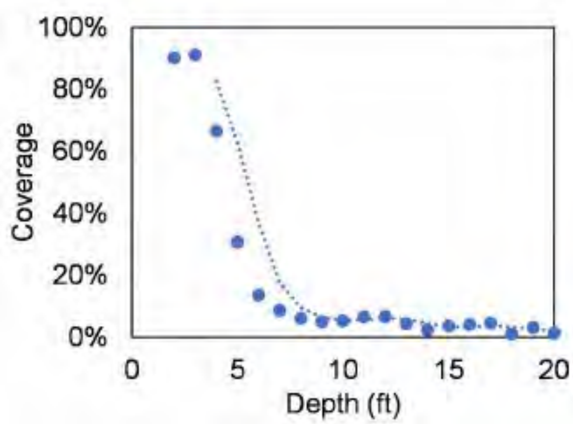



*Fig. 35. Percentage of sites at a given depth where plants were present in 2021. Dashed line represents a three point moving average.*

ord of curlyleaf pondweed was made in 1981 and Eurasian watermilfoil in 2004 (Wenck 2017).

Hydroacoustic surveys by Limnopro in 2021 indicate that plants do reach the surface in the Northern more shallow bays and by the Pine City river landing.

In general, the plant community is typical of a lake with poor water quality. Our recommendation is to manage for increase in coverage of plants, particularly of species that do not favor surface growth. There is some concern for continued reduction of plant mass with negative feedback loop leading to poorer water quality.

It is a common misperception that aquatic plants are limited in growth by nutrients in the water column. It is not correct to think that as lake nutrient level increases, there are more plants in the lake. In fact, just the opposite usually occurs. As nutrients increase in the water, microscopic algae (i.e., phytoplankton) use them to grow, which creates shading and reduces rooted plant growth. At the extreme, lakes with extraordinarily high nutrients may grow so much algae that there are no rooted plants. Rooted plants get their nutrients from the sediments at the bottom of a lake, not the water column. There is abundant nutrients in the sediments.

Aquatic plants are not limited by nutrients, but by the availability of light.

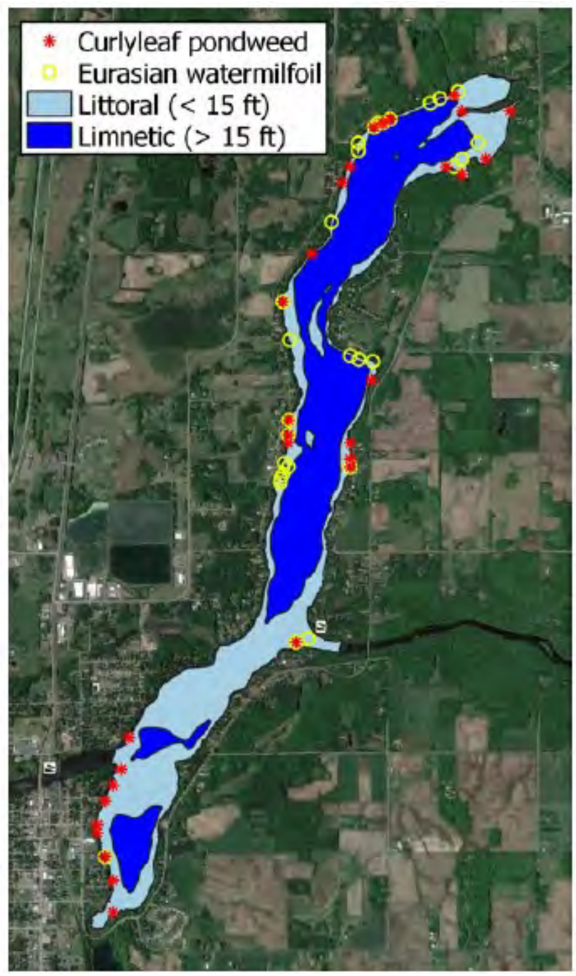



*Fig. 36. Locations of aquatic invasive species found in Cross Lake for surveys in 2021.*

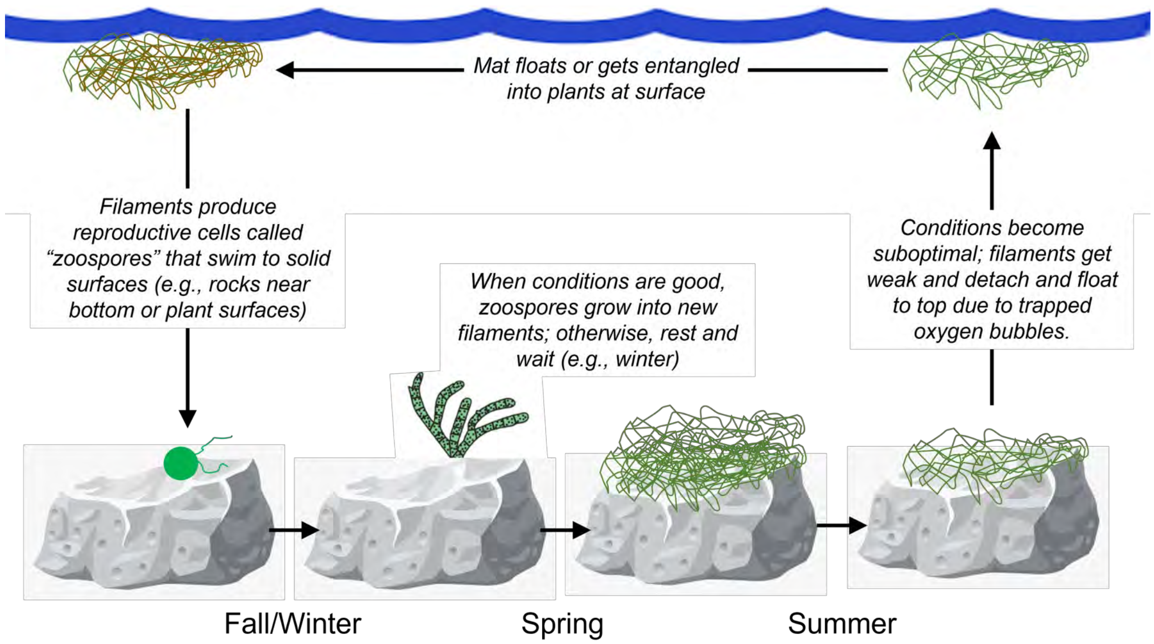



*Fig. 37. Simplified life cycle for filamentous algae through the year. Rocks or other hard surfaces are colonized on the bottom of the lake. Algae grows to a mass on the rock surface, detached and floats to the surface or gets entangled in surface plant growth.*

High water clarity can lead to dense plant growth throughout the littoral zone. On the flipside of this, low water clarity can lead to minimal plant growth throughout the littoral zone. The shallowest areas can still grow plants that are able to grow in lower light conditions can still reach nuisance levels by growing to the surface to increase light availability.

Not unlike many Minnesota lakes, residents on lake struggle with growth of nuisance filamentous green algae (FGA). Coming out of the winter, FGA exists either as zoospores (single celled reproductive cells) or partially grown filaments from the last year (Fig. 37). In the spring, as conditions become warmer and light becomes more intense, these leftovers from last year start to grow into new filaments. At some point conditions become too warm or they start to get shaded and growth slows down. This causes a general weakening of the filaments that can break when disturbed by lake currents or other water movement. and the algae becomes stressed. The filaments become weak and dislodge. Because FGA are photosynthesizing they are producing oxygen which gives them buoyancy and allows them to float to the surface where they surf until they run into something like plants or a shoreline. Later in the year, if the FGA gets trapped in plants, they can continue their growth and even produce new zoospores.

One potential experimental way of alleviating FGA is through chemical or mechanical means. Chemical products containing copper are used sometimes to control algae. Mechanical harvesting can also be useful by scooping up surface mats. These are both temporary fixes as FGA is fast growing and will replace lost mass quickly. One experimental way that to our knowledge has yet to be tried would be applying a phosphorus precipitating compound (e.g., alum or Phoslock) to areas where FGA removal was occurring with the hope that this removes additional nutrients to keep the FGA from returning so quickly.

FGA is not only hard to recreate around but also is known to create fouling of shorelines. This has been written about a lot with Great Lakes, and it's been shown that decomposing FGA on shorelines can create fowl odors and can also provide habitat for fecal coliform bacteria that may cause illness in people or pets.

**Importance of Plants in Lakes**

While lake users sometimes see aquatic plants and algae as a nuisance, they do serve a role in the lake ecosystem. They reduce wave impacts to shorelines as well as stabilize sediments, keeping nutrients out of the water column that might otherwise lead to poor water quality. Aquatic plants also provide habitat and food for other organisms in a lake. These benefits refer to the "conservation value" of plants.

Just because aquatic plants have conservation value, it does not follow that more plants equals greater value. In fact, it is well known that the highest conservation value for a plant community occurs at (1) intermediate coverage and densities, (2) highest species diversity, and (3) the highest growth form diversity, meaning mixes of broadleaf, narrow leaf, canopy forming and lower growth forms.

With regards to fish, a common misunderstanding is that the more vegetation there is on a lake, the better the fishing. In fact, most studies on optimal coverage of plants in the littoral zone suggest between 40 and 60 percent to be best for fish (Verhofstad and Bakker 2019, Valley 2004, Dibble 1997).

Plants in a lake only provide one sort of habitat for fish; there are other types of habitats of importance including open space, gravel, edges, coarse woody debris and more. For example, walleye spawn in open shallow gravel areas. Members of the sunfish family (e.g., largemouth bass, bluegill, pumpkinseed, and etc.) and crappie build nests in open water. The more plants in a lake, the less of the other types of habitat.

Fish rely on plants for both habitat (e.g., refuge/hiding) and for food (e.g., the insects, snails, worms, zooplankton, and smaller fish) that are living within the plant matrix. Studies show that when there are too many plants, predatory fish, particularly young of the year fish have a harder time finding prey and as a result grow slower and have a lower probability to making it through their first winter to recruit to the adult population (Bettoli et al. 1992, Dibble 1997, Olson et al., 1998).

Another problem for fish living among dense plants is that dense plants restrict water movement. As such, areas within dense beds of plants can lose oxygen. Fish need abundant oxygen to live and grow, and macrophyte induced hypoxia is known to be detrimental to fish growth and survival (Moore et al., 1994, Miranda and Hodges 2000, Killgore and Hoover 2001).

For all of the preceding reasons, managing for intermediate rather than maximum amounts of plants in a lake is best for a healthy fishery.

In a 2019 scientific review paper entitled "*Classifying nuisance submerged vegetation depending on ecosystem services*" published in the Journal of Limnology by Michiel Verhofstad and Elisabeth Bakker, based on dozens of published studies, they found that people experience nuisance plant growth both when total coverage of the bottom is high and when the plants that grow, grow near to the surface (Verhofstad and Bakker 2019).

Subsequently, their recommendations focus on working to achieve optimal depth of the canopy below the water surface (i.e., distance from surface of the water to the top of plants) and optimal plant coverage (i.e., the percentage of lake bottom that grows plants) to support both recreation and habitat for organisms that live in lakes, particularly fish (Fig. 38).

**MANAGEMENT OBJECTIVE #17**

ACHIEVE AVERAGE LITTORAL ZONE AQUATIC PLANT COVERAGE OF 40-60% WITH CANOPY DEPTH OF LESS THAN 3 FT

**Minnesota Rules and Regulations for Plant Management**

Minnesota has a well codified set of rules for plant management, and different rules apply to invasive species than to native species.

Chemical or mechanical treatment of offshore areas where invasive plant species such as Eurasian watermilfoil or curlyleaf pondweed are growing requires an Invasive Aquatic Plant Management (IAPM) permit, which is approved by the regional MN DNR AIS Specialist within Ecological and Water Resources Division with a general allowance of up to 15% chemical treatment over the littoral zones of each lake.

The "15% Rule" is a rather arbitrary

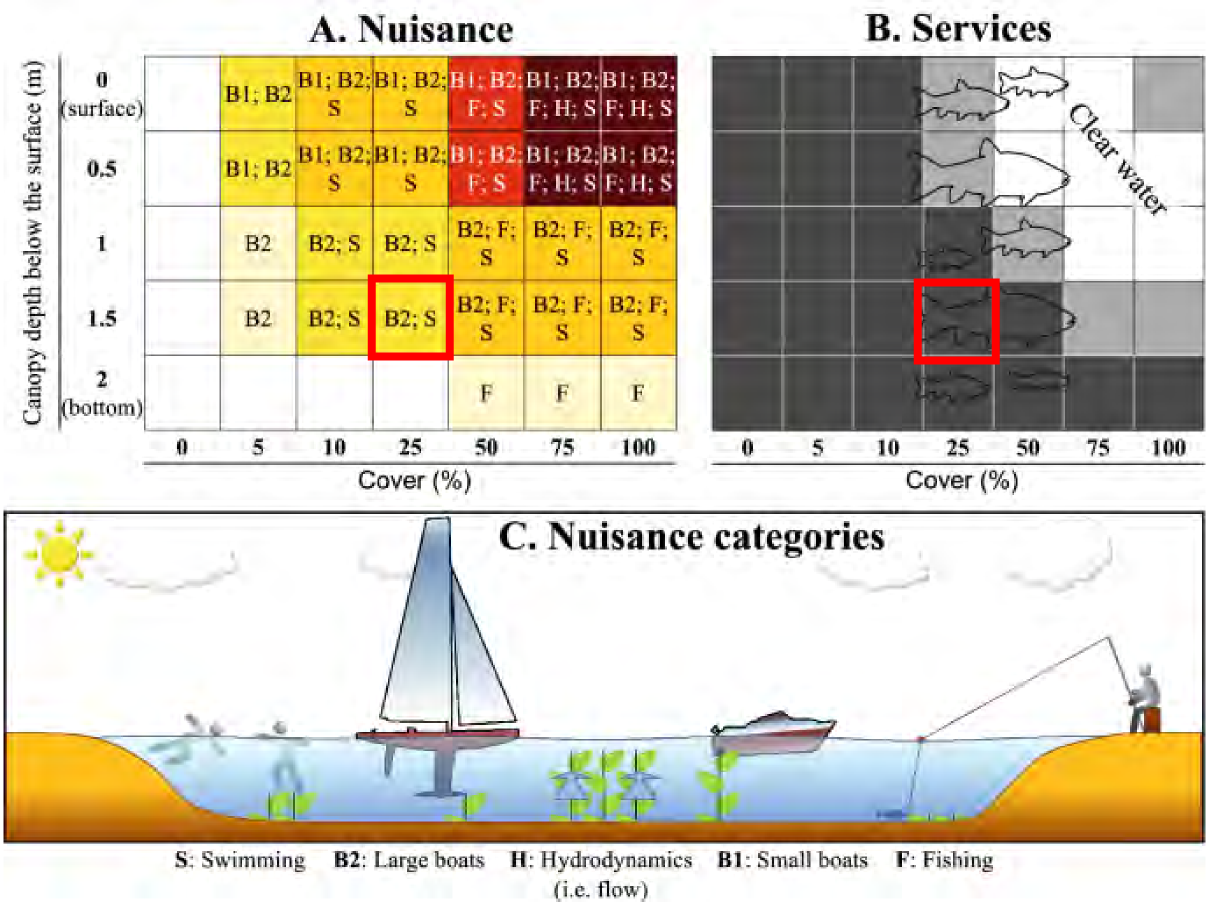



*Fig. 38. **A** Case study (water depth = 2 m) classification of nuisance macrophyte vegetation by plant canopy depth and plant cover depending on ecosystem services provided by the aquatic system. Letters indicate that macrophytes are classified as nuisance for each anthropogenic function: B1 = small recreational boats; B2=large recreational boats; F= fishing; S= swimming; H=hydrodynamics, i.e. water flow in this case. For a graphical representation, see **C**. Darker (red) fills indicate more services are impaired by macrophytes. **B** Probability of maintaining two important ecosystem services (i.e. clear water and fish populations) in shallow aquatic systems considering the total area of the ecosystem. Lighter fills are generally considered more desirable for the stability of the clear water state. The school of fish indicates the plant cover that is suggested as optimal for fish populations. Fish size has no informative meaning. **C** Graphical representation of the ecosystem services impaired by submerged plant growth, as reported in **A**. Modified from Verhofstad and Bakker 2019. Red boxes on plots indicate average conditions of Cross Lake during 2021 survey.*

percentage. There is not good scientific support to fix the treatable acreage to 15% over any other number.

Chemical herbicides allowed by the MN DNR for curlyleaf pondweed in Minnesota are of the contact variety and include endothall (Aquathol K or Hydrothol 191) or diquat. As contact herbicides, these chemicals will kill portions of the plants they come into contact with but leave underground portions of the plants as well as turions behind to grow back. Of the two contact herbicides, diquat is much less expensive. It requires less contact time so that it does better at treating smaller areas compared to endothall.

One concern for using diquat is that it has a tendency to bind with clays in suspended sediments. It is not appropriate for lakes with high suspended sediment or in conditions when high winds have stirred up sediments. Endothall does not bind in a similar way to sediments as diquat. There is also some suspicion, though weak data support, that suggests diquat is more damaging to some fish, principally newly hatched walleye. As such the MN DNR has a list of diquat-restricted lakes where diquat is not allowed to be used until after June 1, which is too late to be used for curlyleaf pondweed. Cross Lake is not on the diquat restricted list and as such would not need to use endothall.

In our experience, diquat provides better control than does endothall and endothall comes at a cost of 4-12 times that of diquat depending on the concentration used. That being said, using diquat in plots on the southern portion of the lake may be less effective as it may bind to sediments present in the water from inputs to the Snake River.

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**MANAGEMENT OBJECTIVE #18**

ASSESS SPRING COVERAGES ANNUALLY OF CURLYEAF PONDWEED FOR DETERMINATION OF HERBICIDE TREATMENT OPTIONS

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Treating Eurasian watermilfoil is generally done differently than curlyleaf pondweed. Eurasian watermilfoil can be treated later in the year and there are systematic herbicides that can be used to garner long-term control. We have had very good success doing late season treatments of Eurasian watermilfoil using 2,4-D. The MN DNR and some other applicators have been using a new product called ProcellaCOR that also seems to be effective but costs more than 2, 4-D. The drawback of using systematic herbicides like 2,4-D or ProcellaCOR is that it takes longer to get a kill, generally it can take 3-4 weeks to see dieback. The benefit is that you can kill entire plants. Late season treatments can really help keep populations low the next year. If Eurasian watermilfoil is causing current year nuisance issues, a systematic can be mixed with diquat or another contract herbicide to get some immediate relief coupled with longer term control.

*Fig. 39. Mechanical harvester removing nuisance plants.*

**MANAGEMENT OBJECTIVE #19**
ATTEMPT TO ERADICATE OR CONTROL EURASIAN WATERMILFOIL USING SYSTMATIC HERBICIDES SUCH 2,4D OR PROCELLACOR DURING SUMMER

While MN Statutes allows up to 15% of the littoral zone to be treated, local MN DNR AIS Specialist has complete discretion at granting permits and may not be willing to permit this maximum. MN rules allow for direct appeal to the MN DNR Commissioner for reconsideration if the local MN DNR AIS Specialist does not provide a ruling you agree with (MN Rules Part 6280.0250).

In some cases where an invasive species is especially severe lake associations can petition the MN DNR under the same rule, for a variance to the 15% rule so that they can treat more, try novel chemical types, or use other regularly restricted activities. A number of conditions need to be met to have a variance granted including the development of a technical management document written by the MN DNR AIS specialist called a Lake Vegetation Management Plan, or LVPM.

Whether or not a variance is granted is up to the regional MN DNR AIS Specialist, although there is a provision for appeal if decisions are not favorable. Typically, for consideration of an LVMP there has to have been a number of prior years of active management program, including surveys and treatments that fall under the standard rules. A first step in this direction is to write a Cooperator LVMP Request & Lake Data Summary, which presents to the MN DNR a record of past plant manage-

*Table 10. Some typical methods for controlling nuisance plant growth in lakes.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Biological** | Insect control | Experimental with Eurasian watermilfoil and purple loosestrife. No current commercially available solution currently. Results vary. | | | | | |
| | Native plant transplantation | Native plant transplanting of beneficial species to compete with nuisance plants. Permits can currently be obtained. Cost is mostly labor. Not practical over large areas | | | | | |
| **Chemicals** | **Chemical** | **Family** | **Halflife (days)** | **Plant response** | **Use restrictions (Irrigation)** | **Target Plants** | **Cost per acre** |
| | Copper | Contact | 3 | 10 days | 0 days | Algae | $500.00 |
| | Diquat | Contact | 7 | 7 days | 3-5 days | Most submerged vegetation | $350.00 |
| | Endothall | Contact | 7 | 14 days | 0 days | Most submerged vegetation | $800.00 |
| | 2,4D | Systematic | 7.5 | 2 weeks | 21 days | Watermilfoils, coontail, water lilies | $650.00 |
| | Fluridone | Systematic | 21 | 90 days | 30 days | Most submerged vegetation | $200.00 |
| | Glyphosate | Systematic | 14 | 4 weeks | 0 days | Emergent and floating leaved plants | $250.00 |
| | ProcellaCOR | Systematic | 2 | 2 weeks | 30 days | Watermilfoils, coontail, water lilies | $400.00 |
| **Mechanical** | Harvesting | Method is nonselective, cosmetic, and short-term. May spread invasives and stir nutrients into water column. Costs vary between $1,000 - $1,500 per acre. | | | | | |
| | Hand pulling | Great for new, small infestations of AIS. Not practical for large infestations. Labor costs only. | | | | | |
| **Physical** | Dredging | Removes whole plants and seeds/turions. Long term and effective soluiton but is expensive (~$5,000-$10,000 per acre) with many logistical problems to overcome. | | | | | |
| | Drawdown | Winter drawdown can freeze kill plants and propagule banks. Must have somewhere to move water. Not always practical. Water regulation infrastructure can be expensive. | | | | | |

ment and requests activities outside of what would be allowed by normal rules.

Mechanical harvesting is another common way allowed to treat nuisance aquatic invasive species. It can provide some immediate relief but can also lead to spread of plant fragments so they drift around (Fig. 39). Harvesters used in Minnesota do not remove entire plants but rather remove the top portion of plants, leaving some stems behind for grow back. This effectively means that it is necessary to wait to harvest plants until they are near fully grown, mature, and reproductively active.

Minnesota rules allow treatment of up to 50% of the littoral zone where AIS exist. Costs for doing mechanical harvesting vary by company, but currently average between $1,000-$1,200 per acre, which is approximately 3-4 times the cost of treatment with chemical herbicides per unit area.

It is also possible to mix chemical and mechanical control, but if both are used the total amount of acreage treated cannot exceed 50% of the littoral zone. The upshot is that when combined the maximum treatable acreage would be 15% littoral acreage with chemical plus 35% littoral acreage mechanical.

While there are other ways that nuisance plants are controlled in lakes, chemical treatments are generally more effective, affordable, and less disturbing to the ecosystem than other methods that might be relied upon (Table 10).

The Lake User Opinion Survey indicated that 31% of people surveyed supported the legal use of chemical to control plants, 57% support mechanical harvesting, and 36% indicate they support the use of both.

Minnesota rules for managing native plant species such as water celery or filamentous algae are much more strict than those that apply to invasive species. Management permits for treating native plants is done through the MN DNR Fisheries Division Aquatic Plant Management (APM) program. APM permits can be applied for and granted for either navigational channels in the lake or individual property owners.

In the case of navigational channels, standard permits grant treatment of a 50 ft wide channel through portions of the lake boaters are likely to use to move through the lake.

In the case of individual shoreline APM permits, homeowners may be allowed to treat just a portion of their personal shoreline, most often up to half of the width of the shoreline they own out to 50 or 100 feet lakeward.

In either case, whether APM permits are applied to navigational channels or individual shorelines, these permits allow up to two seasonal chemical treatments of aquatic plants along property owner shorelines if aquatic plants impede the ability of the property owner to use the lake. Treatments associated with APM permits can either be administered through a commercial application company or the lakeshore resident themselves.

In addition to chemical treatments, there is some experimental work that is being done in transplanting desirable native plants in areas where there is an abundance of nuisance native and AIS. Permits can be obtained from the APM program for native transplants. Helping to establish desirable natives may help to control undesirable plants.

We recommend to continue management of invasive species and improve water quality to allow for the growth of more desirable species. In general, monitoring conditions to be able to adapt to changes quickly is ideal. Point intercept surveys once every three years at a minimum to provide a baseline can help to stay on top of emerging problems before they get out of hand. Given the lake has curlyleaf pondweed, dividing up the survey into two bouts similar to the 2021 Limnopro survey is advised.

# *CHAPTER 7*
## AQUATIC INVASIVE SPECIES MANAGEMENT

### Overview

Minnesota has at least 29 different aquatic invasive species (AIS) present in lakes or rivers (Table 11). Most of these were transported to the USA through the Great Lakes by transatlantic shipping vessels. Some of the ones that cause the biggest issues in Minnesota are native to lakes in Europe and Asia.

In their native habitat, our AIS do not

*Table 11. Aquatic invasive species reported to occur in Minnesota lakes or rivers by either the MN DNR or EDDMaps, which is a national repository for AIS reports.*

| Aquatic Invasive Species | First Year | Lakes | Rivers | Total |
|---|---|---|---|---|
| *Minnesota DNR Infested Waters List* | | | | |
| Zebra mussel | 1995 | 495 | 93 | 588 |
| Eurasian watermilfoil | 1995 | 389 | 21 | 410 |
| Spiny waterflea | 1995 | 40 | 27 | 67 |
| Faucet snail | 2009 | 40 | 18 | 58 |
| Flowering rush | 2007 | 38 | 14 | 52 |
| Bighead carp | 2012 | 22 | 22 | 44 |
| Silver carp | 2012 | 22 | 22 | 44 |
| Starry stonewort | 2015 | 21 | 1 | 22 |
| Grass carp | 2015 | 0 | 12 | 12 |
| Brittle naiad | 2007 | 9 | 0 | 9 |
| Round goby | 1996 | 1 | 2 | 3 |
| Ruffe | 1995 | 1 | 2 | 3 |
| VHS | 2010 | 1 | 2 | 3 |
| White perch | 1995 | 1 | 2 | 3 |
| New Zealand mud snail | 2007 | 1 | 1 | 2 |
| Red swamp crayfish | 2016 | 1 | 0 | 1 |
| *EDD MapS Database* | | | | |
| Purple loosestrife | | | | 6,947 |
| Nonnative phragmites | | | | 1,544 |
| Curlyleaf pondweed | | | | 1,167 |
| Chinese mystery snail | | | | 594 |
| Narrow leaved cattail | | | | 490 |
| Banded mystery snail | | | | 321 |
| Rusty crayfish | | | | 219 |
| Yellow flag iris | | | | 186 |
| Common carp | | | | 118 |
| Goldfish | | | | 83 |
| Sea lamprey | | | | 30 |
| Brazilian waterweed | | | | 3 |
| Java waterdropwort | | | | 3 |

cause problems and are typically only a minor part of the flora or fauna. This is because in their native lakes, they have natural competitors and predators that they have equilibrated with over a long period in time. When these AIS find their way to Minnesota lakes, those natural competitors and predators are missing and so population growth of AIS can explode.

As far as we know, Cross Lake is infested with curlyleaf pondweed, Eurasian watermilfoil, and common carp. Other AIS that are not yet in Cross Lake but of concern because of their impacts on lakes or their proximity include starry stonewort, zebra mussels, spiny waterflea and rusty crayfish.

## Curlyleaf Pondweed

Our current understanding of curlyleaf pondweed is that it is native to the continents of Africa, Asia, Australia, and Europe and was introduced to Minnesota lakes in the 1880's either intentionally or inadvertently along with carp.

Curlyleaf pondweed is easy to identify when mature, having a "lasagna noodle" like leaf appearance (Fig. 40). It is Minnesota's only pondweed with curly leaves that has serrated, or toothed, leaf margins and a rounded, rather than pointed, tip. It may be difficult to iden-

*Fig. 40. Curlyleaf pondweed form. Left shows the characteristic lasagna noodle appearance with round tip while right shows a close up of the toothed leaf margin.*

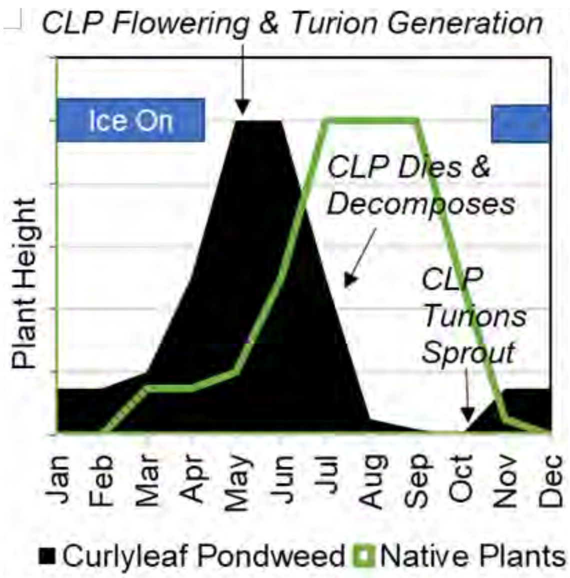


*Fig. 41. Curlyleaf pondweed idealized life cycle (black solid area) interposed with "native" plants (hollow green area).*

tify for many people when immature because it does not have the characteristic curling and can be mistaken for other similar looking plants.

Two of the reasons curlyleaf pondweed is such a successful invader is that (1) its mode of reproduction occurs vegetatively through turions, and (2) the timing of its life cycle allows it to avoid competition for resources with native plants by growing earlier in the year than most other aquatic plants in Minnesota.

Curlyleaf pondweed can reproduce both sexually (flower stalks protrude from the water surface to produce seeds) and vegetatively by creating structures called "turions". Studies indicate that rates of germination for seeds is very low, suggesting that most new growth of curlyleaf pondweed occurs through turions (Bolduan et al., 1994).

Turions grow at the nodes of branches on the curlyleaf pondweed plant. Turions looks like miniature pine cones, can last for many seasons, and are very hardy against extreme conditions, including being resistant to herbicide treatments. The consequence of this is that even if plants are controlled in a given year, the bank of turions that remain behind means that the next year population growth will continue unabated. This makes long-term control of curlyleaf pondweed very difficult.

The general life history schedule of curlyleaf pondweed in Minnesota where Cross Lake occurs starts at ice-out. Curlyleaf pondweed is one of the first plants to grow in the spring after ice-out before most native plants have grown (Fig. 41).

Once determining the timing of turion generation and aiming to treat plants prior to such, progress can be made toward evaluating long term success but direct sampling of turions year over year in treated areas compared to non treated areas.

### Eurasian watermilfoil

Eurasian watermilfoil is the other aquatic invasive plant species in Cross Lake. The 2021 survey by Limnopro indicates it is growing in small areas around the lake.

*Fig. 42. Example of nuisance growth of Eurasian watermilfoil surface matting.*

Eurasian watermilfoil shares some of the characteristics of curlyleaf pondweed, particularly an affinity for lakes with low water clarity in the summer brought about by high nutrient loads and a propensity to grow to the surface (Fig. 42).

Eurasian watermilfoil is native to Europe and Asia and was introduced to the eastern United States in the early 1900's, first discovered in Minnesota in 1987 at Lake Minnetonka in central Minnesota.

The best way to identify Eurasian watermilfoil from the majority of native watermilfoils, of which approximately half a dozen exist in Minnesota, is the "leaflet" counts. All watermilfoils have four leaves coming off of a central axis. The extensions off of the leaves are called leaflets. If there is more than eleven pairs of leaflets, it may be suspected of being Eurasian watermilfoil (Fig. 43).

Recently, in Minnesota there has been a developing hybrid watermilfoil problem in lakes. Hybrid watermilfoils are crosses that occur naturally in lakes where Eurasian watermilfoil have been introduced and native watermilfoils already exist. Hybrid watermilfoil has been shown to grow more aggressively in lakes than Eurasian watermilfoil and displayed some resistance to typical chemicals used to control Eurasian watermilfoil (Glisson and Larkin 2021).

Hybrid watermilfoils can be difficult to identify because it has characteristics of both Eurasian watermilfoil and native watermilfoils. Keeping an eye on the watermilfoil population in the lake will be important to stay on top of any sudden increase in spread.

In lakes with both curlyleaf pondweed and Eurasian watermilfoil, there can develop codominance of the two plants in the spring and dominance of Eurasian watermilfoil later in the summer. Unlike curlyleaf pondweed which dies off at the beginning of July, Eurasian watermilfoil remains a part of the plant

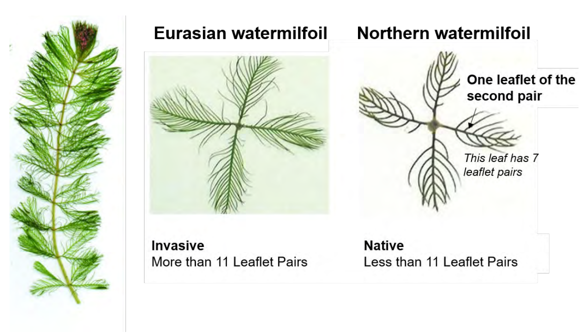


*Fig. 43. Leaflets as identifying characteristics of Eurasian watermilfoil.*

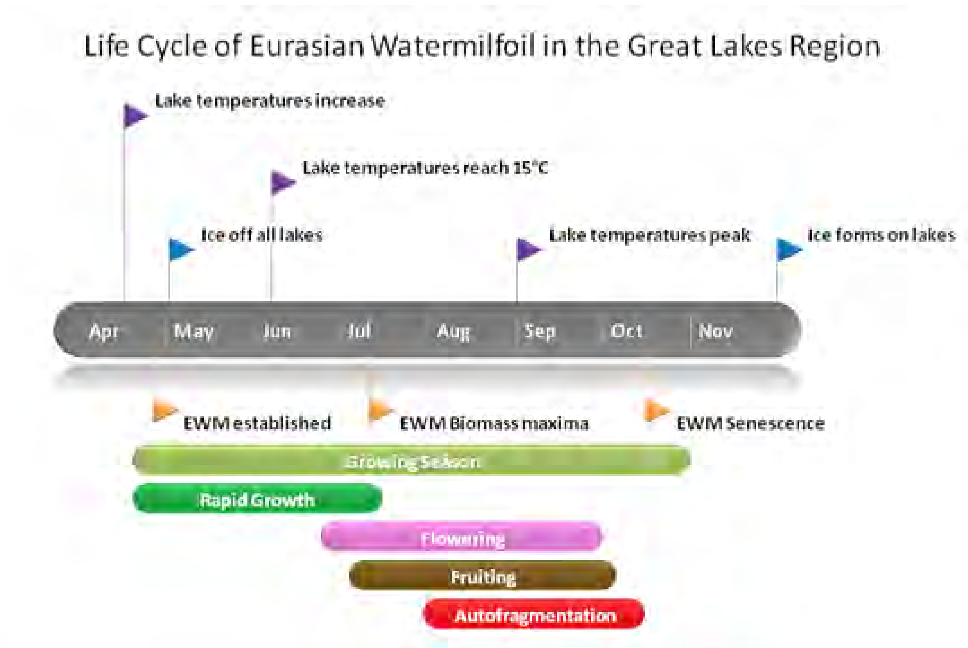


*Fig. 44. Eurasian watermilfoil (EWM) generalized life cycle in the Upper Midwest. Source: Michigan Tech Research Institute.*

community through the year (Fig. 44).

***Starry stonewort*** is a macroalgae first detected in Minnesota in Lake Koronis (Stearns County) in 2015. Currently (2024), there are 28 different lakes in the state known to have starry stonewort. Since first discovered, they have infested an average of 2.5 additional lakes a year. While this number is low relative to the total number of lakes in Minnesota, it is important to understand that approximately 12 of these infestations occur in lakes with public accesses within 100 miles of Cross Lake. The closest starry stonewort infested lake is Medicine Lake which is approximately 60 miles south Cross Lake (Fig. 45).

Starry stonewort can be identified using the star-shaped bulbils along with

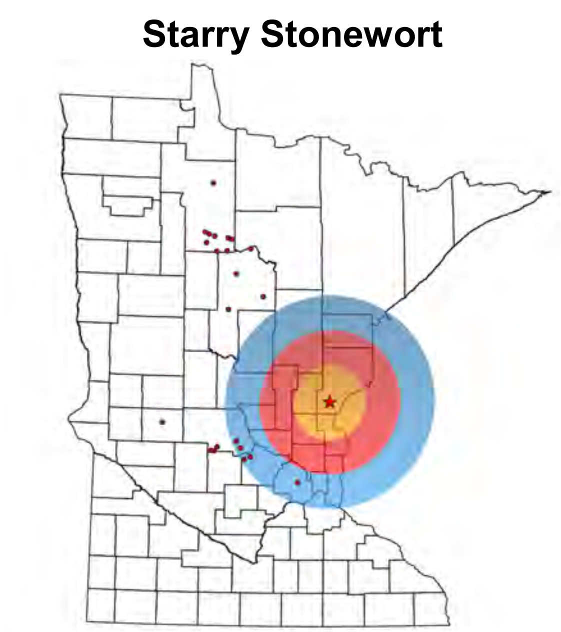


*Fig. 45. Maps show points where starry stonewort currently known to exist. Bullseye is centered at Cross Lake with yellow ring showing 25 mile radius, yellow + red ring showing 50 mile radius, and the yellow + red + blue ring showing  mile radius.*

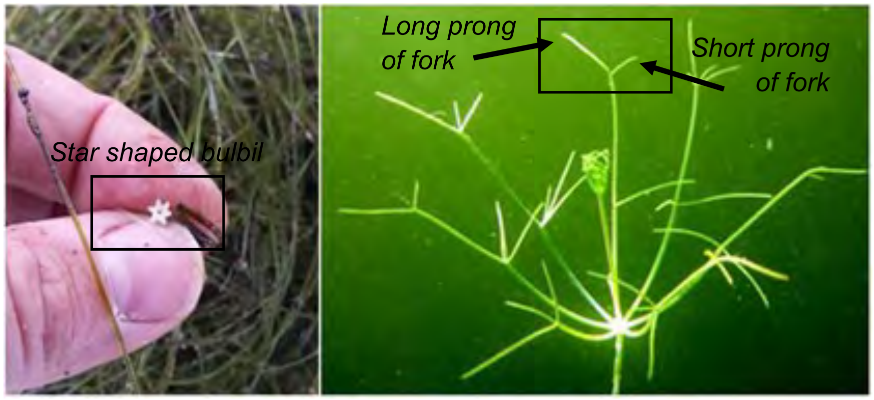


*Fig. 46. Starry stonewort characteristics. The star-like bulbils (left) are not always present but often visible in late summer. The forked ends of the branches of the plant are asymmetric with one prong longer than the other (right). Photo credit:NY Dept of Environment.*

asymmetric forked ends (Fig. 46). The best time to search for starry stonewort is August-September when the plant reaches its peak seasonal biomass and they produce their characteristic white starshaped bulbils.

The Minnesota Aquatic Invasive Species Research Center (MAISRC) has a program called the Starry Trek, where volunteers will perform spot checks during this time. Purposeful searching from volunteers or professionals each fall is highly recommended in order to launch a rapid response should it be found.

Costs of treating starry stonewort have been high and effectiveness in control has been difficult in some lakes. For example, Lake Koronis has spent upwards of a million dollars on the problem. In other lakes, early detection has seemed to aid greatly (e.g., Grand Lake) in keeping the infestation under control.

**MANAGEMENT OBJECTIVE #20**
ANNUALLY SEARCH AT PUBLIC BOAT LAUNCHES FOR STARRY STONEWORT AND/OR PARTICIPATE IN "STARRY TREK"

**Zebra mussels**

Zebra mussels are ecological engineers meaning they change the lake in a way that has system wide impacts.

Zebra mussels have several negative impacts to lakes that includes biofouling (i.e., making a mess at high density on shorelines and hard surfaces), risks from being cut when their shells are stepped on, and by changing the ecology of lakes in a number of ways that includes increasing water clarity, plant coverage and biomass, and reducing oxygen (Fig. 47).

Zebra mussels compete with zooplank-

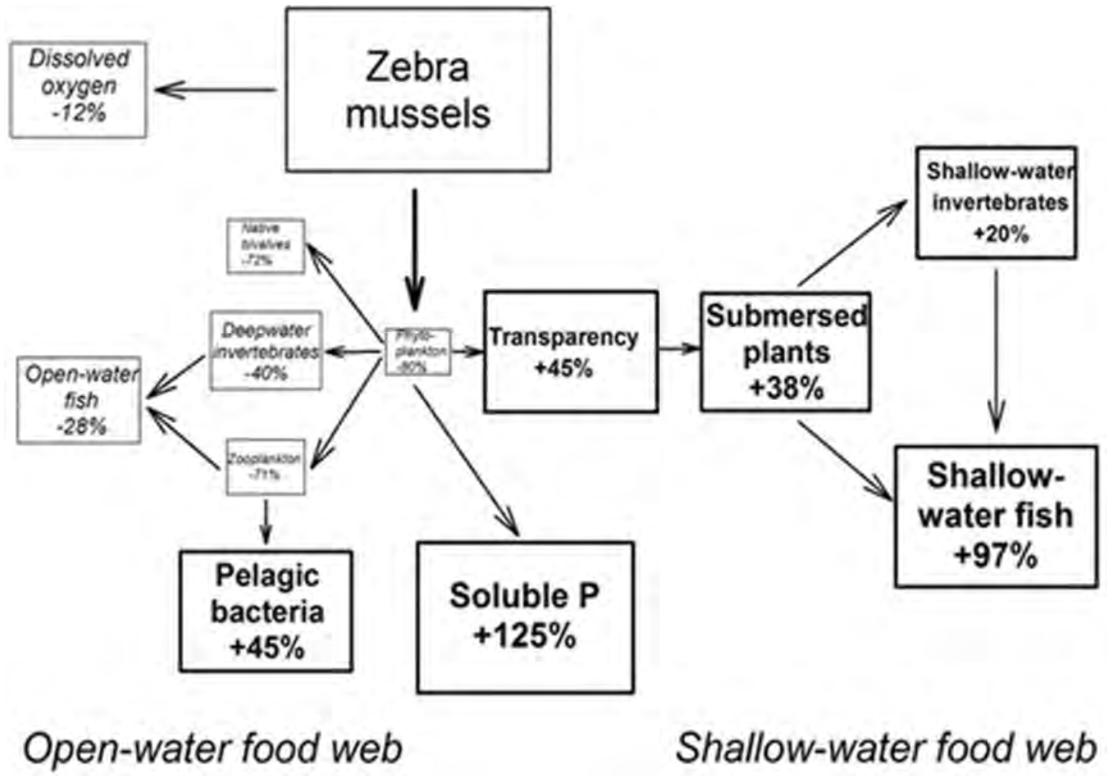


*Fig. 47. Typical impacts of zebra mussels on lakes. Zebra mussels decrease oxygen, increase available phosphorus, increase aquatic plants, and increase water quality. Source: Strayer, D.L. 2009. Frontiers in Ecology and the Environment.*

ton for algae changing how energy is distributed through the food web. Recent research has shown that they likely have negative impact on walleye populations and maybe entire fish communities (Hansen et al. 2020).

Zebra mussels can also change the algal community structure via selective feeding on green algae. They ignore cyanobacteria in favor of the smaller and more palatable green algae species. Cyanobacteria, or blue green algae, are responsible for harmful algal blooms.

Zebra mussels are easy to identify as triangular fingernail-sized bivalves (i.e., having two connected shells) with distinctive "zebra-like" striping (Fig. 48).

They were first detected in Mississippi River and Lake Superior in 1995. They did not turn up in inland lakes until

*Fig. 48. Zebra mussels are small triangular shaped bivalves (left). They commonly attach to hard surfaces and aquatic plants (right).*

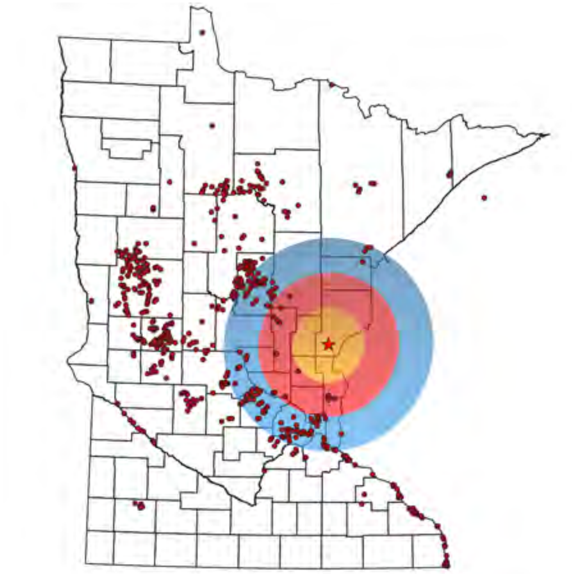

*Fig. 49. Maps show points zebra mussels (right) currently known to exist. Bullseye is centered at Cross Lake with yellow ring showing 25 mile radius, yellow + red ring showing 50 mile radius, and the yellow + red + blue ring showing mile radius.*

2004, first in Ossawinnamakee Lake within Crow Wing County.

They are now found in nearly every lake-rich area in Minnesota (Fig. 49). They are currently listed as being found in 628 lakes, rivers and streams. In 2022 alone 43 new waterbodies were listed, with 28 being added in 2023. The rate of lake infestation in Minnesota is higher for zebra mussels than any other AIS that is being tracked.

Of all lakes listed as infested, 554 of 628 occur within 150 miles of Cross Lake. Mille Lacs, which is one of the more popular lakes in the state, is nearby to Cross Lake is infested with zebra mussels.

While some experimental methods are being tried around the state to control new infestations, there has yet to be approved any effective way to remove zebra mussels once they get into a lake.

### Spiny Waterflea

Spiny waterflea are microscopic zooplankton that so far are concentrated in the arrowhead region of the Minnesota; however, they are known to occur in the Rum River watershed in Mille Lac Lake. These animals can be problematic because they compete with native zooplankton and can replace them. While native zooplankton are a favorite food for young of the year fish, spiny waterflea are difficult for young of the year fish to eat because of their “spiny tails”. Consequently, spiny waterflea may reduce fish recruitment in a lake. There is currently no effective way to remove spiny waterflea from lakes. Sixty eight lakes in Minnesota are currently known to be infested with spiny waterflea.  The closest is Mille Lacs lake.

### Rusty Crayfish

**Rusty crayfish** are an invasive crayfish that can replace native crayfish. Rusty crayfish eat plants among other things and as such they can reduce lake plants. When lake plants are reduced, sediments become suspended and nutrients introduce to the water, which can lead to algae blooms. Rusty crayfish can have similar effects as carp in that respect. They have a higher metabolic rate, meaning they need to feed much more than native crayfish, and tend to forage during day, which is not common for native crayfish.

Currently, rusty crayfish occurs in concentrated areas of Cass and Hubbard counties in addition to the metro area and Mille Lacs. There is currently no effective way to control for rusty crayfish once they get into a lake.

There is a known infestation of rusty crayfish in the Snake River with two individuals being found near the Mora River Access in 2019 and 2022.

**Miscellaneous**

Three emergent plant species that have been causing problems in Minnesota include ***purple loosestrife, reed canary grass*** or ***flowering rush***. All can outcompete native emergent plants such as cattails and bulrush, creating near monocultures. This reduction in biodiversity can impact nutrient cycling and wildlife habitat. Purple loosestrife was detected within Pine City south of the lake in 1991. Reed canary grass has been discovered east of the lake in Chengwatana State Forest in 2009. There is no flowering rush in the immediate vicinity of Cross Lake.

A number of invasive fishes exist in Minnesota lakes and include several carp species (common, bighead, silver, and grass), round goby, ruffe, and white perch. Cross Lake has historically had a moderate biomass of common carp. A full discussion of the carp issue is provided in Chapter 2 on water quality.

Other, less known probably less distributed aquatic invasive species known to exist in Minnesota lakes include banded and Chinese mystery snails, brittle naiad, faucet snails, New Zealand mud snails, and red swamp crayfish. None of these are present in Cross Lake.

Managing invasives species risks is best done when infestations are new and not widespread (Fig. 50). This demands purposeful searching for new infestations, which can be done through specific early detection activities or plant searches.

Whether it be by hiring surveys professionally or using volunteers, annual

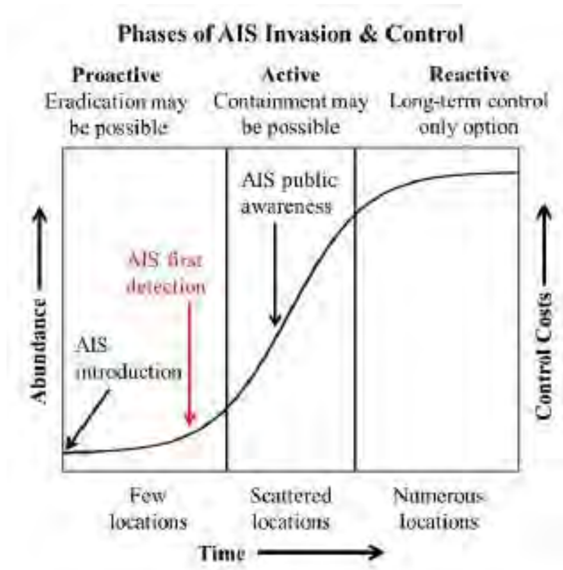


*Fig. 50. Generalized AIS invasive curve.*

searches of AIS should occur at points where AIS would be most likely to infiltrate the lake, which includes public boat launches, beaches, fishing piers, resorts, and inlets.

In addition to a program to search for AIS, a rapid response plan that includes a budget reserve for emergency and rapid treatments along with steps to take to be in a position to quickly address new infestations.

The AIS early detection and rapid response plan should focus most closely on searching for starry stonewort as it is one of the only where quick action and management can provide control. Early detection portion of the plan involves how you will search for new infestations on the lake annually, while the rapid response portion needs to identify individuals and processes to follow if a suspected AIS is found (e.g., Limnopro, MN DNR AIS Specialist, and etc.). The rapid response portion of the plan should also have some funds allocated for paying for an attempt at eradication as the state may not fund an adequate response.

**MANAGEMENT OBJECTIVE #21**
DEVELOPMENT OF AN AQUATIC INVASIVE SPECIES EARLY DETECTION AND RAPID RESPONSE PLAN

MAISRC offers a program that prepares citizens for early detection of common AIS in the state. Their training provides for training in identification and processes for responding. Having someone or better a group of individuals on the lake with such training could help with early detection to give the best chance possible of control.

**MANAGEMENT OBJECTIVE #22**
BOARD MEMBERS OR RESIDENTS ENROLL INTO MINNESOTA AQUATIC INVASIVE SPECIES RESEARCH CENTER EARLY DETECTOR COURSE

## *CHAPTER 8*
## FISHERIES MANAGEMENT

### Overview

Fishing in Minnesota lakes is one of the primary reasons people choose to live on or visit Minnesota lakes annually. Many of the decisions made by the MN DNR about what management activities can occur on a lake, whether that be water quality improvements or reducing of nuisance plant growth, centers around attempts to create strong, sustainable fisheries.

The Lake Opinion User Survey administered for this lake management plan had 92% of respondents indicating that they actively fish on Cross Lake with 19% saying their main form of recreation is fishing. The most popular fish species targeted were crappie (25%), walleye (20%), and sunfish (18%). The least targeted species was bass which is targeted by 7% of respondents.

MN DNR Fisheries Division surveys have been done approximately every four years on Cross Lake since 1981. Detailed summaries of each of these surveys, including data and a narrative summary are provided on the MN DNR lakefinder link.

The general theme of these narratives from the perspective of MN DNR Fisheries are as follows. The lake has been historically managed for walleye and musky through active stocking even though there is some evidence of natural reproduction of both species in the lake. More recently, sunfish management has ensued with experimental bag limits. The diversity of species (i.e., the number of different species) in Cross Lake is higher than other comparable lakes. For most gamefish species, catch rates are low but opportunities for catching large fish are present.

Some evidence exists to suggest that there is natural reproduction occurring for each of these species. In particular for walleye, stocking efforts to date have been evaluated to have very little impact on the walleye fishery, which has low catch rates relative to other fisheries. This result is consistent with published research that indicates walleye stocking to not be an effective way to improve fisheries when there is natural reproduction going on. Recently, management has expanded to panfish by reducing bag limits from 20 to 10 per day. Musky were assessed using a mark-recapture method (see below) as part of a targeted survey in 2015. At that time, a statistical assessment of musky population in the lake was between 47 and 68 fish. That survey concluded that opportunities to catch musky are low when compared to other musky lakes in the state but that if a fish is caught the likelihood that the fish would be large is high.

During spring of 2022, a special regulation went into effect that reduced bag limit of sunfish from 20 to 10 per day as an attempt to product current size structure of the fishery and improve opportunities to catch large sunfish. A targeted survey was done in 2022 to get a baseline of fish densities and size, finding an average catch of 5 fish per trap net with an average length of 8 inches. These data can be compared with future catch rates for comparison after the special regulations have been in place for a period of time.

Approximately 82% of respondents stated that the quality of the fishing is average or better, and 60% think the quality has not changed much in recent years. At the same time, 35% say that the fishery has gotten worse.

Standard MN DNR surveys use a combination of gillnets and trap nets to survey fish communities. Gillnets are generally placed offshore and target larger fish, best for assessing adult walleye and northern pike, while trap nets do a fair job of assessing nearshore communities of smaller fish, including panfish (i.e., members of the sunfish family). Neither of these methods are adequate for assessing true density of fish but do potentially give an indication of relative abundance between years in a given lake.

We note that some fish species are not well sampled by either standard gillnets or trapnets. In particular for Cross Lake, these include musky and bass. Musky require larger than standard gillnet to get an adequate representation and bass and generally assessed by electrofishing.

In general for most fish species, electrofishing will give a better indication of density than trap nets. It is more labor intensive and not used as frequently as gillnets and trapnets by the MN DNR. Most recently, in 2021, electrofishing was used to estimate carp population densities.

The best methods for assessing fish population density is to use what is called a "mark-recapture" efforts. This is a series of capture events over a short time where fish are caught, marked, released, and recaptured. The ratio of marked to unmarked fish in the recapture is used with standard statistical methods to estimate entire population sizes. With the number of lakes the

*Table 12. Fish species caught in Cross Lake (1981-2022) as reported by MN DNR.*

| Family | Common Name |
|---|---|
| | **Top Predators** |
| Catfish | Channel catfish |
| Perch | Walleye |
| Pike | Muskellunge |
| Pike | Northern pike |
| Sturgeon | Lake sturgeon |
| Sturgeon | Shovelnose sturgeon |
| Sunfish | Largemouth bass |
| Sunfish | Smallmouth bass |
| | **Panfish** |
| Sunfish | Black crappie |
| Sunfish | Bluegill |
| Sunfish | Hybrid sunfish |
| Sunfish | Pumpkinseed |
| Sunfish | White crappie |
| | **Forage Fish** |
| Catfish | Tadpole madtom |
| Minnow | Common shiner |
| Minnow | Emerald shiner |
| Minnow | Fathead minnow |
| Minnow | Golden shiner |
| Minnow | Spottail shiner |
| Mudminnow | Central mudminnow |
| Perch | Iowa darter |
| Perch | Johnny darter |
| Perch | Log perch |
| Perch | Yellow perch |
| Stickleback | Brook stickleback |
| Temperate Bass | White bass |
| Trout-Perch | Trout-perch |
| | **Rough fish** |
| Bowfin | Bowfin (dogfish) |
| Catfish | Black bullhead |
| Catfish | Brown bullhead |
| Catfish | Yellow bullhead |
| Cod | Burbot |
| Drum | Freshwater drum |
| Lamprey | Chestnut lamprey |
| Minnow | Common carp |
| Sucker | Golden redhorse |
| Sucker | Greater redhorse |
| Sucker | Northern hogsucker |
| Sucker | Quillback |
| Sucker | River redhorse |
| Sucker | Shorthead redhorse |
| Sucker | Silver redhorse |
| Sucker | Spotted sucker |
| Sucker | White sucker |
| Sunfish | Rock bass |

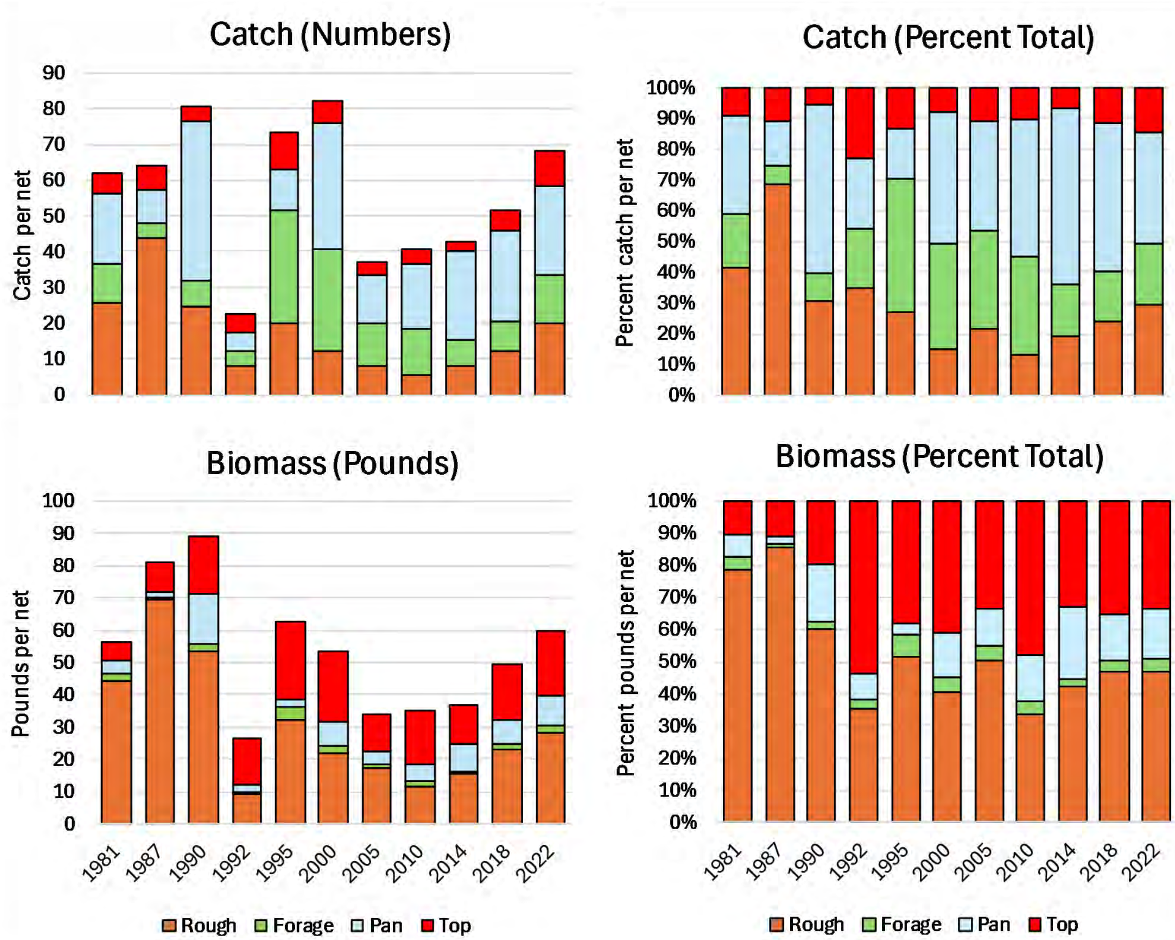


*Fig. 51. Summary of MN DNR Fisheries survey data categorized by trophic group. "Catch" on the top is the total number of fish caught per unit (net) effort. "Biomass" on the bottom is the total catch per unit (net) effort multiplied by the average size of the fish.*

MN DNR is in charge of managing, doing mark–recapture methods on a regular basis over many lakes is not feasible. Thus, the standard surveys with gill nets and trap nets provide some information while trading off accuracy.

With those caveats in mind, the following is a summary of the standard surveys done on Cross Lake.

Over all surveys, a total of 45 different species have been caught in Cross Lake back to 1981 (Table 12). These can be assigned to different trophic level classification to assess high level patterns. By catch, for all time periods, panfish were most often caught group (37%) but by biomass it has been biomass (52%) although there has been significant annual variability (Fig. 51). These data also indicate that both the catch per unit effort and biomass has been increasing for fish since the 2005 survey.

On a species by species basis, the highest catch rate for any fish overall since 1981 has been yellow perch, which

*Table 13. Number of fish caught per unit effort in Cross Lake (1981-2022) as reported by MN DNR. First two columns are percentages based on all data combined (1981-2022) and the most recent year only (2022). Percentages listed as "0%" have rate of <0.05%.*

| Species | 1981-2022 | 2022 | 1981 | 1987 | 1990 | 1992 | 1995 | 2000 | 2005 | 2010 | 2014 | 2018 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yellow perch | 22% | 19% | 10.4 | 3.8 | 7.5 | 4.3 | 31.5 | 28.0 | 11.8 | 12.6 | 7.1 | 8.2 | 12.9 |
| Bluegill | 14% | 11% | 5.0 | 2.0 | 5.9 | 0.3 | 7.8 | 12.4 | 7.0 | 12.2 | 16.2 | 11.4 | 7.3 |
| Black crappie | 12% | 24% | 5.8 | 2.1 | 1.8 | 2.6 | 2.6 | 14.3 | 5.5 | 5.0 | 8.2 | 11.3 | 16.4 |
| Freshwater drum | 11% | 12% | 4.8 | 13.8 | 6.8 | 3.8 | 7.1 | 5.0 | 4.3 | 2.8 | 3.6 | 7.0 | 8.4 |
| White crappie | 11% | 1% | 8.8 | 5.3 | 36.8 | 2.4 | 1.1 | 8.5 | 0.5 | 0.6 | 0.2 | 2.2 | 0.9 |
| Shorthead redhorse | 6% | 6% | 12.8 | 8.1 | 3.6 | 0.7 | 2.4 | 2.1 | 0.6 | 0.8 | 1.3 | 0.8 | 4.0 |
| Silver redhorse | 5% | 1% | | 13.9 | 6.6 | 0.5 | 6.1 | 2.7 | 1.3 | | 0.8 | 1.6 | 0.5 |
| White sucker | 4% | 4% | 5.7 | 3.5 | 3.6 | 2.9 | 2.1 | 0.7 | 0.8 | 0.5 | 1.5 | 2.3 | 2.5 |
| Channel catfish | 4% | 3% | 0.6 | 4.6 | 1.1 | 3.7 | 3.8 | 3.4 | 1.3 | 1.7 | 1.0 | 2.3 | 1.9 |
| Northern pike | 3% | 5% | 0.5 | 0.7 | 1.6 | 0.8 | 4.6 | 2.3 | 1.3 | 1.4 | 0.8 | 2.2 | 3.3 |
| Walleye | 2% | 2% | 3.8 | 1.1 | 0.6 | 0.3 | 0.8 | 0.6 | 0.8 | 0.9 | 0.7 | 1.0 | 1.5 |
| Common carp | 1% | 0% | 1.0 | 3.0 | 2.6 | | 0.4 | 0.1 | | 0.1 | | 0.3 | |
| Lake sturgeon | 1% | 5% | | | 0.7 | 0.5 | 0.6 | 0.1 | 0.3 | 0.2 | 0.2 | 0.3 | 3.3 |
| Black bullhead | 1% | 3% | 1.1 | 0.3 | 0.1 | | | | | 0.2 | 0.1 | | 2.2 |
| Golden redhorse | 1% | 0% | | 1.1 | 0.6 | 0.1 | 1.3 | | 0.1 | 0.2 | 0.3 | | 0.2 |
| Yellow bullhead | 0% | 2% | 0.1 | | 0.3 | | 0.1 | | 0.3 | | 0.7 | 0.1 | 1.4 |
| Brown bullhead | 0% | 0% | | | | | 0.1 | 1.6 | 0.1 | 0.1 | | 0.2 | |
| Pumpkinseed | 0% | 0% | 0.4 | | | | 0.3 | 0.1 | 0.3 | 0.5 | | 0.3 | 0.1 |
| White bass | 0% | 1% | 0.3 | 0.2 | | | 0.1 | 0.3 | 0.2 | 0.2 | | 0.1 | 0.7 |
| Muskellunge | 0% | 0% | 0.4 | 0.1 | 0.3 | 0.1 | 0.1 | 0.1 | 0.3 | | 0.2 | | |
| Greater redhorse | 0% | 0% | | | | | 0.2 | | 0.5 | 0.3 | | | 0.2 |
| Rock bass | 0% | 1% | | | 0.1 | | 0.2 | | | | | | 0.4 |
| Shovelnose sturgeon | 0% | 0% | 0.3 | 0.3 | | | | | | | | | |
| Smallmouth bass | 0% | 0% | | 0.2 | | | 0.2 | | 0.1 | 0.1 | | | |
| Bowfin (dogfish) | 0% | 0% | 0.3 | | | | | 0.1 | | | | 0.1 | |
| Chestnut lamprey | 0% | 0% | | | | | | | | 0.1 | 0.2 | 0.2 | 0.1 |
| River redhorse | 0% | 0% | | | | | | | | 0.4 | | | |
| Golden shiner | 0% | 0% | | | | | | | | 0.2 | 0.1 | 0.1 | |
| Largemouth bass | 0% | 0% | | | | | 0.1 | 0.1 | 0.2 | | | | |
| Quillback | 0% | 0% | | | 0.1 | | | 0.1 | 0.1 | | | | |
| Bigmouth buffalo | 0% | 0% | | | | | | | | | | | 0.1 |

were 22% of all fish caught. The most recent 2022 survey showed similar proportion of catches for yellow perch at 19%. Historically, yellow perch were followed by bluegill (14%), black crappie (12%), and freshwater drum (11%). These proportions were similar in 2022 except that black crappie was the most captured fish at 24% of numbers (Table 13).

For biomass, which is a multiple of catch and average weight, historically most of the catch has been comprised of rough fish, specifically silver redhorse (15%) and freshwater drum (12%). These were followed by the gamefish channel catfish (12%) and northern pike (11%). In 2022, results were consistent except that freshwater drum make up 23% of biomass and black crappie were a top producer at 10% (Table 14).

*Table 14. Biomass (CPUE x Ave Weight) in pounds of fish caught per unit effort in Cross Lake (1981-2022) as reported by MN DNR. First two columns are percentages based on all data combined (1981-2022) and the most recent year only (2022). Percentages listed as "0%" have rate of <0.05%.*

| Species | 1981-2022 | 2022 | 1981 | 1987 | 1990 | 1992 | 1995 | 2000 | 2005 | 2010 | 2014 | 2018 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silver redhorse | 15% | 3% | | 32.3 | 20.5 | 1.3 | 13.1 | 7.6 | 4.3 | | 3.1 | 4.2 | 1.6 |
| Freshwater drum | 14% | 23% | 5.4 | 11.2 | 3.1 | 1.8 | 7.2 | 7.9 | 7.8 | 3.7 | 7.0 | 10.0 | 13.7 |
| Channel catfish | 12% | 11% | 2.2 | 2.8 | 3.7 | 8.9 | 11.2 | 11.0 | 5.6 | 7.9 | 4.8 | 8.2 | 6.5 |
| Northern pike | 11% | 12% | 2.4 | 3.6 | 8.2 | 3.5 | 9.7 | 10.1 | 2.4 | 6.2 | 2.3 | 6.4 | 7.4 |
| Common carp | 8% | 0% | 6.8 | 12.7 | 20.1 | | 3.7 | 0.7 | | 1.7 | | 3.2 | |
| Shorthead redhorse | 8% | 8% | 24.7 | 6.0 | 2.7 | 0.8 | 2.3 | 2.3 | 0.9 | 1.1 | 2.0 | 0.9 | 4.8 |
| White sucker | 6% | 7% | 5.8 | 5.0 | 4.9 | 5.2 | 2.1 | 1.2 | 1.4 | 0.8 | 2.1 | 4.3 | 4.2 |
| Bluegill | 4% | 5% | 1.2 | 0.6 | 1.9 | 0.1 | 1.4 | 2.3 | 2.0 | 3.4 | 5.4 | 3.0 | 2.9 |
| Black crappie | 4% | 10% | 1.3 | 0.4 | 0.8 | 1.1 | 0.6 | 3.0 | 1.7 | 1.6 | 3.0 | 3.4 | 5.8 |
| White crappie | 3% | 1% | 1.3 | 0.7 | 12.8 | 0.9 | 0.4 | 2.0 | 0.2 | 0.1 | 0.1 | 0.9 | 0.6 |
| Yellow perch | 3% | 3% | 2.5 | 0.8 | 2.5 | 0.8 | 4.1 | 2.2 | 1.3 | 1.3 | 0.8 | 1.4 | 1.9 |
| Muskellunge | 2% | 0% | 0.2 | 0.2 | 4.1 | 0.5 | 1.2 | 0.1 | 1.9 | | 4.2 | | |
| Walleye | 2% | 3% | 0.7 | 1.9 | 0.1 | 0.1 | 0.7 | 0.8 | 1.3 | 1.9 | 0.5 | 2.1 | 1.6 |
| Lake sturgeon | 2% | 7% | | | 1.5 | 1.3 | 0.8 | 0.1 | 0.1 | 0.7 | 0.3 | 0.6 | 4.2 |
| Golden redhorse | 1% | 0% | | 1.8 | 1.3 | 0.1 | 3.1 | | 0.1 | 0.4 | 0.8 | | 0.2 |
| Greater redhorse | 1% | 1% | | | | | 0.4 | | 1.7 | 1.6 | | | 0.6 |
| Yellow bullhead | 0% | 1% | 0.1 | | 0.2 | | 0.1 | | 0.3 | | 0.7 | 0.0 | 0.8 |
| River redhorse | 0% | 0% | | | | | | | | 2.2 | | | |
| Bowfin (dogfish) | 0% | 0% | 1.0 | | | | | 0.3 | | | | 0.5 | |
| White bass | 0% | 1% | 0.0 | 0.1 | | | 0.1 | 0.3 | 0.2 | 0.1 | | 0.1 | 0.6 |
| Bigmouth buffalo | 0% | 3% | | | | | | | | | | | 1.6 |
| Brown bullhead | 0% | 0% | | | | | 0.0 | 1.1 | 0.1 | 0.0 | | 0.2 | |
| Quillback | 0% | 0% | | | 0.5 | | | 0.5 | 0.5 | | | | |
| Black bullhead | 0% | 1% | 0.2 | 0.1 | 0.0 | | | | | 0.2 | 0.0 | | 0.3 |
| Shovelnose sturgeon | 0% | 0% | 0.2 | 0.4 | | | | | | | | | |
| Smallmouth bass | 0% | 0% | | 0.1 | | | 0.2 | | 0.0 | 0.0 | | | |
| Pumpkinseed | 0% | 0% | 0.1 | | | | 0.0 | 0.0 | 0.1 | 0.1 | | 0.0 | 0.0 |
| Largemouth bass | 0% | 0% | | | | | 0.0 | 0.1 | 0.1 | | | | |
| Rock bass | 0% | 0% | | | 0.0 | | 0.0 | | | | | | 0.1 |
| Golden shiner | 0% | 0% | | | | | | | | 0.0 | 0.0 | 0.0 | |
| Chestnut lamprey | 0% | 0% | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 |

Following is a brief summary of select species often targeted by anglers of some historical trends and biology for fish found in Cross Lake. Much of the life history characteristics and data are summarized from two different MN DNR guides, including their general guidebook for doing fish surveys (MN DNR 2017) and the evaluation of the same (McInerny 2014).

**Walleye**

Cross lake has a long history of walleye management through stocking activity, which began in 1984. Over the past 10 years, 7 of these years were stocked by a variety sized walleyes (Table 15). Nearly every narrative summary of the fish community from the MN DNR indicate their assessment that stocking walleye is not having a positive meas-

*Table 15. Walleye stocking for past 10 years on Cross Lake.*

| Year | Size | Numbers | Pounds | Average size (lbs) |
|---|---|---|---|---|
| 2014 | fingerlings | 10,166 | 557 | 0.05 |
| 2015 | adults | 46 | 29 | 0.63 |
| | yearlings | 236 | 79 | 0.33 |
| | fingerlings | 6,274 | 535 | 0.09 |
| 2016 | adults | 411 | 265 | 0.64 |
| | fingerlings | 3,968 | 263 | 0.07 |
| 2017 | adults | 853 | 530 | 0.62 |
| | fingerlings | 684 | 171 | 0.25 |
| 2019 | fingerlings | 3,804 | 317 | 0.08 |
| | yearlings | 6,444 | 528 | 0.08 |
| 2021 | fingerlings | 22,090 | 660 | 0.03 |
| 2023 | fingerlings | 19,430 | 670 | 0.03 |
| | fry | 254,000 | 2 | <0.01 |

fry = newly hatched fish
fingerlings = one-to-six months
yearlings = a minimum of one year but not sexually mature
adult = sexual mature fish, typically older than two years

urable effect on the fishery. Artificial stocking tends to provide positive impacts to populations in lakes and reservoirs where natural reproduction is not occurring but not in those where natural reproduction can occur. Particularly in Cross Lake where there is not an abundance of vegetation to provide refuge for stocked fish, it's probable that stocked fish are easy targets and simply become prey items for larger fish. Rather than putting forth efforts at continued stocking, we might recommend searching for and protecting walleye spawning substrate and increasing availability of plant coverage in the lake to provide refuge for newly hatched fish.

**MANAGEMENT OBJECTIVE #23**

SEARCH FOR AND PROTECT WALLEYE SPAWNING HABITAT AND INCREASE PLANT COVERAGE TO PROVIDE REFUGE FOR YOUNG OF THE YEAR FISH

Walleye numbers have been lower than expected for similar type lakes for as long as they have been surveyed (Fig. 52). The average size of a fish has historically been either within or below expected range but, on average, the size of an individual fish has increased since

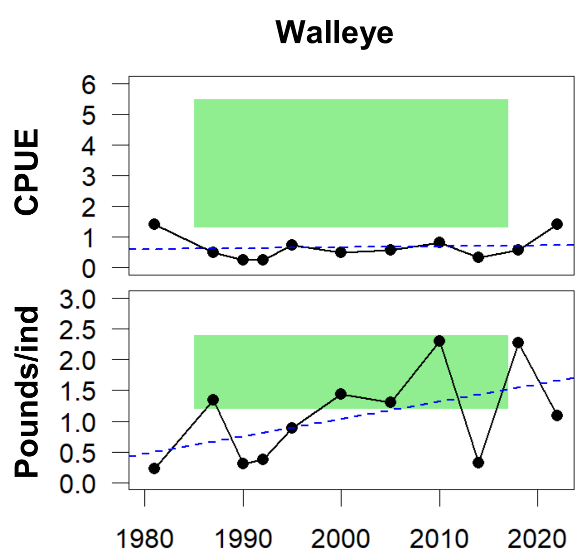


*Figure 52. Walleye summary for MN DNR historical standard fisheries surveys (gillnet only). Upper panels show the total number of fish caught per net and the lower panel shows the average size of a fish. Green boxes indicate average expected ranges for a given species in similar lakes. The dashed lines indicate the best fit line for a trend.*

the first survey done on them in 1981.

In the most recent survey (2022) commentary, MN DNR indicate 41% of walleye caught were over 12 inches in length, which they deem as good. and thought this was good.

Walleye are the most sought after gamefish in Minnesota lakes with 20-30% of anglers targeting them during any given fishing event. On Cross Lake, 20% of users said they are targeting walleye when they fish.

They spawn in the spring when water temperatures are between 45-50 °F. Walleye prefer clean gravel or rubble shores or shoal areas exposed to wave action. Spawning occurs over a few days, happens at night, and may occur upstream in connected tributaries for lake population.

MN DNR speculate that walleye are naturally reproducing in Cross Lake and spawning may be occurring either in the lake proper or in Snake River somewhere.

Walleye can be long–lived, up to 17 years. They recruit to the stock if they can survive past their first couple years of life when mortality is highest. At the youngest ages they feed on zooplankton and insects until they are large enough to effective prey on smaller fish, primarily small perch and other young walleye.

They are one of the more photosensitive fish species in Minnesota. Behaviorally, they will avoid strong light during the day by moving to deep water or shading underneath structures. Lakes that are ideal for walleye have moderate levels of phosphorus and water clarity.

**Muskie**

Cross Lake is also managed for muskie (i.e., "Muskellunge"). Even though there are approximately 4,300 lakes managed activity for fish in Minnesota, only 99 lakes are activity managed for muskie (MN DNR 2016). Muskie have been found in an additional 50 lakes in small number. Cross Lake is thus one of a very small number of lakes in Minnesota with muskie and managed as such. Muskie are a larger relative of northern pike but are found in far fewer lakes in Minnesota (Fig. 53).

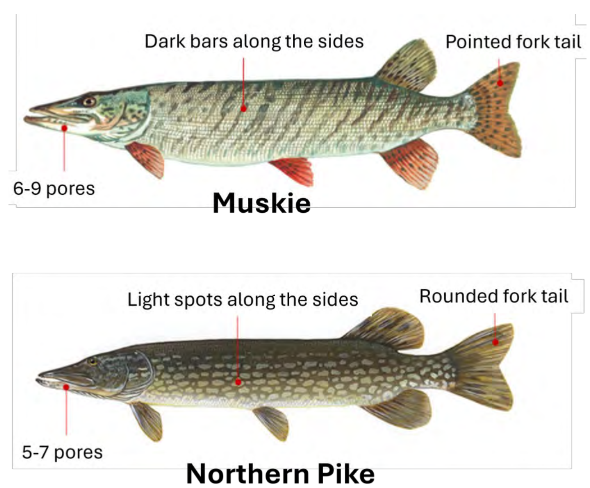


*Figure 53. Morphological differences between muskie and northern pike. Adapted from norrik.com.*

*Table 16. Muskie stocking for past 10 years on Cross Lake.*

| Year | Numbers | Pounds | Average size (lbs) |
|---|---|---|---|
| 2014 | 256 | 52 | 0.20 |
| 2015 | 500 | 135 | 0.27 |
| 2016 | 358 | 119 | 0.33 |
| 2017 | 500 | 94 | 0.19 |
| 2018 | 39 | 16 | 0.40 |
| 2019 | 1,011 | 211 | 0.21 |
| 2022 | 500 | 50 | 0.10 |
| 2023 | 37 | 8 | 0.21 |

The MN DNR has been stocking Cross Lake with muskie fingerlings at least since 2014 (Table 16). Although they have been stocked longer than that, we were unable to find a record for when it began. Initial population to the lake is listed as introduced by the state, but fish survey data do indicate some natural reproduction is currently occurring.

Muskie are a highly sought after gamefish and sportsman groups exist that specialize in fishing them. They are desirable trophy gamefish likely south after for their size and rarity.

Standard survey methods are not ideal for sampling muskie, so while the MN DNR reports catch data back to 1981, they are not very useful for understanding trends or status with the exception of finding clues about their presence and potential source (i.e., stock or natural reproduction). Data that do exist indicate that population numbers in Cross Lake are low but that the size of muskie in the lake are larger than average (Fig. 54).

The most complete survey for muskie on Cross Lake was a multi-method assessment in 2015 that included specialized sized nets designed for muskie, electrofishing, and mark-recapture methods. During that survey 39 muskie were captured including 21 males and 18 females. Males averaged 19.4 pounds (range 9.3-25.6 pounds) and females averaged 29.5 pounds (range 13.4-38.6 pounds). The mark-recapture method estimated a total population of muskie in the lake of between 47 and 68 fish. Annual survival of 10+ year old fish was estimated at 74%, which is normal and does not seem to be excessively influenced by anglers.

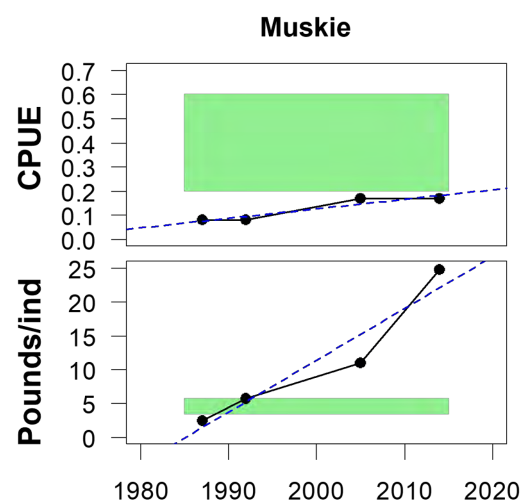


*Figure 54. Muskie summary for MN DNR historical standard fisheries surveys (gillnet only). Upper panels show the total number of fish caught per net and the lower panel shows the average size of a fish. Green boxes indicate average expected ranges for a given species in similar lakes. The dashed lines indicate the best fit line for a trend.*

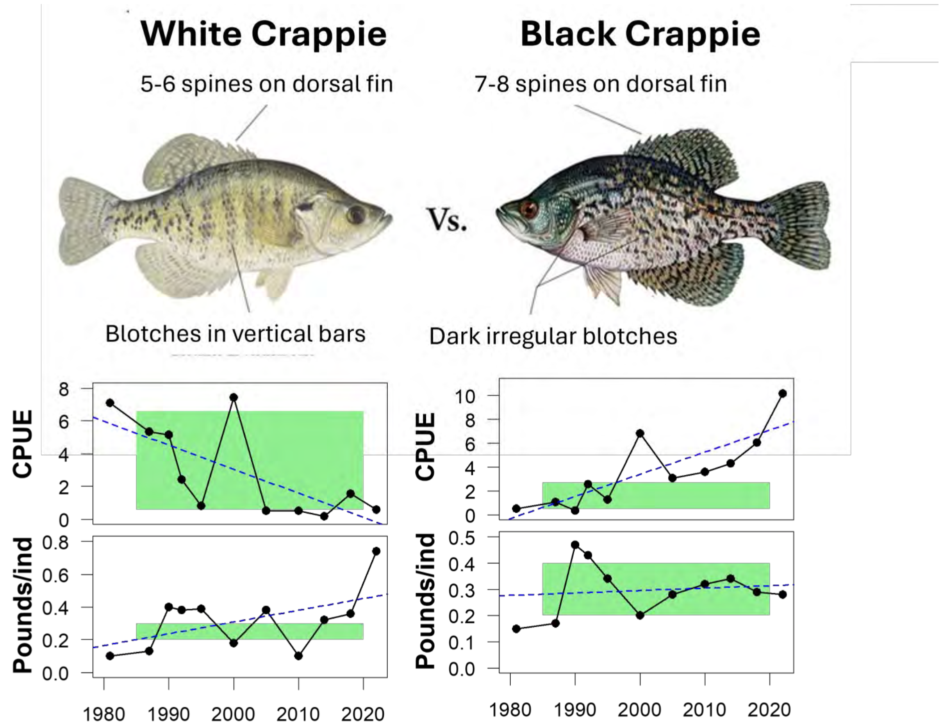


*Figure 55. Morphological differences between white and black crappie. Survey summary for MN DNR historical standard fisheries surveys (gillnet only). Upper panels show the total number of fish caught per net and the lower panel shows the average size of a fish. Green boxes indicate average expected ranges for a given species in similar lakes. The dashed lines indicate the best fit line for a trend.*

The MN DNR concluded from this study that the overall opportunity to catch muskie was lower than some other muskie lakes but that if anglers were successful in catching a fish, there was a good probability it would be a large one.

We should anticipate that the MN DNR will continue to manage muskie on the lakes and this should generally be supported.

### Crappie

Historically and recently, Cross Lake has had healthy populations of catchable crappie. Cross Lake has populations of two different species of crappie: black and white (Fig. 55). There has been a shift in dominance from white crappie (1981-1990) to black crappie 2005-2022) over time. Since 2005, by total biomass, black crappie have been 76%-96% of the crappie population. Overall catch numbers of white crappie have declined while black crappie populations have been increasing. Even though population sizes of white crappie have declined, the average size of them have increased. Sizes of black crappie have remained relatively stable through time and within the range of expected sizes for them in similar lakes.

Crappie are specifically targeted for catch 10-15% of the time anglers are out on the water in Minnesota. On Cross Lake, 25% of lake resident responders said they target crappie when they fish. In the Lake User Opinion Survey, crappie were chosen as the most targeted fish of all in the lake by anglers.

In the latest (2022), the MN DNR indicated that the outlook for black crappie fishing on the lake is good with occasional opportunities to catch white crappie.

Crappie are nest builders and usually spawn in water one-half to three feet deep in May to June when water temperatures reach 50-60 $^{o}$F. Males clear a section of the bottom of sand, gravel, or mud, where there is some vegetation, sometimes where protection is offered by an undercut bank Nests are often built along undeveloped shorelines with emergent vegetation but without submergent vegetation. Residents can help to maintain positive reproductive conditions of crappie by being sensitive to not disturbing crappie nests nearshore during early spring.

**Sunfish (Bluegill, Pumpkinseed, and Hybrid).**

Bluegill are the most common sunfish on Cross Lake followed by pumpkinseed with a few catches of hybrid sunfish, a cross between bluegill and pumpkinseed (Fig. 56). By catch bluegill have always been over 92% of sunfish catch and as such best represent "sunfish" on the lake.

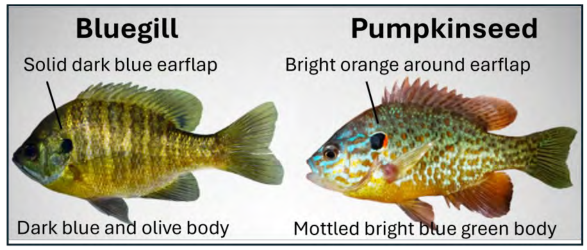


*Figure 56. Morphological differences between bluegill and pumpkinseed sunfish.*

Trap nets are the standard sampling method for bluegill surveys. MN DNR reports that densities of bluegills have historically been low but individual sizes, at least recently, have been quite large on average (Fig. 57). In the spring of 2022 a special regulation went into effect to reduce bag limits of sunfish from 20 to 10 in order to attempt an increase in densities of bluegills. Future surveys targeting sunfish will be able to determine whether a correlation with the regulation and increased densities result.

Panfish are specifically targeted for catch 10-15% of the time anglers are out on the water overall in Minnesota Lakes. Anglers in Cross Lake are targeting panfish at a higher rate of approximately 40% based on the 2023 Lake User Opinion Survey.

All members of sunfish family (i.e.,

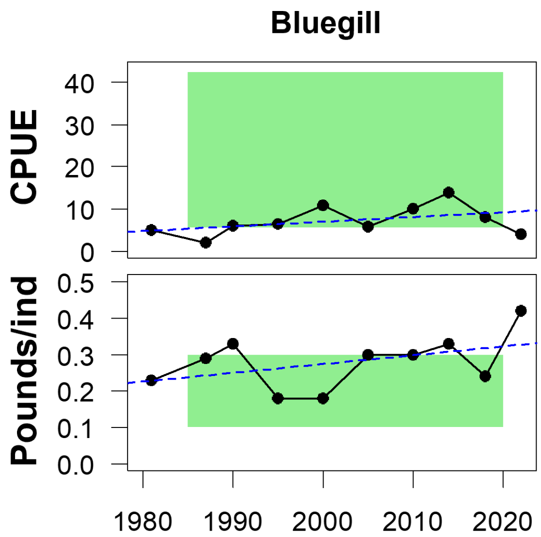


*Figure 57. Bluegill summary for MN DNR historical standard fisheries surveys (trapnet only). Upper panels show the total number of fish caught per net and the lower panel shows the average size of a fish. Green boxes indicate average expected ranges for a given species in similar lakes. The dashed lines indicate the best fit line for a trend.*

crappie, bluegill, pumpkinseed and bass) build nests and prefer firm gravel or coarse sand bottoms in two to five feet of water. Preferred sites are protected from heavy wave action. Weedy lakes are usually well suited to these species.

Young of the year panfish are important forage for northern pike, walleye, largemouth bass, crappie, and larger yellow perch.

**Largemouth Bass**

Largemouth bass were not caught in gill nets or trap nets in 2018 and were only caught in 1995, 2000, and 2005. They were below normal size and catch rates during those years.

Overall in the state of Minnesota, largemouth bass are one of the lower targeted species by anglers. Between 5-10% of anglers target them specifically when they are out fishing. This is consistent with proportion of anglers on Cross Lake who responded that they target largemouth bass approximately 7% of the time when fishing.

Largemouth bass build nests after spawning typically between May and June when water temperatures reach 50 -60 $^{o}$F. They prefer firm gravel or coarse sand bottoms in two to five feet of water. Often the gravel or sand may be overlain by muck or detritus. Soft, unstable bottoms are not commonly used unless roots or detritus provide a firm substrate. Preferred sites are protected from heavy wave action. Weedy lakes are usually well suited to these species.

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**MANAGEMENT OBJECTIVE #24**

PROTECT NEARSHORE NESTS IN LATE SPRING FOR MEMBERSHIP OF SUNFISH FAMILY INCLUDING CRAPPIE, SUNFISH AND BASS

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**Channel Catfish**

While not generally targeted in many

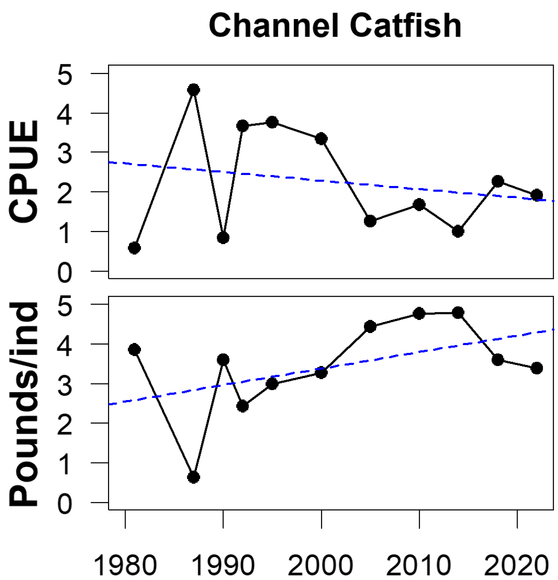


*Figure 58. Channel summary for MN DNR historical standard fisheries surveys (gillnet only). Upper panels show the total number of fish caught per net, a proxy for how abundant fishes are and the lower panels shows the average size of an individual fish. The dashed lines indicate the best fit line for a trend. Note state of MN does not publish average ranges for channel catfish.*

lakes of Minnesota, Cross Lake has historically been noted by the MN DNR based on survey data to have a good catfish fishery. The state of Minnesota does not have published expected ranges for populations or average sizes but since 1981 on average two channel catfish have been caught in each net and the average size has been nearly 3.5 pounds (Fig. 58). The latest survey (2022) concludes that there are good numbers of quality sized catfish for anglers with 90% of catches being fish over 17 inches in length.

**Northern Pike**

Approximately 10-15% of people who fish in Minnesota lakes are specifically targeting northern pike when they fish. The recent Lake Opinion User Survey for lake residents indicates that users are not currently targeting pike most of the time with only 8% of anglers indicating they target northern pike.

Northern pike populations are lower than expected ranges for similar lakes (Fig. 59). The average size of a northern pike has historically been within normal size ranges. The most recently MN DNR survey indicates that, based

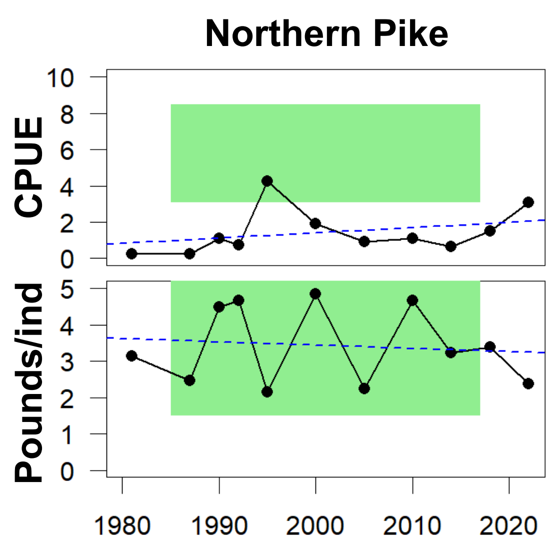


*Figure 59. Northern pike summary for MN DNR historical standard fisheries surveys (gillnet only). Upper panels show the total number of fish caught per net, a proxy for how abundant fishes are and the lower panels shows the average size of an individual fish. Green boxes indicate average expected ranges for a given species in similar lakes. The dashed lines indicate the best fit line for a trend.*

on size structure of the northern pike population, anglers can expect to catch a good number of pike over 26 inches.

Northern Pike spawn during late winter/early spring when water temperature are below 50 °F. They prefer to spawn in shallow, marshy areas, particularly in temporarily flooded meadows or marshlands. Good spawning marshes should have slowly dropping spring water levels, to avoid trapping fry or fingerlings. They have also been known to spawn over deep beds of muskgrass and *Nitella* sp. They have strong native spawning fidelity, meaning they return to the same areas to spawn annually.

**Yellow Perch**

Yellow perch numbers are variable in Cross Lake and within the normal range. Average size is also within the normal range and stable year to year (Fig. 60). The targeted survey in 2022 indicates a good fishery with perch numbers being above average for Cross Lake and most are of a good size.

Yellow perch are one of the most important forage items for gamefish in a lake. Northern pike, largemouth bass, crappie, and larger yellow perch feed on yellow perch.

Of all the species discussed here, yellow perch is targeted least by anglers. Less than 5% of anglers fishing in lakes are specifically targeting perch. Less than 1% of Cross Lake respondents according to the Lake User Survey target perch.

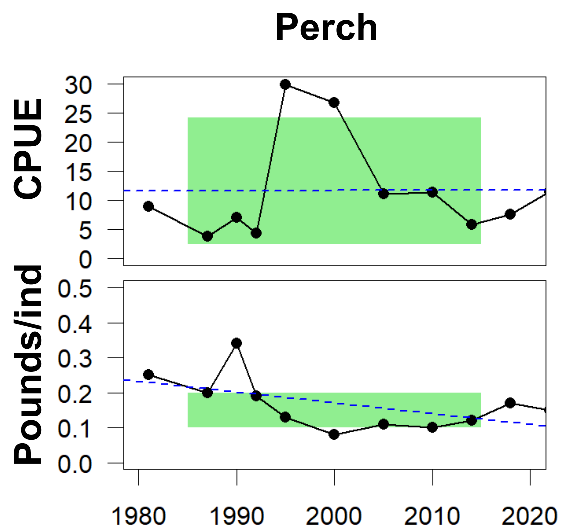


*Figure 60. Yellow Perch summary for MN DNR historical standard fisheries surveys (gillnet only). Upper panels show the total number of fish caught per net, a proxy for how abundant fishes are and the lower panels shows the average size of an individual fish. Green boxes indicate average expected ranges for a given species in similar lakes. The dashed lines indicate the best fit line for a trend.*

Yellow Perch spawn in open, shallow water, usually near rooted vegetation, submerged brush, or fallen trees, but sometimes over sand or gravel. They time their spawning in April-May when water temperatures are around 50 °F.

Given their importance as a forage species, attention to their management would be advisable even if they are not a highly sought after target for anglers.

### General Strategies for Fish Management

A variety of tools are used by managers to attempt to improve or sustain good fisheries. The most used are artificial stocking and/or limiting either the number of fish caught or the size of fish kept by anglers.

As described above, both walleye and muskie have a history of being stocked in Cross Lake. Stocking of lakes with can have variable success. Particularly, some research indicates that in lakes where natural reproduction of walleye occurs, stocking has no impact on population but where natural reproduction does not occur it is useful. A general explanation for this is that in lakes with natural reproduction, lake are already at a carrying capacity, meaning they already have the maximum size of population that the lake can handle. Stocked fish are genetically inferior and get outcompeted by native walleye and thus have high levels of mortality. Cross Lake has natural reproduction of walleye and as such walleye stocking may be having little impact on the population. It is likely that the low densities of walleye in Cross Lake simply indicate it is inferior habitat for walleye.

The same may also be true for muskie; however, muskie stocked in lakes tend to be much larger than other fish like walleye and as such may have greater production from predation mortality. There seems to be some evidence of natural production of muskie in Cross Lake but it is unclear whether it is enough to support a population.

For bag limits, ross Lake has special fishing regulations on sunfish but no size based limits on any fish. Experimental regulations aim for two impacts. First, reducing bag limits aims to leave more fish in the lake to reproduce, although a large body of research indicates that anglers rarely harvest limits during any given fishing event. Subsequently, reducing bag limits may have limited positive impacts. Second, size-based harvesting rules, whether that be minimum or maximum size limits can have both direct and indirect impacts on fish stocks. The obvious direct impact of size based limits is it keeps fish in the lake. In terms of indirect effects, maximum size limits protect larger fish aiming to preserve older animals with presumably high genetic integrity to reproduce and improve the genetic stock. It also is the case that removing smaller fish from the lake reduces intra-specific competition for the larger older fish to continue to thrive. Additionally, the small fish that remain part of the population may have an increased growth rate.

Both stocking and bag limits can be done in order to improve angling opportunities, but managing fish is sometimes done to improve water quality by manipulating a trophic cascade.

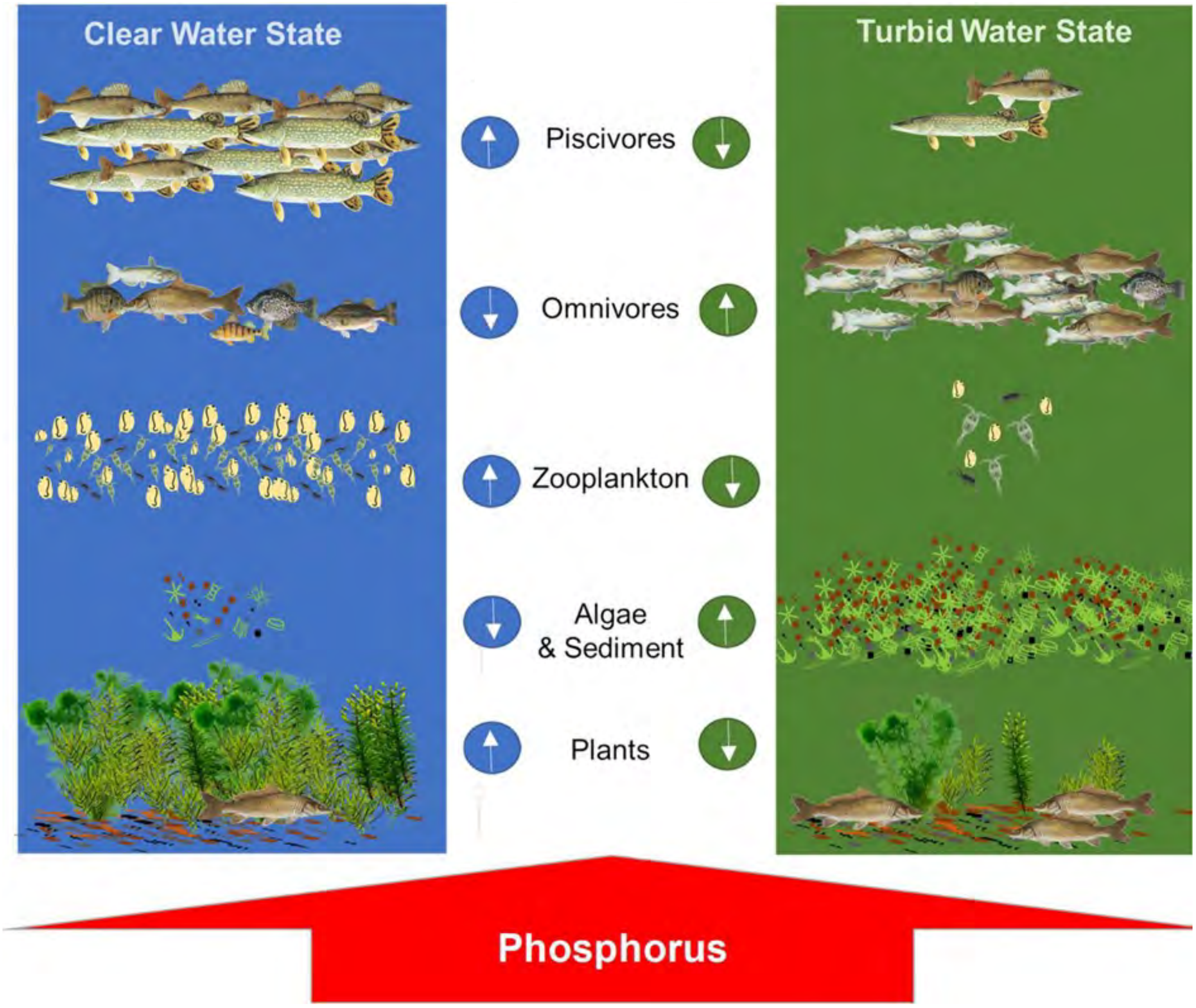


*Fig. 61. Top-down processes occur when groups in a food chain forage and reduce groups below them. Bottom-up processes are driven by nutrient additions from watersheds and the shape and physical nature of the lake basin.*

**Top-Down Control of Water Quality**

Fish community structure can impact water quality directly through "top-down" impacts (i.e., biological) (Fig. 61).

Bottom-up processes are those most are familiar with and include productivity in the lake as it applies to excess nutrients, principally phosphorus. Top-down processes also can impact water quality. A strong and abundant zooplankton community (i.e., principally Daphnia) are needed to keep algae under control. When there are too many small fish that graze down *Daphnia*, *Daphnia* cannot control algae, which allows them to grow in abundance and create poor water conditions.

Top down control of water quality can

occur either by stocking of predator fish or target removal of lower trophic groups through commercial fishing or even on a large scale using fish poisons. Sometimes fish poisons are used to kill all the fish in a lake with a following up of stocking beneficial mixes of fish communities. This is generally referred to as “reclamation”. Top down manipulation of fish communities has a long history of successes in the literature.

Finally, building consensus with individuals and groups not living on but who use Cross Lake may be important. Our experience indicates that there is suspicion by some ardent sport anglers on lake who see management efforts precipitated by lake associations as being overbearing and harmful to fishing on lakes. We are reminded by some of these individuals as we meet them at boat launches, at meetings or even by phone call that lake associations do not own lakes. While some concerns of anglers are not based on good information, working with these groups can go a long way to building consensus and providing a healthy and useable lake for all.

## *CHAPTER 8*
## CONCLUSIONS

A number of analyses and priorities are presented in this lake management plan. We urge short term goal setting and prioritizing because lakes are dynamic and complicated and sure to bring surprises in the near future that may alter goals and approaches.

Overall, available evidence indicates that water quality on Cross Lake is poor, which likely is influencing both aquatic plant growth (or lack of) and fisheries population dynamics.

Relative to most lakes in Minnesota, data quality for water quality on Cross Lake is extremely poor. A top priority for the Cross Lake/Snake River Association will be to establish and maintain a minimal monitoring program where a volunteer collects water samples on the lake monthly from June through September to have analyzed for total phosphorus and chlorophyll *a*. At the same time Secchi depth measurements should be taken. Our recommendation is to repeat this process on three deepest sites for every identified basin in Cross Lake. The approximately annual cost for this would be $1,000 plus a volunteer(s) being willing to do the sampling.

Given our claim that water quality is poor, and available evidence pointing to internal phosphorus loading being a primary cause, we suggest beginning a feasibility assessment of having an alum treatment done, beginning at the deep area of the north basin of Cross Lake.

The expected impact of doing an alum treatment would be to reduce phosphorus and algae concentrations, increase water clarity and aquatic plant coverage and diversity, and improve vegetative refuge for the lake's young-of-the-year fisheries annually.

As part of such an assessment, additional monitoring will need to take place that includes oxygen and temperature profiles at depth and the construction of a phosphorus budget that includes sediment analysis. Costs for doing a robust feasibility assessment can be up to $15,000, which is expensive, but would provide data that will assist in any alum treatment, which can cost hundreds of thousands of dollars, to have the highest probability of success. We note that both feasibility analysis and alum treatment itself can be cost shared with Minnesota Board of Water and Soil Resources (BWSR) through competitive grant applications for monies collected through the Minnesota Clear Water Fund.

These two activities, establishment of a water quality monitoring program and feasibility assessment of an alum treatment, are, to our estimation the most important and fundamental projects to be considered. Other priorities discussed in this report will benefit from these and build from these efforts.

Fisheries are moderately good and being managed by the state. Fisheries could be improved by expanding plant habitat and improving the plant community and water quality. Plant coverage and densities are low and likely creating nuisance conditions in a sense that low light penetration and forces the dominant plants in the lake to be high canopy or floating vegetation. The lack of plant coverage reduces fish habitat and allows sediments to be resuspended easily.

Aquatic invasive species, including curlyleaf pondweed and Eurasian watermilfoil, can be activity monitored and treated where they create nuisance. Property owners with nuisance plants around their shoreline are encouraged to apply for APM permits to treat along section of their properties. We do suggest that if possible where plants do not create a significant nuisance, they be left given the low overall coverage of plants already in the lake.

We would recommend aquatic plant surveys at a minimum of once every three years or as often as budget allows. Aquatic plants are an important component of lake systems and their increase or decrease in coverage can be telling of a number of conditions. Additionally, it is a chance to track existing AIS and look for potential new invaders such as starry stonewort. Costs for an aquatic plant survey would be approximately $5,000-10,000 per event.

This lake management plan presented should be thought of as a living document. Should any reader of the lake management plan have additional information, corrections, or new ideas, they should be considered and incorporated where appropriate.

The Lake User Opinion Survey that was administered as part of this process is included, in full, in the appendix. We strongly recommend offering the Opinion Survey annually to update people's views of the lake.

**MANAGEMENT OBJECTIVE #25**
ANNUALLY ADMINISTER A LAKE USER OPINION SURVEY TO GET AN UPDATE ON USERS PERCEPTION FOR CHANGES

We note the obvious, that lake management activities have a cost and as such Cross Lake/Snake River Association budgets will limit what is able to be done. As such it is important to provide specific budget parameters for operations and then determine priorities. There is no doubt that not everything wished to be done can be done.

Our general advice is to develop a specific management budget amount that can be divided between annual regular monitoring/projects and a second budget for special projects. Examples of potential annual regular monitoring might include annual chemical herbicide treatments, AIS early detection surveys, aquatic plant surveys/monitoring and water quality monitoring. As described above, an important initial special project would be a feasibility assessment for alum treatment.

Many additional priorities and goals are presented through this lake management plan and appear in red boxes throughout. These should be seen as supportive and as additional activities that can be implemented as able.

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**MANAGEMENT OBJECTIVES**

**Cross Lake User Opinion Survey 2023**

The leadership of the Cross Lake/Snake River Lake Association is in the process of gathering information from lake residents. As someone who lives on or uses the lake, your views are important to how they might think about management activities. Please take 5-10 minutes to answer the following questions. All survey entries are anonymous.

1. Are you a dues-paying member of the Lake Association?

| Responses | Count | Percent |
|---|---|---|
| Never | 7 | 5% |
| Yes, current | 113 | 85% |
| Yes, in the past, but not currently | 13 | 10% |
| **Grand Total** | **133** | **100%** |

2. How many years have you lived on the lake?

| Responses | Count | Percent |
|---|---|---|
| I don't live on the lake | 13 | 10% |
| Less than 1 year | 3 | 2% |
| 1-2 years | 7 | 5% |
| 3-5 years | 21 | 16% |
| 6-10 years | 17 | 13% |
| More than 10 years | 73 | 54% |
| **Grand Total** | **134** | **100%** |

**QUESTIONS ON WATER QUALITY**

3. According to your recollections in using the lake over the past couple of years, how did you experience the impact of algae on the water clarity?

| Responses | Count | Percent |
|---|---|---|
| Not quite crystal clear -- a little algae present/visible. | 7 | 5% |
| Definite algae - green, yellow, or brown color apparent | 44 | 33% |
| High algae levels with limited clarity and/or mild odor apparent | 51 | 38% |
| Severe high algae levels with one or more of the following: massive floating scums on the lake or washed up on shore; strong, foul odor; or fish kill | 32 | 24% |
| **Grand Total** | **134** | **100%** |

4. According to your recollection in using the lake over the past couple years, did you experience problems with algae blooms? A bloom is a temporary (from a few hours up to a couple of weeks) interruption of clear water phase by algae rapidly growing and then over a period of time disappearing.

| Responses | Count | Percent |
|---|---|---|
| No | 23 | 17% |
| Yes | 110 | 83% |
| **Grand Total** | **133** | **100%** |

5. According to your recollection in using the lake over the past couple years, how did you experience the overall quality of the water as it affected your decision to recreate?

| Responses | Count | Percent |
|---|---|---|
| Beautiful , could NOT be better | 1 | 1% |
| Very minor aesthetic problems; excellent for swimming, boating | 4 | 3% |
| Swimming and aesthetic enjoyment are slightly impaired due to algae levels | 53 | 40% |
| Desire to swim and level of enjoyment of the lake substantially reduced due to algae levels (i.e. would not swim but boating is okay) | 61 | 46% |
| Swimming and aesthetic enjoyment of the lake nearly impossible due to algae levels | 14 | 11% |
| **Grand Total** | **133** | **100%** |

6. Overall, how would you judge the change in clarity of the lake over the recent years? For the purpose of this question "improve" means to become more clear & "decline" means to become more turbid, green, brown, cloudy or otherwise not clear.

| Responses | Count | Percent |
|---|---|---|
| It has improved dramatically over the past years, becoming much more clear. | 2 | 2% |
| It has been improving slightly over the past years, becoming slightly more clear. | 10 | 8% |
| It has stayed relatively constant over the past years | 43 | 33% |
| It has been declining slightly over the past years, becoming slightly more turbid. | 47 | 36% |
| It has been severely declining over the past years, becoming much more turbid | 29 | 22% |
| **Grand Total** | **131** | **100%** |

## QUESTIONS ON AQUATIC PLANTS

7. According to your recollection in using the lake over the past couple years, did you experience problems with nuisance plant growth on the lake?

| Responses | Count | Percent |
|---|---|---|
| Yes | 94 | 71% |
| No | 38 | 29% |
| **Grand Total** | **132** | **100%** |

8. Over the past few years, how would you describe the state of the aquatic plant environment on your lake?

| **Responses** | **Count** | **Percent** |
|---|---|---|
| There has been a more severe decline in plant coverage and density in growth than I ever remember | 8 | 6% |
| There has been a slight decline in plant coverage and density of growth than I remember | 12 | 10% |
| The amounts of plant coverage and density hasn't changed significantly over the past | 42 | 33% |
| There has been a slight increase in plant coverage and density of growth relative to what I remember | 40 | 32% |
| There has been a severe increase in plant coverage and density of growth relative to what I remember | 24 | 19% |
| **Grand Total** | **126** | **100%** |

9. How confident are you to identify aquatic invasive plants such as curlyleaf pondweed or Eurasian watermilfoil?

| **Responses** | **Count** | **Percent** |
|---|---|---|
| Very confident | 13 | 10% |
| Fairly Confident | 65 | 49% |
| Not Confident | 56 | 42% |
| **Grand Total** | **134** | **100%** |

10. What means do you support in controlling nuisance plants in the lakes?

| **Responses** | **Count** | **Percent** |
|---|---|---|
| Chemical Herbicides | 31 | 25% |
| Chemical Herbicides and/or Mechanical Harvesters | 57 | 46% |
| Mechanical Harvesters | 36 | 29% |
| **Grand Total** | **124** | **100%** |

**QUESTIONS ON FISHING**

11. How would you rate the quality of fishing currently?

| **Responses** | **Count** | **Percent** |
|---|---|---|
| Excellent | 4 | 3% |
| Average | 93 | 79% |
| Terrible | 20 | 17% |
| **Grand Total** | **117** | **100%** |

12. How would you rate the change in the quality of fishing over the past few years?

| Responses | Count | Percent |
|---|---|---|
| Become better | 6 | 5% |
| Stayed the same | 69 | 60% |
| Worsened | 40 | 35% |
| **Grand Total** | **115** | **100%** |

13. If/when you are out fishing, what you are you most often targeting? Choose all that apply.

| Responses | Count | Percent |
|---|---|---|
| Crappie | 71 | 25% |
| Walleye | 55 | 20% |
| Sunfish | 50 | 18% |
| Anything that bites | 36 | 13% |
| Northern Pike | 22 | 8% |
| Bass | 21 | 7% |
| Don't fish | 23 | 8% |
| Other | 3 | 1% |
| **Grand Total** | **281** | **100%** |

## QUESTIONS ON GENERAL LAKE CONDITIONS

14. According to your recollection in using the lake last year, what is your view of the number of waterfowl (e.g. ducks and geese) using the lake?

| Responses | Count | Percent |
|---|---|---|
| Too many | 5 | 4% |
| The right amount | 89 | 70% |
| Too few | 33 | 26% |
| **Grand Total** | **127** | **100%** |

15. There is often a tradeoff in lakes where you can have either clear water with lots of plants or turbid (i.e., "cloudy") water with fewer plants. If you could choose the condition of the lake, how might you like to see the these balanced?

| Responses | Count | Percent |
|---|---|---|
| Favor a lake with fewer plants even if it means it will not be super clear and may have some nuisance algae growth | 3 | 2% |
| Exactly intermediate with moderate clarity and moderate plant growth. | 52 | 40% |
| Favor a clearer lake and willing to put up with some nuisance plant growth. | 69 | 53% |
| Very clear lake with densely growing plants covering many areas. | 6 | 5% |
| **Grand Total** | **130** | **100%** |

16. How concerned are you about the impact of the lakes condition on the value of your property investments?

| **Responses** | **Count** | **Percent** |
|---|---|---|
| Not | 12 | 9% |
| Moderately | 64 | 48% |
| Very | 56 | 42% |
| Grand Total | 132 | 100% |

17. Which of the following would you be willing to do to keep the lake healthy?

| **Responses** | **Count** | **Percent** |
|---|---|---|
| Consideration of changes to use of your property to reduce harmful runoff | 71 | 34% |
| Financial contributions | 54 | 26% |
| Contribution of manual labor | 44 | 21% |
| Service on a board, committee, or task group | 22 | 10% |
| Contribution of special skills to the upkeep of the lake | 20 | 9% |
| **Grand Total** | **211** | **100%** |

18. Which of the following activities are you most likely to perform on the lake?

| **Responses** | **Count** | **Percent** |
|---|---|---|
| Swimming | 115 | 22% |
| Pontoon rides | 108 | 21% |
| Fishing | 100 | 19% |
| Kayaking | 64 | 12% |
| Tubing | 64 | 12% |
| Jetskiing | 33 | 6% |
| Wakeboarding | 17 | 3% |
| Waterskiing | 17 | 3% |
| **Grand Total** | **518** | **100%** |

19. The Lake Association Board makes decisions about how to spend your membership fees and other dollars they are able to get through grant applications. The following is a list of activities that might be worthy of your dollars. In your view, which activities are you in support of?

| **Responses** | **Count** | **Percent** |
|---|---|---|
| Annual lake monitoring | 43 | 15% |
| Reducing nutrient runoff through engineered solutions at lake inlets in hopes to reducing algae growth and increasing water clarity | 42 | 15% |
| Chemical control of nuisance plant growth | 39 | 14% |
| Stocking walleye | 39 | 14% |
| Reducing nutrient inputs from the lake sediment in hopes of reducing algae and increasing water clarity. | 39 | 14% |
| AIS Inspectors at boat launch | 28 | 10% |
| Fireworks | 25 | 9% |
| Social activities | 24 | 9% |
| **Grand Total** | **279** | **100%** |