Watershed assessment and trends update

Lake Superior- South

Lake Superior Basin

Summary

The Minnesota Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MNDNR), and partners have completed a study of the Lake Superior-South Watershed, which stretches from Duluth to Silver Bay. This watershed encompasses 624 square miles and contains 16 lakes (>10 acres) and numerous streams. These streams are generally small to moderate in size, short, and rocky, particularly as they flow down the escarpment bordering Lake Superior. The waters found within this watershed not only produce some of the highest quality stream trout fisheries in the state but also offer visitors many scenic and natural views.

Water quality throughout this watershed is in good condition overall but problem areas do occur and persist. Water quality impairments found within this watershed are likely a function of both natural and anthropogenic stressors. Although several streams do not meet water quality standards, many are higher quality and may warrant additional protections. Most of the streams within this watershed are cold-water resources that support robust Brook, Brown, and/or Rainbow Trout populations. In addition, multiple rare and/or state threatened aquatic macroinvertebrate (mayflies, dragonflies, etc.) species have been collected. Relatively few lakes exist within the Lake Superior-South Watershed. Five lakes were evaluated during this more recent monitoring and all met standards designed to protect aquatic recreation.

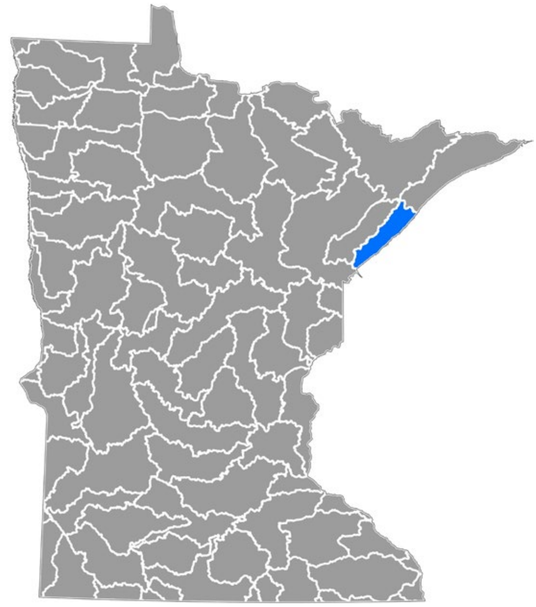
Instead of relying on chemical testing of the water alone, scientists reached their conclusions by studying the variety of fish and macroinvertebrates living in the waters. Doing so offers a more comprehensive understanding of the watershed's health over time. Volunteer water quality monitors contributed to this monitoring effort, which is funded by Minnesota's Clean Water Land and Legacy Amendment. Details in the full report will shape decisions on watershed management and pollution reduction measures for years to come.

Watershed study

Water monitoring is essential to determining whether lakes and streams meet water quality standards that are designed to ensure that waters are fishable and swimmable. While local partners and state agencies monitor water quality on an ongoing basis, the Minnesota Pollution Control Agency (MPCA) and local partners conduct an intensive monitoring of major lakes and streams in each of the state's 80 watersheds every 10 years to detect any changes in water quality. This intensive monitoring looks at fish and aquatic macroinvertebrate communities as well as water chemistry to gauge water quality. The partners use the data to determine which waters are healthy and need protection and which are impaired and need restoration. Waters are considered impaired if they fail to meet water quality standards.

The MPCA and partners monitored water quality conditions within the Lake Superior-South Watershed (Figure 1) in 2011 and again in 2022. Chemistry data collected by local partners between 2014 and 2023 were used to assess the conditions of waterbodies within the watershed, with a focus on whether they are meeting water quality standards that are designed to protect aquatic life, recreation, and consumption. The overall goal of these assessments is to determine which waters are healthy and in need of protection or are polluted and require restoration.

Figure 1. Lake Superior-South Watershed is located along Lake Superior, stretching from Duluth to Silver Bay, MN.



Changes in water quality

To detect any changes in water quality, this recurring investigation looks at fish and macroinvertebrate communities as well as water chemistry. Scientists use a tool called the Index of Biological Integrity (IBI) to assess the health of biological communities in lakes, rivers, and streams. High IBI scores indicate a healthy aquatic community, which are more likely to be attained when water quality, habitat, and hydrology are not compromised by human activities.

MPCA scientists monitored the fish and macroinvertebrates, along with several water quality parameters, in the Lake Superior-South Watershed as part of the statewide effort to gauge the health of major lakes and rivers.

Over the past decade, scientists observed little change in water quality in the Lake Superior-South Watershed. While the biological condition of individual streams may have improved or declined between 2011 and 2023, the overall health of fish communities did not change. However, macroinvertebrate community health did improve significantly over this period. Continued problems include elevated bacteria, excess sediment (turbidity), chloride, and low dissolved oxygen levels.

- Flow in Big Sucker Creek and the Beaver River did not significantly change in the past decade but measurements tended to be more variable. Monitoring conducted more recently reflected intense flooding during the spring snowmelt and early summer, followed by a long dry period.

- Although an Aquatic Life (AQL) impairment still exists on the Beaver River due to other parameters (fish bioassessments and turbidity) not meeting state standards, more recent monitoring indicated that pH (an AQL indicator) is now now meeting standards.
- Several existing Aquatic Recreation (AQR) impairments due to high levels of Escherichia coli (E. coli) bacteria were reaffirmed on urban streams like Skunk, Tischer, and Chester Creek. In addition, new AQR impairments were found on portions of Lester River, Amity and Tischer Creeks (Figure 3).
- There were new AQL impairments on Tischer, Tributary to Tischer, and Chester Creek. Some pockets of higher quality biological communities are found within these drainages, which may allow for a more rapid recolonization and recovery when restoration work is completed.
- Several other streams were added to the impaired waters list due to chemical parameters not meeting AQL standards. These streams include: Tischer, Chester, and Big Sucker Creek, as well as the West Branch of the Beaver River.

Highlights of monitoring

- Fish and macroinvertebrate communities are largely intact throughout this watershed, with 24% of streams monitored having excellent biology (see success story for more details).
- Several streams are considered vulnerable due to one or more parameter near the aquatic life impairment threshold. These vulnerable streams are Beaver River, Little Stewart River, and Unnamed Creek (Stream Number 30).
- Agate Bay, Leif Erickson Park, and Burlington Bay Beaches continue to not meet water quality standards for aquatic recreation due to high levels of E. coli bacteria. In addition Twin Points Public Access Beach was identified as impaired in 2024.
- Total suspended sediment (TSS) continues to be an issue as streams flow into Glacial Lake Duluth sediments. These impairments are likely a function of both natural and anthropogenic stressors.
- The Ocellated Darner dragonfly (Boyeria grafiana) has been collected at numerous sites within this watershed. In 2013, the Ocellated Darner was listed as a species of special concern in Minnesota due to its limited range and restrictive habitat requirements which include, cold, clear, shallow, rocky, fast-flowing waters, shaded by a tree canopy. Climate change and severe weather are threats to this species.

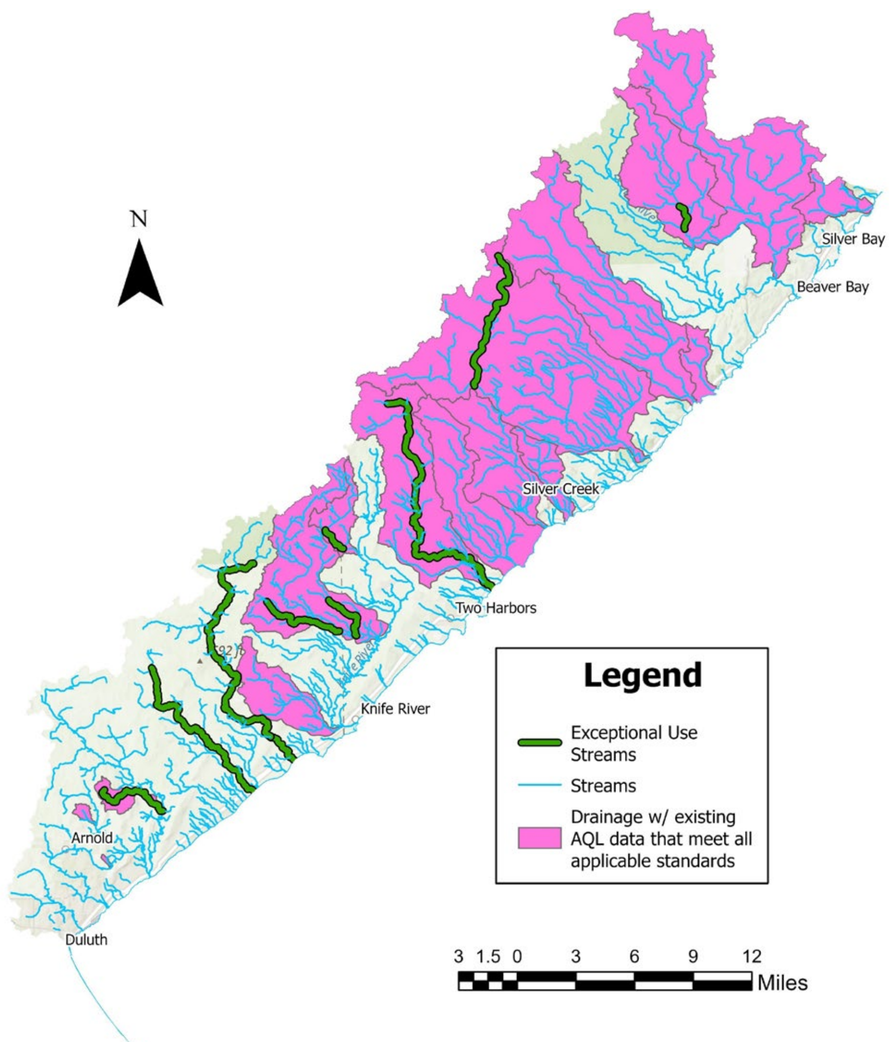
Success story

Biological monitoring is an important component of a comprehensive monitoring program because it is the most direct measurement of aquatic life (AQL). Although there are other measurements of AQL, biological communities integrate multiple stressors and can discern natural and anthropogenic variation. These tools not only allow us to identify impaired waters but also identify waters that have exceptional biological communities. This designation allows for the protection of streams that are of exceptional value.

McCarthy Creek designated as an exceptional stream.

Many of the stream segments within the Lake Superior-South Watershed met biological criteria for both fish and macroinvertebrates, and in some cases, significantly surpassed the biological thresholds (Figure 2). Biological monitoring results identified numerous sensitive fish and macroinvertebrate species throughout this watershed. Twenty-four percent of streams monitored during the most recent sampling event (2022) meet the exceptional use standard for both biological indicators. Portions of Stewart, Big Sucker, French, Gooseberry, Captain Jacobson, McCarthy, Big Thirty-nine, Tributary to Lester, and West Branch Little Knife River/Creeks are now considered exceptional waters. These streams will be afforded a higher AQL standard to protect their valuable aquatic resources. In addition, several drainages remain free of AQL impairments (Figure 2). Although these streams do not meet the exceptional use standard, they should also be considered for protection to maintain their water quality.

Figure 2. Drainages with monitored data that do not have any aquatic life impairments and stream reaches that meet the exceptional use threshold

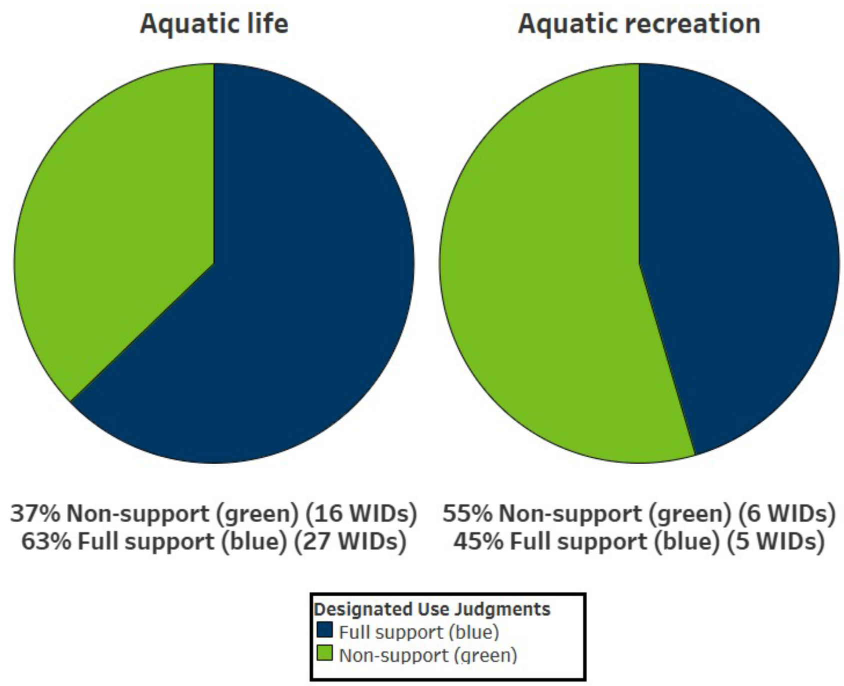


Watershed assessment results

Streams and rivers

Overall, about two-thirds of the stream reaches that were monitored met aquatic life standards within the Lake Superior-South Watershed (Figure 3). While streams like the Gooseberry River have fish and macroinvertebrate communities that are in good condition, other streams within urbanized areas tend to have biological communities that are degraded (Figure 4). In general, fish and macroinvertebrate communities in the watershed have benefited from little developmental pressure, but continue to show signs of high sensitivity to anthropogenic stressors like most northern Minnesota aquatic ecosystems. A continued vigilance is necessary to monitor areas where developmental pressures are or will be expected to occur.

Figure 3. Watershed assessment results for aquatic life and aquatic recreation in streams.



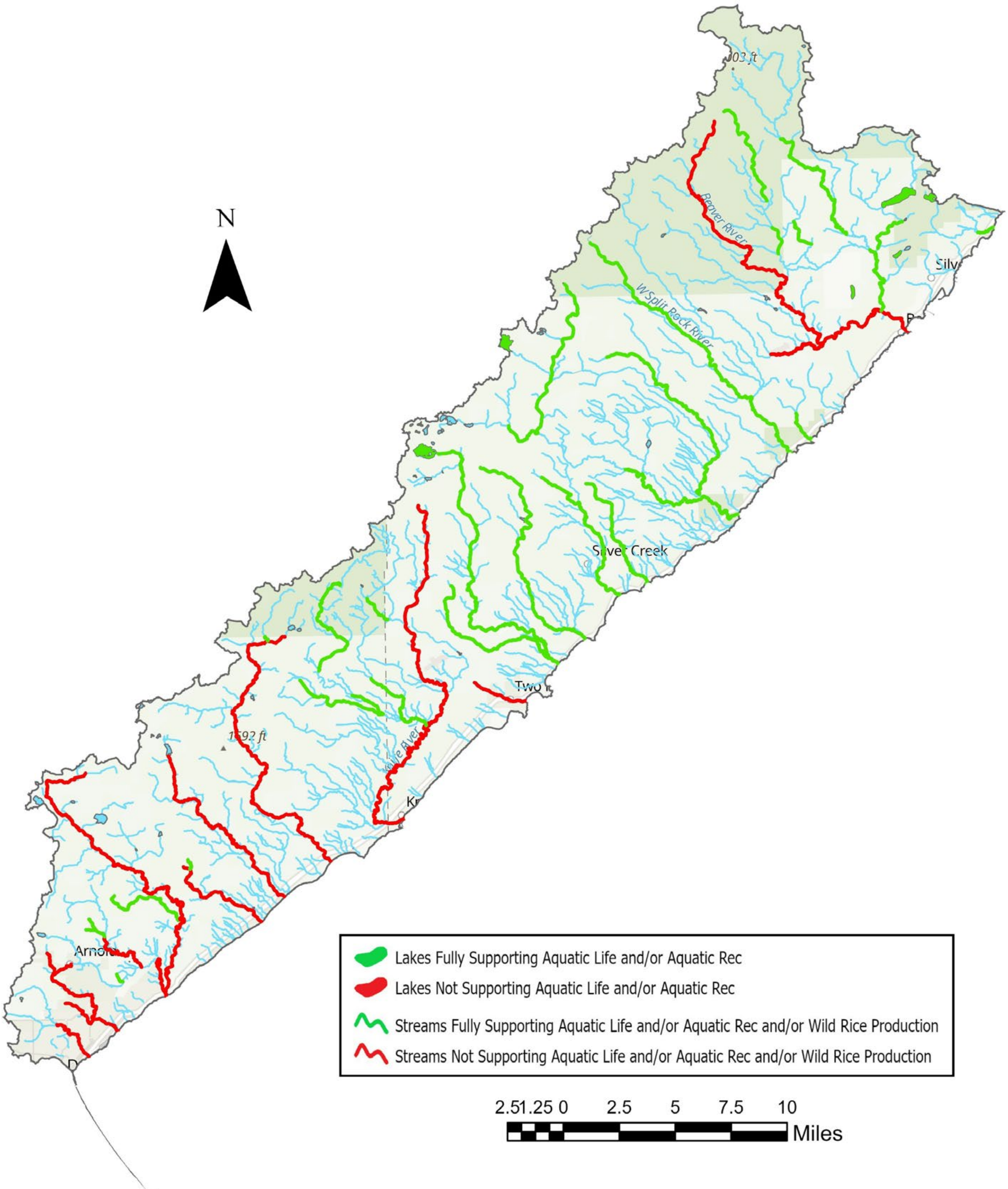
In the Lake Superior-South Watershed, TSS (total suspended solids), chloride, and low dissolved oxygen were the primary chemical impairments. As these streams make their way towards Lake Superior they drop into glacial Lake Duluth sediments, which are deposits of clay and clayey silts that are highly erodible. Higher levels of turbidity occur in some streams in the watershed due to the combination of higher stream gradient and more erodible soils. The conditions are in part natural, but may be amplified by poor land use practices, especially during periods of higher stream flows. Land use consists of mostly mixed forest and wetlands but some urban and industrial development has occurred in select locations throughout the watershed. In drainages that have been impacted, an emphasis should be given to maintaining natural vegetative buffer areas along shorelines to prevent overland runoff and reduce erosion potential.

Lakes

In general, lakes in the Lake Superior-South Watershed met water quality standards. Tetagouche, Bear, Lax, Bean, and Stewart lakes were identified as having very good water quality. Many of the lakes were also deep (more than 15 feet). Lakes with intensively developed watersheds, flow-through lakes, and shallow lakes are more susceptible to impairment. Christianson and Hartley Pond lakes are not currently impaired but were identified as vulnerable to exceeding water quality standards as nutrient concentrations were elevated and clarity was low.

Protection priority should be given to lakes particularly sensitive to an increase in phosphorus with a documented decline in water quality (measured by Secchi transparency), a comparatively high percentage of developed land use in the area or monitored phosphorus concentrations close to the water quality standard.

Figure 4. Assessment results for aquatic life and aquatic recreation on rivers, streams, and lakes.



Trends

A key objective of the 2022 monitoring effort was to evaluate if and how water quality has changed since the initial monitoring a decade ealier. If water quality has improved, it is important to understand to what extent human actions may be responsible for the change. It is equally important to understand if water quality does not appear to be changing or is declining. Either way, the knowledge will help inform future activities.

Trends in four different aspects of water quality were analyzed to provide the most robust picture of water quality within the Lake Superior-South Watershed.

1) Streamflow, sediment (total suspended solids), TP, and nitrogen (nitrate)
2) Biological communities
3) Clarity of lakes
4) Climate

Figure 5. Average TSS flow weighted mean concentration (FWMC) by major waterhed. Big Sucker Creek watershed is highlighted with the bold black outline.

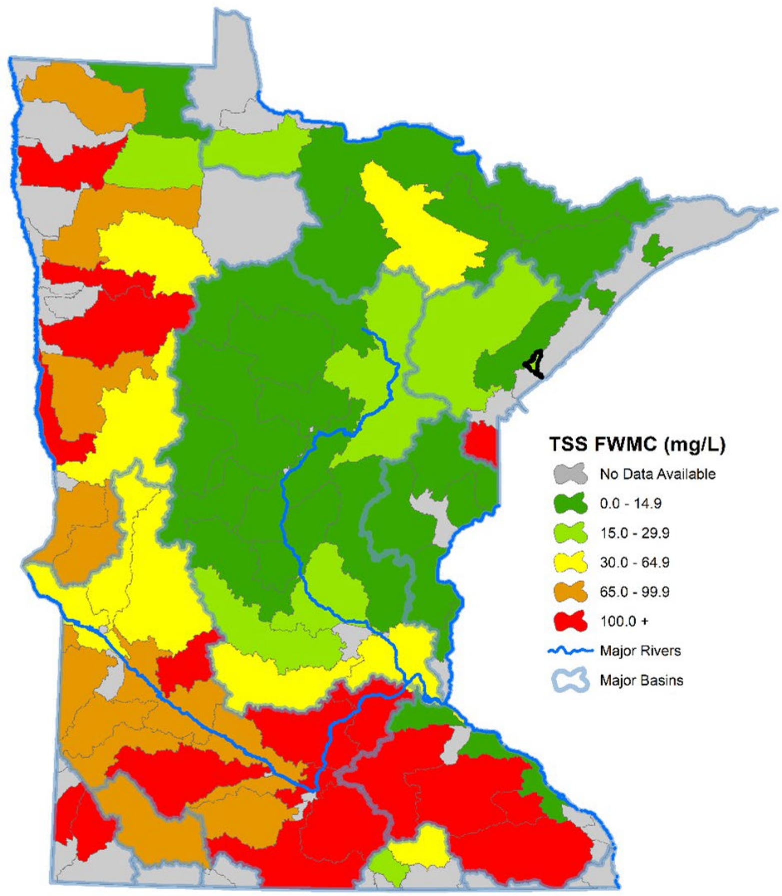
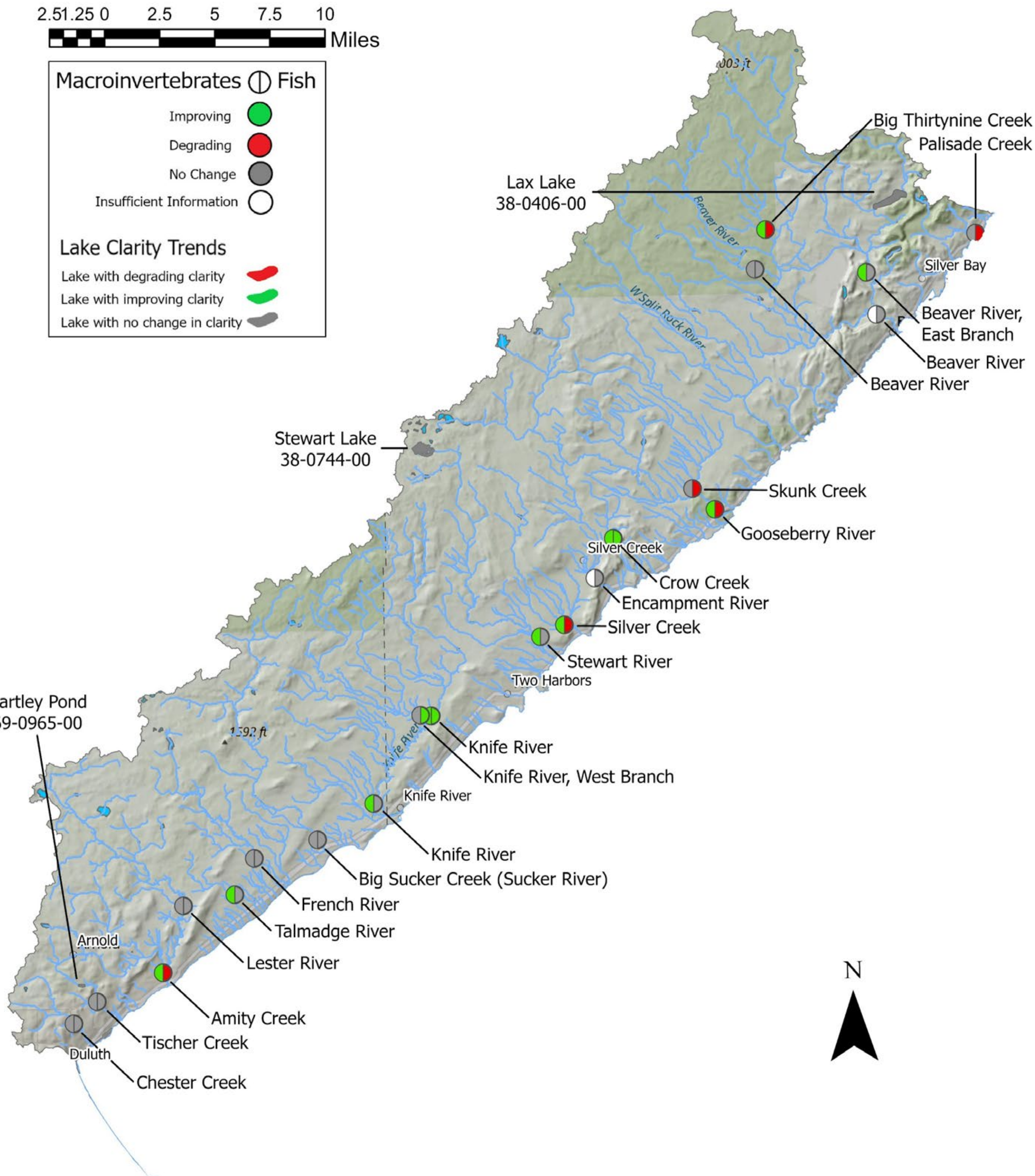


Figure 6. Change in water quality in the Lake Superior-South Watershed.



Streamflow and pollutant concentrations

In addition to the intensive monitoring completed every ten years, approximately 200 Watershed Pollution Load Monitoring Network (WPLMN) sites are operational year-round across Minnesota. At these sites, streamflow data collected in collaboration with the United States Geological Survey (USGS) and the MNDNR is paired with water chemistry data collected by state and federal agencies, Metropolitan Council Environmental Services, state universities, and local partners. This combination of regular streamflow and pollutant monitoring is crucial for conducting trend analysis, assessing year-over-year variability and identifying pollutant sources and their contributions to downstream waters. Two WPLMN sites (Big Sucker Creek & Beaver River) are currently established in the Lake Superior-South Watershed, which is a unique watershed for our program as they both flow directly into Lake Superior, whereas other watersheds are nested and flow into large river systems before flowing into larger basins (Figure 5).

Table 1. WPLMN sites within the Lake Superior Watershed. Samples are collected by MPCA staff. Lab parameters are total suspended solids (TSS), total phosphorus (TP), nitrate + nitrite nitrogen (NOX), total Kjeldahl nitrogen (TKN), and dissolved orthophosphate phosphorus (DOP).

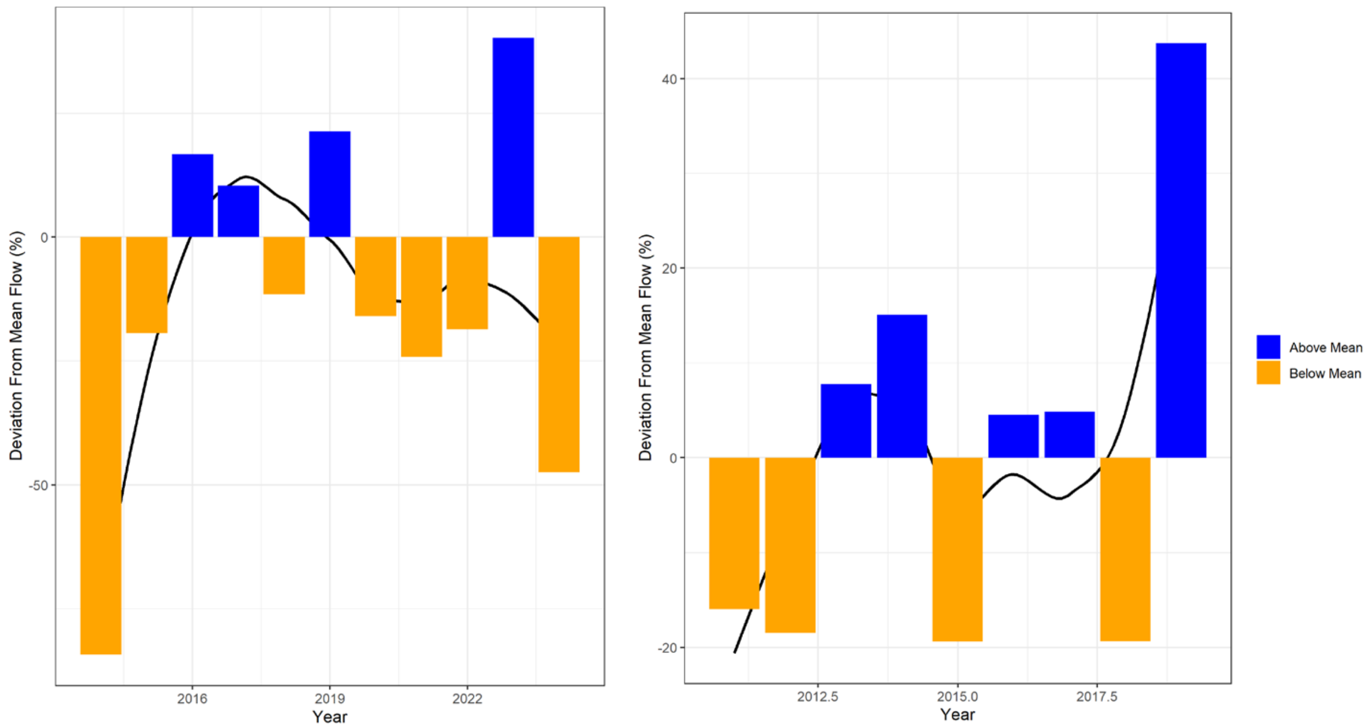
Site Name (WISKI ID)	Streamflow data available	Pollutant concentration data available	Sample collection	Lab Parameters
Big Sucker Creek near Palmers	2014-current	2008-current	28-35 samples collected year-round (MPCA)	NOX, TKN, TSS, TP, DOP
Beaver River near Beaver Bay	2011-current (MN DNR)	2015-current	20-25 samples collected from ice out to Oct. 31 (MPCA)	NOX, TKN, TSS, TP

Water samples collected at WPLMN sites are analyzed for pollutants that are known to have an impact on water quality (Table 1). Combining sampled pollutant concentrations with streamflow data allows for the calculation of a flow-weighted mean concentration (FWMC) and a total pollutant load. Loads represent the total amount of a pollutant moving through a system. FWMCs are important when considering the impact of pollutants on downstream resources such as Lake Superior where the pollutants may accumulate. These statistics can also be used to determine what the water quality is like on average, allowing for the equal comparison between watersheds differing in size and streamflow volume. During the period analyzed, both watersheds experienced some extreme rain events which can lead to variability in the daily pollutant concentrations and potential increase of the FWMCs. FWMC in the Lake Superior South watershed are similar to other watersheds in the Great Lakes basin.

Neither river saw a significant trend in flow in the past decade. the variability of flow appears to have increase in recent years (9-11 years) with intense flooding in the spring followed by long dry periods of drought in the summer.

To determine if sample pollutant concentrations (not FWMCs) in the Lake Superior Watershed experienced statistically significant changes over time, a seasonal Mann-Kendall trend test was applied to TSS, TP, and NOX data were run at the Big Sucker Creek near Palmers site. No parameters showed a statistically significant change from 2008-2022. More information regarding the WPLMN program can be found at: https://www.pca.state.mn.us/water/watershed-pollutant-load-monitoring.

Figure 7. Annual mean discharge departure from overall average discharge for both Big Sucker Creek (0=42 cfs - Left) and the Beaver River (0=197 cfs - Right). Blue bars show higher than average flow and yellow bars show below average flow.

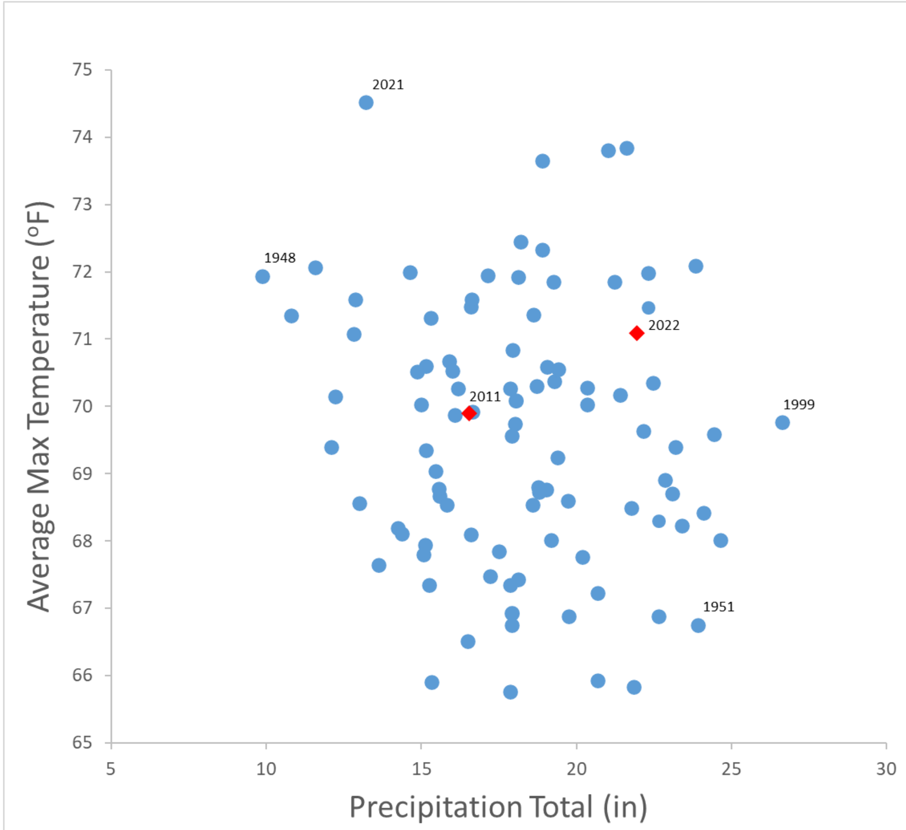


Biological communities

Paired t-tests of fish and macroinvertebrate IBI scores were used to evaluate if the biological condition of the watershed's rivers and streams has changed between time periods. Independent tests were performed on each community with 19 sites evaluated for macroinvertebrates and 21 sites evaluated for fish (i.e., sites that were sampled in both time periods). The average macroinvertebrate IBI score for the watershed increased by 9.2 points between 2011 and 2022, which is a statistically significant change. The fish IBI scores also increased (2.7 points) but not significantly. While the overall health of fish communities across the watersheds did not change significantly between time periods, biological condition at individual stream sites may have improved or degraded (± 19.6 IBI points).

The health of biological communities can be influenced by the climate and/or extreme weather events and obscure changes that result from restoration/protection efforts, changes in land use, and hydrologic alteration (i.e., changes related to policies, regulations, and management activities). Specifically, climatic conditions can affect stream aquatic life in a variety of ways such as altered flow, increased temperatures, decreased dissolved oxygen, habitat degradation, and decreased connectivity. However, it is difficult to make predictions of the impact of climatic conditions/weather events on stream aquatic life due to the specificity of possible responses that are dependent on the timing, magnitude, frequency and duration of events as well as the type of stream or biological community. For instance, a severe drought may negatively affect fish communities in headwater streams due to stressful conditions created by lack of flowing water (i.e., ↑temperature, ↓dissolved oxygen). While in larger streams that retain flow during a drought, biological condition may be unaffected or possibly somewhat inflated during such conditions due to a "concentrating" effect of the fish community to this limited habitat in the watershed. Nonetheless, it is important to characterize the climatic conditions during each Intensive Watershed Monitoring (IWM) cycle and compare these two periods in order to better interpret the causation of any observed changes (or lack thereof) in biological condition.

Figure 8. Characterization of air temperature and rainfall conditions for May-September period across the historical record (1928-2023) of climate data for the Lake Superior South watershed. Red diamonds = IWM years.



Across the historical record watershed-wide rainfall totals were estimated for May-September based on the gridded precipitation data set (State Climatology Office). Temperature was summarized for the May-September period by calculating the average maximum temperature at a monitoring station centrally located in the watershed that had a period of record sufficient to determine a normal value (*source:* Western Regional Climate Center, https://wrcc.dri.edu/summary/mnF.html). Rainfall and temperature normal values were determined by averaging each statistic over a 30-year period (1981-2010). Departure from normal values were calculated and used to characterize climatic conditions for each IWM year. This information was then used to estimate the likelihood (high, medium, or low) that climate/weather influenced biological condition in either IWM cycle. For instance, if both time periods fall within the bounds of near normal conditions then there would be a low likelihood that results in either time period are affected by climate/weather and thus any observed changes in condition are presumably driven by watershed scale factors.

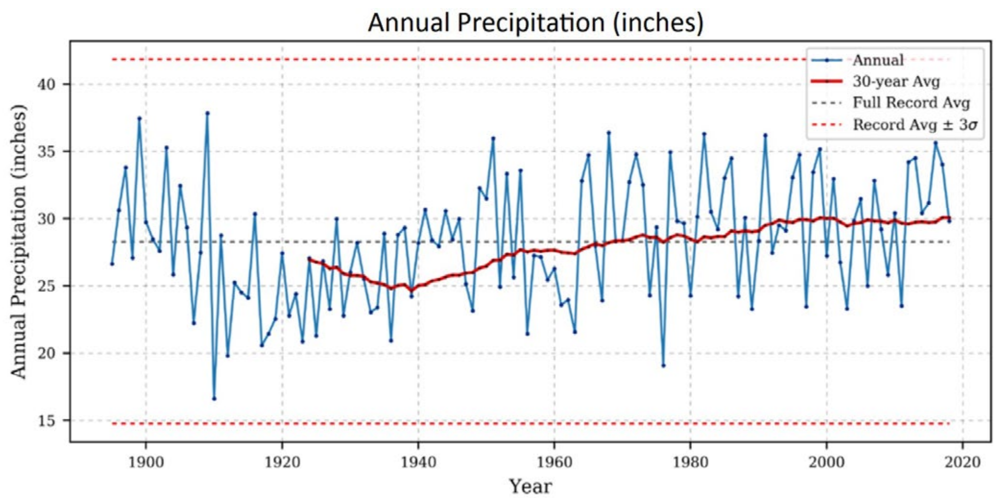
In 2011, the Lake Superior - South watershed experienced near normal rainfall (-2.0 in) and near normal temperatures (+0.4 °F) during the May to September time period. In comparison, the watershed had above normal precipitation (+3.4 in) and abnormally high temps (+1.6 °F) in 2022 over the May to September time period (Figure 8). Given the relatively wetter and warmer conditions affecting the watershed in 2022, there is a moderate likelihood that any observed changes in biological condition at either the watershed or individual site scale are at least partially due to differences in climatic conditions between the two periods.

Clarity of lakes

The Lake Superior-South Watershed has seven lakes with historical Secchi Disk transparency data. Trend analysis (Figure 6) was conducted on three lakes (Lax, Stewart, & Hartley) that met data requirements (50 Secchi measurements, eight years of data). There was no trend in water clarity for all three of the lakes. Lax and Stewart Lakes met water clarity standards, while Hartley Pond, an urban, shallow impoundment, did not.

Climate

Figure 9: Average annual precipitation for the Lake Superior-South Watershed (1895-2018).



The Lake Superior-South Watershed now receives on average 1.8 additional inches of rain from the historical average (1895-2018). Furthermore, climate scientists suggest that precipitation events are becoming more intense (Figure 9). In addition, temperatures in the watershed have increased by about one degree in spring and fall over this time period. Increased rainfall and temperature can worsen existing water quality problems. More precipitation and reduced snow cover can increase soil erosion, pollutant runoff, and stream flows. Increased stream flows in turn can lead to stream channel erosion and degraded habitat for fish and other aquatic life. Longer growing seasons with higher temperatures can lead to more algal blooms. These changes will complicate efforts to protect and restore the watershed. For more information on the climate of Lake Superior-South Watershed, please visit: DNR climate summary for the Lake Superior-South Watershed.

For more information

This study of the Lake Superior-South Watershed was conducted as part of Minnesota's Watershed Approach to restoring and protecting water quality. Efforts to monitor, assess, study, and restore impaired waters, and to protect healthy waters are funded by Minnesota's Clean Water, Land, and Legacy Amendment. Stressor identification for new impairments and updates to the Watershed Restoration and Protection Strategy follow the completion of monitoring and assessment. This approach allows for efficient and effective use of public resources in addressing water quality challenges across the state. The data and assessments produced by this study can inform local efforts to restore and protect waters in the Lake Superior-South Watershed, such as the One Watershed One Plan document, a comprehensive watershed management plan that targets projects to protect and restore the watershed's most valuable resources. For more information, go to the MPCA Lake Superior-South webpage, or search for "Lake Superior-South" on the MPCA website.

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