Root River Watershed Stressor Identification Report

A study of local stressors limiting the biotic communities in the Root River Watershed.

Minnesota Pollution Control Agency

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Authors

Tiffany Schauls, MPCA Rochester
Kim Laing, MPCA St. Paul

Contributors/acknowledgements

Shaina Keseley, MPCA Rochester
Justin Watkins, MPCA Rochester
Joe Magee, MPCA Rochester
Ashley Ignatius, MPCA Rochester
Jenna Roebuck, MPCA Rochester
Kelsey Budahn, MPCA Rochester
Chandra Carter, MPCA St. Paul
Mike Koschak, MPCA St. Paul
Dave Tollefson, MDA

Editing and graphic design

Cathy Rofshus
Jan Lehner-Reil
Jennifer Holstad

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Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 | www.pca.state.mn.us | 651-296-6300

Toll free 800-657-3864 | TTY 651-282-5332

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Contents

List of tables

List of figures

Key terms and abbreviations

AUID – Assessment Unit ID

BMP – Best Management Practices?

BOD – Biological Oxygen Demand

CADDIS – Causal Analysis/Diagnosis Decision Information System

CBI – Coldwater Biotic Index

cfs – cubic feet per second

CL – Confidence Limits

CPOM – course particulate organic matter

DELT – Deformities, Eroded fins, Lesions, and Tumors

DO – Dissolved Oxygen

EDA – Environmental Data Access

EPA – U.S. Environmental Protection Agency

EPT – Ephemeroptera, Plecoptera, and Trichoptera

ET – evapotranspiration

FWC – Flow weighted concentration

GIS – Geographic Information System

GROS – gasoline range organics

HOBO – Temperature data logger

HUC – Hydrologic Unit Code

IBI – Index of Biotic Integrity

IHA – Impacts of Hydrologic Alteration

IWM – Intensive Watershed Monitoring

LMB – Lower Mississippi River Basin

MDNR – Minnesota Department of Natural Resources

mg/L – milligrams per Liter

MDA – Minnesota Department of Agriculture

MDH – Minnesota Department of Health

MGS – Minnesota Geological Survey

MIBI – Macroinvertebrate IBI

MPCA – Minnesota Pollution Control Agency

MSHA – MPCA Stream Habitat Assessment

NLCD – National Land Cover Dataset

NTU – Nephelometric Turbidity Units

NWI – National Wetlands Inventory

NWS – National Weather Service

SSC – suspended sediment concentration

SID – Stressor Identification

SOE – Strength of Evidence

SVOC – Soluble volatile organic compound(s)

TIV – Tolerance Indicator Value

TMDL – Total Maximum Daily Load

TP – Total Phosphorus

TSS – Total Suspended Solids

TSVS – Total Suspended Volatile Solids

USFWS – US Fish and Wildlife Service

USGS – United States Geological Survey

VOC – volatile organic compound(s)

WA – weighted averages

WRAPS – Watershed Restoration and Protection Strategies

WWTP –Wastewater Treatment Plant

YOY – young of year

Executive summary

Over the past few years, the Minnesota Pollution Control Agency (MPCA) has substantially increased the use of biological monitoring and assessment as a means to determine and report the condition of the state's rivers and streams. This basic approach is to examine fish and aquatic macroinvertebrate communities and related habitat conditions at multiple sites throughout a major watershed. From these data, an Index of Biological Integrity (IBI) score can be developed, which provides a measure of overall community health. If biological impairments are found, stressors to the aquatic community must be identified.

Stressor identification is a formal and rigorous process that identifies stressors causing biological impairment of aquatic ecosystems and provides a structure for organizing the scientific evidence supporting the conclusions (Cormier et al. 2000). In simpler terms, stressor identification is the process of identifying the major factors causing harm to fish and other river and stream life. It is a key component of the major watershed restoration and protection strategies being carried out under Minnesota's Clean Water Legacy Act.

This report summarizes stressor identification work on 40 biological impairments in the Root River watershed. Due to the sheer size of the watershed, and overall complexity, it is difficult to evaluate potential stressors to aquatic life without further stratifying the Root drainage into smaller sections. Although there may be some consistent chemical and physical stressors found throughout the watershed, some are likely acting locally, driven by landscape characteristics specific to a certain region of the watershed. For the purpose of addressing biological impairments in the Root River, the watershed was broken up by 10 digit HUC watersheds. In this report, each 10 digit HUC watershed will have further analysis of biological impairments.

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

- Dissolved Oxygen (DO)
- Temperature
- Nitrate
- Total Suspended Solids (TSS)
- Physical Habitat
- Connectivity

In the Root River watershed, there are multiple reaches with only macroinvertebrate impairments, a handful with both fish and macroinvertebrate impairments (6), and one reach with a fish (only) impairment. All of the fish impairments occur on coldwater streams in the Root River. Fish impairments were not identified on any warmwater streams. There are multiple hypotheses regarding why macroinvertebrate impairments may predominate, which include sensitivity to habitat degradation and sensitivity to chemical pollutants like nitrate, both which are common in the watershed. A summary of the stressors identified in each stream reach is found at the end of this document, in Table 59.

1. Introduction

1.1. Monitoring and assessment

Water quality and biological monitoring in the Root watershed have been ongoing for many years. As part of the MPCA's Intensive Watershed Monitoring (IWM) approach, monitoring activities increased in rigor and intensity during the year of 2008, and focused more on biological monitoring (fish and aquatic macroinvertebrates) as a means of assessing stream health. The data collected during this period, as well as historic data obtained prior to 2008 were used to identify stream reaches that were not supporting healthy fish and macroinvertebrate communities (Figure 1).

Once a biological impairment is determined, the next step is to identify the source(s) of stress on the biological community. A Stressor Identification (SID) analysis is a step-by-step approach for identifying probable causes of impairment in a particular system. Completion of the SID process does not result in a finished Total Maximum Daily Load (TMDL) study. The product of the SID process is the identification of the stressor(s) for which a TMDL may be developed. For example, the SID process may help investigators nail down excess fine sediment as the cause of biological impairment, but a separate effort is then required to determine the TMDL and implementation goals needed to restore the impaired condition.

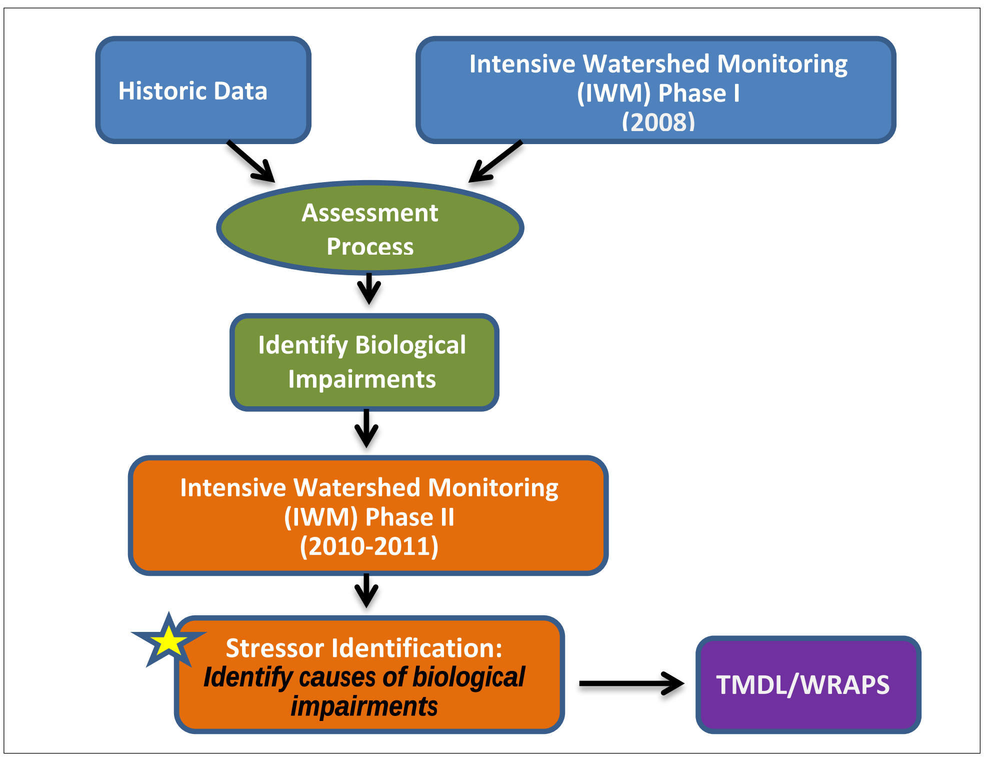


Figure 1. Process map of Intensive Watershed Monitoring, Assessment, Stressor Identification and TMDL processes.

1.2. Stressor identification process

The MPCA follows the Environmental Protection Agency's (EPA) process of identifying stressors that cause biological impairment (Cormier et al. 2000; MPCA 2008). The EPA has also developed an updated, interactive web-based tool, the Causal Analysis/Diagnosis Decision Information System (CADDIS; EPA 2010). This system provides an enormous amount of information designed to guide and assist investigators through the process of Stressor Identification. Additional information on the Stressor Identification process using CADDIS can be found here: http://www.epa.gov/caddis/.

Stressor Identification is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act. SID draws upon a broad variety of disciplines and applications, such as aquatic ecology, biology, geology, geomorphology, hydrology, chemistry, land-use analysis, and toxicology. A conceptual model showing the steps in the SID process is shown in Figure 1. Through a review of available data, stressor scenarios are developed that aim to characterize the biological impairment, the cause, and the sources/pathways of the various stressors.

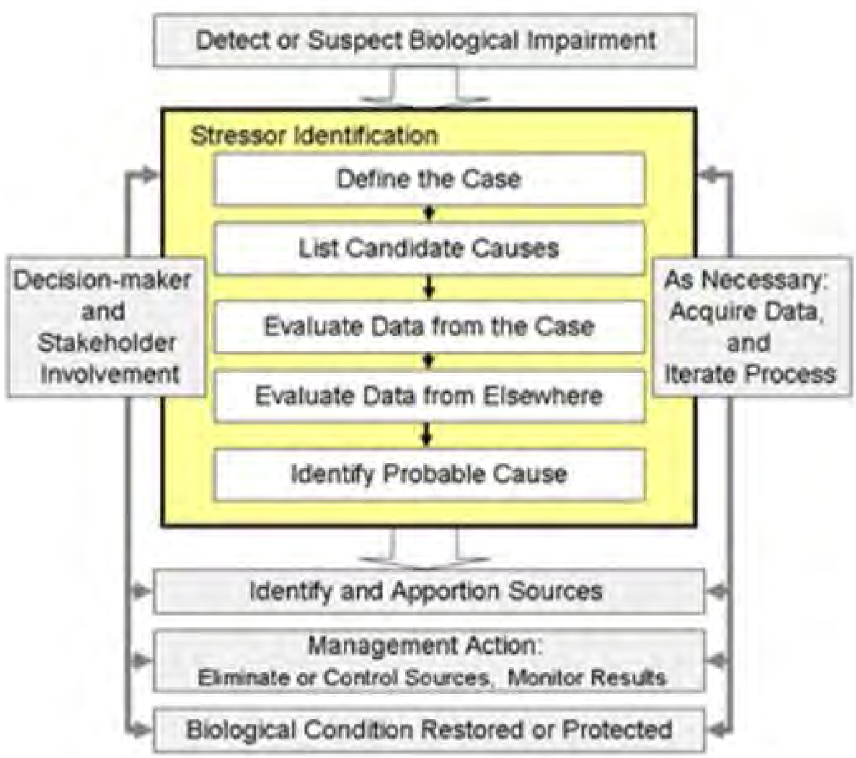


Figure 1. Conceptual model of Stressor Identification process (Cormier et al. 2000).

Strength of evidence (SOE) analysis is used to evaluate the data for candidate causes of stress to biological communities. The relationship between a stressor and a biological response are evaluated by considering the degree to which the available evidence supports or weakens the case for a candidate cause. Typically, much of the information used in the SOE analysis is from the study watershed (i.e., data from the case). However, evidence from other case studies and the scientific literature is also used in the SID process (i.e., data from elsewhere).

Developed by the EPA, a standard scoring system is used to tabulate the results of the SOE analysis for the available evidence (Table A1). A narrative description of how the scores were obtained from the evidence should be discussed as well. The SOE table allows for the organization of all of the evidence, provides a checklist to ensure each type has been carefully evaluated and offers transparency to the determination process.

The existence of multiple lines of evidence that support or weaken the case for a candidate cause generally increases confidence in the decision for a candidate cause. The scoring scale for evaluating each type of evidence in support of or against a stressor is shown in Table A2. Additionally, confidence in the results depends on the quantity and quality of data available to the SID process. In some cases, additional data collection may be necessary to accurately identify the stressor(s) causing impairment. Additional detail on the various types of evidence and interpretation of findings can be found here: http://www.epa.gov/caddis/si_step_scores.html.

1.3. Five components of stream health

The five major elements of a healthy stream system are: stream connections, hydrology, stream channel assessment, water chemistry and stream biology. If one or more of the components are unbalanced, the stream ecosystem may fail to function properly and is listed as an impaired water body. Table 1 lists the common stream stressors to biology relative to each of the major stream health categories.

Table 1. Common streams stressors to biology (i.e., fish and macroinvertebrates).

Stream Health	Stressor(s)	Link to Biology
Stream Connections	**Loss of Connectivity** · Dams and culverts · Lack of Wooded riparian cover · Lack of naturally connected habitats/causing fragmented habitats	Fish and macroinvertebrates cannot freely move throughout system. Stream temperatures also become elevated due to lack of shade.
Hydrology	**Altered Hydrology** **Loss of habitat due to channelization** **Elevated Levels of TSS** · Channelization · Peak discharge (flashy) · Transport of chemicals	Unstable flow regime within the stream can cause a lack of habitat, unstable stream banks, filling of pools and riffle habitat, and affect the fate and transport of chemicals.
Stream Channel Assessment	**Loss of Habitat due to excess sediment** **Elevated levels of TSS** · Loss of dimension/pattern/profile · Bank erosion from instability · Loss of riffles due to accumulation of fine sediment · Increased turbidity and or TSS	Habitat is degraded due to excess sediment moving through system. There is a loss of clean rock substrate from embeddedness of fine material and a loss of intolerant species.
Water Chemistry	**Low Dissolved Oxygen Concentrations** **Elevated levels of nutrients** · Increased nutrients from human influence · Widely variable DO levels during the daily cycle · Increased algal and or periphyton growth in stream · Increased nonpoint pollution from urban and agricultural practices · Increased point source pollution from urban treatment facilities	There is a loss of intolerant species and a loss of diversity of species, which tends to favor species that can breathe air or survive under low DO conditions. Biology tends to be dominated by a few tolerant species.
Stream Biology	Fish and macroinvertebrate communities are affected by all of the above listed stressors	If one or more of the above stressors are affecting the fish and macroinvertebrate community, the IBI scores will not meet expectations and the stream will be listed as impaired.

2. Overview of Root River Watershed

2.1. Background

Of all the rivers that drain to the Mississippi, the Root River in Southeast Minnesota holds a unique distinction. It is one of the largest watersheds in the state, 1,670 square miles, and touches six Minnesota counties. The tributary headwaters originate in glacial till of Mower and Olmsted counties. It flows eastward in Fillmore County, through some of the most unique geology in the world; Karst. Here, the erosive effects of water have sculpted thick layers of limestone over thousands of years. The landscape is characterized by abundant sinkholes, springs, caverns, and underground waterways. From the Karst region, the Root River transitions to the towering blufflands of Houston County to the Mississippi River. The river's unique topography, geology, and location, make it an outstanding example of a river in need of extra consideration.

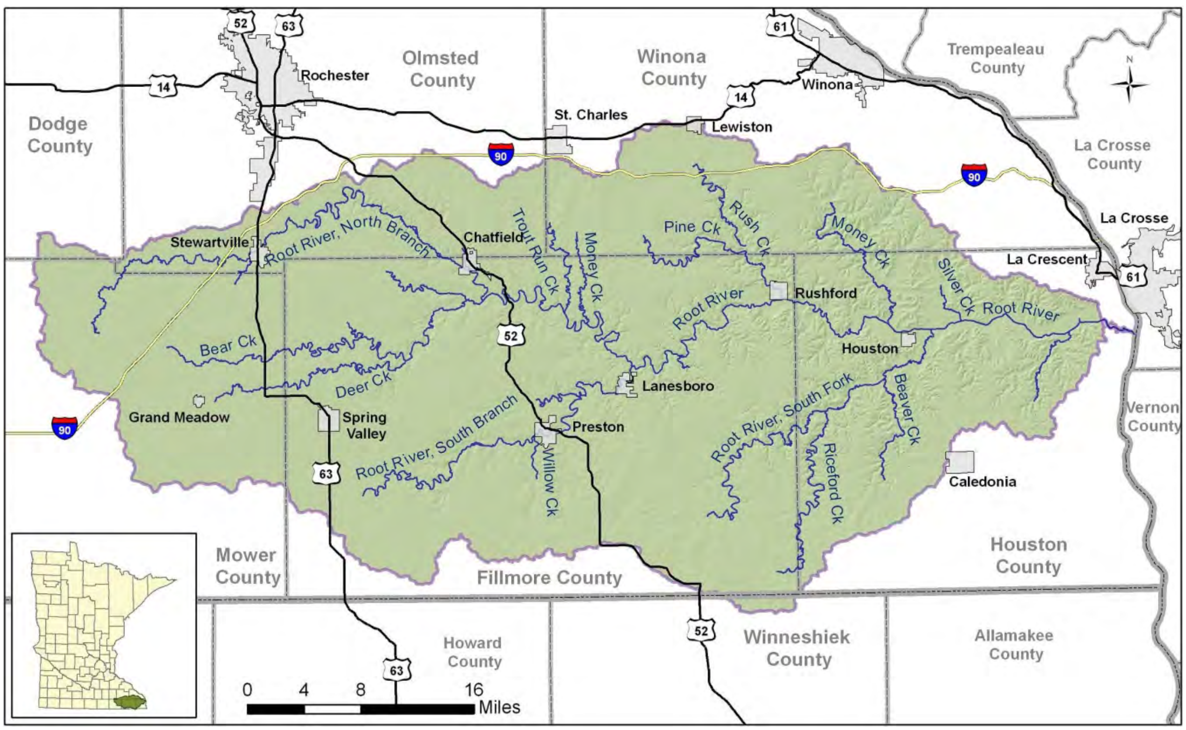


Figure 2. Root River Watershed in Southeast Minnesota.

Official watershed assessments took place in June 2011. The Root River Monitoring and Assessment Report can be found here: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/root-river.html#overview.

Much of the background and introductory information has been intentionally left out of this report, and should be referenced in the Root River Monitoring and Assessment Report.

2.1.1 Subwatersheds and report format

Due to the sheer size of the watershed, and overall complexity, it is difficult to evaluate potential stressors to aquatic life without further stratifying the Root drainage into smaller sections. Although there may be some consistent chemical and physical stressors found throughout the Root Watershed, some are likely acting locally, driven by landscape characteristics specific to a certain region of the watershed. For the purpose of addressing biological impairments in the Root River, the watershed was broken up by 10 digit Hydrologic Unit Code (HUC) watersheds. Each 10 digit HUC will have biological impairments with further analysis in this report.

There were some opportunities within each 10 digit HUC watershed for grouping, and that was done in a select few cases where stressors and biological response were similar. An example of a place where impairments were grouped was multiple reaches on the main stem Root River.

Within the summary (Section 3), there is information about how the stressor relates broadly to the Root Watershed, water quality standards, and general effects on biology. Section 4 is organized by impaired Assessment Unit ID (AUID) and discusses the available data and relationship to fish and macroinvertebrate metrics in more detail.

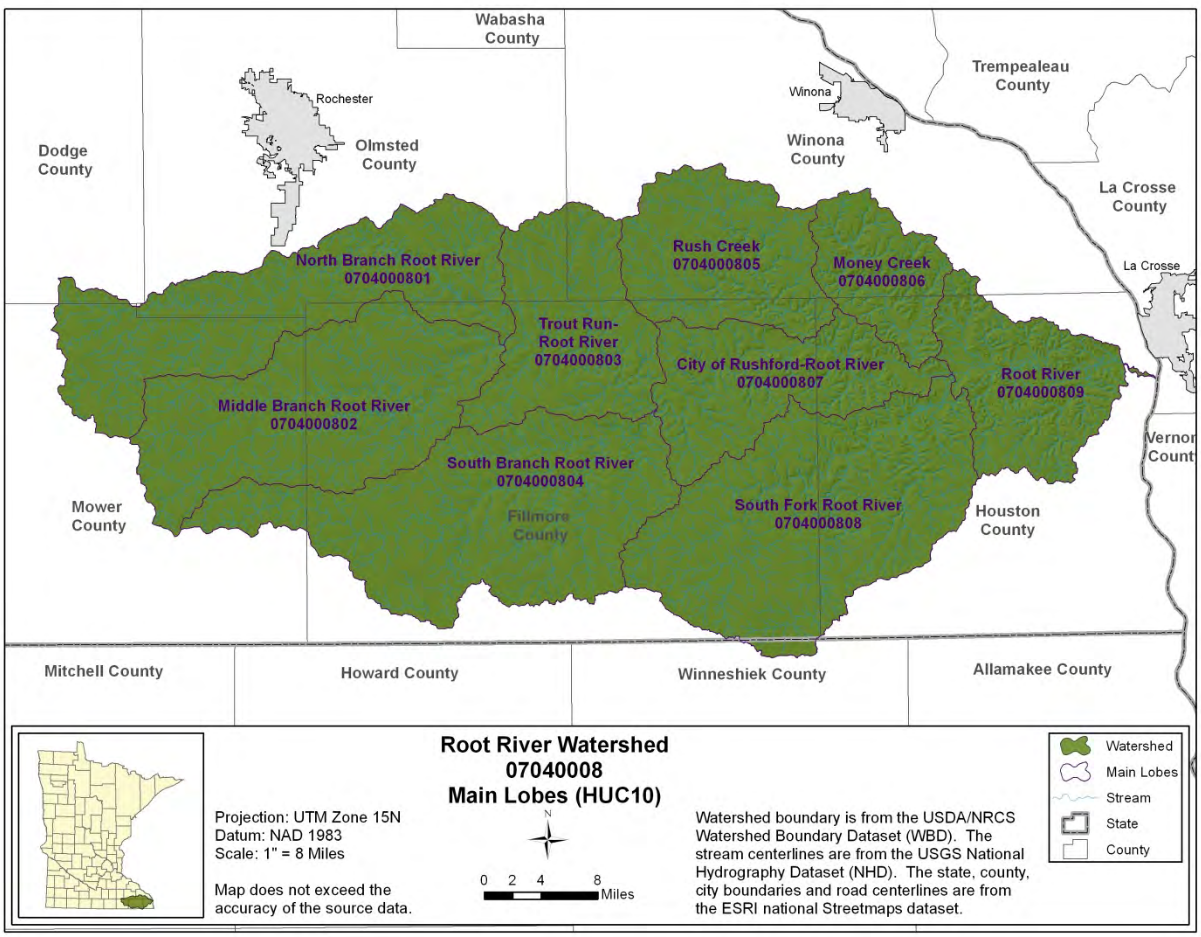


Figure 3. Root River Watershed 10 digit HUC subwatersheds.

2.1.2 Geomorphic regions of the Root River Watershed

There are three major geomorphic regions that are considered when working in the Root River. These three zones vary greatly in their geology, topography, hydrology, and pollutant transport. Impairments and stressors to biology are similar among the three zones, and separating them provides opportunity in the understanding of stressors as they spatially co-occur throughout the watershed. Originally, the stressors to the biologic communities were to be grouped based on this geographic context; however, upon further analysis the complexity of watersheds within each of these regions was too specific to effectively group them. The importance and relevance of the three regions remain important in not only stressor identification, but future restoration and protection.

1) Uplands, Till Covered Karst
2) Driftless, Near-Surface Karst
3) Driftless, Bluffland Karst

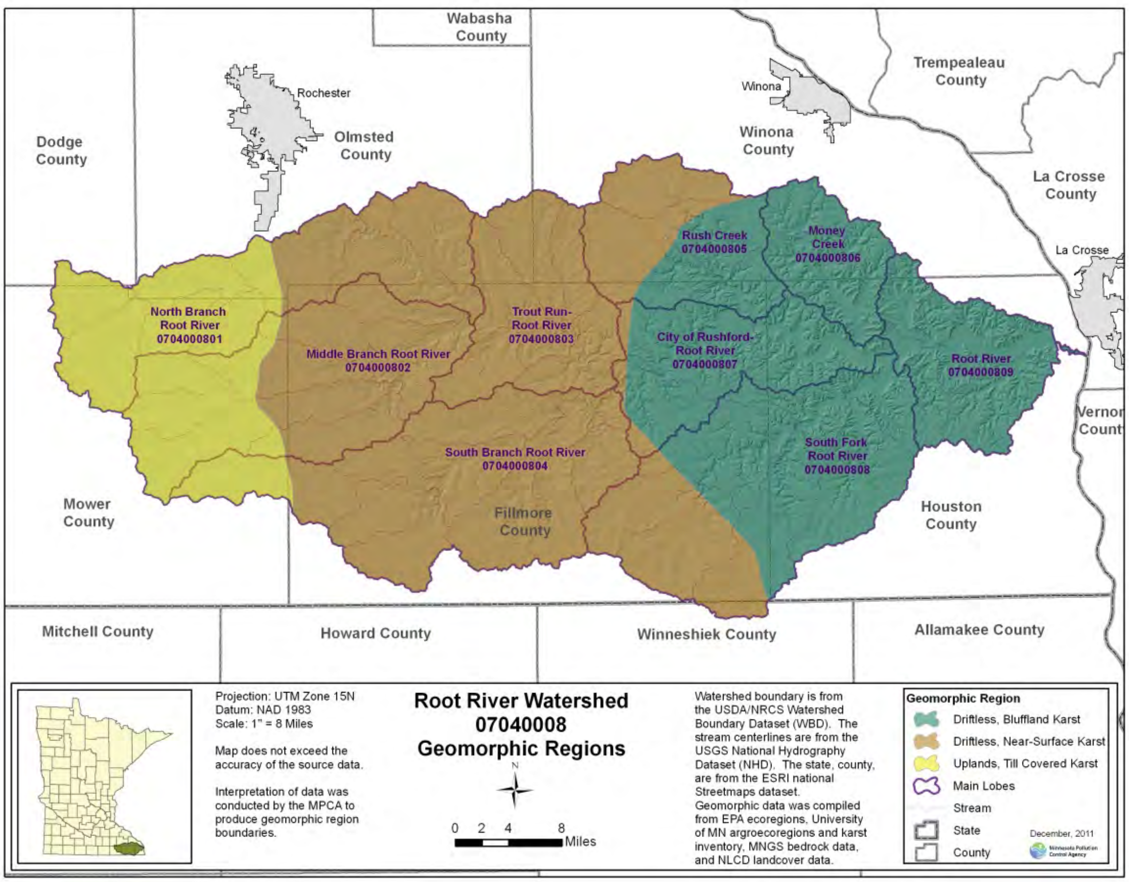


Figure 4. Three Root River Watershed Geomorphic Regions (GIS data used geomorphic data compiled by EPA ecoregions, the University of Minnesota agroecoregions, Minnesota Geological Survey (MGS) bedrock data, and NLCD land cover data).

Uplands, till covered Karst region

This zone encompasses the headwater streams of the Root River (North Branch, Middle Branch, and South Branch). The land use in this zone is predominately agriculture, where ditching and field tile are common. The gradient is gentle. Some Karst features exist, but are not as visibly present on the surface. The majority of this zone resides in Mower County.

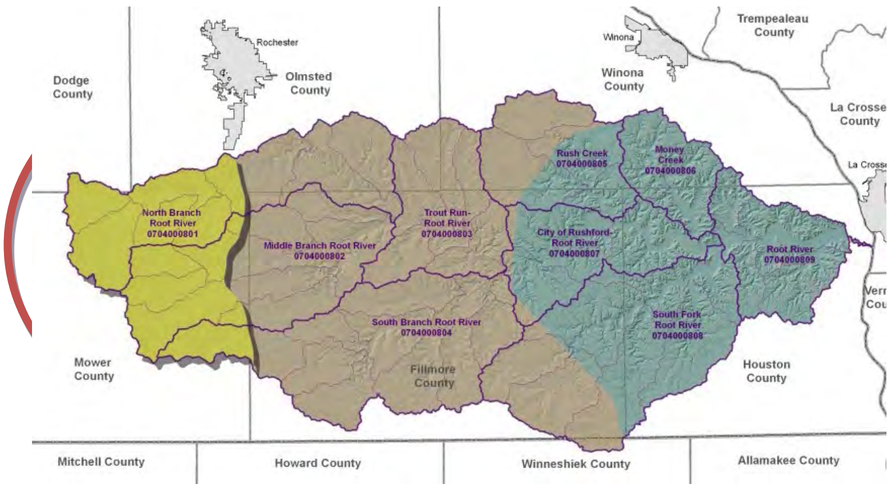


Figure 5. Upland zone highlighted

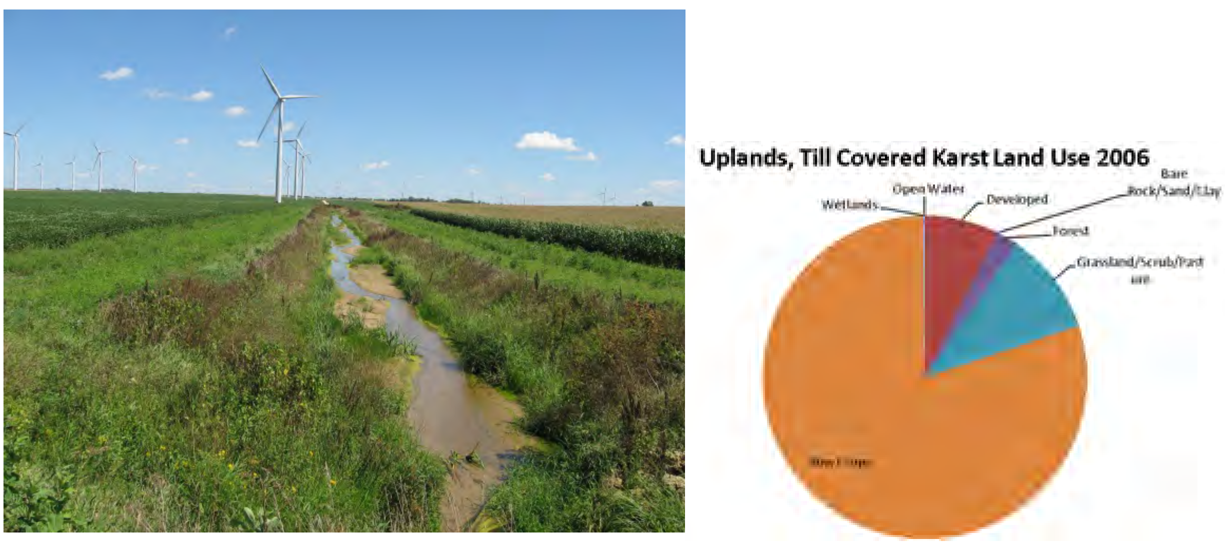


Figure 6. Photo of a ditch in the headwaters, and land use statistics from 2006.

Driftless, near-surface Karst region

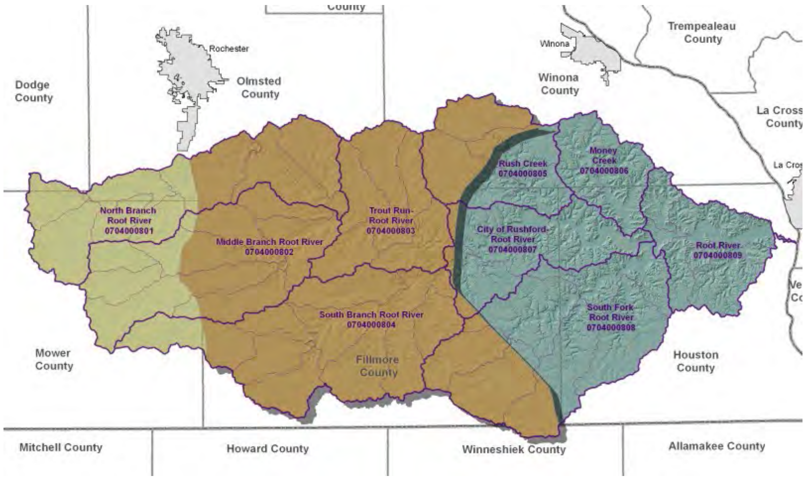


Figure 10. Driftless, near surface Karst zone

Figure 7. Sinkhole: "From Field to Watershed" Photo courtesy Kevin Kuehner, MDA

The hydrology changes dramatically in the "near-surface Karst" zone of the Root River. This zone is characterized by numerous springs, sinkholes and caves. There is a high degree of connection between the surface and groundwater in aquifers, due to the highly fractured nature of Karst bedrock. Open sinkholes and fissures in bedrock serve as connections to the groundwater. This makes groundwater more susceptible to contamination from certain land uses, as pollutants can easily move from the land surface into aquifers. Groundwater in Karst regions can move up to several miles per day, compared to many regions which groundwater travels only several feet per year. Precipitation moves rapidly from the surface to surface water, then find its way to groundwater, and that groundwater may quickly resurface in the form of a spring.

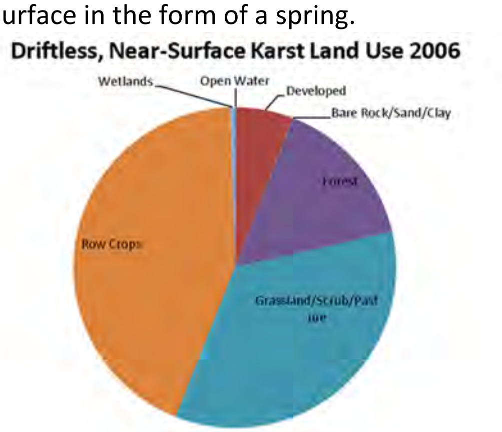


Figure 8. Moth Spring

Figure 9. South Branch Root River, disappearing

Driftless, bluffland Karst region

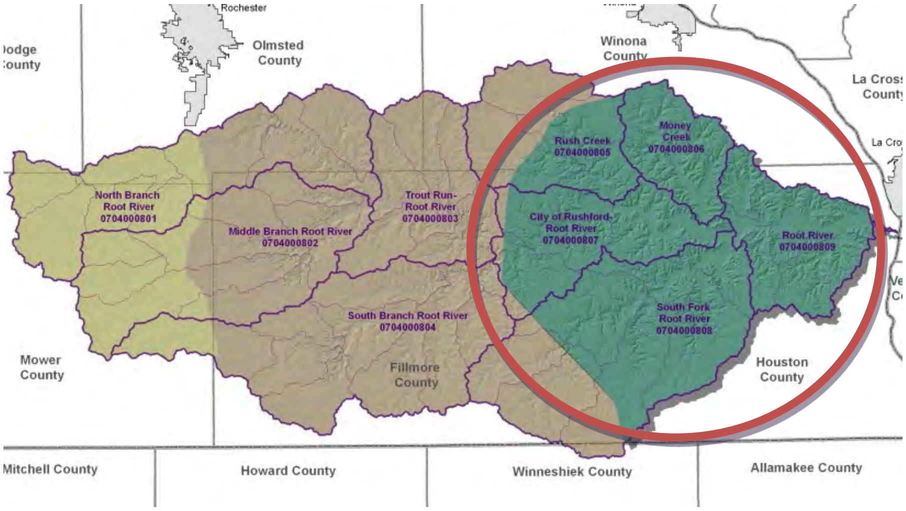


Figure 11. Driftless bluffland Karst zone

In this zone, Karst features still exist, they are just not as prominent on the landscape. This area provides soaring limestone bluffs and diverse natural communities. Similar to the Karst region, numerous coldwater trout streams feed this section of the Root River. High gradient streams, different main geologic units, direct tributaries, etc.

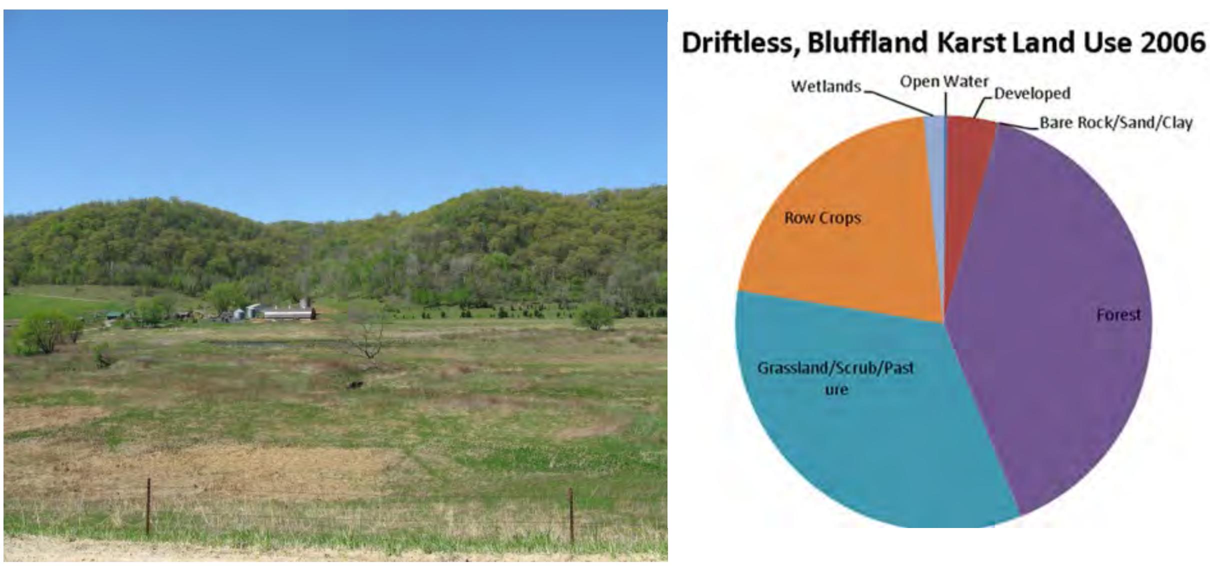


Figure 12. Left: (Photo of Bluffland zone). Right: Land Use Distribution in Bluffland zone, 2006.

2.1.3 Hydrologic events; August 2007 and June 2008

Very heavy rain on Saturday and Sunday, June 7-8th 2008, resulted in record flooding across a large portion of the region, along with a few bouts of hail, damaging winds, and tornadoes (NWS).

The Root River subwatersheds that were most affected by this event were the South Branch and South Fork. The effect from this flood was a concern because 2008 was the year biology was sampled in the watershed. There is uncertainty regarding how some of the stream substrate and channel changes as a result of the flooding may have affected habitat and fish populations sampled that year. There was also concern with macroinvertebrate populations and their ability to re-colonize at some sites by the time they were sampled in August. To address these concerns, selective re-sampling was done in 2010 and 2011 to allow for comparison to the 2008 data (08LM060, 08LM038, 08LM035, 08LM026, 08LM018). Resampling was also done for two sites that were originally sampled in 2004 (04LM113, 04LM095). The selective resampling of sites in those subwatersheds which were greatly impacted by the flooding confirmed that data collected in 2008 was fairly representative of overall conditions in 2008. The stressors to biology are there regardless of the flooding that happened in 2007. While there may have been some shifts in the fish and the macroinvertebrate communities present due to flooding, the overall IBI scores are similar and do not vary greatly in most situations. However, this is a limited sample set, and additional information over time will help in understanding this potential issue.

Table 2. Fish and invertebrate IBI score comparison before and after recent floods

Station	Stream	Invert IBI 2010 or 2011	Invert IBI 2004 or 2008	Fish IBI 2010 or 2011	Fish IBI 2008 or 2004
08LM060	Silver Creek	24.49	17.87	NA	34
08LM038	Willow Creek	60.27	63.67	60	49
08LM035	Trib. to Willow Creek	31.03	45.87	46	28
08LM026	Etna Creek	47.08	41.96	67	60
08LM018	Corey Creek	44.13	53.96	36	34
04LM113	Root River, South Fork	31.63	5.79	60	NA
04LM095	Pine Creek	45.4 (2008)	45.4 (2004)	75 (2008)	68 (2004)

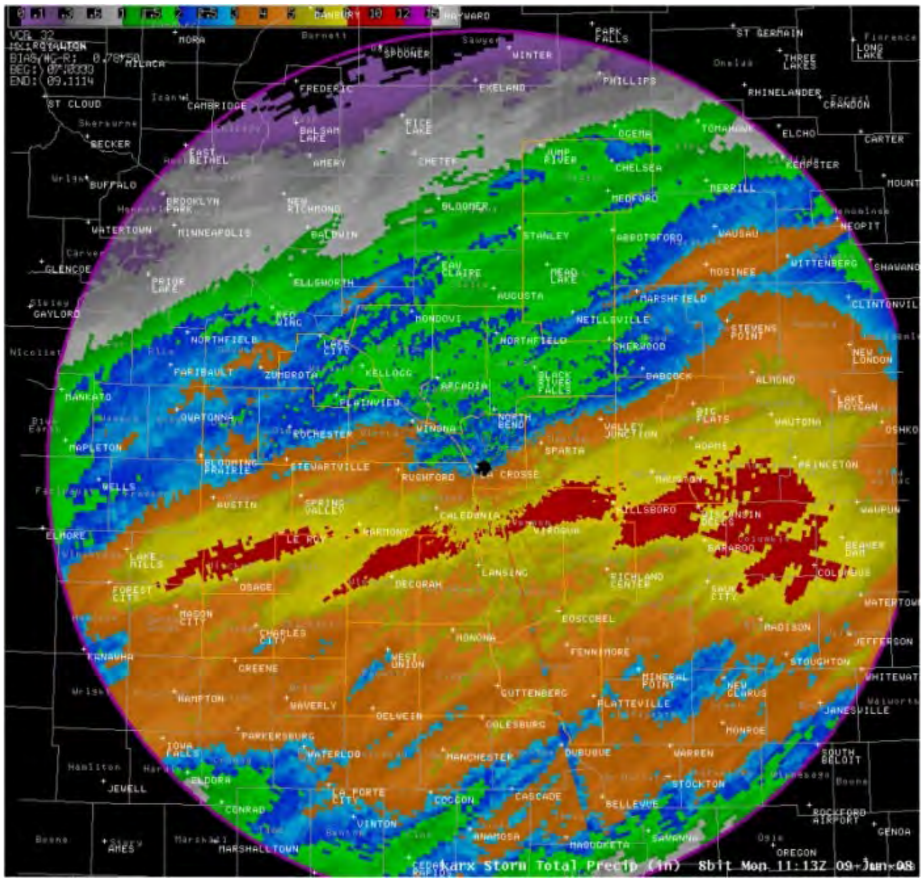


Figure 13. Two-day radar rainfall estimates from Saturday the 7th through Monday morning (the 9th), June 2008 National Weather Service (NWS).

Fillmore County, Minnesota

- Southern half of county was flooded.
- South Branch of Root River crested above flood stage at both Preston and Lanesboro on June 9.
- 7.25" of weekend rain in Harmony, Minnesota

Houston County, Minnesota

- Flooding was so widespread that all roads were closed at one point.
- Several Civil Emergency Messages were sent by their request for evacuations in mainly the southern half of the county.
- The Root River crested over flood stage at Houston early on June 10.

Mower County, Minnesota

- Creeks ran very high in Austin area.
- Numerous roads, especially near Iowa state line were closed.

August 2007 event

A series of thunderstorms moving along a stalled frontal boundary dropped extremely heavy rain on much of southern Minnesota on August 18, 19, and 20, 2007. The heaviest rainfall reports came from Winona, Fillmore, and Houston counties, where 36-hour totals exceeded 14 inches. The largest multi-day rainfall total reported (through Monday, August 20) was 20.85 inches observed near the town of Houston in northern Houston County. An official National Weather Service climate observer near Hokah in Houston County reported a storm total of 16.27 inches. Of the 16.27 inches, 15.10 inches fell within the observer's 24-hour observation cycle ending at 8:00 AM on Sunday, August 19. This is the largest 24-hour rainfall total ever recorded by an official National Weather Service reporting location in Minnesota (NWS). To read additional details see: http://climate.umn.edu/doc/journal/flash_floods/ff070820.htm.

Certain areas were more impacted by this event. For example, areas near Houston (Rush, Pine, Money Creek) showed over-widened channels and sediment deposition, or severe scour. The Whitewater River watershed was studied extensively following the August 2007 rainfall event and found mixed results regarding rebounding macroinvertebrate populations. "Densities of some invertebrate groups recovered within months of the flood, but others were still recovering after nearly two years. Taxa richness and community structure returned to pre-flood levels at most sites within one year, but total densities at many sites remained below long-term averages 22 months post-flood. Invertebrate assemblages were impacted differently by flooding in small versus large streams, resulting in differing patterns and degrees of recovery." (Mundahl, 2011)

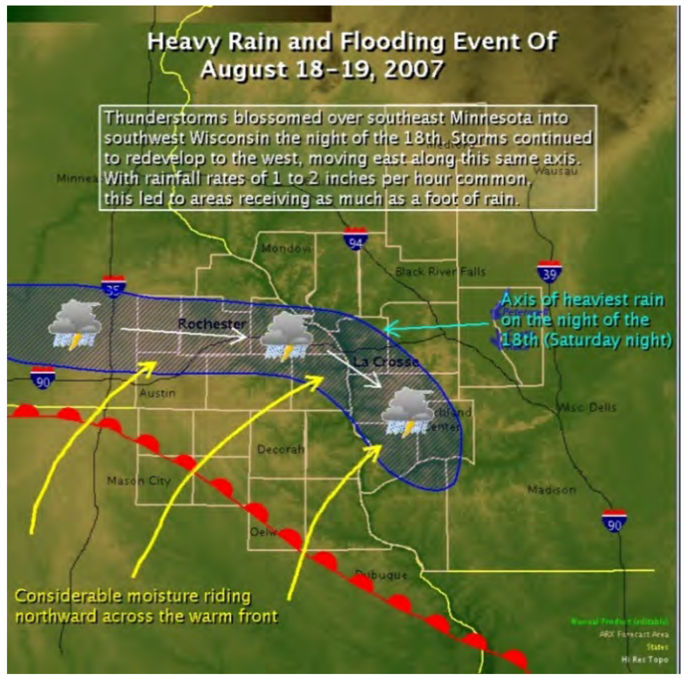


Figure 14. Location of heaviest rain from August 18, 2007 (NWS)

Minnesota Department of Natural Resources (MDNR) fisheries staff has indicated that brown trout populations recovered very quickly after flooding and population composition was mostly unaffected. Most fish were likely able to find refuge during this event. It is possible that effects from the flooding that happened in 2007 still remain to be seen. Many sites have had a complete change in stream channel type and sediment transport. The sites most impacted by this severe flooding will be important to analyze when re-sampled in 2018.

2.2. Monitoring overview

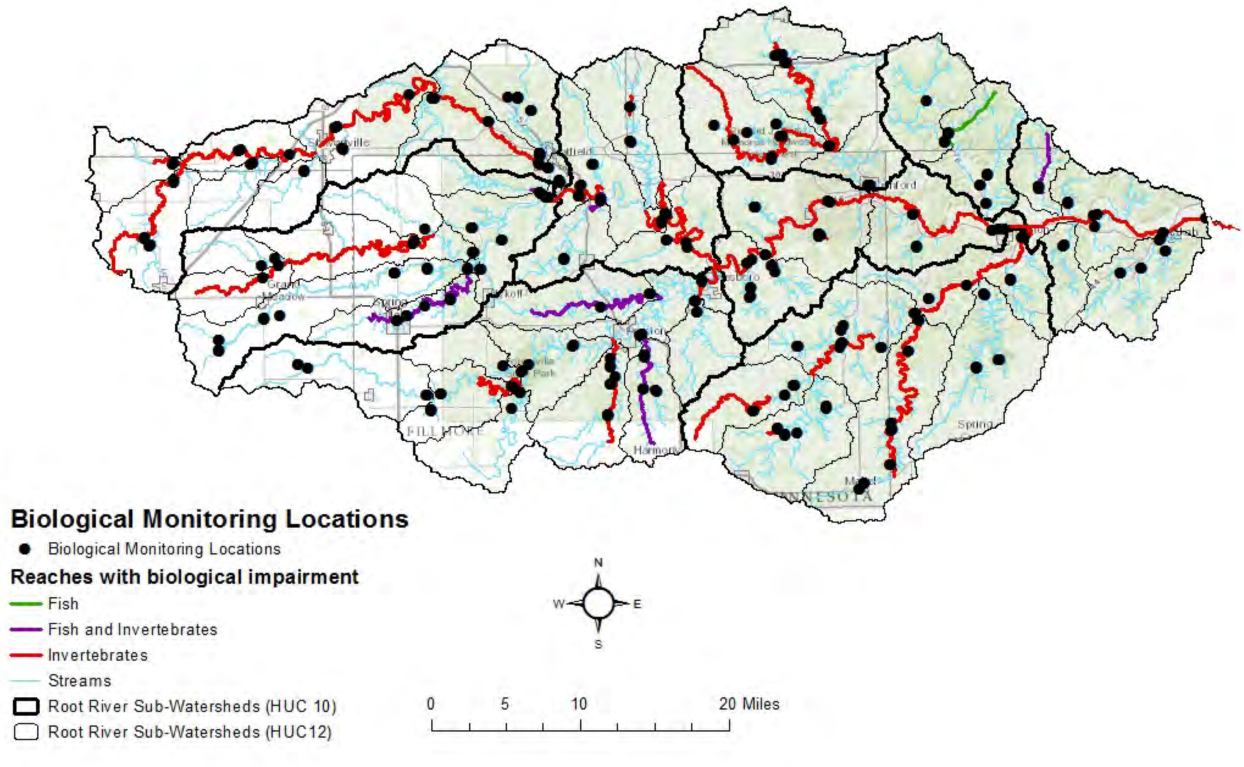


Figure 15. Biological monitoring locations and reaches with identified biological impairment in the Root River.

The Root River Assessment Report, which contains detailed information on the biological monitoring process, and impairment decisions can be found here: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/root-river.html#overview

2.3. Summary of biological impairments

The approach used to identify biological impairments includes assessment of fish and aquatic macroinvertebrates communities and related habitat conditions at sites throughout the watershed. The resulting information is used to develop an IBI. The IBI scores can then be compared to a range of thresholds.

The fish and MIBI within each AUID were compared to a regionally developed threshold and confidence interval to determine biological impairment. In the Root Watershed, 40 AUIDs are currently impaired for a lack of biological assemblage (Table 3).

Table 3. Biologically impaired AUIDs in the Root Watershed.

10 Digit HUC	Watershed Name	Description	AUID	Biological Impairment
Root River	Root River	Thompson Cr to Mississippi R	07040008-501	Macroinvertebrate
	Root River	S Fk Root R to Thompson Cr	07040008-502	Macroinvertebrate
	Silver Creek	T105 R6W S35, north line to T104 R6W S14, south line	07040008-640	Fish and Macroinvertebrate
City of Rushford-Root River	Root River	Money Cr to S Fk Root R	07040008-520	Macroinvertebrate
	Root River	Rush Cr to Money Cr	07040008-522	Macroinvertebrate
	Unnamed creek	T104 R8W S32, east line to Unnamed cr	07040008-659	Macroinvertebrate
	Root River	M Br Root R to Rush Cr	07040008-527	Macroinvertebrate
Trout Run-Root River	Trout Run Creek	T105 R10W S18, north line to Unnamed cr	07040008-G87	Macroinvertebrate
	Root River, Middle Branch	Trout Run Cr to S Br Root R	07040008-528	Macroinvertebrate
	Root River, Middle Branch	N Br Root R to Lynch Cr	07040008-534	Macroinvertebrate
	Money Creek	Unnamed cr to M Br Root R	08040008-F48	Macroinvertebrate
	Wadden Valley Creek (Unnamed Creek)	Unnamed cr to M Br Root R	07040008-605	Macroinvertebrate
	Rice Creek	T104 R11W S23, west line to M Br Root R	07040008-581	Fish and Macroinvertebrate
Middle Branch Root River	Root River, Middle Branch	Upper Bear Cr to N Br Root R	07040008-506	Macroinvertebrate
	Upper Bear Creek	T104 R11W S18, west line to M Br Root R	07040008-540	Fish and Macroinvertebrate

10 Digit HUC	Watershed Name	Description	AUID	Biological Impairment
	Bear Creek	Headwaters to Kedron Cr	07040008-544	Macroinvertebrate
	Spring Valley Creek	T103 R13W S29, west line to Deer Cr	07040008-548	Fish and Macroinvertebrate
	Curtis Creek	Headwaters to M Br Root R	07040008-541	Macroinvertebrate
Money Creek	Corey Creek	T105 R6W S18, east line to Money Cr	07040008-631	Fish
North Branch Root River	Unnamed creek	Unnamed cr to N Br Root R	07040008-706	Macroinvertebrate
	Root River, North Branch	Unnamed cr to Mill Cr	07040008-716	Macroinvertebrate
	Unnamed creek	Unnamed cr to Unnamed cr	07040008-F46	Macroinvertebrate
	Root River, North Branch	Headwaters to Carey Cr	07040008-717	Macroinvertebrate
Rush Creek	Rush Creek	Unnamed cr to Pine Cr	07040008-524	Macroinvertebrate
	Pine Creek	T104 R9W S4, north line to Rush Cr	07040008-526	Macroinvertebrate
	Pine Creek	Headwaters to T105 R9W S32, south line	07040008-576	Macroinvertebrate
South Branch Root River	Root River, South Branch	Duschee Cr to M Br Root R	07040008-550	Macroinvertebrate
	Watson Creek	T103 R11W S30, west line to S Br Root R	07040008-552	Fish and Macroinvertebrate
	Root River, South Branch	T102 R12W S21, north line to Canfield Cr	07040008-556	Macroinvertebrate
	Willow Creek	T101 R11W S12, west line to S Br Root R	07040008-558	Macroinvertebrate
	Camp Creek	Headwaters to S Br Root R	07040008-559	Fish and Macroinvertebrate
	Etna Creek	T102 R13W S36, west line to Unnamed cr	07040008-597	Macroinvertebrate
South Fork Root River	Root River, South Fork	Beaver Cr to Root R	07040008-508	Macroinvertebrate
	Root River, South Fork	Riceford Cr to Beaver Cr	07040008-509	Macroinvertebrate
	Root River, South Fork	Wisel Cr to T102 R8W S2, east line	07040008-510	Macroinvertebrate
	Riceford Creek	T101 R7W S19, south line to	07040008-518	Macroinvertebrate

10 Digit HUC	Watershed Name	Description	AUID	Biological Impairment
		T102 R7W S30, north line		
	Riceford Creek	T102 R7W S19, south line to S Fk Root R	07040008-519	Macroinvertebrate
	Root River, South Fork	Headwaters to T102 R9W S27, east line	07040008-573	Macroinvertebrate
	Sorenson Creek	Unnamed cr to Unnamed cr	07040008-F52	Macroinvertebrate
	Bridge Creek	Unnamed cr to Unnamed cr	07040008-F54	Macroinvertebrate

To measure the health of aquatic life at each biological monitoring station, the MPCA calculated IBI scores for fish and macroinvertebrates. These indices are based on monitoring data collected for each community. Minnesota has assigned a goal IBI for rivers and streams based on drainage area, gradient, water temperature and geographic region.

The MPCA uses IBIs to determine if segments of rivers and streams are impaired for biology, meaning the fish and macroinvertebrate populations fail to meet expectations as far as species and numbers. The agency also uses confidence levels around the thresholds for impairments to decide if more information is needed. For example, if an IBI score falls within the confidence level for impairment, then the agency and local partners will look for potential stressors causing the impairment including water chemistry, physical habitat, land use activities and other factors. These decisions and further information on the assessment process can be found in the Root River Monitoring and Assessment report: http://www.pca.state.mn.us/index.php/view-document.html?gid=17986.

The IBI scores and thresholds for stations sampled in the Root River watershed can be found in Table 4 and Table 5.

Table 4. Fish classes with respective IBI thresholds and upper/lower confidence limits (CL) found in the Root Watershed.

Class	Class Name	Fish IBI Thresholds	Upper CL	Lower CL
1	Southern Rivers	39	50	28
2	Southern Streams	45	54	36
3	Southern Headwaters	51	58	44
10	Southern Coldwater	45	58	32

Table 5. Macroinvertebrate classes with respective IBI thresholds and upper/ lower confidence limits (CL) found in the Root Watershed.

Class	Class Name	Macroinvertebrate IBI Thresholds	Upper CL	Lower CL
2	Prairie Forest Rivers	30.7	41.5	19.9
5	Southern Streams RR	35.9	48.5	23.3
6	Southern Streams GP	46.8	60.8	33.2
9	Southern Coldwater	46.1	59.9	32.3

The purpose of stressor identification is to interpret the data collected during the biological monitoring and assessment process. Trends in the IBI scores can help to identify causal factors for biological impairments. In the Root River there are multiple reaches with only macroinvertebrate impairments, a handful with both fish and macroinvertebrate impairments (six), and one reach with an exclusively fish impairment. All fish related impairments occur on coldwater streams in the Root River Watershed. No fish impairments on warmwater streams were identified. There are multiple hypotheses regarding why macroinvertebrate impairments may predominate, including: sensitivity to habitat degradation and other sensitivity to chemical pollutants like nitrate which are common in the watershed.

In addition, overall, the macroinvertebrate communities in the Root River appear to be lacking Odonata (dragonflies and damselflies). On the mainstem Root River, the biological stations are dominated by a tolerant mayfly (trichorythodes), which is not seen as often in other parts of the state on that same stream class. The significance of this is unknown, but should be explored further.

3. Possible stressors to biological communities

A comprehensive list of potential stressors to aquatic biological communities compiled by the EPA can be found here (http://www.epa.gov/caddis/si_step2_stressorlist_popup.html). This comprehensive list serves two purposes. First, it can serve as a checklist for investigators to consider all possible options for impairment in the watershed of interest. Second, it can be used to identify potential stressors that can be eliminated from further evaluation. In some cases, the data may be inconclusive and limit the ability to confidently determine if a stressor is causing impairment to aquatic life. It is imperative to document if a candidate cause was suspected, but there was not enough information to make a determination of whether the candidate cause is harming/harmful to aquatic life. In this case, management decisions can include modification of sampling plans and future evaluation of the inconclusive case. Alternatively, there may be enough information to conclude that a candidate cause is not causing biological impairment and therefore can be eliminated. The inconclusive or eliminated causes will be discussed in more detail in the following section.

In the Root River Watershed, a list of candidate causes was developed at the beginning of the Stressor Identification work. Each subwatershed (10 digit HUC) area was then further examined and stressors in each watershed zone were determined. A comprehensive review of the biological, chemical, and physical data was performed to select probable causes for the impairments. An initial (comprehensive) list of candidate causes was developed, and then further narrowed down after data analysis, leaving six candidate causes for biological impairment in the Root River. The three that were found to be of limiting information and thus eliminated were pesticides, toxics and flow alteration. Detailed analyses for each 10 digit HUC are addressed later in this report in Section 3 and 4.

Comprehensive Candidate Cause List Examined for the Root River Watershed:

- Dissolved Oxygen (DO)
- Temperature
- Nitrate
- Total Suspended Solids (TSS)
- Physical Habitat
- Flow Alteration
- Connectivity
- Pesticides
- Toxics

3.1. Inconclusive causes

There were three candidate causes that were determined to be inconclusive. Additional information about each of these causes is provided in Section 3.1.

1) Pesticides
2) Flow Alteration
3) Toxics

In many of the samples, although numerous pesticides were present, none were above the state or federal standards. With the limited data available, the effects of pesticides on the biological community within the Root River are inconclusive at this time. Currently, the additive effect of pesticides on aquatic organisms at levels below state or federal standards is unknown. More research needs to be developed to characterize this potential effect. Additional monitoring is recommended to further understand the presence of pesticides and their potential impacts to the biological community. Given the current gaps in understanding of the additive effects, pesticide toxicity can neither be ruled out as a possible stressor nor concluded to be a stressor.

The existing data is limited, and chemical information on toxics in the Root River was very limited. Both the flow alteration as a cause and toxics as a cause lack connecting biological response data to prove these stressors are impacting the biological communities. More needs to be learned in order to conclude theses stressors exist.

3.1.1. Candidate cause: Pesticides

A pesticide defined by the EPA as "any substance intended for preventing, destroying, repelling or mitigating any pest." For the purpose of this document, pesticides refer to fungicides, insecticides, and herbicides used to control various pests.

Herbicides are chemicals used to manipulate or control undesirable vegetation. The most frequent application of herbicides occurs in row-crop farming. Herbicide application occurs before or during planting to minimize other vegetation, maximizing crop productivity. Herbicides may also be applied to crops in the fall to improve harvesting. In suburban and urban areas, herbicides are applied to lawns, parks, golf courses, and other areas. Herbicides are also applied to water bodies to control aquatic weeds that impede irrigation withdrawals or interfere with recreational and industrial uses of water (Folmar et al., 1979).

Insecticides are chemicals used to control insects by killing them or preventing them from engaging in behaviors deemed undesirable or destructive. Many insecticides act upon the nervous system of the insect, such as Cholinesterase (ChE) inhibition, while others act as growth regulators. Insecticides are commonly used in agricultural, public health, and industrial applications, as well as household and commercial uses (control of roaches and termites). The U.S. Department of Agriculture (2001) reported that insecticides accounted for 12%of total pesticides applied to the surveyed crops. Corn and cotton account for the largest shares of insecticide use in the United States. To learn about insecticides and their applications, along with associated biological response/affects, refer to the EPA website on insecticides and causal analysis located at http://www.epa.gov/caddis/ssr_ins_int.html.

The Minnesota Department of Agriculture (MDA) annually collects samples from various surface water bodies throughout the state and analyzes those samples for the presence of pesticides and degradates.

The MDA attempts to capture the influence of different land uses on surface water resources. Out of the 100-plus pesticides this program routinely analyzes for, three have been named a "surface water pesticide of concern" in Minnesota — acetochlor, atrazine, and chlorpyrifos. Detection frequency and detection maximums can vary among years for individual pesticides. When detection maximums reach certain thresholds, the MDA may focus monitoring and response efforts in the location of the detection. For more information about the MDA surface water monitoring program, visit: http://www.mda.state.mn.us/monitoring.

3.1.1.1 Water quality standards

Since 1985, MDA and Minnesota Department of Health (MDH) have been monitoring the concentrations of common pesticides in groundwater near areas of intensive agricultural land use. In 1991, these monitoring efforts were expanded to include surface water monitoring sites on select lakes and streams. To learn more about the MDA pesticide monitoring plan and results visit: http://www.mda.state.mn.us/protecting/cleanwaterfund/pesticidemonitoring.aspx.

Surface water reference values (text from MDA, 2010)

The MPCA has developed toxicity-based (for aquatic life) or human health-based enforceable chronic standards for pollutants detected in surface water. The toxicity-based standard is designed to be protective of aquatic life exposure, and is typically based on exposure duration of four days. The human health-based standard (protective for drinking water plus fish consumption) is based on exposure duration of 30 days. For the most current MPCA water quality rules see Chapter 7050: Standards for Protection of Waters of the State. A summary of MPCA's chronic and maximum standard values for common pesticides used in Minnesota are shown in **Table 6**.

Table 6. Summary of MPCA surface water standards associated with target pesticides analytes.

Pesticide Analyte	Class 2A[3]	Class 2B[4]	Maximum Standard[2]
Acetochlor	3.6	3.6	86
Alachlor	59	59	800
Atrazine	10	10	323
Chlorpyrifos	0.041	0.041	0.083
Metolachlor	23	23	271

[1] Chronic standards are defined in Minn. R. ch. 7050 as toxicity-based for aquatic organisms and is protective for an exposure duration of 4 days

[2] Maximum standard value for aquatic life & recreation as defined in Minn. R. ch. 7050. Values are the same for all classes of surfacewaters.

[3] State water classification for coldwater streams and all recreation.

[4] State water classification for cool and warmwater streams and all recreation.

3.1.1.2 Sources and causal pathways model for pesticides

For the background and to see the Conceptual Model for herbicides, follow this link: http://www.epa.gov/caddis/ssr_herb_int.html.

3.1.1.3. Overview of pesticides in the Root River Watershed

Pesticides (including herbicides, fungicides, and insecticides) are considered potential stressors in the Root River Watershed due to the surrounding land use. Table 7 describes the pesticide compounds that have been detected in the Root River Watershed. Since 2002, a total of 39 different pesticide or pesticide degradates have been detected in rivers or streams in the Root River Watershed. When comparing water quality pesticide results to Minnesota State standards and reference values, the duration of pesticide occurrence in a waterbody must be assessed in conjunction with the numeric result. For example, MPCA Class 2Bd Chronic Standards were developed with a duration exposure of four days and where applicable, Class 2A Chronic Standards were developed with a duration exposure of 30 days. Of the detected compounds in the Root River Watershed, only atrazine and alachlor have lower standards for Class 2A waters when compared to Class 2Bd waters. The Class 2A standard for atrazine is 3.4 µg/L and 3.8 µg/L for alachlor. All of the data collected by MDA is reviewed annually by MPCA for the assessment of water quality standards. As of the 2012 303 (d) list there are no water quality impairments related to pesticides in the Root River Watershed.

All of the historic pesticide compound detections were well below the acute, 1-day maximum standards. Of the 39 pesticide compounds detected, only one acetochlor sample has been detected above the chronic, four-day standard. This sample was collected as a grab sample from Bridge Creek in 2011. Starting in 2012, Bridge Creek and two additional Root River subwatersheds are a part of the Root River Pesticide Pilot Study. Acetochlor concentrations from Bridge Creek in 2012 were all below laboratory quantification levels. A closer evaluation of the broader acetochlor statistics show a 95th percentile concentration of 0.79 µg/L, or less than 22% of the chronic, four-day standard. Atrazine has been detected approaching the Class 2Bd 4-day standard of ten µg/L in a Class 2B water. The 95th percentile for atrazine all detections was 3.24 µ/L. These samples were collected from Class 2A, 2Bd, and 2B waters within the watershed. No stream has had atrazine measured above 3.4 µg/L over a 30-day period associated with the lower Class 2A standard. Several pesticides are detected frequently; however, 19 different pesticide compounds were detected in fewer than 10% of samples. Pesticide monitoring will continue in the Root River Watershed for the foreseeable future and will provide additional information related to pesticide detections.

The data presented in the pesticide sampling results table contains data collected from Class 2A, 2Bd, and 2B waters. Individual streams should be assessed for pesticides with site specific results; however, the data presented provides a watershed level view of pesticide detections in the Root River Watershed.

Table 7. Detected pesticides and pesticide compounds in the Root River Watershed River and Stream Pesticide Sampling, 2002-2012

Pesticide Name[1]	Pesticide Type	Detects	Total Samples	Detection Frequency	Detection Concentration Distribution (µg/L)					Water Quality Standards and/or Reference Values (µg/L)			
					Median	75th %-tile	90th %-tile	95th %-tile	Maxi-mum	MPCA Class 2Bd[5] Chronic Standard[3]	MPCA Maximum Standard[4]	EPA Acute Value Aquatic Life Benchmark (µg/L)[2]	EPA Chronic Value Aquatic Life Benchmark (µg/L)[2]
2,4-D	Herbicide	43	70	61%	0.015	0.094	0.204	0.453	5.27	70 H	--	12,075 (f)	13.1 (v)
Acetochlor	Herbicide	187	442	42%	nd	0.06	0.39	0.79	20.2	3.6 T	86 T	na	na
Acetochlor ESA	Degradate	126	143	88%	0.15	0.377	0.606	0.79	1.2	--	--	> 62,500 (i)	9,900 (n)
Acetochlor OXA	Degradate	60	143	42%	nd	0.12	0.404	0.634	1.75	--	--	--	--
Alachlor	Herbicide	5	442	1%	nd	nd	nd	nd	0.31	4.2 H; 59 T	800 T	na	na
Alachlor ESA	Degradate	139	143	97%	0.19	0.271	0.346	0.489	0.67	--	--	52,000 (f)(i)	–
Atrazine	Herbicide	425	442	96%	0.06	0.22	1.23	3.24	9.4	3.4 H; 10 T	323 T	na	na
DEDI Atrazine	Degradate	20	70	29%	nd	0.058	0.077	0.091	0.12	--	--	> 50,000 (f)(i)	--
Deisopropylatrazine	Degradate	68	442	15%	nd	nd	P(<0.2)	P (<0.2)	0.33	--	--	8,500 (f)	2,500 (n)
Desethylatrazine	Degradate	432	442	98%	0.09	0.13	0.22	0.3	0.73	--	--	--	1,000 (n)
Hydroxyatrazine	Degradate	70	70	100%	0.034	0.047	0.0677	0.073	0.094	--	--	> 1,500 (f)	>10,000 (n)
Azoxystrobin	Fungicide	4	70	6%	nd	nd	nd	0.007	0.347	--	--	130 (i)	44 (i)
Bentazon	Herbicide	24	70	34%	nd	0.002	0.003	0.003	0.022	--	--	> 50,000 (f)(i)	4,500 (n)
Clopyralid	Herbicide	1	70	1%	nd	nd	nd	nd	0.072	--	--	56,000 (i)	--
Clothianidin	Insecticide	3	70	4%	nd	nd	nd	nd	0.034	--	--	>46,800 (f)	120 (i)
Dicamba	Herbicide	2	70	3%	nd	nd	nd	nd	0.089	--	--	14,000 (f)	61 (n)
Dimethenamid	Herbicide	150	442	34%	nd	P(<0.05)	0.06	0.13	1.57	--	--	3,150 (f)	5.1 (v)[6]
Dimethenamid ESA	Degradate	62	143	43%	nd	0.042	0.078	0.133	0.64	--	--	--	--
Dimethenamid OXA	Degradate	17	143	12%	nd	nd	0.013	0.039	0.2	--	--	--	--
Diuron	Herbicide	4	70	6%	nd	nd	nd	0.012	0.331	--	--	80 (i)	2.4 (n)

Pesticide Name[1]	Pesticide Type	Detects	Total Samples	Detection Frequency	Detection Concentration Distribution (µg/L)					Water Quality Standards and/or Reference Values (µg/L)			
					Median	75th %-tile	90th %-tile	95th %-tile	Maxi-mum	MPCA Class 2Bd[5] Chronic Standard[3]	MPCA Maximum Standard[4]	EPA Acute Value Aquatic Life Benchmark (µg/L)[2]	EPA Chronic Value Aquatic Life Benchmark (µg/L)[2]
Imazapyr	Herbicide	2	70	3%	nd	nd	nd	nd	0.00946	--	--	50,000 (f) (i)	24 (v)
Imazethapyr	Herbicide	21	70	30%	nd	0.009	0.03	0.034	0.155	--	--	> 55,000 (f)(i)	8.10 (v)
MCPA	Herbicide	1	70	1%	nd	nd	nd	nd	0.053	--	--	90 (i)	20 (v)
Mesotrione	Herbicide	5	70	7%	nd	nd	nd	0.112	0.239	--	--	> 60,000 (f)	9.8 (v)
Metalaxyl	Fungicide	1	70	1%	nd	nd	nd	nd	0.01	--	--	14,000 (i)	100 (i)
Metolachlor	Herbicide	362	442	82%	P (<0.07)	0.2	0.94	1.68	7.2	23 T	271 T	na	na
Metolachlor ESA	Degradate	143	143	100%	0.995	1.46	1.91	2.06	3.25	--	--	24,000 (f)	> 95,100 (v)
Metolachlor OXA	Degradate	110	143	77%	0.07	0.19	0.355	0.506	0.65	--	--	7,700 (i)	57,100 (n)
Metribuzin	Herbicide	5	345	1%	nd	nd	nd	nd	0.16	--	--	2,100 (i)	8.7 (n)
Prometon	Herbicide	2	156	1%	nd	nd	nd	nd	P (<0.10)	--	--	6,000 (f)	98 (n)
Propazine	Herbicide	28	342	8%	nd	nd	nd	P (<0.10)	P (<0.10)	--	--	>2,660 (i)	24.8 (n)
Propiconazole	Fungicide	2	336	1%	nd	nd	nd	nd	P (<0.20)	--	--	425 (f)	21 (n)
Saflufenacil	Herbicide	11	70	16%	nd	nd	0.031	0.036	0.07	--	--	> 49,000 (f)(i)	42 (n)
Simazine	Herbicide	5	264	2%	nd	nd	nd	nd	0.7	4 H	--	500 (i)	36 (n)
Tembotrione	Herbicide	1	70	1%	nd	nd	nd	nd	0.078	--	--	915 (f)	310 (n)
Tetraconazole	Fungicide	1	433	0%	nd	nd	nd	nd	P(<0.15)	--	--	1,315 (i)	190 (i)
Thiamethoxam	Insecticide	4	70	6%	nd	nd	nd	0.016	0.092	--	--	17.5 (i)	20,000 (f)
Triclopyr	Herbicide	1	70	1%	nd	nd	nd	nd	0.089	--	--	180 (f)	100 (n)

Key to value types and symbols in surface water reference values

$\boxed{–}$ – For some analytes, reference values have not been identified or evaluated

$\boxed{na}$ – not applicable

$\boxed{(f)}$ – USEPA/OPP benchmark value for fish.

$\boxed{(i)}$ – USEPA/OPP benchmark value for invertebrates.

$\boxed{(n)}$ – USEPA/OPP benchmark value for nonvascular plants

$\boxed{(v)}$ – USEPA/OPP benchmark value for vascular plants.

$\boxed{H}$ – "H" Chronic Standard values are human health-based and protective for an exposure duration of 30 days.
$\boxed{T}$ – "T" Chronic Standard values are toxicity-based for aquatic organisms and protective for an exposure duration of 4 days.

[1] **Reference Values** are given for all detected target and non-target analytes. They are also given for non-detected target analytes when a reference value is available. Other non-detected analytes do not have an available reference value from the sources listed below.

[2] **Aquatic Life Benchmarks** based on toxicity values derived from data available to the USEPA OPP supporting registration of the pesticide are provided only when an MPCA value is not available. Current values posted by the USEPA's OPP may differ from those of previous MDA reports. See USEPA's web site for more detailed information and definitions.

[3] **Chronic Standard** as defined in Minn. Rule Chap. 7050. "H" value is human health-based and is protective for an exposure duration of 30 days. Human health-based values are shown only when they are less than toxicity-based values. "T" value is toxicity-based for aquatic organisms and is protective for an exposure duration of 4 days.

[4] **Maximum Standard Value for Aquatic Life & Recreation** as defined on MPCA's web site and Minn. Rule Chap. 7050. Values are the same for all classes of surface waters.

[5] **State Water Classification for aquatic life** (2B – sport and commercial; 2C – non-commercial; 2D – wetlands) & recreation (2B – all types; 2C,D – limited types). Not protected as drinking water sources.

[6] **For the Dimethenamid Chronic Value,** the MPCA has calculated a non-promulgated criterion for aquatic plants using two point estimates of toxicity to the vascular plant duckweed**.**

3.1.2. Candidate cause: Flow alteration

Flow alteration is the change of the streamflow regime caused by anthropogenic sources. These sources can include channel alteration, water withdrawals, land cover alteration, agricultural tile drainage, and impoundment. To learn more about flow alteration go to the EPA CADDIS webpage here.

Across the conterminous U.S., Carlisle et al. (Carlisle, Wolcock, & Meador, 2010) found that there is a strong correlation between diminished streamflow and impaired biological communities. Habitat availability can be scarce when flows are interrupted, low for a prolonged duration, or extremely low, leading to a decreased wetted width, cross sectional area, and water volume. Aquatic organisms require adequate living space and when flows are reduced beyond normal baseflow, competition for resources increases. Pollutant concentrations can increase when flows are lower than normal, making it more difficult for populations to maintain a healthy diversity. Often tolerant organisms that can out compete others in such limiting situations will thrive. Low flows of prolonged duration lead to macroinvertebrate and fish communities comprised of generalist species or that have preference for standing water (U.S.EPA, CADDIS Volume 2 Sources, Stressors & Responses, 2012).

Baseflow reduction

Flow conditions can have an effect on the type of fish species that are present. When baseflows are reduced, fish communities respond with an increase in nest guarding species over simple nesters (Carlisle et al., 2010). This adaptation increases the reproductive ability for nest guarders by protecting from predators and providing “continuous movement of water over the eggs, and to keep the nest free from sediment” (Becker, 1983). Active swimmers, such as the green sunfish, contend better under low velocity conditions (Carlisle et al., 2010). Streamlined species have bodies that allow fish to reduce drag under high velocities (Blake, 1983). Similarly, the macroinvertebrate communities exhibit changes with increasing swimming species and decreasing taxa with slow crawling rates. EPA’s CADDIS lists the response of low flow alteration with reduced total stream productivity, elimination of large fish, changes in taxonomic composition of fish communities, fewer species of migratory fish, fewer fish per unit area, and a greater concentration of some aquatic organisms (potentially benefiting predators).

Altered hydrology (channelization)

Increasing surface water runoff and seasonal variability in streamflow have the potential for both indirect and direct effects on fish populations (Schlosser, 1990). Indirect effects include alteration of habitat suitability, nutrient cycling, production processes, and food availability. Direct effects include decreased survival of early life stages, oxygen stress and potentially lethal temperature for adult fish (Bell, 2006).

Increased flows may directly impair the biological community or may contribute to additional stressors. Increased channel shear stresses, associated with increased flows, often cause increased scouring and bank destabilization. With additional stress to the stream, the fish and macroinvertebrate community may be influenced by the negative changes in habitat and sediment. High flows can also cause the displacement of fish and macroinvertebrates downstream if they cannot move into tributaries or refuges along the margins of the river, or if refuges are not available. Such aspects as high velocities, the mobilization of sediment, woody debris and plant material can also be detrimental, especially to fish and invertebrate. When high flows become more frequent, species that do not manage well under those conditions will be reduced, leading to altered population. Macroinvertebrates may shift from those of long life cycles to short life cycles needing to complete their life history within the bounds of the recurrence interval of flow conditions (CADDIS, 2011).

3.1.2.1 Water quality standards

There currently is no applicable standard for flow alteration.

The standard for minimum streamflow, according to Minn. R. 7050.0210, subp. 7 is:

> *Point and nonpoint sources of water pollution shall be controlled so that the water quality standards will be maintained at all stream flows that are equal to or greater than the $7Q_{10}$ [the lowest streamflow for 7 consecutive days that occurs on average once every 10 years] for the critical month or months, unless another flow condition is specifically stated as applicable in this chapter.*

3.1.2.2 Types of flow alteration data

Each 8-HUChas a minimum of four continuous recording stream gages located at various points within the watershed. The pour point of the 8-HUC has a permanent gage that will be collecting continuous stream stage data and corresponding discharge measurements for rating table calculations. Within the 8-HUC there is some variability statewide as to the design and location of the representative 12-HUC scale stream gage locations. At a minimum there should be three smaller scale (12-HUC) stream gages that can be used to review flow conditions during the time of biological monitoring and post biological monitoring conditions. The data from the previously mentioned gages can be used for SPFModel calibration and can be extrapolated for smaller size streams with the 8-HUC. In some instances special short term gages can be installed to collect a 2-3 year record of stream discharge at smaller scale subwatersheds such as a 14-HUC level. This data would be available upon request and would need to be coordinated with the MPCA regional field staff or Local partner for installation and operation. All relevant flow data shall be stored and calculated in the Hydstra database.

3.1.2.3 Sources and causal pathways model for flow alteration

The conceptual model for flow alteration can be found on the USEPA webpage. The causes and potential sources for altered flow are modeled at EPA's CADDIS Flow Alteration webpage.

3.1.2.4 Overview of flow alteration in the Root River Watershed

There are multiple drivers for potential flow alteration can be found on the USEPA webpage. The causes and potential sources for altered flow are modeled at EPA's CADDIS Flow Alteration webpage

Tile drainage and altered watercourses in the Root River

GIS (geographic information system) analysis estimates that approximately 60% of the North Branch and Middle Branch is managed cropland. Of that 60%, based on GIS analysis, much of it is tile drained. In addition, much of the upper parts of the South Branch watershed are also tile drained. However, tile drainage is difficult to quantify accurately due to absence of specific data. As a result, the direct impact is hard to understand. Current research suggests impacts are likely when tile drainage is present. "Artificial drainage is a significant driver of changes in flow. Artificial drainage reduces water residence time-thus decreasing time for evapotranspiration (ET), which means more water available to the river. Water that used to evaporate is now routed to rivers. (Hypothesis) Increased flow causes river channels to widen. Widening is a source of non-field sediment." (Shawn Schottler, regarding heavily tiled Minnesota River streams).

Altered watercourses have also been quantified by GIS analysis (Figure 16). While altered watercourses may be an indication of altered stream habitat, a lack of connecting biological response information in the Root River makes it difficult to verify it is driving biological impairment. Altered watercourses are not as prevalent in the Root River as compared to other neighboring watersheds. Additional information should be collected and data analyzed before this can be deemed as a driver of biological impairment.

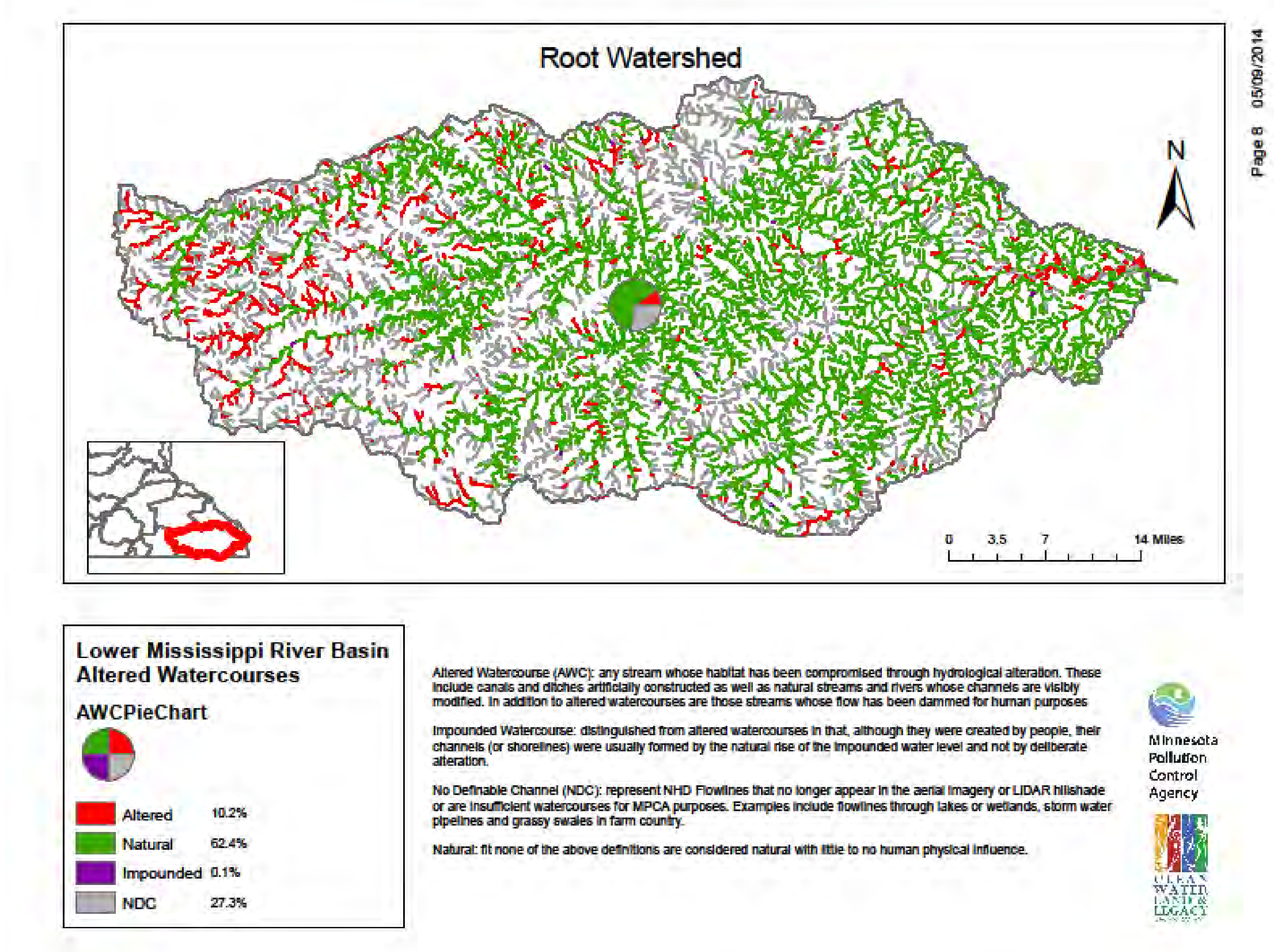


Figure 16. Altered watercourse information for the Root River Watershed

Drained wetlands in the Root River

GIS analysis from the National Wetlands Inventory (NWI) by the USFWS, demonstrates the estimated percent of wetlands lost in upland HUC 10s of the Root River watershed (Figure 17). Aerial photographs, United States Geological Survey (USGS) quadrangle maps, and soil surveys were used to make this determination. While the percentages of drained wetlands do not appear high overall, the impacts to local areas in the headwaters of these tributaries may be larger than quantified or understood.

Figure 17. Estimated percentage area of wetlands which are drained in three upland watersheds of the Root River

The combination of increases in tile drainage and loss of wetlands in the watershed have an affect on hydrology and overall water storage and. Water is more quickly being routed to the streams which as a result are likely impacting flow, water chemistry, sediment delivery, stream bank instability, and ultimately habitat loss.

Flow trends in the Root River

Lenhart et al, 2013 used Impacts of Hydrologic Alteration (IHA) analysis in 16 watersheds in Minnesota, Wisconsin, and eastern North and South Dakota. Flow in the 1980-2009 time period was compared to that of the 1940-1979 time period. For the Root River near Houston, the change in mean annual stream flow was computed at 57%. All twelve months showed a significant median monthly change. Eighty-three 83% of the 12 months showed a significant low flow change. Increased low to moderately high flows seem to have increased on average overall on streams in the Upper Midwest. Though annual precipitation has increased across southern and western Minnesota, it was determined that this, increase in annual precipitation, alone could not account for the high percent change of annual streamflow in the Minnesota River Basin rivers. The largest percent flow increase occurred during months that are typically baseflow periods, suggesting a mechanism for increased flow (some combination of increased subsurface tile drainage and groundwater flow that altered the pathway with which water is delivered to streams).

A separate analysis of the Root River at Houston gage was done by Patrick Belmont, and shows similar results (Figure 17). The analysis by Belmont demonstrates increasing streamflow in the last half century, with a 60% increase in high flow discharges, and an 80% increase in baseflow discharges (Root River at Houston). Again, while many data types show the potential for flow alteration in the Root River, the complication of climate change and other variables make it difficult to conclude its driving biological impairment in this watershed. Flow alteration should continue to be analyzed in coming years to determine its impact on biological communities.

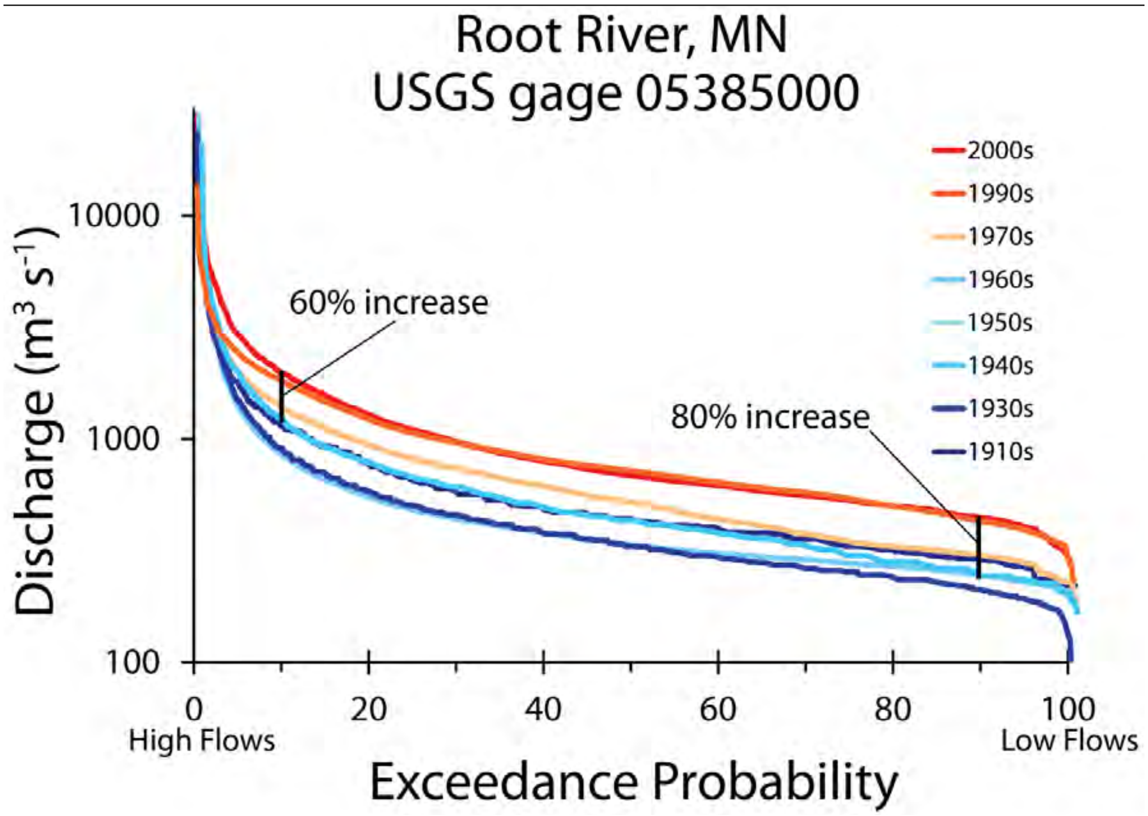


Figure 18. Discharge analysis from the Root River near Houston, (Belmont, 2011)

3.1.3. Candidate cause: Toxics

Toxicity refers to a chemical's potential to harm living organisms. Toxicity can vary by species, and is a function of concentration and duration of exposure. Toxic chemicals are individual chemicals or mixtures of chemicals and their by-products that originate from human activities. These chemicals and their toxicities may be unknown because they have not been measured or measurement is difficult (e.g., due to episodic occurrence, unique chemistry, or low concentrations). Their effects on organisms may be suspected but, because of absent or incomplete chemical monitoring data, exposure cannot be confirmed. Under these circumstances, "toxic chemicals" are listed as a potential stressor. In the case of the Root River, toxic metals, insecticides, and herbicides are treated separately.

3.1.3.1 Water quality standards

There currently is no applicable standard for toxics. There are a limited number of water quality criteria supporting regulation, and only a fraction of chemicals have established criteria.

3.1.3.2. Sources and causal pathways model for flow alteration

The conceptual model for toxics can be found on the USEPA webpage. The causes and potential sources for toxics are modeled at EPA's CADDIS webpage.

3.1.3.3. Overview of toxics in the Root River

Toxic chemicals information is not widely available in the Root River Watershed. Additional information on petroleum toxics was collected in the watershed, specifically on Spring Valley Creek, because of the following indicators: Local residents witnessed sheens on the water in past years, MPCA petroleum remediation staff documented spills and violations in the watershed, and geologists Jeff Green and Calvin Alexander have been involved in dye tracing and studying geology of the area.

In Karst geology, toxic pollutants can persist for long periods of time. The question is, whether these pollutants continue to have residual effects, or if the effects occurred during specific hydrological conditions such as a high or low water table. Gasoline floats on top of water and it also ponds underground. As the water level goes down, gasoline could make its way out of the water table during low flows. On the opposite end, high flows can push it out as well. Over the years, monitoring well data at the BP terminal facility near the City of Spring Valley has shown free product (personal communication, Calvin Alexander). The wells have extended to the north and east of the facility where the pollution plume is thought to be. Dye tracing by Alexander and Green has demonstrated that much of the pollution plume is migrating northeast, which puts it in the Freiheit Springshed. The stream "sinks" on the tributary west of the Freiheit springshed. The geologists have traced those streams sinks and confirmed this potential pollutant migration. These sinks will catch overland flow from near the facility. In this same tributary, there are also sinks that go to Moth/Grabbau spring, which are closer to the facility. Also, some nearby dye traces in Spring Valley Creek found peaks of something organic, and it was not dyes used in any of the traces. This phenomenon has not happened anywhere else in southeast Minnesota. It remains a mystery. Alexander and Green have also attempted to dye trace the stream sinks in the surface drainage way just north of the BP facility four times. They never found the dye from those traces.

"In 2000, BP reported an oil spill that occurred in 1997 at its terminal east of Spring Valley. At the time, the company was ordered to clean up contamination from several smaller spills that took place at the terminal over a 40-year period. According to a Post-Bulletin story from August 25, 2000, 40 truckloads of

dirt each day for 11 days were removed from the site. A sample from a nearby well tested positive for a small amount of chemicals that could have come from the terminal."
http://karstpreserve.com/BPArticle.html

The first goal of sampling in Spring Valley Creek was to decide if something from the BP terminal facility might be making its way to the Freiheit Spring area. This is where biology seemed to be suffering the most (near biological Station 08LM006). By targeting sampling closer to the source, there would have been a better chance of detecting contaminants.

In September of 2011, during baseflow conditions, MPCA sampled five locations for toxics in Spring Valley Creek: Volatile organic compounds (VOCs), soluble volatile organic compounds (SVOCs), and gasoline range organics (GROs). The five sites included: Freiheit Spring, upstream of the spring, downstream of the spring, Highway 16, and County Road 1. The last two are closer to Spring Valley and provide a longitudinal look and understanding of the whole system. All results of that sampling were "non-detect," meaning no toxics were detected. The sites were planned to be sampled again during a rain event. However, dry weather persisted through the fall of 2011, and did not allow a rain event sample. Because of the lack of information, toxics were removed from the list of candidate causes. Additional information on toxics should be collected in the future, during various flow regimes, specifically in Spring Valley Creek.

3.2. Summary of candidate causes in the Root Watershed

The initial list of candidate/potential causes was narrowed down after the initial data evaluation/data analysis resulting in six for final analysis in this report. The candidate causes selected as possible drivers of biological impairments in the Root River Watershed are detailed in the next section. After analyzing the data, a team of watershed experts selected the following factors as candidates for stressing the biology in the Root River Watershed.

3.2.1. Candidate cause: Temperature

Coldwater streams

Temperature can be a major factor in determining macroinvertebrate and fish species composition in coldwater streams. Increases in temperature due to altered watersheds can lead directly to extirpation of coldwater assemblages. Warmer water impacts organisms indirectly due to the relationship with lower DO and directly through changes in growth and reproduction, egg mortality, disease rates, and direct mortality. Macroinvertebrate species have well-known tolerances to thermal changes, and community composition of invertebrates is useful in tracking the effects of increasing temperature. Fish assemblages, likewise, change with temperature, and coldwater adapted species either leave, are unable to reproduce, or die in warmer regimes.

Fish in coldwater systems can suffer adverse effects due to increases in temperature (Raleigh et al., 1986). When temperatures rise near 21°C, other fish can have a competitive advantage over trout for the food supply (Behnke, 1992). The temperature at which fish continue to feed and gain weight is considered their functional feeding temperatures. The limits for brown trout growth at 4 – 19.5°C (Elliot and Elliot, 1995); however, for egg development, brown trout need temperatures between 0 and 15°C (Elliot, 1981). According to Bell 2006, brown trout may be physiologically stressed in the thermal window of 19-22°C. These temperatures are near the upper metabolic limit for trout and may affect the ability to maintain normal physical function and ability to gain weight.

Brook trout functional feeding temperatures are between 12.7°C and 18.3° (Raleigh, 1982). They can briefly tolerate temperatures near 22.2°C, but temperatures of 23.8°C for a few hours are generally lethal (Flick, 1991). Juvenile brook trout density is negatively correlated with July mean water temperatures (Hinz and Wiley, 1997). Growth and distribution of juvenile brook trout is highly dependent on temperature (McCormick et al., 1972).

Warmwater streams

Stream temperature naturally varies due to air temperature, geology, shading, and the inputs from tributaries and springs. Different organisms are adapted to and prefer different temperature regimes. Water temperature regulates the ability of organisms to survive and reproduce (EPA, 1986). Thermal pollution can increase stream temperatures through loss of riparian shading, urban and agricultural runoff, and direct discharges to the stream. Warmer water holds less DO, and higher water temperatures also affects the toxicity of numerous chemicals in the aquatic environment. Algal blooms often occur with temperature increases (EPA, 1986).

3.2.1.1 Water quality standards

Warmwater: The standard for Class 2B (warmwater) waters of the state is not to exceed five degrees Fahrenheit (°F) above natural (Minnesota Statute 7050.0222 subp. 4), based on monthly average of maximum daily temperature. In no case shall it exceed the daily average temperature of 86° Fahrenheit (30° Celsius).

Coldwater: The state standard for temperature in Class 2A streams is “no material increase” (7050.0222 Specific Water Quality Standards for Class 2 Waters of the State; Aquatic Life and Recreation).

3.2.1.2 Types of temperature data

Both one time and continuous temperature data is available in the watershed. Continuous data is available both at 15 minute and one hour increments.

3.2.1.3 Sources and causal pathways model for elevated temperature

The causes and potential sources for excess temperature are modeled at EPA’s CADDIS Temperature webpage.

3.2.1.4 Overview of temperature in the Root River Watershed

Temperature stressors in the Root River were found on only a few coldwater reaches.

In warmwater reaches, temperatures did not reach unsuitable ranges (>30°C), and therefore no temperature stressors were identified on those reaches. Many coldwater stations had continuous temperature data available for analysis. In addition, Figure 19 displays water temperature community index scores based on the fish community present at time of fish sample and corresponding water temperature. Generally, those points shown in red are showing a community that has more warmwater species present, while the blue points show stronger presence of coldwater species. In coldwater streams, a presence of warmwater species does not always mean temperature is a stressor, but can be an indication that temperature is not suitable. In addition to community composition, in-field temperature measurements are used to understand thermal regime and dynamics when determining temperature stressors.

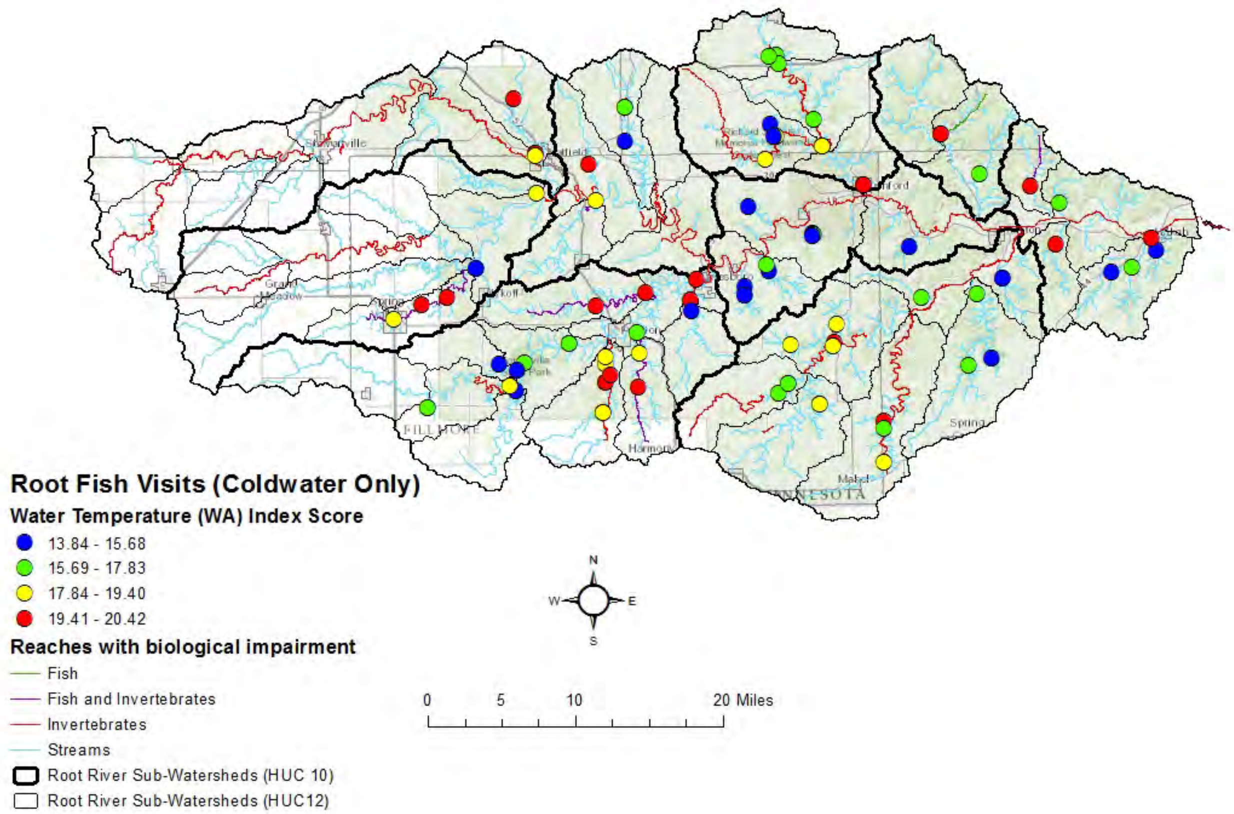


Figure 19. Water temperature index scores (WA-weighted averages) for Coldwater stations in the Root River quartiled based on data shown.

3.2.2. Candidate cause: Dissolved Oxygen

DO refers to the concentration of oxygen gas within the water column. Low or highly fluctuating concentrations of DO can have detrimental effects on many fish and macroinvertebrate species ((Davis, 1975); (Nebeker, 1991)). DO concentrations change seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995). For more detailed information on DO go to the EPA Caddis webpage following this link. (U.S.EPA, CADDIS:Sources, Stressors & Responses)

Fish require oxygen for respiration. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995). Some macroinvertebrates that are intolerant to low levels of DO include mayflies, stoneflies and caddisflies (Marcy, 2011). Many species of fish avoid areas where DO concentrations are below five mg/L (Raleigh, 1986). Additionally, fish growth rates can be significantly affected by low dissolved oxygen levels (Doudoroff and Warren, 1965).

In most streams and rivers, the critical conditions for stream DO usually occur during the late summer season when water temperatures are high and stream flows are reduced to baseflow. As temperatures increase, the saturation levels of DO decrease. Increased water temperature also raises the DO needs for many species of fish (Raleigh et al., 1986).Low DO can be an issue in streams with slow currents, excessive temperatures, high BOD, and/or high groundwater seepage (Hansen, 1975). Heiskary et al. (2013) observed several strong negative relationships between fish and macroinvertebrate metrics and DO flux.

3.2.2.1. Water quality standards

The class 2B (warmwater) water quality standard for DO in Minnesota is 5 mg/L as a daily minimum. The class 2A (coldwater) water quality standard for DO in Minnesota is 7 mg/L as a daily minimum. Additional stipulations have been recently added to this standard. The following is from the Guidance Manual for Assessing the Quality of Minnesota Surface Waters (MPCA, 2009). http://www.pca.state.mn.us/index.php/view-document.html?gid=16988

> *Under revised assessment criteria beginning with the 2010 assessment cycle, the DO standard must be met at least 90 percent of the time during both the 5-month period of May through September and the 7-month period of October through April. Accordingly, no more than 10 percent of DO measurements can violate the standard in either of the two periods.*
>
> *Further, measurements taken after 9:00 in the morning during the 5-month period of May through September are no longer considered to represent daily minimums, and thus measurements of > 5 DO later in the day are no longer considered to be indications that a stream is meeting the standard.*
>
> *A stream is considered impaired if 1) more than 10 percent of the "suitable" (taken before 9:00) May through September measurements, or more than 10 percent of the total May through September measurements, or more than 10 percent of the October through April measurements violate the standard, and 2) there are at least three total violations.*

3.2.2.2. Types of Dissolved Oxygen data

1) **Point measurements**
   Instantaneous DO data is available throughout the watershed and can be used as an initial screening for low DO. These measurements represent discrete point samples. Because DO concentrations can vary significantly with changes in flow conditions and time of sampling, instantaneous measurements need to be used with caution and are not completely representative of the DO regime at a given site.
2) **Longitudinal (Synoptic)**
   A series of longitudinal synoptic DO surveys were conducted throughout the Root River in 2010. A synoptic monitoring approach gathers data across a large spatial scale and minimal temporal scale (as close to simultaneously as possible). In terms of DO, the objective was to sample a large number of sites from upstream to downstream under comparable ambient conditions. For the most part, the surveys took place in mid to late summer when low DO is most commonly observed. Dissolved oxygen readings were taken at pre-determined sites in the early morning in an attempt to capture the daily minimum DO reading.
3) **Diurnal (Continuous)**
   YSI sondes were deployed for time intervals (days to weeks) at sites located in the Root River in late summer to capture the diurnal fluctuations. This data revealed the magnitude and pattern of diurnal DO flux at each site. The diurnal DO sampling results for the Root River can be found on throughout this report.

3.2.2.3. Sources and causal pathways model for low Dissolved Oxygen

Dissolved oxygen concentrations in streams are driven by a combination of natural and anthropogenic factors. Natural background characteristics of a watershed, such as topography, hydrology, climate, and biological productivity can influence the DO regime of a stream. Agricultural and urban land uses, impoundments (dams), and point-source discharges are just some of the anthropogenic factors that can cause unnaturally high, low, or volatile DO concentrations. The conceptual model for low DO as a candidate stressor in the Root River Watershed is shown in EPA CADDIS website by following this link: Dissolved oxygen simple conceptual diagram | CADDIS: Sources, Stressors & Responses | US EPA.

3.2.2.4. Overview of Dissolved Oxygen in the Root River Watershed

Dissolved oxygen was measured at multiple locations in the Root River Watershed. All stations had a least one DO measurement taken during fish sample, and some others had diurnal DO data collected during the SID process. Community composition can be an important to look at when analyzing DO, in addition to water chemistry information. Fish Tolerance Indicator Values (TIVs) for common fish species in the Root River were grouped into categories (quartiles) based on their tolerance to low DO levels (Figure 20).

1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
CommonName	*DO*	*CommonName*	*DO*	*CommonName*	*DO*	*CommonName*	*DO*
blackside darter	0.39	carmine shiner	0.56	longnose dace	0.8	slimy sculpin	1
johnny darter	0.37	central stoneroller	0.54	largescale stoneroller	0.79	brown trout	0.99
common shiner	0.35	bigmouth shiner	0.53	quillback	0.78	rainbow trout	0.98
rock bass	0.33	white sucker	0.52	smallmouth bass	0.74	American brook lamprey	0.97
bluegill	0.28	slenderhead darter	0.51	banded darter	0.71	brook trout	0.88
green sunfish	0.27	hornyhead chub	0.47	blacknose dace	0.7	rainbow darter	0.86
common carp	0.19	creek chub	0.45	stonecat	0.66	black redhorse	0.85
fathead minnow	0.17	freshwater drum	0.43	shorthead redhorse	0.65	fantail darter	0.84
brook stickleback	0.09	bluntnose minnow	0.42	sand shiner	0.63	mottled sculpin	0.83
black bullhead	0.03	spotfin shiner	0.41	silver redhorse	0.61	northern hogsucker	0.82
		greater redhorse	0.4	golden redhorse	0.6	southern redbelly dace	0.81

Tolerant to Low Dissolved Oxygen ← Intolerant to Low Dissolved Oxygen

Figure 20. Root River Watershed common fish species in quartiles by tolerance to low DO. Fish species must be present in at least 10% of fish visits to be included in this analysis.

Invertebrates also used a similar TIV tool, which groups the community together and provides and overall score for that site (Figure 22). In this analysis, the stations were separated as either coldwater or warmwater, because coldwater species are generally more sensitive to low DO.

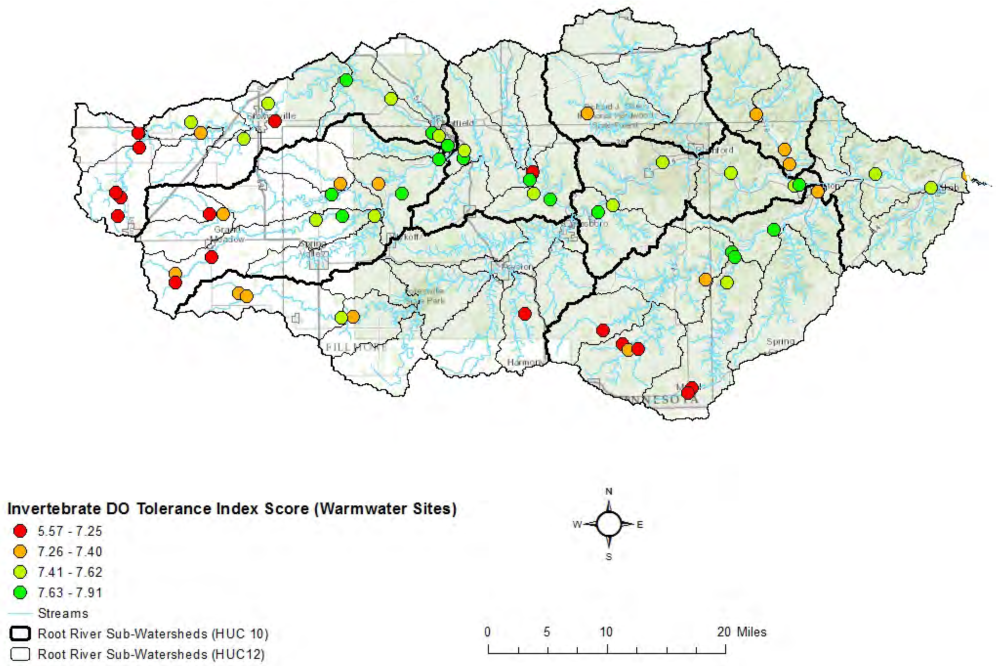


Figure 21. Station index scores for fish tolerance to DO in the warmwater biological stations of the Root River Watershed; quartiled based on data shown. ***Note: This analysis is comparative among stations in the Root River only, and does directly translate to low DO. This tool is used for understanding community composition, and species which are tolerant to low DO, can also be responding to other stressors present.***

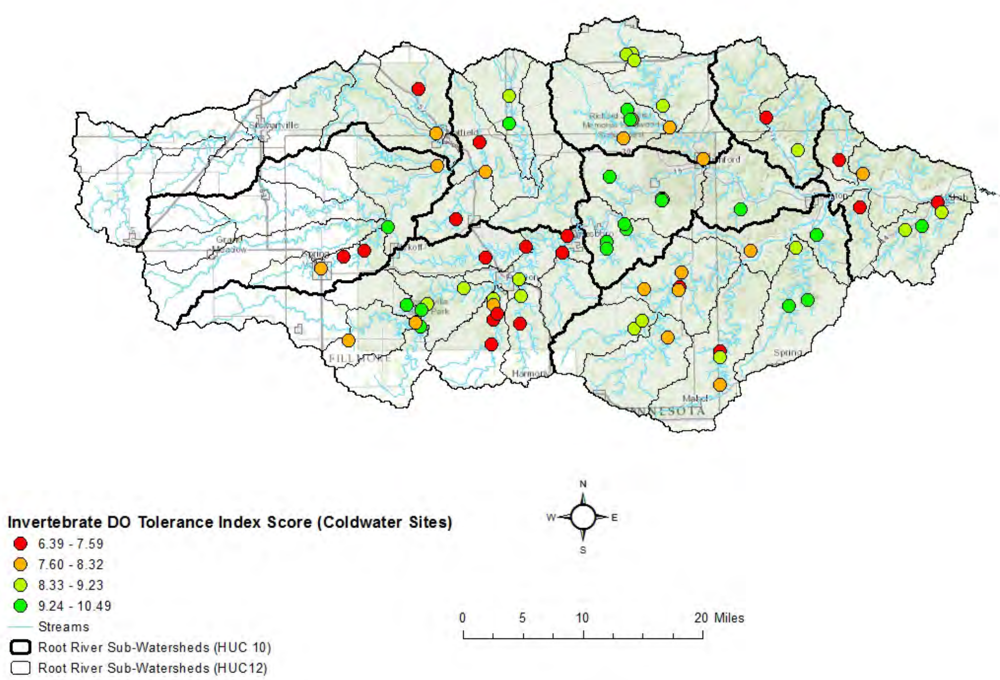


Figure 22. Station index scores for fish tolerance to DO in the coldwater biological stations of the Root River Watershed; quartiled based on data shown. ***Note: This analysis is comparative among stations in the Root River only, and does directly translate to low DO. This tool is used for understanding community composition, and species which are tolerant to low DO, can also be responding to other stressors present.***

3.2.3. Candidate cause: Nitrate

Nitrate toxicity to freshwater aquatic life is dependent on concentration and exposure time, as well as the overall sensitivity of the organism(s) in question. Certain species of caddisflies, amphipods, and salmonid fishes seem to be the most sensitive to nitrate toxicity according to Camargo and Alonso (2005). Camargo et al (2005) cited a maximum level of 2.0 mg/L nitrate-N as appropriate for protecting the most sensitive freshwater species and that NO_3-N concentrations are under 10.0 mg/L to be protective of several sensitive fish and aquatic invertebrate taxa. The intake of nitrite and nitrate by aquatic organisms has been shown to convert oxygen-carrying pigments into forms that are unable to carry oxygen, thus inducing a toxic effect on fish and macroinvertebrates (Grabda et al, 1974; Kroupova et al, 2005).

3.2.3.1 Water quality standards

Streams classified as Class 1 waters of the state, designated for domestic consumption, in Minnesota have a nitrate water quality standard of 10.0 mg/L (*Minn. Stat.* 7050.0222 subp. 3). Minnesota currently does not have a nitrate standard for other waters of the state except for Class 1; however an aquatic life nitrate standard is being drafted.

3.2.3.2 Types of nitrate data

Stream and river water samples are collected at various locations throughout the Root Watershed. Samples are sent to a state certified laboratory and analyzed for a number of water quality parameters including nutrients. Laboratory analytical data is then stored in the EQUIS database and can be accessed via the MPCA webpage here.

3.2.3.3 Sources and causal pathways model for nitrate

The conceptual model for nitrogen as a candidate stressor is modeled at EPA's CADDIS Nitrogen webpage. Lefebvre et al. (2007) determined that fertilizer application and land-cover were the two major determinants of nitrate signatures observed in surface water and that nitrate signatures in surface waters increased with fertilization intensity. Nitrogen is commonly applied as a crop fertilizer, predominantly for corn. A statewide nitrogen study found that cropland commercial fertilizers make up 47% of nitrogen added to the landscape, 21% occurs through cropland legume fixation, 16% from manure application, and 15% from atmospheric deposition (MPCA, 2013). These land applications can reach waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013).

3.2.3.4 Overview of nitrate in the Root River Watershed

Nitrate is a systemic issue in much of the Root River Watershed. Nitrate data was collected at each biological station on the same date as fish sampling. Additional data assists in the understanding of the magnitude and duration under various conditions (Table 8). Many locations in the Root River Watershed are in need of additional monitoring to assist in that understanding. Ammonia was evaluated for all sites in the Root River, based on the chemistry grab sample taken during fish sample. No ammonia samples were found to be at a level of concern, anywhere in the watershed, but the dataset was limited.

Table 8. Summary of nitrate statistics from major subwatersheds of the Root River Basin.

Location/AUID	Years	# Samples	Max Nitrate (mg/L)	Mean Nitrate (mg/L)
South Branch, Lanesboro (550)	2008-2010	73	7.1	6.13
South Branch, Carimona (555)	1999-2010	155	15	7.7
North Branch, Chatfield (716)	2008-2010	120	19	5.69
Root Mainstem, Mound Prairie (502)	2008-2013	213	12	4.8
Middle Branch, Pilot Mound (528)	2009-2010	45	12	5.42

According to Runkel et al (2013), the most important factor identified that impacts both the magnitude and variability of nitrate concentration in spring water and stream baseflow is the proportion of regionally sourced, nitrate-poor water contributed from deep aquifers relative to more locally sourced, nitrate-enriched water from shallower aquifers.

Nitrate-nitrogen concentrations in southeast Minnesota's trout streams show a strong linear relationship to row crop land use. A linear regression showed a slope of 0.16, suggesting that the average baseflow nitrate concentration in the trout stream watersheds of southeast Minnesota can be approximated by multiplying a watershed's row crop percentage by 0.16 (Watkins, et al.). The strong correlation between nitrate-nitrogen concentrations in streams and watershed row crop percentage suggests that, in general, nitrogen application over a span of decades has impacted the condition of the underlying aquifers that are the source of these streams' baseflow (Watkins, et al.). Nitrate concentrations have been compared among the watersheds of southeast Minnesota (Figure 23). The Root River is represented in black.

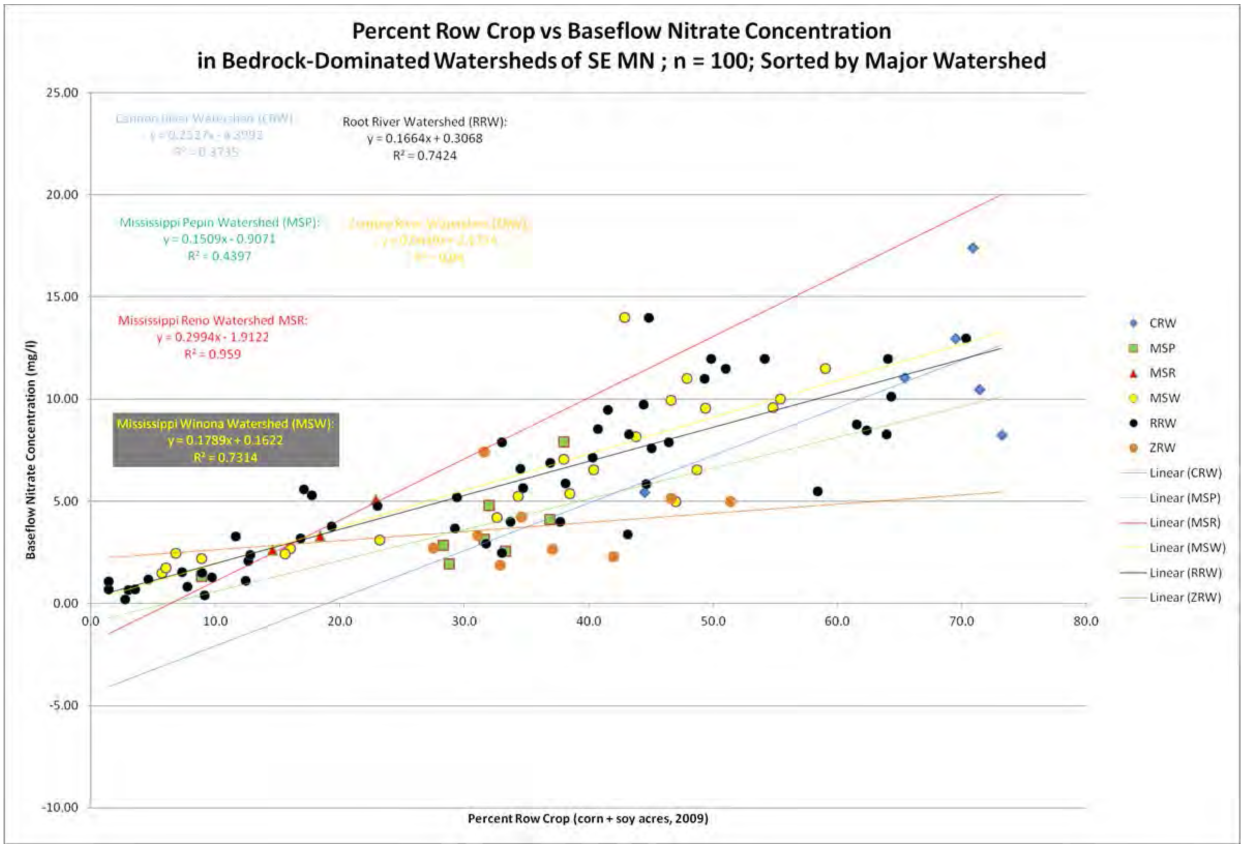


Figure 23. Nitrate concentration vs row crop percentage in southeastern Minnesota (Watkins et al.)

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. The macroinvertebrate response is different in warmwater and coldwater systems. In coldwater reaches, the macroinvertebrate metrics: percentage of Trichoptera taxa (TrichopteraChTxPct) and a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart(HBI_MN) respond to elevated nitrate at the time of fish sampling.

Nitrate tolerance values were developed utilizing the nitrate concentration at the biological station and the macroinvertebrate data. In coldwater stations, the number of nitrate tolerant taxa has a relationship with the Southern Coldwater MIBI. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI. At 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI, and at 22.60 nitrate tolerant taxa there is a 10% probability of meeting the Southern Coldwater MIBI. There has been a high prevalence of nitrate tolerant taxa in the coldwater stations of the Root River, ranging from 9-29 (Figure 24). Similarly in warmwater stations, elevated percentages of nitrate tolerant macroinvertebrate individuals have a relationship with the MIBI for each of the three warmwater classes present in the Root River. The percentage of nitrate tolerant macroinvertebrate individuals ranges from 32.3-96.8% (Figure 25). Elevated percentages of nitrate tolerant macroinvertebrate individuals can suggest that nitrate may be an issue. Nitrate tolerant macroinvertebrate individuals can also be present when other stressors dominate, which is why it is important to have multiple lines of evidence.

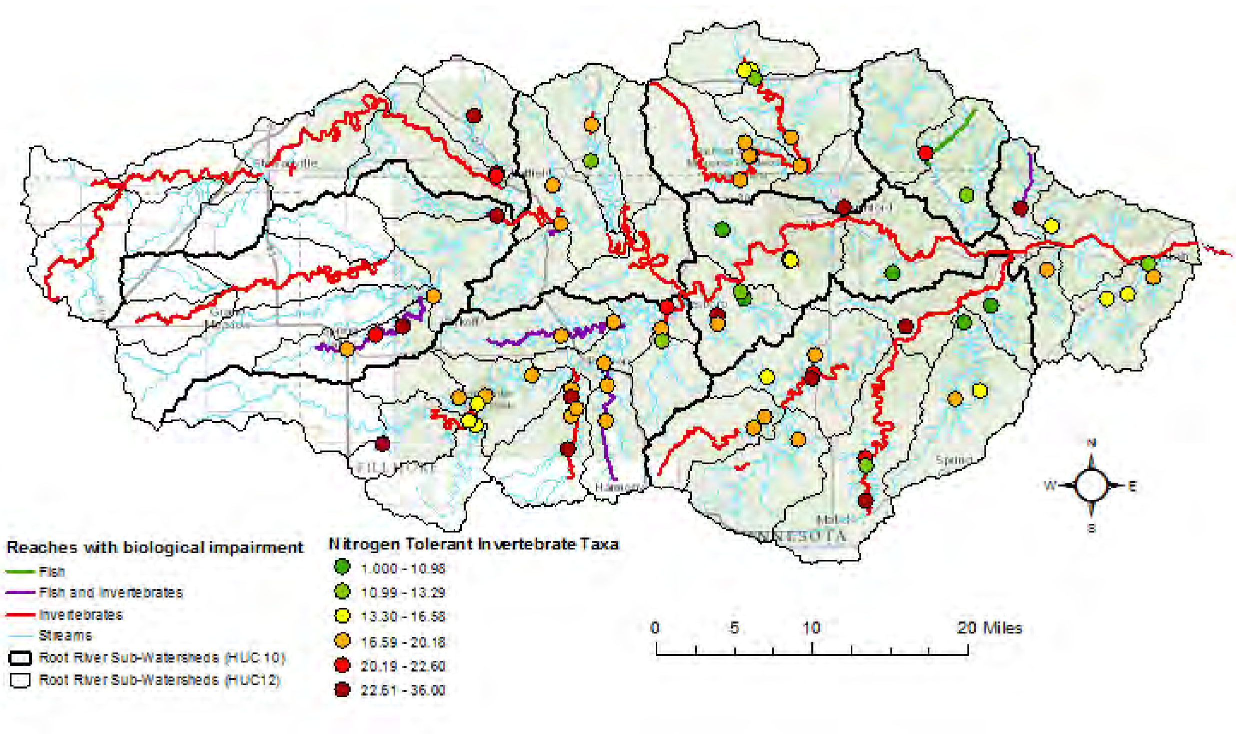


Figure 24. Map of the number of nitrate tolerant macroinvertebrate taxa in coldwater stations in the Root River Watershed

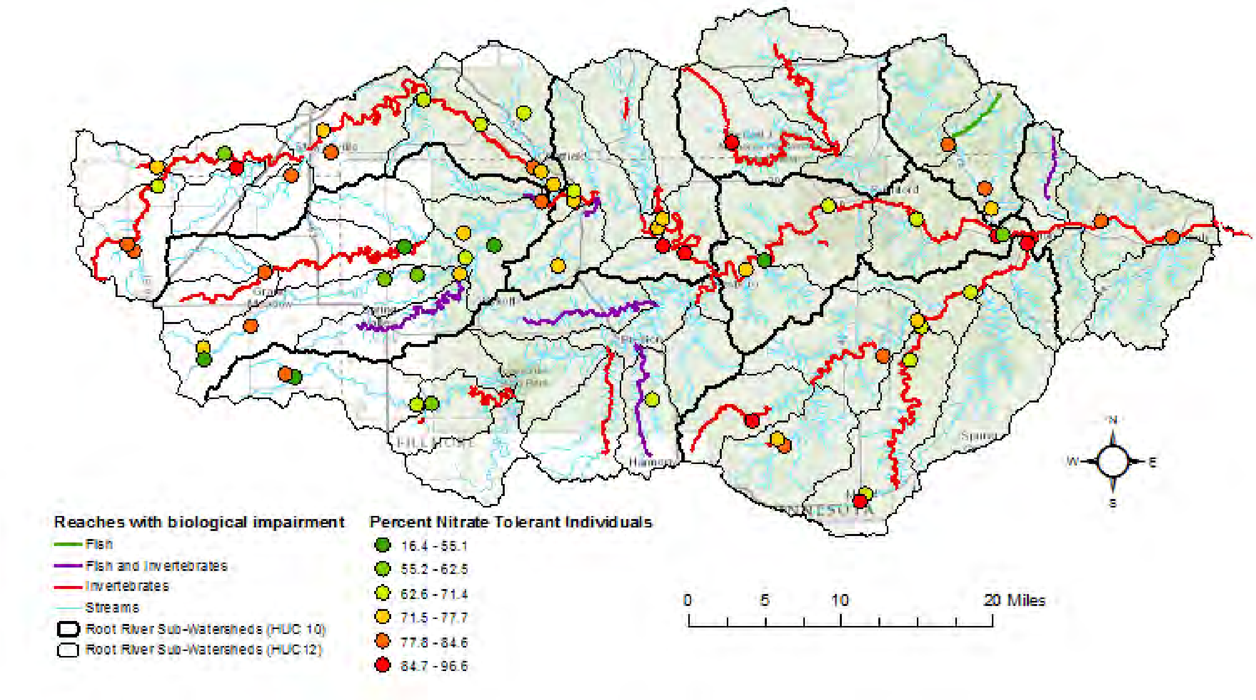


Figure 25. Map of the percent nitrate tolerant macroinvertebrate individuals in warmwater stations in the Root River Watershed

Nitrogen in Minnesota Surface Waters Report estimated that agricultural groundwater and agricultural drainage comprise of 80% of the nitrogen sources in the Lower Mississippi River Basin. The Lower Mississippi River Basin has 47% of its area in cropland. Nitrogen leaching into groundwater is the dominant pathway to surface waters in the Karst dominated landscape of the Lower Mississippi River Basin, where groundwater contributes an estimated 58% of all N. The point source TN loading in the Lower Mississippi River Basin is primarily from municipal sources. At the major watershed scale, SPARROW modeled nonpoint source N loadings were highest for the Zumbro and Root Rivers of southeastern Minnesota, which are large watersheds where N loadings from discharge, drainage and runoff are all significant.

Nitrate trends assessed in two springs feeding fish hatcheries in southeastern Minnesota's Root River Watershed both showed statistically significant (p=0.001) increasing trends over the past two decades (Streitz, 2012). The springs were monitored approximately monthly at Peterson and every other month at Lanesboro by the MDNR. Average annual nitrate-N concentrations in the Lanesboro spring increased from about 5.2 mg/L to 6 mg/L between 1991 and 2010. Nitrate increased by a larger amount in the spring at the Peterson, Minnesota, fish hatchery, with average annual concentrations rising from less than 2 mg/L in 1989 to 4 mg/L in 2011.

The Nitrogen in Minnesota Surface Waters Report also offers Best Management Practices (BMP) adoptions for reducing nitrogen loads (Root River Watershed table on page F1-19). Efforts to reduce nitrate should be accelerated in this watershed since the Root River ranks 7th in the state in terms of percent total nitrogen delivered to the Mississippi River (5.2% of statewide load).

Nitrate is a stressor to the macroinvertebrate communities in many of these reaches of the Root River.

3.3.3. Candidate cause: Suspended sediment (Turbidity/TSS)

Increases in suspended sediment and turbidity within aquatic systems are now considered one of the greatest causes of water quality and biological impairment in the United States (EPA, 2003). Although sediment delivery and transport are an important natural process for all stream systems, sediment imbalance (either excess sediment or lack of sediment) can result in the loss of habitat and/or direct harm to aquatic organisms. As described in a review by Waters (1995), excess suspended sediments cause harm to aquatic life through two major pathways: (1) direct, physical effects on biota (i.e., abrasion of gills, suppression of photosynthesis, avoidance behaviors); and (2) indirect effects (i.e., loss of visibility, increase in sediment oxygen demand). Elevated turbidity levels and total suspended solids (TSS) concentrations can reduce the penetration of sunlight and can thwart photosynthetic activity and limit primary production (Munawar et al., 1991; Murphy et al., 1981).). Sediment can also cause increases in water temperature through particles trapping heat.

Total suspended solids and bedded sediment are related through several common watershed sources and processes, but each can affect aquatic biota in different ways. Due to the inter-related nature of these parameters, they are grouped together in this report for causal analysis purposes, but ultimately each of these candidate causes will be evaluated independently in terms of impact on fish and macroinvertebrate populations.

Whereas suspended solids and turbidity are potential stressors operating in the water column, bedded (deposited) sediments impact the stream substrate. Excessive deposition of fine sediment can impair macroinvertebrate habitat quality and productivity (Rabeni et al., 2005). Quantitative field measurement of bedded sediment (bedload) is very difficult. However, a significant amount of data on substrate composition and embeddedness, (the degree in which fine sediments surround coarse substrates on the surface of a streambed) has been collected in the Root River Watershed. These data will be used to determine whether natural coarse substrate (a very important habitat type) is being covered up or filled in by excess fine sediment.

TSVS (Total Suspended Volatile Solids)

The presence of algae and other volatile solids, such as detritus in the water column can contribute to elevated TSS concentrations and high turbidity. Total suspended volatile solids (TSVS) can provide a rough estimation of the amount of organic matter present in suspension in the water column. Elevated TSVS concentrations can impact aquatic life in a similar manner as suspended sediment-with the suspended particles reducing water clarity, but unusually high concentrations of TSVS can also be indicative of nutrient imbalance and an unstable DO regime.

To learn more about sediment effects on aquatic organisms go to the EPA CADDIS webpage here.

3.3.3.1 Water quality standards

The water quality standard for turbidity is 25 Nephelometric Turbidity Units (NTUs) for Class 2b waters. For Class 2a waters, the standard is 10 NTUs. Total suspended solids and transparency tube/Secchi tube measurements can be used as surrogate standard. A strong correlation exists between the measurements of TSS concentration and turbidity. In 2010, MPCA released draft TSS standards for public comment (MPCA, 2009). The new TSS criteria are stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The draft TSS standard for the Root River Watershed has been set at 30 mg/L for warmwater streams and 10 mg/L for coldwater streams. For assessment, this concentration is not to be exceeded in more than 10% of samples within a 10-year data window. There is no current standard for bedded sediment in Minnesota. There is currently no standard for TSVS.

For the purposes of stressor identification, TSS results will be relied upon to evaluate the effects of suspended solids and turbidity on fish and macroinvertebrate populations. Results are available for the watershed from state-certified laboratories, and the existing data covers a much larger spatial and temporal scale in the watershed.

3.3.3.2 Types of sediment data

TSS data is collected by collecting a stream water sample and having the sample filtered and weighed to determine the concentration of TSS in the sample. Bedded sediment is visually estimated by looking at the fine material surrounding rock or woody substrate within the stream channel. Bedded sediment is also analyzed by conducting pebble counts in stream reaches and analyzing the D^{50} particle size in both the stream reach and the representative riffle site.

3.3.3.3 Sources and causal pathways model for sediment

High turbidity occurs when heavy rains fall on unprotected soils, dislodging the soil particles, which are transported by surface runoff into the rivers and streams (MPCA and MSUM, 2009). The soil may be unprotected for a variety of reasons, such as construction, mining, agriculture, or insufficiently vegetated pastures. Decreases in bank stability may also lead to sediment loss from the stream banks, often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, and increases in impervious surfaces.

Rangeland and pasture are also common landscape features in Minnesota. Cattle pasture within the riparian corridor of rivers and streams has been shown to increase streambank erosion and reduce substrate quality (Kauffman, 1984). In some areas, the riparian corridor has been cleared for pasture and is heavily grazed, resulting in a riparian zone that lacks deep-rooted vegetation necessary to protect streambanks and provide shading. Exposures of these areas to weathering, trampling, and shear stress (water friction) from high flow events are increasing the quantity and severity of bank erosion.

The causes and potential sources for increases in sediment are modeled at EPA's CADDIS Sediments webpage.

3.3.3.4. Overview of suspended sediment in the Root River Watershed

TSS has been measured at multiple locations in the Root River Watershed. All stations had at least one DO measurement taken during fish sample, and some others had extensive TSS data collected and analyzed as part of the SID process. Turbidity TMDL projects collected a wealth of TSS information, including continuous turbidity which was also used for analysis. Community composition can be an important tool to look at when analyzing TSS, in addition to water chemistry information.

The invertebrate community composition was analyzed and a score was created for each site, based on potential tolerance to high TSS (Figure 26 and Figure 27). In this analysis, the stations were separated as either coldwater or warmwater, because coldwater species are generally more sensitive high TSS. In addition, there are common fish species in the Root River, and using fish TIV's, the fish captured are grouped into categories (quartiles) based on their tolerance to high TSS (Figure 28 and Figure 29). The fish are broken up based on coldwater and warmwater assemblages, similar to the macroinvertebrates.

A product of that analysis, can allow better understanding of longitudinal differences in the watershed, and how certain fish communities may be comprised of more tolerant fish species than others (Figure 30).

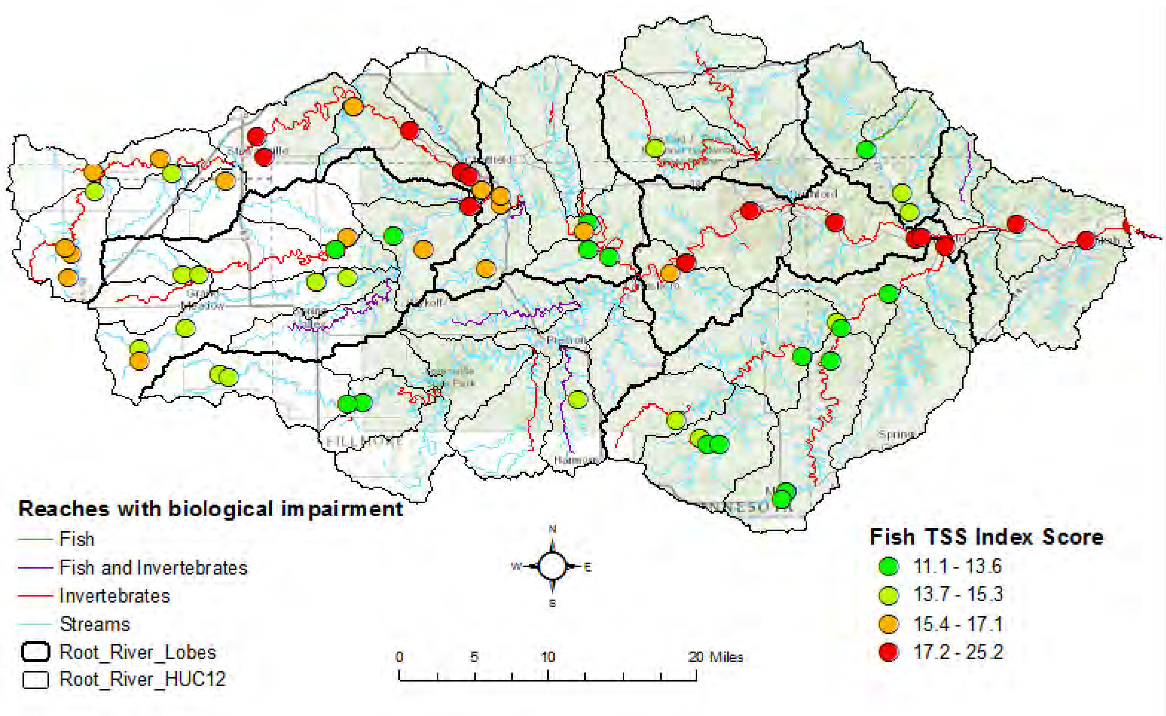


Figure 26. Station index scores for fish tolerance to TSS in the warmwater biological stations of the Root River Watershed; quartiled based on data shown. ***Note: This analysis is comparative among stations in the Root River only, and does directly translate to high TSS. This tool is used for understanding community composition, and species which are tolerant to high TSS, can also be responding to other stressors present.***

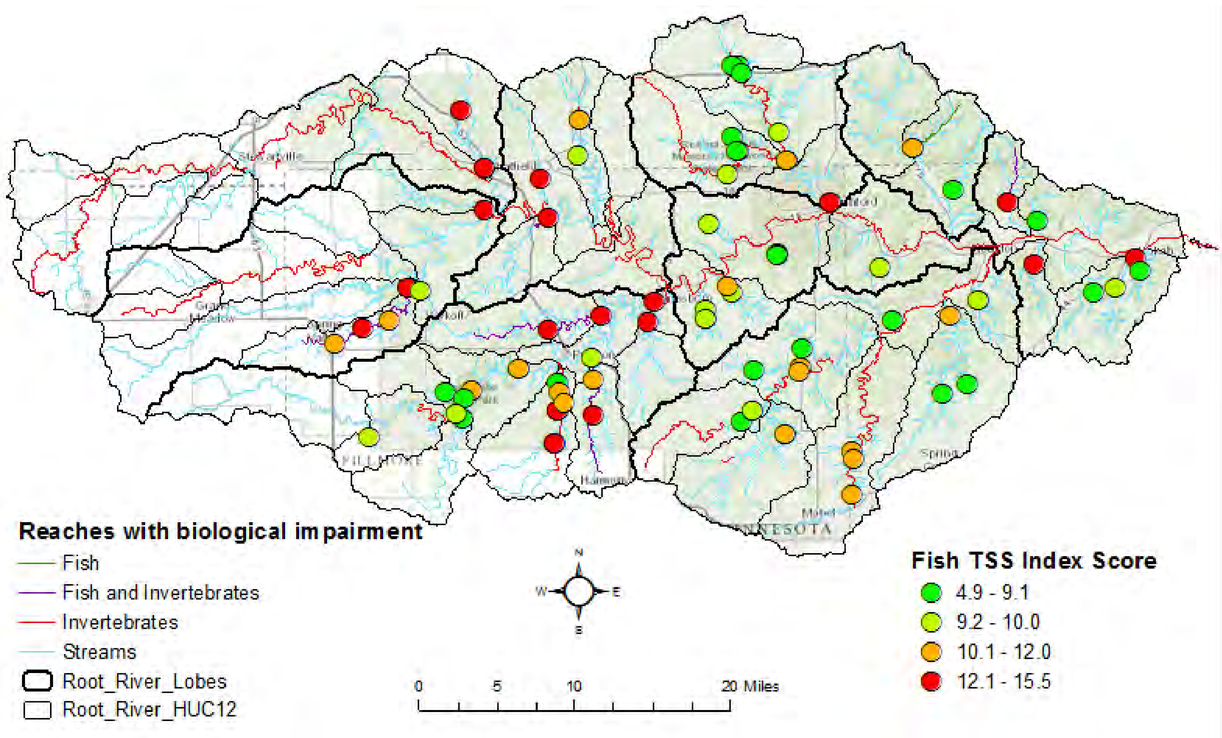


Figure 27. Station index scores for fish tolerance to TSS in the coldwater biological stations of the Root River Watershed; quartiled based on data shown. ***Note: This analysis is comparative among stations in the Root River only, and does directly translate to high TSS. This tool is used for understanding community composition, and species which are tolerant to high TSS, can also be responding to other stressors present.***

Coldwater							
4th Quartile		3rd Quartile		2rd Quartile		1st Quartile	
CommonName	*TSS*	*CommonName*	*TSS*	*CommonName*	*TSS*	*CommonName*	*TSS*
central stoneroller	17.52	northern pike	12.46	hornyhead chub	8.88	rainbow trout	4.15
bigmouth shiner	18.42	american brook lamprey	12.90	rainbow darter	9.23	slimy sculpin	4.84
shorthead redhorse	18.71	white sucker	13.04	brown trout	9.49	brook trout	5.23
stonecat	19.28	creek chub	14.23	central mudminnow	9.81	chesnut lamprey	5.46
banded darter	21.43	silver redhorse	14.43	largemouth bass	10.31	mottled sculpin	6.78
bluntnose minnow	21.81	golden redhorse	14.55	blackside darter	10.72	longnose dace	7.03
walleye	22.93	black redhorse	14.99	common shiner	10.75	rock bass	7.19
black bullhead	24.03	hybrid sunfish	15.98	bluegill	10.98	smallmouth bass	7.35
green sunfish	25.69	largscale stoneroller	16.39	johnny darter	11.09	southern redbelly dace	7.6
fathead minnow	26.79	carmine shiner	17.02	fantail darter	11.52	greater redhorse	8.47
spotfin shiner	32.84	northern hogsucker	17.15	brook stickleback	12.30	blacknose dace	8.73
sand shiner	33.72						

Tolerant to high TSS ⟵ Intolerant to high TSS

Figure 28. Root River Watershed common fish species (coldwater only) in quartiles by tolerance to high TSS

Warmwater							
4th Quartile		3rd Quartile		2rd Quartile		1st Quartile	
CommonName	*TSS*	*CommonName*	*TSS*	*CommonName*	*TSS*	*CommonName*	*TSS*
bullhead minnow	24.65	hybrid sunfish	15.98	largemouth bass	10.31	rainbow trout	4.15
green sunfish	25.69	iowa darter	16.21	blackside darter	10.72	brook trout	5.23
fathead minnow	26.79	largescale stoneroller	16.39	common shiner	10.75	chesnut lamprey	5.46
highfin carpsucker	28.58	river shiner	16.61	bluegill	10.98	blacknose shiner	6.19
emerald shiner	29.33	carmine shiner	17.02	johnny darter	11.09	logperch	6.44
spotfin shiner	32.84	northern hogsucker	17.15	weed shiner	10.31	brook silverside	6.54
sand shiner	33.72	central stoneroller	17.52	fantail darter	11.52	mottled sculpin	6.78
quillback	35.38	bigmouth shiner	18.42	brook stickelback	12.30	longnose dace	7.03
auger	36.48	shorthead redhorse	18.71	american brook lamprey	12.90	rock bass	7.19
smallmouth buffalo	39.54	channel shiner	19.00	white sucker	13.04	micmic shiner	7.33
gizzard shad	41.23	stonecat	19.28	creek chub	14.23	smallmouth bass	7.35
channel catfish	41.69	longnose gar	20.08	silver redhorse	14.43	southern redbelly dace	7.60
shovelnose sturgeon	42.85	silver lamprey	20.28	suckermouth minnow	14.48	greater redhorse	8.47
common carp	44.38	banded darter	21.43	golden redhorse	14.55	blacknose dace	8.73
orangespotted sunfish	44.38	bluntnose minnow	21.81	black redhorse	14.99	hornyhead chub	8.88
freshwater drum	49.67	walleye	22.39	black crappie	15.54	rainbow darter	9.23
white bass	50.75	mooneye	22.62	western sand darter	15.94	brown trout	9.49
shortnose gar	52.01	black bullhead	24.03	slenderhead darter	15.94	central mudminnow	9.81
river carpsucker	55.94					gravel chub	10.12

Tolerant to high TSS ← Intolerant to high TSS

Figure 29. Root River Watershed common fish species (warmwater only) in quartiles based on tolerance to high TSS

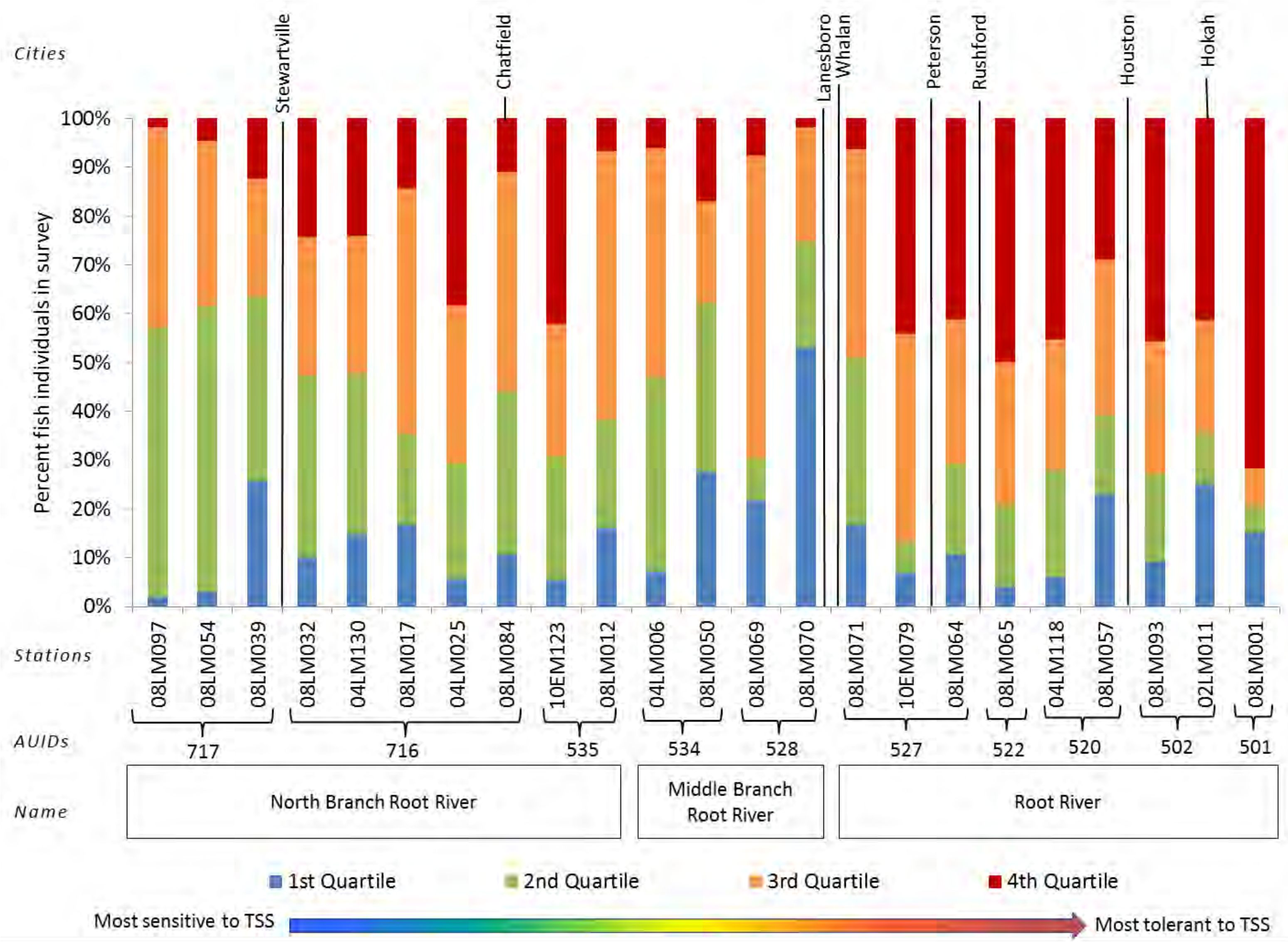


Figure 30. Percent fish individuals by biological station along the Root River, for each quartile based on total suspended sediment tolerance values for fish species, weighted on the warmwater species present in the Root River Watershed.

3.3.4. Candidate cause: Physical habitat

Habitat is a broad term encompassing all aspects of the physical, chemical, and biological conditions needed to support a biological community. This section will focus on the physical habitat structure including geomorphic characteristics and vegetative features (Griffith, Rashleigh, & Schofield, 2010). Physical habitat is often interrelated to other stressors (e.g., sediment, flow, dissolved oxygen) and will be addressed separately.

Excess fine sediment deposition on benthic habitat has been proven to adversely impact fish and macroinvertebrate species that depend on clean, coarse stream substrates for feeding, refugia, and/or reproduction (Newcombe et al., 1991). Aquatic macroinvertebrates are generally affected in several ways: (1) loss of certain taxa due to changes in substrate composition (Erman and Ligon, 1988); (2) increase in drift (avoidance) due to sediment deposition or substrate instability (Rosenberg and Wiens, 1978); and (3) changes in the quality and abundance of food sources such as periphyton and other prey items (Pekarsky, 1984). Fish communities are typically influenced through: (1) a reduction in spawning habitat or egg survival (Chapman, 1988); and (2) a reduction in prey items as a result of decreases in primary production and benthic productivity (Bruton, 1985; Gray and Ward, 1982).

Specific habitats that are required by a healthy biotic community can be minimized or altered by practices on our landscape by way of resource extraction, agriculture, forestry, silviculture, urbanization, and industry. These landscape alterations can lead to reduced habitat availability, such as decreased riffle habitat; or reduced habitat quality, such as embedded gravel substrates. Biotic population changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (Griffith, Rashleigh, & Schofield, 2010).

Degraded physical habitat is a leading cause of impairment in streams on 303(d) lists. According to the USEPA CADDIS website six attributes are the main features of physical habitat structure provided by a stream: stream size and channel dimensions, channel gradient, channel substrate size and type, habitat complexity and cover, vegetation cover and structure in the riparian zone, and channel-riparian interactions. To learn more about physical habitat go to the EPA CADDIS webpage here.

3.3.4.1 Water quality standards

There are no state water quality standards for physical habitat.

3.3.4.2 Types of physical habitat data

MPCA biological survey crews conduct a qualitative habitat assessment using the MPCA Stream Habitat Assessment (MSHA) protocol for stream monitoring sites. The MSHA protocol can be found here. MSHA scores can be used to review habitat conditions at biological sampling locations and compare those conditions against similar size streams and a variety of IBI scores. MPCA and MDNR partners are collecting stream channel dimension, pattern and profile data at select stream locations of various sizes and biological condition. This data can be used to compare channel departure from a reference condition. Habitat features can be analyzed to determine if a stream is lacking pool depth, pool spacing, adequate cross sectional area to convey discharge, and various other physical habitat features that are too numerous to list here. The applied river morphology method created by (Rosgen, 1996) is the accepted method for this data collection by the MPCA and MDNR.

3.3.4.3 Sources and causal pathways model for lack of physical habitat

Alterations of physical habitat, defined here as changes in the structural geomorphic or vegetative features of stream channels, can adversely affect aquatic organisms. Many human activities and land uses can lead to myriad changes in in-stream physical habitat. Mining, agriculture, forestry and silviculture, urbanization, and industry can contribute to increased sedimentation (e.g., via increased erosion) and changes in discharge patterns (e.g., via increased stormwater runoff and point effluent discharges), as well as lead to decreases in streambank habitat and instream cover, including large woody debris (see the Sediment and Flow modules for more information on sediment- and flow-related stressors).

Direct alteration of streams channels also can influence physical habitat, by changing discharge patterns, changing hydraulic conditions (water velocities and depths), creating barriers to movement, and decreasing riparian habitat. These changes can alter the structure of stream geomorphological units (e.g., by increasing the prevalence of run habitats, decreasing riffle habitats, and increasing or decreasing pool habitats).

Typically, physical habitat degradation results from reduced habitat availability (e.g., decreased snag habitat, decreased riffle habitat) or reduced habitat quality (e.g., increased fine sediment cover). Decreases in habitat availability or habitat quality may contribute to decreased condition, altered behavior, increased mortality, or decreased reproductive success of aquatic organisms; ultimately, these effects may result in changes in population and community structure and ecosystem function. Narrative and conceptual model can be found on the USEPA CADDIS webpage here.

3.3.4.4 Overview of Lack of Physical Habitat in the Root River Watershed

Habitat is variable throughout the Root River watershed and is important in understanding the biological communities. Throughout the Root River watershed, qualitative habitat was measured with the Minnesota Stream Habitat Assessment (MSHA) along with the fish survey (Figure 31). The MSHA is useful in describing the aspects of habitat needed to obtain an optimal biological community. It includes five subcategories: land use, riparian zone, substrate, cover, and channel morphology.

Fish and macroinvertebrate communities can both respond to varying types of habitat stress. Biological metrics are used to help in understanding the biological response associated with potential habitat related stress. The metrics used for analysis in the Root River Watershed specifically, are found in Table 9. Many of these metrics also respond to other stressors as well, so understanding all potential stressors is important. Multiple lines of evidence are used to determine which stressors are producing the largest affect. When multiple habitat related metrics are responding, the evidence is stronger that habitat is playing a primary role. In addition, sometimes macroinvertebrates will respond to habitat stress, when fish do not, and vice versa.

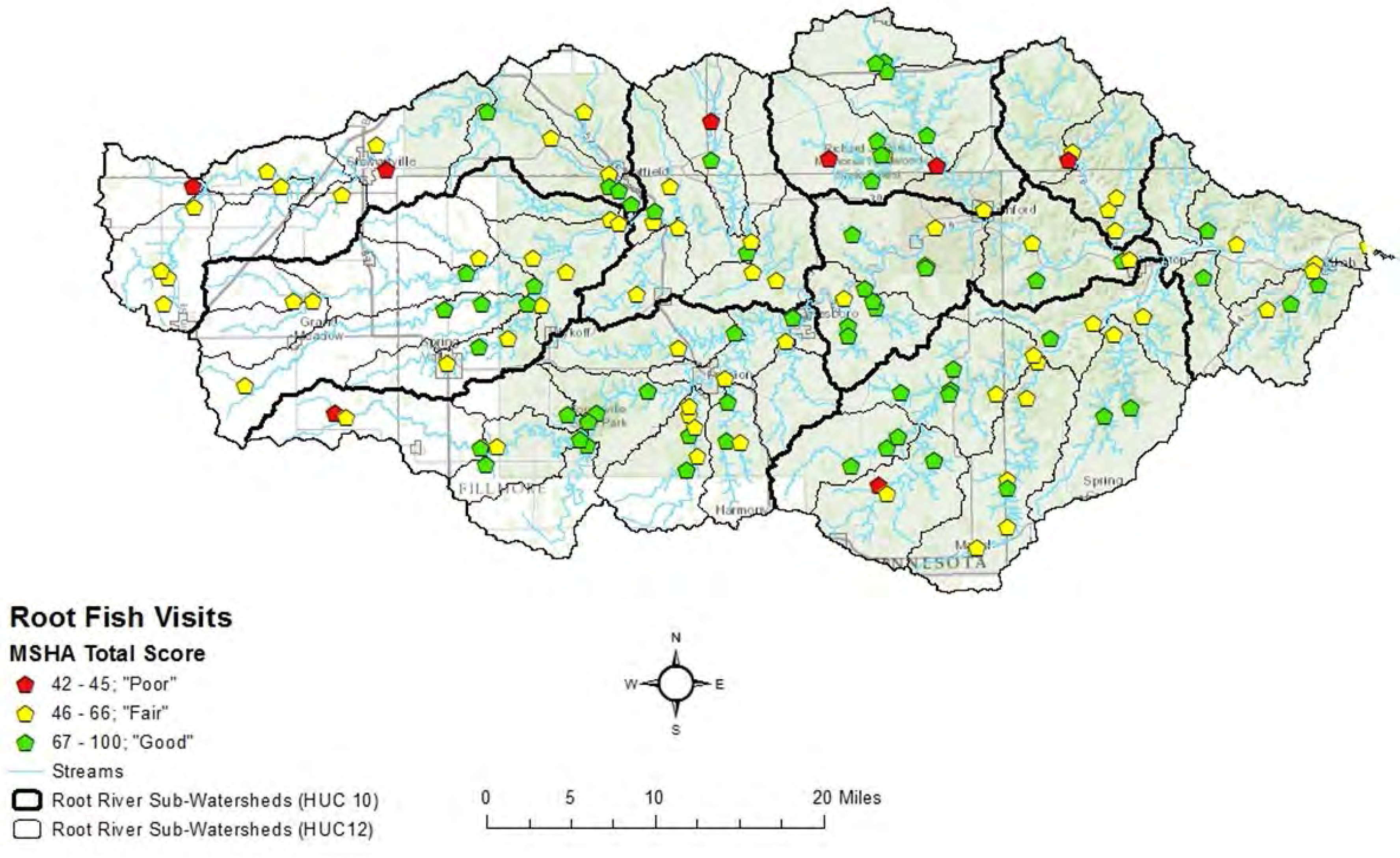


Figure 31. Root River MSHA scores for each biological station

Table 9. Selected fish and macroinvertebrate metrics for analysis of habitat stress in the Root River Watershed

	Metric Description	Explanation	Expected Response to Habitat Stress
Fish			
BenInsect-TolPct	Relative abundance (%) of individuals that are non-tolerant benthic insectivore species	Benthic insectivores are found in riffle habitats, with clean gravel substrates	*Decrease*
SLithopPct	Relative abundance (%) of individuals that are simple lithophilic spawners	Simple lithophilic spawners require clean gravel or cobble substrates for reproductive success	*Decrease*
DarterSculpSucPct	Relative abundance (%) of individuals that are darter, sculpin, and round bodied sucker species	Darter, sculpin, and round bodied suckers require shallow riffle habitats	*Decrease*
RifflePct	Relative abundance (%) of individuals that are riffle-dwelling species	Riffle dwelling species are important indicators of available riffle habitat	*Decrease*
PiscivorePct	Relative abundance (%) of individuals that are piscivore species	Piscivores require pool habitats for predator-prey relationship. Proper substrate will also benefit piscivores	*Decrease*
LithFrimPct	Relative abundance (%) of individuals that are lithophilic spawners	Require interstitial spaces within stable, coarse gravel, cobble, or boulder substrate unembedded by fines	*Decrease*
TolPct	Relative abundance (%) of individuals that are tolerant species	Tolerant fish species are able to survive generally adverse stream conditions	*Increase*
PioneerPct	Relative abundance (%) of individuals that are pioneer species	Pioneer species are able to thrive in unstable environments and are the first to invade after disturbance	*Increase*
Macroinvertebrates			
BurrowerPct	Relative abundance (%) of burrowers in subsample	Burrower species “burrow” in fine sediment indicating potential siltation in riffles	*Increase*
ClimberPct	Relative abundance (%) of climbers in subsample	Climber species use habitat such as overhanging vegetation or woody debris	*Decrease*
ClingerPct	Relative abundance (%) of climbers in subsample	Clinger species attach to rock or woody debris. Clingers may decrease in stream reaches with homogeneous substrate composition, velocity, and depth.	*Decrease*
EPTPct	Relative abundance (%) of Ephemeroptera, Plecoptera & Trichoptera individuals in subsample	EPT are a sensitive group of macroinvertebrates commonly used to measure overall health of ecosystems	*Decrease*
LeglessPct	Relative abundance (%) of legless individuals in subsample	Legless macroinvertebrates are tolerant species like midges/worms, and snails	*Increase*
SprawlerPct	Relative abundance (%) of sprawler individuals in subsample	Sprawlers are macroinvertebrates which sprawl on top of fine sediments or vegetation, but some also require course substrates and lack of embeddedness	*Increase or Decrease*
SwimmerPct	Relative abundance (%) of swimmer individuals in subsample	Swimmers require low velocity water and their abundance or decline may indicate changes in water flow or pool abundance	*Increase or Decrease*

3.3.5. Candidate cause: Physical connectivity

Connectivity in river ecosystems refers to how waterbodies and waterways are linked to each other on the landscape and how matter, energy, and organisms move throughout the system (Pringle, 2003). Impoundment structures (dams) on river systems alter steamflow, water temperature regime, and sediment transport processes – each of which can cause changes in fish and macroinvertebrate assemblages (Cummins, 1979; Waters, 1995). Dams also have a history of blocking fish migrations and can greatly reduce or even extirpate local populations (Brooker, 1981; Tiemann et al., 2004). In Minnesota, there are more than 800 dams on streams and rivers for a variety of purposes, including flood control, wildlife habitat, and hydroelectric power generation.

Dams, both human-made and natural, can cause changes in flow, sediment, habitat and chemical characteristics of a waterbody. They can alter the hydrologic (longitudinal) connectivity, which may obstruct the movement of migratory fish causing a change in the population and community structure. The stream environment is also altered by a dam to a predominately lentic surrounding (Mitchell and Cunjak, 2007). Longitudinal connectivity of flowing surface waters is of the utmost importance to fish species. Many fish species' life histories employ seasonal migrations for reproduction or overwintering. Physical barriers such as dams, waterfalls, perched culverts and other instream structures disrupt longitudinal connectivity and often impede seasonal fish migrations. Disrupted migration not only holds the capacity to alter reproduction of fish, it also impacts mussel species that utilize fish movement to disperse their offspring. Structures, such as dams, have been shown to reduce species richness of systems, while also increasing abundance of tolerant or undesirable species (Winston et al*.* 1991, Santucci et al*.* 2005, Slawski et al. 2008, Lore 2011).

Longitudinal connectivity of a system's immediate riparian corridor is an integral component within a healthy watershed. Continuous corridors of high quality riparian vegetation work to sustain stream stability and play an important role in energy input and light penetration to surface waters. Riparian connectivity provides habitat for terrestrial species as well as spawning and refuge habitat for fish during periods of flooding. Improperly sized bridges and culverts hinder the role of riparian connectivity as they reduce localized floodplain access, disrupt streambank vegetation, and bottle neck flows that can wash out down stream banks and vegetation.

Lateral connectivity represents the connection between a river and its floodplain. The dynamic relationship amongst terrestrial and aquatic components of a river's floodplain ecosystem comprises a spatially complex and interconnected environment (Ickes et al. 2005). The degree to which lateral connectivity exists is both a time-dependent phenomenon (Tockner et al. 1999) and dependent upon the physical structure of the channel. Rivers are hydrologically dynamic systems where their floodplain inundation relates to prevailing hydrologic conditions throughout the seasons. Riverine species have evolved life history characteristics that exploit flood pulses for migration and reproduction based on those seasonally predictable hydrologic conditions that allow systems to access their floodplains (Weclomme 1979, McKeown 1984, Scheimer 2000). When a system degrades to a point where it can no longer access its floodplain, the system's capacity to dissipate energy is lost. Without dissipation of energy through floodplain access, sheer stress on streambanks builds within the channel causing channel widening. Channel widening reduces channel stability and causes loss of integral habitat that in turn reduces biotic integrity of the system until the stream can reach a state of equilibrium once again.

3.3.5.1. Water quality standards

There is no applicable water quality standard for connectivity impacts.

3.3.5.2. Sources and causal pathways model for physical connectivity

The conceptual model for physical connectivity as a candidate stressor is found in Figure 32.

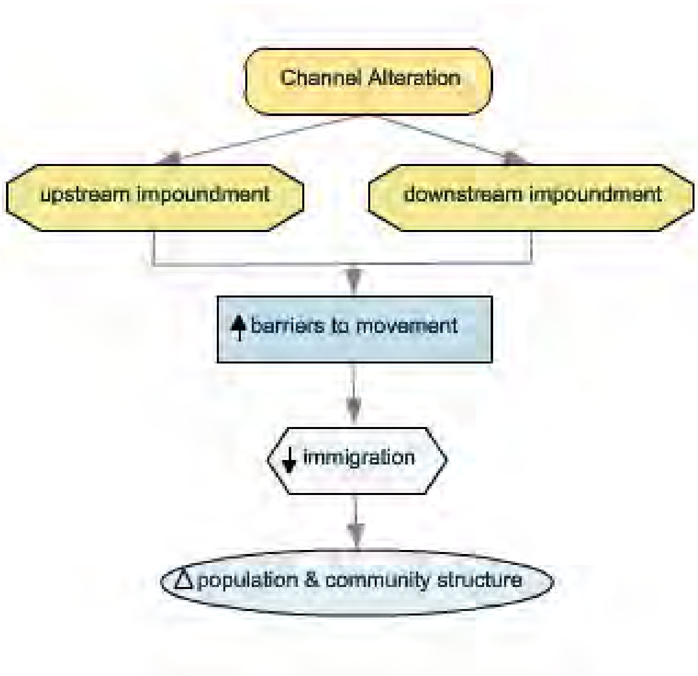


Figure 32. Conceptual model for connectivity.

3.3.5.3. Overview of physical connectivity in the Root River Watershed

Connectivity in the Root River Watershed is altered mainly in the form of culverts and bridges, but there are a few dams also present (Figure 33). Connectivity can also be temporarily disrupted by beaver dams and other woody debris, but these are typically seasonal and washed away by floods or other high water. During the SID process, perched culverts were found in a few locations of the watershed, but most did not appear to be affecting fish passage.

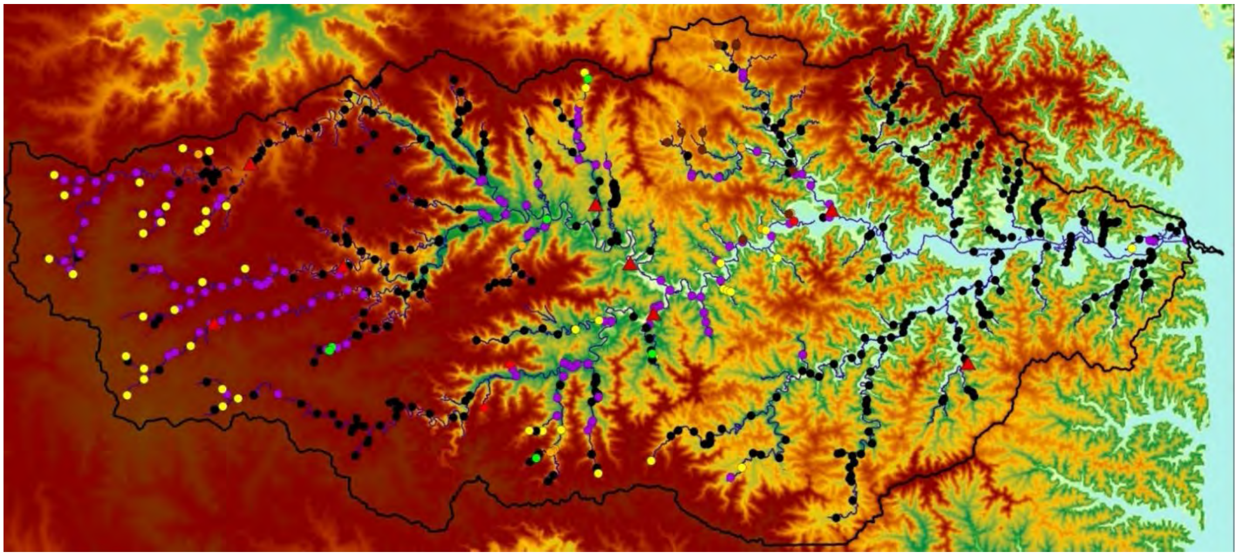
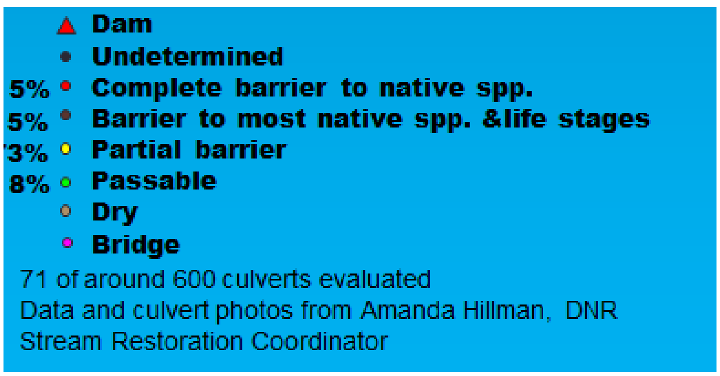


Figure 33. Culverts evaluated in the Root River, data and map provided by MDNR



4. Evaluation of Candidate Causes by 10 digit HUC

4.1. City of Rushford-Root River

This 10 digit HUC section covers three AUIDs on the mainstem Root River (from Lanesboro to Houston; combined in one section), and also addresses a small coldwater tributary; Camp Hayward Creek (Figure 34). The mainstem Root River is impaired for macroinvertebrates throughout, and Camp Hayward Creek is also impaired for macroinvertebrates. Fish are doing well in both areas.

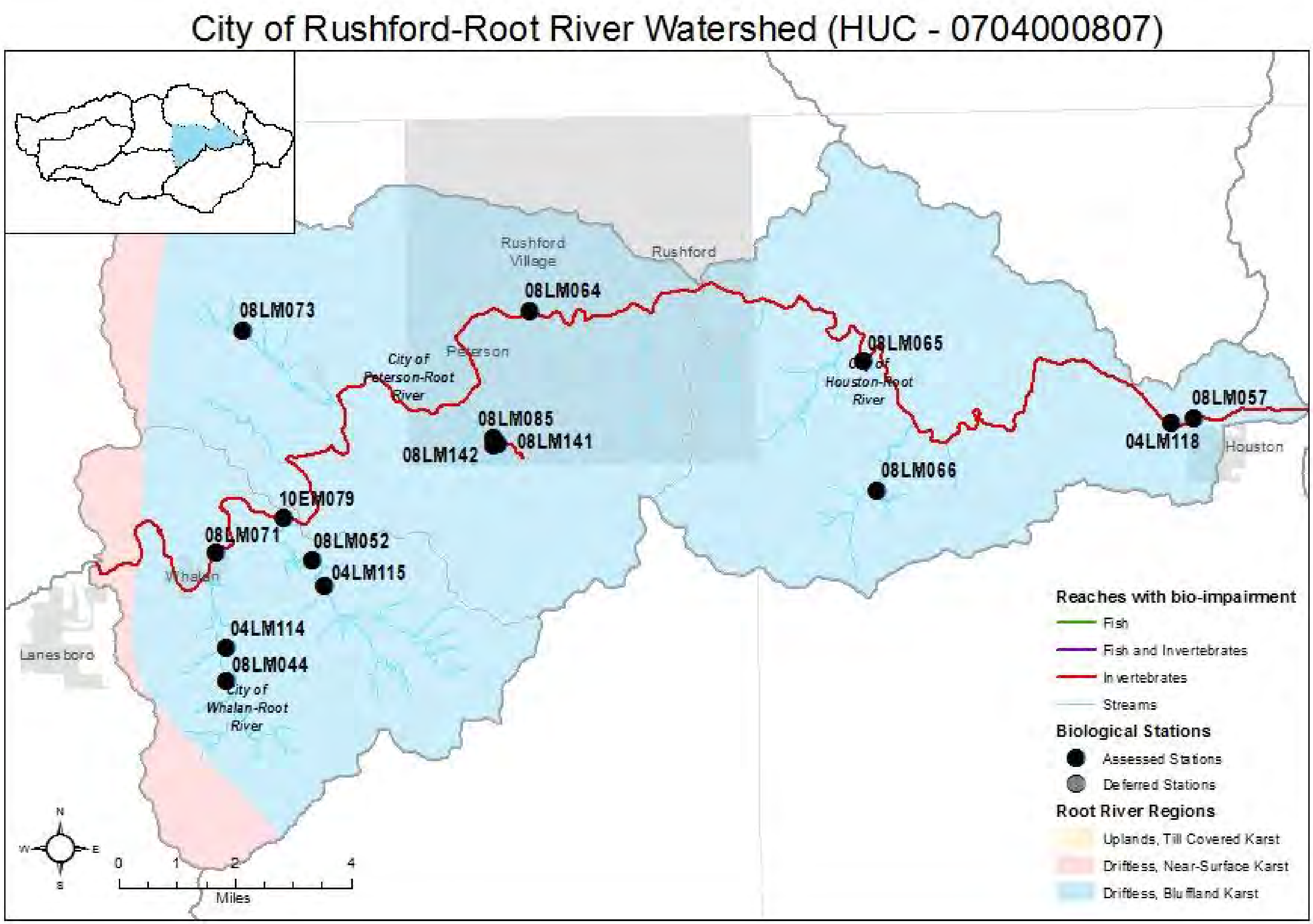


Figure 34. Map of City of Rushford-Root River watershed showing reaches of biological impairment and biological sampling locations

4.1.1. Root River mainstem

For the purposes of reporting, this section includes three AUIDs: 520, 522 and 527, all which are on the mainstem of the Root River. This section of the main-stem river is impaired for macroinvertebrates throughout; and stressors and biological response is similar.

Supporting information

Fish at all six biological stations are doing well on these stream reaches, with IBI scores well above impairment thresholds. Macroinvertebrate IBIs (MIBI) were consistently below impairment thresholds; five of the six sites' score were below impairment threshold. The two worst scoring sites are on AUID 527, which both scored below the threshold and confidence interval. The MIBI metrics which consistently scored poorly are due to a lack of sensitive macroinvertebrate taxa (Intolerant2lessCh), lack of Odonata taxa (Odonata; dragonflies and damselflies), lack of predator taxa (Predator), and overall reduced taxa counts (TaxaCountAllChir). All of these metrics demonstrate reduced richness in the macroinvertebrate community. Other sites show a mixed response throughout metrics (Figure 35).

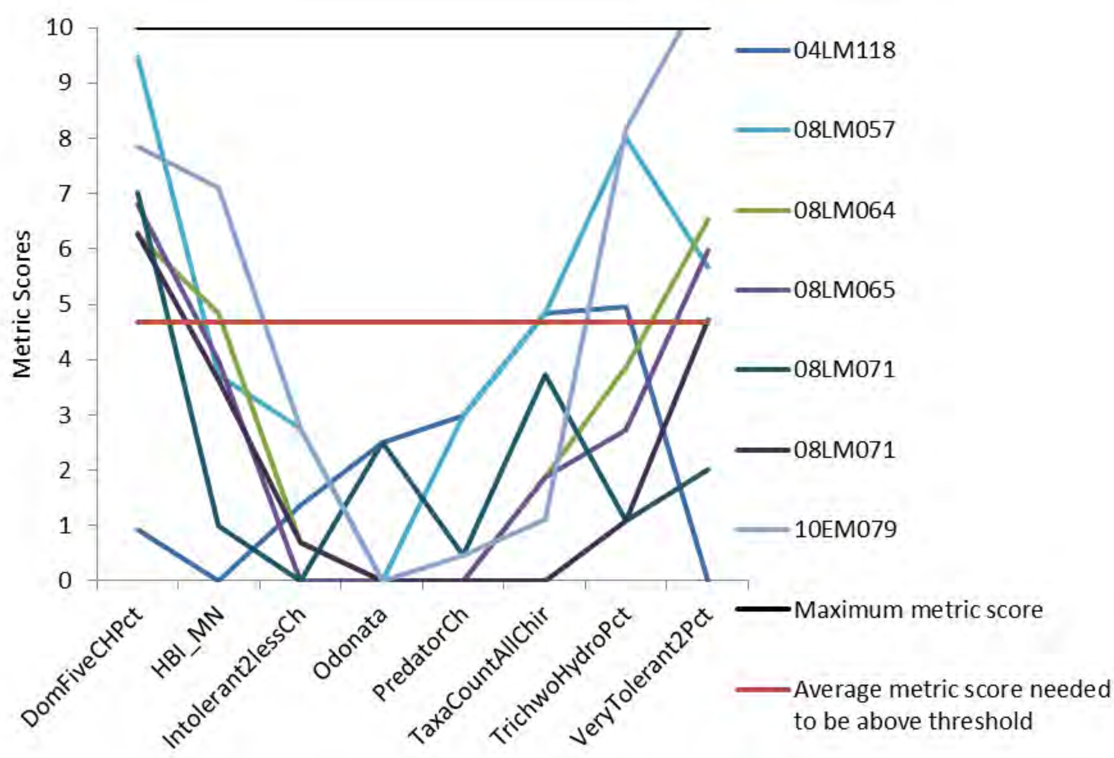


Figure 35. Macroinvertebrate IBI metrics for biological stations on AUIDs 520,522,527; Prairie Forest Rivers (Class 2).

Temperature

This part of the river (includes all three AUIDs) is currently classified warmwater, and the maximum temperature measured of 287 data points was 25°C on AUID-527. Aquatic life in warmwater systems may begin to stress when temperatures reach closer to 30°C. Even though this dataset is limited, and does not include all three AUIDs, it is believed that temperature is fairly well represented in the current dataset, and elevated temperature is not a stressor to the macroinvertebrate community on the mainstem Root River.

Dissolved Oxygen

The only DO data (aside from data collected at time of biological sampling) that exists on these three stream segments was on AUID 520. There were 34 points from April through November 2008. The average concentration was 9.7 mg/L, maximum was 12.48 mg/L and minimum was 8.13 mg/L. No exceedence of the DO water quality standard (5 mg/L in warmwater streams) was observed during this time, but the dataset is limited. There were only four measurements taken before 9:00 am. Additional information, or continuous data, would help in the understanding of DO flux and diurnal patterns at this location.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. Station S004-820 (on AUID 520) had 69 water quality grab samples and 33 pH values were available from April-November 2008. The range was 7.97-8.66, average value was 8.19, and maximum was 8.66. The pH values were all within expected ranges. There were 36 total phosphorus (TP) values ranging from 0.04-1.34 mg/L, the average was 0.208 mg/L, and the maximum was 1.34 mg/L. Both the average and maximum phosphorus is greater than the draft nutrient standards. Neither BOD nor Chlorophyll-a data were available for analysis on these stream reaches, at this time. To date, there is not a nutrient response stressor that has been found to be greater than expectations (chlorophyll-a, DO flux, and BOD).

The macroinvertebrate community does not strongly indicate a DO stressor. The DO TIV aggregate scores for macroinvertebrates among the sites were better than average, indicating a community that is fairly sensitive to low DO. Overall, there are few individuals present at the biological sites which are considered tolerant of low DO. The number of intolerant to low DO taxa varies across sites (8-14 taxa). The number of intolerant taxa decreases while moving downstream. Station 08LM057 had the highest percentage of *Plecoptera* (stoneflies) of any sample in the entire Root Watershed. While this isn't conclusive evidence, it does show that species that are sensitive to low DO are present in this reach of the river.

Fish in this section of river also do not indicate DO stress. DO TIV aggregate scores for fish at all the biological stations were in the most sensitive group of sites in the Root River, indicating a fish community that is sensitive to low DO, compared to other sites in the Root River. The biological and chemical data do not provide evidence to suggest DO is a stressor to the mainstem Root River at this time.

Nitrate

Nitrate concentrations on all three AUIDs average between 4-6 mg/L. AUID 520, Station S004-820, has the most nitrate data available, with 35 data points from April through November of 2008. The average concentration was 6.1 mg/L with a maximum of 8.5 mg/L. Nitrate concentrations at the time of fish sampling at the two biological stations on this AUID were 3.9 and 4.9 mg/L (Stations 04LM118 and 08LM057). On AUID 522 and 527, the only nitrate data was from the fish sampling. At Station 08LM065, on September 3, 2008, nitrate was 4.5 mg/L. In 2008, at Stations 08LM064 and 08LM071, nitrate was 4.9 and 5.1 mg/L (August 25 and September 3, respectively). On August 24, 2010, Station 10EM079 had a nitrate concentration of 5.2 mg/L.

The total taxa in this section of the Root River ranged from 13 to 26 taxa (21.9 taxa is the average for class 2 stations in the Lower Mississippi River Basin (LMB). All but the two lowest Stations (04LM118 and 08LM057) had taxa counts less than the average. Only Station 08LM057 had one intolerant taxon present during the survey, resulting in less than 1% of the individuals present.

At 78.7% nitrate tolerant individuals, there is a 10% probability of meeting the Prairie Forest Rivers MIBI (class 2). Only two visits were above 78.7%, Station 08LM071 and Station 04LM118. The second visit at Station 08LM071 had the third highest percentage of nitrate tolerant individuals. The lowest percentage of nitrate tolerant individuals was at Station 10EM079 with 50.8%, which is relatively low. Stations 10EM079, 04LM118, and 08LM057 each had two nitrate intolerant taxa present.

Nitrate is relatively moderate in this reach for warmwater systems. The biological response is quite mixed throughout the biological stations within these AUIDs. It is possible that another stressor is producing the inconsistent result and not the elevated nitrate. With a mixed biological response and lack of chemical information a nitrate stressor is inconclusive at this time.

Suspended sediment

There is an existing turbidity listing on AUID 527 (Lanesboro to Rushford). This entire stretch of river is dominated by a shifting sand bottom. The AUIDs immediately downstream of this (501-502) are very similar and are discussed further in the Root River 10 digit HUC Section.

Transparency data from AUID 527 has a total of 247 points. The average transparency was calculated at 41 cm. Of those measurements, 16% exceeded 20 cm transparency (<20 cm is generally considered poor). The chemical information for TSS collected at the three biological stations was 8, 9, and ten mg/L. The only TSS chemical information on AUID 522 was during fish sampling, and was 12 mg/L on September 3, 2008. On AUID 520, there were 36 data points from April through November 2008. The average concentration during that time period was 146 mg/L, with a max of 1200 mg/L and minimum of 5.2 mg/L. The chemical data presented does show the potential for high TSS concentrations. This is expected given the existing turbidity listing.

The chemical data is supported well by biological data. The macroinvertebrates within these reaches are generally tolerant to TSS (Table 10). All of the stations are lacking in intolerant macroinvertebrates and nearly all have reduced long-lived macroinvertebrates. The TSS station index scores are variable throughout the reach, but some are quite elevated including Station 04LM118 with a score of 27.87.The upstream stations have a lack of TSS intolerant taxa compared to the average and four of the seven visits had elevated TSS tolerant taxa. The macroinvertebrate community is influenced by the elevated TSS levels throughout these reaches.

Table 10. Macroinvertebrate metrics relevant to TSS for stations in the Root River compared to averages for warmwater stations in the Root River watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics		**TSS Station Index Score**	**TSS Intolerant Taxa**	**TSS Tolerant Taxa**	**Percentage TSS Tolerant Invertebrate Individuals**	**Percentage of Intolerant Invertebrate Individuals**	**Percentage of Long-lived Invertebrate Individuals**
Upstream		16.94	**0**	7	27.94	**0**	**0.31**
	08LM071	**21.98**	**0**	**12**	**52.75**	**0**	**2.22**
	10EM079	16.67	**1**	8	26.05	**0**	**0.95**
	08LM064	16.84	**1**	7	27.61	**0**	**1**
	08LM065	**18.73**	**0**	**11**	**46.28**	**0**	**0**
	04LM118	**27.87**	2	**19**	**87.5**	**0**	**0.94**
Downstream	**08LM057**	**22.83**	2	**14**	**66.46**	**0.32**	7.28
Expected response with increased TSS stress		increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed		17.96	1.52	9.32	35.45	0.48	3.16

Fish communities in the mainstem Root River have a high proportion of TSS tolerant individuals (Figure 36). All biological sites do appear to be dominated by just a few (fish) taxa, including species that are tolerant to TSS, like the emerald shiner and sand shiner. Some species intolerant to TSS are found (smallmouth bass, mimic shiner) but in much smaller quantities overall. Given the strong chemical and supporting biological information, elevated TSS is a stressor to the biology on the mainstem Root River.

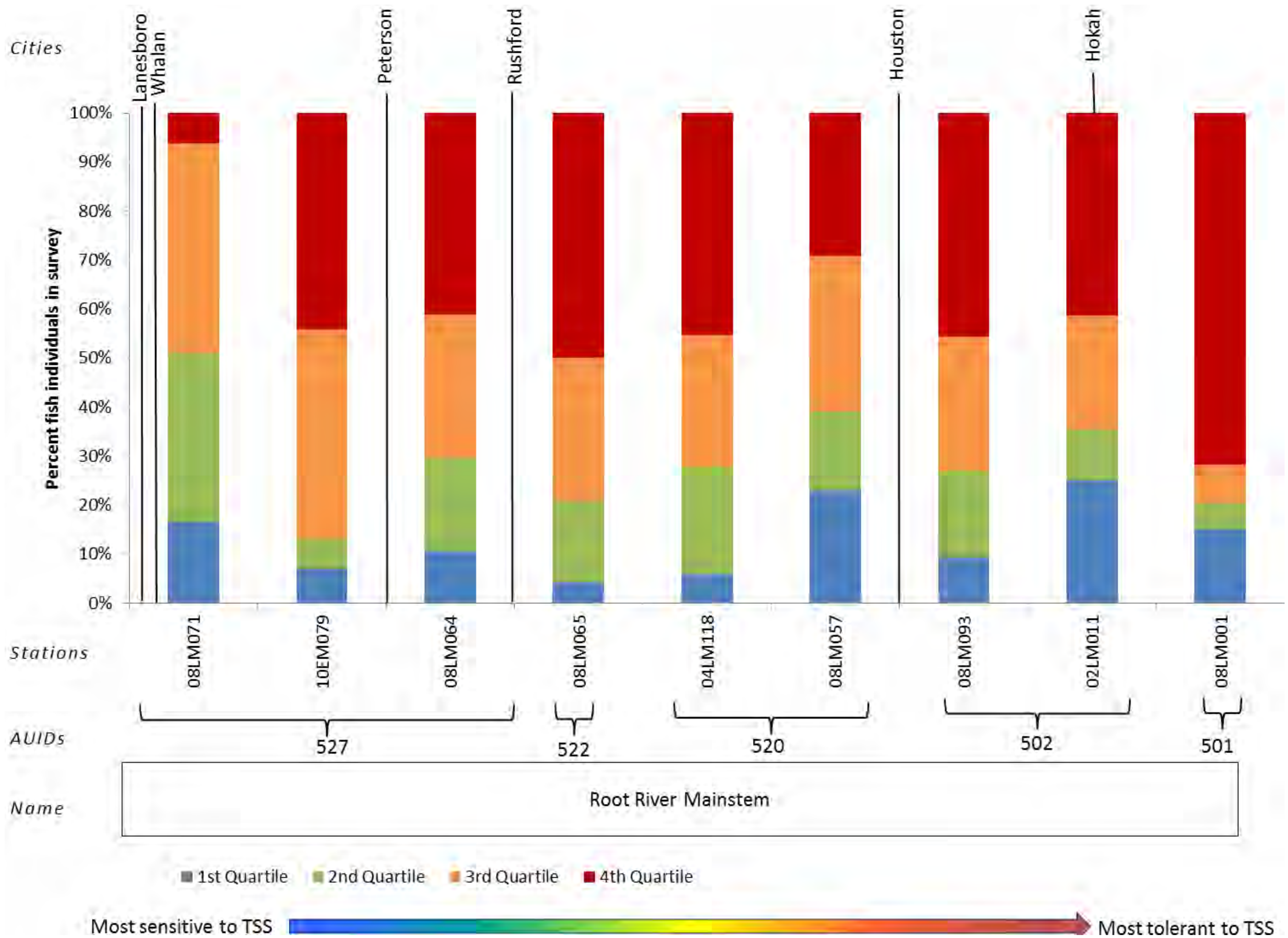


Figure 36. Root River mainstem fish TSS TIV's (tolerance indicator values) from Lanesboro to mouth, demonstrating fish community composition and overall tolerance to TSS.

Physical habitat

The habitat on the mainstem Root River and these three stream reaches varies slightly (Table 11). The MSHA scores for most sites fall within the fair category, with a couple sites showing a slightly better score (likely due to more coarse substrate types present). In addition, the macroinvertebrate habitat types sampled also vary among sites as shown in Table 11.

Table 11. Habitat characteristics on stream reaches 527, 522, and 520 (Lanesboro to Houston)

Biological Station (upstream to downstream)	**AUID**	**Invert Habitat Sampled**	**MIBI Score** (Class 2 impairment threshold =30.7)	**MSHA Score**	**Dominant Run/Glide and Pool Substrate**	**Percent Run**
08LM071	527	Woody Debris Riffle/Rock Undercut Banks Overhanging Vegetation Aquatic Macrophytes	16.39	48	Gravel/Sand and Sand/Silt/Clay	90%
10EM079	527	Woody Debris Riffle/Rock	38.33	74	Cobble/Gravel	55%
08LM064	527	Woody Debris Riffle/Rock	24.03	55	Gravel/Sand	70%
08LM065	522	Woody Debris	21.36	54	Sand/Silt/Clay	100%
04LM118	520	Woody Debris Riffle/Rock Undercut Banks Overhanging Vegetation	17.60	71	Boulder/Cobble	70%
08LM057	520	Woody Debris	37.47	53	Sand/Silt/Clay	75%

There was not an abundance of burrowers found at any of the sites, which would suggest potential sedimentation in riffles. The percentage of Ephemeroptera, Plecoptera, and Trichoptera (EPT) individuals was greater than the statewide average for this stream class except at Stations 08LM064 and 08LM071. Also, the macroinvertebrates that are known to cling to large substrate and woody debris were found in abundance at some sites, except at Stations 04LM118 and 08LM071. The percentage of macroinvertebrates that climb was reduced at all locations except those sites which sampled overhanging vegetation (Stations 08LM071 and 04LM118), this is expected. The percentage of legless macroinvertebrates was slightly higher than average at Stations 08LM064, 08LM065, and 08LM071, but lower at the rest of the locations.

The MSHA attributes are fairly consistent throughout biological stations, with the exception of Station 10EM079 (Figure 37). Cover appears to be limited throughout, and 10LM079 appears to have the best habitat attributes overall. While habitat varies slightly throughout this stretch of river, the reduced IBI scores, and macroinvertebrate response with various habitat related metrics, show habitat is a stressor to the macroinvertebrate communities in this reach.

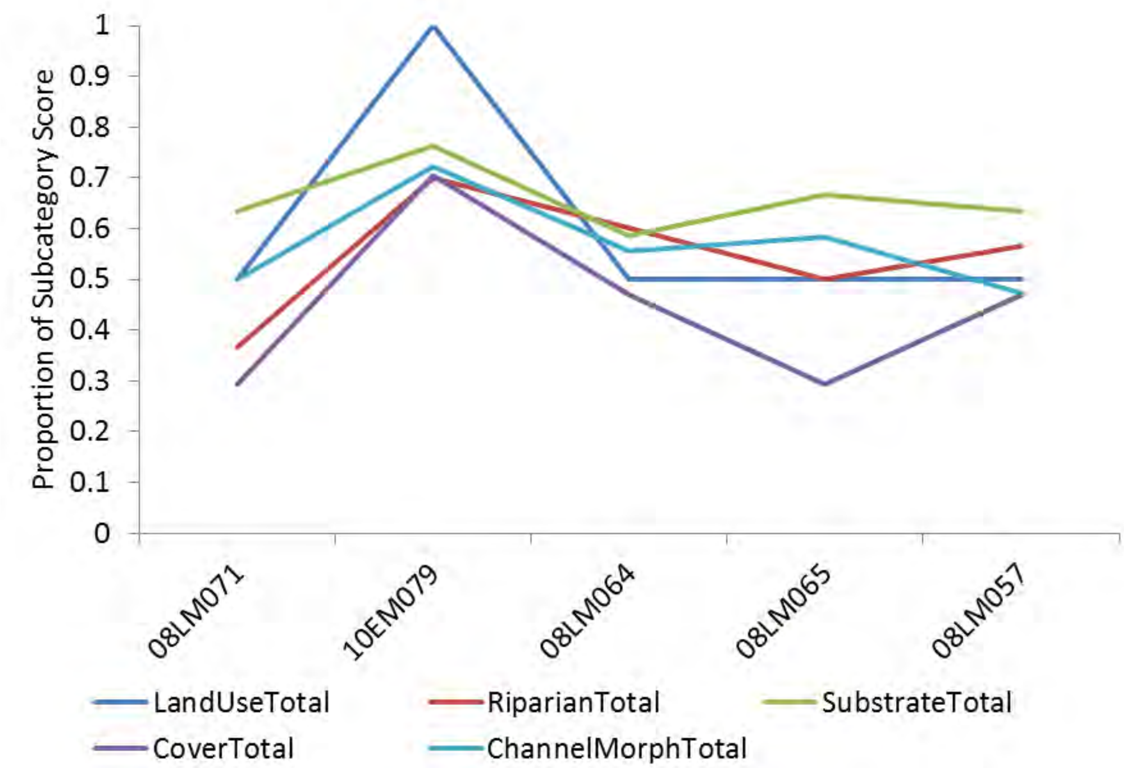


Figure 37: MSHA scores for sites by subcategory for biological stations on AUIDs 520, 522 and 527.

Physical connectivity

No information was available or collected on physical connectivity on the Root River. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in the Root River at this time.

Strength of evidence, conclusions, and recommendations

The stressors to the macroinvertebrate community in this reach of the mainstem Root River is elevated suspended sediment concentrations, and habitat as a secondary stressor. The biological and chemical data both provide good evidence that elevated TSS is playing a primary role in shaping the macroinvertebrate community present here. Habitat is likely an additive stressor, but secondary to TSS. Temperature and DO are both suitable in this reach of the river and the biology reflects that. Nitrate is showing mixed results in terms of nitrate and biological response. The levels of nitrate are moderate in this reach, but not enough evidence was available and nitrate as stressor is inconclusive.

Results from work done by Belmont (2013) show that a “substantial percentage and likely the majority of suspended sediment in the Root River today is derived from stream banks and floodplains (estimated range of 40-80%)”. In addition, work by Belmont points out that the main stem of the Root is a “dynamic alluvium system” which can act as a sediment source or sink at different times. The yield of sediment from the watershed is dependent on the “magnitude and frequency of floods” and there are “many near channel sources of sediment.” Belmont’s work shows that not only is the Root River increasing baseflows, but high flows have increased over recent decades as well. High flows tend to control geomorphic dynamics of channels. “When high flows systematically increase, the channel will tend to enlarge (by widening and/or deepening) and will tend to increase lateral migration rates (i.e., erosion of one bank and deposition that may or may not keep pace on the opposite bank). These findings are therefore consistent with our finding that near channel erosion contributes a significant proportion of sediment." Changing hydrology may be affecting the levels of sediment depositing in the watershed's streams or being transported downstream.

Currently, it appears there are multiple drivers that could be responsible for the changes in suspended sediment and habitat dynamics seen in the main stem Root River. Altered hydrology (including climate change and tile drainage) is one potential area of concern. However, an altered landscape should also be considered as an impact. It is not fully understood the relative contribution each of these variables has on the entire Root River system, therefore the link to stressors is unknown. There is a lack of connecting information to conclude altered hydrology is a stressor at this time (which is why it is considered inconclusive as a stressor in this report), but should be considered for further analysis, as a potential driver for sediment and habitat issues in the mainstem.

Regardless, the majority of the changes which will improve the macroinvertebrate community in the mainstem Root River are needed on an entire watershed-wide scale, and will take many years to implement. Most changes that are localized may not have success, or be sustainable if the larger river system contributions are not addressed.

4.1.2. Camp Hayward Creek Tributary

Supporting information

This small tributary stream watershed is only 5.42 square miles. The topography is very steep. The fish community appears fairly healthy, while the macroinvertebrate community seems to be suffering a bit. The score at Station 08LM142 was just below the IBI threshold for macroinvertebrates. Aerial photography shows stream instability; perhaps caused by 2007 flood or other recent high water events in the area. Local land use may also play a role.

The macroinvertebrate IBI score difference between the two Stations (08LM141 and 08LM142is only 14 points. Station 08LM141 is below the impairment threshold, whereas Station 08LM142, on the adjacent tributary in watershed, is above. The macroinvertebrate IBI metrics score similarly (Figure 38), with the larger differences in two metrics, Intolerant2Ch and TrichopteraChTxPct. This demonstrates fewer generally intolerant taxa and Trichoptera (caddisfly) taxa present at 08LM041 compared to 08LM142. There was one intolerant taxon at Station 08LM142. Station 08LM142 had 13.3% caddisfly taxa, whereas Station 08LM141 had 7.7%. Certain orders of macroinvertebrates, like Trichoptera, are representative healthy stream habitat.

Fish IBIs differed at the two stations. While both above the threshold Station 08LM141 had a FIBI score of 58 and Station 08LM142 had a FIBI of 92. The difference in fish IBI scores between the two sites is 34 points. Station 08LM142 had higher abundance of brook trout, slimy sculpin, and brown trout; and no other taxa present. Station 08LM141 had lower abundance of native coldwater individuals, as well as an influx of additional species (white sucker, blacknose dace, creek chub, fathead minnow, and longnose dace).

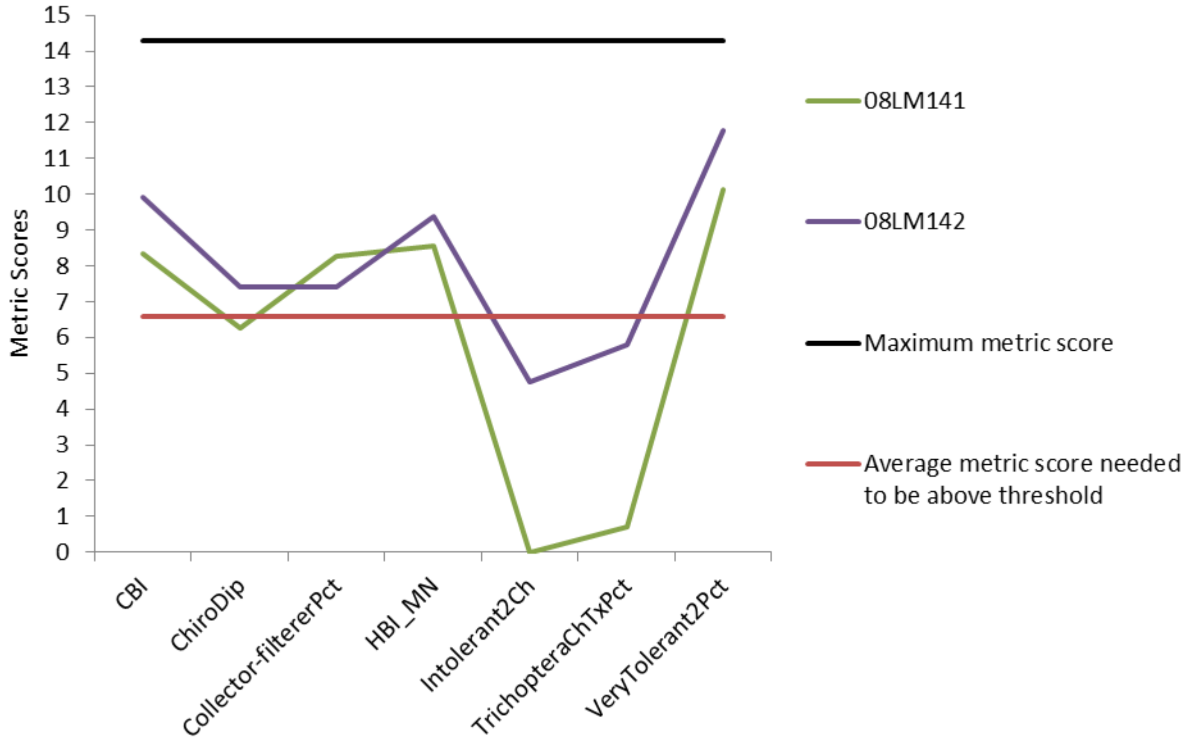


Figure 38. Metric scores for stations in the Camp Hayward Creek Watershed of the Southern Coldwater macroinvertebrate IBI

Temperature

The only temperature data available for Station 08LM141 was the temperature measurement taken during fish sampling (21.3°C) on July 28, 2008. At this location, 5 brook trout and 18 slimy sculpin were sampled, both of which require cold temperatures. Coldwater Biotic Index (CBI) for macroinvertebrates scored fairly high, which suggests a high presence of coldwater macroinvertebrate taxa.

At this time, temperature is not believed to be a stressor in Camp Hayward Creek. However, continuous temperature data would be helpful in ruling out this stressor completely.

Dissolved Oxygen

On the day of fish sample, the DO concentration was 9.55 mg/L (July 28, 2008). This was the only oxygen data point available for analysis. As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The only data on phosphorus and pH were from the fish sample on July 28, 2008. At Station 08LM141, the TP concentration was 0.106 mg/L and pH was 8.24. Both of these appear to be slightly elevated. Nearby stream, Station 08LM142, was sampled the same day had a TP of 0.09 and pH of 7.86. Neither BOD nor chlorophyll-a data were available for analysis.

The fish community is dominated by fish sensitive to low DO (slimy sculpin, brook trout). The macroinvertebrate DO TIV index score for this site scores in the most sensitive quartile for Root River stations. However, there are few DO intolerant and few DO tolerant taxa present. The macroinvertebrate taxa count is low overall. Taxa richness can be decreased with DO stress, along with other stressors. However, an abundant blackfly population was found. Blackflies require high velocity features which typically support very good oxygen levels. The biological data does not strongly point towards DO stress. Given the limited information, DO is not believed to be a stressor to Camp Hayward Creek.

Nitrate

The nitrate concentration on the day of fish sample at Station 08LM141 was 3.3 mg/L (July 28, 2008). In comparison, Station 08LM142 the concentration was 2.9 mg/L, on the same day. The levels found at the two sites compare well, and are typical for small coldwater tributary streams in the Bluffland region of the Root River. A site just downstream from Station 08LM141 was sampled on August 3, 2010, with a result of 4.2 mg/L nitrate. Overall, these values are lower than most coldwater stations in the Root River Watershed, and can be explained partially by the topography and hydrogeology. Nitrate trends in the Peterson Fish Hatchery spring from the mid 1980s to present, show an increasing trend (from about 2 mg/L to 4 mg/L nitrate). However, trends in the last 10 years at this same spring have appeared to stabilize (Runkel et al, 2013). This hatchery is in close proximity to Station 08LM141.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate survey in Unnamed Creek, Station 08LM141 had 13 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class in the LMB is 19. There were no intolerant taxa present, while the average for coldwater stations in the Root is 0.6 taxa. The number of Trichoptera taxa (2) in Unnamed Creek was also below the coldwater average (3.8 taxa), comprising of 7.1% of the TrichopteraChTxPct. The resulting a low metric score; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold. Similar to Station 08LM141, nearby Stations 08LM085 and 08LM142 also had low metric scores for TrichopteraChTxPct.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Unnamed Creek, the metric score was 8.6 (out of 14.3), above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). Additionally, the stations nearby also had higher HBI_MN metric scores.

The HBI_MN value increases with increased nitrate. At Station 08LM141 the HBI_MN value was 6.42 in 2008, just greater than the average HBI_MN value for stations meeting the MIBI (6.27). The nearby stations were also just near or below this average ranging from 6.14 to 6.33. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the

HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM141 had 16 nitrate tolerant taxa (54% individuals); and 11 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in the 2008 macroinvertebrate survey.

The Unnamed Creek macroinvertebrate community exhibits low taxa count and low Trichoptera taxa resulting in low metric score for TrichopteraChTxPct. Station 08LM141, along with nearby stations, have decent HBI_MN values. Along with the limited nitrate data set that has relatively lower concentrations than much of the watershed; it is not likely that nitrate is a stressor. It is likely that other stressor(s) are contributing to the degraded macroinvertebrate condition. Continued monitoring to ensure protection from elevated nitrates should be conducted.

Suspended sediment

TSS concentration on the day of fish sample at Station 08LM141 was 42 mg/L (July 28, 2008), which is somewhat elevated. The nearby site of 08LM142 was also sampled on July 28, and the TSS concentration was 1.2 mg/L, markedly less. National Weather Service precipitation information from Rushford shows zero rainfall from July 21-July 31, 2008. The site was sampled on July 28, and the last measureable rainfall event was on July 18, then again on July 20. Photographs taken on day of fish sampling look slightly turbid, but 42 mg/L still seems high. Some question remains on the quality of that measurement and also the pasture upstream, which may account for higher TSS concentrations without rainfall. In addition, one transparency measurement from 2010 showed very clear water at >100 cm just downstream from Station 08LM141.

The Peterson fish hatchery does have some discharge points near the stream. However, those discharge and permit records were researched, and there was no discharge to the stream on that day. The discharge station that is closest to Station 08LM141 does not normally discharge. The main discharge point is downstream of Station 08LM141.

The fish sample was dominated by slimy sculpin, which are intolerant to high TSS. Other species which are also intolerant to TSS were also found during fish sampling (brook trout, blacknose dace and longnose dace), although they were found in much lower abundance than at Station 08LM142. Only a handful of the species present in the sample are considered tolerant to TSS (white sucker, creek chub, and fathead minnow).

At Station 08LM141, there were no intolerant macroinvertebrates and no long-lived macroinvertebrates, which often decrease with increases in TSS. The macroinvertebrate index score for TSS was 14.48, better than the average for coldwater stations in the Root River Watershed (15.13). The station at the time of sampling had five taxa tolerant to TSS and no taxa intolerant to TSS. Both of these metrics reveal conditions less than desirable when compared to averages of coldwater stations in the Root River. The survey had 12.5% of the individuals in the survey considered tolerant to TSS; the average for coldwater stations in the Root River is 9.94%. The macroinvertebrate community data suggests that TSS may be an issue at this location, but the evidence is not strong.

Given the lack of strong evidence, TSS is unable to be confirmed as a stressor at this time. Additional information should be collected to help understand this potential stressor.

Physical habitat

The habitat characteristics found at Station 08LM141 (MIBI below threshold) and neighboring site 08LM142 (above impairment threshold) have large differences in dominant substrate types (Table 12). Coarse substrates are present at both locations; however sand has invaded much of the stream bottom as shown in Table 12. There is also a fairly large difference in the amount of riffle habitat, substrate and cover between the two stations (Figure 40). Both sites noted moderate to high velocity over the riffle, likely due to the high gradient nature of these streams. Simulidae (blackfly), who prefer fast velocity water, are common (32% at Station 08LM141).

Table 12. Habitat characteristics comparison between 08LM141 (impaired) and 08LM142 (not impaired).

Station	MIBI	MSHA	Invert Habitat Sampled	Gradient	%Riffle	Dominant Run/Glide Substrate	Dominant Pool Substrate
08LM142	56.4	82-Good	Riffle/Rock Undercut Bank Overhanging Vegetation	9.7	60%	Cobble/Gravel	Sand/Gravel
08LM141	42.2	63-Fair	Riffle/Rock Undercut Bank Overhanging Vegetation	9.1	25%	Sand/Silt/Clay	Sand/Silt/Clay

The biological metrics which are closely related to habitat show a slight difference between stations. The percentage of EPT taxa at Station 08LM141 was only 15% compared to the statewide average of coldwater stations, which is 39%. In addition, there were a higher percentage of more tolerant legless taxa (50% compared to the statewide average for coldwater stations of 32%). Both of these metrics reveal less than desirable habitat conditions for the macroinvertebrate community. Station 08LM142 was also showed response with these two metrics, but not as great as the impaired Station, 08LM141. The macroinvertebrates that cling were higher at Station 08LM141, but this is likely due to the high abundance of blackflies. As noted in the MSHA, the local land use at these two sites is slightly different (Figure 39), along with dominant substrate types, which is likely contributing to the differences in available habitat and macroinvertebrate IBI scores.

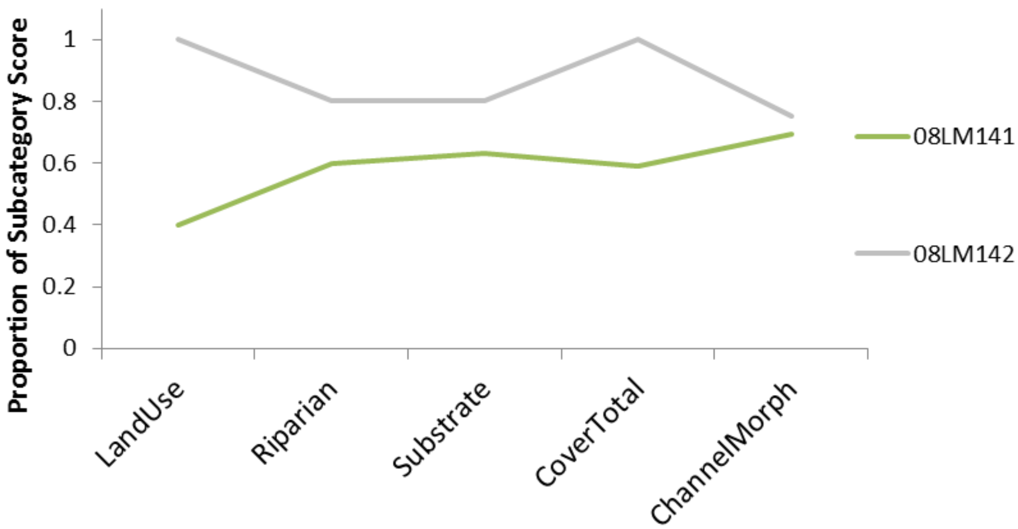


Figure 39. Components of the MSHA comparison for 08LM141 and 08LM142.

Figure 40. Biological monitoring Station 08LM141, on the downstream end.

Top Right: Biological Station 08LM041. Bottom right: Station 08LM142, showing improved substrate and cover.

Physical connectivity

No information was available or collected on physical connectivity on Camp Hayward Creek. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in Camp Hayward Creek at this time.

Strength of evidence, conclusions, and recommendations

The only stressor identified in Camp Hayward Creek is physical habitat. The reduced EPT taxa present in Camp Hayward Creek is likely due to sediment (sand) covering and limiting available riffle habitat. Also, there is higher percentage of more tolerant legless macroinvertebrates, which can thrive in these less than ideal habitat conditions.

Site visits, photographs, and aerial photography demonstrate that local land use in this area could be creating some instability in the creek resulting in an influx of sand and deposition at Station 08LM141. Upstream from the biological station there is some pasturing and lack of vegetative bank protection which may be impacting sediment (sand) deposition and subsequent habitat loss. The steep topography of this area is also a factor, and farming fields in the upstream portion of the watershed may be a source of sediment if proper erosion protection practices are not in place.

Additional work on identifying exactly which areas are contributing to instability and sediment transport in Camp Hayward Creek may be necessary. Additional chemical information could be helpful in making more concrete determinations in ruling out temperature, DO, and TSS as potential stressors. Currently, there is a fair amount of information suggesting these stressors are not present, but additional information may aid in further understanding of this system. Additionally, while nitrate is not considered a stressor because levels are low (relatively), care should be made to ensure nitrate levels do not increase over time. (i.e., Peterson Fish Hatchery Spring nitrate trends).

4.1.3. Summary of stressors in the City of Rushford-Root River

Physical habitat is the consistent stressor identified in all of these three stream reaches (Table 13). In addition, elevated TSS and nitrate are also contributing to the macroinvertebrate impairments found on the mainstem Root River.

Table 13. Stressors identified in the City of Rushford-Root River. (● = stressor (yes); o = inconclusive stressor; 'blank'-no stressor)

								Stressors:					
Reach Name	***Geo Region***	**AUID**	**Reach Description**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Impairment(s)**	**Temperature**	**Dissolved Oxygen**	**Nitrate**	**Suspended Sediment**	**Habitat**	**Physical Connectivity**
Root River	*Bluffland Karst*	07040008-520	Money Creek to South Fork Root River	2B	08LM057 04LM118	Upstream of Hwy. 76, 0.5 mi. N of Houston Upstream of Hwy. 76, 0.5 mi. NW of Houston	Invert IBI			O	●	●	
Root River	*Bluffland Karst*	07040008-522	Rush Creek to Money Creek	2B	08LM065	Adjacent to Hwy. 16, 3.5 mi. SW of Rushford	Invert IBI			O	●	●	
Root River	*Bluffland Karst*	07040008-527	Middle Branch Root River to Rush Creek	2B	08LM064 10EM079 08LM071	Upstream of Hwy. 16, 2 mi. NE of Peterson Adjacent to Hwy. 16, 2 mi. NE of Whalan Adjacent to Hwy. 16, 1 mi. NE of Whalan	Invert IB Turbidity			O	●	●	
Unnamed Creek	*Bluffland Karst*	07040008-659	T104 R8W S32, east line to Unnamed Creek	2A	08LM141	Upstream of CSAH 25, 1.5 mi. S of Peterson	Invert IBI				O	●	

4.2. Middle Branch Root River

All of the streams in this 10 digit HUC are addressed separately. One section will discuss Bear Creek, a warmwater tributary which exists in the far upland section of the Middle Branch Watershed. The next section includes the Middle Branch mainstem, which is a larger drainage towards the mouth of this watershed (Figure 41). Finally, three coldwater tributaries will be analyzed which include: Spring Valley Creek, Curtis Creek and Upper Bear Creek (Lost Creek).

The Middle Branch Root River and Bear Creek are both warmwater streams with macroinvertebrate impairments. Curtis Creek, a coldwater tributary near Wykoff, is also impaired for macroinvertebrates. This stream is not officially listed as impaired due to a use classification change (warmwater to coldwater), but is still addressed in this report. Spring Valley Creek and Upper Bear Creek (Lost Creek) are both impaired for fish and macroinvertebrates, with multiple stressors contributing to impairment.

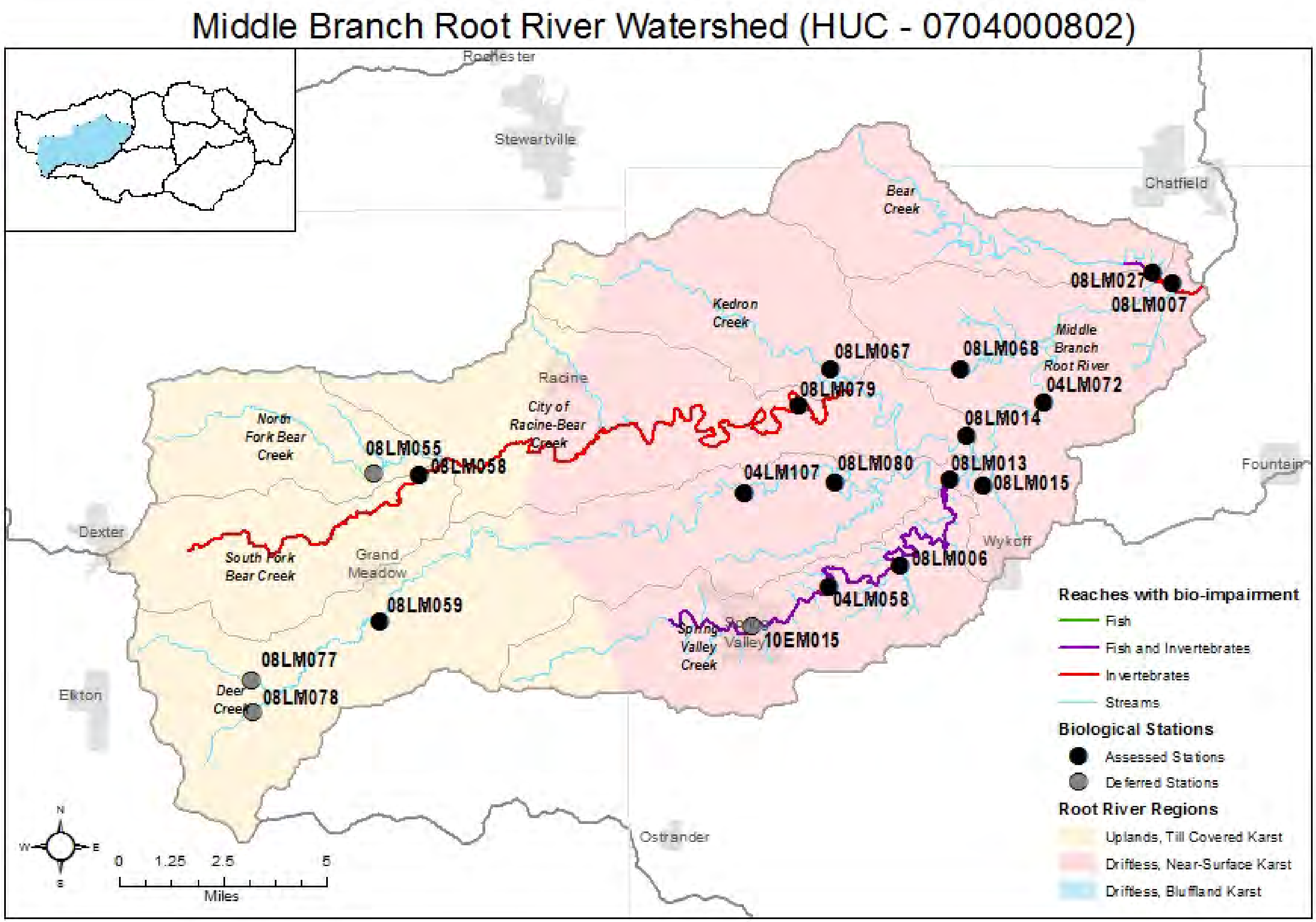


Figure 41. Map of the Middle Branch Root River watershed showing reaches of biological impairment and biological sampling locations

4.2.1. Bear Creek

Supporting information

On this stream reach, the macroinvertebrates scored below impairment threshold at Station 08LM058 and above impairment threshold at Station 08LM079. Both stations had good fish IBI scores; well above impairment threshold.

Station 08LM058 had quite low metric scores for a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), percentage of clinger taxa (ClingerChTxPct) , and taxa richness of Plecoptera (stoneflies) and Trichoptera (caddisflies; Figure 42). Station 08LM079 did have similarities in metric response although it did score better in most areas. The percentage of clinger taxa (ClingerChTxPct) was much higher offset by a lower taxa richness of climbers (ClimberCh). This station also had a better percentage of taxa with tolerance values equal to or greater than six, using MN TVs (Tolerant2ChTxPct). Taxa richness of Plecoptera (stonefiles) was also reduced similar to 08LM058. Both sites had decent scores with respect to relative percentage of insect taxa (InsectTxPct), and DomFiveChTxPct, a metric representing the relative percentage of the dominant five taxa.

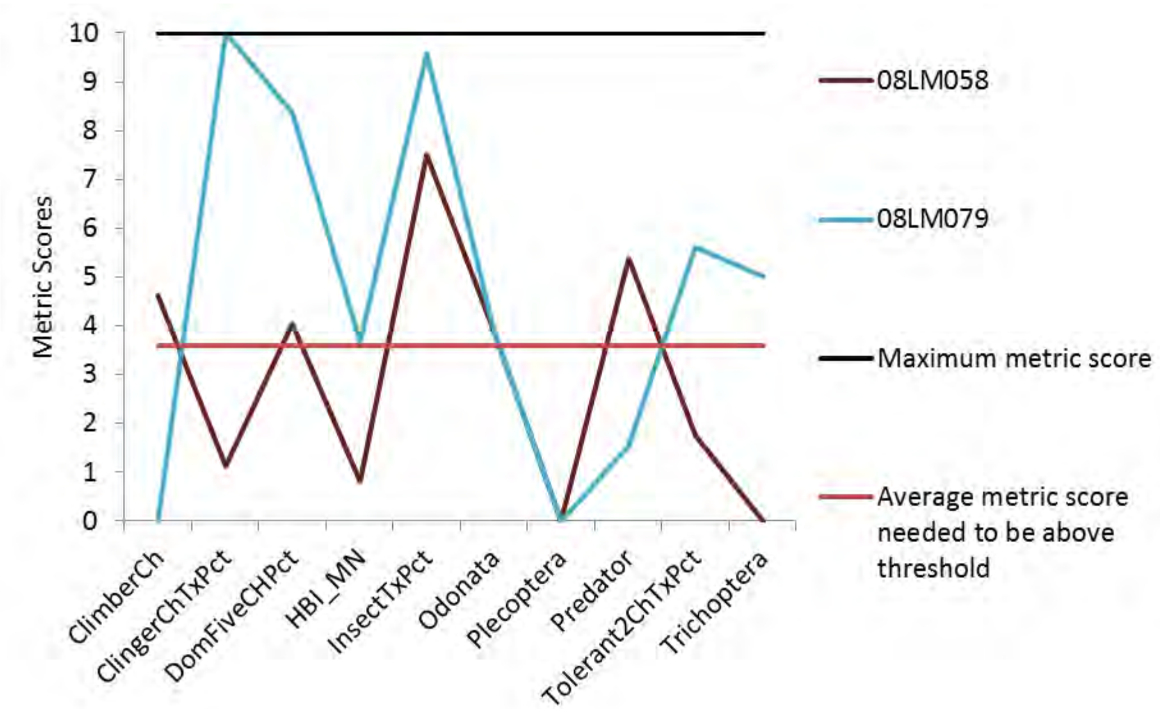


Figure 42. Metric scores for stations in Bear Creek of the Southern Streams RR macroinvertebrate IBI

Temperature

Temperature ranged in the normal range for warmwater streams in the region, 18-22°C. No additional information on temperature is available for analysis. In warmwater streams, stress is often not seen until temperature is closer to 30°C. Temperature is not considered a stressor to this reach given current information.

Dissolved Oxygen

There were two DO samples on this stream. During biological sampling, Station 08LM079 was sampled before 9:00 am, and resulted in a DO concentration of 9.44 mg/L. Station 08LM058 was sampled in the afternoon and the DO was 12.48 mg/L.

As interacting variables to DO, phosphorus and pH were compared to normal ranges and standards. The pH values collected during biological sampling on Stations 08LM079 and 08LM058 were 8.05 and 8.15, respectively. Total phosphorus concentration sampled at 08LM079 and 08LM058 were 0.065 and 0.04 mg/L. These values presented do not violate any water quality standards, and are considered within normal range.

The fish community is comprised of fish that are generally more tolerant to low oxygen concentrations. The two biological stations had DO TIV aggregate scores that were slightly lower than what is considered average for Root River fish sites (based on tolerance to low DO). The macroinvertebrate community at the two biological stations is showing a varied response. The station upstream (08LM058) had a below average macroinvertebrate DO TIV score, had 22% low DO tolerant species, and only five low DO intolerant taxa. In contrast, Station 08LM079 had an above average macroinvertebrate DO TIV score, only 5% low DO tolerant species, and a high number (14) of low DO intolerant taxa. The percentage of EPT individuals was greater than the statewide average (43.1%) for Station 08LM079; and far below statewide average for at Station 08LM058 (only 6.2%). EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux. The taxa counts are above average for both stations. Overall, the evidence suggests there is more potential upstream for DO related issues, but the data are not conclusive, and the biological response throughout the stream is mixed.

While the information is limited, the data do suggest the potential for oxygen stress to the biological community (farther upstream, near 08LM058). Without additional chemical information, a DO stressor cannot be confirmed. Additional information on DO flux and concentrations should be collected to better understand the DO regime of this stream.

Nitrate

The only data available on nitrate is from the time of fish sampling; 8 mg/L and 8.5 mg/L on July 22 and August 6, 2008. Additional nitrate information would help in understanding the range of concentrations present in Bear Creek, as they are most likely variable.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Forest RR) streams in Minnesota shows a 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

The macroinvertebrate community at Stations 08LM079 and 08LM058 had good taxa richness with 27 and 26 total taxa when the average for class 5 stations statewide is 24.2 (with chironomid and baetid taxa each treated as one taxon). However, Station 08LM058 has a low number of Trichoptera taxa (2), compared to Station 08LM079 which is above average, at 7 Trichoptera taxa. The number of intolerant taxa showed a similar trend with Station 08LM058 having only one intolerant taxon while Station 08LM079 had 6 intolerant (the average for class 5 stations is 3).

Similarly, at Station 08LM079, there were two nitrate intolerant taxa and 54.2% of the macroinvertebrate individuals were nitrate tolerant. At Station 08LM058, there were no nitrate intolerant taxa and 79.6% of the macroinvertebrate individuals were nitrate tolerant. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI, and at 68.7% nitrate tolerant individuals there is a 50% probability of meeting the MIBI.

The macroinvertebrate community suggests a potential stressor for nitrate at 08LM058, but not 08LM079. The mixed biological response between the two stations can likely be attributed to another stressor, so nitrate it is not believed to be the driver of biological impairment; however it is currently inconclusive due to the limited data. Additional information on chemistry would be useful in determining the magnitude of nitrate concentrations in this reach.

Suspended sediment

The only suspended sediment information on Bear Creek were TSS samples taken during biological sampling. Both values were low at 2.8 and 10 mg/L.

The fish communities at these two stations are doing well, and they comprised of fish which are generally intolerant to high TSS concentrations. The TSS TIV index score for fish at these stations was better than the average score for Root River warmwater stations, indicating the fish community on average is more sensitive to TSS.

The macroinvertebrate community in Bear Creek does have a fair amount of taxa and percent macroinvertebrate individuals that are tolerant to TSS (Table 14). Station 08LM058 had five out of six metrics respond poorer than the average for warmwater stations in the Root River watershed. Station 08LM079 did not show the same negative response in regard to TSS intolerant taxa, intolerant individuals, or long-lived individuals (metrics that often decrease with increased TSS stress). The macroinvertebrate TSS station index scores are in the middle of those in the Root River Watershed warmwater stations and better than the average for the watershed, but Station 08LM058 is nearer that average than Station 08LM079.

There is not enough chemical evidence to understand the range of TSS concentrations in this stream, and the biological response data is weak. More data should be collected, particularly at Station 08LM058 where the macroinvertebrate data is more suggestive of stress from TSS. At this time, a TSS stressor is inconclusive in this reach.

Table 14. Macroinvertebrate metrics relevant to TSS for stations in Bear Creek compared to averages for warmwater stations in the Root River watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long -lived Macroinvertebrate Individuals
08LM058	16.83	**0**	**11**	**39.35**	**0**	**0.93**
08LM079	16.53	5	**12**	**37.69**	0.92	4.89
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed	17.96	1.52	9.32	35.45	0.48	3.16

Physical habitat

The MSHA scores for Stations 08LM079 and 08LM058 were rated as good and fair, respectively (71.7 and 65.2). At Station 08LM058 there is erosion, but gravel and cobble do exist. The main difference in MSHA score is cover, with both sites having fairly decent substrate and channel morphology scores (Figure 43). The lowest scoring part of the MSHA at both locations is land use. In this area, the land use is 70-80% agriculture. The MSHA and subcategory scores are not greatly different (Figure 43), but the biology does show a different response between the two sites.

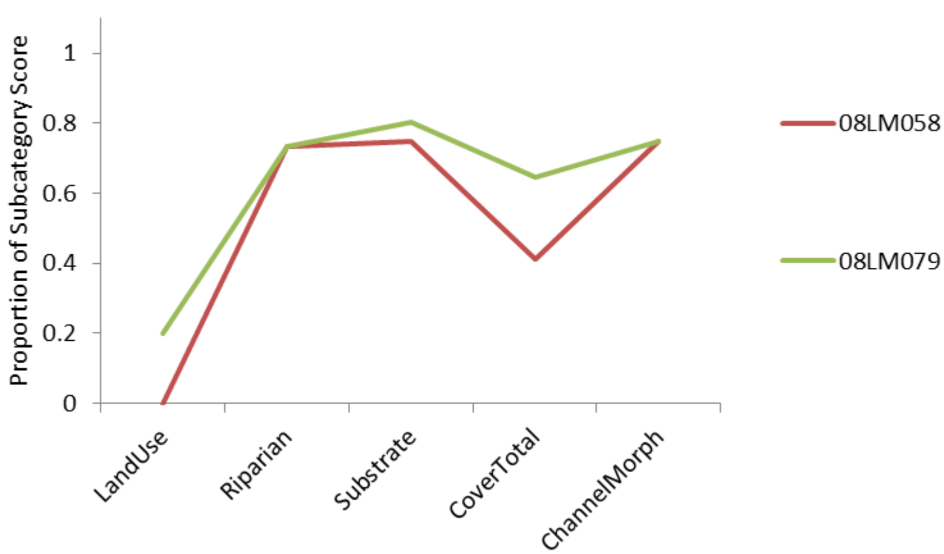


Figure 43. MSHA and subcategory scores for Bear Creek.

Station 08LM058 is farther up in the watershed where channelization is more prevalent (another station nearby-08LM055, was deferred due to channelization). Station 08LM079 is farther downstream where these impacts may be further mitigated. The macroinvertebrate habitat related metrics further confirm the difference between the two biological stations.

The two macroinvertebrate habitats sampled at Station 08LM079 were riffles and woody debris (considered the dominant habitat types). At Station 08LM058, the habitats sampled included: riffles, undercut banks/overhanging vegetation and woody debris with woody debris being the dominant habitat type.

Midges dominate the population at Station 08LM058 (top three species), where 90% of the community is made of legless macroinvertebrates. The percentage of EPT individuals was greater than the statewide average (43.1%) for Station 08LM079; and far below statewide average for at Station 08LM058 (only 6.2%). Similarly, there was an abundance of burrowers found at Station 08LM058, compared to Station 08LM079 which would suggest potential fine bedded sedimentation issues at Station 08LM058. Even though both sites had above average percentages of climbers and clingers, there was a higher percentage of macroinvertebrates that climb at Station 08LM058, and lower percentage of clingers comparatively (macroinvertebrates that are known to cling to large substrate and woody debris). This is demonstrated further in Figure 42, with IBI metric scores. The high percentage of tolerant legless insects and burrowers indicate a lack of quality, diverse habitat at Station 08LM058. This evidence points to sedimentation and overall degradation at Station 08LM058. Habitat issues do not appear to be limiting the macroinvertebrate community at Station 08LM079, as demonstrated in community composition and MIBI score. Habitat is a stressor in Bear Creek, restricted to the upper end of the reach. Habitat increases in quality when moving downstream towards Station 08LM079.

Physical connectivity

No information was available or collected on physical connectivity on Bear Creek. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not a stressor to Bear Creek at this time.

Strength of evidence, conclusions, and recommendations

The main stressor identified in Bear Creek is habitat, but is restricted to the upper end of the reach, at biological Station 08LM058. Farther downstream at Station 08LM079, there is more cover and riparian area which are aiding in better available habitat for macroinvertebrates. In addition, sedimentation and degradation is demonstrated much more at Station 08LM058 compared to Station 08LM079. It is possible that naturally the higher gradient found downstream allows for sediment movement, and that deposition upstream is degrading habitat conditions. Overall, better management of the riparian zone and stream bank erosion would be helpful in reducing overall sediment loading and subsequent embeddedness to this reach of Bear Creek. Upstream reaches of this watershed are also susceptible to impacts from channelization (other upstream biological stations considered channelized).

There is some evidence that points to potential DO, TSS, and nitrate stress at the upper Station 08LM058. Currently, there is lack of connecting information (chemical data) to conclude these stressors, but the biological community is showing some signals of stress. Additional chemical information (continuous DO) data, TSS data, and magnitude and duration of nitrate concentrations would be useful in ruling out these potential stressors.

4.2.2. Middle Branch Root River

Supporting information

Fish are doing well at Station 08LM007, but macroinvertebrates are scoring below impairment threshold, and within the confidence interval. The macroinvertebrate metrics at Station 08LM007 are characterized by a low percentage of clinger taxa (ClingerChTxPct), a low metric score for a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), reduced taxa richness of plecoptera (stoneflies), Trichoptera (caddisflies), and Predators (excluding chironomid taxa; Table 15). Also, the Tolerant2ChTxPct metric is reduced, demonstrating the site has a high percentage of generally tolerant taxa.

Table 15. Station 08LM007, in the Middle Branch Root River, macroinvertebrate metrics of the Southern Streams RR IBI; bold indicates metric score is below average metric score needed for IBI to be greater than threshold (3.6), maximum metric score possible is 10.

Site	ClimberCh	ClingerChTxPct	DomFiveCHPct	HBI_MN	InsectTxPct	Odonata	Plecoptera	Predator	Tolerant2ChTxPct	Trichoptera
08LM007	4.6	**1.3**	4.6	**0.5**	4.6	6.1	**0**	**0.8**	**1.6**	**0**

Temperature

The temperature values are within normal range for warmwater stream, and are not at a level of concern. There were 19 temperature measurements taken in 2008 and 2009, with a maximum value of 22°C. In warmwater streams, stress is not seen until temperature approaches 30°C. Temperature is not considered a stressor to this reach given the current information.

Dissolved Oxygen

The DO collected during biological sampling on Station 08LM007 was 11.63 mg/L in the afternoon on August 20, 2008. At Station S004-821, (10X site) there were 10 samples which had a DO range of 8.5-14.65 mg/L. All samples were taken after 9:00 am.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. During biological sampling, pH and TP collected at Station 08LM007 were 8.35 and 0.069 mg/L, respectively. At Station S004-821, there were 28 pH samples from 2008-2009. The pH values range from 8.0-8.52 with an average pH value was 8.225. The phosphorus values were analyzed between May and September 2008. The phosphorus values ranged from 0.038-0.274 mg/L, with an average of 0.0785 mg/L. In 2008, a site was sampled four times in the Middle Branch of the Root River three miles south of Chatfield. The results from the chlorophyll-a analysis ranges from 1.39 ug/L to 2.75 ug/L.

The fish community is comprised of fish that are generally more tolerant to low dissolved oxygen concentrations. The biological station has DO TIV aggregate score that is slightly lower than what is considered average for Root River fish stations (in terms of tolerance to low DO).

Macroinvertebrates show a similar signal. The macroinvertebrate community DO TIV aggregate score was also near average for the Root River. There were nine taxa collected at 08LM007 which are considered intolerant to low DO, which is average for the Root River. The percentage of EPT individuals was also near average for this stream class. EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux. The macroinvertebrate community at Station 08LM007 has good taxa richness with 27 total taxa when the average for class 5 stations in the LMB which is 23.67 (with chironomid and baetid taxa each treated as one taxon).

The biological data do not have a strong signal either way, with a very weak response for both fish and macroinvertebrates. More data should be collected to determine DO flux and concentrations. Given the current information, DO is not considered a stressor at this time.

Nitrate

At time of fish sample at Station 08LM007, the nitrate concentration was 5.7 mg/L, on August 20, 2008. At monitoring Station S004-821, collocated with Station 08LM007, the nitrate concentration had an average of 6.0 mg/L and ranged from 4.8 to 9.4 mg/L, from 10 samples taken in 2008. The maximum concentration, of 9.4 mg/L, was on June 10, 2008 (storm event; subsequent tile flow likely).

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Forest RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

The macroinvertebrate community at Station 08LM007 has good taxa richness with 27 total taxa when the average for class 5 stations in the LMB which is 23.67 (with chironomid and baetid taxa each treated as one taxon). However, it is low on Trichoptera taxa (two) and for intolerant taxa (zero).

At Station 08LM007, there were no nitrate intolerant taxa and 80% of the macroinvertebrate individuals were nitrate tolerant. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI. The macroinvertebrate community suggests a stressor for nitrate, with a lack of chemical information.

Suspended sediment

During fish sampling at Station 08LM007, the TSS concentration was 7.6 mg/L. At monitoring Station S004-821, the TSS concentration had an average of 28.0 mg/L from 10 samples taken in 2008. The maximum concentration was recorded on June 10, 2008, at 170.0 mg/L, which corresponds to a storm event. The remaining values were all 30.0 mg/L and lower. No other chemical data were available for analysis on this stream reach.

While the fish community at this station is doing well, they are comprised of fish generally more tolerant to high TSS concentrations. The TSS TIV index score for fish at this station is in the most tolerant quartile compared to other warmwater stations in the Root River, indicating a TSS tolerant community overall. In addition, the percent carnivore metric is lower than average (only 10% at Station 08LM007), which also supports a potential TSS issue. The percent carnivore metric have been shown to correlate with TSS concentrations.

At Station 08LM007, there were no intolerant macroinvertebrates and less than 3% long-lived macroinvertebrates, which often decrease with increases in TSS. The macroinvertebrate index score for

TSS was 20.86, worse than the average for warmwater stations in the Root River watershed (17.96). The station at the time of sampling had 15 taxa tolerant to TSS and none intolerant to TSS. Both of these metrics reveal conditions less than desirable compared to averages of warmwater stations in the Root River. The survey had 61% of the individuals in the survey considered tolerant to TSS; the average for warmwater stations in the Root River is 35.45%. The macroinvertebrate community data suggests that TSS is a likely stressor at this location.

While there is a lack of chemical information, both fish and macroinvertebrate communities signal a TSS stressor. More chemical information would help understand sediment dynamics in this system, and help confirm if a TSS stressor is present or not.

Physical habitat

The MSHA score at Station 08LM007 was considered fair (52). The MSHA score was lacking in land use and cover categories. The macroinvertebrate habitat sampled at this location were riffles, undercut banks/overhanging vegetation and woody debris. The flow was noted as slow and the stream was wide, which may be impacting substrate related habitat (Figure 44).

There was not an abundance of burrowers found (6.7%), which would suggest potential sedimentation issues in riffle habitat. The percentage of EPT individuals was near average for this stream class. Additionally, there was a high percentage of macroinvertebrates that climb (31% compared to the average of 9.5%). The macroinvertebrates known to cling to large substrate and woody debris were below average for this stream class (only 18.7% compared to statewide average of 43.1%). This is demonstrated further in Table 15, where the clinger IBI metric scored below the average needed to be above the IBI threshold. The percentage of legless macroinvertebrates was slightly higher than average at 49.5%, which show a shift in generally tolerant species present. The higher percentage of more legless macroinvertebrates, with a shift to more climbers and less clingers is a result of habitat stress in this reach, and may be indicative of poor quality substrate.

Figure 44. Station 08LM007, middle of reach, looking upstream.

Physical connectivity

No information was available or collected on physical connectivity on the Middle Branch Root River. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in the Middle Branch Root River at this time.

Strength of evidence, conclusions, and recommendations

The stressors identified in this reach are nitrate and habitat. The macroinvertebrate individuals present here are very tolerant to high nitrate. However, additional chemical information would help understand the potential magnitude and duration of nitrate in this reach.

Habitat is the stressor in the Middle Branch Root River; however, the strength of the evidence is rather weak. It appears that based on site photos, the stream has over widened, which may be playing a role in habitat issues and loss of quality substrate.

Additional understanding of TSS and DO dynamics would be useful in understanding potential issues in the Middle Branch Root River. TSS appears to be a potential stressor at this time, due to stream bank erosion and upstream channelization. There is simply a lack of connecting chemical information to make conclusions on these stressors at this time.

4.2.3. Spring Valley Creek

Supporting information

Both fish and macroinvertebrates are scoring below impairment thresholds at Stations 04LM058 and 08LM006. All macroinvertebrate metrics, of the Southern Coldwater IBI, were below the average metric score needed to be above the threshold at Station 08LM006 (Figure 45). Those that were most severe in response were the CBI, ratio of chironomid abundance to total dipteran abundance (ChiroDip), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs (Intolerant2Ch), and relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct).

The two upstream stations on this reach (04LM059 and 10EM015) have better metric scores related to the CBI metric, and VeryTolerant2Pct metric. These scores indicate better numbers of coldwater macroinvertebrate individuals and fewer tolerant individuals at these locations compared to Station 08LM006, which has a very low CBI score.

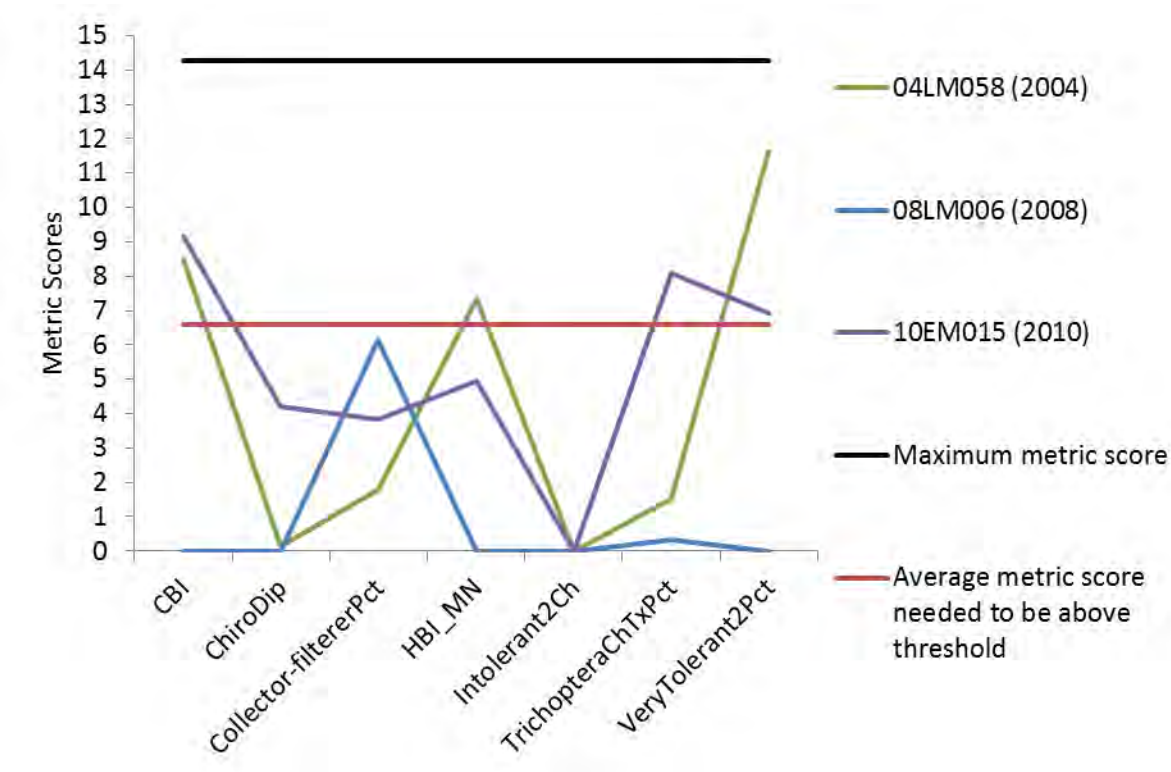


Figure 45. Metric scores for stations in Spring Valley Creek of the Southern Coldwater macroinvertebrate IBI.

The fish IBI metrics also show a consistent response throughout Spring Valley Creek. The fish community had a lack of sensitive coldwater individuals (CWSensitivePct_10DrgArea), lack of native coldwater individuals (NativeColdPct and NativeColdTxpct_10DrgArea). At the two downstream Stations (04LM058 and 08LM006) there was an abundance of taxa where detritus constitutes at least 5% of their diet, represented by the SdetTxPct_10DrgArea metric (Figure 46).

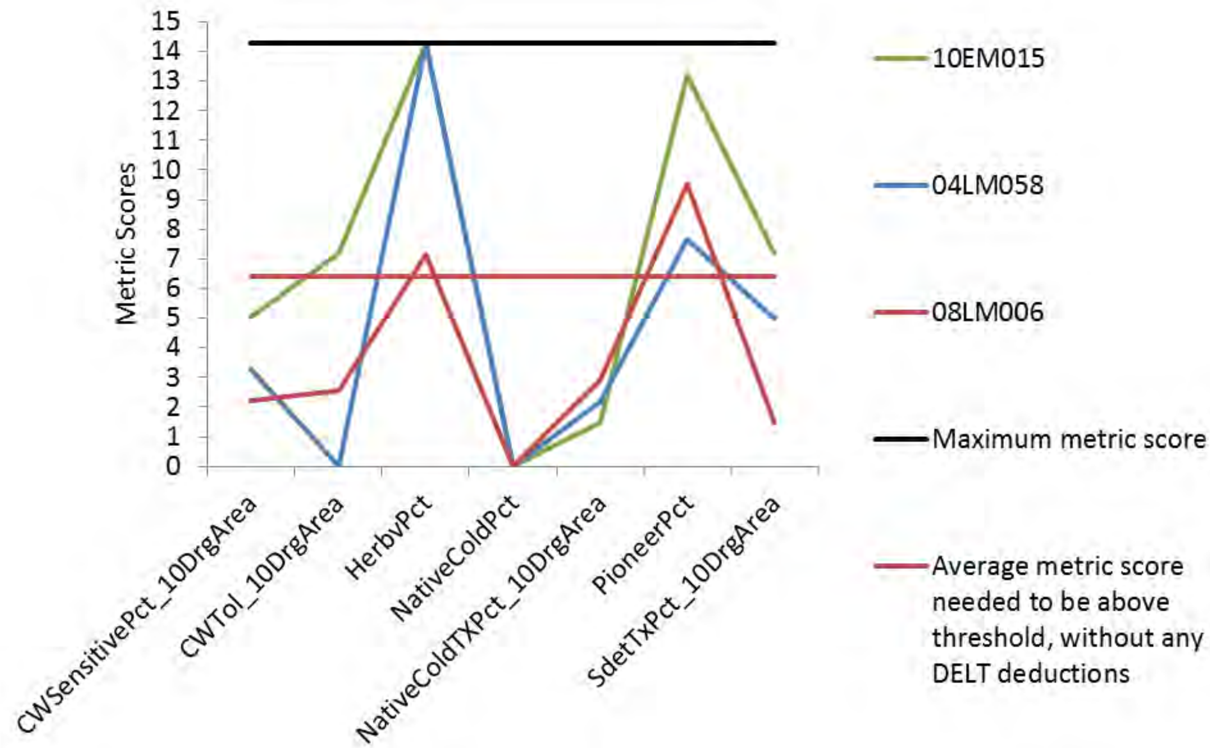


Figure 46. Fish IBI metric scores (Southern Coldwater IBI) for 3 stations in Spring Valley Creek.

Temperature

Temperature data found in Spring Valley Creek had a total of 231 records at multiple locations. The temperature range was between 3°C and 22°C. Excluding other data beyond July and August, the range is 13°C to 22°C. A multiparameter sonde was deployed in 2011, July 25 – August 4 and August 5-18, and had a temperature range of 14.8°C to 23.4°C.

MDNR had high resolution temperature data from 2006 at multiple sites in Spring Valley Creek. These data show some peak temperatures at MDNR Station 5.95, which corresponds to MPCA biological site 08LM006. The temperatures in this part of the stream were near 24°C, similar to what was seen in 2011.

The fish communities present at the sites in Spring Valley Creek show a downward trend in the percentage of coldwater fish species present when moving downstream. At station 10EM015 in the city of Spring Valley the percentage of coldwater fish species was near average, at 39%. However, both Stations 04LM059 and 08LM006 were well below average in the number of coldwater fish species present (5.6 and 7.1%, respectively). In addition, the coldwater macroinvertebrate individuals appear to be suffering most at the farthest site downstream, 08LM006. The CBI metric scored zero, while the other two sites did score fairly well, as shown in Figure 45.

Elevated stream temperature was identified as a limiting factor for trout in previous surveys (1945, 1959 and 1987). A general lack of shade was a suggested cause of high maximum water temperatures. Based upon the maximum recorded temperatures in 2006, shade remains a potential limiting factor that could be addressed through various riparian management techniques. Importance of riparian shade in maintaining cold water temperatures is increasing, as global temperature appears to be warming. Low coldwater IBI scores and low number of obligate coldwater species support the contention that water temperatures are a limiting to coldwater fishes in Spring Valley Creek.

According to the MDNR 1998 Management Plan, the private trout hatchery has two ponds (mile 11.17 and 11.20) which discharge at 3.40 cfs and 1.00 cfs into Spring Valley Creek. Water temperature increases from 48°F at the spring to 55°F after flowing through the ponds. This spring would be contributing 3.40 cfs of water at 48°F if the trout ponds were not present. The location of this hatchery is shown in Figure 47. The percentage of the time in the summer Spring Valley Creek is above 19°C increases when moving downstream, with the exception of the coldwater tributary input (Mahoods Creek). Downstream of Mahoods Creek confluence, the temperatures are reduced again. The location with the largest percentage of time above 19°C is Station 5.95 or 08LM006 (Figure 47).

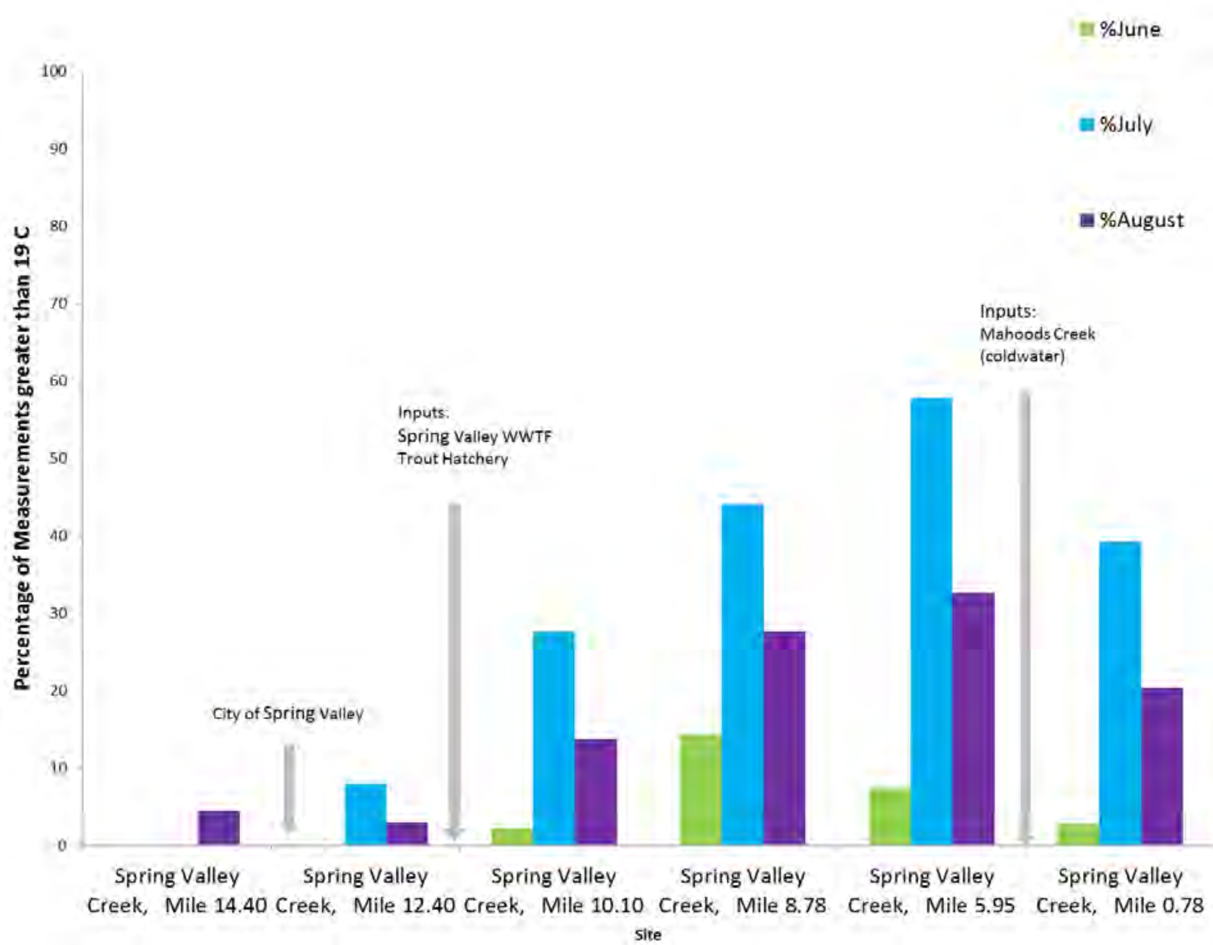


Figure 47. Spring Valley Creek percent temperature measurements above 19°C with geographical and input consideration (MDNR continuous temperature data from 2006).

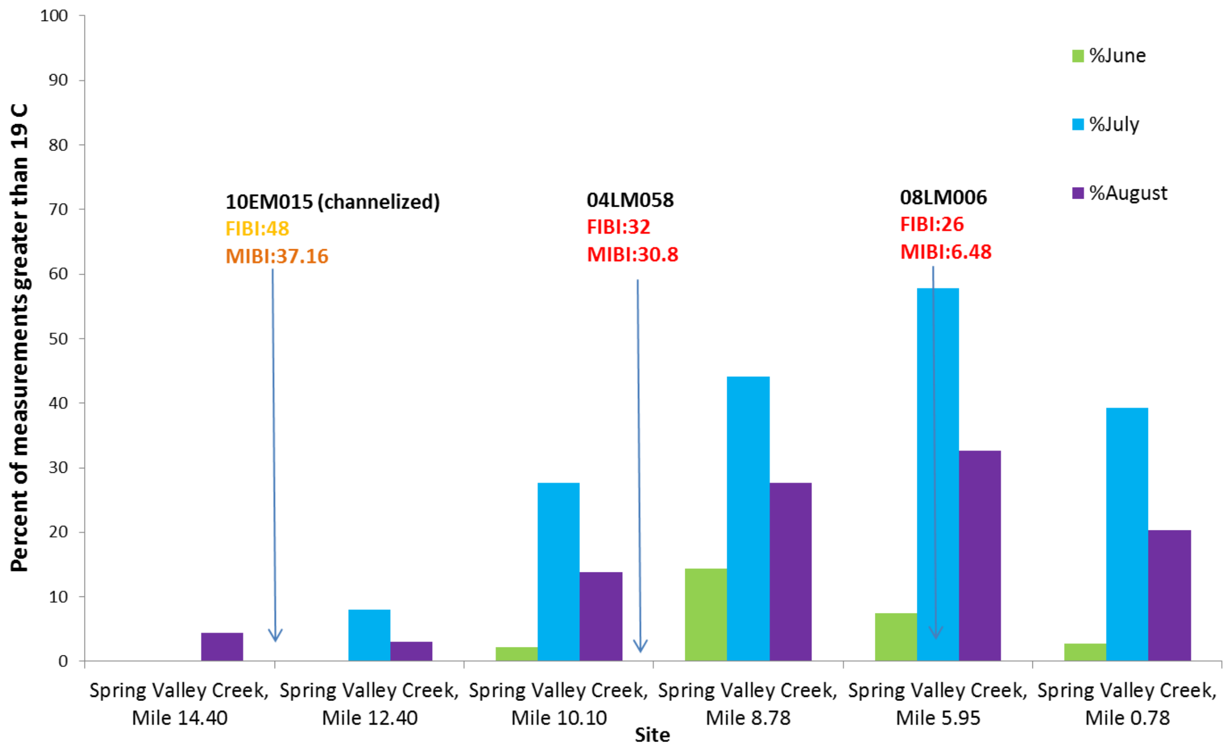


Figure 48. Spring Valley Creek percent temperature measurements above 19°C with biological information at multiple stations along the creek, for all summer months (MDNR continuous temperature data from 2006).

The information shown in Figure 49, Figure 50, and Figure 51 shows the duration which the chronic temperature thresholds for trout are exceeded for some period of time. Based on a seven day moving average, site 5.95 was above the Brown Trout chronic temperature threshold during the time periods of July 15 - August 10, 2006 (approximately 26 days). Site 8.78 was above the Brown Trout chronic temperature threshold during the time periods of July 16 - 22, 2006 (approximately six days) and again July 29 - August 6, 2006 (approximately nine days).

Based on the continuous data and biological data, temperature is limiting the biological communities in Spring Valley Creek.

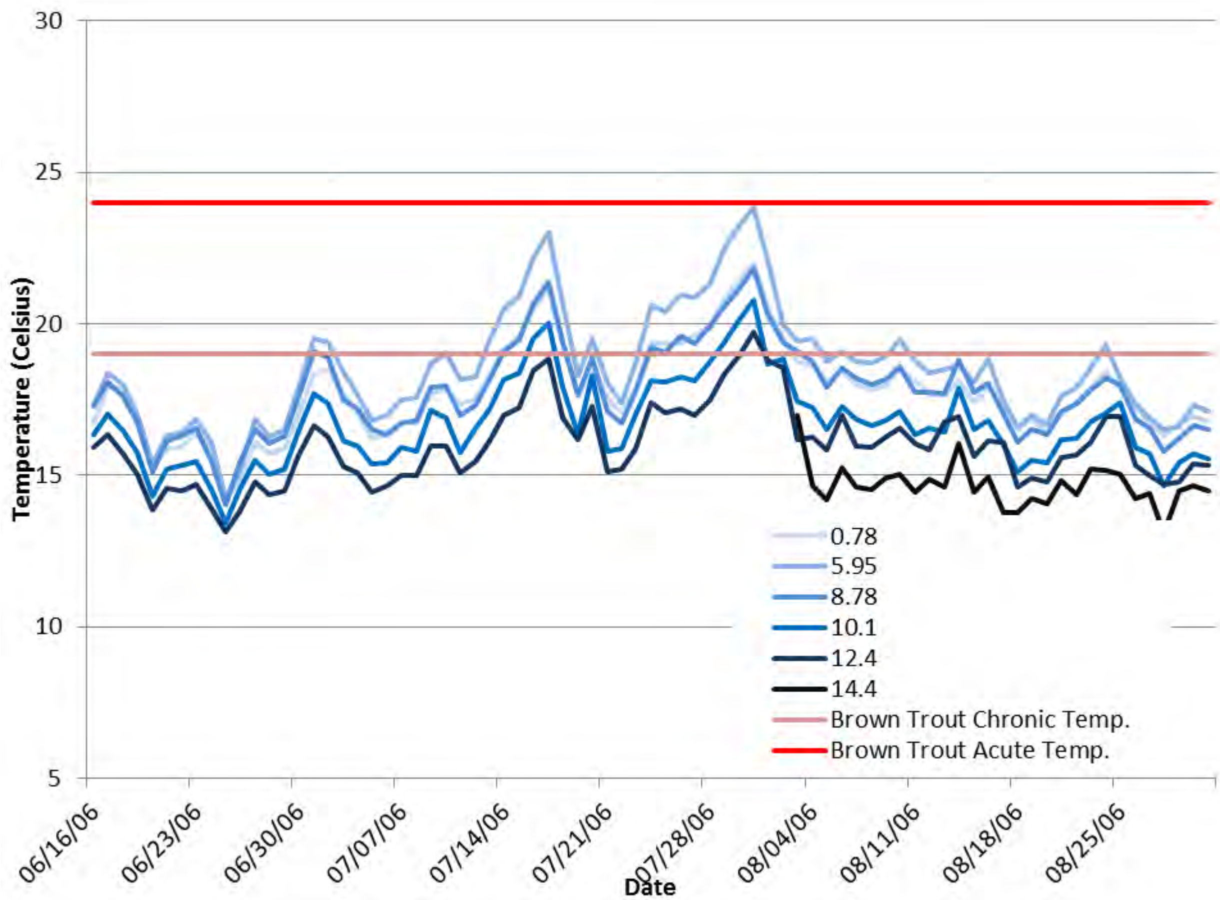


Figure 49. Spring Valley Creek continuous temperature measurements at multiple locations June-August 2006 (MDNR data).

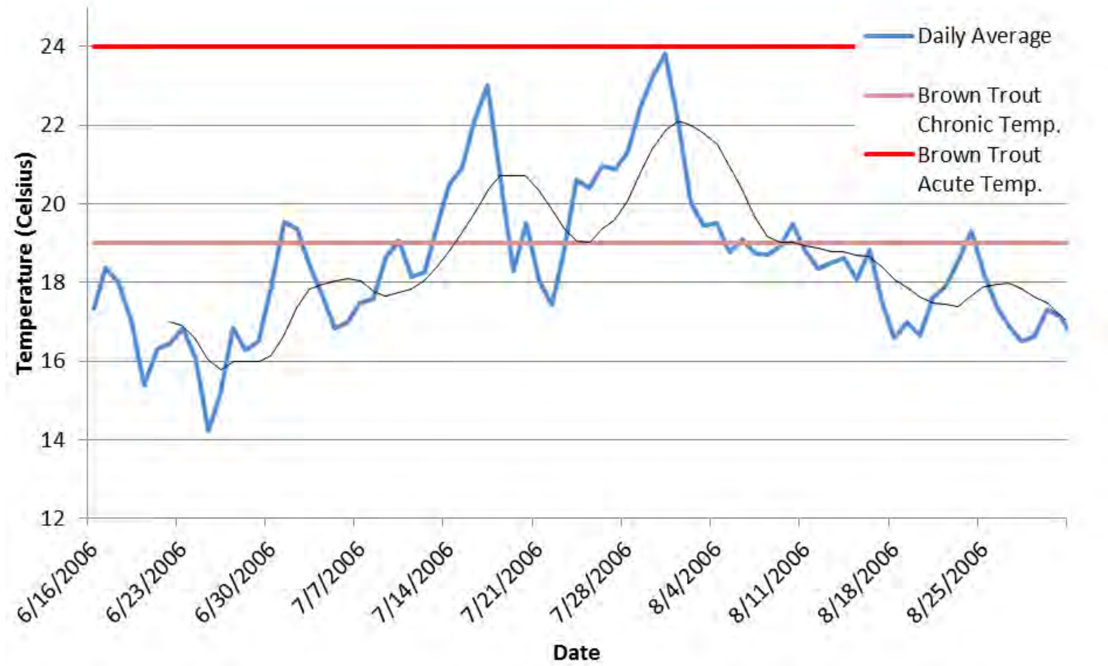


Figure 50. MDNR Station 5.95 (at 08LM006), daily average temperature with weekly average temperature.

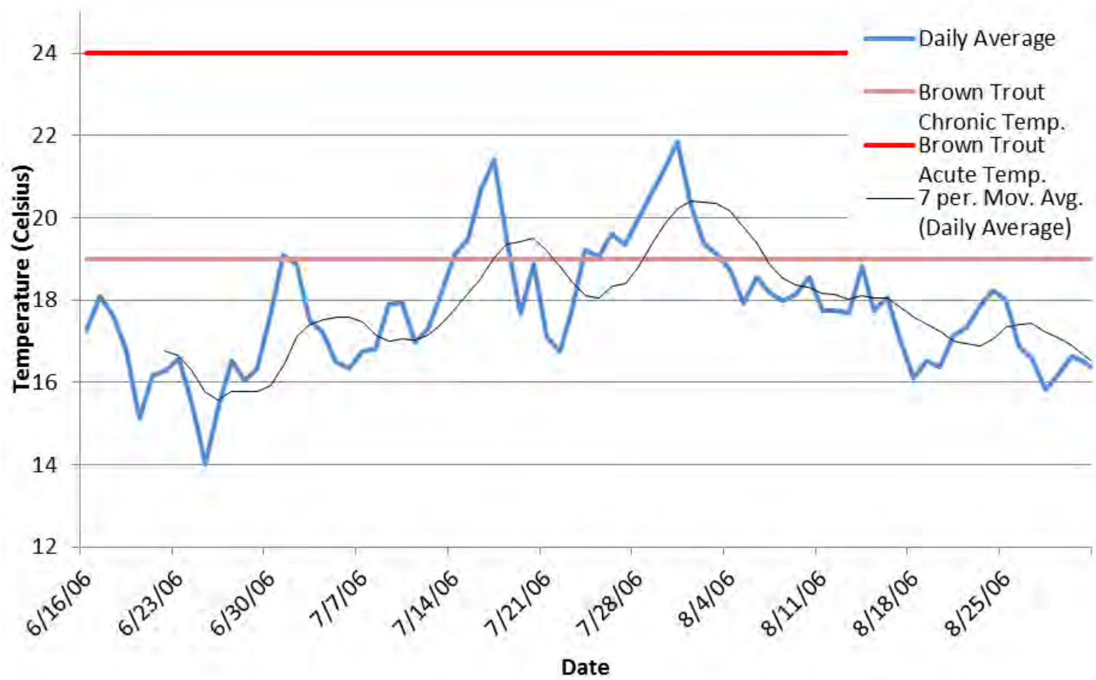


Figure 51. MDNR Station 8.78 (near 04LM058) daily average temperature and weekly average temperature.

Dissolved oxygen

At all three sites the DO concentration measured during biological sampling ranged from 9-10.0 mg/L. Thirteen synoptic samples were collected in 2008 and 2011, with a DO range from 8.3-15.06 mg/L. No samples were taken before 9:00 am A multiparameter sonde was deployed in 2011 at Station 08LM006. The range of DO was from 6.75 mg/L to 11.0 mg/L (July 25 - August 4, 2011 and August 5 - 18, 2011). The daily DO flux was about 4.0 mg/L on most days. On July 31, the stream dipped below the DO standard (7 mg/L) for 7 hours. On August 7, the standard was violated again for a four hour period in the early morning hours.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH values collected during sonde deployment ranged from 7.89-8.51. Station S000-769 was sampled 10 times between May and September 2008 for TP and pH. The pH range of values collected at the site was 7.8-8.5. Total phosphorus concentrations ranged from 0.052-0.184 mg/L, with an average value of 0.121 mg/L.

In 2008, four different sites were sampled in Spring Valley for Root River Watershed Monitoring. The results for the chlorophyll-a ranged from 1.8 µg/L to 1.32 µg/L. In 2004, one sample was collected and analyzed for BOD and measured 0.5 mg/L.

The fish community is made up of a mix of tolerant and sensitive individuals to low DO as shown in Figure 52. The more tolerant species appear to increase in abundance when moving downstream to Station 08LM006. All of the biological stations have fish DO TIV aggregate scores which are below normal for the Root River, but not in lowest 25%, however.). Percent of sensitive fish exhibit a strong negative response to increasing TP and DO flux (Minnesota Nutrient Criteria Development for Rivers, 2013). The percentage of sensitive fish in Spring Valley Creek is below average at all sites compared to other coldwater stations in the Root River. The average percentage of sensitive fish for coldwater stations in the Root River is 60%, and Spring Valley Creek ranged from16 - 39%, with the lowest found at 08LM006. However, there are a number of fish sensitive to low DO found in these streams as well, as shown in blue in Figure 52. The more sensitive species found in Spring Valley Creek include trout, fantail darter, and southern redbelly dace.

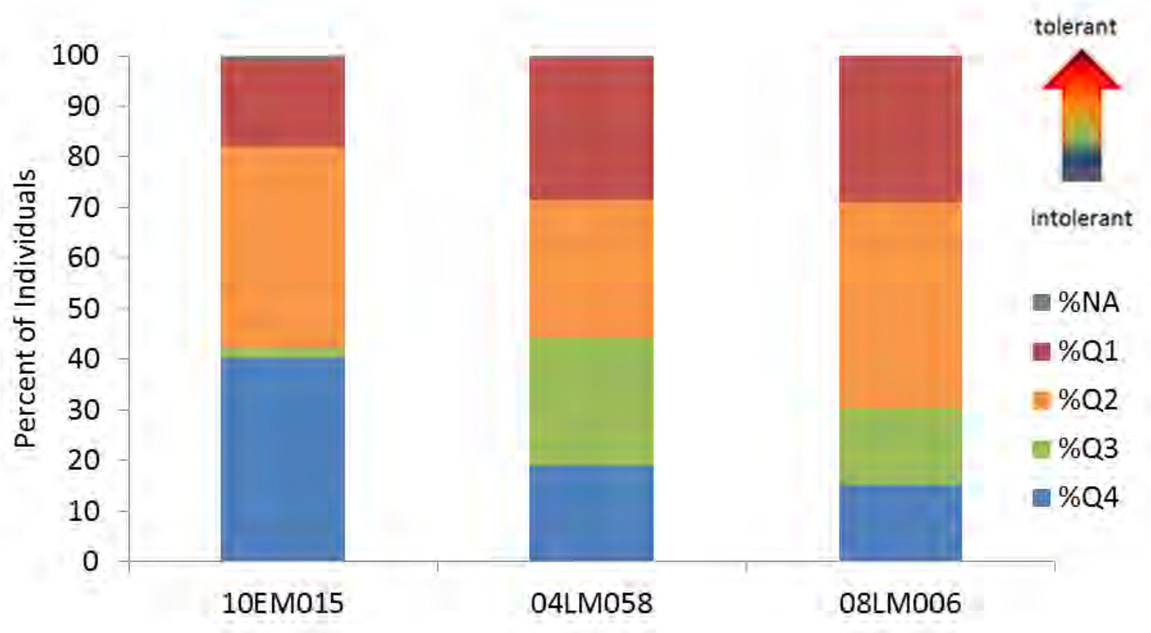


Figure 52. Fish community tolerance to low DO at three stations in Spring Valley Creek.

The macroinvertebrate community at the three biological stations shows mixed tolerance to low DO. The upstream Station 04LM057 had a DO TIV macroinvertebrate index score better than average compared to all Root biological stations. The lowest Station (08LM006) had a DO TIV index score below average, in the lowest quartile for Root River biological stations. This score suggests a more tolerant community is present at that site. The number of low DO intolerant taxa is considered average for all three biological stations. The percentage of macroinvertebrates tolerant to low DO at the biological stations was better than average (only 2-3%) in the upstream stations, and the farthest downstream station had more tolerant individuals (5%). EPT are typically intolerant of low DO levels. The percentage of EPT taxa is reduced below average at Station 08LM006, but well above average at Station 04LM058. Taxa richness can also be decreased with increases in DO flux. The macroinvertebrate surveys in Spring Valley Creek in had taxa counts from 16 to 27 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the Southern Coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Station 04LM058 had the lowest taxa count in 2004, with the other two Stations (08LM006 and 10EM015) having better than average taxa counts.

The chemical data in Spring Valley Creek do show slight exceedence of the DO standard (7 mg/L), yet the biological response is not conclusive. In addition, some limited data on phosphorus does suggest some elevated average concentrations, but the dataset is small. DO flux is slightly higher than the recommended river eutrophication criteria for the “Central” region (3.5 mg/L). The fish and macroinvertebrates present do not show a strong tolerance to low DO, but there are mixed results. The farthest downstream site, 08LM006, does seem to be most impacted (Figure 52). This location is also plagued with other issues, including local land use (pasturing) and potential temperature and habitat problems that the other site locations are not demonstrating. More information on DO dynamics (diurnal DO) throughout the creek would be useful in assessing this stressor. In addition, more information on TP levels and chlorophyll-a throughout the creek would be helpful. A DO stressor cannot be confirmed at this time, due to mixed biological response, inconclusive chemical datasets, and difficultly sorting out the cumulative stressor impacts, especially at 08LM006.

Nitrate

During biological sampling at the three biological sites, the nitrate concentrations ranged from 9-14.0 mg/L. When comparing other monitoring sites in the Spring Valley Creek Watershed, concentrations ranged from 6.5-13.0 mg/L. There were 16 samples total; 10 from 2008 alone. While the data were not strong enough to provide support for a drinking water impairment listing, the values were very near the impairment threshold of 10.0 mg/L. As seen with other coldwater streams in this area, high nitrate concentrations are persistent during baseflow conditions.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern coldwater macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12.0 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6.0 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in Spring Valley Creek had taxa counts from 16 to 27 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the southern coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Station 04LM058 had the lowest taxa count in 2004, with the other two stations having higher than average taxa counts (2008 and 2010). There were no intolerant taxa in Spring Valley Creek.

There were three Trichoptera taxa at Stations 04LM058 and 08LM006, and five Trichoptera taxa at Station 10EM015. The Trichoptera taxa in Spring Valley Creek comprised of 6.7 to 16.2% of the total taxa (TrichopteraChTxPct). The resulting very low metric scores for Stations 04LM058 and 08LM006; less than the average metric score needed to be at the southern coldwater MIBI threshold. Station 10EM015 had higher TrichopteraChTxPct metric scores in 2010. Utilizing quantile regression analysis for stations in the southern coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Spring Valley Creek, the HBI_MN metric score ranged from 0 to 7.3 (out of 14.3). Station 04LM058 was the only station to not fall below the average metric score needed to be at the southern coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. The HBI_MN values in Spring Valley Creek ranged from 6.74 to 8.03. All HBI_MN values were greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the southern coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10.0 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Nitrate tolerant taxa ranged from 19 to 26 in Spring Valley Creek (73.4 to 92.4% individuals), and 14 to 18 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the southern coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the southern coldwater MIBI. There were no nitrate intolerant taxa present in Spring Valley Creek.

The abundance of nitrate tolerant taxa, lack of nitrate intolerant taxa, along with low metric scores at for HBI_MN and TrichopteraChTxPct, show that the macroinvertebrate response to the elevated nitrate is present. Nitrate is high in Spring Valley Creek and is playing a role in stressing this degraded macroinvertebrate community.

Suspended sediment

During biological sampling, TSS sample results showed low concentrations. The three biological stations had results which ranged from 1.2 mg/L- 5.6 mg/L. There were a total of 11 chemistry samples from three different locations taken in 2004 and 2008. The average TSS concentration of those samples is 7.0 mg/L. There was one sample above 10.0 mg/L, which was taken on June 10, 2008, at 42.0 mg/L. The chemical information presented shows a general trend of low TSS during baseflow conditions, with elevated concentrations during events. This is considered normal and typical for streams in the driftless area.

The fish community present at all three biological stations does show some tolerance to high TSS, but also some sensitive species are present as well, as demonstrated in Figure 53. The most abundant fish found at Station 08LM006 was white sucker at 409 individuals. White sucker is fairly tolerant to high TSS concentrations. White sucker was also the most abundant fish individual captured at Station 10EM015. Conversely, the most abundant fish found at Station 04LM058 was the blacknose dace, a species which is considered very sensitive to high TSS. The percentage of carnivores, which shows a correlation with TSS, shows a decreasing trend when moving downstream, suggesting a potential increase in TSS stress. The farthest upstream station had 40% carnivores, which is near average for coldwater stations in the state. At Station 08LM006, which is farthest downstream, carnivores decrease to 14%, which is below statewide coldwater fish class average of 47%. The middle Station, 04LM058, was also below average for carnivores, at 24%. At this time, the fish community present at all three locations does not provide strong evidence for a TSS stressor.

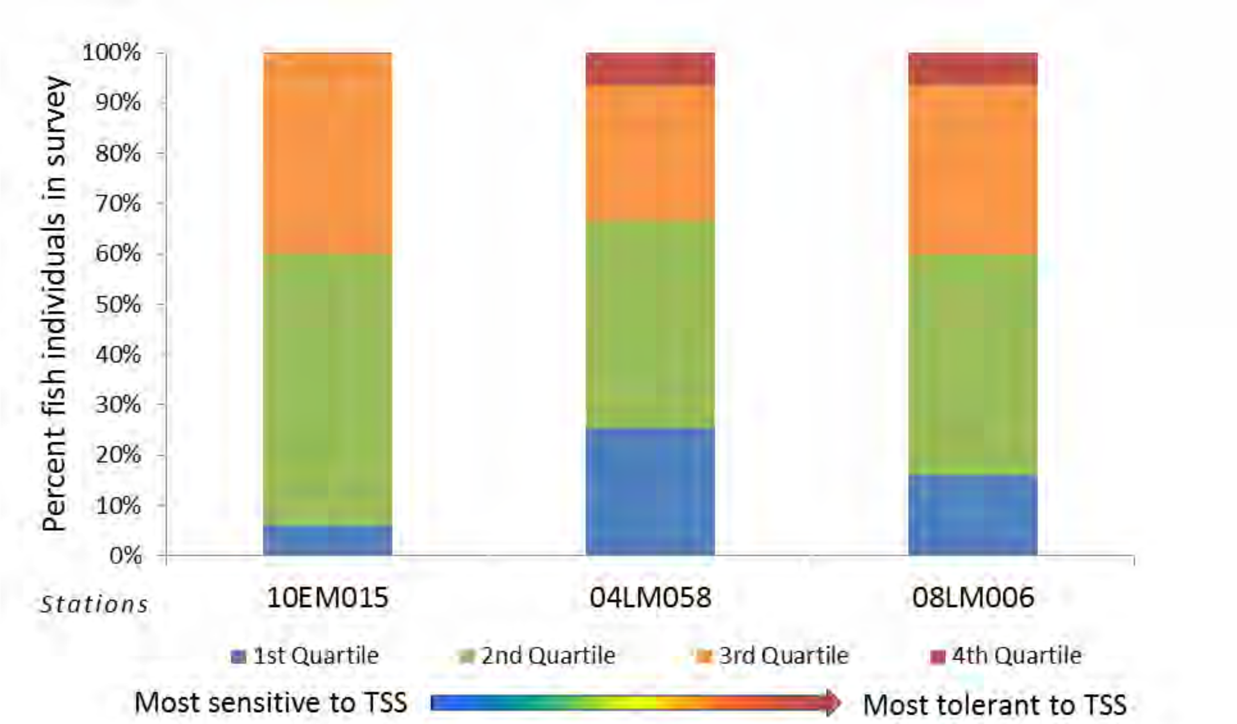


Figure 53. Fish TSS TIVs for three biological stations in Spring Valley Creek.

In Spring Valley Creek, the macroinvertebrate TSS station index scores generally worsen longitudinally downstream, yet these samples were taken in various years and may show variability due to differing conditions among those years (Table 16). All surveys resulted in the finding of no TSS intolerant taxa and a high percentage of TSS tolerant macroinvertebrate individuals. Station 10EM015 had no generally intolerant macroinvertebrate individuals and had few long-lived macroinvertebrate individuals. Station 08LM006 had a higher percentage of both intolerant and long-lived individuals. The macroinvertebrate community in Spring Valley Creek may be influence by elevated TSS, but the evidence is not overwhelming, and it is likely that other stressors are contributing to the degraded condition.

Table 16. Macroinvertebrate metrics relevant to TSS for stations in Spring Valley Creek compared to averages for coldwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long -lived Macroinvertebrate Individuals
10EM015 (2010)	**15.14**	**0**	3	**10.4**	**0**	**0.31**
04LM058 (2004)	**15.92**	**0**	**6**	**13.26**	**0**	2.42
08LM006 (2008)	**17.6**	**0**	**12**	**27.81**	10	10.7
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River watershed	15.13	0.99	4.38	9.94	0.95	1.23

Physical habitat

The MSHA scores for both stations on Spring Valley Creek resulted in a fair score. Station 04LM058 was characterized as having light embeddedness, and multiple substrate types (riffles made of gravel). Station 08LM006 had little to no shade, no riparian buffer, and heavy bank erosion (i.e. heavy grazing). Undercut banks, deep pools, and overhanging vegetation were present, but it was considered sparse (5-25%).

Both Station 08LM006 and 04LM058 had a fish community fairly rich in riffle dwelling fish (40.47 and 33.33%), non-tolerant benthic insectivores (17.86 and 25.79%), simple lithophilic spawners (60.54 and 39.62%), and darter, sculpin and round bodied suckers (16.47 and 18.87%). These habitat related fish metrics were all well above averages for stations statewide and stations in the southern coldwater fish class. The percentage of lithophilic spawners is also better than average and close to average compared to other southern coldwater fish stations statewide. However, tolerant white suckers dominate the fish community found in Spring Valley Creek (409 individuals at Station 08LM006), and this one species makes up large percentage of many of these metrics. The next most abundant fish found at Station 08LM006 was the common shiner, with 284 individuals present. The most abundant fish species found at 04LM058 were blacknose dace, white sucker, brook stickleback, and creek chub.

Piscivores were found in reduced percentages at both locations in comparison to other sites in the southern coldwater fish class average of 37% (5.6 and 7.1%, at Stations 04LM058 and 08LM006 respectively). In addition, the percentage of pioneer species was higher than average for the Southern Coldwater fish class which are species that can thrive in instable environments. This is further reinforced by a high percentage of tolerant fish species in Spring Valley Creek in comparison to other coldwater sites (53 and 67% classified as tolerant).

The macroinvertebrate habitats sampled at both locations included riffle/run/rock, undercut bank/overhanging vegetation, and aquatic macrophytes. The percentage of EPT taxa is below average at

Station 08LM006, but well above average at Station 04LM058. The percent of burrowers, macroinvertebrates that climb and cling, were all below the coldwater average at Station 04LM058, but near average or above average for Station 08LM006. The percentage of more tolerant legless macroinvertebrates is high at both locations. It appears that varying habitat factors are potentially limiting the communities found at these two locations.

From MDNR 1998 Management Plan: "Instream cover is limited in much of the stream. Overhanging vegetation and occasional logjams are the dominant cover types. Pools often lack cover. Poor access to the stream limits development of instream cover. Beaver dams have degraded trout habitat by causing sedimentation in pools."

The MDNR collected stream geomorphology classification information in 1997. The agency did this for five sites in 2006 (Figure 54). At Station 5.95, which is also at MPCA biological Station 08LM006, the channel was classified as a C4, a riffle/pool reach with a well-developed floodplain, meanders, and point bars, with gravel riffles. Riparian lands were heavily grazed and bank erosion was considered significant. The width to depth ratio (44.1) was the highest measured among the five sampling stations, indicating that it is overly widened. An approximately 150 foot-long section of the station was divided into two channels by an island in the center of the stream. Upstream from the station boundary, the stream also exhibits traits of a braided channel. Therefore Station 5.95 may be moving towards a D4 classification; multichannel stream. At the stations farther upstream and downstream was a mix of B and C channel types. Station 14.14, farthest upstream, was also classified as a C4c channel but appears very dissimilar to Station 5.95. Therefore Station 5.95 may very well be transitioning from a C4 channel to a D4 channel, due to the over widening and lack of stream power to move sediment. Overall, the most striking differences longitudinally were the smaller size of the stream in Station 14.14, and the large differences in bankfull width, width/depth ratio, and flood-prone width in Station 5.95 (i.e. 08LM006). The channel is quite unstable within and upstream from the station for an additional 1,000 feet. The instability was noted as a result from over-grazing of the riparian zone.

Based on the fish and invertebrate response, along with physical data on geomorphology and MSHA, habitat is a stressor to Spring Valley Creek. Stream instability appears limiting the biological community, especially at 08LM006.

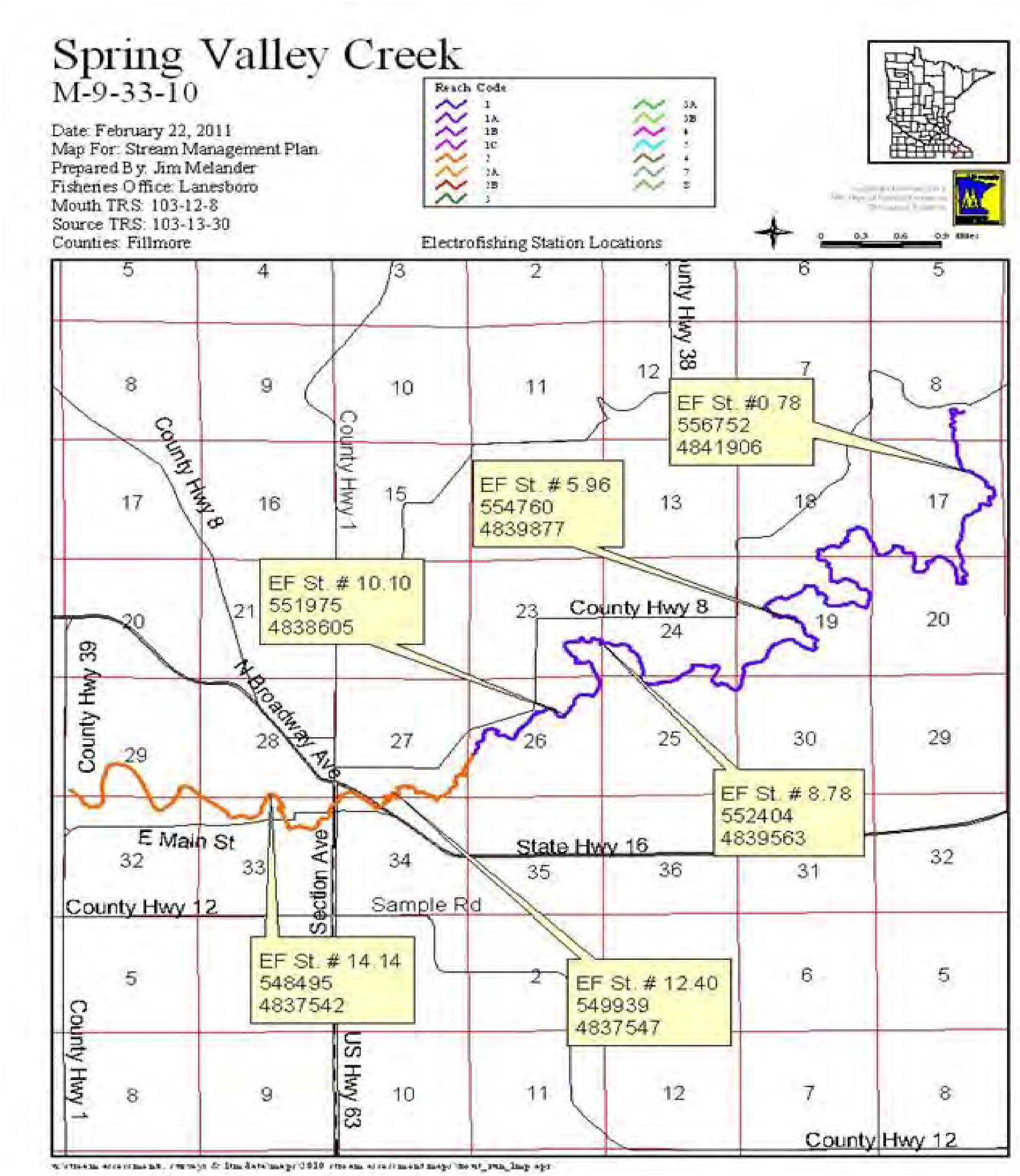


Figure 54. MDNR monitoring stations on Spring Valley Creek.

Physical connectivity

MDNR identified some potential connectivity issues with culverts and fish passage, but only during high flows. According to an MDNR report (Full Survey 2007), there are two locations of potential connectivity disruption on Spring Valley Creek involving road crossings. One location at mile 7.73 consists of two large, corrugated steel culverts through which the stream flows. At high discharge, velocities within the culverts may prevent fish passage. These culverts are also subject to blockage by debris carried during high flows. A cement-slab stream crossing located at mile 3.85 can also function as a fish barrier and point of blockage during high flows. However, since this is not a low flow fish passage issue, it is not disrupting connectivity completely. Migratory fish are found throughout the creek which support that connectivity is likely adequate. Connectivity is not considered a stressor to Spring Valley Creek at this time. However, incorrectly placed culverts can cause stream instability which is present in Spring Valley Creek. Corrective actions to place culverts correctly should be taken.

Strength of evidence, conclusions, and recommendations

The stressors to the fish and macroinvertebrate communities in Spring Valley Creek are temperature, habitat, and nitrate. Temperature and habitat have both been identified previously as limiting factors to the fish community by MDNR. Temperature loggers were placed upstream and downstream of the wastewater treatment plant outfall in 2013, showing there was minimal impact on summer temperature from that continuous discharge. However, just downstream from there, there is a private trout hatchery with two ponds that discharge into Spring Valley Creek. Water temperature increases from 48°F at the spring to 55°F after flowing through the ponds. This spring would be contributing 3.40 cfs of water at 48°F if the trout ponds were not present, demonstrating potential thermal impact at that location. A lack of shade appears to be a factor for increased stream temperatures, as noted in MDNR reports. Improvements in the riparian area, including methods for shade and cover would be beneficial to the thermal regime of Spring Valley Creek. Habitat improvement projects or methods to improve the riparian buffer width, along with and managed grazing, may all help improve habitat and stream temperatures.

Nitrate is elevated in Spring Valley Creek (very close to drinking water impairment), and the macroinvertebrate response is consistent throughout sites. Duration and magnitude along with sources of nitrate to Spring Valley Creek should be examined further.

Dissolved oxygen was not able to be confirmed as a stressor, but should continue to be monitored. There is some indication that oxygen levels could be improved, especially near Station 08LM006, where short violations of the DO standard were documented in 2011. In addition, some limited data on phosphorus does suggest some elevated average concentrations, but the dataset is small. DO flux is slightly higher than the recommended river eutrophication criteria for the “Central” region (3.5 mg/L). Station 08LM006 is experiencing cumulative stressor impacts, including local land use (pasturing), along with potential temperature and habitat problems, not seen at other site locations. More information on DO dynamics (diurnal DO) throughout the creek would be useful in assessing this stressor in a broad context. In addition, more information on total phosphorus levels and chlorophyll-a throughout the creek would be helpful.

Toxics were investigated in 2011, and results were inconclusive. Based on local knowledge, it seemed that petroleum related pollution was a potential in Spring Valley Creek. While there wasn’t indication of recent petroleum related pollution, there had been documented events in the past. The most probable source for this type of toxic contamination was the BP Terminal Facility, just south of the City of Spring Valley. There was some speculation that spills and migrating pollution plumes from this area might be making its way to the Freiheit Spring area. This is just upstream of the location where biology seemed to be suffering the most in Spring Valley Creek (near Station 08LM006). A round of baseflow sampling throughout the watershed in 2011 provided no detection of VOCs (volatile organic compounds) or gasoline range organics (GROs) at five different sites, including Freiheit Spring itself. The monitoring plan included a rain event sample, but no events took place to capture an adequate sample. Additional sampling is needed to capture multiple flow regimes, including a rain event, at multiple locations throughout the creek. Any additional investigation should also be directed near the Freheit Spring source, as this may be a location of interest.

4.2.4. Curtis Creek

Supporting Information

This stream is not currently on draft TMDL list due to a use class change from Class 7 to 2A. This change was due to the Wykoff wastewater treatment discharge, which has a continuous discharge to Curtis Creek. At the time of original stream classification, it was believed that Curtis Creek had little or intermittent flow. The NPDES Permit says the discharge has a design flow of 0.04 MGD, or 40,000 gallons/day, or about 0.6 cfs. That is the maximum amount of wastewater flow, and it appears the flow is typically around half that. Currently, Curtis Creek appears to have adequate flow, temperature, and biology to change to a 2A (coldwater) classification.

A significant brown trout population is present in Curtis Creek. The two sampling visits yielded 57 and 70 brown trout individuals representing a range of age classes and included adults as large as 365 mm. Curtis Creek is not stocked for trout by MDNR. The population is natural, likely migrating from the Middle Branch Root River. While the fish population is not suffering, macroinvertebrates are falling below impairment thresholds (Table 17). Those that were most severe in response were the ratio of chironomid abundance to total dipteran abundance (ChiroDip), percentage of macroinvertebrates that are collector-filterer (Collector-FiltererPct), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs (Intolerant2Ch), and relative percentage of taxa belonging to Trichoptera or caddisflies (TrichopteraChTxPct).

Table 17. Curtis Creek (Station 08LM015) Southern Coldwater macroinvertebrate IBI metrics. Bold indicates metric score is below average metric score needed for IBI to be greater than threshold, maximum metric score possible is 14.3.

Site	CBI	ChiroDip	Collector-filtererPct	HBI_Minnesota	Intolerant2Ch	TrichopteraChTxPct	VeryTolerant2Pct
08LM015	10.2	1.2	0	6.7	0	4.7	11.2

Temperature

On July 22, 2008, at time of fish sample the stream temperature was, 15°C. On August 14, 2008, it was 12.2°C. In addition, there were ten sample points taken from four days in 1986. The average temperature was 12.1°C, with a maximum of 15°C. Given the cold temperatures during fish samples, a high macroinvertebrate CBI score (coldwater biotic index; Table 17), and the significant brown trout population, suitable temperature is not limiting biology in Curtis Creek.

Dissolved Oxygen

During biological sampling on July 22, 2008 (9:10 am) the DO was 11.4 mg/L. On August 14 (12:02 pm) the concentration was 11.07 mg/L. There were ten DO data points from 1986, all ranging from 8-10.0 mg/L. These were taken a few days in July and August (a couple pre-9:00 am, most in the afternoon).

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. Limited pH and TP data exist, but do suggest elevated values. In 2008, two pH values were 8.3 and 8.81. One of those values (8.81) violates the pH standard for class 2A streams (6.5-8.5). The corresponding phosphorus values for those samples were 0.196 and 0.168. While these values are elevated, and do suggest some nutrient enrichment and potential oxygen issues, the data are limited. These concentrations are explained by the wastewater discharge to this stream. Neither BOD nor chlorophyll-a data were available for analysis at this time.

The fish community on Curtis Creek is comprised entirely of fish that are sensitive to low DO (brown trout). The station had DO TIV aggregate scores that were in the top 10% of all sites sampled in the Root Watershed, which indicate sensitivity to low DO. The macroinvertebrate community is comprised of a mixture of some species which are tolerant, and some which are intolerant to low DO. However, overall the macroinvertebrate community is sensitive to low DO in comparison to other stations in the Root River, including a good percentage of EPT taxa which are generally sensitive to low DO.

The chemical and biological data do not indicate that DO is a stressor to Curtis Creek at this time. However, the nutrients and pH do indicate the potential and additional DO information would help rule this stressor out completely and ensure DO concentrations remain adequate.

Nitrate

In 2008, during fish sampling, nitrate levels were measured at 13.0 mg/L in July and August. In 1986, there were 14 nitrate samples taken from five stations and four different days, with average concentration of 11.6 mg/L; maximum of 15.0 mg/L and minimum of 5.6 mg/L. Although the data are not recent, it is important to understand that it is likely these elevated nitrate concentrations have persisted for numerous years. Additional nitrate data would be beneficial to further understand duration, magnitude, and sources.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of southern coldwater macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12.0 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6.0 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

In Curtis Creek, there was a general lack of diversity in the macroinvertebrate community (50% of the sample dominated by two taxa). One of the most dominant species sampled was *Baetis* (44%); a tolerant mayfly. Seventy 8% of the macroinvertebrate community collected is classified as tolerant. Station 08LM015 had 14 taxa (with chironomid and baetid taxa each treated as one taxon). This is below the average taxa count for the southern coldwater class for the Lower Mississippi River Basin of 19. Station 08LM015 also had no generally intolerant taxa.

Curtis Creek, Station 08LM015, had only three Trichoptera taxa comprising of 12% of the total taxa (TrichopteraChTxPct) and a resulting metric score lower than the average metric score needed to be at the southern coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the southern coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. At Station 08LM015, in Curtis Creek, the metric score was 6.7, just above the average metric score needed to be at the southern coldwater MIBI threshold.

The HBI_MN value increases with increased nitrate. At Station 08LM015 the HBI_MN value was 6.59, greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the southern coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM015 had 17 nitrate tolerant taxa (88.6% individuals); and 12 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the southern coldwater MIBI. There were no nitrate intolerant taxa present in 2008.

With the elevated prevalence of tolerant individuals, nitrate tolerant taxa, low Trichoptera taxa percent, and an elevated HBI_MN value, it is likely that nitrate is a primary stressor to the macroinvertebrate community. As noted above, given the high nitrate levels sampled in this stream, the probability of a biological station meeting biocriteria is reduced when nitrate concentrations are above 12.0 mg/L. The chemical and biological information confirm nitrate is a stressor to the macroinvertebrate community in Curtis Creek.

Suspended sediment

During biological sampling on July 22, 2008, the TSS concentration was 4.0 mg/L. This is considered normal for a coldwater stream during baseflow conditions. No other chemical information was available for analysis. Some stream bank erosion at this location is apparent in site photos.

The fish community (100% brown trout) is moderately intolerant to high TSS compared to many other fish species in the Root River. This stream is not stocked for trout, and the presence of trout, in absence of other more tolerant fish species; suggest fairly good conditions in terms of TSS concentrations.

At Station 08LM015, there were no intolerant macroinvertebrates and less than 1% long-lived macroinvertebrates, which often decrease with increases in TSS. The macroinvertebrate index score for TSS was 14.44, better than the average for coldwater stations in the Root River Watershed (15.13). The station at the time of sampling had two taxa tolerant to TSS and two intolerant to TSS. Both of these metrics reveal conditions better than averages of coldwater stations in the Root River. The survey had only 6.87% of the individuals in the survey considered tolerant to TSS; the average for coldwater stations in the Root River is 9.94%. Although there is a general lack of intolerant and long-lived macroinvertebrates, the TSS specific metrics are all better than average. The limited available chemical and biological data suggest that TSS is not a stressor in Curtis Creek at this time.

Physical habitat

The MSHA scores for both fish site visits resulted in a fair score (56 and 63). The MSHA metric which scored worst was land use, but was conflicting between two visits.

The macroinvertebrate community was sampled according to dominant habitat types. In Curtis Creek, those two dominant habitat types were overhanging vegetation and riffles. As noted during site visits, the erosion was fairly prominent and some very high banks were noted. There was fairly good substrate, despite the erosion present (Figure 55). It is possible the stream gradient is helping combat any potential sediment accumulation to the streambed. In support of this, there was not an abundance of burrowers found, which would suggest potential fine bedded sedimentation issues. The percentage of EPT individuals was greater than the statewide averages, but dominated by *Baetis*, a tolerant mayfly. However, the macroinvertebrates that are known to cling to large substrate and woody debris, in addition to macroinvertebrates that climb, were found in reduced numbers (percentages lower than average for coldwater stations statewide). Habitat may be limiting the macroinvertebrate community found at this station, but appears to be secondary to a more prominent stressor. There are aspects of habitat that could be improved in Curtis Creek, which include improvements in the riparian area and pasturing. A study on streambed movement may be useful in understanding potential impacts on habitat degradation.

Figure 55. Curtis Creek, both photos from Station 08LM015.

Physical connectivity

No information was available or collected on physical connectivity of Curtis Creek. The impairment on this AUID is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor to Curtis Creek at this time.

Strength of evidence, conclusions, and recommendations

The primary stressor impacting the macroinvertebrate community is elevated nitrate. Curtis Creek had one of the highest nitrate concentrations measured during intensive watershed monitoring in 2008, at 13.0 mg/L. A synoptic sample in 1986 suggests the nitrate concentration is not elevated due to wastewater impact. Therefore, it is assumed that the springs feeding the stream are the likely contributors to the elevated stream nitrate concentrations. This finding is consistent with other streams in this area, which are susceptible to nitrate contamination due to the local Karst geology and regionally sourced groundwater flow.

Physical habitat is considered a secondary stressor in Curtis Creek. There are aspects of habitat that could be improved, including improvements to the riparian area and local land use. Site photos document some bank erosion and instability within the sampling reach. While the substrate in Curtis Creek appears adequate, the macroinvertebrates that rely on this type of habitat (clingers) are reduced in numbers. This could be attributed to overall channel instability and potential streambed movement.

The impacts of DO on this reach are not quantified. The wastewater impacts show potential for impacts to DO issues due to high amounts of total phosphorus during baseflow conditions. Without more detailed chemical information on DO, this stressor cannot be confirmed. Additional information should be collected for DO.

4.2.5. Upper Bear Creek (Lost Creek)

Supporting information

This stream is split into several AUIDs alternating between cold and warm water use designations. (Figure 56). This AUID is the most downstream and is a short coldwater reach before confluence with Root River. Both fish and macroinvertebrates are scoring below impairment thresholds at Station 08LM027. Surber investigated Lost Creek in the fall of 1918 and described the springs as of considerable size.

Figure 56. Upper Bear Creek (Lost Creek) with Trout Designation (blue) and Angling Easement (gray). Middle section; undesignated due to disappearing water. (MDNR Map)

According to MDNR, brown trout fingerling stocking has been discontinued (2004) in the downstream reaches of Lost Creek because of excellent natural reproduction in recent years (1997-2004). A habitat improvement project is being initiated in the state angling easement corridor and will involve restoring the important spring flows in this area and sloping the stream banks. Lost Creek is likely an important source of brown trout for the Middle Branch Root River and vice versa. The numbers of brown trout >12 inches/mile has only been calculated once during Lost Creek's assessment history and that resulted in 179/mile in a downstream station. Total brown trout biomass has been increasing and was last estimated at 231 lbs/acre in the same station.

All macroinvertebrate metrics, of the southern coldwater IBI, were below the average metric score needed to be above the threshold at Station 08LM027 (Figure 57). Those that were most severe in response were: taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs (Intolerant2Ch), and the relative percentage of taxa belonging to TrichopteraChTxPct. Tolerant macroinvertebrate taxa make up 77% of the community found at this station, which is not surprising given all macroinvertebrate metrics are showing degradation.

The fish community in Upper Bear Creek, at Station 08MN027, scored low on the southern coldwater IBI (37). The fish community had a lack of native coldwater taxa and individuals (NativeColdPct and NativeColdTxPct_10DrgArea), and an abundance of taxa where detritus constitutes at least 5% of their diet, represented by the SdetTxPct_10DrgArea metric (Figure 58). The site had a small percentage of pioneer taxa, resulting in a good metric score. "Pioneering species predominate in unstable environments that have been affected by temporal desiccation or anthropogenic stressors, and are the first to reinvade sections of headwater streams following periods of desiccation" (Barbour et al.,1999).

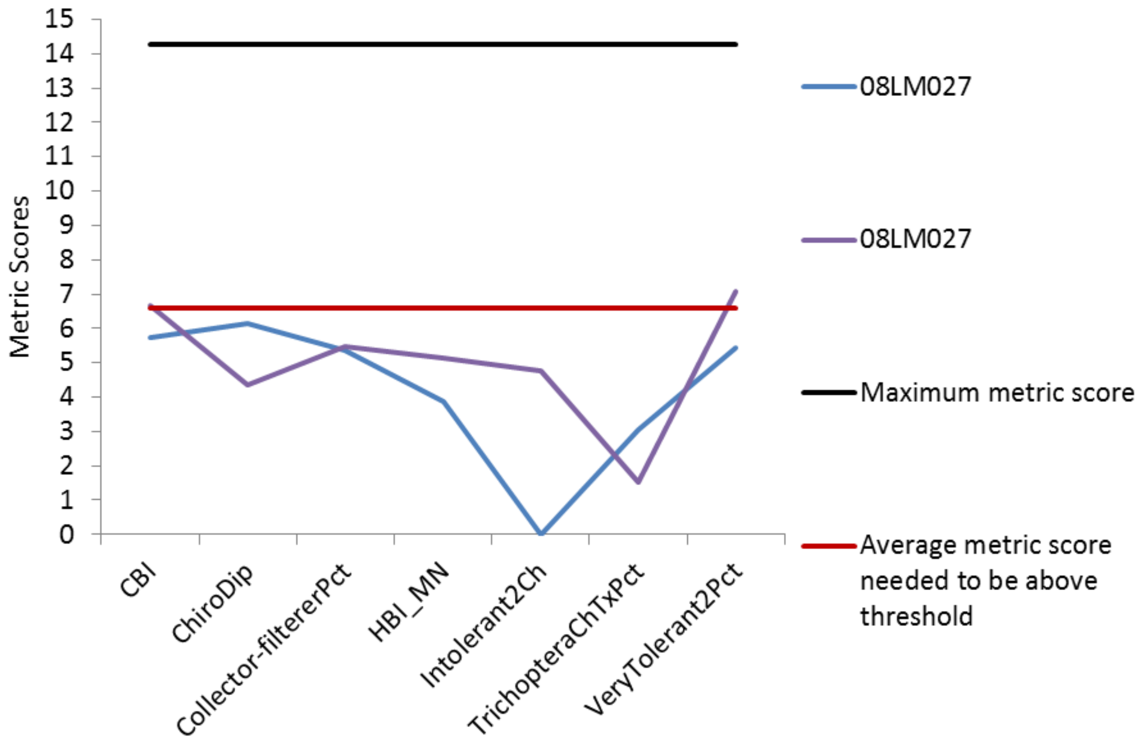


Figure 57. Metric scores for Station 08LM027 in Upper Bear Creek of the southern macroinvertebrate coldwater IBI.

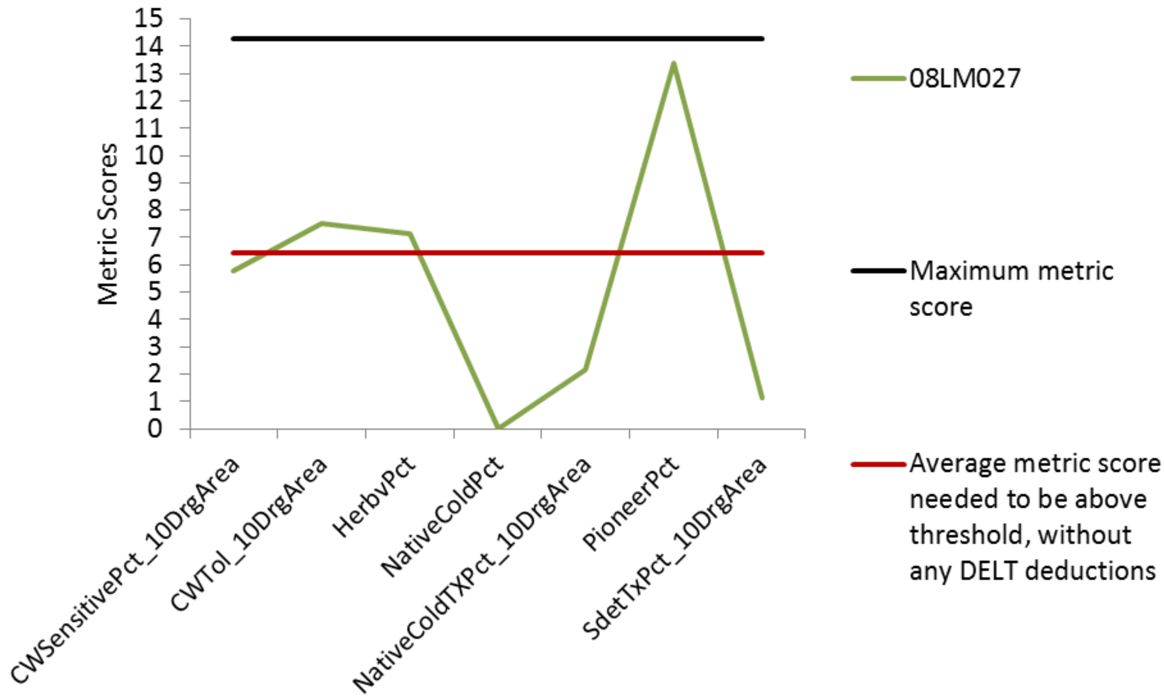


Figure 58. Fish metric scores for Station 08LM027 in Upper Bear Creek of the southern Fish Coldwater IBI.

Temperature

At the time of fish sample on July 22, 2008, the water temperature was 17.7°C. There were five temperature values on the stream which ranged from 13°C to 20.3°C. A continuous temperature logger was deployed at Station 08LM027 in 2008, and the average summer temperature was 15.5°C. These values are considered healthy for coldwater streams in southeast Minnesota. The percentage of coldwater fish species present at 08LM029, at 33%, was just slightly below normal in 2008. Native coldwater species are absent, as demonstrated in Figure 58. However, the coldwater sensitive species metric did score near average, in addition to the CBI metric for macroinvertebrates (Figure 57).

However, MDNR mentions in its management plan that the stream can really suffer during dry years. Station S004-725, at CR101 (just upstream of Station 08LM027 but in the same vicinity of MDNR 6.56 site) the temperature can fluctuate during low flows years. This was shown in 2012, which was a low flow and very dry and very hot year. There were some temperature measurements that were approaching 23-24°C in the middle of summer. Contrast that with 2011 and 2010 temperatures, which had a maximum summer temperature of approximately 20°C. In 2009, also a low flow year, maximum temperatures were approaching 23°C. There is clearly an impact on flow and temperature due to the Karst hydrology and disappearing streams which fluctuate on any given year. See the data here: http://www.pca.state.mn.us/customPHP/eda/stationInfo.php?ID=S004-725&ORG=MNPCA.

Additional information on temperature and thermal dynamics of this stream is necessary over multiple years. Given the current dataset, temperature cannot be confirmed as a stressor at this time. However, there is indication that during low flow years this stream could suffer from temperature stress, and further information would assist in that understanding.

Dissolved Oxygen

On July 22, 2008, DO was measured at 10.95 mg/L (3:24 pm) at Station 08LM027. One other DO value was recorded at the site (S003-386 which is co-located) and was 9.6 mg/L.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. Monitoring site S003-386 was sampled for pH 5 times between 2003-2006. The range of values found was 6.18-8.65. One of those values (8.65) violates the pH standard for Class 2A streams (6.5-8.5). The only TP data available was taken during fish sample, at 0.062 mg/L. Neither BOD nor chlorophyll-a data were not available for analysis at this time.

Almost 50% of the fish community at this station is made up of species which are very sensitive to low DO concentrations (brown trout, fantail darter) as shown in Figure 59. The macroinvertebrate community in this station is made up of quite a few species which are intolerant to low DO concentrations (12, considered above average for the Root River). The macroinvertebrate DO TIV station score was also above average for the Root River, indicating the community is relatively sensitive to low DO concentrations. The percentage of EPT taxa were found to be just below average. EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux**.** The macroinvertebrate surveys in Upper Bear Creek had 25 and 22 taxa (with chironomid and baetid taxa each treated as one taxon); above the average taxa count for the coldwater macroinvertebrate class. The chemical and biological information do not suggest a DO stressor on Upper Bear Creek at this time.

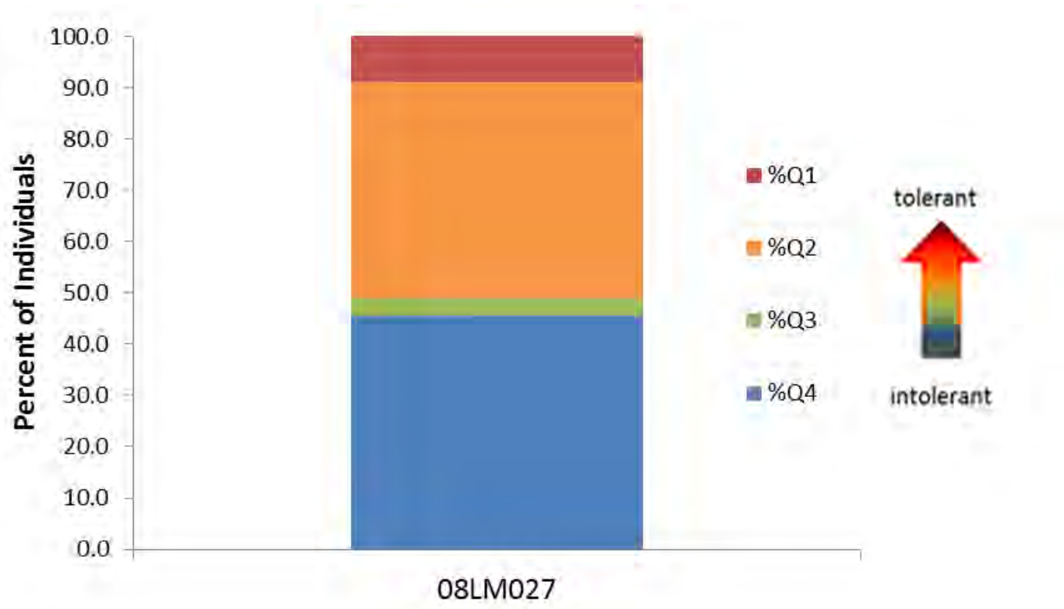


Figure 59. Fish DO TIV for Station 08LM027.

Nitrate

On July 22, 2008, at the time of fish sampling at Station 08LM027, nitrate was 4.9 mg/L. On August 2, 2010, two additional samples were taken in the watershed. On the same AUID Station S003-386 had 4.3 mg/L nitrate (collocated with Station 08LM027) and on an upstream AUID, at Station S006-345, nitrate was 5.0 mg/L.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of southern coldwater macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12.0 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in Upper Bear Creek had 25 and 22 taxa (with chironomid and baetid taxa each treated as one taxon), above the average taxa count of 19 for the coldwater macroinvertebrate class for the LMB. Also, the macroinvertebrate surveys resulted in 0 and 1 intolerant taxa. Upper Bear Creek also had a range of Trichoptera taxa near average and just above average (3 and 4 taxa), comprising of 8.1 and 10% of the total taxa (TrichopteraChTxPct) and a resulting metric score lower than the average metric score needed to be at the southern coldwater MIBI threshold (6.6). Utilizing quantile regression analysis for stations in the southern coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. At Station 08LM027, in Upper Bear Creek, the metric score was 3.9 and 5.2 (out of 14.3), below the average metric score needed to be at the southern coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM027 the HBI_MN value was 6.98 and 7.13, both greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the southern coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of ten mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM027 had 23 and 26 nitrate tolerant taxa (69.2 and 73.7% individuals); and 15 and 17 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the southern coldwater MIBI. At 20.18 nitrate tolerant taxa there is a 25% probability of meeting the southern coldwater MIBI, and at 22.60 nitrate tolerant taxa there is a 10% probability of meeting the southern coldwater MIBI. There were no nitrate intolerant taxa present.

With low metric scores for TrichopteraChTxPct and HBI_MN, and high number of nitrate tolerant taxa, the macroinvertebrate community is responding to stress from elevated nitrate. The watershed does have elevated nitrate levels, but there should be more information collected.

Suspended sediment

During biological sampling on July 22, 2008, the TSS concentration was 6.4 mg/L. This is considered normal for a small coldwater stream during baseflow conditions. No other chemical information was available for analysis.

The fish community shows a mix of tolerant and intolerant species to TSS. The most abundant fish present (brown trout), is moderately intolerant to high TSS concentrations. There were also some species tolerant to TSS found at these stations (i.e. white sucker, central stoneroller). Overall, the fish community does not provide strong evidence towards a TSS stressor.

The macroinvertebrate community at Station 08LM027 had a worse than average TSS station index score (Table 18). Each sample had five TSS tolerant taxa and an elevated percentage of TSS tolerant individuals compared to the average for coldwater stations in the Root River watershed. One survey resulted in one TSS intolerant taxa, but the other survey resulted in no TSS intolerant taxa. There was an above average presence of long-lived individuals, but a low percentage of generally intolerant individuals. The macroinvertebrate community is suggestive that elevated TSS is a potential stressor.

Table 18. Macroinvertebrate metrics relevant to TSS for stations in Spring Valley Creek compared to averages for coldwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
08LM027	**15.55**	1	**5**	**15.38**	**0.32**	1.95
	16.17	**0**	**5**	**14.53**	**0**	4.67
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for coldwater stations in the Root River Watershed	15.13	0.99	4.38	9.94	0.95	1.23

Even though the macroinvertebrate community slightly suggest the potential for TSS issues, the lack of adequate chemical information and mixed biological response from the fish community do not support the confirmation of TSS stressor in Upper Bear Creek at this time. More chemical information should be collected to help determine if TSS levels are indeed causing stress to biological communities.

Physical habitat

Station 08LM027 received a fair MSHA score (65). The site was characterized by having a moderate riparian zone with little erosion, decent substrate, moderate cover and light embeddedness. MDNR also noted some severe erosion and embeddedness on multiple sites. On Station 0.06 (nearest MPCA site 08LM027), substrate was composed of mostly sand and some gravel and silt. Embeddedness was noted as severe. Sparse habitat (5-25%) and was comprised of undercut banks, deep pools and root wads.

The available habitat types sampled for macroinvertebrates were riffles, woody debris, and undercut banks/overhanging vegetation. There was not an abundance of burrowers found, whose presence would suggest potential fine sedimentation issues in riffle habitats. However, there were a high percentage of generally more tolerant legless macroinvertebrates (41 and 50% for the two visits). The percentage of EPT individuals found was also worse than the statewide averages for coldwater stations at only 32 and 27%, compared to the expected average for coldwater stations statewide (39%). The macroinvertebrates that are known to cling to large substrate and woody debris were near statewide averages (36 and 37%, compared to the statewide average of 36%). There was a good amount of macroinvertebrates that climb (just above statewide average of 11%). The macroinvertebrate habitat specific metrics do suggest some potential for habitat issues, but the data are not overwhelming. There are certainly some aspects of habitat that could be improved in Upper Bear Creek.

Station 08LM027 had a fish community rich in riffle dwelling fish (55.17%), non-tolerant benthic insectivores (17.93%), simple lithophilic spawners (46.90%), and darter, sculpin and round bodied suckers (17.24%). Lithophilic spawners were also well above average at 88%. The percentage of piscivores was close to the statewide average for coldwater sites of 37%. In addition, the percentage of pioneer species was low, (3.45%) which is considered good as pioneering species thrive in unstable environments. Similarly, the percentage of tolerant fish species was not overly elevated (normal range for coldwater fish stations). All the habitat related metrics for fish indicate that lack of physical habitat is not limiting the fish community found in Upper Bear Creek.

Physical connectivity

In 2012, a survey of all road crossings in the watershed showed little physical connectivity issues for fish (the assessed AUID is very short, due to lack of water in the upper parts of the stream). However, visual inspection of the culverts did show water that is very shallow. During the macroinvertebrate sample, beaver dams were noted in the reach near Station 08LM027.

According to a MDNR management plan from 2011, stretches of the creek between the lower station, just upstream from the bridge and MDNR Station 6.56 go underground and at times, and can become thermal barriers for trout. Station 08LM027 is downstream of the bridge. MDNR Station 0.06, which corresponds closely with our monitoring location 08LM027, shows history of beaver dams and habitat problems. During the 2011 assessment, MDNR had to move their station downstream of the first bridge due to log jams present. (This is closer to the MPCA site which is also downstream of the first bridge)

It appears that Upper Bear has natural connectivity issues in the upper reaches. Beaver dams/logs jams, and disappearing stretches of stream are contributing to issues seen with the fish and macroinvertebrate communities and causing stress mainly in terms of temperature and habitat loss. Station 08LM027 had 75% migratory fish in 2008, so fish passage is not likely affected. It is possible that low flow years are most likely making more of an impact overall.

Physical connectivity cannot be confirmed as a stressor in Upper Bear Creek at this time. More information should be collected to understand this potential issue, especially during low flow years.

Strength of evidence, conclusions, and recommendations

The stressors identified in Upper Bear Creek are lack of habitat and elevated nitrate. Fish are not responding to habitat stress, however. Available habitat has the potential to be variable, given this highly dynamic stream system and likely change from year to year. As noted in the MDNR Management Plan 2011, a habitat improvement project is already being planned by Trout Unlimited within the state angling easement. There is also pending easement acquisition near the mouth of Lost Creek (Upper Bear Creek) that will most likely result in additional habitat improvement projects (which would likely coincide with MPCA biological site 08LM027).

Further investigation into the magnitude and duration of nitrate in Upper Bear Creek, would be beneficial. It is uncertain the direct sources; however, in the Nitrogen in Minnesota Surface Waters Report it is estimated that agricultural groundwater and agricultural drainage comprise of 80% of the nitrogen sources in the Lower Mississippi River Basin (pg. D1-11).

Suspended sediment and dissolved oxygen appear to be adequate and both communities are showing sensitivity to both of those parameters. However, the affects of temperature and connectivity are not well quantified, and have the potential to be large, especially for the fish community. Currently, continuous temperature data does not indicate temperature issues; however, MDNR reports show that this stream can suffer during dry years, due to changes in stream flow (sections of stream disappearing). Additional understandings on temperature dynamics during varying years, and flow conditions, as well as subsequent connectivity issues are needed.

4.2.6. Summary of stressors in the Middle Branch Root River

The stressors found in the Middle Branch Root River are found in Table 19.

Table 19. Stressors identified in the Middle Branch Root River. (● = stressor (yes); o = inconclusive stressor; 'blank'-no stressor)

Reach Name	*Geo Region*	AUID	*Reach Description*	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Habitat	Physical Connectivity
Bear Creek	***Uplands, Till covered Karst***	**07040008-544**	*Headwaters to Kendron Creek*	2B	08LM079 08LM058	Downstream of Twp 422, 6 mi. NW of Wykoff Downstream of CSAH 2, 2 mi. NE of Grand Meadow	Invert IBI			o	o	●	
Root River Middle Branch	***Driftless, Bluffland Karst***	**07040008-506**	*Upper Bear Creek to North Branch Root River*	2B	08LM007	Downstream of CSAH 7, 3 mi. S of Chatfield	Invert IBI Bacteria			o	o	●	
Spring Valley Creek	***Driftless, Bluffland Karst***	**07040008-548**	*T103 R13W S29, west line to Deer Creek*	2A	08LM006 04LM058 10EM015	Downstream of Orchard Rd, 2.5 mi. W of Wykoff Along County Route 8, Spring Valley Township, 5.4 mi. SW of Fillmore Upstream and downstream of Hwy. 63, in Spring Valley	Fish IBI Invert IBI E. Coli	●	o	●	o	●	
Curtis Creek	***Driftless, Bluffland Karst***	**07040008-541**	*Headwaters to Middle Branch Root River*	2A	08LM015	Downstream of CSAH 5, 2 mi. N of Wykoff	Invert IBI			●		●	
Upper Bear Creek	***Driftless, Bluffland Karst***	**07040008-540**	*T104 R11W S18, west line to Middle Branch Root River*	2A	08LM027	Downstream of CSAH 5, 2 mi. S of Chatfield	Fish IBI Invert IBI	o		●	o	●	o

4.3. Money Creek

Corey Creek was the only stream in Money Creek that was listed for aquatic life after the 2011 assessments. However, Money Creek was listed in 2009 for turbidity. During assessment in 2010, Money Creek was noted as "flowing through high gradient change, which drives bank and bed erosion during high flow events. In 2007, this watershed experienced an extreme flow event driven by heavy rainfall in a short time. Citizen Stream Monitoring Program measurements both before and after this event show that the stream can return quickly to clarity after events later in the summer and fall, but will be slower to recover in spring and early summer when successive rain events are common. Suspended solids and stream channel disturbances are a likely stressor for biology in some years."

There are three biological stations on Money Creek; all scored above the threshold for both fish and macroinvertebrates. In 2010, when Money Creek was assessed, it was not impaired for biology. One site was very near the threshold for both indicators, and may be moving towards impairment.

Corey Creek, a tributary to Money Creek, has an aquatic life (fish) impairment that will be discussed in the following section (Figure 60).

Money Creek Watershed (HUC - 0704000806)

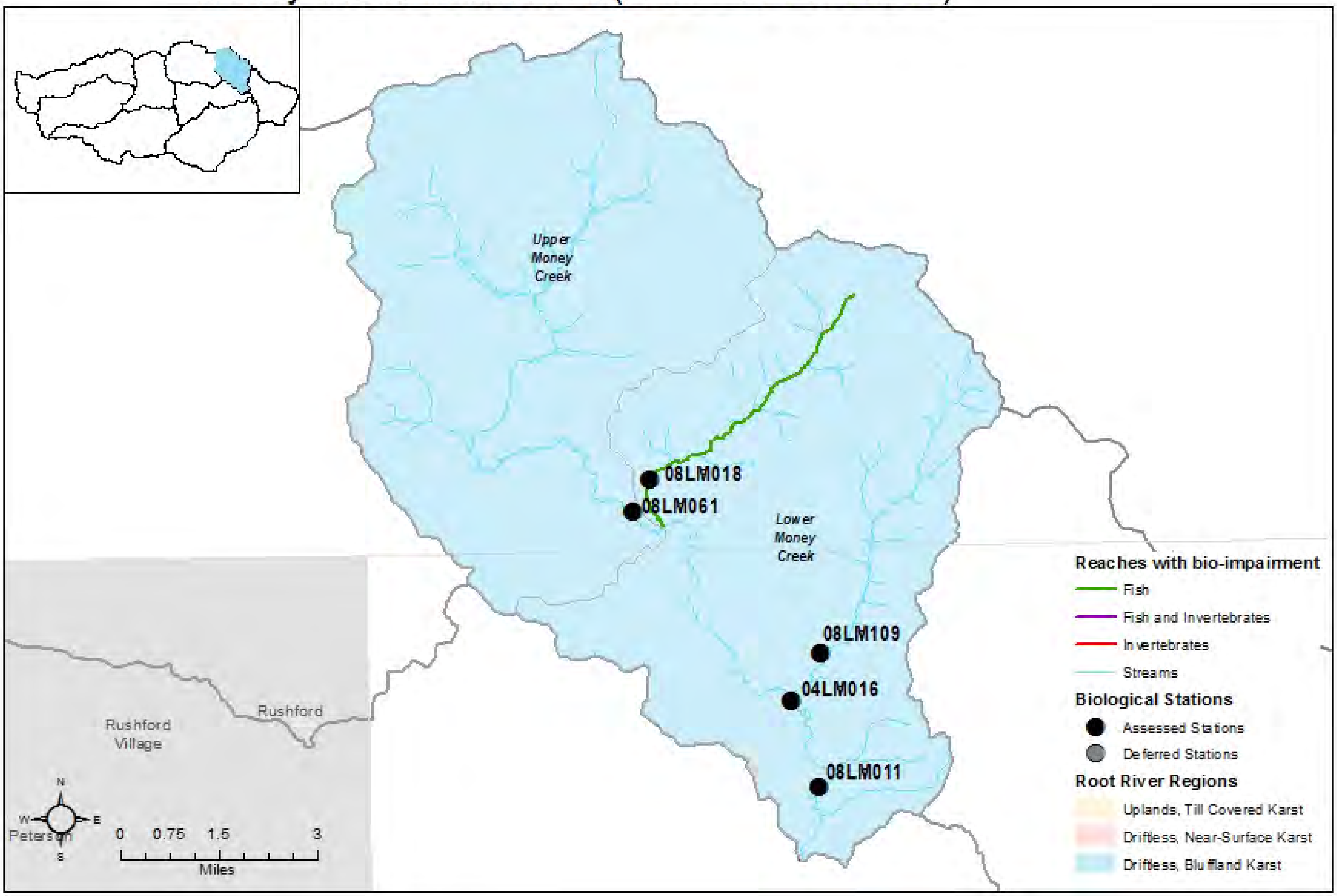


Figure 60. Money Creek biological monitoring stations and aquatic life impairments.

4.3.1 Corey Creek

Supporting information

Corey Creek is a small, 5.79 square mile watershed, and is comprised mainly of forest and rangeland. Agriculture makes up very little of the land use in the watershed (2.8%). Corey Creek is the only stream that is impaired for aquatic life based solely on its fish assemblage (i.e. macroinvertebrates at this station are above impairment threshold). During biological assessment, it was noted that temperature and the fish community demonstrate warmwater characteristics. However, the stream was reviewed with MDNR and the decision was to leave it as a coldwater stream. The macroinvertebrate community present supports the coldwater designation, and is not currently impaired. In 2008 the macroinvertebrate IBI score was 54, then 44 in 2010. The fish IBI score was 34 in 2008 and 36 in 2010.

The riparian corridor is heavily disturbed in the watershed. Trees in the riparian area have been removed in multiple locations. The watershed is extremely steep, and drops 340 feet in the first 3/4 mile (MDNR survey 1991). As a result of the steep topography, severe flash flooding is common.

According to MDNR's Corey Creek Survey in 1991, previous surveys from 1924, 1945, and 1955 found the stream to be unsuitable for trout. The 1985 and 1991 surveys found the stream to have fair trout habitat in the upper half of the stream. Biological Station 08LM018 is located in the lower 1/3 of the stream. Landowners have said there were no trout in the creek before it was stocked in 1980. Trout fishing was good in 1985 in the upper part of the creek. Stocking was discontinued in 1995 after a self-sustaining wild population became established in the upper portions of the creek (MDNR, 2001).

The fish IBI metrics shown in Figure 61, demonstrate the lack of coldwater individuals present in Corey Creek (Station 08LM018). Both 2008 and 2010 show very similar results. Those results were compared to Campbell Creek (Station 08LM109), which is a neighboring small watershed with good fish IBI scores.

Corey Creek was comprised of a large number of pioneering species, when compared to Campbell Creek. The percent pioneering species found in Corey Creek was just over 50% both years it was sampled. Campbell Creek had a fish community comprised of 3.45% pioneering species was 3.45%. "Pioneering species predominate in unstable environments that have been affected by temporal desiccation or anthropogenic stressors, and are the first to reinvade sections of headwater streams following periods of desiccation" (Barbour et al.,1999).

The fish population in Campbell Creek consisted of 96% of individuals with a female mature age greater than three years. Corey creek, in contrast, has only 14 and 20% in the two years sampled. The majority of the female fish in Corey Creek are maturing before they are two years old. This supports that conditions are not favorable for older fish to thrive in Corey Creek, and reproduction may be lacking. The fish that were collected during the surveys in Corey Creek complete their life cycle much quicker by out competing or having adaptations to survive adverse conditions.

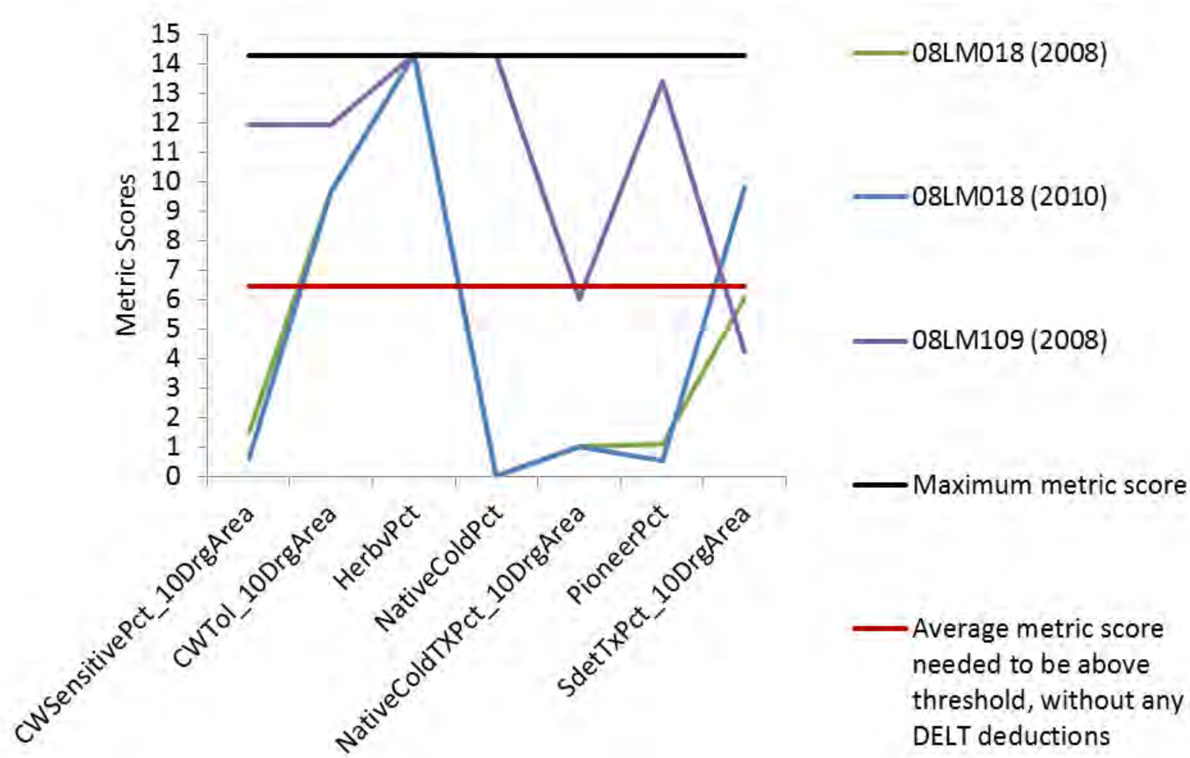


Figure 61. Metric scores for stations in Corey Creek and Campbell Creek of the southern coldwater fish IBI, with no deductions for DELTs Corey Creek

Temperature

A HOBO temperature logger was placed at Station 08LM018 in 2010. Data were collected from June 4 to September 22, 2010. During that time period the maximum temperature recorded was 24.4°C on August 12, 2010. In July and August, there were 25 days where temperature was at, or above, 22°C. In July and August, both months each had an average temperature of 18°C. The MWAT (maximum weekly average temperature) for trout is 19°C (chronic) and 24°C (acute). That temperature threshold was exceeded based on weekly average temperature from August 13 to 18, 2010, for approximately a 5 day period. There were 80 consecutive days where the temperature reached 19°C or higher in 2010.

In 2008, temperature data was also collected using a HOBO temperature logger. Those data look very similar to the 2010 data. The maximum temperature in 2008 was 23.5°C on July 15, 2008. The MWAT temperatures were not exceeded using the 2008 dataset. Figure 5 shows that on average, Corey Creek is spending about 30% of its time in June, July, and August above 19°C.

Neighboring biologically healthy watershed of Campbell Creek shows a different temperature pattern. In Campbell Creek, July and August average temperatures were a little colder, at 17°C. The maximum temperature recorded was 21.1°C.

Aside from continuous temperature data, there were 79 temperature measurements from Corey Creek from 2007-2011. The maximum temperature recorded from those points was 21.7°C on July 16, 2007.

A MDNR survey from 1985 noted that 3 ponds (impoundments) located on the tributaries to Corey Creek make it somewhat warmer than if the ponds were free flowing streams. Anecdotal information suggests that one of the headwater springs has had large decreases in flow, especially after the 2007 flood. Natural geologic conditions and anthropogenic activities like these aren't well understood, but could certainly impact the creeks thermal regime.

Air temperature and rainfall data conclude that this stream's temperatures are very dependent on the air temperature. Rainfall and overland flow appear to decrease the streams temperature, although only over a short time period. The maximum air temperatures recoded nearby in Houston (National Weather Service data) correlate well with the maximum stream temperatures seen in Corey Creek.

Fish were sampled in 2008 and 2010 at Corey Creek. The percentage of coldwater fish individuals in 2008 was 1.9 and 0% in 2010. In comparison, nearby Campbell Creek had 91% coldwater fish individuals in 2008. Other evidence includes few to no native coldwater species, and a lack of sensitive species. In coldwater streams, it is expected to see coldwater fish individuals present in much higher numbers. Less than ideal temperatures, along with other stressors are preventing coldwater species from establishing at this location in Corey Creek.

While this downstream location appears to be unsuitable for trout and other coldwater species, it does appear that temperatures closer to the spring source(s) are more suitable. Since natural reproduction is occurring (MDNR, 2001) in the upper reaches, it is suggestive that there are adequate temperatures for spawning. Pasturing, loss of the riparian corridor and excess sediment on the streambed are all potential contributors to the temperature increases seen downstream in Corey Creek. While daily average water temperatures are just reaching the 19°C trout temperature thresholds, Corey Creek's maximum daily temperatures are spending the majority of the time above those thresholds. While temperature is not the main limiting factor for the fish community in Corey Creek, it is believed to contribute to the absence of coldwater fish species.

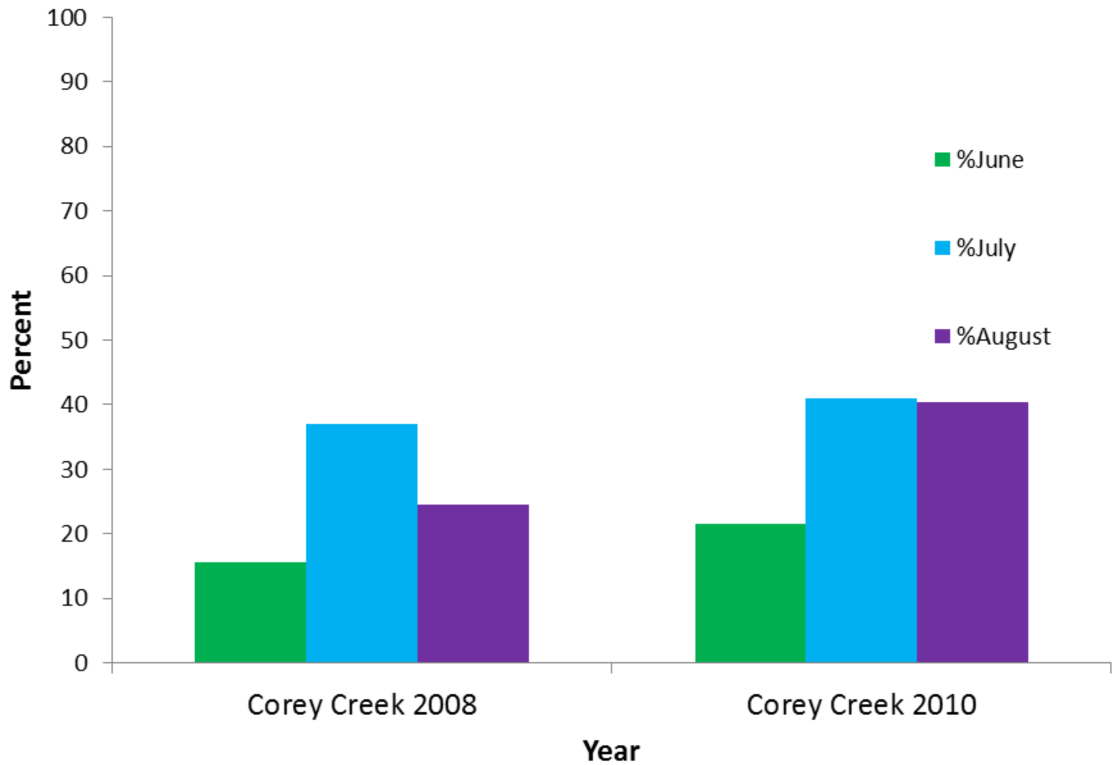


Figure 62. Corey Creek percent temperature measurements above 19°C, for Station 08LM018, 2008 and 2010.

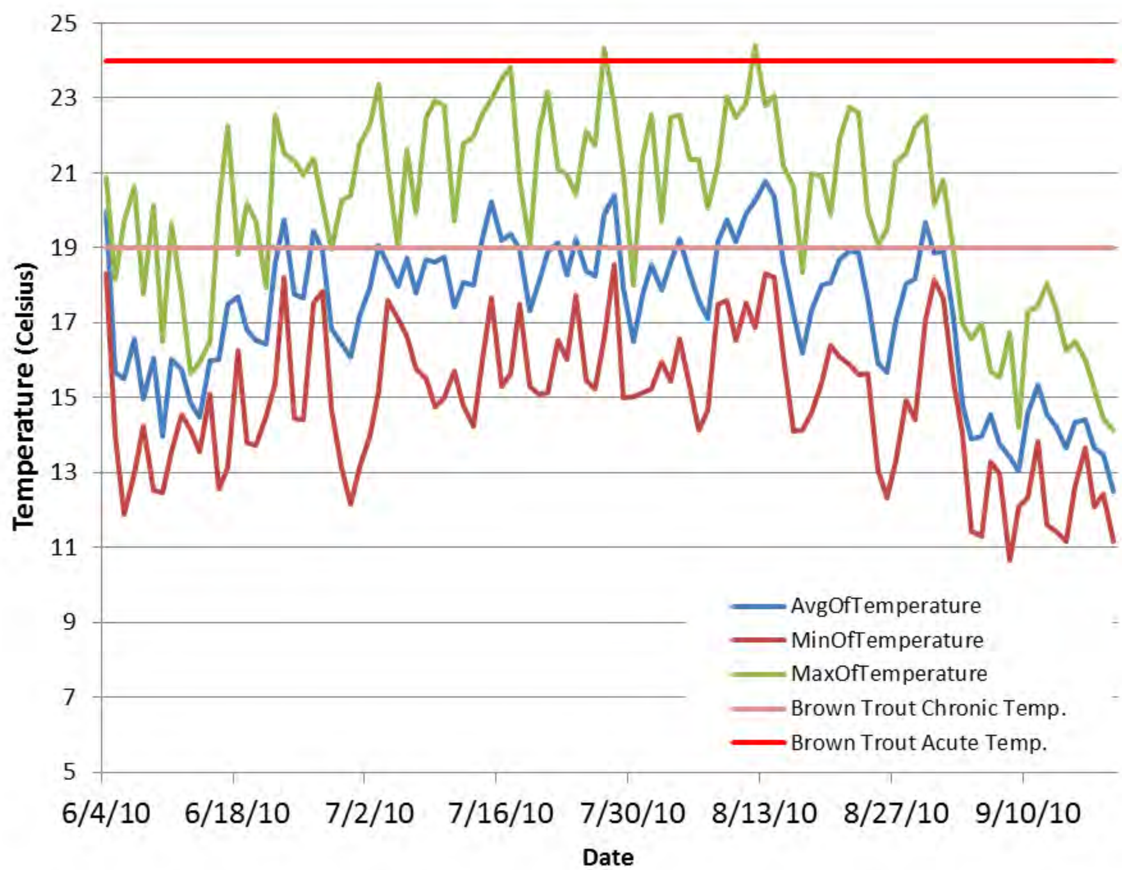


Figure 63: Corey Creek Daily average, maximum and minimum temperatures for 2010.

Dissolved Oxygen

A multiparameter sonde was deployed from August 18 to 31, 2010. During that time period the maximum DO concentration was 10.62 mg/L, minimum was 7.58 mg/L, and average flux was 2-3 mg/L per day. The limited dataset does not show any exceedence of the DO standard for coldwater streams, at 7 mg/L. The daily oxygen flux is also not concerning, and very typical of coldwater streams in the region.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. Total phosphorus in 2010 and 2011 were fairly high during rain events, but not baseflow conditions. There were a total of eight samples with an average of 0.215 mg/L, and a maximum concentration of 0.445 on June 23, 2010.

Data collected from the sonde in 2010 also showed pH levels near normal. The range was 8.07-8.4, within the pH standard values of 6.5-8.5. Six values from grab samples, taken from 2010 and 2011, also showed an acceptable pH range of 7.47-8.21. Neither BOD nor chlorophyll-a data were available for analysis.

Tolerance indicator values do suggest the fish community is generally tolerant to low DO, but that information alone cannot confirm DO as a stressor. Species that are tolerant to low DO, are often tolerant to other stressors as well. Given the macroinvertebrate community is doing fairly well, it can suggest oxygen levels are likely sufficient. The macroinvertebrate community has 14 taxa which are intolerant to low DO, which is quite good compared to other sites across the basin. The macroinvertebrate sample also showed only a few species which are tolerant to low DO compared to other sites, including a high percentage of EPT taxa. EPT are sensitive to low DO and DO flux. In addition, sonde and grab sample data do not suggest issues with DO. The biological and chemical evidence show DO is not a stressor to Corey Creek at this time.

Nitrate

Ten chemistry samples from 2010-2011, including baseflow and events at Corey Creek show a maximum nitrate concentration of 1.3 mg/L. At Station 08LM018, the nitrate concentration taken at time of fish sampling in 2008 was 0.66 mg/L and in 2010 was 0.61 mg/L. These levels are some of the lowest in all coldwater streams of the Root River.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of southern coldwater macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in Corey Creek (two visits; 2008 and 2010) had 19 and 23 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the LMB is 19. Both macroinvertebrate surveys had zero intolerant taxa present, below the LMB average of 0.6 taxa. Corey Creek Trichoptera taxa were both above the average (3.8 taxa) for both visits (five taxa sampled).

Although there is a presence of a high number of nitrate tolerant taxa and individuals, the metrics scores for HBI_MN and TrichopteraChTxPct, were above the average metric score needed to be at the southern coldwater MIBI threshold (6.6) in 2008 and just below in 2010. The macroinvertebrate community was not doing as well in 2010 as it was in 2008, but it is likely due to other stressors present in Corey Creek.

Considering the biological data along with the low nitrate levels, it is unlikely that nitrate is a stressor in Corey Creek. In addition, the impairment on Corey Creek is for fish only. Continued protection against elevated nitrate concentrations should be strived for as well as continued monitoring.

Suspended sediment

There is limited suspended sediment data on Corey Creek. Transparency data from 2006-2010, which includes 22 observations, have an average transparency of 37 cm. For two weeks, when the multiparameter sonde was deployed, the turbidity probe read less than 25 NTUs. Suspended sediment issues appear to be mainly during storm events.

Over half of the fish population is made up of species that are sensitive to increased TSS concentrations (dace and darters). This potentially indicates that TSS is not a main stressor at this location.

TSS index scores for the macroinvertebrate visits were close to the coldwater average for Root River stations. Macroinvertebrates do not appear particularly sensitive to elevated TSS, but there is not enough information to conclude on a stressor at this time. Since the biological impairment is to the fish community on Corey Creek, and there are sensitive TSS fish species present, a TSS stressor does not seem likely. However, additional resources to collect TSS information in this reach would be helpful for further understanding of TSS dynamics and would help rule out this stressor.

Physical habitat

The MSHA score was considered fair for both sampling years (56 in 2008 and 68 in 2010). A quantitative habitat assessment was done in 2010, and the reach was found to have 28% riffle, 59% run, and 11% pool. It was also noted there were few pools overall and lack of depth to pools. This was confirmed after multiple site visits, and also demonstrated in the fish data. Larger fish, which require deeper pools and cover, were not found in Corey Creek. The majority of the fish community sampled in 2008 was five inches long and smaller.

A MDNR survey from 1991 noted that, “fish habitat in this part of the stream is poor because it contains 71% silt muck, 19% sand, and 9% clay. Aquatic vegetation is absent.” Other areas (upstream) seem to demonstrate better fish habitat characteristics.

A Rosgen “Level 2” geomorphology survey was completed at Station 08LM018 on Corey Creek in 2010. A Level 2 analysis requires extensive field surveys of bankfull features and stream pattern, profile and dimension. The survey’s pebble counts confirmed that the entire biological station was comprised mainly of sand, silt, and clay, with little gravel or cobble (Table 20). Also, as part of the survey, a stream longitudinal profile and riffle and pool cross sections were also measured. The longitudinal profile of Corey Creek is shown in Figure 64. Along with the longitudinal profile reading, a measure of embeddedness was also taken (i.e. a copper rod was pushed into the stream bottom and measured at point consolidated material was reached). In Figure 64, the lighter color shows the amount of sediment deposition assumed to be mobile during high flows (because it is loose and unconsolidated). The survey was only done in 2010, and it hasn’t been repeated; therefore it is unknown how it changes seasonally. This graphic illustrates how the pools and runs are filled in and how the fish habitat has been affected. It also shows that with the exception of a few riffles, the stream is showing severe embeddedness. A quantitative habitat assessment was done in 2010 and showed that 47% of the reach was embedded.

Table 20. Results from 2010 Pebble Count at biological Station 08LM018 on Corey Creek.

	Cobble %	Gravel %	Sand %	Silt/Clay %
Reach	2	20	**77.2**	**36**
Riffle	0	22.8	**77.2**	**24**

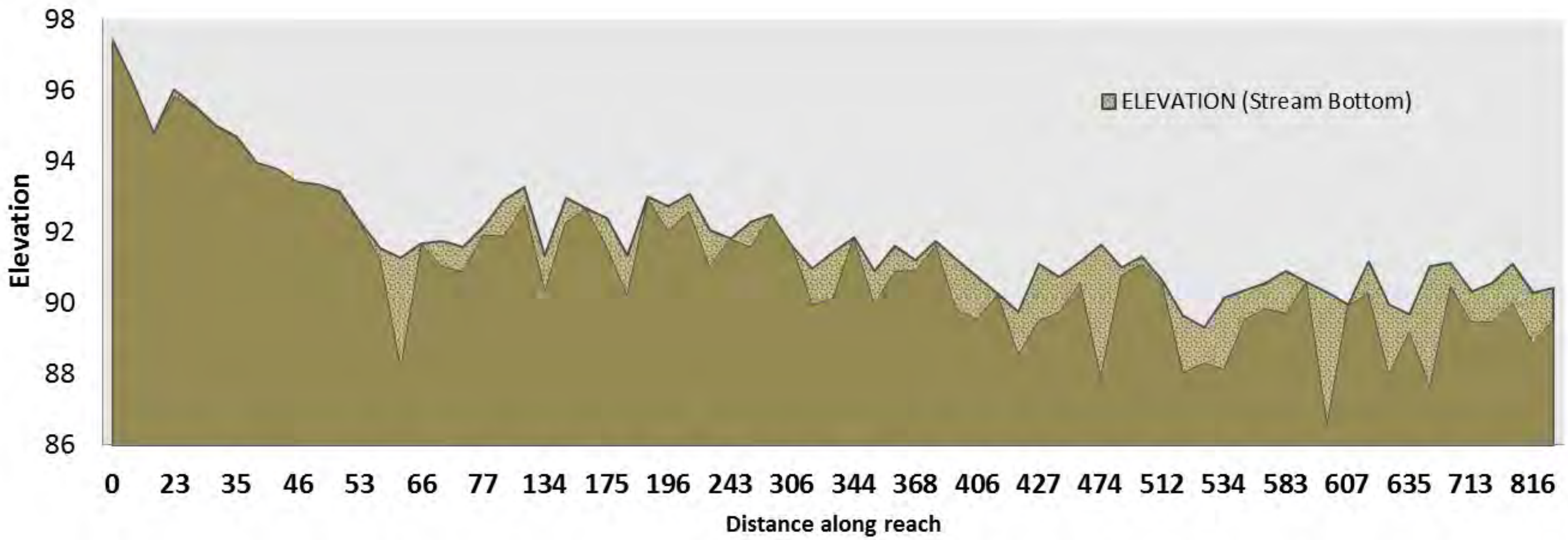


Figure 64. Graph of longitudinal profile geomorphology data demonstrating substrate embeddedness and sediment deposition in Corey Creek

The macroinvertebrate habitats sampled were based on dominant habitat types, including riffles, woody debris and undercut banks/overhanging vegetation. The macroinvertebrate community at Station 08LM018 was below average for the percentage of climbers (1-5%) but well above average for percentage of clingers (53% and 41%). Burrowers were below the average of 8% (3.3% for both visits). An increase in burrowers could potentially indicate siltation in the riffle, which is not the case here. Excess siltation and substrate embeddedness is documented in the pools and runs (Figure 64) instead. The percentage of EPT was very high at 62% and 64%; well above average for coldwater stations statewide (39.2%). There were a slightly higher percentage of macroinvertebrates that are considered swimmers than the average for coldwater stations statewide (26% and 34%). These habitat specific metrics do not indicate much habitat stress to the macroinvertebrate community in Corey Creek.

The habitat metrics specific to the fish community show percentages near average for riffle dwelling fish (28%), non-tolerant benthic insectivores (38%), simple lithophilic spawners (37%), and darter/sculpin/round-bodied suckers (35%). These habitat related fish metrics were all well above averages for stations statewide and stations in the Southern Coldwater fish class. This is explained by a community dominated by creek chub, white sucker, and johnny darter. However, over half of the community is made up of species which are considered pioneer species (creek chub, johnny darter, fathead minnow), which are the first fish species to invade headwater streams after periods of desiccation and thrive in unstable environments. In addition there were few piscivore species present (less than 2% in both samples, which is below the average of 37%). The lithophilic spawners metric also showed a slightly lower than average percentage for statewide coldwater stations.

There are major habitat issues in the section of Corey Creek as noted by the embedded substrate and lack of pools and pool depth, which are clearly impacting the fish community. The macroinvertebrate community has the potential to be threatened by these types of habitat issues as well, but is not showing much stress currently. It will be important to continue to monitor Corey Creek to document any changes that may occur in the macroinvertebrate community.

Connectivity

The biological station on Corey Creek, 08LM018, is located just downstream from a culvert that is perched about 18 inches from the streambed. This culvert is cutting off movement for fish to travel throughout the creek (Figure 65). During site visits, it was noted that water was only flowing through one of the two culverts. It is possible this culvert is oversized, and is potentially impacting the downstream sediment delivery and subsequent habitat problems.

The fish samples in 2008 and 2010 from Corey Creek show a reduced presence of migratory fish species. Campbell Creek's community, in contrast, has an abundance of migratory species. In addition to the culvert issue, some other connectivity issues may be contributing to issues in Corey Creek. A MDNR report from 1991, notes beaver dams and other connectivity issues causing fish barriers (Table 21).

Figure 65. Perched culvert at CR17 and Station 08LM018. MPCA photograph March 18, 2011.

Table 21. Fish Barriers noted in Corey Creek, MDNR report 1991.

Type	Miles from Mouth	Head	Length of Dam	Type of Control Structure	Use	Fish Barrier	Owner	Condition or Status
Beaver dam	2.76	1'	8'	xx	xx	Yes	xx	Active
Beaver dam	2.79	1'	7'	xx	xx	Yes	xx	Active
Beaver dam	2.93	0.5'	4'	xx	xx	No	xx	Inactive
Beaver dam	2.98	0.5'	5'	xx	xx	No	xx	Inactive
Bridge apron	4.17	0.5'	85'	Cement	Crossing	Yes	State	Permanent
Culvert	5.30	1'	102'	Steel	Crossing	Yes	Unknown	Permanent

Strength of evidence, conclusions, and recommendations

Corey Creek's fish community at Station 08LM018 is degraded due to multiple stressors (habitat, connectivity, and temperature). The evidence points to degraded habitat as the main stressor to the fish community in Corey Creek. Another contributing stressor to the fish community is the perched culvert located at County Road (CR) 17. The only fish that can easily migrate to this reach are from Money Creek itself, which is a warmwater system. The biological station on Corey Creek is located on a 0.5-1 mile stretch before it empties into Money Creek. MDNR has found trout in the upstream reaches and has documented some natural reproduction there as well. In 2001, MDNR noted that the upstream portion of the creek is meeting the long range goal for brook trout in the stream management plan of 250 fish/mile. So, the fish appear to be suffering most at this specific location on the creek (Station 08LM018), based on current information.

Figure 66. Removal of the riparian corridor. MPCA photo 4/27/2010.

The perched culvert at CR17 also causes issues with habitat loss due to bedded sediment. In 2007, after the flood, a new culvert was placed at this location. Multiple habitat and geomorphology measurements indicate a streambed with severe siltation. Pools and riffles are filled in with fine sediment. If the culvert were properly sized, and the grade corrected to more natural conditions, it's possible the increased velocity could move the sediment that has collected on the streambed. However, the source of excess sediment and siltation can be linked back to local land use in the watershed (i.e. pasturing and loss of riparian corridor in upper reaches). The land use in the riparian corridor has caused instability throughout the entire watershed. Restricting cattle access to the stream, as well as providing adequate buffers and riparian area along the entire creek would help this issue and the instability upstream contributing to it. There are culverts in the upper part of the watershed that may demonstrate similar issues (barriers to fish movement), but are not currently.

The temperature stressor is likely linked to lack of stream cover (tree removal in riparian area), pasture, and fine sediment in the stream bottom which absorbs more solar energy. The temperature data does suggest warmer temperatures (near 24°C) and a lack of coldwater species present.

Additional data collection upstream on the thermal regime, habitat, and instability may help inform further work in this watershed. This data would help understand the differences upstream to downstream. While this is a small watershed, another biological monitoring station upstream may help assess the difference in fish community present upstream of Station 08LM018. The last MDNR assessment (brook trout population assessment) of Corey Creek was in April of 2001. Updated information and assessment may be helpful in understanding changes in population over time.

4.3.1. Summary of stressors in Money Creek

The stressors found to limiting the biological (fish) community in Corey Creek are found in Table 22.

Table 22. Stressors identified in Money Creek. (● = stressor (yes); o = inconclusive stressor; 'blank'-no stressor)

Reach Name	Geo Region	AUID	Reach Description	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Physical Habitat	Physical Connectivity
Corey Creek	***Driftless, Bluffland Karst***	**07040008-631**	T105 R6W S18, east line to Money Cr	2A	08LM018	Downstream of CSAH 17, 3.5 mi. NW of Money Creek	Fish IBI	●			O	●	●

4.4. North Branch Root River

The macroinvertebrate only impairments in the North Branch Root River will all be addressed in separate sections (Figure 67). First, a very long stream reach of the mainstem North Branch Root River (from about Stewartville to Chatfield) will be addressed. Following that, another long stream reach (headwaters to Stewartville) will be addressed. Both of these reaches also have existing turbidity listings. Lastly, two tributary streams will be addressed in this section (Evanger Church and Unnamed Tributary).

Other streams in this watershed do have information worth mentioning (they are not currently impaired). Information suggests that brook trout were indigenous to Cary's Creek. Historical references refer to its excellent fishing opportunities. In the early 1970s, Cary's Creek supported a stocked brown trout population. However, sedimentation in the recent decades has deteriorated the fish habitat to where it is no longer a MDNR designated Class ID marginal trout fishery. Cary's Creek is now a MDNR Class IV rough fishery: forage fish population completely dominated by rough fish and forage species. Stream conditions deteriorated because of pollutants caused by upland soil erosion and the presence of cattle in the stream. The loss of recreational use for trout fishing is valued at $15,600 annually. (Watershed Plan-Environmental Assessment: Upper North Branch Root River Watershed, September 1992).

Mill Creek was not assessed because of channelization at Station 04LM029, and Station 08LM043 was also deferred from assessment due to lack of water at time of sampling. Station 11LM103 was established in the natural channel of Mill Creek, near Mill Creek Park in Chatfield. It's important to note that MDNR stocks fish heavily in the park for angling purposes. The FIBI in 2011 was 50 and MIBI was 9. Based on that information, the macroinvertebrates in Mill Creek would most likely be listed as impaired in the future. Mill Creek may be a watershed to consider for protection. The watershed may need some attention, and restoration, even though there are no official listings yet. Nitrates are also high in this watershed, and near drinking water standards.

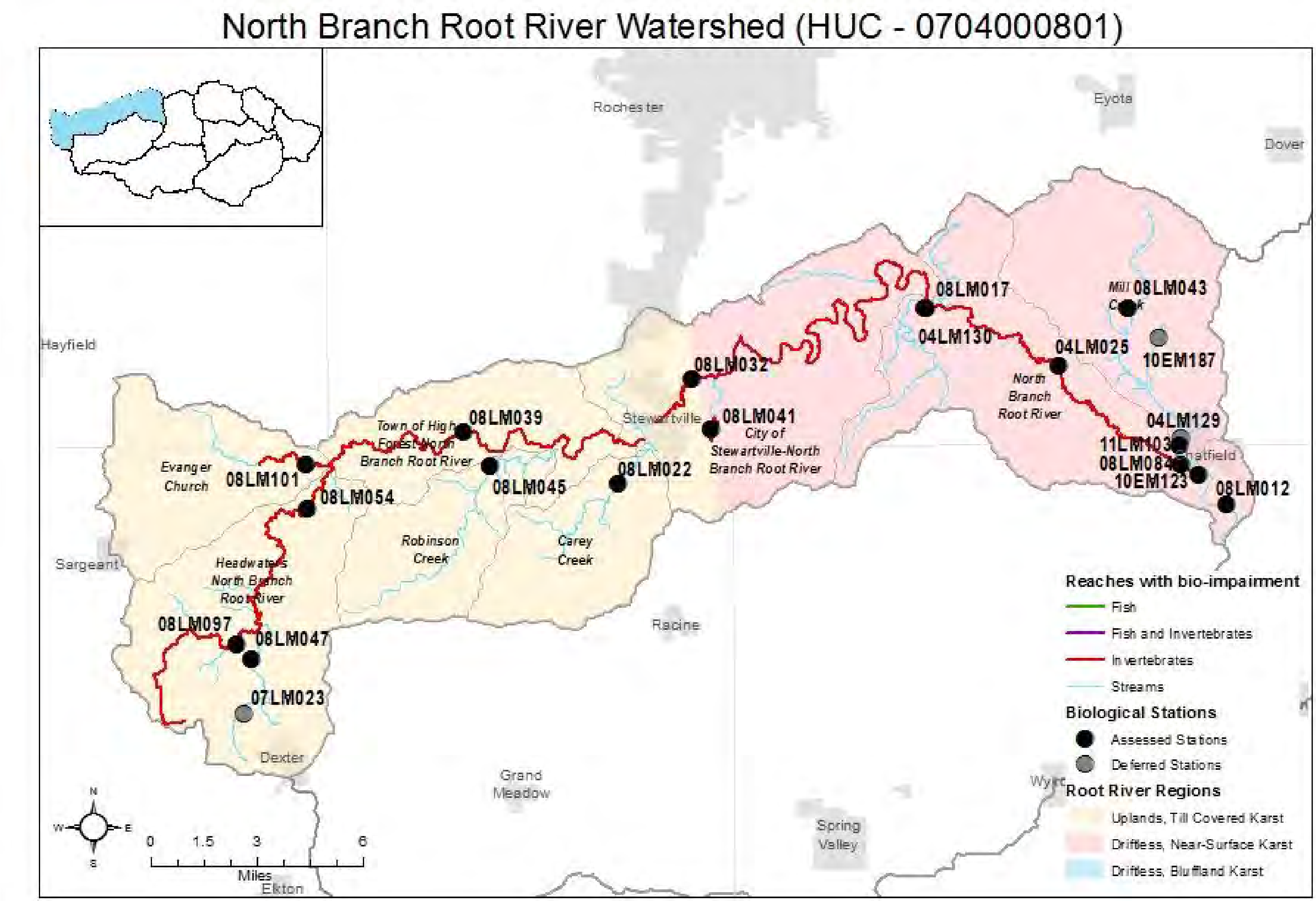


Figure 67. Map of the North Branch Root River Watershed showing reaches of biological impairment and biological sampling locations

4.4.1. North Branch Root (Main)

Supporting information

The lower reach of the North Branch Root River contains moderately deep pools, many riffles and occasional large boulders providing some good smallmouth bass cover. The channel substrate consists of abundant gravel and cobble. Approximately 1,900 acres of palustrine emergent wetlands occur in the study area. Palustrine emergent saturated (type 2) wetlands occur on approximately 1750 acres and are generally used for pasture. The majority of palustrine emergent seasonally and semi-permanently flooded (type 3, 4) wetlands occur in one state wildlife management area (Schumann WMA) located approximately three miles west of Stewartville. (Upper North Branch Root River Watershed: Tri-agency Biology Report April, 1991).

The original pre-settlement vegetation was tall grass prairie with trees along the streams. The watershed has mostly dark colored soils that were formed in silty sediments overlying glacial till. The soils are generally of the silty prairie types that are typical in southeastern Minnesota Land Resource Area 104 (Eastern Iowa and Minnesota Till Prairies). Soil Erosion on sloping soils and wetness of level areas are the main concerns for land use (Watershed Plan-Environmental Assessment: Upper North Branch Root River Watershed, September 1992).

Five biological stations were sampled for fish on this AUID of the North Branch Root River (716). The fish data is from two visits in 2004 and four visits in 2008. All fish IBI scores were above the threshold. The macroinvertebrates were sampled in 2004 and 2008; seven visits total at five biological stations. Five of the seven visits were above the threshold and two below.

Station 08LM084 was less than one point under the threshold and scored poorly in a couple of metrics in the Southern Forest RR IBI. Station 08LM084 scored a zero for the taxa richness of Plecoptera, and taxa richness of predators (excluding chironomid predator taxa; Predator) metrics. This station also scored low on the relative percentage of taxa with tolerance values equal to or greater than six, using Minnesota tolerance values (Tolerant2ChTxPct) and taxa richness of Trichoptera (Trichoptera). Throughout the AUID, the metrics of taxa richness of climbers (excluding chironomid climber taxa; Climbers) and a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN) also scored moderately low (Figure 68).

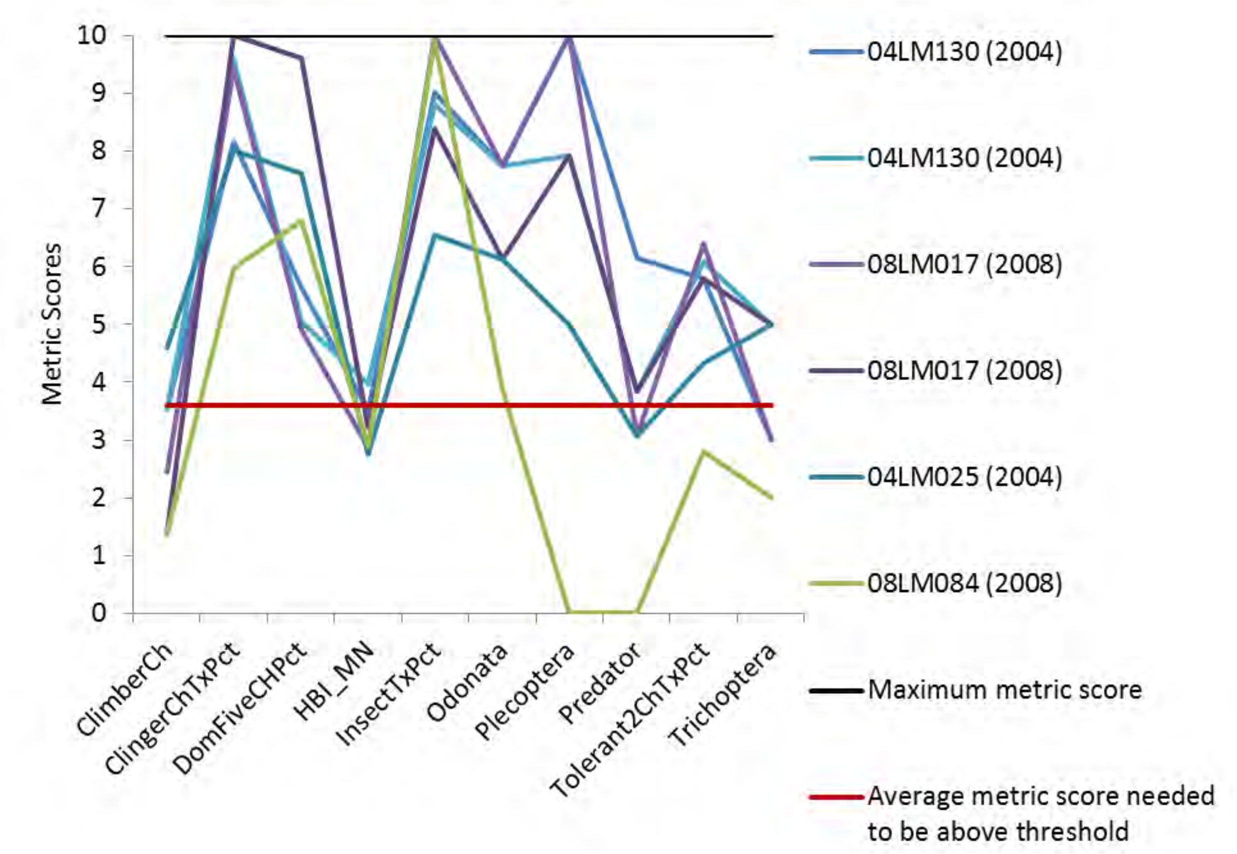


Figure 68. Metric scores for stations of MIBI Class 5, Southern Forest RR (716)

In a different macroinvertebrate class (6), Station 08LM032 was below the threshold with an IBI of 38.48 (threshold 46.8). The metrics that scored low at Station 08LM032 were a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota tolerance values (Intolerant2Ch), and taxa richness of predators (PredatorCh). Additionally, relative abundance of collector-filterer individuals in subsample (Collector-filtererPct), relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct), and relative abundance of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct) were moderately low (Figure 69).

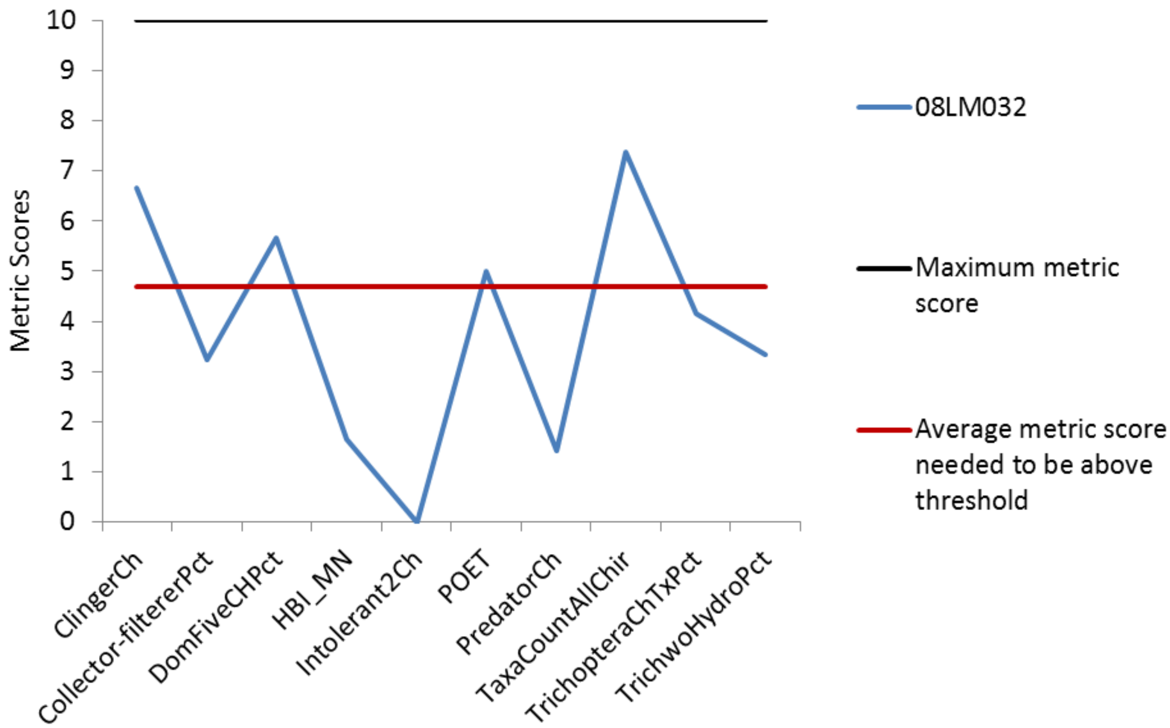


Figure 69. Metric scores for stations of MIBI Class 6, Southern Forest GP (716)

Temperature

There were 181 temperature measurements from five stations on this AUID. The highest temperature measured in this section of the river was 30°C on August 12, 2010. There were 44 measurements taken in July and August, and had an average of 23°C. The maximum temperature is high, but the healthy fish communities at all stations support that temperature is not a stressor to the warmwater biological communities present in this reach of the North Branch Root River.

Dissolved Oxygen

During biological sampling, all biological stations sampled DO (Table 23). In addition, there were ten measurements on this AUID, only two prior to 9:00 am. Early morning DO measurements are useful for determining the lowest concentration found on a stream. All others measurements for DO are within normal and expected range.

Table 23. Chemistry during biological sampling summary for biological stations on AUID: 716.

	Dissolved Oxygen Date/Time	Dissolved Oxygen (mg/L)	pH	Total phosphorus (mg/L)
08LM084	7/8/2008, 8:20 am	8.55	8.06	0.223
08LM017	7/24/2008, 8:43 am	8.55	8.15	0.137
08LM032	7/21/2008, 1:10 pm	9.51	8.0	0.162
04LM025	8/10/2004, 2:00 pm	9.55	7.87	0.092
04LM130	8/9/2004, 3:45 pm	9.65	8.19	0.084

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH and total phosphorus data during biological sampling was recorded (Table 23). The pH data during biological sampling was within an expected normal range, while the TP concentrations were elevated in some stations. Additional phosphorus data on the downstream part of this AUID at S004-841 was sampled for phosphorus 63 times between 2008 and 2010. The range of concentrations was 0.012-1.23 mg/L, with an average of 0.236 mg/L. At S004-919, 60 samples spanning from 2008-2012, showed a range of concentrations from 0.009-1.36 mg/L. The average concentration was 0.208 mg/L. The phosphorus values are elevated, but were taken for pollutant load-based monitoring, which focuses on events when phosphorus concentrations are typically the highest. Chlorophyll-a and BOD data were not available for analysis.

While fish at all stations are not impaired, the community is showing some tolerance to low DO. The stations in this reach (716) had fish DO TIV aggregate scores just below average for Root River stations, meaning the fish community does have a presence of some fish tolerant to low DO. However, fish do not show a strong tolerant or intolerant signature at these stations.

The macroinvertebrates, in general, on this section of river do show some sensitivity to low DO. All but one Station (08LM032) scored fairly well for DO TIV index scores. The other Stations (08LM017, 04LM030, 04LM025 and 08LM034) have between 10 and 17 intolerant taxa present, which are considered good, as the average for the Root River is 10 intolerant taxa. The percent tolerant taxa are also above average or near average for all the sites (with the exception of Station 08LM032). The only site which signals the potential for DO stress at this time is Station 08LM032, which is the farthest upstream station. EPT are typically intolerant of low DO levels. The percentage of EPT taxa is also reduced at this location only (08LM032). Taxa richness can also be decreased with increases in DO flux. Taxa counts are well above average across all stations.

It is not clear whether the community at 08LM032 is responding to low DO or some other stressor. Since this stream reach is not showing the same biological response throughout, it cannot be concluded that low DO is a stressor in this reach without additional chemical information.

Nitrate

Nitrate in this reach is elevated at times. From data collected in 2008 to 2010, nitrate concentration on this AUID ranged from 1.5 to 19 mg/L (Figure 70). Nitrate concentrations episodically elevate up to 19 mg/L. Station S004-919 is furthest upstream and has the highest nitrate concentrations. Station

S004-841 mimics that of the upstream station but does not get quite as elevated. The duration of the episodes with elevated nitrate are of particular interest along with the magnitude. Further consistent monitoring after events may help understand the duration of nitrate.

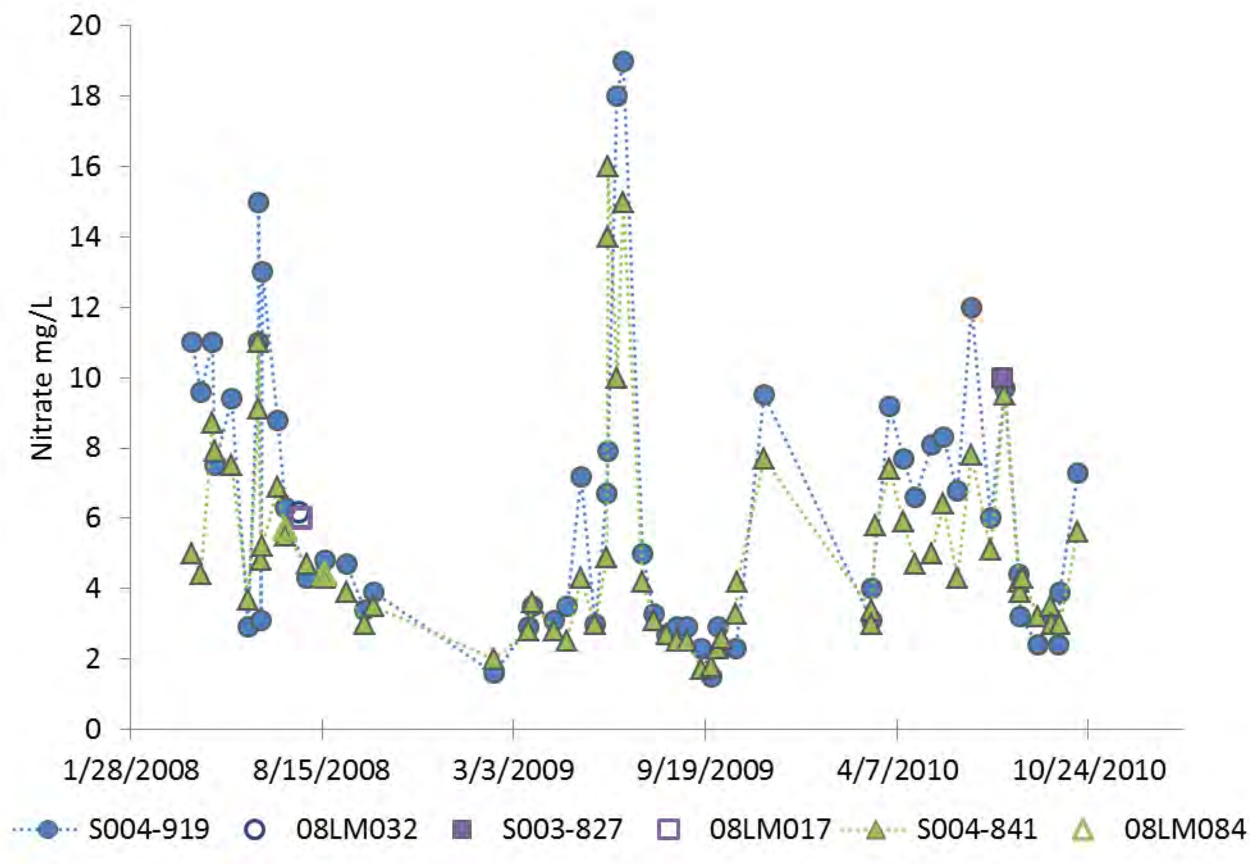


Figure 70. Range of nitrate concentrations from 2008-2010 on AUID 716.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Forest RR) streams in Minnesota shows a 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

The macroinvertebrate community shows a mixed response to nitrate (Table 24). At Station 08LM017 there were up to six nitrate intolerant taxa surveyed, along with low percentages of nitrate tolerant individuals. Stations 08LM032 and 08LM084 had elevated percentages of nitrate tolerant individuals and no nitrate intolerant taxa. However, the response is not consistent throughout biological stations on this reach. It's likely the biological response is driven by another stressor which is more localized. It's also possible cumulative stressor response is being observed in these locations as well.

The inconsistency of biological response is likely due to a different primary stressor, but nitrate is elevated. It is inconclusive whether nitrate is negatively influencing the macroinvertebrate community. Further understanding of the duration of elevated nitrate concentrations would be beneficial.

Table 24. Macroinvertebrate metrics in the North Branch (717) that may be influenced by elevated nitrate levels. Bold and highlighted means the number lower than expected, expect for the percent nitrate tolerant individuals, where it is high than expected.

Station	Class	MIBI	Taxa Count	Trichoptera Taxa	Intolerant Taxa	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	% Nitrate Tolerant Individuals
08LM032	6	**38.5**	29	**3**	**0**	**0**	**0**	**77**
04LM130	5	61.5	34	7	4	2	2	56.6
04LM130	5	62.5	35	5	3	4	2	47.3
08LM017	5	59.9	26	5	2	2	1	65.4
08LM017	5	61.3	33	7	4	6	3	65.3
04LM025	5	53	32	7	1	3	2	68.4
08LM084	5	**35.6**	**16**	**4**	**0**	**0**	**0**	**83.2**

Suspended sediment

TSS in this reach of the North Branch Root River (716) has been as high as 980 mg/L and averaged 85.9 mg/L from data collected from 2008-2010. A continuous turbidity probe read conditions from 2008 to 2010 at Station S004-828 in Chatfield. The percent of time that 25 NTU was exceeded was 8.88% (with a power regression to convert the probe readings of FNU to NTU). The greatest duration above the 25 NTU standard was 7.88 days.

The fish community, while not impaired on this reach of the river, does signal tolerance to high TSS. The TSS station index scores for fish are in the most tolerant quartile of all warmwater stations in the Root River. The percent carnivore metric, which is correlated to TSS, shows near average for most of the stations on this reach, but falls below average (Root River watershed fish class two average of 14.9%) when moving downstream. Stations 04LM025, 10EM123 and 08LM084 all have percent carnivores between 3-5%, which is considered low and potentially indicate TSS stress to the fish community.

In the North Branch Root River, most TSS station index scores for macroinvertebrates were worse than the Root River warmwater average (Table 25). Although there were TSS intolerant taxa present, TSS tolerant taxa and the percentage of TSS tolerant macroinvertebrates was high through much of the reach. The percentage of intolerant macroinvertebrates and long-lived macroinvertebrates were mixed throughout the reach. TSS is in part shaping this macroinvertebrate community, but is not likely the only stressor present.

Table 25. Macroinvertebrate metrics relevant to TSS for stations in the North Branch Root River compared to averages for warmwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics		**TSS Station Index Score**	**TSS Intolerant Taxa**	**TSS Tolerant Taxa**	**Percentage TSS Tolerant Macroinvertebrate Individuals**	**Percentage of Intolerant Macroinvertebrate Individuals**	**Percentage of Long -lived Macroinvertebrate Individuals**
Upstream	**08LM032**	**18.16**	**0**	**11**	28.33	**0**	**2.88**
	04LM130	17.35	7	**12**	25.5	2.25	6.75
		21.26	6	**14**	**55.7**	1.26	8.83
	08LM017	**19.54**	7	**11**	**47.37**	1.54	13.23
		20.3	4	**13**	**53.4**	**0.32**	9.06
	04LM025	**21**	4	**13**	**49.12**	**0**	4.15
	08LM084	**18.53**	**1**	9	**49.33**	**0**	**0.97**
Downstream	**10EM123**	**19.11**	2	**14**	**42. 99**	0.62	8.67
Expected response with increased TSS stress		increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed		17.96	1.52	9.32	35.45	0.48	3.16

Given the chemical and biological information available, TSS is considered a stressor to the North Branch Root River. Both fish and macroinvertebrates show increased tolerance for TSS, especially when moving downstream. This data supports the current turbidity listing, even despite the fact the continuous turbidity data is not showing turbidity standard violation, the evidence is there that TSS is elevated and impacting biology in the downstream locations.

Physical habitat

The details of the habitat characteristics found on the North Branch Root River are shown in Table 26. The macroinvertebrate IBI scores vary throughout this reach as well as corresponding MSHA (habitat) scores. The MSHA scores seem to show a similar trend throughout the North Branch watershed, with reduced scores in most subcategories found at 08LM032 (Figure 71). The "Land use" subcategory is scoring poorly at most of the stations.

Table 26. Habitat characteristics of stations found on AUID-716. Sites with red font are where macroinvertebrates are scoring below impairment threshold.

Biological Station (upstream to downstream)	Invert Habitat Sampled	MIBI Score	MSHA Score	Dominant Run/Glide and Pool Substrate
08LM032	Riffles Overhanging Veg/Undercut banks Woody Debris	38.48	46-Fair	Sand/silt/clay
04LM130 (8/23/04)	Riffles Woody Debris	61.54	77.5-Good	Boulder/cobble and cobble/gravel
04LM130 (9/8/04)	Riffles Overhanging Veg/Undercut Banks Woody Debris	62.54	77.5-Good	Boulder cobble and sand/silt/clay
08LM017(8/4/08)	Riffles Woody Debris	59.85	60.6-Fair	Cobble/gravel and sand/silt clay
08LM017 (8/19/08)	Riffles	61.29	60.6-Fair	Cobble/gravel and gravel/sand
04LM025	Riffles Woody Debris	53.08	57.10-Fair	Cobble/gravel and cobble/gravel
08LM084	Riffles Woody Debris	35.63	67.5-Good	Cobble/gravel and gravel sand

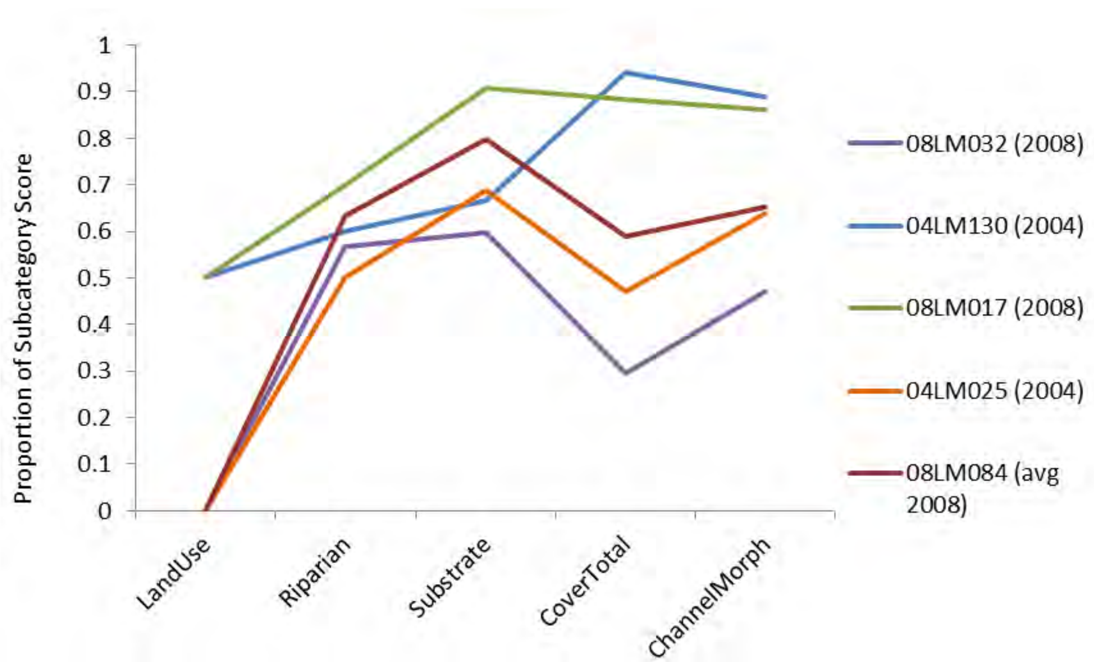


Figure 71. MSHA and subcategory scores for biological stations in the North Branch.

Burrowers, which may suggest potential fine sedimentation issues in the riffles, were not found in high abundance (riffles were sampled at all locations). The percentage of EPT individuals was greater than the statewide averages at all locations, except they were reduced at Station 08LM032 (only 14.7%). Additionally, there were a high percentage of macroinvertebrates than climb at Station 08LM032, coupled with a high percentage of legless macroinvertebrates (78%). The other stations in this reach had reduced percentages of macroinvertebrates that climb when compared to statewide averages. Although percentages of macroinvertebrate individuals were reduced, Stations 04LM130 and 04LM025 had sufficient climber taxa, allowing for a metric score greater than the average metric score needed to be above the threshold. Stations 04LM084 and 08LM017 had reduced numbers of climber taxa; 4-5 climber taxa at each station.

The macroinvertebrates that are known to cling to large substrate and woody debris were found in near average at all locations. The stations with slightly reduced percentages of clingers were Stations 08LM032, 04LM025 and 08LM084 (32.3%, 37.7% and 30.6% respectively, compared to the statewide average of 43.1%). Based on the macroinvertebrate information collected, habitat appears to be a limiting factor at Station 08LM032 with overall reduced percentage of EPT taxa with an abundance of more tolerant, legless macroinvertebrates. The other stations are showing a slight indication of habitat stress, but the data are not as strong. Overall, it can be concluded that habitat is a stressor to the macroinvertebrate communities in the North Branch Root River.

Physical connectivity

No information was available or collected on physical connectivity on the North Branch Root River. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in the North Branch Root River at this time.

Strength of evidence, conclusions, and recommendations

The stressors to the macroinvertebrate community in the North Branch Root River are TSS and habitat. Habitat stress appears to be largest in the upstream location, 08LM032. While habitat stress is demonstrated at other stations as well, the data are not as strong. In addition, TSS stress evidence appears to be strongest at this location. This may point to potential local issues related to habitat, stream bank erosion and sedimentation on this part of the stream reach, where it is not as apparent elsewhere.

Figure 72. Station 08LM032, middle of reach; looking downstream. Sedimentation visible on streambed near right edge of water.

Additional information should be collected for DO near 08LM032 as well. This is the only station which signaled the potential for DO stress on this entire stream reach. Without adequate chemical information, a DO stressor could not be confirmed at this time.

It is inconclusive whether nitrate is negatively influencing the macroinvertebrate community, but nitrates are elevated in this reach. Further understanding of the duration of elevated nitrate concentrations would be beneficial in this part of the North Branch Root River.

4.4.2. North Branch Headwaters

Supporting information

The fish community in this headwaters reach of the North Branch Root River had three visits at the three biological stations and all scored above the threshold. The macroinvertebrate community was below the threshold and within the confidence interval at all three stations, indicating impairment.

The macroinvertebrate community composition at the upstream Station 08LM097 was similar to the macroinvertebrate community at Station 08LM032 in the AUID downstream, showing that stressors are likely prevalent through some of the next AUID as well. The metrics that scored low at Station 08LM097 were relative abundance of collector-filterer individuals in subsample (Collector-filtererPct), a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota tolerance values (Intolerant2Ch), and relative abundance of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct). Additionally, the relative abundance of dominant five taxa in subsample (chironomid genera treated individually; DomFiveChPct) were moderately low (Figure 73).

In 1991, the Upper North Branch Root River Watershed Tri-agency Biology report said "The upper reach of the North Branch Root River has an average depth of 1.1 ft. The channel is obstructed by many log jams, lodged trees and beaver dams. The channel substrata consists of 95% sand and silt, 4% gravel and 1% rubble. The fish habitat in this section of the river is generally unsuited for smallmouth bass and channel catfish due to inadequate flow, excessive sedimentation, fertilizer, pesticides and turbidity."

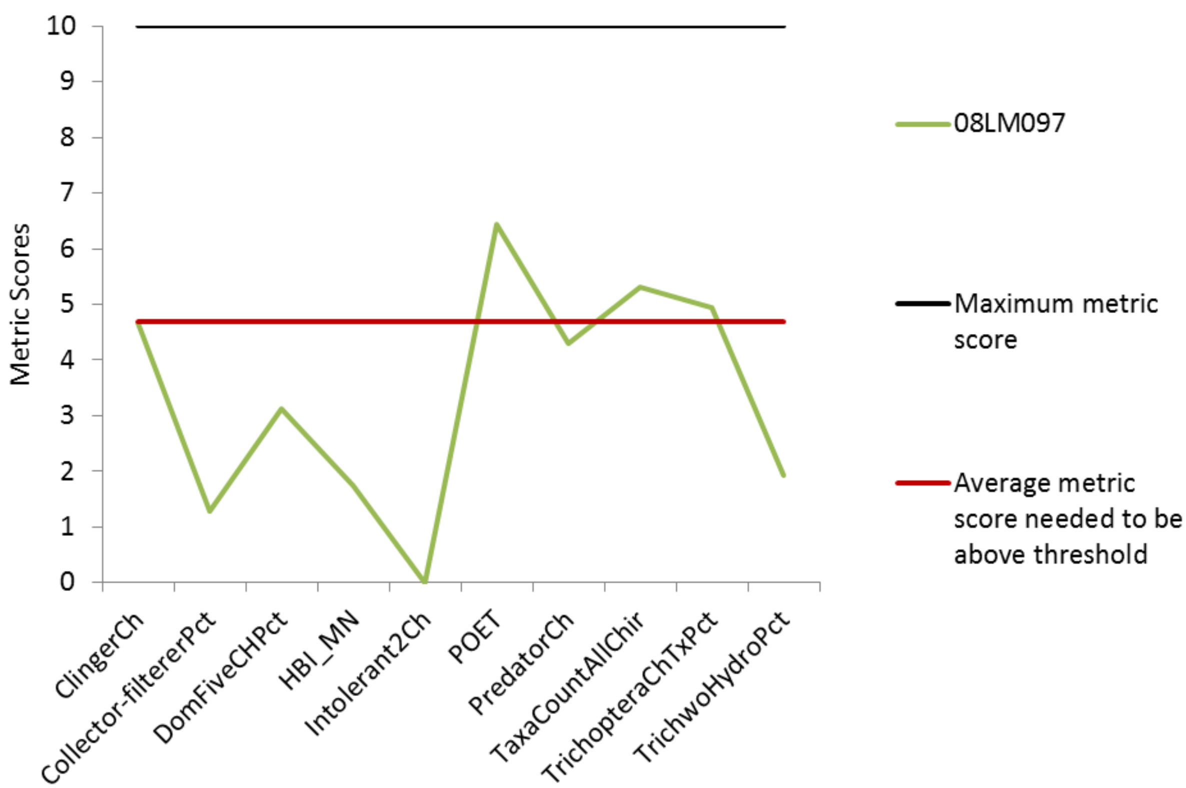


Figure 73. Metric scores for Stations (AUID 717) of the Southern Forest Streams GP macroinvertebrate IBI

Stations 08LM054 and 08LM039 exhibited similar metric scores for the Southern Forest RR macroinvertebrate class. The lowest scoring metrics for these stations were Plecoptera, taxa richness of predators (excluding chironomid predator taxa; Predator), Tolerant2ChTxPct, Trichoptera. ClimberCh and HBI_MN were also low (Figure 74).

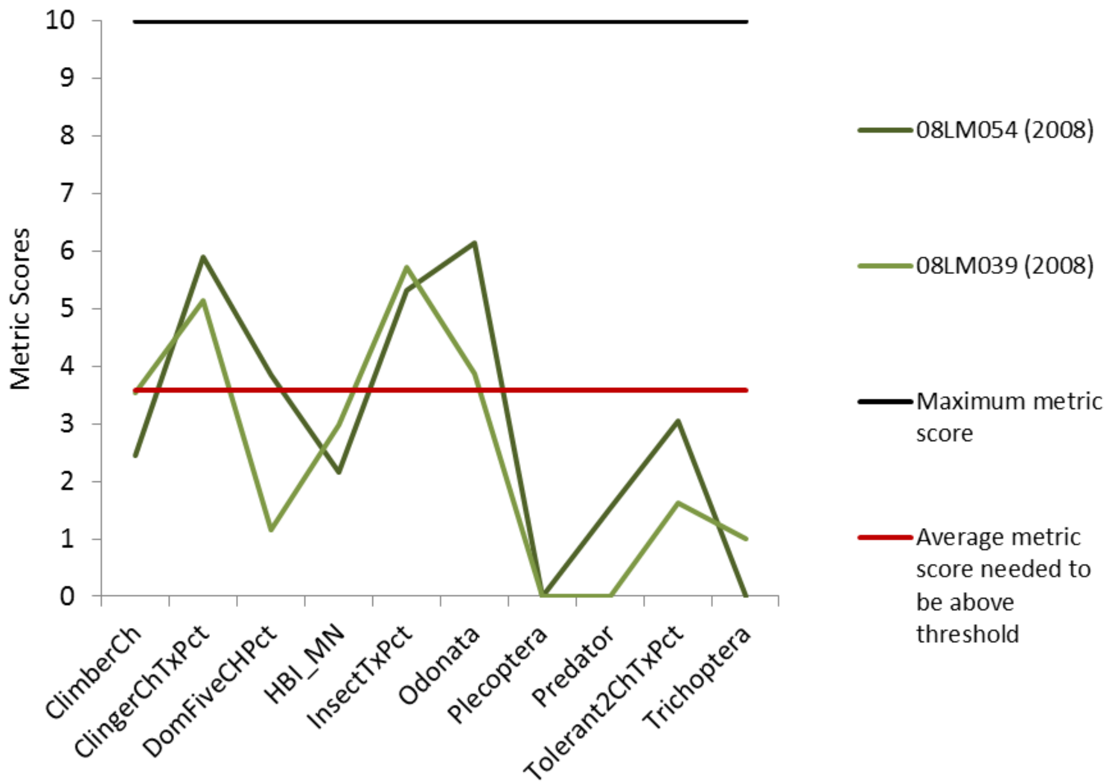


Figure 74. Metric scores for stations of MIBI Class 5, Southern Forest RR (717)

Temperature

Temperature does not appear to be an issue in this stream reach. The highest temperature measured in this section of the river was 27°C. The healthy fish communities at all stations support that temperature is not a stressor to the warmwater biological communities present in this reach of the North Branch Root River.

Dissolved Oxygen

During biological sampling in 2008, all stations were sampled for chemistry, including dissolved oxygen (DO, Table 27). In the headwaters of the North Branch, AUID-717, the DO concentrations at the time of fish sample from Stations 08LM097 and 08LM039 were low for the time of day they were measured to cause inquiry to low DO as a potential stressor, even though the numbers didn't violate the standard concentration of 5 mg/L. Available historical DO data showed a DO range from 6 mg/L to 14 mg/L, during the years of 1989 and 1990; and ranged from 6.49 mg/L to 13.18 mg/L from data spanning 2008 to 2011. No recent synoptic samples were measured prior to 9:00 am, and only one sample in 1990 was measured prior to 9:00 am.

Table 27. Chemistry during biological sampling summary in 2008 from four biological stations on 717 in the North Branch Root.

	Dissolved Oxygen Date/Time	Dissolved Oxygen (mg/L)	pH	Total phosphorus (mg/L)
08LM054	7/21/2008 5:45 pm	10.24	8.14	0.069
08LM097	8/13/2008 10:25 am	6.49	7.86	0.062
08LM039	8/6/2008 8:33 am	5.55	7.82	0.066

In 2010 and 2011, a multiparameter sonde was deployed at Station 08LM097 to capture diurnal DO data (Hydstra Station ID: W43098001). The sonde collected 15 minute interval field measurements from July 8 – 21, 2010, and August 5 -17, 2010. The data collected in 2010, showed measurements very close to the standard. In 2011, additional data was collected from July 25 to September 2, 2011. In August 2011, multiple days had violations of the DO standard (5 mg/L), as shown in Figure 75.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. During biological sampling, pH and TP data were collected for each site (Table 27). The values collected were within normal ranges and standards and do not cause concern. Additional data collected from AUID 717, showed seven total phosphorus concentrations ranging from 0.006 mg/L to 0.550 mg/L in 2010 and 2011 (average of 0.244 mg/L). No additional phosphorus data was available for AUID 706. Chlorophyll-a and BOD data were not available for analysis on either AUID.

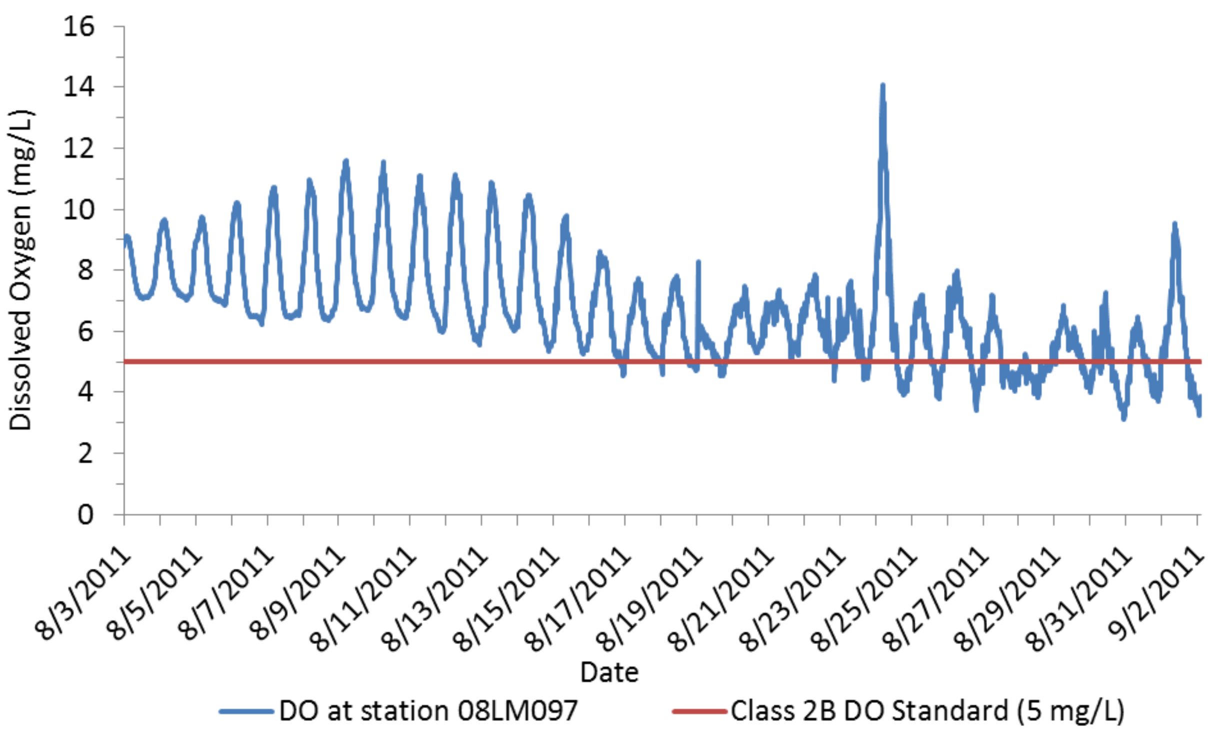


Figure 75. Dissolved oxygen data from 08LM097 from 8/3/2011-9/2/2011.

The fish community, while not impaired at any of these sites, is comprised of many DO tolerant fish. The stations had DO TIV scores in the lower 10% for all sites in the Root River basin, indicating the community is dominated by fish tolerant to low DO (Figure 76). Although a small percentage, there were some DO intolerant fish at each of the stations as well.

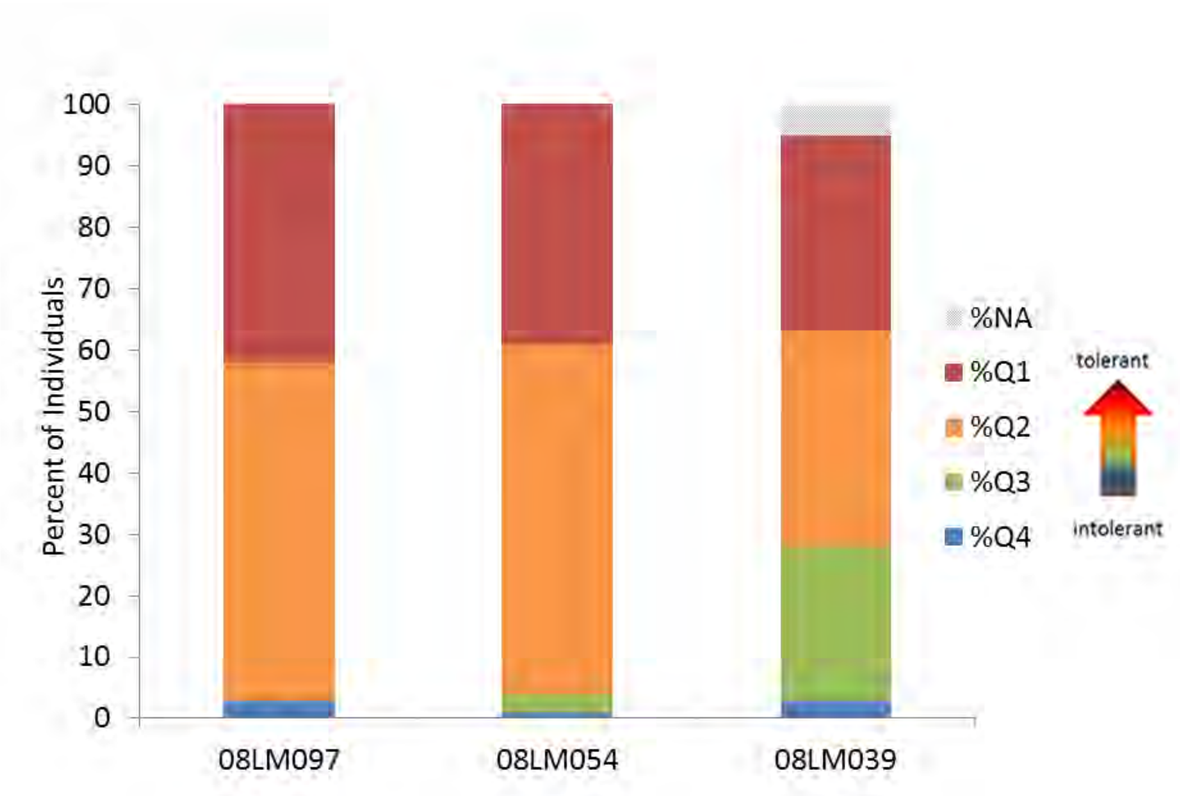


Figure 76. Fish DO TIV's for three biological stations on AUID 717.

The macroinvertebrate community TIV index scores were in the most tolerant quartile at all three biological stations, in comparison to other sites in the Root River. They also had few DO intolerant taxa and many DO tolerant taxa present in comparison to other sites (Table 28).

EPT taxa are generally sensitive to low DO and large DO fluxes, which can be reflected in the metrics percentage of EPT individuals and number of EPT taxa. In 2008, the percentage of EPT individuals at the three stations in the headwaters of the North Branch Root River ranged from 9.1 to 31.5%. Two of the stations were well below the average percentage of EPT for all macroinvertebrate classes in the Root River Watershed. However, all stations had above average number of EPT taxa. The HBI_MN, a pollution tolerance metric, was elevated at all stations, indicating a negative response. Taxa richness is also known to decrease with increases in stress related to DO. The macroinvertebrate taxa richness decreased upstream to downstream, with Station 08LM039 having the lowest taxa count.

In summary, EPT percent and number of DO intolerant taxa are low; while DO tolerant percent is high at all three stations in this reach (Table 28). Since both fish and macroinvertebrate communities show a response to low DO, the available chemical information shows exceedence of the DO standard, and there is a DO flux of 4-6 mg/L on average, DO has been confirmed as a stressor to the biological community.

Table 28. Macroinvertebrate Metrics Summary related to DO stress in the North Branch Headwaters. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

	Station	Macroinvertebrate Class	MIBI	EPT%	Taxa Count	HBI_MN	DO Tolerant %	DO Intolerant Taxa
Upstream	08LM097	6	33.72	**9.1**	24	**8.34**	**12**	**3**
	08LM054	5	30.42	**31.5**	21	**7.61**	**15**	**8**
Downstream	08LM039	5	25.01	**11.0**	**16**	**7.33**	**28**	**4**
Average for Root River Watershed (all classes)				**37.8**	**20.1**	**7.1**	**6**	**10**

Nitrate

Nitrate was collected at two stations in this reach on nine sampling dates in 1989 and 1990; ranged from 0.16 to 21 mg/L. During sampling in 2008, 2010, and 2011 nitrate ranged from 0.31 to 19 mg/L.

Table 29. Measurements of nitrate in the NB of the Root River (717)

Biological Station		**08LM097**			**08LM054**	**08LM039**
EQuIS Station	S006-314	S006-310	S005-119	S006-309	S006-308	
7/21/2008					5	
8/6/2008						2.5
8/13/2008		0.31				
6/18/2010		17	15	14	14	
9/23/2010		4.5			3.9	
3/17/2011		5.3			6.1	
6/7/2011	19	16			14	

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate Class 5 (Southern Forest RR) streams in Minnesota shows a 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class. The three biological stations have no intolerant taxa present. Taxa counts and Trichoptera taxa were reduced at two of the three stations, with the exception of Station 08LM097 which is just above average for its class.

At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. The upstream Station 08LM097 had the highest percent of nitrate tolerant individuals

(83.9%) and the percentage decreased with each station downstream; 08LM054 (71.3%) and 08LM039 (55.2%). However, Station 08LM097 also had two nitrate intolerant taxa, which is neither high nor absent. Station 08LM039 had one nitrate intolerant taxa.

There is a mixed biological response to the elevated nitrate levels. It is likely that some of the biological response is due to the elevated nitrate, particularly at the upstream Station 08LM097. However, it could be that the other stressor(s) present in the reach, particularly at Station 08LM097, are influencing the biological response making it appear stressed from nitrate. Regardless, nitrate is elevated and efforts should be taken to reduce the loss of nitrate. Further identification of the magnitude and particularly the duration of elevated nitrate in this headwater reach would be beneficial. Nitrate as a stressor is inconclusive in the headwaters of the North Branch Root River.

Suspended sediment

At time of fish sampling, in 2008, TSS ranged from 3.6 to 17 mg/L. TSS was also sampled 38 times in 1989 and 1990, with an average of 172 mg/L.

The fish community, while not impaired on this reach of the river, does show some potential tolerance to TSS. The TSS station index scores for fish are near average compared to all warmwater stations in the Root River. The percent carnivore metric, which is correlated to TSS, is near average for Station 08LM054 and better than average for Stations 08LM097 and 08LM039. The percent intolerant metric, which is also correlated to TSS, is very low (near 0%) for Stations 08LM097 and 08LM054, but jumps up to 22% for Station 08LM039. The results for this reach are mixed in terms of fish and tolerance to TSS, and do not present a strong signal either way.

In the headwaters reaches of the North Branch Root River, the TSS macroinvertebrate relevant metrics generally point to a tolerance to elevated TSS concentrations (Table 30). Station 08LM097, the furthest upstream station, has the highest TSS station index score with the other stations decreasing as you move downstream. Additionally, the upstream two stations have the highest percentage of TSS tolerant macroinvertebrate individuals. It is likely that TSS is having the largest impact on the upstream reaches of this AUID, but is likely contributing to shaping the community throughout the AUID. Elevated TSS is a contributing stressor to the macroinvertebrate community.

Table 30. Macroinvertebrate metrics relevant to TSS for stations in the North Branch Root River compared to averages for warmwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics		TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
Upstream	08LM097	**18.5**	2	8	**58.2**	**0**	**1.5**
↓	08LM054	17	**1**	7	**42.9**	**0**	4.7
Downstream	08LM039	14.6	**1**	9	16.4	**0**	**1**
Expected response with increased TSS stress		increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River Watershed		17.96	1.52	9.32	35.45	0.48	3.16

Physical habitat

Station 08LM097 had a fair MSHA score (58.8). This station has local land use consisting of primarily row crop agriculture, although it has a wide riparian buffer with little erosion present in the reach. At the time of fish sampling it was recorded that there were more than four substrate types and moderate embeddedness, with cobble and gravel the dominant substrates in the riffles. There was a moderate amount of cover present including undercut banks, overhanging vegetation, deep pools, boulders, woody debris and rootwads. Channel stability was noted as moderate with good sinuosity. The macroinvertebrate habitat sampled was riffles, overhanging vegetation/undercut banks, and woody debris.

Station 08LM054 had a fair MSHA score (54.7). It also had row crop as the surrounding land use. It has a slightly lesser riparian width than Station 08LM097, with little to no erosion and moderate shade. In the riffles and runs, gravel and sand were the most dominant, with run features comprising of approximately 80% of the reach. There was moderate embeddedness at the reach along with a lack of diverse substrate types. There was sparse (5-25%) cover in this reach, yet many types of cover present. At the time of fish sampling, the reach was noted as having moderate stability with good channel development. The macroinvertebrate habitat sampled was riffles, overhanging vegetation/undercut banks, and woody debris.

Station 08LM039 scored slightly better MSHA score than the two stations upstream but was still considered fair (62.1). Similar to the other two stations on this reach, had a moderate riparian width, little bank erosion and moderate shade. Eighty-five percent of the reach was run features, with only 10% pool and 5% riffle. The riffle features did have cobble and gravel substrate while the other 95% of the channel was dominated by gravel and sand. This reach did have a greater diversity of substrate types and light embeddedness. Cover was sparse in this reach, with only overhanging vegetation, woody debris and boulders. It was noted that this reach had high channel stability along with many areas of differing velocities within the reach. The Macroinvertebrate habitat sampled was riffles, overhanging vegetation/undercut banks, and woody debris.

Each station MSHA score and subcategory scores are found in Figure 77. Each station scored poorly in the “Land Use” subcategory, suggesting a lack of good riparian area throughout this reach.

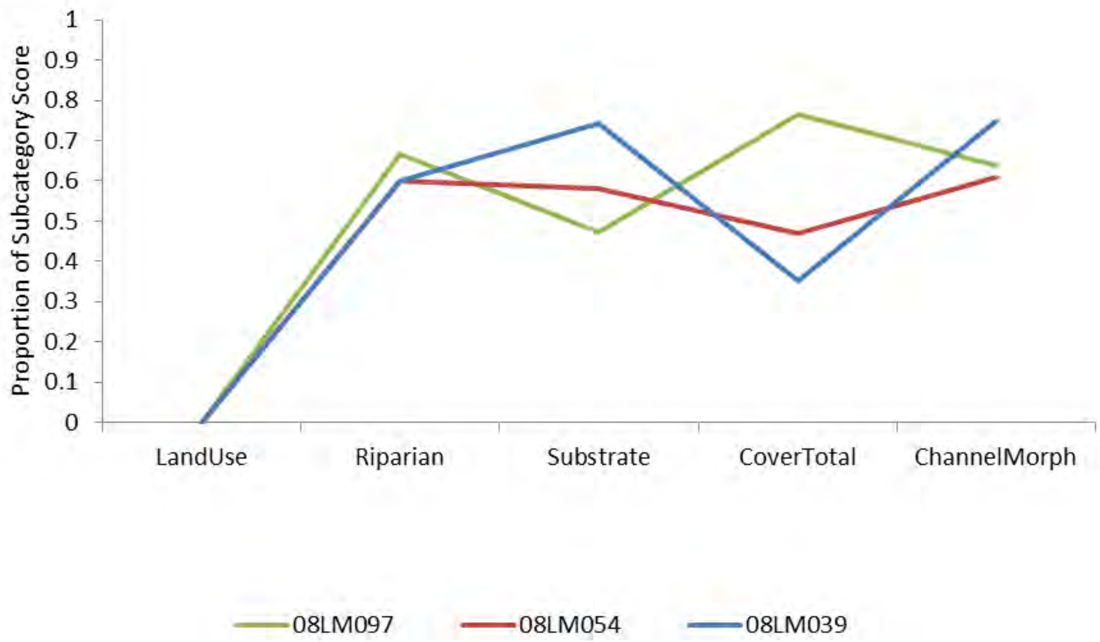


Figure 77. MSHA and subcategory scores for Stations in the North Branch Headwaters

There was not an abundance of burrowers found, which would suggest potential fine sedimentation issues in riffle habitat, except at Station 08LM054. This station had slightly higher than average number of burrowers present. The percentage of EPT individuals was less than the statewide average for each sites macroinvertebrate class. In addition there was large percentage of more tolerant legless macroinvertebrates found at all three Stations (63-87%). The macroinvertebrates that are known to cling to large substrate and woody debris were found in abundance (above statewide averages for the invert class) at 08LM054 and 08LM039. However, they percentage of clingers was reduced at 08LM097 (only 15%) and replaced with a higher percentage of macroinvertebrates that climb (66%). The percentages of macroinvertebrates that climb were near average for the other two sites. The percentages of swimmers and sprawlers were reduced at all three locations compared to statewide averages. The macroinvertebrate related habitat metrics do suggest habitat stress at all three biological stations, mainly related to the low percent EPT taxa and high percentage of legless individuals. Station 08LM097 appears to exhibit the most habitat related stress comparatively.

Sedimentation impacts which include filling in of pool and riffle habitats were documented during longitudinal surveys of two sites in the North Branch (Figure 78 and Figure 79). A copper rod was used to measure embedded sediment and understand the amount of unconsolidated material covering the streambed.

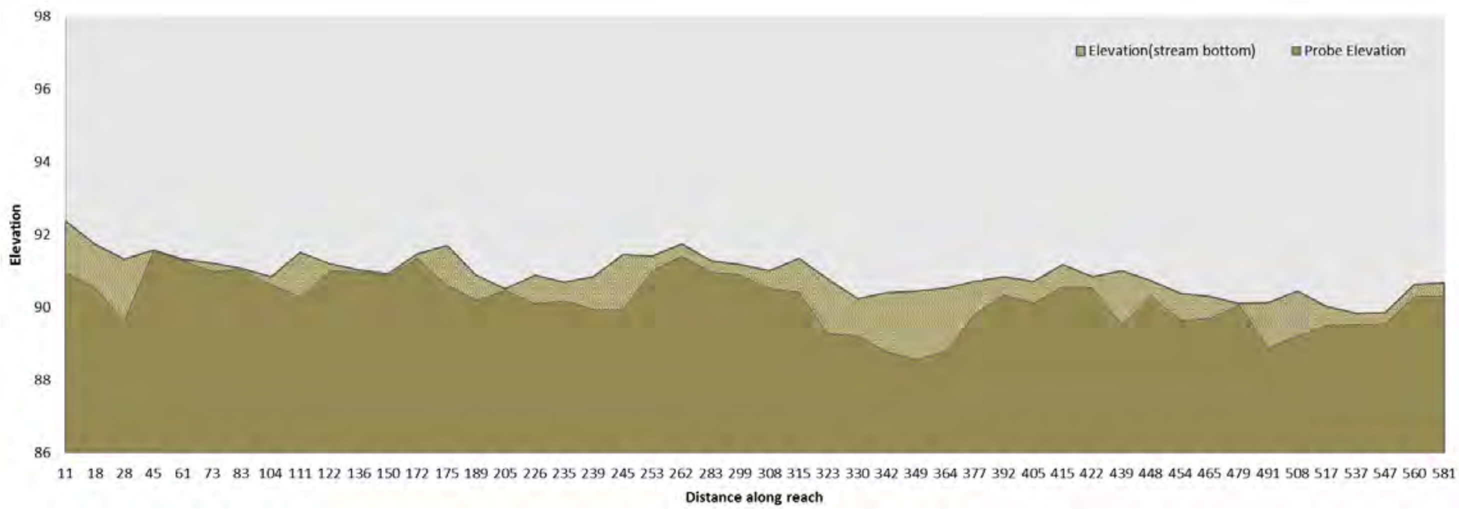


Figure 78. Station 08LM097 longitudinal profile and sediment deposition

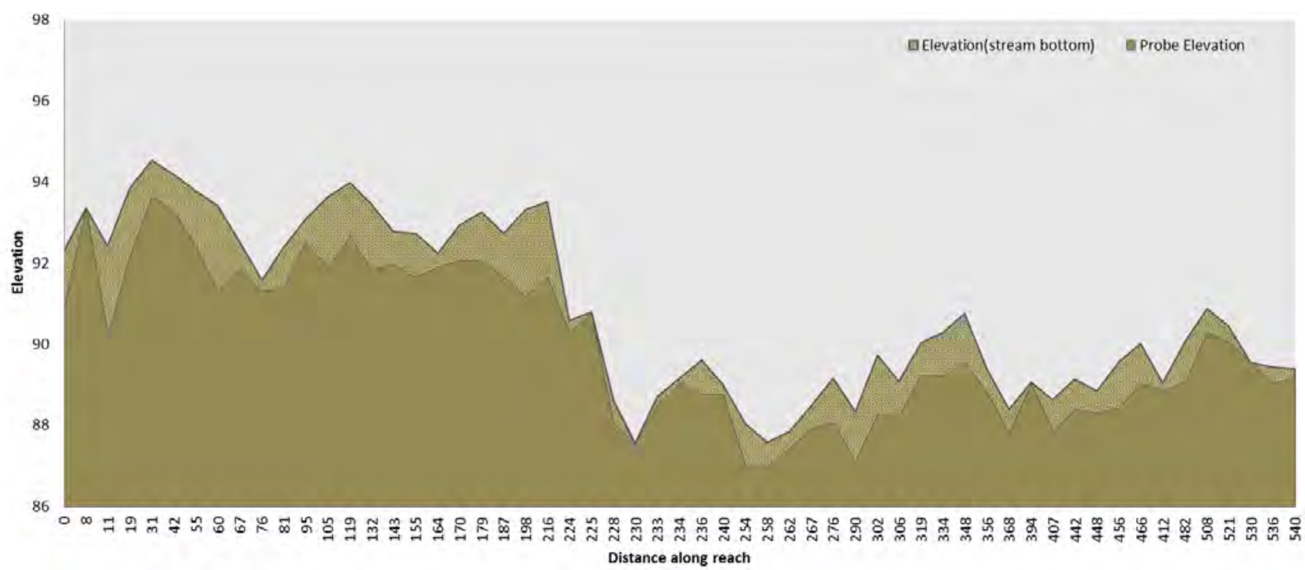


Figure 79 Station 08M054 longitudinal profile and sediment deposition

Physical connectivity

No information was available or collected on physical connectivity on the North Branch Root River Headwaters. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in the North Branch Root River Headwaters at this time.

Strength of evidence, conclusions, and recommendations

The main stressors to this reach of the North Branch Root River are habitat, TSS and DO. All three stressors appear to be making the most impact (in terms of biology response) at the farthest upstream Station, 08LM097. However, the other stations in this reach are also showing some response to all of these stressors just not to the same degree.

Phosphorus and TSS values do become elevated during storm events. A few grab samples do indicate that the phosphorus values are generally low during baseflow conditions. This may indicate that phosphorus levels are not driving the oxygen issues, but little data is available to make that determination. The gradient is low, the flow and velocity are slow in the upper parts of the reach. Some organic material in the stream may also be a consideration as a source of oxygen related issues BOD. In summary, the driver of oxygen issues in the stream is not quantified or known.

There is a mixed biological response to the elevated nitrate levels. Nitrate is elevated and efforts should be taken to reduce the loss of nitrate to the river. Further identification of the magnitude and particularly the duration of elevated nitrate in this headwater reach would be beneficial. At this time, nitrate as a stressor is inconclusive in the headwaters of the North Branch Root River.

TSS and sediment delivery to this part of the North Branch is partially explained by the high amount of channelization, tile drainage, and stream bank erosion. Better efforts to protect riparian corridor and stream bank erosion in this area would be beneficial. These factors would also improve habitat which has been linked to sedimentation, in addition to improving other habitat characteristics in these reaches.

4.4.3. Evanger Church

Supporting information

The macroinvertebrate community composition at Station 08LM101 showed reduced IBI metrics scores in most categories (Figure 80). Those that scored low at Station 08LM101 were relative abundance of collector-filterer individuals in subsample (Collector-filtererPct), the relative abundance of dominant five taxa in subsample (chironomid genera treated individually; DomFiveChPct), a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota tolerance values (Intolerant2Ch).

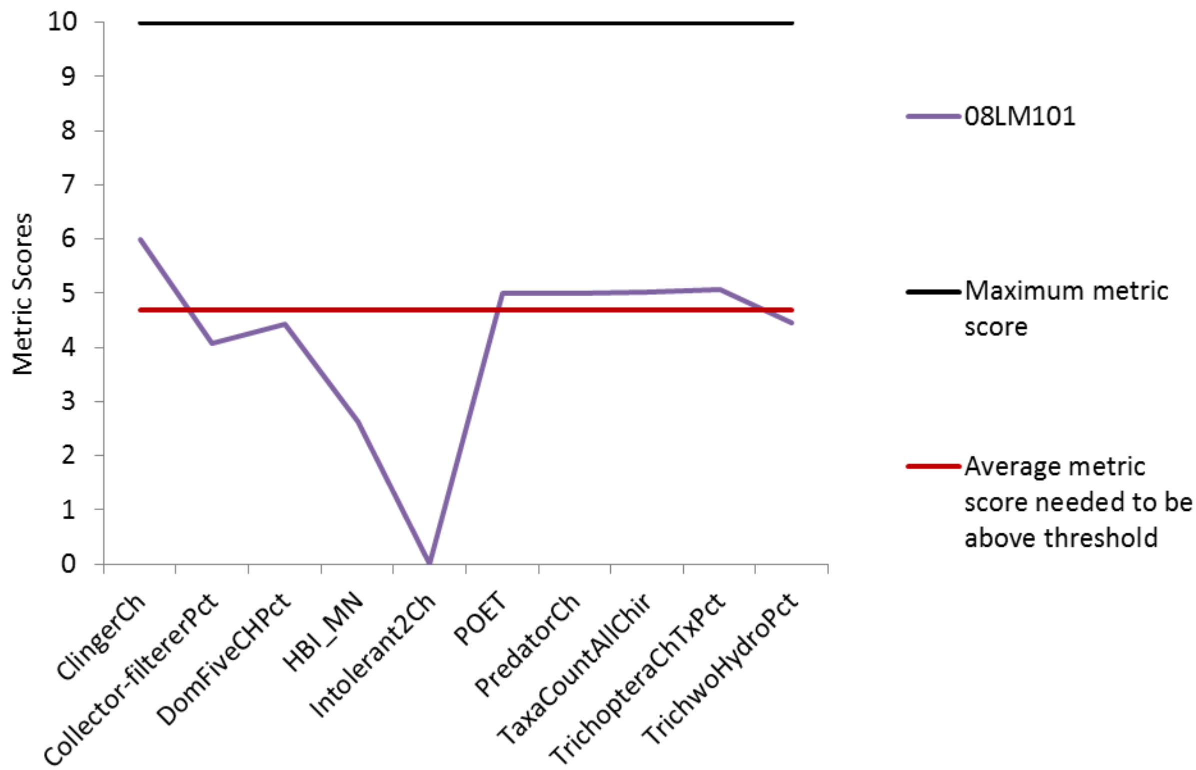


Figure 80. Metric scores for Station 08LM101 of the Southern Forest Streams GP macroinvertebrate IBI

Temperature

The only data available was taken during biological sampling. That temperature value is within a normal range (23°C). While a temperature stressor is not likely here, with such limited information, it is difficult to make determinations about temperature as a stressor.

Dissolved Oxygen

At Station 08LM101, there was only has one DO value for analysis taken during biological sampling (9.91 mg/L on July 24th, 2008, 12:12 pm). As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. During biological sampling, pH and total phosphorus data were 8.10 and 0.124 mg/L, respectively.

The fish community is not impaired at this location, but is comprised of tolerant fish. The station in this reach had a DO TIV aggregate score in the lowest 10% of all sites in the Root River, indicating a fish community very tolerant to low DO concentrations.

The macroinvertebrate community does show some signs of DO stress as well. There were only two low DO intolerant taxa present at this site (average for Root River Watershed is ten taxa). There were also 14% DO tolerant taxa found at Station 08LM101, which is high compared to the Root River Watershed average of 6%. EPT are typically intolerant of low DO levels, and the percentage of EPT taxa in this reach is also low. Taxa richness can also be decreased with increases in DO flux**.** The taxa count for this station is near average. The macroinvertebrate community overall has an index score in the lowest quartile for Root River Watershed stations, demonstrating a community tolerant to low DO.

While the biological information does show some signal to DO stress, more chemical information is needed to confirm DO as a stressor.

Nitrate

The nitrate concentration during fish sampling at Station 08LM101 was 3.1 mg/L, on August 4, 2008. It was the only nitrate measurement available at Unnamed Creek (Evanger Church).

As noted in previous sections, fish lack a strong biological response to elevated nitrate concentrations. The macroinvertebrate community at Station 08LM101 showed a mixed response to nitrate stress compared to other Class 6 sites from the Lower Mississippi River basin. Sampling from Station 08LM101 had 20 total taxa; including three Trichoptera taxa which are better than average (Class 6 averages; 19.8, and 2.2 respectively). There were no intolerant taxa present. There were 75% nitrate tolerant individuals and no nitrate intolerant taxa. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI.

The macroinvertebrate metrics that often respond to nitrate show a mixed response, and there is a lack of good chemical information to confirm stream nitrate concentrations. It may be likely that the nitrate value sampled in August is low compared to other times of the year (as seen in other nearby areas of the North Branch Watershed). It would be beneficial to better understand the magnitude and duration of nitrate concentrations in this reach. Given the lack of solid chemical information and mixed biological response, a nitrate stressor is inconclusive.

Suspended sediment

The TSS concentration during biological sampling at Station 08LM101 was 26 mg/L. While this value is elevated, it does not violate the TSS standard of 30 mg/L. Surrounding land use and riparian area, as well as dominant substrate (sand/silt) suggest a potential for high sediment concentrations in this reach. However, without additional information, it is difficult to conclude if suspended sediment is a stressor to this reach.

The fish community, while not impaired at this location, does show some potential to tolerance to TSS. The TSS station index scores for fish are among average compared to all warmwater stations in the Root River. The percent carnivore metric, which is correlated to TSS, is near average for Station 08LM101. While the fish community shows some tolerance, the response does not strongly indicate TSS issues.

Only 4% of the macroinvertebrate individuals were long lived and none were generally intolerant, which often decrease with increases in TSS. The macroinvertebrate index score for TSS was 17.69, just a bit better compared to average for warmwater stations in the Root River watershed (17.96). The station at the time of sampling had 11 taxa tolerant to TSS and only one intolerant to TSS. Fifty percent of the individuals in the survey are considered tolerant to TSS.

The macroinvertebrate community data suggests that TSS may be an issue at this location, but the biological data is mixed, and response is not strong. Additional chemical information is needed to understand TSS dynamics and confirm TSS as a stressor.

Physical habitat

Biological Station 08LM101 received a poor habitat score (42). The surrounding land use is row crop with a moderate (30 to 150 ft) riparian buffer. There is little shade as well as little bank erosion present in this reach. This reach is dominated by run features and consists of sand and silt, with moderate embeddedness. There was no riffle present in the reach. The macroinvertebrate habitat that was sampled was overhanging vegetation/undercut banks and woody debris/snags. There is little cover present in the reach; 5 to 25% present.

The percentage of EPT individuals was less than the statewide average (10% compared to the statewide average of 18%). In addition, there were a large percentage of tolerant legless macroinvertebrates (81%) at the station. The percentage of macroinvertebrates considered swimmers and sprawlers were also found to be less than average for this macroinvertebrate class. However, there were a high percentage of macroinvertebrates that climb (likely due to overhanging vegetation being a dominant habitat type). The macroinvertebrates that are known to cling to large substrate and woody debris were found at this site near statewide averages.

There are certainly aspects of habitat that could be improved in this reach. The local land use, photos, MSHA, and some macroinvertebrate metrics reveal habitat conditions which are less than ideal (Figure 81). Habitat is considered a stressor to this reach.

Figure 81. Biological Station 08LM101 (Middle of reach looking downstream).

Physical connectivity

No information was available or collected on physical connectivity on this reach. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

Habitat is the main stressor for the macroinvertebrate community at this time, but the biological connections are somewhat weak. The habitat assessment was rated as poor, in addition to the reach being mostly run with no riffle habitat. Embeddedness was noted, and visually observed in field visits and site photos. There are certainly aspects of habitat that could be improved in this reach. The local land use, photos, MSHA, and macroinvertebrate metrics all reveal habitat conditions which are less than ideal.

There are some indications that DO and TSS could be potential stressors, but with a lack of connecting chemical information, those stressors cannot be confirmed at this time. Overall, there is little chemical information on this reach, and additional information should be collected to confirm or rule out these potential stressors. Given the lack of solid chemical information and mixed biological response, a nitrate stressor is also inconclusive.

4.4.4 Unnamed tributary

Supporting information

The macroinvertebrate data is from one biological Station (08LM041) on this AUID, sampled once in 2008. Macroinvertebrate IBI score is below the threshold and the lower confidence limit. The fish at Station 08LM041 were just one point above the threshold. Although it may not be impaired, it is important to consider for future monitoring and assessment.

The macroinvertebrate community composition at Station 08LM041 showed reduced IBI metrics scores in many categories (Figure 82). Those that scored low at Station 08LM041 were relative abundance of collector-filterer individuals in subsample (Collector-filtererPct), a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota tolerance values (Intolerant2Ch), Taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (baetid taxa treated as one taxon) as described in the POET metric, and both metrics related to abundance of Trichoptera or caddisflies (TrichopteraChTXPct and TrichwoHydroPct).

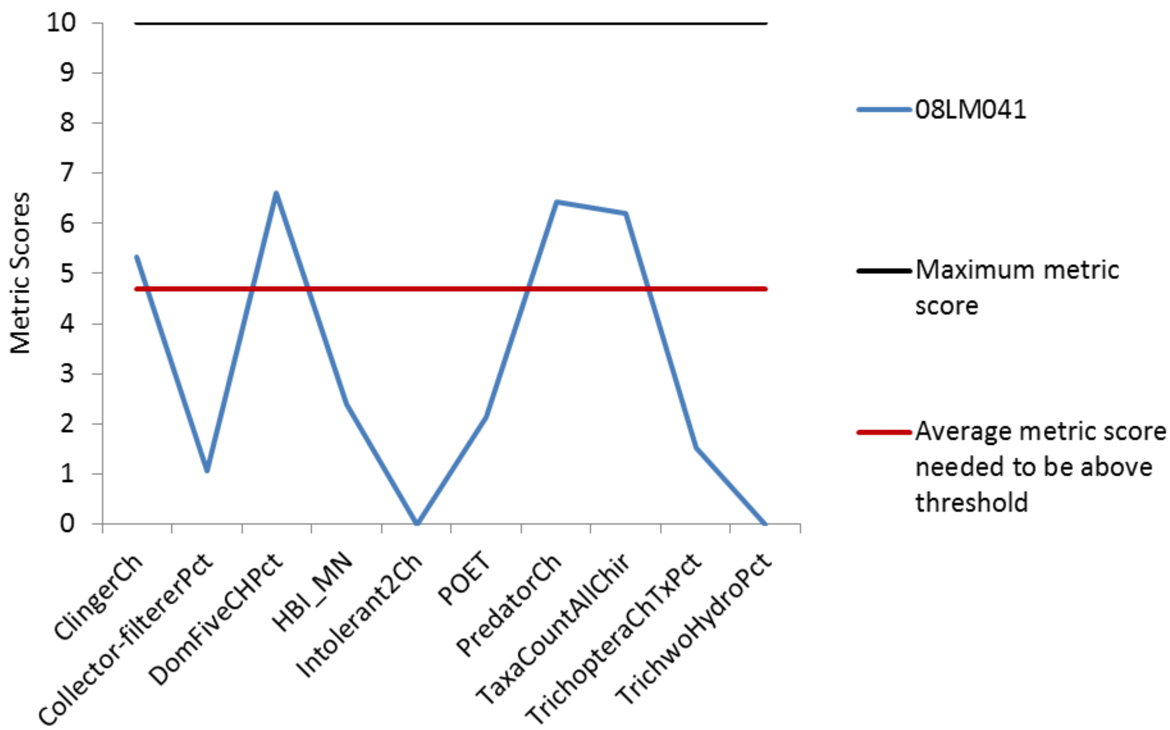


Figure 82. Metric scores for Station 08LM041 (F46) of the Southern Forest Streams GP macroinvertebrate IBI

Temperature

The temperature at the time of biological sampling is a little bit on the cool side for a warmwater stream, with a temperature measurement of 17.8°C at 8:33 am on July 22, 2008. This is the only temperature data available on this stream. However, temperature is not a likely stressor to a warmwater stream unless temperature reaches closer to 30°C. Therefore, temperature is not considered a stressor to the biological community at this time.

Dissolved Oxygen

During biological sampling, Station 08LM041 had a DO concentration of 8.41 mg/L (July 22, 2008 8:33 am). The DO was above the standard and was before 9:00 am. This is the only DO data point available.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH and total phosphorus concentrations during biological sampling were 7.89 and 0.097 mg/L, respectively. Both of these values, along with the oxygen concentration collected are within normal ranges and standards. Chlorophyll-a and BOD data were not available for analysis.

The fish community is comprised of fish which are tolerant to low DO. Station 08LM041 had fish DO TIV aggregate score that is in the lowest 10% of all sites in the Root River, indicating a very DO tolerant fish community is present at this location.

Macroinvertebrates show a similar response. The macroinvertebrate community has a DO TIV index score in the lowest quartile for Root River stations, indicating a DO tolerant community is present. At Station 08LM041, there were only six intolerant taxa found (Root River average is ten taxa), and 20% of the macroinvertebrate species are considered tolerant to low DO (Root River Watershed average is 6%). EPT are typically intolerant of low DO levels. EPT taxa were reduced (only 1%) which is well below average. Taxa richness can also be decreased with increases in DO flux**.** However, taxa richness is near average at this station for macroinvertebrates.

While the biological information does show some potential signal to DO stress, more chemical information is needed to confirm DO as a stressor.

Nitrate

Nitrate was seven mg/L at the time of fish sampling at Station 08LM041 on August 5, 2008. No other chemical information was available for analysis.

As noted in previous sections, fish lack a strong biological response to elevated nitrate concentrations. The macroinvertebrate metrics which respond to nitrate stress at Station 08LM041 show a mixed response compared to other Class 6 sites from the Lower Mississippi River basin. Sampling from Station 08LM041 had 22 total taxa, which is better than average (Class 6 averages; 19.8). There were no intolerant taxa present, and Trichoptera taxa was also reduced (1). In class 6 sites in the LMB, the average is 2.2 Trichoptera taxa. Similarly there were no nitrate intolerant taxa and 82.4% of the macroinvertebrate individuals were nitrate tolerant. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is a 10% probability of meeting the MIBI.

The macroinvertebrate metrics generally demonstrate a potential for nitrate stress. However, there is a lack of good chemical information to confirm stream nitrate concentrations. It is likely the nitrate value sampled in August could be low compared to other times of the year (as seen in other nearby areas of the North Branch). It would be beneficial to better understand the magnitude and duration of nitrate concentrations in this reach. Given the lack of solid chemical information, a nitrate stressor is inconclusive.

Suspended sediment

The TSS at Station 08LM041 was 34 mg/L and the t-tube was 20 cm at the time of fish sampling on August 5, 2008. While this value is considered elevated for baseflow conditions, it is difficult to establish and understanding of the suspended sediment dynamics of this system with such little chemical information.

The fish community, while not impaired at this location, shows some tolerance to TSS. The TSS station index score for fish at this location was in the most tolerant quartile when compared to all warmwater stations in the Root River. The percent carnivore metric, which is correlated to TSS, is average for 08LM041. The percent intolerant metric, also correlated to TSS issues, was 0% at 08LM041. This may indicate potential for TSS issues, but there is a general lack of conclusive biological response information. Therefore, it is difficult to conclude if TSS is stressing the fish community at this time, given such limited information.

Just over 8% of the macroinvertebrate individuals were long lived and none were generally intolerant, both which decrease with increases in TSS. The macroinvertebrate index score for TSS was 17.07, just a bit better compared to average for warmwater stations in the Root River Watershed (17.96), but right at the median for the watershed. The station at the time of sampling had six taxa tolerant to TSS and none intolerant to TSS. The percentage of TSS tolerant individuals was 32.1 at Station 08LM041.

The biological community data suggests a moderate tolerance to TSS, but additional chemical information is needed to determine if TSS is stressing the biological communities at this location.

Physical habitat

This site scored poorly on the MSHA (43.8). The station is in an area with the surrounding land use row crop. The substrate is approximately 80% run with little pool and riffle habitat existing in the reach. It is characterized as having little gravel in the substrate, as it is mostly silt and sand particles comprising the bed material. The cover available to the biological communities was noted as sparse in this reach, ranging from 5 to 25%and mostly overhanging vegetation with undercut banks. Areas of significant bank erosion are present at the site. The only habitat sampled for macroinvertebrates was overhanging vegetation/undercut banks, meaning riffles or woody debris were not found as dominant habitat types. This information alone indicates less than ideal habitat diversity.

The percentage of EPT individuals at Station 08LM041 was only 1% (average for this class is 18.6%). The percentage of macroinvertebrates that are known to cling to large substrate and woody debris were found to be just below average. Clinger taxa scored just above the average metric score needed to meet the IBI threshold (Figure 82). The percentage of climbers was high (41%), but likely due to overhang vegetation being the only habitat type sampled. The percentage of tolerant legless macroinvertebrates was also very high, at 80%. Many of these metrics reveal less than desirable habitat conditions for macroinvertebrates at Station 08LM041.

The fish community at this location scored just above impairment threshold, and is likely being impacted by stressors present, including habitat. The percent pioneers are high; at 42% indicating much of the community is able to thrive in unstable conditions. In addition, 94% of the species sampled are considered tolerant. The percentage of non-tolerant benthic insectivores (2.5%), simple lithophilic spawners (14%) and darter, sculpin and round bodied suckers (2.5%) are all below average for the Southern Headwater fish class. The only habitat related fish metric showing above average percentages is the percent riffle dwelling species. The habitat related fish metrics show that fish are suffering due to habitat issues even though the community is not currently impaired. The macroinvertebrates are also demonstrating similar stress due to a lack of quality, diverse habitat.

Physical connectivity

No information was available or collected on physical connectivity on this reach. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

Habitat is the main stressor for the macroinvertebrate community on this reach at this time. While fish are not impaired, they are only a few points above impairment threshold and are also showing habitat related stress. The habitat assessment was poor, in addition to the reach being 80% run with little riffle or pool habitat. The banks and riparian area appear very homogenous and document potential for bank failure and erosion (Figure 83). Both fish and macroinvertebrate communities are demonstrating stress due to habitat related issues in this reach and all available evidence demonstrates habitat is causing the most stress at this location.

There are some indications that DO and TSS could be potential stressors, but with a lack of connecting chemical information, those stressors cannot be confirmed at this time. Overall, there is little chemical information on this reach, and additional information should be collected to confirm or rule out these potential stressors. There is also a lack of good chemical information to confirm stream nitrate concentrations. It is likely the nitrate value sampled in August could be low compared to other times of the year (as seen in other nearby areas of the North Branch). It would be beneficial to better understand the magnitude and duration of nitrate concentrations in this reach. Given the lack of solid chemical information, a nitrate stressor is inconclusive at this time.

Figure 83. 08LM041 (above), middle of reach and photo (below) documenting bank erosion within the sampling reach.

4.4.5. Summary of Stressors in the North Branch Root River

The stressors found to limiting the biological communities in the North Branch Root are found in Table 31.

Table 31. Stressors identified in the North Branch Root River. ● = stressor (yes); o = inconclusive stressor; 'blank'-no stressor

Reach Name	***Geo Region***	**AUID**	**Reach Description**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Impairment(s)**	**Stressors:** **Temperature**	**Dissolved Oxygen**	**Nitrate**	**Suspended Sediment**	**Physical Habitat**	**Physical Connectivity**
Unnamed Creek	***Uplands, Till Covered Karst***	**07040008-706**	Unnamed Creek to North Branch Root River	2B	08LM101	Upstream of 680th Ave, 8 mi. SE of Hayfield	Invert IBI		o	o	o	●	
Root River, North Branch	***Uplands, Till Covered Karst***	**07040008-717**	Headwaters to Carey Creek	2B	08LM039 08LM054 08LM097	Upstream of County Rd 115, 5 mi. W of Stewartville Upstream of 680th Ave, 8.5 mi. SE of Hayfield Upstream of CSAH 7, 4 mi. NW of Dexter	Invert IBI Turbidity		●	o	●	●	
Unnamed Creek	***Splits between Uplands and Driftless Karst***	**07040008-F46**	Unnamed Creek to Unnamed Creek	2B	08LM041	Upstream of Hwy. 30, 1 mi. E of Stewartville	Invert IBI		o	o		●	
Root River, North Branch	***Driftless, Near Surface Karst (with small fraction in Uplands)***	**07040008-716**	Unnamed Creek to Mill Creek	2B	08LM084 04LM025 08LM017 04LM130 08LM032	Downstream of CSAH 2, 0.5 mi. W of Chatfield Upstream of Hwy. 30, 4 mi. NW of Chatfield Upstream of CSAH 19, 6 mi. SW of Eyota Upstream of County Rd 19, 4 mi. NW of Cummingsville Upstream of 15th Ave NE, 1.5 mi. NE of Stewartville	Invert IBI Turbidity			o	●	●	

4.5. Root River

This 10 digit HUC section covers two AUIDs on the mainstem Root River (Houston to mouth; combined in one section), and also addresses a small coldwater tributary, Silver Creek (Figure 84). The mainstem Root River is impaired for macroinvertebrates throughout, and Silver Creek is impaired for fish and macroinvertebrates.

Crystal Creek, another small tributary to the mainstem Root River (not impaired for biota; not addressed in this report), was just above impairment threshold for both fish and macroinvertebrates. This area should be explored further in the future if impairments are identified. Protection efforts to reduce chances of further degradation would be also recommended.

Root River Watershed (HUC - 0704000809)

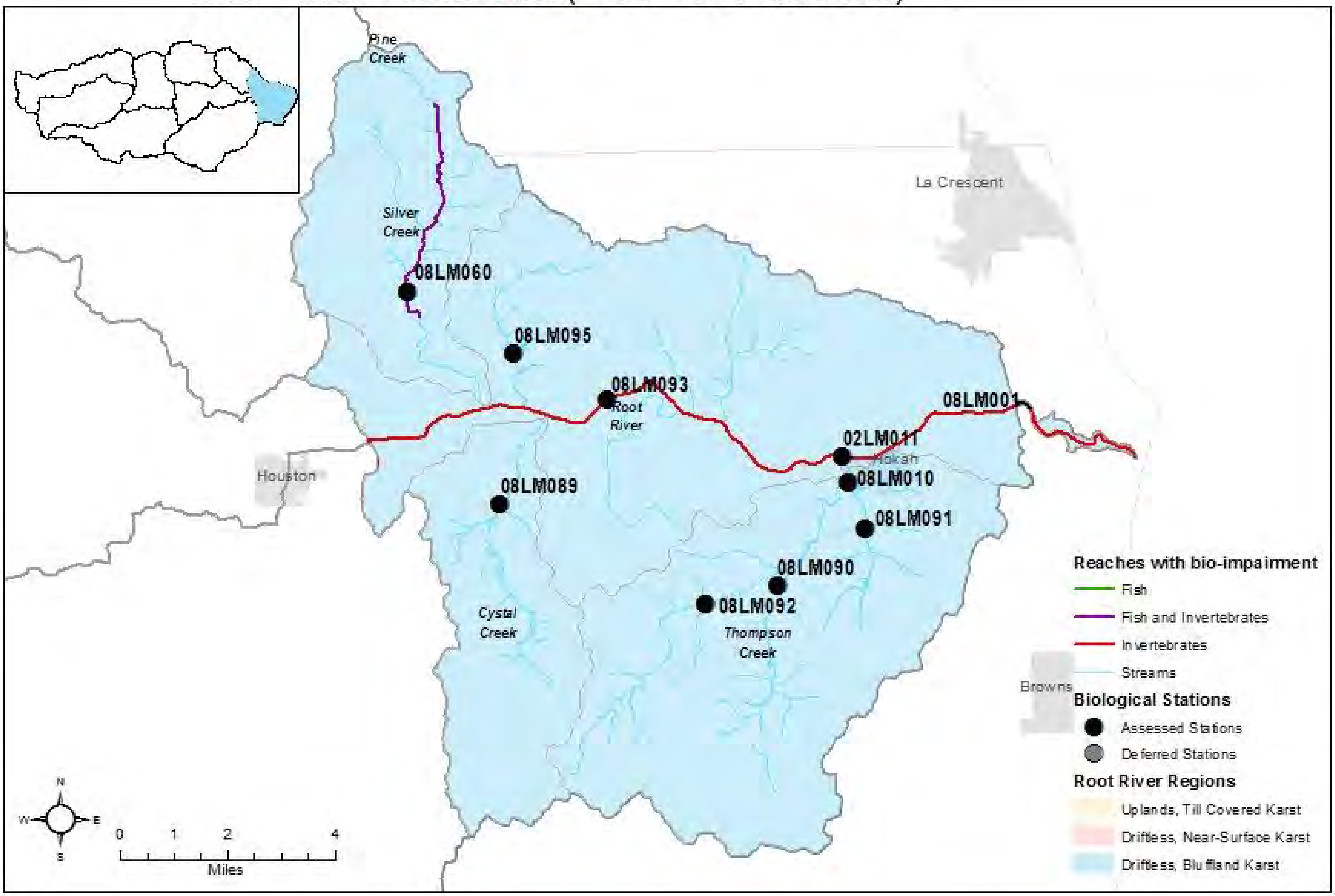


Figure 84. Map of Root River 10 HUC, showing reaches of biological impairment and biological sampling locations

4.5.1. Root River Mainstem (Houston to Mouth)

Supporting information

On AUID 501, there is one biological Station (08LM001). Fish in this reach score above the threshold and confidence interval, but macroinvertebrates are below the threshold and confidence interval.

On AUID 502, there are two biological Stations (02LM011 and 08LM093). Fish are above the threshold and confidence interval at both locations. For macroinvertebrates, one site is below the threshold and confidence interval and the other is below the threshold within the confidence interval. The sites in this AUID, as well as other sites in the lower Root River main stem appear severely habitat limited.

The macroinvertebrate metrics for these two AUIDs are shown in Figure 85. The low MIBI scores are a result of degradation among multiple metrics. There are low metric scores for a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN) and taxa richness of macroinvertebrates with tolerance values less than or equal to four, using Minnesota TVs (Intolerant2lessCh). In addition, Odonata (dragonflies and damselflies) and predators were less abundant, and there were a higher percentage of very tolerant species (VeryTolerant2Pct).

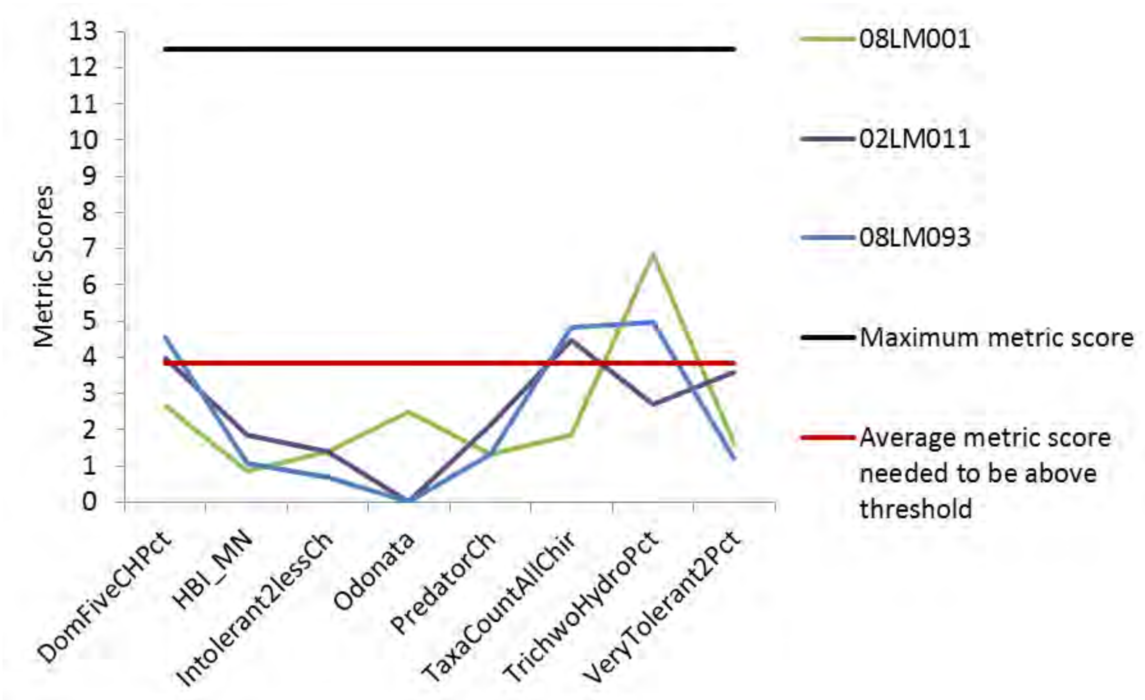


Figure 85. Metric scores for stations in Root River (AUID 501 and 502) of the Prairie Forest Rivers macroinvertebrate IBI

Temperature

On AUID 501, there were 361 temperature measurements taken in this reach from 1958-2009. The maximum temperature recorded was 31°C in 1989. There were 20 measurements total (5%) that were above 25°C. Some of those measurements were in recent years (2006 and 2009).

On AUID 502, there were 159 temperature measurements taken from 2008-2012. Of those measurements, the maximum recorded was 26.1°C in August 2010.

This part of the river is currently classified warmwater and aquatic life in warmwater systems may begin to stress when temperatures reach close to 30°C. Even though this dataset is limited, and does reach close to this threshold, it is believed that temperature is fairly well represented in the current dataset, and is not a stressor to the macroinvertebrate community on the mainstem Root River.

Dissolved Oxygen

On AUID 501, at Station 08LM001, DO was measured at 9.32 mg/L, on August 28, 2008 at 1:00 pm. On AUID 502 at Station 08LM093 DO was measured at 9.71 mg/L, on August 27, 2008 at 6:45 pm. At Station 02LM011, the DO concentration was 8.99 mg/L, on August 26, 2008 at 12:30 pm. Other data available from AUID 501 had 56 synoptic DO values ranging 6.69-16.05. The majority (49) of those values were between 7 and 11 mg/L. Other data from monitoring Station S004-458 (AUID 502) had 106 readings from 2008-2012. The concentrations ranged from 7.39-17.5 mg/L, with an average DO concentration of ten mg/L. No data points violate the DO standard of 5 mg/L. There were no DO measurements before 9:00 am, or measurements of DO flux.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. Monitoring Station S000-065, was sampled 49 times from 1958-2009. The pH values range from 6.3-9.65; average pH was 8.07. Monitoring Station S004-458 was sampled 177 times from 2008-2012. The pH values range from 7.2-9.94; average pH was 8.22. The pH standard was exceeded only three times (above 9) for the 177 samples.

The phosphorus values ranged from 0.025-1.86 mg/L; average phosphorus was 0.259 mg/L. It is important to note that these samples are taken from a load based monitoring location, which focuses on events when total phosphorus concentrations are generally high. In 2008, 2011 and 2012 there were 12 chlorophyll-a samples taken. The values ranged from 0.84 ug/L to 21.1 ug/L. The maximum value of chlorophyll-a was 21.1ug/L on June 20, 2011. BOD was measured in 2008, and ranged from 1.8mg/L to 0.6mg/L.

The fish community is comprised of fish that are somewhat tolerant to low DO. The stations in these two reaches had TIV aggregate scores that were lower than average for those in the Root River, indicating some potential for DO tolerance. However, they aren't in the most tolerant quartile.

The macroinvertebrate community also shows a similar signal. All three stations in these two reaches have DO TIV index scores just below average for Root River Stations. They also have an average amount of DO intolerant species, with better than average found at Station 08LM093 (13 intolerant species). Station 02LM011 also has a better than average percent tolerant species compared to other sites in the Root River. The percentage of EPT individuals found in this part of the river are well above average. EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux. The macroinvertebrate taxa counts for the three biological stations hovered just below and above the average for similar Prairie Forest River stations in the Lower Mississippi River Basin (LMB).

The chemical and biological data do not strongly point towards a DO stressor. The biology is showing some limited response, and there is little chemical information showing exceedence of the DO standard. However, some high DO values potentially signal a large DO flux (while this hasn't been quantified). Given the limited information available, DO is not considered a stressor to the biological community of the Root River at this time. Additional information on DO should be collected.

Nitrate

On the dates of fish sampling the nitrate concentrations at the three biological stations ranged from 3.89 mg/L to 4 mg/L. On AUID 501, there were 31 nitrate measurements which ranged from three to seven mg/L. The ranges of nitrate concentrations found on AUID 502 were 0.84 to 12 mg/L (Figure 86). The measurements captured a wide range of concentrations over the course of a five year period demonstrating varying flow conditions, sources, sources, and pathways.

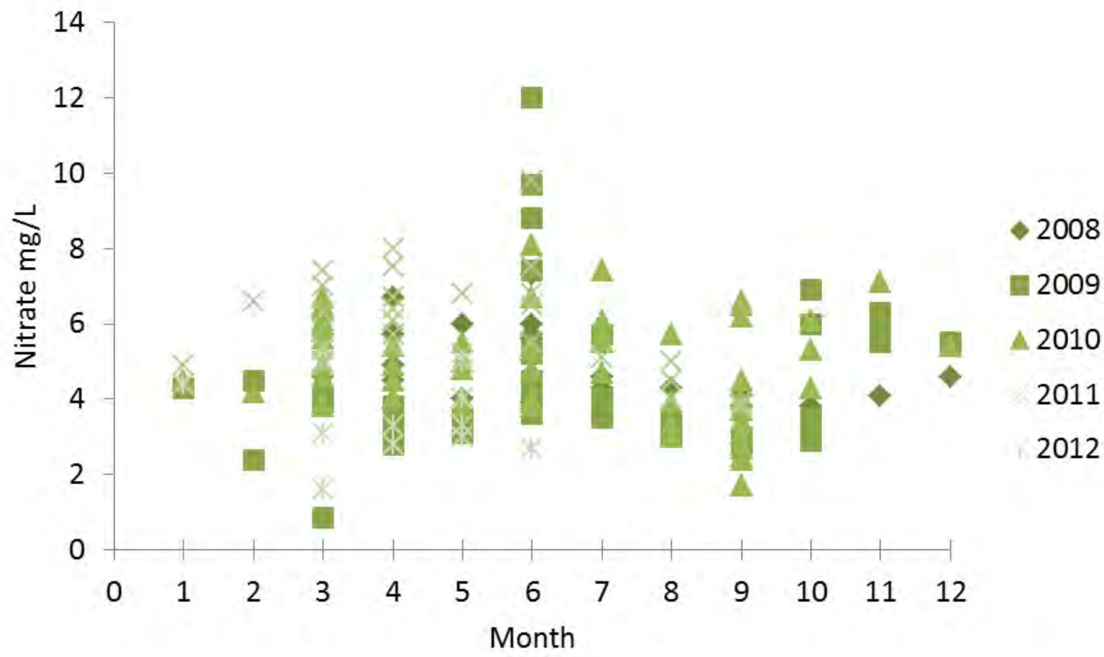


Figure 86. Nitrate concentrations for the mainstem Root River, Station S004-858 (Mound Prairie, 2008-2012)

The macroinvertebrate taxa counts for the three biological stations hovered just below and above the average for similar Prairie Forest River Stations in the LMB. Stations 08LM001 and 08LM093 had above average Trichoptera taxa (five each) and Station 02LM011 was just under the average with four Trichoptera taxa. None of the stations had intolerant taxa present during the surveys. Stations 08LM093 and 02LM011 had one nitrate intolerant taxon each. Station 08LM001 had no nitrate intolerant taxa. The percent of nitrate tolerant individuals ranged from 80.5 to 87.0%, with Station 08LM001 having the most abundance. At 78.7% nitrate tolerant individuals, there is a 10% probability of meeting the Prairie Forest Rivers (class 2) MIBI.

With the biological response evidence and the elevated nitrate concentrations, nitrate is a stressor to the macroinvertebrate community. Reductions in elevated nitrate should be conducted to impact these two AUIDs.

Suspended sediment

Chemical data available from AUID 501 is limited but show TSS concentrations up to 490 mg/L. More information is available on AUID 502, where a more active monitoring site is located. Given the proximity of the two AUIDs it is assumed chemistry is very similar. Chemical data available from AUID 502 show TSS concentrations ranging from 3.2 mg/L to 2200 mg/L. The average concentration found was 186 mg/L of 181 total samples. The samples collected are weighted towards rain events, which target high TSS for computing pollutant loads. The TSS FWMC (flow weighted mean concentration) in the Root River is in the highest category (over 100 mg/L TSS) in a statewide assessment of pollutant load monitoring from 2007-2009. For more information see: http://www.pca.state.mn.us/index.php/view-document.html?gid=19202.

The chemical information strongly points to a potential TSS stressor, and the biological data also support that. The fish community present at all three locations are dominated by species that are tolerant to high TSS (Figure 36). For example, at Station 08LM001, the emerald shiner made up 40% of the entire fish community (283 individuals). While the mimic shiner and smallmouth bass (sensitive to TSS) were present in moderate numbers, they were not as prevalent as the TSS tolerant species.

The macroinvertebrate communities in the mainstem Root River were highly tolerant to TSS (Table 32). The TSS station index scores were well above the average for warmwater stations in the Root River and were in the upper most quartile, indicating a high level of tolerance to TSS. There was one taxon present in each of the surveys that was intolerant to TSS, but all of the stations had a large percent of the macroinvertebrate individuals tolerant to TSS and over 46% of the individuals in each sample were very tolerant to TSS. The evidence that the macroinvertebrate metrics provide is that the community is overly tolerant to TSS and TSS is a stressor to the macroinvertebrate community.

Table 32. Macroinvertebrate metrics relevant to TSS for stations in the Mainstem Root River compared to averages for warmwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
08LM093	**24.98**	**1**	**14**	**77.29**	**0**	4.73
02LM011	**23.62**	**1**	9	**66.67**	**0**	**2.63**
08LM001	**25.84**	**1**	**11**	**77.59**	**0**	**2.33**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed	17.96	1.52	9.32	35.45	0.48	3.16

Physical habitat

The MSHA score for both Stations 08LM001 and 08LM093 were considered fair. The riffle, pools and runs in these reaches are both comprised of all sand. The majority of the reaches are considered “run”, with only small percentages of pools and riffles. Cover was considered sparse and the riparian are was classified as moderately wide, with little bank erosion.

The only habitat sampled at both biological stations was woody debris; meaning other habitat types were not available. This information alone suggests a lack of quality diverse habitat for macroinvertebrates.

The percentage of EPT individuals was well above the statewide averages at both biological stations. However, the percentage of macroinvertebrates that climb and the macroinvertebrates that are known to cling to large substrate and woody debris were found below statewide averages. The percentage of sprawlers was also abnormally high compared to statewide averages (61% and 46%). Sprawlers can be found in areas with excess sediment, and generally do not prefer rocky substrate, but are more common with smaller fine substrates.

Given the lack of quality diverse habitat types (only woody debris was sampled), homogenous sand substrate, and reduced percentages of particular invertebrate groups, habitat is considered a stressor to this reach.

Connectivity

No information was available or collected on physical connectivity on this reach. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The stressors to the macroinvertebrate community in this reach of the mainstem Root River is elevated suspended sediment concentrations, habitat, and nitrate. The biological and chemical data all provide good evidence that these stressors are playing a role in shaping the macroinvertebrate community present here. Temperature and DO are both suitable in this reach of the river. Habitat is likely an additive stressor, but secondary to TSS and nitrate.

Results from work done by Belmont (2013) show that a “substantial percentage and likely the majority of suspended sediment in the Root River today is derived from stream banks and floodplains (estimated range of 40-80%)”. In addition, work by Belmont points out that the main stem of the Root is a “dynamic alluvium system” which can act as a sediment source or sink at different times. The yield of sediment from the watershed is dependent on the “magnitude and frequency of floods” and there are “many near channel sources of sediment”. Changing hydrology is noted as a potential driver of this. Belmont’s work shows that not only is the Root River increasing baseflows, but high flows have increased over recent decades as well. High flows tend to control geomorphic dynamics of channels. “When high flows systematically increase, the channel will tend to enlarge (by widening and/or deepening) and will tend to increase lateral migration rates (i.e., erosion of one bank and deposition that may or may not keep pace on the opposite bank). These findings are therefore consistent with our finding that near channel erosion contributes a significant proportion of sediment.”

Currently, it appears there are multiple drivers that could be responsible for the changes in suspended sediment and habitat dynamics seen in the main stem Root River. Altered hydrology (including climate change and tile drainage) is one potential area of concern. However, an altered landscape should also be considered as an impact. It is not fully understood the relative contribution each of these variables has on the entire Root River system, therefore the link to stressors is unknown. There is a lack of connecting information to conclude altered hydrology is a stressor at this time (which is why it is considered inconclusive as a stressor in this report), but should be considered for further analysis, as a potential driver for sediment and habitat issues in the mainstem.

Regardless, the majority of the changes which will improve the macroinvertebrate community in the mainstem Root River are needed on an entire watershed-wide scale, and will take many years to implement. Most changes that are localized may not have success, or be sustainable if the larger river system contributions are not addressed.

4.5.2. Silver Creek

Supporting information

The Silver Creek Watershed is dominated by forested bluffs and a narrow stream valley made up of mostly agricultural land. In 1920, Surber evaluated Silver Creek, and concluded that the stream was not suitable for trout stocking. According to MDNR reports, the stream continually improved over time, and since 1972 trout populations have improved. According to the 2009 management plan, MDNR noted that brook trout populations were above average for Southeastern Minnesota streams. The stream hasn't been stocked since 1985 and is managed as a wild brook trout fishery (only in the upper half; MPCA biological monitoring station is not in this reach, but rather in the lower reaches).

Figure 87. Downstream end of Station 08LM060, MPCA photograph 2008.

This stream suffered significant channel morphology effects resulting from August 2007 flood event; the channel over widened, deposited sand, and became shallow in many places as shown in Figure 87. The MDNR 2009 management plan also indicates that severe flooding is the major limiting factor for Silver Creek.

Silver Creek is impaired for both fish and macroinvertebrates based on 2008 sampling data. Due to the 2007 flood, and heavy rains which impacted this area, macroinvertebrates were resampled in 2011. In 2011, the macroinvertebrate community still demonstrated severe impairment. Fish were not able to be sampled because the bridge was under repair. However, it was noted that the site and vegetation was somewhat recovered in 2011 compared to 2008.

The macroinvertebrate metrics in Silver Creek are all reduced at Station 08LM060 and below the average metric score needed to be at or above the threshold (Figure 88). Those that were most severe were the ratio of chironomid abundance to total dipteran abundance (ChiroDip), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs

(Intolerant2Ch), and relative percentage of taxa belonging to Trichoptera or caddisflies (TrichopteraChTxPct).

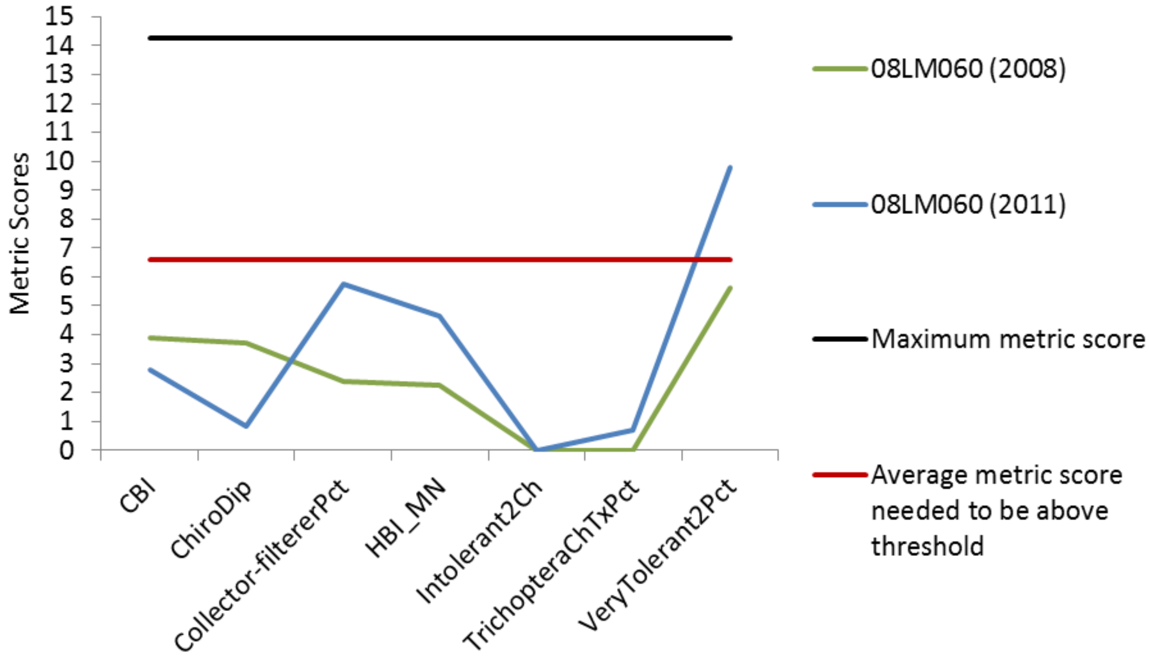


Figure 88. Metric scores for Station 08LM060 in Silver Creek of the Southern Coldwater Macroinvertebrate IBI

The fish community in Silver Creek, at Station 08MN060, scored low on the Southern Coldwater IBI (34). The fish community had a lack of sensitive coldwater individuals, lack of native coldwater taxa and individuals, and an abundance of taxa where detritus constitutes at least 5% of their diet, represented by the reduced SdetTxPct_10DrgArea metric (Figure 89). Silver Creek's fish community was comprised of a large percentage of pioneering species (PioneerPct). "Pioneering species predominate in unstable environments that have been affected by temporal desiccation or anthropogenic stressors, and are the first to reinvade sections of headwater streams following periods of desiccation" (Barbour et al.,1999).

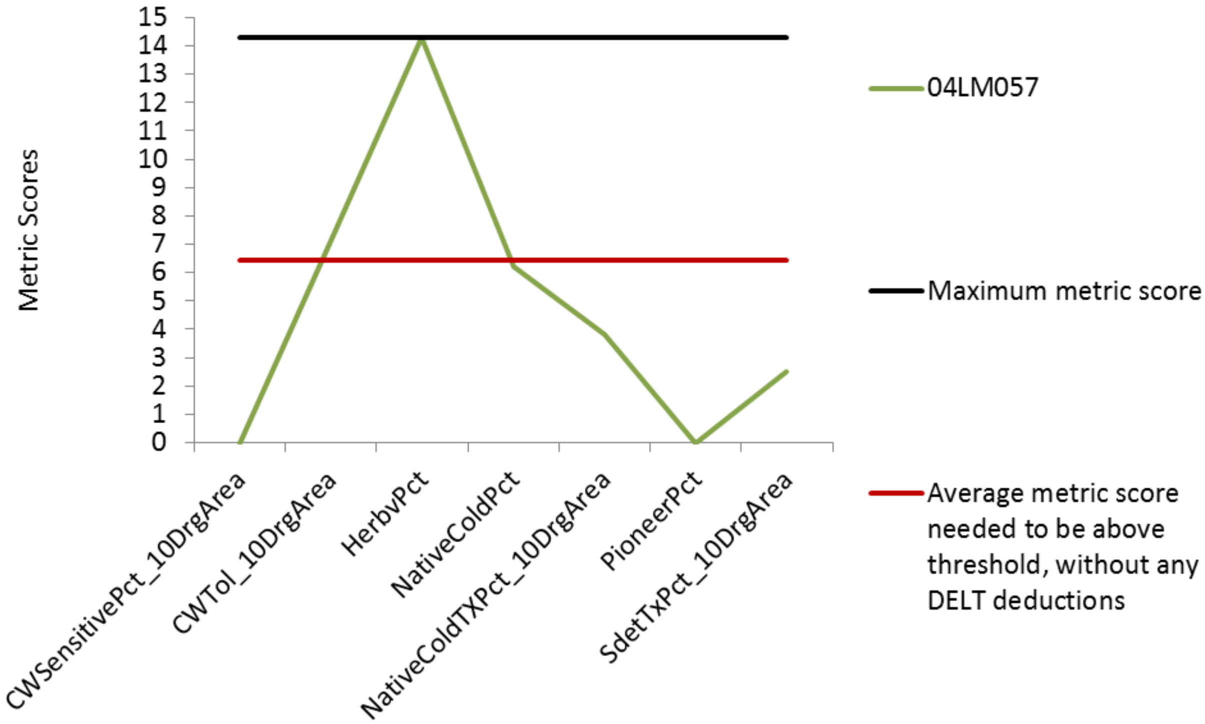


Figure 89. Metric scores for Station 08LM060 in Silver Creek of the Southern Coldwater Fish IBI.

Temperature

The temperature on the day of fish sample was 17.4°C. No additional temperature data was available for analysis. However, the MDNR management plan from 2009 states that Reach 1 (lower half of the eight mile stream, where Station 08LM060 exists) is unsuitable for trout due to high stream temperatures, sedimentation, and lack of cover.

The percentage of coldwater fish species at Station 08LM060 is only 6.2%, compared to the average for coldwater stations in the Root (50%). Based on MDNR surveys, the upper reaches of this watershed are suitable for temperature since they contain a healthy brook trout population. The lower reaches are more likely limited by habitat (over widened- shallow channel, with little to no cover) and as a result, temperature may also inadequate. In addition to reduced coldwater fish individuals, the coldwater macroinvertebrate individuals are also reduced (CBI metric) as shown in Figure 88. More information (high resolution temperature data) is needed. At this time, adequate information doesn't exist to confirm a temperature stressor in Silver Creek, but evidence suggests there is a potential temperature issue. Temperature as a stressor in Silver Creek is inconclusive.

Dissolved Oxygen

During biological sampling, on September 3, 2008 (10:42 am) the DO concentration was ten mg/L. This is the only oxygen data point available on this stream.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH value collected during biological sampling was 8.2. Total phosphorus was measured at 0.07 mg/L. Neither BOD nor chlorophyll-a data were available for analysis. All available chemical information meets standards and is within normal ranges for a coldwater stream.

However, the fish community was comprised of fish that are generally more tolerant to low DO, but may be responding to other stressors present. Station 08LM060 had a fairly large proportion of DO tolerant fish (Figure 90). The fish sample was made up of 55% creek chub, which are fairly tolerant to low DO- Quartile 2 (Q2). Yet, the presence of 18 brook trout and two species of dace, which are intolerant to low DO (Q4), may suggest adequate DO levels.

The macroinvertebrate community has ten macroinvertebrate taxa which are considered intolerant to low DO, which is near average with respect to all the biological stations in the Root River. The percent of macroinvertebrate taxa which are considered tolerant to low DO are also near average. EPT are typically intolerant of low DO levels, and taxa richness can also be decreased with increases in DO flux**.** Both of these metrics are reduced in Silver Creek, and may indicate DO stress, but may be as a result of other stress as well.

The limited chemical and biological information does not point to a DO as a stressor. The information in terms of biology is mixed, and it's difficult to determine if oxygen is a stressor, because both communities are so degraded. Collection of additional chemical information would ensure that adequate levels are present in Silver Creek.

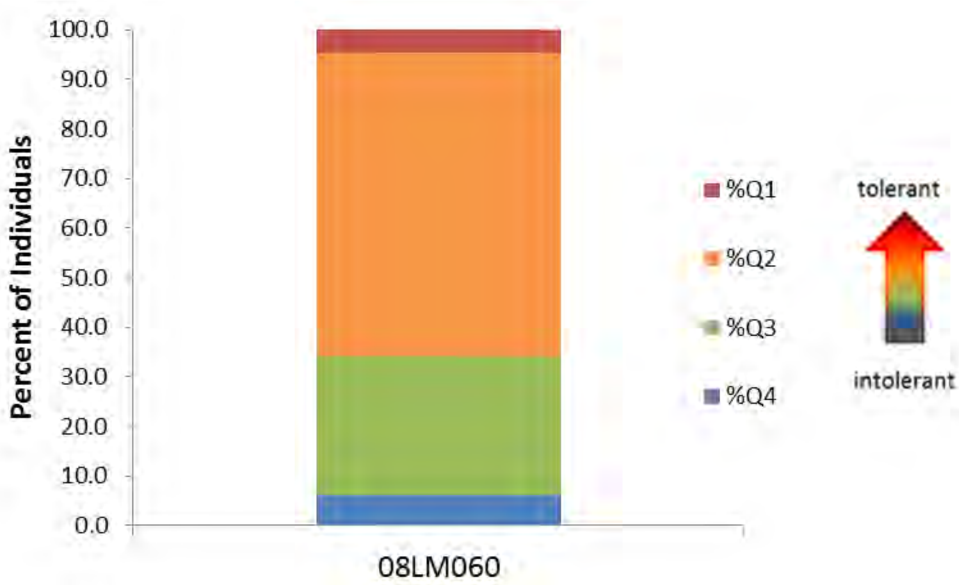


Figure 90: DO TIV for fish at Station 08LM060.

Nitrate

At Station 08LM060, the nitrate concentration at the time of fish sampling was 0.47 mg/L, September 3, 2008. Additionally there were two nitrate samples taken August 3, 2010, both less than 1 mg/L. Given the coldwater signature of this stream along with hydrogeology, these values are representative of typical in stream nitrate concentrations in this region.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in Silver Creek had 14 and 19 taxa (2008 and 2011, respectively, with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the LMB is 19. Both macroinvertebrate surveys had zero intolerant taxa present. Silver Creek Trichoptera taxa were below the average (3.8 taxa) for both visits (with one and three taxa present).

Silver Creek, Station 08LM060 comprising of 2.8 and 7.1% of the total taxa (TrichopteraChTxPct) and a resulting metric score lower than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased nitrate. At Station 08LM060, in Silver Creek, the metric score was 2.3 and 4.6 (2008 and 2011, respectively, out of 14.3), below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM060 the HBI_MN value was 7.26 in 2008 and 6.99 in 2011, both greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that the HBI_MN will be less than or greater than 6.65. At a concentration of ten mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM060 had 21 and 23 nitrate tolerant taxa (63.3 and 70.7% individuals); and 16 and 17 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI. At 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI, and at 22.60 nitrate tolerant taxa there is a 10% probability of meeting the Southern Coldwater MIBI. There were two nitrate intolerant taxa present in 2008 and 2011.

Although the macroinvertebrate community is degraded in a manner comparable with a potential nitrate issue, the low nitrate values make it difficult to conclude that nitrate is a stressor. The biological response may be due to other stressors present. There is not adequate information to conclude nitrate as a stressor in Silver Creek. Additional monitoring of nitrate levels during spring runoff and other seasons would be recommended.

Suspended sediment

During fish sample the TSS concentration was fairly low, at 13 mg/L. No other chemical data is available. The fish community at this site shows that 34% of the fish community is made up of species which are intolerant to high TSS concentrations (brook trout, longnose dace, and blacknose dace). However, some fairly tolerant to TSS species are also present at this site. The percent carnivore metric was well above average for coldwater sites in the Root River, at 63%. The percent carnivore metric is expected to decrease with increases in TSS. The average percent carnivore for statewide coldwater sites is 47%.

In 2008, Station 08LM060 had a worse than average TSS station index score for macroinvertebrates, but in 2011 the score was better than the average for coldwater stations in the Root River Watershed (Table 33). Both years there was a lack of TSS intolerant taxa, lack of generally intolerant and long-lived macroinvertebrate individuals. The percentage of TSS tolerant individuals was greater than the average both years. The difference between 2008 and 2011 data may be due to the flood of 2007. In 2008, the stream was still recovering from that very large event and this stream was one of the hardest hit in the entire Root River Basin.

The macroinvertebrate community indicates a moderate tolerance to TSS; however it is difficult to conclude due to the lack of chemistry data and the conflicting fish data that suggests intolerant fish are present it fairly high percentages. Additional TSS data should be collected at this location to understand the potential impacts to the biotic communities.

Table 33. Macroinvertebrate metrics relevant to TSS for stations in Silver Creek compared to averages for coldwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
08LM060 (2008)	**15.5**	**0**	**1**	**17.03**	**0**	**0**
08LM060 (2011)	**14.42**	**0**	**5**	**10.61**	**0**	**0**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River watershed	15.13	0.99	4.38	9.94	0.95	1.23

Physical habitat

Station 08LM060 received a poor MSHA score in 2008 (33). The station was characterized as having no riparian width, with an overgrazed pasture adjacent to the site. Bank erosion was noted as moderate to heavy with sparse cover (5-25%). Shade was non-existent. There was low channel stability and poor channel development also noted. No riffle was present and stream features were considered 100% run. The dominant substrate in the reach was sand. This site was impacted by the flood of 2007; but the direct impact is not well understood or documented. There is suggestion that the stream channel was starting to recover when visited in 2011.

The MDNR management plan from 2009 for Silver Creek notes that good in stream cover in the form of undercut banks and overhanging vegetation develop in many parts of the stream. However, MDNR notes that flooding scours the stream causing banks to cave in and sand to deposit in the pools. The MPCA monitoring location occurs in an area where this is common. Also, a reach upstream from MPCA monitoring location has been channelized which has degraded habitat and has potential to impact habitat at MPCA biological Station 08LM060.

The only habitat which was sampled for macroinvertebrates was undercut banks and overhanging vegetation. Riffles are expected in this type of stream, but were absent. The percentage of EPT individuals was worse than the statewide average for coldwater stations during both visits, in part due to the habitats that were sampled. EPT macroinvertebrates are sensitive to habitat disturbances among other stressors. The macroinvertebrates that are known to cling to large substrate and woody debris were found in abundance in 2011 (above statewide averages) but were not in abundance in 2008. Additionally, a higher percentage of macroinvertebrates that climb found during both sampling years. A large percentage of macroinvertebrate individuals that are legless (72% in 2008 and 29% in 2011) coupled with a high percentage of chironomids, and no long lived individuals, indicate very unstable habitat conditions where tolerant individuals are able to thrive.

Brook trout, which are found upstream (MDNR reports), were not in abundance here (only 14 individuals captured in 2008; but the presence is worth noting). The percent benthic feeders at this site are also low (7%) which indicate a community lacking individuals who rely on benthic habitats to feed. The percent riffle dwelling fish (7.32%), non-tolerant benthic insectivores (1.74%), and darter, sculpin, and round-bodied suckers (0%) are all below the statewide average for southern coldwater streams. Simple lithophilic spawners and general lithophilic spawners were above average due to presence of blacknose dace which are also tolerant and short-lived. All of the fish captured were five inches or less; demonstrating the potential lack of habitat for larger fishes. There was a lack of piscivore species (only 6%) and the fish sample had 55% creek chub. Creek chub are considered pioneers and are the first to invade a site after disturbance. In addition to this, 91% of the fish community is classified as tolerant.

The habitat information, site notes, photographs, and biological information confirm that habitat is a driving stressor for both the fish and macroinvertebrate communities found at this station in Silver Creek. (Figure 91) It is not certain how this stream has recovered since it was sampled in 2008. It appeared that the stream had started to recover since then (as noted in 2011), but the biological communities were still impacted. This stressor will be important to re-evaluate to determine changes over time and impacts to habitat.

Figure 91. Station 08LM060, September 3, 2008. MPCA photograph

Connectivity

A watershed connectivity survey in 2012 found no disconnections of the stream channel. There was a new bridge being installed on the main road, but was not expected to cause any issues with connectivity. While the information is limited, currently connectivity is not believed to be a stressor to the fish and macroinvertebrate communities in Silver Creek.

Strength of evidence, conclusions, and recommendations

The main stressor to the fish and macroinvertebrate communities found in Silver Creek is lack of physical habitat. This is characterized well by a number of site photographs, habitat assessments, as well as a strong biological response from both fish and macroinvertebrates. The fish specific habitat metrics are all showing reduced numbers of important types of fish species. In addition, during the macroinvertebrate visit, no riffle was available indicating a lack of that important habitat type. The macroinvertebrate community metrics showed a lack of EPT taxa, and a large percentage of tolerant legless macroinvertebrates. The site was impacted by the 2007 flood, which also resulted in large widening of the stream channel, which made water depth shallow, and altered physical habitat in the reach. Severe flooding is noted as a limited factor for Silver Creek by MDNR. Examination of aerial photography reveals areas of severe channel instability that is potentially due to localized land use practices (overgrazed pastures). Upstream portions of this small watershed experienced the same rainfall event and physical and biological integrity was not nearly as degraded. Better management of the riparian area in this part of the creek would allow better stream channel stability in addition to improving in-stream habitat for both fish and macroinvertebrates.

Other potential stressors that may exist in Silver Creek include temperature, suspended sediment, and DO. At this time, the information doesn’t appear to point to these stressors, but more chemical information or high resolution (continuous) temperature and DO data would help rule out these stressors completely.

4.5.3. Summary of stressors in the Root River (10 HUC)

The stressors found in the Root River 10 HUC are found in Table 34.

Table 34. Stressors identified in the Root River. (● = stressor (yes); o = inconclusive stressor; 'blank'-no stressor

Reach Name	Geo Region	AUID	Reach Description	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:					
								Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Physical Habitat	Physical Connectivity
Root River	***Bluffland Karst***	**07040008-501**	Thompson Creek to Mississippi River	2B	08LM001	Downstream of Hwy. 26, 3 mi. NE of Hokah	Invert IBI Turbidity Bacteria	O		●	●	●	
Root River	***Bluffland Karst***	**07040008-502**	South Fork Root River to Thompson Creek	2B	02LM011 08LM093	Upstream of Hwy. 16 bridge, 0.5 mi. NW of Hokah At CSAH 25, 6 mi. NE of Houston	Invert IBI Turbidity			●	●	●	
Silver Creek	***Bluffland Karst***	**07040008-640**		2A	08LM060	T105 R6W S35, North line to T104 R6W S14, south line	Fish IBI Invert IBI	O		O	O	●	

4.6. Rush Creek

There are three biological impairments (macroinvertebrate) identified in Rush Creek (Figure 92). One includes Rush Creek itself, and the other two are on Pine Creek; a warmwater stream reach in the headwaters and the next reach just downstream (coldwater). Each of these streams will be addressed separately in this section of the report.

Some recent geological information suggests that the St. Lawrence formation is likely transmitting water much faster than previously thought (Jeff Green, MDNR). This has been confirmed in recent dye tracing work done in the Rush Creek Watershed, where the St. Lawrence is a primary geologic bedrock formation. Information suggests that some streams in this watershed are sinking and coming out in nearby springs. It appears the St. Lawrence formation is much more like other Karst aquifers like the Galena group, with higher rates of water travel. The reason for this is unknown, and may affect management options of this watershed.

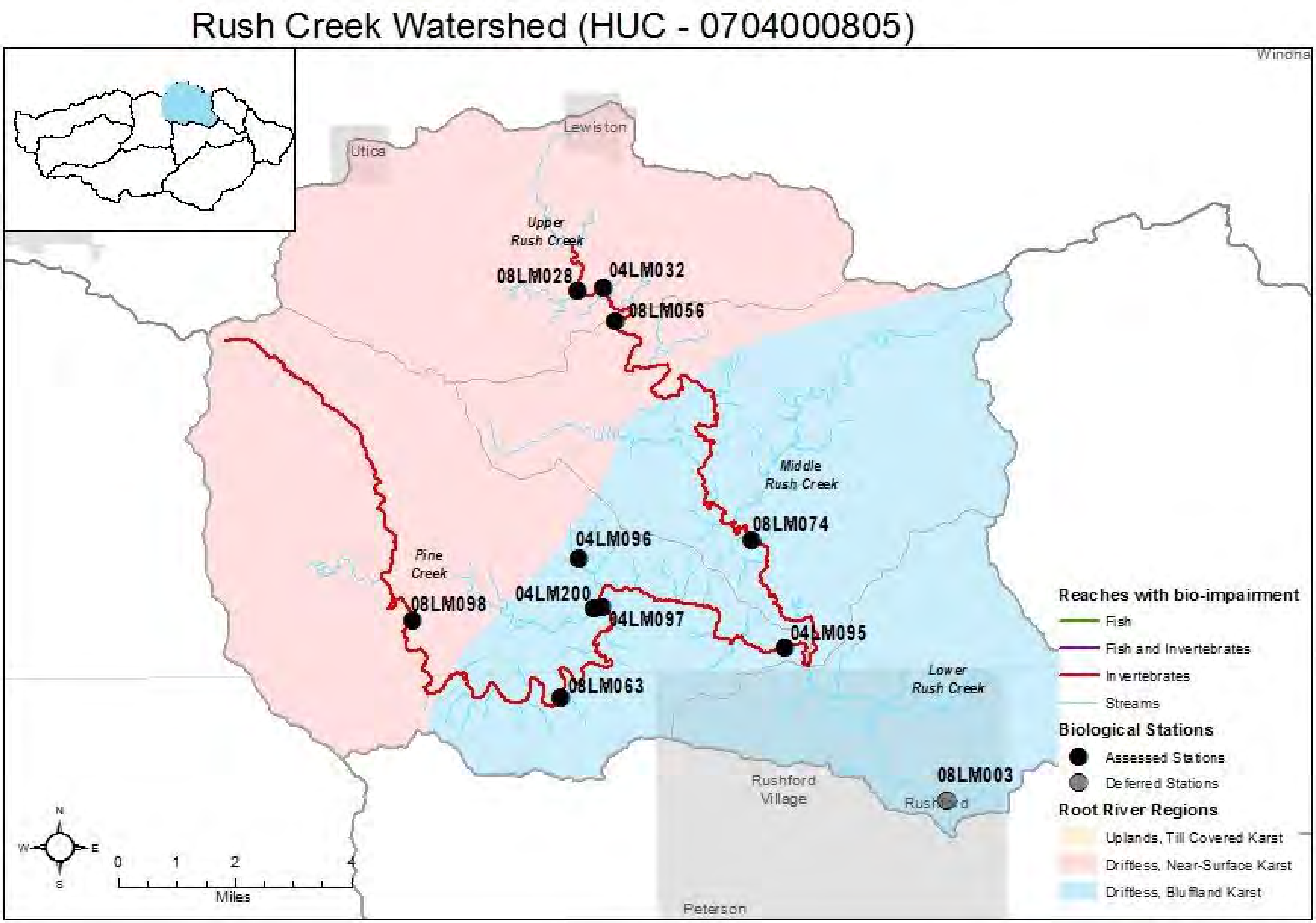


Figure 92. Rush Creek biological monitoring stations and aquatic life impairment

4.6.1. Rush Creek

Supporting information

On Rush Creek (AUID 524), there were three biological stations sampled in 2004 and 2008. All scores for fish were doing well, but all three scores for macroinvertebrates scored below the impairment threshold (Figure 93). The majority of the metrics of the Southern Coldwater IBI were below the average metric score needed to be above the threshold at all stations (Figure 93). Those that were most severe were the ratio of chironomid abundance to total dipteran abundance (ChiroDip), relative abundance (%) of collector-filterer individuals in subsample (Collector-filtererPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs (Intolerant2Ch). The metrics with mixed response among stations were: relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct), CBI, and measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN). The scores for VeryTolerant2Pct were moderate, demonstrating the communities are not dominated by very tolerant macroinvertebrate taxa.

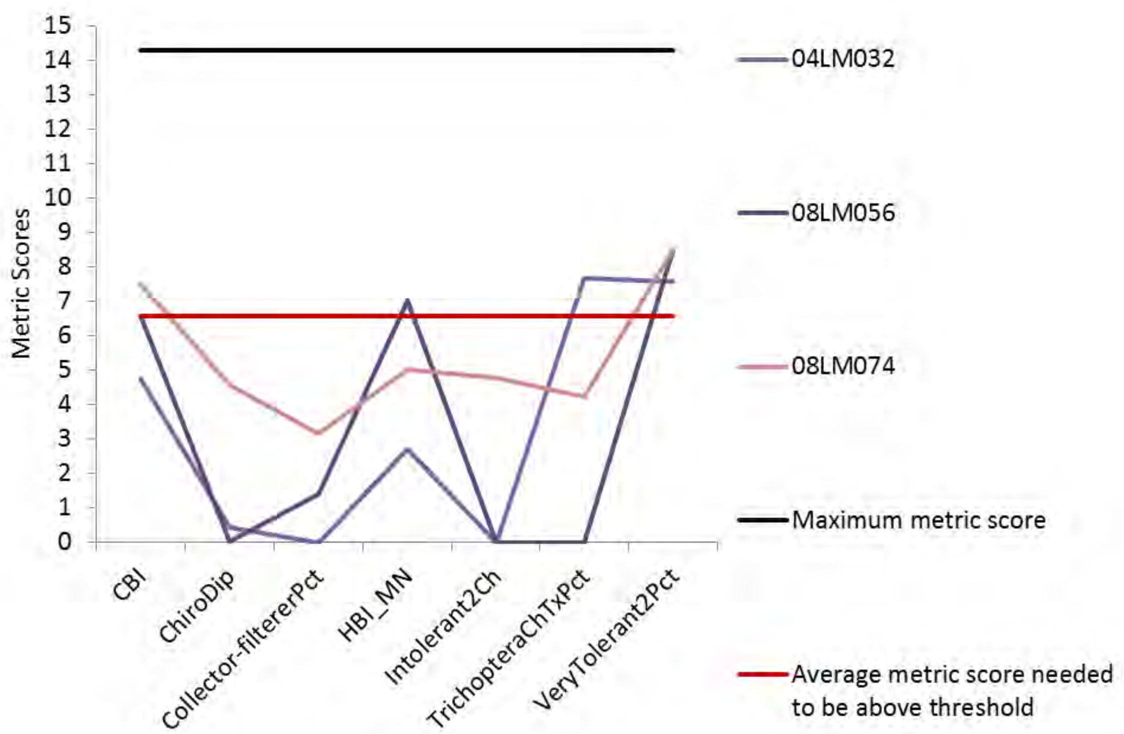


Figure 93. Metric scores for stations in Rush Creek of the southern coldwater macroinvertebrate IBI

Temperature

During biological sampling the temperature at the three biological stations ranged from 11°C-16.1°C. Continuous temperature data collected at Station 08LM074 (May-September 2008), showed a maximum temperature of 19.98°C (July 16, 2008). The July monthly average temperature was 17.35°C and August monthly average temperature was 16.35°C. At Station 08LM056 (May-June 2008), there was a maximum temperature of 18.44°C on June 12, 2008. July and August data were not available. Even though continuous temperature information was not available at all three site locations, the existing data at Station 08LM074 (the farthest downstream station on this AUID) shows suitable temperatures for coldwater species. A strong coldwater fish community is present at all three biological stations (range of 82-95% coldwater fish species for the three biological stations). The biological and chemical evidence confirm temperature is not a stressor in Rush Creek.

Dissolved Oxygen

During biological sampling at Stations 08LM074, 08LM056, and 04LM032, DO concentrations ranged from 8.65 to 11.67 mg/L. This is the only oxygen data for this stream reach. The stream reach immediately downstream (AUID 523), had 11 DO readings collected in 2008 (Station S001-689). The range of DO was 8.62-11.04 mg/L. These ranges are normal and suitable for coldwater streams.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. Total phosphorus data collected at the three biological stations ranged from 0.054-0.174 mg/L. The stream reach downstream, AUID 523 had 28 samples of pH and phosphorus collected in 2008 (Station S001-689). Eighteen pH values ranged from 8.11-8.35, with an average pH of 8.23. The ten phosphorus values ranged from 0.047-0.277 mg/L, with an average total phosphorus value of 0.091 mg/L. Neither BOD) nor Chlorophyll-a data were available for analysis at this time.

All three biological stations show fish communities that are more sensitive to low DO. The stations in this reach had DO TIV aggregate scores in the upper quartiles indicating the sensitivity of the fish community to low DO. Trout and sculpin, which are very sensitive to low DO, are found in abundance at all three biological stations.

The macroinvertebrate community shows mixed results in terms of potential DO stress. The macroinvertebrate community at the furthest upstream Station, 04LM032, has a DO TIV index score in the most tolerant quartile indicating potential for DO stress. In addition, 18% of the community at this station is considered tolerant, and there are reduced percentages of EPT taxa. EPT taxa are generally intolerant to low DO. The other two biological stations are near average for their TIV index score, and percent tolerant macroinvertebrates to low DO. All three biological stations have few (less than eight; worst quartile) DO intolerant taxa present. The percentage of EPT taxa are also better at these sites compared to 04LM032.

The macroinvertebrate community signals some potential for DO stress in the upper reaches of Rush Creek, yet the fish community does not show the same response. Given the conflicted information, and limited chemical data set, a DO stressor cannot be concluded at this time. More information should be collected, especially in the upper reaches of Rush Creek to rule this stressor out completely.

Nitrate

In Rush Creek, AUID 524, there were only three available nitrate samples. In 2004, Rush Creek at Station 04LM032 had a nitrate level of 6.5 mg/L at the time of fish sampling. In 2008, Station 08LM056 and Station 08LM074 had nitrate measurements of 7.8 and 5 mg/L, respectively. Within the watershed there are two additional measures of nitrate. On August 4, 2008, Station 08LM028, on a tributary to Rush Creek in the northern part of watershed, with the confluence upstream of Station 04LM032, had 8.7 mg/L nitrate. The macroinvertebrate community at Station 08LM028 scored quite well on the Southern Coldwater MIBI (75). On August 4, 2010, Station S006-355 on Ahrensfeld Creek, a tributary to Rush Creek with the confluence approximately one mile upstream of Station 08LM074, had a nitrate measurement of 1.8 mg/L.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in Rush Creek had a range of taxa counts from 12 to 23 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the LMB is 19. Station 08LM028 also had a relatively low taxa count of 17 taxa. Stations 04LM032 and 08LM056 had no intolerant macroinvertebrates, and Stations 08LM074 and 08LM028 had one intolerant taxon each. Station 08LM056 had the lowest number of Trichoptera taxa with one taxon, the other stations in the watershed resulted in four to six Trichoptera taxa. The average number of Trichoptera taxa in the Southern Coldwater stations of the Lower Mississippi River Basin is 3.8.

The Trichoptera taxa in Rush Creek comprised of 4 to 15.6% of the total taxa (TrichopteraChTxPct). The tributary Station 08LM028 had 23.1% Trichoptera taxa. The resulting very low metric scores for Stations 08LM056 and 08LM074; less than the average metric score needed to be at the southern coldwater MIBI threshold. Station 04LM032 had a higher TrichopteraChTxPct metric scores (7.7), and Station 08LM028 had a near maximum TrichopteraChTxPct score (13.8). Utilizing quantile regression analysis for stations in the southern coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Rush Creek, the HBI_MN metric score ranged from 2.7 to 7 (out of 14.3). Station 08LM056, on Rush Creek, and Station 08LM028, on the tributary to Rush Creek, did not fall below the average metric score needed to be at the southern coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. The HBI_MN values in the Rush Creek Watershed ranged from 6.6 to 7.28, Station 08LM028 had the lowest HBI_MN values. All HBI_MN values were greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the southern coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of ten mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Nitrate tolerant taxa ranged from 13 to 17 in Rush Creek (75.8 to 90% individuals); and 9 to 12 nitrate very tolerant taxa. Stations 08LM056 and 08LM074 had 1 and 2 nitrate intolerant taxa, respectively. Station 08LM074 also had 1 nitrate very intolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the southern coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the southern coldwater MIBI.

The macroinvertebrate community is mixed in the response to nitrate; however there is evidence of biological response, such as elevated HBI_MN values. It is likely that an additional stressor is present and nitrate is a secondary stressor.

Suspended sediment

During the fish sampling events at Stations 08LM074 and 08LM056, the TSS concentrations were 3.8 and 3.6 mg/L, respectively. Both of these concentrations are low, and do not cause concern. In 2004, at Station 04LM032, the TSS concentration was 25 mg/L. This is slightly elevated, but could be due to high flow conditions during sampling. The other data available on this AUID is transparency tube measurements. In 2007, there were 17 measurements, 14 of them which were greater than 60 cm, and only two were less than 20 cm.

The fish communities at the three biological stations are comprised of fish that are intolerant to high TSS concentrations. The stations had TSS TIV index scores in the most sensitive quartile for sites in the Root River, indicating overall a community which is sensitive to high TSS concentrations. The dominant fish found at these sites include sculpin and trout, which are considered some of the more sensitive species to high TSS found in the Root River watershed.

The macroinvertebrates in Rush Creek are not highly tolerant (Table 35). Station 08LM074 has a worse than average TSS station index score related to the presence of a greater number of TSS tolerant taxa, but they are present in a low percentage. Although generally intolerant macroinvertebrate individuals and long-lived individuals are low, it is likely due to another stressor and not TSS. The biological and chemical information do not suggest a TSS stressor in Rush Creek at this time.

Table 35. Macroinvertebrate metrics relevant to TSS for stations in Rush Creek compared to averages for coldwater stations in the Root River watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
04LM032 (2004)	14.72	**0**	1	1.94	**0**	**0**
08LM056 (2008)	14.53	1	2	0.4	**0**	**0**
08LM074 (2008)	**16.02**	2	**6**	3.85	**0.32**	**0**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River watershed	15.13	0.99	4.38	9.94	0.95	1.23

Physical habitat

Overall, there were good MSHA scores in Rush Creek at all three biological stations (Scores of 67, 69, and 75). Land use is the lowest scoring subcategory in the MSHA scores. Station 08LM074 was characterized as having narrow riparian width, heavy shade, and little to no bank erosion. The dominant substrate was cobble, gravel and sand with riffles comprised of cobble and gravel. Moderate embeddedness and fish cover were noted. There was high channel stability and good channel development. The macroinvertebrate habitat available for sample was macrophytes, undercut bank/overhanging vegetation and woody debris. Station 08LM056 was characterized as having very narrow riparian width, moderate shade on right, but none on left. No bank erosion was present at this location. The substrate was all boulder and cobble, and the riffle was comprised of those as well. Light embeddedness was noted, with sparse cover. There was high channel stability and excellent channel development. The macroinvertebrate habitat available for sample was riffles, macrophytes, and undercut banks/overhanging vegetation.

All four macroinvertebrate habitat types were available and sampled at Station 04LM032. While adequate macroinvertebrate habitat appears to exist in all of these locations, there was an abundance of burrowers found at Stations 04LM032 and 08LM056, which may suggest potential sedimentation issues in the riffles. The percentage of EPT individuals at these two sites was also less than the statewide average for coldwater stations. EPT taxa are commonly used to measure overall health of ecosystems, due to their sensitivity to many stressors including habitat. The macroinvertebrates that are known to cling to large substrate and woody debris were reduced at all three stations (below statewide coldwater averages). Clingers can decrease in stream reaches with homogenous substrate composition, velocity, and depth. (CADDIS 2009). In addition, the percentage of legless macroinvertebrates ranged from 38%-

60% which indicates a shift to more tolerant individuals. In contrast, there were a good percentage of individuals that climb at all three stations.

An abundance of burrowers reveal potential sedimentation issues, in addition to lower percentage of EPT individuals and clingers. The biological metrics related to habitat for macroinvertebrates reveal issues with available and quality habitat in Rush Creek.

Physical connectivity

No information was available or collected on physical connectivity on Rush Creek. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The stressors identified in Rush Creek include lack of habitat and nitrate. It appears sedimentation may be affecting habitat quality in the headwater area of Rush Creek, as the overall habitat stress is more apparent there. There is an abundance of invertebrates that burrow in fine substrates and a lack of good habitat indicator taxa at all locations in Rush Creek (EPT and clingers are reduced). The riparian corridor of Rush Creek could be improved (more forested riparian area), which would also improve in stream habitat as well. Rush Creek has a good amount of row crop agriculture, and increasing the number of filter strips and grassed waterways could help with sediment reduction and habitat loss for invertebrates in Rush Creek.

The macroinvertebrate community is mixed in the response to nitrate; and is considered a secondary stressor to habitat. There is evidence of biological response, such as elevated HBI_MN values. Further investigation into the magnitude and duration of nitrate in Rush Creek, and sources of nitrate would be beneficial. The Nitrogen in Minnesota Surface Waters Report has estimated that agricultural groundwater and agricultural drainage comprise of 80% of the nitrogen sources in the Lower Mississippi River Basin (pg. D1-11).

Both temperature and TSS appear adequate in this reach. Additional information should be collected on DO, namely in the upper reaches of Rush Creek, to help rule out this potential stressor.

4.6.2. Pine Creek (coldwater)

Supporting information

Fish appear to be thriving at all three stations in Pine Creek (IBI scores ranged from 68-83), while macroinvertebrates are suffering. Two of the three sites on Pine Creek had IBI scores below the impairment thresholds (Stations 04LM097 and 04LM095). The metrics of the southern coldwater IBI show more negative response at Station 04LM097 compared to the other two sites (Figure 94). The metrics that were most severe were the CBI, ratio of chironomid abundance to total dipteran abundance (ChiroDip), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs (Intolerant2Ch), and relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct). The metrics with moderate response among stations were: relative abundance (%) of collector-filterer individuals in subsample (Collector-filtererPct), and measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN). The scores for VeryTolerant2Pct scored moderately well, demonstrating the communities are not dominated by very tolerant macroinvertebrate taxa (with the exception of Station 04LM097).

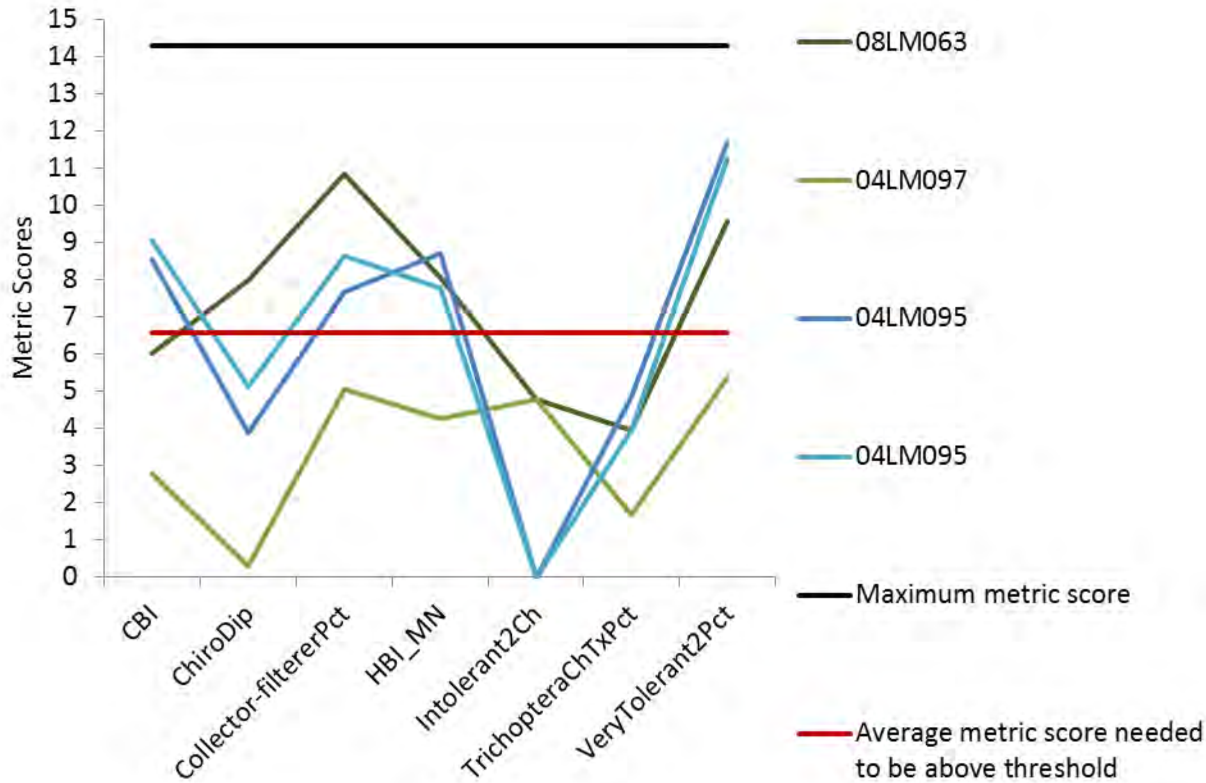


Figure 94. Metric scores for stations in Pine Creek of the southern coldwater macroinvertebrate IBI

Temperature

All three biological stations had HOBO temperature loggers installed in 2008, which showed normal or average temperatures for coldwater stream in southeast Minnesota. Also, the percentage of coldwater fish found at all of the sites is above average, from 54%-70% among the three sites (50% is average for Root River Watershed coldwater stations).

At Station 04LM095, there was temperature data from 2004 (May-September). The maximum temperature was 21.79°C. The monthly July average temperature was 17.38°C, while the monthly August average temperature was 15.84°C.

At Station 04LM097, there was temperature data from 2004 (May-August 16). The maximum temperature was 21.79°C on June 7th, 2004. The monthly July average temperature was 17.72°C, while the monthly August average temperature was 16.17°C.

At 08LM063, there was temperature data from 2008 (May-September). The maximum temperature was 19.10°C on July 16, 2008. The monthly July average temperature was 15.82°C, while the monthly August average temperature was 15.18°C.

Given the high resolution temperature data is showing adequate temperature, coupled with a good percentage of coldwater fish in these reaches and a fair number of CBI metric, temperature is not likely a limiting factor to the biological communities found in Pine Creek.

Dissolved Oxygen

During biological sampling at Stations 04LM095, 04LM097, and 08LM063 DO concentrations ranged from 10.65 mg/L to 11.78 mg/L (afternoon samples; not pre-9:00 am). There was one additional oxygen point on this stream reach from July 25, 2005, with a concentration of 10.21 mg/L. None of these values are at a level of concern or near the standard of 7 mg/L, but the only available data was taken after 9:00 am.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The values for pH taken during biological sampling ranged from 8.15-8.30. One additional pH measurement (8.37) was taken in July of 2005. The values taken for total phosphorus during biological sampling ranged from 0.051-0.108. Neither BOD nor Chlorophyll-a data were not available for analysis at this time.

The fish community has a mix of tolerant/intolerant species to low DO. The three stations in this reach have fish DO TIV aggregate scores near what is considered average for the Root River. Macroinvertebrates show a similar response to low DO. All three stations have DO TIV index scores for macroinvertebrates near average for the Root River. The number of intolerant and percent tolerant to low DO taxa is also near average, with a slight improvement near the mouth of the watershed (at Station 04LM095). The percentage of EPT individuals was greater than or close to the statewide average for coldwater sites at all locations, but slightly reduced at Station 04LM097. EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux**.** Taxa counts are above average for all stations.

Due to the lack of chemical information, and ambiguity of the biological response, a DO stressor cannot be concluded on Pine Creek at this time. More chemical information on DO would help ensure adequate levels in the stream and rule this stressor out completely.

Nitrate

This AUID of Pine Creek (526) had six measurements of nitrate ranging from 2.9 to 5.4, taken in 2004, 2008 and 2010. Coolridge Creek and Hemingway Creek are small tributaries to Pine Creek. At Station 04LM096, Coolridge Creek, nitrate was 7.4 mg/L on June 24, 2004. On Hemingway Creek, Station 04LM200 had 3.4 mg/L nitrate on July 1, 2004.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate community in this coldwater reach of Pine Creek had a taxa count ranging from 20 to 30 (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Stations 08LM063 and 04LM097 each had one intolerant taxon in the surveys, whereas Station 04LM095 had no intolerant taxa.

All of the macroinvertebrate surveys had at least four Trichoptera taxa, greater than the average of coldwater stations in the Lower Mississippi River Basin. In Pine Creek, Trichoptera comprised 8.3 to

12.2%of the total taxa (TrichopteraChTxPct). The resulting low metric scores; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Pine Creek, the metric score ranged from 4.3 to 8.7 (out of 14.3). Station 04LM097 was below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. Pine Creek HBI_MN values ranged from 6.73 to 7.18, all greater than the average HBI_MN value for stations meeting the MIBI (6.27). Station 04LM097 has the highest HBI_MN value. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Pine Creek biological stations ranged in nitrate tolerant taxa from 18 to 25 (54.5 to 72.7% individuals); and 14 to 19 nitrate very tolerant taxa. Station 04LM097 had the highest nitrate tolerant taxa and percent individuals. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. Station 04LM097 and 08LM063 each had one nitrate intolerant taxa present. Station 04LM095 had no intolerant taxa present during either survey.

Pine Creek had a high number of nitrate tolerant taxa, along with low metric scores for TrichopteraChTxPct. Although most stations scored moderately for HBI_MN metric scores, all HBI_MN values were greater than average of those stations with MIBIs greater than the threshold. There is not an overwhelming amount of chemical data, but there is a presence of elevated nitrate. It is possible that nitrate is a stressor along with additional stressor(s), but a nitrate stressor cannot be confirmed at this time.

Suspended sediment

During fish sampling at Stations 04LM097 and 08LM063 the TSS concentrations were 7.6 and 8 mg/L, respectively. Station 04LM095 has three TSS data points from fish sampling; 16 mg/L, 5.2 mg/L and 17 mg/L. No other chemical data was available for analysis.

The fish community at these sites is comprised of a mixed population, some species which are sensitive and some tolerant to high TSS. The site farthest downstream, Station 04LM095 has the most abundance of species tolerant to high TSS. Using fish TIV's for TSS for the three biological stations, 55-70% of the fish populations were in the two most sensitive quartiles. This indicates the majority of the community present is sensitive to high TSS. Some tolerant species are also present, but in smaller numbers overall.

The macroinvertebrate community in this coldwater reach of Pine Creek had TSS station index scores greater than the average for coldwater stations in the Root River Watershed (Table 36). Most visits results in a high number of TSS tolerant taxa and high percentage of TSS tolerant individuals. Three of the four visits had a higher percentage of long-lived macroinvertebrates than average, which is expected to decrease with increased stress. It is likely that TSS may play a role in shaping the macroinvertebrate communities within this reach, particularly the downstream two stations, but there is a lack of connecting data to confirm TSS as a stressor.

Table 36. Macroinvertebrate metrics relevant to TSS for stations in Pine Creek compared to averages for coldwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
08LM063 (2008)	**15.67**	1	4	**13.96**	4.01	1.85
04LM097 (2004)	**16.54**	1	**9**	**19.48**	**0.28**	5.29
04LM095 (2004)	**16.07**	**0**	**12**	**10.59**	**0**	2.45
04LM095 (2008)	**15.67**	**0**	**7**	7.5	**0**	**0.61**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River watershed	15.13	0.99	4.38	9.94	0.95	1.23

The lack of solid chemical information on TSS and the mixed biological response to TSS, it cannot be confirmed as a stressor at this time. More chemical information on this reach would be useful in ruling this stressor out completely.

Physical habitat

Land use is the worst scoring subcategory for the MSHA scores in Pine Creek (specifically Stations 04LM095 and 04LM097). Station 04LM095 had a poor MSHA score in 2004 (42), but scored better in 2008 (61, considered fair). Overall, the MSHA and quantitative habitat assessment which documented erosion, raw banks and high percent fines in the stream channel. There was little cover, riparian area, and land use affecting a contributing issue. Station 04LM097 had an MSHA score (63, fair) and quantitative habitat assessment was a little better than 04LM095. The higher gradient might be a contributing factor.

Station 08LM063 had an MSHA score considered good (89). It appears to be much better, in terms of habitat availability. The substrate was characterized here as all cobble and gravel, with 30% of the reach being riffle, and only light embeddedness noted. The riparian width was noted as extensive (greater than 300’). There was no bank erosion and heavy shade. All four habitat types for macroinvertebrates were available and sampled.

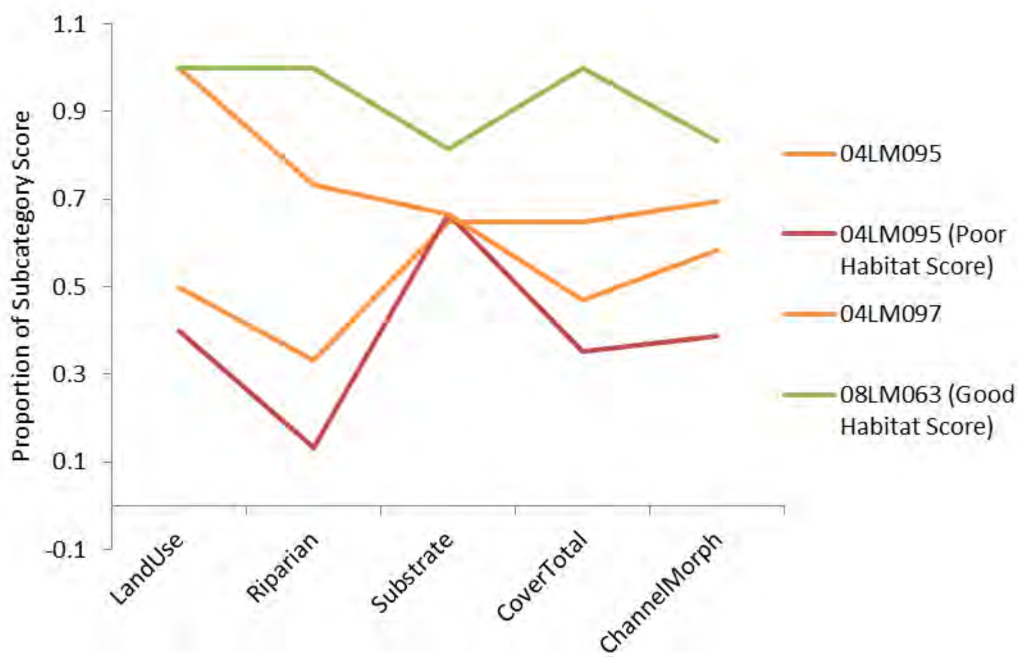


Figure 95. Pine Creek MSHA and subcategory scores.

There was not an abundance of burrowers found at any location, but they were higher than average at Station 04LM097, which does suggest potential sedimentation issues in the riffles. The percentage of EPT individuals was greater than or close to the statewide average for coldwater sites at all locations, but slightly reduced at Station 04LM097. In addition, the macroinvertebrates that are known to cling to large substrate and woody debris were found at or near average at all the sites, but slightly reduced again at downstream at both Stations 04LM097 and 04LM095. There were fewer percentages of macroinvertebrates that climb at all three stations except Station 04LM097. In addition Station 04LM097 also had a larger percentage of more tolerant legless macroinvertebrates (59%), compared to the statewide average of 32%. The other sites were near average in the percentage of legless macroinvertebrates.

Overall, it appears that lack of habitat is having the most impact at the middle Station 04LM097 and least impact at the most upstream of Station 08LM063. There are some slight habitat related response seen at the downstream Station 04LM095, but they are not as apparent. It's likely that watershed riparian land use, stream bank instability and sedimentation are all having an impact on the habitat available in Pine Creek, with the most impact seen at Station 04LM097. Habitat is considered a primary stressor in this reach.

Physical connectivity

No information was available or collected on physical connectivity on Pine Creek. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The stressor to the biological community in Pine Creek is the lack of habitat. Overall, it appears that lack of habitat is having the most impact at the middle Station 04LM097, and least impact at the most upstream Station 08LM063. There are some slight habitat related response seen at the downstream Station 04LM095, but it is not as apparent. It's likely that watershed riparian land use, stream bank instability and sedimentation are all having an impact on the habitat available in Pine Creek, with the most impact seen at Station 04LM097.

Currently, much of the near-stream land use in lower Pine Creek is pasture, so BMP which improve grazing practices in Pine Creek could have a positive impact on habitat and sedimentation. Better riparian management (forested riparian areas) would also help improve stream stability and habitat.

There is not an overwhelming amount of chemical data, but there is a presence of elevated nitrate in Pine Creek and its tributaries. Macroinvertebrates are showing a slight response to elevated nitrate in Pine Creek. Nitrate levels are moderate in this reach, and should be monitored and protected from further increase.

Temperature in Pine Creek is adequate, but additional information should be collected on DO and TSS, due to conflicting biological response. Additional chemical data would help rule out these potential stressors.

4.6.3. Pine Creek Headwaters (Warmwater)

Supporting information

This section on Pine Creek includes biological monitoring Station 08LM098. This occurs in the warmwater section of Pine Creek (upstream reach). The fish community appears to be doing very well (score of 85), however the macroinvertebrate IBI score was below the threshold and confidence interval. This section of stream is currently classified warmwater. Presence of brook trout and sculpin may indicate this may be a cool or coldwater reach that has been degraded.

The macroinvertebrate metrics which scored poorly were taxa richness of climbers (ClimberCh), a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of odonata (dragonflies and damselflies), taxa richness of predators (excluding chironomid predator taxa), relative percentage of taxa with tolerance values equal to or greater than six, using MN TVs (Tolerant2ChTxPct), and taxa richness of Trichoptera (caddisflies). The other metrics were scoring only fair, demonstrating overall degradation at this location (Table 37).

Table 37. Station 08LM098, in the headwaters of Pine Creek, macroinvertebrate metrics of the Southern Streams RR IBI; bold indicates metric score is below average metric score needed for IBI to be greater than threshold (3.6), maximum metric score possible is 10

Site	ClimberCh	ClingerChTxPct	DomFiveCHPct	HBI_MN	InsectTxPct	Odonata	Plecoptera	Predator	Tolerant2ChTxPct	Trichoptera
08LM098	**1.4**	4.0	4.6	**2.3**	6.6	**0**	**0**	**0.8**	**2.5**	**1.0**

Temperature

The temperature value taken on July 28, 2008 was 19.6°C. This falls in the range of normal for a headwater stream, especially as it's currently classified as warmwater. This would also be a fairly normal temperature for a coldwater stream as well.

Two brook trout were captured in 2008 at this station. This is the only Class 3 (southern headwater) site in the Root River with the presence of brook trout. In addition, 67 mottled sculpin were captured. In addition to these classic coldwater species, there were a number of other warmwater/coolwater species, such as white sucker that comprised of nearly 25% of the community. The significance of this is not known, but may indicate springs or other sources of coolwater are near this headwater area.

Additional information on the thermal regime of Pine Creek in this area would be beneficial. There is a mixed community present, and that may or may not be dictated by temperature. Continuous temperature measurements would help understand the thermal dynamics this headwater area.

Dissolved Oxygen

During biological sampling at Station 08LM098 the DO concentration on July 28, 2008 was 8.02 mg/L. This was the only DO data available on this stream reach.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH during biological sampling was 7.62, and TP was 0.171 mg/L. While pH is within normal range, TP appears elevated which can likely be attributed to the cattle accessing the stream (noted during fish visit). Neither BOD nor Chlorophyll-a data were available for analysis at this time.

The fish community is made up of species which are fairly tolerant to low DO. Station 08LM098 has a DO TIV aggregate score in most tolerant quartile compared to other sites in the Root River, indicating community is generally tolerant to low DO. However, there were some sensitive species present as well; including two brook trout and 67 sculpin (out of 1450).

The macroinvertebrate community has a DO TIV Index score near average for Root River Watershed sites. The number of DO intolerant taxa (9), are also near average for the Root River Watershed. The percent tolerant taxa are relatively high; at 13.5% (average for Root River sites is 2.6%). The percentage of EPT taxa found at 08LM098 was above average. EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux**.** The macroinvertebrate community at Station 08LM098 had low taxa richness with only 16 taxa when the average for Class 5 stations statewide is 24.2.

The biological communities have a slight signal to DO stress, but it is unclear if they are responding to DO or another stressor. It is difficult to conclude DO is a stressor at this time, especially given the lack of strong chemical and biological response information. More information on DO should be collected in this reach to rule this stressor out completely.

Nitrate

The only nitrate measurement available was taken at the time of fish sampling in 2008 which resulted in a value of 5.2 mg/L. This value is higher than what has been measured in the downstream locations, in the downstream AUID (see Pine Creek 526 for more information).

The macroinvertebrate community at Station 08LM098 had low taxa richness with only 16 taxa when the average for Class 5 stations statewide is 24.2 (with chironomid and baetid taxa each treated as one taxon). Additionally, it is lower than average for Trichoptera taxa (3) and intolerant taxa (0). Station 08LM098 had no nitrate intolerant taxa and had 88.5% nitrate tolerant individuals. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (Class 5) MIBI, and at 83.8% nitrate tolerant individuals there is a 10% probability of meeting the MIBI.

The macroinvertebrate community is degraded in a way which suggests a potential stressor for nitrate; however more nitrate data is needed to understand the magnitude and duration of this potential stressor. It is not certain whether the community is responding to nitrate or another stressor. The one available nitrate concentration is elevated along with downstream indications of even higher nitrate concentrations possible. Additional information on nitrate concentrations in this reach would be helpful to understand the impacts to the biological communities.

Suspended sediment

The TSS concentration on day of fish sample at this site was 40 mg/L. This elevated value can likely be attributed to cattle access in the reach, which was noted during the fish visit. The fish sample was dominated by white sucker, central stoneroller, and creek chub. These species are moderately intolerant to high TSS, but not the most intolerant species found in the Root River Watershed. The fish sample comprised of more species intolerant to high TSS, than tolerant to TSS. Therefore, the fish data do not strongly point to a TSS stressor.

At Station 08LM098, there were no intolerant macroinvertebrates and less than 1% long-lived macroinvertebrates, which often decrease with increases in TSS. The macroinvertebrate index score for TSS was 16.4; better than the average for warmwater stations in the Root River Watershed. The station at the time of sampling had five taxa tolerant to TSS and no intolerant to TSS. The survey had 25.43% of the individuals in the survey considered tolerant to TSS; the average for warmwater stations in the Root River Watershed is 35.45%. Although there are no intolerant macroinvertebrates to TSS, it also shows that the tolerant are not dominating the population either. Three of the six metrics analyzed for TSS stress resulted in conditions poorer than the average of warmwater stations; however these may be influence by other stressors.

Given the lack of chemical data, and lack of strong biological data, a TSS stressor cannot be confirmed at this time. Even though a TSS stressor does not appear likely given the biological information, more data would be helpful in making this determination.

Physical habitat

The MSHA score for Station 08LM098 scored poor (41). This section of stream is habitat limited, likely due to local land use issues (pasture). The reach is characterized as having 75% run, 10% pool, and 15% riffle features. There was cattle access to stream throughout reach, as noted during the fish visit (Figure 96). The predominant surrounding land use was row crop; with one side of the stream having a wide riparian zone, and the other side, none. The substrate was a mix of cobble, gravel, clay, sand and silt. Moderate embeddedness was noted along with sparse cover. The macroinvertebrate habitat that was available and sampled in 2008 included riffles, undercut banks/overhanging vegetation, and woody debris.

Figure 96. Biological Station 08LM098, downstream end.

There was not an abundance of burrowers found, which may suggest potential sedimentation issues in the riffle habitat. The percentage of EPT individuals was greater than the statewide average. Additionally, there were a high percentage of macroinvertebrates than climb, which is demonstrated in the low IBI metric score for climbers (Table 37). The macroinvertebrates that are known to cling to large substrate and woody debris were found in less abundance (fewer than average for statewide sites). Also, the percentage of macroinvertebrates that were legless was higher than average showing some shift towards more tolerant individuals (snails, worms, etc.).

While the macroinvertebrate specific habitat metrics do not show a strong signal towards habitat degradation, but do provide some indication that habitat is potentially limited, especially for clingers. The high percentage of legless individuals also shows degradation of the macroinvertebrate community in general. Better management of local land use and the riparian area could certainly have a positive affect on the macroinvertebrate community in Pine Creek.

Physical connectivity

No information was available or collected on physical connectivity on Pine Creek headwaters. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

While the macroinvertebrate specific habitat metrics do not show a strong signal towards habitat degradation, they do indicate that habitat is potentially limited in this part of Pine Creek. Better management of local land use and the riparian area could certainly have a positive affect on the macroinvertebrate community in Pine Creek. MSHA scores are low, and site photos show a degraded riparian area.

The macroinvertebrate community is degraded in a way which suggests a potential stressor for nitrate; however more nitrate data is needed to understand the magnitude and duration of this potential stressor. It is not certain whether the community is responding to nitrate or another stressor. The one available nitrate concentration is elevated along with downstream indications of even higher nitrate concentrations possible.

While temperature is not believed to be a stressor (as this is currently a warmwater reach), it should be explored further for additional information. Additional continuous temperature data would help understand thermal dynamics in this reach. With brook trout and sculpin present, there is potential for this to be coldwater. However, this reach may also be degraded thermally, and may have supported better temperatures in the past.

Additional information on DO and TSS would also be useful. The biological response to those two stressors was not clear, and chemical data would help confirm or refute those potential stressors.

4.6.4. Summary of stressors in Rush Creek

The stressors found to limiting the biological (macroinvertebrate) communities in Rush Creek are found in Table 38.

Table 38. Stressors identified in the Rush Creek Watershed. ● = stressor (yes); o = inconclusive stressor (IF); 'blank'-no stressor

Reach Name	Geo Region	AUID	Reach Description	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Physical Habitat	Physical Connectivity
Rush Creek	***Both Driftless, Bluffland Karst and Driftless Near Karst Surface***	**07040008-524**	Unnamed Creek to Pine Creek	2A	08LM074 08LM056 04LM032	Downstream of CSAH 25, 4 mi. NW of Rushford Downstream of Enterprise Valley Dr, 3.5 mi. S of Lewiston Downstream of Hwy. 29, 2 mi. S of Lewiston	Invert IBI		O	●		●	
Pine Creek	***Driftless, Bluffland Karst (near transition)***	**07040008-526**	T104 R9W S4, North line to Rush Creek	2A	04LM095 04LM097 08LM063	Upstream of Hwy. 2, 3 mi. NW of Rushford Fremont Township, just upstream of mouth of Hemingway Creek, 6 mi. NW of Rushford Upstream of Dendal Dr, 7 mi. NW of Rushford	Invert IBI		O	O	O	●	
Pine Creek	***Driftless, Bluffland Karst (near transition)***	**07040008-576**	Headwaters to T105 R9W S32, south line	2B	08LM098	Downstream of Grover Dr, 8 mi. SE of St. Charles	Invert IBI		O	O	O	●	

4.7. South Branch Root River

All of the biologically impaired streams in the South Branch Watershed are coldwater streams, and in the driftless, near-surface Karst zone. The stressors affecting these biological communities are very similar, but some differences do exist among areas within the watershed.

There are a handful of stream reaches in the South Branch that are not listed for aquatic life, but have nitrate impairments for drinking water use. Forestville Creek (563), South Branch Root (555), Canfield Creek (557) and Etna Creek (562) are all streams reaches on the impaired waters list due to nitrate impairment. They were assessed for nitrate based on the drinking water standard of 10 mg/L, while the current proposed aquatic life toxicity standard is still under development. The standard is projected to be available in 2015. It may or may not be lower than the current drinking water standard of 10 mg/L.

On Duschee Creek, Station 08LM048 was not assessed due to its sampling location. There was concern the sampling location was not in a representative location. A new site was established, Station 11LM102, and scores fairly well for both fish (57) and macroinvertebrates (55); both above impairment thresholds). A new site was also established on Crystal Creek, a small tributary to Willow Creek. Station 12LM103 had a fish IBI score of 41, which was below the impairment threshold.

Macroinvertebrate impairments are throughout the watershed, but Watson and Camp also have fish impairments. Multiple stressors exist in those watersheds which have an additive impact on aquatic life. Fish are doing quite well in most other locations in the South Branch Root River. The biological stations, in relation to the identified reaches of biological impairment, are shown in Figure 97.

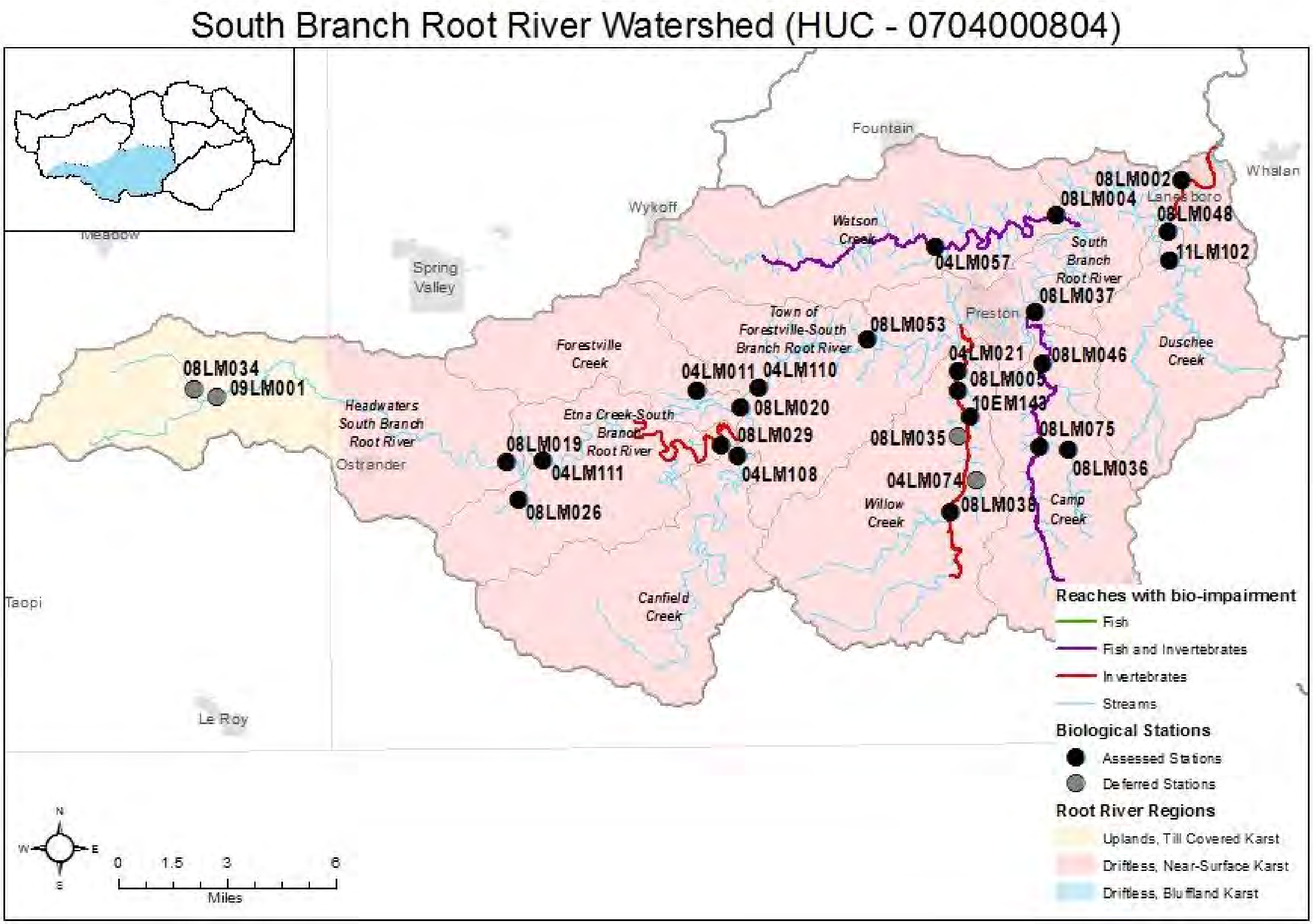


Figure 97. Map of South Branch Root River Watershed showing reaches of biological impairment and biological sampling locations

4.7.1. South Branch Root River (Lanesboro Area)

Supporting information

There is one biological station on this coldwater AUID, Station 08LM002 (Figure 98). Fish data indicate this station is in a transition from coldwater to warmwater, despite decent fish IBI scores. While the fish community is doing fairly well, the invert community is not. There is a weak community present, and scores below macroinvertebrate IBI thresholds for coldwater or warmwater assemblages.

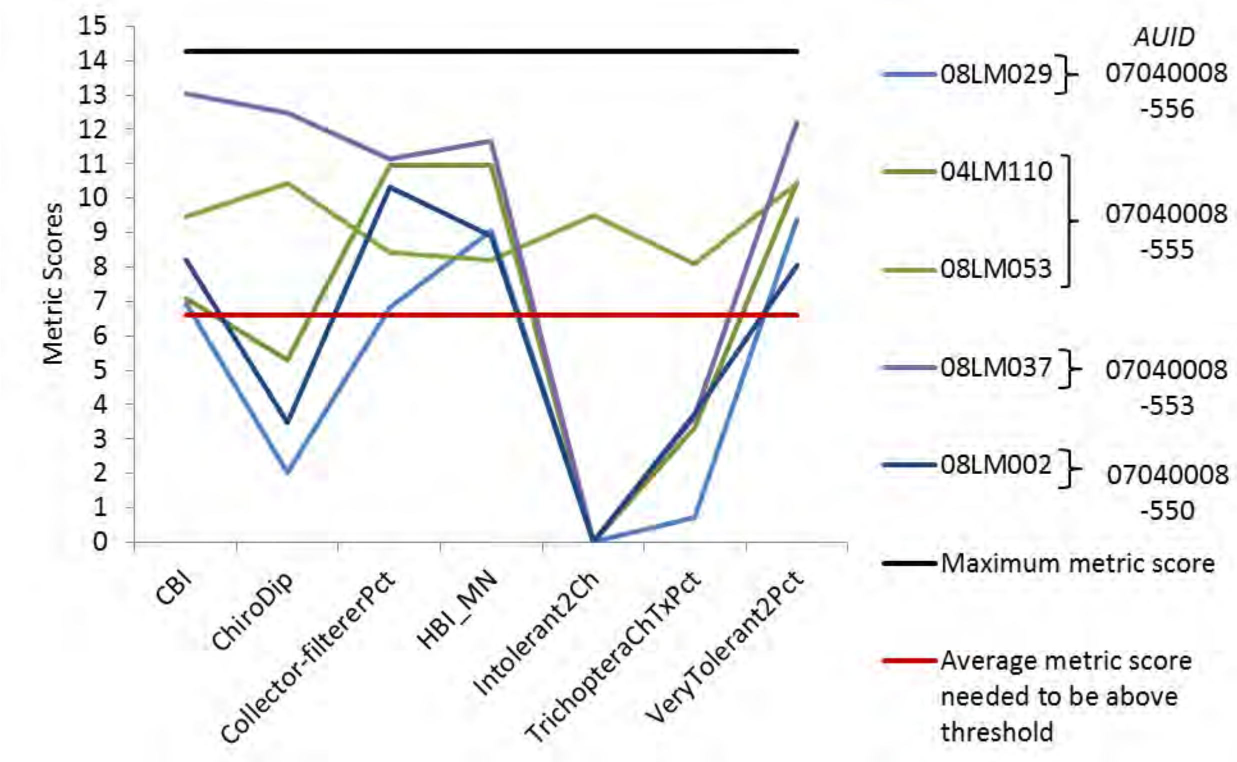


Figure 98. Metric scores for stations in the South Branch Root River of the Southern Coldwater macroinvertebrate IBI

The consistency of macroinvertebrate biological stress in the coldwater main stem of the South Branch Root River is demonstrated in Figure 98. This suggests some system-wide type stressors, which are reducing the macroinvertebrate community quality overall. One exception is Station 08LM053, in the middle part of the watershed (near Carimona), which may or may not be reflective of something unique in that area. While Figure 98 displays the entire South Branch Watershed, Station 08LM002 is the site addressed in this section of the report.

Station 08LM002 is characterized by a few metrics scoring poorly, which include: a ratio of chironomid abundance to total dipteran abundance (ChiroDip), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs (Intolerant2Ch), and a low percentage of taxa belonging to Trichoptera or caddisflies (TrichopteraChTxPct).

Temperature

In this area, the biological community has a stronger presence of warmwater taxa than would be expected as noted by biologists. However, this area is in a transition zone, as the South Branch is close to entering the larger Root River system. Continuous temperature data in Lanesboro, show annual maximum temperatures of: 22.6, 21.7, and 22.4°C for data from 2008-2010. July and August averages for all three years were around 18°C. Although this is a thermal transition area, temperatures appear suitable. While there is a dam upstream, which may be warming the water slightly, the water in this area naturally would be slightly warmer given its proximity to the Mainstem Root River.

There were 69 synoptic temperature values on the AUID from field measurements. Of those values, two in 2009 were at 23°C. Differences in sampling location, personnel, and equipment may account for some differences in temperature when comparing to the continuous data (above).

The robust continuous dataset does not appear to show anything of concern in regards to temperature in this coldwater stream. While we would expect the stream to be naturally warmer here, with July and August average values for three years near 18°C, temperature is not believed to be limiting the biological communities found at Station 08LM002.

Dissolved Oxygen

During biological sampling at Station 08LM002, on September 4 2008 (12:05pm), the DO concentration was 9.78 mg/L. DO grab sample data was also available at Station S004-829, which had a maximum of 11.97 mg/L, and minimum of 7.87mg/L.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. During fish sample at Station 08LM002 the pH was 8.08. The total phosphorus concentration was 0.07 mg/L. Monitoring Station S004-829 had pH values which ranged from 8.02-8.30. There were also 10 total phosphorus samples which ranged from 0.04 mg/L to 0.364 mg/L. The average value collected was 0.0971 mg/L. Also at Station S004-840, there were 63 total phosphorus samples collected from 2008-2010. The range of values was from 0.024 mg/L to 2.28 mg/L, with an average of 0.292 mg/L. Consideration should be given since many of these samples were collected during storm events when phosphorus concentrations are typically at their highest. During low flow conditions, the phosphorus concentrations return to normal and are not at a level of concern.

In 2008, Station S004-829 was sampled eight times for chlorophyll-a on the South Branch of the Root River in Lanesboro. The results from the chlorophyll-a monitoring ranges from 1.18ug/L to 3.55ug/L, which are not at a level of concern. This is important to note given the potential influence of water that is backed up by the dam in Lanesboro. Given the samples taken in 2008, this evidence does not suggest excess productivity which would have potential influence on DO levels in the stream. No BOD was available at this time.

The fish community at Station 08LM002 had 40% of species that are considered quite tolerant to low DO. The DO TIV index score is just below average for Root River biological stations, indicating the community present has some tolerance to low DO, but the community is not completely dominated by tolerant to low DO species either. The fish community suggests potential for DO issues, but the data are not overwhelming.

The macroinvertebrate community DO TIV index score for 08LM002 is 7.7, which is slightly better than average for Root River biological stations. The number of DO intolerant species is much better than average at 15 (average Root River Stations is 10). There are only 2.5% tolerant to low DO species, which is also better than average. The macroinvertebrate survey in Station 08LM002 had 21 taxa (with chironomid and baetid taxa each treated as one taxon), above the average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin of 19. Taxa richness can be decreased with increases in DO flux. Also a high percentage of EPT taxa are present at this site. EPT taxa are typically intolerant of low DO levels. At this time, the macroinvertebrate community is not signaling DO stress.

The biological and chemical evidence supports that low DO is not a stressor to this reach on the South Branch Root River.

Nitrate

The average concentration of nitrate on this AUID is 6.1 mg/L (73 samples from 2008-2010). The maximum concentration recorded in that dataset was 9.6 mg/L. During fish sampling, the nitrate sample result was 6 mg/L. While the numbers are not exceeding the drinking water standard for nitrate (10 mg/L), they are elevated. The seasonal distribution of nitrate concentrations is illustrated in (Figure 99).

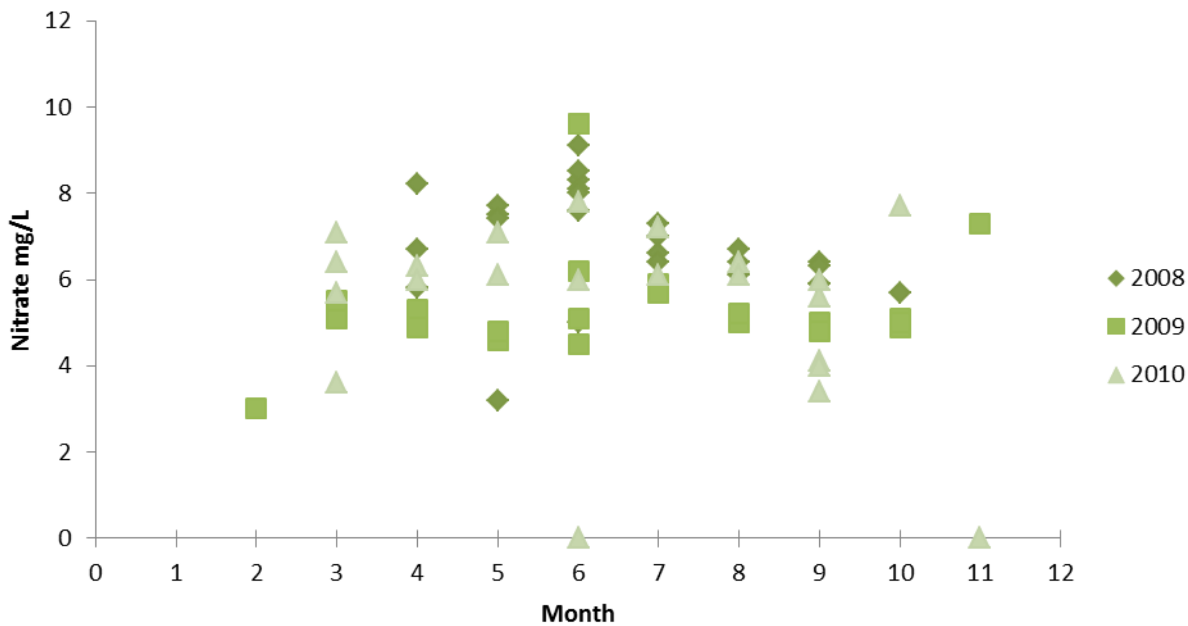


Figure 99. Grab sample nitrate concentration for South Branch Root River, at Lanesboro 2008-2010

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of six mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate survey in Station 08LM002 had 21 taxa (with chironomid and baetid taxa each treated as one taxon), above the average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin of 19. Station 08LM002 had no intolerant taxa and four Trichoptera taxa, comprising of 10.8% of the total taxa (TrichopteraChTxPct). The result is a very low MIBI metric score;

less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In the South Branch Root River, the metric score was 8.9 (out of 14.3), above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM002 the HBI_MN value was 7.00 in 2008, greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling (p≤0.001). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM002 had 22 nitrate tolerant taxa (64.4% individuals); and 13 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in the macroinvertebrate survey.

The abundance of nitrate tolerant taxa, lack of nitrate intolerant taxa, along with low metric scores for TrichopteraChTxPct; show that the macroinvertebrate response to the elevated nitrate is present. Nitrate is elevated in the South Branch Root River and is playing a role in shaping this degraded macroinvertebrate community.

Suspended sediment

TSS data from 2008-2010 was collected as part of the turbidity TMDL for the South Branch Root River. This stream reach is not impaired for turbidity, but monitored as comparison since it represents the entire South Branch Watershed. The data showed TSS concentrations get very high during events. During baseflow conditions, the stream TSS concentrations remain slightly elevated. The average concentration of TSS in July and August (most probable baseflow conditions) in 2008, 2009, and 2010 were 22, 17, and 28 mg/L, respectively. The draft TSS standard for this region and 2A streams is 10 mg/L. In addition, there were a total of 17 other samples collected in July and August over the three year period. The average concentration of these values is 22.9 mg/L, with only two of the 17 values meeting the draft TSS standard of 10 mg/L.

Much of the TSS data from this AUID were targeted during storm events. There were 11 TSS samples collected during IWM in 2008, with scheduled sampling frequency. The results showed that 6 of 11 samples were greater than 10 mg/L (10 mg/L is the draft TSS standard, 2A streams).

A continuous turbidity sensor was installed at this site from 2008-2010. Regression analysis shows the data exceeds the turbidity standard, (10 NTU for coldwater streams) about 11.5% of the time. At this time it is not clear on the translation to the TSS standard, but the two are correlated.

While the fish community at Station 08LM002 is doing well (i.e. not impaired), they are comprised of fish which are generally more tolerant to high TSS concentrations. The TSS TIV index score for fish at this station is in the most tolerant quartile compared to other coldwater stations in the Root River, indicating that overall; a TSS tolerant fish community is present. The percent carnivore fish metric, which is correlated to TSS, is low at Station 08LM002 (11%). The average percentage of carnivores in the Root River coldwater fish class is 23%.

Looking closer at the macroinvertebrate community, there were no intolerant macroinvertebrates and less than 2% long-lived macroinvertebrates, which are two metrics that often decrease with increases in TSS. The macroinvertebrate index score for TSS was 16.24, worse than the average for coldwater stations in the Root River Watershed (15.13). The station at the time of sampling had nine taxa tolerant to TSS and none intolerant to TSS. Both of these metrics reveal conditions less than desirable compared to averages of coldwater stations in the Root River. The survey had 25.4% of the individuals in the survey considered tolerant to TSS; the average for coldwater stations in the Root River is 9.94%. The macroinvertebrate community data suggests that TSS is a stressor at this location.

Both chemical and biological evidence support that elevated TSS concentrations are causing stress to the biological community found at Station 08LM002.

Physical habitat

At Station 08LM002, the total MSHA score was rated as good (79). The attributes of the MSHA were characterized as having good cover (multiple cover types), and a wide riparian area. Only light embeddedness was noted, with cobble and boulder present. The sampling reach was 40% riffle. There was high channel stability and excellent channel development also noted in the MSHA. Based on the attributes of the MSHA, it doesn't appear that bedded sediment is a huge issue at this location. This is further confirmed by a high percentage of EPT taxa (46%) and clinger taxa (50%). The percentage of taxa which burrow was also low, showing that sedimentation in the riffle is not an issue. The percentage of macroinvertebrates that climb are slightly worse than statewide averages, potentially suggesting a lack of vegetative habitat. However, given almost all the habitat related macroinvertebrate metrics are not responding in a manner suggestive of habitat issues for this site, habitat issues are not driving the macroinvertebrate impairment at Station 08LM002.

Physical connectivity

Little information is available on connectivity in the South Branch Root River. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

However, it is worth noting that the large dam on the South Branch in Lanesboro does cause a disconnect for the fish community in that area. Even so, fish do not appear to be suffering in this location, potentially due to the proximity of the mainstem Root River.

Strength of evidence, conclusions, and recommendations

The main stressors affecting the macroinvertebrate community in this stream reach are elevated TSS and nitrate. Temperature, DO, habitat, and connectivity are all considered suitable and not impacting the macroinvertebrate community as this time.

Nitrate is elevated on this reach and there is an apparent macroinvertebrate response to the stressor. Further investigation into the sources of nitrate would be beneficial, along with continued monitoring.

The TSS grab sample data on this reach shows elevated concentrations even during baseflow conditions. In addition, both fish and macroinvertebrate communities are demonstrating consistent response to elevated TSS. Field evidence on this AUID and upstream areas shows fairly prevalent bank erosion; which is likely contributing to TSS levels seen in this reach.

Both of these stressors are the result of watershed-wide influence and are not as a result local site issues. Improvements within the watershed, including stream channel stability, local land use, and nutrient management would be helpful in reducing the stress from Nitrate and TSS to the macroinvertebrate community found in the Lower South Branch Root River.

4.7.2. South Branch Root River (Upstream Canfield Creek)

Supporting information

There is one biological station on this coldwater AUID, 08LM029. Fish are doing well at this station, but macroinvertebrates are just below impairment threshold (Figure 98). The coldwater macroinvertebrate community was noted as “weak” during assessment. Station 08LM029 is characterized by a few metrics scoring poorly, which include: the ratio of chironomid abundance to total dipteran abundance (ChiroDip), taxa richness of macroinvertebrates with tolerance values less than or equal to 2, using MN TVs (Intolerant2Ch), and a low percentage of taxa belonging to Trichoptera or caddisflies (TrichopteraChTxPct).

Temperature

Continuous temperature measurements from Station 08LM029 in 2008 (May-September), show a maximum temperature of 21.7°C on July 20, 2008. The July and August average temperatures were 17.26 and 17.15°C, respectively.

Along with this data, there were 362 temperature measurements from this AUID. The data was collected at two different CSMP (citizen stream monitoring) sites from 1999-2011. There were only 24 (6%) measurements above 22°C. The maximum temperature recorded was 25.6°C. While this temperature value is high, it is an outlier in the dataset, and could be explained by error or equipment. The robust dataset collected in 2008 ensures the stream is maintaining adequate temperatures. The temperature data, coupled with biology with a strong coldwater signature, provides good evidence that temperature is a likely stressor in this stream reach.

Dissolved Oxygen

The only DO data on this stream AUID was the data collected during fish sampling at Station 08LM029. The value collected on July 29, 2008, was 9.30 mg/L at 8:39 am.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH value collected during biological sampling was 8.06. The total phosphorus result was 0.041. While this data is limited, the values are considered within normal range and do not suggest altered nutrient dynamics which could impact oxygen concentrations. Chlorophyll –a, and BOD data was not available for analysis.

The majority of the fish community collected here is made up of mottled sculpin and brown trout, which suggest adequate oxygen levels. These two species are some of the most sensitive species to low DO found in the entire Root River basin. The macroinvertebrate community is also made up of individuals that are generally considered more sensitive to low DO. The macroinvertebrate DO TIV index score is better than average for Root River stations. However, neither DO tolerant or DO intolerant taxa are greatly abundant. The percentage of EPT individuals found at 08LM029 was greater than the statewide average for coldwater stations. EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux. The macroinvertebrate survey in Station 08LM029 had only 12 taxa (with chironomid and baetid taxa each treated as one taxon), much lower than the average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin of 19.

The evidence shows intolerant to low DO biological communities overall, and the reduced taxa count are most likely due to another stressor, not DO. The biological and chemical evidence confirm that DO is not a stressor at this time.

Nitrate

There is limited chemical information on this AUID. However, the AUID immediately downstream of this one is listed for drinking water use impairment of nitrate (555). The conditions in this AUID are not likely to be too different from the downstream AUID that is impaired for nitrate. The only nitrate data available for analysis was during the time of fish sampling at 08LM029. On July 29, 2008 there was 7.3 mg/L nitrate, is likely representative of nitrate conditions during baseflow. On the downstream AUID, samples were taken at Station S001-320 on July 8 and 31, 2008, with nitrate measurements of 9.0 and 8.7 mg/L, respectively. Station S001-320 is located before the confluence with Forestville Creek, and after the confluence with Canfield Creek, approximately 2.8 miles downstream of the Biological Station 08LM029.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of six mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate survey in Station 08LM029 had only 12 taxa (with chironomid and baetid taxa each treated as one taxon), much lower than the average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin of 19. Station 08LM029 had no intolerant taxa and only 2 Trichoptera taxa, comprising of 7.1% of the total taxa (TrichopteraChTxPct). The result is a very low metric score; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increases in nitrate. In the South Branch Root River, the metric score was 9.1 (out of 14.3), above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM029 the HBI_MN value was 6.75 in 2008, greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM029 had 15 nitrate tolerant taxa (73.3% individuals); and 10 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at

20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in the macroinvertebrate survey.

Although there is limited nitrate data on this AUID, along with downstream AUID nitrate information and the biological response, nitrate is a stressor to the macroinvertebrate community. The abundance of nitrate tolerant individuals, lack of nitrate intolerant taxa, along with low metric scores for TrichopteraChTxPct; show that the macroinvertebrate response to the elevated nitrate is present. Nitrate is elevated in the South Branch Root River and is playing a role in shaping this degraded macroinvertebrate community.

Suspended sediment

The downstream AUID (555) is currently impaired for turbidity; however that listing is based on a small transparency tube dataset. A more vigorous dataset of TSS and turbidity, collected in 2008-2010 at the South Branch in Carimona, showed only a 9% exceedence of the turbidity standard (using regression analysis). This included continuous data collected from an optical turbidity probe, over the course of two years. This data does suggest this section of creek and upstream does not likely have strong TSS driven issues.

There were 391 transparency tube measurements from two CSMP sites on this AUID. The data showed an average transparency of 40 cm. Overall, it appears the stream is turbid during events, but clears up quickly and is not turbid for extended durations (which would have a larger impact to biological communities).

While the fish community at this station is doing well, they are comprised of fish which are tolerant and intolerant to high TSS concentrations. The TSS TIV index score for fish at this station is among average for that of other coldwater stations in the Root River. The percent carnivore metric, which is correlated to TSS, is below average at Station 08LM029 (23%), in comparison to other coldwater stations statewide (47%). The fish community does potentially signal TSS stress, but the data are not strong.

At Station 08LM029, there were 0.32% intolerant macroinvertebrates and long-lived macroinvertebrates, which often decrease with increases in TSS. The macroinvertebrate index score for TSS was 15.9, worse than the average for coldwater stations in the Root River Watershed (15.13). The station index score for TSS was also in the upper most quartile of tolerance, indicating tolerance to TSS. The station at the time of sampling had five taxa tolerant to TSS and one intolerant to TSS. The tolerant metric reveals conditions less than desirable compared to averages of coldwater stations in the Root River and about average for the intolerant macroinvertebrate taxa. The survey had 25.24% of the individuals in the survey considered tolerant to TSS; the average for coldwater stations in the Root River is 9.94%. The macroinvertebrate community data suggests that TSS is a potential stressor at this location.

The biological and chemical evidence is conflicting, and does not strongly support a TSS stressor at this location, at this time. However, the macroinvertebrate community does provide some indication that TSS may be a parameter to monitor over time to ensure adequate concentrations in this reach.

Physical habitat

At Station 08LM029, the MSHA score was 76, which is rated as good. The substrate composition was boulder and cobble with no embeddedness. There was very little bank erosion noted as well. The riparian width was very narrow (comprised of pasture), but the floodplain and pasture were noted as relatively in tact. Overall, the habitat attributes are quite good, with the exception of the pastured riparian area. Riffles and woody debris were the habitats sampled for macroinvertebrates.

There was not an abundance of burrowers found, which would suggest potential fine sedimentation issues in riffle habitat. The percentage of EPT individuals was greater than the statewide average for coldwater stations. The macroinvertebrates that are known to cling to large substrate and woody debris and macroinvertebrates that climb were found near average for coldwater stations statewide. Although there may be some aspects of habitat that could be improved, with some diverse habitat present, it is unlikely that a lack of habitat is currently having a direct effect on the invert community and not currently a driver of macroinvertebrate impairment in this reach.

Physical connectivity

No information was available or collected on physical connectivity on this reach of the South Branch. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The main stressor affecting the community in this stream reach is elevated nitrate. The AUID immediately downstream of this one is listed for drinking water use impairment of nitrate (555). Although there was limited nitrate data on this AUID, the concentrations were elevated. The macroinvertebrate community response to the elevated nitrate includes abundance of nitrate tolerant individuals, lack of nitrate intolerant taxa, along with low metric scores for TrichopteraChTxPct.

Temperature, DO and habitat all appear suitable in this reach based on the available chemical and biological metric response information. However, while TSS was not able to be confirmed as a stressor, its status as a stressor remains inconclusive. The chemical information does not strongly point to TSS related issues, but the macroinvertebrate community did suggest some potential for TSS tolerance. TSS should be monitored over time to make sure conditions remain favorable.

4.7.3. Etna Creek

Supporting information

There is one biological Station (08LM026) on this AUID of Etna Creek. Fish are doing well at this station, but macroinvertebrates are just below impairment threshold. Elevated nitrate levels were noted at time of fish sampling, and habitat was noted as fairly good. There may have been some localized affects from the 2008 flood in this area.

The macroinvertebrate community had an IBI score of 41.9 in 2008 and 47.1 in 2011. The macroinvertebrate metrics in the Southern Coldwater macroinvertebrate IBI that scored low both years were the Coldwater Biotic Index score based on coldwater tolerance values derived from Minnesota taxa and temperature data (CBI) and the ratio of chironomid abundance to total dipteran abundance (ChiroDip; Figure 100). In 2008, the relative abundance (percent) of collector-filterer individuals in subsample metric (Collector-filtererPct), and the metric that is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN) scored low, but these did not in 2011. In 2011, the metric of taxa richness of macroinvertebrates with tolerance values less than or equal to 2, using MN TVs (Intolerant2Ch) scored lower than expected.

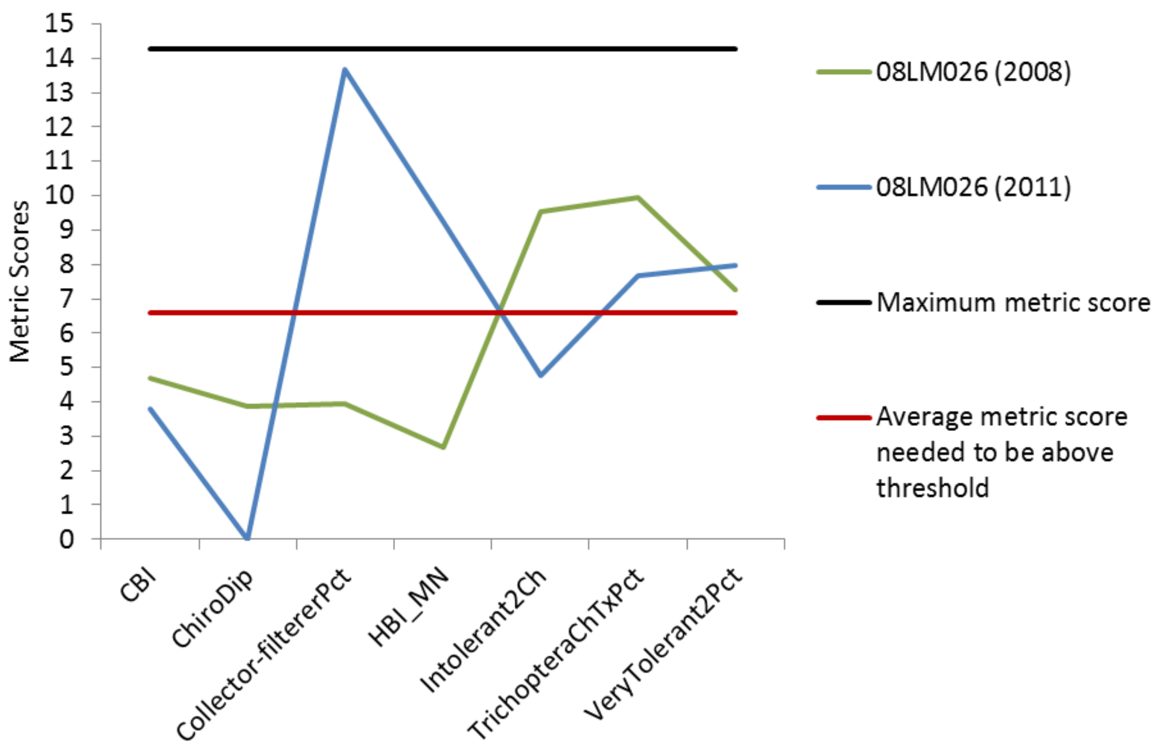


Figure 100. Metric scores for stations in Etna Creek of the Southern Coldwater macroinvertebrate IBI

Temperature

Continuous temperature measurements from Station 08LM026 in the summer of 2008 show the maximum temperature of 18.9°C occurred on July 11, 2008. The July and August average temperatures were 15.11 and 13.03°C, respectively. This data, coupled with a fish community with a strong coldwater signature, provides good evidence temperature is not a stressor in Etna Creek.

Dissolved Oxygen

There were eight DO) values collected in 2008 and 2009 on this AUID, and showed a minimum of 8.16 mg/L. The average value was 10 mg/L, with a maximum of 14.07 mg/L on April 10, 2009. On June 26, 2008, at the time of fish sampling at Station 08LM026 (8:45 am), the DO concentration was 9.26 mg/L.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH data collected during biological sampling was 7.72. Total phosphorus was 0.028 mg/L. Neither chlorophyll -a, nor BOD data were available for analysis on Etna Creek.

Given the robust fish community, most of which are intolerant to low DO (i.e. mottled sculpin and brown trout); it is not likely this stream is being impacted by low DO levels. The macroinvertebrate DO TIV index score is better than average for Root River Stations, also suggesting a community which is somewhat sensitive to low DO. Station 08LM026 had an average amount of DO intolerant taxa, and a higher percentage of tolerant to low DO taxa (7% tolerant taxa; average Root is 2.6%). In addition, the percentage of EPT individuals was better than the statewide average in Etna Creek. EPT are typically intolerant of low dissolved oxygen levels. Overall the biological communities do not strongly indicate DO stress, and the chemical data is limited. Given this information, DO is not believed to be a stressor in Etna Creek at this time.

Nitrate

The downstream AUID (562) on Etna Creek is listed for drinking water use impairment of nitrate, with levels up to 12 mg/L on June 28, 2000 (baseflow conditions). However, no nitrate samples have been taken since 2001 on the downstream AUID. The upstream AUID (597) is impaired for lack of macroinvertebrate assemblage. The only nitrate data available for analysis was during the time of fish samples in 2008 and 2011 (9.1 and 7.4 mg/L, respectively).

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate survey in Station 08LM026 had 23 taxa in 2008 and 16 taxa in 2011 (with chironomid and baetid taxa each treated as one taxon). The taxa counts were on either side of the average taxa count for the Southern Coldwater macroinvertebrate class for the LMB of 19. Station 08LM026 had two and one intolerant taxa (2008 and 2011 respectively).

Etna Creek, Station 08LM026, had seven and five Trichoptera taxa comprising of 18.4 and 15.6%of the total taxa (TrichopteraChTxPct) and a resulting metric score greater than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. At Station 08LM026, in Etna Creek, the metric score was 2.7 and 9.2 (2008 and 2011, respectively, out of 14.3), below and above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM026 the HBI_MN value was 7.05 in 2008 and 6.32 in 2011, both greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of ten mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM026 had 20 and 23 nitrate tolerant taxa (79.9 and 66.1% individuals); and 14 and 18 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI. At 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI, and at 22.60 nitrate tolerant taxa there is a 10% probability of meeting the Southern Coldwater MIBI. There were two nitrate intolerant taxa present in 2008 and 2011.

The impairment is moderate, with MIBI scores just above (2011) and just below (2008) the Southern Coldwater Streams MIBI threshold. Etna Creek has demonstrated high nitrate concentrations on the adjacent downstream AUID, which led to a drinking water use listing for nitrate. There are only two nitrate data points on this AUID, both elevated; however the station downstream (on the downstream AUID 562) is approximately 0.25 miles downstream of Station 08LM026. While the biological response is not consistent among all metrics, there were a high percentage of nitrate tolerant taxa and a low number of nitrate intolerant taxa collected in 2008 and 2011, along with elevated HBI_MN values. It is likely that nitrate is the stressor affecting the macroinvertebrate community and any further nitrate inputs or additional stressors would lessen the community assemblage further.

Further investigation into the magnitude and duration of nitrate in this AUID of Etna Creek, and sources of nitrate would be beneficial. Questions that may be answered may include: how much nitrate is coming from Etna Creek (597) and how much from adjacent Etna Creek Tributary (971). Both reaches have a large amount of agricultural land use as well as ponds upstream. The Nitrogen in Minnesota Surface Waters Report estimates that agricultural groundwater and agricultural drainage comprise of 80% of the nitrogen sources in the Lower Mississippi River Basin (pg. D1-11). The underlying geology of the watershed is also playing an important role in sources and pollutant transport.

Suspended sediment

During biological sampling on August 24, 2011, the TSS concentration at Station 08LM026 was less than one mg/L. Co-located monitoring Station S005-074, in 2008 and 2009, had eight measurements with all but one greater than 60 cm. The limited chemical information suggests the stays clear during most conditions, and is turbid only for a short time after rain events.

The fish community was dominated by brown trout and mottled sculpin, both of which are sensitive to elevated levels of TSS. There were a few tolerant fish species present, including white sucker. The TSS TIV fish aggregate station scores near average for coldwater sites in the Root River.

In 2008 and 2011, Station 08LM026 had 3.7 and 1.97% intolerant macroinvertebrates, and 10.8 and 3.95% long-lived macroinvertebrates, respectively, which often decrease with increases in TSS. The macroinvertebrate index scores for TSS were 15.0 and 15.34, on either side of the average for coldwater stations in the Root River watershed (15.13). In 2008, the station had two taxa tolerant to TSS and three intolerant to TSS. In 2011, the station had four taxa tolerant to TSS and one intolerant to TSS. The surveys had 7.4 and 16.14% of the individuals in the survey considered tolerant to TSS; the average for coldwater stations in the Root River is 9.94%. The metrics reveal that there is moderate tolerance to TSS, without dominance of TSS tolerant or intolerant macroinvertebrates, but rather somewhere in the middle.

The macroinvertebrate community data suggests that TSS is unlikely stressor at this location; however the macroinvertebrate community is more intolerant in 2011 than it was in 2008. It would be advantageous to continue to monitor Etna Creek to ensure conditions remain favorable for the biotic communities in terms of TSS. The combination of limited chemical information and biological information suggests that TSS is not a stressor to Etna Creek at this time.

Physical habitat

MSHA score at Station 08LM026 was rated as good at both fish visits in 2008 (67.5) and 2011 (67.8). Both visits had notes of light embeddedness, with 25% riffle in 2008 and 10% riffle habitat in 2011. The riffles dominate substrate type was cobble and gravel. Undercut banks, overhanging vegetation and woody debris all present in this sampling location. Macroinvertebrates were sampled by the dominant habitat types, riffles and overhanging vegetation. The land use adjacent to the station is pasture and row crop. Photographs of the station show some light pasturing at the site, and no riparian corridor with trees (). The stream banks are made up mainly homogeneous grasses. The riparian width was noted as zero. The land use and riparian subcategory scores were the lowest scoring in 2008, both below 50% of the maximum points for each subcategory (Figure 102).

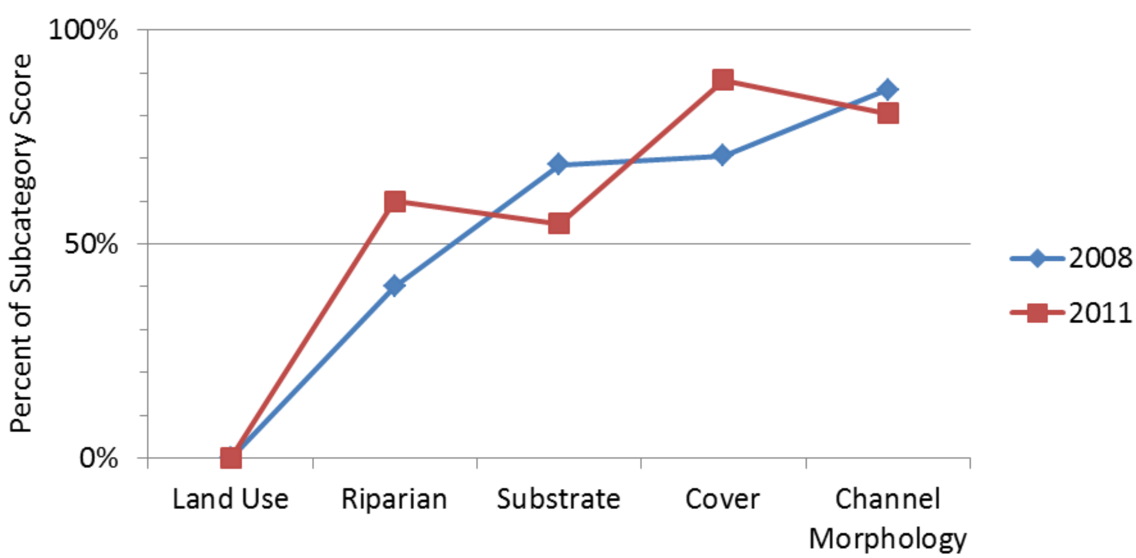


Figure 101. Percent of MSHA subcategory scores at Station 08LM026 in 2008 and 2011

The percentage of EPT individuals in Etna was greater than the average for Southern Coldwater stations. (Dominated by 39% *Baetis*, a tolerant mayfly) Additionally, there were a high percentage of macroinvertebrates than climb, as overhanging vegetation/undercut banks were found to be the dominant habitat type. In addition to overhanging vegetation and undercut banks the other habitats sampled for macroinvertebrates were riffles and aquatic macrophytes.

Figure 102. Photograph of station 08LM026 on June 26, 2008 from upstream portion of station viewing downstream

The percentage macroinvertebrates that are known to cling to large substrate and woody debris were slightly below average for coldwater stations in 2008, but well above in 2011. Burrowers were found in low percentages, suggesting minimal sedimentation in riffle habitat. This reach does have large trout present, in part due to the available habitat such as undercut banks and deep pools. Although some aspects could be improved, it is unlikely that a lack of habitat is currently having a direct effect on the macroinvertebrate community in Etna Creek.

Physical connectivity

No information was available or collected on physical connectivity on Etna Creek. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The stressor identified affecting Etna Creek's macroinvertebrate community is nitrate. The IBI scores for macroinvertebrates are very close to impairment thresholds which hinder the ability to demonstrate clear biological response to stressors.

Etna Creek has demonstrated high nitrate concentrations on the adjacent downstream AUID, which led to a drinking water use listing for nitrate. The limited nitrate data on this AUID is also elevated. While the biological response is not consistent among all metrics, it is likely that nitrate is the stressor affecting the macroinvertebrate community and any further nitrate inputs or additional stressors would lessen the community assemblage further. Further investigation into the magnitude and duration of nitrate in this AUID of Etna Creek, and sources of nitrate would be beneficial.

It is probable that habitat could both be playing some type of role in the macroinvertebrate community present, but the biological response is not clear. Some aspects of habitat that could be improved for macroinvertebrates include an addition of trees to the riparian corridor, which would introduce not only stream cover, but woody debris as habitat within the stream. Currently the site has very little riparian corridor and is made up of only homogenous grasses. The two sampling years (2008 and 2011) showed varying results in not only the macroinvertebrate IBI score but also the macroinvertebrate community makeup. It’s possible that varying stream conditions between the two years can partially explain the difference. In June of 2008, there was a large rain event in this geographic area, which may have caused some additional stress to the macroinvertebrate community that year in particular. The macroinvertebrate sample in 2011 was above impairment threshold, and it will be important to assess its condition again to ensure it continues to meet biological standards.

4.7.4. Watson Creek

Supporting information

There are two biological stations on Watson Creek, one near the central portion of the watershed (04LM057) and one near the mouth (08LM004). Both fish and macroinvertebrates scores at both sites are below impairment threshold. Field sampling in 2008 noted severe bank erosion, excess sedimentation and channel incision.

MDNR reports (Watson Creek Management Plan from 2010) state that the limiting factors for Watson Creek are largely temperature and habitat. A MDNR survey in 1990 noted that low flow in Watson Creek is less than desirable in dry years. Natural reproduction (fish) has been lacking in all areas of the creek except more recently, the upper end (near the source, Stagecoach Spring) has shown some potential for natural reproduction. In 2005, brown trout stocking was discontinued following five years of summer YOY (young of year) assessments. MDNR is currently working on re-introducing brook trout into one of the upper tributaries (referred to as Tributary 2) as well. Past investigations by MDNR have shown the water temperatures to increase significantly from the source to the end of Reach 3, which is only 3.74 miles long. MPCA information also confirms this fact of dramatically increasing water temperatures from the source spring.

The macroinvertebrate metrics in the Southern Coldwater IBI that scored low at both sites were: the ratio of chironomid abundance to total dipteran abundance (ChiroDip; Figure 103), the relative abundance (percent) of collector-filterer individuals in subsample metric (Collector-filtererPct), the metric that is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), the metric of taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch), and relative percentage of taxa belonging to Trichoptera or caddisflies (TrichopteraChTxPct).

The Coldwater Biotic Index score based on coldwater tolerance values derived from Minnesota taxa and temperature data CBI did fairly well, as did the VeryTolerant2Pct metric.

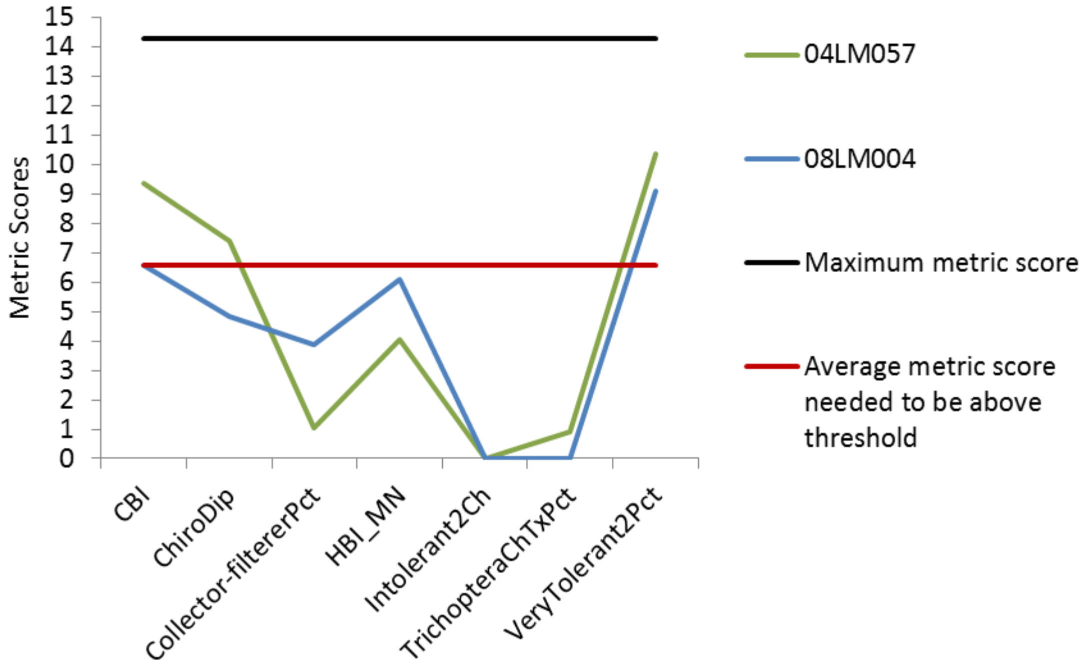


Figure 103. Metric scores for stations in Watson Creek of the Southern Coldwater macroinvertebrate IBI

The fish community in Watson Creek scored low on the Southern Coldwater IBI at both locations. The fish community had a lack of sensitive coldwater individuals, lack of native coldwater taxa and individuals, and an abundance of taxa where detritus constitutes at least 5% of their diet, represented by the SdetTxPct_10DrgArea metric (Figure 104). In addition, Watson Creek is scoring low in the Pioneer metric, demonstrating a community with a large number of pioneering species, which predominate in unstable environments.

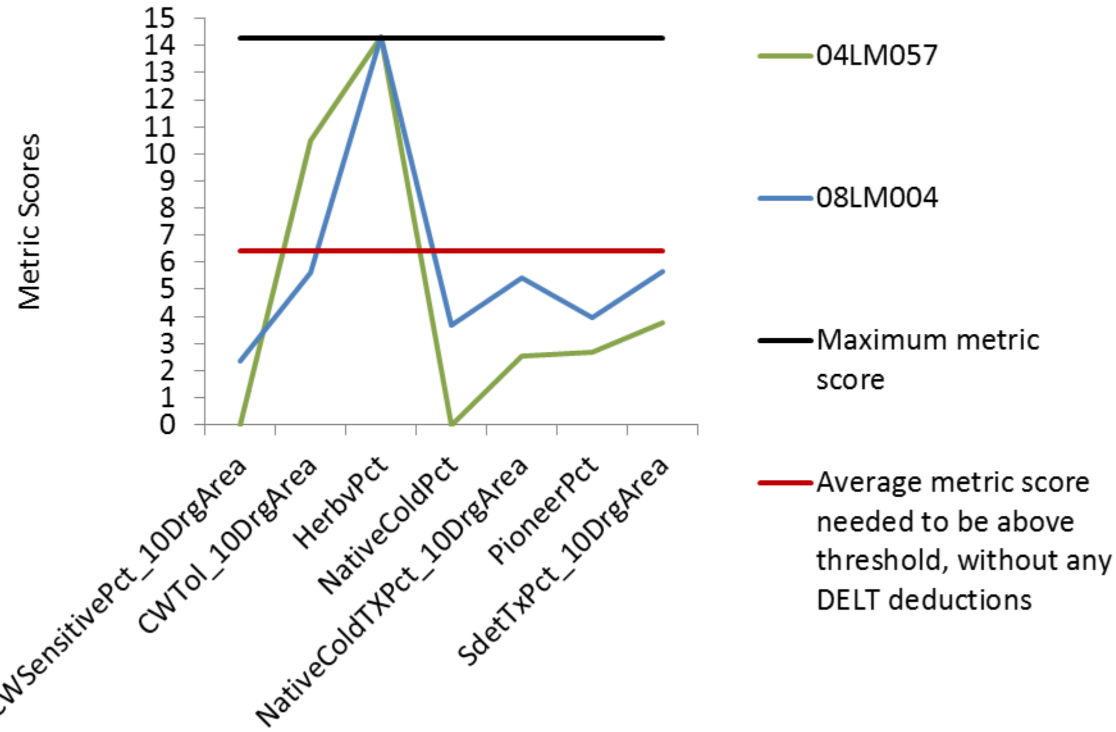


Figure 104. Metric scores for stations in Watson Creek of the Southern Coldwater fish IBI, with five point deduction for DELTs at Station 04LM057

Temperature

Surber (1924) noted that water temperatures of Watson Creek were higher than all other streams in the region. He attributed water temperatures to excessive surface water coming through the spring sources. This observation is confirmed today, as many of Watson's spring sources are in hydrogeology which made up of regionally sourced, shallow groundwater flow (Runkel et al, 2013). Surber also mentioned that is was doubtful if Watson had any value as a Trout stream.

MDNR reports suggest temperature is a limiting factor for Watson Creek throughout. Field observation and data confirm this fact. While temperatures are suitable near the source of Watson Creek, Stagecoach Spring, but only a few miles downstream-temperature warms up dramatically. In June 2010 and August of 2010, some longitudinal temperature monitoring included most of the road crossings in the watershed. From the source (Stagecoach Spring) to the next road crossing (Hwy 117), the temperature increased by almost 2°C. The next road crossing downstream (CR11), the temperature had increased another 2-3°C. This does suggest the potential of a lack of deep cold water sources feeding the stream, along with other factors, including stream sinks.

While temperature increase moving downstream is normal, a change this dramatic doesn't appear to be normal for a coldwater streams in this area. Flow measurements along multiple stations on the creek might suggest this upper reach may be a losing stream. A few mapped springs exist in this section of stream, and a stream sink on the creek is mapped just upstream from CR11. Discharge measurements in three places from 2011 show very little change from the source (TWP13) to approximately four miles downstream at CR11. All three places recorded discharge near five cubic feet per second (cfs). Some spring inputs do exist downstream of Stagecoach Spring (MDNR's Trib 2; Thunderhead Spring). It seems like a possibility that any inputs in this area are being lost to stream sinks. Downstream of CR11 and Hwy 52, discharge picks up and is near 12 cfs by TW-216 (Ivy Rd). This appears to be due to multiple springs or tributaries just downstream of Highway 52. The other potential contributor to flow is the Fountain wastewater treatment plant, which discharges to a tributary just downstream of CR11. It is estimated this treatment discharge could contribute around 0.05 cfs when discharging (but it is not a continuous discharge). Given the percentage of flow from the treatment plant is small; it's not likely having a large impact on the overall temperature regime of the creek.

Continuous temperature data from 2008 at Station 08LM004 (farthest downstream site; May-September) showed a maximum of 21.65°C on July 16, 2008. The July and August average temperatures were 17.44, and 17.21°C, respectively (Table 39). In 2010, continuous temperature data was expanded to include three locations on Watson Creek. A temperature logger was placed again at Station 08LM004, but was lost. Another logger was placed at Highway 52, roughly halfway in the watershed. The yearly maximum temperature there was 23.66°C on August 30, 2010. The July and August average temperatures were 16.53 and 18.72°C, respectively. The final site with continuous temperature data collection was near the spring source (Stagecoach Spring). The logger was placed at the first road crossing, and recorded a July and August average temperature of 9.1 and 9.2°C, respectively. Maximum temperature at that site was 14.9°C on June 21, 2010. Temperature spiked again at this site in late September of 2010. These two temperature spikes can be explained by large runoff events. Without these runoff events, the maximum stream temperature would have been near about 10°C near Stagecoach Spring. Since the logger was not placed directly in Stagecoach Spring, it is not clear if the temperature peaks were observed there as well. There is a potential overland flow source between the spring and the road crossing.

There were 54 temperature field measurements from grab samples on Watson Creek. Those measurements show a maximum temperature of 26.1°C on August 9, 2007. Two of those measurements were also at 23°C.

Table 39. Continuous temperature measurements from multiple sites in Watson Creek.

Temperature Logger Data(degrees C)	Data Maximum	July Average	August Average
TWP 13, near Stagecoach Spring (2010)	14.9	9.1	9.2
04LM057 (2004)	24.05	16.1	15.8
Hwy 52 (2010)	23.66	15.53	18.72
08LM004 (2008)	21.65	17.44	17.21

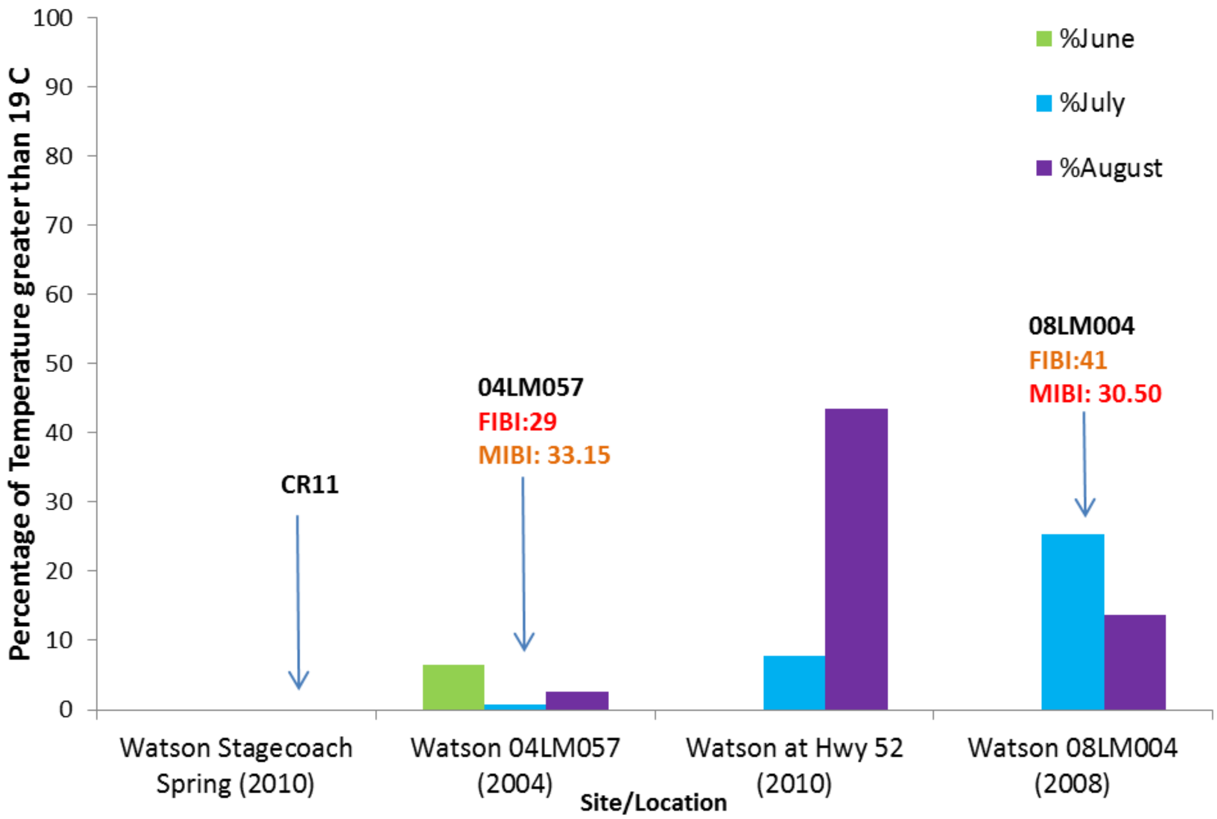


Figure 105. Watson Creek percentage of temperature measurements above 19°C, at 4 locations.

While daily average temperatures may be suitable, the peak temperatures are of concern. Also, it seems highly variable from different between years and different locations. In addition, Figure 105, demonstrates that certain times Watson Creek's temperatures are spending a fair amount of time above 19°C, which is the temperature considered a threat to brown trout (EPA Goldbook). When temperatures spend a sustained amount of time above 19°C, stress can start to impact the fish community. There are a number of times the temperature peaks were close to or at 24°C, which is considered the upper maximum temperature limit for trout. Natural reproduction has been limited in Watson Creek until recently, as noted by MDNR. Adequate temperatures are required for reproduction to occur, and that progress will be important for improvement in the fish community found in Watson Creek.

The percentage of coldwater fish found at Stations 08LM006 and 04LM057 were 1.49% and 10.2%, respectively. These percentages are expected to be much higher for coldwater streams (near 50% is average for coldwater streams in the Root River). There are also a lack of generally sensitive fish species (much lower than average) at both sites also demonstrating that temperature is impacting the fish community. It is not clear if temperature is impacting the macroinvertebrate community. Coldwater macroinvertebrate individuals are found in reduced numbers at both stations (i.e. reduced CBI score).

While temperature is not likely the main limiting factor to the biological communities, improvement in temperature would be beneficial. The complex hydrogeology of this region complicates the understanding of temperature impacts and mitigation. It is possible that with some increased vegetative shading, improvements in stream stability, and better riparian land use, there could be improvement of temperature dynamics in Watson Creek.

Dissolved Oxygen

During fish sample on July 1, 2008 the DO concentration at Station 08LM004 (1:30 pm) was 11.57 mg/L. On June 23, 2004, Station 04LM057 had an oxygen concentration of 9.5 mg/L. Analysis of DO data from monitoring Station S003-388, ranged from 8.7 mg/L to 12.2 mg/L with an average of 10.3 mg/L. While those values do not suggest impairment or unreasonable oxygen values, Figure 106 shows the fish community is fairly tolerant to low DO levels. Fish that are tolerant to low DO can be tolerant to other pollutants as well.

The macroinvertebrate community shows mixed tolerance to low DO. Stations 08LM004 and 04LM057 have DO index station scores which are near average and slightly better than average compared to other sites in the Root River. The DO intolerant taxa at Station 08LM004 is considered worse than average, but the percent tolerant to low DO is much better than the average for Root River Stations. In addition, the percentage of EPT individuals was greater than the statewide average at Station 04LM058 (55%), but just near average for Station 08LM004 (38%). EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux. The macroinvertebrate surveys in Watson Creek each had 16 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Overall, the macroinvertebrate community does not strongly signal DO stress at this time.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH values collected at Stations 08LM004 and 04LM057 were 8.21 and 8.03, respectively. Total phosphorus collected during biological sampling was 0.152 mg/L at Station 04LM057 and 0.08 mg/L at Station 08LM004. It appears that the sample in 2004 may have been taken shortly after a storm event, as multiple parameters appear elevated. At Station S003-388, there were 13 TP values collected between 2008 and 2011. The range of concentrations found was from 0.048-1.28 mg/L. The average concentration was 0.126 mg/L. With the exception of three samples (taken during storm events; or periods of higher turbidity) the TP concentration returned to normal during baseflow conditions. Multiple samples taken during baseflow conditions in 2008 (9 of 11) were below 0.150 mg/L.

In 2008, Watson Creek sampled four times for chlorophyll-a. The results ranged from 0.79ug/L to 2.28ug/L, and not at a level of concern. BOD data is not available for Watson Creek.

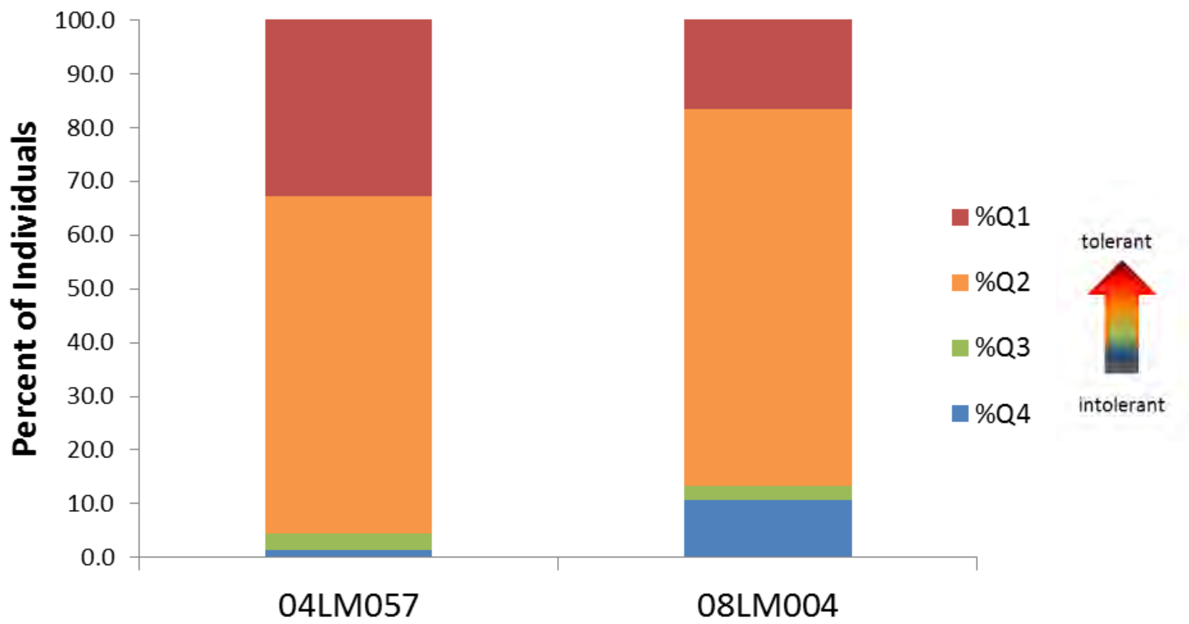


Figure 106. Dissolved oxygen, fish tolerance indicator values for Watson Creek at the two biological stations

Unsuitable temperatures, excess sedimentation, and other issues common to Watson Creek are common in combination with oxygen issues. More detailed information on oxygen should be collected on this stream to determine if oxygen issues are present.

Given the mixed biological response (fish and macroinvertebrates) it cannot be confirmed that DO is not a stressor in Watson Creek. Additional information on DO dynamics would be helpful in ruling this stressor out completely.

Nitrate

Watson Creek is listed impaired for drinking water use from nitrate. The average nitrate concentration from 24 values, 2001-2008, is 9.7 mg/L. During fish sampling, the nitrate concentration at 08LM004 and 04LM057 were 10 and 14 mg/L respectively. The maximum concentration of nitrate measured in Watson Creek was 14 mg/L (n=27).

In 2010, longitudinal surveys of nitrate concentrations show concentrations decrease longitudinally downstream, but are still elevated throughout the creek.

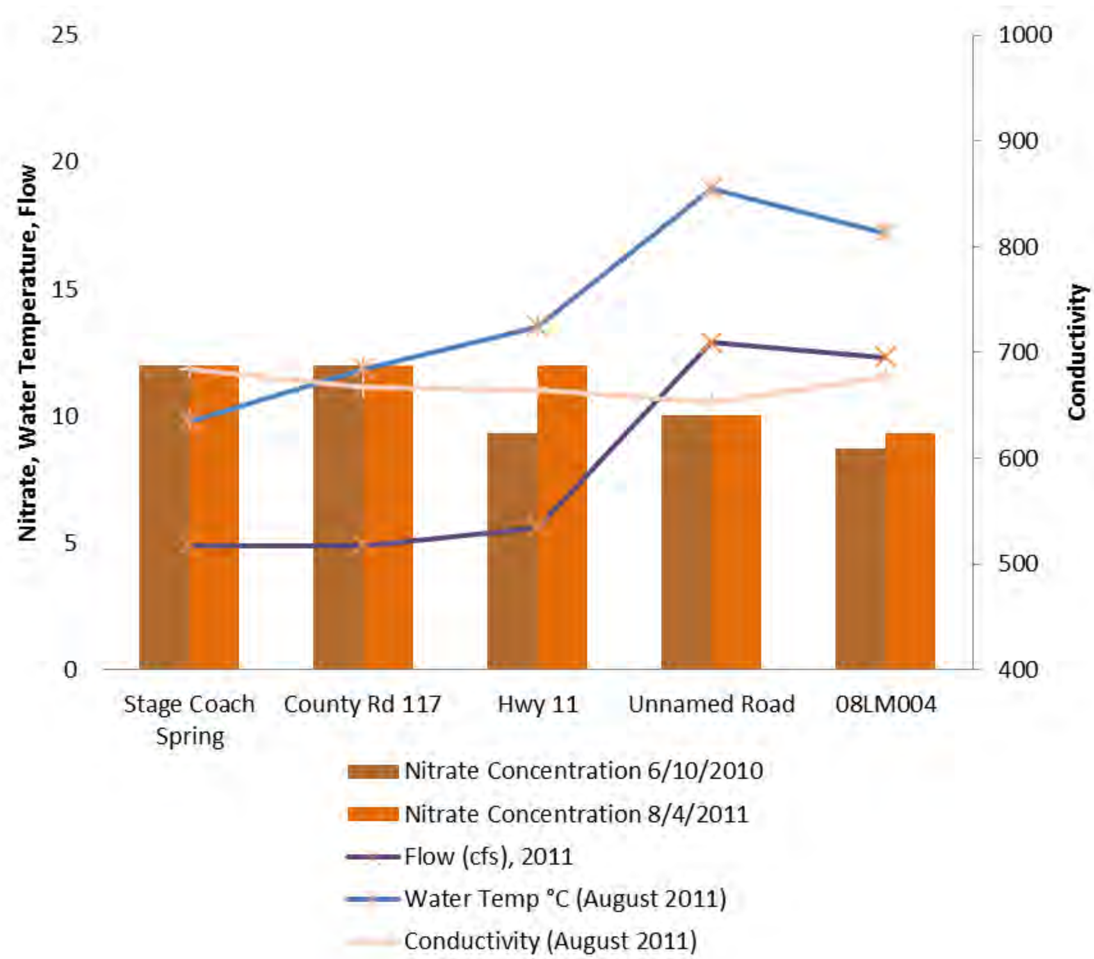


Figure 107. Watson Creek Longitudinal Nitrate Concentration with Conductivity Water Temperature, and Flow

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in Watson Creek each had 16 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Neither of the macroinvertebrate surveys resulted in any intolerant taxa.

Watson Creek had only two Trichoptera taxa in 2004 and only one in 2008, comprising of 7.4 and 3.2% of the total taxa (TrichopteraChTxPct). The resulting very low metric scores; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Watson Creek, the metric score was 4.1 and 6.1 (2004 and 2008, respectively, out of 14.3), below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 04LM057 the HBI_MN value was 7.13 in 2004 and at Station 08LM004 the value was 6.97 in 2008, both greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of ten mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 04LM057 had 18 nitrate tolerant taxa and Station 08LM004 had 18 nitrate tolerant taxa (87.4 and 72.8%individuals); and 16 and 14 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in either of the macroinvertebrate surveys.

The abundance of nitrate tolerant taxa, lack of nitrate intolerant taxa, along with low metric scores for HBI_MN and TrichopteraChTxPct; show that the macroinvertebrate response to the elevated nitrate is present. Nitrate is high in Watson Creek and is playing a role in shaping this degraded macroinvertebrate community.

Suspended sediment

During fish sampling, both biological stations were sampled for TSS. In both cases, TSS was elevated. At Station 04LM058, on June 23, 2004 the TSS concentration was 42 mg/L. At Station 08LM004, on July 1 2008 the TSS concentration was 24 mg/L.

During assessment in 2011, it was noted that the dataset of assessment sampling showed rate of exceedence that is only slightly larger than is what is considered supporting for turbidity. While photographs taken at the biological stations did show incised channels, severely eroded banks and sediment deposition, the evidence wasn't strong enough to move towards listing the creek for turbidity.

A closer look at the sampling data showed an average TSS concentration of 67 mg/L with a maximum of 420 mg/L (after rain event). If you take out the 420 mg/L sample, the average falls to 28 mg/L. These values exceed the draft TSS standard of 10 mg/L for coldwater streams. For turbidity, the average was 139 NTU, and the turbidity standard was exceeded (10 NTU) in seven of the 10 samples.

Transparency tube data, which is biased towards events, shows similar pattern. Of 155 transparency tube measurements from 2004, at multiple locations, show an average of 27 cm.

The fish population does show a number of fish species that are tolerant to high TSS (Figure 108). Over 65% of the population at both biological stations was found in the two most tolerant quartiles for TSS. It also shows that the population composition doesn't vary widely across the Watson Creek watershed, suggesting a system-wide issue. Both biological stations in Watson Creek have TSS index scores for fish that are in the upper quartile indicating a fish community very tolerant to high TSS concentrations when compared to other stations in the Root River. The percent carnivore metric, which is correlated to TSS, shows below average percentages at both biological stations, further demonstrating TSS stress to the fish community.

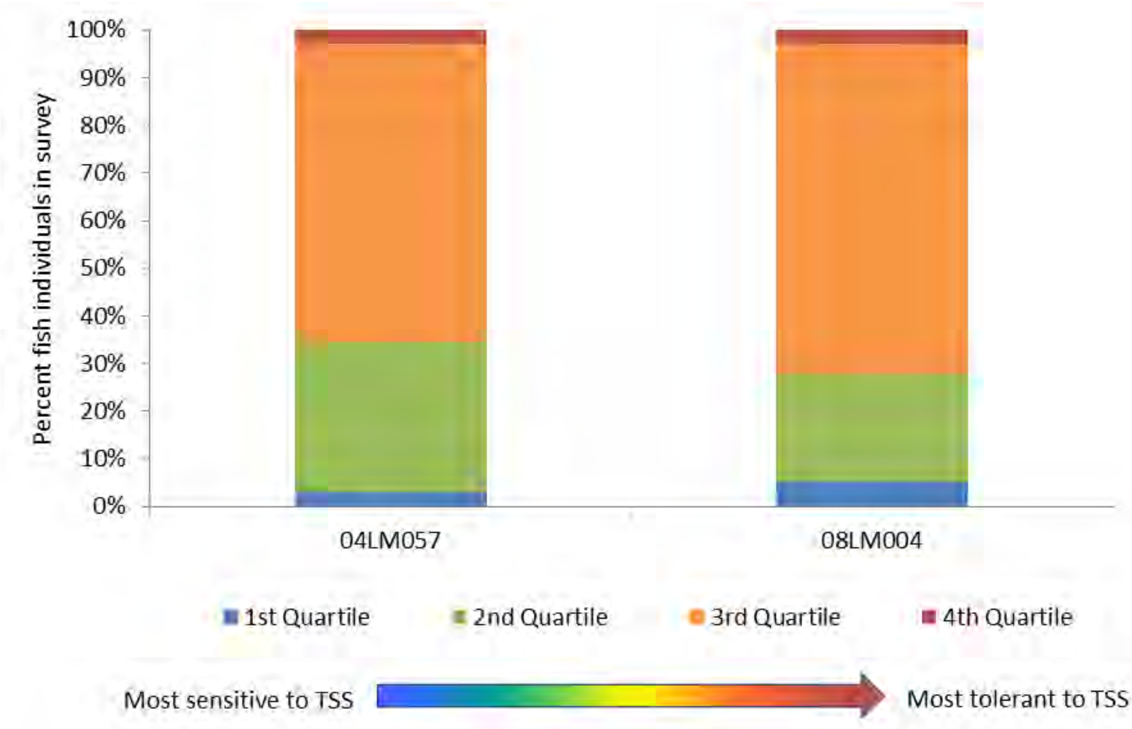


Figure 108. Watson Creek fish TSS TIV's (tolerance indicator values) at Stations 04LM057 and 08LM004

In Watson Creek the biological stations had macroinvertebrate TSS station index scores, which are worse than average compared to the average for coldwater stations in the Root River Watershed (15.13; Table 40). Both stations also had no TSS intolerant taxa and six TSS tolerant macroinvertebrate taxa. The percentage of TSS tolerant macroinvertebrate individuals was greater than the average for coldwater stations in the Root River Watershed. Additionally both stations lacked generally intolerant macroinvertebrates. Station 08LM004 had a low percentage of long-lived macroinvertebrate individuals. The intolerant individuals and long-lived individuals often decrease with increased stress. The macroinvertebrate community in Watson Creek points to TSS as a stressor. A majority of the metrics are worse than the average for similar stations in the watershed.

The biological and chemical evidence confirm that TSS is a stressor to Watson Creek and is shaping the biological (fish and macroinvertebrate) communities present.

Table 40. Macroinvertebrate metrics relevant to TSS for stations in Watson Creek compared to averages for coldwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
04LM057	**18.24**	**0**	**6**	**13.18**	**0**	6.55
08LM004	**16.15**	**0**	**6**	**19.08**	**0**	**0.62**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River watershed	15.13	0.99	4.38	9.94	0.95	1.23

Figure 109. Bank erosion, land use, instability and entrenched channel at Station 04LM057. MPCA photograph, 2004.

Physical habitat

MSHA habitat scores at the two biological stations were ranked at fair and good. The 08LM004 Station received a good ranking, but upon further review, it appears that score was inflated. A rapid geomorphic assessment in 2010, at the downstream Station 08LM004, showed a lack of floodplain connectivity and high degree of incision. A large number of flow deflectors were also noted, along with moderate to heavy bank erosion. All of these factors increase stream bank instability and excess sedimentation within the stream channel which can contribute to habitat loss for both fish and macroinvertebrates. The MDNR fish surveys of Watson Creek have noted a lack of natural reproduction and habitat related issues. MDNR's 2010 Management Plan explain that trout habitat is limited by severe stream bank erosion in all of Watson Creek, which results in little permanent cover for fish. A lack of riffle habitat in some reaches is also a limiting factor.

A detailed habitat assessment showed severe embeddedness (60%) at Station 04LM057. The site was considered 70% run, with no riffle noted during that assessment. Cover was considered good, with woody debris. In fact, the only habitat sampled for macroinvertebrates was woody debris at this site, which further demonstrates a lack of diversity in available invert habitat. The habitat sampled at the downstream Station 08LM004 was undercut banks/overhanging vegetation and woody debris.

The fish community present at both locations had abundant amounts of riffle dwelling fish, non-tolerant benthic insectivores, simple lithophilic spawners, darter, sculpin and round bodied suckers. These habitat related fish metrics were all well above averages for stations statewide and stations in the Southern Coldwater fish class. Lithophilic spawners are also above average for both locations. White sucker dominated the fish communities at both locations, followed by creek chub, and johnny darter. These species are driving up these metric percentages but are also either tolerant or pioneers.

The percentage of pioneers is considered high for both stations (44% and 39%; compared to the statewide coldwater average of 14%). Piscivores are lacking at both stations, at 1.4% and 7.8%, compared to the statewide average for coldwater sites, 37%. In addition, generally tolerant fish species are found in abundance (68% and 73%).

The macroinvertebrate community shows a mix of response to habitat, but overall demonstrates habitat related stress. The percentage of EPT individuals was greater than the statewide average at Station 04LM058 (55%), but just near average for Station 08LM004 (38%). At both sites, there were a large percentage of *Baetis*, a tolerant mayfly (58% at 04LM058, and 34% at 08LM004). The macroinvertebrates that are known to cling to large substrate and woody debris were reduced for both sites (below statewide averages), most likely due to the lack of riffle and good quality substrate. The percentage of swimmers was above statewide averages for both locations. The percentages of macroinvertebrates that climb were above average at Station 08LM004 and below average at Station 04LM058 (where only woody debris was sampled).

Habitat diversity in Watson Creek is clearly lacking for macroinvertebrates, but fish are showing a mixed response. No riffles sampled at either site, also demonstrate a lack of habitat and quality substrate which is important for both fish and macroinvertebrates. Channel stability and excess sedimentation is a clear limiting factor, which strongly links to other stressors found in Watson Creek.

Physical connectivity

There are only seven road crossings in Watson Creek watershed, all which have been evaluated and found no barriers to fish moment. There have however, been MDNR reports (1989) that do mention beaver dams and log jams which have blocked the channel. Log jams, including lodged trees and snags in Watson Creek appear to be common and are typically only temporary and are washed out seasonally by floods. The fish community at both biological stations shows that roughly half of the species are migratory species. The affect of beaver dams on the fish community currently is not well known, and therefore it cannot be concluded that connectivity is a stressor at this time.

Strength of evidence, conclusions, and recommendations

Multiple stressors exist throughout Watson Creek. Elevated nitrate, suspended sediment, temperature, and physical habitat are all influencing the biological communities present. TSS and habitat, and nitrate all appear to be playing primary roles in the degradation of the biological community. There is strong field evidence of severe stream bank erosion, and subsequent habitat degradation. The lack of channel stability and excess sedimentation throughout the creek is a clear limiting factor. Both fish and macroinvertebrate communities are showing consistent biological response to support this.

In MDNR’s 2010 Management Plan, one of the recommendations is to protect the spring source (Stagecoach) spring at any cost. “Further development or agriculture use near the spring source should be discouraged and setbacks need to be enforced.” It is also noted that Tributary Two, (Thunderhead Spring) which is considered to be the most significant tributary to Watson Creek, should also be protected from development and degradation. Both of these are important sources of coldwater to Watson Creek and will be important for improvement in the fish community found in Watson Creek

More information should be collected on DO, as there is simply a lack of chemical information and a mixed biological response. Additional information will help further the understanding of whether DO is a stressor to the biological communities. While a good amount of temperature information has been collected on Watson Creek, additional information spanning multiple years may be important in understanding affects in varying flow conditions each year. The impact of Fountain WWTP is largely unknown, but should be monitored over time. Connectivity is not well understood in Watson Creek, but may warrant further investigation of both natural causes of barriers and anthropogenic.

4.7.5 Willow Creek

Supporting information

There are multiple biological stations along Willow Creek. Fish data from four different stations all score above impairment thresholds. Macroinvertebrate data show mixed results with the downstream stations falling below impairment thresholds (10EM143, 08MN005, and 04LM21). The upstream Station 08LM038 was sampled in 2008 and 2010, with both visits scoring above the threshold. A tributary to Willow Creek with Station 08LM035 was deferred from assessment due to channelization of the AUID. Station 04LM074, on a tributary to Willow Creek, was only sampled in 2004 for fish and not macroinvertebrates. The station was sampled under low flow conditions therefore not assessable. In 2012, a new station was sampled on Crystal Creek, 12LM103, a tributary to Willow Creek.

The macroinvertebrate metrics that scored low were: the ratio of chironomid abundance to total dipteran abundance (ChiroDip), a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minneosta TVs (Intolerant2Ch), and the relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct). The percentage of collector-filterers (Collector-filtererPct) also scored low but only at Stations 10EM143 and 04LM021. Station 08MN005 may not show a similar metric score as the three lower stations were all sampled in different years.

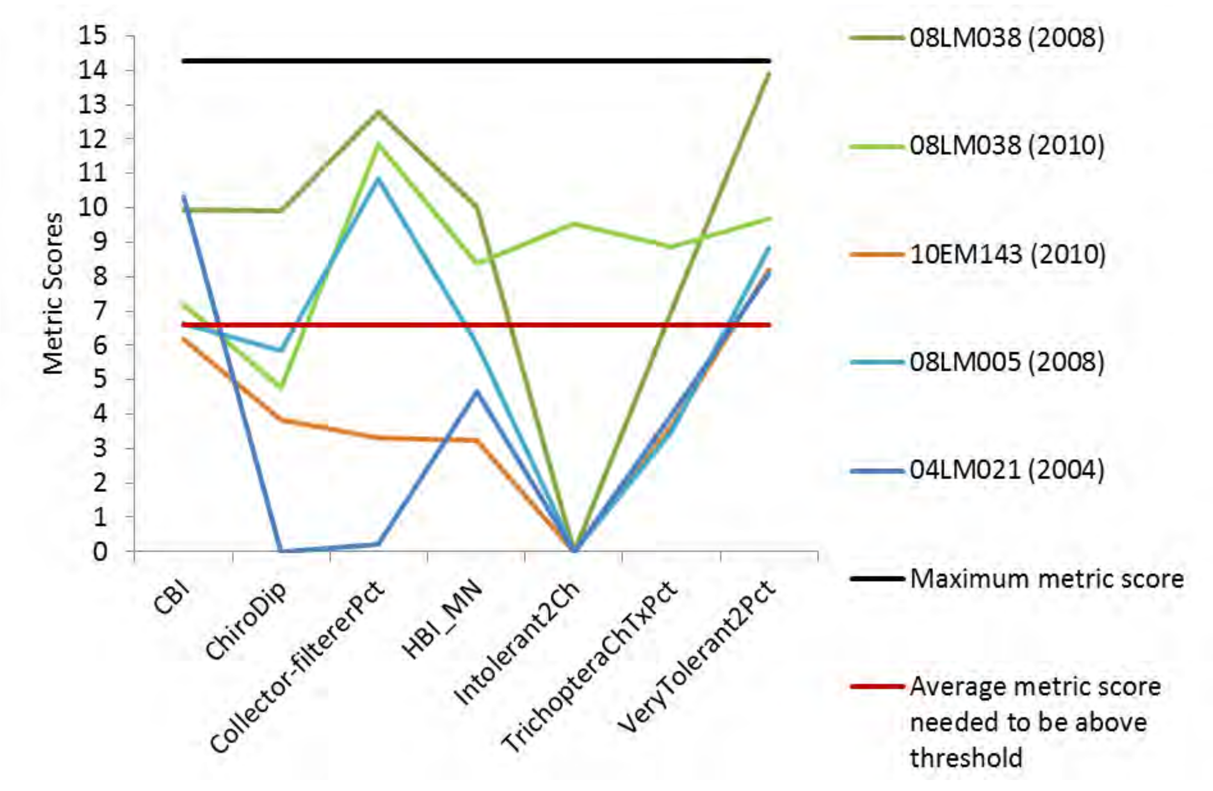


Figure 110. Metric scores for stations in Willow Creek, Southern Coldwater macroinvertebrate IBI

Temperature

As shown in Table 39, temperatures in Willow Creek appear to be fairly comparable to other coldwater streams in the area. Maximum temperatures are getting on the high end, especially for the sites in the lower end of the watershed (Station 08LM005) and on the tributary (Station 08LM035). On the same date as fish sampling, all sites had grab samples, with field temperature measurements (2004, 2008, and 2010). Those values ranged from 11 to 17.9°C.

The relative abundance (%) of individuals that are coldwater species (ColdPct) varied among biological stations in Willow Creek. The average ColdPct for Root River coldwater stations is 27.89%. In 2008, Station 08LM038 had 18-22% coldwater fish, and 33% in 2010. Station 10EM143 showed a ColdPct value at 19%, then 08LM005 at 32%. Station 04LM021, closest to the mouth of Willow Creek had a ColdPct of 71%. Fish IBI's are meeting standards at all of these sites despite the variation, and the fish community among sites are showing average or above average coldwater fish individuals. Given the chemical and supporting biological information, temperature is not a stressor to the macroinvertebrate community in Willow Creek.

Table 41. Continuous temperature measurements from multiple sites in Willow Creek.

Temperature Logger Data(degrees C)	Data Maximum	July Average	August Average
08LM038 (2010)	20.65	14.40	15.81
08LM038 (2008)	20.93	15.56	16.26
08LM035-(Trib-2010)	22.15	16.55	17.18
08LM005 (2008)	23.32	17.44	16.76

Dissolved Oxygen

A YSI sonde was deployed at a couple stations in Willow Creek in 2010. Station 08LM038 (Jumper Road) had a sonde deployed from September 2 to 16, 2011, and captured a range of DO concentration from 8-11 mg/L. The maximum was 11.83 mg/L on September 14, 2010 and the minimum was 8.41 mg/L on September 16, 2010. The highest measured DO flux during this time was on September 15, 2010 (2.99 mg/L).

A YSI sonde was also deployed at Station 08LM035 from September 2 to 16, 2010. At this Willow Creek tributary station, results showed a similar DO flux, maximum of 3.02 mg/L. The maximum was 11.66 mg/L on September 14, 2010 and minimum was 7.95 on September 6, 2010. This station was deferred from assessment due to channelization, but is included for comparison purposes only.

At the time of fish sampling, the DO ranged from 8-12 mg/L at the four biological stations within Willow Creek. Twenty data points, all after 9:00 am, from stations throughout the watershed showed a range of 9.06 - 12.72 mg/L. While the data are not strong; the values do not exceed standards for DO.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. From 2008-2011, 16 phosphorus samples were collected from stations throughout the watershed. The range of total phosphorus was 0.035 mg/L to 1.03 mg/L with an average of 0.246 mg/L (11 of 16 values were less than0.1 mg/L). During this same timeframe, pH values were collected and were 7.21-8.24, within an acceptable range. In 2008, Willow Creek was sampled four times for chlorophyll-a. The results ranged from 0.42 - 1.92 ug/L, and are not at a level of concern. BOD data were not available for analysis.

The fish community shows a mix of tolerant and intolerant species to low DO. All of the sites have an abundance of white suckers, which are tolerant to low DO. However, every station had mottled sculpin present, and in high numbers as well. The highest abundance of mottled sculpin was found at Station 04LM021, with 221 individuals present. The farthest upstream Station 08LM038 had 42 mottled sculpin and 21 brown trout sampled in 2011. These two species make up 31% of the fish community present at this site, and are also the least tolerant to low DO levels.

The macroinvertebrate community DO TIV index scores are near average for all biological stations in Willow Creek. The range of scores are from 7.6 - 7.9 (average for Root Stations is 7.6) at all biological stations. The intolerant to low DO macroinvertebrates are not as common in the three downstream locations, but are found in abundance at Stations 08LM035 and 08LM038 (13 and 14 taxa respectively, which is significantly above average for Root River stations). The percent tolerant to low DO shows a similar signature, with the fewest tolerant individuals in the two upstream locations. The downstream locations are slightly worse than average and near average for percent tolerant individuals. EPT are typically intolerant to low DO levels. The percentage of EPT individuals ranged from 24.6 - 41.6% in Willow Creek. The average percent of EPT in the Root is 37.8; and in coldwater stations 37.6%. Taxa richness can be decreased with increases in DO flux. In Willow Creek, macroinvertebrate taxa richness ranges from 13 - 22 taxa. The average number of taxa in coldwater stations of the Root River Watershed is 18.4. The metric responses indicate that DO is likely not a stressor to the macroinvertebrate community. The metric HBI_MN, measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart, is low at the downstream three stations (Figure 110), potentially indicating an issue with nutrients in general which can be related to DO, but not necessarily.

The macroinvertebrates in Willow Creek show mixed response towards a potential low DO stressor. However, since the fish show presence of sensitive species and there is a lack of low DO data, DO is not considered a stressor to the macroinvertebrate community at this time.

Nitrate

Willow Creek is listed impaired for drinking water use from nitrate. At the time of fish sampling, the four biological stations had nitrate concentrations from 10-12 mg/L (2004, 2008, and 2010). Nineteen chemistry samples taken from three chemistry stations in the watershed, from 2008-2011 showed an average concentration of 9.4 mg/L. Nine of the nineteen values were above 10 mg/L. The range of nitrate concentration was 7-11 mg/L. The maximum measured nitrate concentration was 12 mg/L. A longitudinal survey in 2010 showed concentrations ranging from 4.8 to 11 mg/L throughout the watershed (Figure 111).

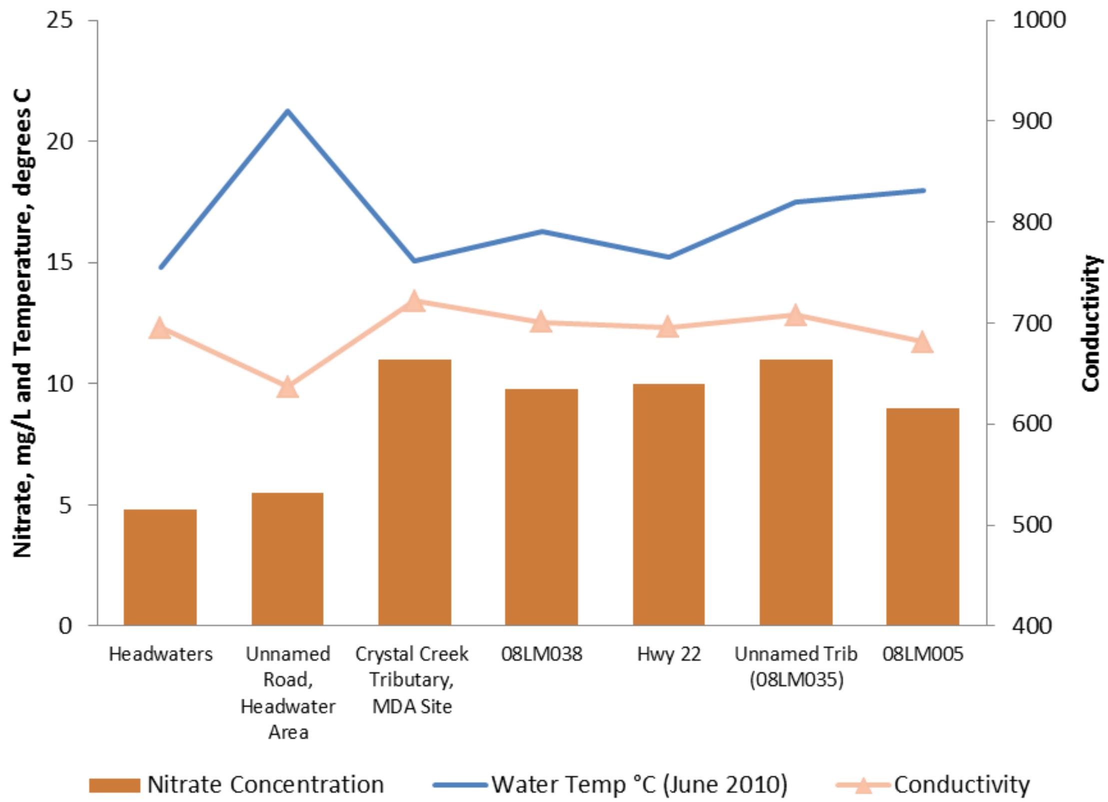


Figure 111. Willow Creek longitudinal nitrate concentration with conductivity and water temperature, June 9, 2010

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in Willow Creek in had taxa counts from 13 - 22 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the Southern Coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Station 08LM038 had a taxa count of 21 in 2010 and Station 08LM005 of 22 taxa in 2008; the remaining visits were 14 taxa or less. There is no longitudinal nor temporal pattern observed. Only one visit resulted in taxa that are intolerant. That visit was at Station 08LM038 in 2010, with two intolerant taxa.

The Trichoptera show a similar pattern to intolerant taxa, with the visit in 2010 at Station 08LM038 with 7 Trichoptera taxa, whereas the other visits resulted in 3 or 4 Trichoptera taxa.

The Trichoptera taxa in Willow Creek comprised of 10.5 to 17% of the total taxa (TrichopteraChTxPct). The resulting very low metric scores for Stations 10EM143, 08LM005, and 04LM021; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Station 08LM038 had higher TrichopteraChTxPct metric scores in both 2008 and 2010. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50%probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Willow Creek, the HBI_MN metric score ranged from 3.2 to ten (out of 14.3). Station 08LM038, both in 2008 and 2010, was the only station to not fall below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. The HBI_MN values in Willow Creek ranged from 6.4 - 7.14; again Station 08LM038 had the lowest HBI_MN values. All HBI_MN values were greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Nitrate tolerant taxa ranged from 18 - 23 in Willow Creek (55.6 - 94.9% individuals); and 12 - 18 nitrate very tolerant taxa. The lowest percentage of nitrate tolerant individuals was at Station 08LM038, additionally in 2010 the station had two nitrate intolerant taxa present. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI.

With the information available, the macroinvertebrates suggest nitrate as one of the stressors present in Willow Creek. There are longitudinal differences in Willow Creek. The macroinvertebrate response indicates that the stress is not as great at Station 08LM038 as it is in the downstream reaches of the creek, which may be responding to cumulative stressors.

Suspended sediment

During biological sampling on Willow Creek, the TSS values never exceeded 10 mg/L for six different sampling dates, at four different biological stations (summarized below).

- 04LM021 on September 4, 2004, had a TSS result of 9.6 mg/L.
- 08LM005 on July 1, 2008, had a TSS result of 5.6 mg/L
- 08LM038 on August 4, 2008 had a TSS result of 8 mg/L
- 08LM038 on June 24, 2008 had a TSS result of 7.2 mg/L
- 08LM038 on July 19, 2010 had a TSS result of 2.8 mg/L
- 10EM143 on July 19, 2010 had a TSS result of 4.4 mg/L

Sampling data was also collected from stations S003-400 and S004-948 in 2008. The maximum TSS sampled was 120 mg/L, which followed a large rain event. Of the 10 samples collected in 2008, only a single value (120 mg/ on June 11, 2008) exceeds the 10 mg/L TSS standard.

Sensitive to TSS fish species increase near the mouth of the watershed, which is where the sampling site is located as shown in Figure 112. While there are a fair number of species which are tolerant to high TSS concentrations in Willow Creek, there is also a notable amount of species which are sensitive to high

TSS concentrations. The TSS TIV aggregate scores for fish in Willow Creek show a score near average for the two upstream sites, but a better than average score for the station farthest downstream (04LM021) as shown in Figure 112.

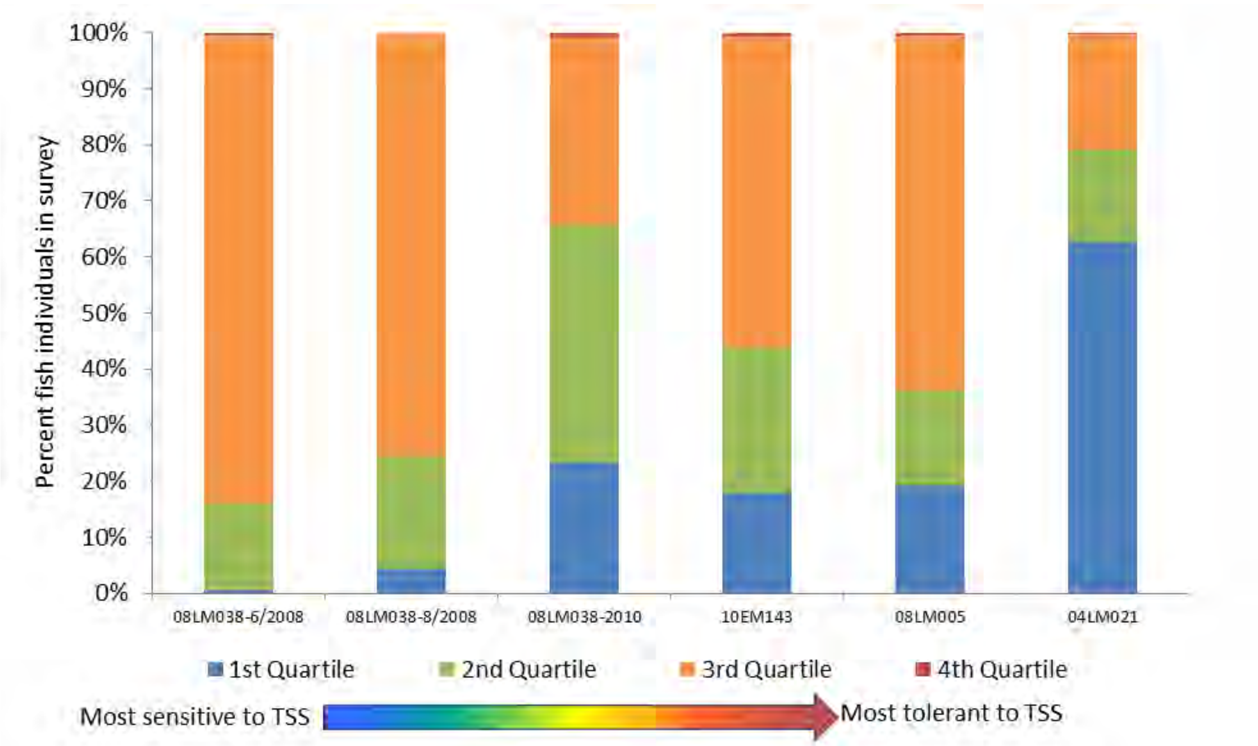


Figure 112. Fish TSS TIV's (tolerance indicator values) for Willow Creek (upstream to downstream)

In Willow Creek, TSS station index scores for the macroinvertebrates worsen as you move longitudinally downstream. Three downstream stations resulted in scores worse than the average and in the second highest tolerance quartile. In 2004 and 2008, the visits resulted in no TSS intolerant taxa, but at Station 08LM038, in 2010, two TSS intolerant taxa were surveyed. Yet only two visits resulted in TSS tolerant taxa greater than the average for coldwater stations in the Root River Watershed. Station 08LM005 had the highest percentage of TSS tolerant macroinvertebrate individuals. All visits resulted in fewer percentages of general intolerant macroinvertebrate individuals and long-lived macroinvertebrate individuals, which often decrease with increased stress. The macroinvertebrate community is comprised of an assemblage of organisms that generally tolerate elevated TSS, particularly Station 08LM005.

Table 42. Macroinvertebrate metrics relevant to TSS for stations in Willow Creek compared to averages for coldwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
08LM038 (2008)	14.37	**0**	4	5.14	**0**	**0**
08LM038 (2010)	14.34	2	**5**	**10.93**	**0.61**	**0.61**
10EM143 (2008)	**15.32**	**0**	4	**13.82**	**0**	**0**
08LM005 (2008)	**15.26**	**0**	**6**	**15.41**	**0**	**0**
04LM021 (2004)	**15.74**	**0**	3	0.78	**0**	**0.7**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River watershed	15.13	0.99	4.38	9.94	0.95	1.23

While the macroinvertebrate community looks more tolerant to TSS when moving longitudinally downstream, the fish community looks more sensitive to TSS when moving downstream. Both fish and macroinvertebrates are showing some potential TSS stress, however the data are not strong. Given lack of consistent evidence among biological indicators, and lack of strong chemical information, TSS is not a stressor to Willow Creek at this time. The potential for TSS issues does exist in this watershed, however, and should be monitored over time when additional data become available.

Physical habitat

Station 08LM038 scored well on the MSHA (83), while the other three stations scored fair. The largest limiting factor in terms of habitat scores is the lack of riparian area and land use within the riparian area, at these lower fair scoring stations. In most locations severe bank erosion was recorded, along with light embeddedness. There are differences exhibited in each of the sites that are captured in the quantitative habitat statistics for Willow Creek (Table 2). While substrate is decent at most sites, embeddedness due to erosion and local land use, and sparse cover in some locations is limiting the macroinvertebrate population.

At Station 04LM021 the MSHA characterized the site as having a very narrow/no riparian zone with severe bank erosion. There was light embeddedness with boulder and cobble in the riffle (the reach was 60% riffle). Cobble and gravel were noted in the runs and pools, and cover was sparse.

Similarly at Sation 08LM005, there was a very narrow riparian zone with moderate/heavy bank erosion. In addition, there was light embeddedness, with cobble and gravel in riffle and sand and silt in the pools and runs. Bedrock also noted in the runs. A stream channel assessment in 2010 at Station 08LM005 scored 49, in the moderately unstable category.

At Station 10EM143, there was moderate and narrow riparian, and some bank erosion. Light embeddedness with cobble and gravel in the riffle and some sand noted in the pools. Particle size analysis from the stream reach surveyed was 10% silt/clay, 30% sand, 26% gravel, and 32% cobble.

Some differences were found at Station 08LM038 with a wide to moderate riparian, little to no bank erosion, and heavy shade. Dominant substrate in the riffle was cobble and gravel with light embeddedness. Extensive cover was also noted. Walking surveys showed some embeddedness in the upper parts of the watershed. Gradient differences among sites may suggest some areas are accumulating sediment and others have the ability to remove it more easily.

There was an abundance of burrowers found at Stations 04LM021 and 10EM143 which support the suggestion of fine substrate embeddedness and potential sedimentation issues. At three of the four biological stations, EPT taxa was reduced (exception was Station 08LM005) and below statewide averages. In addition, all but Station 04LM021 showed a lower than average percentage of macroinvertebrates that climb. The macroinvertebrates that are known to cling to large substrate and woody debris were found in abundance at three of the four sites (above statewide averages). However, they were dramatically reduced at Station 04LM021 (only 8%). These macroinvertebrate related habitat metrics reveal less than desired habitat conditions present in Willow Creek.

Table 43. Habitat statistics in Willow Creek.

Habitat Statistics (Quantitative Habitat Assessment)	**Percent Riffle**	**Percent Embedded**	**Percent Fines**	**Max Depth of Fines**	**Macroinvertebrate Habitat's Sampled**
10EM143	20%	46%	13%	2.63	RiffleRunRock Aq Macro UCBank/OH Veg
08LM038	30%	48%	3%	0.60	RiffleRunRock UCBank/OH Veg Snag_Woody Debris
04LM021 (June 2004)	37%	23%	0%	1.75	RiffleRunRock UCBank_OH Veg
04LM021 (September 2004)	19%	49%	13%	0.83	RiffleRunRock UCBank_OH Veg

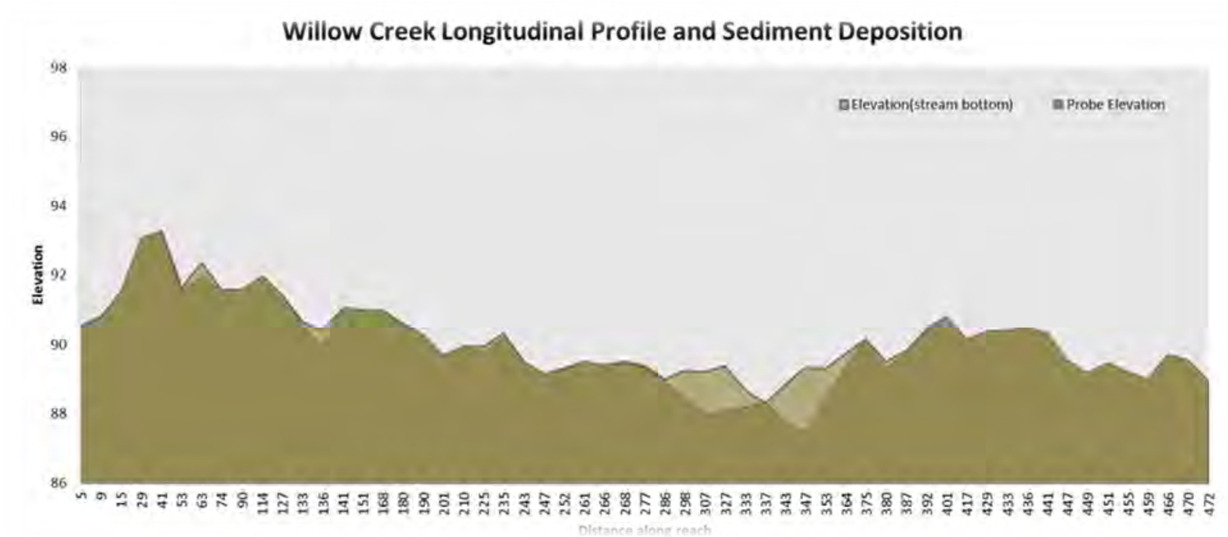


Figure 113. Sediment deposition (shown in light brown) in pools on longitudinal profile, Willow Creek-10EM143.

In the field, the visual observation was that riffles were located where the pools should be. This instability seems to be exacerbated by riparian land use (pasturing) and recent high flow events. There were also many areas of severe bank erosion, as shown in Figure 114.

Figure 114. Bank erosion at 08LM005.

Physical connectivity

Willow Creek does not currently have fish impairment, but in some locations, fish are near the impairment threshold and should be monitored. While investigating the macroinvertebrate impairment, there are at least two locations in the watershed with perched culverts which could be disrupting fish migration and passage. These perched culverts may be affecting stream channel stability, sediment movement and deposition which could ultimately affect fish habitat in addition to the already impacted macroinvertebrate community. The Station 08LM038 on Jumper Road has a perched culvert (approximately 1-2 ft. drop) and this also is the site which is near impairment threshold for fish in the watershed. The biological stations do have between 50-90% migratory fish species present at this time. However, this should continue to be monitored over time to ensure free passage of fish throughout the creek.

Strength of evidence, conclusions, and recommendations

Multiple stressors exist throughout this watershed. Elevated nitrate and habitat loss due to bedded sediment appear to be co-existing factors contributing to the decline of the macroinvertebrate community. Temperature and DO data appear adequate at this time. Suspended sediment , while not considered a stressor at this time should be monitored to ensure levels remain adequate. Connectivity should also be monitored, as it could eventually impact the fish population since a few perched culverts are located within the watershed.

Nitrate is elevated with concentrations as high as 12 mg/L. While the macroinvertebrate communities are responding to nitrate stress, the macroinvertebrate response indicates that stress is not as great at Station 08LM038 as it is in the downstream reaches of the creek.

Macroinvertebrates that respond to habitat stress show consistent response among multiple metrics and throughout Willow Creek. Stream bank instability appears to make up a large portion of the sediment in Willow Creek. Increased riparian buffers, and managed grazing in the riparian area could help alleviate these sediment and habitat issues.

4.7.6. Camp Creek

Supporting information

According to a MDNR report in 1989, Camp Creek is considered to be one of the best fishing streams in the area by experienced bait fishermen. There are two MPCA biological stations on Camp Creek, Station 08LM046 (towards the mouth), and Station 08LM075 (closer to the headwaters). The downstream station, 08LM046 was sampled twice in 2008. The macroinvertebrate IBI scores were very good (66, 61), compared to Station 08LM075 (30). Similarly, fish at Station 08LM046 were doing fairly well (above, but near IBI thresholds) while the fish IBI at Station 08LM075 scored very poorly. Evidence of significant bank erosion and channel instability were noted by the field sampling crew, in spite of what were considered high habitat scores. Notes of excess sedimentation in the stream channel were also noted, and also confirmed with MDNR surveys and reports. Large differences in temperature, habitat, and flow (between the two sites) were noted in MDNR surveys as well. These differences are the driving factors for the discrepancy in aquatic life IBI scores between the two stations.

Special concerns on Camp Creek were listed in a MDNR report from 1989. The first concern was that quarrying operations have damaged (especially warmed) the headwater spring to Camp Creek. During quarrying operations, the aquifer was penetrated which fed Kraling spring. Secondly, liquid manure facilities at the headwaters have caused at least one large fish kill in 1986, and cattle manure stored in a barnyard washed into the stream and presumably caused a trout kill in 1988.

In years past, the majority of the trout probably originated from various stockings because spawning conditions have been very poor (MDNR Stream Survey, 1989) More recent MDNR surveys from 2005-2010 (Summer Brown Trout assessment program), shows Camp Creek very favorable to switching to a wild brown trout stream. In the report, MDNR planned to discontinue stocking in 2011 and allow annual sampling of the long term monitoring station (at mile 2.70) which will allow staff to monitor changes in brown trout recruitment as a result of this change in management. This does suggest that there have been some type of improvement from the 1980s to present day, due to the ability of trout to naturally reproduce in this section of Camp Creek. The upper section of the creek however, is still lacking trout according to the more recent MDNR surveys. Station 10.41, about 2 miles upstream of Station 08LM075, included only a one-pass estimate in the MDNR survey, because there were so few fish.

The fish IBI metrics in Camp Creek also vary widely among sites as shown in Figure 115. Station 08LM075 is characterized as having reduced scores in all metrics across the board. Both stations were similar in their reduced score related to native coldwater species (NativeColdPct and NativeColdTxPct_10DrgArea). Station 08LM046 is showing better metric scores related to the percentage of coldwater sensitive species (CWSensitivePct_10DrgArea), the percentage of herbivores (HerbPct) and percentage of pioneer species.

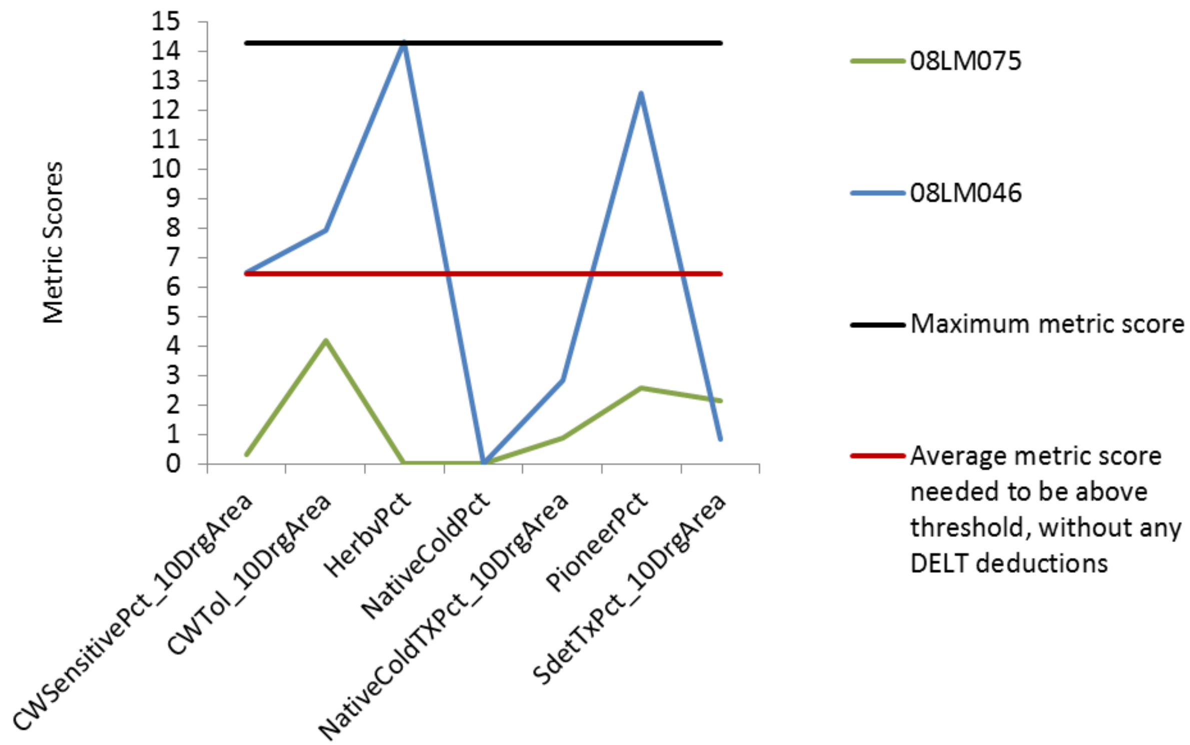


Figure 115. Metric scores for stations in Camp Creek of the Southern Coldwater fish IBI, with no deductions for DELTs

The macroinvertebrate metrics in the Southern Coldwater macroinvertebrate IBI are displayed in Figure 116. The majority of metrics get better scores at Station 08LM046, except the relative abundance (%) of collector-gatherer individuals (Collector-filtererPct). Station 08LM075 is showing reduced scores in the metrics of: the Coldwater Biotic Index score based on coldwater tolerance values derived from Minnesota taxa and temperature data CBI, the ratio of chironomid abundance to total dipteran abundance (ChiroDip), the taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TIVs (Intolerant2Ch), and percentage of taxa belonging to Trichoptera or caddisflies (TrichopteraChTxPct).

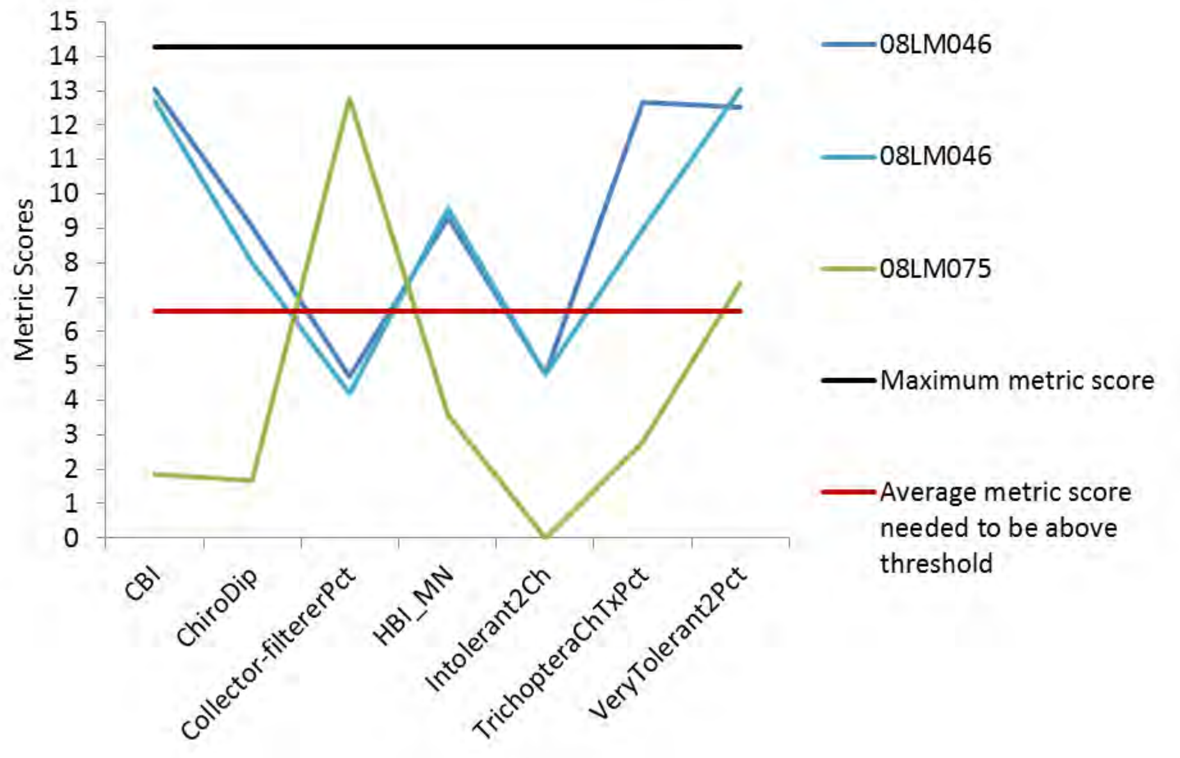


Figure 116. Metric scores for stations in Camp Creek of the Southern Coldwater macroinvertebrate IBI.

Temperature

Camp Creek has a good amount of temperature data downstream, near Station 08LM046, but lacks good temperature data farther upstream, at Station 08LM075. Continuous temperature data from 2008 at Station 08LM046 show a maximum temperature of 17.89°C on June 7, 2008. July and August data were not available for analysis. However, MDNR's temperature logger data (near Station 08LM046) from 2009 show a yearly maximum temperature of 16.4°C on 6/23/2009. The July average was 11.6°C and August average temperature was 11.8°C. This is quite cold compared to many other trout streams in the area, especially when this is in such close proximity to the mouth of the watershed. This suggests some additional spring inputs in the lower reaches of Camp Creek, which allow for cooler stream temperatures. MDNR reports and maps springs confirm this fact.

The percentage of coldwater fish species varies between the two sites with only 2.4% coldwater fish species found at upstream Station 08LM075, compared to 42.7% coldwater fish species found at Station 08LM046. This is near what is considered average for coldwater fish stations in the Root River Basin (50%). In addition, the CBI (metric) matches this trend, showing a much worse score at Station 08LM075 than Station 08LM046 (Figure 116). Both of these demonstrate evidence of much fewer coldwater fish and macroinvertebrate individuals overall upstream at Station 08LM075. Station 08LM046 does not appear to be showing the same response.

Measurements taken from field samples on the lower end of Camp Creek (near the mouth) had a maximum of 17.5°C (total of 13 data points). Further upstream, at Station 08LM075, detailed temperature information is lacking. This information should be collected, and is critical to the understanding of temperature impacts from upstream areas.

At Station 08LM046, which is in MDNR sector "1" (Stream Mile 0-3.50), stream temperature is listed as "good". In contrast in sector 3, where Station 08LM075 is located, the stream temperatures are listed as "unsuitable". According to a MDNR report from 1989, "Sector 1 (mile 0-3.5) has a stream flow of 11 cfs at low stage. Seventeen springs keep this stream at ideal temperatures. Two of these springs rank amongst the largest springs in the Root River basin".

In addition, cattle kept the water turbid all of the time during the survey of Sector 3. Pollution from livestock was noted in 1989 and water temperatures have become much warmer because of mining through the aquifer at the quarry site above the stream source. The water temperature was noted as 76-81°F in this sector (24-27 °C). In sector "2", (mile 3.5 to 4.25) temperatures were considered "fair".

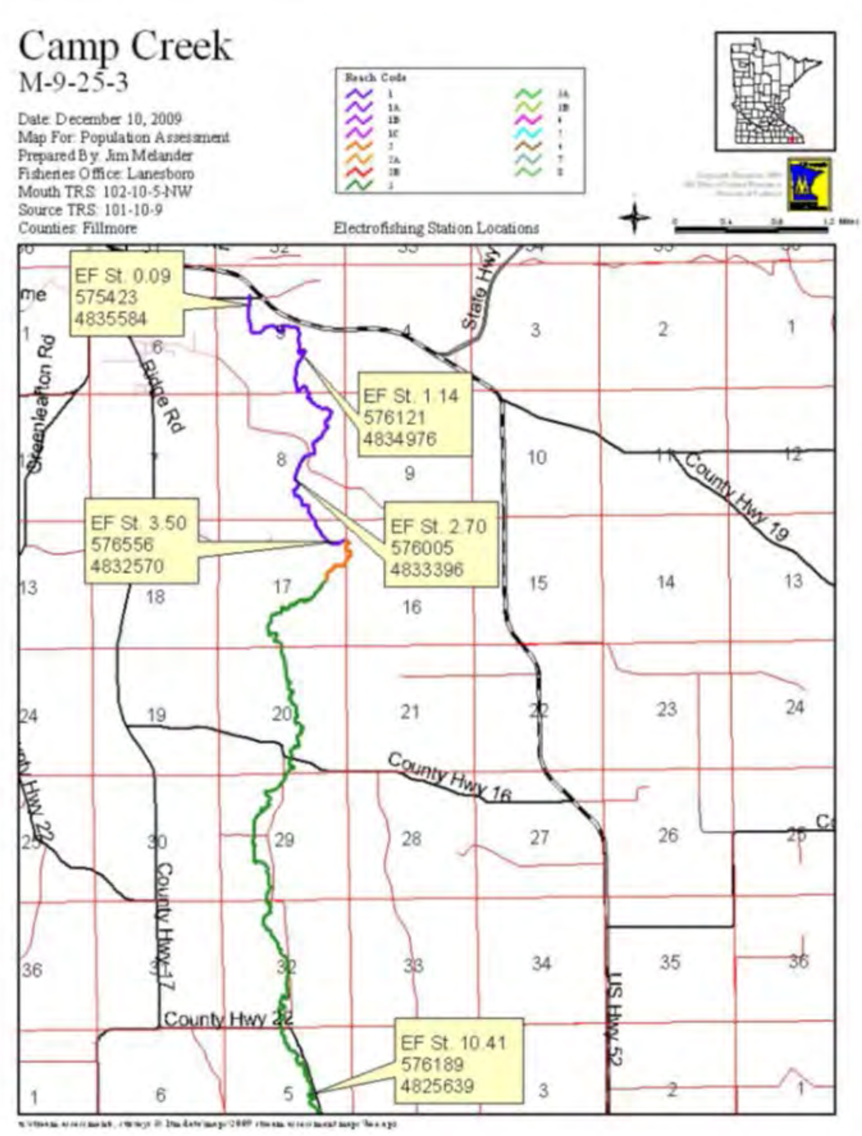


Figure 117. MDNR sectors of Camp Creek

"A new warm tributary (T-2) was created in the headwaters when quarrying operations penetrated the aquifer that fed Kraling Spring. Tributary 2 emerged from a crevice (48°F) in the quarry, and then flowed through a large holding pond where it warmed to 80°F, then through an artificial channel and into an old dry run where it eventually entered Camp Creek at 86°F. This construction damage to the headwater spring makes almost all of Sector 3 poor for trout."

According to a MDNR report on Quarries and Impacts, "the quarry has had a profound impact o the local ground-water flow system. Based on the 1995 springshed map in the geologic atlas and the additional tracing work done as part of this project, approximately 90% of the flow in the Big Spring basin is now being routed through the quarry. This exposes the conduit water to thermal impacts and makes it more vulnerable to pollution from quarrying activities. A round of temperature measurements was taken July 15, 2003, to begin quantifying the thermal impacts on the ground-water system. Water emanating from A238 (the main discharge point on the east side of the quarry) was about 49°F (9.3°C). As it flowed through the quarry and into the quarry pond, it warmed to a measured maximum of about 70°F (21.3°C). The water flowing out of the quarry via the surface stream was about 64.5°F (18.6°C) (several other springs in the quarry also discharge to this stream). The temperature of Big Spring, the headwater spring of Camp Creek, was about 56°F (13.6°C). In contrast, Little Big Spring, which has not had its basin pirated by the quarry, was 48.2°F (9°C). The warming of the water at the stream's headwater spring could have significant impacts on the stream's ecosystem. The water surfacing in the quarry is significantly affected by the surface air temperature, changing the thermal regime of the Big Spring and the upper reaches of Camp Creek." The temperature monitoring points are shown in Figure 118.

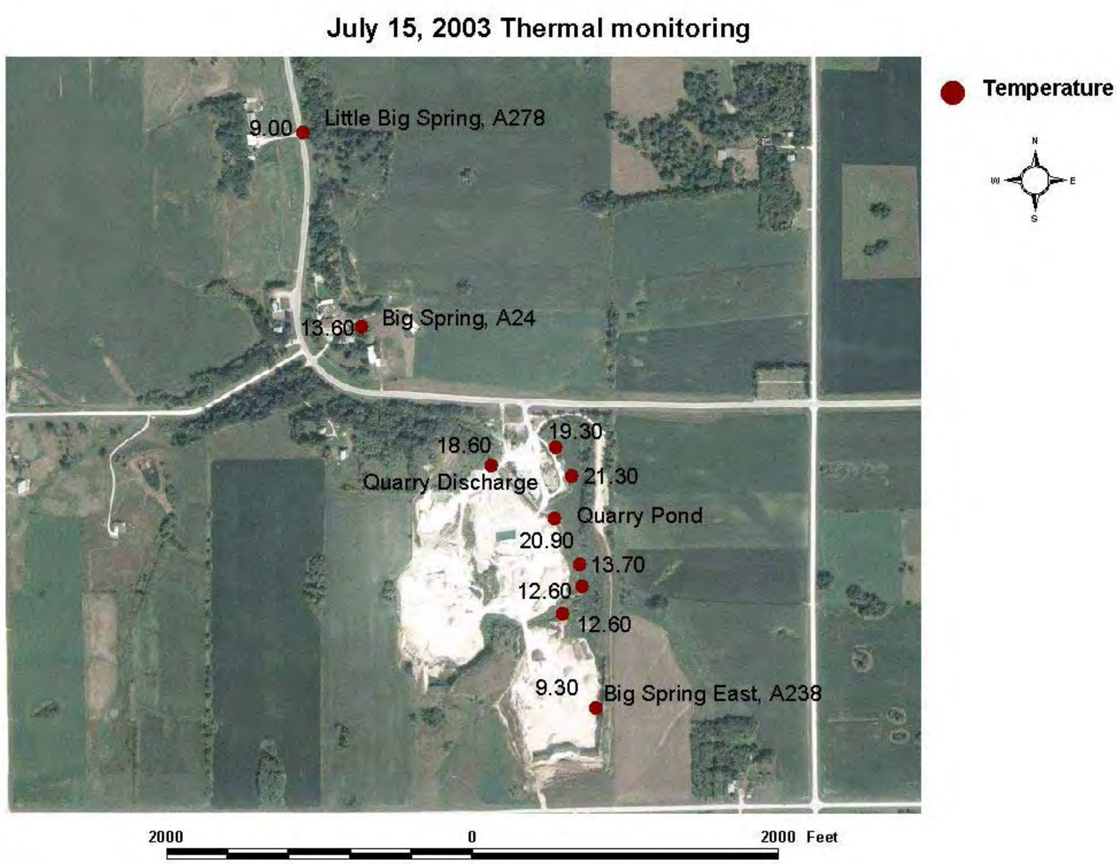


Figure 118. Temperature (degrees Celsius) monitoring results. MDNR study (2003).

Trout Unlimited also put together a nice summary of the issues, detailed in their newspaper from March 2013:

> *"A MDNR study of the Big Spring quarry near Harmony, MN in Fillmore county provides a good illustration of how quarries can disrupt groundwater conduit flow paths and cause great environmental harm. Although the Big Spring Quarry (35 acres actively mined) is located above the water table, quarrying operations penetrated the springshed system, causing groundwater that formerly discharged at the Big Spring on Camp Creek to discharge in the quarry. This water either sinks back into the limestone to re-emerge (warmer) at the Big Spring or flows overland to Camp Creek. Dye-Tracing at the site demonstrated that approximately 90% of the groundwater basin is now being routed through the quarry. Without any dewatering occurring, this quarry has permanently altered groundwater flow paths. This water is exposed to thermal impacts and is more vulnerable to pollution from quarrying activities. Temp measurements indicated that the Big Spring was 8 degrees F warmer in July than the water that first discharges in the quarry, and the stream flowing out of the quarry to Camp Creek was 17 degrees warmer! Temperature changes of this magnitude obviously can have significant negative effects on trout populations in nearby streams."*

One fish pond was built in a spring run at Mile 7.96 (close to biological Station 08LM075). It had no outlet flow during the survey and the landowner said his stocked trout had disappeared during the 1988 drought. Other impoundments are also found in this area, but the impact of these to the water temperature of the creek is uncertain and has not been quantified.

Further upstream, at Station 08LM075, detailed temperature information is lacking. Temperature does appear more suitable towards the mouth of Camp Creek. The available temperature information and MDNR study shows temperature has been altered in the headwaters of the creek. Our biological monitoring information confirms this, with fewer coldwater fish and macroinvertebrate species present in the upper reaches compared to the lower reaches of the creek. Continued monitoring and a better understanding of the temperature dynamics in the upstream part of the watershed would be beneficial.

Dissolved Oxygen

During biological sampling on Camp Creek, Station 08LM075 had a DO concentration of 11.96 mg/L on June 24, 2008 (11:30 am). Station 08LM046 had a DO concentration of 11.32 mg/L on July 9, 2008 at (6:00 pm). In addition, there were nine DO readings from 2004, 2008 and 2009 all towards the mouth of the watershed, nearby Station 08LM046. The lowest concentration found was 9.53 mg/L, and the samples had an average of 12 mg/L. These values are in the normal range for oxygen, and are not at a level of concern.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. During biological sampling, Stations 08LM075 and 08LM046 had pH values of 8.31 and 7.81. Total phosphorus concentration was 0.06 mg/L for Station 08LM075 and 0.058 mg/L for Station 08LM046. No other pH or phosphorus data was available. Neither chlorophyll –a, nor BOD data were available for analysis on Camp Creek.

In general the fish species found at Station 08LM075 are much more tolerant to low DO when compared to Station 08LM046 (Figure 119). Station 08LM046 is showing a large percentage of individuals (approximately 40%) that are in the most sensitive quartile to low DO. Given other differences between the two sites, this inconsistency is not surprising.

The macroinvertebrates show the same trend between upstream and downstream sites. The DO TIV index scores for macroinvertebrates are worse than average for Station 08LM075, indicating some tolerance to low DO. In contrast, Station 08LM046 has an index score in the most sensitive quartile, indicating a sensitive to DO community overall. The percent DO tolerant metric varies greatly between the two sites as well; with 0.32% at Station 08LM046 and 15.9% at Station 08LM075. The average percent tolerant for Root River biological sites is 2.7%. At both locations, the number of intolerant taxa is near average (slightly better for Station 08LM046). In addition, the percentage of EPT individuals was better than the statewide average at Station 08LM046, but worse than average for Station 08LM075. EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux. In Camp Creek, the macroinvertebrate surveys in 2008 had a range of taxa counts from 14 to 18 taxa (highest at Station 08LM075; with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19.

While the biological information does show some indication of the potential for a DO stressor in the upper part of Camp Creek (near Station 08LM075), but there is not enough chemical information to be sure DO is a stressor at this time. More information needs to be collected, to better characterize the oxygen concentrations in Camp Creek throughout. It is uncertain whether the response is due to DO or other stressors. It may be especially important to monitor the upstream reaches where the potential for oxygen issues is higher and the biological communities are indicating potential stress.

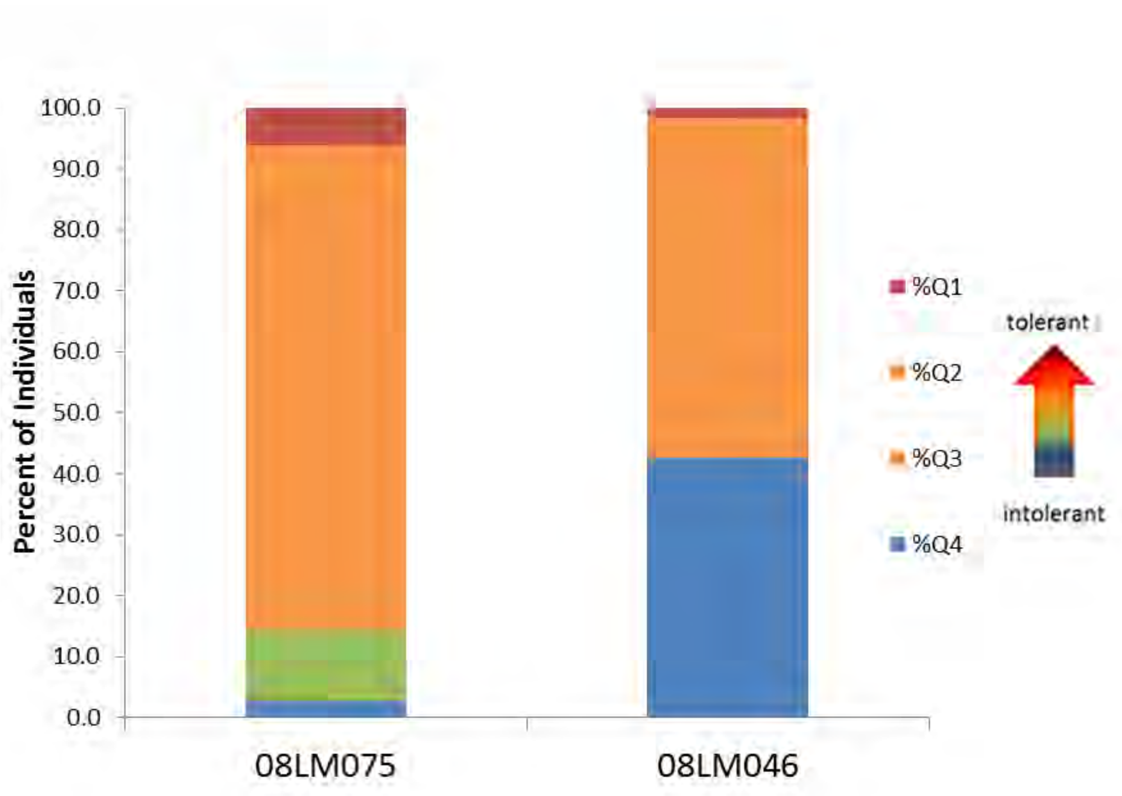


Figure 119. Dissolved Oxygen, fish tolerance indicator values for Camp Creek

Nitrate

Only three nitrate values are available on Camp Creek. Two of them were during fish sampling on June 24 and July 9, 2008. The values were 7.6 and 6.3 mg/L, respectively. On August 3, 2010, downstream of the two biological stations, Station S006-359 had one nitrate sample of 5.9 mg/L. According to a MDNR survey from 1989, in 1971 the stream was investigated for water pollution, nitrate concentrations ranged from 3.6 in the headwaters to 2.15 farther downstream. This suggests a fairly significant increase in nitrate concentrations have taken place in Camp Creek since then. However, the method of analysis is not known and may be different in comparison to today's methods. From MDNR survey, 1989 - "Water quality in the headwaters of Camp Creek was almost the worst recorded in Root River basin streams. The extremely high nitrogen and phosphorus content established the significant pollution taking place in the aquifer and the stream."

Additionally, the Eastern tributary, Partridge Creek, had elevated nitrate (8.9 mg/L) at the time of fish sampling on July 22, 2008. Partridge Creek is not currently impaired for biology, although the macroinvertebrate community scored an MIBI near the threshold.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in Camp Creek in 2008 had a range of taxa counts from 14 to 18 taxa (highest at Station 08LM075; with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Station 08LM046 had one intolerant taxa, but Station 08LM075 had none.

Camp Creek had a range of Trichoptera taxa from 3 to 5, comprising of 9% of the total taxa (TrichopteraChTxPct) at Station 08LM075 and 17 to 22% of the total taxa (TrichopteraChTxPct) at Station 08LM046. Station 08LM075 had a lower metric score than Station 08LM046 and was less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Camp Creek, the metric score ranged from 3.6 at Station 08LM075 to 9.6 at Station 08LM046 (out of 14.3), below and above, respectively, the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM075 the HBI_MN value was 7.09 and at Station 08LM046 the value was 6.55 and 6.52 in 2008, both greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling (p≤0.001). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

The three visits at Stations 08LM046 and 08LM075 resulted in 15 to 20 nitrate tolerant taxa (54.3 to 84.2% individuals); and 13 to 16 nitrate very tolerant taxa. Station 08LM046 had a greater percentage of nitrate tolerant individuals than Station 08LM075. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in any of the macroinvertebrate surveys in Camp Creek. Partridge Creek also had 63% nitrate tolerant individuals along with no nitrate intolerant taxa.

The abundance of nitrate tolerant taxa, lack of nitrate intolerant taxa, along with low metric scores at Station 08LM075 for HBI_MN and TrichopteraChTxPct, show that the macroinvertebrate response to the elevated nitrate is present. Nitrate is high in Camp Creek and is playing a role in shaping this degraded macroinvertebrate community.

Suspended sediment

During fish sampling, TSS concentrations were 6.4 mg/L at Station 08LM075 and 7.2 mg/L at Station 08LM046. There were eight values of turbidity and t-tube measurements towards the mouth of Camp Creek. All transparency tube measurements were greater than 60 cm and turbidity less than 10. This limited dataset does suggest support of the turbidity standard.

However, looking at fish community composition, Station 08LM075 has 42% of the most tolerant quartile to TSS compared to Station 08LM046 which has only 5% in the most tolerant quartile to TSS (Figure 120). This demonstrates a large difference between these two biological stations, in terms of fish community composition. Certainly, impacts from the headwater area in Camp Creek are having an impact at both stations, but to a lesser degree at Station 08LM046. The presences of two species of dace, which are intolerant to TSS, make up a small portion of the community (approximately10%) at Station 08LM075. However, this is quickly overshadowed by the 40% of species which are very tolerant to high TSS. The fish community was also made up of 67% minnows.

Fish TSS TIV index scores vary between the two stations. In fact, Station 08LM075 has the worst possible score for Root River coldwater sites, indicating its fish community overall is very tolerant to high TSS. In contrast, the downstream station on Camp Creek is near average for the number of TSS tolerant species present. This correlates to the percent carnivore metric at each site as well. At Station 08LM075, the percent carnivores are at 16%, far below average for statewide coldwater sites. At Station 08LM046, the percent carnivores are higher, at 42%. The average for coldwater stations in the state is 47% and has been shown to have a relationship with TSS concentration.

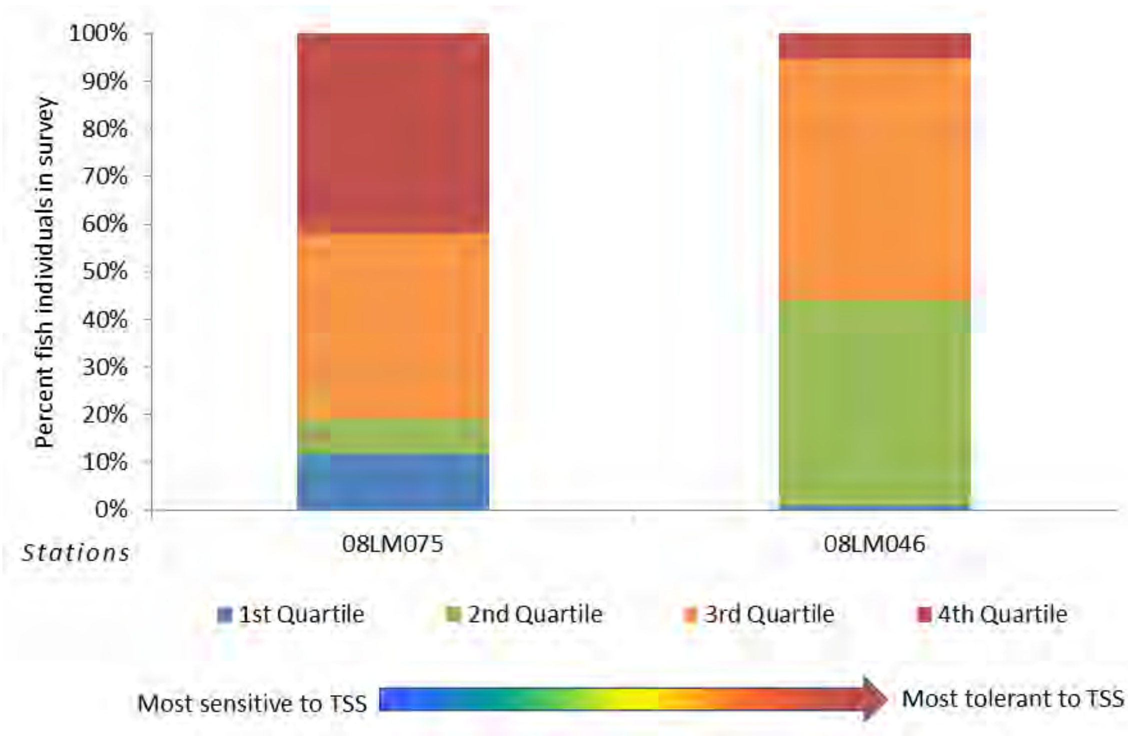


Figure 120. Camp Creek fish TIV's (tolerance indicator values)

Macroinvertebrates in Camp Creek also show a stronger signal to TSS stress at Station 08LM075 in comparison to Station 08LM046. Both stations have TSS index station scores for macroinvertebrates that are considered near average for Root River Stations. However, Station 08LM075 has worse than average intolerant taxa and the percent TSS tolerant individuals is quite high compared to the average in the Root River (Table 44). Interestingly, the percentage of long-lived individuals at this location is above average, and TSS tolerant taxa are near average for coldwater stations in the Root River. Station 08LM046 does show improvement, with some TSS intolerant taxa present, and only a few TSS tolerant taxa.

Currently, the limited chemical information on this AUID is farther downstream, near biological Station 08LM046. When looking at that biological information and chemical information, TSS issues are not apparent. However, biological Station 08LM075, farther upstream is signaling TSS stress in both the fish and macroinvertebrate communities present. The lack of chemical information makes it difficult in understanding the sediment dynamics on this stream. More information, collected throughout the system would aid in understanding the differences between the upstream and downstream locations.

Given the lack of chemical information and the differences in biological information, a TSS stressor is not able to be confirmed at this time. There are certainly indications that the upstream station is being impacted by TSS, but additional chemical information is needed to confirm.

Table 44. Macroinvertebrate metrics relevant to TSS for stations in Willow Creek compared to averages for coldwater stations in the Root River watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
08LM075	**15.39**	**0**	4	**16.26**	**0**	1.32
	15.18	1	3	4.5	**0.3**	**0.61**
08LM046	15.11	1	2	4.22	**0.63**	**0**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River watershed	15.13	0.99	4.38	9.94	0.95	1.23

Physical habitat

The MSHA from both sites in Camp Creek scored good, but significant bank erosion and sedimentation was noted at Station 08LM075 compared to only light erosion at Station 08LM046. At Station 08LM075, 70% of the reach was a considered run.

Multiple habitat types were sampled for macroinvertebrates. At Station 08LM075, riffles, undercut banks, and woody debris were sampled. At Station 08LM046 all four habitat types were sampled. There was not an abundance of burrowers found at either station, which would suggest potential sedimentation issues. The percentage of EPT individuals was better than the statewide average at Station 08LM046, but worse than average for Station 08LM075. The legless macroinvertebrate percentage at Station 08LM075 was also high, indicating a number of overall tolerant macroinvertebrates present at that location. Surprisingly, the macroinvertebrates that are known to cling to large substrate and woody debris were found in abundance (65%) at Station 08LM075 (above statewide averages). They were found at Station 08LM046, but only 26%, which is below the statewide average. Additionally, a low percentage of macroinvertebrates that climb were found at both stations.

Habitat characteristics were very different between the two sites, according to a MDNR report from 1989. At Station 08LM046 (MDNR Sector 1) there were several deep runs, boulders, adequate riffles, whereas near Station 08LM075 (MDNR Sector 3) there were no deep runs, only one area with boulders and adequate riffles. All sectors reported severe bank erosion. Also, according to the MDNR report from 1989, "the upper half of the stream continues to have bad habitat problems cited in the old surveys. Trout habitat was damaged in Sector 1 and substantially in Sector 3 by landowners who allow livestock to overgraze the stream banks. Many of the pools are much too wide and the current too slow which causes an abnormal amount of silt to settle in the pools. This stream became completely weed-chocked in 1988-even the riffles filled in with silt during the hot and dry summer, but high water (5’) cleaned out the stream fairly well in March, 1989.” Additional notes from the MDNR report in 1989 showed good riffle area in the lower parts of the creek. Aquatic macroinvertebrates associated with good trout streams were abundant in this area. In contrast, Sector 3 (Mile 4.25 to Mile 11.75) was noted as having habitat problems. In this reach, maximum flow never exceeded 0.86 cfs anywhere during a survey in 1989. The flow in the lower section of the creek was measured to be near 11 cfs.

Both stations in Camp Creek had a fish community rich in riffle dwelling fish (51% and 49%), and simple lithophilic spawners (51% and 36%). Lithophilic spawners are average for Station 08LM075 and above average for Station 08LM046) Darter, sculpin and round bodied suckers were limited at both stations (only 1% and 5%). Non-tolerant benthic insectivores were found in lower percentages than average for Station 08LM046, but better than average for Station 08LM075. Fish which are considered pioneers were much more abundant at Station 08LM075 (45%) than Station 08LM046 (6%). "Pioneering species predominate in unstable environments that have been affected by temporal desiccation or anthropogenic stressors, and are the first to reinvade sections of headwater streams following periods of desiccation" (Barbour et al., 1999). Piscivores show a similar trend; much more abundance at Station 08LM046 (42%) compared to Station 08LM075, (2%). Further evidence shows there is a higher percentage of generally tolerant fish species at Station 08LM075 (83%) compared to Station 08LM046 (56%).

The metrics and data show that habitat is a limiting factor for fish and macroinvertebrates at Station 08LM075, but the data do not show as dramatic response at Station 08LM046. Certainly aspects of habitat could be improved throughout Camp Creek. It is important to note that MDNR does have habitat improvement projects on Camp Creek, but all are located in the reach just downstream of Station 08LM046. This may be positively impacting the fish community found at Station 08LM046, due to its close proximity.

Physical connectivity

There were six road crossings evaluated in this watershed and none were found to be barriers to fish movement. There is a presence of migratory fish found at both biological stations. No other data was available or collected to analyze connectivity as a stressor, but it is not believed to be a driver to biological impairment in the watershed.

Strength of evidence, conclusions, and recommendations

Multiple stressors exist throughout this watershed and appear to be making the most impact on the upstream site, 08LM075. This includes: temperature, nitrate, and habitat. Every stressor shows wide differences in condition and biological response between upstream and downstream site locations. The field evidence and biological response for habitat are giving the strongest signal of stress in this watershed. The available temperature information, while limited, does show temperature has impact in the upper reaches of this watershed. Further upstream, at Station 08LM075, detailed temperature information is lacking. This information should be collected, and is critical to the understanding of temperature impacts from upstream areas.

Camp Creek’s Watershed, including Partridge Creek, has elevated concentrations of nitrate. The abundance of nitrate tolerant taxa, lack of nitrate intolerant taxa, along with low metric scores at Station 08LM075 for HBI_MN and TrichopteraChTxPct, show that the macroinvertebrate response to the elevated nitrate is present.

The quarry in the upstream part of the watershed, in addition to some local land issues may be drivers for issues found at 08LM075. MDNR reports document thermal changes in the headwater area due to the quarry. As noted in site photos, severe stream bank erosion and local land use practices may be also playing a role in habitat loss found throughout Camp Creek.

More chemical information should be collected on DO and TSS to help understand the varying impacts of those stressors. Currently limited chemical information exists to completely confirm or rule out those two stressors. Additional DO data may be especially important in the upstream reaches where the potential for oxygen issues is higher and the biological communities are indicating potential stress. At Station 08LM075, the fish and macroinvertebrate communities indicate potential stress from elevated TSS. The lack of chemical information makes it difficult in understanding the sediment dynamics on this stream. More information, collected throughout the system would aid in understanding the differences between the upstream and downstream locations.

4.7.7. Summary of stressors in the South Branch Root River

The most consistent stressor affecting the biological communities in the South Branch Root River is elevated nitrate. All sites impaired for biology in the South Branch are showing nitrate related stress (Table 45). The Nitrogen in Minnesota Surface Waters Report has estimated that agricultural groundwater and agricultural drainage comprise of 80% of the nitrogen sources in the Lower Mississippi River Basin (pg. D1-11). In the South Branch Root River, geologic controls play an important role in nitrate transport and loading. The most important factor identified that impacts both the magnitude and variability of nitrate concentration in spring water and stream baseflow, is the proportion of regionally sourced, nitrate-poor water contributed from deep aquifers relative to more locally sourced, nitrate-enriched water from shallower aquifers (Runkel et al, 2013).

Both fish and macroinvertebrate communities are impaired in Camp Creek and Watson Creek due to multiple stressors. The biological response in these watersheds is more severe and the implementation associated with each will require more effort. Both reaches also have temperature stressors, which are complicated by Karst hydrology.

While there are reaches in the South Branch with turbidity impairments, not all are demonstrating biological response (nor were addressed in this report). A TSS stressor was not able to be confirmed on AUID 556 due to insufficient information. The biological response did not strongly support or refute TSS as a stressor. However, farther downstream on AUID 550, a TSS stressor was confirmed (this reach does not have a current turbidity listing). This supports the notion that TSS may still be an issue throughout the watershed, but may have more impact in some areas of the stream than others.

Additional information and monitoring on specific parameters (i.e. DO) may be useful in assessing stressors in the future. Many reaches lacked good chemical datasets required to fully understand stressors.

Table 45. Stressors identified in the South Branch Root River. (● = stressor (yes); o = inconclusive stressor; 'blank'-no stressor)

Reach Name	Geo Region	AUID	Reach Description	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Habitat	Physical Connectivity
South Branch Root River	***Driftless, Near Surface Karst***	**07040008-550**	*Duschee Creek to Middle Branch Root River*	2A	08LM002	Downstream of CSAH 8, in Lanesboro	Invert IBI Bacteria		O	●	●		
South Branch Root River	***Driftless, Near Surface Karst***	**07040008-556**	*T102 R12W S21, North line to Canfield Creek*	2A	08LM029	Downstream of Maple Rd, 6 mi. S of Wykoff	Invert IBI Turbidity			●	O		
Etna Creek	***Driftless, Near Surface Karst***	**07040008-597**	*T102 R13W S36, west line to Unnamed Creek*	2A	08LM026	Downstream of 153rd Ave, 8 mi. SW of Wykoff	Invert IBI			●		O	
Watson Creek	***Driftless, Near Surface Karst***	**07040008-552**	*T103 R11W S30, west line to South Branch Root River*	2A	04LM057 08LM004	Downstream of U.S. Route 52, 2 mi. NW of Preston Downstream of CSAH 17, 4 mi. NE of Preston	Fish IBI Invert IBI Nitrate Bacteria	●		●	●	●	

Reach Name	Geo Region	AUID	Reach Description	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:					
								Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Habitat	Physical Connectivity
Willow Creek	***Driftless, Near Surface Karst***	**07040008-558**	*T101 R11W S12, west line to South Branch Root River*	2A	04LM021 08LM005 10EM143 08LM038	Downstream of Hwy. 15, 1 mi. SW of Preston Downstream of CSAH 12, 1 mi. S of Preston 0.75 mi. upstream of CSAH 15, 3 mi. SW of Preston Downstream of Jumper Rd, 5 mi. NW of Harmony	Invert IBI Bacteria Nitrate			•		•	
Camp Creek	***Driftless, Near Surface Karst***	**07040008-559**	*Headwaters to South Branch Root River*	2A	08LM046 08LM075	Upstream of Cottage Grove Rd, 1 mi. SE of Preston Downstream of CSAH 16, 4 mi. S of Preston	Fish IBI Invert IBI	•	O	•	O	•	

4.8. South Fork Root River

This part of the report is broken into seven sections and addresses eight reaches with biological (all macroinvertebrate) impairments (Figure 121). The first section groups together two AUIDs in the Lower South Fork and addresses them together. Then, farther upstream the coldwater section of the South Fork is discussed. Riceford Creek has two AUIDs with biological impairment; one coldwater reach farther upstream, and another warmwater reach closer to the mouth. The headwaters of the South Fork (warmwater) are also addressed separately. Finally, two tributary streams; Sorenson Creek (warmwater) and Bridge Creek (coldwater) are also addressed in separate sections.

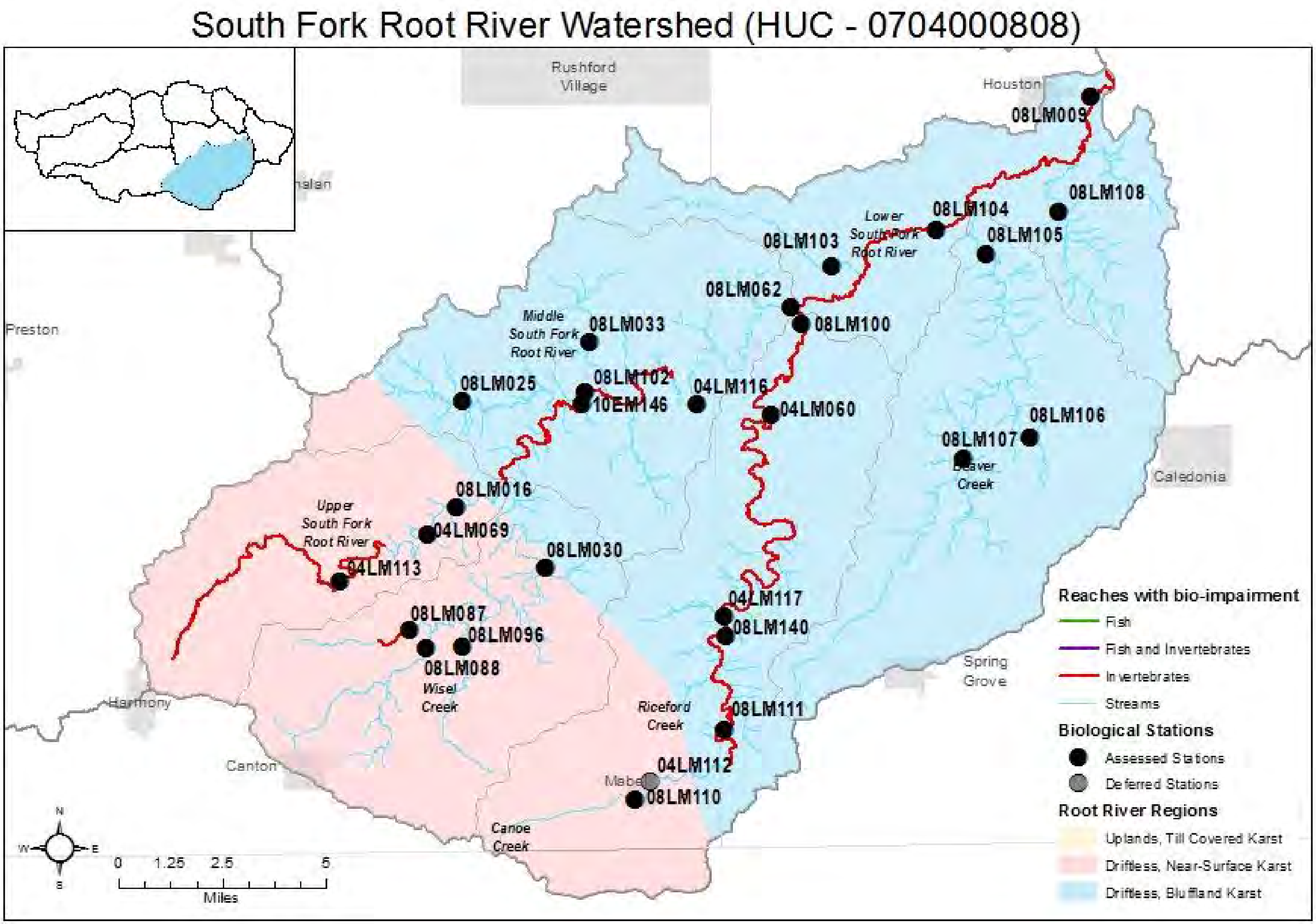


Figure 121. South Fork Root River biological monitoring stations and aquatic life impairments

4.8.1. Lower South Fork Root River

Supporting information

This section will discuss two AUIDs, 508 and 509. One biological station was sampled on each AUID, 08LM009 and 08LM104, respectively. Fish IBIs were well above the impairment threshold and upper confidence interval at both sites, in spite of the fact that habitat was noted as poor due to severe bank erosion and sedimentation at Station 08LM009. This location is also very close to the mainstem Root River, which may influence the composition of the fish community at that location.

At both locations the macroinvertebrate data scored just below the impairment threshold, within the confidence interval. Biological Station 08LM062 is upstream of the other two stations and is above impairment threshold (just before Riceford creek confluence).

The macroinvertebrate IBI metrics between the three biological stations on these two AUIDs are shown in Figure 122. The response is fairly consistent among the three locations. The sites can be characterized by having reduced taxa counts overall (TaxaCountAllChir), as well as a low score for taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch), and low taxa richness of predators (excluding chironomid predator taxa; Predator).

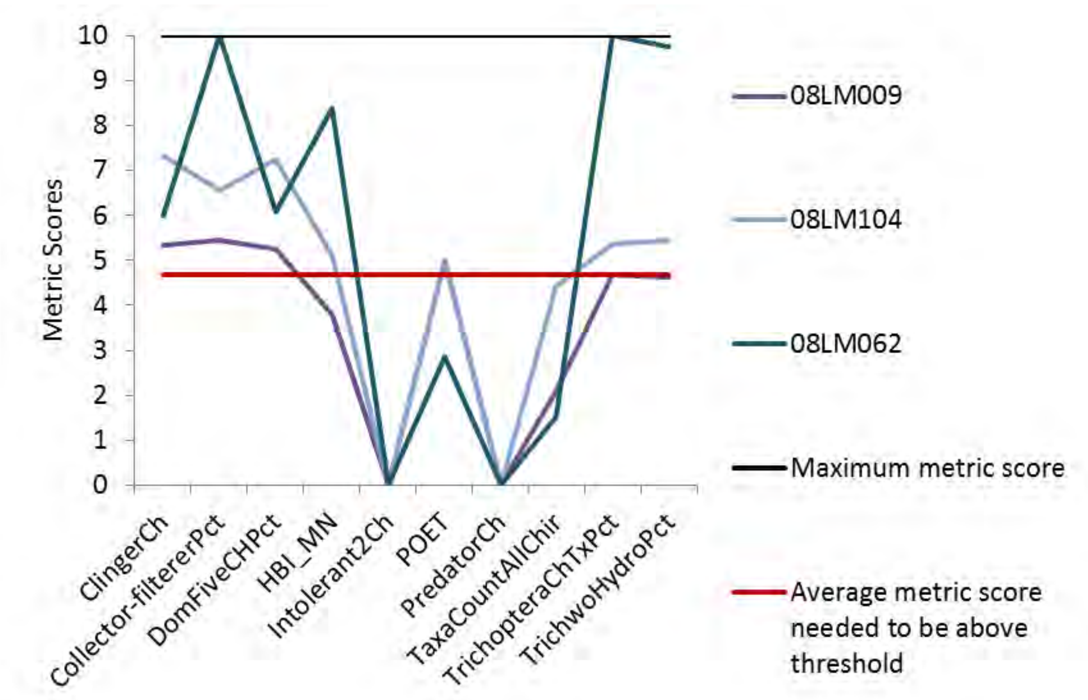


Figure 122. Metric scores for stations in the South Fork Root River of the Southern Forest Streams GP macroinvertebrate IBI

Temperature

Temperature measurements were taken during fish sampling in 2008. At Station 08LM009, the temperature was 14.6°C on August 27, 2008. At Station 08LM104, the temperature was 19.7°C on September 2, 2008.

From 2008-2010, temperature was sampled 65 times near Station 08LM009. The maximum temperature recorded during that time was 23°C. The temperature found is within normal and suitable ranges for warmwater streams.

Dissolved Oxygen

In 2008, both biological stations had DO measurements taken during fish sampling. At Station 08LM009, the DO concentration was 10.13 mg/L. At Station 08LM104, the concentration was 8.45 mg/L. A stream monitoring station near Station 08LM009 (S004-830), showed a DO range of 8-10.76 mg/L.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. Station S004-830, adjacent to Station 08LM009, was sampled 27 times for pH in 2008 and 2009. The average pH was 8.19 and maximum was 8.3. Just downstream from that location, Station S004-860 was sampled 105 times between 2008 and 2010. The 44 pH values ranged from 7.49 to 8.89. Two high pH values (which near the pH standard, but did not violate the standard) occurred on August 12, 2010 and April 1, 2008. Total phosphorus concentrations paired with those two samples were also elevated (0.176 mg/L, and 0.479 mg/L, respectively). The average pH at that site was 8.13. In addition, there were nine phosphorus values available from Station S004-830, collected from May-September 2008. The range of concentration was 0.085-0.543 mg/L. The average phosphorus concentration was 0.185 mg/L. At another nearby site, S004-860 had 61 phosphorus values which ranged from 0.052-2.7 mg/L, and an average of 0.037 mg/L. While phosphorus values in the Lower South Fork are elevated, the samples collected were taken based on pollutant load monitoring which targets events, when phosphorus and TSS concentrations are the highest. During low flow conditions, when the water was clear, total phosphorus concentrations were much lower, and within normal range.

In 2008, this location was sampled four times for chlorophyll-a. The results ranged from 0.81ug/L to 4.13ug/L, which are low and do not cause concern. BOD data were not available for analysis on either AUID.

The fish community at both stations scored worse than average for DO TIV index scores. Station 08LM009 scored in most tolerant category and indicates a more tolerant community is present at that location in comparison.

The macroinvertebrate community however showed a very different response. The DO TIV index scores for invertebrates scored better than average, with Station 08LM104 scoring in the most sensitive quartile when compared to other sites in the Root River. This indicates a community sensitive to low DO is present at both locations. In addition, the number of low DO intolerant species are found in higher number than most stations in the Root River. The two sites found 12 and 17 taxa which are considered intolerant to low DO, and the average for Root River Stations is 10 taxa. The percent tolerant to low DO species is also very low compared to other stations. EPT taxa are also found in abundance at both locations, and are generally intolerant to DO stress. Taxa richness can be decreased with increases in DO flux. Station 08LM009 does have reduced taxa count, but 08LM104 does not (compared to averages of that same stream class). The macroinvertebrate data do not signal that DO is a stressor in this part of the South Fork Root River.

While the fish community shows some moderate tolerance to low DO, the macroinvertebrate community is showing quite a bit of sensitivity to low DO. The chemical information does indicate adequate DO levels in this reach and the current biological information does not suggest that DO is stressor to the Lower South Fork. Additional monitoring of DO may be useful in understanding DO levels in this reach.

Nitrate

Nitrate was analyzed separately on these two stream reaches because of different biological response and differences in available chemical information. On AUID 508 in 2008, the nitrate concentration collected during fish sampling at Station 08LM009 was 4.3 mg/L on August 27. On stream reach (AUID 508), nitrate was sampled 71 times from 2008-2010. The concentrations peaked at 5.2 mg/L, and averaged 3.66 mg/L.

Station 08LM009 had a low taxa count (16; with chironomid and baetid taxa each treated as one taxon), lower number of Trichoptera taxa (2) and no intolerant taxa. This station had no nitrate intolerant taxa and 84.9% nitrate tolerant. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. Nitrate is a contributing stressor to the macroinvertebrate community.

On AUID 509 in 2008, the nitrate concentration collected during fish sampling at 08LM104 was 4.8 mg/L on September 2. This was the only nitrate data available on 0704008-509. Station 08LM104 had a higher than average taxa count (with chironomid and baetid taxa each treated as one taxon), along with a higher than average number of Trichoptera taxa (3), but no intolerant taxa. This station had one nitrate intolerant taxa and 67.1% nitrate tolerant. There is limited chemical data on this AUID (509) and the biological response is unclear to the nitrate levels. At this time, nitrate is inconclusive as a stressor on this specific stream reach.

Suspended sediment

TSS concentrations collected during biological sampling at Stations 08LM009 and 08LM104 were 40 and 22 mg/L, respectively. This reach is listed as a current turbidity impairment. Data collected during 2008-2010 further supports that impairment. TSS was sampled 71 times and resulted in an average concentration of 283 mg/L; minimum of 23 mg/L and maximum of 2400 mg/L. The draft TSS standard for warmwater streams is 30 mg/L TSS. Only four samples, of the 71, meet (or are below) the proposed standard. In other words, 94% of those samples taken are exceeding the draft TSS standard of 30 mg/L in the central region of the state. It’s important to note that these samples were taken focused on events for pollutant load monitoring samples. However, multiple samples were also taken during baseflow, and show increased TSS as well. Continuous turbidity monitoring data also supports the impairment. Data collected from the open water season from 2008-2010 was analyzed for percent exceedence of the turbidity standard. Power regression was used to relate turbidity sensor units (FNU) to stream chemistry samples for turbidity (NTU). Based on this analysis, the stream was exceeding the turbidity standard 11.9% of the duration of its deployment. The maximum continuous days above the turbidity standard (25 NTU) was 9.57 days. This demonstrates a sustained turbidity issue which is present on the Lower South Fork Root River.

The fish community is comprised of some fish that are tolerant to high TSS concentrations. The station in this reach had a TSS TIV aggregate score in the most tolerant quartile indicating a TSS tolerant fish community compared to others in the Root River Watershed. The most tolerant to TSS fish, including species like the fathead minnow and emerald shiner make up 26% of the fish community at Station 08LM006. However, there are also some species present which are sensitive to TSS, including longnose dace and smallmouth bass. The percent carnivore metric correlates with TSS (TSS document). At Station 08LM009, the percent carnivore species is slightly reduced at 10%, compared to an average of 15% for all Class 2 sites in the Root River. The fish community is showing somewhat conflicted information, but generally trends towards TSS tolerance.

The stations in the Lower South Fork River had worse than average TSS station index scores for macroinvertebrates and most other metrics that measure response to elevated TSS (Table 46). The percentage of TSS tolerant macroinvertebrates was greater than 44% at both stations, whereas the average for warmwater stations in the Root River watershed is 35.45%. The macroinvertebrate community at these stations is impacted by elevated TSS levels. Given the strong chemical and biological response information, TSS is confirmed as a stressor in the Lower South Fork Root River (both stream reaches).

Table 46. Macroinvertebrate metrics relevant to TSS for stations in the Lower South Fork Root River compared to averages for warmwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Invertebrate Individuals	Percentage of Intolerant Invertebrate Individuals	Percentage of Long-lived Invertebrate Individuals
08LM104	**20.87**	**1**	**13**	**44.52**	**0**	**2.85**
08LM009	**23.08**	**1**	7	**44.62**	**0**	**0.31**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed	17.96	1.52	9.32	35.45	0.48	3.16

Physical habitat

The habitat assessment results from Station 08LM009 showed very little to no riparian zone, with moderate to severe bank erosion. Surrounding land use predominately row crop and open pasture. No riffles were present; only pools and runs. The reach was dominated by sand, and considered 90% run. Cover was considered sparse. During macroinvertebrate sampling, cows were present up to and in the water, and there was hardly any bank vegetation. The site was mostly sandy and muddy with evidence of mass wasting. There were a few intermittent logs/snags. The only habitat sampled was, woody debris since the water was too deep and fast to sample other habitat. The stream gage just upstream from this location, on this day of sampling was flowing at 250 cfs, which is considered normal baseflow conditions.

Similar to Station 08LM009, site 08LM104 had very little riparian width and moderate bank erosion. The surrounding land use was row crop. Sand was also the dominant substrate. The only habitat sampled here was also woody debris. Some gravel was present in the riffle, but the reach only consisted of 5% riffle. Moderate cover and embeddedness was noted, and the water color was brown.

The percentage of EPT individuals was greater than the statewide average at both sampling locations. The macroinvertebrates that are known to cling to large substrate and woody debris were also found in abundance (above statewide averages). However, the percentages of macroinvertebrates that climb were much less than the class average of 24.1%; Station 08LM009 had 4.3% and Station 08LM104 had 7.0%). The percentages of macroinvertebrates that are considered sprawlers were also below average, but swimmers were above the average for this stream class. Also, the percentage of legless invertebrates was better than normal for this macroinvertebrate class (burrowers were also not found in abundance at Station 08LM009).

Habitat is not likely the primary stressor in the South Fork, but secondary to a more prominent stressor. The biological response is not highly indicative of habitat stress, but site sampling information indicates that there are some aspects of habitat that could be improved in this reach (i.e. no riffles, 90% run, little cover and adjacent land use).

Physical connectivity

No information was available or collected on physical connectivity on this reach. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The main stressor affecting these reaches in the South Fork Root River is elevated TSS, with habitat as a secondary stressor. Temperature and DO all appear within suitable ranges. The fish community does show some tolerance to low DO; however the macroinvertebrate community is showing sensitivity to low DO. TSS gets very high during storm events, and stays fairly elevated during baseflow conditions. Of 71 water quality samples taken from 2008 to 2010, there was a 94% exceedence of the proposed TSS standard (30 mg/L) demonstrating a sustained turbidity/TSS issue. In addition, continuous turbidity data also show that over this same time period, the maximum continuous number of days the stream was above the turbidity standard was approximately 9.5 days. The local land use, and subsequent stream bank erosion, is increasing suspended sediment, and reducing habitat available for macroinvertebrates. Better management of the riparian corridor and increasing buffers are critical in this part of the South Fork Root Watershed. Protecting soil loss and stream bank erosion are the primary ways in which sediment and habitat issues in the South Fork Root River will be addressed. Agricultural setbacks and better riparian corridor management would be helpful in this effort, but needs to be managed on a watershed wide scale.

Nitrate is also considered a stressor at AUID (508). The macroinvertebrate community is demonstrating stress to moderate levels of nitrate present in this reach. However, there is limited chemical data on this AUID (509) and the biological response is unclear to the nitrate levels. At this time, nitrate is inconclusive as a stressor on this specific stream reach.

Pesticides were not addressed in this section of the report, but do warrant further investigation. Atrazine was detected above the 30 day drinking water standard of 3.4 ug/L at the South Fork Root River at Houston. Also, in 2011, the maximum concentration was 5.12 ug/L, which was measured at the South Fork Root near Houston on May 23, 2011. This was the highest statewide detection of atrazine since 2009 (MDA 2011 Monitoring Report, pg 134).

4.8.2. South Fork (Middle-Coldwater)

Supporting information

This AUID (510) includes two biological Stations, 08LM102 and 10EM146. Current information suggests this AUID is starting to transition from coldwater to warmwater. The fish community is diverse, and would score well for either fish class (cold or warm). The macroinvertebrate score at both of these sites scored below the threshold, within the lower confidence interval. The coldwater community is poorly represented overall. The IBI metrics for both stations are shown in Figure 123. The macroinvertebrate metrics in the Southern Coldwater IBI that scored low at both stations were the ratio of chironomid abundance to total dipteran abundance (ChiroDip), percentage of collector-gatherer individuals (Collector-filtererPct), the metric that is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), and percentage of taxa belonging to Trichoptera or caddisflies (TrichopteraChTxPct).

The Coldwater Biotic Index score, based on coldwater tolerance values derived from Minnesota taxa and temperature data (CBI), and taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch) both had differences among the two sites.

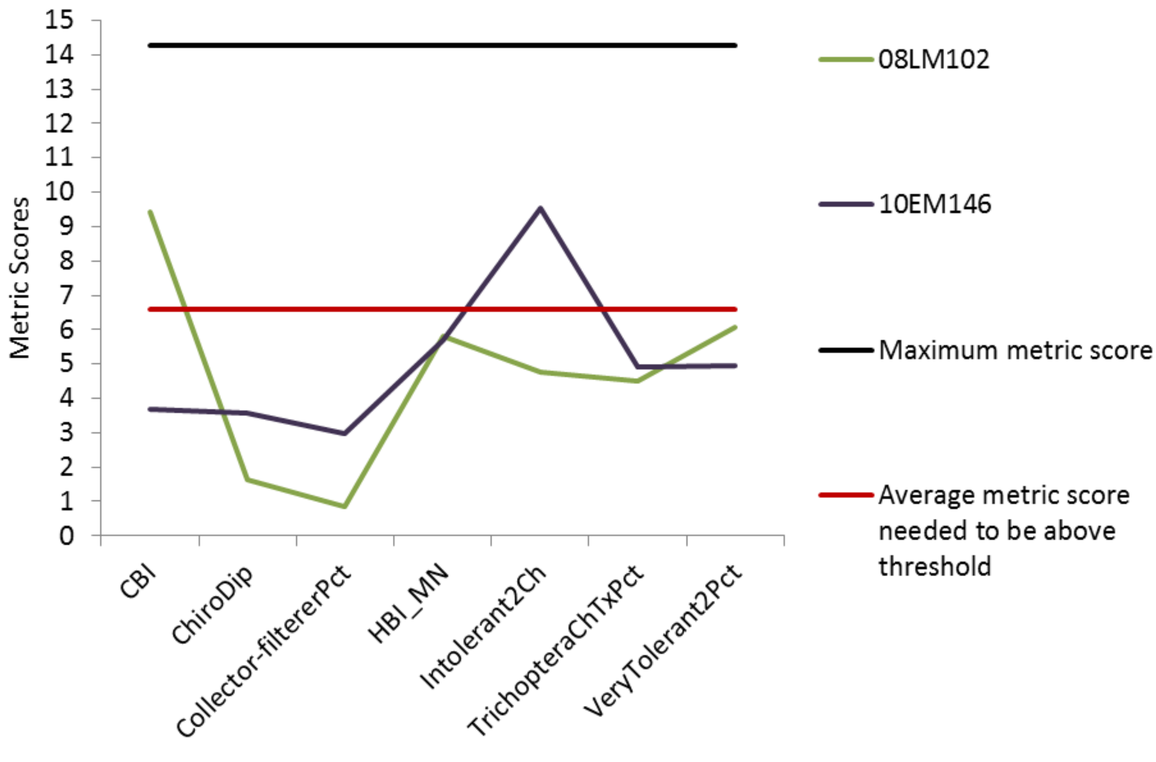


Figure 123. Metric scores for stations in the South Fork Root River of the Southern Coldwater invertebrate IBI

Temperature

Limited temperature information is available for this stream reach. During fish sample, Station 08LM102 had a temperature of 14.8°C while Station 10EM146 was 16.7°C. There were three other measurements of temperature available from 2006 and 2007 at Station S004-123. March 13, 2007 had a temperature of

3.9°C, October 1, 2007, had a temperature of 14.9°C, and June 26, 2006 had a temperature of 15.1°C. Neither site had continuous temperature data available for analysis.

The fish community at 10EM146 is mixed, yet brook trout and sculpin were found in fairly good numbers (50 brook trout and 25 mottled sculpin). Brook trout and sculpin were also present at Station 08LM102, but in reduced numbers and the community was dominated by more cool or warmwater species. These two stations are in close proximity to one another, so it's possible another stressor is changing the community composition at these two locations.

More information should be collected on temperature (continuous temperature data collection) in order to ensure these sites are maintaining adequate coldwater temperatures. At this time, a temperature stressor cannot be confirmed, but additional information would help rule that out completely. The presence of brook trout does provide good indication that temperature is adequate.

Dissolved Oxygen

DO was measured during fish sample in 2008 and 2010. At Station 08LM102 the DO concentration was 9.98 mg/L, on August 12, 2008 at 8:27 am. At Station 10EM146 the concentration was 8.51 mg/L. One other DO value from June 26, 2006 at Station S004-123 was 10.09 mg/L.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. Site S004-123 was sampled for pH three times, once in 2006 and twice in 2007. The pH value in 2006 was 8.4 and the pH values in 2007 were 7.92 and 7.97. Those values fall within the water quality standards for pH (6-5-8.5). The total phosphorus concentrations were also low during fish sample, at 0.07 mg/L and 0.06 mg/L. One sample BOD value was from 1982, but not considered for analysis given the lapse in time since sampling. No chlorophyll-a data were available for analysis.

The fish community at these sites is comprised of fish which are not overly tolerant or intolerant to low DO. The DO fish TIV index scores are near average and slightly worse than average compared to other stations in the Root River.

The macroinvertebrate community at these sites show mixed results, but generally trend towards presence of species with sensitivity to low DO. At 08LM102, the macroinvertebrate DO TIV index score is in the most sensitive quartile compared to other stations in the Root River. In contrast, Station 10EM146 was slightly worse than average when comparing DO TIV index scores with other Root River stations. Both biological stations had a better than average number of DO intolerant individuals (13 at both sites; Root average is 10), and were better than average when comparing the percent tolerant species to low DO. The percentage of EPT individuals was slightly reduced below normal, but taxa richness was above average among the two sites. EPT are typically intolerant of low DO levels, and taxa richness can also be decreased with increases in DO flux.

At this time, the biological and chemical evidence do not indicate a DO stressor is present in this section of the South Fork.

Nitrate

Nitrate was measured at the time fish sampling in 2008 and 2010. At Station 08LM102 the nitrate concentration was 6 mg/L. In 2010, Station 10EM146 had a nitrate concentration of 4.8 mg/L. One additional sample was collected from Station S004-123 on October 1, 2007 of 6.7 mg/L nitrate. This sample was taken during storm flow conditions (transparency was 6 cm).

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in the South Fork Root River had 20 and 27 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Station 08LM102 had one intolerant taxa and Station 10EM146 had two intolerant taxa.

Station 08LM102 had four Trichoptera taxa and Station 10EM146 had six Trichoptera taxa, comprising of 11.8 and 12.2% of the total taxa (TrichopteraChTxPct). The resulting low metric scores; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In the South Fork Root River, the metric score was 5.8 and 5.7 (Station 08LM102 and Station 10EM146, respectively, out of 14.3), below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM102 the HBI_MN value was 7.17 in 2008 and at Station 10EM146 the value was 7.18 in 2010, both greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p\leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM102 had 22 nitrate tolerant taxa and Station 10EM146 had 16 nitrate tolerant taxa (88.4 and 69.4% individuals); and 16 and 21 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. Station 08LM102 had two nitrate intolerant taxa present and Station 10EM146 had one nitrate intolerant taxa present.

The abundance of nitrate tolerant taxa, lack of nitrate intolerant taxa, along with low metric scores for HBI_MN and TrichopteraChTxPct, show that the macroinvertebrate response to the elevated nitrate is present. Nitrate is elevated in the South Fork Root River and is playing a role in shaping this degraded macroinvertebrate community.

Suspended sediment

Suspended sediment samples were taken during fish sampling in 2008 and 2010. At Station 08LM102 the TSS concentration was 15 mg/L, while at Station 10EM146 the concentration was 11 mg/L. These values are just slightly above the proposed TSS standard of 10 mg/L (which is based on a 10% exceedence of 10 mg/L for coldwater streams). The only other information related to suspended sediment was from transparency tube measurements on three samples taken at Station S004-123, from 2006 and 2007. On June 26, 2006 the transparency was 37 cm. In 2007, two samples were taken during high flow conditions. On March 13, 2007, the stream had a transparency of 4 cm, while on October 1, the transparency was 6 cm. Those were during snowmelt and a large rainfall event which occurred in 2007.

The fish community is comprised of a mixed composition of TSS tolerant and intolerant fish but do have a majority in the two most sensitive quartiles (approximately 70%), as shown in Figure 124. The TSS TIV station index scores for fish are near average for Root River coldwater sites. The AUID upstream (511; not impaired for biology) is also displayed in Figure 124, with high percentages of TSS sensitive species present. Interestingly, AUID 511 is listed as impaired for turbidity. While the fish data do not point to TSS stress, it should be monitored over time given the upstream TSS issues, as potential for impact exists.

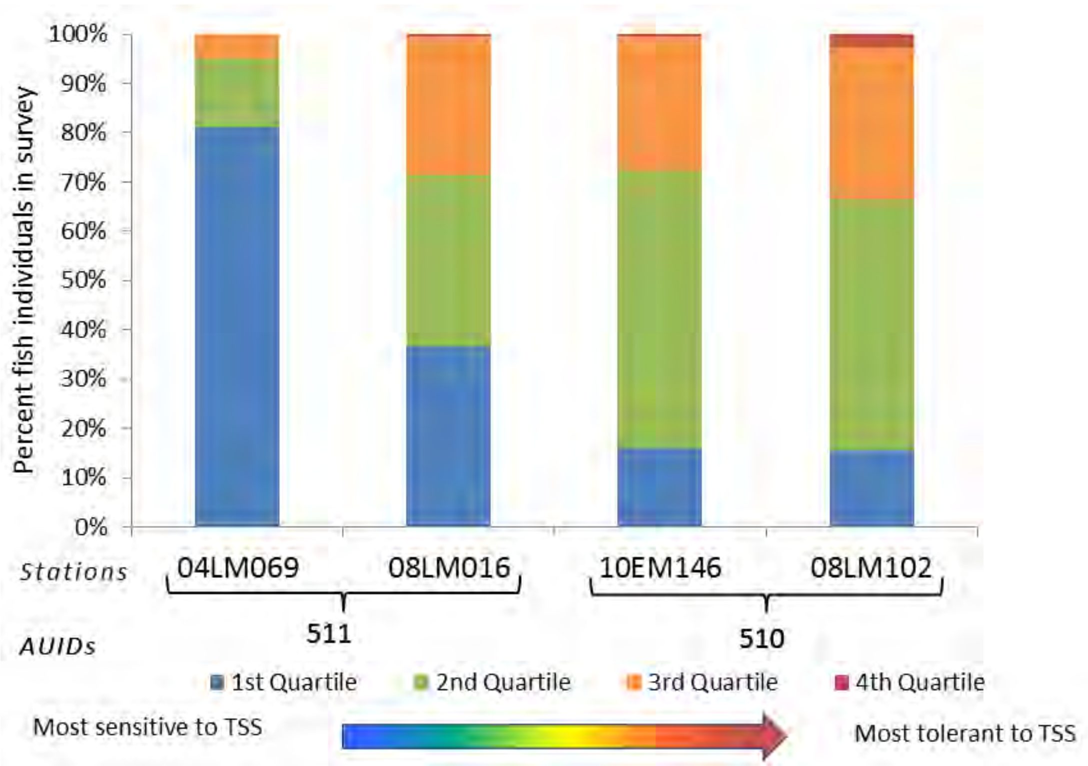


Figure 124: TSS TIV for Coldwater stations in the South Fork Root

The macroinvertebrate community in the Middle South Fork Root River has the greatest tolerance to TSS at Station 10EM146, with an elevated TSS station index score, a high number of TSS tolerant taxa and a high percentage of TSS tolerant macroinvertebrate individuals (Table 47). Station 08LM016, in the upstream AUID, and Station 08LM102 have TSS station index scores at or slightly above the average for the coldwater stations in the Root River Watershed. Throughout both AUIDs in the Middle South Fork Root River, there is presence of TSS intolerant macroinvertebrate taxa. The macroinvertebrate metric evidence suggests that TSS is likely a contributing stressor to the community in the downstream AUID (510) of the Middle South Fork Root River.

Table 47. Macroinvertebrate metrics relevant to TSS for stations in the Middle South Fork Root River compared to averages for coldwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress. The gray stations are on the stream reach upstream, which is impaired for turbidity, but not biology. They are displayed here for comparison purposes only.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Invertebrate Individuals	Percentage of Intolerant Invertebrate Individuals	Percentage of Long-lived Invertebrate Individuals
04LM069 (2004)	**15.05**	2	3	6.77	**0**	**0.71**
08LM016 (2008)	**15.13**	3	2	3.29	**0.3**	**0**
10EM146 (2010)	**16.18**	3	**9**	**21.37**	1.25	1.88
08LM102 (2008)	**15.17**	1	**5**	**10.26**	**0.32**	**0.64**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River watershed	15.13	0.99	4.38	9.94	0.95	1.23

There is some indication the TSS issues may be present at this location, but the evidence is not strong enough to confirm TSS is a stressor at this time. The fish and macroinvertebrate responses to TSS are mixed. The fish are showing some sensitivity to TSS, while the macroinvertebrates are showing more tolerance. It is difficult to conclude that TSS is stressing the communities at this location. The stream reaches farther upstream and downstream of these sites are also impaired for turbidity. This stream reach is not showing a consistent response, but should be monitored over time as the potential for TSS issues are likely. Efforts to reduce TSS can still be undertaken within this reach. TSS as a stressor in this reach is inconclusive at this time.

Physical habitat

Station 08LM102 had a good MSHA score (79). The site was characterized by having a very rocky bottom with moderate cover. The riparian zone was extensive on one side of the stream channel and not on the other. There was just little bank erosion, with no embeddedness. Riffle features consisted of 60% of the reach and were comprised of cobble and gravel. The available and sampled habitat for macroinvertebrates included riffle/rock, undercut banks/overhanging vegetation, and woody debris.

Station 10EM146 also had a good MSHA score (72). The site was characterized as having an extensive riparian zone on both sides, little bank erosion, and light embeddedness. The substrate in the riffle features (which was 50% of the reach) consisted of boulder and cobble. The run features also had cobble and gravel substrate. Cover was noted as sparse. The available and sampled habitat for macroinvertebrates included riffle, undercut banks/overhanging vegetation, aquatic macrophytes, and woody debris.

There was a higher than average percentage of burrowers found at Station 10EM146 (14%) which suggests the potential for fine bedded sedimentation in the riffle. The percentage of EPT individuals and individuals that climb was just slightly below the statewide averages at both sites (31% and 36% compared to statewide average of 39%). The macroinvertebrates that are known to cling to large substrate and woody debris were found in abundance at Station 10EM146 (above statewide averages, at 53%), but not as much at Station 08LM102 (only 31%). In addition, there was a higher percentage than average of legless invertebrates found at both locations (51% and 59%, compared to the statewide average of 32%).

While the data are not overwhelming, the metrics do point to some issues in terms of habitat. The reduced percentages of EPT individuals (those EPT individuals present are dominated by *Baetis*, a tolerant mayfly) climbers, and a shift to more tolerant (legless and burrower) macroinvertebrates demonstrates physical habitat is a stressor to this reach for macroinvertebrates.

Physical connectivity

No information was available or collected on physical connectivity on this reach. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The stressors to this part of the South Fork Root River are habitat and nitrate, with multiple macroinvertebrate metrics are showing a response to these stressors. There is some indication that TSS could be a stressor but the data are not strong enough to confirm at this time. Stream bank stability is an issue in these reaches which may be contributing to TSS and habitat related issues. In addition, the upstream reaches of this watershed (with existing turbidity impairments and sediment problems) are also potentially contributing. Addressing problems upstream could have beneficial affects to this reach.

The information on temperature in this reach is limited, and better temperature data should be collected (continuous) to ensure that this reach has adequate temperatures. The fish community is showing a mix of species with thermal preference which may indicate this is a natural thermal transition area. The biology was fairly sensitive to low DO, but some additional chemical information may be helpful in completely understanding DO dynamics in this reach.

4.8.3. Riceford Creek (Coldwater)

Supporting information

This coldwater section of Riceford Creek includes three biological Stations, 04LM117, 08LM140, and 08LM111 sampled in 2004 and 2008. One macroinvertebrate IBI scored below the threshold and lower confidence interval, another below the threshold but within the confidence interval and the other was above the threshold and upper confidence interval. All three sites scored above the threshold for fish IBI.

The three stations show some consistent response among IBI metrics (Figure 125). Those metrics which are doing poor consistently include the taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs (Intolerant2Ch), and relative percentage of taxa belonging to Trichoptera or caddisflies (TrichopteraChTxPct).

There was a wide range of scores among sites related to the metrics of ratio of chironomid abundance to total dipteran abundance (ChiroDip), the relative abundance (percent) of collector-filterer individuals (Collector-filtererPct), and taxa richness of macroinvertebrates with tolerance values equal to or greater than eight (excluding very tolerant chironomid and baetid taxa; VeryTolerant2Pct).

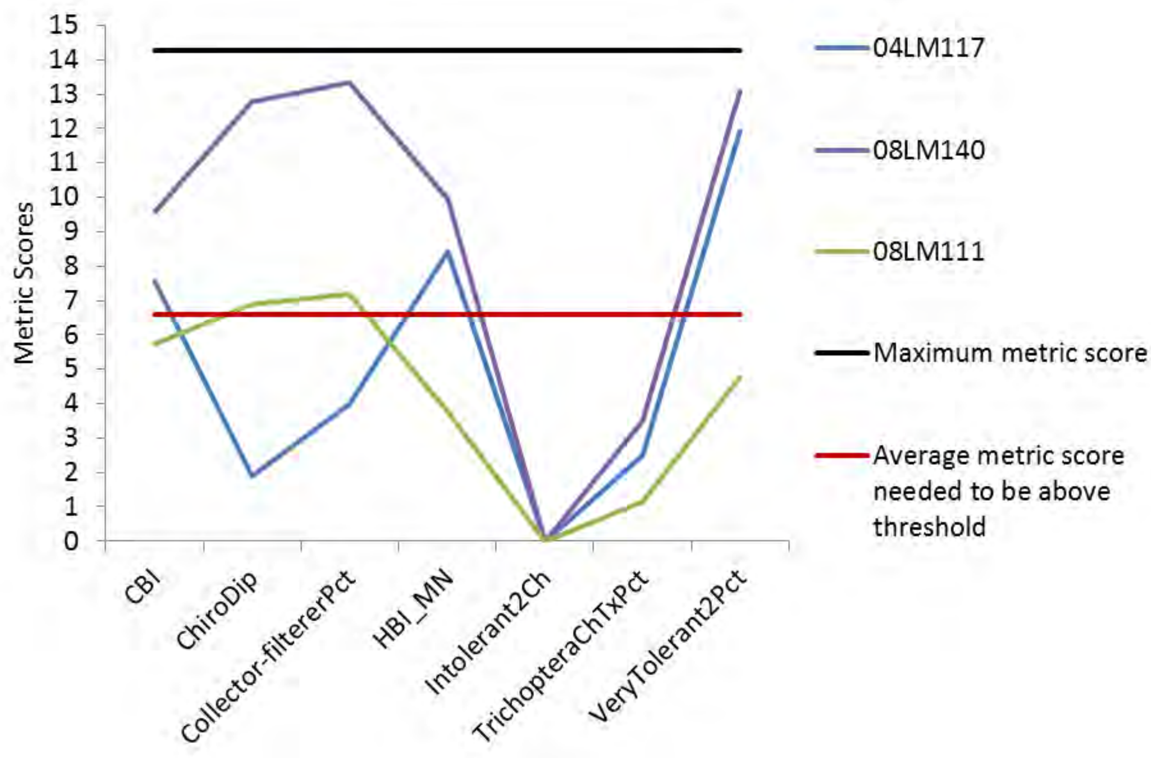


Figure 125. Metric scores for stations in Riceford Creek of the Southern Coldwater macroinvertebrate IBI

Temperature

Temperature in Riceford Creek appears to be suitable and comparable to most coldwater streams in the region. During fish sampling, temperature was recorded at all three sites on Riceford Creek (04LM117: 13.6°C, 08LM140: 14.9°C, 08LM111: 13.9°C). Two other temperature values were available, which were

11.5 and 15°C. Station 04LM117 did have a continuous temperature logger, however data and notes show the logger became buried in May, and data was not able to be used for analysis.

At Station 08LM140, a continuous temperature logger was deployed from June 28 to September 8, 2008. The maximum temperature recorded was 20.15°C on July 7, 2008. The July average temperature was 15.4°C and August average temperature was 14.34°C. These temperatures appear normal and comparable to other coldwater streams in the area.

Dissolved Oxygen

Limited DO values were available for analysis on this stream reach. During fish sampling the DO values recorded at the three sites ranged from 9.89 mg/L to 12.1 mg/L. The sample taken at 08LM140 was collected before 9:00 am (9.89 mg/L).

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH values taken during biological sampling were normal (7.71-8.01). The phosphorus values were slightly elevated, and ranged from 0.07 to 0.14 mg/L. While pH and phosphorus data was available from 1982, the values weren't used in analysis given the length of time since the samples were taken. Neither BOD nor chlorophyll-a data were available on Riceford Creek for analysis at this time.

The fish community found at the three stations shows mixed tolerance to low DO. At Station 04LM117, the DO TIV station index score was worse than average, while at Stations 08LM140 and 08LM111 the DO TIV index scores were better than average, indicating a more sensitive community is present at those locations.

The macroinvertebrate community also shows mixed tolerance, but with a stronger signal towards low DO sensitivity. The DO TIV index scores for macroinvertebrates were worse than average for Station 08LM111, and better than average for Station 04LM117. At Station 08LM140, the index score was in the least tolerant quartile, indicating a very DO sensitive community was present. Also, all three sites were either average or just above average with the number of low DO intolerant taxa were present. The percent tolerant taxa were very low for Station 08LM140, as expected, but worse than average for the other two stations. The percentage of EPT individuals was greater than the statewide average for coldwater stations at Stations 04LM117 and 08LM140, but not Station 08LM111. EPT are typically intolerant of low DO levels. Taxa richness can also be decreased with increases in DO flux. The taxa counts ranged from 12 to 26 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the Southern Coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Station 08LM140 had a taxa count of 12 in 2008. Stations 04LM117 and 08LM111 had greater than average taxa counts. The macroinvertebrate community is showing mixed results among the three stations to DO.

The mixed biological response, and lack of chemical information, make it difficult to conclude that DO is a stressor to Riceford Creek at this time. Additional information about DO would be useful in understanding if the biological communities are responding to inadequate oxygen levels or some other stressor. The upstream biological stations of Riceford Creek (headwaters; not in this stream reach) do signal a strong DO tolerant macroinvertebrate community, which may or may not have an impact on this downstream reach.

Nitrate

In Riceford Creek, there were only three available nitrate measurements, one at each biological station at the time of fish sampling. In 2004, Station 04LM117 had 7 mg/L nitrate, and in 2008, Station 08LM140 had 8.3 mg/L and Station 08LM111 had 9.7 mg/L. There was also one sample in 1982 at 5.2 mg/L of nitrate.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys in the coldwater AUID of Riceford Creek in had taxa counts from 12 to 26 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the Southern Coldwater macroinvertebrate class for the Lower Mississippi River Basin is 19. Station 08LM140 had a taxa count of 12 in 2008. Stations 04LM117 and 08LM111 had greater than average taxa counts. There is no longitudinal nor temporal pattern observed. None of the visits resulted in taxa that are intolerant.

Along with the low taxa count, Station 08LM140 also had only two Trichoptera taxa. Station 08LM111 had three Trichoptera taxa and Station 04LM117 had 4. The Trichoptera taxa in Riceford Creek comprised of 7.7 to 10.5% of the total taxa (TrichopteraChTxPct). The resulting very low metric scores for all three stations; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Riceford Creek, the HBI_MN metric score was 3.8 at Station 08LM111, 8.4 at Station 04LM117, and 9.9 at Station 08LM140 (out of 14.3). Station 08LM111 was the only station to fall below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. The HBI_MN values in Riceford Creek ranged from 6.53 to 7.18; again Station 08LM111 had the lowest HBI_MN values. All HBI_MN values were greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Nitrate tolerant taxa was high at Station 04LM117 (21) and Station 08LM111 (28). Station 08LM140 only had 12 nitrate tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. Similar to the nitrate tolerant taxa, the percent of nitrate tolerant individuals was lowest at Station 08LM140 (49%). Station 08LM111 and Station 04LM117 had 67 and 78% nitrate tolerant individuals, respectively. Nitrate very tolerant taxa ranged from eight to 22 taxa and there were no nitrate intolerant taxa present.

With the information available, the macroinvertebrates suggest nitrate as one of the stressors present in Riceford Creek. The macroinvertebrate response indicates that the nitrate stress may be greatest at Station 08LM111.

Suspended sediment

The only chemical data available for suspended sediment were collected during fish sampling in 2004 and 2008 (04LM117: 3.2 mg/L, 08LM140: 26 mg/L 08LM111: 12 mg/L). The values appear fairly normal, with the exception of Station 08LM140, which does appear elevated.

The fish community is comprised of a mixed composition of TSS tolerant and intolerant fish. However, some of the most abundant fish found at these sites include mottled sculpin, brown trout, and johnny darter, all of which are rather sensitive to high TSS. There are only a few species present at these sites which are considered very tolerant to high TSS. At this time the fish community does not point towards a TSS stressor.

The macroinvertebrate community had a worse than average TSS station index score at Station 08LM111 (Table 48). The other downstream stations hovered just below and above the average compared to other stations in the watershed. However, Station 08LM111 was the only station to have the presence of one TSS intolerant taxa, but this is balanced by a high number of TSS tolerant taxa and a high percentage of TSS tolerant invertebrate individuals. The macroinvertebrate metric data does point to a potential TSS stressor at Station 08LM111, with average tolerance at the downstream two stations.

Table 48. Invertebrate metrics relevant to TSS for stations in the Middle South Fork Root River compared to averages for coldwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Invertebrate Individuals	Percentage of Intolerant Invertebrate Individuals	Percentage of Long-lived Invertebrate Individuals
08LM111 (2008)	**16.61**	1	**5**	**16.61**	**0**	**0.96**
08LM140 (2008)	15.11	**0**	2	6.76	**0**	2.33
04LM117 (2004)	**15.16**	**0**	**7**	6.04	**0**	**0.34**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Coldwater stations in the Root River Watershed	15.13	0.99	4.38	9.94	0.95	1.23

With the limited data, mixed results of fish and invertebrate metrics connected to TSS, this stressor cannot be confirmed. Additional TSS data should be collected, particularly at Station 08LM111 where a TSS stressor appears to be more likely.

Physical habitat

Station 04LM117 had a fair MSHA score (60.6). The site was characterized as having no riparian zone, with moderate bank erosion with surrounding land use as row crop. Light shade was present with moderate embeddedness noted. There was boulder and cobble in riffle (riffle comprised 35% of reach). The cover and stability was considered moderate. The quantitative habitat assessment showed a fair amount of embeddedness in the pools and runs. These important habitat details, along with the macroinvertebrate types sampled are found in Table 49.

Station 08LM140 had a good MSHA score (72.6) with a good macroinvertebrate IBI score. The riparian width was considered narrow with no bank erosion and substantial shade in a mix of forest and row crop. There was light embeddedness noted, with boulder and cobble in the riffle. The cover was sparse, and channel stability was high.

Station 08LM111 had a fair MSHA score (63.4). The site was characterized as having a moderate riparian zone with little bank erosion, in a mix of open pasture and row crop. Embeddedness and cover was noted as moderate. The riffle was comprised of gravel and cobble.

There was an abundance of burrowers found at Stations 04LM117 and 08LM111 in comparison to Station 08LM140, which suggests potential fine bedded sedimentation. This is further supported by Table 49, which demonstrates embeddedness at these locations. Similarly, both of these locations had a high percentage of generally tolerant legless invertebrates. The percentage of EPT individuals was greater than the statewide average for coldwater stations at Stations 04LM117 and 08LM140, but not Station 08LM111. The higher percentage of EPT individuals found at Stations 04LM117 and 08LM140 are due to a high percentage of tolerant mayfly, *Baetis* (04LM117: 37%, 08LM140: 27%). The macroinvertebrates that are known to cling to large substrate and woody debris were found in abundance or near statewide averages for coldwater stations. There are some aspects of habitat that are impacting this reach in Riceford Creek. Sedimentation is likely increasing the percentages of burrowers and legless invertebrates, both which demonstrate tolerance to bedded sediment. Additionally, the percentage of EPT taxa is reduced at Station 08LM111. This is also the same site which appears to be showing TSS related stress. While habitat issues do not appear severe, it is still shaping the macroinvertebrate community present in Riceford Creek and is stressing the macroinvertebrate community.

Table 49. Habitat assessment statistics in Riceford Creek.

Habitat Statistics (Quantitative Habitat Assessment)	MIBI	Habitat Sampled	MSHA Score	Percent Riffle	Percent Embedded	Percent Fines	Max Depth of Fines
04LM117	36.23	Riffle/Rock Macrophytes Undercut Bank/Overhanging Vegetation	60.6	25%	31%	11%	2.63
08LM140	62.15	Riffle/Rock Woody Debris	72.60	No data	No data	No data	No data
08LM111	29.52	Riffle/Rock Undercut Bank/Overhanging Vegetation Woody Debris	63.4	31%	31%	28%	2.29

Physical connectivity

No information was available or collected on physical connectivity on this reach. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The main stressors in this coldwater reach of Riceford Creek are habitat and nitrate. The habitat appears limited at all locations related to potential sedimentation issues. TSS has the potential to be a stressor here as well, but there is a lack of connecting (chemical) information to support this stressor at this time. TSS and habitat issues appear to be mostly impacting Station 08LM111, which suggests some potential localized riparian or sediment issues or heavy influence from activities in the watershed upstream. There is a quarry immediately upstream of this location, but the impact of that is not quantified or known. Additionally, the macroinvertebrate response indicates that the nitrate stress may be greatest at Station 08LM111. The response seems consistent with other stressors, and together they appear to be having a cumulative affect at this particular Station (08LM111).

Additional monitoring should be conducted to characterize the duration and magnitude of nitrate, as well as additional source information. The Nitrogen in Minnesota Surface Waters Report has estimated that agricultural groundwater and agricultural drainage comprise of 80% of the nitrogen sources in the Lower Mississippi River Basin (pg. D1-11).

Management practices to reduce sedimentation and improve the riparian corridor in Riceford Creek would be beneficial. Best management practices to reduce nitrate levels in the stream are also important.

There is a lack of good chemical data related to DO in this reach; however, there appears to be some sensitivity to DO in the community found at Station 08LM140. Temperature is suitable and considered normal for this reach.

4.8.4. Bridge Creek

Supporting information

One sampling location on Bridge Creek, Station 08LM103, showed a good IBI score for fish, and very poor IBI score for macroinvertebrates. The macroinvertebrate IBI from 2008 scored six, which is the lowest macroinvertebrate score from all sites in the entire Root Watershed. The dominant fish at this site was brook trout; 52 individuals were caught representing 77% of the total fish population. The macroinvertebrate population numbers are reduced overall, as all IBI metrics are suffering at Bridge Creek when compared to neighboring streams (Figure 4).

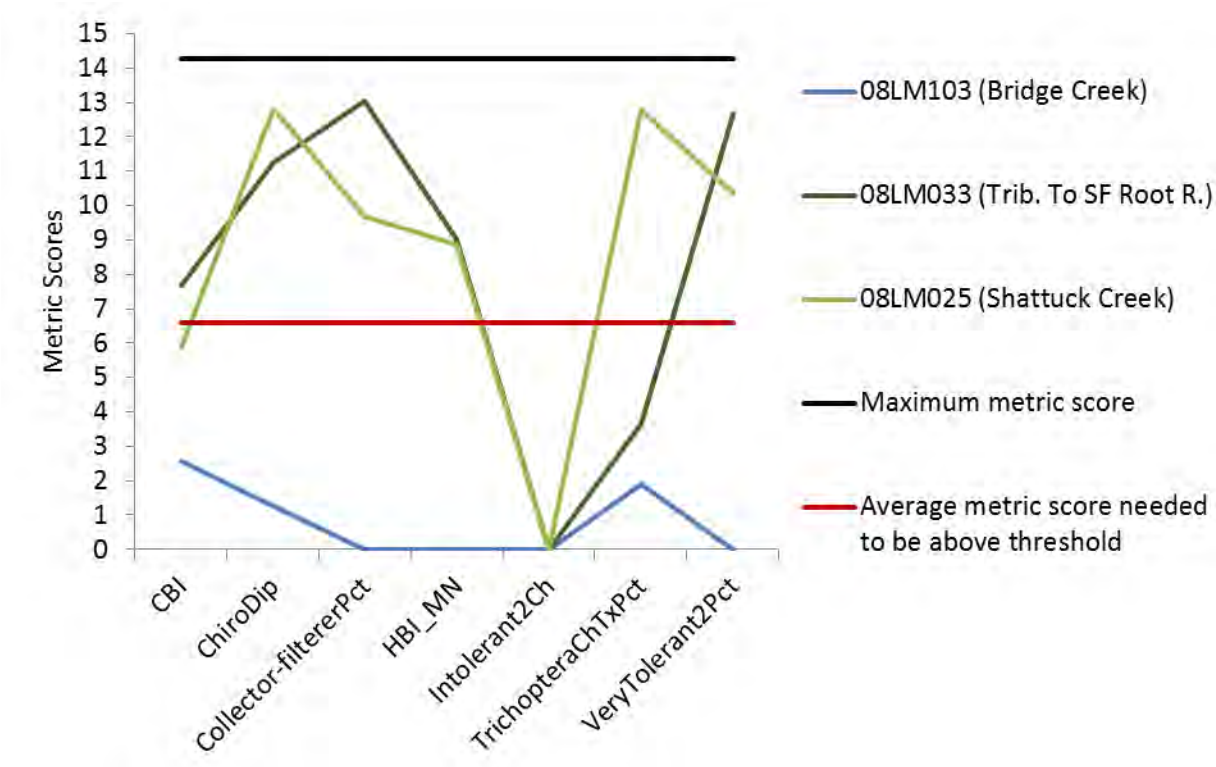


Figure 126. Metric scores for stations in Bridge Creek with comparison to Tributary to SF Root River and Shattuck Creek of the Southern Coldwater macroinvertebrate IBI

Temperature

On August 4, 2008, as the time of fish sampling, the water temperature was 15.1°C. Continuous temperature data from the MDA site has continuous temperature data from 2010-2012. This monitoring site is at the same location as Station 08LM103. The maximum temperature recorded was 20.0°C on June 23, 2010. This peak in temperature does correspond to a rain event. Aside from this event, temperature stays much lower during the summer months. The July and August average temperatures were near 15-16°C. The abundance of brook trout supports the coldwater signature of this stream. The macroinvertebrate sample was dominated by Physa (snails) and some signature coldwater taxa (Baetis, Gammarus). However, there were few macroinvertebrate individuals overall, contributing to the low IBI score. Given the high resolution temperature data and biological species found at this site, temperature is not considered to be a stressor to Bridge Creek.

Dissolved Oxygen

Bridge Creek is in a small tributary to the South Fork Root River, with fairly steep topography. It is expected that due to the gradient within this region, adequate oxygen levels should be present. At biological monitoring Station 08LM103, the DO concentration on the day of fish sample was 9.5 mg/L (August 4, 2008 at 5:30pm). This is the only oxygen data point available for analysis on Bridge Creek.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The co-located MDA monitoring site (S006-648) has 373 total phosphorus values which range from 0.017 to 24.2 mg/L (collected in 2010-2012). The average concentration of those 373 samples is 1.5 mg/L. The minimum concentrations occur with samples taken during baseflow, and maximum concentrations occur with samples taken during rain events. The majority of samples collected were taken during rain events, which elevates the average concentration. It does appear the phosphorus levels are abnormally high within this reach, but during low flow conditions phosphorus levels are meeting standards. The only available pH measurement was on August 4, 2008, pH was 7.86, which is considered normal and within range of the MPCA pH standard. Neither BOD nor chlorophyll-a data were available on Bridge Creek.

The fish community DO TIV index score is better than average compared to other stations in the Root River. This is likely due to a sample dominated by brook trout, which are sensitive to low DO. The macroinvertebrate community has DO TIV index scores which are in the most tolerant quartile when compared to other stations in the Root River. The number of DO intolerant taxa are near average, but the percent tolerant to low DO taxa is quite high, at 12% (compared to the Root River average of 2.7%). While tolerant taxa are high, there is still DO intolerant taxa present in Bridge Creek, and in fair numbers. EPT are typically intolerant of low DO levels. The percentage of EPT individuals in this macroinvertebrate sample was above average for coldwater stations in the Root River. Taxa richness can also be decreased with increases in DO flux**,** and taxa richness was near average for Bridge Creek.

There is limited chemical information, and the conflicting biological response information does not allow a DO stressor in Bridge Creek to be confirmed at this time. It appears the macroinvertebrates may be responding to another stressor that is present. Fish do not appear affected by DO. The high phosphorus concentrations are of concern and may indicate some potential for DO fluctuations to exist in this stream. Some additional chemical data to understand DO dynamics and phosphorus regimes during varying flow conditions would be useful in completely ruling DO out as a stressor in Bridge Creek.

Nitrate

The nitrate value collected during fish sampling on August 4, 2008, at Station 08LM103 was 2.5 mg/L. The MDA monitoring Station S006-648 had 364 nitrate samples available for analysis. The results of those samples ranged from 0.4 mg/L to 10.2 mg/L from samples collected between 2010 and 2012. The average concentration of those samples is 2.8 mg/L. On May 22, 2011, one event resulted in a short-lived spike in nitrate concentration (13 samples from this event alone) with a duration of 17 hours over 4 mg/L. The entire record aside from this event had nitrate concentrations lower than 4 mg/L.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

At Station 08LM103, the macroinvertebrate survey in Bridge Creek had 18 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class in the Lower Mississippi River Basin is 19. At Station 08LM103, there were three intolerant taxa present; well above average for coldwater stations in the Root (0.6 taxa). The number of Trichoptera taxa (3) is just below the coldwater average (3.8 taxa), comprising of 8.6% of the total taxa (TrichopteraChTxPct) and a resulting metric score less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. At Station 08LM103, in Bridge Creek, the metric score was zero (out of 14.3), below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM103 the HBI_MN value was quite elevated with 8.06 in 2008, greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM103 had 24 nitrate tolerant taxa (86.6% individuals); and 18 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI. At 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI, and at 22.60 nitrate tolerant taxa there is a 10% probability of meeting the Southern Coldwater MIBI. There was one nitrate intolerant taxa present in 2008.

Bridge Creek had presence of intolerant taxa, but it had low taxa count, low TrichopteraChTxPct resulting in a low metric score, a HBI_MN metric score of zero due to a high value, and a high number of nitrate tolerant taxa. The macroinvertebrate data is suggestive of a potential of nitrate as a stressor, or is due to another stressor(s) adding to the biological response. Although nitrate is lower than other reaches in the Root River Watershed, there have been documented short bursts of nitrate. At this time, nitrate cannot be confirmed as a stressor, nor can it be ruled out as a stressor. Further refinement of our biological understanding at this level of nitrate would be beneficial. Also an extensive data set at the same time of nitrate and macroinvertebrate data would be helpful.

Suspended sediment

The TSS concentration collected during fish sampling at Station 08LM103 was fairly low, at 6.8 mg/L. This level would be expected as the flow was noted to be normal on August 4, 2008. The MDA site has continuous turbidity data available from 2010-2012. Even though the site shows some dramatic increases in turbidity, the duration is not sustained and often clears up within a few hours to one day. TSS data from the Bridge Creek MDA site also show some very high TSS concentrations during storm events. Of 357 samples collected from 2010-2012 (via auto-sampler, focused on storm events) the average TSS concentration and maximum TSS concentrations recorded are very high. However, approximately 80% of fish individuals in Bridge Creek belong to the most sensitive group of species to elevated TSS concentrations. This also supports that suspended sediment issues in Bridge Creek are episodic and not sustained.

At Station 08LM103, there were no intolerant macroinvertebrates and less than 1% long-lived macroinvertebrates, which often decrease with increases in TSS. The macroinvertebrate index score for TSS was 16.53 worse than the average for coldwater stations in the Root River watershed (15.13). The station at the time of sampling had two taxa tolerant to TSS and no intolerant to TSS. The survey had only 5.43% of the individuals in the survey considered tolerant to TSS; the average for coldwater stations in the Root River is 9.94%. Although there are no intolerant macroinvertebrates to TSS, it also shows that the tolerant are not dominating the population either. Four of the six metrics analyzed for TSS stress resulted in conditions poorer than the average of coldwater stations. It is likely that elevated TSS is playing a role in shaping the macroinvertebrate community.

Using the current information, a TSS stressor cannot be confirmed in Bridge Creek at this time. Chemical evidence does show some potential for elevated TSS, but the biological response is mixed. This location should be monitored over time to ensure that TSS levels are not affecting the biology.

Physical habitat

The MSHA at Station 08LM103 resulted in a good score (73). Although the total score was good, photographs and macroinvertebrate visit notes suggest some poor habitat conditions that would be critical for macroinvertebrates. Key elements of habitat were available for the fish, and lacking for the macroinvertebrate community.

The surrounding land use at the site is forest and row crop with a riparian zone that is wide to moderate (ranging from 30 to 300 feet), with little bank erosion present at the time of fish sampling. Aerial photos demonstrate a non-existent wooded riparian corridor in the lower reaches of the watershed (lower 0.5-one mile), where Station 08LM103 is located. Above this area the riparian corridor is more heavily wooded. Channel morphology was good, with moderately high stability.

Flow throughout the sampling reach was slow, and the runs and pools had a dominant substrate of sand/silt/clay. Riffles only were present in approximately 5% of the reach and some gravel with sand was noted in the small section of riffle habitat. In similar small coldwater streams a greater percentage of riffle habitats are typical. The pools and runs were dominated by gravel and sand. Extensive cover was noted, with multiple cover types including undercut banks, overhanging vegetation, deep pools, and macrophytes. The site is lacking good quality riffles and woody debris, as the only habitat available to sample invertebrates was under cut banks and overhanging vegetation.

The macroinvertebrates that cling, known as clingers, are reduced in comparison to other coldwater reaches in the state. At Station 08LM103, the percentage of clingers was only 4.3%, where the average for macroinvertebrate coldwater stations in the state was 36.9%. The lack of clingers at this station is due to the lack of coarse substrate and woody debris. Over half of the macroinvertebrates sampled were non-insects and 62.5% of the macroinvertebrates were legless, much higher than the average for coldwater stations. The percentage of macroinvertebrates that climb is quite high for the Root River Watershed (39.7%). This high percentage is likely due to their prevalence on overhanging vegetation, which was the main habitat sampled in this reach. The percentage of swimmers, burrowers, and sprawlers were each near the average for the Root Watershed. The shifts of macroinvertebrates adapted to climbing and the lack of clingers along with the high amount of legless and non-insects are strong evidence for habitat as a stressor to the macroinvertebrate community.

An upstream perched culvert is likely contributing to some instability and changes in the overall stream slope and sediment dynamics including transportation and deposition through the sampling reach. Figure 6 shows a perched culvert on the upstream end of the biological sampling reach. Further discussion of the perched culvert is addressed in the next section on connectivity.

A monitoring report from Neal Mundahl (Winona State University, December 2011) showed some local site differences from 2010 to 2011. In 2011, beaver had constructed a dam within the sampling reach and as a result macroinvertebrate and fish communities were slightly different between the two years. It is not known if a beaver dam was a factor during 2008 sampling, but it may account for changes in habitat in the sampling reach. The biological sampling noted slow water, and a high number of swimmer taxa were sampled compared to other Southern Coldwater macroinvertebrate sites.

Figure 127. Bridge Creek biological monitoring Station, 08LM103 (middle of reach)

Physical connectivity

Biological monitoring Station 08LM103 is located downstream of John Deere Road. At this road crossing, the culvert is slightly perched which may disrupt fish passage in the future if the drop increases. There are migratory fish present at 08LM103, which is downstream of the perched culvert. It is not known if migratory fish are present upstream of the culvert. The potential for beaver dams in this area could also disrupt fish passage, but are typically temporary given seasonal floods and high water. While connectivity is not a stressor to Bridge Creek at this time, it should be monitored over time to ensure adequate fish passage.

Figure 128. The upstream end of biological monitoring Station 08LM103, looking upstream at culvert on John Deere Road

Strength of evidence, conclusions, and recommendations

Habitat is the main stressor identified that is affecting the macroinvertebrate community in Bridge Creek. While the habitat appears sufficient for fish, macroinvertebrate habitat is lacking. The dominant substrate is sand and silt, and very little riffle habitat is present (only 5% of entire reach is riffle). There were also no woody debris and lack of riparian corridor. The culvert on the road crossing upstream is a likely contributor to the habitat issues seen downstream. While this isn't the only cause present, it is making an impact on the channel and sediment delivery and transport within the biological station.

Although nitrate is lower than other reaches in the Root River watershed, there have been documented short bursts of nitrate. At this time, nitrate cannot be confirmed as a stressor, nor can it be ruled out a stressor. Further refinement of our biological understanding regarding duration at this level of nitrate would be beneficial.

Additional biological Information upstream in the watershed would help determine if better habitat exists and macroinvertebrates are found in higher numbers. If not, it may suggest some other stressor is present that has not been identified. More information is currently being collected by MDA regarding pesticides in this watershed. This study collects very high resolution water quality data at small scales (three sites in the Root River Watershed.) A sample from June 21, 2011, showed an elevated acetachlor result (20.2 ug/L). This was the highest concentration of acetachlor sampled anywhere in the state in 2011 and has ever been detected anywhere in the Root basin over all sampling years. While this does not violate current standards since it was a grab sample (standards are based on a four-day duration; 3.6 µ/L chronic, 86 µ/L acute), additional pesticide information will help with identifying if pesticides are a potential stressor in Bridge Creek. No other sample collected at Bridge Creek has violated water quality standards for pesticides. More information on this sample and others in the watershed can be found in the Root River pesticide section of this document, Section 3.1.1. of this report.

Temperature appears suitable in this reach and is not considered a stressor. However, as additional chemical information is collected on Bridge Creek, it should be analyzed. Both TSS and DO did not provide enough biological response information to confirm stressors at this time, but should be considered as potential stressors to this reach. This may require supplemental monitoring for DO, as that parameter is not included in the MDA dataset.

4.8.5. Riceford Creek (Warmwater)

Supporting information

This stream reach (519), includes two biological stations, 08LM100 and 04LM060. Both sites score near impairment threshold, one just above and the other just below. Severe bank erosion and excess sedimentation were noted at both locations, particularly at 08LM100. The macroinvertebrate IBI metrics appear to be showing stress similarly as shown in Figure 129. The metrics scoring poorly among the two sites include: taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TVs (Intolerant2Ch), and taxa richness of predators (excluding chironomid predator taxa) (Predator). Other metrics with a moderate amount of response include: POET, taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (baetid taxa treated as one taxon), and overall taxa count (TaxaCountAllChir). Clinger taxa (ClingerCh) had good scores at both stations, as well as Trichoptera taxa (ThrichopteraChTxPct).

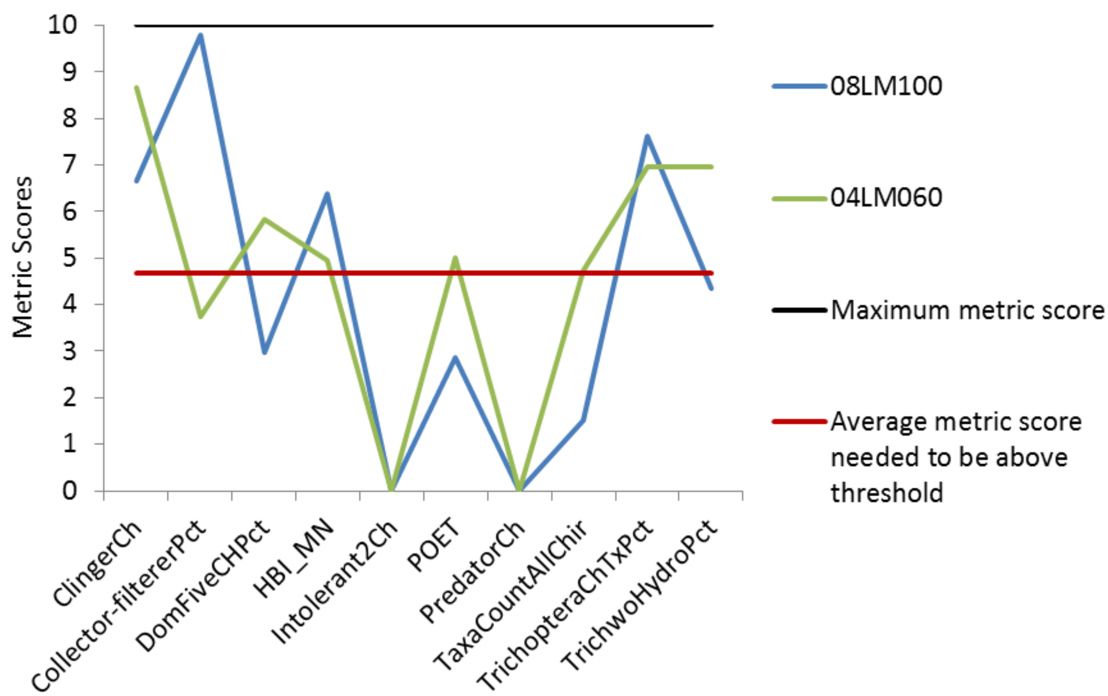


Figure 129. Metric scores for stations in the Riceford Creek of the Southern Forest Streams GP invertebrate IBI

Temperature

Very little temperature data was available for this stream reach. Temperature was measured during fish sampling at each site. At Station 08LM100, the water temperature was 18.2°C. At Station 04LM060, the water temperature was 18.0°C. There were also seven data points from 1967-68, with a maximum of 20.56°C. Temperatures in this range are considered acceptable and normal for warmwater streams. Even though limited information is available, the limited data does not show elevated values, and temperature is not a likely stressor at this location on Riceford Creek.

Dissolved Oxygen

Dissolved oxygen data was also limited for this stream reach. DO was measured during fish sampling. At Station 08LM100, the oxygen was 9.22 mg/L, at 9:00 am on July 16, 2008. At Station 04LM060, the oxygen was 11.1 mg/L.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. During fish sample, the pH at Station 04LM060 was 8.4. At Station 08LM100, the pH was 8.13. Both of these values are considered normal, and fall within the pH standard (6.5-8.5). Total phosphorus at 08LM100 was elevated at 0.152 mg/L, in conjunction with an elevated TSS reading as well, TP was low at 04LM060 (0.04 mg/L)

A stream site (S000-124) had some chemistry data available from 1967-1968 which includes TP, BOD, pH data. However, given the time that has lapsed since these samples were collected, the data were not used for analysis.

The fish community for these two locations had a DO TIV index score which is considered slightly worse than average for Root River Stations. The community is not dominated by tolerant or intolerant individuals. The macroinvertebrate community at Station 08LM100 does show sensitivity to low DO. The DO TIV index for this location scored better than average when compared to other Root River stations. The number of DO intolerant individuals and percent tolerant to low DO also scored better than average, with the percent tolerant in the most sensitive quartile. EPT are typically intolerant of low DO levels. The percentage of EPT individuals was well above average for Station 08LM100, but near the statewide average at Station 04LM060. Taxa richness can also be decreased with increases in DO flux**.** Similarly, taxa counts were above average for 08LM100, and less than average for 04LM060.

Given the lack of chemical information, and strong biological connection, a DO stressor does not appear likely in Riceford Creek. Additional information about DO dynamics would be useful in ruling this stressor out completely.

Nitrate

The only nitrate information available on this stream reach was taken during the time of fish samples. On July 16, 2008, at Station 08LM100, the result was 6.2 mg/L nitrate. Station 04LM060 had a concentration of 3.9 mg/L on June 29, 2004. Station 08LM100 had an above average taxa count and Station 04LM060 had a below average taxa count. Both stations had an above average number of Trichoptera taxa and lacked intolerant taxa. Similarly, neither of the biological stations had nitrate intolerant taxa. Station 08LM100 had 65.3% nitrate tolerant individuals and Station 04LM060 had 70.9% nitrate tolerant individuals. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. There is a mixed biological response that does not conclude strongly whether nitrate is a stressor with limited nitrate data. At this time, nitrate is inconclusive as a stressor in Riceford Creek (519). Further information should be collected on the magnitude and duration of nitrate in Riceford Creek.

Suspended sediment

The only suspended sediment information available on this stream reach was taken during the time of fish sample. At Station 08LM100, the TSS result was 66 mg/L, which is elevated. At Station 04LM060, the TSS result was 12 mg/L.

The fish community is comprised of fish that are generally more sensitive to high TSS concentrations. Both biological stations in this reach had TSS TIV aggregate scores in the most sensitive quartile indicating a community that is sensitive to high TSS. The macroinvertebrates in the warmwater reach of Riceford Creek were neither highly sensitive nor highly tolerant (Table 50). Both stations had TSS station index scores less than the average and Station 08LM100 was in the more sensitive quartile of the warmwater stations in the Root River. Although both stations have a lack of general intolerant macroinvertebrates and long-lived macroinvertebrates, this is likely due to a different stressor since the index scores are so low.

Table 50. Invertebrate metrics relevant to TSS for stations in the Riceford Creek compared to averages for warmwater stations in the Root River watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Invertebrate Individuals	Percentage of Intolerant Invertebrate Individuals	Percentage of Long-lived Invertebrate Individuals
04LM060	16.79	**0**	**10**	22.66	**0**	**1.41**
08LM100	15.58	**0**	5	15.58	**0**	**0.96**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed	17.96	1.52	9.32	35.45	0.48	3.16

The biological and chemical data do not suggest TSS is a stressor at this location on Riceford Creek. The fish community remains sensitive to TSS, the macroinvertebrates show a slight trend towards tolerance, but the data are weak. In addition, a weak chemical dataset does not allow further connections to be made.

Physical habitat

The surrounding land use in this area is predominantly row crop. The riparian zone is narrow with heavy bank erosion and heavy shade. While fish habitat appears available, macroinvertebrate habitat is lacking. At Station 08LM100, the only habitat sampled was woody debris. The channel substrate was moderately embedded, with gravel and sand in the riffles (only 5% of the reach was riffle) and predominately sand/silt/clay substrate in the pools and runs. The water color noted as brown at the time of fish sampling and corresponds to an elevated TSS sample. Moderate cover was present, with deep pools and woody debris noted as only cover types.

Upstream at Station 04LM060, the habitat characteristics appear similar. No riffle was present at the site, and the reach had 92% fines and was considered 31% embedded. The flow at the site was measured at 26.8 cfs (0.76 cubic meters/sec). There was not an abundance of burrowers found at Station 08LM100, which would suggest potential sedimentation issues, but there was a higher percentage of them found at 04LM060 (12.7%). The percentage of EPT individuals was well above average for Station 08LM100, but near the statewide average at Station 04LM060. The macroinvertebrates that are known to cling to large substrate and woody debris were found in abundance at Station 08LM100, but were less than average at Station 04LM060. However, at both sites, the clinger metric did score fairly well; above average needed to be above the IBI threshold (Figure 129). In addition, the percentage of more tolerant legless macroinvertebrates was much higher at Station 04LM060. Conversely, the macroinvertebrates known to climb were found in abundance at Station 04LM060 and much less at Station 08LM100, potentially due to the habitats sampled. These habitat related metrics show that the habitat is limited in this reach; overall lacking quality, diverse habitat. While the issues may not be the same at both locations, habitat is considered a stressor in Riceford Creek, and appears to be more dramatic at Station 04LM060.

Figure 130. Biological Station 08LM100; woody debris and eroding banks.

Physical connectivity

No information was available or collected on physical connectivity on this reach. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The main stressor identified on this reach is habitat. The habitat related metrics for macroinvertebrates show that the habitat is likely limited throughout the reach; lacking overall quality, diverse habitat. While the issues may not be the same at both locations, Station 04LM060 appears to be showing the most stress. Photographs and biological response suggest the stream channel is experiencing some severe bank erosion which is resulting in sedimentation and habitat loss, especially at Station 04LM060. No riffle was present at that location, and siltation and embeddedness was documented. Photographs also show a large amount of woody debris in the channel which may be impacting stability and stream bank erosion.

Limited information was available TSS and DO in these reaches, and additional chemical information could help in understanding the potential influence of those stressors. However, the biological evidence does not provide strong indication that either of these two stressors is likely. Limited chemical information and mixed biological response also give inconclusive results to a nitrate stressor. More information on the magnitude and duration of nitrate levels in this reach would be helpful.

4.8.6. Upper South Fork (Headwaters)

Supporting information

Station 04LM113 was first sampled in 2004. It was resampled again in 2011 for fish and macroinvertebrates. A third sampling for macroinvertebrates was done in 2012. In 2004 for fish sample was considered inadequate, due to high water and few fish captured, which prompted the fish resample in 2011. The fish IBI score improved dramatically in 2011, and scored above impairment thresholds.

The macroinvertebrates IBI score was very low in 2004, and then again in 2012 (5.79 and 6.34, respectively). In 2011, more habitat types were available for sample and the macroinvertebrate score was elevated to 31, although was still below impairment threshold. Varying habitat and flow are potential contributors to the differences between the three years.

- flow on August 23, 2004; 0.29 m3/sec or 10.24 cfs (taken during fish sampling)
- flow on September 28, 2011; 1.7 cfs (Amherst Monitoring Station)
- flow on July 30, 2012, 0.5 cfs (Amherst Monitoring Station)

The macroinvertebrate IBI metrics at Station 04LM113 are reduced in almost all categories, with slight variations among different years (Figure 131). In 2012, multiple metrics score very poorly compared to other years, yet the metric that is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN) scored better than other years. The increase in percentage of clingers (ClingerCh) in 2011 may have been due more adequate flow conditions or increased habitats sampled. The taxa count was also higher this year compared to other years.

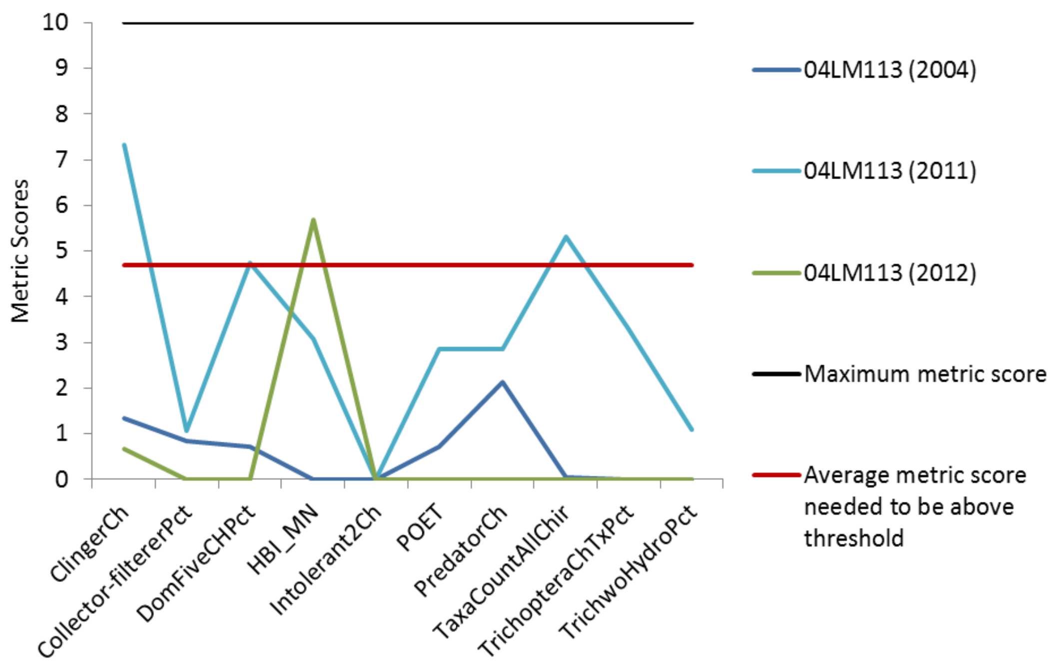


Figure 131. Metric scores for stations in the Upper South Fork Root River (04LM113) of the Southern Forest Streams GP macroinvertebrate IBI

Temperature

There were a total of 64 temperature measurements at Amherst monitoring site S004-851, which is less than one mile downstream of Station 04LM113. In 2004 the temperature measurements at time of fish sampling was 12.9°C. In 2011, when the site was resampled, the temperature was 25.1°C. A multiparameter sonde was deployed in September 2011 for two weeks, and the maximum temperature recorded during that time was 25.61°C.

The South Fork Root Amherst monitoring site also shows some fairly high stream temperatures; measured with a continuous turbidity sensor. The sensor was often times close to the water surface, due to the lack of water depth, so it's possible some of these values are not completely representative of actual in stream temperatures.

1. 2008 Max: 26.9°C on July 16
2. 2009 Max: 30.3°C on June 23 (corresponds to max air temp for this site, 2009)
3. 2010 Max: 28.5°C on July 17
4. 2011 Max: 29.7°C on July 31
5. 2012 Max: 34.3°C on July 6 (max air temp on this day at this site was 98°F; or 36°C)

Regardless, temperatures are clearly linked to flow conditions on any given year. It is possible that temperature reaches unsuitable levels during warm conditions and low flow years. At this time, temperature is not considered a likely stressor, however there is some indication this should be monitored to ensure adequate temperatures exist within this reach.

Dissolved Oxygen

At Station 04LM113, the DO data that was collected during fish sampling was 9.05 mg/L on June 22, 2004 and 10.4 mg/L on August 24, 2011. One additional data point was collected just downstream of monitoring Station S004-851, at 8.21 mg/L, on July 14, 2010.

A multiparameter sonde was deployed at Station 04LM113 from September 9 to 27, 2011 (Figure 132). These were warm and dry baseflow conditions, when the likelihood of seeing low DO levels is common. During this time the DO maximum was 20.04 mg/L on September 23, 2011 and minimum was 4.76 mg/L on September 13, 2011. The average DO flux was about 10 mg/L each day; and maximum DO flux was 14 mg/L on September 13, 2011 (Figure 132). August, which had higher air and water temperatures, would have potentially seen multiple violations of the 5 mg/L standard. Only for 2.5 hours on September 13 did the DO levels go below the 5 mg/L standard.

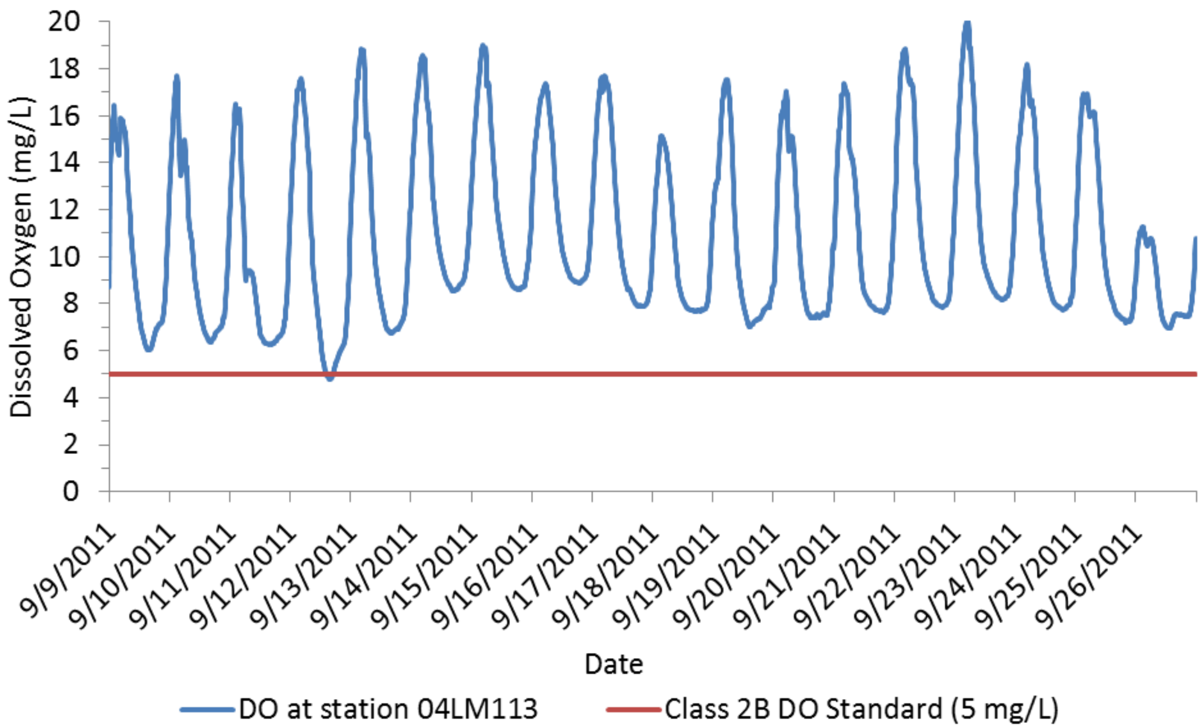


Figure 132. Diurnal DO data from Station 04LM113, September 9 - 26, 2011

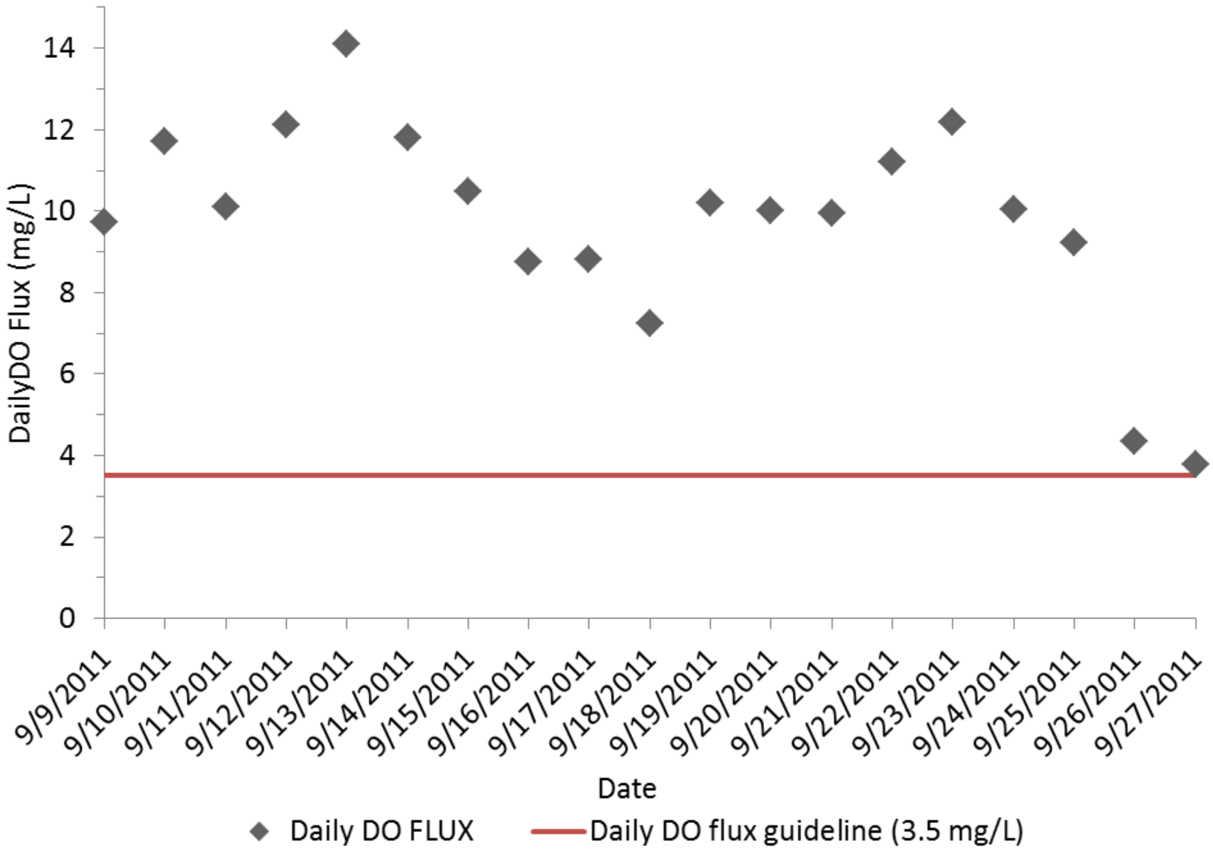


Figure 133. Daily dissolved oxygen flux at 04LM113, in September 2011.

For comparison, a sonde was placed downstream a few miles, in the coldwater reach of this stream, during the same timeframe (located near Deer Road and Station 04LM069). At this site the DO values were much different. The maximum DO concentration was 12.31mg/L on September 17, 2011 and minimum of 8.09 on September 13, 2011. The average DO flux was only about 3 mg/L. The maximum temperature was only 14.7°C in this coldwater section.

During low flow periods, there is not much water to sustain this stream. While the sonde was deployed, the daily average flow at the Amherst monitoring site (just one mile downstream) was one- two cfs on average. Often times, the water velocity is slow and stagnant. In 2012, the site was flowing less than two cfs for the majority of the open water season (very dry year). In contrast, the maximum discharge recorded at the site (from 2008-2012) was 1,534 cfs on June 8, 2008.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The Amherst monitoring Station (S004-851) was sampled for phosphorus 74 times from 2008-2011. The range of concentrations sampled was 0.047-2.78 mg/L. The average phosphorus value was 0.453 mg/L. During biological sampling the phosphorus concentrations were elevated; 0.143 mg/L in 2004, and 0.378 mg/L in 2011. Analysis of 21 phosphorus values from 2008-2010, taken during baseflow conditions (May-October), showed an average TP concentration of 0.162 mg/L for samples with a TSS concentration of less than 30 mg/L. This shows that phosphorus concentrations remain elevated, even during baseflow conditions. In 2004, the pH result during biological sampling was 8.18, then 8.38 in 2011. Also in September 2011, the sonde recorded pH values ranging from 7.6-8.76. Neither BOD nor chlorophyll-a data were available for analysis at this time.

While the fish community at Station 04LM113 is not impaired, the fish species present at the station are very tolerant to low DO concentrations. Statewide data on DO tolerance values were calculated for Station 04LM113 (Figure 134). Over half of the fish community is made up of fish species that are considered to have the highest tolerance to low DO in the Root River basin (common shiner, fathead minnow, johnny darter). Additionally, there were no fish at this station that fall in the lowest quartile indicating the most sensitive to low DO concentrations. The station in this reach (04LM113), had a DO TIV aggregate score (6.94 in 2011), which is in the lowest 10% of all sites in the Root River, indicating the fish community found here is comprised of the most DO tolerant species compared to other biological stations in the Root River watershed.

The macroinvertebrate community shows a similar response. The macroinvertebrate DO TIV index score was in the most tolerant category compared to all Root River stations. In addition, only two low DO intolerant taxa were present, which is very low compared to the Root River average of ten taxa. The percent tolerant to low DO is also much worse than average, at 14%.

EPT taxa are generally sensitive to low DO and large DO fluxes, which can be reflected in the metrics percentage of EPT individuals and number of EPT taxa. The percentage of EPT individuals during all three visits ranged from 0 to 5%; well below the median for the watershed (39%). The percentage of EPT individuals surveyed was also much lower than the average for the Southern Forest Streams GP class in the Root River watershed, 18.5%. Similarly, the average number EPT taxon in the Southern Forest Streams GP class was 4.7. In 2011, there were five EPT taxa, just above the average for the invertebrate class; and in 2004, there was one taxon, and in 2012, there were no EPT taxa.

The HBI_MN metric, based on tolerance to pollution, had a variable response with the differing years data was collected. In 2004 and 2011, the HBI_MN metric scored below the average metric score needed to be above the threshold. In 2012, the HBI_MN metric did much better.

Taxa richness is also known to decrease with increases in stress related to DO. The macroinvertebrate taxa richness was variable during the three visits with 12, 20, and eight taxa (2004, 2011, and 2012 respectively). Within stations of the Southern Forest Streams GP class within the Root River Watershed the average taxa richness was 17.2. Two of the visits had taxa richness less than the average; these years also exhibited lower flows than 2011. Taxa richness can respond to numerous stressors which may have been in play in 2004 and 2012, and not in 2011.

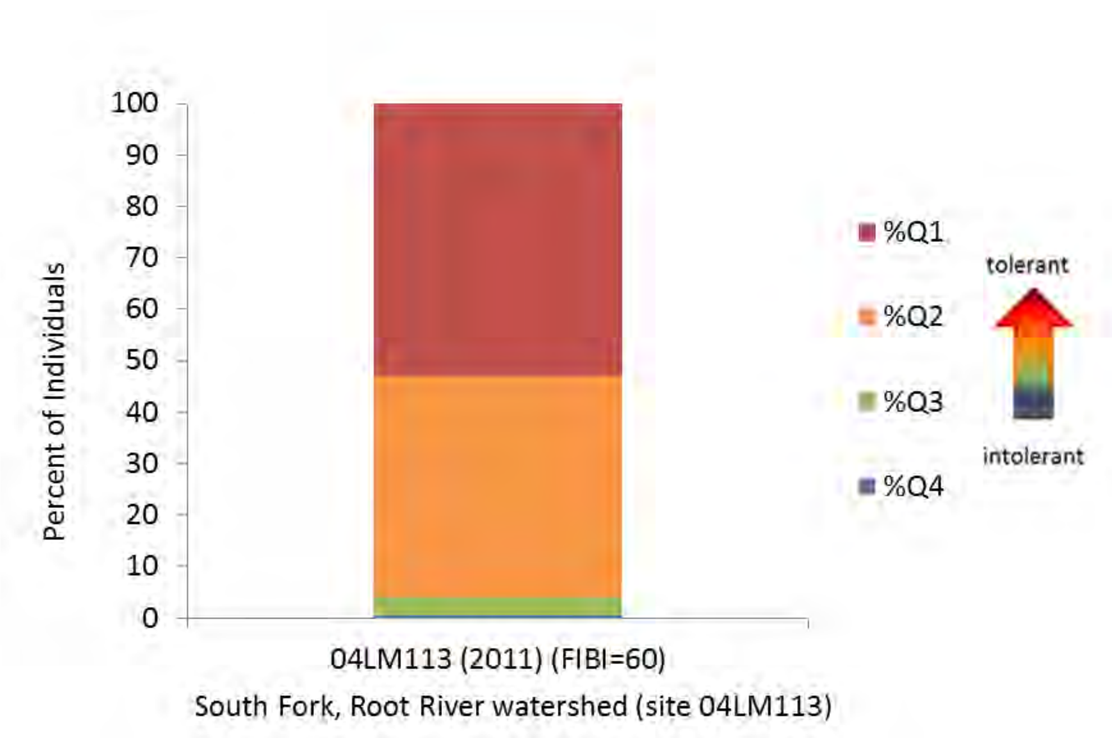


Figure 134. Dissolved oxygen tolerance indicator values for Station 04LM113 based on individuals present in fish community (2011).

There were violations of the DO standard, along with a large daily flux (10 mg/L) documented in September 2011. The conditions at this time period were not optimal for seeing the lowest DO concentrations possible in this stream. A drought year, similar to 2009 and 2012, could have produced even lower DO concentrations. The data was collected in September, and not the warmest months (July-August), which are the most common time periods to observe low DO levels. Total phosphorus concentrations are elevated in this reach not only during events, but during baseflow conditions as well. The phosphorus concentrations are likely contributing to the in-stream productivity and subsequent DO issues. The flow conditions in this reach are also variable, which have the potential to impact DO levels. The fish community, while not impaired, is comprised of very DO tolerant fish individuals. The macroinvertebrate community overall has very few intolerant and many tolerant to low DO taxa present compared to other sites in the Root River. The chemical and biological information supports that DO is a stressor in the Upper South Fork Root River.

Nitrate

At Station 04LM113, on June 22, 2004, the nitrate concentration was 7.8 mg/L. On August 24, 2011, the nitrate concentration was 4.7 mg/L. At the downstream Amherst Monitoring Station S004-851, 76 samples showed a maximum of 9.6 mg/L, with an average of 4.76 mg/L, from 2008-2012. Nitrate concentrations typically stayed above 5 mg/L during wet years, then were diluted during snowmelt, but typically were elevated during events. In 2009, a dry year, many nitrate samples were below 3 mg/L. In this area, there are less groundwater inputs (proven by warmer water temperature; lack of flow). The nitrate concentrations in the stream are heavily influenced by the Karst hydrology and surrounding land use.

In 2004 and 2012, Station 04LM113 had less than average taxa counts, and in 2011, the taxa count was just greater than the average for similar stations in the Lower Mississippi River Basin. Similarly, in 2004 and 2012, there were no Trichoptera taxa, but in 2011, there were two, yet that is still below the average for the Southern Forest Streams GP stations in the LMB. None of the visits resulted in intolerant taxa. In 2004, there were 94.4% nitrate tolerant individuals. In 2012, they were similarly as high with 92.5%. In 2011, the percentage of nitrate tolerant individuals was high, but lower than the other two sampling years, with 80.5%. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (Class 6) MIBI, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. Only the 2011 survey resulted in one nitrate intolerant taxa. Nitrate is a stressor to the macroinvertebrate community, as expressed with very high percentages of nitrate tolerant individuals and additional biological response.

Suspended sediment

During fish sampling TSS concentrations were 21 mg/L in 2004 and 110 mg/L in 2011. During assessment in 2011, this stream reach was added to the impaired waters list as a new turbidity listing. The downstream coldwater AUID (511) is also listed for turbidity impairment. The Amherst monitoring Station S004-851, had 73 TSS values from 2008-2011. The maximum concentration sampled was 2300 mg/L, minimum of six, with an average of 202 mg/L of 73 values. Based on those values, the stream was exceeding 30 mg/L (draft TSS standard) 64% of the time. While the samples were collected and aimed towards rain events, there were also many samples collected during baseflow conditions.

Continuous turbidity data was analyzed from the Amherst monitoring site S004-851 from 2008-2012. The data confirms turbidity listing, and turbidity issues seen in this reach. Using power regression, lab turbidity and field turbidity with the continuous turbidity sensor were related, and then the percent exceedence rate, based on the 25 NTU turbidity standard was calculated (Table 51).

Table 51. Percent exceedances of 25 NTU from 2008 to 2012 at Amherst monitoring site S004-851

Year	Percent Exceedances of 25 NTU
2008	16%
2009	5%
2010	24%
2011	25%
2012	10%

Using all of the data in the dataset, the calculated percent exceedence of the turbidity standard was 16% (above 10% considered impaired for assessment purposes). The maximum consecutive number of days above the water quality standard of 25 NTU was 9.4 days. The only other place (with available turbidity sensor data) which had a longer duration above the water quality standard was the South Fork Houston outlet site, at 9.5 days. Both of these examples represent longer periods of time where the stream has sustained turbidity.

The macroinvertebrate community is not overly tolerant or sensitive to TSS (Table 52). The TSS station index scores fall near average for warmwater stations in the Root River. There is a lack of TSS intolerant and generally intolerant macroinvertebrates, along with a low percentage of long-lived macroinvertebrate individuals. The taxa count for this reach is also low, which may explain why there are fewer overall tolerant taxa present. There aren't high percentages of tolerant individuals, but the lack of intolerant taxa does point to stress. Elevated TSS is playing a role in shaping the macroinvertebrate community, but likely is not the only stressor present.

Table 52. Macroinvertebrate metrics relevant to TSS for stations in the Upper South Fork Root River compared to averages for warmwater stations in the Root River watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Invertebrate Individuals	Percentage of Intolerant Invertebrate Individuals	Percentage of Long-lived Invertebrate Individuals
04LM113 (2004)	**18.07**	**0**	5	17.29	**0**	**0.7**
04LM113 (2011)	16.44	**0**	5	8.71	**0**	**2.16**
04LM113 (2012)	**18.04**	**0**	2	9.35	**0**	**2.49**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River Watershed	17.96	1.52	9.32	35.45	0.48	3.16

In 2011, the fish community showed species with mixed tolerance to TSS. The 2004 fish sample was not used due to the high water when the survey took place. The TSS TIV aggregate score for this site in 2011 was near average for warmwater sites in the Root River. The dominant species present were slightly sensitive high TSS (approximately 75%), with a few tolerant species (19% fathead minnow) also present. Therefore the fish community does not show a strong signal towards high TSS.

While the chemical data supporting TSS is strong, the biological response is somewhat weak. Both fish and macroinvertebrates do not show a strong signal towards TSS stress, but are not intolerant either. However, there are some indications the communities are being affected by TSS related issues. The complexity of varying years of sampling and flow conditions during sampling adds difficulty in understanding the biological response completely. A study by Winona State Water Resources Center determined that this reach had high levels or organic fractions of suspended sediment concentrations (SSC) during baseflow conditions which were likely tied to near stream agricultural land uses (Pletta and Dogwiler, Year). Other stressors appear to be making more of an impact to biology at this time and TSS is a secondary stressor to more prominent stressors.

Physical habitat

The surrounding land use in the area is pasture and row crop. The riparian zone was noted as narrow to moderate in 2004, with moderate bank erosion. The water was stained/brown in color, and the substrate was considered to be moderately embedded. A detailed habitat assessment was completed in 2004, and the reach was comprised of 10% riffle, and 57% run. Fines were measured at 23%, and embeddedness at 44%. Boulder and cobble were in the riffle, but cobble and clay were dominant substrate types found in the pools. Moderate cover was present.

In 2004, the only habitat sampled for macroinvertebrates was macrophytes. This may be attributed to the flow conditions during the 2004 sampling which were considered higher than normal. In comparison, 2011 had multiple habitat types sampled: riffles, undercut banks and woody debris (snags). This visit noted many of the same characteristics as 2004, except sand and silt were the dominant substrate in the pools and runs, and cover was noted as sparse. It was also noted that the upper half of the reach was low gradient, and the downstream half mostly riffle. The MSHA score was 40 in 2011 compared to 70 in 2004. However, it's likely the 2004 score not likely representative of conditions. The macroinvertebrate sample on July 30, 2012 had riffles as the only habitat sampled. It's possible, given the dry year that more riffle habitat was exposed compared to previous years. The flow at the monitoring station (Amherst) was 0.5 cfs on July 30, 2012.

There was an abundance of burrowers found in the two years riffles were sampled (2011 and 2012), which demonstrates sedimentation issues (23% and 68% respectively). The percentage of EPT individuals was much less than the statewide average for Southern Forest Streams GP macroinvertebrate class (EPT was less than 5% at all three invertebrate sampling visits). The percentage of generally tolerant legless macroinvertebrate individuals was dramatically high at all visits (between 81% and 97%). The macroinvertebrates that are known to cling to large substrate and woody debris were not greatly abundant (below statewide averages for this class), except in 2011 when they were slightly above average. This may have been due to not only riffles being sampled but woody debris, two places where clingers are more common. However, in 2011 the number of individuals that climb was reduced compared to 2004 and 2012 when percentages were above average, would be expected since their habitat was not sampled. Overall, MSHA information, site conditions/photos, and macroinvertebrate response strongly support habitat as a stressor in this reach. It does seem that different flow years exhibit different habitat type stress. Substrate embeddedness and lack of quality riffle/woody debris habitat are likely the largest limiting factors of habitat in this reach.

Physical connectivity

No information was available or collected on physical connectivity in the Upper South Fork. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

The stressors to the biological community are habitat, DO, suspended sediment, and nitrate. Habitat issues appear to be driving the stress seen at this location. There is mixed biological responses to other stressors among sampling years, and stress becomes difficult to tease apart, showing variable responses in the biological communities. The severity and connection of these three stressors is largely tied to the flow in any given year (demonstrated by invertebrate samples in 2004, 2011 and 2012). Different flow years exhibit different habitat or chemical stress. Substrate embeddedness and lack of quality riffle and woody debris habitat are likely the largest limiting factors for habitat in this reach. In addition, nitrate is a stressor to the macroinvertebrate community, as expressed with very high percentages of nitrate tolerant individuals.

This is a headwater stream, and is heavily impacted by local land use. Better management of the riparian area (pasturing and buffers) would be helpful in reducing sediment and pollutants impacting all of the stressors present. Total phosphorus and high organic matter (TSVS) during low flow conditions are likely connected and contributing the low DO, DO flux, and TSS levels seen in this reach. Upstream pasturing can also be a contributor to TSS, embeddedness, overall stream bank instability, and organic matter (TSVS). A study by Winona State Water Resources Center determined that this reach had high levels or organic fractions of SSC during baseflow conditions which were likely tied to near stream agricultural land uses (Dogweiler 2010).

Temperature in this reach is showing some concern, but the evidence is not strong enough to confirm it's a stressor at this time. It does seem probable that during low flow conditions, when the stream is flowing low and slow, temperature could rise dramatically. The lack of riparian corridor provides little to no shading and sedimentation provides solar gain during hot summer months when flows are low. This potential warming is also connected to DO as warmer water is not able to hold as much oxygen. Temperature should be monitored, but will likely improve if habitat and sediment related issues are addressed.

4.8.7. Sorenson Creek

Supporting information

This is a small headwater stream, with fish doing well for their class, and macroinvertebrates struggling. Station 08LM087 was reviewed with the local MDNR fisheries staff to determine if water temperature should be considered cold, not warm. The decision was to leave it as warmwater and collect more information. If the site were scored against the coldwater IBI it would score a 31, and would still be considered impaired.

Sorenson Creek scores poorly among a few metrics of the macroinvertebrate IBI (Figure 135) which include: taxa richness of macroinvertebrates with tolerance values less than or equal to two, using Minnesota TIVs (Intolerant2Ch), taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera baetid taxa treated as one taxon (POET). In addition, Sorenson Creek scores poorly among two Trichoptera metrics: taxa richness of Trichoptera or caddisflies (Trichoptera), and relative abundance (%) of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct).

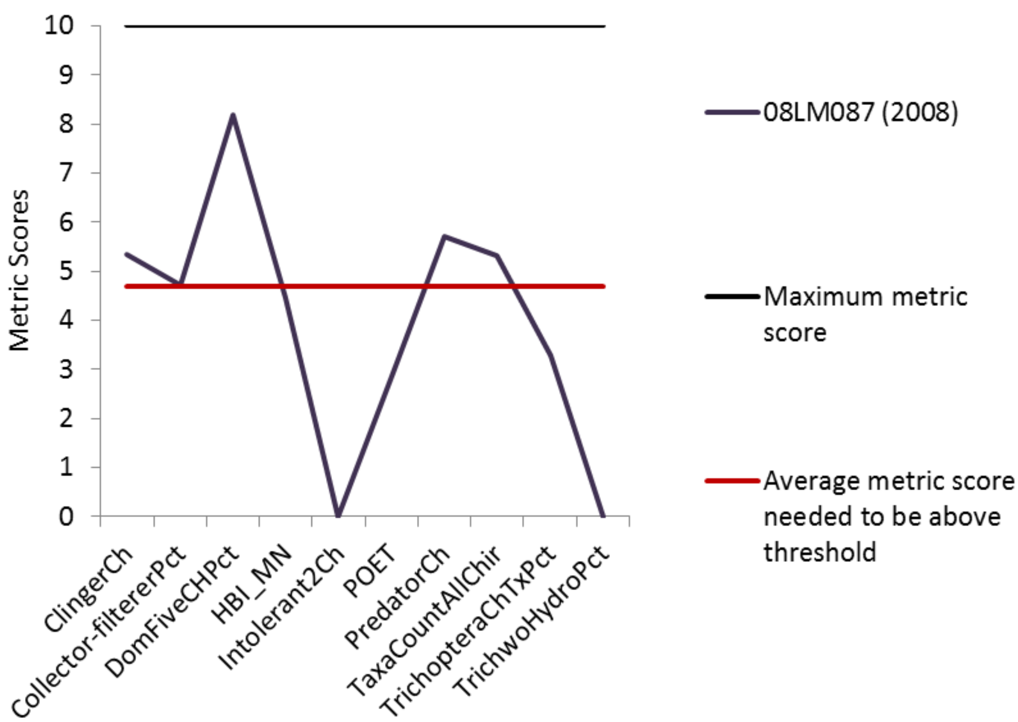


Figure 135. Metric scores for stations in the Upper South Fork River and Sorenson Creek (08LM087) of the Southern Forest Streams GP macroinvertebrate IBI

Temperature

On June 25, 2008, this site was sampled for fish and chemistry. The temperature at Station 08LM087 was 14.80°C. Since this is considered a warmwater stream, and that temperature value is rather low, at HOBO temperature logger was deployed in 2010 to get a better idea of the temperatures found within the creek. Unfortunately, the logger was buried in sediment and was out of the main channel once the water level went down. It was apparent the logger was reading air temperature starting at the end of June. This did not give us meaningful data to help understand the temperature dynamics at this site.

More data should be collected, but deploying a logger in this stream is difficult due to the very small extremely embedded channel with unstable (silt/clay) substrate. Temperature information on this stream is lacking and even though a temperature stressor is unlikely, there is not enough information to conclude it is or is not a stressor.

Dissolved Oxygen

The DO concentration at Station 08LM087 during fish sampling was 11.06 mg/L (June 25th, 2008). No other oxygen data is available on this stream.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The TP concentration during sampling was 0.104 mg/L. pH was measured at 8.3. Neither BOD nor chlorophyll-a data were available for analysis at this time.

The fish community, while not impaired, shows a community that is very tolerant to low DO levels. The DO TIV for fish scores in the worst 10% of all sites in the Root River. The macroinvertebrate community also signals DO stress. There were only five DO intolerant taxa present (Root River average is 10), and the percent tolerant to low DO was elevated at 4% which is worse than average for Root River stations (average is 2.7%). The percentage of EPT individuals and taxa count is below average at this location. EPT are typically intolerant of low DO levels and taxa richness can also be decreased with increases in DO flux.

The biological response indicates a potential for DO stress to this stream. However, without more solid chemical information, it is difficult to conclude that DO is a stressor to Sorenson Creek at this time. More information should be collected, including diurnal and pre-9:00 am DO data.

Nitrate

The only nitrate value available for analysis on Sorenson Creek was 11 mg/L, collected on June 25, 2008. This was the only chemical point available for analysis.

Station 08LM097 had a just below average taxa count, similarly had low number of Trichoptera taxa, and no intolerant taxa. This station had two nitrate intolerant taxa and 83.9% nitrate tolerant individuals. The macroinvertebrate community shows response consistent with nitrate degradation. It is difficult to confirm that nitrate is a stressor in Sorenson Creek with such little chemical information, even though it is suggestive by the macroinvertebrate response. Further samples documenting the magnitude and duration of nitrate would be useful in understanding this stressor. The one nitrate value was elevated and nutrient reductions in this watershed are likely warranted.

Suspended sediment

The only suspended sediment data available for analysis on Sorenson Creek was a TSS sample of 29 mg/L, collected on June 25, 2008.

The fish community is made up of fish that are generally more sensitive to high TSS concentrations. The station in this reach was made up of johnny darter, creek chub, brook stickleback and white sucker. Many of these species are in the slightly more sensitive category of TSS TIVs. In addition, no very tolerant to TSS species are present.

At Station 08LM087, there were no intolerant macroinvertebrates and less than 2% long-lived macroinvertebrates, which often decrease with increases in TSS. The macroinvertebrate index score for

TSS was 16.85, better than the average for warmwater stations in the Root River Watershed (17.96). The station at the time of sampling had nine taxa tolerant to TSS and one intolerant to TSS. The survey had 34.89% of the individuals in the survey considered tolerant to TSS; the average for warmwater stations in the Root River is 35.45%. Although there are no intolerant macroinvertebrates to TSS, it also shows that the tolerant are not overly dominating the population either. Three of the six metrics analyzed for TSS stress resulted in conditions poorer than the average of warmwater stations in the Root River.

There is potential that elevated TSS may be playing a role in shaping the biological communities, but likely is not the only stressor in Sorenson Creek and there is a lack of connecting data to conclude it as a stressor. The biological response evidence is weak, and there simply a lack of chemical information.

Physical habitat

The MSHA score for Sorenson Creek was rated as poor (43). Row crop is the predominant land use in the area with a narrow riparian zone but extensive cover. The land use and substrate were the largest factor reducing the MSHA score. It was noted as an incised stream.

The habitats sampled for macroinvertebrates were undercut banks and woody debris. Field crew noted that the site had very poor macroinvertebrate habitat for sampling and had very little flow. There was not a riffle was present, along with no course substrate. The water was stained and brown. The reach was considered 90% run, which was comprised on only silt substrate. Silt substrate was also dominant in the pools.

The percentage of EPT individuals was less than the statewide average for this class. The percentage of macroinvertebrates that climb was near average. The macroinvertebrates that are known to cling to large substrate and woody debris were near average for this class as well. However, there was also a large percentage of legless invertebrates present (85%) indicating a shift towards more tolerant individuals.

While the macroinvertebrate metric data are not overwhelming, habitat stress is suggested. In addition the poor MSHA score, and detailed habitat information confirm this is a stressor and likely impacting the macroinvertebrate community found in Sorenson Creek. The impact the culvert/road crossing has on this site should also be considered, as the station is downstream of here and the impacts seem apparent (Figure 136).

Figure 136. Upstream of biological Station 08LM087; at road crossing (potential culvert impacts on stability)

Physical connectivity

No information was available or collected on physical connectivity on Sorenson Creek. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor at this time.

Strength of evidence, conclusions, and recommendations

Limited information on Sorenson Creek suggests that habitat and nitrate are impacting the biological community present. During macroinvertebrate sampling it was noted by the biologist that little macroinvertebrate habitat was available, and that the reach was dominated by silt substrate with little diverse habitat. The biological metrics related to habitat demonstrate this, with a reduced percentage of EPT taxa and a shift to a higher percentage of tolerant legless invertebrates.

The macroinvertebrate community shows response consistent with nitrate degradation. Further samples documenting the magnitude and duration of nitrate would be useful in determining this as a stressor. Regardless, the one nitrate value was elevated and nutrient reductions in this watershed are likely warranted.

It is assumed that Sorenson Creek is somewhat similar in flow regime as the Upper South Fork. The habitat issues also seem to mirror each other. Temperature regime appears to be much different, but more information should be collected in order to understand the temperature dynamics of Sorenson Creek completely. The cooler temperatures in Sorenson Creek would also likely ensure more adequate DO levels, but without the chemical information to validate that, it is difficult to make conclusions regarding DO. The biological metrics do suggest potential for DO issues, so DO should be investigated further.

4.8.8. Summary of stressors in the South Fork Root River

The stressors found to limiting the biological (invertebrate) communities in the South Fork Watershed are found in Table 53.

Table 53. Stressors identified in the South Fork Watershed. (● = stressor (yes); o = inconclusive stressor; 'blank'-no stressor)

Reach Name	Geo Region	AUID	Reach Description	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Physical Habitat	Physical Connectivity
Root River, South Fork	***Driftless, Bluffland Karst***	**07040008-508**	*Beaver Creek to Root River*	2B	08LM009	Upstream of Swede Bottom Rd, 1 mi. E of Houston	Invert IBI Turbidity Bacteria			●	●	●	
Root River, South Fork	***Driftless, Bluffland Karst***	**07040008-509**	*Riceford Creek to Beaver Creek*	2B	08LM104	Downstream of East Twin Ridge Rd, 4 mi. SW of Houston	Invert IBI			O	●	●	
Root River, South Fork	***Driftless, Bluffland Karst***	**07040008-510**	*Wisel Creek to T102 R8W S2, east line*	2A	08LM102 10EM146	Downstream of Hwy. 43, 9 mi. N of Mabel Upstream of Hwy. 43, 9 mi. N of Mabel	Invert IBI	O		●	O	●	
Riceford Creek	***Driftless, Bluffland Karst***	**07040008-518**	*T101 R7W S19, south line to T102 R7W S30, North line*	2A	04LM117 08LM140 08LM111	2 mi. N of Riceford Upstream of Elm Dr, 4 mi. NE of Mabel Downstream of Mapleleaf Rd, 3 mi. E of Mabel	Invert IBI		**O**	●	O	●	
Bridge Creek	***Driftless, Bluffland Karst***	**07040008-F54**	*Unnamed Creek to Unnamed Creek*	2A	08LM103	Downstream of John Deere Dr, 6.5 mi. SW of Houston	Invert IBI		**O**	O	O	●	
Riceford Creek	***Driftless, Bluffland Karst***	**07040008-519**	*T102 R7W S19, south line to South Fork Root River*	2B	08LM100	Downstream of Creamery Dr, 8.5 mi. NW of Spring Grove	Invert IBI				O	●	

Reach Name	***Geo Region***	**AUID**	**Reach Description**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Impairment(s)**	**Stressors:** Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Physical Habitat	Physical Connectivity
					04LM060	Upstream of County Rd 4, 6.8 mi. N-NW of Spring Grove							
Root River, South Fork	***Driftless, Near Surface Karst***	**07040008-573**	*Headwaters to T102 R9W S27, east line*	2B	04LM113	Downstream of County Rd 18, 5 mi. NE of Harmony	Invert IBI Turbidity	O	●	●	●	●	
Sorenson Creek	***Driftless, Near Surface Karst***	**07040008-F52**	*Unnamed Creek to Unnamed Creek*	2B	08LM087	Downstream of Diamond Dr, 4 mi. NE of Canton	Invert IBI		**O**	●		●	

4.9. Trout Run-Root River

This section of the report is broken into six sections, and addresses seven biological impairments (Figure 137). The majority are macroinvertebrate impairments, with Rice Creek having both fish and macroinvertebrates listed as impaired.

The first section will discuss Trout Run (headwater area; coldwater). The next will address the coldwater stream, Rice Creek. Following that, two stream reaches with larger drainages will be addressed (Middle Branch mainstem). These two reaches (AUID 534 and AUID 528), could not be grouped because stressors identified were different. Finally, two small warmwater tributaries will be addressed and are grouped together (Wadden Valley Creek and Money Creek).

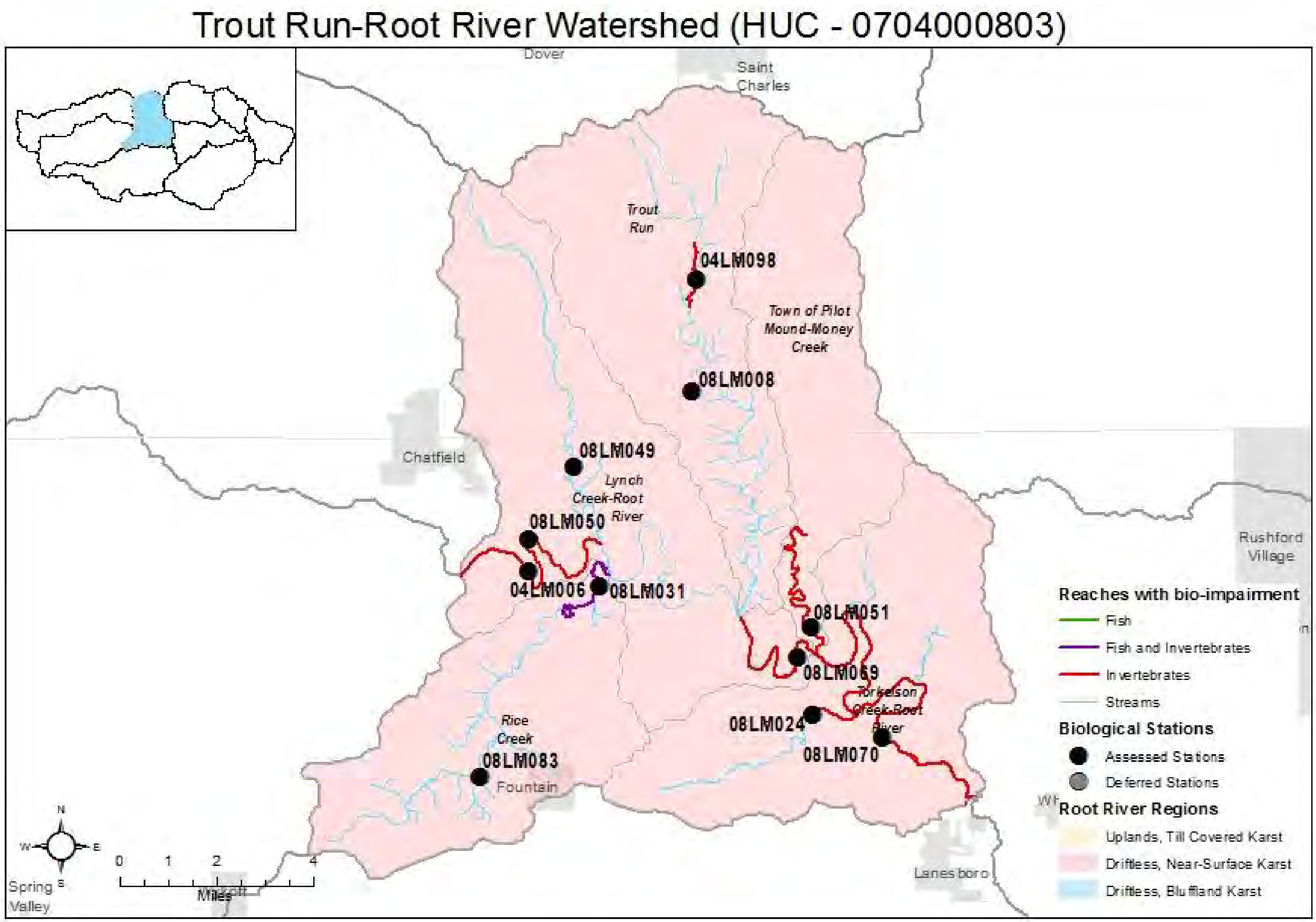


Figure 137. Trout Run-Root River biological monitoring stations and aquatic life impairments

4.9.1. Trout Run

Supporting information

Trout Run, a popular trout fishing stream in southeast Minnesota, was split into two stream segments for stream assessment. A new stream reach or Assessment Unit ID (AUID) was created after the stream was split at County Road 10. The macroinvertebrate impairment addressed by this stressor identification exists solely on this far headwater section of Trout Run Creek, including Station 04LM098. The fish community is doing fairly well here with IBI scores above the impairment threshold (49 and 68). Both fish stations farther downstream of this location, were also well above impairment thresholds. The 2004 macroinvertebrate survey resulted in a very low IBI score (13.98), below the threshold and confidence interval. It would be advantageous to repeat sampling at this station to understand more current conditions.

All macroinvertebrate metrics, of the Southern Coldwater IBI, were below the average metric score needed to be above the threshold at Station 04LM098 (Figure 138). Those that were most severe were ratio of chironomid abundance to total dipteran abundance (ChiroDip), relative abundance (%) of collector-gatherer individuals in subsample (Collector-filtererPct), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TIVs (Intolerant2Ch), and relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct).

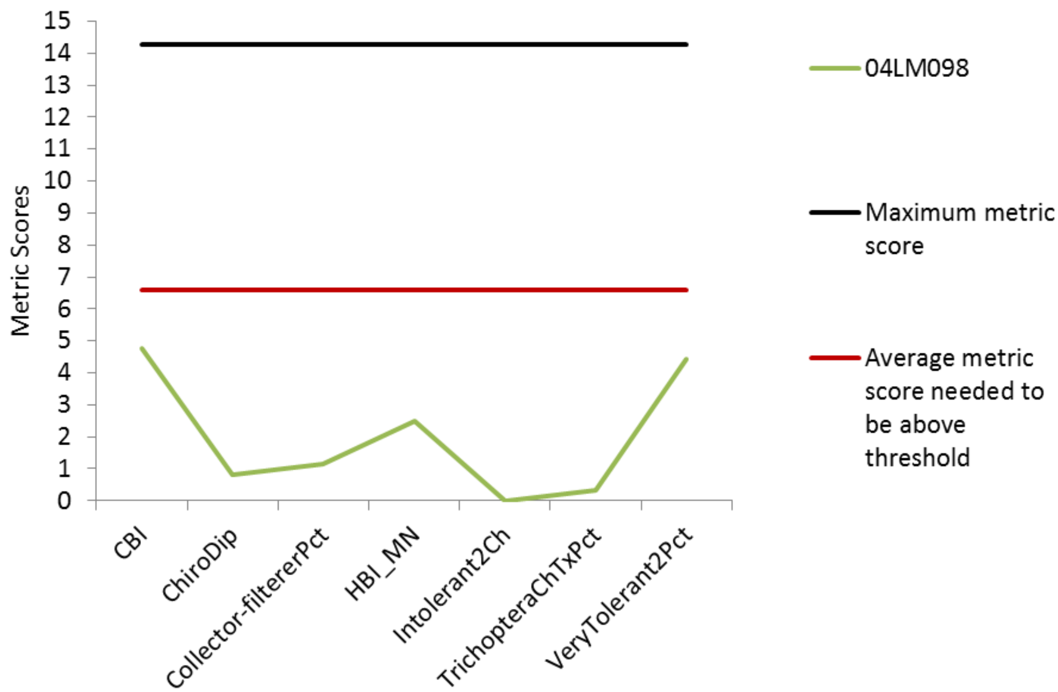


Figure 138. Metric scores for Station 04LM098, in Trout Run, of the Southern Coldwater macroinvertebrate IBI

Temperature

During biological sample at Station 04LM098, the temperature was very cold; 12.2°C in June and 11°C in August. There was a temperature logger placed at this site in 2004; with a July average temperature of

11.5°C and an August average of 10.88°C (only through August 17, 2007). The only other temperature information available was from two samples at the headwater springs; (11.1°C and 9.5°C).

The chemical information strongly supports suitable temperatures for a coldwater stream. Also, given its close proximity to springs and the fact that sculpin are in the fish sample strongly support the notion that temperature is likely adequate at this location and not a stressor to the biology.

Dissolved Oxygen

DO was measured during biological sampling at Station 04LM098 twice in 2004. In June the DO was 9.5 mg/L and August it was 8.2 mg/L. The only other DO data available is from the headwater area. There were two samples taken in 2005; both 10 mg/L.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. During biological sample on June 29, 2004, the pH was 7.2 and TP was 0.058 mg/L. Then in August 2004, the site was resampled. The pH was 4.6 and TP 0.104 mg/L. The pH value was disregarded due to probable field equipment error (nearby site 04LM006 also had a low pH reading on that same day). Neither BOD nor chlorophyll-a data were available for analysis at this time.

The fish sample at this site was dominated by slimy sculpin during both visits in 2004. There were few total fish individuals captured at this site, (less than 50 fish). Aside from sculpin, the fish community consisted of a few brown trout, minnow, white sucker, and bluegills each. Sculpin and trout are sensitive to low DO and would not likely be present in the stream if dissolved oxygen was not adequate.

In contrast, the macroinvertebrate community does signal tolerance to low DO. The macroinvertebrate DO TIV station index score was in the most tolerant quartile of all Root River biological stations. In addition, there were only seven intolerant taxa found at this site (Root River average is 10 taxa). The percent of tolerant taxa was also elevated at 6.5%. EPT are typically intolerant of low DO levels and taxa richness can also be decreased with increases in DO flux**.** Both of these metrics are reduced below average at this location.

The chemical and fish information does not suggest DO is a stressor to Trout Run. The macroinvertebrate information does show some signs of potential DO issues, however they are likely responding to some other stressor instead of DO. The lack of consistency among biological indicators does not allow a DO stressor to be confirmed at this time.

Nitrate

Station 04LM098 was sampled for nitrate in June and August of 2004. Both sample results were 7.0 mg/L nitrate. There were also two springs sampled in the upstream part of the watershed in 2003 (S003-607 and S003-608), with levels at 9.9 mg/L and 6.7 mg/L. The downstream AUID (G88) had one biological Station 08LM008, sampled in 2008 for macroinvertebrates and fish. At the time of fish sampling at Station 08LM008, July 8, 2008, the nitrate was 6.9 mg/L.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate survey in Trout Run had 16 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class in the LMB is 19. There were no intolerant taxa present, while the average for coldwater stations in the Root is 0.6 taxa. The number of Trichoptera taxa (two) in Trout Run was also below the coldwater average (3.8 taxa), comprising of 6.7% of the total taxa (TrichopteraChTxPct). The resulting very low metric scores; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Trout Run, the metric score was 2.5 (out of 14.3), below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 04LM098 the HBI_MN value was 7.18 in 2004, greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling (p≤0.001). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 04LM098 had 17 nitrate tolerant taxa (85.4% individuals); and 12 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. There was one nitrate intolerant taxa present in the 2004 macroinvertebrate survey. The downstream Station 08LM008 had few nitrate tolerant taxa but the nitrate tolerant individuals comprised of 91.4% of the macroinvertebrate survey in 2008.

The abundance of nitrate tolerant taxa and nitrate tolerant individuals, along with low metric scores for HBI_MN and TrichopteraChTxPct, show that the macroinvertebrate response to the elevated nitrate is present. Nitrate is elevated in Trout Run and is playing a role in shaping this degraded macroinvertebrate community. Additionally, there are indications that the downstream reach may also be impacted by the elevated nitrate, but is not degraded enough to be impaired yet.

Suspended sediment

Trout Run only has two sampling dates; taken at the time of fish sampling. On June 29 and August 24, 2004 the transparency was greater than 60 cm, the turbidity was less than two NTUs and the TSS was 6.8 and 6 mg/L, respectively. It is likely that these measurements were taken during base flow conditions and do not capture the events that may have greater impact to the suspended sediment in this reach.

Trout Run, at Station 04LM098, has over 50% of the individuals belonging to the most sensitive quarter of species found in coldwater reaches of the Root River Watershed (slimy sculpin). Station 08LM008, downstream also has a fairly sensitive composition with 610 brown trout surveyed in the second most sensitive quartile.

None of the macroinvertebrate individuals were long lived and none were generally intolerant, which often decrease with increases in TSS. The macroinvertebrate index score for TSS was 14.72, a good score compared to average for coldwater stations in the Root River Watershed (15.13). The station at the time of sampling had six taxa tolerant to TSS and none intolerant to TSS. Only a little over 4% of the individuals in the survey are considered tolerant to TSS. The macroinvertebrate community data suggests that TSS is likely not an issue at this location.

The biological and chemical evidence show TSS is not a stressor in Trout Run Creek. Upstream springs have had elevated concentrations of TSS. Continued monitoring and protection of Trout Run would be important to prevent increases in the stream.

Physical habitat

Station 04LM098 had quantitative habitat measurements completed on two visits which resulted in poor conditions. The surrounding land use was row crop with moderate and narrow riparian areas. Cover within the station was noted as nearly absent in June and sparse in August. The converted MSHA score (from the quantitative habitat assessment) was poor, with scores of 29 and 41 (out of 100). The only habitat that was available for sampling macroinvertebrates was overhanging vegetation and undercut banks.

The reach was predominately run, with 5% pool. The substrate was homogeneous, dominated by sand, silt, and clay. There was no riffle habitat available within Station 04LM098, and severe embeddedness was noted during the surveys (100% embedded). Of 43 stations in the Root River Watershed with quantitative habitat assessment, this station was the only one with 100% embeddedness. The maximum depth of fines was 32 cm with a mean depth of fines at 23 cm; which was the highest mean depth of fines in the Root River Watershed as well. The station had poor channel development, and moderate stability.

Flow at Station 04LM098 was 2.1 cfs on June 29, 2004 and 1.7 cfs on August 24, 2004. Notes of slow velocity and slow stagnant water were made during the visit. These conditions may have allowed for the aggradation of sediment due to the low flow (Figure 139).

Figure 139. Biological Station 04LM098, downstream end looking upstream.

Station 04LM098 had very low percentage of EPT individuals (below 4%). This was the lowest of all coldwater stations. There were a high percentage of burrowers (41%) and high percent oligochetes (23%), indicative of potential sedimentation issues. In addition, there were few macroinvertebrates that cling (6%), which demonstrate a lack of substrate or hard surfaces like rock or woody debris to cling to, and indicative of the habitat types that were sampled. There were a greater abundance of macroinvertebrates that climb (25.5%) than the average for coldwater stations. There is a lack of quality diverse habitat for the macroinvertebrate community to thrive and an excess amount of fine sediment/quality substrate. Lack of habitat is a stressor to the macroinvertebrate community in Trout Run Creek.

Physical connectivity

No information was available or collected on physical connectivity on this stream reach of Trout Run. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in the Trout Run at this time. However, there is information about dams farther downstream in the watershed (on reaches not impaired for biology) and the potential for a connectivity stressor over time is more likely. This potential stressor should be monitored to ensure no impacts to biology.

Strength of evidence, conclusions, and recommendations

Lack of physical habitat is the main stressor to Trout Run in addition to nitrate. The stream is suffering from lack of riparian corridor, sedimentation, and lack of quality diverse habitat. The reach is predominately run, with little quality substrate for macroinvertebrates due to sedimentation of the streambed. These habitat characteristics appear segregated to this area of Trout Run, as further downstream (next AUID) habitat characteristics improve.

Macroinvertebrates are showing response to the elevated nitrate. There are also indications that the downstream reach may also be impacted by the elevated nitrate, but is not degraded enough to be impaired yet. Further investigation into the magnitude and duration of nitrate in Trout Run would be beneficial. It is uncertain the direct sources in Trout Run; however in the Nitrogen in Minnesota Surface Waters Report it is estimated that agricultural groundwater and agricultural drainage comprise of 80% of the nitrogen sources in the Lower Mississippi River Basin (pg. D1-11).

While DO and TSS do not appear to be likely stressors, some additional information on DO dynamics in this stream may helpful. Site photos indicate the stream has a fair amount of algae, which can impact DO levels. At this time, given the sensitive fish community present, DO did not appear to be an issue. The situation should be monitored to ensure adequate DO levels continue.

4.9.2 Rice Creek

Supporting information

This stream is heavily influence by Karst. The headwaters begin in two separate branches near Fountain, Minnesota. These two tributary springs are locally known as Sugar Creek, and Big Springs Creek. These are thought to be the principal sources of flow for Rice Creek. The stream changes from coldwater in its headwaters, to warmwater in the middle section, back to coldwater near the mouth. In the warmwater section, multiple surveys have confirmed no flow. In 2012, a survey by MPCA staff also indicated no flow in this warmwater reach. The monitoring Station 08LM031 demonstrates multiple impacts present in Rice Creek at different flow conditions (Figure 140 and Figure 141).

In 1959, a survey describes the stream as drying up in parts and that flows had decreased and the stream had degraded since a 1943 survey (Rice Creek Management Plan, MDNR 2010). The plan also notes that lack of flow and seasonally poor water quality, are the largest trout population limiting factors on Rice Creek. “Severe bank erosion and in stream sedimentation are problems in all reaches” “The lack of permanent adult cover is limiting the brown trout populations and natural reproduction is very limited in all of Rice Creek.”

A MDNR survey in 1990 notes: a) low flow in Rice Creek is much less than desirable in dry years, b) agricultural pollutants enter the stream from farmland after heavy rains, c) excessive grazing in two tracts damages trout habitat, d) two landowners quarreling over DOW permit (one posted against stream fishing). This survey also notes that the best tract of trout water in Rice Creek is from mile 0-1.21, but that stream bank erosion is extremely severe from mile 0.0 to 2.31 which results in pools filling in with silt. Also, there is 76% pasture-land adjacent to the creek.

Figure 140. Road crossing near 08LM031, which clearly demonstrates grazing, nutrient, and sediment impacts to Rice Creek in 2012 (low flow conditions).

Figure 141. Station 08LM031 in 2008

The fish community in Rice Creek, at Station 08MN031, scored low on the Southern Coldwater IBI (36). The fish community had a lack of sensitive coldwater individuals, lack of native coldwater taxa and individuals, and an abundance of taxa where detritus constitutes at least 5% of their diet, represented by the low scoring SdetTxPct_10DrgArea metric (Table 54). A brown trout population exists (61 individuals sampled); however, the community at Station 08MN031 also exhibits warmwater characteristics.

Table 54. Station 08LM031, in Rice Creek, fish metrics of the Southern coldwater IBI; bold indicates metric score is below average metric score needed for IBI to be greater than threshold (6.4; without DELTs), maximum metric score possible is 14.3; DELT deduction of five points present at this station

Site	CWSensitivePct_10DrgArea	CWTol_10DrgArea	HerbvPct	NativeColdPct	NativeColdTXPct_10DrgArea	PioneerPct	SdetTxPct_10DrgArea
08LM031	2.9	10.6	14.3	0.0	2.8	10.8	0.0

The macroinvertebrate community was sampled twice at Station 08LM031, (Figure 142) resulting in Southern Coldwater IBIs less than desirable (29.6 and 30.43). Both samples resulted in similar results in metric scores. The lowest metrics were the ratio of chironomid abundance to total dipteran abundance (ChiroDip), relative abundance of collector-filterer individuals in subsample (Collector-filtererPct), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch), and relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct).

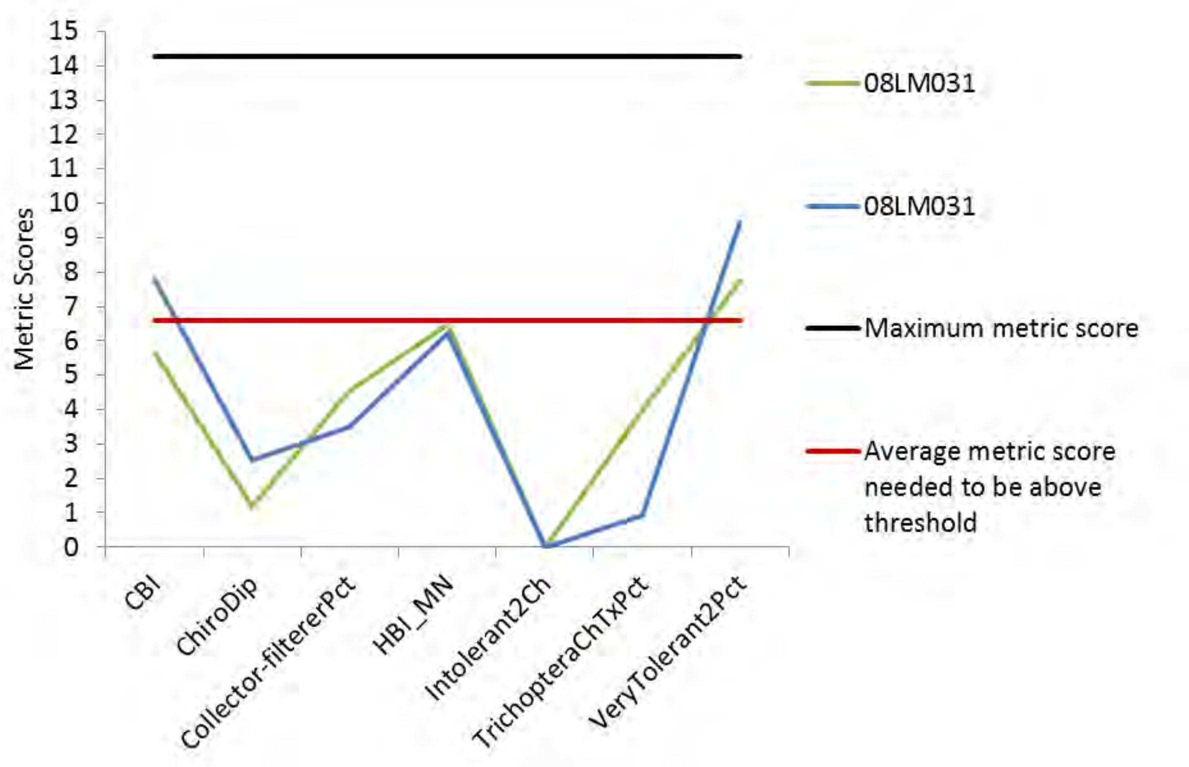


Figure 142. Metric scores for visits at Rice Creek, Station 08LM031, of the Southern Coldwater macroinvertebrate IBI

Temperature

At Rice Creek, Station 08LM031, the temperature during biological sampling was 15°C. A temperature logger was deployed at this site and recorded the summer temperatures in 2008. The July monthly average was 16.07°C, with a maximum of 20.15°C. In August the average was 14.4°C, with a maximum of 19.98°C. These temperature are adequate and within a suitable range for coldwater species. However, the site only had 17% coldwater fish species present during biological sampling.

While high resolution temperature data from 2008 shows suitable coldwater temperatures, the stream may not always have adequate flow during dry years (noted by MDNR reports). If low flow conditions are present, the potential for stream temperature issues increase. In 2008, the year was not characterized as dry, so additional data during dry years would confirm adequate temperatures for coldwater fish in Rice Creek. While at this time a temperature stressor does not exist on Rice Creek, more information would help determine if there are flow temperature variations year to year which may impact the biological communities.

Dissolved Oxygen

During biological sampling at Station 08LM031, the DO was 9.20 mg/L (July 30, 2008; 8:45 am). One DO data point at a site downstream in 2004 was 11.40 mg/L. These two data points were the only data available on this stream reach of Rice Creek.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. The pH value during biological sampling was 7.58 and total phosphorus concentration was 0.074 mg/L. Neither BOD nor chlorophyll-a data were available for analysis at this time. The limited chemical information presented does not violate standards and appear within normal ranges.

The fish community at Station 08LM031 was made up of 202 white suckers (57%). White suckers are fairly tolerant to low DO. However, the fish community did have a fair number of species intolerant to low DO (brown trout, redhorse, dace). As shown in Figure 143, the fish community is made up of individuals that are both tolerant and intolerant to low DO.

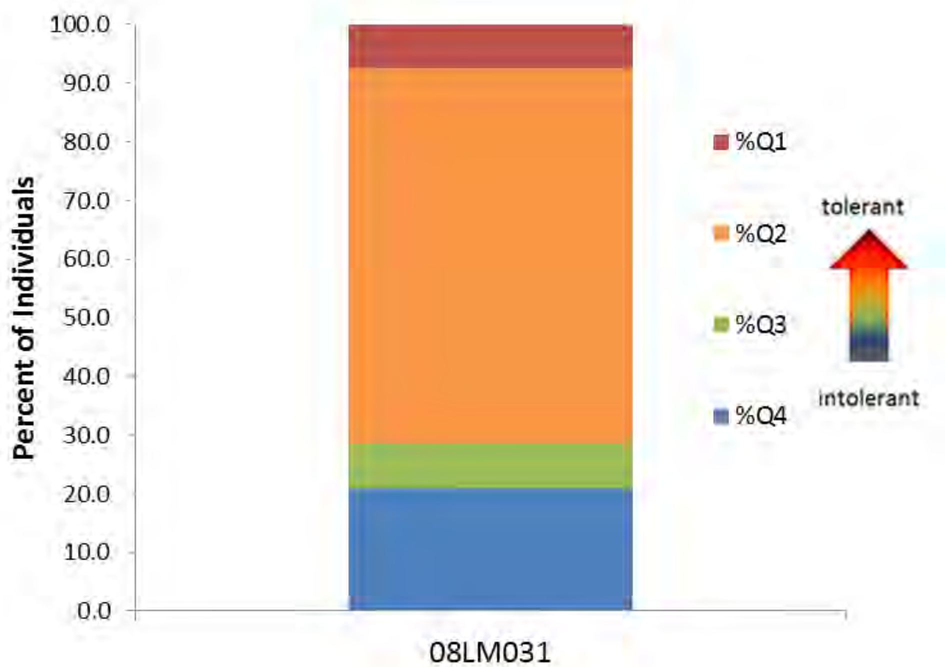


Figure 143: Dissolved Oxygen tolerance indicator values for 08LM031.

The macroinvertebrates in Rice Creek show a slight sensitivity to low DO. The macroinvertebrate DO TIV index scores were better than average for Rice Creek compared to other stations in the Root River. The percent tolerant individuals were also better than average, but the number of intolerant to low DO taxa were worse than average (only eight taxa, compared to 10 as the average). So, while the community was lacking DO intolerant taxa, they aren't dominated by DO tolerant taxa either. In addition, EPT are typically intolerant of low DO levels and taxa richness can also be decreased with increases in DO flux**.** Both of these metrics are reduced below average at this location in Rice Creek.

In Rice Creek there is a lack of strong chemical information and weak biological evidence which would support a DO stressor. At this time, a DO stressor is not likely in Rice Creek, but additional chemical information would help rule that out.

Nitrate

At Station 08LM031, the nitrate concentration was 8.3 mg/L, at the time of fish sampling in 2008. There was one other sample downstream, at Station S003-387, taken on August 3, 2010, at 7.9 mg/L. A tributary to Rice Creek, Sugar Creek, had an elevated nitrate concentration at the time of fish sampling at Station 08LM083 of 15 mg/L. Sugar Creek originates near Fountain Big Spring and spring data from 1976-1991 had nitrate concentrations ranging from 7.3 to 18.5 mg/L (Spong, 2011).

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys at Station 08LM031 in Rice Creek (two visits in 2008) had 13 and 14 taxa (with chironomid and baetid taxa each treated as one taxon). The average taxa count for the coldwater macroinvertebrate class for the LMB is 19. Both macroinvertebrate surveys had no intolerant taxa present, which is lower than the average for coldwater stations in the LMB. Rice Creek Trichoptera taxa were below the average (3.8 taxa) for both visits (with two and three taxa present), comprising of 7.4 and 11.1% of the total taxa (TrichopteraChTxPct). The resulting low metric scores; less than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling ($p=0.006$). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased in nitrate. In Rice Creek, the metric score was 6.2 and 6.5 (out of 14.3), just below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At Station 08LM031 the HBI_MN values were 6.90 and 6.87, greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that that the HBI_MN will be less than or greater than 6.65. At a concentration of ten mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 08LM031 had 18 and 20 nitrate tolerant taxa (77.1 and 73.4% individuals); and 13 and 15 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in the 2008 macroinvertebrate surveys. Sugar Creek, at Station 08LM083, had 25 nitrate tolerant taxa (72.4% individuals) and no nitrate intolerant taxa present.

The abundance of nitrate tolerant taxa and nitrate tolerant individuals, along with low metric scores for HBI_MN and TrichopteraChTxPct, show that the macroinvertebrate response to the elevated nitrate is present. Nitrate is elevated in Rice Creek and is playing a role in shaping this degraded macroinvertebrate community.

Suspended sediment

In Rice Creek, there was only one measurement of TSS, 9.6 mg/L. The sample was taken at the time of fish sampling, at Station 08LM031, on July 30, 2008. Of the nine transparency tube measurements between August 2003 and August 2010, three are below 20 cm (poor).

Station 08LM031 in Rice Creek is dominated by white suckers (202 of 350 individuals). The tolerant fish individuals comprise of 65% of the community, likely in part due to the dominance of white suckers. Based on statewide tolerance values, that were then quartiled by their presence in coldwater reaches of the Root River, Rice Creek also has presence of fish in the most sensitive quarter, longnose dace and blacknose dace, yet they aren't as abundant to comprise a greater proportion of the sample.

Long-lived macroinvertebrates ranged from 0 to 0.64% and none were generally intolerant, which often decrease with increases in TSS. The macroinvertebrate index score for TSS was 15.28 and 15.45, a mediocre score compared to average for coldwater stations in the Root River Watershed (15.13). The station at the time of sampling had three taxa tolerant to TSS and none intolerant to TSS, each time sampled. A little over 9 and 15% of the individuals in the survey are considered tolerant to TSS. The average for coldwater stations in the Root River Watershed is 9.94, indicating that one of the samples was greater than this average. The macroinvertebrate community data suggests that TSS is a probable issue, but lacks connecting data. The macroinvertebrate community is neither highly tolerant nor intolerant to elevated TSS levels.

There is a lack of solid chemical information and a mixed biological response on Rice Creek. Both fish and macroinvertebrates do not signal strong TSS tolerance or intolerance. At this time, the information available does not suggest TSS is a primary stressor in Rice Creek.

Physical habitat

Station 08LM031 received a fair MSHA score (59). The surrounding land use was dominated by pasture, with a narrow riparian area. There was little to moderate amounts of bank erosion with no shade. The habitats that were sampled for macroinvertebrates were: riffles, undercut banks/overhanging vegetation, woody debris, and macrophytes. The dominant substrate was cobble and gravel in run features, and sand, silt and clay in pool features. Approximately 20% of the reach was riffle with cobble and gravel substrate. Light embeddedness was noted at the time of fish sampling in 2008. Instream cover and channel stability were moderate.

In 2010, MDNR conducted a habitat survey near Station 08LM031, known as Station 1.51. The MSHA score for Station 1.51 was on the lower end of fair (45.45). Land use was noted the same as in 2008 with open pasture with a disturbed riparian area. Bank erosion was noted as heavy (50-75%) and there was no shade provided by any stream side vegetation. Mesohabitat types consisted of 35% pools, 25% riffles, 20% runs, and 20% glides. Substrate embeddedness was light. Instream cover was provided by deep pools only and total cover amount was considered sparse (5-25%). Pool width was greater than riffle width and channel development was good (MDNR 2010 assessment of Rice Creek).

The macroinvertebrate community at Station 08LM031 was near the statewide average for coldwater stations for the percentage of climbers and clingers (over 36 and 34% respectively). Burrowers were slightly more abundant in one of the samples (16.6%), but the other was lower (8.0%) both above average and potentially indicate fine sedimentation in riffle habitat. The percentage of EPT was 27 to 38%, slightly worse than average for coldwater stations statewide (39.2%). There were slightly higher percentages of macroinvertebrates that are considered swimmers than the average for coldwater stations statewide. The macroinvertebrate community does signal some potential for habitat stress, but habitat issues may be playing a secondary role to a more prominent stressor.

Station 08LM031 had a fish community rich in riffle dwelling fish (63.71%), non-tolerant benthic insectivores (17.71%), simple lithophilic spawners (68.86%), and darter, sculpin and round bodied suckers (17.14%). Lithophilic spawners were found in abundance as well, 92%. However, tolerant white suckers dominate the fish community found in Rice Creek (202 individuals), and this one specie makes up large percentage of many of these metrics. Additionally, pioneer percent was near average (13%) for coldwater stations in the state. These habitat related fish metrics were all well above averages for stations statewide and stations in the Southern Coldwater fish class. However, piscivores were found in reduced abundance (only 17%), compared to the statewide average of 37%. In addition, there was a high percentage (65%) of generally tolerant fish species present. It does not appear as though habitat is a major limiting factor for the fish community, yet still could be shaping the community present.

Although there are areas for improvement of habitat in Rice Creek, the fish and macroinvertebrate community is mixed in it's response to degraded habitat. The biotic community may be impacted by a lack of quality habitat, but likely it is a secondary stressor to a more prominent stressor and appears to be impacting both the fish and macroinvertebrate communities present.

Physical connectivity

A connectivity survey done in 2012, show Rice Creek drying up, just upstream of the coldwater designation. In the coldwater stream reach no connectivity issues were found (a total of three road crossings were evaluated for fish barriers).

The MDNR Rice Creek Survey from 1990 reports that beaver dams were causing some trout habitat problems in the lower ½ mile of the creek. MDNR also notes that this stream is lacking natural production and needs to be stocked.

Rice Creek is on a small coldwater reach, and potentially dries up during low flow years upstream. There are no mapped springs in this section of the creek, even though temperature appears to be suitable. Trout and other migratory fish do not have access to headwater areas (which in some streams can provide good spawning areas due to coldwater temperatures), and are potentially cut off from the Middle Branch by beaver dams. There are potential issues that could cause problems with migration and spawning success.

More information on temperature, flow, and how they relate to connectivity in any given year, may help in further understanding of this system. At this time, there is not enough information to conclude that connectivity is a stressor to Rice Creek.

Strength of evidence, conclusions, and recommendations

Both fish and macroinvertebrates are demonstrating some habitat stress in Rice Creek, and the macroinvertebrate community is also showing stress to elevated nitrate. The riparian area in Rice Creek is heavily disturbed by pasture and bank erosion is prominent with little to no cover.

Further investigation into the magnitude and duration of nitrate in Rice Creek and its tributaries would be beneficial. It is uncertain the direct sources in Rice Creek; however there is evidence of heavy pasture land use and elevated nitrates in springs. In the Nitrogen in Minnesota Surface Waters Report it is estimated that agricultural groundwater and agricultural drainage comprise of 80% of the nitrogen sources in the Lower Mississippi River Basin (pg. D1-11).

The effects of temperature and connectivity are not well quantified, and have the potential to be large, especially for the fish community. Currently, continuous temperature data does not indicate temperature issues; however MDNR reports show that this stream can suffer during dry years, due to changes in stream flow (karst; stream disappearing). Additional understandings on temperature dynamics during varying years, and flow conditions, as well as subsequent connectivity issues are needed. In addition, better information on DO during varying stream conditions would be useful as they may be suitable depending on temperature and flow.

4.9.3. Middle Branch Root River - 534

Supporting information

This reach Stations 04LM006 and 08LM050 are within the near surface Karst zone. Both stations had fish IBIs well above the thresholds set for attainment of a healthy fish community. Station 08LM050 macroinvertebrate IBI was above the threshold and within the confidence interval (45.5). Station 04LM006 was below the threshold and within the confidence interval (32.7).

The metric scores are compared for both stations in Figure 144. Station 04LM006 had quite low metric scores for a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), relative percentage of insect taxa (InsectTxPct), and taxa richness of Plecoptera (Plecoptera). Other metrics were also low included taxa richness of climbers (ClimberCh), taxa richness of predators (excluding chironomid predator taxa) (Predator), relative percentage of taxa with tolerance values equal to or greater than six, using MN TVs (Tolerant2ChTxPct), and taxa richness of Trichoptera (Trichoptera). Station 08LM050 did have similar metric response although it did score better in some areas. Station 08LM050 had low metric scores for a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of Plecoptera (Plecoptera), taxa richness of predators (excluding chironomid predator taxa) (Predator) and taxa richness of Trichoptera (Trichoptera).

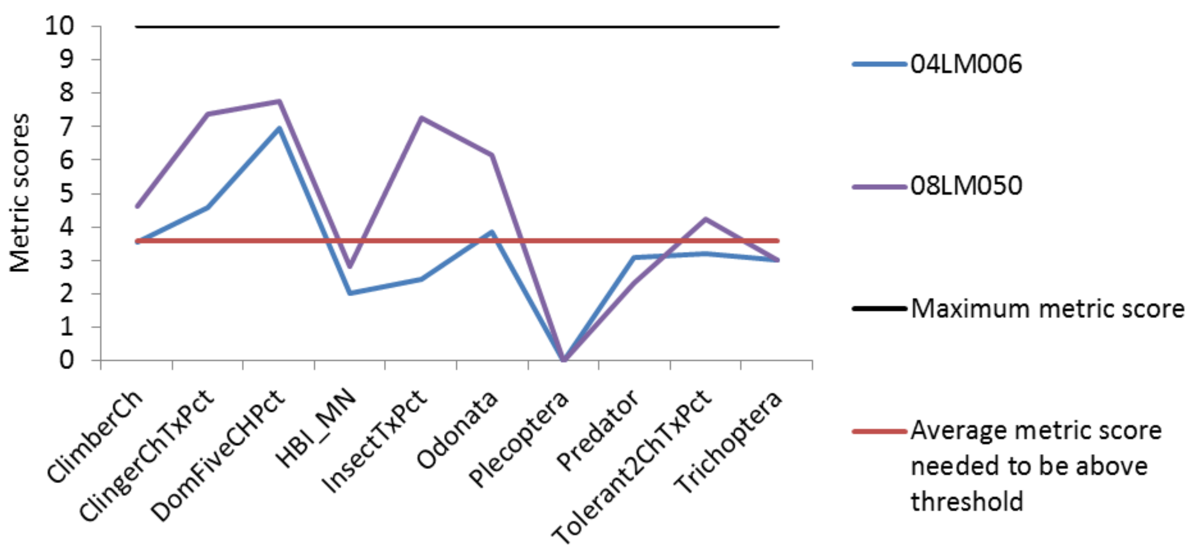


Figure 144. Metric scores for stations in Middle Branch Root River of the Southern Streams RR macroinvertebrate IBI

Temperature

In 2008, during fish sampling at Station 08LM050 the temperature was 17.4°C. At Station 04LM006 the temperature was 19.6°C at the time of fish sampling in 2004. The only additional temperature information was 12 temperature measurements from 2007-2008 at Station S005-301, with a maximum temperature of 25°C, and an average 21°C. The temperatures are within a normal range for what is expected of warmwater streams in the area. Temperature is not considered a stressor to the Middle Branch Root River at this time.

Dissolved Oxygen

The only DO data available was from biological sampling in 2004 and 2008. At Station 04LM006 the DO was 8.95 mg/L on August 17, 2004. At Station 08LM006, the DO was 8.96 mg/L at 8:20 am on August 13, 2008.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. At Stations 04LM006 and 08LM050, pH values were 4.9 and 8.10, respectively. TP concentrations were 0.099 mg/L and 0.069 mg/L, respectively. Neither BOD nor chlorophyll-a data were available for analysis at this time. The pH value at Station 04LM006 appears to be an anomaly, as a nearby site had a similar low pH reading that same day (Trout Run at Station 04LM098). It is unknown, but likely due to equipment or calibration error of the field meter.

The fish community at all of the sites is comprised of fish that are moderately tolerant to low DO. The stations had a fish DO TIV aggregate scores that were just below what is considered average for the Root River, showing mixed DO tolerance.

The macroinvertebrate community is displaying moderate tolerance to low DO at the two biological stations (534). The DO TIV index scores for both locations were worse than average for stations in the Root River. In fact, Station 08LM050 was in the most tolerant quartile among all Root stations. The number of intolerant to low DO taxa, and percent tolerant taxa were all worse than average as well. The macroinvertebrate taxa count at both stations was better than the average of Southern Streams RR stations in the LMB. However, the percentage of EPT individuals was reduced at both locations. EPT are typically intolerant of low DO levels and reduced taxa richness can indicate increases in DO flux.

Low DO has the potential to be shaping the macroinvertebrate community on this stream reach, but with a lack of connecting information it is difficult to conclude DO is a stressor to this reach at this time. This stream reach should have additional chemical data collected in order to rule out this potential stressor.

Nitrate

The only nitrate information available on this stream reach was collected during fish sampling. On August 13, 2008, Station 08LM050 had a nitrate concentration of 5.3 mg/L, and on August 17, 2004, Station 04LM006 had a concentration of 7.6 mg/L. As related from the Middle Branch Root River (528), the nitrate concentrations in this area likely fluctuate depending on the time of year.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate Class 5 (Southern Forest RR) streams in Minnesota shows a 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

The macroinvertebrate taxa count was greater at Stations 08LM050 and 04LM006 than the average of Southern Streams RR stations in the LMB. Similarly, both stations had five Trichoptera taxa whereas the average in comparable LMB stations is 4.4. Station 08LM050 had no intolerant taxa and Station 04LM006 has one intolerant taxon. Station 08LM050 had three nitrate intolerant taxa and Station 04LM006 had one nitrate intolerant taxon. Each survey also resulted in one nitrate very intolerant taxon. Station 04LM006 had the greater percent of nitrate tolerant individuals (74.6%). Station 08LM050 had 64.5% nitrate tolerant individuals. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (Class 5) MIBI, and at 68.7% nitrate tolerant individuals there is a 50%t probability of meeting the MIBI.

There is not enough information to conclude nitrate as a stressor to the biology at this time. The concentration of nitrate in the Middle Branch Root River (534) is elevated. Action should be taken to mitigate this issue before it is seen making a larger impact to the biological community.

Suspended sediment

In the Middle Branch Root River, on AUID 534, there is limited suspended sediment data. There were five transparency tube measurements in 2008 with an average of 70 cm with none below 20 cm. The fish in this AUID exhibit some tolerance to TSS with a TSS tolerance station score of 16.5 at Station 04LM006 and 16.6 at Station 08LM050 (both fall within the third most sensitive quartile of TSS tolerance station scores for Root warmwater fish stations).

Stations 04LM006 and 08LM050 had low TSS station index scores for macroinvertebrates. Similarly they had a presence of three TSS intolerant taxa. Station 04LM006 did have an above average number of TSS tolerant macroinvertebrate taxa, but the percentage of TSS tolerant macroinvertebrate individuals was less than average at both stations. Both stations had a small percentage of generally intolerant macroinvertebrate individuals and Station 04LM006 had a low percentage of long-lived macroinvertebrate individuals. There are some macroinvertebrate metrics that appear to respond to potential elevated TSS, but there are a greater number of metrics that are faring well respective to TSS. It is unlikely that TSS is a stressor to the macroinvertebrate communities at Stations 04LM006 and 08LM050 at this time.

Table 55. Macroinvertebrate metrics relevant to TSS for stations the Middle Branch Root River compared to averages for warmwater stations in the Root River watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	**TSS Station Index Score**	**TSS Intolerant Taxa**	**TSS Tolerant Taxa**	**Percentage TSS Tolerant Macroinvertebrate Individuals**	**Percentage of Intolerant Macroinvertebrate Individuals**	**Percentage of Long-lived Macroinvertebrate Individuals**
04LM006	17.03	3	**11**	33.2	**0.36**	**2.5**
08LM050	16.53	3	9	27.78	**0.31**	11.88
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed	*17.96*	*1.52*	*9.32*	*35.45*	*0.48*	*3.16*

Physical habitat

Station 04LM006 had dominant riffle run rock and undercut banks/overhanging vegetation habitats sampled for macroinvertebrates in 2004. The MSHA score was fair (50.6). The surrounding land use around Station 04LM006 was row crop. The riparian area was very narrow (3 – 15 ft.), with little erosion and light shade. Within the reach, there were greater than four substrate types. Riffle habitat comprised of 30% of the reach, with gravel and sand as the dominant substrate. Run habitat made up the greatest of the reach at 65%, with sand and cobble. Pool habitat only comprised of 5% with sand substrate. There was light embeddedness in 2004. The cover available was sparse (5-25%) comprised of overhanging vegetation, deep pools, woody debris, and boulders. There was good depth variability and moderate channel stability.

The MSHA score for Station 08LM050 was good (66.5).The dominant surrounding land use for Station 08LM050 is row crop and pasture. The riparian area was noted as narrow to moderate in 2008. There was no bank erosion and moderate shade (25-50%). Run habitat was dominant with 80% of the reach and the other 20% was pool habitat. There was no riffle noted in the station. Throughout the reach the dominant substrate was sand and gravel, with no embeddedness. There was moderate cover (25-50%) available in the reach with overhanging vegetation, deep pools, woody debris, boulders, and rootwads. The station had good depth variability with moderately high channel stability. Channel development was noted as fair. There was rock in the run habitat, and woody debris/rootwads were the habitat sampled for macroinvertebrates. The subcategories of the MSHA are compared between the two stations, in Figure 145.

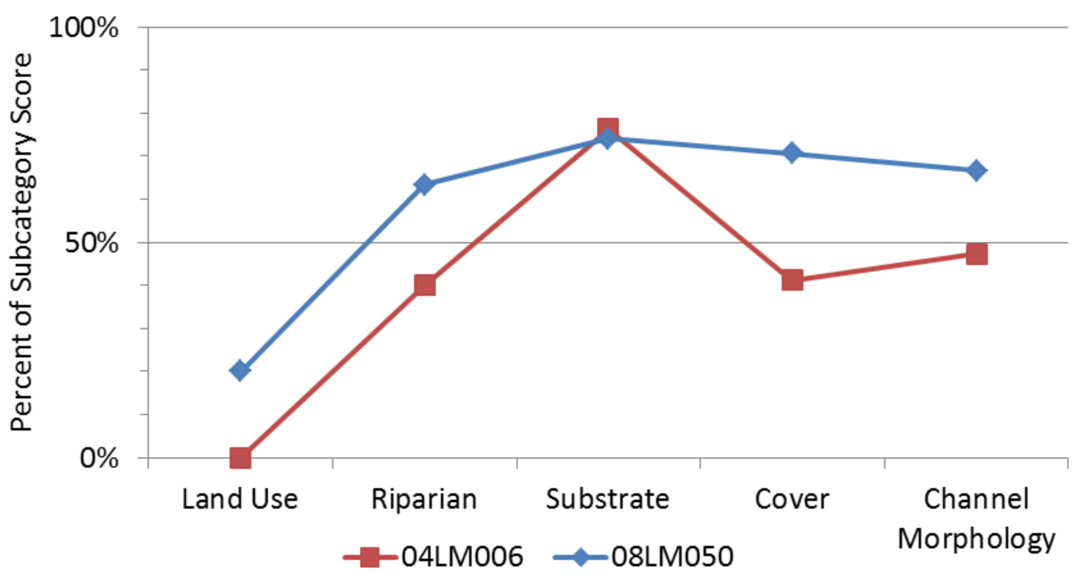


Figure 145. MSHA percent of subcategory scores for Stations 04LM006 and 08LM050 in the Middle Branch Root River

At both stations there was not an abundance of burrowers that would suggest potential fine sedimentation issues in riffle habitats. Station 04LM006 had above average percent of climbers (35%) compared to statewide Southern Streams RR stations average (18.7%), and Station 08LM050 had below average (10.6%). Station 08LM050 had an abundance of individuals that are adapted to cling to substrate or woody debris in swift flowing water (66%), compared to Station 04LM006 which had a reduced percentage of clingers (31%; statewide average is 43%). The percentage of EPT individuals was low at both stations when compared to average of Southern Streams RR stations statewide (26% and 21%, compared to the statewide average of 38%). In addition, the percentage of (generally tolerant) legless individuals was higher than average for the Southern Streams RR macroinvertebrate class (both 63%, compared to the statewide average of only 41%). All of these metrics reveal potentially less than desirable habitat characteristics at both stations, with more habitat related stress demonstrated at Station 04LM006.

Connectivity

No information was available or collected on physical connectivity on the Middle Branch Root River. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in the Middle Branch Root River at this time.

Strength of evidence, conclusions, and recommendations

The main stressor to the macroinvertebrate community is lack of habitat. Both stations in this reach had reduced percentages of EPT taxa. Station 04LM006 had a worse MIBI and a reduced percentage of clingers. Additionally, both sites showed a shift to more tolerant macroinvertebrate species, with a high percentage of legless individuals. Site photographs show a wide channel with somewhat slow flow, and fair stability. Upstream contributions, as this site captures a large drainage, should be considered as a potential source of sediment to this reach.

There is little chemical information on this reach for TSS, but the macroinvertebrate community overall is showing some sensitivity to TSS. While impairments and stressors for TSS have been identified upstream and downstream of this location, TSS should have further attention and monitoring to ensure adequate levels.

Both fish and macroinvertebrates do show some indication of DO tolerance, but its uncertain if the communities are responding to DO or some other stressor. Additional chemical information on DO dynamics in this reach would be useful in ruling out this potential stressor.

At this time, nitrate may be playing a role in the macroinvertebrate communities but there is not sufficient evidence to conclude on whether it is a stressor. The nitrate concentrations in the stream are elevated and action should be taken to reduce nitrate before it is seen making a larger impact to the biological community.

4.9.4. Middle Branch Root River - 528

Supporting information

This reach sites within the near surface Karst zone, had fish IBIs well above the thresholds set for attainment of a healthy fish community. Biological Stations 08LM069 and 08LM070 are on AUID 528. Station 08LM069 was above the threshold and confidence interval with a macroinvertebrate IBI of 43. At 08LM070, the MIBI was very low (15.35), below the threshold and confidence interval, which resulted in the impairment on this reach. All of the metrics found at Station 08LM070 were found below average, except for overall taxa count (Figure 146). Station 08LM070 had low metric scores for a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), and VeryTolerant2Pct, indicating an abundance of very tolerant macroinvertebrates.

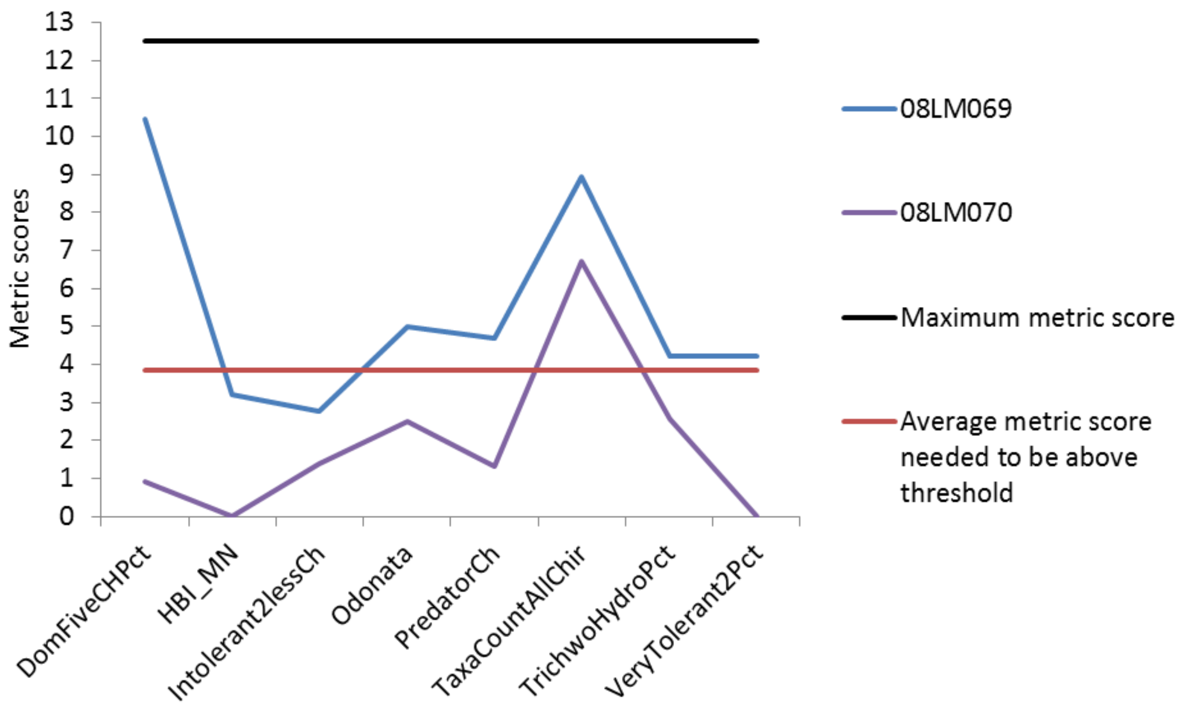


Figure 146. Metric scores for stations in Middle Branch Root River of the Prairie Forest Rivers macroinvertebrate IBI

Stream reconnaissance in 2011 documented changes throughout this reach of the Root River. The upstream portion of the AUID there was more stable, course substrate, and rock outcrops (closer to Station 08LM069). Further downstream, closer to Station 08LM070, the stream channel changed, and there was documentation of severe bank erosion, channel incision, and bank sloughing (Figure 147). Station 08LM070 has a much lower IBI score (15).

Figure 147. Kayak reconnaissance photograph, October10, 2011

Figure 148. Kayak reconnaissance photograph, October 10, 11, showing incised channel and instability accelerated by land use and lack of vegetation, near Station 08LM070.

Temperature

During biological sampling temperatures were within a normal range. At Station 08LM070 the temperature was 18.80°C and Station 08LM069 was 20.10°C. In addition, there were 42 temperature measurements from 2007-2010 at Station S004-842 (co-located with Station 08LM069). The maximum temperature recorded 26.5°C on August 12, 2010. All temperature measurements appear normal for a warmwater system and do not cause concern. Temperature is not a stressor to this reach.

Dissolved Oxygen

The only DO data available was from biological sampling in 2008. At 08LM069 the DO was 12.85 mg/L at 1:30 pm, and at 08LM070 the DO was 10.18 mg/L at 2:47 pm.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. At 08LM069 and 08LM070, pH values were 8.28 and 8.22, respectively. TP concentrations were 0.064 mg/L and 0.054 mg/L, respectively. At chemistry monitoring Station S004-842, pH and total phosphorus were sampled 81 times from 2009-2010. The pH ranged from 7.6 to 8.79. The TP ranged from 0.01 to 1.9 mg/L, with an average of 0.227 mg/L. Since the samples collected during this time frame were for load based monitoring, the high concentrations are likely explained by a larger percentage of storm events which carry higher amounts of TSS and TP. Neither BOD nor chlorophyll-a data were available for analysis at this time.

The fish community at all of the sites is comprised of fish that are neither tolerant nor intolerant to low DO. The stations had a fish DO TIV aggregate scores that were just below what is considered average for the Root River, showing a mixed tolerance.

The macroinvertebrate community shows more sensitivity to DO on this stream reach, especially at Station 08LM069. The DO TIV index scores for macroinvertebrates are only slightly worse than average for Root River stations (both Stations 08LM069 and 08LM070). However, the number of intolerant taxa found at Station 08LM069 is quite high (18) compared to the Root River average of 10. Station 08LM070 had nine intolerant taxa, which is just slightly below average. In addition Station 08LM069 also had percent tolerant taxa which slightly better than average and Station 08LM070 was near average. EPT are typically intolerant of low DO levels and taxa richness can also be decreased with increases in DO flux**.** Both EPT individual percent, along with taxa count were above average for both stations.

The lack of good chemical information, and weak biological response suggests DO is not a stressor to the Middle Branch Root River (528) at this time.

Nitrate

During fish sampling at Station 08LM070 the nitrate concentration was 5.5 mg/L. Similarly, at Station 08LM069, the concentration was 5.8 mg/L. In addition to these samples, there were 45 nitrate samples taken from 2007-2010 at Station S004-842 (Pilot Mount Monitoring Station; collocated with Station 08LM069). There are apparent increases in relationship to storm events, typically in May and June, with flushing of tile flow from the contributing uplands. During low flows, when the tile drainage stops, concentrations are around 5 mg/L.

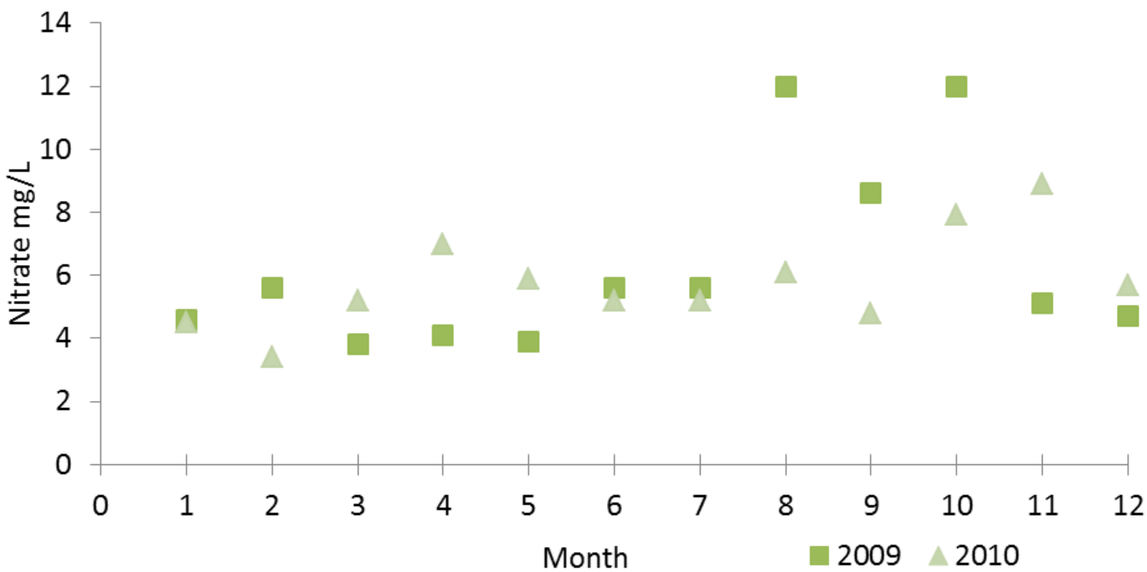


Figure 149. Nitrate concentration ranges from 2009 and 2010 at Station S004-842 (Pilot Mount monitoring station).

The macroinvertebrate taxa count was greater at Stations 08LM069 and 08LM070 than the average of Prairie Forest Stations (class 6) in the LMB. Similarly, both stations had a greater number Trichoptera taxa than the average in similar LMB stations. Station 08LM070 had no intolerant taxa and Station 08LM069 has one intolerant taxa. Both stations had presence of nitrate intolerant taxa. At Station 08LM069, there were two nitrate intolerant taxa, and at Station 08LM070, there was one nitrate intolerant taxon. Station 08LM069 had 74.3% nitrate tolerant individuals, whereas Station 08LM070 had 89.9% nitrate tolerant individuals, and 84.5% of the total individuals were very nitrate tolerant. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is a 10% probability of meeting the MIBI. The downstream Station 08LM070 shows a greater stress from nitrate than Station 08LM069. There may be additional stressors that may be present downstream that are distinguishing the two stations.

At this time, nitrate may be playing a role in the macroinvertebrate communities but there is not sufficient evidence to conclude on whether it is a stressor. Nitrate is inconclusive as a stressor to the macroinvertebrate community in the Middle Branch Root River (528). The nitrate concentrations in the stream are elevated. Additional data should be collected in tandem at the two locations to further the understanding of the nitrate stress to the macroinvertebrate community. Action should be taken to mitigate this issue before it is seen making a larger impact to the biological community.

Suspended sediment

There were 45 TSS samples from 2009-2010 at Station S004-842 (event monitoring samples), which averaged 113 mg/L. Transparency tube measurements were made at Station S004-842. Including all measurements made with the 60cm tube and 100 cm tube, the average transparency was 64.6 from the 52 measurements. Of those transparency tube measurements, 11 were below 20 cm (21%). The maximum TSS concentration was from an event on June 9, 2009, at 1200 mg/L. There were 30 of the 45 values which met the TSS standard (30 mg/L), and 15 which violated the TSS standard (32%

exceedence). However, the data are biased towards storm events, and would not likely be assessed for impairment. During baseflow conditions the stream does not appear to have sustained turbidity, however these samples were taken on the upstream portion of this AUID, and the biological sites are on the downstream end of the AUID where concentrations may be slightly different.

At Station 08LM069, the fish TSS tolerance station score was 16.6, whereas the downstream Station 08LM070 was 12. The average score for warmwater stations in the Root River is 15.4. Overall, the fish data show a mix of tolerant and intolerant to TSS species at the two locations. Fish which are intolerant to high TSS are found in higher numbers at Station 08LM070. Fish are mobile and have the ability to seek out refuge during high TSS timeframes in comparison to macroinvertebrates. The fish community does not appear to be showing stress from elevated TSS.

Stations 08LM069 and 08LM070 had elevated TSS station index scores for macroinvertebrates; both scores were in the most tolerant quartile of scores from warmwater stations in the Root River. Station 08LM070 had no TSS intolerant taxa, whereas the upstream Station 08LM069 had three TSS intolerant taxa. Both stations had an elevated presence of TSS tolerant taxa and individuals. Station 08LM070 also had a low percentage of generally intolerant macroinvertebrate individuals and a low percentage of long-lived macroinvertebrate individuals. The macroinvertebrate community in this reach is likely influenced by the elevated TSS, with more response demonstrated on the downstream reach near Station 08LM070.

Table 56. Macroinvertebrate metrics relevant to TSS for stations the Middle Branch Root River compared to averages for warmwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	**TSS Station Index Score**	**TSS Intolerant Taxa**	**TSS Tolerant Taxa**	**Percentage TSS Tolerant Macroinvertebrate Individuals**	**Percentage of Intolerant Macroinvertebrate Individuals**	**Percentage of Long-lived Macroinvertebrate Individuals**
08LM069	**20.35**	3	**13**	**58.65**	0.64	3.21
08LM070	**24.14**	**0**	**10**	**75.38**	**0**	**1.52**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed	*17.96*	*1.52*	*9.32*	*35.45*	*0.48*	*3.16*

Physical habitat

At Station 08LM070 the MSHA was rated as fair (63.7). The macroinvertebrate IBI was very low (15) There were three habitat types sampled for macroinvertebrates (rock, undercut banks/overhanging vegetation and woody debris). The surrounding land use was forest, wetland, prairie, and shrub. No riffle was noted. The reach was 50% run with gravel and sand, 30% pool with all sand. Light embeddedness was noted with sparse cover and fairly decent channel stability and development.

At Station 08LM069 the MSHA rated as good (75). The macroinvertebrate IBI was also quite a bit higher here (43). The same three habitat types were sampled (same as Station 08LM070). The surrounding land use forest, wetland, prairie, and shrub. The riparian zone noted as moderately wide. No bank erosion was present with substantial shade. The reach was characterized as 100% run, with all boulder and cobble. Light embeddedness, with moderate cover, and high channel stability were noted.

The percentage of EPT individuals was found above statewide averages for this class at both sampling locations. There was not an abundance of burrowers found, which may suggest potential fine sedimentation issues. The macroinvertebrates that are known to cling to large substrate and woody debris were low (below statewide average of 41.1%). Station 08LM070 was much lower (only 11%) than 08LM069 which was near average at 39%. The percentage of macroinvertebrates that climb was near average for Station 08LM069 (13%), and well above average for 08LM070 (36%). There was also a higher percentage of generally tolerant legless individuals at Station 08LM070 (43%), compared to fewer at Station 08LM069 (19%).

Although there may be some aspects of habitat that could be improved, with some diverse habitat present, it is not likely that habitat is currently a driving force of macroinvertebrate impairment in the majority of this reach. Station 08LM070 has issues more consistent with macroinvertebrate habitat degradation, with a reduced percentage of clingers and a higher percentage of tolerant legless individuals. Habitat is limiting at Station 08LM070 and a stressor to the macroinvertebrate community.

Connectivity

No information was available or collected on physical connectivity on the Middle Branch Root River. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in the Middle Branch Root River at this time.

Strength of evidence, conclusions, and recommendations

Currently, the stressors to the macroinvertebrate community in this reach are elevated TSS and lack of habitat, but are restricted to the lower part of the reach, near Station 08LM070. Field observation shows that when moving downstream, instability increases which likely contribute to higher TSS concentrations and subsequent habitat loss within the lower reaches.

Loss of riparian vegetation, pasturing, and near channel row crop land use all could be improved in the immediate riparian area of the lower part of this reach. All of these things were documented during field reconnaissance, and demonstrated clear impact on stream bank instability.

At this time, nitrate may be playing a role in the macroinvertebrate communities but there is not sufficient evidence to conclude on whether it is a stressor. The nitrate concentrations in the stream are elevated and action should be taken to reduce nitrate before it is seen making a larger impact to the biological community.

4.9.5. Wadden Valley Creek and Money Creek

Supporting information

The fish IBIs in Wadden Valley Creek and Money were above the threshold and above the confidence interval. The fish community in Wadden Valley Creek, Station 08LM024, comprised of white suckers, blacknose dace, northern hogsucker, central stoneroller, shorthead redhorse, brown trout, and longnose dace. Station 08LM051 had 16 fish taxa including dace, darters and trout. The community was dominated by 222 white suckers.

The macroinvertebrate community in the Southern Streams RR class resulted in IBIs of 28.7 at Station 08LM024, and 30.9 and 31.2 at Station 08LM051. The macroinvertebrate IBI scores were all below the threshold and within the confidence interval. The macroinvertebrate metrics scores for the Southern Streams RR IBI class show similarity between the three visits (Figure 150). The metrics that had the lowest scores were taxa richness of climbers (ClimberCh), taxa richness of Plecoptera (Plecoptera), taxa richness of predators (excluding chironomid predator taxa) (Predator), and taxa richness of Trichoptera (Trichoptera). The metrics of relative percentage of taxa with tolerance values equal to or greater than six, using MN TVs (Tolerant2ChTxPct), taxa richness of Odonata (Odonata), and relative percentage of insect taxa (InsectTxPct) were less than the average metric score needed to be above threshold during one of the visits as well.

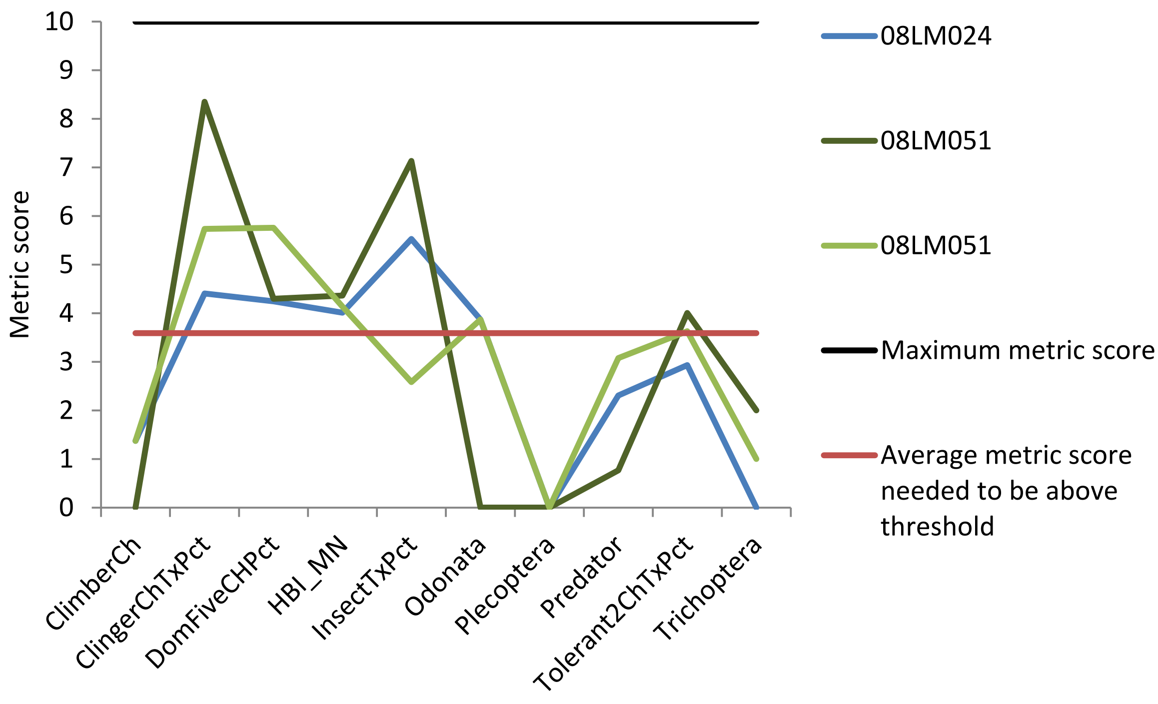


Figure 150. Metric scores for stations in Wadden Valley Creek and Money Creek of the Southern Streams RR macroinvertebrate IBI

Temperature

In Wadden Valley Creek the temperature taken at Station 08LM024 during biological sampling was cold, at 14.3°C. There was only one other temperature measurement on Station S003-389, from August 19, 2003, which was 15.8°C). The site was analyzed and reviewed site with MDNR in 2010 to see if they had information about the use classification (warmwater or coldwater), and decision was leave as warmwater in lieu of information to suggest otherwise. There are a number of springs mapped in the headwaters.

In Money Creek, the temperature taken at Station 08LM051 during biological sampling was also fairly cold, at 16.6°C. There was no other temperature information on this reach to help characterize temperature. The site was also reviewed by MPCA and MDNR and decided to leave as warmwater. The site has trout but they are not stocked. It possibly could be designated coldwater in future, but more temperature logger data would be needed to confirm temperatures are suitable. There is one mapped spring in the headwater area.

Both of these streams really have some potential to be coldwater, given they are small drainages in heavily Karsted area where springs and prominent. Additional information on temperature dynamics (continuous temperature data) on both of these streams is needed, and therefore temperature cannot be analyzed as a stressor at this time.

Dissolved Oxygen

The only DO data available for Wadden Valley Creek or Money Creek was during biological sampling. At Wadden Valley Creek, Station 08LM024, the DO at 8:40 am on June 24, 2008, was 10.25 mg/L. At Money Creek, Station 08LM051, the DO at 11:22 am on June 24, 2008, was 13.25 mg/L. These values may be elevated given the time of day, especially for Money Creek.

As interacting variables to DO, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. At Wadden Valley Creek, Station 08LM024, the pH and TP during biological sampling was, 8.21 and 0.071 mg/L, respectively. At Money Creek, Station 08LM051, the pH and TP sample during biological sampling was 7.84 and 0.054 mg/L. Neither BOD nor chlorophyll-a data were available for analysis at this time.

The fish community at both stations is comprised of fish that are generally more tolerant to low oxygen concentrations, especially Money Creek. The stations had DO TIV aggregate scores that were below average in comparison to other Root River fish stations.

The macroinvertebrate community does not show a similar response between the two streams. Wadden Valley Creek had a DO TIV index score slightly worse than average for Root River stations, while Money Creek had a score better than average. Money Creek also showed better than average percent tolerant to low DO, and DO intolerant taxa. In comparison, Wadden Valley Creek was just below average in all DO related metrics. Both were sitting near average in all metrics, just on either side of what is considered average for the Root River. This information does not strongly suggest DO is a stressor in either location.

Given the lack of chemical information and lack of consistent biological response, both stream reaches have insufficient data to confirm DO is a stressor. Additional chemical information would be useful in better understanding of the stream oxygen dynamics.

Nitrate

Station 08LM024 had one nitrate sample taken on June 24, 2008, at 6.6 mg/L. During this visit the stream conductivity was 600 um/cm, which is slightly high for a warmwater stream and may suggest some groundwater input to this location where nitrate is elevated.

Station 08LM051 also had only one nitrate sample taken on June 24, 2008, at 8.5 mg/L. During this visit the conductivity was 628 um/cm, which also seems slightly high for a warmwater stream and may suggest groundwater inputs to this location (similar to Wadden Valley Creek).

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate Class 5 (Southern Forest RR) streams in Minnesota shows a 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

Both streams had reduced numbers of taxa, except the second visit to Station 08LM051. All three visits resulted in a lower than average number of Trichoptera taxa. Station 08LM024, on Wadden Valley Creek, had a higher percentage of nitrate tolerant individuals (84.8%). At 78.2% nitrate tolerant individuals, there is a 25% percent probability of meeting the Southern Streams RR (class 5) MIBI, and at 68.7% nitrate tolerant individuals there is a 50% probability of meeting the MIBI. Station 08LM051 had 68.8 and 73.5% nitrate tolerant individuals, both lower than Wadden Valley Creek Station. Money Creek, Station 08LM051, had one intolerant taxon during each survey. Similarly, there was one nitrate intolerant taxon at each visit of Station 08LM051.

There is a lack of chemical data on both of these reaches. The macroinvertebrate community in Wadden Valley Creek is suggestive of a possible nitrate stress, but there is little to confirm those indications. Money Creek does not have as much macroinvertebrate indications of nitrate stress, but nitrate still may be influencing the community. There is little confirmation available to date. Additional monitoring should be conducted to further the understanding of nitrate in both of these reaches.

Suspended sediment

In Wadden Valley Creek the only TSS data was at the time of fish sampling and resulted in 2.8 mg/L TSS at Station 08LM024. There have only been three measurements utilizing the transparency tube of 12, 24 and 60 cm (at Station S003-2005).

Although only impaired for macroinvertebrates, the fish can assist in narrowing down the potential stressors. The station score generated by fish tolerance to TSS was 12.7 (in the most sensitive quartile of TSS tolerance station scores for Root warmwater fish stations). The relatively more sensitive fish present were longnose dace, blacknose dace and brown trout. In Money Creek the only TSS was at the time of fish sampling and resulted in 4.8 mg/L TSS at Station 08LM051. Similarly to Wadden Valley the fish community had a tolerance station score for TSS of 13.4 (in the most sensitive quartile of TSS tolerance station scores for Root warmwater fish stations).

The macroinvertebrate communities in Wadden Valley Creek and Money Creek have a low percentage of TSS intolerant taxa, generally intolerant individuals and long-lived individuals; all of which decrease with increased stress (Table 57). However, the metrics that generally increase with increased stress are better than the averages for warmwater stations in the Root River. It is likely that the stressor(s) that are causing the intolerant metrics and long-lived metric to be reduced are not related to TSS.

The biological information supports that TSS is not a likely stressor at either Money Creek or Wadden Valley Creek. While the chemical information is limited, both biological indicators show increased sensitivity to TSS.

Table 57. Macroinvertebrate metrics relevant to TSS for stations in Wadden Valley Creek and Money Creek compared to averages for warmwater stations in the Root River Watershed. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

TSS Relevant Metrics	TSS Station Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	Percentage TSS Tolerant Macroinvertebrate Individuals	Percentage of Intolerant Macroinvertebrate Individuals	Percentage of Long-lived Macroinvertebrate Individuals
08LM024	14.75	**0**	4	7.22	**0**	**0.67**
08LM051	15.35	**1**	7	12.93	**0.33**	**0.66**
08LM051	15.88	**1**	6	24.32	**0.33**	**2.66**
Expected response with increased TSS stress	increase	decrease	increase	increase	decrease	decrease
Averages for Warmwater stations in the Root River watershed	*17.96*	*1.52*	*9.32*	*35.45*	*0.48*	*3.16*

Physical habitat

In Wadden Valley Creek (Station 08LM024), the MSHA was rated as fair (64). Row crop was the surrounding land use. The riparian zone was noted as narrow, with moderate bank erosion and substantial shade. The reach was 65% riffle, made up of cobble and gravel. There were three habitats sampled for macroinvertebrates (riffles, undercut banks/overhanging vegetation and woody debris).

There was not an abundance of burrowers found, which would suggest potential sedimentation issues in the riffle. However, the percentages of EPT taxa, climbers (macroinvertebrates that climb) and clingers (macroinvertebrates that are known to cling to large substrate and woody debris) were found slightly below statewide averages for this stream class. While it appears there may be some habitat improvement in Wadden Valley Creek, with diverse habitat present and a lack of strong biological response, it is unlikely that lack of habitat is currently having a direct impact to the macroinvertebrate community.

In Money Creek (Station 08LM051), the MSHA was rated as fair (62). Forest, open pasture, and row crop are all surrounding land uses. The riparian zone noted as narrow. There was little bank erosion, but moderate embeddedness noted. The reach was 15% riffle made up of cobble and gravel. All four macroinvertebrate habitat types were sampled.

There was not an abundance of burrowers found, which would suggest potential fine sedimentation in the riffle habitats. The percentage of EPT taxa was found above average at both visits in 2008 in Money

Creek. The percentage of climbers (macroinvertebrates that climb) were reduced and below average for both visits. In addition, clingers (macroinvertebrates that are known to cling to large substrate and woody debris) were found near statewide averages for this stream class. While it appears there may be some habitat improvement in Money Creek, with diverse habitat present and a lack of strong biological response, it is unlikely that lack of habitat is currently having a direct impact to the macroinvertebrate community.

Physical connectivity

No information was available or collected on physical connectivity on the Wadden Valley Creek or Money Creek. The impairment is for macroinvertebrates, and they would likely be less impacted by connectivity issues. Connectivity is not considered a stressor in the Wadden Valley Creek or Money Creek at this time.

Strength of evidence, conclusions, and recommendations

The stressors to these two watersheds are unable to be determined.

Habitat is likely playing some type of role in shaping the macroinvertebrate community in Wadden Valley Creek but the data are not strong. In Money Creek habitat does not appear to be the issue.

The macroinvertebrate community in Wadden Valley Creek is suggestive of a possible nitrate stress, but there is little to confirm those indications. Money Creek does not have as much macroinvertebrate indications of nitrate stress, but nitrate still may be influencing the community.

Both of these watersheds are lacking connecting information. In particular, DO, temperature, and nitrate are parameters that need additional information. There is a potential signal of DO stress in both watersheds, and currently both are classified as warmwater. However, there appears to be some potential to be coldwater as some parameters indicate (low temperature, high conductivity, and high nitrate during baseflow). High resolution temperature data may be useful in understanding temperature dynamics in both of these systems, which would also ensure the proper use (coldwater/warmwater) classifications, are applied as well.

4.9.6. Summary of stressors in Trout Run-Root River

The stressors found to limiting the biological communities in the Trout Run 10 digit HUC watershed are found in Table 58.

Table 58. Stressors identified in the Trout Run-Root River Watershed. (● = stressor (yes); o = inconclusive stressor; 'blank'-no stressor)

Reach Name	*Geo Region*	AUID	Reach Description	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Physical Habitat	Physical Connectivity
Trout Run	***Driftless, Near Surface Karst***	***07040008-G87***	*T105 R10W S18, North line to Unnamed Creek*	2A	04LM098	Upstream of County Rd 10, 6 mi. NE of Chatfield	Invert IBI		**O**	●		●	
Rice Creek	***Driftless, Near Surface Karst***	***07040008-581***	*T104 R11W S23, west line to Middle Branch Root River*	2A	08LM031	Downstream of 308th St, 5 mi. SE of Chatfield	Fish IBI Invert IBI	O		●	O	●	O
Root River, Middle Branch	***Driftless, Near Surface Karst***	***07040008-528***	*Trout Run Creek to South Branch Root River*	2B	08LM070 08LM069	Adjacent to Goodview Dr, 3.5 mi. NW of Lanesboro Upstream of CSAH 21, 5 mi. NW of Lanesboro	Invert IBI			O	●	●	
Root River, Middle Branch	***Driftless, Near Surface Karst***	***07040008-534***	*North Branch Root River to Lynch Creek*	2B	08LM050 04LM006	Upstream of Hwy. 52, 3 mi. SE of Chatfield Upstream of Hwy. 52, 1 mi. SE of Chatfield	Invert IBI Bacteria		**O**	O		●	
Unnamed Creek (Wadden Valley Creek)	***Driftless, Near Surface Karst***	***07040008-605***	*Unnamed Creek to Middle Branch Root River*	2B	08LM024	Adjacent to Hobbit Ln, 4 mi. NW of Lanesboro	Invert IBI		**O**	O		**O**	

Reach Name	*Geo Region*	AUID	Reach Description	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment	Physical Habitat	Physical Connectivity
Money Creek	***Driftless, Near Surface Karst***	***07040008-F48***	*Unnamed Creek to Middle Branch Root River*	2B	08LM051	Upstream of Harrow Rd, 5 mi. NW of Lanesboro	Invert IBI		**o**	o		**o**	

5. Summary conclusions and recommendations for the Root River Watershed

5.1. Summary of stressors

The table below summarizes the stressors in the Root River Watershed.

Table 59. Summary of stressors in the Root River Watershed

10 Digit HUC	Watershed Name	Description	AUID	Biological Impairment	Stressors					
					Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment (TSS)	Physical Habitat	Physical Connectivity
Root River	Root River	Thompson Cr to Mississippi R	07040008-501	Macroinvertebrate			●	●	●	
	Root River	S Fk Root R to Thompson Cr	07040008-502	Macroinvertebrate			●	●	●	
	Silver Creek	T105 R6W S35, north line to T104 R6W S14, south line	07040008-640	Fish and Macroinvertebrate	o		o	o	●	
City of Rushford-Root River	Root River	Money Cr to S Fk Root R	07040008-520	Macroinvertebrate			o	●	●	
	Root River	Rush Cr to Money Cr	07040008-522	Macroinvertebrate			o	●	●	
	Unnamed creek (Camp Hayward Creek)	T104 R8W S32, east line to Unnamed cr	07040008-659	Macroinvertebrate				o	●	
	Root River	M Br Root R to Rush Cr	07040008-527	Macroinvertebrate			o	●	●	
Trout Run-Root River	Trout Run Creek	T105 R10W S18, north line to Unnamed cr	07040008-G87	Macroinvertebrate		o	●		●	

10 Digit HUC	Watershed Name	Description	AUID	Biological Impairment	Stressors					
					Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment (TSS)	Physical Habitat	Physical Connectivity
	Root River, Middle Branch	Trout Run Cr to S Br Root R	07040008-528	Macroinvertebrate			o	●	●	
	Root River, Middle Branch	N Br Root R to Lynch Cr	07040008-534	Macroinvertebrate		o	o		●	
	Money Creek	Unnamed cr to M Br Root R	08040008-F48	Macroinvertebrate		o	o		o	
	Wadden Valley Creek (Unnamed Creek)	Unnamed Cr to M Br Root R	07040008-605	Macroinvertebrate		o	o		o	
	Rice Creek	T104 R11W S23, west line to M Br Root R	07040008-581	Fish and Macroinvertebrate	o		●	o	●	o
Middle Branch Root River	Root River, Middle Branch	Upper Bear Cr to N Br Root R	07040008-506	Macroinvertebrate			o	o	●	
	Upper Bear Creek	T104 R11W S18, west line to M Br Root R	07040008-540	Fish and Macroinvertebrate	o		●	o	●	o
	Bear Creek	Headwaters to Kedron Cr	07040008-544	Macroinvertebrate			o	o	●	
	Spring Valley Creek	T103 R13W S29, west line to Deer Cr	07040008-548	Fish and Macroinvertebrate	●	o	●	o	●	
	Curtis Creek	Headwaters to M Br Root R	07040008-541	Macroinvertebrate			●		●	
Money Creek	Corey Creek	T105 R6W S18, east line to Money Cr	07040008-631	Fish	●			o	●	●
North Branch Root River	Unnamed creek (Evanger Church)	Unnamed cr to N Br Root R	07040008-706	Macroinvertebrate		o	o	o	●	
	Root River, North Branch	Unnamed cr to Mill Cr	07040008-716	Macroinvertebrate			o	●	●	

10 Digit HUC	Watershed Name	Description	AUID	Biological Impairment	Stressors					
					Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment (TSS)	Physical Habitat	Physical Connectivity
	Unnamed creek	Unnamed cr to Unnamed cr	07040008-F46	Macroinvertebrate		o	o		●	
	Root River, North Branch	Headwaters to Carey Cr	07040008-717	Macroinvertebrate		●	o	●	●	
Rush Creek	Rush Creek	Unnamed cr to Pine Cr	07040008-524	Macroinvertebrate		o	●		●	
	Pine Creek	T104 R9W S4, north line to Rush Cr	07040008-526	Macroinvertebrate		o	o	o	●	
	Pine Creek	Headwaters to T105 R9W S32, south line	07040008-576	Macroinvertebrate		o	o	o	●	
South Branch Root River	Root River, South Branch	Duschee Cr to M Br Root R	07040008-550	Macroinvertebrate		o	●	●		
	Watson Creek	T103 R11W S30, west line to S Br Root R	07040008-552	Fish and Macroinvertebrate	●		●	●	●	
	Root River, South Branch	T102 R12W S21, north line to Canfield Cr	07040008-556	Macroinvertebrate			●	o		
	Willow Creek	T101 R11W S12, west line to S Br Root R	07040008-558	Macroinvertebrate			●		●	
	Camp Creek	Headwaters to S Br Root R	07040008-559	Fish and Macroinvertebrate	●	o	●	o	●	
	Etna Creek	T102 R13W S36, west line to Unnamed cr	07040008-597	Macroinvertebrate			●		o	
South Fork Root River	Root River, South Fork	Beaver Cr to Root R	07040008-508	Macroinvertebrate			●	●	●	
	Root River, South	Riceford Cr to Beaver Cr	07040008-509	Macroinvertebrate			o	●	●	

10 Digit HUC	Watershed Name	Description	AUID	Biological Impairment	Stressors					
					Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment (TSS)	Physical Habitat	Physical Connectivity
	Fork									
	Root River, South Fork	Wisel Cr to T102 R8W S2, east line	07040008-510	Macroinvertebrate	o		●	o	●	
	Riceford Creek	T101 R7W S19, south line to T102 R7W S30, north line	07040008-518	Macroinvertebrate		o	●	o	●	
	Riceford Creek	T102 R7W S19, south line to S Fk Root R	07040008-519	Macroinvertebrate				o	●	
	Root River, South Fork	Headwaters to T102 R9W S27, east line	07040008-573	Macroinvertebrate	o	●	●	●	●	
	Sorenson Creek	Unnamed cr to Unnamed cr	07040008-F52	Macroinvertebrate		o	●		●	
	Bridge Creek	Unnamed cr to Unnamed cr	07040008-F54	Macroinvertebrate		o	o	o	●	

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

5.2. Recommendations and protection

Recommendations for management of stressors for the Root River Watershed are found in Table 60. Any stream suffering from multiple stressors may warrant higher priority for restoration. In the case of many stressors, implementation activities can address multiple stressors simultaneously. For example, better riparian management can improve suspended sediment concentrations, habitat, DO, and temperature.

Table 60. Recommended prioritization relative to the stressors contributing to the biological impairment in the Root River Watershed

Stressor	Priority	Comment
TSS	High	Focus on reducing sediment input from riparian corridor (cattle pastures) and immediate stream channel (stream banks). Focus may be warranted in the upper parts of the subwatersheds.
Habitat	High	Aim to re-establish quality riparian corridor to increase woody debris, course particulate organic matter (CPOM) inputs, and stream shading. TSS strategies can also be important in habitat issues related to sedimentation, and stream shading will also have a positive impact on stream temperature.
Nitrate	High	Priority 1: Any stream > 10 mg/L nitrate (likely impaired for drinking water already), and showing biota impairment (majority in “near-surface Karst” zone). Priority 2: Other streams >10 mg/L nitrate. Other areas of focus: Streams with elevated (6-10 mg/L) and/or the western (Mower County) streams that have heavy nitrate loads but no drinking water impairments or high baseflow concentrations.
Dissolved Oxygen	Low	Current DO streams (2) with DO stressors. Many reaches lack adequate DO information and additional information should be collected (Spring Valley, etc). However, DO issues will likely resolve with attention given to other stressors (above).
Temperature	Medium	Collect additional information on streams with potential temperature issues (Upper Bear Creek-Lost Creek and Rice Creek).
Physical Connectivity	Low	Areas with fish impairment need a better analysis of potential connectivity issues.

Based on the MPCA’s current assessment of aquatic life, many areas in the Root River watershed are doing well biologically. However, it is important to consider areas that may need some extra support to help sustain a high functioning aquatic environment, or to help the threatened aquatic environment. Protection can broken into two categories; 1) Exceptional, very good biological condition; and 2) Vulnerable biologically.

1) Exceptional: The watersheds with the highest IBI scores are: (both fish and macroinvertebrates well above impairment thresholds)

- Forestville Creek and Tributary Creek
- Beaver Creek (2 of 3 stations)
- Thompson Creek
- South Branch Root River (select locations)

- South Fork Root River (select locations)
- Badger Creek
- Rush Creek Tributary
- Lower Trout Run Creek
- Daley Creek
- Big Springs Creek
- Shattuck Creek
- Diamond Creek
- Coolridge Creek
- Deer Creek

2) Vulnerable: The watersheds that are near impairment thresholds include: (fish and macroinvertebrates within 10 points of impairment threshold)

- Mill Creek
- Money Creek
- Duschee Creek
- Willow Creek (fish)
- Crystal Creek
- Wisel Creek (inverts)
- Upper North Branch (fish)

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7. Appendix

A weight of evidence approach was used to determine stressors in each impaired reach. The scores for each stream reach can be made available upon request. Due to the large volume of impairments in the Root River, they are not included in this report because each stream reach requires a one page weight of evidence table. The following tables demonstrate the scoring process for weight of evidence analysis.

Table A1. Values used to score evidence in the Stressor Identification Process.

Rank	Meaning	Caveat
+++	*Convincingly supports*	*but other possible factors*
++	*Strongly supports*	*but potential confounding factors*
+	*Some support*	*but association is not necessarily causal*
0	*Neither supports nor weakens*	*(ambiguous evidence)*
-	*Somewhat weakens support*	*but association does not necessarily reject as a cause*
--	*Strongly weakens*	*but exposure or mechanism possible missed*
---	*Convincingly weakens*	*but other possible factors*
R	*Refutes*	*findings refute the case unequivocally*
NE	*No evidence available*	
NA	*Evidence not applicable*	
D	*Evidence is diagnostic of cause*	

Table A2. Strength of evidence scores for various types of evidence

Types of Evidence	**Possible values, high to low**
Evidence using data from case	
Spatial / temporal co-occurrence	+, 0, ---, R
Evidence of exposure, biological mechanism	++, +, 0, --, R
Causal pathway	++, +, 0, -, ---
Field evidence of stressor-response	++, +, 0, -, --
Field experiments / manipulation of exposure	+++, 0, ---, R
Laboratory analysis of site media	++, +, 0, -
Temporal sequence	+, 0, ---, R
Verified or tested predictions	+++, +, 0, -, ---, R
Symptoms	D, +, 0, ---, R
Evidence using data from other systems	
Mechanistically plausible cause	+, 0, --
Stressor-response relationships in other field studies	++, +, 0, -, --
Stressor-response relationships in other lab studies	++, +, 0, -, --
Stressor-response relationships in ecological models	+, 0, -
Manipulation of exposure experiments at other sites	+++, +, 0, --
Analogous stressors	++, +, -, --
Multiple lines of evidence	
Consistency of evidence	+++, +, 0, -, --
Explanatory power of evidence	++, 0, -