Watershed assessment and trends update

Redeye River Watershed

Upper Mississippi River Basin

Summary

The Minnesota Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MNDNR), and partners have completed a study of the Redeye River Watershed. The Redeye River Watershed (07010107) lies within the northwestern to north-central portion of the Upper Mississippi River Basin in central Minnesota. The watershed has 28 stream assessment units (AUIDs) and 73 lakes greater than 10 acres. The recreational value of lakes and streams are assets to the health and wealth of local economies throughout the watershed. Major rivers within the watershed are the Redeye, Leaf, and Wing. Major lakes in the watershed include Wolf, Gourd, and the chain of West, Middle, and East Leaf Lakes. These waterbodies are significant to the regions ecological integrity and provide valuable recreational and economic services to the surrounding communities.

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

Watershed Study

The MPCA and partners monitored water quality conditions in 2011-2012 and again in 2022-2023. The data used to assess the condition of Minnesota waterbodies, focus on whether or not they are meeting water quality standards for aquatic life, recreation, and consumption. The overall goal of these assessments is to ultimately determine which waters are healthy and in need of protection or are polluted and require restoration.

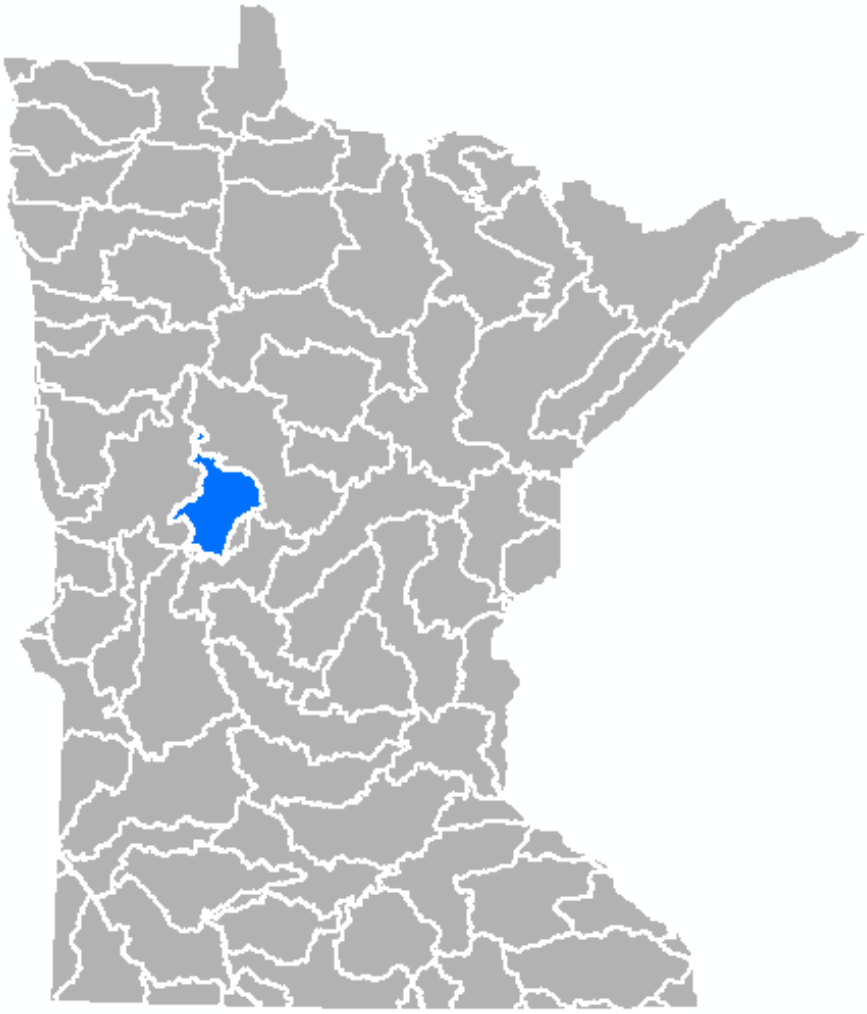
Water monitoring is essential to determining whether lakes and streams meet water quality standards designed to ensure that waters are fishable and swimmable. While local partners and state agencies monitor water quality on an ongoing basis, the MPCA and local partners conduct an intensive examination 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 macroinvertebrate (bug) communities as well as water chemistry to gauge water quality. The partners use the data to see 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.

Changes in water quality

To detect changes in water quality, this recurring monitoring effort 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, streams, and wetlands. High IBI scores indicate a healthy aquatic community, which often can only be attained when human disturbances do not significantly impact water quality, habitat, and hydrology.

Over the past decade, scientists observed positive change in water quality in the Redeye River Watershed. While the biological condition in individual streams may have improved or declined between 2011 and 2022, there were significant increases across macroinvertebrate communities during this period. Problems with high levels of bacteria are still present. Water monitoring is essential to determining whether lakes and streams meet water quality standards designed to ensure that waters are fishable and swimmable.

Figure 1. Location of the Redeye River HUC8 Watershed.



Across the watershed, there is no significant change in stream biological condition over the last 10 years for fish, however macroinvertebrates showed a significant improvement in biological integrity. This may be in part to multiple small scale best management practices in the watershed aimed at reducing sediment and nutrient loads.

- The FIBI impairment on South Bluff Creek (-553) has been delisted from the impaired waters list. Although, the reason for the improved fish assemblage is not known, there have been several restoration activities that may have helped.
- Oak Creek is a high quality stream that is included in the MPCA Biological Monitoring Program's Long Term Biological Monitoring Network (LTBM). Macroinvertebrate communities have been sampled in Oak Creek seven times since it was first monitored in 2011. MIBI scores are consistently good making Oak Creek one of the best examples of a well-preserved small stream in west-central Minnesota.

MPCA scientists monitored the fish and bugs, along with several water chemistry parameters, in the Redeye River Watershed as part of the statewide effort to gauge the health of major lakes and rivers.

Highlights of monitoring

- The Redeye River from Hay Creek to the Leaf River and Bluff Creek are both near the threshold needed for delisting of the aquatic recreation impairments. For *E. coli* these are "Barely impaired" and additional years of monitoring may solidify this as a delisting candidate.
- MPCA fish sampling in 2022 and 2023 in the Redeye River Watershed yielded forty-seven species totaling 61,022 fish. The most sampled species included Common Shiner, White Sucker, Western Blacknose Dace, and Johnny Darter. Several sensitive species sampled include Burbot, Blacknose Shiner, Iowa Darter, and Mottled Sculpin.
- Forested lands and those held in conservation status within the watershed have helped to maintain high water quality and habitat necessary to support the diverse biological communities.
- A total of 40 fish species were collected in lakes during the MNDNR fisheries IBI sampling. Of these, 12 were considered intolerant species – those susceptible to pollution, shoreline habitat disturbance, or watershed disturbance. Notable species include Cisco (Tulllibee) a coldwater species requiring cold, oxygenated water to survive. Both the Least Darter (state species of concern) and the Pugnose shiner (threatened) were also collected.

Success story

In 2020, the Redeye River Comprehensive Watershed Management Plan was completed. This plan has several goals aimed at improving water quality in the watershed. Best management practices (BMPs) include: reducing Phosphorus, Nitrogen, and *E. coli*, while enhancing stream habitats, barrier removal, and protecting land in the watershed.

So far, over 700 pounds of Phosphorus and 255.7 tons of sediment reductions have happened at the watershed outlet. Nearly 10,000 acres of land have been enrolled in nitrogen management practices. 18 of 20 bacteria reduction projects have been completed. Over ¾ of a mile of habitat improvement enhancements have been implemented on the Middle Leaf River.

The recently completed, ongoing, and future projects in the watershed will all have a positive impact on the water quality in the Redeye River Watershed. Continued efforts to enhance and restore waters as well as protect the high-quality resources that remain should be prioritized.

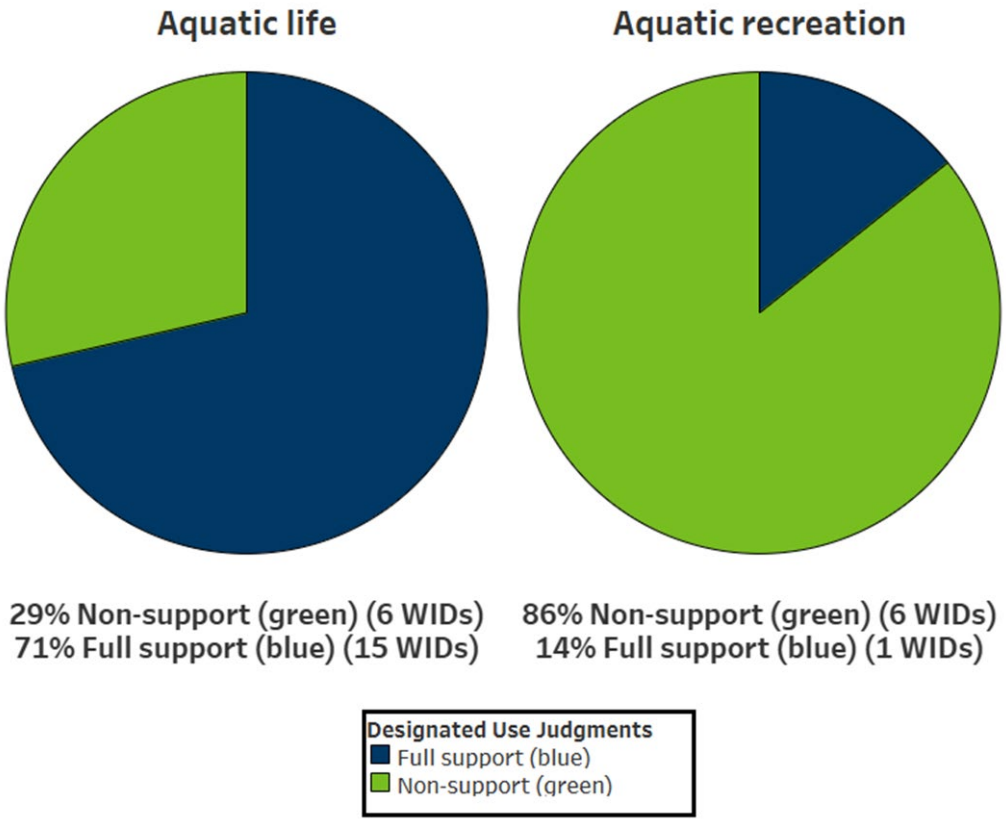
Maintained watercourse buffers like below help to protect and maintain water quality by using vegetation to stop additional sediment coming into a riverine system, but also provide excess nutrient uptake.

Watershed assessment results

Streams and rivers

Overall, seventy-one percent of the stream reaches in the Redeye River Watershed meet standards for aquatic life use (Figure 2). In general, fish communities in the watershed exhibit signs of degradation characterized by a dominance of pollution-tolerant species. Macroinvertebrate communities are much more intact throughout the watershed with a few visits exceeding exceptional use criteria. Although majority of the streams support aquatic life uses, some larger streams particularly the mainstem Redeye, Leaf, and Wing rivers of the watershed are not meeting Aquatic Recreation (AQR) Standards (Figure 3). The Redeye River and its smaller tributaries have high levels of *E. coli*, and do not support Aquatic Recreation use. *E. coli* levels in Bluff Creek keep the stream from fully supporting Aquatic Recreation although it does support aquatic life.

Figure 2. Watershed assessment results for aquatic life in streams and aquatic recreation in streams and lakes.



Low dissolved oxygen was the primary chemical issue found throughout the watershed. The headwaters of the Redeye River have many wetlands and shallow lakes such as Wolf Lake and the Leaf chain of lakes. These waterbodies likely contribute to the low dissolved oxygen levels on some of upstream reaches of the Leaf and Redeye rivers. Further downstream in the watershed land use transitions to row crops, pastures, and forests. Nearly half of the land use within the watershed is agricultural.

The lower reach of the Wing River is currently impaired for *E. coli*. This portion of the Wing River was first listed as impaired for *E. coli* during the 2013 assessment cycle. It previously exceeded geometric mean standards from June to August. August was the only month that exceeded standards during the 2022 -2023 monitoring cycle so the system is still impaired, but concentrations are decreasing greatly and could be eventually removed from the impaired waters list if *E.coli* levels continue to decrease. All other water quality parameters meet standards.

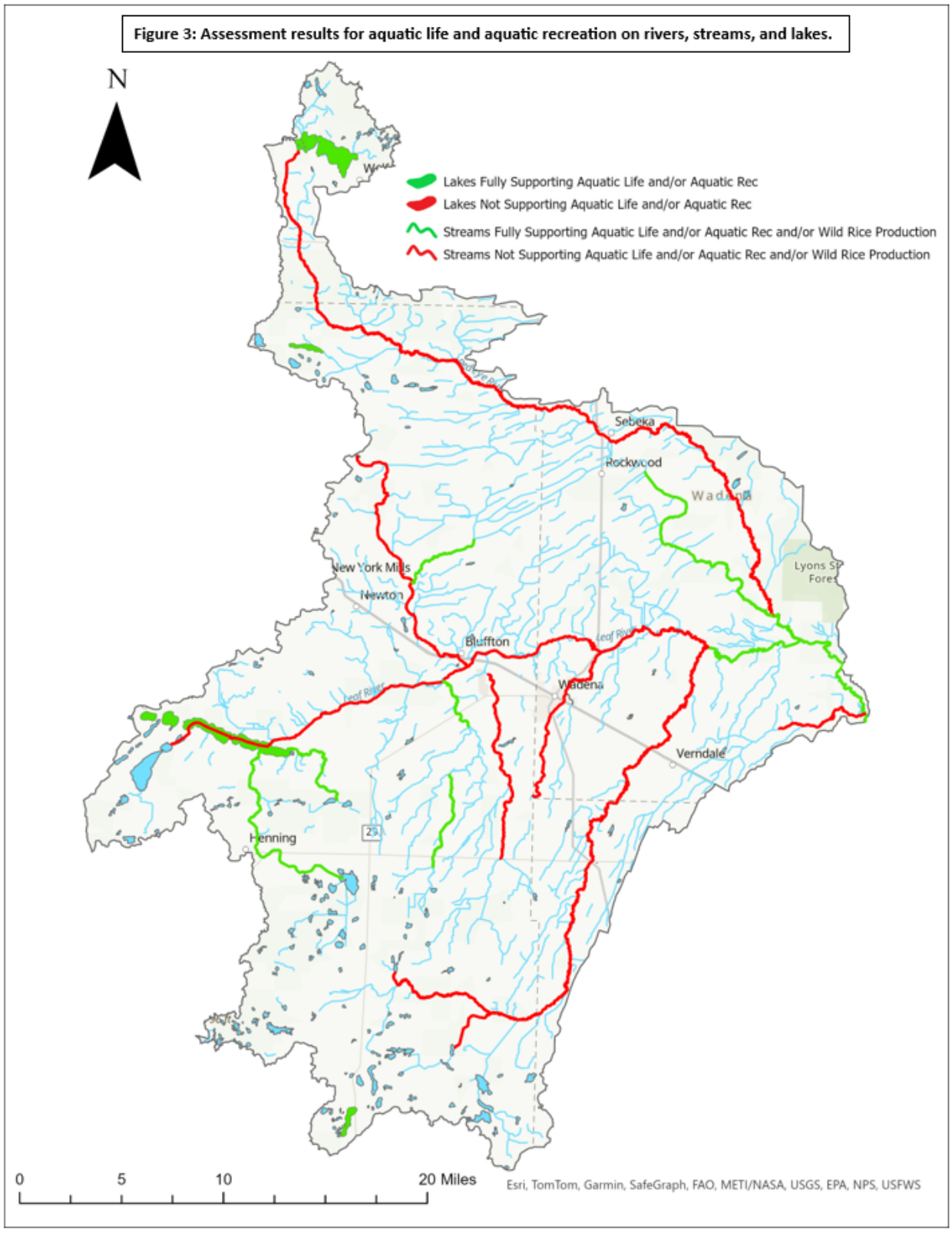
Lakes

There are no current or new impairments on lakes in the Redeye River Watershed. East Leaf Lake has been flagged as nearly impaired for nutrients. Chlorophyll-a concentrations in East Leaf Lake consistently increase in the later summer months (Aug-Sept). Data from 2019-2022 show that both TP and Chlorophyll-a fluctuate around their respective impairment thresholds. An extreme

drought may have contributed to the increase in TP and Chlorophyll-a concentrations. Outside of East Leaf Lake all other lakes in the watershed are well above aquatic recreation standards.

Seven lakes within the watershed were assessed for aquatic life use standards for the first time using the fish-based Index of Biological Integrity (FIBI) developed for Minnesota lakes. One lake, Wolf Lake, was not considered assessable due to frequent winterkills. The six remaining lakes (Adley, Donalds, East Leaf, Middle Leaf, West Leaf, and Portage) were all found to fully support aquatic life use. Shoreline habitat quality of the lakes was generally considered 'moderate' and similar to statewide average for shoreline development pressure. East Leaf Lake is also considered vulnerable to further degradation as the FIBI score is near the impairment threshold. East Leaf Lake has a high watershed to lake surface area ratio, with about half of the upstream watershed being disturbed (cultivated, pastured, or urban). Shoreline development and watershed Best Management Practices BMPs should be considered to prevent further degradation of water quality.

Figure 3: Assessment results for aquatic life and aquatic recreation on rivers, streams, and lakes.



Trends

A key objective of the 2022-2023 monitoring effort was to evaluate if and how water quality has changed since the initial monitoring. If water quality has improved, it is important to understand to what extant 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 was analyzed to provide as robust a picture as possible of what is happening in the Redeye River Watershed:

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

Figure 4. Average TP flow weighted mean concentration by major watershed.

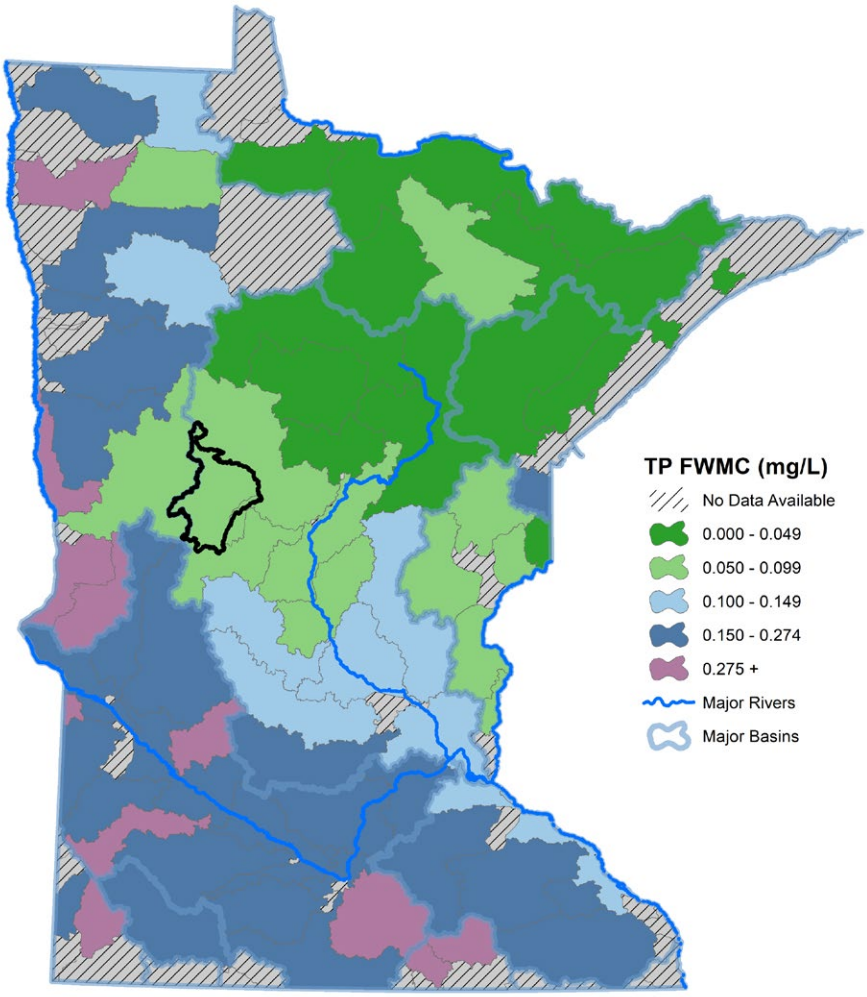
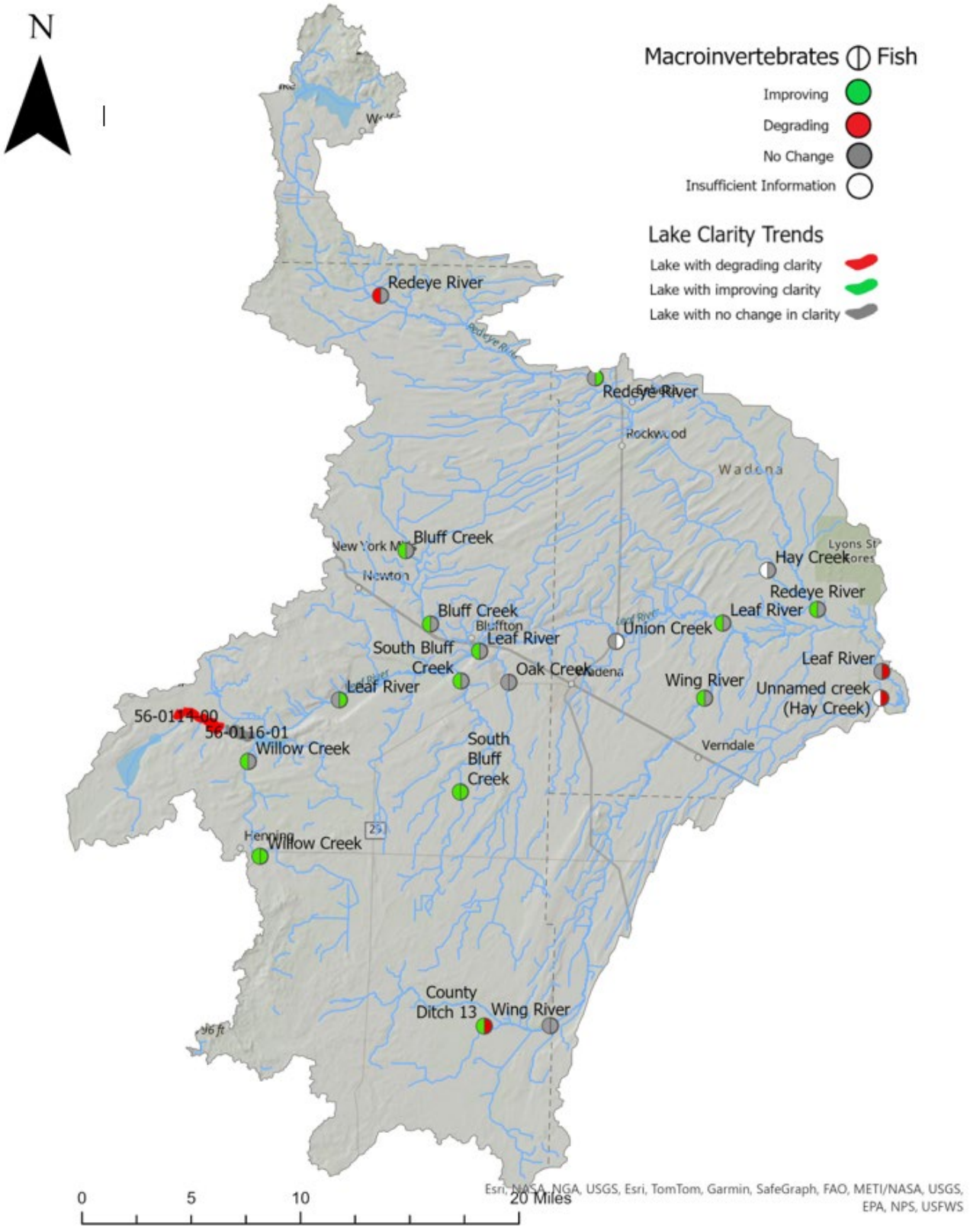


Figure 5. Change in water quality in the Redeye River Watershed.



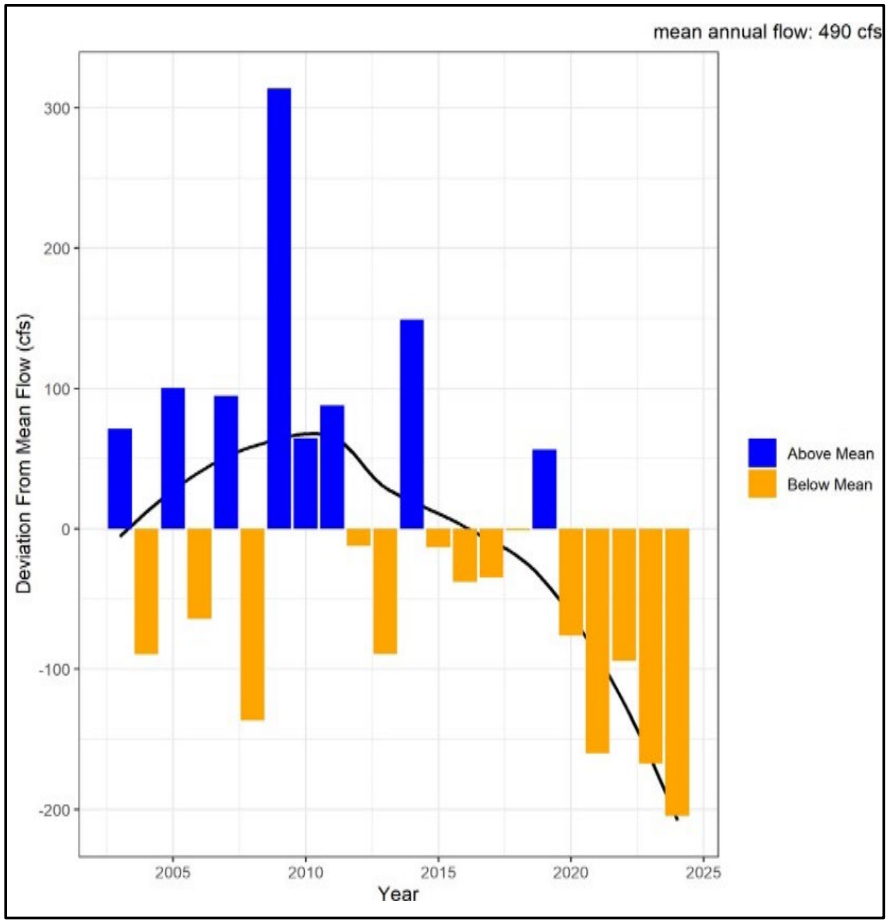
Streamflow and pollutant concentrations

Long-term water quality and stream flow monitoring occurs annually throughout Minnesota, with intensive sampling across a range of flow conditions. For more information about this sampling, please visit: https://www.pca.state.mn.us/wplmn

Annual streamflow (discharge) data for the Redeye River Watershed is available since 2003 and water chemistry data is available since 2008, both measured at the watershed outlet on the Leaf River near Staples at CSAH 29, approximately four miles upstream of the confluence with the Crow Wing River.

Seasonal Kendall trend tests on suspended sediment (TSS), phosphorus (TP), and nitrate-nitrogen concentrations were used to determine if changes over time were statistically significant. In this case, trends were analyzed using data from 2008-2022. There were no trends in Nitrate-nitrogen, TP and TSS over this timeframe according to the test.

Figure 6. Redeye River Watershed (Leaf River) percent deviation from normal flow over time (CFS).



There are two additional stations upstream of the outlet station where flow and water chemistry data are also collected, although only since 2017 and only during the open water season. One site is on the Redeye River which flows into the Leaf River five miles upstream of the outlet station and the other site is on the Leaf River roughly one mile upstream of the confluence of the Redeye and Leaf Rivers. Average annual water chemistry data from 2017-2021 show similar relationships to those mentioned above for the outlet station. When specifically comparing the upstream Leaf River station to the downstream (outlet) station, nitrate-nitrogen concentrations increase roughly 0.1mg/L from upstream to downstream while TP and TSS concentrations stay roughly the same between stations. The Redeye River varies in its pollutant contributions to the Leaf River outlet station. Nitrate-nitrogen average concentrations have minimal impact, roughly 10x lower at the Redeye River station vs the Leaf outlet station (0.06mg/L vs 0.68mg/L, respectively), while average TP concentrations are roughly the same at both stations and TSS concentrations are nearly 2x lower at the Redeye station versus the Leaf outlet (4.2mg/L vs 7.8, respectively).

The Redeye River Watershed is located within a transitional area of the state where nutrient and sediment concentrations are nearly the same or lower in watersheds to the east and northeast but higher in watersheds to the west and southwest (Figure 7). In general, nutrient concentrations are relatively low in this watershed when compared to other parts of the state. Although currently not a concern in the Redeye River Watershed, nitrate-nitrogen concentrations are trending higher throughout the state. Management efforts that strive to keep nutrient and sediment

concentrations low and/or from rising within this watershed would be beneficial in the long-term. Streams that contribute to the Leaf River upstream of the Redeye River confluence appear to be a more significant source of nitrate-nitrogen than the Redeye River and its tributaries.

Figure 6 shows the percent deviation from normal flow over time at the Redeye River Watershed outlet station. The changing yearly average flow (black line) is calculated using LOESS (locally estimated scatterplot smoothing) with the yellow and blue bars showing each years' deviation as above or below the average (490cfs). The data shows that a significant decrease in flow has occurred each year since 2020. This flow reduction can likely be attributed to a decline in precipitation in recent years throughout this watershed. For example, when flows were near average from 2016-2019 this area received an average of roughly 20.4" of precipitation per year, whereas from 2020-2023 the average fell to 13.6" per year (11.9" average from 2021-2023). This significant decline in precipitation has likely led to the sharp decline in flows since 2020.

Significant increases in flow have negative implications for stream channel conditions and pollutant loading. This could mean more channel erosion and possibly more pollutant loading, even if pollutant concentrations are stable. Contrary, low flows (similar to recent trends in the Redeye Watershed), may result in lower concentrations for some pollutants. Loads represent the total amount of a pollutant moving through a system, providing important information for downstream resources such as the Crow Wing and Mississippi Rivers, where these pollutants may accumulate.

Biological communities

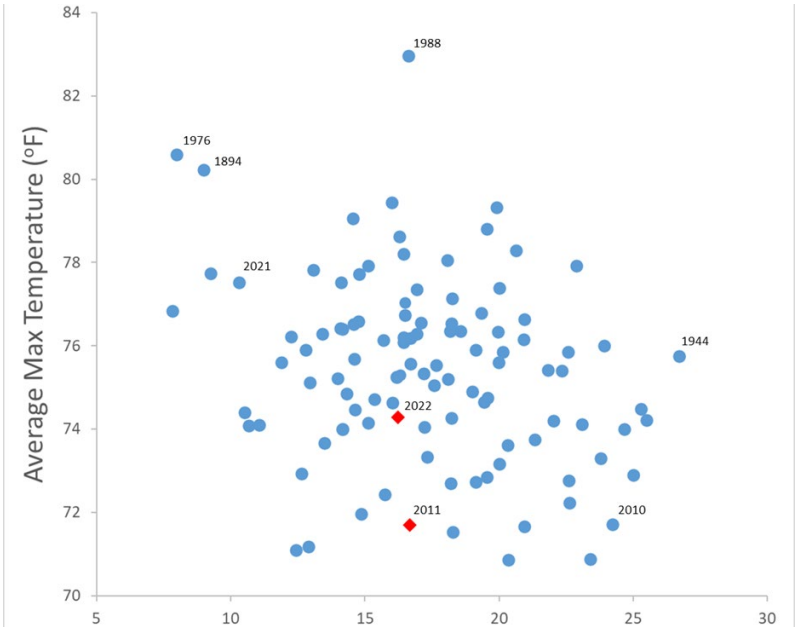
Paired t-tests of FIBI and MIBI scores were used to evaluate if biological condition of the watershed's rivers and streams has changed between time periods. Independent tests were performed on each community with 18 sites evaluated for macroinvertebrates and 19 sites evaluated for fish (i.e., sites that were sampled in both time periods). The average MIBI score for the watershed increased by 13.3 points between 2011 and 2022, which is a statistically significant change. Factors like climate, changing land use practices or slight changes in the sampling approach used to collect macroinvertebrates may all contribute to the increase in MIBI scores. Similarly, FIBI scores across the Redeye River Watershed decreased by 0.6 points, which was not statistically significant. While the overall health of fish communities across the watersheds did not change between time periods, biological condition at individual stream sites may have improved or degraded (Figure 5).

Context for the change analysis results is provided by a characterization of the conditions under which biological monitoring occurred in each monitoring period. In 2011, the Redeye River Watershed experienced near normal rainfall (0.4 inches below normal) and was abnormally cold (-3.8 ^{o}F) during the May to September time period. In comparison, the watershed had near normal precipitation (-0.8 in) and was cooler than normal (-1.2 ^{o}F) in 2022 over the May to September time period. Overall, given the relatively similar conditions observed in 2011 and 2022, there is a low likelihood that any observed changes in biological condition at either the watershed or individual site scale are due to differences in climatic conditions between the two periods. It should be noted, however, that summers the year prior to each cycle of IWM monitoring saw extreme weather patterns. In 2010 the amount of rainfall between May and September was approximately seven inches above normal for that period, while the summer months of 2021 experienced an historic drought with a 6.8 inch rainfall deficit (Figure 1). It is unclear at this time whether these climatic conditions impacted stream aquatic communities the following year.

Clarity of lakes

There are 15 lakes in the Redeye River Watershed with available transparency data. Trend analysis was conducted on only one lake that met data requirements (50 Secchi measurements, eight years of data) that lake being West Leaf Lake. West Leaf water clarity is degrading. Most lakes in the watershed do not exhibit a significant trend and more lakes have improving clarity than declining.

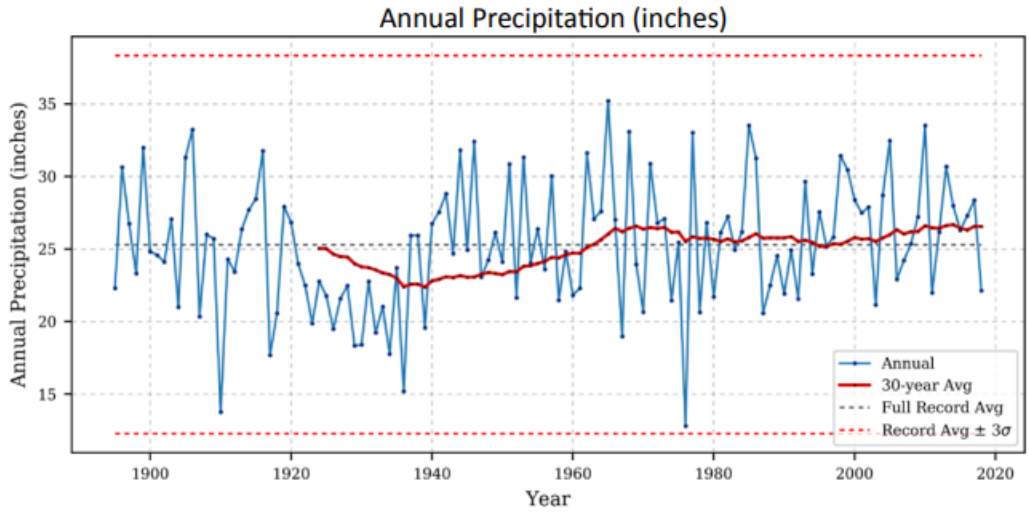
Figure 7. Characterization of air temperature and rainfall conditions for May-September period across historical record for the Redeye River Watershed. Biological monitoring years for the watershed highlighted in red.



Climate

The Redeye River 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. In addition, temperatures in the watershed have increased by about one degree in spring and fall over this period. Increased rainfall and temperature can worsen existing water quality problems. More precipitation and reduced snow cover can increase soil erosion, pollutant runoff, and streamflow's. Increased streamflow's 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. Climate Summary for Watersheds, Redeye River.

Figure 8: Average annual precipitation for the Redeye River Watershed (1989-2018).



For more information

This study of the Redeye River 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 Redeye River 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 Redeye River | Minnesota Pollution Control Agency, or search for "Redeye River" on the MPCA website.

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