Mississippi River-Winona Watershed Biotic Stressor Identification Report

A study of local stressors limiting the biotic communities.

Minnesota Pollution Control Agency

March 2015

Legislative Charge

Minn. Statutes § 116.011 Annual Pollution Report

A goal of the Pollution Control Agency is to reduce the amount of pollution that is emitted in the state. By April 1 of each year, the MPCA shall report the best estimate of the agency of the total volume of water and air pollution that was emitted in the state the previous calendar year for which data are available. The agency shall report its findings for both water and air pollution, etc., etc.

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Contents

Acronyms

AUID – Assessment Unit ID

BEHI –

BHR – Bank Height Ratio

BOD – biological oxygen demand

CADDIS – Causal Analysis/Diagnosis Decision Information System

CBI coldwater biotic index

CCSI – channel condition stability index

ChE – Cholinesterase

CL – confidence limits

cm – centimeter

DELT – Deformities, Eroded fins, Lesions, and Tumors

DO – Dissolved Oxygen

EDA – Environmental Data Access

EPA – Environmental Protection Agency

EPT – Ephemeroptera, Plecoptera, and Trichoptera

FIBI – Fish Index of Biological Integrity

FWC – Flow weighted concentration

GP – Glide/Pool

HUC – Hydrologic Unit Code

IBI – Index of Biotic Integrity

IWM – Intensive Watershed Monitoring

LMB – Lower Mississippi Basin

MBWW – Middle Branch White Water

MDA – Minnesota Department of Agriculture

MDH – Minnesota Department of Health

MDNR – Minnesota Department of Natural Resources

MIBI – Macroinvertebrate Index of Biological integrity

mg/L – milligrams per Liter

MPCA – Minnesota Pollution Control Agency

MR-Winona – Mississippi River Winona

MSHA – MPCA Stream Habitat Assessment

N – Nitrate

NBS – near bank stress

NBWW – North Branch Whitewater

NTU – Nephelometric Turbidity Units

PDSI – Palmer Drought Severity Index

POET – Taxa Richness of Plecoptera, Odonata, Ephemeroptera &Trichoptera

RR – Riffle Run

SBWW – South Branch Whitewater

SID – Stressor Identification

SOE – Strength of Evidence

SSURGO – Soil Survey Geographic Database

TIV – Tolerance Indicator Value

TMDL – Total Maximum Daily Load

TP – Total Phosphorus

TSS – Total Suspended Solids

TSVS – Total Suspended Volatile Solids

USDA – United States Department of Agriculture

USEPA – United States Environmental Protection Agency

USGS – United States Geological Survey

W/D – width to depth ratio

WRAPS – Watershed Restoration and Protection Strategies

WWTP – Wastewater Treatment Plant

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, Index of Biological Integrity (IBI) scores are calculated, which provide 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, it is the process of identifying the major factors causing harm to aquatic life. Stressor identification is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act.

This report summarizes stressor identification work in the Mississippi River-Winona Watershed. There were 10 reaches identified with biological impairment in the MR-Winona Watershed. However, this report addresses 12 reaches – the 10 identified and two with imminent impairments.

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

- **Dissolved oxygen (DO)**
- **Temperature**
- **Nitrate**
- **Total suspended solids (TSS)**
- **Habitat**
- **Connectivity**

In the MR-Winona watershed, there were four streams with fish and macroinvertebrate impairment, while the remaining eight were macroinvertebrates only. A summary of the stressors identified in each stream reach is found at the end of this document, in Table 47.

1. Introduction

1.1 Monitoring and assessment

Water quality and biological monitoring in the MR-Winona have been ongoing. As part of the MPCA's Intensive Watershed Monitoring (IWM) approach, monitoring activities increased in rigor and intensity during 2010, and focused more on biological monitoring (fish and macroinvertebrates) as a means of assessing stream health. The data collected during this period, as well as historic data obtained prior to 2010 were used to identify stream reaches that were not supporting healthy fish and macroinvertebrate assemblages (Figure 1).

Once a biological impairment is discovered, 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 the TMDL may be developed. In other words, 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.

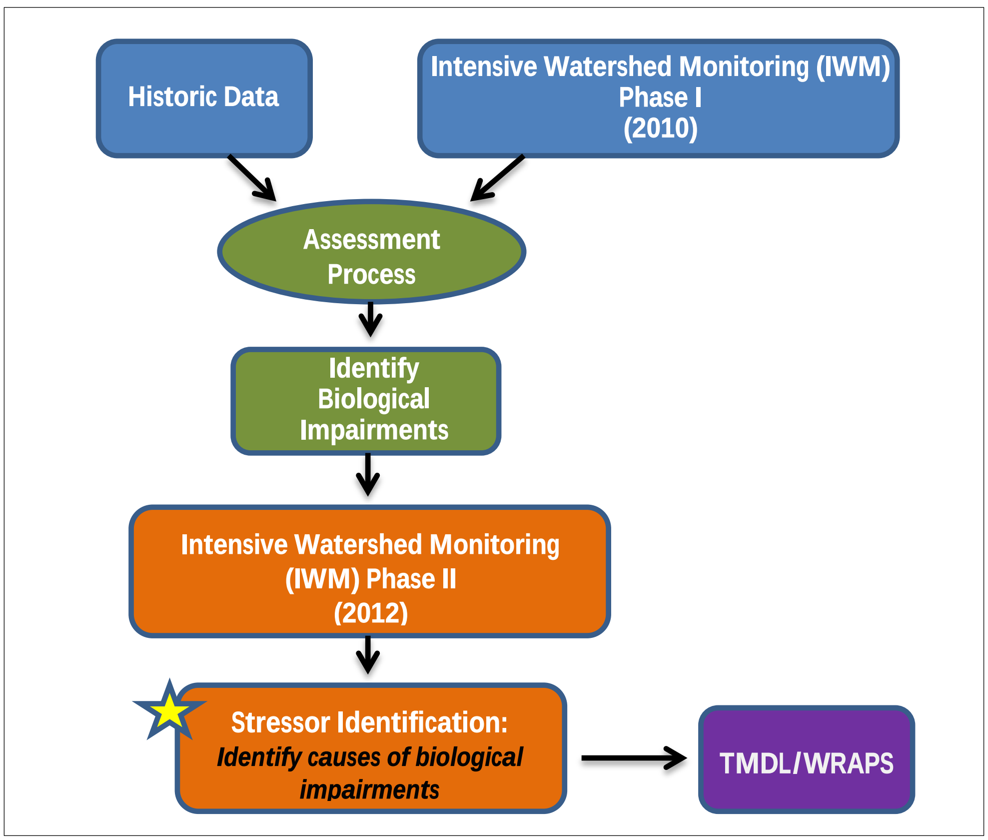

Figure 1. Process map of the Intensive Watershed Monitoring, Assessment, Stressor Identification and TMDL processes.

1.2 Stressor identification process

The MPCA follows the U S Environmental Protection Agency (EPA)'s process of identifying stressors that cause biological impairment, which has been used to develop the MPCA's guidance to stressor identification (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, geology, geomorphology, chemistry, land-use analysis, and toxicology. A conceptual model showing the steps in the SID process is shown in Figure 2. 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.

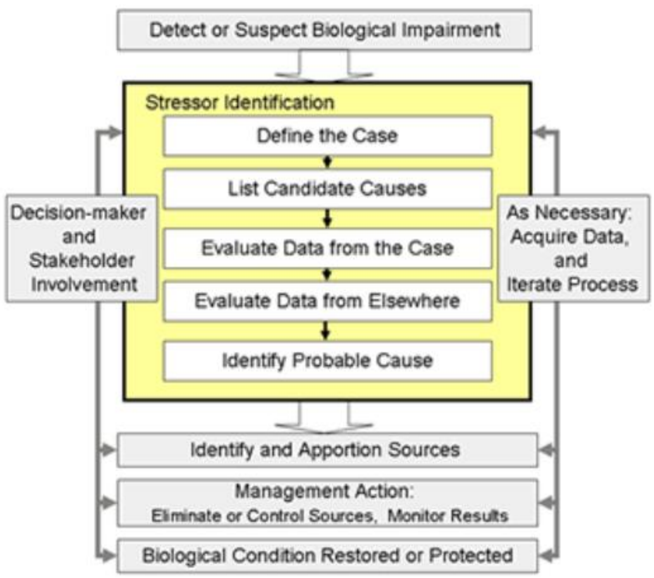

Figure 2. Conceptual model of stressor identification process (Cormier et al. 2000)

Strength of evidence (SOE) analysis is used to evaluate the data for candidate causes of stress to biological communities. The relationship between stressor and biological response is 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. A narrative description of how the scores were obtained from the evidence should be discussed as well. The SOE table allows for 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. 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 Common stream stressors

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 stream 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 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) · Lack of baseflow · 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 DO Concentrations** **Elevated levels of Nutrients** · Increased nutrients from human influence § Increased nonpoint pollution from urban and agricultural practices and/or increased point source pollution from urban treatment facilities Ø Increased algal and or periphyton growth in stream Ø Widely variable DO levels during the daily cycle	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 the MR-Winona Watershed

The western portion of the watershed consists of gently rolling land that is heavily row cropped. The eastern portion of the watershed is dissected by steep valleys with wooded slopes (Figure 3). The crop fields in the western portion are smaller, with more hay and pasture present. Dairy and beef are the major livestock types in the watershed.

The lower portion of the watershed supports a healthy population of brown trout, and flows through the Whitewater Wildlife Management Area. Picturesque limestone bluffs and deep ravines make Whitewater State Park a popular destination. Anglers find brown, brook, and rainbow trout in the spring-fed Whitewater River and many tributaries. The watershed has a history of damaging floods, including one in 2007 that reshaped the river.

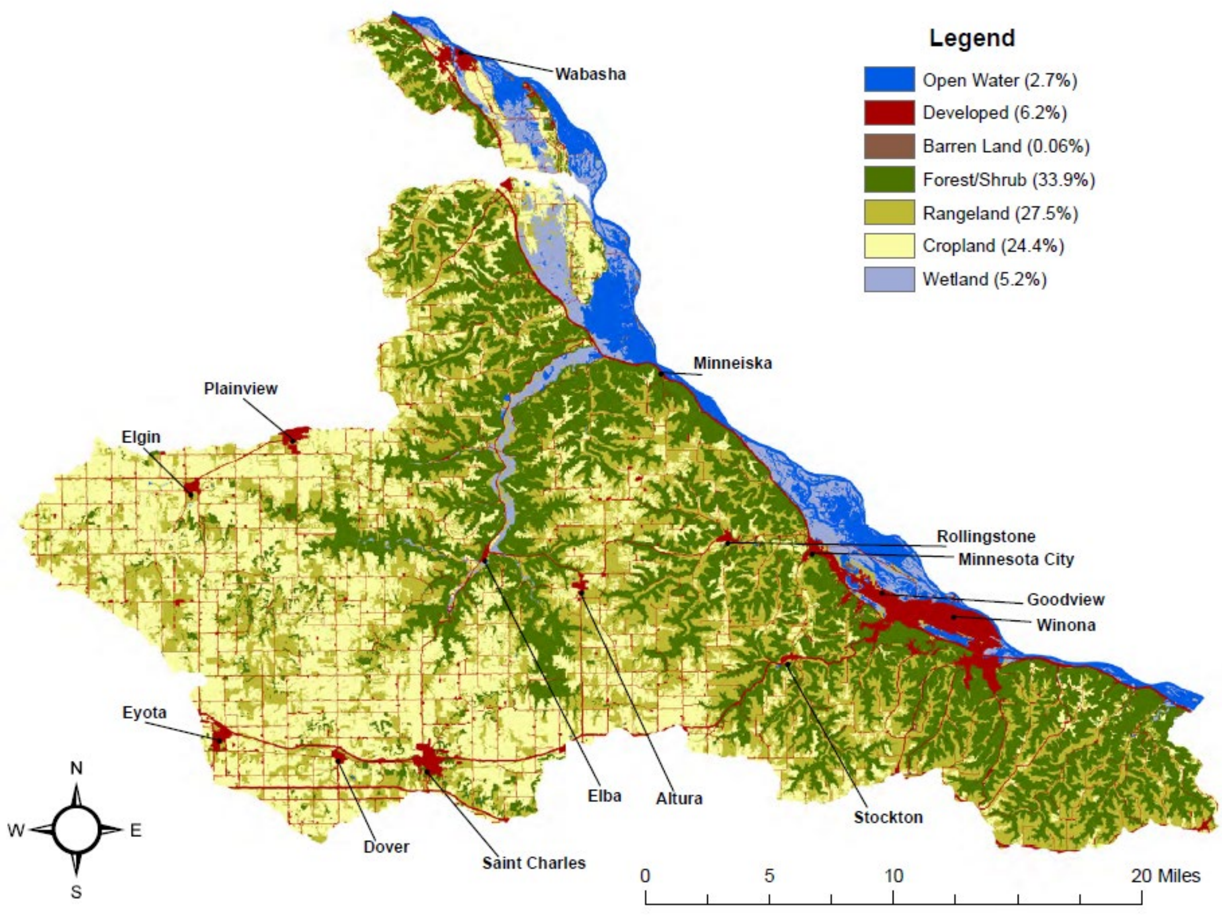

Figure 3. Map of land use in the MR-Winona Watershed.

Official watershed assessments took place in 2012. This SID report investigates the impairments found during assessments, and should be seen as a companion to the Monitoring and Assessment Report. Background information on the watershed can be found in that report to avoid duplication here.

2.1 Monitoring overview

In 2010, the MR-Winona Watershed was sampled intensively (44 sites) for fish and macroinvertebrates. Samples were collected at the biological stations shown in Figure 4. The MR-Winona Monitoring and

Assessment Report, which contained detailed information on the biological monitoring process, and impairment decisions, can be found here: http://www.pca.state.mn.us/index.php/view-document.html?gid=19935.

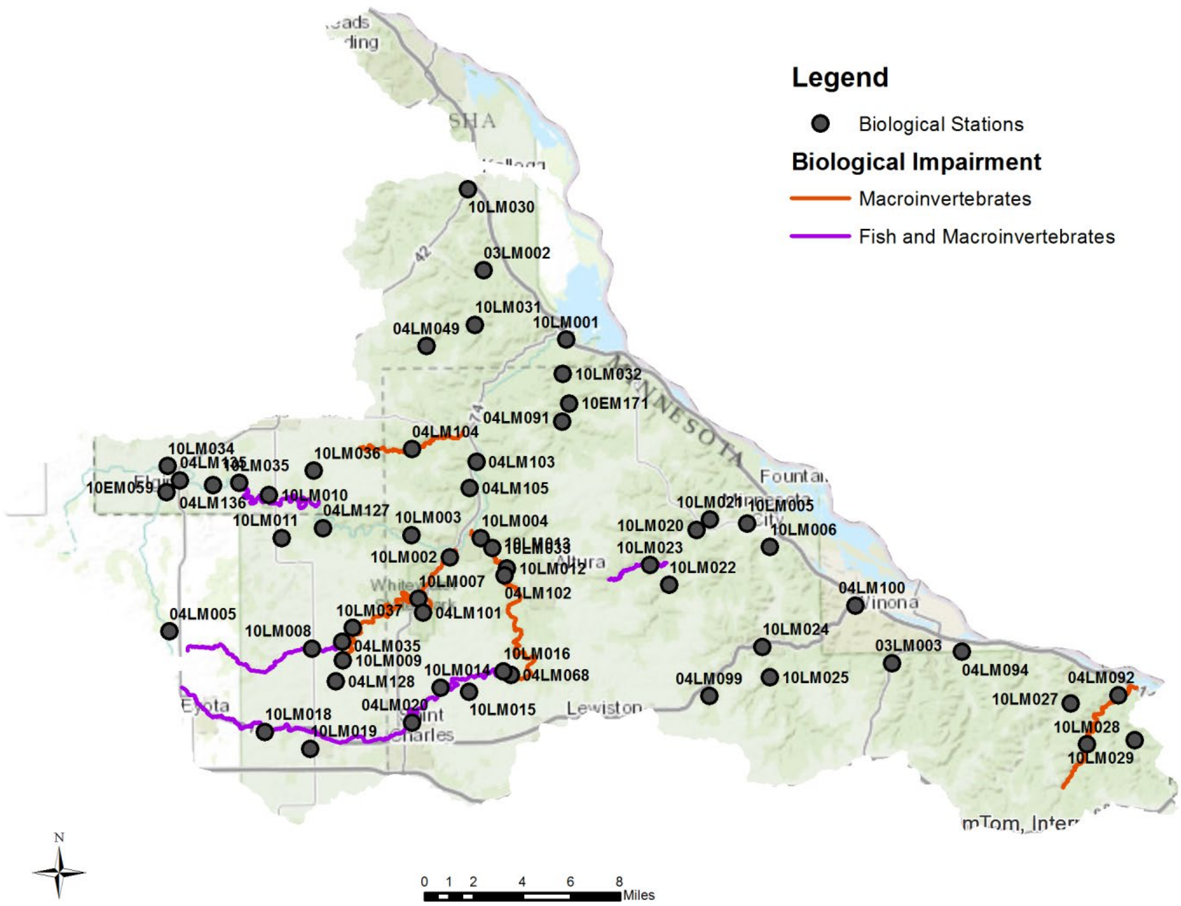

Figure 4. Biological monitoring locations and reaches with identified biological impairment in the MR-Winona Watershed.

2.2 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 a watershed. The resulting information is used to calculate IBI scores for both communities. These IBI scores can then be compared to developed IBI thresholds for the appropriate stream class.

The fish and macroinvertebrates within each Assessment Unit Identification (AUID) were compared to regionally developed threshold IBI thresholds and confidence interval and the assessment process utilized a weight of evidence approach. Minnesota's water quality standards are set for the maintenance of a healthy community of aquatic life. IBI scores provide a measurement tool to assess the health of the aquatic communities. IBI scores higher than the impairment threshold indicate that the stream reach supports aquatic life. Conversely, scores below the impairment threshold indicate that the stream reach does not support aquatic life. The process of identifying stream impairments is defined in the Monitoring and Assessment report for the MR-Winona.

In the MR-Winona Watershed, 10 AUIDs are currently impaired for a degraded biological assemblage, and 12 AUIDs are addressed in this report (Table 2). The two additional AUIDs were deferred during the original assessment. Unnamed Creek (609) is pending given new information on the thermal regime. Based on continuous temperature data, the stream is now classified as coldwater and will be assessed as such in subsequent years. Gorman Creek (569) was deferred due to the AUID having a large percentage of stream channelization, but was chosen to move forward with stressor identification because the sample reach was not channelized and future impairment was forecasted.

Table 2. Biologically impaired AUIDs in the MR-Winona Watershed. Two additional AUIDs are pending official impairment, but still addressed in this report.

			Impairments	
Stream Name	**AUID #**	**Reach Description**	**Biological**	**Water Quality**
North Branch Whitewater	553	T108 R11W S30, west line to Unnamed Creek	Fish and Macroinvertebrates	Turbidity, Bacteria
Middle Branch Whitewater	515	Headwaters to T107 R11W S34, east line	Fish and Macroinvertebrates	Turbidity, Bacteria
Middle Branch Whitewater	F19	Crow Spring to N Fork Whitewater R	Macroinvertebrates	Turbidity, Bacteria, Nitrates
Crow Spring	611	Unnamed Creek to M Fork Whitewater R	Macroinvertebrates	
South Branch Whitewater	F16	Headwaters to St Charles Township Rd 7	Fish and Macroinvertebrates	Turbidity, Bacteria
South Branch Whitewater	512	T106 R10W S1, west line to N Fork Whitewater R	Macroinvertebrates	Turbidity, Bacteria, Nitrates
South Branch Whitewater	F17	St Charles Township Rd 7 to T106 R10W S2, east line	Macroinvertebrates	Turbidity, Bacteria
Beaver Creek	566	T108 R11W S24, west line to Unnamed Creek	Macroinvertebrates	
Bear Creek	581	Unnamed Creek to Rollingstone Creek	Fish and Macroinvertebrates	
Big Trout Creek (Pickwick Creek)	592	Unnamed Creek to Mississippi R	Macroinvertebrates	
Gorman Creek	569	T110 R10W S27, west line to Unnamed Creek	Macroinvertebrates *(pending)*	
Unnamed Creek	609	Unnamed Creek to Whitewater R	Macroinvertebrates *(pending)*	

The IBI thresholds for stream classes sampled in the MR-Winona Watershed can be found in Table 3 and Table 4. The stream classes and IBI scores for all the biological stations in the watershed can be found in the MR-Winona Monitoring and Assessment Report.

Table 3. Fish classes with respective IBI thresholds and upper/lower confidence limits (CL) found in the MR-Winona 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 4. Macroinvertebrate classes with respective IBI thresholds and upper/lower CL found in the MR-Winona 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

3. Possible stressors to biological communities

A comprehensive list of potential stressors to aquatic biological communities compiled by the EPA can be found on its website (http://www.epa.gov/caddis/si_step2_stressorlist_popup.html). This 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 candidate stressor is causing impairment to aquatic life. It is imperative to document if a candidate cause was suspected but not enough information was available for a scientific determination. 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.

3.1 Inconclusive causes *(insufficient information)*

Some candidate causes were unable to be considered further due to the lack of connecting data between the potential stressor and the biological community; and/or there was not enough data available. The potential causes that were inconclusive included pesticides and flow alteration. While there is a wealth of information on pesticides in the MR-Winona Watershed, there is an overall lack of good biological response information specific to pesticides for stressor analysis. Similarly, insufficient information is available on flow alteration, potential causes, and biological affects in this watershed.

Pesticides

A pesticide is 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, where they are applied before or during planting to maximize crop productivity by minimizing other vegetation. They also may 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 problems, refer to the EPA website on insecticides and causal analysis on the EPA website (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 analyzed, three have been named a "surface water pesticide of concern" - 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. 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 understand more about the MDA surface water monitoring program, visit the MDA website (www.mda.state.mn.us/monitoring).

Pesticides in the Mississippi River-Winona

The MDA has been monitoring for pesticides in surface waters since 1991. Annually, MDA collects approximately 600-800 samples from rivers, streams, and lakes across the state. In general, MDA looks for pesticides that are widely used and/or pose the greatest risk to water resources. The purpose of MDA's pesticide monitoring program is to determine the presence and concentration of pesticides in Minnesota waters. Samples are collected statewide during the late spring and throughout the summer when the potential for pesticide movement is the greatest.

The MDA has conducted pesticide monitoring in the Whitewater River Watershed since 1992. This represents the longest continuous watershed pesticide monitoring record in Minnesota. Since 1992, the MDA has collected and analyzed more than 1,100 pesticide samples from seven different stream locations. A majority of the samples (more than 800) have been collected from the Middle Branch of the Whitewater at County Road 107 in Quincy Township (station S001-831). This station is a "Tier 3" station in MDA's design document and is fully automated to collect pesticide water quality data. "Tier 3" stations receive the most intensive and comprehensive pesticide monitoring effort in the state. This station is one of the seven "Tier 3" sites that MDA operates. In addition to this "Tier 3" station, several additional locations in the watershed have been sampled over several years (Table 5).

Table 5. River and stream locations where pesticide data has been collected in the Whitewater River Watershed.

Location	EQuIS ID	Sample Events	Monitoring Period	Latitude	Longitude
Cedar Valley Creek, Upstream Of South-Bound Us-61 Lane	S004-245	8	2005-2006	44.0068	-91.4961
Garvin Brook At CSAH-23, Southwest Of Minnesota City	S000-828	8	2005-2006	44.0712	-91.7642
Mid Fork Whitewater R At Cr-107, 5 Miles N Of St. Charles	S001-831	804	1993-2013	44.0371	-92.1046
N Fork Whitewater R 0.15 Miles W Tr-16, 2.2 Miles W Of Elba	S000-451	13	2005-2007	44.0925	-92.0637
S Fork Whitewater R At CR-112 2 Miles West Of Altura	S000-321	290	1992-2013	44.0706	-91.9793
Trout Creek Adjacent To CSAH-31, 11.5 Miles E Of Plainview	S006-655	2	2010	44.1707	-91.9253
Whitewater R, N Fork, At CSAH-2, .7 Miles S Of Elgin (10EM059)	S006-689	1	2010	44.1207	-92.2594

Pesticides are considered potential stressors in the Whitewater River Watershed due to the surrounding land use. Since 1992, a total of 46 different pesticide or pesticide degradates have been detected in rivers or streams in the Whitewater River Watershed (Appendix, Table 49). Additionally, six pesticide or pesticide degradates were detected in Lake Winona (85-0011) in 2010 or 2011 (Appendix, Table 50). When comparing water quality pesticide results to standards and reference values, duration of pesticide occurrence in a waterbody must be assessed in conjunction with the numeric result. For example, MPCA Class 2Bd Chronic Standards are developed with a duration exposure of four days and where applicable, Class 2A (coldwater) Chronic Standards are developed with a duration exposure of 30 days. As with the assessment of any toxin, duration (the time the chemical is present in the system) must be considered in conjunction with the concentration data. Of the detected compounds in the Whitewater River Watershed, only atrazine (3.4 µg/L) and alachlor (3.8 µg/L) have lower standards for Class 2A waters than Class 2Bd waters. All of the data collected by MDA are reviewed annually by MPCA for the assessment of water quality standards. As of 2014, there were no water quality impairments related to pesticides in the Whitewater River Watershed.

The Whitewater River Watershed contains many Class 2A streams. The data presented in the pesticide sampling results table may contain data collected from Class 2A, 2Bd, and 2B waters. Individual streams should be assessed for pesticides with targeted sampling; however, the data presented provide a watershed level view of pesticide detections.

All the detections were well below the acute, one-day maximum standards. Of the 46 pesticide compounds detected, only acetochlor, alachlor, and atrazine has been detected about their applicable chronic, four-day standards. The long monitoring history in the Whitewater River Watershed allows for further examination of acetochlor, alachlor, and atrazine concentrations over time. Further discussion of pesticide concentrations is found in Appendix B. Pesticide monitoring will continue in the Whitewater River Watershed for the foreseeable future and will provide additional information related to pesticide detections. Due to the lack of proper biological response information related to pesticides, stressors to biology are considered inconclusive at this time.

Flow alteration

Increasing surface water runoff and seasonal variability in stream flow have the potential for both indirect and direct effects on fish populations (Schlosser, 1990). Indirect effects include alteration in habitat suitability, nutrient cycling, production processes, and food availability. Direct effects include decreased survival of early life stages and potentially lethal temperature and oxygen stress on adult fish (Bell, 2006). Increased channel shear stress, associated with increased flows, results in increased scouring and bank destabilization. The fish and macroinvertebrate communities may be influenced by the negative changes via loss of habitat and increased 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 macroinvertebrates and causing significant dislodgement. When high flows become more frequent, species that do not manage well under those conditions will be reduced, leading to altered populations. Macroinvertebrates may shift from those having long life cycles to short life cycles. These species can complete their life history within the bounds of the recurrence interval of the elevated flow conditions (CADDIS, 2011).

Across the conterminous United States, Carlisle et al. found a strong correlation between diminished streamflow and impaired biological communities (2010). 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 often increase when flows are lower than normal, making it more difficult for populations to maintain a healthy diversity. Often tolerant species that can outcompete in limiting situations will thrive. Low flows of prolonged duration tend to lead to macroinvertebrate and fish communities that have preference for standing water or are comprised of generalist species (CADDIS, 2011).

When baseflows are reduced, fish communities respond with an increase in nest guarding species than 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 invertebrate 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).

Flow alteration in the Mississippi River-Winona

There were five United States Geological Survey (USGS) monitoring stations with sufficient flow records to analyze discharge trends in the MR-Winona (Olmsted County, 2012). For three of the five stations, no trend in discharge was identified (South Fork-Altura, North Fork-Elba, and Garvin Brook). Both records near the Whitewater at Beaver showed an upward trend in discharge from 1939-1999. Due to the lack of long-term, continuous data, it cannot be determined whether flow across the entire watershed has increased or decreased in the last 10-20 years. However, the Palmer Drought Severity Index (PDSI) was found to positively correlate to annual flows, and the PDSI itself is increasing. In addition, since the 1950s there has been an upward trend in annual precipitation within the region. Other studies (Lenhart, et al, 2011), which can be extrapolated to the MR-Winona, can also predict that these streams will likely have a long-term increasing trend in discharge. Changes in land cover, field tile, and channelization can all result in flow alteration and are potential contributors in this watershed. The effects of increasing stream discharge, peak flow discharge, or alterations of baseflow on biology in this watershed in particular are not well understood due to lack of long-term flow information. For this reason, flow alteration was not able to be addressed as a stressor in these watersheds, but should be considered in the future as more information becomes available.

3.2 Causes eliminated

- Chloride
- Physical trampling
- Ammonia

Chloride

Chloride values were evaluated throughout the watershed of the MR-Winona. The highest value sampled was 227.6 mg/L from an unnamed tributary to the South Fork Whitewater River near St. Charles off I-90. There are not any biological data on this reach. The AUID with the next highest chloride value is the portion of the South Fork Whitewater River that the tributary flows into. The highest value recorded here was 59 mg/L, well below the standard. With the available data, chloride is an unlikely stressor to the biological community.

Physical trampling

Rangeland and pasture land use makes up 27.7% of the watershed. Pastured animals in the stream or river would be the most likely cause of crushing or trampling. While there are impaired reaches where cattle have direct access to the river, these are limited in scope and are not a likely stressor to the biological impairments.

Ammonia

Unionized ammonia values were evaluated throughout the watershed of the MR-Winona. The highest value sampled was 0.01 mg/L, with the majority of values at 0. With the available data, unionized ammonia is an unlikely stressor to the biological community.

3.3 Summary of candidate causes in the MR-Winona Watershed

Eight candidate causes were selected as possible drivers of biological impairments in the MR-Winona watershed. The list of candidate causes was then narrowed down after initial data evaluation resulting in six candidate causes for final analysis in this report. The six remaining candidate causes are:

- Temperature
- Dissolved oxygen (DO)
- Nitrate
- Total suspended solids (TSS)
- Habitat
- Connectivity

3.3.1 Candidate cause: Temperature

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 macroinvertebrates 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. When temperatures rise to 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 called their functional feeding temperatures. The limits for brown trout growth are 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 temperature range 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 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).

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).

Water quality standards

The standard for Class 2B (warmwater) waters of the state is not to exceed 5° Fahrenheit (°F) above natural (*Minn. Stat.* 7050.0222 subp. 4), based on monthly average of maximum daily temperature. In no case shall it exceed the daily average temperature of 86° F (30° C).

The state standard for temperature in Class 2A streams is “no material increase” (7050.0222 subp.2).

Temperature in the Mississippi River-Winona

Temperature stress in the MR-Winona was found on only two coldwater reaches: Bear Creek and the South Branch of the Whitewater (F17). The North Branch of the Whitewater, while not currently stressed by temperature, does show some potential for higher than optimal temperatures. However, the North Branch and South Branch both have stream segments in natural thermal transition zones (between warmwater and coldwater). In warmwater reaches, temperatures did not reach unsuitable ranges (>30°C), and temperature stress seemed unlikely. Many coldwater stations had continuous temperature data available for analysis. In coldwater streams, a presence of warmwater species or lack of coldwater species can indicate temperature is a stressor, but it can also be in response of other stressors. In addition to community composition, in-field temperature measurements are used to understand thermal regime and dynamics when determining temperature stress.

Sources and causal pathways

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

3.3.2 Candidate cause: Dissolved oxygen

Low DO

Dissolved oxygen 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 et al., 1991). DO concentrations and fluctuations are affected by shifts in ambient air and water temperature, precipitation, stream flow, atmospheric pressure, plant/algal growth and decomposition, salinity, and ammonia concentrations. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995).

Fish require oxygen for respiration. 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 5 mg/L (Raleigh, 1986). Additionally, fish growth rates can be significantly affected by low DO 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 biological oxygen demand (BOD), and/or high groundwater seepage (Hansen, 1975). Heiskary et al. (2013) observed several strong negative relationships between fish and macroinvertebrate metrics and daily DO flux.

DO flux and eutrophicatn

Increased phosphorus levels lead to increased algal and macrophyte growth which in turn leads to increased decomposition and respiration rates. Increased plant and algal growth causes increased oxygen production through photosynthesis during the day. The excess plant material eventually dies, and bacterial activity during decomposition strips oxygen from the water. This leads to low early morning DO readings in streams, and high readings in the afternoon. Streams dominated with submerged macrophytes experience the largest swings in DO and pH (Wilcox and Nagels 2001).

Water quality standards

Low DO

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.

DO flux and eutrophication

Phosphorus is an essential nutrient for all aquatic life, but elevated phosphorus concentrations can result in an imbalance which can impact stream organisms. Excess phosphorus results in indirect impacts to fish and macroinvertebrates, and direct impacts to aquatic communities from response variables such as DO flux, chlorophyll-a, and BOD (Heiskary et al., 2013). Elevated phosphorus levels increase algae and aquatic plant growth and decomposition, resulting in changes in DO and pH concentrations, water clarity, and available food resources and habitat.

There is currently no water quality standard for total phosphorus (TP); however, there is a draft nutrient standard for rivers of Minnesota (Heiskary et al., 2013). The current draft standard for the central region of the state is a maximum concentration of 0.10 mg/L with at least one response variable out of desired range (BOD, DO flux, chlorophyll-a, and/or pH). The draft standard for DO flux is 3.5 mg/L, chlorophyll-a is 18 µg/L, and BOD is 2 mg/L.

Dissolved oxygen in the Mississippi River-Winona

Dissolved oxygen was measured at multiple locations in the MR-Winona Watershed. All stations had at least one DO measurement taken during biological visits, and others had measurements taken during diurnal DO data collected during the SID process. Biological community composition can be important to look at when analyzing DO patterns, in addition to water chemistry information. One tool used is "Fish Tolerance Indicator Values" (TIVs). The common fish species in the MR-Winona were grouped into categories (quartiles) based on their tolerance to low DO levels (Table 6). Community composition at each site can then be evaluated by the relative abundance of fish from each quartile.

Table 6. Fish species in the MR-Winona Watershed separated by tolerance values (Sandberg, 2013). Species found in the 1st quartile are the most tolerant to low DO, while species in quartile 4 are the most intolerant to low DO.

1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
CommonName	*DO*	*CommonName*	*DO*	*CommonName*	*DO*	*CommonName*	*DO*
central mudminnow	0.1	common shiner	0.3	bigmouth shiner	0.53	fantail darter	0.84
brook stickleback	0.1	johnny darter	0.4	central stoneroller	0.54	brook trout	0.88
fathead minnow	0.2	bluntnose minnow	0.4	blacknose dace	0.7	American brook lamprey	0.97
Iowa darter	0.2	creek chub	0.4	longnose dace	0.8	rainbow trout	0.98
green sunfish	0.3	white sucker	0.5	southern redbelly dace	0.81	brown trout	0.99
brassy minnow	0.3			mottled sculpin	0.83	slimy sculpin	1.00

Tolerant to Low Dissolved Oxygen ← Intolerant to Low Dissolved Oxygen

DO values ranged from 4.88 to 18.9 mg/L in the watershed. Continuous data collection produced values below the water quality standard, but elevated values and daily DO flux were more prevalent. Daily DO fluxes in the warmwater system were as high as 12.07 mg/L, which is more than three times the proposed standard. Coldwater streams naturally have elevated DO due to colder water temperatures holding more oxygen. However, large daily fluxes (up to 7.28 mg/L) in the coldwater tributaries of the South Branch, North Branch, and Middle Branch of the Whitewater River are unusual in coldwater systems. Additional DO flux information in coldwater streams will help understand DO dynamics in these coldwater systems in the future. The only stream reaches where low DO is a stressor is the warmwater reach of the Middle Fork Whitewater River, Bear Creek, and the North Branch. DO flux and eutrophication is a stressor on some of the warmwater reach of the South Fork Whitewater River. While there are indications that eutrophication may be stressing some of the coldwater systems in the watershed, there is a lack of biological response information in coldwater streams compared to warmwater streams. Therefore, all coldwater reaches are considered inconclusive for DO flux and eutrophication.

Sources and causal pathways

Dissolved oxygen concentrations in lotic environments are driven by a combination of natural and anthropogenic factors. Natural characteristics of a watershed, such as topography, hydrology, climate, and biological productivity define the DO regime of a waterbody. Agricultural and urban land-uses, impoundments (dams), and point-source discharges are 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 is modeled at EPA's CADDIS Dissolved Oxygen webpage.

Increased plant and algal growth causes increased oxygen production through photosynthesis during the day. The excess plant material eventually dies, and bacterial activity during decomposition strips oxygen from the water. This leads to low early morning DO readings in streams, and high readings in the afternoon. Streams dominated with submerged macrophytes experience the largest swings in DO and pH (Wilcox and Nagels 2001). Phosphorus is delivered to streams by wastewater treatment facilities, urban stormwater, agricultural runoff, and direct discharges of sewage. The causes and potential sources for excess phosphorus are modeled at EPA's CADDIS Phosphorus webpage.

3.3.3 Candidate cause: Nitrate

Nitrate toxicity to freshwater aquatic life is dependent on concentration and exposure time, as well as the particular 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 mg/L nitrate-N as appropriate for protecting the most sensitive freshwater species and that nitrate concentrations under 10 mg/L, are protective of several sensitive fish and aquatic macroinvertebrate taxa. The intake of nitrite and nitrate by aquatic organisms converts 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).

In Minnesota coldwater streams there appears to be some biological response trends to elevated nitrate concentrations. The data on coldwater streams indicate that when concentrations exceed 12 mg/L, it becomes fairly rare for streams to meet standards for invertebrates. It appears the macroinvertebrates are more sensitive to high nitrate concentrations (likely due to smaller size), as fish do not show the same response in terms of impairment. It is unknown what concentrations affect reproduction and other important parts of the life cycle. In general, when concentrations are below ~4 mg/L, it is much more common for macroinvertebrates to meet standards.

At this time, it is difficult to understand exactly what concentrations are detrimental to fish and macroinvertebrates, as they appear to have a different tolerance and response. Many factors can contribute to a biological response including, but not limited, to timing, duration, and flux of nitrate concentrations. There are efforts underway to help understand these issues.

Water quality standards

Minnesota's Class 1 waters, designated for domestic consumption, have a nitrate water quality standard of 10 mg/L (Minn. Stat. 7050.0222 subp. 3). Minnesota currently does not have a nitrate standard for other use classes though an aquatic life nitrate standard is being drafted.

Nitrate in the Mississippi River-Winona

Nitrate is a systemic issue in much of the MR-Winona Watershed. Nitrate data were collected at each biological station on the same date as fish sampling. Additional data assisted in understanding the magnitude and duration of nitrate concentrations under various conditions and is summarized in this report. The major branches of the Whitewater have had many years of nitrate sampling with the last few years summarized in Figure 5. Many locations in the watershed are in need of additional monitoring to assist in further understanding nitrate dynamics here.

Biological stress due to nitrate has been identified in multiple reaches in this watershed including: the North Branch, Middle Branch, South Branch, Crow Spring and Bear Creek. Two existing drinking water impairments currently exist on two reaches, one in the Middle Branch Whitewater and one in the South Branch Whitewater.

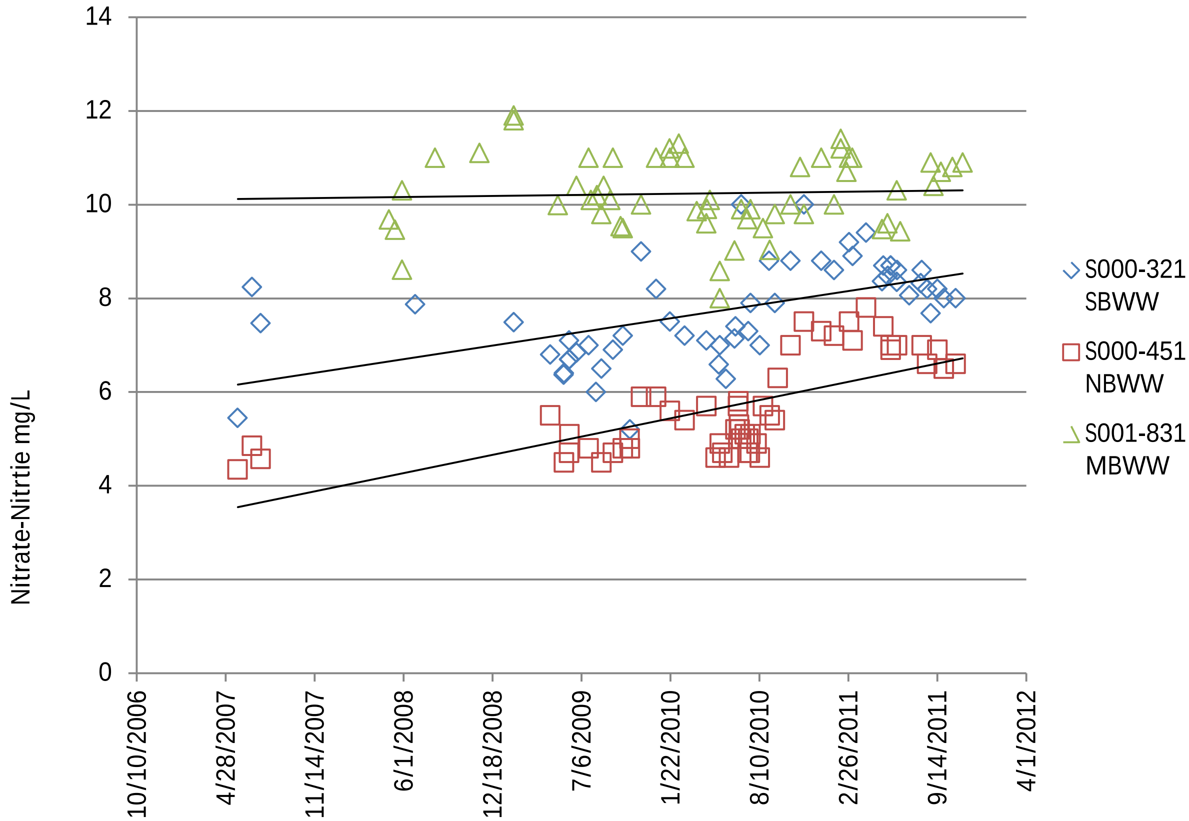

Figure 5. Baseflow (> 60 cm transparency) nitrate concentrations of the South Branch Whitewater (SBWW), Middle Branch Whitewater (MBWW), and North Branch Whitewater (NBWW) from 2007-2012.

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. In addition, 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., 2011). 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, 2011).

In 2012, Streitz measured a statistically significant rising trend in Crystal Spring (Spring 1), but it is based on analysis from a small dataset (only 10 years). According to the Minnesota Geological Survey, over approximately a five year period, the water from Crystal Springs Fish Hatchery Spring 1, with rare exception, has a lower nitrate concentration than the nearby upstream surface water. Springs emanating from the lower parts of incised valleys, such as this one sourced through the St Lawrence Formation, commonly dilute the nitrate concentration of streams. This is significantly different from many areas in the region which have higher nitrate concentration in spring water compared to the surface waters to which they discharge.

Olmsted County in 2012 analyzed five monitoring stations within the MR-Winona Watershed and found them all to have increasing trends in nitrate concentration. For example, nitrate at the South Fork

Whitewater (S000-288) has increased from 4.2 to 11.0 mg/L from 1974 to 2011 and the North Fork Whitewater (S000-451) has increased from <1.0 mg/L to 6.0 mg/L from 1967 to 2010.

Sources and causal pathways model for nitrate and nitrite

The conceptual model for nitrate 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, while 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).

3.3.4 Candidate cause: Total suspended solids

Increases in suspended sediment and turbidity within aquatic systems are 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 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.

TSS 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 watershed. The 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.

Total Suspended Volatile Solids (TSVS)

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.

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. For the central region the draft TSS standard has been set at 65 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 were 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 cover a much larger spatial and temporal scale in the watershed.

Total suspended solids in the Mississippi River-Winona

The macroinvertebrate community composition was analyzed and a score was created for each site, based on tolerance to high TSS. In addition, there are common fish species in the MR-Winona, and using fish TIVs, the fish captured are grouped into categories (quartiles) based on their tolerance to high TSS (Table 7). Streams with fish communities dominated by species in the 3rd and 4th quartiles are likely impaired by high TSS or deposited sediment levels. Fish that are tolerant to TSS can also be tolerant of many other stressors, which is why multiple lines of evidence are used to support determination of stressors. TSS stressors were identified on some of the AUIDs of the major branches of the Whitewater; the North Branch (-553), warm (-515) and cold (-F19) sections of the Middle Branch, and warm (-F16) and cold (-F17) sections of the South Fork Whitewater River. TSS is not a stressor on any of the smaller tributary streams addressed in this report. Sediment loads in many of these streams are high, so the susceptibility to TSS related stress can be high as well.

Table 7. Fish species in the MR-Winona watershed separated by tolerance values (Sandberg, 2013). Species found in the 1st quartile are the most intolerant to high TSS, while species in 4th quartile are the most tolerant to high TSS.

1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
CommonName	*TIV*	*CommonName*	*TIV*	*CommonName*	*TIV*	*CommonName*	*TIV*
brook trout	5.2	fantail darter	12	creek chub	14	central stoneroller	18
rainbow trout	4.2	brown trout	9.5	white sucker	13	bluntnose minnow	22
longnose dace	7	blacknose dace	8.7	brook stickleback	12	green sunfish	26
southern redbelly dace	7.6	common shiner	11	Iowa darter	16	bigmouth shiner	18
mottled sculpin	6.8	johnny darter	11	American brook lamprey	13	fathead minnow	27
slimy sculpin	4.8	central mudminnow	9.8			brassy minnow	33

Intolerant to High Suspended Sediment → Tolerant to High Suspended Sediment

Sources and causal pathways for total suspended solids

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.

3.3.5 Candidate cause: 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) but will be addressed separately here.

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, refuge, 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 increase the amount of sediment inputs to streams, and 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).

According to the USEPA CADDIS website, there are six attributes 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.

Water quality standards

There currently is no applicable standard for degraded habitat due to deposited sediment for biotic communities.

Habitat in the Mississippi River-Winona

Habitat is variable throughout the MR-Winona Watershed and is important in understanding the biological communities. Throughout the watershed, qualitative habitat was measured with the Minnesota Stream Habitat Assessment (MSHA) along with the fish survey (Figure 6). 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.

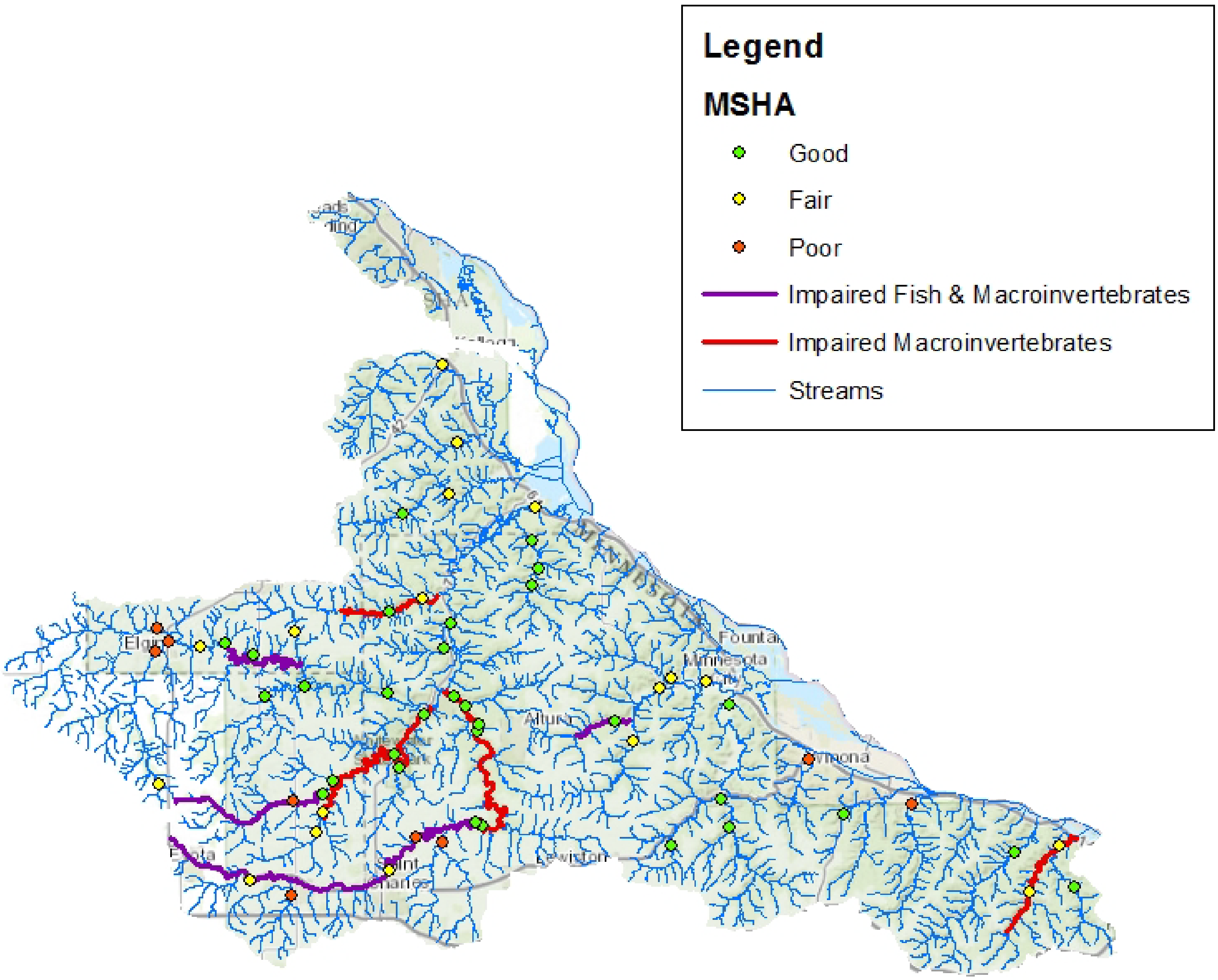

Figure 6. MSHA scores for sites in the MR-Winona Watershed.

Fish and macroinvertebrate communities can both respond to varying types of habitat stress. Biological metrics are used to help understand the biological response associated with habitat-related stress. The metrics examined in the MR-Winona can be found in Appendix A. Many of these metrics can respond similarly to other stressors as well, so understanding all potential stressors is important. Habitat stress was found in all but two of the reaches analyzed in the SID process. Many of the habitat stressors in these reaches demonstrate excessive sediment deposition and substrate embeddedness. Erosion, lack of riparian corridor and land use (including historical land use in this watershed) have contributed to the habitat stress observed.

Sources and causal pathways

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.

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 U.S. EPA CADDIS web page here.

3.3.8 Candidate cause: 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).

Lateral and 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 scour downstream banks and vegetation.

Lateral connectivity also 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 bank erosion resulting in 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.

Water quality standards

There currently is no applicable standard for connectivity.

Connectivity in the Mississippi River-Winona

Connectivity in the MR-Winona Watershed is altered mainly by culverts and bridges, with a few dams also present. Impoundments placed on rivers and streams can create barriers to fish passage and can alter the aquatic community through sediment accumulation. Connectivity can also be temporarily disrupted by beaver dams and other woody debris, but these are non-permanent structures and can be washed away by floods or other high water. Perched culverts were found in a few locations of the watershed, but none were identified as stressors leading to fish impairment. Impoundments were found on both Big Trout (Pickwick) Creek and Gorman Creek, but connectivity was only found to be a stressor on Gorman Creek.

Sources and causal pathways

Bridges and culverts can alter the channel creating less sinuosity, while dams create impoundments, all leading to a change in the habitat structure of a stream. This can affect plant, fish, and macroinvertebrate diversity and richness. The conceptual model for physical connectivity as part of flow alteration as a candidate stressor can be found on the U.S. EPA CADDIS webpage here.

4.0 Evaluation of candidate causes

Candidate causes were evaluated in the MR-Winona Watershed by each major branch (North, Middle, and South), and also addressed in each direct tributary with biological impairment.

4.1 North Branch Whitewater River (07040003-553)

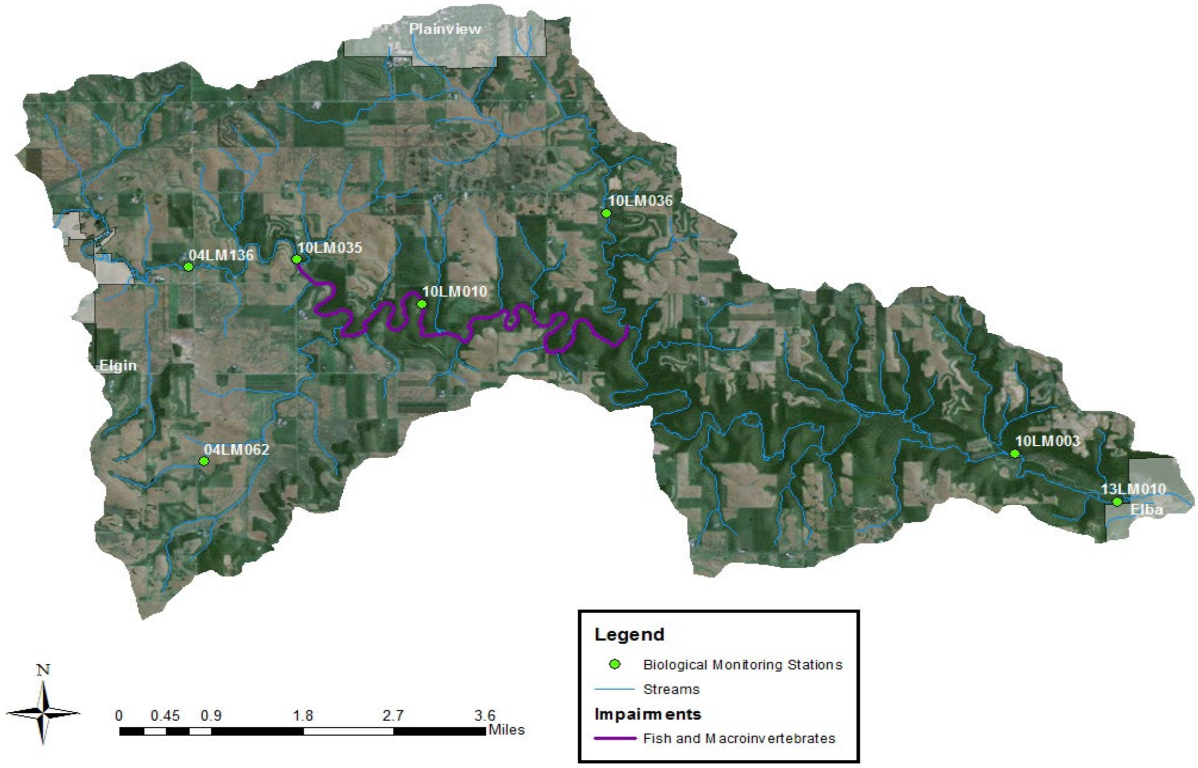

Figure 7. Map of the North Branch Whitewater Subwatershed, biological stations, and impaired AUID.

Supporting information

The upstream AUID of the coldwater section of the North Branch Whitewater is impaired for fish and macroinvertebrates (Figure 7). Although some coldwater species are still present (including trout), warmwater and tolerant fish species become abundant, and populations are highly skewed (dominated by individuals of one or two species). Stations 10LM035 and 10LM010 are on the impaired AUID. Station 10LM003 is on the downstream AUID, which is not impaired for biology, but included for comparison purposes. All three stations are in the southern coldwater fish class, which has an impairment threshold of 45. Station 10LM010 was above impairment threshold with a FIBI score of 54.6 while station 10LM035 scored below impairment threshold with FIBI score at 34.9. Station 10LM003 scored much higher during two visits in 2010, with FIBI scores at 87 and 85, and with better scores for six of the seven metrics (station 10LM010 has the same herbivore percent as the two visits at station 10LM003). The two stations on the impaired AUID score poorly for the native coldwater metrics, with both scoring zero for native coldwater percent (Figure 8).

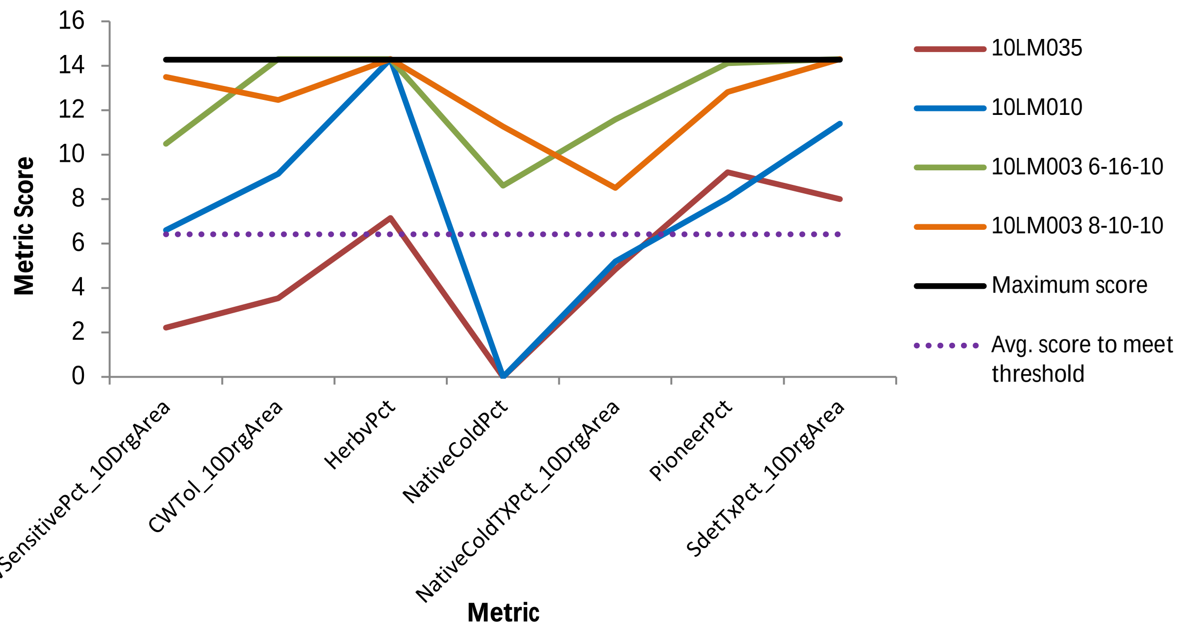

Figure 8. Fish IBI metric scores for the North Branch Whitewater (Southern Coldwater fish class).

All three stations are in the coldwater macroinvertebrate class, which has an impairment threshold of 46.1. Both station 10LM010 and 10LM035 were below impairment threshold with MIBI scores at 29.2 and 24.7, respectively. Station 10LM003 scored much higher; at 65.5 (thus AUID is not impaired). The macroinvertebrate IBI metric scores at downstream station 10LM003 are higher for each metric than at impaired stations 10LM035 and 10LM010, except the ratio of Chironomidae abundance to total Dipteran abundance (Figure 9), where 10LM003 and impaired site 10LM010 tied for the highest score among the three sites. The lowest scoring metrics are the percentage of very tolerant individuals, CBI, and HBI_MN. The intolerant taxa richness score at 10LM035 was 0. This measures the taxa richness of macroinvertebrates with tolerance values less than or equal to two. These taxa are sensitive to organic pollution and low DO (Hilsenhoff 1987). The upper reaches of the entire North Branch show more variability in macroinvertebrate scores, which is likely associated with a higher proportion of channelized streams, agricultural land use and limited habitat. Farther in the valley and closer to the mouth of the watershed, the riparian area becomes predominately forested, and habitat improves resulting in better macroinvertebrate scores.

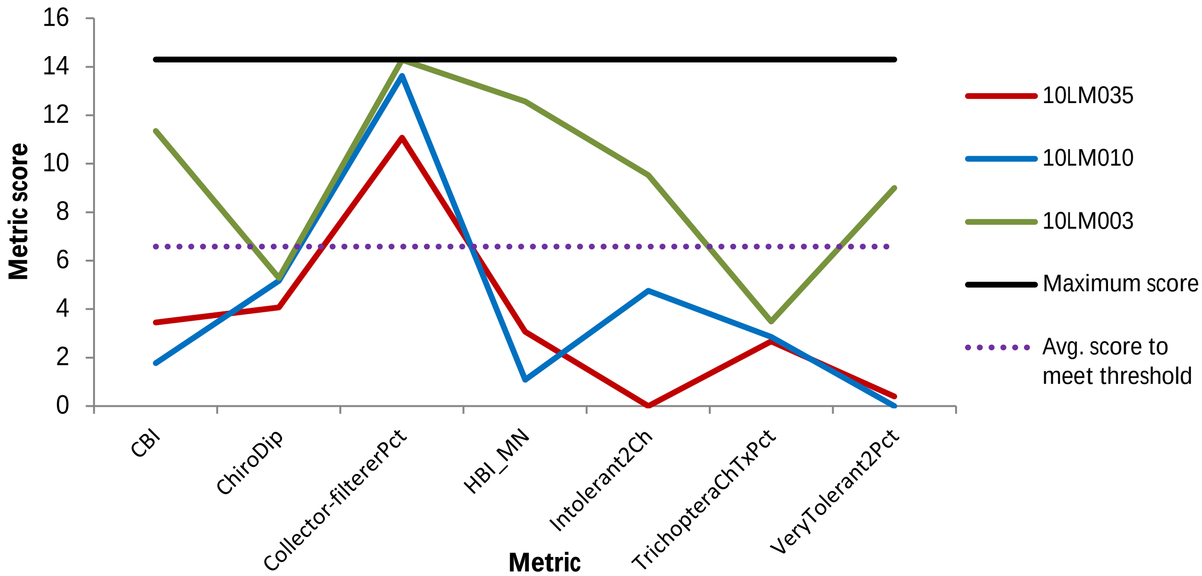

Figure 9. Macroinvertebrate IBI metrics in the North Branch Whitewater

Temperature

During the summer of 2010, temperature loggers were placed at biological stations 10LM010 and 10LM035. The July and August average temperature for station 10LM010 was 19.9°C and 19.7°C, respectively. The July and August average temperature at station 10LM035 was slightly warmer, at 20.03°C and 19.88°C. Both stations had a maximum temperature at 21°C. Multiparameter sondes were placed at the two stations in August 2013. The maximum temperature collected was 17.5°C at station 10LM010 and 18.3°C at station 10LM035. On this stream reach, there was 202 other temperature data points from multiple monitoring stations collected from 2000-2012. Of the 202 temperature measurements, 11 of them were above 21°C.

The fish communities present in these locations show a general lack of coldwater fish species, which can indicate thermal degradation, but can also respond to other stressors. At both stations, the percentage of coldwater fish species (ColdPct), coldwater sensitive fish species (CWSensitivePct) and native coldwater species (NativeColdPct) were all well below average when compared to other coldwater stations in the MR-Winona Watershed (Table 8). This is also demonstrated in Figure 8, with resulting lower than average IBI metric scores for 10LM010 and 10LM035 compared to downstream station 10LM003. Farther downstream, more springs enter the stream, which contributes colder water and more suitable temperatures.

Similarly, coldwater macroinvertebrate taxa are limited at 10LM010 and 10LM035 compared to 10LM003. The CBI (coldwater biotic index) metric for both stations scored below the average metric score needed to be above impairment threshold (Figure 9). Stream reaches that are in a transitional zone between cold and warmwater can have community characteristics of both stream types, resulting in an imperfect fit for IBI classification and calculation.

Table 8. Fish metrics for the North Branch Whitewater compared to Class 10 (coldwater) averages for the MR-Winona Watershed. Green color shows above average=; red shows below average. Note: station 10LM003 is not on this stream reach and is displayed for comparison purposes.

Site	Stream	Visit Date	ColdPct	CWSensitivePct	NativeColdPct
10LM035	North Branch Whitewater	10-Aug-10	2.55	5.04	0.00
10LM010	North Branch Whitewater	14-Jun-10	10.41	32.10	0.00
10LM003	North Branch Whitewater	16-Jun-10	51.18	51.89	14.15
10LM003	North Branch Whitewater	10-Aug-10	59.10	71.62	34.05
		MR Winona Class 10 Averages	51%	61%	22%

This impaired reach is heavily influenced by the upstream warmwater tributaries, and is a natural transition area from warmwater to coldwater. While this reach does show maximum temperatures that are on the upper end of the optimal range, the temperature regime is very similar to other coldwater streams in this area and for this size. It's more likely that other stressors are having more of an impact on the biology here. Even though there is biological response evidence (fewer coldwater fishes and macroinvertebrates), it is difficult to separate from other stressors because the thermal regime is not completely unsuitable. At this time there is not enough information to definitively conclude that elevated temperature is a stressor to this reach, and therefore remains inconclusive.

Dissolved oxygen

Low DO

Seven DO readings are available on this reach from 2010 and 2012, with five of the readings taken prior to 9 a.m. The values range from 7.21 to 9.0 mg/L. Station 10LM035 had a DO concentration of 7.21 mg/L, which is close to the 7 mg/L standard set for coldwater streams.

The abundance of fish individuals where the females mature at greater than three years in age decreases with low DO conditions. All stations had lower numbers of fish that take longer to mature than the basin average (41%). Station 10LM010 had fish species percentages of 10.41% and station 10LM035 had 2.55%. In comparison, station 10LM003 had percentages of 25.05 and 40.09%, but still less than the basin average for coldwater sites (Table 9). Low DO values also correspond with increased tolerant species and decreased sensitive fish species. Stations 10LM010 and 10LM035 had fewer sensitive fish individuals than station 10LM003 (32.1% and 5.04% respectively), and were below the average in the basin (51.67%). In comparison station 10LM003 had 51.9 and 71.6% sensitive fish during the two biological visits. Similarly, the percent of tolerant fish individuals was higher at the two upstream stations than at station 10LM003. The tolerant percent individuals were 56.4% at station 10LM010, 93.65% at station 10LM035, and 47.88 and 27% at station 10LM003. Only one visit at station 10LM003 was below the basin average (40.61%) for percent tolerant individuals.

The early morning DO TIVs for fish at the two samples show more-tolerant fish communities at stations 10LM035 and 10LM010, while station 10LM003 is predominantly comprised of species less tolerant to low DO (Figure 10). Fish data were placed into quartiles (i.e. 0-25%; 25-50%; 51-75%; and 76-100%) depending on their tolerance to low DO values, and then the number of fish in each quartile was added together for each site. The majority of the fish collected at the upstream North Branch Whitewater River sites are comprised of species in the first and second quartiles (tolerant of low DO).

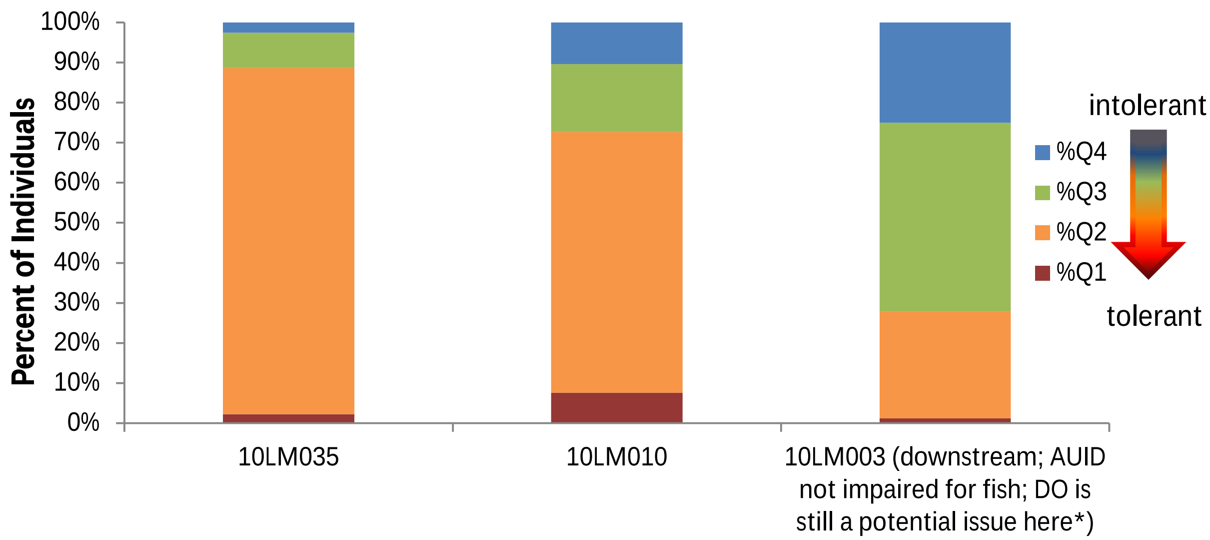

Figure 10. DO tolerance indicator values for fish at three biological stations in the North Branch Watershed.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. At station 10LM035, eight macroinvertebrate taxa that are intolerant to low DO were collected and 7.0% DO tolerant taxa were collected (Table 9). At station 10LM010, 12 macroinvertebrate taxa that are intolerant to low DO were collected and 3.21% DO tolerant taxa were collected. In comparison, at station 10LM003, the numbers of macroinvertebrate taxa collected that are intolerant to low DO were 12, and the percentage of DO tolerant species collected were 2.19. The average number of intolerant taxa collected in coldwater sites in the Lower Mississippi River basin was 9.6 and the average percentage of DO tolerant taxa was 2.6. The average number of low DO intolerant taxa at sites above the threshold was 10.1, and the DO tolerant taxa average percentage collected in streams above the threshold was 1.7. Station 10LM035 had tolerant taxa percentage below the average of coldwater sites in the basin, and below the average needed to meet the threshold. Station 10LM035 also had a percentage of tolerant DO taxa above the coldwater basin average, as did station 10LM010 but not to the same extent. Based on the overall evidence of the majority of stations 10LM035 and 10LM010 fish populations being in the second most tolerant to low DO quartile, the above average intolerant DO taxa at station 10LM010, the below average intolerant DO taxa at station 10LM035 and the higher than average values of DO tolerant taxa percentages, low DO seems to be a potential stressor to the macroinvertebrate and fish community at station 10LM035.

Table 9. Fish and Macroinvertebrate metrics relevant to DO for stations in North Branch Whitewater. Bold and highlighted equals the metric score is higher or lower than average for the MR-Winona Watershed, depending on expected response with increased stress.

Station	MA>3 years	Sensitive Fish Percentage	Tolerant Fish Percentage	Percentage DO Tolerant Macroinvertebrate Taxa	Intolerant Macroinvertebrate Taxa	Tolerant Macroinvertebrate Percentage
10LM035	**2.55**	**5.04**	**93.65**	**7.0**	**8**	35.28
10LM010	**10.41**	**32.1**	**56.4**	**3.21**	12	33.96
10LM003	**25.05**	51.89	27.00	2.19	12	38.11
10LM003	**40.09**	71.62	47.88	-	-	-
Averages for coldwater stations in the Lower Mississippi River basin	41	51.67	40.61	2.6	9.6	42.68
Expected response to stress	↓	↓	↑	↑	↓	↑

The presence of low DO tolerant fish, low numbers of sensitive fish, early-maturing fish species, and the high numbers of tolerant fish at station 10LM035 point to the effects of DO on the biological community. The preponderance of evidence suggests low DO is also a potential stressor to the fish communities, particularly at station 10LM035. However some of these indicators are also affected by other stressors and there is not a robust chemical dataset suggesting low DO conditions are present. These sites should continue to be monitored under differing flow conditions such as drought and stream flushing to expand the DO data set and better understand DO dynamics in this AUID. Until the DO dynamics are better understood, low DO is considered to be inconclusive as a stressor.

DO flux/Eutrophication

A longitudinal study of DO took place in 2012, and the river was sampled in the morning (prior to 9 am) and again in the afternoon at four sites to quantify DO flux between these periods (Figure 11). The highest flux and lowest DO both occurred at station 10LM010 (7.49 mg/L and 4.26 mg/L respectively). The other three stations are on the warmwater AUID upstream (Headwaters to Elgin).

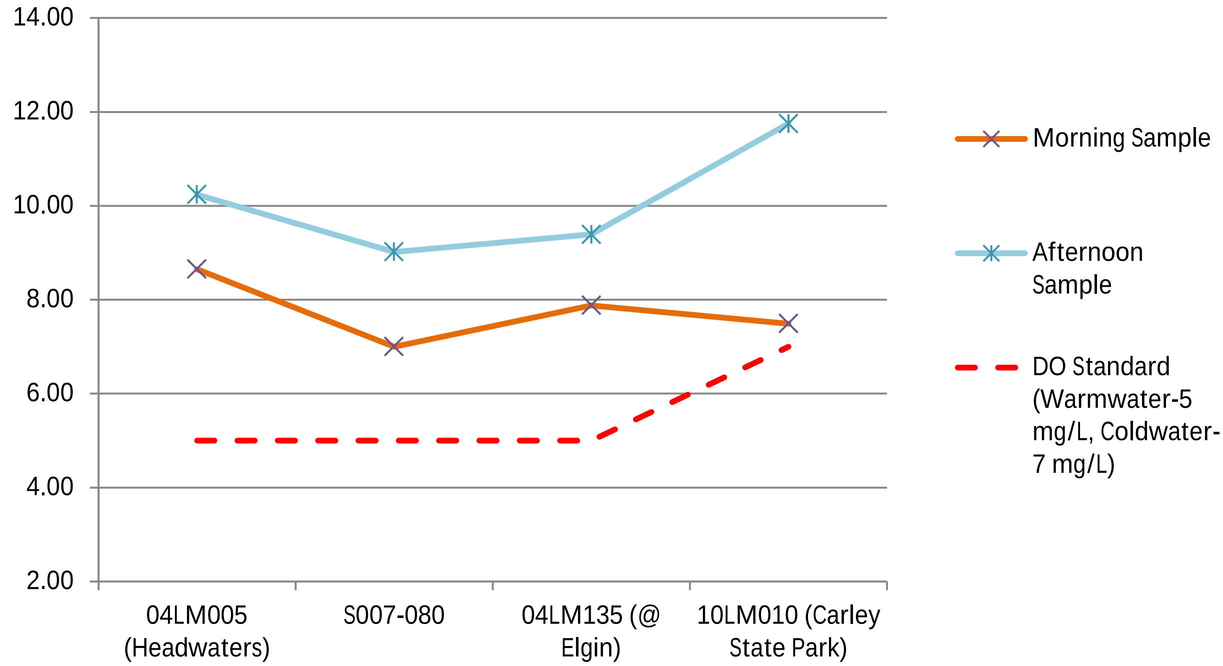

Figure 11. Longitudinal DO measurements on July 9, 2012.

Continuous DO data was collected at three locations on the North Fork Whitewater River in 2013. DO values were above the coldwater standard of 7 mg/L at all three sites throughout the deployment (Figure 12). While low DO values were not observed during this time, the continuous data showed elevated DO values. Elevated nutrients can increase macrophyte and algal growth which in turn increases photosynthesis, respiration, and decomposition. This cycle creates large fluctuations in DO levels. Macrophyte and algae growth are also influenced by increased temperature, sedimentation, and a decrease in shading along the stream channel. Daily flux values at the most upstream site (10LM035) were all below the DO flux standard of 3.5 mg/L, while the majority of samples at station 10LM010 and all of the values at station 10LM003, in the downstream AUID were above the standard with flux values up to 4.76 mg/L (Figure 13).

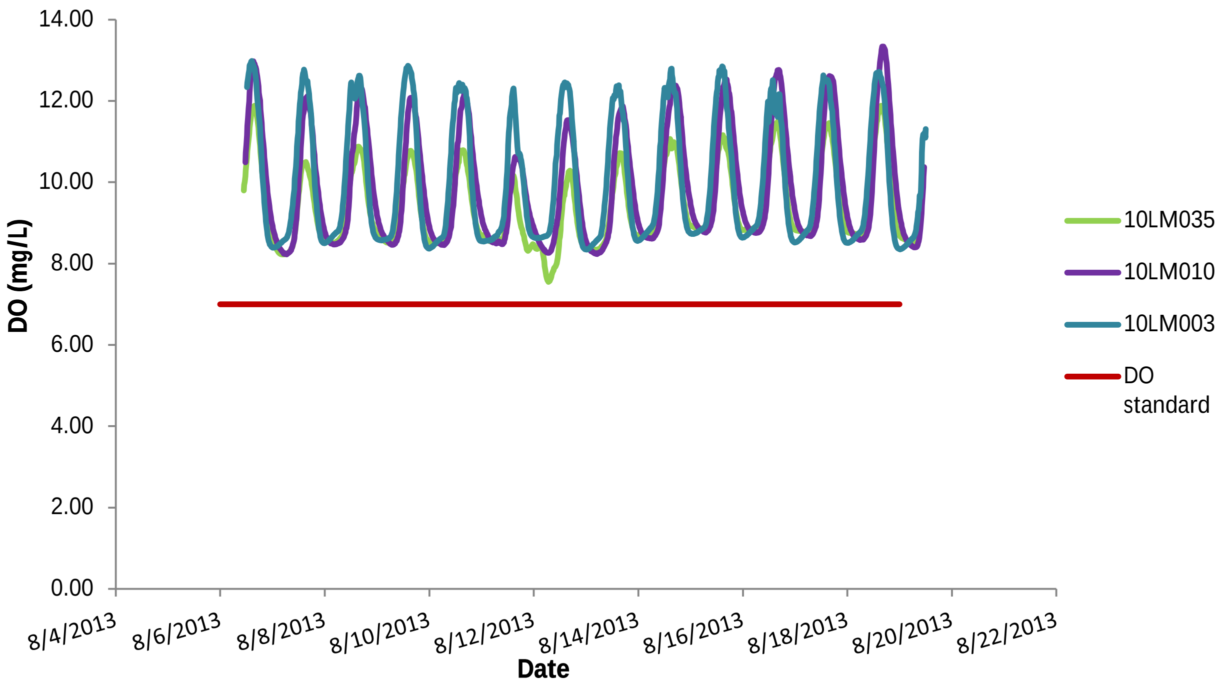

Figure 12. Continuous DO data collected at three biological stations in 2013.

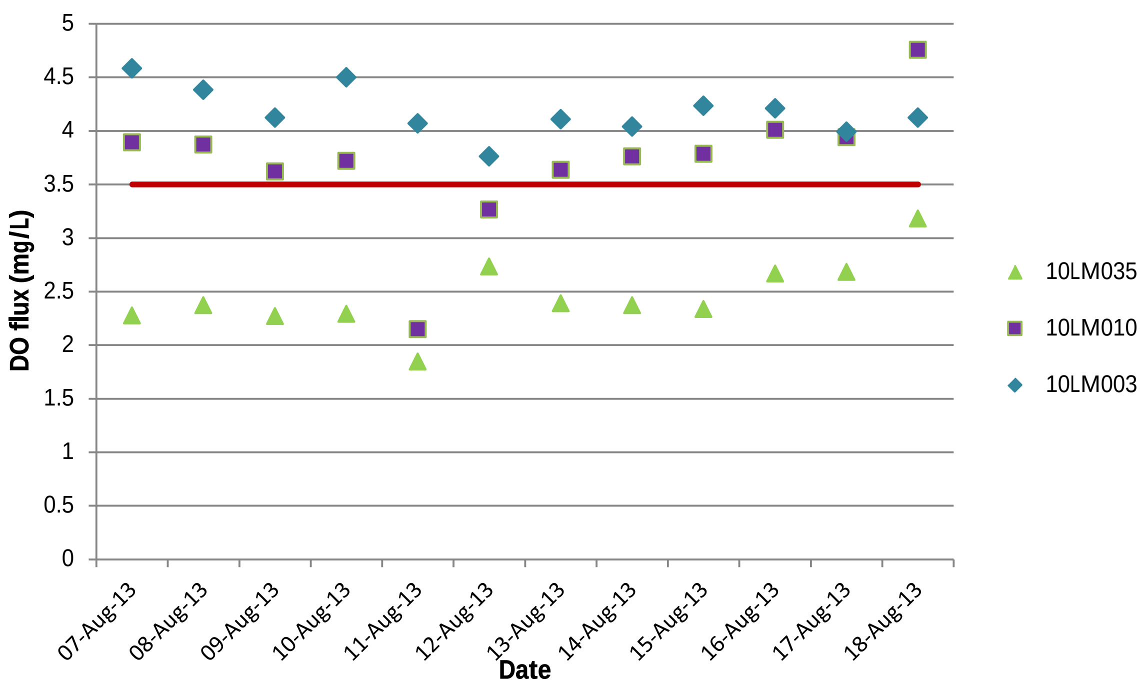

Figure 13. DO flux from three biological stations in 2013.

As interacting variables to eutrophication, phosphorus, pH, and chlorophyll-a were compared to normal ranges and standards. During fish sampling, TP was 0.193 and 0.143 at stations 10LM010 and 10LM035, respectively. These values are elevated, and correspond to elevated TSS concentrations here. The proposed phosphorus standard for the central region of the state is 0.100 mg/L. On this reach there were only two additional total phosphorus data points, with values of 0.077 mg/L and 0.096 mg/L. On the entire North Branch, the phosphorus mean value was 0.244 mg/L over nine years with a maximum of 2.145 mg/L, which is more than 14 times the proposed standard. Continuous pH data from 2013 ranged from 7.89 to 8.27. The AUID had 30 pH measurements in the last 10 years with a range of 7.5-8.2. All collected pH data were below levels usually connected to elevated nutrients. pH flux values at stations 10LM035 and 10LM010 ranged from 0.16 to 0.32. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013).

At station S000-978 in Carley State Park, chlorophyll-a samples were collected 26 times in 2000, with values ranging from 0.36 ug/L to 28.60 ug/L. The chlorophyll-a standard for the central region is 18 mg/L. Only one of the values collected violated the standard (28.60 ug/L on May 25, 2000). The location was also sampled 13 times throughout the spring and summer of 2001 where values ranged from 0.68 to 17.93 ug/L. As expected, the highest chlorophyll-a concentrations corresponded with the highest phosphorus concentrations (Figure 14). However, in-stream work without erosion controls was being completed (which was disturbing the streambed) on a bridge upstream of station 10LM003 on the day of sample. This may have an effect on elevated TSS and phosphorus concentrations seen that day.

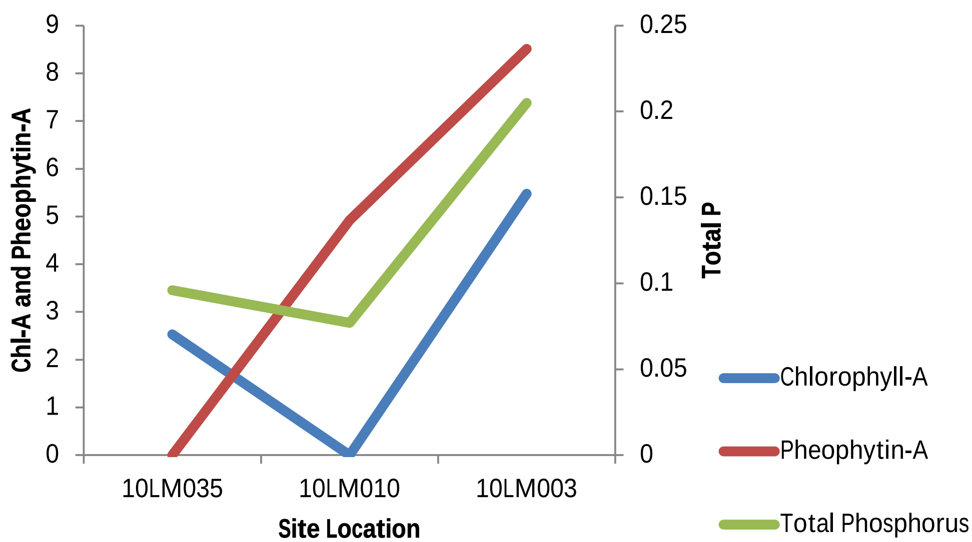

Figure 14. Chlorophyll a, pheophytin a, and TP samples from August 19, 2013.

EPT communities have an inverse correlation with chlorophyll-a, low DO, and DO flux values. The percentage of EPT individuals were 43.7 at station 10LM035, and 56.9 at station 10LM010 which are both higher than the average percentage of EPT individuals for coldwater streams in the Lower Mississippi River basin (39.55). Phosphorus is also positively correlated with the percentage of tolerant taxa for both fish and macroinvertebrates. Tolerant fish percentages ranged from 56.4 to 93.65%, while tolerant macroinvertebrates percentages ranged from 33.96 to 35.28%. The average tolerant fish percentage for coldwater sites in the watershed is 40.61; the average for macroinvertebrates is 42.68.

Elevated phosphorus, chlorophyll-a, and DO flux conditions exist on this stream reach, but there is currently not enough data statewide to make connections with eutrophication and coldwater biological communities. There were also some elevated temperatures recorded during continuous data collection which can enrich stream production. Nutrient management to prevent further eutrophication is important here. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

Nitrate

During biological sampling in 2010, nitrate concentrations were 7.4 mg/L at station10LM010 and 7.5 mg/L at station 10LM035. Additional nitrate data from this stream reach showed concentrations ranging from 8.8 mg/L to 10 mg/L (3 samples in 2011 and 2012).

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 stations 10LM035 and 10LM010 had 41 and 42 taxa (TaxaCountAllChir), above the average taxa count for coldwater stations in the LMB (30.01). There were four trichoptera taxa at each station (9.5% and 9.7% taxa; TrichopteraChTxPct). The low numbers of Trichoptera (both types and individuals) is reflected in a low IBI metric score; less than average needed to meet the Southern coldwater MIBI threshold (Figure 9).

Both stations had 21 nitrate tolerant taxa (77% and 76% 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 only a 25% probability of meeting the Southern coldwater MIBI. There were no nitrate intolerant taxa present at either station as well.

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 metric score and HBI_MN value have a significant relationship with nitrate. The HBI_MN metric score decreases with increased nitrate concentration. In the NBWW, the metric scores were 1.1 and 3.1 (out of 14.3), below the average metric score needed to meet the Southern coldwater MIBI threshold of 6.6 (Figure 9). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. Both stations show an elevated HBI_MN value (7.39 and 7.64). Utilizing quantile regression analysis for stations in the Southern coldwater class, there is a significant changepoint at 6.95 mg/L nitrate ($p \leq 0.001$). 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 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57. Both values are in the North Branch are well above this.

Both stations in this reach demonstrate macroinvertebrate metrics which show a response to the elevated nitrate concentrations here. The macroinvertebrate taxa richness is expected to be lower in coldwater streams in southeastern Minnesota, and there is increased richness in this location. There is an abundance of nitrate tolerant taxa, a lack of nitrate intolerant taxa, and low metric scores for both TrichopteraChTxPct, and HBI_MN; these metrics demonstrate a macroinvertebrate response consistent with elevated nitrate. The biological and chemical information confirm that nitrate is a stressor to this reach of the North Branch Whitewater.

TSS

This reach has an existing turbidity impairment. During biological sampling at station 10LM010, the TSS concentration was 20 mg/L. Station 10LM035 had a TSS concentration of 17mg/L. Both of these concentrations are elevated, and above the TSS standard of 10 mg/L for 2A streams. At station S000-978, TSS was measured 53 times between 2000 and 2011, with a range of concentrations from 1 mg/L to 1,533 mg/L. The average TSS concentration was 124.6 mg/L. At this same station, transparency was measured 65 times; with an average of 34 cm. Station S001-879 had 85 transparency measurements with an average of 40 cm. Similarly, station S004-708 had 30 measurements from 2007-2011, with an average of 36 cm.

The biological stations had macroinvertebrate TSS index scores that are below the average of coldwater stations in the MR-Winona Watershed (Table 10). Both stations also had a high percentage of TSS tolerant individuals and TSS tolerant taxa. Intolerant and long lived macroinvertebrates typically decrease with increased TSS stress. These two metrics in particular did not show as much response, but station 10LM035 did have fewer than average intolerant species.

Table 10. Macroinvertebrate metrics relevant to TSS for stations in North Branch Whitewater compared to averages for coldwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
10LM035	**17.45**	**0**	**9**	**48.16**	**2**	9.06
10LM010	**17.87**	2	**5**	**49.36**	5	**2.51**
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for coldwater stations in the MR-Winona Watershed	15.11	1.41	4.45	10.94	2.69	3.36

The fish community consists of a number of fish species that are tolerant to high TSS (Figure 15). Almost 90% of the fish at station 10LM035 belong to the two most TSS tolerant quartiles. Station 10LM010 had nearly 60% of its fish community in those quartiles (species include white sucker, creek chub,). Farther downstream, at station 10LM003, which is not impaired for biology; there are fewer TSS tolerant species and many more TSS - sensitive species present (e.g. trout and sculpin). Both biological stations had TSS index scores for fish that were below the MR-Winona Watershed average of 39.7 (11.4 and 13.5).). The percent carnivore metric, which is correlated to TSS, also shows below average percentages at both biological stations on this reach, further demonstrating TSS stress to the fish community (19.6% at 10LM010 and 22.5% at station 10LM035 compared to the average of 34.6%). MDNR geomorphic characterization in this reach has demonstrated aggradation, entrenchment, and the loss of floodplain storage causing channel instability. This reach also receives lots of silts and clays from upstream due to the extensive channelization, straightening and subsequent incision in the upper North Fork Watershed. The biological, chemical, and physical evidence suggests that TSS is a stressor to both the fish and macroinvertebrate communities in this reach.

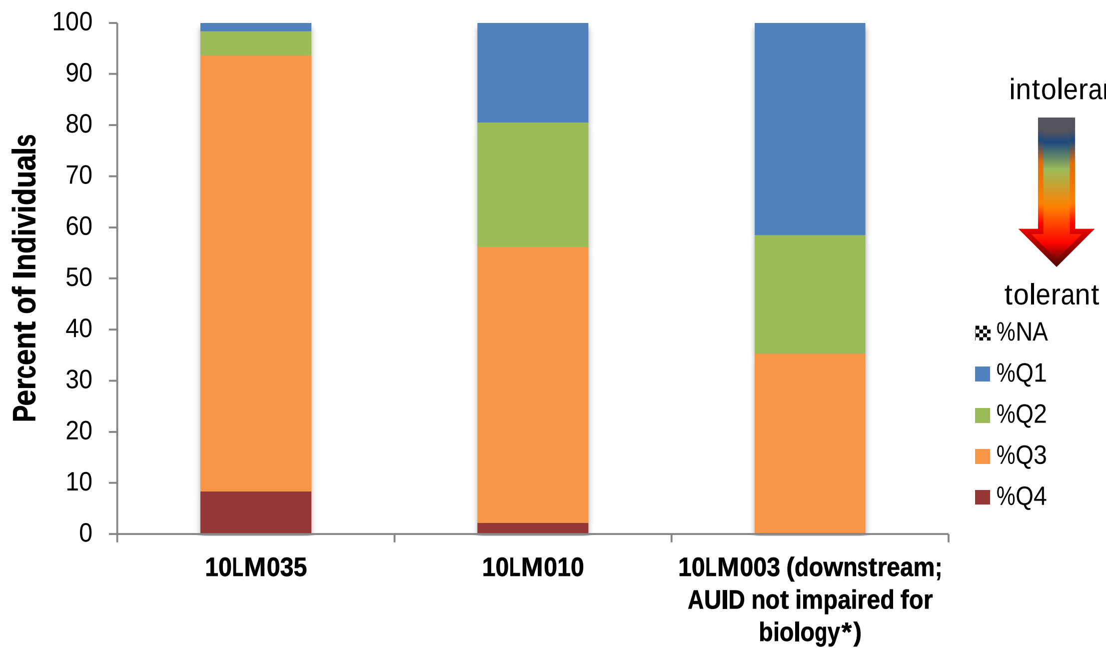

Figure 15. TSS TIVs for fish showing community composition of tolerant and intolerant fish species (Sandberg, 2013)

Habitat

Station 10LM010 had a good MSHA score of 83.6. Station 10LM035 also had a good MSHA score of 67.6. The land use subcategory scored low (0) at station 10LM035, but five out of five at station 10LM010. Similarly, the subcategory scores for substrate (15.1/27) and channel morphology (25/36) were reduced at station 10LM035. The substrate score was lowered due to moderate embeddedness of coarse substrate by silt, and the channel morphology score was lowered by a lack of channel sinuosity. The channel stability ranking channel condition stability index CCSI) at stations 10LM010 and 10LM035 both scored in the fairly stable category.

Geomorphic characterization by MDNR (Ellefson and Zytkovicz):

MDNR completed more detailed surveys on stream geomorphology and stability in the Whitewater Watershed (Ellefson and Zytkovicz, 2014). According to MDNR, this AUID in the North Branch is characterized as homogenous in terms of geomorphology, except for a distinct change in grade which occurs near the County Highway 4 Bridge. The grade upstream of the bridge is approximately 0.12% whereas downstream it more than doubles to 0.25%. The existing stream type is a B4c/C4 and the valley is vertically and horizontally controlled by bedrock. Stations 10LM010 and 10LM035 are both located on the lower-sloped portion of the AUID upstream of the County Highway 4 Bridge. MDNR site 131 (10LM035) classifies as a B4c, with site 35 (10LM010) classifying as a C4. The Pfankuch stability rating for all of the sites in this reach had a good rating, and had an average score of a 74.

In pre-settlement times, this reach was likely a C4 stream type, but due to the post-settlement aggradation of the floodplain, the stream has become incised to the point that the entrenchment ratio now forces this stream into the B4c class. Floodplain connectivity is not good in this reach. Site 35 (10LM010), which is still connected to its floodplain, is only 0.5 feet away from losing its connection. The historical Happ valley cross sections attest to the magnitude of floodplain area lost to the deposition of fine sediments. They also indicate that in addition to the floodplain aggrading, the channel bed is also potentially aggrading. This argument is strengthened by the competency calculations for both sites, which predict channel aggradation in this case. Whatever aggradation is occurring, it is likely to be slow and possibly localized as portions of this stream are still controlled vertically by bedrock. Most of the banks in this reach are very stable with a very low erosion potential. Where the stream encounters the valley wall the bank consists of bedrock/boulders/cobble on the outside bank and the inside bank is heavily vegetated and is either sufficiently low, or sloped enough to allow the root mass to penetrate nearly the entire profile of the bank. The average BEHI rating for the entire reach is moderate, and the average near bank stress (NBS) is moderate to low. Overall the reach is eroding at an average rate of 0.17 ft/yr and contributing an estimated 0.0542 tons/ft/yr of sediment from the banks, for a total annual load of 1,160 tons. The riffles seem to show no adverse effects of the bank erosion occurring in the reach. In aggregate, the riffle pebble counts show <15% silt/clay sized material and <20% sand sized particles. Fine sediment has not filled pools, which range from 1.5ft - 2.5ft deep at low flow conditions. The bottoms of the large compound pools are layered over with fines but remain greater than three feet deep.

Overall, these sites are incised or moderately entrenched. However, they can be considered stable despite the fact that they are classified, or nearly classified as B4c channels instead of C4s due to the heavy influence the valley walls play in stabilizing the channel. The biggest impact the floodplain aggradation and subsequent entrenchment has is keeping higher magnitude flood waters in the channel. This increases stream power, which mobilizes more bed material that is then dumped out at the points where gradient decreases, destabilizing those areas and initiating excessive bank erosion, which then contributes yet more fine sediment to the stream. The loss of floodplain storage also limits the ability to clean the water and is probably a contributor to the turbidity impairment in this AUID in addition to the destabilizing effect described above. This reach also receives significant loads of silts and clays from upstream due to the extensive channelization, straightening and subsequent incision in the North Branch Watershed.

Biological response:

Fish biological metrics were compiled for the North Branch, and then compared to statewide averages of this stream class (Southern Coldwater; Class 10). The two stations were both sampled in 2010, and both had fish communities with above average percentages of riffle dwelling fish (77% at 10LM035 and 69% at 10LM010), simple lithophilic spawners (69% and 56%), and lithophilic spawners (96% and 81%). However, tolerant white suckers were the dominant fish found at both stations (934 individuals at 10LM035 and 191 at 10LM010), and this species makes up a large percentage of these metrics.

At 10LM035, non-tolerant benthic insectivores and the darter, sculpin and round bodied suckers metric were below average (3.8% and 2.2%, respectively) while station 10LM010 had above average percentages of those metrics. White suckers and trout are not a part of these metrics. The only coldwater fish that is found in these two metrics is sculpin (not present at either station). The percentage of pioneering fish species was higher than average at both stations (19% and 24%) compared to other coldwater stations in the state. Pioneer species thrive in unstable environments and are the first to invade a stream after disturbance. In addition, piscivores were found in reduced abundance (only 3% and 10%), compared to the statewide average of 37%. Piscivores generally require good substrate, and pool habitats for predator-prey relationships. There was a high percentage of tolerant species found at both locations, and a reduced percentage of sensitive species, especially at station 10LM035. These habitat metrics reveal that habitat is limiting the fish community on this reach, with more evidence of impact at station 10LM035.

The macroinvertebrate community is sampled based on dominant habitat types found at each station. The macroinvertebrate habitat sampled at station 10LM035 included: riffle/run, woody debris, and undercut bank/overhanging vegetation. At station 10LM010, only riffle/run and undercut bank/overhanging vegetation was sampled. The macroinvertebrate metrics were compiled for this reach on the North Branch, and then compared to statewide averages of this stream class (Southern Coldwater; Class 9) (Figure 16). The percentage of burrowers was slightly higher than average at both stations, coinciding with embeddedness of fine sediments in riffle, run, and pool habitats recorded at station 10LM035. The same effect is not seen at downstream station 10LM003, where macroinvertebrates are not impaired. Similarly, a higher than average percentage of (generally tolerant) legless individuals was present at both stations as well. On the other hand, the percentage of clingers and EPT individuals were found in good percentages at both stations (above the statewide averages). Climbers were found near statewide averages at both stations as well (13% and 12%). Swimmers and sprawlers were below average at both stations.

The macroinvertebrate community demonstrates slight habitat issues due to elevated percentages of burrowers and legless individuals. Fine sedimentation is likely driving the issues for macroinvertebrates, evidenced by a higher than average percentage of burrowing species at both locations. However, clingers and climbers are good, which demonstrate some diversity in habitat types. The fish community demonstrates habitat stress in the number of tolerant species like white sucker and creek chubs, the reduction of piscivores, and increase in pioneer species throughout the reach. Additionally, station 10LM035 exhibits more stress due to reductions in non-tolerant benthic insectivores and darter/sculpin/round bodied suckers. These fish depend on healthy productive benthic habitats with minimal embeddedness. This further supports sediment issues in this reach, and contributing upstream impact. Lack of suitable habitat is a stressor to both fish and macroinvertebrate communities in this reach.

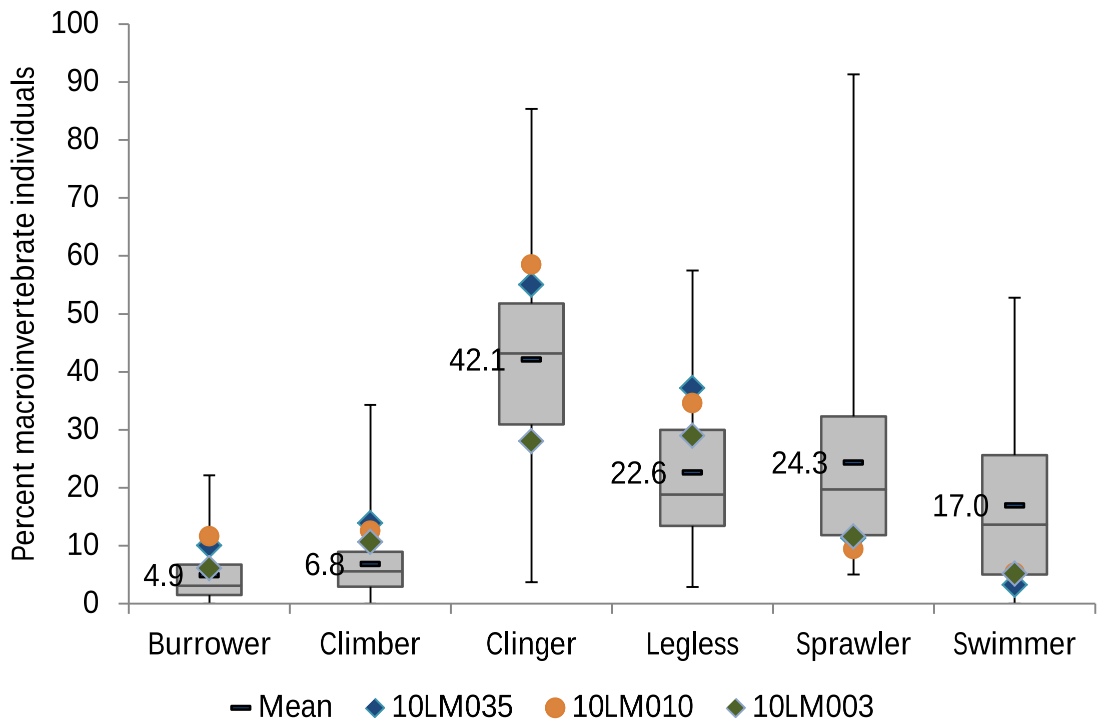

Figure 16. A comparison box plot of macroinvertebrate habitat metrics representing the average class 9 (Coldwater) stations statewide. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

Conclusions and recommendations

The stressors found in this reach are summarized in Table 11. The main stress to this reach is due to elevated nitrate concentrations, TSS, and sediment effects on habitat. The upstream watershed land use has a large impact on this reach. It receives lots of silts and clays from upstream due to the extensive channelization, straightening and channel incision. The nitrate concentrations are also higher in the upper watershed, which impacts this reach. Better management of nutrients and fine sedimentation from upstream sources would be helpful. Ensuring adequate buffers to ditches and perennial waterways in this part of the watershed would be useful as well. Habitat impacts are shown to fish and macroinvertebrates due to the excessive sediment being routed to this area from upstream.

As already mentioned, this reach is heavily influenced by the upstream warmwater reach, and in a natural transition area from warmwater to coldwater. Maximum stream temperatures are on the upper end of optimal for a coldwater stream, yet similar to other coldwater streams in this area and of this size. Temperature is not considered a stressor at this time, as other stressors are having more of an impact on the biology. However, temperature should continue to be evaluated to ensure it remains suitable. Similarly DO is a potential stressor, and continued monitoring to further understand the DO dynamics in the stream would be beneficial in the future. Addressing the other stressors in this reach may have a positive impact on DO as well.

Table 11. Summary of stressors found in the North Branch Whitewater (553).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-553 Whitewater River, North Fork, T108 R11W S30, west line to Unnamed Creek	7.91	1B, 2A, 3B	10LM035 10LM010	Upstream of Township Rd 244, 2.5 mi. E of Elgin 0.5 mi. upstream of CSAH 4, 3 mi. S of Plainview, in Carley State Park	Fish IBI Macroinvertebrate IBI Turbidity Bacteria	○	○	●	●	●

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.2 South Fork Whitewater River
(Warmwater; 07040003-F16)

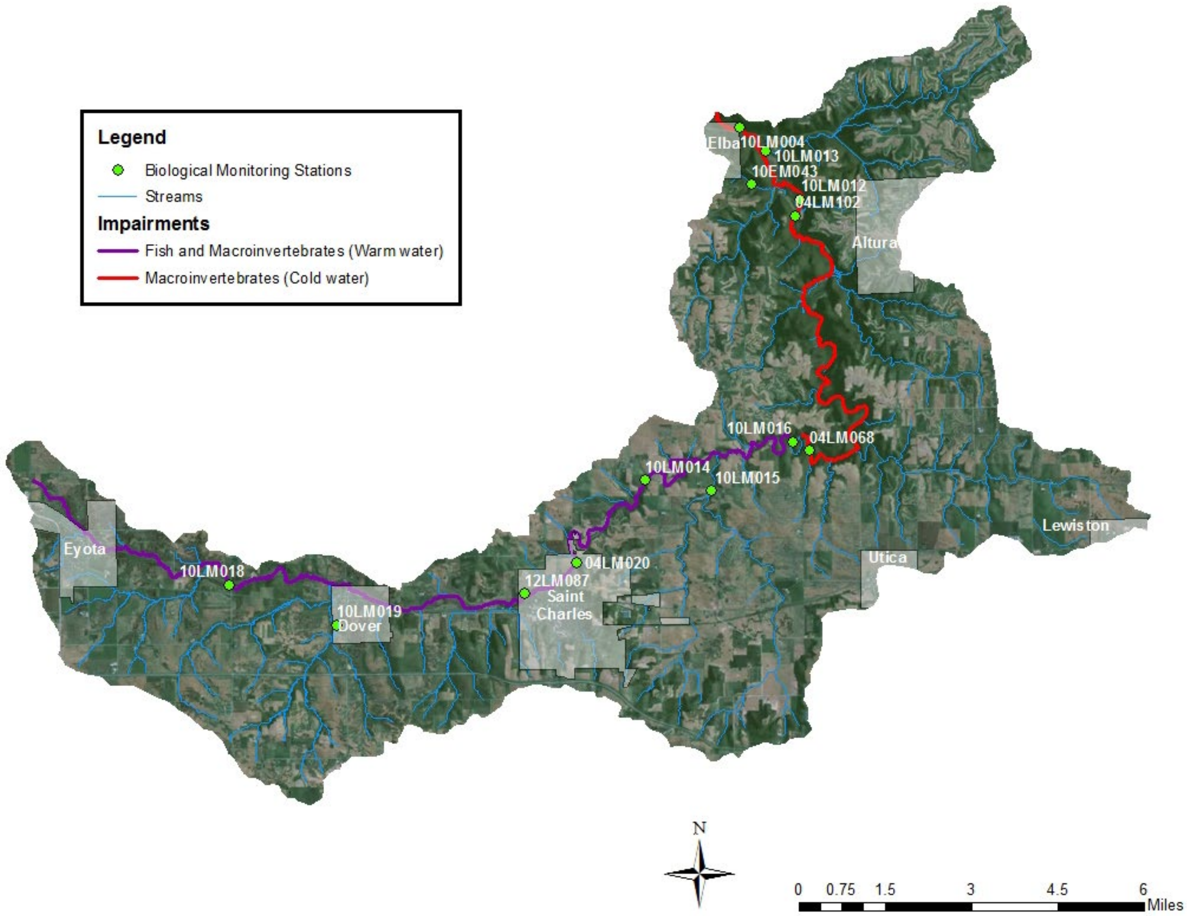

Figure 17. South Fork Whitewater Watershed map showing both coldwater and warmwater impaired AUID's and biological stations.

Supporting information

The warmwater reach of the South Fork Whitewater River is impaired for fish and macroinvertebrates. The biological community degrades moving down the reach while the biota at the upstream station (10LM018) meets aquatic life use standards. The presence of abundant coldwater taxa in these reaches show signs of coldwater influence, despite warmwater designation. Poor IBI scores reflect an abundance of tolerant taxa and decreasing numbers of sensitive taxa, despite a relatively diverse EPT community for macroinvertebrates. Poor habitat conditions observed in the reach including excess sedimentation, bank erosion, lack of riparian cover and poor channel development, all consistent with anthropogenic stress present in the watershed. The Whitewater River Regional Wastewater Treatment plant is a permitted wastewater facility located a few miles upstream of site 10LM014.

There are four biological stations on the warmwater section of the South Fork Whitewater River. Two sites are in the southern headwaters fish class, and two sites are in the southern streams fish class. Stations 10LM018 and 12LM087 are located in the southern headwaters fish class (Figure 18). The sensitive taxa and the percentage of taxa that are detritivorous metrics are the lowest scores, but all the metric scores were at or above the average score needed to meet the threshold. Both sites in the southern headwaters class met the threshold.

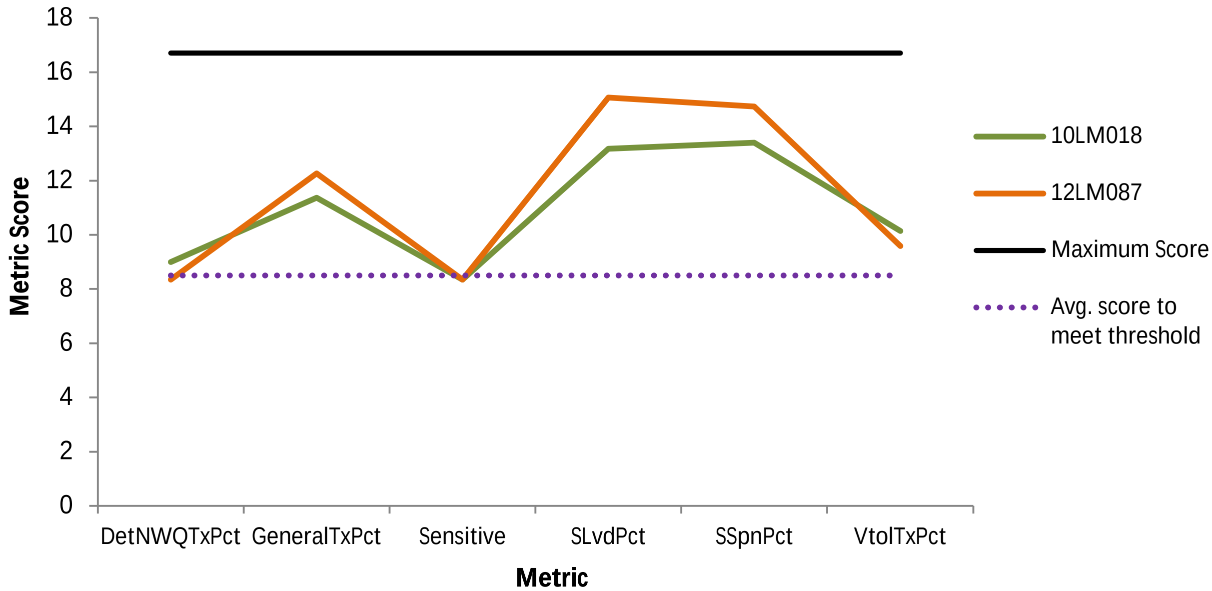

Figure 18. Fish IBI metric scores for the South Fork Whitewater (Southern Headwater Fish Class)

The two stations in the southern streams had three biological visits. All three visits had a score of 0 for the percentage of tolerant individuals metric (Figure 19). Station 10LM014, the most downstream site on the warmwater section of the river had the lowest fish IBI score in this reach, at 44. Station 04LM020 had two visits in 2004, with scores at 46 and 39. The sensitive taxa percent was lowest at station 10LM014.

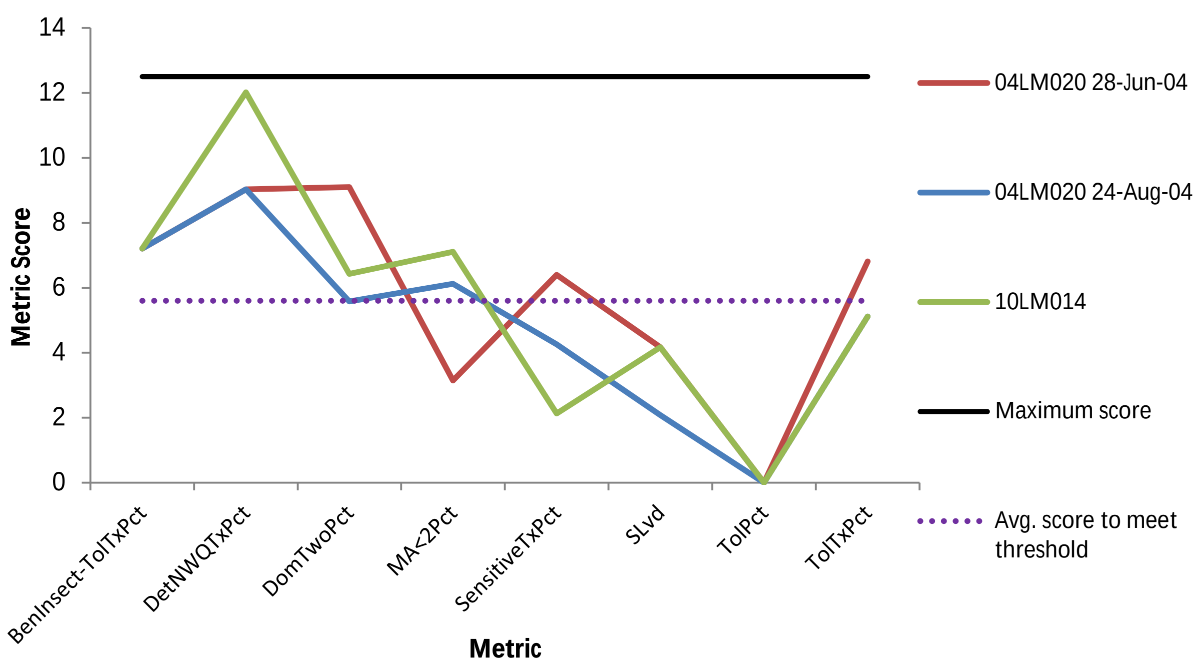

Figure 19. Fish IBI metric scores for the South Fork Whitewater (Southern Streams Riffle/Run(RR))

Stations 10LM018, 10LM014 and 04LM020 are all in the Southern Streams Riffle/Run (RR) macroinvertebrate stream class, which has an impairment threshold of 35.9. Station 10LM018 scored the highest with a score of 42.4. Station 10LM014 was sampled twice; once in 2010 and again in 2012. The results were 36.1 and 35.2, respectively. In 2004, station 04LM020 had the worst MIBI scores in this stream reach (24.3 and 35.0), below the threshold. The Plecoptera (stoneflies) taxa richness metric was zero during all five macroinvertebrate visits on the warmwater section of the South Fork Whitewater River (Figure 20). Stoneflies are one of the most sensitive macroinvertebrate species (Heiskary et. al, 2013). Clinger taxa percentage was much higher during the 2012 sample at station 10LM014 than during any of the other four visits. Clinger taxa are adapted to be able to attach to substrate in fast moving water. A diverse group of clingers is evidence that stream substrate has not been covered in fine sediments.

Station 12LM087 is in a separate macroinvertebrate class (6) than the other stations, based on glide and pool habitats being sampled versus riffle and run habitats at the other stations. The MIBI score for this station scored very low with a score of 20.1. Overall, station 12LM087 also had low scores in the intolerant and POET taxa richness and percent of Trichoptera taxa and non-hydropsychid Trichoptera individuals (Figure 21).

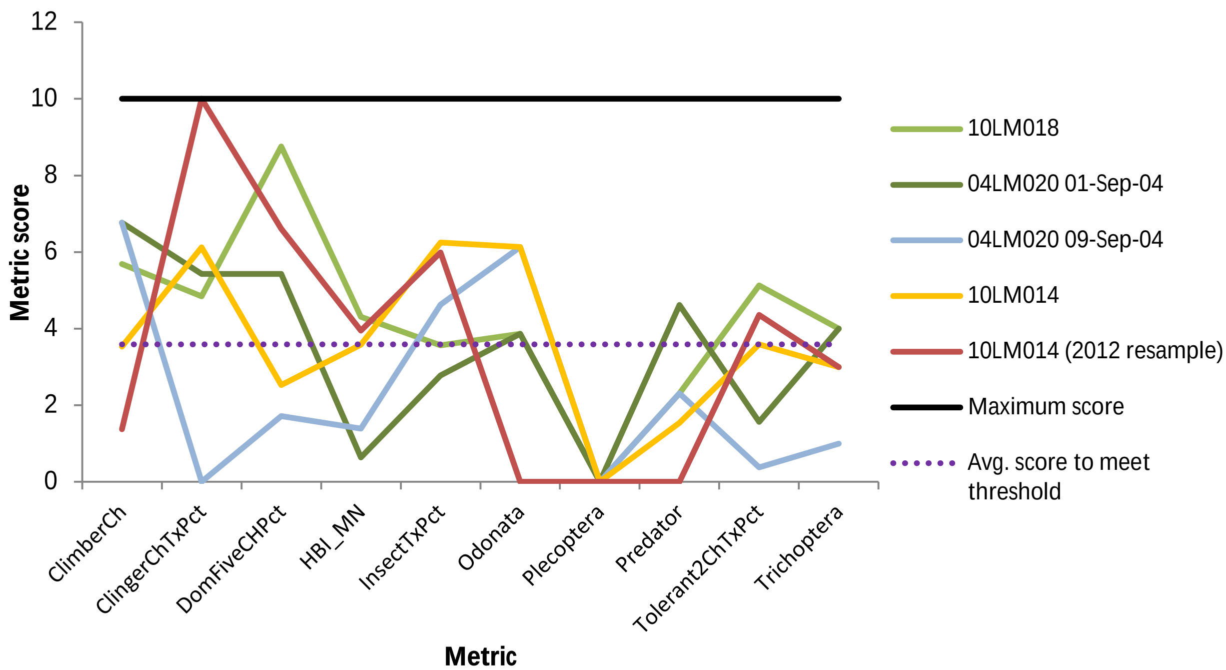

Figure 20. Macroinvertebrate IBI metrics for the South Fork Whitewater.

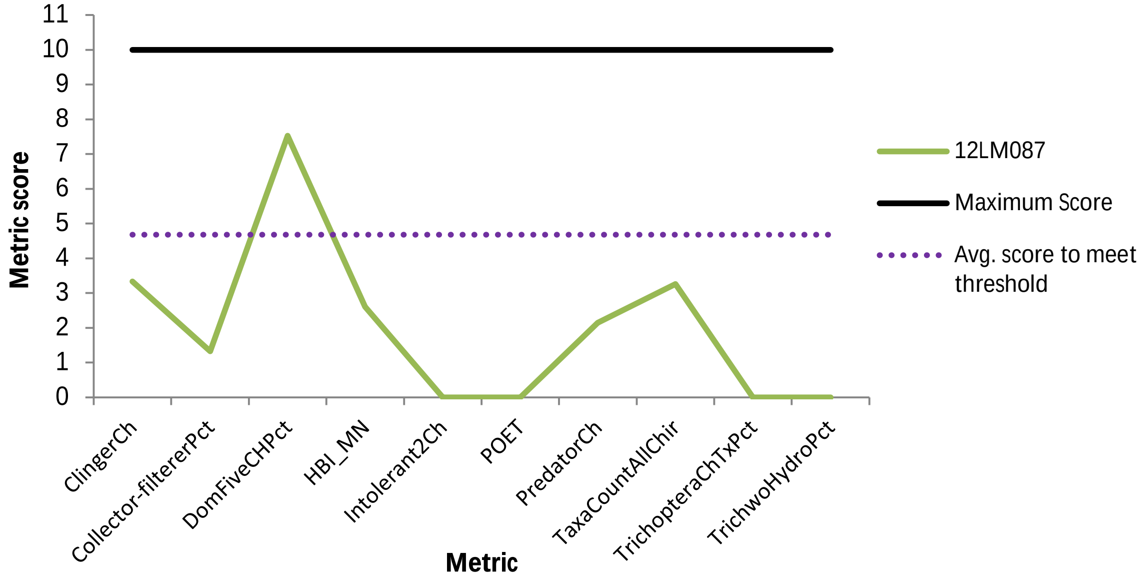

Figure 21. Macroinvertebrate IBI metrics for 12LM087 in the South Fork Whitewater.

Temperature

There were five temperature measurements taken during fish sampling at the three biological stations (values ranged from 16.0°C to 20.4°C). In addition, there were 463 temperature measurements taken at multiple locations on this stream reach between years 2001-2012. The maximum temperature recorded during that time was 27°C, which is an acceptable maximum temperature for a warmwater stream in this area. Temperature is not considered a stressor to this reach, given the current information.

Dissolved oxygen

Low DO

There is a sizeable DO dataset on this reach from the last 10 years. Concentrations values ranged from 6.6 to 15.0 mg/L. Two samples were taken before 9 a.m., with values of 7.6 and 7.8 both above the 5.0 mg/L standard for warmwater streams.

Continuous DO data was collected at two locations on this reach in 2012. DO values were above the water quality standard of 5.0 mg/L at both sites throughout the deployment, although values at station 04LM020 get as low as 5.77 mg/L (Figure 22). Further downstream at station 10LM014, values ranged between 5.93 mg/L and 11.65 mg/L (Figure 23).

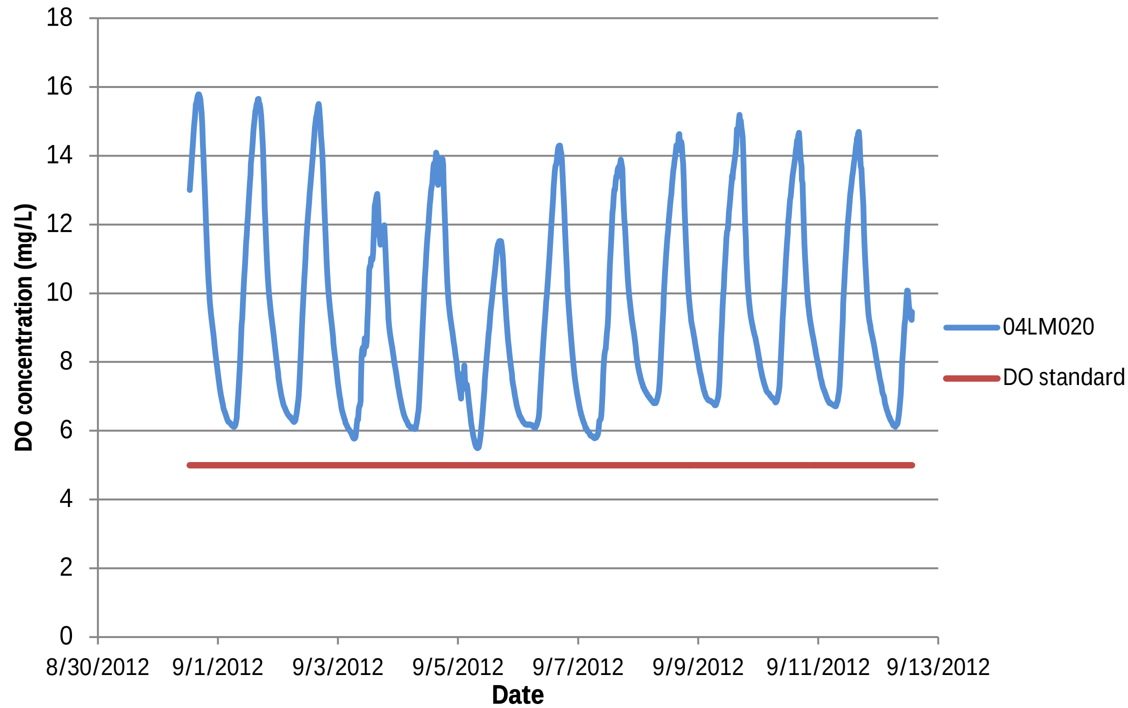

Figure 22. Continuous DO data collected in 2012 at 04LM020.

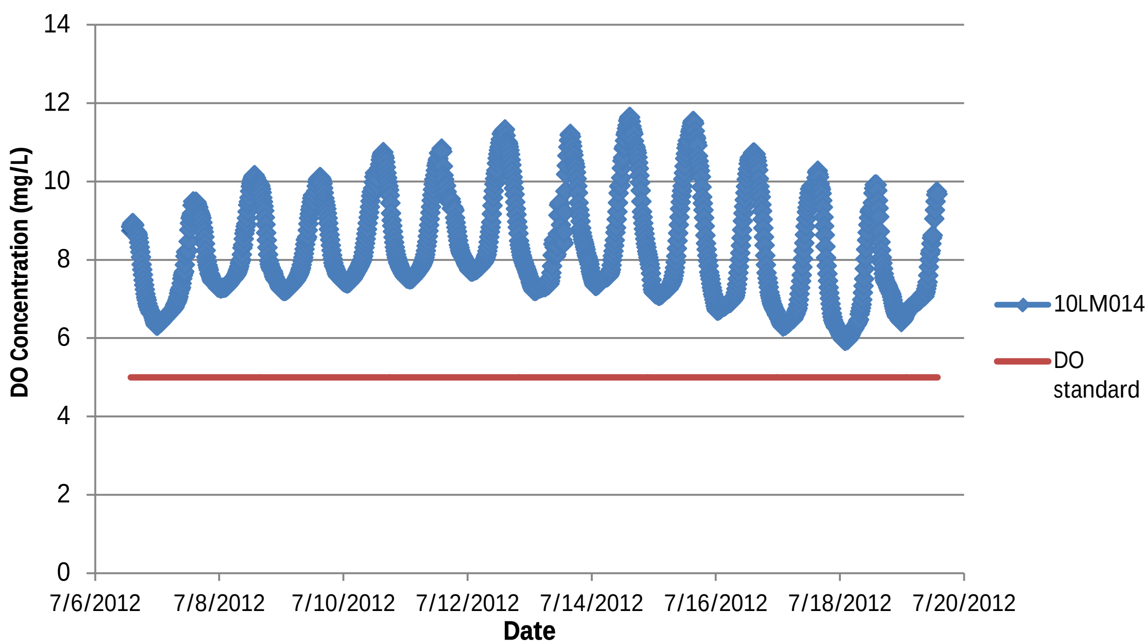

Figure 23. Continuous DO data collected in 2012 at 10LM014.

Low DO values correspond with increased tolerant species, decreased sensitive fish, and decreased fish that mature at greater than three years of age. Both the fish and macroinvertebrate communities are dominated by tolerant taxa on this reach. The five macroinvertebrate samples taken on the South Fork Whitewater had a range of tolerant taxa percentage from 69.76 to 91.89, averaging 82.99. The tolerant individual fish percentages during five samples ranged from 58.99 to 89.55 (Table 12). The tolerant communities were highest at visits on stations 04LM020 and 12LM087. Taxa richness of fish ranged from 13 to 16. The average taxa count for warmwater streams in the Lower Mississippi River basin is 17. Taxa richness of macroinvertebrates ranged from 30 to 44. The average taxa count for warmwater streams in the Lower Mississippi River basin is 35. Sensitive individual fish percentage ranged from 0.94 at station

12LM087 to 26.96 at station 10LM014. The average for warmwater sites in the Lower Mississippi basin was 13.73. The percentage of individual fish that mature at greater than three years of age ranged from 0 to 1.02%, which is very low and indicates stress to fish that are therefore not able to reach mature age. The average for warmwater sites in the Lower Mississippi basin was 12.65%.

Longitudinally from upstream to downstream, the early morning DO tolerance indicator values for fish at the five samples show fairly tolerant fish communities (Figure 24). The majority of the fish collected at the South Branch Whitewater River sites are comprised of species in the first and second quartiles (early morning low DO tolerance). Station 04LM020 had the highest percentage of fish in the first and second quartile at 74 and 77.4% at the two visits, with the predominant fish being white suckers, creek chubs, and johnny darters.

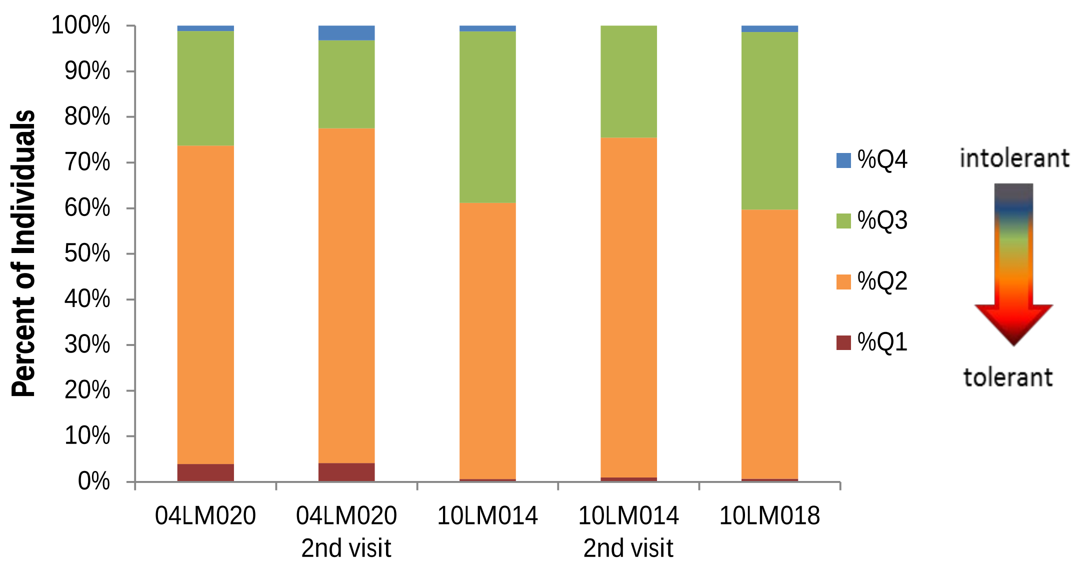

Figure 24. DO TIV's for fish at biological stations in the South Fork.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. At station 10LM018, there were 12 macroinvertebrate taxa collected that are intolerant to low DO, and 0.35% DO tolerant taxa. At station 12LM087 only one macroinvertebrate taxon that is intolerant to low DO were collected, and 12.19% DO tolerant taxa were collected. At station 04LM020, 9 and 7 intolerant to low DO taxa were collected during the two visits, and 5.65 and 11.56% DO tolerant taxa were collected. At station 10LM014, 9 and 11 macroinvertebrate taxa that are intolerant to low DO were collected at the two visits and 3.31 and 0.33% DO tolerant taxa were collected. The average number of intolerant taxa collected in warmwater sites in the Lower Mississippi River basin was 7.31 and the average percentage of DO tolerant taxa was 10.79. Based on high tolerant individual percentages, low sensitive percentages, low percentages of fish that mature at greater than three years of age, and communities dominated by fish in the first and second quartile of low DO tolerance, low DO is determined to be a stressor to the fish community on this reach. While there were also high tolerant macroinvertebrate percentages, there were average taxa counts and DO tolerant macroinvertebrate percentages, therefore low DO is inconclusive as a macroinvertebrate stressor at this time, but should continue to be monitored.

Table 12. Fish and macroinvertebrate metrics relevant to DO for stations in South Fork Whitewater. Bold and highlighted equals the metric score is higher or lower than average for the MR-Winona Watershed, depending on expected response with increased stress.

Station (Year sampled)	MA>3 years	Sensitive Fish Percentage	Tolerant Individual Fish Percentage	Percentage DO Tolerant Macroinvertebrate Taxa	DO Intolerant Macroinvertebrate Taxa	Tolerant individual Macroinvertebrate Percentage
04LM020 (2004)	**0.78**	**2.33**	**76.26**	5.65%	9	**67.11**
04LM020 (2004)	**0**	**3.99**	**86.32**	**11.56%**	**7**	**89.33**
12LM087 (2012)	**0.86**	**0.94**	**89.55**	**12.19%**	**1**	**97.19**
10LM014 (2010)	**0.28**	6.33	**76.20**	3.31%	9	52.44
10LM014 (2012)	**1.02**	26.96	**58.80**	0.33%	11	42.00
10LM018 (2010)	**0.52**	**1.38**	**82.18**	0.35	12	56.23
Averages for warmwater stations in the Lower Mississippi River basin	10.66	13.73	62.15	10.79	7.31	61.29
Expected response to stress	↓	↓	↑	↑	↓	↑

DO flux/Eutrophication

While the continuous data showed daily minimums above the water quality standard, the daily DO flux at station 04LM020 was above the standard each day (Figure 25). Daily DO flux values were as high as 10.55 mg/L, with values ranging from 6.05 mg/L to 14.09 mg/L. Periphyton growth was prevalent on the rocks present at station 04LM020, likely contributing to DO flux (Figure 26). High water temperature can also impact how much oxygen the water can hold, and the continuous temperature taken during this time frame was normal. However, values were taken during early September when water temperature is not typically its highest. Daily temperatures did not exceed 20°C when the sonde was deployed, and pH values were also within the standard (within the range of 6.5-9.0). Further downstream, the daily fluxes at station 10LM014 were below the water quality standard each day (Figure 27).

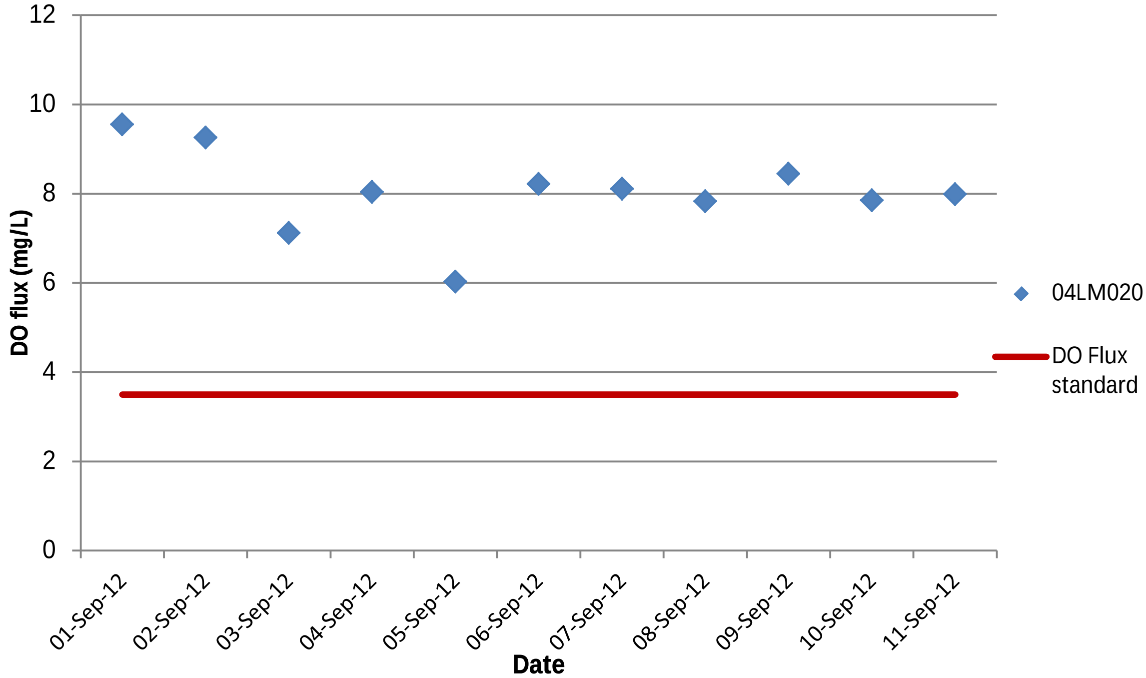

Figure 25. DO flux collected in 2012 at 04LM020.

Figure 26. Periphyton at station 04LM020

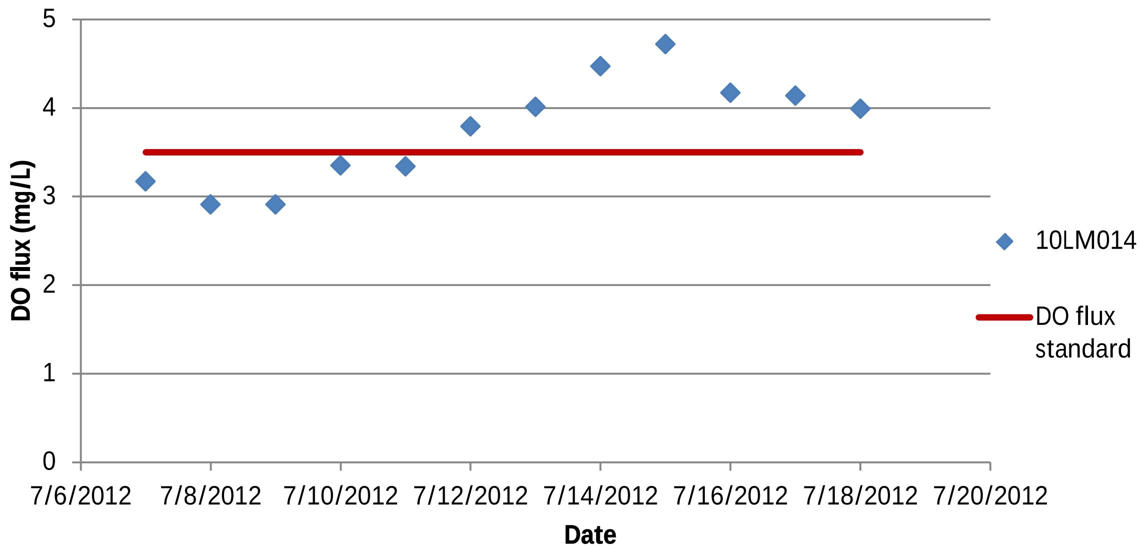

Figure 27. DO flux collected in 2012 at 10LM014.

As interacting variables to eutrophication, phosphorus and pH were compared to normal ranges and standards. The total phosphorus concentrations collected during fish sample ranged from 0.062 mg/L up to 0.339 mg/L, with an increasing trend when moving downstream. The mean phosphorus concentration in this entire reach was 0.645 mg/L, with six years of data. The maximum concentration recorded was 1.45 mg/L at station S000-288. During a longitudinal survey, TP was highest at station S000-323, which is downstream of the wastewater treatment plant (Table 13). Corresponding pH values from these samples ranged from 7.62 to 8.27. All collected pH data were below levels usually connected to elevated nutrients. pH flux values at stations 04LM020 and 10LM014 ranged from 0.09 to 0.45. Both sites had daily pH fluxes above typical values. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013).

Table 13. Water chemistry measurements at multiple locations on the South Fork on June 22, 2012 and July 19, 2012.

	5/22/12			7/19/12		
Stations (upstream to downstream)	**DO**	**pH**	**TP**	**DO**	**pH**	**TP**
S000-328	11.97	7.77	NA	10.05	7.94	0.052
S007-096	10.19	7.91	NA	7.23	8.2	0.076
S007-085 (Upstream WWTP)	13.02	8.12	NA	13.34	7.91	0.029
S000-323 (Downstream WWTP)	11.21	8.32	NA	9.59	8.43	**0.992**

EPT communities are inversely correlated with low DO and DO flux. The percentage of EPT individuals ranged from 2.33 to 34.53, averaging 24.13. Station 04LM020 which had the lowest DO values (5.77 mg/L) and the highest flux values (all over 6 mg/L) also had the highest tolerant taxa percentage value (91.89) and the lowest EPT individual percentage value (2.33). As DO flux increases above 4.0 mg/L per day, the sensitive fish population falls to less than 10% (Heiskary, 2008). Sensitive fish individual percentage ranged from 0.94 to 26.96% on the South Fork Whitewater River (Table 12). Five out of six visits on the warmwater section have less than 7% sensitive fish individuals. This corresponds with continuous DO data at stations 04LM020 and 10LM014 where the flux averages 8.04 mg/L and 3.74 mg/L respectively.

Based on the preponderance of low percentages of sensitive fish, the high numbers of tolerant fish and macroinvertebrate taxa, and the low EPT individuals, DO flux, pH flux, and eutrophication is determined to be a stressor. The stress is most concentrated at stations 12LM087 and 04LM020, which are both upstream of the wastewater treatment plant. The lack of shading, elevated sedimentation, nutrient values, and algal growth (Figure 28) are all interacting variables affecting the DO dynamics in the stream.

Figure 28. Algae at station 04LM020

Nitrate

The nitrate concentrations collected at the time of fish sampling ranged from 10 mg/L to 16 mg/L at the four biological stations in this reach of the South Fork. The 16 mg/L nitrate result was measured in June 2004 at station 04LM020. When that same site was resampled in August of 2004, the concentration was 11 mg/L. The other sites were sampled in 2010 or 2011, and all results were either 10 mg/L or 11 mg/L. During baseflow conditions in 2012, a longitudinal survey of nitrate was completed at four stations in the South Branch (Table 14). This shows a slight decrease in nitrate concentration just downstream of the city of St. Charles and a slight increase downstream of the Wastewater discharge point (Figure 29).

Table 14. Longitudinal nitrate concentrations on the South Branch Whitewater from sampling dates (May 22 and July 19, 2012)

Stations (upstream to downstream)	Nitrate mg/L 5/22/12	Nitrate mg/L 7/19/12
S000-328	11	9.2
S007-096	13	9.4
S007-085 (Upstream WWTP)	9.5	5
S000-323 (Downstream WWTP)	11	8.2

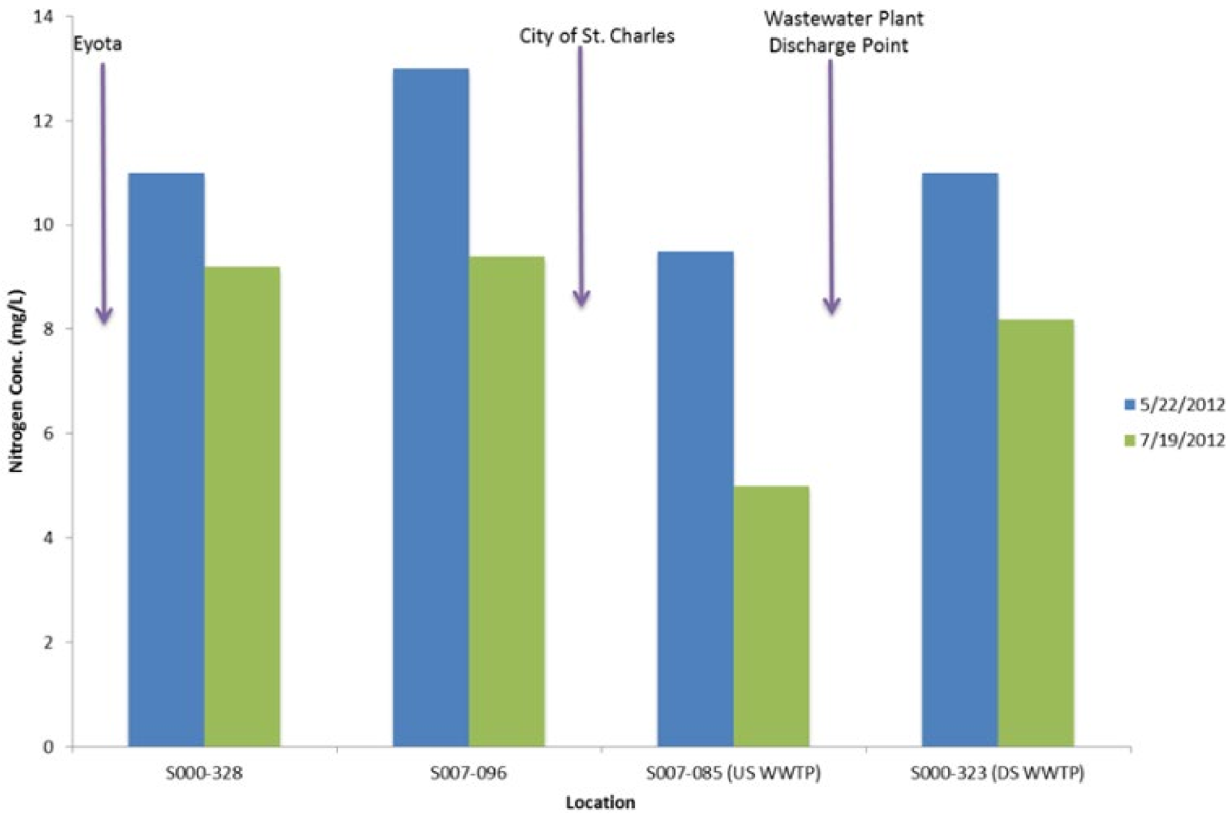

Figure 29. Longitudinal nitrate concentrations from two days and four sampling locations on the South Branch Whitewater. Arrows indicate geographic location on the stream.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. At 65.71% nitrate tolerant individuals, there is a 50% probability of meeting the Southern Forest Streams GP (class 6) MIBI. The one sample taken in this stream class, station 12LM087, had 69.39% nitrate tolerant species collected. The other three stations on this warmwater reach were all part of the Southern Streams RR macroinvertebrate (class 5). There were 58.22% nitrate tolerant individuals species collected at one of the samples at station 10LM014. At 54.66% there is a 75% probability of meeting the MIBI in this stream class. One of the samples at station 04LM020 had 83.99% nitrate tolerant individuals collected. At 83.78%, there would only be a 10% probability of meeting the MIBI. The average percentage of nitrate tolerant individuals on this reach was 71.18%. The two highest percentages of nitrate tolerant individuals were both collected at station 04LM020.

Overall, the macroinvertebrate communities at biological stations in the South Fork Whitewater have fairly good taxa richness with a range of total taxa from 30 to 44. The average for class 5 stations in the Lower Mississippi basin (LMB) is 37.76 (TaxaCountAllChir). Similarly, most sites also had a fair number of Trichoptera taxa (3-6), but few intolerant taxa. There were no nitrate intolerant taxa at station 10LM014, but one nitrate intolerant taxon at 10LM018 and 04LM020. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (caddisfly) individual percentages in warmwater streams. Non-hydropsychid Trichoptera are all caddisflies that do not spin nets. The individual percentages on South Fork Whitewater River sites range from 0% to 15.63%, and average 6.21%. Sites in the Lower Mississippi basin average 3.39%. Station 04LM020 had the lowest percentages, at 1.66% and 0.667% non-hydropsychid Trichoptera during its two visits in 2004.

The biological response data do not show evidence to support nitrate as a stressor throughout this reach, rather localized or temporal, even though concentrations are consistently elevated. Elevated nitrate can impact macroinvertebrate communities more at stations with multiple stressors acting on the community. It also appears to have more of an impact on macroinvertebrate communities in conjunction with poor habitat conditions. Therefore, elevated nitrate is acting as a localized stressor at station 04LM020 due to decreased non-hydropsychid Trichoptera, increased nitrate tolerant percentage, and increased nitrate tolerant taxa. If habitat further degrades at other stations, the impact of nitrate may become more apparent.

TSS

The TSS concentrations at time of fish sampling ranged from 9.2 mg/L to 52 mg/L, which captured a range of conditions over multiple years (Table 15). No additional TSS information was available on this particular stream reach, although the two reaches downstream have large TSS datasets. This reach has existing turbidity impairment, with multiple stations having transparency information which support the current listing.

Table 15. TSS data from fish sampling in 2004, 2010, and 2012.

Site	Date	TSS mg/L
04LM020	June 28, 2004	6.8
04LM020	August 24,2004	14
10LM018	June 8, 2010	30
10LM014	June 15, 2010	52
10LM014	June 5, 2012	9.2
12LM087	June 5, 2012	40

In the South Branch Whitewater, two biological stations had macroinvertebrate TSS station index scores which are worse than average compared to the average warmwater stations in the MR Winona Watershed (Table 16). These stations (04LM020 and 10LM014) also had a high percentage of TSS tolerant taxa. Station 10LM014 also had a very high percentage of TSS tolerant macroinvertebrate individuals.

Table 16. Macroinvertebrate metrics relevant to TSS for stations in South Fork Whitewater compared to averages for warmwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
10LM018	15.22	1	**8**	21.40	3	5.75
04LM020 (August 2004)	**17.21**	1	**14**	16.73	3	**0.33**
04LM020 (June 2004)	16.72	1	6	6.57	**1**	**0.33**
10LM014	**17.30**	1	**8**	**35.31**	3	9.77
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for Warmwater stations in the MR-Winona Watershed	16.92	0.61	7.66	28.95	1.75	3.78

The fish population consists of a number of fish species that are tolerant to high TSS. Many of the stations had high percentages of fish like creek chub, central stoneroller, bigmouth shiner, and bluntnose minnow, all which are tolerant to high TSS levels. More than half of the fish communities in this reach are in the two most tolerant TSS quartiles, with a large percentage in the most tolerant quartile (Figure 30). All biological stations had TSS index scores for fish that were below the MR-Winona Watershed average of 39.7. The percent carnivore metric, which is correlated to TSS, also shows below average percentages at all biological stations on this reach, further demonstrating TSS stress to the fish community. On average, stations in the MR-Winona Watershed consist of 34% carnivores. The percentage of carnivores among sites ranged from 9.15% to 27.87%. Almost all the stations in this reach have decreased percentages of long-lived fish species, and intolerant fish species, which respond to increases in TSS stress as well. The biological and chemical evidence show TSS is a stressor to both fish and macroinvertebrate communities in this reach. Currently fish are showing more consistent biological response among multiple metrics.

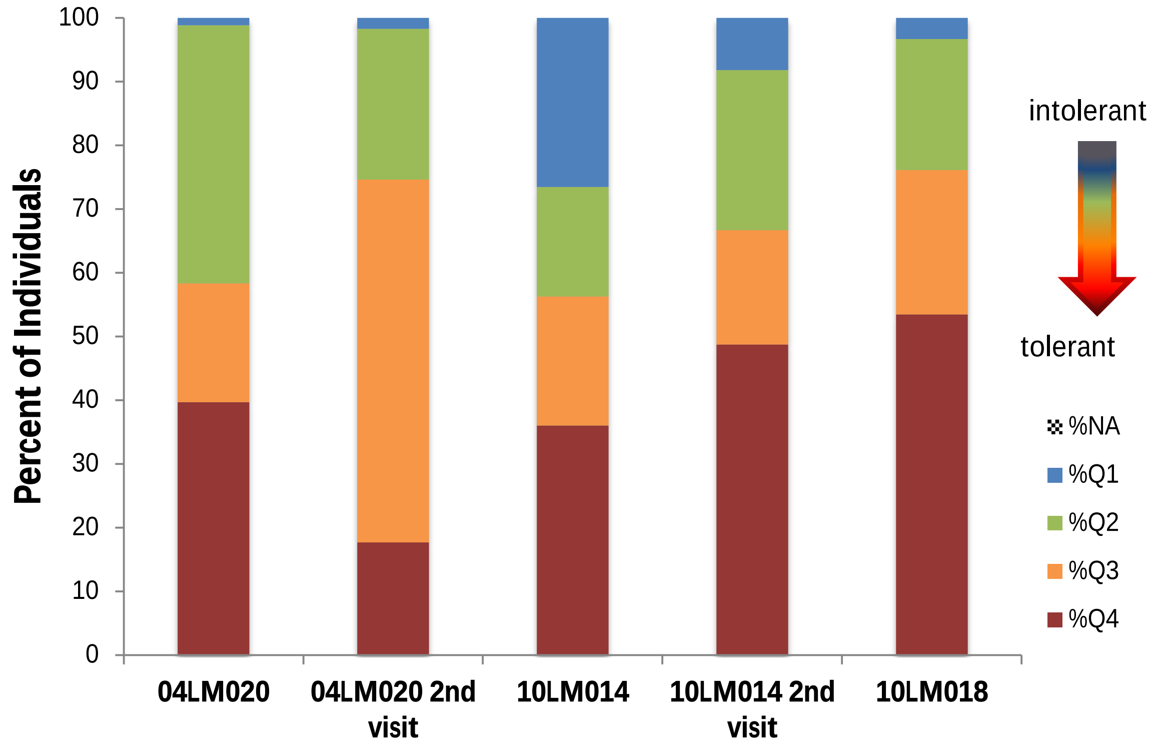

Figure 30. TSS TIVs for the South Branch Whitewater, (Sandberg, 2013)

Habitat

Stations 10LM014 and 12LM087 had poor MSHA scores (44.2 and 41, respectively). Station 10LM018 had a fair MSHA score of (48.6). Both visits to station 04LM020 resulted in fair MSHA scores (52 and 54.05). The land use subcategory was poor throughout the AUID, with a zero score for all sites except station 10LM018. All the other subcategories were also slightly reduced throughout, showing less than ideal habitat conditions across subcategories and stations. Problems include lack of riffles, lack of depth variability, and embeddedness as noted during fish visits at all biological stations. The channel stability ranking CCSI at station 10LM018 had a score of 83, in the severely unstable category. At station 10LM014, the score was 57, and in the moderately unstable category. A score was not available for station 04LM020, because the station was sampled in 2004, when the CCSI was not being measured routinely.

Geomorphic characterization by MDNR (Ellefson and Zytkovicz):

This stream is classified as an E4 channel, which is the reference stream type for this reach. Most of this reach upstream of the town of Dover has not been modified to the extent of the rest of the Whitewater Watershed. Many of the streams in the South Fork are still in their original E classification with a higher width/depth ratio. Everything downstream to St. Charles has lost much of the sinuosity that was still visible in the 1930s aerial photos. The streams are also visibly much wider. The Pfankuch stability rating for the three sites on this reach are all rated as fair. Near biological station 10LM018, the riparian area is grazed throughout the reach, but the grass looked healthy with no signs of over grazing. Site 04LM020 is forested on the steep side slopes of the valley and un-grazed grass on the opposing side. The riparian condition is not an issue in this area. Being slightly incised, the average BEHI rating is considered moderate, despite the good rooting depth and density that exists on this reach. The high NBS is what drives the erosion rate up. Higher NBS values are typical of highly sinuous E channels. The lateral migration rate is 0.28 ft/yr and the sediment loading is 0.071 tons/ft/yr. Much of the stability to this reach can be attributed to the high density tree coverage of the riparian area. A major component of the channel bed for this AUID is sand. It is visually apparent when on the river that South Fork streams have far more sand on the channel bed. It's especially apparent in the higher width to depth (W/D) channels downstream of Dover. They look very similar to the main stem river channel. Many portions of the stream classify as gravel beds but there is a large sand component to the bed. The upper part of the South Fork Watershed has around 50% sand content in the soil according to SSURGO dataset. This contrasts with below 15% for the rest of the Whitewater. Sand is influencing the quality of aquatic habitat in the South Fork.

This AUID is very sensitive to riparian changes due to the vast number of E channels present. Overall, much of the channel is not being encroached on by row crops. Most of the floodways on the upper third of the AUID remain in a grassy state. This is most likely due to the fact that the streams are for the most part still attached to their floodplains. This reach could most benefit from re-meandering, partially through reclamation of abandoned channels. The middle third (between Dover and St. Charles) is encroached by row crops but is still attached to its floodplain and classifies as an E channel. The floodplain of the AUID is heavily impacted by road crossings. The stream parallels Hwy 14 for most of the time the valley is a type VIII(c). This causes the stream to cross the highway eight times plus another five times for other road crossings. A railroad line also crosses it eight times. Paralleling the highway has made it the victim of straightening at five different locations. This has roughly cost it about 7% of its total length. The channel straightening causes some incision, combined with the historical floodplain aggradation as shown in the Happ XS's, leads to increased stream power captured in the channel during flood flows. This works to erode the banks held together by fair riparian cover (Figure 31). This channel widening adds significant amounts of sand to the channel. This sand also works to widen the channel by filling the cross-sectional area of the channel. These increased flood flows and added sand are passed to the downstream reach.

Figure 31. Habitat conditions and bank erosion at station 04LM020

Biological response:

Fish metrics were compiled for the South Fork for four biological stations and six visits, and then compared to statewide averages of the stream classes (Southern Headwaters; Class 3 and Southern Streams; Class 2). Simple lithophilic spawners and general lithophilic spawners were found above average at all stations and visits. These spawners need clean gravel for spawning and will decrease in streams with degraded habitat and increased depth of fines (Figure 32). However, non-tolerant benthic insectivores and darter, sculpin and round bodied suckers were found in reduced percentages are three locations (stations 12LM087, 04LM020 and 10LM018). These fish depend on healthy productive benthic habitats with minimal embeddedness. The percentage of riffle dwelling species was above statewide averages for all sites, except at station 04LM020 (June 28, 2004 visit; 19%). The percentage of tolerant fish individuals was high across stations (range of 58% to 89%), and percentage of sensitive fish species was low (majority of stations had less than 10%).

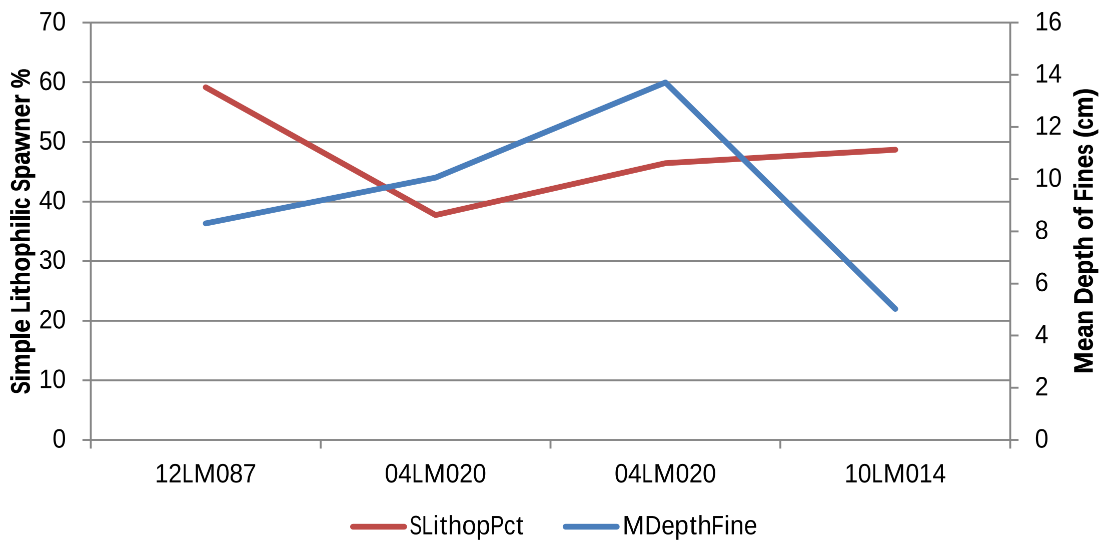

Figure 32. Simple lithophilic spawners in relation to depth of fines in the South Fork.

The macroinvertebrate community is sampled based on dominant habitat types found at each station. The habitat sampled at each site in this reach varied. At station 10LM018 riffle/run and undercut banks/overhanging vegetation were sampled. At station 04LM020, riffle/runs, woody debris, and undercut banks/overhanging vegetation were sampled during both visits. The two visits at station 10LM014 sampled different habitat during each visit. One sampled riffle/runs, woody debris, and undercut banks/overhanging vegetation (2010) while the other visit (2012) only sampled riffle/runs. The macroinvertebrate metrics were compiled for this reach on the South Fork, and then compared to statewide averages of these stream classes (Southern Forest Streams GP; Class 6 and Southern Streams RR; Class 5). Station 04LM020 had the highest percentage of burrowers suggesting potential fine sedimentation in riffle habitats (Figure 33). The percentage of burrowers was at 41%, coinciding with 67% embeddedness on average. Similarly, a higher than average percentage of (generally tolerant) legless individuals was present at many stations as well. Clingers were found below average at all visits except one (10LM014 in 2012; 71%). Clinger species attach to rocks or woody debris. Clingers can decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). Clingers generally decrease with an increase in percentage of fine sediments (Figure 34), and were lowest at station 12LM087 where fine sediments were highest (82.69). The reduction in the percentage of clingers and increased percentages of burrowers support that adequate substrate and sedimentation is limited throughout most of this reach. In addition, the percentage of EPT individuals was lower than average at most locations. EPT taxa are commonly used to measure overall health of ecosystems, due to their sensitivity to many stressors including habitat. Swimmers and sprawlers were lower than average at all sites except station 10LM018.

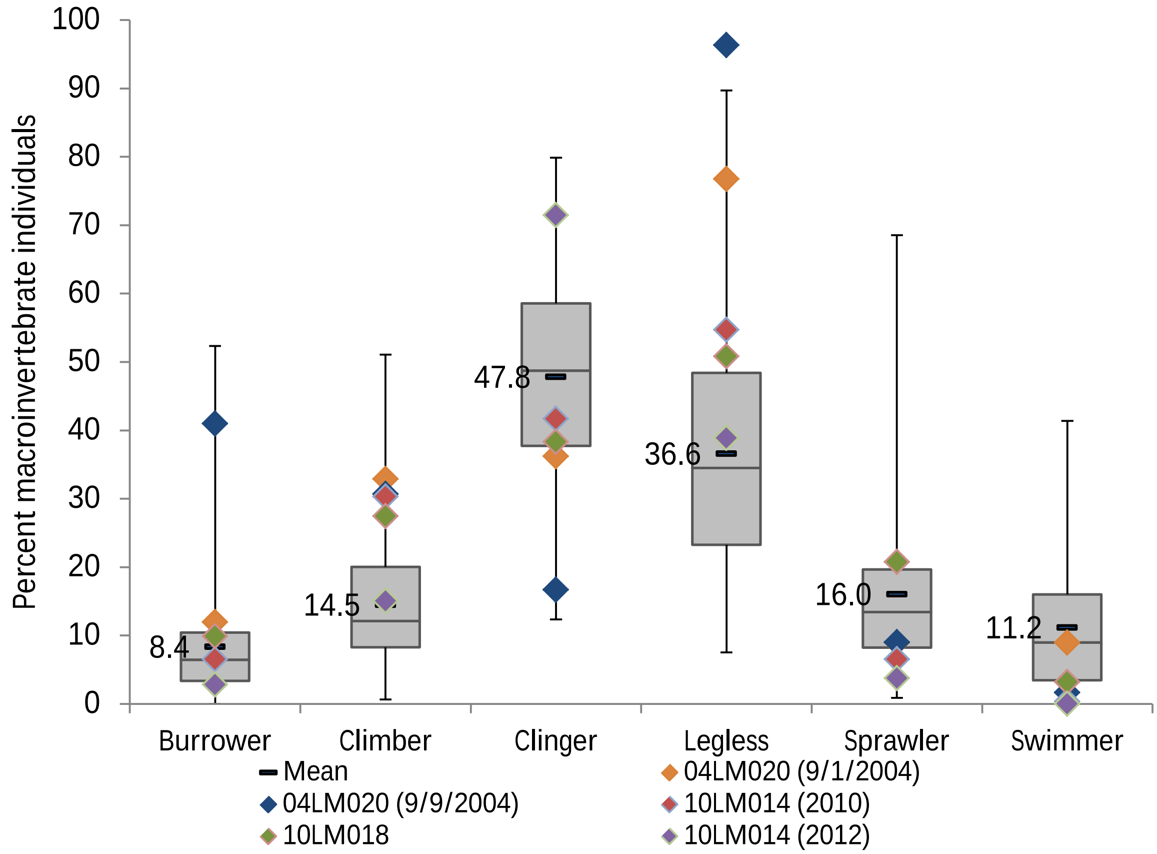

Figure 33. A comparison box plot of macroinvertebrate habitat metrics representing the average class 6 (Southern Streams RR) stations statewide. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

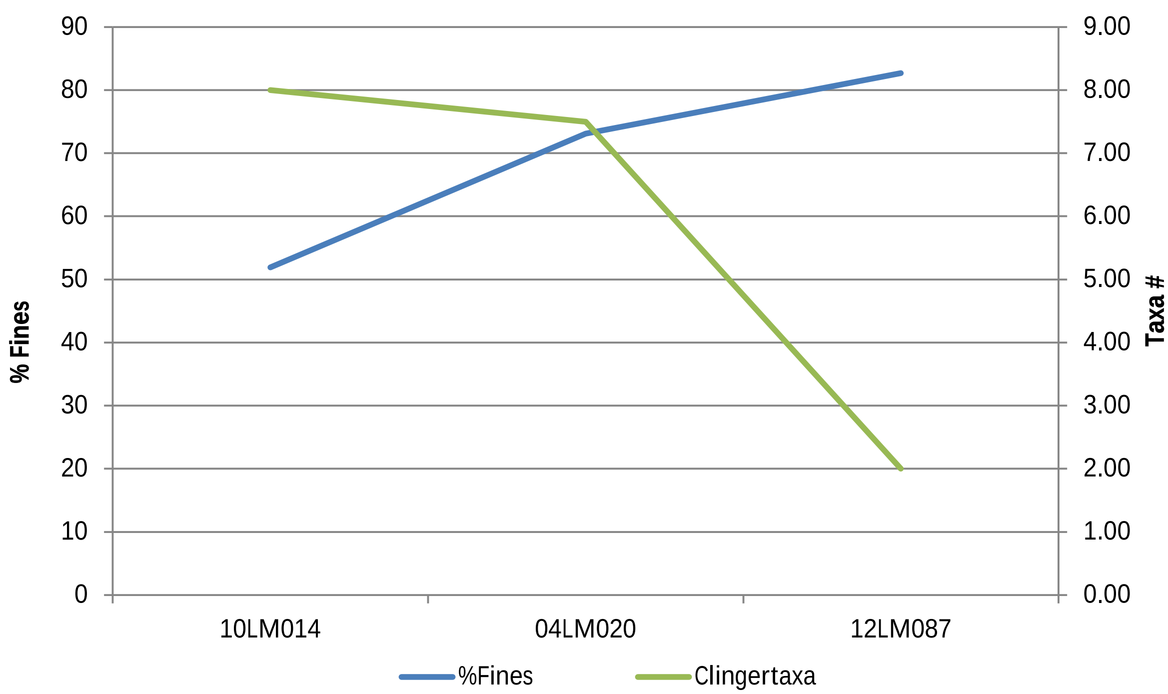

Figure 34. Percent fines and clinger taxa in the South Fork.

The low MSHA scores, reduced percentage of clingers and EPT individuals, and percentage of burrower and legless species at most locations show that a lack of quality habitat and substrate embeddedness is limiting the macroinvertebrate communities in this reach. The fish community also shows a reduction in the percentages of non-tolerant benthic insectivores, darters, sculpin, and round bodied suckers, all which rely on healthy productive benthic habitats with minimum embeddedness. The modification of the stream channels and encroachment of row crops in this reach has led to channel incision and erosion, which results in channel widening and sand deposition in the stream bed. Lack of suitable habitat is a stressor to both the fish and macroinvertebrate communities in this reach, with the most consistent biological response at 04LM020.

Conclusions and recommendations

The stressors found in this reach are summarized in Table 17. Multiple stressors are acting on the biological community in this reach. The most consistent biological response is seen with the habitat limitations and substrate embeddedness, particularly at 04LM020. Additionally, elevated TSS, low DO, and nitrate are all also impacting the communities, with stress most prominent at 04LM020.

Geomorphic characterization by MDNR points out that the channel straightening in this reach causes stream channel incision. That combined with historical floodplain aggradation leads to increased stream power captured in the channel during flood flows. This works to erode the banks held together by only fair riparian cover. This channel widening adds significant amounts of sand to the channel. This sand also works to widen the channel by filling the cross-sectional area of the channel. These increased flood flows and added sand are passed to downstream reaches, contributing to habitat loss within this reach, and farther downstream. According to MDNR, stream re-meandering and/or floodplain reattachment and improving riparian cover are the most needed management options in this reach. Downstream of St. Charles the most important management options are to exclude cattle from the stream in grazing areas. Improvement to the upstream portions of the watershed would help drive recovery in this reach. The deep incision of the reach is its biggest limitation to recovery. Reconnection to the old floodplain using grade control or creation of a new floodplain by excavation would be the quickest recovery option.

Table 17. Summary of stressors found in the South Fork (F16).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:				
						Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-F16 Whitewater River, South Fork, Headwaters to St Charles Township Rd 7	22.16	2B, 3C	10LM018 04LM020 10LM014 12LM087	Upstream of CSAH 32, 2 mi. W of Dover Adjacent to Township Rd 17, 0.5 mi. NE of St Charles Upstream of CR 119, 2.5 mi. NE of St Charles	Fish IBI Macroinvertebrate IBI Turbidity Bacteria		●	●	●	●

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.3 South Fork Whitewater River (Coldwater; 07040003-512 and 07040003-F17)

Supporting information

There are two coldwater stream reaches with macroinvertebrate impairment in the South Fork that are addressed in this section (Figure 17). They are addressed here together because one reach (F17) is very short and are adjacent to one another. The stream starts the transition from warmwater to coldwater on AUID F17. Farther downstream, more springs enter the system on AUID 512. All sites on both stream reaches were assessed against the Southern coldwater macroinvertebrate class (Class 9), which has an impairment threshold of 46.1.

AUID 512

In this reach, the reduced macroinvertebrate IBI scores are isolated to two stations; 04LM068 (MIBI 42.44) and 04LM102 (MIBI 33.62) were sampled in 2004. Stations 10LM012 (MIBI 62.7) and 10LM004 (MIBI 66.04), sampled in 2010, perform above upper confidence intervals demonstrating a healthy coldwater community. Station 04LM102 was resampled in 2012, and showed a similar poor score as in 2004, at 31.9. Disparities in condition may signal other differences within this reach. Fish communities perform well above coldwater biocriteria across the AUID with exceptional habitat conditions for fish throughout. At five of the six macroinvertebrate visits on the coldwater section had low metric scores of Chironomidae to Dipteran ratio (Figure 35). Other low scoring metrics include intolerant taxa richness and Trichoptera taxa percent.

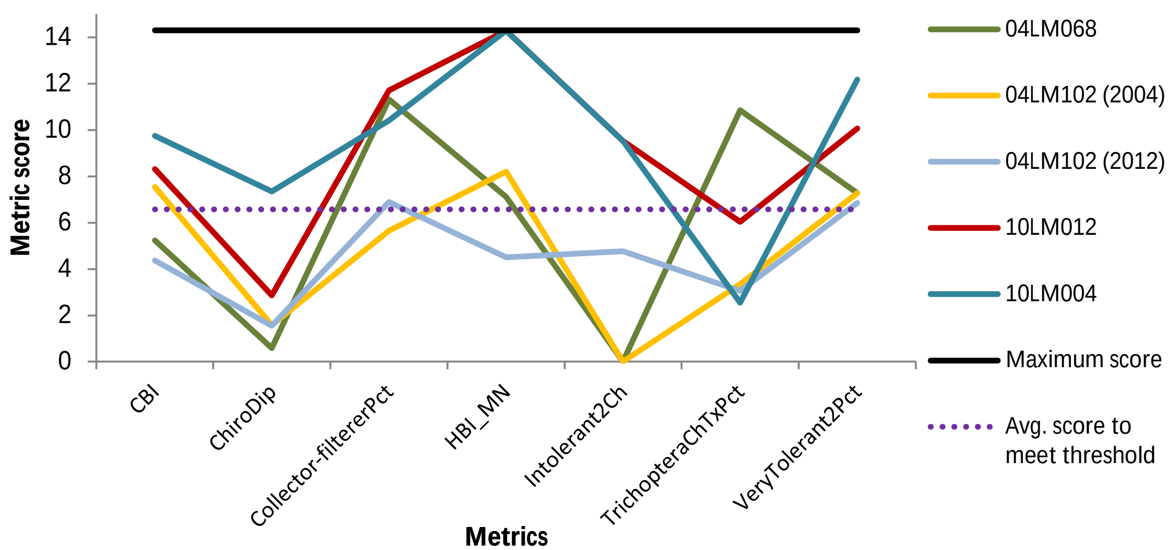

Figure 35. Macroinvertebrate IBI Metrics for the South Fork Whitewater (AUID 512)

AUID F17

This reach is transitional from upstream warmwater AUID (07040003-F16) to downstream coldwater AUID 512. The one macroinvertebrate sample on this reach at station 10LM016 in 2010 was below impairment threshold with a MIBI score of 38.60. Most MIBI metrics scored below the average score needed to meet the impairment threshold (Figure 36). The macroinvertebrate community does not have a strong coldwater signature at station 10LM016, as evidenced by the low scoring CBI metric. This may indicate that this is a transitional coolwater community or may be a result of stress. Contrary to macroinvertebrate results, the fish IBI results were above impairment threshold and in agreement with coldwater expectations with excellent habitat conditions observed at the station.

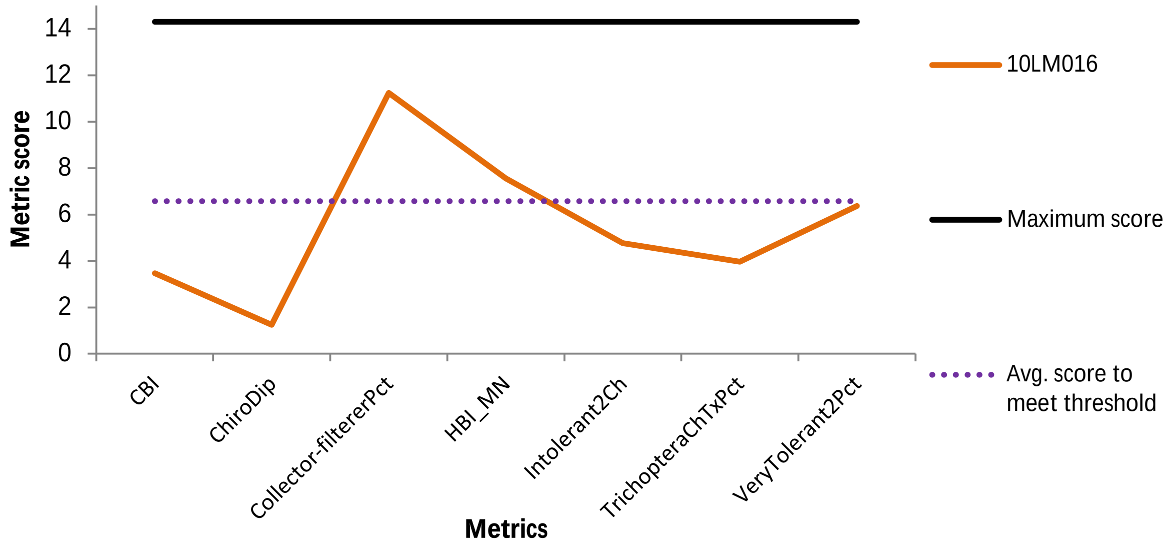

Figure 36. Macroinvertebrate IBI Metrics for the South Fork Whitewater (AUID F17)

Temperature

AUID 512

The temperature collected during biological sampling on this reach ranged from 14.4°C to 21°C. There were 350 temperature measurements taken at multiple locations from 2000-2012. The maximum temperature recorded was 23.74°C. Of the 350 measurements, 23 were above 21°C. In addition, continuous temperature loggers were placed at stations 04LM102, 04LM068, 10LM004 and 10LM012 (Figure 37). The July and August average temperature for the four stations ranged from 17.6°C to 19.4°C in July and 15.8 to 16.4°C in August. The maximum temperature for the four biological stations in July and August ranged from 18.09°C to 21.9°C. Station 10LM012 had the highest maximum temperature during both months (21°C).

The coldwater biotic index (CBI) macroinvertebrate metric score varied among sites in the South Branch. The visit at station 04LM102 in 2012 had a low CBI score; compared to 2010 when it scored much better. It's possible that the low flow year of 2012 was impacting the coldwater macroinvertebrate individuals present at this site compared to in 2010. The CBI scores for other sites/visits all scored above the average score needed to be above the IBI threshold. This indicates there are adequate numbers of coldwater macroinvertebrate taxa present in most locations across most time periods in this reach.

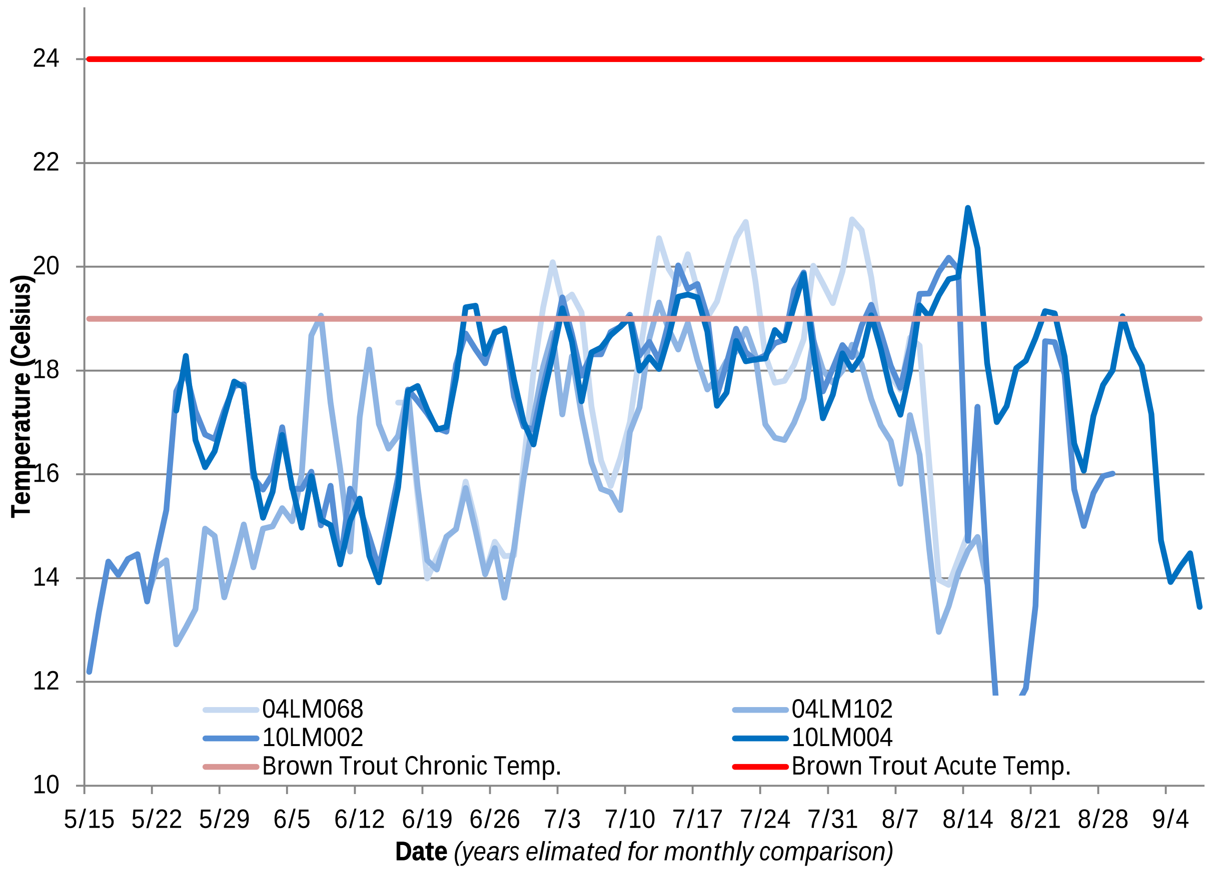

Figure 37. Daily average temperatures for sites in the South Fork across multiple years with temperature thresholds for Brown Trout (512).

AUID F17

There were 220 temperature measurements taken at station S000-288, which showed a maximum temperature of 26.42°C on July 30, 2007. Of the 220 temperature measurements at this location, 36 of them were above 21°C. Station 10LM016 is the farthest upstream on both of these coldwater AUID's, and is in a thermal transition area. Overall, the July averages are warm; additional springs just downstream of this site maintain colder water (Figure 38).

The CBI macroinvertebrate metric score varied among sites in the South Branch. However, comparatively-the sites in this reach (AUID F17; near the warm to cold transition) scored lower. This makes sense given the thermal regime of this area where fewer springs exists.

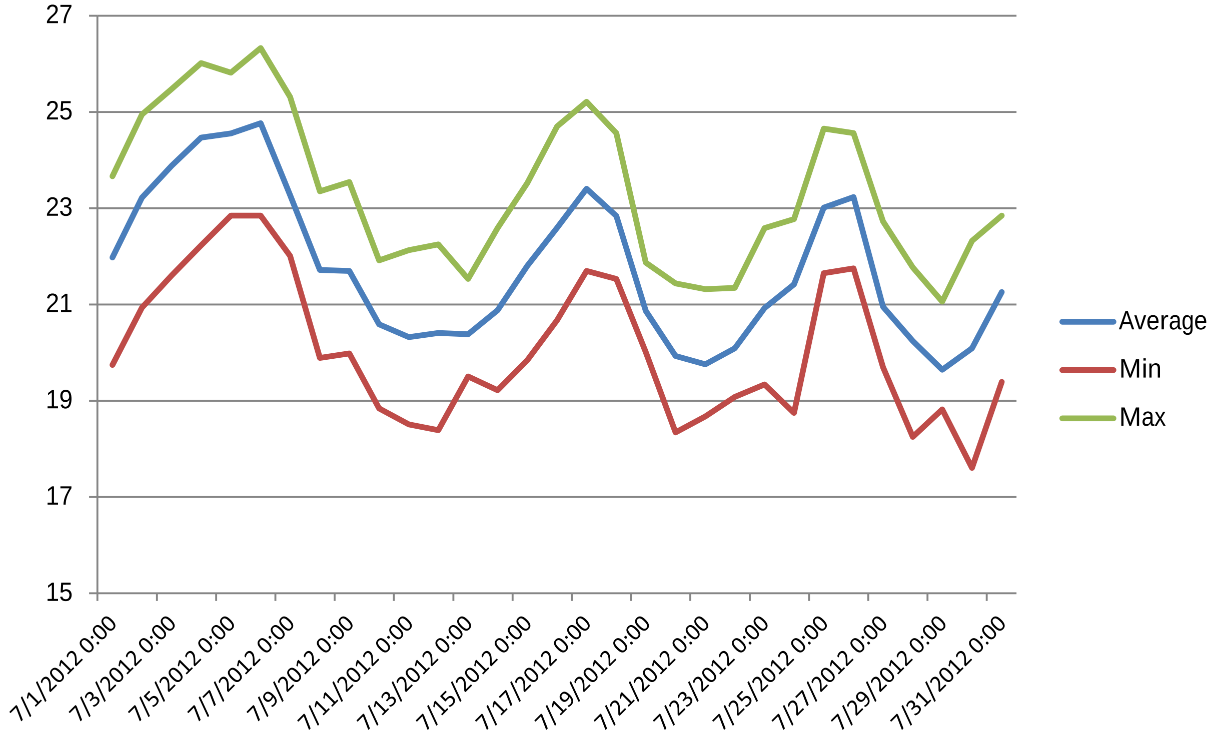

Figure 38. Temperature from 10LM016 (transitional area) in July showing daily average, daily maximum, and daily minimum temperatures.

The fish communities on both AUIDs, while not impaired, do show a general lack of coldwater fish species. The percentage of coldwater fish species (ColdPct), was found below average for most sites compared to other coldwater stations in the MR-Winona Watershed. Station 10LM004 was the only site that had above average percentage of coldwater species (65%), compared to the watershed average of 51%. The other sites ranged from 7%-33% coldwater species (ColdPct). Coldwater sensitive fish species (CWSensitivePct) were near average (61%) or above average for the stations (range of 53% to 70%). This metric includes species like trout and longnose dace which were found in decent numbers at many of the sites. Native coldwater species (NativeColdPct) were all well below average when compared to other coldwater stations in the MR-Winona Watershed. The native coldwater species found in the MR-Winona include Brook Trout and Sculpin, which were not found in abundance in the South Fork, explaining the low percentage. They also aren't necessarily expected for a stream of this size, as they more typically inhabit smaller headwater streams.

There is a bit of a mixed biological response present, with more response demonstrated to the fish communities overall. Macroinvertebrates appear to be most impacted in the upper reach, in the thermal transition zone (F17). It's possible that fish in this transition zone simply migrate downstream where more suitable temperatures exists during hot summer months. Macroinvertebrates could be suffering more so because of that lack of mobility. Just downstream more springs enter the system, and temperature does become more suitable, even though it is on the higher side of optimal. While temperature could use some improvement, it's unlikely that temperature is a main contributor to the impaired macroinvertebrate communities in the downstream reach of the South Branch (AUID 512). It is likely that high temperatures are impacting the ability of macroinvertebrates to thrive in the upstream reach/natural thermal transition zone (AUID F17). Therefore, temperature is considered a stressor to macroinvertebrates on AUID F17, but not to AUID 512.

Dissolved oxygen

Low DO

AUID 512

The DO data collected during fish sample ranged from 9.81 mg/L to 11.65 mg/L. At monitoring station S000-321, there were 48 DO measurements taken in 2009 and 2010. The values ranged from 6.2 mg/L to 16.5 mg/L. Six of these DO readings in 2010 were before 9 am, and one was below the coldwater standard of 7 mg/L. Three others were very close to the DO standard of 7 mg/L. The minimum value was 6.2 mg/L with maximum values near 14 mg/L. Station S001-743 had 17 DO measurements in 2010 and 2011. The average value measured was 10.69 mg/L with a range of 8.06 mg/L to 13.08 mg/L. No measurements were recorded before 9 am. Exceedances of the DO standard were observed within this stream reach however, the numbers of exceedances were below the assessment threshold for the minimum number of samples. Continuous data was collected at station 10LM012 in 2012. Readings were just below the water quality standard of 7 mg/L for coldwater streams on three days (Figure 39).

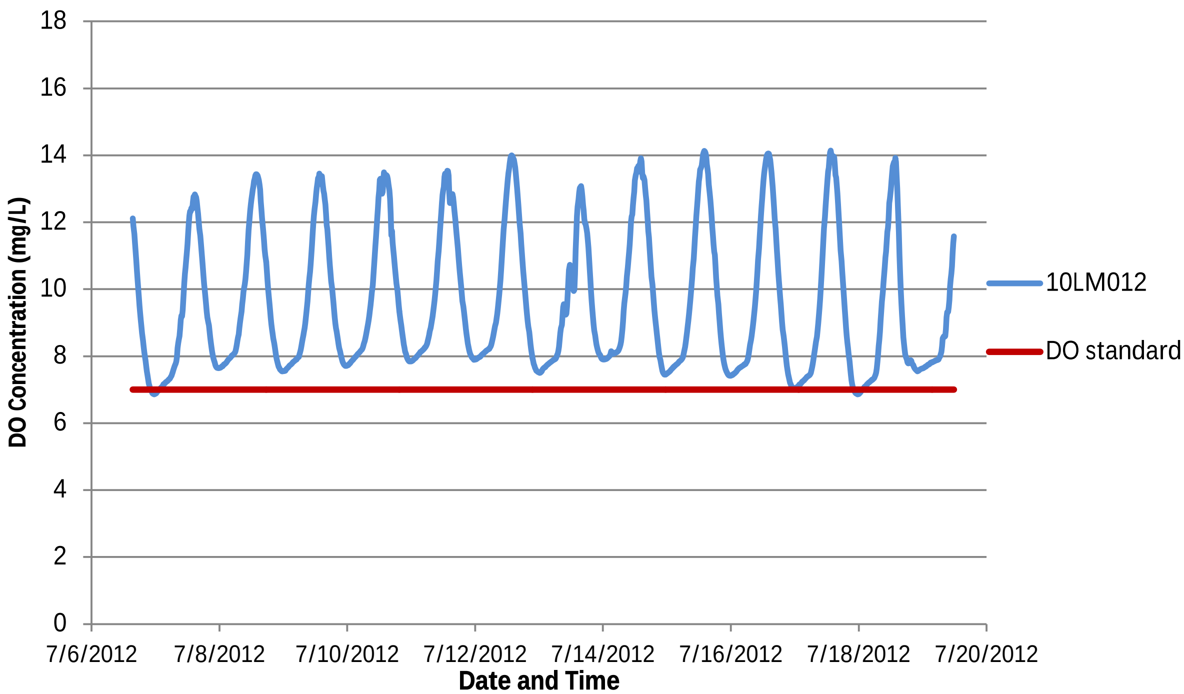

Figure 39. Continuous DO on station 10LM012

Low DO is inversely correlated with tolerant macroinvertebrate percentages (Table 18). Station 04LM102 had higher than basin averages during both visits, and the tolerant percentage increased from 2004 to 2012. Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. At station 04LM068, 14 macroinvertebrate taxa that are intolerant to low DO were collected and 3.62% DO tolerant taxa were collected. At station 04LM102, the numbers of macroinvertebrate taxa collected that are intolerant to low DO were 14, and the percentage of DO tolerant species collected were 1.38. At station 10LM012, the number of DO intolerant taxa collected was 12, and the percentage of DO tolerant taxa was 3.59. The average number of intolerant taxa collected in coldwater sites in the Lower Mississippi River basin was 9.6 and the average percentage of DO tolerant taxa was 2.6. The average number of intolerant taxa at sites above the threshold was 10.1, and the DO tolerant taxa average percentage collected in streams above the threshold was 1.7. All of the sites had numbers of intolerant taxa greater than the coldwater average in the basin, and the average of those sites that met the threshold. Stations 04LM068 and 10LM012 both had tolerant taxa percentages slightly above the average of coldwater sites in the basin, the other three sites were below the average.

Table 18. DO metrics on AUID 07040003-512

Station (Year sampled)	Tolerant Macroinvertebrate Percentage	Percentage DO Tolerant Macroinvertebrate Taxa	DO Intolerant Macroinvertebrate Taxa
04LM068 (2004)	37.41	3.62%	14
04LM102 (2004)	44.44	0%	10
04LM102 (2012)	55.59	1.38	14
10LM012 (2010)	24.18	3.59%	12
Averages for coldwater stations in the Lower Mississippi River basin	42.68	2.6	9.6
Expected response to stress	↑	↑	↓

Longitudinally from upstream to downstream, the early morning DO tolerance indicator values for fish at the four samples show fish communities primarily comprised of fish in the third and fourth quartiles that are intolerant to low DO (Figure 40). Based on the predominance of fish that are intolerant to low DO, above average intolerant DO macroinvertebrate taxa, and the low values of DO tolerant macroinvertebrate taxa percent, low DO is not a stressor to the macroinvertebrate or fish communities.

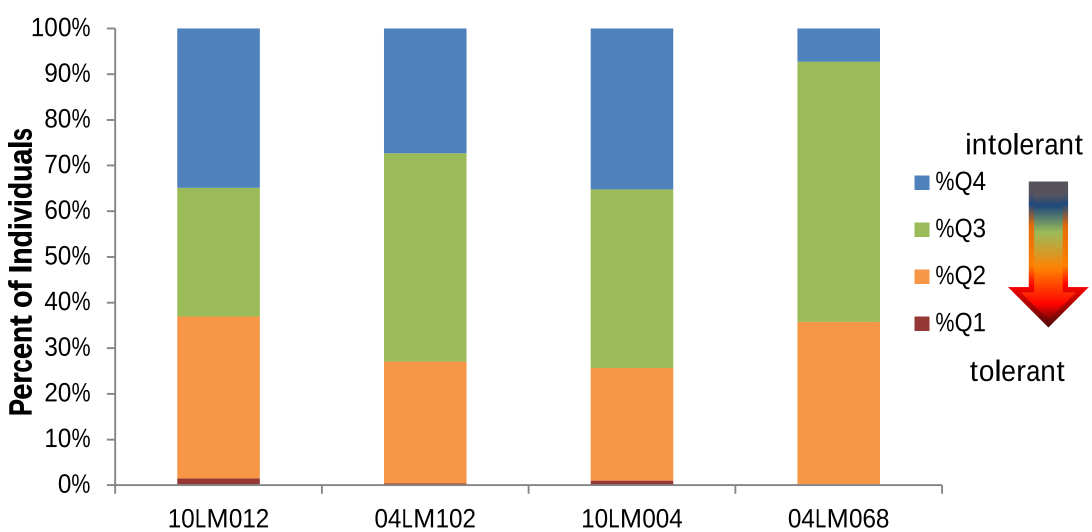

Figure 40. DO TIV's for fish at biological stations

AUID F17

Farther upstream at monitoring station S000-288 (at the transition from AUID F16 to F17) there were 46 DO measurements between 2001 and 2009. The range of concentrations found was between 6.6 mg/L and 14.97 mg/L. None of these measurements were taken before 9 am.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. At station 10LM016, 11 intolerant taxa that are intolerant to low DO were collected and 1.04% DO tolerant taxa were collected (Table 18). The average number of intolerant taxa collected in coldwater sites in the Lower Mississippi River basin was 9.6 and the average percentage of DO tolerant taxa was 2.6. Similar to the upstream stations, the early morning DO tolerance indicator values for fish at station 10LM016 was predominantly comprised of fish in the third and fourth quartiles that are least tolerant to low DO (Figure 41). Based on the number of intolerant to low DO macroinvertebrate taxa, DO tolerant macroinvertebrate taxa percent, and percentage of fish that are intolerant to low DO, low DO is not a stressor on this reach of the river.

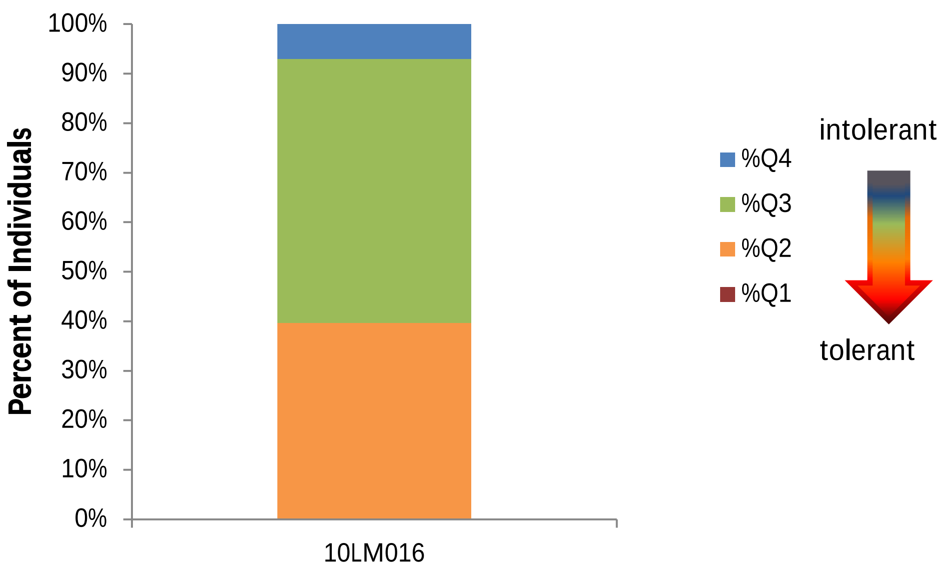

Figure 41. DO TIVs for fish at station 10LM016

DO Flux/Eutrophication

AUID 512

Continuous DO data was collected at station 10LM012. The daily DO flux at station 10LM012 was well above the daily flux standard of 3.5 mg/L each day it was recorded (Figure 42). Daily flux was recorded as high as 7.28 mg/L. This sort of daily flux is unusual in coldwater streams and can be symptom of high total phosphorus concentrations and eutrophication.

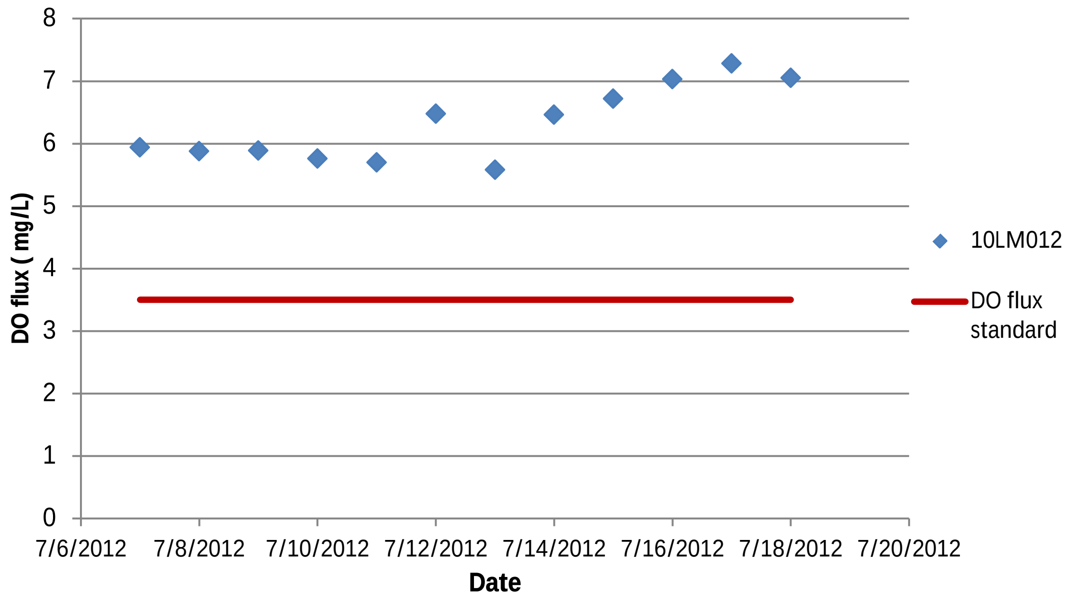

Figure 42. DO flux at station 10LM012

As interacting variables to eutrophication, phosphorus, pH, BOD and chlorophyll-a were compared to normal ranges and standards. There were 8 pH readings over 8.5 (8.51-9.3). Values over 8.5 and large daily pH fluctuations can be tied to nutrient enrichment. Typical daily pH fluctuations in streams are 0.2-0.3 (Heiskary et al., 2013). Continuous pH data showed daily fluxes ranging from 0.61 to 0.79 at station 10LM012. The total phosphorus mean in this reach (station S000-321) from seven years of data, and 98 samples was 0.315 mg/L with a maximum of 3.02 mg/L. At the time of fish sampling, the total phosphorus concentrations ranged from 0.126 mg/L to 0.238 mg/L (with low TSS concentrations; <10 mg/L). At station S000-321, there was 43 samples of chlorophyll-a, with concentrations ranging from 0.10 to 53.45 ug/L. At this same location, pH was measured 115 times between 1974 and 2012. The pH values ranged from 7.3 to 9.58. The average pH was 8.24.

EPT communities are inversely correlated with chlorophyll-a, low DO, and high DO flux values. The average percentage of EPT individuals at coldwater streams in the Lower Mississippi River basin was 39.55. The percentage of EPT individuals ranged from 32.63 to 67.32%, averaging 51.38. Station 10LM012 where the sonde was deployed had daily flux values over 5.58 mg/L, all over the proposed standard of 3.5 mg/L. The EPT individual percent at this location was 67.32%. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average for coldwater sites in the Lower Mississippi River basin was 42.68%. Tolerant macroinvertebrates percentages ranged from 24.18 to 44.44%.

Elevated phosphorus, DO flux and pH conditions all exist on this stream reach, but there is currently not enough statewide data to make connections with eutrophication and coldwater biological communities. Nutrient management to prevent eutrophication is vital. DO should continue to be evaluated to ensure DO levels and flux are not impacting the biological communities in this reach. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

DO Flux/Eutrophication

AUID F17

Farther upstream at monitoring station S000-288 (at the transition from AUID F16 to F17) the BOD values ranged from <0.5 mg/L to 9.6 mg/L, and the chlorophyll-a values ranged from 1.31 to 36.7ug/L. Total phosphorus was measured 41 times between 2000 and 2012 with a range of 0.087 mg/L to 1.45

mg/L. The average total phosphorus concentration was 0.574 mg/L. There were 20 pH readings over 8.5 (8.51-9.58) at station S000-288. Values over 8.5 can be an indicator of nutrient enrichment.

EPT communities are inversely correlated with chlorophyll-a, low DO, and high DO flux. The average percentage of EPT individuals at coldwater streams in the Lower Mississippi River basin was 39.55. The percentage of EPT individuals was above the basin average at 52.88%. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average for coldwater sites in the Lower Mississippi River basin was 42.68%. The tolerant macroinvertebrates percentage at station 10LM016 was 37.52%.

Elevated phosphorus and pH conditions exist on this stream reach, but there is currently not enough statewide data make connections with eutrophication and coldwater biological communities. Nutrient management to prevent eutrophication is vital. DO flux data should be collected to further DO understanding on this reach. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

Nitrate

AUID 512

During biological sampling the nitrate concentrations ranged from 6.9 mg/L to 8.3 mg/L. This reach is listed as impaired for nitrate (drinking water use). Station S000-321 was sampled for nitrate 91 times between 2009 and 2012. The values ranged from 1.1 mg/L to 10 mg/L with an average of 7.24 mg/L. Nitrate data collected in the 1990s compared to recent years does show a slight increase in nitrate concentrations over time at station S000-321 (Figure 43). Station S001-743 was sampled for nitrate 10 times in 2012. The values ranged from 5.8 mg/L to 8 mg/L with an average of 6.5 mg/L. High nitrate levels, ranging from 6.9 mg/L to 11 mg/L, were seen across the entire South Branch, but decrease when moving downstream in this reach. However, it is likely that decreasing levels are a result of increased flow from springs in the lower region of the watershed rather than a result of improved condition. Based on research, Runkel et al, (2013) concluded that 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 further validates this by analyzing spring data from Crystal Springs (Spring 1) in the lower region of the watershed:

“Measured over the same approximately five year period, the water from Crystal Springs Fish Hatchery Spring 1, with rare exception, has a lower nitrate concentration than the nearby upstream surface water. Springs emanating from the lower parts of incised valleys, such as this one sourced through the St Lawrence Formation; commonly dilute the nitrate concentration of streams.”

The macroinvertebrate surveys had between 29 and 44 taxa (TaxaCountAllChir). All except one were above the average taxa count for coldwater stations in the LMB (30.01). There were between three and eight Trichoptera taxa at each station (9.3% to 13.6%; ThichopteraChTxPct). The result is reflected in low IBI metric scores; less than the average needed to meet the Southern coldwater MIBI threshold (Figure 35).

There was a wide range of nitrate tolerant taxa present; between 12 and 24 (55% to 80% individuals). The highest number were found at the two 2004 visits at 04LM068 and 04LM102. At 16.6 nitrate tolerant taxa, there is a 50% 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. The only station in this reach above 22.6 nitrate tolerant taxa was 04LM068 (24). Station 04LM068 and the 2012 sample from site 04LM102 did not have any nitrate intolerant taxa collected. The 2004 sample from station 04LM102 had 1 intolerant taxon, as did the sample at 10LM004, while the sample collected at station 10LM012 had 2 nitrate intolerant taxa collected.

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 IBI metric score and HBI_MN value have a significant relationship with nitrate at the time of fish sampling. The HBI_MN IBI metric score decreases with increases in nitrate. In the South Branch Whitewater, the metric scores were between 4.49 and 14.28 (out of 14.3), most above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. Some stations show a slightly elevated HBI_MN value (04LM102, 04LM068; 6.87 and 6.93). However, 10LM012 and 10LM004 had lower HIBI_MN values, at 5.83 and 6.05. 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 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57.

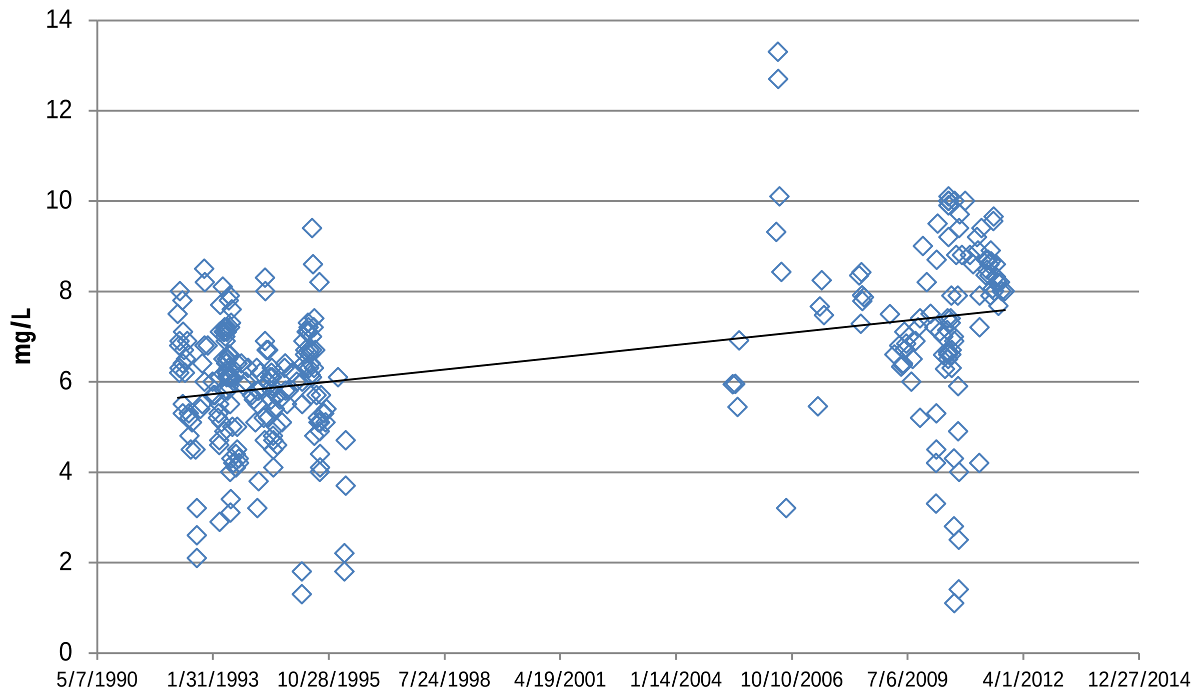

Figure 43. Nitrate concentrations from station S000-321 on the South Fork Whitewater, 1992-2011

AUID F17

Farther upstream, at station S000-288 (old MPCA Milestone site), nitrate was sampled 232 times between 1976 and 2012. The values ranged from 0.9 mg/L to 16 mg/L, with an average of 8.42 mg/L. This upper reach is impacted by the adjacent upstream warmwater reach, in close proximity to stations 10LM016 and 04LM068. A quantile regression analysis of Southern coldwater macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate-nitrite 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-nitrite reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate surveys at 10LM016 had 36 taxa (TaxaCountAllChir), above the average taxa count for coldwater stations in the LMB (30.01). There were four Trichoptera taxa present (11.1%; ThichopteraChTxPct). The result is reflected in low IBI metric score; less than the average needed to meet the Southern coldwater MIBI threshold (Figure 35). Station 10LM016 also had 18 nitrate tolerant taxa present (52% individuals). At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern coldwater MIBI.

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 IBI metric score and HBI_MN value have a significant relationship with nitrate at the time of fish sampling. The HBI_MN IBI metric score decreases with increases in nitrate. At 10LM016 the metric score 7.54 (out of 14.3), above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. Station 10LM016 has a slightly elevated HBI_MN value (6.88). 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 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57.

The biological and chemical data seem to show more consistent stress in the upper reach (F17) with a mixed response in the lower part of this reach (512). This is reasonable given the higher concentrations are found in the upper reaches, with decreasing nitrate concentrations when moving downstream. Nitrate is considered a stressor in the upper part of the South Branch (closer to stations 10LM016 and 04LM068; AUID F17) but not, in the lower part of the watershed (AUID 512).

TSS

AUID 512

Monitoring station S000-321 was sampled for TSS, turbidity, and transparency between 2000 and 2012. TSS was measured 148 times between 2000 and 2012. The TSS values range from <1 mg/L to 3,500 mg/L. The average TSS was 203.512, and the maximum value was 3,500. The transparency values range from 0 cm to >100 cm. The average value was 64.28 cm. The turbidity was measured 180 times between 2000 and 2012. The turbidity values range from 0.49 NTU to 2300 NTU. The average turbidity value was 149.27 NTU. This data supports the existing turbidity listings on these reaches.

Two of the four biological visits in this reach had macroinvertebrate TSS station index scores which were worse (indicating TSS tolerance) than the average coldwater stations in the MR-Winona Watershed (Table 19). Many stations also had a high percentage of TSS tolerant individuals and TSS tolerant taxa, but some of the results were mixed. In particular, station 04LM102 shows a difference between 2004 and 2012 sampling. Station 10LM004, farthest downstream, appears to be showing the least amount of TSS stress based on these metrics.

The TSS index scores for fish that were well below the MR-Winona Watershed average of 39.7 (index scores were either 9 or 10 for all stations, which is in the lowest 25th percentile in this watershed). The percent carnivore metric, which is correlated to TSS, also shows below average percentages at all biological stations on this reach (except 10LM004, which had 64% carnivores), demonstrating potential TSS stress to the fish community, but lacks consistency. The average percentage of carnivores in the MR-Winona Watershed is 34%. Stations 04LM102 and 10LM012 had below average percentages (19.19% and 30.79%, respectively).

AUID F17

Farther upstream (at the transition from AUID F16 to F17), station S000-288 was sampled for TSS and transparency between 2000 and 2012. TSS was measured 45 times between 2000 and 2009. The TSS values range from <1 mg/L to 150 mg/L. The average TSS was 15.56, and the maximum value was 150. Transparency was measured 231 times between 2002 and 2012. The transparency values range from 0 cm to >100 cm. The average value was 44 cm, and the maximum value was >100 cm. The turbidity was measured 62 times between 1990 and 2005. The turbidity values range from 0.2 NTU to 222 NTU. The average turbidity value was 20.01 NTU, and the maximum value was 222 NTU.

Both stations in this reach had macroinvertebrate TSS station index scores worse (indicating TSS tolerance) than the average coldwater stations in the MR-Winona Watershed (Table 19). Both stations had a high percentage of TSS tolerant taxa and individuals, with a lack of TSS intolerant taxa. These two upstream stations are showing the most potential stress, with a more consistent response, more likely due to the influence of the warmwater section of the South Branch.

Table 19. Macroinvertebrate metrics relevant to TSS for stations in South Fork Whitewater compared to averages for coldwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
AUID 512						
04LM102 (2004)	**17.84**	**0**	**7**	**30.23**	**2**	**1.01**
04LM102 (2012)	15.07	2	**7**	7.85	6	**0.9**
10LM012	**15.70**	3	**5**	**19.06**	5	5.88
10LM004	14.74	3	2	7.17	3	**3.63**
AUID F17						
04LM068	**16.48**	**1**	**11**	**23.00**	4	**2.38**
10LM016	**16.90**	**1**	**8**	**39.02**	4	17.30
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for coldwater stations in the MR-Winona Watershed	15.11	1.41	4.45	10.94	2.69	3.36

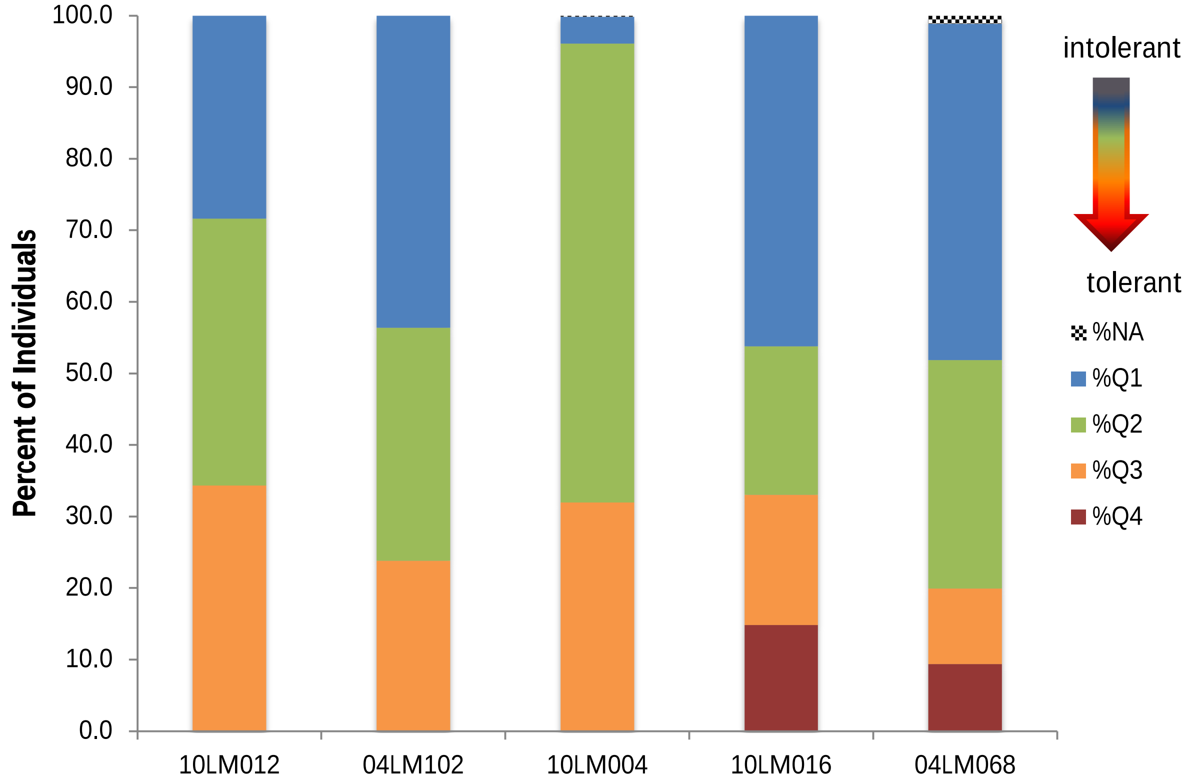

Figure 44. Fish TSS TIVs for the coldwater stations of the South Branch Whitewater (Sandberg, 2013)

Overall, the fish population consists of some fish species that are tolerant to high TSS, but also a large percentage of fish species that are intolerant of high TSS (Figure 44).There were larger percentages of fish tolerant to TSS found in the upper stations of this reach (10LM016 and 04LM068). Stations 10LM016, 04LM068 both had percentages below average (18.46%, 15.41%, respectively). This is also consistent to the response seen with the macroinvertebrate community.

The biological and chemical evidence suggests that TSS is a stressor to the macroinvertebrates in the upper portion of the coldwater reach (AUID F17). Stress from TSS is not consistently seen in AUID 512 (Table 19), therefore TSS as a stressor is considered inconclusive in that reach. Station 04LM102 shows temporal differences between 2004 and 2012, which may or may not be related to TSS. At this point, the temporal difference seems more likely explained by other stressors (i.e. habitat). While the fish are not impaired in both these coldwater reaches, reductions in TSS in the upper warmwater reaches of the South Branch are warranted so fish do not become stressed by TSS and become impaired in the future.

Habitat

All stations in this reach had MSHA scores rated as good. The scores ranged from 68.6 at 10LM004 to 84.7 at 04LM068. Stations 10LM004 and 10LM016 exhibited moderate embeddedness of the coarse substrates present, a lack of channel development at station 10LM014, and fair sinuosity at stations 10LM012 and 04LM068. The channel stability ranking CCSI at stations 10LM004, 10LM016 and 10LM012 all scored in the moderately unstable category.

Geomorphic Characterization by MDNR (Ellefson and Zytkovicz):

AUID 512

The first 1.5 miles of the next reach downstream on the South Fork contain three of among the largest hillslope failures from the 2007 flood. Each failure caused extensive filling of the next one or two downstream pools with gravels and cobbles as well as deposition on the valley inflection points. A half mile downstream of the last failure, the visible effects of the failures are gone and the stream looks stable again. The channel maintains a stable form until it enters Kreidermacher's Valley. Here the absence of a forested riparian causes extreme bank erosion and channel avulsion. A 10,500-foot stretch of continuous D channel exists until it reaches a forested floodplain again. MDNR Site 121 is located here and is also representative of biological station 10LM012. The stream flattens out before reaching County Road 112 and an ATV/Snowmobile bridge. This bridge is a major source of instability due to its encroachment on the channel. From here the stream flattens out and incision wedge builds as the stream approaches the main stem of the Whitewater River. This can be seen by the difference observed in the amount of sedimentation between Happ valley cross sections. Station 10LM004 is located next to MDNR Site 127 (VIII(c), C4) which captures the conditions of the reach. The Pfankuck stability rating at site 121 scored a 114 for a "poor" rating, and site 127 is also rated "poor" with a score of 117. Sites 121 and 127 are aggrading but site 124 is stable. The steep slope of Site 124 (0.00624) allows it to move larger sediments.

Riparian vegetation is very important to C4 stream types. They are very sensitive to disturbance and have high bank erosion potential. Most of this AUID's potential condition is a C4 stream type so it is very prone to disturbance. Sites 124 and 127 have good riparian areas, but site 121 is surrounded by heavily grazed land with only sporadic trees, when the potential condition is a heavily forested floodplain like in the upstream and downstream property lines. There is an excessive amount of bank erosion occurring at Site 121. Site 124 has a moderate BEHI and moderate to Low NBS eroding at 0.17 ft/yr and 0.069tons/ft/yr. Site 121 is eroding a total of 0.238 tons/ft/yr or 0.9 ft/yr laterally. Its average BEHI and NBS is high and high. Site 127 contributes a similar amount, 0.249 tons/ft/yr but as a slower pace of 0.41 ft/yr of lateral erosion. This reach has much higher banks which makes up the difference. The pool depth at site 124 (04LM102) is good until it reaches the long compound pool. Because of the excessive amount of sediment passing through this stream this compound pool is completely filled. Part of this is due to the channel's belt width getting pinched by the ATV/Snowmobile bridge downstream.

Most of the only quality habitat remaining is in the downstream half of the narrow valley area located after the hillslope failures, but before the valley widens out and loses the integrity of its riparian area at Kriedemacher's Valley. No management is needed in this area. In the area impacted by the hillslope erosion, the riffles have converted from "C" to "D" types or high W/D "C" types and the pools have filled with lots of gravel and cobble. Few management options are available in this area. However, C4 streams have good recovery potential and the bedrock walls contain the extent of instability. Lower in the watershed where the valley widens out these large pools are filled with gravel and sand, and habitat is impacted.

AUID F17

The upstream reach (AUID F17 near 10LM016; DNR site 116) extends from roughly one mile upstream of the Lamberton Mill Road Bridge, downstream to the confluence with MDNR Minor Subwatershed 40028. The stream stability degrades rapidly at this confluence. This ephemeral subwatershed is a large source of eroded material to the South Fork. It appears that most of the channel bed is shallowly underlain by bedrock. The riffle used for this site has a stream type of C4. This reach contains steep slopes, bedrock control, and deep extended pools. The stream has good access to its floodplain. The bedrock control seen in this reach coupled with the evidence of no movement of the channel bed from the Happ XS makes risk of aggradation or degradation low. This is despite the competency calculations which indicate aggradation. The riparian condition is native, undisturbed floodplain forest and shear bedrock walls. The riparian is in excellent condition. Bank erosion in this reach is very limited. BEHI ratings average moderate to high and the NBS averages are high. The estimated overall average lateral erosion of the reach is 0.06 ft/yr and the sediment contributed amount to 0.019 tons/ft/yr for a total of 374 tons. The substrate is coarse with a D50 at the riffle of 59.7mm. The riffles are clean of fines and the extended pools are deep at five feet. This area provides high quality fish and invertebrate habitat and shows little signs of floodplain storage loss, channel bed aggradation or channel instability. This geomorphic reach, the extent of which is outlined in the overview requires no management as it exists in a reference condition.

Biological Response:

AUID 512

The macroinvertebrate community is sampled based on dominant habitat types found at each station. Different habitat types were sampled at different stations in this reach of the South Fork. At station 04LM102, all four habitat types were sampled. At stations 10LM012 and 10LM004 riffle/runs and undercut banks/overhanging vegetation were sampled. The percentage of burrowers, which live inside fine sediments, was low at all four stations, except the 2004 visit at station 04LM102 where coarse substrates were over 50% embedded. The burrower percent that year was 16%, but fell to 4.8% when the site was resampled in 2012. Similarly, the percentage of clingers was found above average at three of the four stations (40%-66% individuals). However, at station 04LM102, clingers were lower than average, only at 23% in 2004. Clingers require rock and woody debris and decrease in stream reaches with homogenous substrate composition, velocity, and depth. Again, when the site was resampled in 2012, clinger individuals improved to 39%. Similarly, a higher percentage of more tolerant legless individuals were found at station 04LM102 both years it was sampled (45% and 57%). The percentage of EPT individuals was above average at all locations, with the exception of station 04LM102 in 2012 (32%).

AUID F17

At station 04LM068 and 10LM016, riffle/runs, woody debris and undercut banks/overhanging vegetation were sampled. The macroinvertebrate metrics were compiled for all South Fork stations, and then were compared to statewide averages of this stream class (Southern Coldwater; Class 9) (Figure 45). The percentage of burrowers was low and the percentage of clingers was very high at station 10LM016 (66% individuals). The percentage of EPT individuals was above average as well, and there wasn't an abundance of more tolerant legless macroinvertebrates. These are all positive indications that lack of suitable habitat is not strongly impacting the macroinvertebrate community.

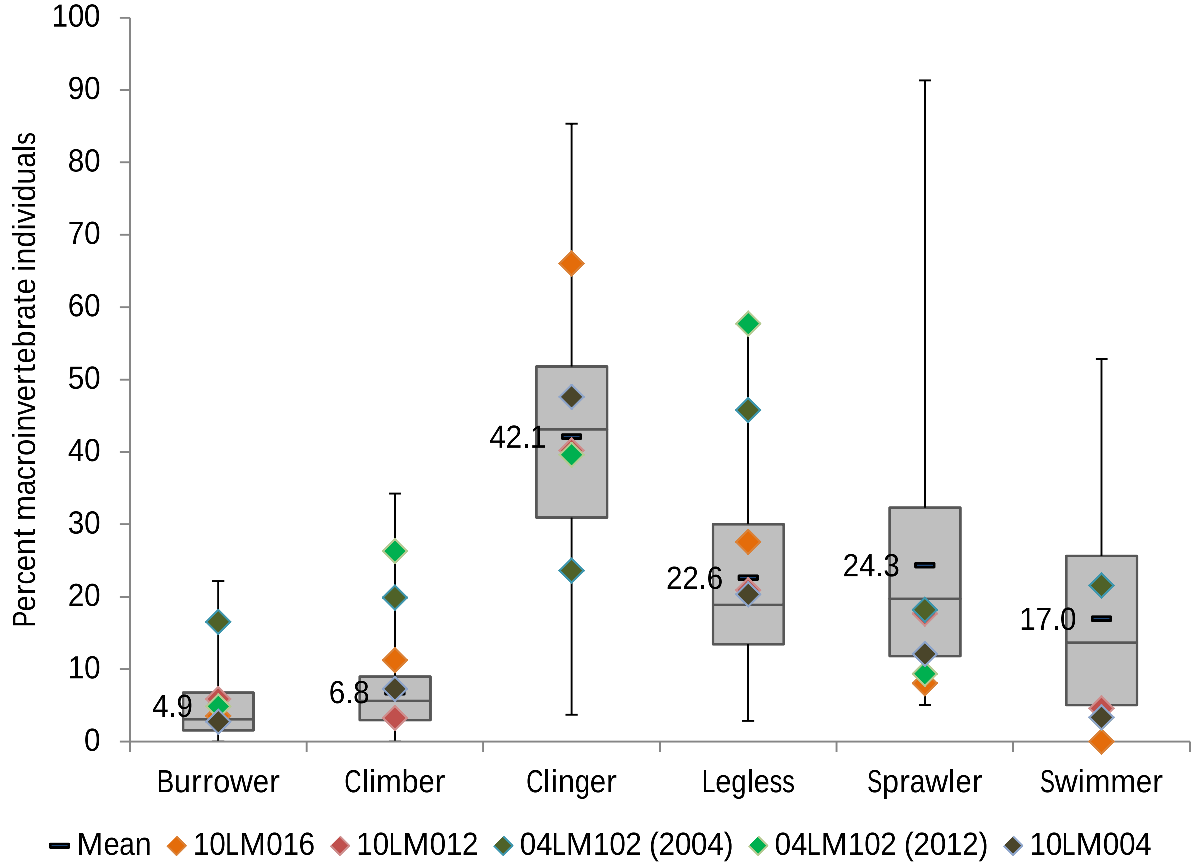

Figure 45. A comparison box plot of macroinvertebrate habitat metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

Habitat issues do not appear to be limiting the macroinvertebrate community consistently throughout these two reaches, rather making isolated impacts in certain areas. This is also supported by geomorphic data provided by MDNR, demonstrating instability and sediment deposition in some areas, but not others. Based on the biological response and geomorphic information, habitat stress to macroinvertebrates is limited to station 04LM102 which shows varying habitat stress across multiple years of sampling compared to the other sites in these two reaches. Therefore, habitat is considered a stressor to AUID 512, but not AUID F17.

Conclusions and recommendations

The stressors found in these two reaches are summarized in Table 20. Habitat is the driving force for macroinvertebrate impairment on AUID 512, but isolated to station 04LM102. Instability and habitat issues are well documented in this one area. There are some minor indications that elevated TSS and nitrate could be playing a role in macroinvertebrate impairment throughout this reach; however the data are not strong and lack a consistent biological response, and therefore they are considered inconclusive at this time. These two parameters, along with DO, should be closely monitored on this reach, as they all appear to be on the edge of causing stress to the macroinvertebrates. If improvements in condition of the upstream warmwater reach can be made, it would certainly have a positive impact on this reach. The fact that habitat is fairly good throughout this reach (except station 04LM102) helps maintain macroinvertebrate communities. Thus, maintaining quality habitat and stream stability is of utmost importance. If habitat further degrades, the effect of other parameters on the macroinvertebrate community (like TSS, nitrate, and DO) could become large. According to MDNR (Ellefson and Zytkkovicz), management priorities should be to exclude cattle grazing from near and in the stream in the lower part of the valley and re-establish a healthy riparian buffer around the stream. The sediment contributed here impacts the stability of the rest of the stream to its outlet. Finally, the small bridge near the stream gaging site (Crystal Springs) needs to be removed or reconstructed with a much wider opening. This is just downstream of 04LM102, and is likely part of the reason habitat is being impacted more so in this specific location.

The upstream coldwater AUID (F17) is in a transition zone and the impact from the upstream warmwater AUID (F16) is more apparent here. Interestingly, this reach is not impacted by habitat issues but rather impacted by inadequate temperatures (which may or may not be part of the natural thermal transition), high nitrate, and suspended sediment (both from the upstream contributing area of the South Branch Watershed). The riparian area in this specific area is in excellent condition, with natural bedrock controls which support the good habitat conditions observed.

Table 20. Summary of stressors in the South Fork Whitewater (512 and F17).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-512 Whitewater River, South Fork, T106 R10W S1, west line to N Fork Whitewater River	12.08	1B, 2A, 3B	04LM068 04LM102 10LM012 10LM004	0.5 mi. E of St Charles Township Rd 7, in Whitewater WMA, 6 mi. NE of St Charles Downstream of CR 112, 2 mi. W of Altura Downstream of CSAH 112, 2.5 mi. W of Altura Downstream of CSAH 26, 1.5 mi. E of Elba	Macroinvertebrate IBI Turbidity Bacteria Nitrate			o	o	•
07040003-F17 Whitewater River, South Fork, St Charles Township Rd 7 to T106 R10W S2, east line	0.88	1B, 2A, 3B	10LM016	Downstream of St Charles Township Rd 7, 5 mi. NE of St. Charles	Macroinvertebrate IBI	•		•	•	

• = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.4 Middle Fork Whitewater River (Warmwater; 07040003-515)

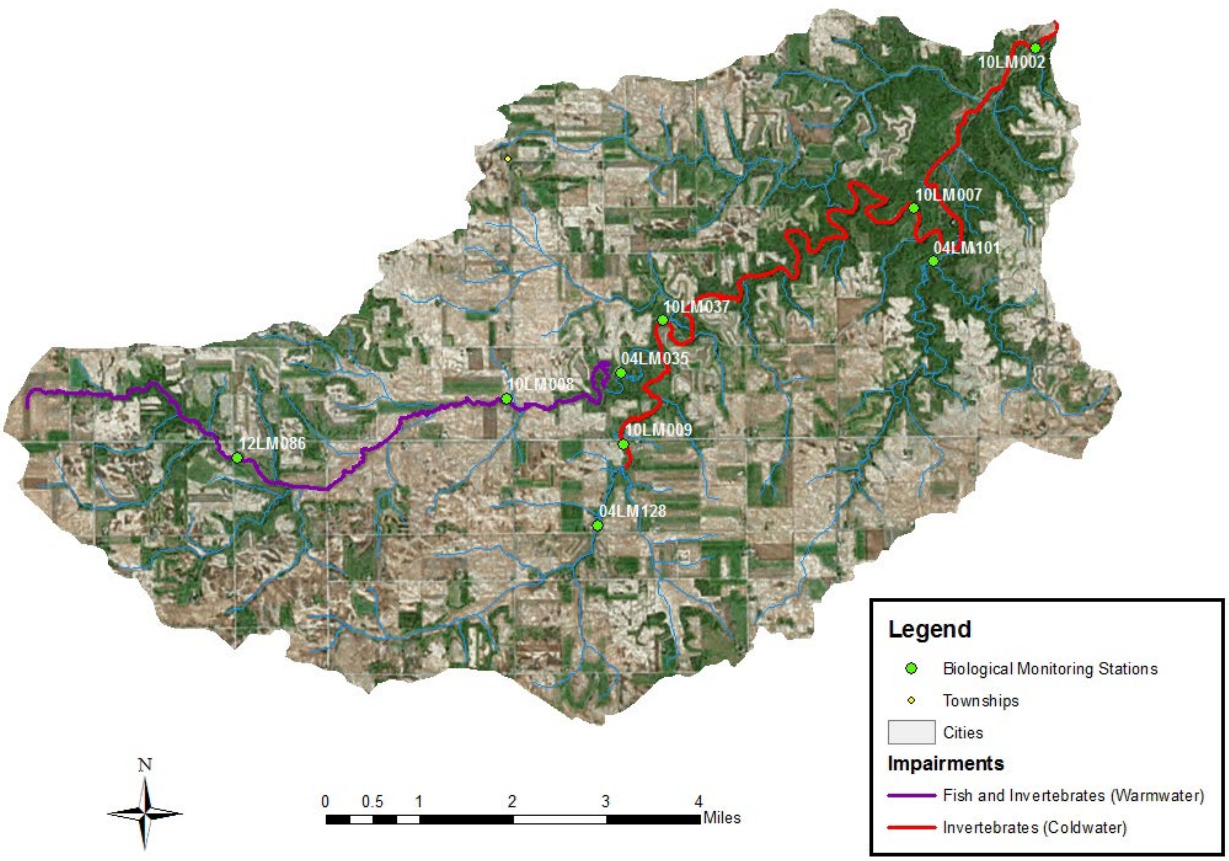

Figure 46. Map of the Middle Fork Whitewater Subwatershed, biological stations, and impaired AUIDs. Both Warmwater and Coldwater impairments are displayed.

Supporting information

According to the assessment report for the MR-Winona Watershed, "The headwaters reach of the Middle Branch are universally degraded, exhibiting the worst condition for invertebrates, fish, E. coli, habitat and morphological condition observed within the subwatershed. It is reflective of the poor conditions in the adjacent landscape including intense agricultural landuse. Recently assessed data confirms the existing turbidity impairment (2008). High nitrate levels were also observed across the watershed ranging from 5.6 mg/L to 9.4 mg/L. "

Station 12LM086 is located in the headwaters of the Middle Fork Whitewater River (AUID 07040003-515). This station was sampled twice in 2012 to help target the location of the biological impairment on the river. The two fish samples scored well (FIBI scores of 74 and 80 respectively). Station 10LM008 is located downstream of station 12LM086 and scored lower than station 12LM086 on every metric (Figure 47). Station 10LM008 also had a lower FIBI score, at 52.8. The sensitive taxa metric in particular scored poorly. The most downstream station in the warmwater section of the river (04LM035) has higher metric scores than station 10LM008, with scores more comparable to station 12LM086. Station 04LM035 is on a separate AUID that is not impaired; therefore, the biological impairment is localized to the middle section of the warmwater part of the river. During the assessment, this small section of the river was proposed to change from coldwater to warmwater. This AUID is in better condition overall, with the riparian zone intact and habitat much improved. Biological information from station 04LM035 is used for comparisons with the impaired reach upstream. The fish community on station 04LM035 is well balanced and includes good numbers of sensitive species taxa. The very tolerant taxa percentage and general taxa percent scores are considerably higher than the scores at station 10LM008.

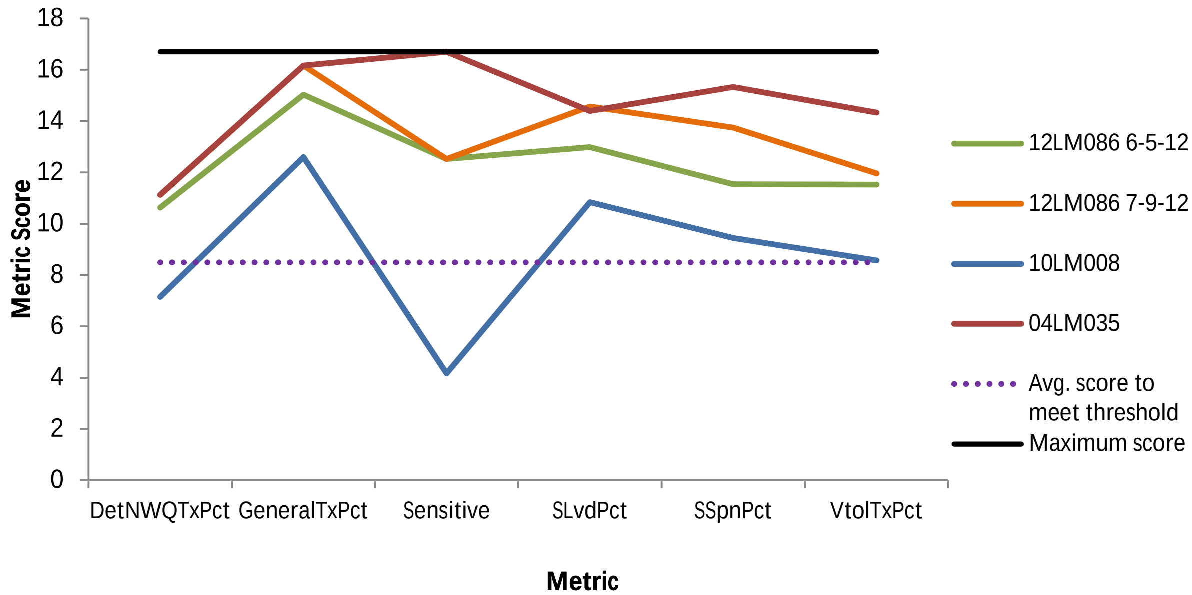

Figure 47. Fish IBI metric scores for the Middle Fork Whitewater

Stations 04LM035 and 12LM086 are both in the Southern Streams RR (Class 5) macroinvertebrate class which has an impairment threshold of 35.9. The MIBI at 04LM035 was 45.5 in 2004, above impairment threshold and is used here for comparison. However, station 12LM086 (in the impaired reach) had a MIBI of 35.3 which is just at impairment threshold. Both stations have scores of 0 for Plecoptera (Figure 48). Station 04LM035 has the maximum score for HBI_MN. The HBI_MN metric is a measure of pollution based on tolerance values assigned to each taxon within Minnesota.

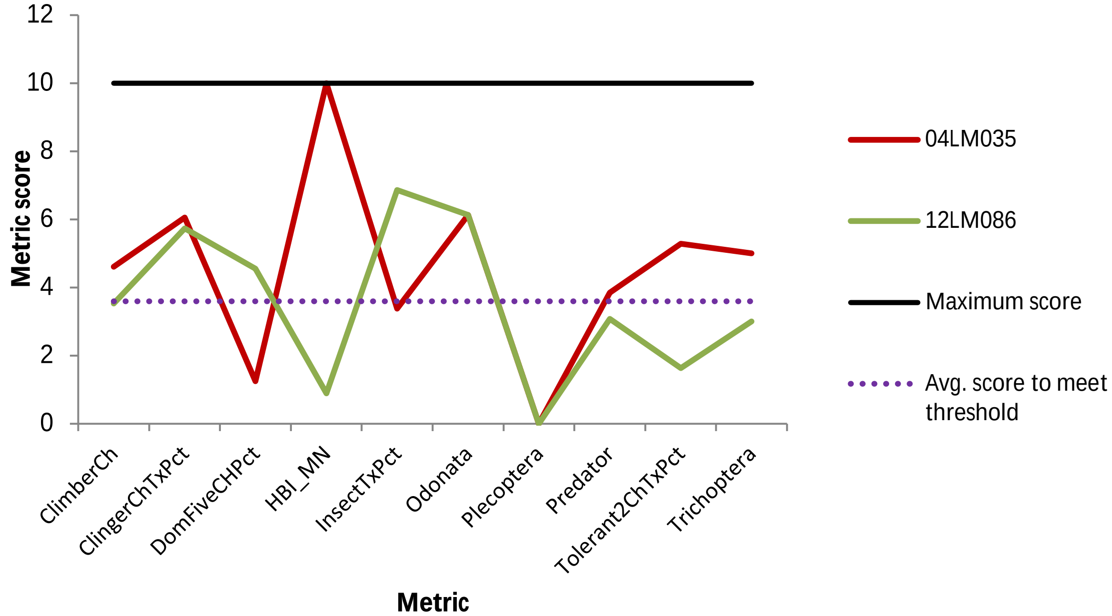

Figure 48. Macroinvertebrate IBI metric scores for the Middle Fork Whitewater (class 5)

Station 10LM008 is in the Southern Forest Streams GP stream class. There were two samples on August 18, 2010; MIBI scores were 35.3 and 26.5, both below the impairment threshold of 46.8 for the stream class. The site scored very poorly in the collector-filterer percentage and the non-hydropsychid Trichoptera individual percentage (Figure 49). The metric scores of the two samples were averaged. The main differences between stations 10LM008 and 04LM035 were lower percentages of clinger taxa (averaging 20.175% t at 10LM008 to 35.7% at 04LM035). Clinger taxa are adapted to cling to substrate in swift flowing water. Station 04LM035 has lower tolerant taxa percent than station 10LM008 (69% versus 88%). The biggest difference is the presence of Trichoptera taxa; seven at station 04LM035 compared to only one at station 10LM008.

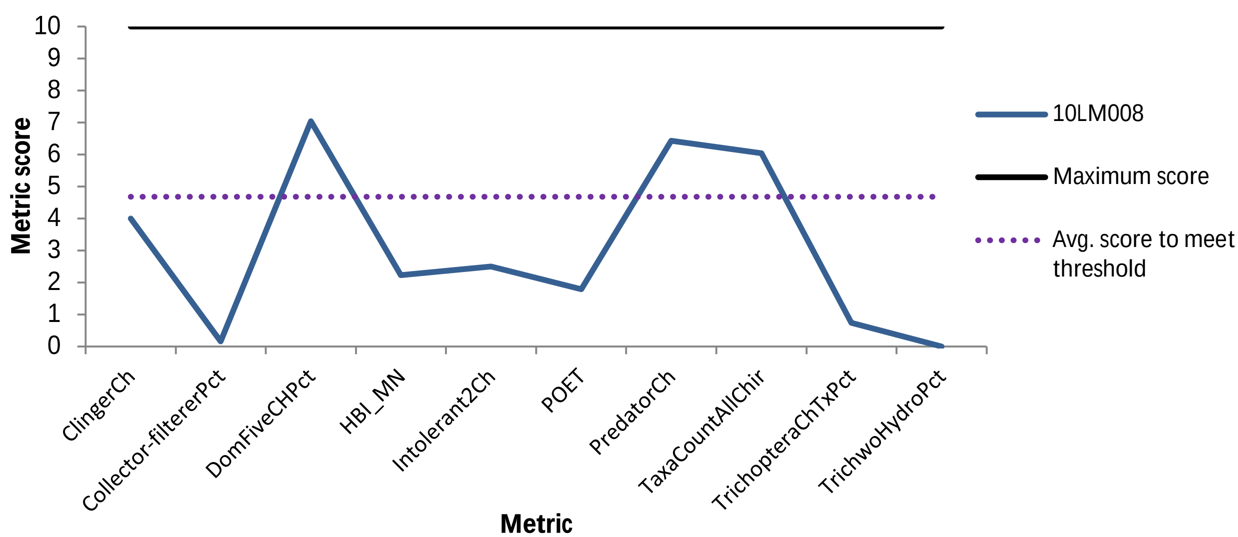

Figure 49. Macroinvertebrate IBI metrics for 10LM008, average of both samples taken on August 18, 2010.

Temperature

There were three temperature measurements taken during fish sampling at the two biological stations (values ranged from 17.7°C to 21.2°C). There were 167 temperature measurements taken on this stream reach, from multiple locations from 2002-2012. The maximum temperature recorded was 27.8°C. The remaining temperature measurements appear normal and within range for warmwater streams. Temperature is not reaching unsuitable ranges for a warmwater stream. Temperature is not considered a stressor to this reach given current information.

Dissolved oxygen

Low DO

There were five dissolved oxygen concentration measurements taken during biological sampling that ranged from 7.3 mg/L to 10.4 mg/L. There was no other DO data available. Two of those values were taken before 9 a.m. (stations 12LM086 and 10LM008; 7.3 mg/L and 8.18 mg/L respectively). The rest were taken in the afternoon.

Continuous DO data was collected at station 10LM008 in 2012 (Figure 50), where DO levels dropped below the warmwater standard of 5 mg/L on three of the five days deployed.

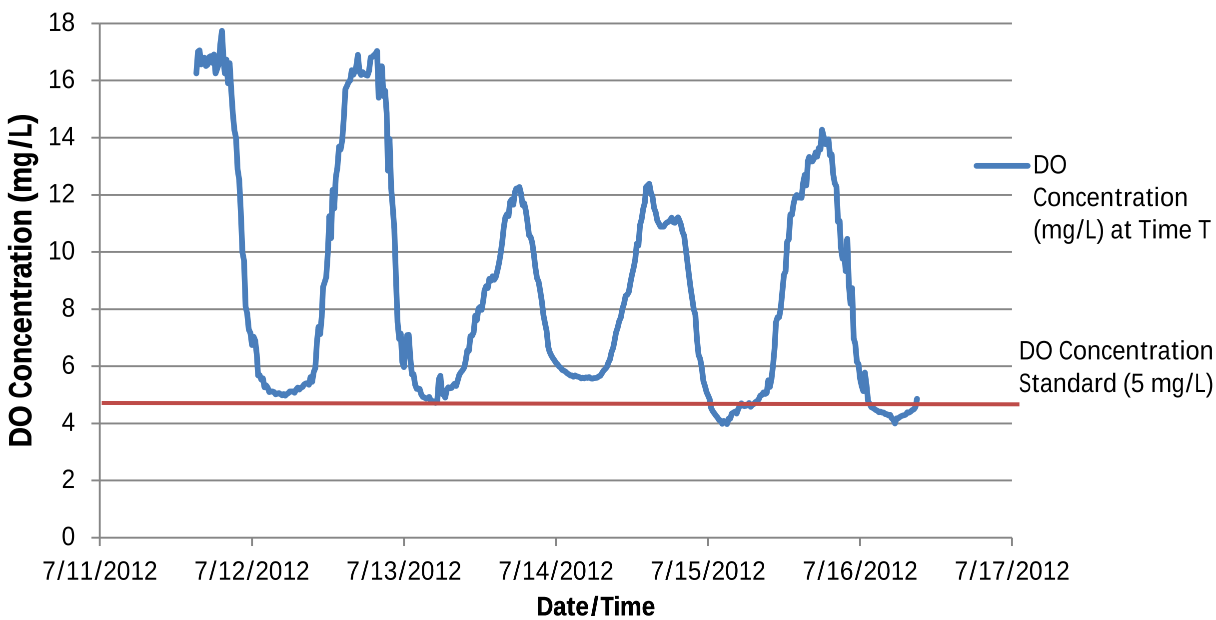

Figure 50. Continuous DO at station 10LM008.

Low DO values correspond with increased tolerant species and decreased sensitive species. Station 12LM086 had low percentages of sensitive individuals (7.21 and 9.53%). Even worse, station 10LM008 had a population comprised of only 0.26% sensitive individuals (Table 21). Differing, station 04LM035 (on downstream AUID) had 27.43% sensitive individuals. The average percentage of sensitive individuals at warmwater sites in the Lower Mississippi River was 13.73%. The average percentage of tolerant individuals at warmwater stations in the Lower Mississippi River basin was 62.15%, only station 04LM035 was lower than this percentage. Tolerant percentages at station 12LM086 were 68.28 and 71.37%, 48.57% at station 04LM035, and 86.99% at station 10LM008. Fish species that reach maturity later in age also decrease with low DO conditions. The two visits on station 12LM086 had no fish that mature at greater than three years of age. Similarly, station 10LM008 had 0.26%, and station 04LM035 had 0.57%. For warmwater sites in the Lower Mississippi River basin, the average percentage of fish that mature after they are three years old is 10.66%.

Table 21. Fish and macroinvertebrate DO metrics

Station (Year sampled)	MA>3 years	Sensitive Fish Percentage	Tolerant Fish Percentage	Percentage DO Tolerant Macroinvertebrate Taxa	DO Intolerant Macroinvertebrate Taxa	Tolerant Macroinvertebrate Percentage
04LM035 (2004)	0.57%	27.43%	48.57%	1.75%	11	41.41%
10LM008 (2010)	0.25%	0.25%	86.99%	34.45%	3	93.19%
12LM086 (2010)	0%	9.53%	68.28%	7.12%	7	77.54%
12LM086 (2010)	0%	7.21%	71.67%	-	-	-
Averages for warmwater stations in the Lower Mississippi River basin	10.66%	13.73%	62.15%	10.79%	7.31	61.29%
Expected response to stress	↓	↓	↑	↑	↓	↑

The early morning low DO tolerance indicator values show fish communities comprised of a range of 49 to 96.5% of fish in the first and second quartile, which are most tolerant to low DO (Figure 51). Station 10LM008 had the highest percentage of fish in the first quartile, which are most tolerant to low DO conditions. The June sample at station 12LM086 was comprised of 51% of fish in the third and fourth quartile which are least tolerant to low DO conditions.

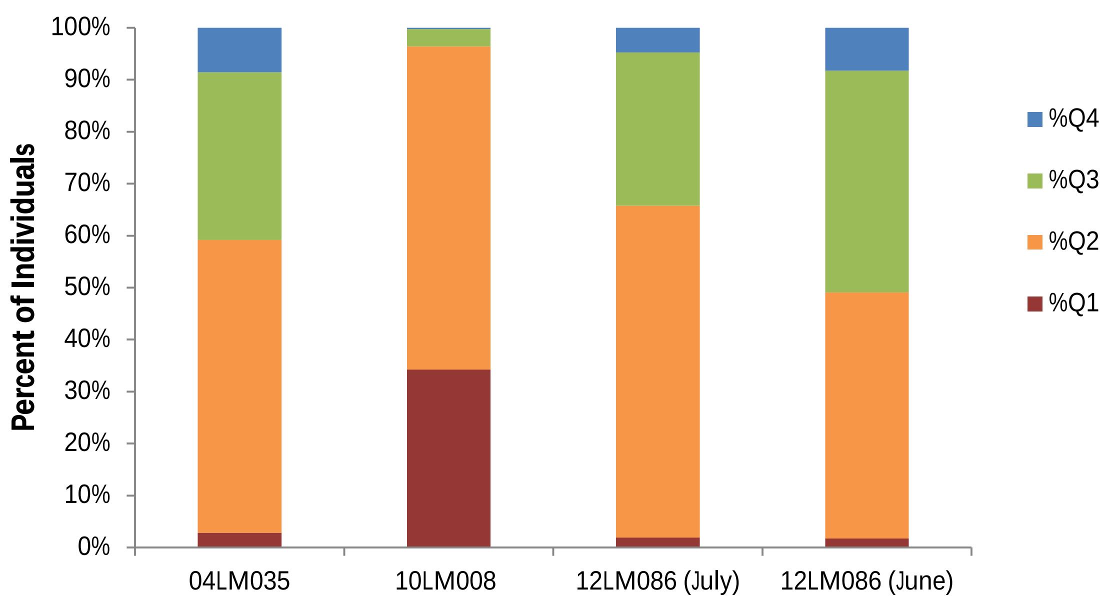

Figure 51. DO TIV scores for the Middle Fork.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. The average number of DO intolerant macroinvertebrate taxa collected in warmwater sites in the Lower Mississippi River basin was 7.31 and the average percentage of DO tolerant taxa was 10.79 (Table 21). At station 12LM086, seven macroinvertebrate taxa that are intolerant to low DO were collected. There were 7.12% DO tolerant taxa were collected. At the two samples at station 10LM008, the numbers of macroinvertebrate taxa collected that are intolerant to low DO were two and four, and the percentages of DO tolerant species collected were 39.6 and 29.63. At station 04LM035, the number of DO intolerant taxa collected was 11, and the percentage of DO tolerant taxa was 1.75.

Based on the lower than average number of intolerant DO species and the high percentages of DO tolerant taxa DO is a localized stressor to the macroinvertebrate community at station 10LM008. Percentages of fish that are later to mature were low at all three biological stations, but sensitive and tolerant percentages were only below basin averages at stations 12LM086 and 10LM008. The early morning DO TIV values at station 10LM008 and one visit at 12LM086 were predominantly comprised of fish in the first and second quartiles which are most tolerant to low DO conditions. Mottled sculpin and fantail darter were collected during both visits and have low tolerance to low DO conditions; however both visits were dominated by the presence of white suckers, creek chubs, and johnny darters which are tolerant to low DO conditions. Similar to the macroinvertebrate community, DO is a localized stressor to the fish community.

DO flux/Eutrophication

Along with low values, DO flux readings were also very high, with values ranging from 5.09 to 16.81 mg/L in one day (Figure 52). Daily flux values were as high as 12.07 mg/L. The proposed water quality standard for DO flux in the central region of the state is 3.5 mg/L. Elevated DO flux is caused by increased algae and macrophyte production, which in turn increases photosynthesis, respiration, and decomposition. High daily fluctuations of DO are connected to increased nutrient concentrations and are often connected to low DO.

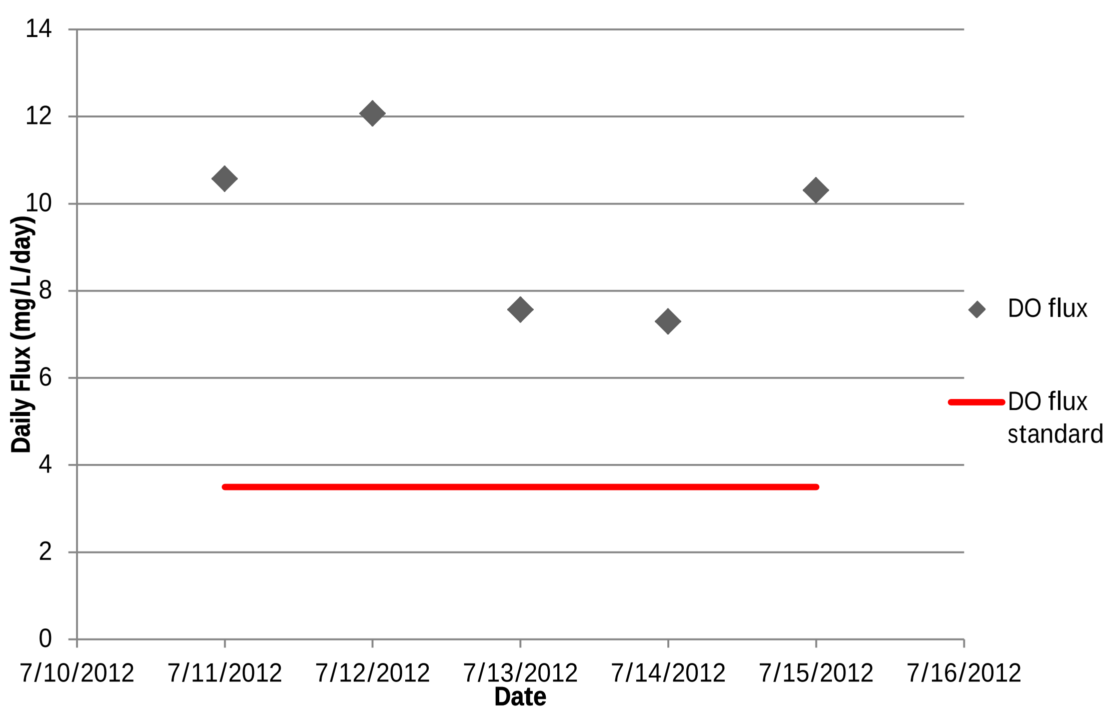

Figure 52. DO flux at station 10LM008.

As interacting variables to eutrophication, phosphorus and pH values were compared to normal ranges and standards. BOD and chlorophyll-a data was not available. Total phosphorus samples taken during biological sampling ranged from 0.062 mg/L to 0.189 mg/L. Corresponding pH values ranged from 8.09 to 8.41. Continuous pH data showed daily fluxes ranging from 0.53 to 0.75 at station 10LM008. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013).

EPT communities are inversely correlated with low DO and DO flux. The average percent EPT individuals in warmwater sites in the Lower Mississippi River basin was 28.6%. The percentage of EPT individuals collected at visits at station 10LM008 was 2.78 and 0.65%. Station 12LM086 had 17.54%, and station 04LM035 had 45.35% EPT individuals. As DO flux increases above 4.0 mg/L per day, the sensitive fish population falls to less than 10% (Heiskary, 2008). With daily fluctuations all over 6 mg/L, station 10LM008 had a population comprised of only 0.26% sensitive individuals. Phosphorus is also positively correlated with the percentage of tolerant taxa for both fish and macroinvertebrates. Tolerant fish percentages ranged from 48.57 to 86.99%, while tolerant macroinvertebrates percentages ranged from 41.41 to 93.52%.

Based on the low sensitive fish percentages, tolerant fish and macroinvertebrate individual percentages, and EPT percentage at station 10LM008, DO flux and eutrophication is determined to be a stressor in this reach. The impacts appear attenuated and are not having the same impact farther downstream, at 04LM035 (next AUID).

Nitrate

The nitrate concentrations reported during biological sampling at stations 12LM086 and 10LM008 ranged from 5.6 to 7.2 mg/L. Additional samples in this stream reach were taken in 2012 ranged from 5.3 to 8.2 mg/L during baseflow conditions (Table 22). No other nitrate data was available on this AUID.

Table 22. Nitrate grab sample concentrations on the Middle Fork Whitewater, AUID -515.

	Nitrate mg/L 5/22/12	Nitrate mg/L 7/6/12
S002-074	7.9	8.2
S002-072	5.3	7.4

In 2010, station 10LM008 had better than average taxa counts during both visits (TaxaCountAllChir; 38 and 41). The average taxa count for this macroinvertebrate class (6; Southern Forest Streams GP) is 33. There were zero and one Trichoptera taxa, which is below the average for the Southern Forest Streams GP stations of the LMB. The stations had between 61% and 81% nitrate tolerant individuals. At 76.8% nitrate tolerant individuals, there is only 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. There were no nitrate intolerant taxa found during either visit.

Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (caddisfly) individual percentages in warmwater streams. Non-hydropsychid Trichoptera are all caddisflies that do not spin nets. Sites in the Lower Mississippi basin average 3.39% non-hydropsychid Trichoptera. Station 10LM008 had no non-hydropsychid Trichoptera, and station 12LM086 had 1.5%.

The nitrate concentrations do appear elevated based on grab sample results, but the data is limited. The lack of Trichoptera taxa, and non-hydrophsychid Trichoptera, nitrate intolerant taxa, and abundance of nitrate tolerant taxa show biological response consistent with elevated nitrate. Nitrate is a stressor in this reach, but is considered secondary to a more prominent stressor. Further characterization of the magnitude and duration of nitrate concentrations here would be helpful.

TSS

This section of the Middle Fork has an existing turbidity impairment. TSS taken during fish sampling at station 12LM086 ranged from 8.4 mg/L in June 2012 to 37 mg/L in July 2012. Station 10LM008 was also sampled for TSS June 2010, with a result of 21 mg/L. Flow conditions were noted as normal for all of these visits.

Transparency was measured 170 times between 2002 and 2012 along this reach, with values ranging from 0 cm to >60 cm, the average was 30.48 cm. Based on this data, the percentage of time those measurements exceeded 20 cm (the surrogate water quality standard), was 29% which supports the turbidity listing.

In this headwater section of the Middle Branch Whitewater, the biological stations had macroinvertebrate TSS station index scores worse than and close to average compared to the average of warmwater stations in the MR-Winona Watershed (Table 23). There were no TSS intolerant taxa present, and a high percentage of TSS tolerant macroinvertebrate individuals at 10LM008. Additionally, this location also had fewer than average intolerant taxa and long-lived macroinvertebrates, both which often decrease with increases in TSS stress.

Table 23. Macroinvertebrate metrics relevant to TSS for stations in Middle Branch Whitewater compared to averages for warmwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
10LM008 (1)	16.89	**0**	5	**38.49**	**0**	**2.92**
10LM008 (2)	**17.47**	**0**	7	**34.56**	**0**	**2.16**
12LM086	16.91	**0**	**12**	22.30	3	**3.69**
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for Warmwater stations in the MR-Winona Watershed	16.92	0.61	7.66	28.95	1.75	3.78

The fish population consists of a number of fish species that are tolerant to high TSS (Figure 53). A high percentage of the population at stations 12LM086 and 10LM008 was found in the two most TSS tolerant quartiles. Farther downstream, at station 04LM035 (not impaired for biology), there were fewer TSS tolerant species and many more sensitive to TSS species present. Both biological stations had TSS index scores for fish that were below the MR-Winona Watershed average of 39.7 (score ranges from 13-17). The percent carnivore metric, which has a relationship with TSS, also shows below average percentages at both biological stations on this reach, further demonstrating TSS stress to the fish community (15.6% at 12LM086 and 8.93% at 10LM008 compared to the average of 34.6%). In addition, generally intolerant fish species and long-lived fish species also were found in below average percentages, both which can also respond to increased TSS. The biological and chemical evidence suggests that TSS is a stressor to both the fish and macroinvertebrate communities in this reach.

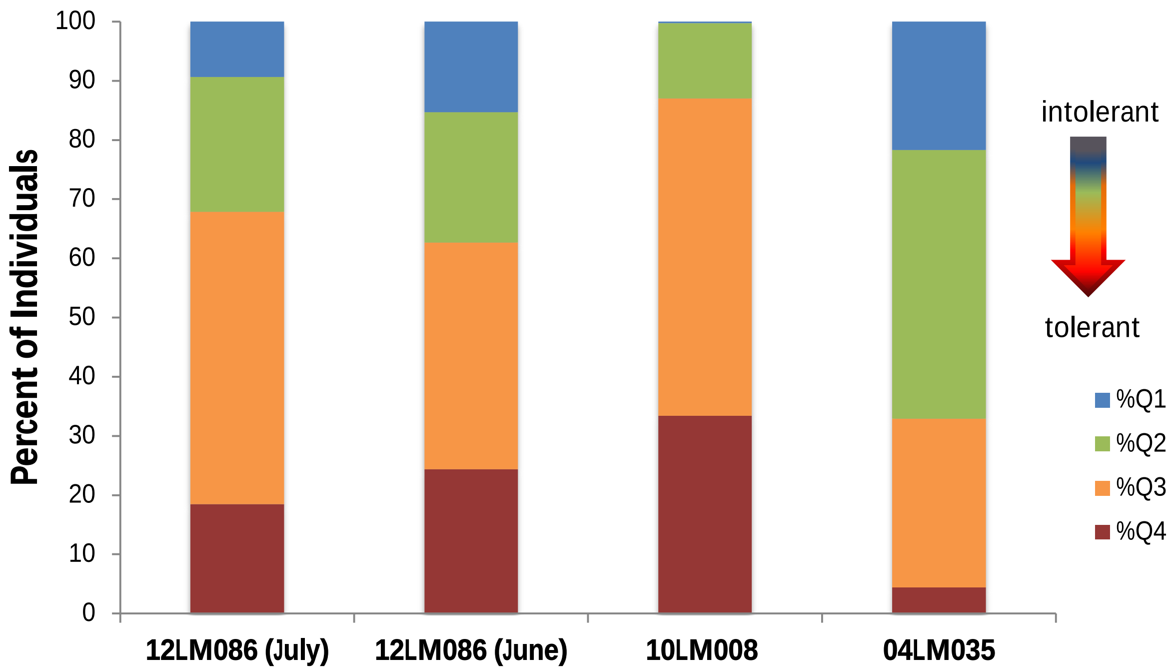

Figure 53. TSS TIVs for the Middle Branch Whitewater (Sandberg, 2013)

Habitat

Station 10LM008 had a poor MSHA score of 37.8. All the subcategory metric scores scored low, attributing to this low MSHA score. Station 12LM086 had two fair MSHA scores in 2012; 57.3 and 59.2. The low MSHA score at station 10LM008 was low due to no riparian buffer, severe embeddedness, a lack of riffle, and lack of channel development. Station 12LM086 had moderate bank erosion, no riparian buffer, and sparse cover for fish. The channel stability ranking at 10LM008 scored a 67 CCSI, which falls in the moderately unstable category.

Geomorphic characterization by MDNR (Ellefson and Zytkovicz):

The channel transitions into an E6 stream very quickly where the land use changes from row cropping to grazing. The valley type remains a VIII(c) but narrows considerably. Station 10LM008 (MDNR site 92) is located on this reach. All of this reach is intensively grazed through the entire width of the floodplain. It is currently an E6, with the potential to be an E4. This reach terminates at the Highway 10 Bridge. Downstream of this the grade steepens and the valley narrows. The Pfankuch stability rating was rated as poor, with a score of 132. It is only slightly incised with a Bank Height Ratio (BHR) of 1.24 and the stream is clearly cutting a new floodplain for itself. It appears there is hydraulic control at the bridge because the channel widens and deepens as it approaches the bridge. Downstream of the bridge there is extensive local channel adjustment indicating the hydraulic control is set higher than the overall grade of the channel. This grade control could be the reason the channel is not as incised at Site 92 as it is upstream at Site 90. Floodplain connectivity is very good at this location. Not only does it have full access to its new floodplain, it can also access the full extent of its old floodplain at the floodprone elevation (2X Dmbkf). Typically E channel types are very efficient channels and have high sediment transport capacity. The deep, narrow channels are able to maintain stability without down cutting. However, they are extremely dependent on vigorous riparian vegetation with a dense root mass to maintain bank integrity. The current riparian vegetation could easily be categorized as overgrazed. This, combined with the added bank depth where the channel is eating away at the old floodplain creates a very thin root profile. The fact that the channel cannot flush out the silt from its channel bottom indicates that the stream is aggrading. The riparian area is dominated by grass and was grazed heavily; cattle have continuous access to the stream where hoof shear on the banks is very frequent. There are also a number of cattle crossings that further destabilize the stream. The channel is still actively creating its new floodplain by cutting into the low terrace frequently. There is frequent slumping, and the lateral erosion rate averaged over the length of the stream is estimated to be 0.29 ft/yr. The banks are predicted to contribute 0.095 tons/ft/yr, which is quite high for such a small stream. With a D50 on the riffle pebble count of 0.04mm, this stream is solidly in the E6 category. The channel bottom is a continuous silt bottom and is easily mobilized. No aquatic vegetation exists in the channel to provide habitat. The pool quality is very poor due to extensive filling. This site is ill equipped to receive the extensive bank erosion contributions and concentrated flows from the channelized reach upstream of it. It exists in a degraded state due to the over grazing of its riparian area. The reach could benefit from rotational grazing and/or cattle exclusion from the immediate channel and banks. Upstream, raising the base level of the stream to reattach its floodplain combined with re-meandering is the best option for recovery.

Biological response:

Fish metrics were compiled for the Middle Fork Whitewater River for two biological stations and three visits, and then compared to statewide averages of the stream classes (Southern Headwaters; Class 3). Both stations had above average percentages of riffle dwelling fish (43%-53%), non-tolerant benthic insectivores (12%-21%), simple lithophilic spawners (38%-43%), and darter, sculpin and round bodied suckers (12%-19%). Lithophilic spawners were found in abundance as well, from 52% to 79%. White sucker were the dominant fish species found at all three visits, and that species makes up a large percentage of two of these metrics. An abundance of tolerant fish species were present (68% to 86%), in addition to a lack of sensitive species (only 0.2%-9%). Both metrics can respond to many different types of stressors and the presence of intolerant species is an indication of a high quality resource. The lower percentages are found at station 10LM008 compared to station 12LM086. While there are certainly aspects of habitat that could be improved in this reach, it doesn't appear to be driving the fish impairment because fish metrics related to habitat look adequate. This is also supported by higher IBI scores for fish at station 12LM086 and a more diverse fish community. If habitat between the two stations was drastically different, then a stronger response would be demonstrated.

The macroinvertebrate community is sampled based on dominant habitat types found at each station. The only habitat sampled at 10LM008 was undercut bank/overhanging vegetation. At station 12LM086, both riffle/run and undercut banks/overhanging vegetation were sampled. The macroinvertebrate metrics were compiled for the stations, and then were compared to statewide averages of these stream classes (10LM008: Southern Streams GP; Class 6 and 12LM086: Southern Streams RR; Class 5). The results are found in Figure 54. The percentage of burrowers was slightly elevated at station 12LM086, suggesting potential fine sedimentation in riffle habitat. Burrowers can be found in other habitats as well, like overhanging vegetation or undercut banks, which may explain the higher percentages found at 10LM008 (which did not sample riffle habitat). Both stations had less than average percentages of clinger and EPT individuals. Clinger species attach to rocks or woody debris. Clingers can decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). EPT taxa are commonly used to measure overall health of ecosystems, due to their sensitivity to many stressors including habitat. In addition, the percentage of tolerant legless individuals was high during all visits at both stations (72%-78%; Figure 55). Snails were the dominant species collected at station 12LM086, which are both legless and climbers, increasing both those numbers. There were a good percentage of climber individuals found at all visits, which is expected (dominant habitat type).

Fish do not appear to be responding to habitat issues in this reach. There are adequate percentages of multiple types of fish species that rely on many diverse types of habitat. The percentage of tolerant fish species and lack of sensitive fish species are likely due to other stressors present. Due to the reduced percentages of clingers, EPT individuals and increased percentages of burrowers and tolerant legless macroinvertebrates, lack of suitable habitat is considered a stressor to the macroinvertebrate community in this reach.

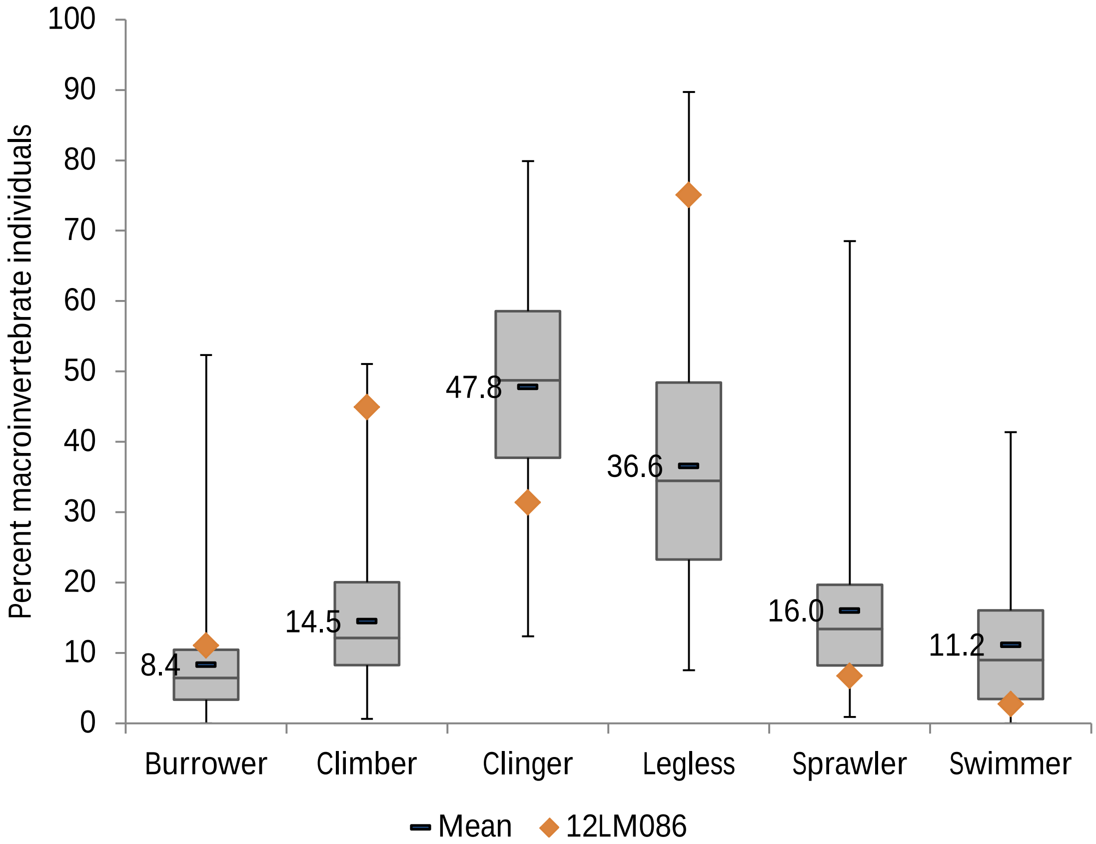

Figure 54. A comparison box plot of macroinvertebrate habitat metrics representing the average class 5 (Southern Streams RR) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

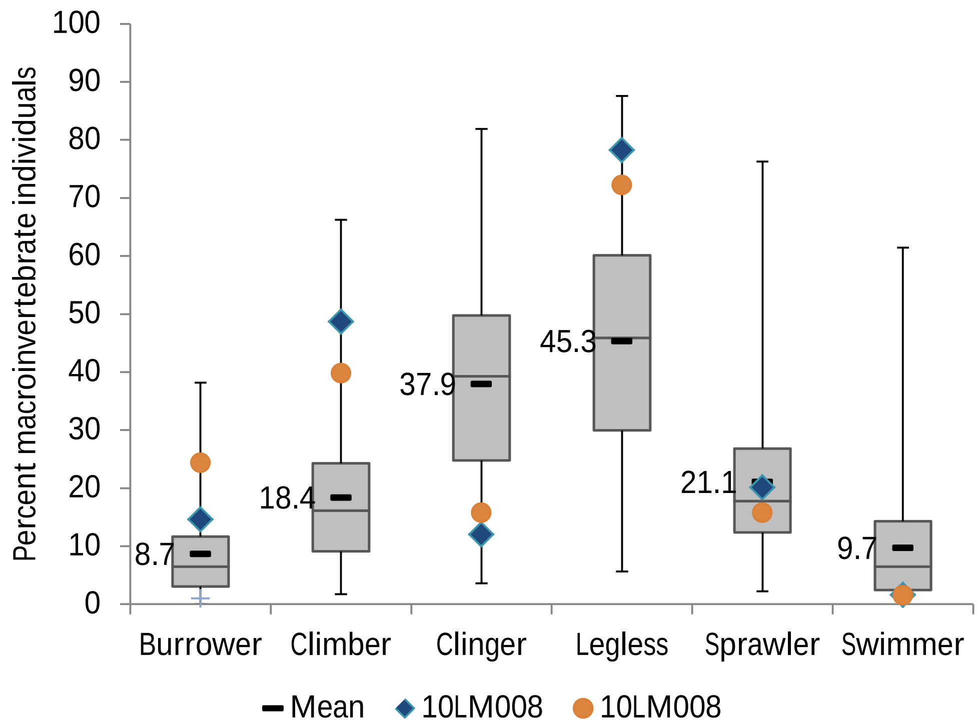

Figure 55. A comparison box plot of macroinvertebrate habitat metrics representing the average class 6 (Southern Streams GP) stations statewide. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

Conclusions and recommendations

The stressors found in this reach are summarized in Table 24. DO, nitrate and TSS are causing stress to both the fish and macroinvertebrate communities in this reach. DO and TSS appear to be driving biological stress in this reach and at 10LM008, while nitrate is considered a secondary stressor. Because of a limited dataset, additional information on magnitude and duration of nitrate concentrations in this reach would be helpful. Habitat stress is seen with the macroinvertebrate community, but not with the fish community.

Table 24. Summary of stressors found in the Middle Fork Whitewater (515).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:				
						Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-515 Whitewater River, Middle Fork, Headwaters to T107 R11W S34, east line	9.56	2B, 3C	10LM008 12LM086	Upstream of CSAH 10, 3.5 mi. N of Dover Downstream of 140th Ave SE, 2.5 mi. NE of Eyota	Fish IBI Macroinvertebrate IBI Turbidity Bacteria		●	●	●	●

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.5 Middle Fork Whitewater River
(Coldwater; 07040003-F19)

Supporting information

This reach in the Middle Fork Whitewater is impaired for Macroinvertebrates (Figure 46). This reach also has existing nitrate, turbidity and bacteria impairments as well. All of the biological stations in this reach are in the coldwater macroinvertebrate class (class 9), which has an impairment threshold of 46.1. The macroinvertebrate community at station 10LM037 is relatively healthy (good richness, decent number of EPT taxa) with an MIBI score in 2010 of 58.94. The middle station (10LM007) visit had an MIBI score of 30.59 in 2010, the lowest score in this reach. The macroinvertebrate community at this station had a large number of tolerant taxa (snails, Diptera) and lacks the numbers of coldwater taxa expected in this stream which indicates stress. The downstream station (10LM002) visit scored 51.61 in 2010. Interestingly, station 10LM007 was resampled in 2012, and scored much higher at 52.9. The biggest increases in scores were the collector-filterer percent, CBI, and very tolerant percent (Figure 56). The very tolerant percent was 47.1 during the 2010 sample and 21.2 during the 2012 sample. The coldwater (CBI) metric also scored higher in 2012 than in 2010.

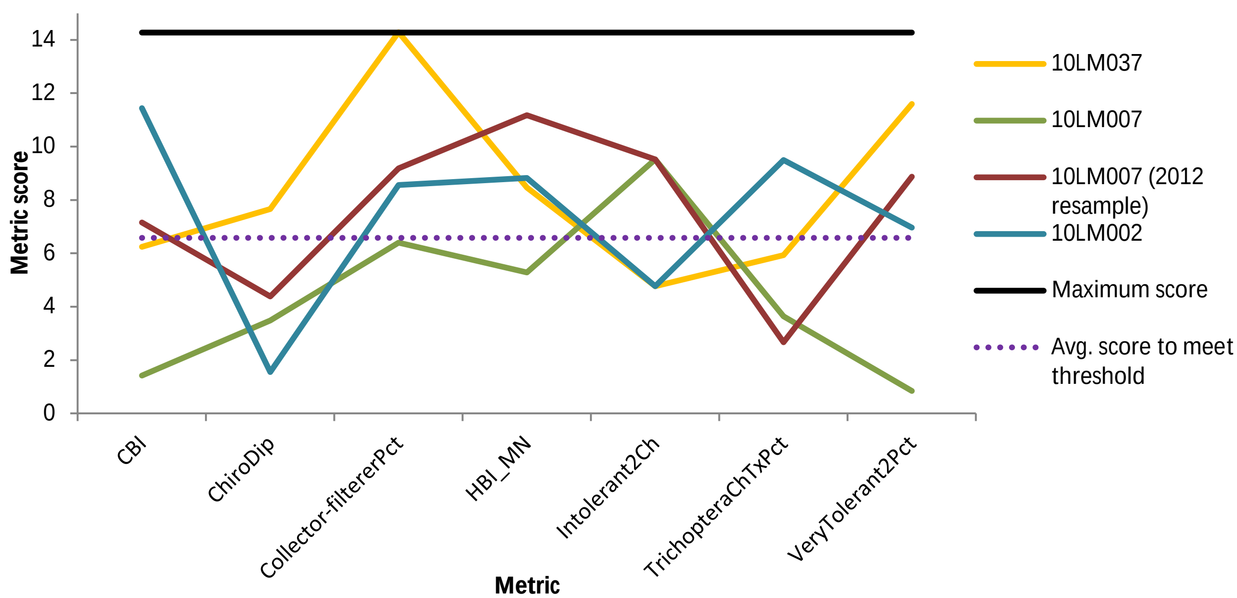

Figure 56. Macroinvertebrate IBI metric scores for the Middle Fork Whitewater

Temperature

There were five temperature measurements taken during fish sampling at the three biological stations (values ranged from 16.1°C to 21.2°C). There were 925 temperature measurements on this stream reach from 2000-2012 at multiple locations. The maximum temperature recorded during that time frame was 24.4°C on July 24, 2006. Of those 925 measurements, 37 of them were above 21°C. In addition, temperature loggers were placed at both locations in 2010. The July and August average temperature for station 10LM002 was 18.6°C and 16.7°C, respectively (Figure 57). The July and August average temperature at station 10LM007 was slightly warmer, at 19.98°C and 19.64°C (Figure 58). Both stations had a maximum temperature for both months at 21°C.

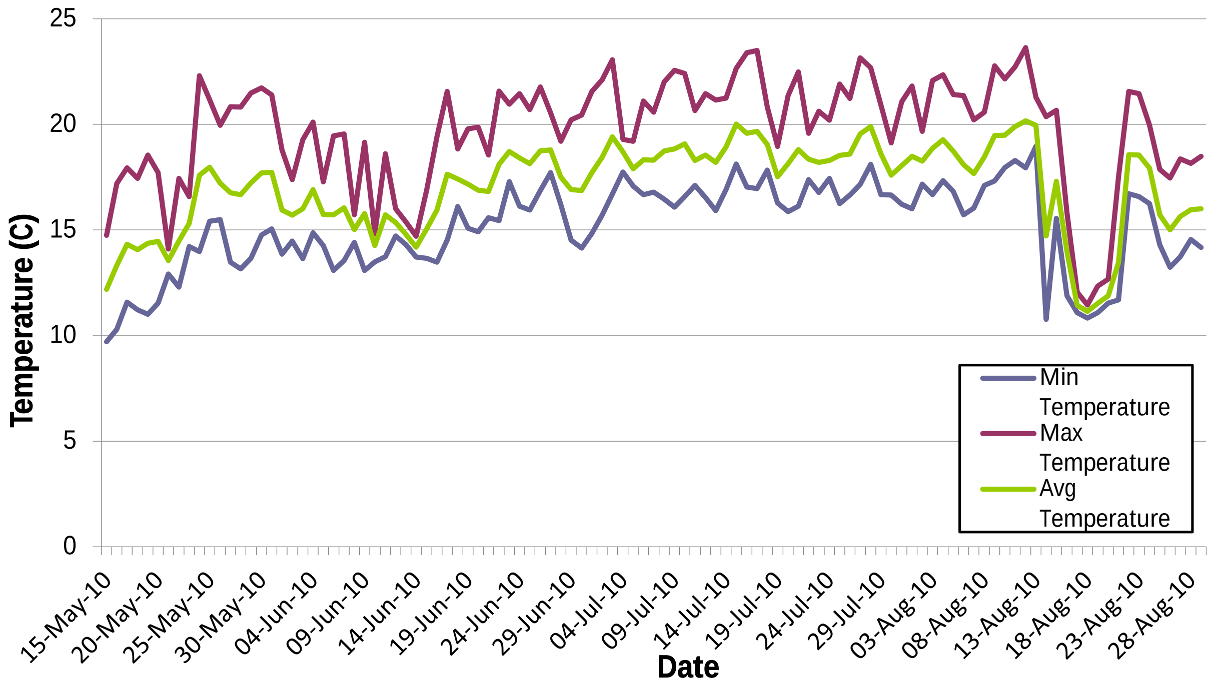

Figure 57. Continuous temperature data at station 10LM002

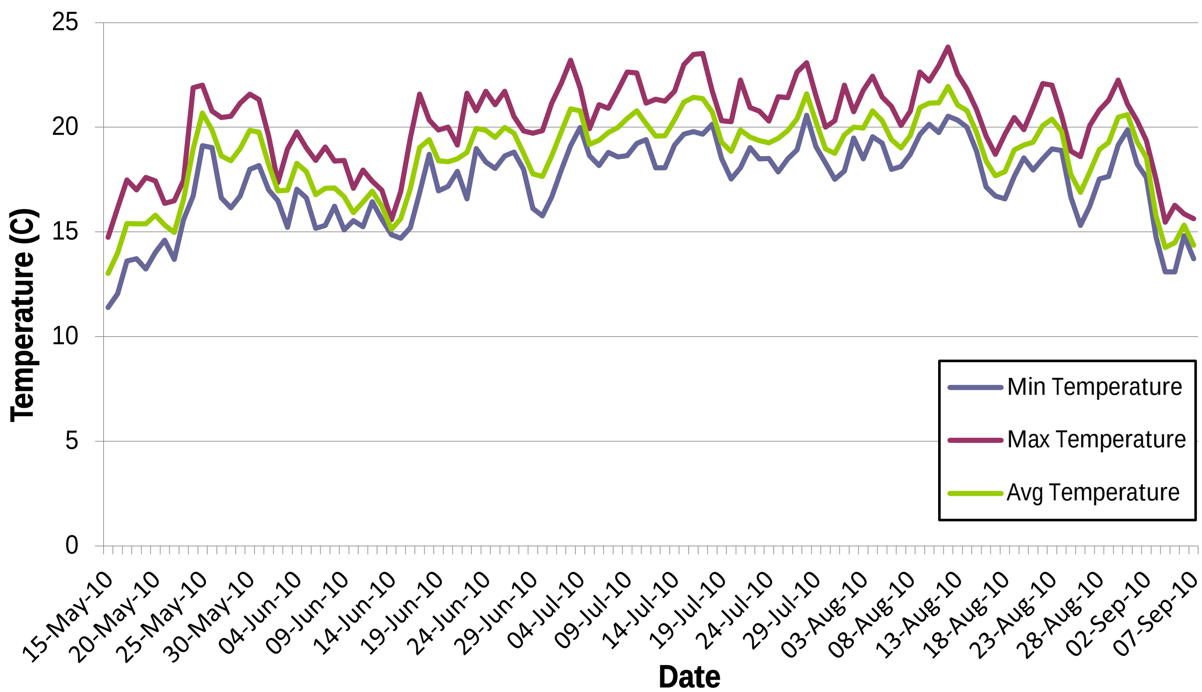

Figure 58. Continuous temperature data at station 10LM007.

The fish community in this reach shows fairly abundant coldwater fish species when compared to other coldwater stations in the MR-Winona Watershed (Table 25). The percentage of coldwater fish species (ColdPct) was above average at all sites except station 10LM007 which was near average. Coldwater sensitive fish species (CWSensitivePct) were also above average at all sites, with the exception of one visit at station 10LM007. Native coldwater species (NativeColdPct) were all above average, except for station 10LM002. The CBI (coldwater biotic index) macroinvertebrate metric scored fair; with most visits near the average and or above the average threshold needed to be above the IBI threshold. One visit at station 10LM007 resulted in a low CBI metric score (Figure 56).

Table 25. Fish metrics on the Middle Branch Whitewater in relation to temperature and compared to Class 10 (coldwater) averages.

Site	Stream	Visit Date	ColdPct	CWSensitivePct	NativeColdPct
10LM037	Whitewater River, Middle Fork	09-Aug-10	65.79	66.67	43.52
10LM002	Whitewater River, Middle Fork	13-Jul-10	64.67	69.10	23.92
10LM007	Whitewater River, Middle Fork	14-Jul-10	42.00	58.64	32.41
10LM007	Whitewater River, Middle Fork	10-Aug-10	50.86	74.33	43.03
10LM002	Whitewater River, Middle Fork	16-Jun-10	73.09	82.33	12.45
MR Winona Class 10 Averages			51%	61%	22%

Continuous data does suggest this water is slightly warmer than optimal for coldwater species, but that is somewhat expected given the larger drainage area of this stream reach. Given the high percentage of coldwater fish species, and decent CBI macroinvertebrate metric scores at most sites, it's not likely the temperature is a stressor in this reach. Most stress appears to be present at station 10LM007, and the response is likely explained by other, more localized stressors. The fish community at most sites in this reach are in excellent biological condition. Temperature, while could use improvement, is not a driver of macroinvertebrate impairment in this reach.

Dissolved oxygen

Low DO

There were five DO samples from fish sampling in 2010, which ranged from 8.38-10.23 mg/L. Two of those values were taken before 9 am (station 10LM002; 8.99 mg/L and station 10LM007; 8.38 mg/L). Monitoring station S001-831, (near station 10LM037), was sampled 19 times for DO in 2012 and 2013. The DO values ranged from 8.28 to 12.90 mg/L. Station S001-825 (near 10LM002) was sampled 18 times in 2010 and 2011. The DO values ranged from 8.84 mg/L to 12 mg/L, with an average of 10.71 mg/L.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. The average number of DO intolerant taxa in coldwater streams in the Lower Mississippi River basin was 9.6, and the average number collected in streams above the threshold was 10.1.

The average percentage of DO tolerant taxa was 2.6 and the average percentage collected in streams above the threshold was 1.7 (Table 26). The number of DO intolerant taxa was 14 at station 10LM037. The percentage of DO tolerant taxa was 1.25%. The number of DO intolerant taxa at station 10LM007 was 12 and 13, and the percentage of DO intolerant taxa was 2.39 and 5.22. The number of taxa intolerant to low DO at station 10LM002 was lower than the other two sites with seven; however the percentage of DO tolerant taxa was also lower at 0.95. The number of DO intolerant taxa was above average, including being above the average for sites that was above the threshold at station 10LM037. The percentage of DO tolerant taxa was also below the basin average and below the average of those sites that met the threshold. Station 10LM007 also had higher than basin average numbers of DO intolerant taxa, but had higher than average percentages of DO tolerant taxa. Station 10LM002 had a lower than average number of DO intolerant taxa along with a lower than average percentage of DO tolerant taxa. The preponderance of data shows that low DO is not a stressor on this reach.

Table 26. Macroinvertebrate DO metrics

Station (Year sampled)	Percentage DO Tolerant Macroinvertebrate Taxa	DO Intolerant Macroinvertebrate Taxa	Tolerant Macroinvertebrate Percentage
10LM007 (2010)	5.23%	13	57.00%
10LM007 (2012)	2.39%	12	41.48%
10LM037	1.25%	14	21.71%
10LM002	0.95%	7	36.81%
Averages for coldwater stations in the Lower Mississippi River basin	2.6	9.6	42.68
Expected response to stress	↑	↓	↑

DO flux/Eutrophication

As interacting variables to eutrophication; phosphorus, pH, and chlorophyll-a values were compared to normal ranges and standards. Total phosphorus concentrations during fish sampling ranged from 0.038 mg/L to 0.067 mg/L. Corresponding pH values ranged from 8.3 to 8.48. Total phosphorus concentrations on the entire stream reach analyzed during assessment revealed the mean concentration was 0.556 mg/L from 11 years of data. The maximum total phosphorus concentration was 2.8 mg/L on this reach, which is much higher than the proposed standard of 0.100 mg/L. In addition, seven of 36 pH readings were above the pH standard of 6.5 to 8.5 at station S001-825 (values ranged from 8.6-9.3). Values over 8.5 are an indicator of nutrient enrichment. Station S001-831 (near station 10LM037) was sampled for chlorophyll-a 42 times in 2000 and 2001. The values ranged from 0.04 to 30.23 µg/L. The majority of readings are from monitoring station S001-831 (MDA site). The highest phosphorus values coincide with rain events but not all of the elevated values are tied to rain events.

EPT individual percentages show an inverse correlation with chlorophyll-a, low DO, and DO flux values. The average percent EPT individuals in coldwater sites in the Lower Mississippi River basin was 39.55%. The percentage of EPT collected at station 10LM037 was 74.92%. The percentages were lowest at the other stations; 25.27% in 2010 and 32.15% in 2012 at station 10LM007, and 33.74% at station 10LM002. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average for coldwater sites in the Lower Mississippi River basin was 42.68%. Tolerant macroinvertebrates percentages ranged from 21.71 to 57.00%.

There are some elevated DO values indicating that DO flux conditions might exist, but there is currently not enough data to make connections with eutrophication and coldwater biological communities. Elevated phosphorus, pH, and chlorophyll-a values also exists, making nutrient management important, considering the elevated DO values. Further DO monitoring including diurnal monitoring should take place to better understand the DO regime. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

Nitrate

During fish sampling, the nitrate concentrations ranged from 6.2 mg/L at station 10LM002 (farthest downstream site) to 9.4 mg/L (farthest upstream site). This is consistent with additional data found at these locations, which show concentrations of nitrate decreasing slightly when moving downstream. Station S001-825 (near station 10LM002) was sampled 10 times between May and September of 2010. The nitrate values ranged from 5.5 mg/L to 7.5 mg/L, with an average of 6.46 mg/L. Station S001-831 (near station 10LM037) was sampled for nitrate 65 times between 2003 and 2011. The range of concentrations was from 0.82 mg/L to 11 mg/L. The average concentration was 8.07 mg/L (Figure 59).

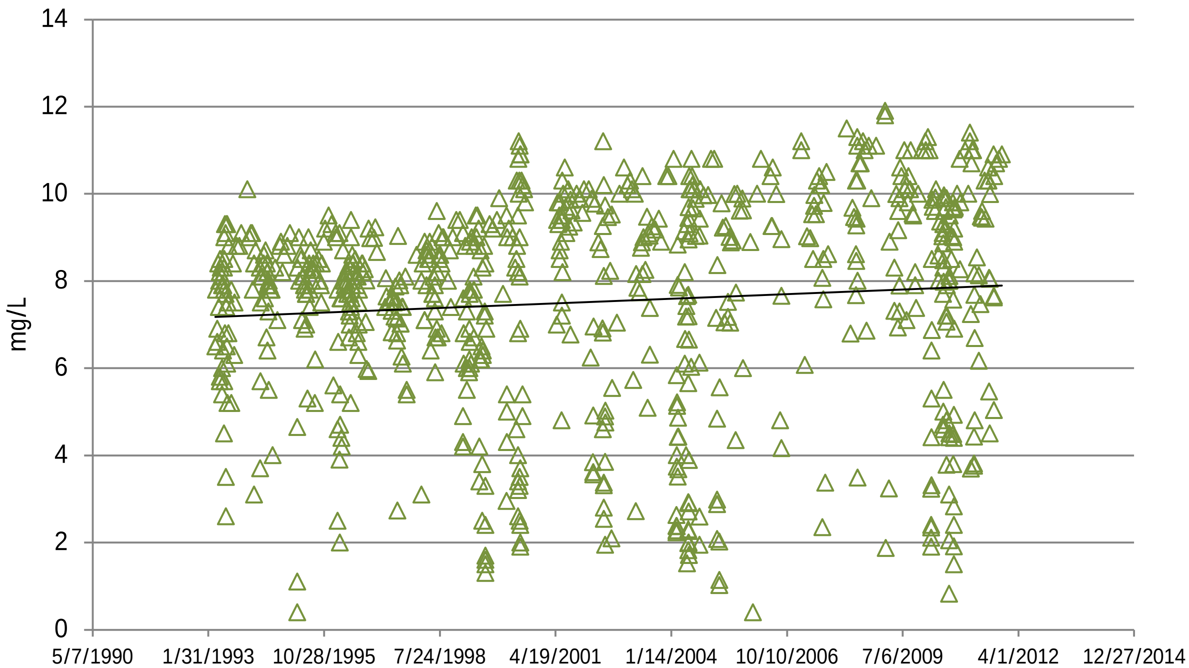

Figure 59. Nitrate concentrations on the Middle Branch Whitewater, monitoring station S001-831, 1993-2011

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 stations 10LM007, 10LM037, and 10LM002 had 37, 56, and 28 taxa (TaxaCountAllChir), compared to the average taxa count for coldwater stations in the LMB (30.01). There were five and six Trichoptera taxa at each station (13.5%, 10.7%, and 17.86% taxa; TrichopteraChTxPct). The result is reflected in a low IBI metric score; less than average needed to meet the Southern Coldwater MIBI threshold for stations 10LM037 and 10LM007. Station 10LM002 had a higher metric score; higher than the average needed to be above the MIBI threshold (Figure 56).

The stations had a range of nitrate tolerant taxa present as shown in Table 27. The corresponding percentage of nitrate tolerant individuals ranged from 53% to 86%, with the highest percentage at station 10LM002. 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. Only station 10LM002 was below the 16.6 taxa. There were no nitrate intolerant taxa present at station 10LM002, but one nitrate intolerant taxon was found at stations 10LM037 and 10LM007 in 2010, and three nitrate intolerant taxa were found at station 10LM007 in 2012.

Table 27. Macroinvertebrate metrics relevant to nitrate for stations in the Middle Fork Whitewater compared to specific benchmarks. Bold and highlighted equals the metric score is higher or lower than expected, depending on expected response with increased stress.

Nitrate Relevant Metrics	Taxa Count TaxaCountAllChir)	Nitrate Tolerant Taxa	HBI_MN Value	HBI_MN IBI metric Score
10LM037	37	**19**	**6.66**	8.45
10LM007 (2010)	56	**22**	**7.09**	**5.28**
10LM007 (2012)	42	**27**	**6.42**	11.17
10LM002	28	15	**6.74**	8.82
Expected response with increased Nitrate stress	Increase	Increase	Increase	Decrease
Benchmarks *(described in text)*	33	16.6	6.27	6.6

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 IBI metric score and HBI_MN value have a significant relationship with nitrate at the time of fish sampling. The HBI_MN IBI metric score decreases with increased in nitrate. In the Middle Branch Whitewater, the metric scores were ranged from 5.28 to 11.17 (out of 14.3), most being above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). The exception was station 10LM007 in 2010, when the HBI_MN value was 5.28 (Table 27). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. All stations show an elevated HBI_MN value (6.74 to 7.09). 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 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57.

All stations in this reach are rich with macroinvertebrate taxa, and many metrics show some response consistent with nitrate degradation. The macroinvertebrate taxa richness is expected to be lower in coldwater streams in Southeastern Minnesota, and the increased richness in some of these locations points to stress. There was an abundance of nitrate tolerant taxa, and elevated HBI_MN values which indicate elevated nitrate is shaping the macroinvertebrate community present. Nitrate related stress appears to be highest where stream concentrations are highest (upstream) at station 10LM007. Nitrate concentrations and subsequent biological response is not as obvious closer to the mouth. Elevated nitrate is likely secondary to a more prominent stressor in this reach.

TSS

The TSS concentrations were all low during fish sampling on this reach. The five values collected in 2010 (stations 10LM002 and 10LM007 were both sampled twice) revealed a range of concentrations from 1.2

mg/L to 7.6 mg/L. There is an existing turbidity impairment on this reach, and it seems well supported by many transparency readings in addition to turbidity and TSS measurements. Monitoring station S001-831 (near station 10LM037) was sampled for TSS 116 times between 2000 and 2011. The TSS values range from 1.2 mg/L to 2800 mg/L, with an average value of 160.19 mg/L. However, it is important to note that the monitoring at this station does target storm events. In conjunction with many of the TSS samples, transparency was also measured 404 times between 2000 and 2012. The transparencies range from 1 to >100 cm, the average value 59 cm. Finally the turbidity was sampled 115 times between 2000 and 2011. The turbidity values range from 1.1 NTU to 1700 NTU, with the average value of 90.75 NTU. Monitoring station S001-825 had TSS and transparency readings as well. TSS was sampled 13 times between 2005 and 2010. The results ranged from 1.2 mg/L to 60 mg/L, with an average TSS concentration of 10.6 mg/L.

In this section of the Middle Branch Whitewater, the biological stations had macroinvertebrate TSS station index scores which were worse than average, compared to the average coldwater stations in the MR-Winona Watershed (Table 28). All stations had a high number of TSS tolerant taxa, and stations 10LM037 and 10LM007 (2010), also had a high percentage of TSS tolerant macroinvertebrate individuals compared to averages for coldwater stations in the watershed. Generally, intolerant macroinvertebrates and long-lived macroinvertebrates often decrease with increased TSS stress. Both of those metrics are not showing much response in terms of potential stress. Additionally station 10LM007 had an above average number of TSS intolerant taxa. The only station scoring below the impairment threshold in this reach is station 10LM007, and this station is showing mixed macroinvertebrate response between 2010 and 2012. This may be reflecting the varying weather and stream conditions between those two years. In 2010, more rainfall and turbid conditions persisted throughout the year. In 2012, the weather was considered dry and low flow. The macroinvertebrate community showed a mixed response among other sites, and the fish population was rather sensitive to TSS. Stress from TSS appears to be the greatest at station 10LM037 and 10LM007, with a high percentage of TSS tolerant and many TSS tolerant taxa compared to the other stations. The macroinvertebrate biological response evidence, along with existing turbidity impairment further supports that TSS is a stressor in this reach.

Table 28. Macroinvertebrate metrics relevant to TSS for stations in Middle Branch Whitewater compared to averages for coldwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
10LM037	**15.96**	**1**	**8**	**20.31**	**2**	4.58
10LM007 (2010)	**15.61**	4	**12**	**23.88**	7	8.28
10LM007 (2012)	14.32	3	**6**	8.19	5	5.46
10LM002	**15.77**	**1**	**6**	3.80	**2**	5.82
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for coldwater stations in the MR-Winona Watershed	15.11	1.41	4.45	10.94	2.69	3.78

Habitat

All stations in this reach had MSHA scores rated as good, from 77.6 at station 10LM037 to 90.1 at station 10LM007. Station 10LM007 scored well throughout all of the subcategories, contributing to these high MSHA scores. Station 10LM037 had a slightly lowered score due to moderate embeddedness. The channel stability ranking at both stations 10LM007 and 10LM037 scored 30 CCSI which falls in the fairly stable category. However, the score at station 10LM002 was slightly worse at 45, in the moderately unstable category.

Geomorphic characterization by MDNR (Ellefson and Zytkovicz):

Station 10LM037 is located on another habitat improvement area (MDNR Site 94). This part of the stream is classified as a C4, with a VIII(b) valley type, which matches its potential condition. The Pfankuck stability rating for site 94 is considered good. The stream is only slightly incised due to the banks being graded back, and has decent floodplain connection. This site is heavily grazed, and where the channel is not bound by a valley wall, it is mostly grass covered with occasional trees. Bank erosion is non-existent due to the lining of the banks with boulders. This artificial channel will not be adjusting for a very long time due to the construction of hardened riffles and banks.

In contrast, station 10LM007 is located in a valley type VI. The reach where this bio site is located is the most densely populated with landslides from the 2007 flood in the whole watershed. Large quantities of sand, gravel and cobble were contributed to the stream at these locations, inducing channel adjustment. The specific location of this bio site is right at one of these landslides. This location best represented by MDNR site 106 which is located just downstream of another large landslide. The riffle XS is a D channel. The Pfankuch stability rating is rated as poor. A high W/D ratio C4 should be the reference for site 106. The W/D ratio is considered highly unstable with a score of 2.45. The site is deeply incised with a BHR of

2.8. There is excellent riparian cover. The point bars created from the accelerated bank erosion at these sites consist of cobbles, gravels and sands and are being colonized by grasses. It would take flood on the order of the 2007 flood for Site 106 to reach its floodplain. However, if the bank heights were roughly 2.5 feet lower this would put it very close to being connected at the floodprone elevation. The site is mostly bound by valley walls, but at the riffle locations they have fast eroding outside cut banks thanks to the over-wide, low W/D channels dropping their sediment on one side of the channel. This creates transverse bars that force most of the flow against the bank rather than down the center of the channel. Due to the numerous landslides on the reach, the reach has a fairly high rate of erosion considering much of its length is bound by bedrock valley walls. The average erosion rate was 0.12 ft/yr and 0.045 tons/ft /yr. The biggest contributor to this total is the landslides that supply the stream with more large material than it can handle and the material drops out at the valley inflection points. This forces the stream to the outside bend at an extreme angle and induces prodigious bank erosion. Overall the reach is moving 0.55 ft/yr and contributing 0.19 tons/ft/yr. This 3500 foot section of river is estimated to be producing a total of 665 tons of sediment to the river each year. Much of the finer materials from the landslides are deposited in the long, deep pools found upstream of the inflection points, partially or nearly filling the pools , but most pools remain very deep (+4ft at low flow), providing adequate refugia for fish.

The channel bottom farther downstream (DNR site 70) is almost continuous gravel with sand. Most of this gravel was observed to be bright in color and obviously very mobile during floods, producing an ever shifting channel bottom. The reach directly upstream is one of the most prodigious sources of bank erosion since the 2007 flood. It is contributing 0.315 tons/ft/yr to the stream. The pools are around 3.5ft at low flow conditions. This site is moderately to deeply incised with a BHR of 1.51. The Pfankuch stability rating is rated as poor. The competency calculations for both site 94 and 106 indicate that these sites are not able to move the largest particles being delivered to them. This is no surprise for site 106 as a D channel would not be expected to. Site 94 is surprising because any proper channel work should be designed to neither aggrade nor degrade. Site 70 was chosen partly as a reference site because it showed that it was roughly able to pass the biggest material delivered to it. The largest particle from the bar sample was 80mm and using the Colorado curve, it is predicted to be able to move a 74mm particle. This is significant because most survey locations in the watershed to date have shown aggradation as the most likely outcome.

At the lower portions of the three Forks of the Whitewater exist some of the highest banks in the watershed. There is a wedge of increasing incision on all three forks as they approach the main channel. Only the Middle Fork seems to be in the process of building a new floodplain at a lower elevation. The landslides produced in the 2007 flood and large amounts of sediments caused a cascading effect, making nearly every foot down river that was not bound by a rock wall, to adjust. This had a particularly bad effect on the portion of river located between Whitewater State Park and the Middle Fork's confluence with the North Fork. Once the stream was no longer tightly bound by the valley walls it was allowed to drop out its excess bedload, which only initiated more bank erosion. Much of the river in this area has a higher than average sand content as well. This made the banks even more prone to failure. Much of the sand was deposited in the pools, filling many of them. The stream repeats a pattern of splays and transverse bars located between extended, over widened and sand filled pools. Poor riparian management like mown lawns up to stream banks exists at the various campgrounds along this reach. Also floodplain encroachment by paralleling roads and bridges exist here. These high W/D C and D channels have a long recovery period.

Biological Response:

The macroinvertebrate community is sampled based on dominant habitat types found at each station. The macroinvertebrate habitats sampled on all three stations in this reach were riffle/runs, and undercut banks/overhanging vegetation. The macroinvertebrate metrics were compiled for the Middle Branch stations, and then were compared to statewide averages of this stream class (Southern

Coldwater; Macroinvertebrate Class 9) (Figure 60). The percentage of burrowers was low at all three stations, suggesting there are not issues with fine sedimentation in riffle habitats. This is also demonstrated in the habitat data, which shows 0% fine sediments at station 10LM007. Clinger species attach to rocks or woody debris. They can decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). The percentage of clingers was found above average at two of the three stations (45% at 10LM007 and 67% at 10LM037). However, at station 10LM002 clingers were lower than average, at only 16%. At station 10LM037, the percentage of EPT individuals was very high, at 74%, but both stations 10LM002 and 10LM007 had EPT taxa percentages less than average (33% and 29%, respectively). Similarly, a higher percentage of more tolerant legless individuals were found at 10LM007 (58%). Snails were the dominant species collected during the 2010 sample at station 10LM007 which contributed to the high legless and climber numbers. Fifty-eight snails were collected in 2010; 8 were collected in 2012 when a caddisfly was the dominant species. A resample of station 10LM007 in 2012 showed very similar habitat metric percentages as in 2010, but the IBI score increased over 20 points (to a MIBI score of 52.9), which is above impairment threshold.

Habitat does not appear to be driving the macroinvertebrate impairment in this reach. There may be things in terms of habitat that could be improved. Stream instability is well documented in the geomorphic characterization of this reach, and it's possible that impacts to habitat have happened, are recovering, or remain to be seen. For this reason, habitat as a stressor should be carefully revaluated as new information is collected, even though it is not considered a stressor at this time.

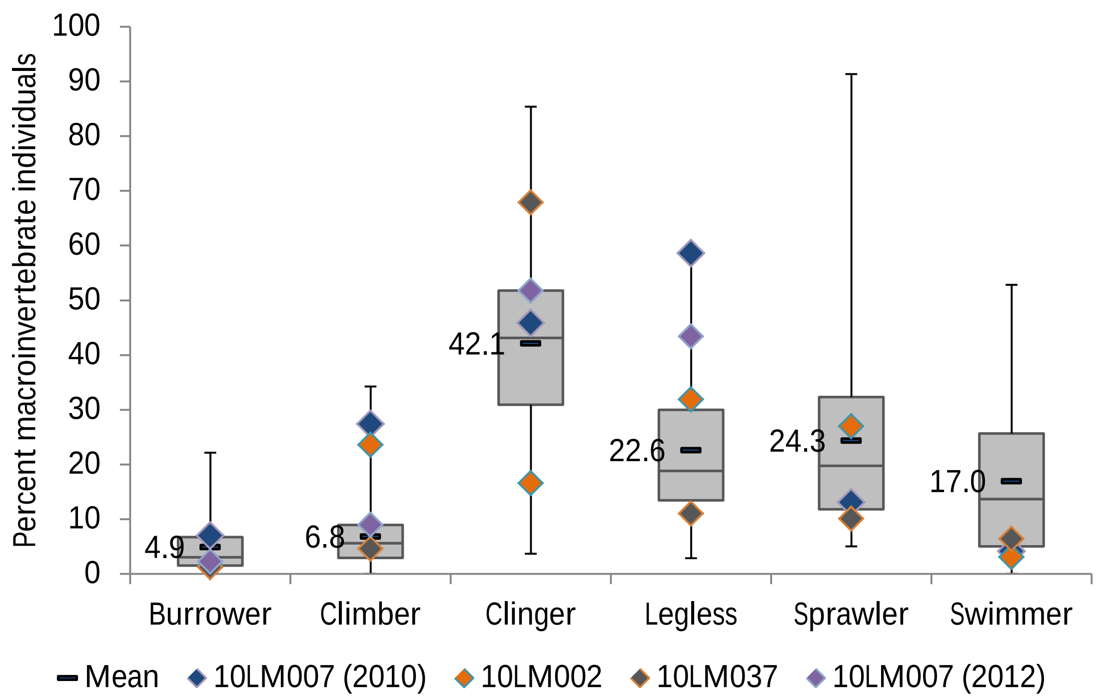

Figure 60. A comparison box plot of macroinvertebrate habitat metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

Conclusions and recommendations

The stressors found in this reach are summarized in Table 29. TSS and nitrate are the main stressors found in this reach, but both are more prominent in the upper end of the reach (10LM037 and 10LM007). The contributions of sediment and nitrate from upstream sources are an important consideration and likely driving many of the issues seen in this reach. However, instability and streambank erosion are also documented in this reach. Habitat is not considered a stressor at this time, but should continue to be monitored. While a DO stressor does not seem likely, additional information on the DO regime in this stream would be useful in completely ruling out that stressor.

Table 29. Summary of stressors found in the Middle Fork Whitewater (F19).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:				
						Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-F19 Whitewater River, Middle Fork, Crow Spring to N Fork Whitewater River	11.39	1A, 2A,3B	10LM037 10LM007 10LM002	Upstream of CR 107 NE, 5 mi. NW of St. Charles Downstream of unnamed road in Whitewater State Park, 5.5 mi. N of St Charles Downstream of Hwy 74,8 mi. N of St. Charles	Macroinvertebrate IBI Turbidity Bacteria Nitrate			●	●	

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.6 Crow Spring (07040003-611)

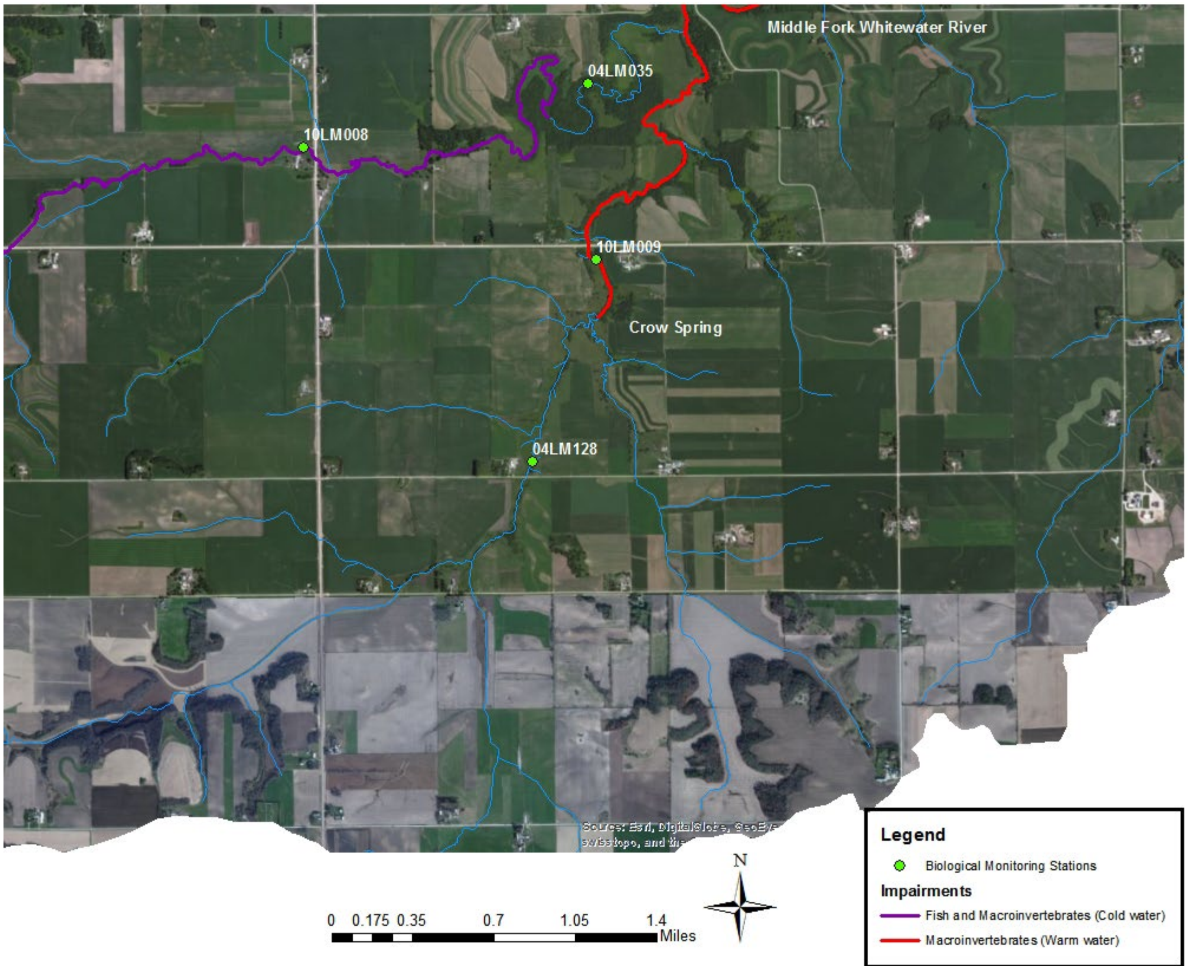

Figure 61. Map of the Crow Spring Subwatershed, biological stations, and impaired AUID.

Supporting information

Biological assessments for the upstream reach of Crow Spring were deferred due to a majority of the reach (55%) being modified consistent with channelization. The downstream reach was assessed as non-supporting of aquatic life based on low macroinvertebrate IBI scores (station 10LM009). The macroinvertebrate community degrades moving downstream. While the community includes coldwater taxa, it lacks sufficient EPT and sensitive taxa. Large quantities of snails were also sampled indicating a stressed community. During biological sampling, pasture was noted in the riparian zone, there was lack of adequate shade/instream cover, and sedimentation was noted as potential stressors to the macroinvertebrate community. In contrast, the fish IBI performs well above upper confidence intervals at both stations. Fish communities of Crow Spring are considered nearly ideal for small cold headwater streams dominated by brook trout, sculpin and brown trout, and have likely benefitted from habitat improvement projects evident throughout the reach.

Biological stations 10LM009 and 04LM128 are on separate AUIDs on Crow Spring, but both are in the coldwater macroinvertebrate class (Class 9) which has an impairment threshold of 46.1. The impaired AUID addressed here includes 10LM009, and while 04LM128 was deferred due to channelization, it is included for comparison purposes. The macroinvertebrate IBI score at station 10LM009 was 27.1 in 2010, and at station 04LM128 scored 44.47 in 2004. The macroinvertebrate IBI metrics for the two stations show a similar response among stations (Figure 62). The lowest scoring metrics were the percentages of collector-filterers and intolerant macroinvertebrates. Both stations scored 0 for intolerant taxa richness, which is a measure of taxa richness of macroinvertebrates with tolerance values less than or equal to 2. Station 10LM009 scored lower than station 04LM128 for the total chironomidae to dipteran abundance, Trichoptera percent, HBI_MN, and very tolerant taxa percentages.

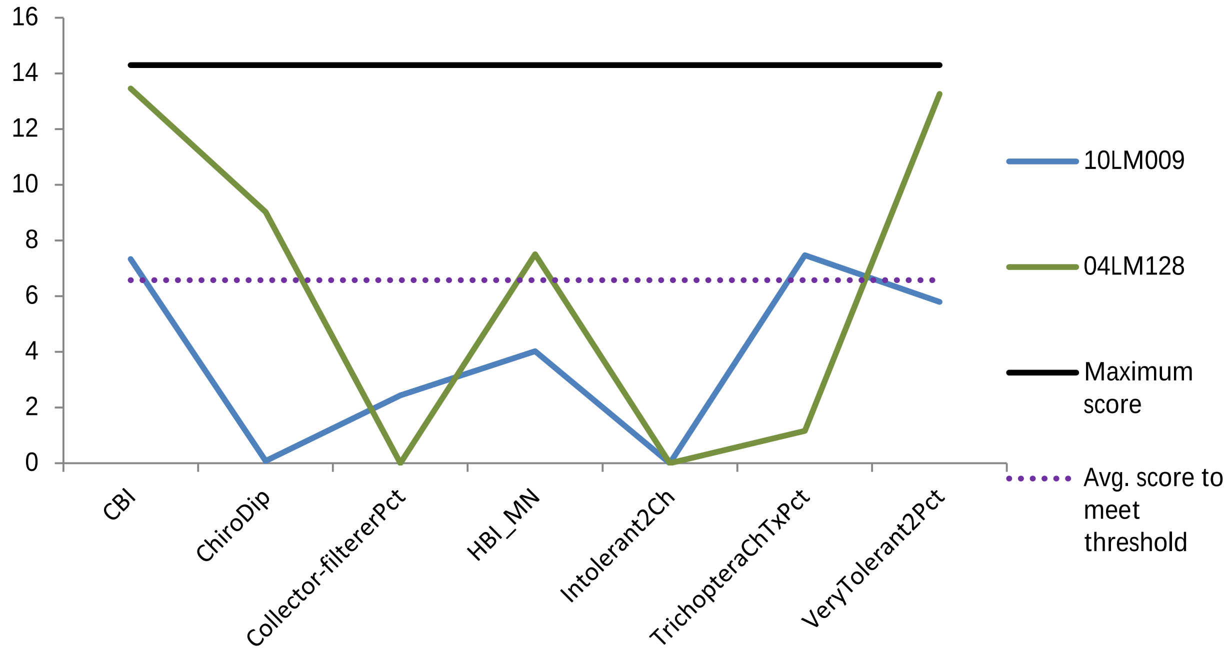

Figure 62. Macroinvertebrate IBI metric scores for Crow Spring

Temperature

There was one temperature measurement (13.5°C) taken during fish sampling at station 10LM009 on June 8, 2010. In addition, temperature loggers were placed at two locations in Crow Spring in 2004 and 2010. The July and August average temperature for station 10LM009 was 14.8°C for both months. Nearby station 04LM028 showed even coldwater temperatures with July and August averages both at 12°C. The average maximum temperature at station 10LM009 was 18°C. In addition, there were 24 temperature measurements taken at station S003-707 in 2011 and 2012. The maximum temperature recorded during this time frame was 17.8°C.

The fish community present in Crow Spring has a strong coldwater signal. The percentage of both coldwater species (ColdPct) and coldwater sensitive species (CWSensitivePct) were 100% for both 10LM009 and 04LM128. Also, both sites showed a high percentage of native coldwater species; 75% and 82% compared to the average of for coldwater stations in the MR-Winona watershed (22%). In addition the macroinvertebrate CBI (coldwater biotic index) metric scored above the average needed to be above the macroinvertebrate IBI threshold (Figure 62). This indicates adequate coldwater macroinvertebrate taxa are present at this site. Suitable temperature is not limiting biology in Crow Spring and temperature is not considered to be a stressor at this time.

Dissolved oxygen

Low DO

During biological sampling at station 10LM009 the DO was measured at 10.6 mg/L on June 2010 at 4:00 pm, and 9.97 mg/L at 5:54 pm in August 2010. The value at station 04LM128 was 10.85 mg/L. At station S005-072, there were 5 DO measurements in 2008 and 2009. The values ranged from 9.88 mg/L to 11.66 mg/L. Continuous data was collected at station 04LM128 in 2012 with values ranging from 7.86 to 13.01 mg/L (Figure 63. Continuous DO at station 04LM128

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. The average number of DO intolerant taxa in coldwater streams in the Lower Mississippi River basin was 9.6, and the average number collected in streams above the threshold was 10.1. The number of DO intolerant taxa was 10 at station 10LM009. The average percentage of DO tolerant taxa was 2.6, above the average percentage collected in streams above the impairment threshold (1.7). In comparison, at station 04LM128, the number of DO intolerant taxa was only 4 and the percentage of DO tolerant taxa was 0.34%. The number of taxa intolerant to low DO at station 10LM009 was above average, including being above the average for sites that were above the threshold. The percentage of DO tolerant taxa at 10LM009 was below the basin average and below the average of those sites that met the threshold. Station 04LM128 had a much lower than basin average number of DO intolerant taxa and a much lower than average percentage of DO tolerant taxa. Based on the DO intolerant taxa and the percentage of tolerant taxa, low DO is not a stressor to the macroinvertebrate community in Crow Spring. These two stations are close in proximity (about 1 mile apart) and it seems unlikely they would have a drastically different DO regimes. The response seen at 04LM128 is likely due to other stress, not low DO stress.

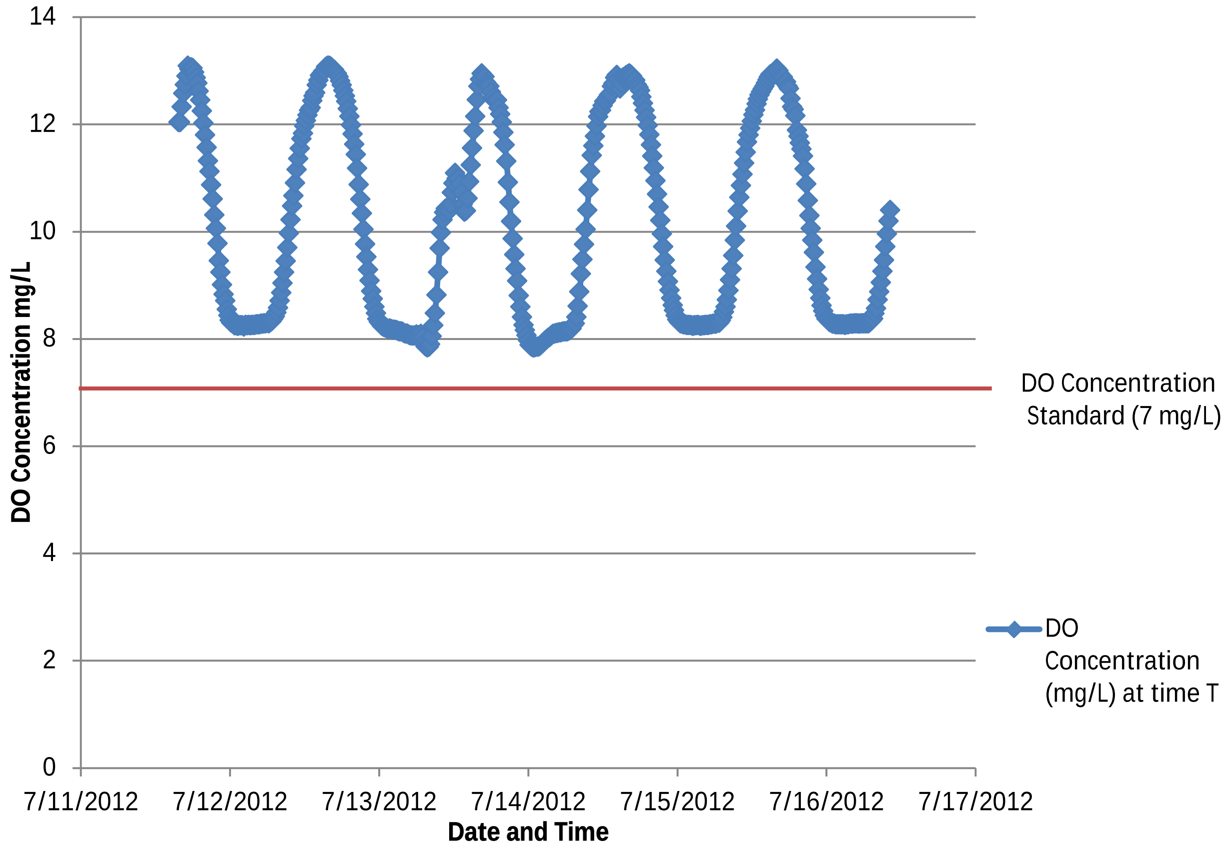

Figure 63. Continuous DO at station 04LM128

DO flux/Eutrophication

Longitudinal morning and afternoon DO sampling in 2012 shows a daily DO flux of 3.45 mg/L at station 10LM009 and 6.71 mg/L at station 04LM128 (Figure 64). Continuous data at station 04LM128 displayed a daily flux range of 4.8 to 5.11 mg/L during the four days the sonde was deployed (Figure 65). The draft standard for DO flux in the central region of the state is 3.5 mg/L.

As interacting variables to eutrophication, phosphorus and pH values were compared to normal ranges and standards. No BOD or chlorophyll-a values were available. The phosphorus concentrations during fish sampling at station 10LM009 and at upstream station 04LM128 were low; 0.025 mg/L and 0.022 respectively. The corresponding pH value during macroinvertebrate sampling was 8.02. At station S003-707, there were 2 pH measurements in 2012; 7.5 and 8.27. Station S003-708 had two samples taken in 2003; 8.0 and 8.2, and a total phosphorus concentration of 0.035 mg/L. Although there is limited data, these values presented do not violate any water quality standards, and are considered within normal range.

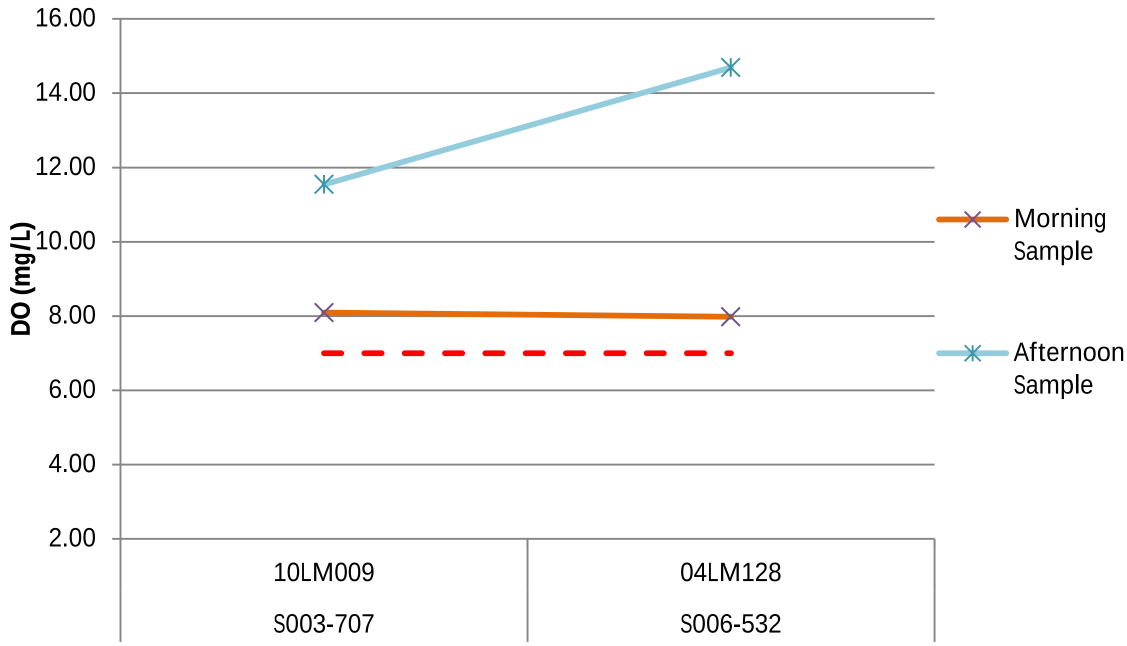

Figure 64. Crow Spring Longitudinal DO on 7/6/12

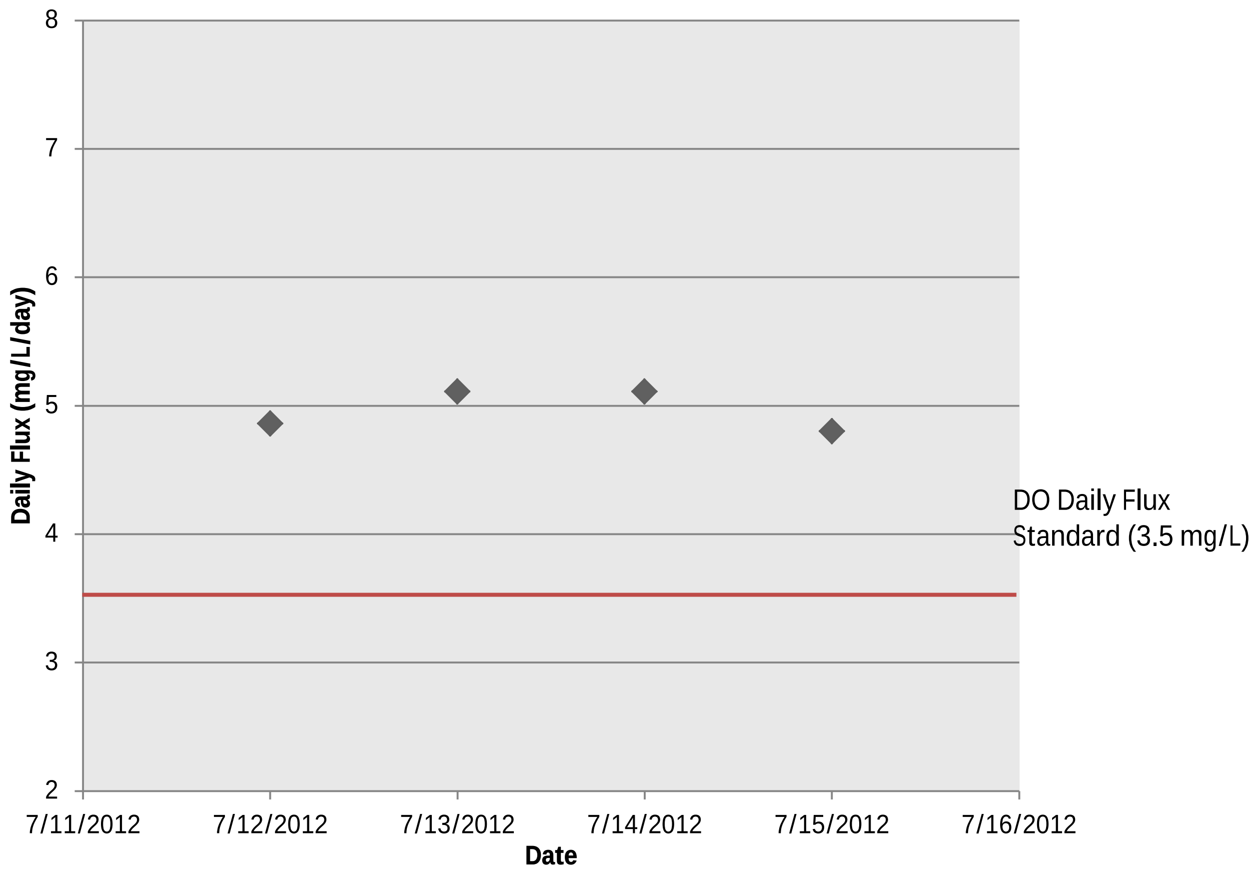

Figure 65. Daily DO flux at station 04LM128

EPT communities are inversely correlated with low DO and DO flux. While there are not any values recorded below the DO standard of 7 mg/L, the morning sample at station 04LM128 was 7.98 mg/L, and the continuous data got to 7.86 mg/L. The average EPT individual percentage in coldwater sites in the Lower Mississippi River basin was 39.55. The percentage of EPT collected at station 10LM009 was 29.5% and 48.66% at station 04LM128. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average for coldwater sites in the Lower Mississippi River basin was 42.68%. Tolerant macroinvertebrates percentage was 44.76% at station 10LM009 and at 8.05% at upstream station 04LM128.

There are some elevated DO values and daily differences in values indicating that DO flux conditions might exist, but there is currently not enough statewide data to make connections with eutrophication and coldwater communities. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

Nitrate

The nitrate concentration during fish sampling at station 10LM009 on June 2010 was 10 mg/L. Upstream at station 04LM128 (in close proximity on AUID 610) had a nitrate sample result of 9.6 mg/L. Other available nitrate information from nearby station S003-707 showed similar elevated concentrations with a range of 9.4 to 11 mg/L from 2003 to 2012

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 stations 10LM009 and 04LM128 had 26 and 13 taxa, respectively (TaxaCountAllChir). This is below the average taxa count for coldwater stations in the LMB (30.01). There were four Trichoptera taxa at station 10LM009 and one at station 04LM128 (7.6% and 15.9% taxa; TrichopteraChTxPct). The corresponding IBI metric score for station 10LM009 was 7.4, above the average metric score needed to be at the IBI threshold. However, for station 04LM128, the metric score was 1.1; below the average metric score needed to be above impairment threshold (Figure 62).

Both stations had a few nitrate tolerant taxa, but not an overwhelming number (9 at station 04LM128 and 14 at station 10LM009). At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI. However, the percentage of nitrate tolerant taxa was high; 96.6% and 83.3%. There were no nitrate intolerant taxa present at either station.

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 IBI metric score and HBI_MN value have a significant relationship with nitrate at the time of fish sampling. The HBI_MN IBI metric score decreases with increased nitrate. In Crow Spring, the metric scores were 7.5 at station 04LM128 and 4.02 at station 10LM009 (out of 14.3). The two results are on either side of the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. Both stations show an elevated HBI_MN value (6.54 and 7.00). 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 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57.

There are fewer nitrate tolerant taxa, but the taxa count is low overall, which is why the percentage of nitrate tolerant taxa is high. No nitrate intolerant taxa were present, and the HBI is mixed, but leans towards nitrate stress. The Trichoptera response is mixed. Stream concentrations are high, and seen at 10 mg/L or above. Nitrate is a stressor to Crow Spring, but the biological response is not strong, so it is not considered the driver of biological impairment. Elevated nitrate concentrations are further stressing the macroinvertebrate community in Crow Spring.

TSS

The TSS concentration during fish sampling at station 10LM009 on June 8th, 2010 was <1 mg/L.

There were 11 transparency measurements taken in 2012. All of the measurements were >100 cm, except for a result from July 25th, 2012 where the transparency was 91 cm.

In Crow Spring, the biological stations had macroinvertebrate TSS station index scores which are only slightly worse than average compared to the average of coldwater stations in the MR-Winona watershed (Table 30). Both stations also had fewer than expected TSS intolerant taxa, but the community wasn't dominated by tolerant taxa or individuals either. Generally intolerant macroinvertebrate individuals and long-lived individuals often decrease with increased stress, which is demonstrated at both locations. The macroinvertebrate community may be responding to TSS, but is more likely responding to another stressor. Channel instability and in stream sedimentation are more likely driving macroinvertebrate issues, instead of suspended sediment. The fish community is very intolerant to elevated TSS, and fish metrics (carnivores, sensitive fish, darter/sculpin, and long-lived fish) are all above average and not suggestive of TSS stress. The chemical data also does not support a TSS stressor, but the dataset is limited. Visual observations also show this stream is clear often. Given the chemical, biological, and physical information, TSS is not a stressor to Crow Spring at this time. Further characterization of TSS concentrations, especially following storm events (magnitude and duration) may be warranted.

Table 30. Macroinvertebrate metrics relevant to TSS for stations in Crow Spring compared to averages for coldwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
04LM128	**15.47**	**0**	2	1.01	**0**	**0**
10LM009	**15.28**	**1**	3	3.70	**1**	**2.85**
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for coldwater stations in the MR-Winona Watershed	15.11	1.41	4.45	10.94	2.69	3.78

Habitat

Station 10LM009 had a MSHA score of 58, which is rated as fair. Nearby station 04LM128 had a MSHA score of 53.6, which is also rated as fair. Station 10LM009 had no riffle, a lack of channel development, a high presence of silt, and fair sinuosity. Station 04LM128 had no riparian buffer or shade. Both stations show a lower score in the land use subcategory. Other metrics are also slightly reduced, but not dramatically. The macroinvertebrate community is sampled based on dominant habitat types found at each station. The channel stability ranking at station 10LM009 scored a 43 CCSI, which falls in the fairly stable category. A score was not available for station 04LM128, because the station was sampled in 2004, before the CCSI was being measured routinely.

Geomorphic characterization by MDNR (Ellefson and Zytkovicz):

Crow Spring has been heavily targeted for habitat enhancements which consist of sloping back the banks reducing incision and entrenchment. They also utilize quarried, boulder-sized rocks to completely line both banks to prevent bank erosion. Many lunker structures are installed on the banks as well. Channel grade is controlled with large rocks or with logs to create plunge pools or steep riffles. Only two sections of this stream remain in their original state and both sections are nearly treeless and grazed. Biological station 10LM009 is located upstream of the Highway 9 and is best represented by DNR site 89 versus site DNR site 91 which is located roughly equal distance downstream. Site 89 is a stream channel type of F4, VI. The potential class is a low W/D C4, as most of the reach is against the valley wall. The Highway 9 crossing is a triple concrete box culvert that has been set low enough to allow for fish passage at low flow through all three culverts. The Pfankuch stability rating at DNR site 89 rated as fair. The channel is entrenched but because it is against the valley wall it has little cutting. Its main issue is it is over-widened and the channel bottom is gravel covered with silt. There is extensive submerged aquatic vegetation on the channel bottom. The BHR is 1.92 making it deeply incised. The channel is poorly connected to its floodplain and the floodplain supports grazing, but the cattle are excluded from the riparian area by fence. The reach representing 10LM009 is quite stable, due partly to lower BEHI ratings (Moderate to High) but mostly because of the overall low NBS rating. The reach is estimated to only be migrating 0.12 ft/yr and contributing 0.023 tons/ft/yr. At this location the grade quickly steepens with a riffle pebble count D50 of 28.9mm, or gravel size. A pebble count taken further downstream near the bio site indicated a far greater portion of silt. The channel overall is also visually filled with silt. Site 89 is not in danger of degrading further. It is entrenched and classifies as an F channel but due to the low bank heights and the rooting depth, it is in overall good shape. Also, the vigor of the riparian plants (due to the fencing out of cattle) results in good root density as well. However, the habitat quality of this site for fish and macroinvertebrates is questionable because of the excessive siltation of the channel bottom.

Biological response

The habitats sampled for macroinvertebrates at station 10LM009 were riffle/runs and undercut banks/overhanging vegetation. At station 04LM128, the habitats sampled were aquatic macrophytes and riffle/runs. The macroinvertebrate metrics were compiled for Crow Spring, and then compared to stations with MIBI greater than the biocriteria for this stream class (Southern Coldwater; Class 9). The results are found in Figure 66. The percentage of burrowers was low at both stations, suggesting there are not issues with fine sedimentation in riffle habitats. However, the percentage of clingers was found below average at both stations (26% at station 10LM009 and 3.6% at station 04LM128). Clinger species attach to rocks or woody debris. They can decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). In addition, EPT taxa are generally impacted by degraded habitat, among other stressors. At station 10LM009, the percentage of EPT taxa was also below average (29%), but above average (48%) at station 04LM128 (Figure 66). Similarly, a higher percentage of more tolerant legless individuals were found at station 10LM009 (38%

compared to 5% at 04LM128). Climbers were found in good percentages at station 10LM009 compared to station 04LM128. Snails were the dominant species collected at station 10LM009, increasing the number of climber and legless numbers at this site. Sprawlers were slightly higher than average at both stations, and swimmers were split. Station 04LM128 was deferred due to channelization, and it's possible that in that location water velocities are likely slower favoring a higher percentage of swimmers, in addition to fine sedimentation favoring sprawlers and reduced clingers.

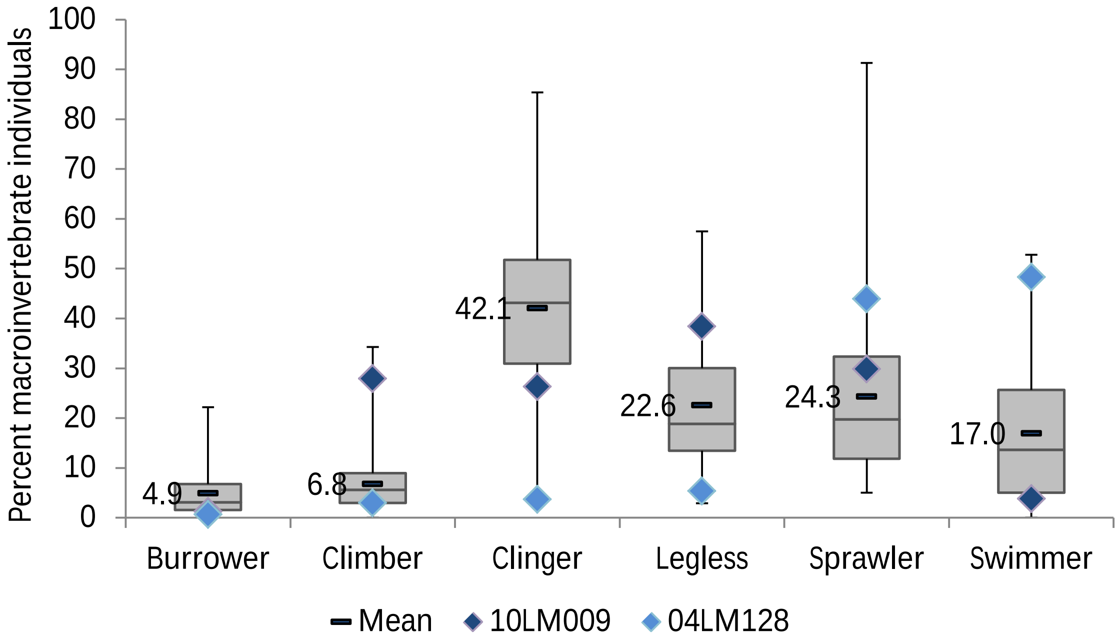

Figure 66. A comparison box plot of macroinvertebrate habitat metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

In stream sedimentation due to upstream pasturing and excessive erosion are most likely contributing to the degraded habitat conditions in Crow Spring. Visual observation of excessive siltation has been documented in this reach (Figure 67). The reduced percentages of clingers and EPT taxa, along with a higher percentage of legless individuals support a habitat stressor to the macroinvertebrate community in Crow Spring.

Figure 67. Crow Spring station 10LM009, middle of reach (MPCA Photo, June 2010)

Conclusions and recommendations

The stressors found in this reach are summarized in Table 31. Habitat loss due to excessive bedded sediment is the driving cause of macroinvertebrate impairment in this reach, followed by high nitrate concentrations. Pasturing and channelization upstream of the reach may explain some of the instability and excess sedimentation found on the stream channel bottom in Crow Spring. Fish are doing well overall. While a DO stressor does not seem likely, additional information on the DO regime in this stream would be useful in completely ruling out that stressor.

Table 31. Summary of stressors found in Crow Spring (611).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors: Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-611 Crow Spring (Middle Fork Whitewater River Tributary), Unnamed Creek to M Fork Whitewater River	2.03	1B, 2A, 3B	10LM009	Upstream of CSAH 9, 4.5 mi. NW of St Charles	Macroinvertebrate IBI			●		●

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.7 Beaver Creek (07040003-566)

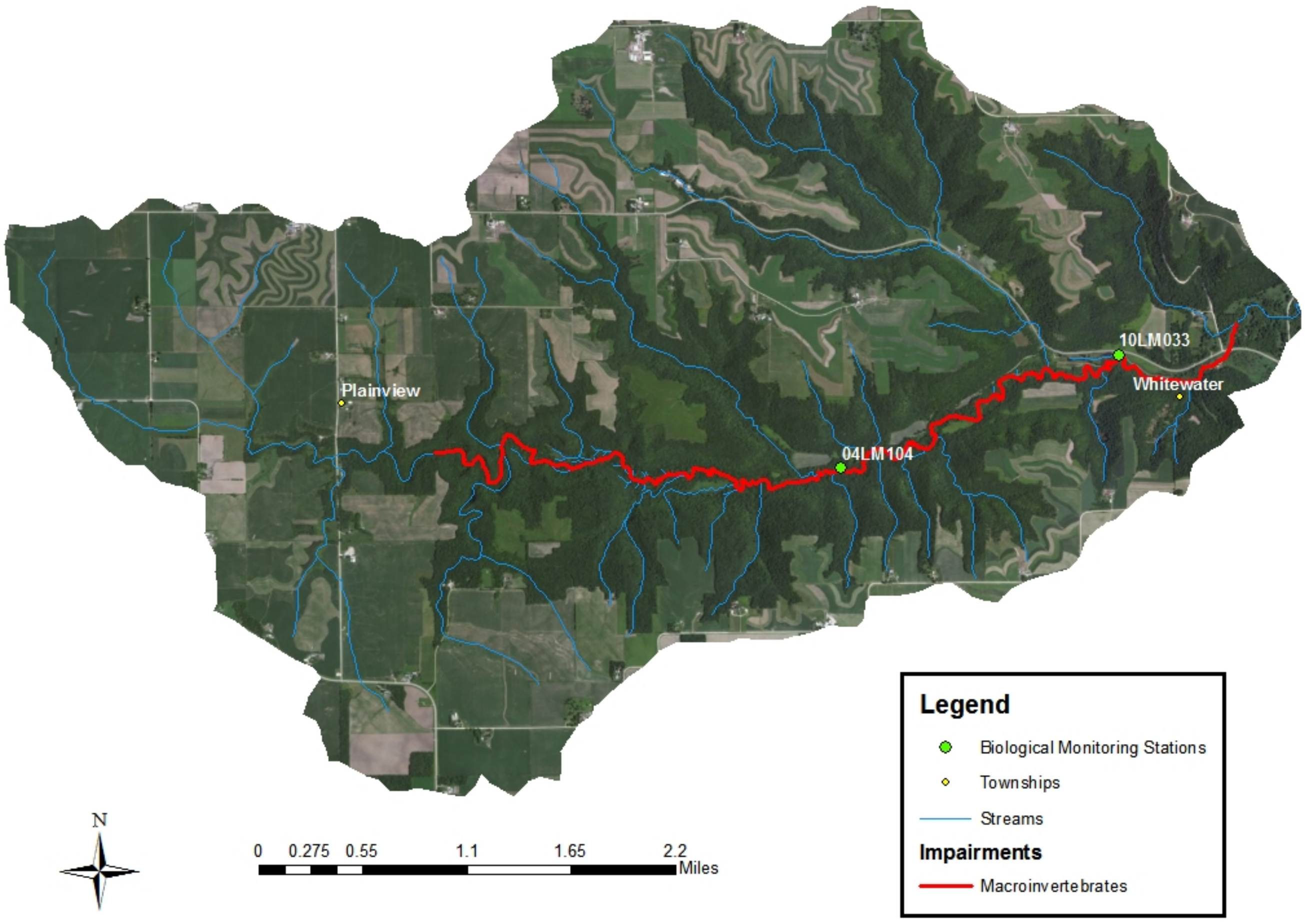

Figure 68. Map of the Beaver Creek Subwatershed, biological stations, and impaired AUID.

Supporting information

Beaver Creek is a small coldwater stream, predominately natural in character (95%) that feeds the mainstem Whitewater River. The observed fish community was typical of a healthy small coldwater stream with low taxa richness dominated by coldwater species, including both brown trout and sculpin, and performed well above upper confidence limits at both stations. The stream was non-supporting of aquatic life use for macroinvertebrates even though turbidity and fish assessments show support (Figure 68). Macroinvertebrate quality increased moving downstream; 2004 visits in the upstream watershed were below lower confidence limits while 2010 visits near the watershed's outlet were above the threshold, indicating localized impairment in the upstream reaches of Beaver Creek (04LM104). During biological sampling, potential habitat issues were noted and include sedimentation of pools, embeddedness of coarse substrates, and a dominance of fine substrates.

There are two stations on this stream reach of Beaver Creek, 04LM104 and 10LM033. Two macroinvertebrate visits occurred at station 04LM104 in 2004, and two replicate samples were taken at station 10LM033 in 2010 for quality assurance purposes. Station 04LM104 was resampled in 2012. All of the sites are in the coldwater macroinvertebrate class (class 9), which has an impairment threshold of 46.1. Both samples in 2004 at station 04LM104 were below impairment threshold (MIBI scores of 27.4 and 43.3). When the site was resampled in 2012, the MIBI increased to 62.1. Both samples at station 10LM033 were above impairment threshold in 2010 (MIBI scores of 65.4 and 65.1). All of the metrics scored above the average scores needed to meet the threshold except for the collector-filterer percentage and the intolerant taxa richness (Figure 69). The ratio of Chironomidae abundance to total Dipteran abundance was the highest score. The chironomid/dipteran ratio measures the number of midges to true flies, and increases with human disturbance. The largest increases in scores at station 04LM104 between 2004 and 2012 were the ratio of Chironomidae abundance to total Dipteran abundance, the collector-filterer individual percentages, and the intolerant taxa richness which were all low during both visits in 2004.

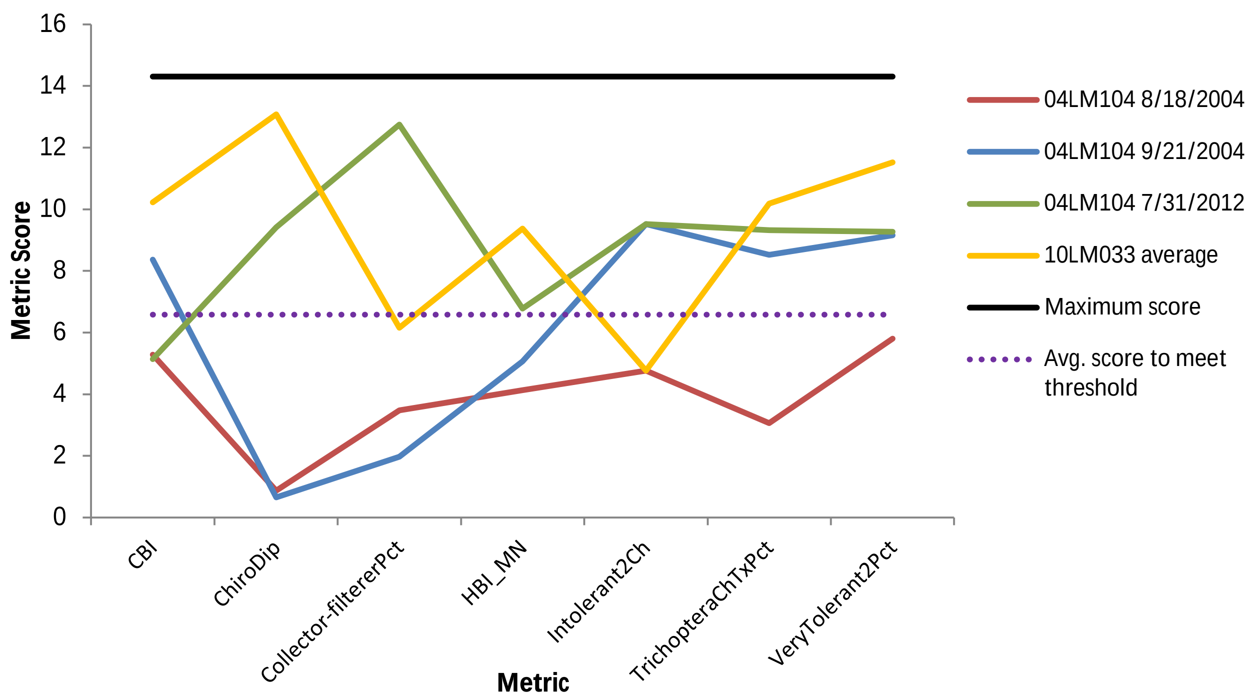

Figure 69. Macroinvertebrate IBI metric scores for Beaver Creek

Temperature

The temperature values recorded during fish sampling ranged from 15.0°C to 17.5°C. On this reach there were 120 temperature measurements taken between 2004 and 2012. The maximum temperature recorded during that time was 18.5°C. In addition, a temperature logger was placed at station 04LM104 in 2004. The average July temperature was 14.9°C, and the August average temperature was 13.8°C (Figure 70). The maximum average temperature of both months ranged from 15.5°C to 17.0°C.

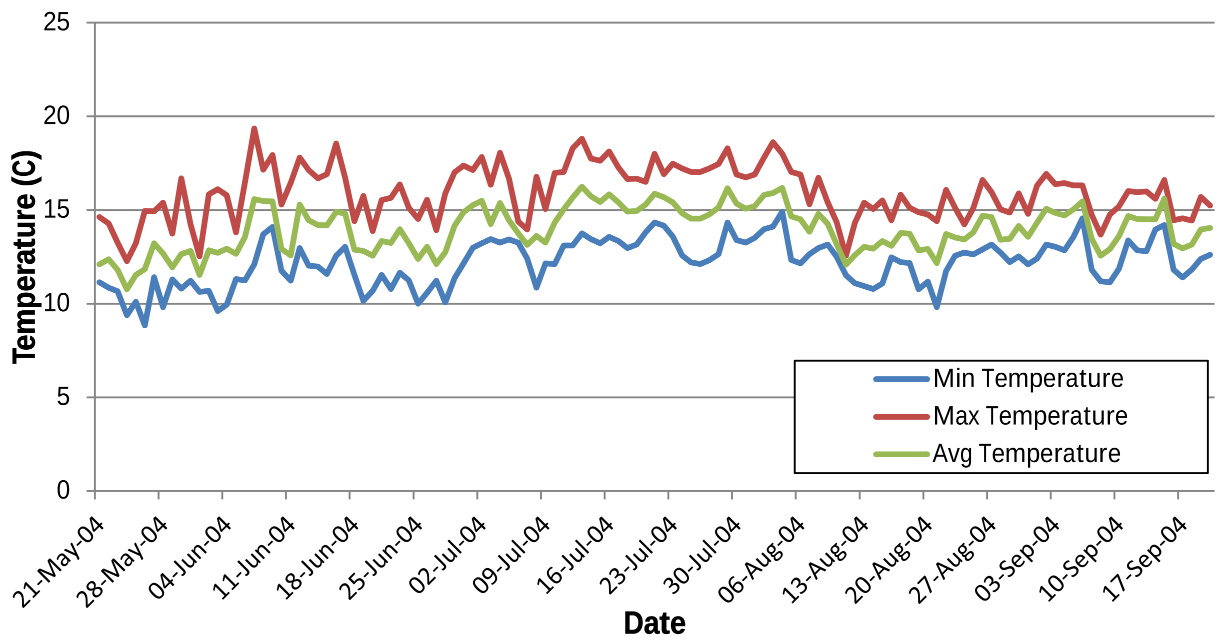

Figure 70. Continuous temperature data collected in 2004 at 04LM104.

The fish community present in Beaver Creek has a strong coldwater signal. The percentage of both coldwater species (ColdPct) and coldwater sensitive species (CWSensitivePct) were near 100% for both 10LM033 and 04LM104. Also, station 04LM104 showed a high percentage of native coldwater species-43%, compared to the average of for coldwater stations in the MR-Winona Watershed (22%). At station 10LM033, the percentage of native coldwater fish species was slightly reduced, at only 15%. The macroinvertebrate CBI (coldwater biotic index) metric scored above the average needed to be above the IBI threshold for two of the four visits on Beaver Creek (Figure 69). The other two visits were just below the average threshold needed (both had a score of 5).

The average summer temperatures are adequate for coldwater streams in the area, the fish community shows a strong coldwater signal, while the coldwater macroinvertebrate individuals appear slightly reduced for two sampling events (CBI metric score). However, there is not strong indication that temperature is stressing the biology in Beaver Creek. Given all the information, including continuous temperature data, lack of coldwater macroinvertebrate taxa is related to another stressor present in Beaver Creek. Temperature is not considered a stressor to Beaver Creek at this time.

Dissolved oxygen

Low DO

During biological sampling the dissolved oxygen concentrations (DO) ranged from 10.2 mg/L to 13.3 mg/L. At station S005-072, there were 5 DO measurements taken in 2008 and 2009. The values ranged from 9.88 mg/L to 11.66 mg/L.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. The average number of DO intolerant taxa in coldwater streams in the Lower Mississippi River basin was 9.6, and the average number collected in streams above the threshold was 10.1.The number of DO intolerant taxa was 9 and 11 at station 04LM104 in 2004, and 11 in 2012 (Table 32). The average percentage of DO tolerant taxa was 2.6% and the average percentage collected in streams above the threshold was 1.7%. The percentage of DO tolerant taxa was 3.78% and 9.16% in 2004, and 3.10% in 2012. The percentage of EPT collected at station 04LM104 was 28.72% and 62.54% in 2004, and 32.5% in 2012. In comparison, the percentage of EPT individuals at station 10LM033 was 62.03%. The number of DO intolerant taxa was 7 and the percentage of DO tolerant taxa was 1.80%. This percentage was also high at station 10LM033. The number of taxa intolerant to low DO at station 04LM104 were just below average at one visit from 2004 and were above average at the other two visits, above average for sites that were above the threshold. Interestingly, station 10LM033 had a lower number of DO intolerant taxa, which was below the coldwater basin average. The percentage of DO tolerant taxa at station 10LM033 was 1.80% which was just above the basin average. While station 04LM104 had two higher than average DO intolerant taxa numbers, this was not the case with DO tolerant percentages. All three percentages were higher than the basin average and average collected in streams that met the threshold, with one 2004 score (9.16) significantly higher. Based on the mixed response, low DO as a stressor is inconclusive.

Table 32. Macroinvertebrate DO metrics

Station (Year sampled)	Percentage DO Tolerant Macroinvertebrate Taxa	DO Intolerant Macroinvertebrate Taxa	Tolerant Macroinvertebrate Percentage
04LM104 (2004)	3.78%	9	63.85
04LM104 (2004)	9.16%	11	29.21
04LM104 (2012)	3.10%	11	57.5
10LM033	1.62%	7.5	32.26
Averages for coldwater stations in the Lower Mississippi River basin	2.6	9.6	42.68
Expected response to stress	↑	↓	↑

DO flux/Eutrophication

Continuous DO data is not available on this creek. As interacting variables to eutrophication, phosphorus and pH values were compared to normal ranges and standards. The total phosphorus concentrations during fish sampling were low; at 0.054 mg/L and 0.046 mg/L. An additional sample from station S007-

073 had a total phosphorus concentration of 0.045 mg/L. Eight pH measurements were available on the stream reach, with values ranging from 7.27 to 8.39 mg/L. These values presented do not violate any water quality standards, and are considered within normal range. BOD and chlorophyll-a data were not available. While nutrient values were low, there was thick macrophyte growth at station 04LM104 (Figure 71). The forested riparian area provides fairly good cover, however the stream is over widened and shallow in some areas.

EPT communities are inversely correlated with low DO and DO flux. The average EPT% in coldwater sites in the Lower Mississippi River basin was 39.55%. The percentage of EPT collected at station 04LM104 was 28.72% and 62.54% in 2004, and 32.5% in 2012. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average percentage of tolerant macroinvertebrates in coldwater sites in the Lower Mississippi River basin was 42.68. Tolerant macroinvertebrates percentages ranged from 29.21 to 63.85%. There are some elevated DO values indicating that DO flux conditions might exist, but there is currently not enough statewide data to make connections with eutrophication and coldwater communities. Further DO monitoring including diurnal monitoring should take place to better understand the DO regime. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

Figure 71. Macrophyte growth in Beaver Creek

Nitrate

The nitrate readings from biological sampling on Beaver Creek ranged from 2.9 mg/L to 3.3 mg/L (3 samples, 2 different biological stations). There was also one nitrate reading taken at S003-562 on March of 2011 and the result was 4.2 mg/L. In addition, another nitrate sample was taken at station 04LM104 in May of 2012 and had a result of 4.1 mg/L. Two samples were taken from springs near station 04LM104 with values of 3.6 mg/L and 4.1 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 at station 04LM104 and 10LM033 had between 23 and 36 taxa (TaxaCountAllChir), which are above and below the average taxa count for coldwater stations in the LMB (30.01). Station 10LM033, (MIBI above threshold) had two visits in 2010 with taxa counts of 20 and 19. In contrast, station 04LM104 (MIBI below threshold) had two visits in 2004 with taxa counts of 30 and 36, There were between 3 and 6 Trichoptera taxa collected at each station (10% to 20% taxa; TrichopteraChTxPct). The result is reflected in the IBI metric score, with all but one visit above the average metric score needed to meet the Southern Coldwater MIBI threshold (Figure 69).

Both stations had a range from 8 to 18 nitrate tolerant taxa (53% to 86% 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. There were fewer nitrate intolerant taxa at the downstream station (10LM033) compared to the upstream station (04LM104). Conversely, there were more nitrate intolerant taxa at station 04LM104 (1-3) compared to the downstream station (only 1-2).

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 IBI metric score and HBI_MN value have a significant relationship with nitrate at the time of fish sampling. The HBI_MN IBI metric score decreases with increased in nitrate. In Beaver Creek, the metric scores ranged from and 4.13 to 9.87 (out of 14.3), most visits which were above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. All visits among the two stations show slightly elevated HBI_MN value (6.53 to 7.00). 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 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57.

Beaver Creek is not dominated by nitrate tolerant taxa, and there are some nitrate intolerant taxa present. Trichoptera, which also respond to elevated nitrate, are found in suitable numbers (reflected in taxa present and IBI metrics). The HBI_MN is slightly elevated, but that information alone is not enough to conclude nitrate is a stressor to Beaver Creek. The nitrate concentrations are slightly elevated, and biological response is weak. The slight biological response observed is likely due to other stressors present, not elevated nitrate. Nitrate is not considered a stressor to Beaver Creek at this time. However, efforts should be made to ensure nitrate concentrations do not increase over time in this watershed.

TSS

At the time of fish sampling in Beaver Creek, the TSS concentrations measured ranged from 2 mg/L to 11 mg/L. During assessment in 2012, the stream was considered fully supporting for turbidity.

In Beaver Creek, the biological stations had macroinvertebrate TSS station index scores near the average for coldwater stations (Table 33). There is variation on sampling dates and years, and the two stations do not show a consistent response. While there is some response shown, most metrics are very near the average for coldwater stations in this watershed and are not demonstrating overwhelming response. Additionally, the fish community at both stations has a high percentage of carnivores (56% and 83%), darters/sculpin, and sensitive species (99% at both stations), all of which can respond to increases in

TSS. The macroinvertebrate response shown in Table 33, is weak and likely due to another stressor. Given the chemical and biological information, TSS is not considered a stressor to Beaver Creek at this time.

Table 33. Macroinvertebrate metrics relevant to TSS for stations in Beaver Creek compared to averages for coldwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
04LM104 (August 2004)	**16.03**	**1**	3	**28.40**	**2**	**3.37**
04LM104 (September 2004)	**15.87**	2	**8**	**11.07**	4	**1.03**
04LM104 (2012)	15.08	3	3	**11.72**	6	**3.75**
10LM033 (2010)	**15.20**	**1**	2	0.72	**2**	**0.31**
10LM033 (2010 Replicate)	14.89	2	1	1.08	**2**	**0**
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for coldwater stations in the MR-Winona Watershed	15.11	1.41	4.45	10.94	2.69	3.78

Habitat

Station 10LM033 had a MSHA score of 64, which is rated as fair. Station 04LM104 had a MSHA score of 87.3, which is rated as good. Station 10LM033 had a lowered score based on lack of depth variability, no riffles, and fair channel development. Station 04LM104 scored well across the board in 2004 but scored slightly lower in 2012 due to the introduction of silt. The channel stability ranking at 10LM033 scored a 46 CCSI, which falls in the moderately unstable category. A score was not available for station 04LM104, because the station was sampled in 2004, before the CCSI was being measured routinely.

Geomorphic Characterization by MDNR (Ellefson and Zytkovicz):

Beaver Creek is classified as a B4c stream channel, in the upper reaches. The width depth ratio is high (7.63), and the channel is deeply incised in some locations. There is a high sediment supply, and moderate deposition was noticed in the reach (Figure 72). The BEHI was considered moderate, with a Pfankuch rating of fair (score 72).

Figure 72. Habitat conditions on Beaver Creek

Biological Response:

The macroinvertebrate community in Beaver Creek shows some biological response to habitat issues in the upper reach, near station 04LM104. The community is sampled based on dominant habitat types found at each station. The habitats sampled in Beaver Creek were riffle/runs, undercut banks/overhanging vegetation, and woody debris at station 04LM104 in 2004. In 2012, all four habitat types were sampled at this site, with the addition of macrophytes. At station 10LM033, riffle/runs, undercut banks/overhanging vegetation, and woody debris were sampled on the first visit, but the second visit only sampled macrophytes and undercut banks/overhanging vegetation.

The macroinvertebrate metrics were compiled for Beaver Creek, and then compared to statewide averages of this stream class (Southern Coldwater; Class 9). There was an abundance of burrowers found at all three visits at station 04LM104, which may indicate sedimentation in riffle habitats. In addition, a higher percentage of more tolerant legless individuals were found at station 04LM104 compared to station 10LM033 (Figure 73). The percentage of clingers was below average for both visits in 2004 at station 04LM104 (18% and 20%). However, in 2012 the clinger percentage was higher at 54%. Clinger percentages at station 10LM033 were below average or just above the average. Clinger species attach to rocks or woody debris. They can decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). The percentage of EPT individuals was also low for two of the three visits at station 04LM104. At station 10LM033, EPT percentages were above average for both visits. Habitat stress is demonstrated at station 04LM104 more so than the downstream station 10LM033.

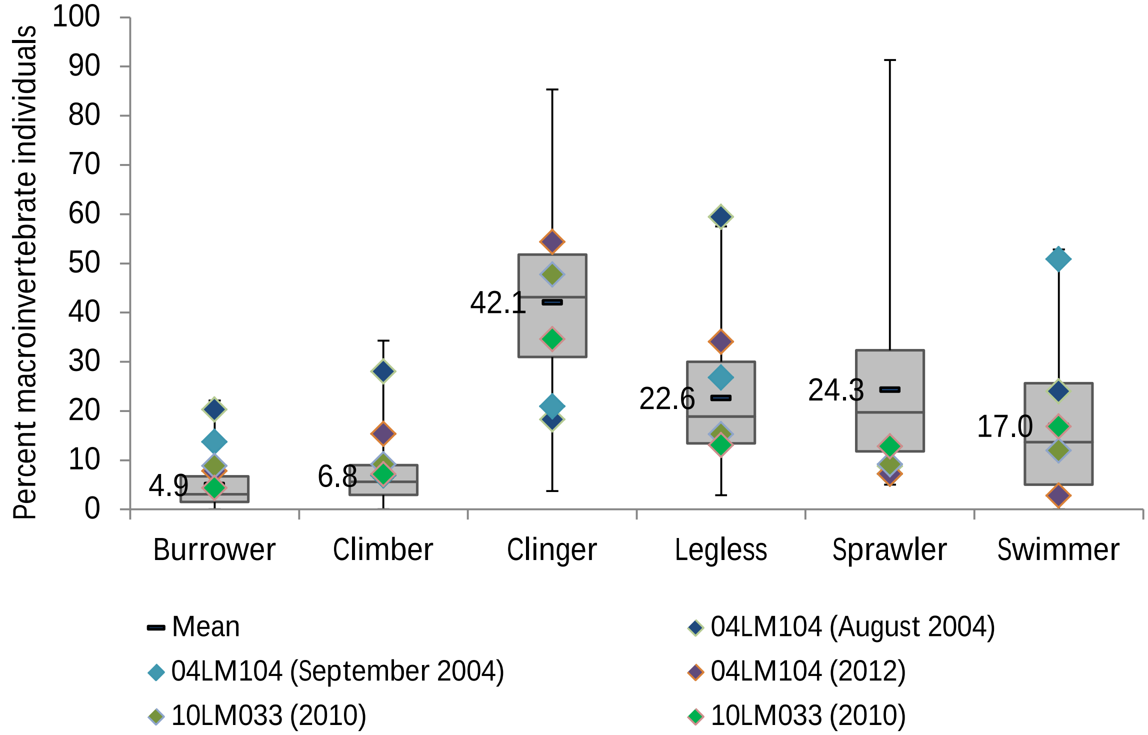

Figure 73. A comparison box plot of macroinvertebrate habitat metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

Conclusions and recommendations

The stressors found in this reach are summarized in Table 34. Habitat is the primary stressor affecting the macroinvertebrate community in Beaver Creek. The high percentage of burrowers and legless macroinvertebrates, coupled with lower percentages of clingers and EPT indicate that habitat stress, especially at station 04LM104. More recently, samples in 2012 show better results at station 04LM104, which may indicate temporal improvement.

Nitrate levels are starting to become elevated (~4 mg/L), and should be monitored over time. Efforts should be taken to ensure nitrate concentrations do not increase in this watershed. Further DO monitoring including diurnal monitoring should take place to better understand the DO regime.

Table 34. Summary of stressors found in Beaver Creek (566).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:				
						Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-566 Beaver Creek, T108 R11W S24, west line to Unnamed Creek	6.6	1B, 2A, 3B	04LM104 10LM033	Adjacent to Whitewater Township Rd 10, in Whitewater State Park WMA, 6 mi. E of Plainview Adjacent to CSAH 30, 7 mi. E of Plainview	Macroinvertebrate IBI					●

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.8 Bear Creek (07040003-581)

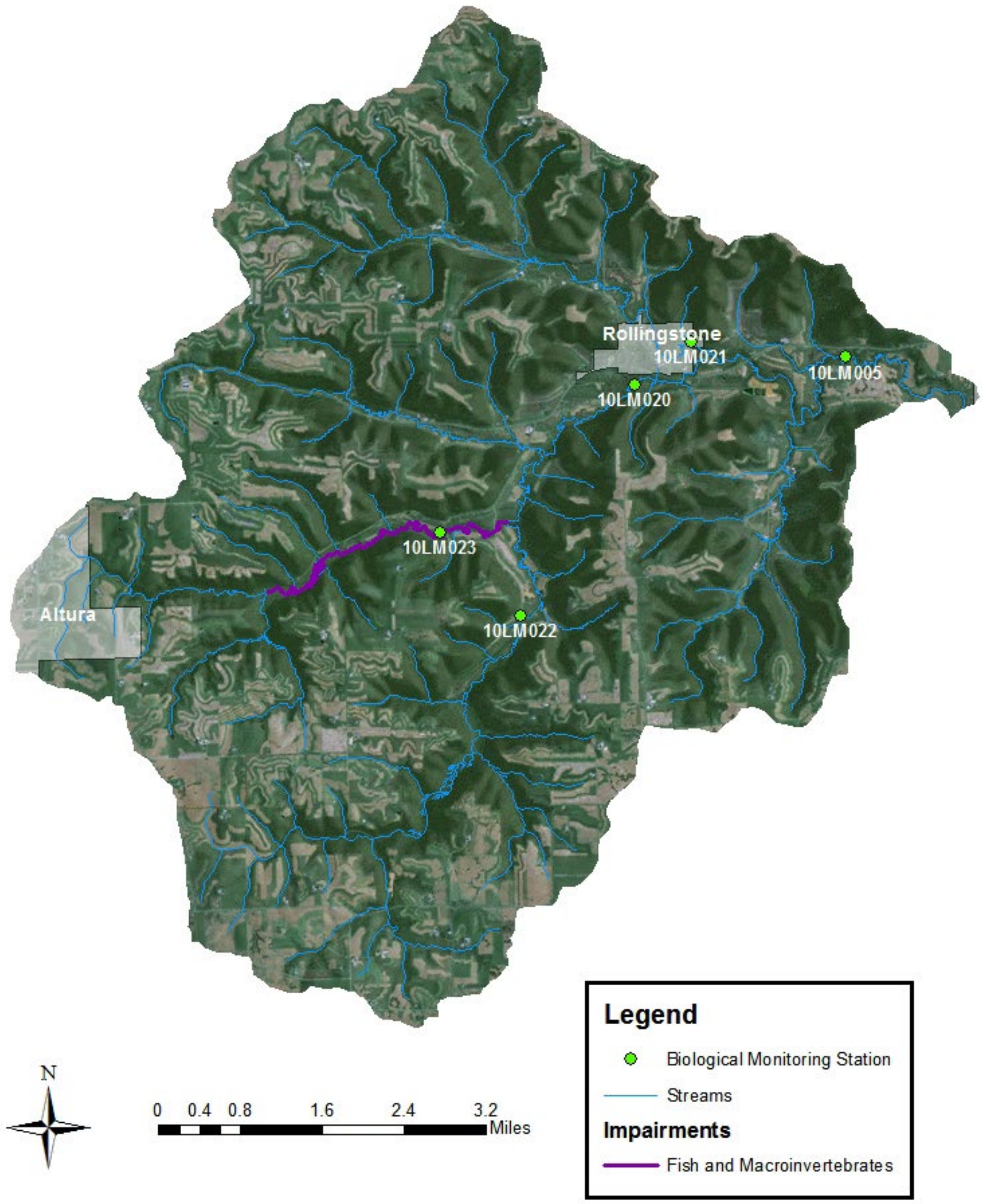

Figure 74. Map of the Bear Creek Subwatershed, biological stations, and impaired AUID.

Supporting Information

Bear Creek station 10LM023 was sampled in 2010, then resampled in 2012 because it scored so close to the threshold in 2010 (FIBI of 46). The FIBI score was lower in 2012 with a score of 39. The biological station is in the southern coldwater fish class (class 10) which has an impairment threshold of 45. The 2012 visit scored lower on the percentage of pioneer individuals and the percentage of detritivorous taxa percent (SdetTxPct) than in 2010 (Figure 75). The native coldwater taxa scores were zero during both visits, and the coldwater taxa percent and coldwater sensitive individual percentage were both also very low during both years. Both visits scored the maximum score for herbivore percentages.

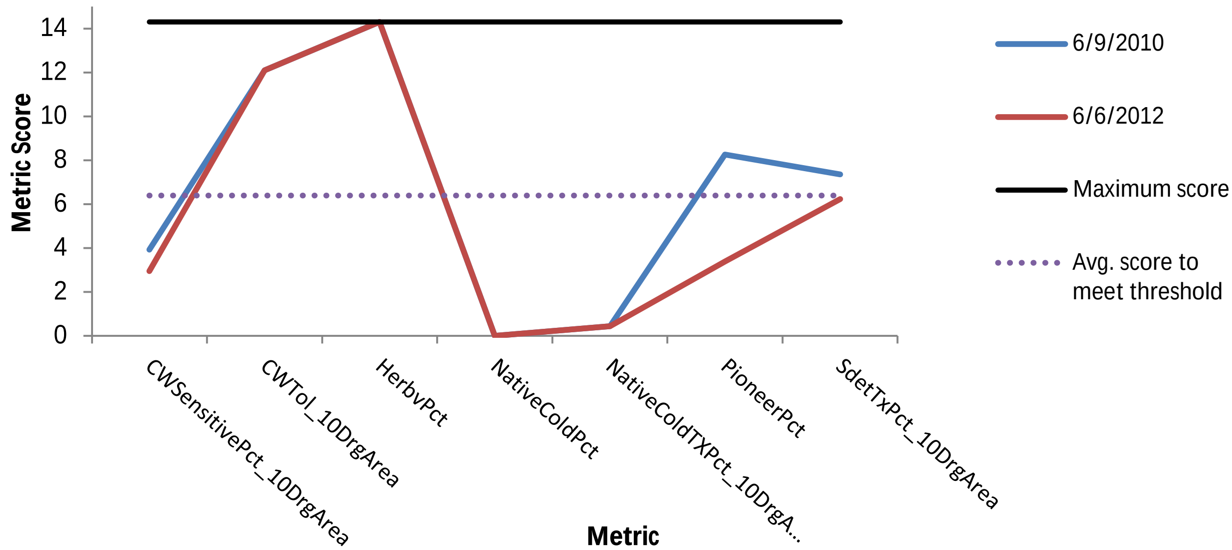

Figure 75. Fish IBI metric scores for Bear Creek

Two macroinvertebrate samples occurred on Bear Creek; one in 2010 and one in 2012. The MIBI in 2010 was 27.3 compared to 32.9 in 2012. Both are below the impairment threshold (46.1) for the coldwater macroinvertebrate class (Class 9). Trichoptera taxa percent was 0 during both visits (Figure 76). The ratio of Chironomidae to Dipteran abundance was also low during both visits. Collector filterers scored poorly in 2010, but scored better in 2012.

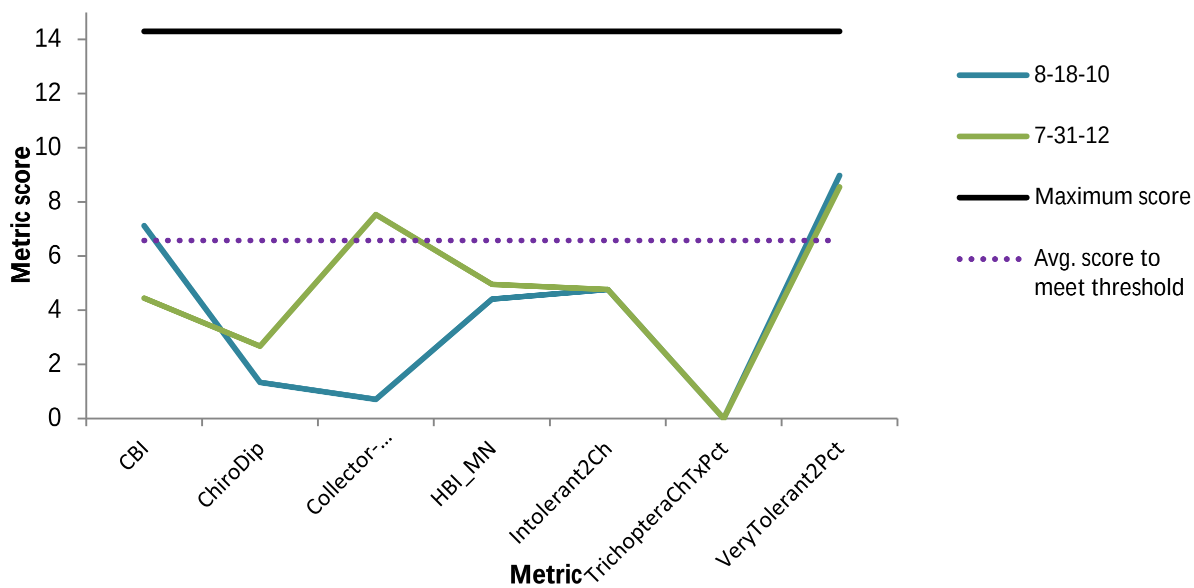

Figure 76. Macroinvertebrate IBI metric scores for Bear Creek.

Temperature

There were two temperature measurements (15.6°C, and 16°C) taken during fish sampling at station 10LM023 on June 2010 and June 2012 respectively. In addition, in 2010 and 2012, continuous temperature was collected (Table 35). The data from 2012 (very dry/low flow year) does show some concern regarding suitable in-stream temperatures, especially in July, while the data from 2010 appears more suitable (Figure 77). Climatologically speaking, 2010 had above average rainfall for most of the spring/summer months (slight deficit in August). The overall air temperature in August was also high in 2010. The maximum stream temperature recorded in August 2010 is significantly higher than the other two months, which supports the climate differences (Table 35). Similarly, while 2012 was dry throughout the summer, the month of July was documented as very warm, with 11 days of air temperature above 90°F in the Rochester area (NWS LaCrosse). This further demonstrates the impact of dry and hot climate conditions on Bear Creek.

Table 35. Summary of continuous temperature information at 10LM023 for two different years. Red text indicates concern regarding temperature.

Year	July Average Temperature °C	July Maximum Temperature °C	August Average Temperature °C	August Maximum Temperature °C
2010	15.8	17.6	17.5	22.4
2012	19.5	24.1	16.9	21.4

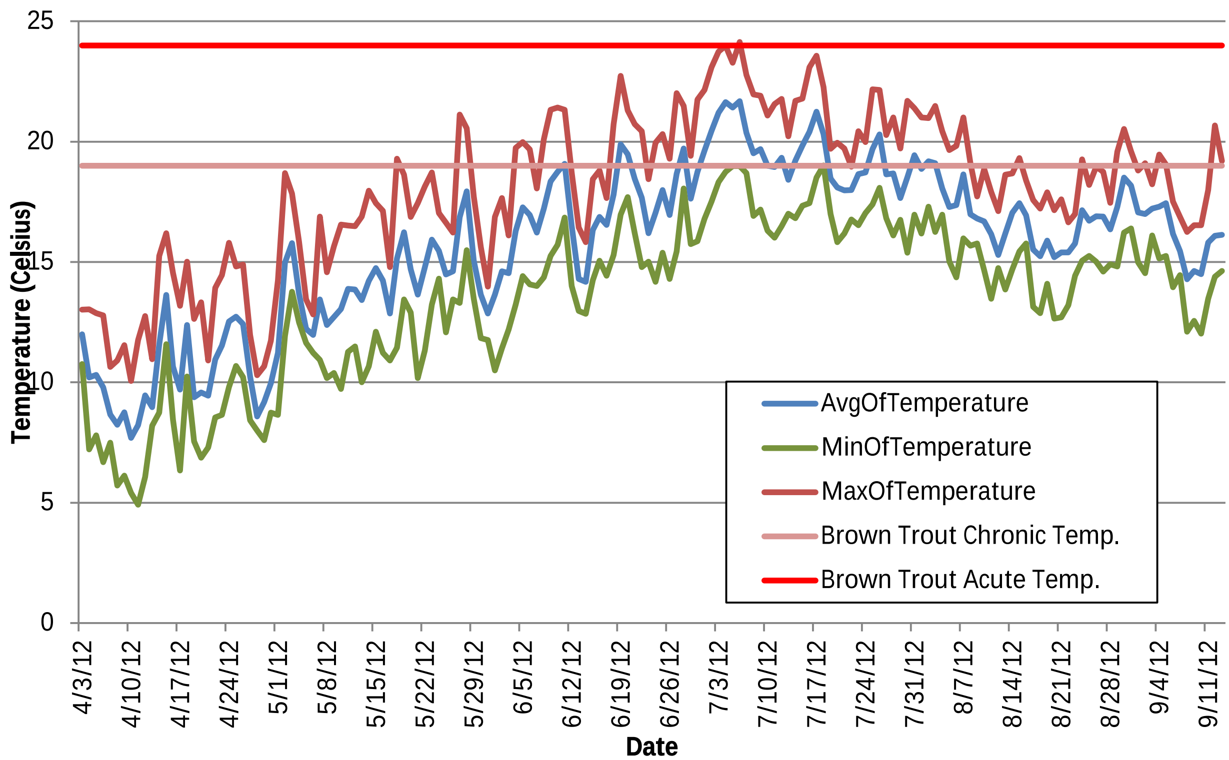

Figure 77. Continuous temperature data collected at 10LM023 in 2012 showing the daily average, daily maximum, and daily minimum temperatures recorded. Brown trout chronic and acute temperatures are also shown for reference.

The fish community in Bear Creek shows a general lack of coldwater fish species, which can indicate thermal degradation. During visits in 2010 and 2012, the percentage of coldwater fish species (ColdPct), coldwater sensitive fish species (CWSensitivePct) and native coldwater species (NativeColdPct) were all well below average when compared to other coldwater stations in the MR-Winona watershed (Table 36). This is also demonstrated in Figure 75, with a resulting lower than average IBI metric scores during both fish visits. The CBI (coldwater biotic index) macroinvertebrate metric scored fair; with one visit near the average (2010) and one just below the average threshold needed to be above the IBI threshold (2012). This indicates there are a fair number of coldwater macroinvertebrate taxa present, but more reduced numbers in 2012 (Figure 76).

Table 36. Fish metrics for Bear Creek related to temperature and compared to the MR-Winona Class 10 (coldwater) averages

Site	Stream Name	Visit Date	ColdPct	CWSensitivePct	NativeColdPct
10LM023	Bear Creek	09-Jun-10	28.57	37.50	0.00
10LM023	Bear Creek	06-Jun-12	16.67	31.03	0.00
		MR Winona Class 10 Averages	***51%***	***61%***	***22%***

The lack of coldwater fish species in conjunction with continuous temperature data, demonstrate thermal stress in Bear Creek. A general lack of riparian shading and sedimentation likely play a role in thermal degradation seen in Bear Creek. It does appear that temperature stress is more pronounced in low flow years with higher temperature measurements and additional biological response (e.g. 2012). Temperature is a stressor to the biological communities (fish and macroinvertebrates) of Bear Creek. Thermal regime should continue to be monitored including identification of groundwater sources, along with other sources, and hydrologic residence time.

Dissolved oxygen

Low DO

The only available DO data were taken during biological sampling at station 10LM023. The results were 9.92 mg/L in 2010 and 10.29 mg/L in 2012 during fish sampling. Both values were taken in the mid-morning hours. Values recorded during macroinvertebrate sampling were 7.99 mg/L at 5:06 pm during 8/2010 and 8.19 mg/L during 7/2012 at 9:50 am. Continuous DO was collected in 2012, with values dropping below the coldwater water quality standard every day except for one day of the deployment (Figure 78).

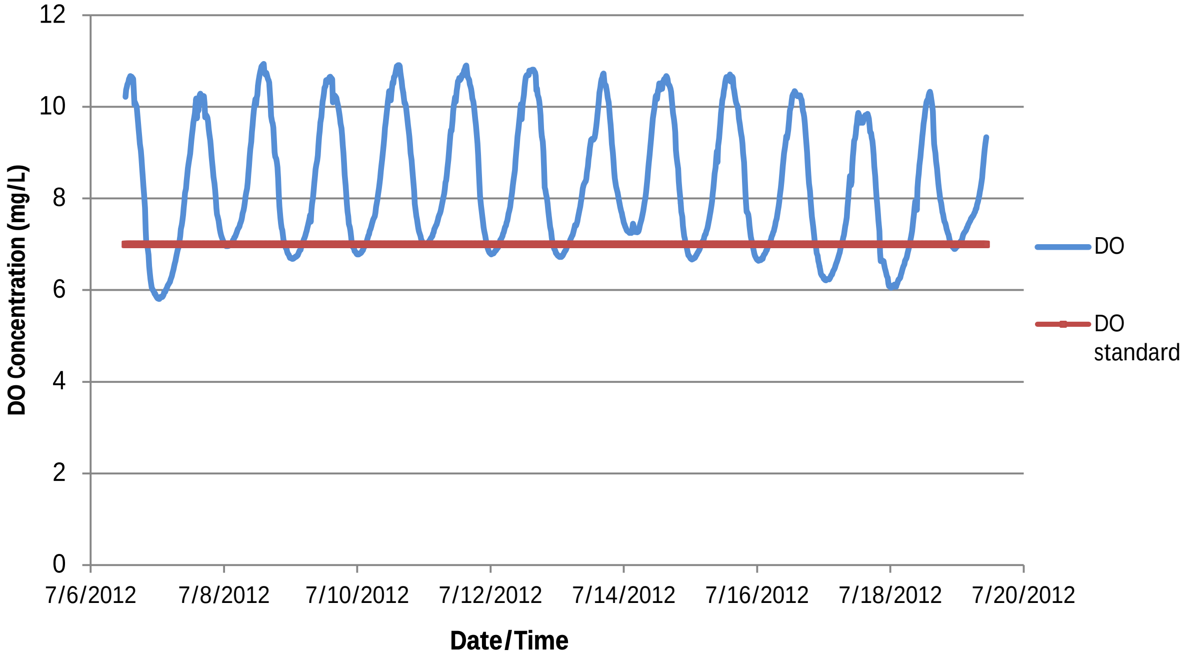

Figure 78**. Continuous DO data collected on Bear Creek in 2012.**

The early morning low DO tolerance indicator values show fish communities comprised of greater than 60% of fish in the second quartile which have generally more tolerance to low DO, which include: white suckers, creek chubs, and johnny darters (Figure 79). Brown trout were also collected, which are in the quartile least tolerant to low DO conditions (Q4). In comparison, Rollingstone Creek which is not impaired is comprised of more than 50% of fish in Q4. Low DO values also correspond with increased tolerant species and decreased sensitive species. The average percentage of sensitive individuals at coldwater sites in the Lower Mississippi River basin was 51.67%, and the average tolerant percentage was 40.61%. The two visits on Bear Creek had samples with sensitive percentages of 37.5% and 31.03%, and tolerant percentages of 48.21% and 31.03%. Comparatively, station 10LM022 on Rollingstone Creek had a population comprised of 84% sensitive individuals and 16% tolerant. Fish that mature at greater than three years of age also decrease with low DO conditions. The average percentage of individuals at coldwater sites in the Lower Mississippi River basin was 41%. The two visits on Bear Creek had 16.67% and 28.57% of fish that mature at greater than three years. In comparison, station 10LM022 on Rollingstone Creek had 58%. Based on the lower numbers of sensitive percentages, mature age individuals, and DO tolerant individuals, low DO is a stressor to the fish community of Bear Creek.

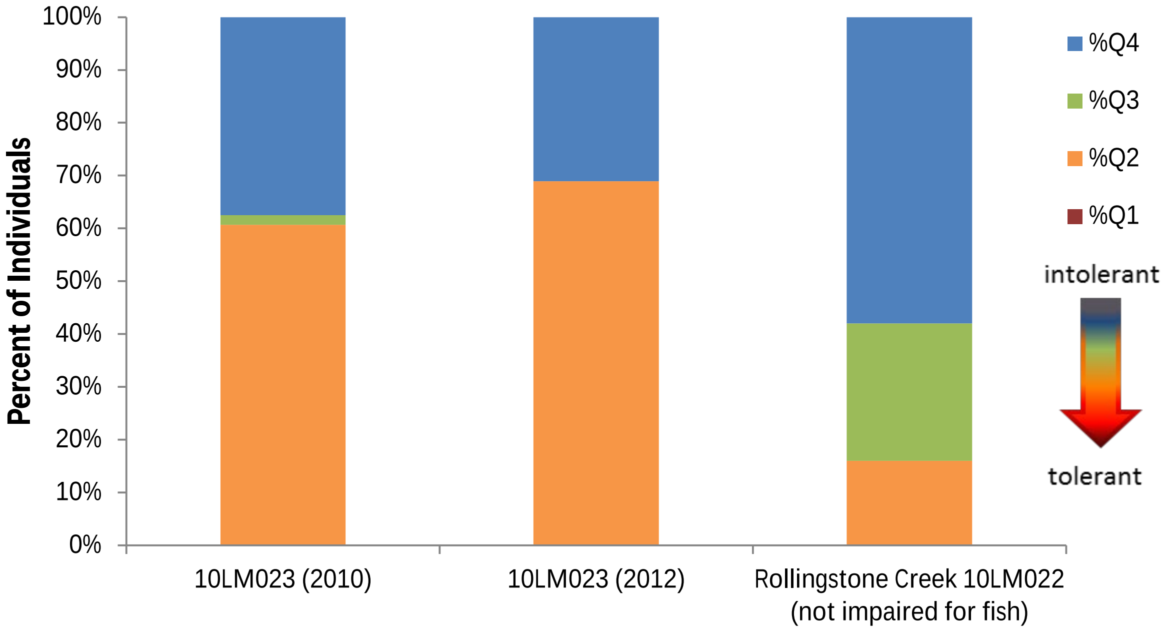

Figure 79. DO TIV's for fish on Bear Creek (comparing to nearby Rollingstone Creek), showing composition of DO tolerant fish individuals.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each visit. The average number of intolerant taxa collected in coldwater sites in the Lower Mississippi River basin was 9.6 and the average percentage of low DO tolerant taxa was 2.9%. During the two visits at station 10LM023, seven and eleven macroinvertebrate taxa that are intolerant to low DO were collected and 2.64% and 2.40% DO tolerant taxa were collected in Bear Creek. The average number of intolerant taxa in those sites that met the coldwater threshold was 10.1 and the average DO tolerant taxa percent in sites that met the threshold was 1.3. The DO intolerant macroinvertebrate taxa were slightly below the average at one visit and both visits had lower than average taxa that are tolerant to Low DO for coldwater sites in the Lower Mississippi River basin. Based on this evidence, low DO is not considered a stressor to the macroinvertebrate community.

DO flux/Eutrophication

Along with low values, DO readings were also high, with daily maximums ranging from 6.78 to 10.91 mg/L (Figure 80). Daily flux values were as high as 4.48 mg/L. The proposed water quality standard for DO flux in the central region of the state is 3.5 mg/L. Plant and algal respiration and photosynthesis are considered the primary drivers of daily flux in DO. Interacting variables include increased temperature, lack of habitat, and lack of shading, all of which are present in Bear Creek. While available phosphorus concentrations are low, algal periphyton growth is present in the stream (Figure 81).

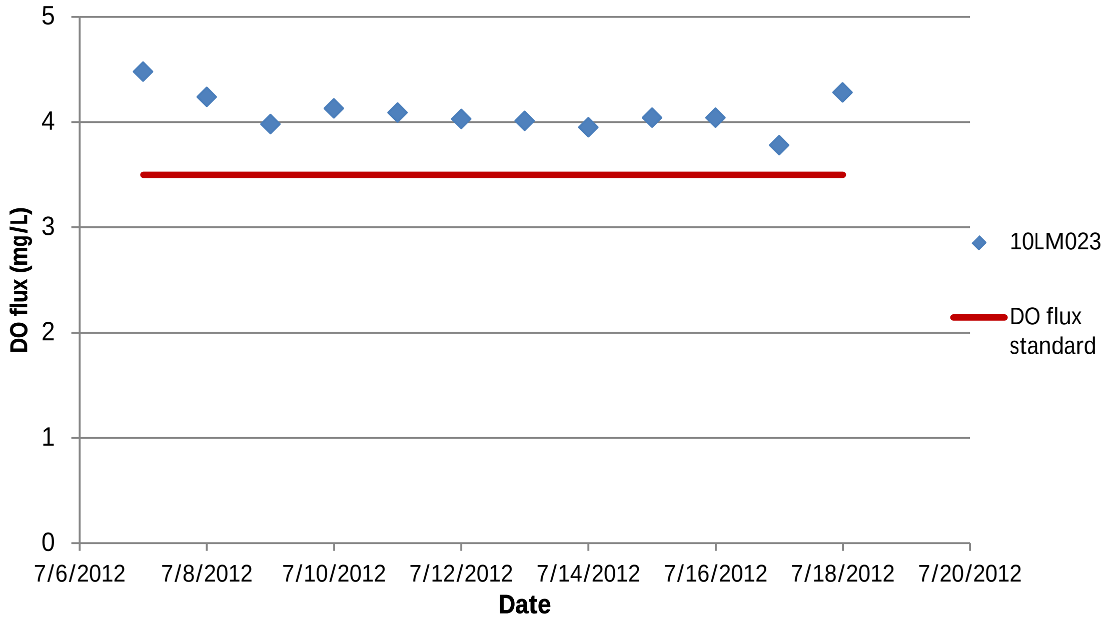

Figure 80. DO flux data collected on Bear Creek in 2012.

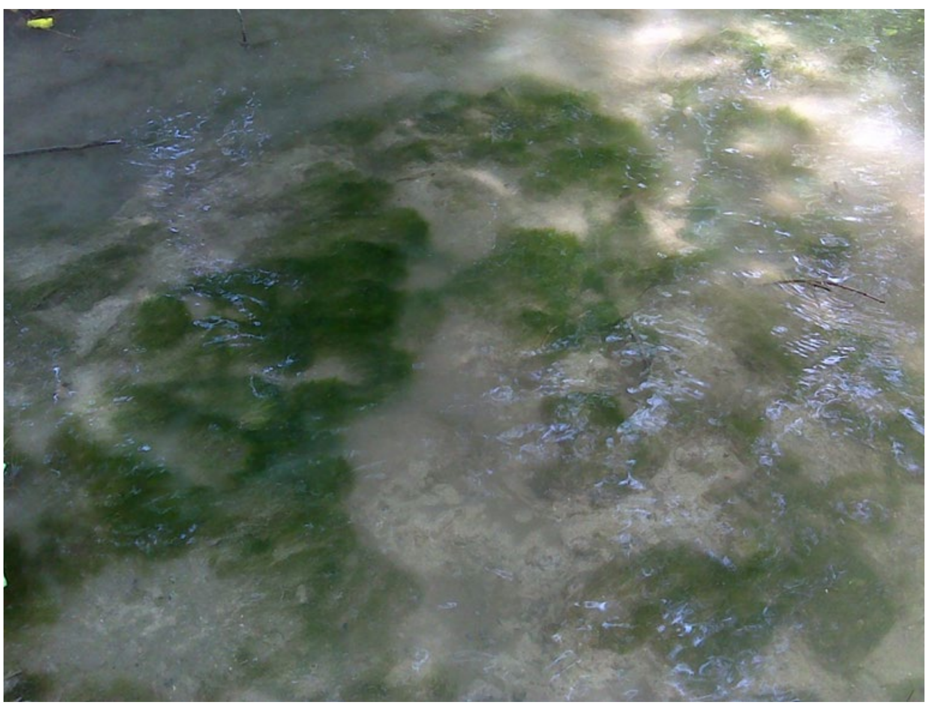

Figure 81. Algal growth in Bear Creek

As interacting variables to eutrophication, available phosphorus and pH values were compared to normal ranges and standards. The range of pH values was 8 to 9.47. A pH of 9.47, which is very high, was collected at station S007-074. The pH values collected while the sonde deployed ranged from 7.85 to 8.44, which is within the pH standard for coldwater streams (6.5-8.5). However, daily pH flux was indicative of nutrient enrichment with a range from 0.35 to 0.49. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013). The total phosphorus concentrations available were low, ranging from 0.038 mg/L to 0.053 mg/L. In this size stream any influx of TP can create accelerated plant growth which can cause increases in daily DO flux.

EPT communities are inversely correlated with low DO and DO flux. The average in coldwater sites in the Lower Mississippi River basin was 39.55%. The percentage of EPT collected at station 10LM023 was 54.52 and 32. The EPT percentages are higher than average during one visit and just below during the other. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average percentage of tolerant macroinvertebrates in coldwater sites in the Lower Mississippi River basin was 42.68. Tolerant macroinvertebrates percentages ranged from 32.26 to 58.93%. There are some elevated DO values indicating that DO flux conditions might exist, but there is currently not statewide data to make connections with eutrophication and coldwater communities at this time. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

Nitrate

There were two nitrate samples (3.2 mg/L and 3.5 mg/L) taken during fish sampling at station 10LM023 on June 10, 2010 and June 6, 2012, respectively. In addition, one sample taken at adjacent site, S007-074 on July 19, 2001, had a result of 3.4 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 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 values found in Bear Creek are below this threshold.

The two macroinvertebrate surveys at station 10LM023 had 38 and 40 taxa (TaxaCountAllChir), above the average taxa count for coldwater stations in the LMB (30.01). There were only two Trichoptera taxa at both visits (5.2% and 5.0% taxa; TrichopteraChTxPct). The result is reflected in a low IBI metric score of 5.2; less than average needed to meet the Southern Coldwater MIBI threshold (Figure 76).

Station 10LM023 had 20 nitrate tolerant taxa in 2010 and 24 in 2012 (86% and 63% 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. There was one nitrate intolerant taxa present during both visits.

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 IBI metric score and HBI_MN value have a significant relationship with nitrate at the time of fish sampling. The HBI_MN IBI metric score decreases with increased in nitrate. In Bear Creek, the metric scores were 4.41 and 4.95 (out of 14.3), below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6) (Figure 76). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. Station 10LM023 shows also shows an elevated HBI_MN values for both visits (6.90 and 6.96). 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 6.65. At a concentration of 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57. Bear Creek's nitrate levels are lower than these two HBI_MN reference values, yet an elevated HBI_MN value remains.

While the stream concentrations are not very elevated (in comparison to nearby streams), the macroinvertebrate metrics are showing a response consistent with nitrate degradation. There are abundance of nitrate tolerant taxa and individuals and the higher than average taxa count in this coldwater stream points to stress. Trichoptera taxa are also reduced, which is reflected in the taxa numbers, percentage, and IBI metrics. However, the presence of one nitrate intolerant taxa at each visit shows some potential sensitivity. It is possible that the slightly elevated nitrate concentrations are stressing the biology in Bear Creek, because of an additive stressor effect, but nitrate is not likely driving impairment. Nitrate is considered a secondary stressor to the macroinvertebrate community in Bear Creek.

TSS

There were two TSS samples (7.6 mg/L and 4.4 mg/L) taken during fish sampling at station 10LM023 in June, 2010 and June 2012, respectively. The corresponding transparency tube measurements with those samples were >100 cm. In addition, one sample taken at adjacent site, S007-074 in July of 2001, had a transparency tube result of >100 cm.

In Bear Creek, biological station 10LM023 had multiple TSS related metrics which are worse than average compared to the average for coldwater stations in the MR-Winona Watershed (Table 37). Both visits at station 10LM023 had few intolerant taxa, and a fair amount of TSS tolerant taxa and individuals. Generally intolerant macroinvertebrate individuals and long-lived individuals often decrease with increases stress. Those two metrics showed response in 2010, but did not in 2012. This may be reflecting temporal differences between the two years.

Table 37. Macroinvertebrate metrics relevant to TSS for stations in Bear Creek compared to averages for coldwater stations in the Mississippi River Winona 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**	**Intolerant Macroinvertebrate Taxa**	**Long-lived Macroinvertebrate Percent**
10LM023 (2010)	**16.03**	**1**	**5**	**13.06**	**2**	**1.29**
10LM023 (2012)	**15.68**	**1**	**7**	**15.41**	4	**0.31**
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for coldwater stations in the MR-Winona Watershed	15.11	1.41	4.45	10.94	2.69	3.78

The fish population consists of a number of fish species that are tolerant, and some which are intolerant to high TSS (Figure 82). Creek chub and white sucker are the main species which are considered more tolerant to TSS found in Bear Creek. Neighboring watershed Rollingstone Creek had a higher percentage of sensitive species (sculpin) which were not present in Bear Creek. Brown trout, fantail darter, and johnny darter make up quartile 2 (Q2) for Bear Creek. Both site visits had TSS index scores for fish that were below the MR-Winona average of 39.7 (11.5 and 11.6). The percent carnivore metric, which is correlated to TSS, was below average in 2012, but above average in 2010 (20.69% in 2012 and 37.50% in 2010, compared to the watershed average of 34.6%). Additionally, there was 0% intolerant fish species and very few sensitive fish species (only 31% and 37% compared to the average of 60%). However, the percentage of darter and sculpin for both years was above average (23% and 52% compared to the average of 21%)

Some response to TSS is seen in the macroinvertebrate community, but the data are not strong. The fish community is showing less stress in relation to TSS. Overall, there is a lack of connecting chemical data to confirm a TSS stressor exists. TSS is inconclusive as a stressor in Bear Creek at this time. Additional TSS information to further characterize concentrations in this reach would be beneficial.

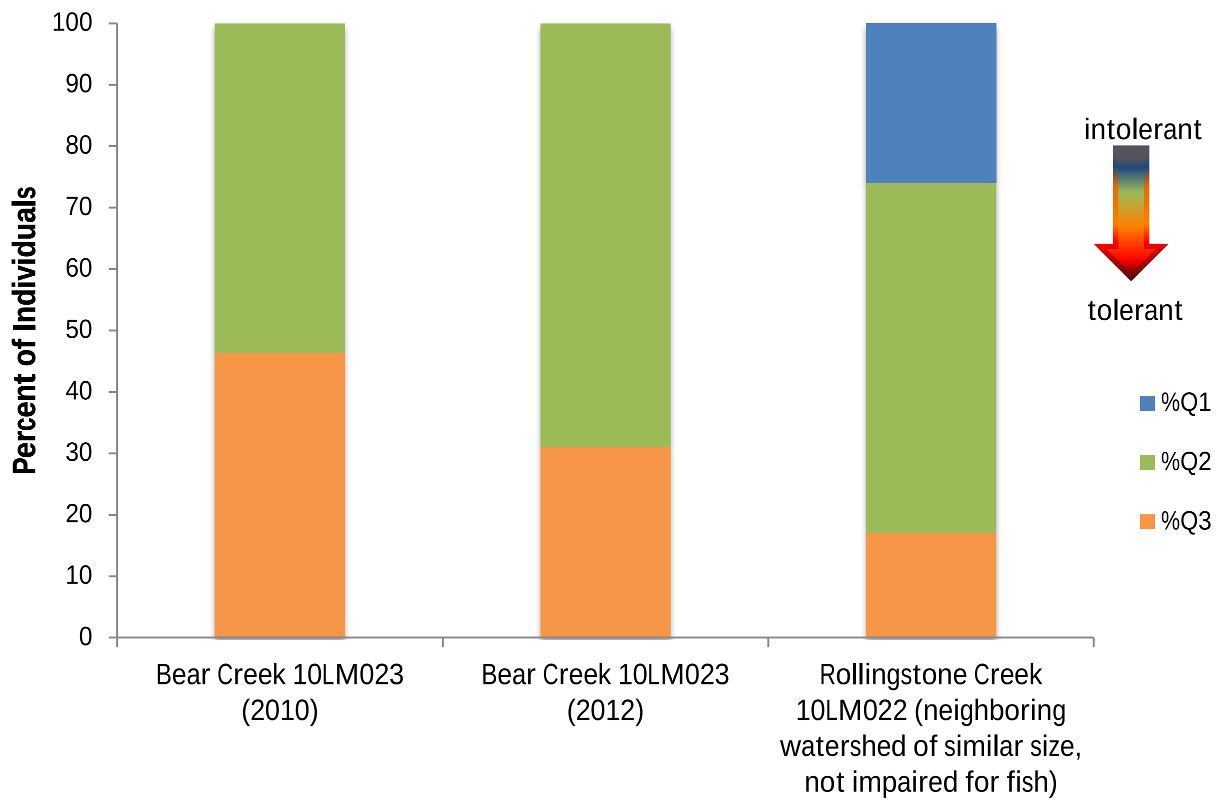

Figure 82. Fish TSS TIV's comparing Bear Creek to Upper Rollingstone Creek (Sandberg, 2013)

Habitat

Station 10LM023 had a MSHA score of 74.6 in 2010, which is rated as good. The subcategory of land use scored slightly lower, as well as the substrate subcategory. The substrate score was lowered due to a lack of diversity in substrate types (only gravel and sand was present). The channel stability ranking for Bear Creek scored a 90 CCSI, which falls in the severely unstable category. Bear Creek was revisited in 2012, and the MSHA was 54, rated as fair.

Bear Creek is pastured along half of its reach with a mostly wide open riparian corridor. There is severe down cutting in areas, sloughing of banks, and new floodplain terraces, indicative of moving sediments (Figure 83). The upstream reach is over widened and substrate is poor overall. Fine sediments comprised over 88% of the substrate, and when coarse substrates were present they were 75% embedded with fine sediments.

Figure 83. Bear Creek stream channel widening, deposition and bank erosion.

Fish metrics were compiled for Bear Creek, and then compared to statewide averages of this stream class (Southern Coldwater; Class 10). Bear Creek was sampled in 2010 and 2012, and had a fish community with above average percentages of riffle dwelling fish (46% and 41%), simple lithophilic spawners (39% and 27%), and general Lithophilic spawners (76% and 47%). However, tolerant white suckers were the dominant fish found in Bear Creek (21 individuals in 2010 and 47 in 2012), and this one species makes up large percentage of two of these metrics. Non-tolerant benthic insectivores and darter, sculpin and round bodied suckers were also two fish metrics found to be above average; but the only coldwater fish in these metrics is sculpin. Sculpin were not found in Bear Creek during either visit, and so the higher percentage is due to other more tolerant coolwater fish found in Bear Creek. Pioneer fish species thrive in unstable environments and are the first to invade a stream after disturbance. The pioneer percent in Bear Creek was higher than average (23% in 2010 and 41% in 2012) compared to other coldwater stations in the state. Piscivores were also found in reduced abundance (only 28% and 16%), compared to the statewide average of 37%. Piscivores generally require good substrate, and pool habitats for predator-prey relationships. These metrics, along with fish community composition, point to habitat stress for fish in Bear Creek.

The macroinvertebrate community in Bear Creek shows some biological response to habitat issues. The community is sampled based on dominant habitat types found at each station. The habitats sampled in Bear Creek were riffle/runs, undercut banks/overhanging vegetation, and woody debris in 2010. However, in 2012 when the site was resampled, the habitat sampled was only undercut banks/overhanging vegetation. If riffles were available, they would have been sampled for macroinvertebrates. The lack of riffle habitat, which is expected in a small coldwater stream, is telling. In 2010, riffles were sampled, but they were not the dominant habitat type. The macroinvertebrate metrics were compiled for Bear Creek, and then compared to statewide averages of this stream class (Southern Coldwater; Class 9). A higher than average percentages of more tolerant legless individuals were found in both years (47% and 32%; Figure 84). The percentage of clingers was above average for both visits (55% in 2010 and 58% in 2012). Clinger species attach to rocks or woody debris. Clingers can decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). The percentage of EPT individuals was above average in 2010 (54%), but below average in 2012 (31%). However, during both years, the macroinvertebrate population was dominated by Baetis, a tolerant mayfly. This explains why the EPT and clinger metrics are seemingly high (Baetis is in these two metrics) Swimmers and sprawlers were both below average.

There is some demonstrated response to habitat stress with both fish and macroinvertebrates in Bear Creek. It appears that 2012 shows more stress to fish and macroinvertebrate communities. While the biology is not signaling as much habitat stress as anticipated, there are many things that could improve habitat conditions in this reach. Habitat is considered a stressor to the aquatic communities in Bear Creek, but is secondary to other more prominent stressors.

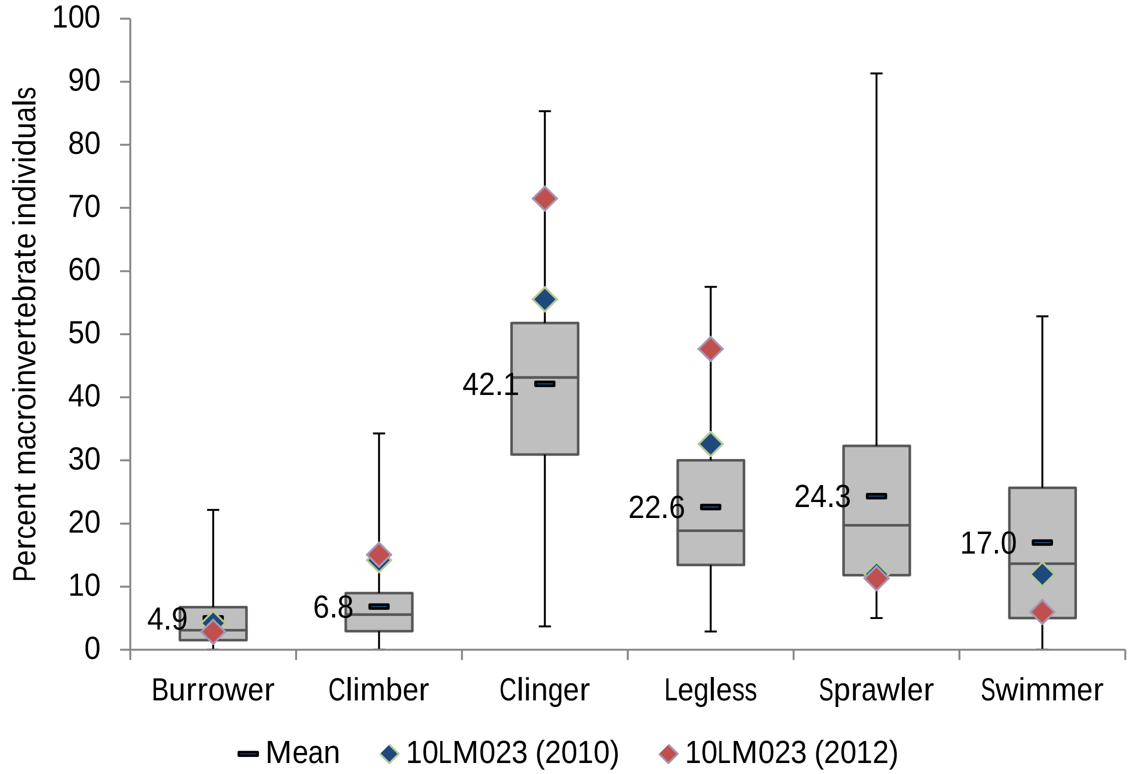

Figure 84. A comparison box plot of macroinvertebrate habitat metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

Conclusions and recommendations

The stressors found in this reach are summarized in Table 38. Temperature seems to have the most consistent biological response and may be driving the issues of biological impairment in Bear Creek. DO is considered a stressor to the fish community, but not the macroinvertebrate community. Nitrate concentrations, while only slightly elevated, is showing biological response. Similarly, habitat conditions are not optimal and biology is suffering. Nitrate and habitat are likely acting as secondary stressors in Bear Creek. TSS is inconclusive as a stressor to Bear Creek at this time, and lacks sufficient chemical data to understand sediment concentrations. Additional TSS information should be collected. Bear Creek would likely benefit from habitat improvement that would control sedimentation and improve refuge for coldwater taxa. Reduction in sedimentation overall, and improved riparian shading would also favor temperature improvement in Bear Creek as well.

Table 38. Summary of stressors found in Bear Creek (581).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:				
						Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-581 Bear Creek, Unnamed Creek to Rollingstone Creek	4.37	1B, 2A, 3B	10LM023	Upstream of CSAH 27, 2.5 mi. SW of Rollingstone	Fish IBI Macroinvertebrate IBI	●	●	●	o	●

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.9 Big Trout (Pickwick) Creek (07040003-592)

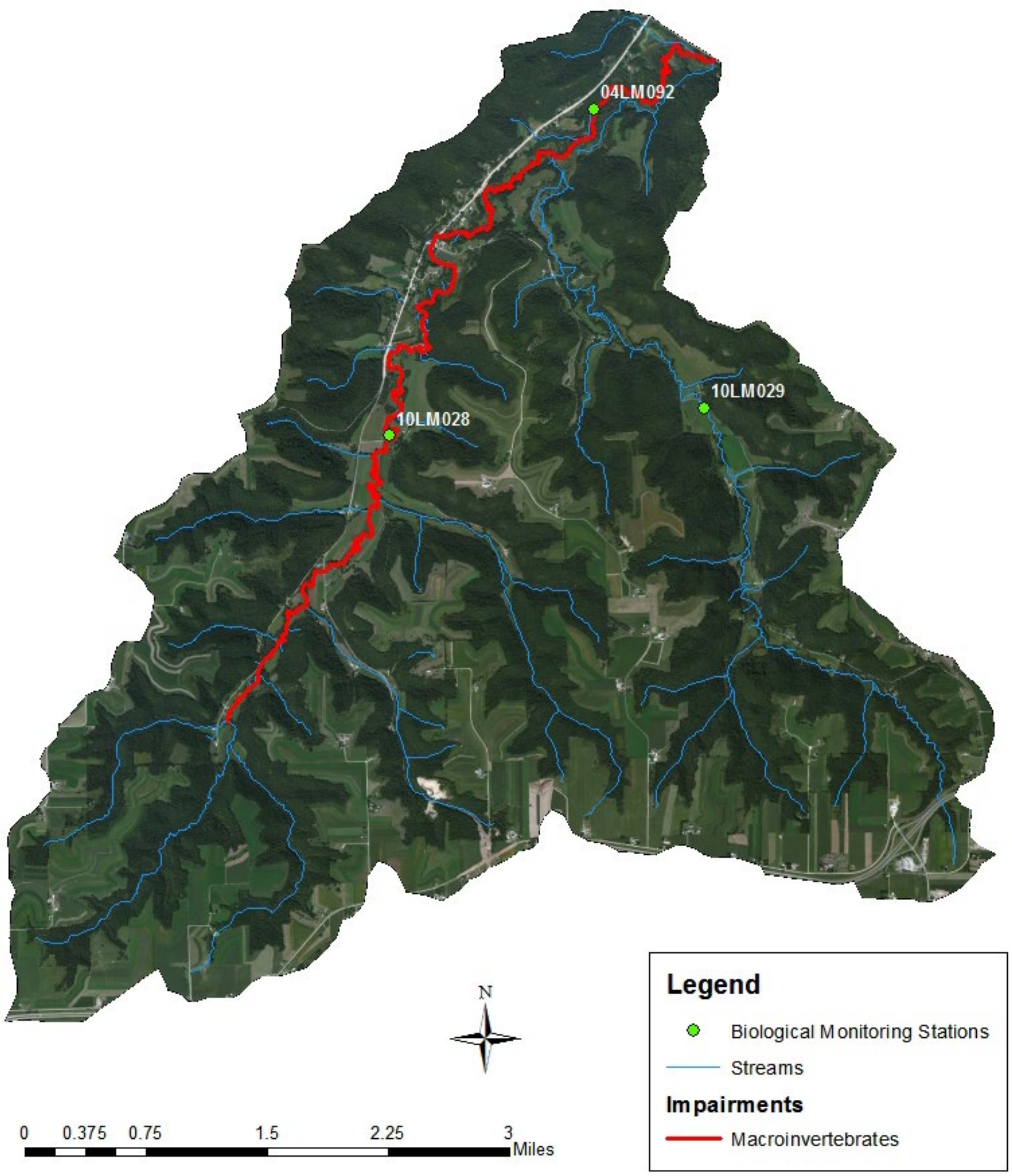

Figure 85. Map of the Big Trout Creek Subwatershed, biological stations, and impaired AUID.

Supporting information

Biological impairment for macroinvertebrates within the Big Trout Creek (Pickwick Creek) Watershed appears to be isolated within the headwaters of Big Trout Creek (biological station 10LM028; Figure 85). Farther downstream is biological station 04LM092 (downstream of Pickwick Dam) which is not showing impairment but fish are only three points above impairment threshold. While fish results exceed upper confidence limits at station 10LM028, with coldwater taxa such as brown trout and slimy sculpin, macroinvertebrates do not fare well at station 10LM028. Macroinvertebrate communities are dominated by large number of oligochaetes which indicates stress.

There were three biological sampling visits on Big Trout Creek; two in 2004 and one in 2010. Station 04LM094 was sampled twice in 2004 with a MIBI of 55.7 in August and an MIBI of 81.2 in September. Station 10LM028 was sampled in August of 2010, with an MIBI of 34.3. Both of these stations on Big Trout Creek are in the coldwater macroinvertebrate class (class 9), which has an impairment threshold of 46.1. Station 10LM028 had a collector and filterer individual percentage score of zero and a very low Trichoptera taxa percent score (Figure 86). Station 04LM092 also had a low Trichoptera taxa percent and a score of zero for intolerant taxa richness during August of 2004. The September visit during 2004 scored well for each metric.

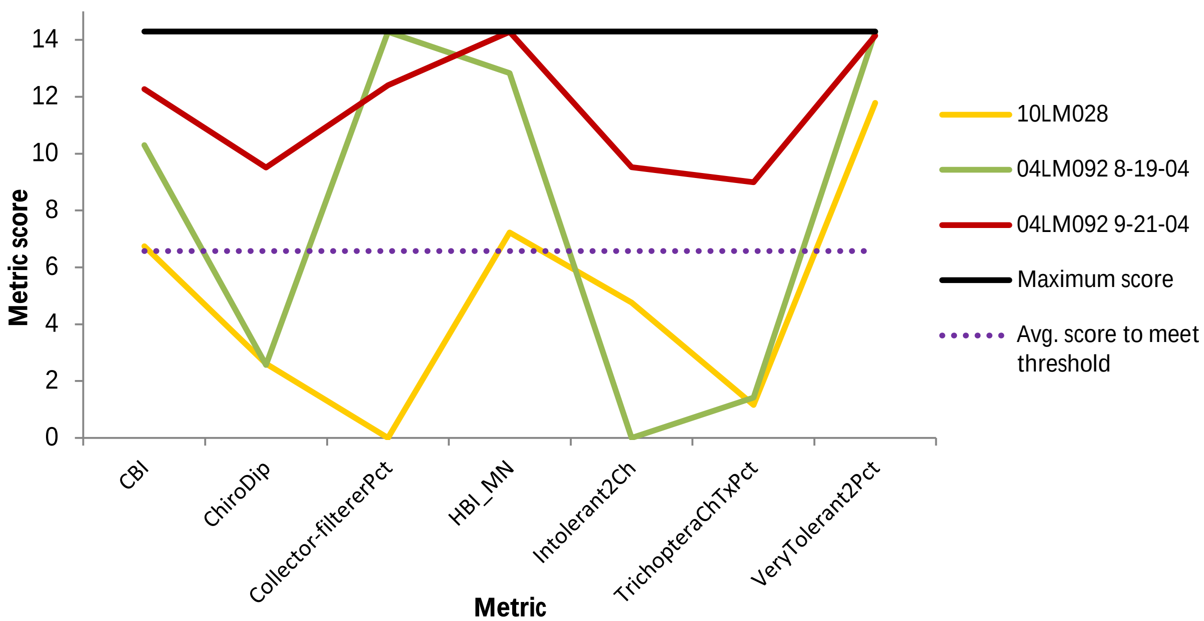

Figure 86. Macroinvertebrate IBI metric scores for Big Trout Creek.

There is a large difference between the Big Trout Creek and Little Trout Creek, which are located parallel to each other and have similar land use and drainage. However, Little Trout Creek had a much higher MIBI score. Comparing the two IBI's and metrics can give an indication about what might be stressing Big Trout Creek, in comparison to Little Trout Creek. The percent of Trichoptera (caddisfly) taxa, the ratio of Chironomidae to Dipteran abundance, and HBI scores are very different between the two watersheds (Figure 87).

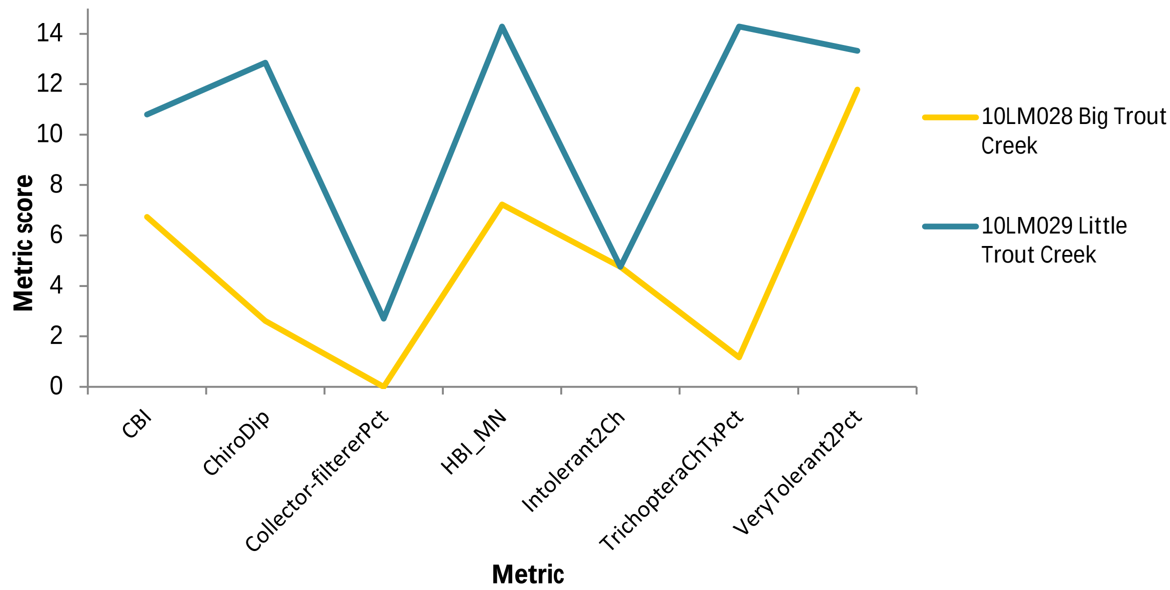

Figure 87. Macroinvertebrate IBI metric scores comparison for Big Trout Creek and Little Trout Creek.

Temperature

There were two temperature measurements (17.7°C, and 17.0°C) taken during fish sampling at station 04LM092 in June 2004 and station 10LM028 in June, 2010, respectively. In addition, continuous temperature data available from 2010 at station 10LM028, showed both a July and August average temperature of 15.6°C (Figure 88). The maximum temperature recorded during deployment was 20.98 on August 13, 2010.

There was also multiple temperature measurements on this stream reach in 2006. At station S004-240, which corresponds to biological station 10LM028, the maximum temperature recorded was 17°C. There were other higher temperatures measurements farther downstream on this stream reach, but are likely impacted by the old Mill Pond in Pickwick. The measurements were taken at the pond and just downstream in 2006 reach as high as 24.5°C. Moving downstream, station 04LM092 also had continuous temperature measurements taken in 2004. The July and August average temperatures were 16.8°C and 17.6°C. It appears, based on this data that any stream warming from the pond is attenuated, and effects are localized near the pond. Little Trout Creek (a coldwater tributary) which enters Big Trout Creek just upstream of station 04LM092 may contribute a fair amount of cold water as well. However, additional information would be useful in confirming this, since the data was collected in 2004 and 2006.

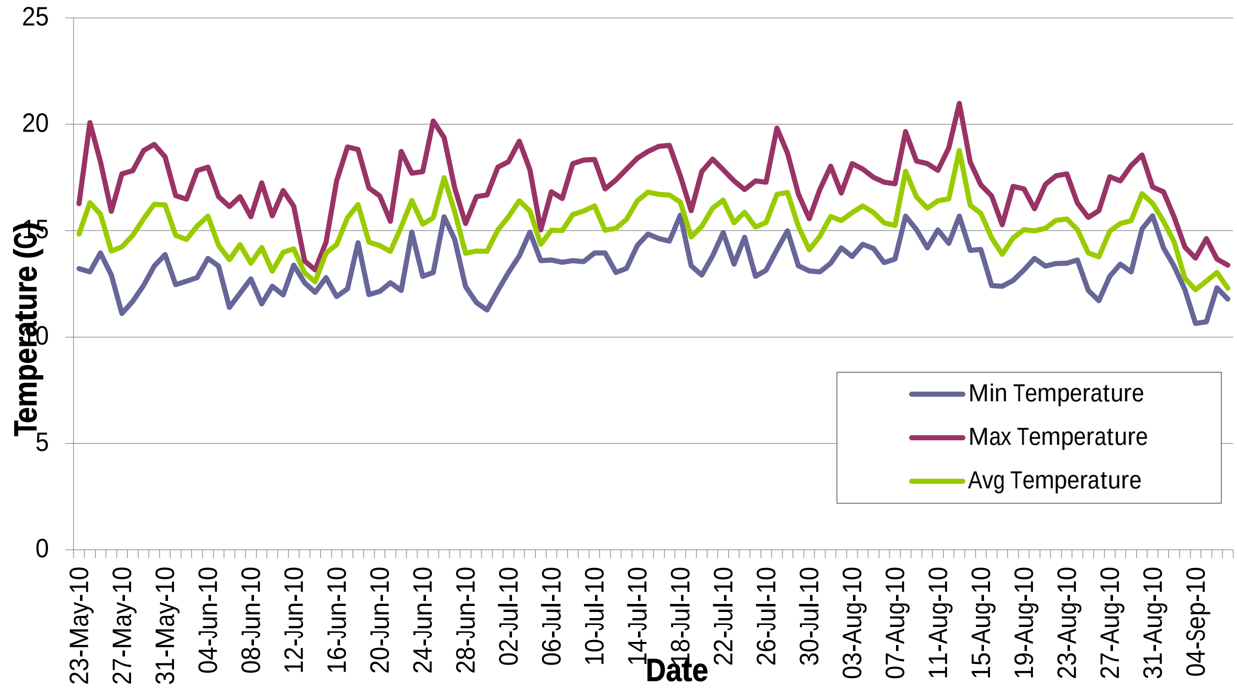

Figure 88. Continuous temperature data collected at 10LM028.

The fish communities at stations 10LM028 and 04LM092 do show a difference in the composition of coldwater fish species (Table 39). This may or may not be related to temperature differences between the two stations. Overall, coldwater species are much more abundant at station 10LM028 when compared to station 04LM092. Fish are not impaired at either site, but do give an indication of thermal regime. Station 04LM092, which is farther downstream does show fewer coldwater species overall, which may be due to factors such as drainage area and temperature influences from the Mill pond.

Table 39. Fish metrics for Big Trout Creek related to temperature and compared to the MR-Winona Class 10 (coldwater) averages

Site	Stream	Visit Date	ColdPct	CWSensitivePct	NativeColdPct
04LM092	Big Trout Creek	22-Jun-04	3.39	18.64	0.00
10LM028	Big Trout Creek	23-Jun-10	73.85	73.85	16.92
	MR Winona Class 10 Averages		*51%*	*61%*	*22%*

The macroinvertebrate CBI metric scored above the average needed to be above the IBI threshold (Figure 86). This indicates adequate coldwater macroinvertebrate taxa are present in adequate numbers at all sites in Big Trout Creek. Since coldwater species for both fish and macroinvertebrates are abundant and continuous temperature data shows suitable temperatures at both stations, temperature is not limiting the macroinvertebrate community at station 10LM028 and is not considered a stressor to Big Trout Creek. Additional monitoring and understanding of the thermal influence of the Mill Pond may be helpful in determining if stress to station 04LM092, even though it is not currently demonstrating biological impairment.

Dissolved oxygen

Low DO

The DO result during fish sampling at station 04LM092 in June 2004 at 3:45 pm was 8.4 mg/L. The DO result during fish sampling at station 10LM028 in June 2010 at 2:00 pm was 10.18 mg/L. The value during the macroinvertebrate sample at station 10LM028 in August of 2010 at 8:14 am was 8.54 mg/L.

There were measurements taken in 2006, when DO was taken at multiple locations on the creek on the same day (Table 40). Some low DO values were recorded just below the Pickwick Dam. Station 10LM028 is upstream of the dam, while station 04LM092 is downstream of the dam. The values upstream of the dam (near 10LM028) do appear more suitable based on this information. However, further quantification and understanding of the influence of the dam on DO levels seen in Pickwick Creek may be useful. It should be noted that the macroinvertebrate community is below impairment threshold at 10LM028, but not at 04LM092.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each station. The number of DO intolerant taxa was seven at station 10LM028. The average number of DO intolerant taxa in coldwater streams in the Lower Mississippi River basin was 9.6, and the average number collected in streams above the threshold was 10.1. The percentage of DO tolerant taxa at 10LM028 was 1.28. The average percentage of DO tolerant taxa was 2.6 and the average percentage collected in streams above the threshold was 1.7. The percentage of EPT collected at station 10LM028 was 51.98%. Similarly, the percentage of EPT individuals at station 04LM092 was 44.78%. The number of DO intolerant taxa was 10 and the percentage of DO tolerant taxa was very low at 0.69%.

The number of taxa intolerant to low DO and the percentage of DO tolerant taxa at station 10LM028 are both below the average for sites that met the impairment threshold. While low DO doesn't seem likely in this location, the biological response is suggestive and further DO monitoring should take place to better understand the DO regime and ensure low DO is not present. Low DO is considered inconclusive as a stressor to the macroinvertebrate community at station 10LM028.

Table 40. DO measurements for five locations on Pickwick Creek for four days in 2006. The sites are organized upstream to downstream and DO values as well as corresponding sample times are in parentheses. Values which are highlighted in red are below the standard of seven mg/L for coldwater streams.

	DO mg/L 7/9/2006	DO mg/L 7/16/2006	DO mg/L 7/23/2006	DO mg/L 8/20/2006
S004-240 (near 10LM028)	11.9 (12:51)	10.7 (10:26)	12.11 (16:00)	10.13 (15:32)
S004-247 (US or @ Dam/pond)	13.6 (13:34)	10.6 (11:15)	12.29 (16:28)	NA
S004-248 (Just DS Dam)	4.9 (14:43)	10.2 (10:52)	6.06 (17:34)	NA
S004-243 (Just DS Dam)	4.3 (14:21)	8.6 (11:54)	8.48 (17:47)	NA
S004-244 (Hwy 61, near 04LM092)	8.6 (15:00)	8.5 (12:05)	7.3 (18:10)	NA

DO flux/Eutrophication

Continuous DO data was not available on this reach. As interacting variables to eutrophication, total phosphorus and pH values, were compared to normal ranges and standards. The total phosphorus concentrations available were at 0.109 mg/L at station 04LM092, and 0.09 mg/L at station 10LM028. The total phosphorus concentration is slightly elevated at station 04LM092, which was taken in 2004. The water level was noted as above normal with an elevated TSS concentration as well. Another possible cause of higher phosphorus is the impact from the Pickwick Dam. The corresponding pH values were measured at 7.5 and 8.13.

EPT communities are inversely correlated with low DO and DO flux. The average in coldwater sites in the Lower Mississippi River basin was 39.55%. The percentage of EPT collected at station 10LM028 was 51.98%. The percentage of EPT individuals is higher than the average for coldwater sites in the Lower Mississippi River basin. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average percentage of tolerant macroinvertebrates in coldwater sites in the Lower Mississippi River basin was 42.68. The tolerant macroinvertebrates percentage at station 10LM028 was 40.43%. There are some elevated DO and phosphorus values, but there is currently not enough statewide data to make connections with eutrophication and coldwater communities. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

Nitrate

The nitrate results from fish sampling at stations 04LM092 and 10LM028 were 1.1 mg/L and 1.2 mg/L, respectively. In addition, on May 2012 a nitrate sample was taken at station S004-240 (near station 10LM028), and had a result of 1.2 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 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 stations 04LM092 and 10LM028 had 25 and 29 taxa (TaxaCountAllChir), below the average taxa count for coldwater stations in the LMB (30.01). There were five and two Trichoptera taxa at each station (17.2% and 7.69% individuals). The corresponding metric results are on either side of the average metric score needed to meet the Southern Coldwater MIBI threshold (Figure 86).

The stations had a range of 9-15 nitrate tolerant taxa (47% to 63% 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. There was one nitrate intolerant taxa present at 10LM028 and three present at 04LM092.

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 IBI metric score and HBI_MN value have a significant relationship with nitrate at the time of fish sampling. The HBI_MN IBI metric score decreases with increased in nitrate. In Big Trout Creek, the metric scores were 7.23 at 10LM028 to 14.28 at 04LM092 (out of 14.3), above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6) (Figure 86). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. The stations do not show elevated HBI_MN values (5.75 to 6.66). 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 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57.

Big Trout Creek is not dominated by nitrate tolerant taxa, and there are a few nitrate intolerant taxa and good metric scores for HBI_MN. Trichoptera are reduced in Big Trout Creek, but they are likely responding to another stressor present, since the stream nitrate concentrations are so low. The biological and chemical information demonstrate that nitrate is not a stressor to Big Trout Creek.

TSS

The TSS results from fish sampling at stations 04LM092 and 10LM028 were 40 mg/L and 14 mg/L, respectively. The sample in 2004 at station 04LM092 indicated an above normal water level. It's possible the stream was recovering from a recent rain event, which explains the elevated TSS (and TP) concentrations.

During assessment in 2012, this stream had enough available information to assess for turbidity. No impairment was identified, given multiple transparency readings throughout the creek, and the stream is considered fully supporting.

In Big Trout Creek, the biological stations both had macroinvertebrate station index scores which were better than average compared to the average stations in the MR-Winona watershed (Table 41). Additionally, the percentage of TSS tolerant individuals was low, and the stations were not dominated by TSS tolerant taxa. The generally intolerant macroinvertebrate taxa and long-lived often decrease with increases in TSS. A slight response to this is shown at station 10LM028, but it is not overwhelming.

The fish community at station 10LM028 is made up of mainly brown trout and sculpin, both which are sensitive to high TSS. There were a few white suckers present, which are slightly more tolerant to TSS, but the community was not dominated by them. Given the chemical information, and little biological response evidence, TSS is not considered a stressor to Big Trout Creek.

Table 41. Macroinvertebrate metrics relevant to TSS for stations in Big Trout Creek compared to averages for coldwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
04LM092 (August 2004)	14.64	**0**	4	6.22	5	4.04
04LM092 (September 2004)	14.56	2	**7**	3.02	8	**0.99**
10LM028	15.14	**1**	4	2.13	**2**	**3.03**
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for coldwater stations in the MR-Winona Watershed	15.11	1.41	4.45	10.94	2.69	3.78

Habitat

Station 04LM092 had a MSHA score of 53.7, which is rated as fair. Station 10LM028 had a MSHA score of 54, which is also rated as fair. Between the two sites, there was a large difference between the land use and riparian subcategory for station 10LM028 compared to station 04LM092. Station 10LM028 scored low in both of those subcategories, while 04LM092 scored well. They scored poorly in the substrate subcategory, with station 04LM092 having no coarse substrate and severe embeddedness at station 10LM028. They were slightly different in the cover and channel morphology subcategories, with station 10LM028 scoring slightly better in both. The channel stability ranking at station 10LM028 scored a 38 CCSI, which falls in the fairly stable category. A score was not available for station 04LM092, because the station was sampled in 2004, before the CCSI was being measured routinely. The low habitat scores at station 10LM028 is likely attributed to pasture within the riparian zone, sedimentation of pools, and severe embeddedness of coarse substrates in the instream zone.

The macroinvertebrate community in Big Trout Creek demonstrates biological response consistent with degraded habitat. The community is sampled based on dominant habitat types found at each station. The habitats sampled in Big Trout Creek (station 04LM092) were woody debris, and undercut banks/overhanging vegetation. At station 10LM028, aquatic macrophytes, riffle/runs, and undercut bank/overhanging vegetation were sampled. The macroinvertebrate metrics were compiled for Big Trout Creek, and then compared to statewide averages of this stream class (Southern Coldwater; Class 9; Figure 89). An abundance of burrowers (24%) was found at station 10LM028 which coincides with over 50% embeddedness of fine sedimentation in riffle, run, and pool habitats (Figure 89). There was also higher percentage of more tolerant legless individuals overall (33%). Station 04LM092 also showed a higher percentage of legless individuals for one visit in 2004, but not the other (41% vs 6%). The percentage of clingers was worse than average at station 10LM028 (only 31%) compared to station 04LM092 (56% and 53%). Clinger species attach to rocks or woody debris. Clingers can decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). EPT taxa are commonly used to measure overall health of ecosystems, due to their sensitivity to many stressors. The percentage of EPT taxa was found above average at all sites and visits.

The high percentage of burrowers and legless macroinvertebrates, coupled with lower percentages of clingers indicate that habitat stress, especially at station 10LM028. Site evidence and local land use support the notion that fine sedimentation is a major driver to substrate embeddedness and subsequent habitat loss found in this reach. Habitat is considered a stressor to the macroinvertebrate community in Big Trout Creek.

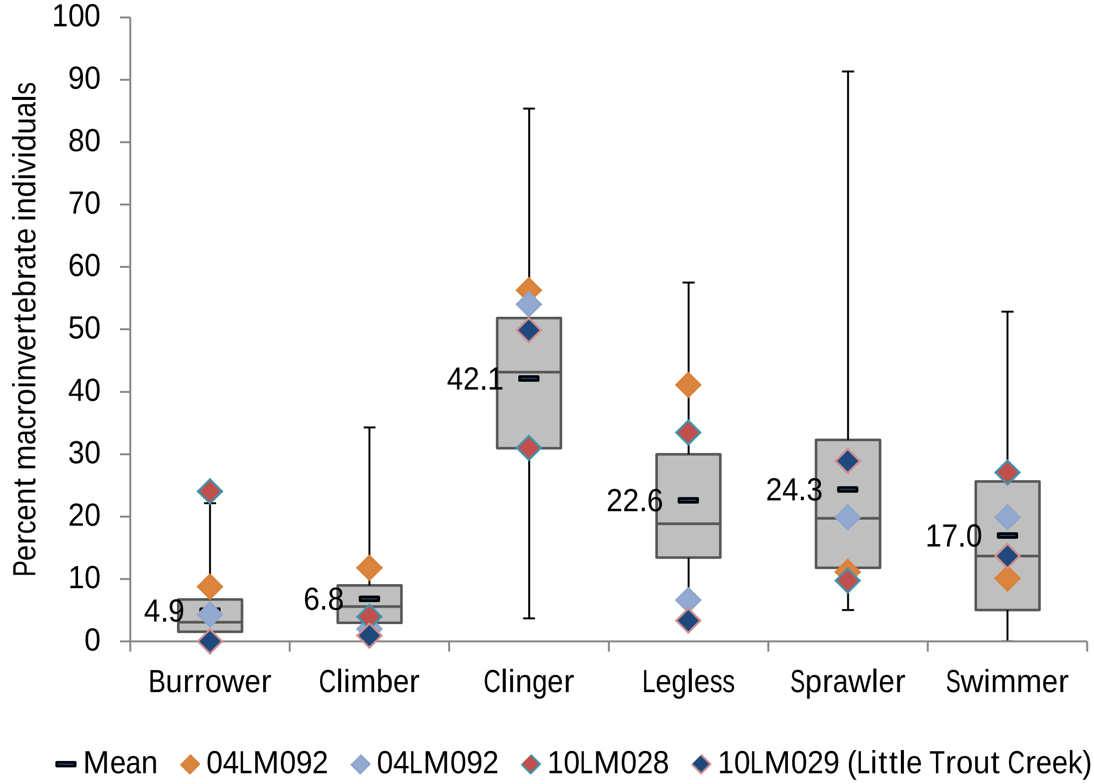

Figure 89. A comparison box plot of macroinvertebrate habitat metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

Connectivity

In-between biological stations 10LM028 and 04LM092 sits Pickwick Dam/Historic Mill (Figure 90). The Mill operated until 1978, but remains a historical landmark, tourist attraction, and important resource for the town of Pickwick. In 2009, an emergency spillway was repaired on the dam. This was one of many places damaged in the 2007 flood.

Figure 90. Pickwick Dam/Mill on Big Trout Creek. Photo courtesy of museumsofmn.com.

While dams and impoundments can alter fish movement, fish are not impaired in this reach and therefore it is of less concern. Migratory fish are found at stations upstream and downstream of the dam. There were three migratory fish taxa found in the station downstream of the dam (23 individuals), and two migratory fish taxa found in the upstream station (54 individuals). However, these impoundments can alter water chemistry, slope, and sediment transport which can impact the entire ecosystem. While macroinvertebrates are impaired at upstream station (10LM028), the Pickwick Dam is likely far enough away that any immediate impacts to the macroinvertebrates are minimal or non-existent. Connectivity is not considered a stressor to Big Trout Creek at this time, but should be evaluated further in the future.

Conclusions and recommendations

The stressors to Big Trout Creek are summarized in Table 42. Habitat is the main stressor to the macroinvertebrate community found at 10LM028. The high percentage of burrowers and legless macroinvertebrates, coupled with lower percentages of clingers indicate habitat stress. Site evidence and local land use (pasturing) support the notion that fine sedimentation is a major driver to substrate embeddedness and subsequent habitat loss found in this reach. Several habitat improvement efforts have been completed near the biological station in recent years. MDNR believes the invertebrate community will improve over time as a result of these past efforts.

Additional temperature monitoring could better define the thermal nature of Big Trout Creek prior to its confluence with the Mississippi River. Other additional monitoring may also determine whether Pickwick dam (between these stations) is influencing biological results. In addition, information on DO levels upstream and downstream of the dam may be warranted. DO was considered inconclusive on Big Trout Creek due to the lack of information.

Table 42. Summary of stressors found in Big Trout Creek (592).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:					
						Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat	Connectivity
07040003-592 Big Trout Creek (Pickwick Creek), Unnamed Creek to Mississippi R	8.63	1B, 2A, 3B	10LM028 04LM092	Downstream of Homer Township Rd 6 (Trout Creek Rd), 9 mi.SE of Winona Adjacent to CSAH 7, 1 mi. S of Lamoille	Macroinvertebrate IBI		o			●	

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.10 Unnamed Creek (07040003-609)

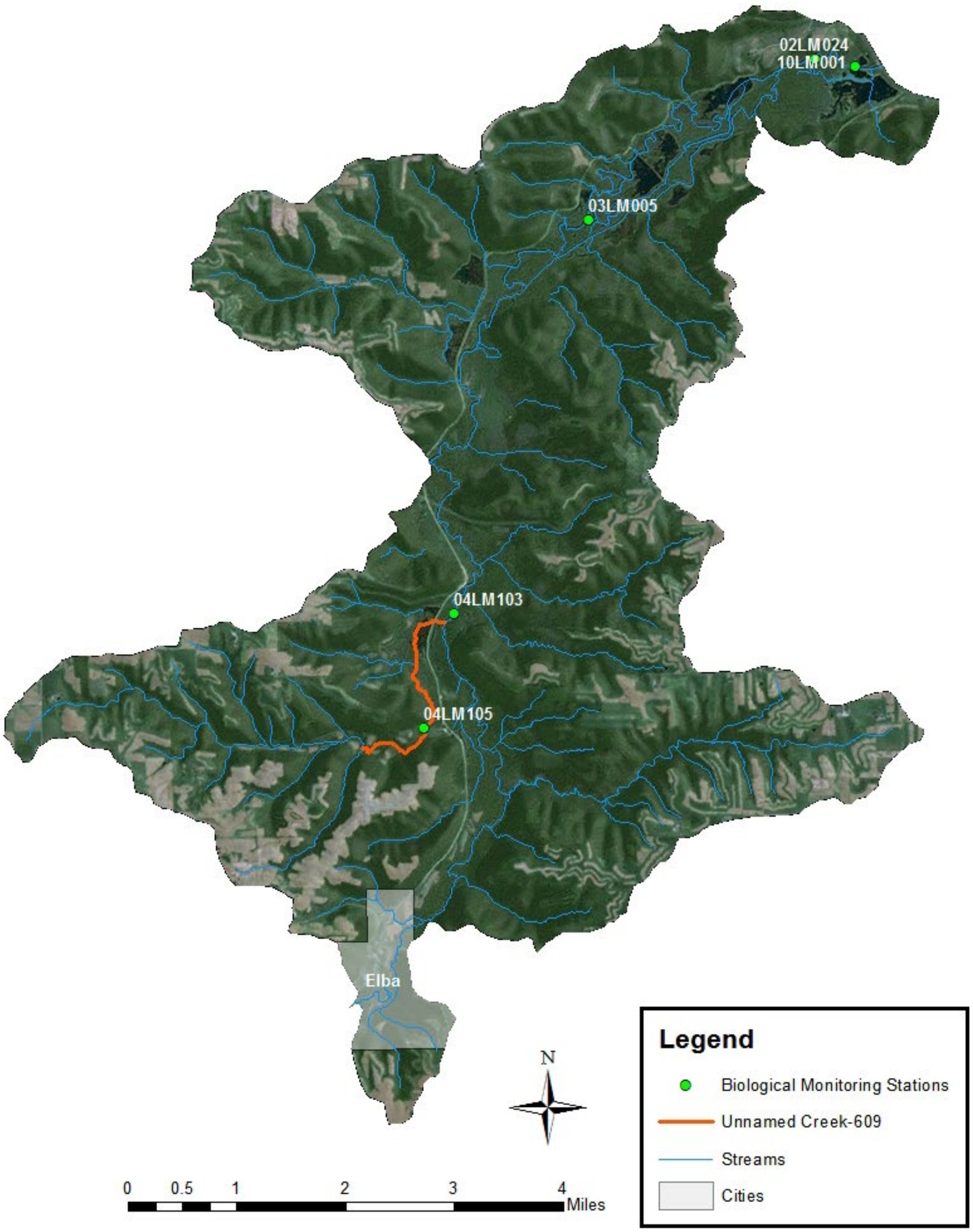

Figure 91. Map of the Unnamed Creek subwatershed, biological stations, and impaired AUID.

Supporting information

Biological station 04LM105 had a macroinvertebrate IBI score of 39.6 in 2012, and 47.6 in 2004. The impairment threshold for macroinvertebrate class 9 (coldwater) streams is 46.1. Due to use class change (from warmwater to coldwater), a macroinvertebrate impairment has not been finalized. Stressor identification was done on this reach in anticipation of upcoming impairment (when coldwater status is finalized).

MDNR staff indicated that waterfowl pools downstream may be limiting fish migration. However, it is difficult to determine if the failure to meet biocriteria is a result of that or other stressors. For that reason, the fish community was not assessed on this reach.

Station 04LM105 had a macroinvertebrate sample in 2004 and again in 2012 (Figure 92). During both macroinvertebrate visits, the intolerant taxa scores were both zero. These taxa have been documented as sensitive to organic pollution/low oxygen levels in streams (Hilsenhoff 1987), meaning that the species most intolerant to pollution were not found to be living in the stream in high numbers. The ratio of chironomid abundance to total dipteran (ChiroDip) abundance and collector-filterer percent scores both significantly decreased from 2004 to 2012. The chironomid/dipteran ratio measures the number of midges to true flies, and increases with human disturbance. Collector-filterer species collect their food by filtering it from the water column. The percent taxa of Trichoptera or caddisflies resulted in a metric score of 0 in 2004, but increased in 2012. Both visits scored well on the percentage of very tolerant individuals collected and the coldwater biotic index. Except for the Trichoptera score, the station scored better in 2004 than in 2012.

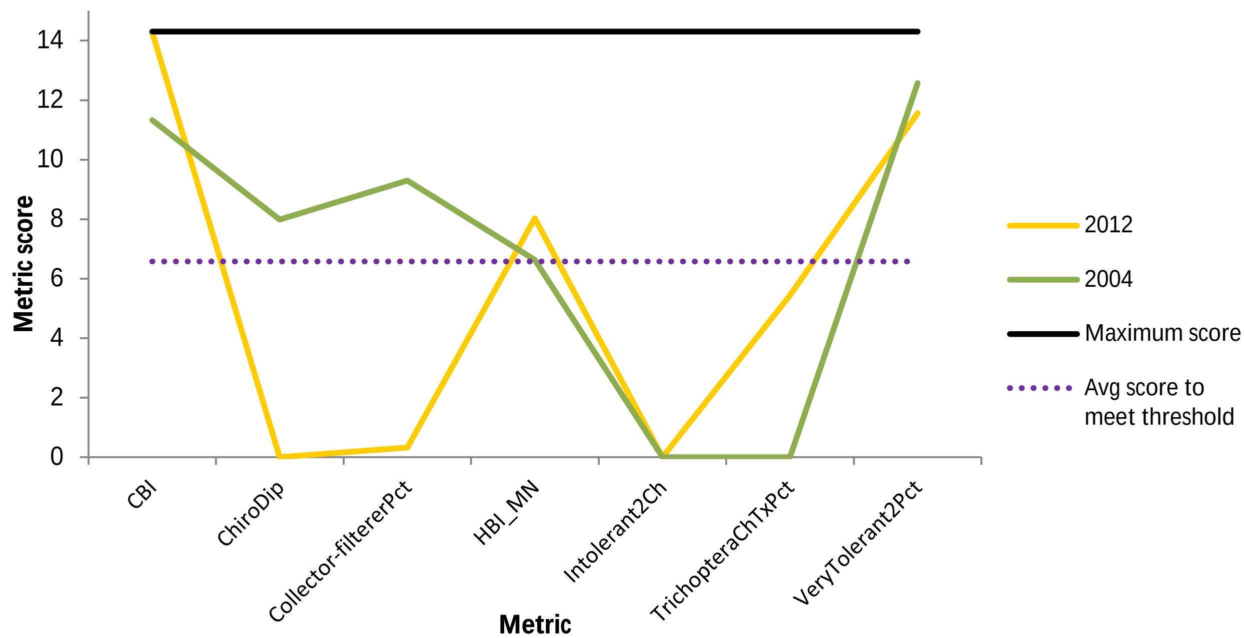

Figure 92. Macroinvertebrate IBI metric score for two samples on Unnamed Creek.

Temperature

This Unnamed Tributary was classified warmwater originally, but later changed to coldwater classification. The macroinvertebrate community had a coldwater signature, and subsequent continuous temperature data proved cold temperatures were present and characteristic of a coldwater system.

There was two temperature measurements (15.1°C and 17°C) taken during fish sampling at station 04LM105 in June 2004 and June 2012 respectively. In addition, in 2012, continuous temperature was collected. The temperature logger was placed just upstream of station 04LM105, from May-September 2012. The maximum temperature recorded at the site was 17.3 °C, with having both a July and August average of 14°C.

Temperature in this reach is considered normal and suitable with respect to other coldwater reaches in this region. The temperature measurements were taken in 2012, a very low flow year, which indicates that coldwater inputs are adequate to maintain proper temperature in this reach. Temperature is not considered a stressor to Unnamed Creek at this time.

Dissolved oxygen

Low DO

The only DO data available on this AUID was taken during biological sampling at station 04LM105. The results were 9.65 mg/L in 2004 and 8.04 and 10.26 mg/L in 2012. All three values were taken in the late afternoon hours when elevated values would be expected.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed at each visit. The percentage of low DO tolerant taxa collected during the macroinvertebrate surveys was 4.39% during the 2004 visit and 0.33 during the 2012 visit. The average for coldwater communities in the Lower Mississippi River basin was 2.9%. The average for sites that were above the threshold was 1.3%. The percentage of DO tolerant taxa was significantly higher in 2004 than in 2012. The percentage during the 2004 visit was higher than the basin average and much higher than the sites that met the coldwater threshold, but the 2012 visit is much lower. The number of taxa that are intolerant to low DO collected during the 2004 visit was ten, and was 11 in 2012. The average number of DO intolerant taxa in coldwater sites in the Lower Mississippi River basin was 9.6. The average number of taxa at sites that met the coldwater threshold was 10.1. Both visits were above the basin average and the average of those sites that met the coldwater threshold. Given the current information, DO is not considered a stressor at this time.

DO flux/Eutrophication

As interacting variables to river eutrophication, phosphorus and pH measurements were compared to normal ranges and standards. Other response variables of BOD, chlorophyll-a, and DO flux were not available for analysis. The total phosphorus concentrations available were both low, at 0.057 mg/L and 0.025 mg/L. The corresponding pH was measured at 7.2, 8.07, and 8.14. These values presented do not violate any water quality standards, and are considered within normal range.

EPT communities are inversely correlated with low DO and DO flux. The average in coldwater sites in the Lower Mississippi River basin was 39.55%. The percentage of EPT collected at station 04LM105 was 39.04% and decreased to 21.63% in 2012. The percentage of EPT individuals was higher than the basin average in 2004, but dropped significantly in 2012. While other stressor could be affecting the EPT percentage, the drop is concerning considering the sensitive nature of the species. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average percentage of tolerant macroinvertebrates in coldwater sites in the Lower Mississippi River basin was 42.68. The tolerant macroinvertebrates percentage at visits at station 04LM105 was 44.83 and 47.60 respectively. Further DO monitoring including diurnal DO is recommended to better understand the DO regime of the system. There is currently not enough statewide data to make connections with eutrophication and coldwater communities. DO flux and eutrophication is inconclusive as a stressor until coldwater biological responses can be further developed.

Nitrate

There was two nitrate samples (1.4 mg/L and 1.6 mg/L) taken during fish sampling at station 04LM105 in June 2004 and June 2012, respectively. No other nitrate data is available.

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 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 04LM105 had 30 and 32 taxa (TaxaCountAllChir), just above the average taxa count for coldwater stations in the LMB (30.01). There were two Trichoptera taxa in 2004 and four taxa in 2012 (6.25% and 13.3% taxa; TrichopteraChTxPct). The corresponding result is reflected in a low IBI metric score in 2004 (6.25); less than average needed to meet the Southern Coldwater MIBI threshold (Figure 92). In 2012, the metric score improved significantly with the additional taxa, to 13.3 (TrichopteraChTxPct).

Both visits at this station had 18 nitrate tolerant taxa (57% and 86% 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. There were no nitrate intolerant taxa present at either station as well.

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 IBI metric score and HBI_MN value have a significant relationship with nitrate at the time of fish sampling. The HBI_MN IBI metric score decreases with increased in nitrate. In Unnamed Creek, the metric scores were 5.04 and 5.59 (out of 14.3), below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6) (Figure 92). The HBI_MN value, (different from the HBI_MN IBI metric) increases with increased nitrate. Both stations show a slightly elevated HBI_MN value (6.44 and 6.63). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant change point 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 10 mg/L nitrate, there is only a 25% probability that HBI_MN will be less than 6.57.

While many of the nitrate specific metrics show a slight biological response, the response isn't strong. The response is likely due to another stressor, especially because the nitrate concentrations in the stream are low. There is also a bit of a mixed response among sampling years, which may indicate a stressor with more temporal variation. Nitrate is not considered a stressor to Unnamed Creek at this time due to the low nitrate concentrations, and a very weak and inconsistent biological response.

TSS

There were two TSS samples (5.2 mg/L and 1.2 mg/L) taken during fish sampling at station 04LM105 in June 2004 and June 2012, respectively. Both of these values are low, and correspond to high transparency readings (>60 cm and >100 cm) for both visits.

The biological station visits both had macroinvertebrate TSS station index scores which were better than average compared to the average stations in the MR-Winona Watershed (Table 43). Additionally, the percentage of TSS tolerant individuals was low, and the stations were not dominated by TSS tolerant taxa. The generally intolerant macroinvertebrate taxa and long-lived often decrease with increases in TSS. A slight response to this is shown in 2012, but it is not overwhelming. The macroinvertebrates are likely responding to another stressor present, not TSS. TSS is not considered a stressor to Unnamed Creek at this time.

Table 43. Macroinvertebrate metrics relevant to TSS for stations in Unnamed Tributary compared to averages for coldwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
04LM105 (2004)	14.65	**0**	**5**	7.45	**2**	**1.71**
04LM105 (2012)	12.51	2	3	2.89	**2**	**3.13**
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for coldwater stations in the MR-Winona Watershed	15.11	1.41	4.45	10.94	2.69	3.78

Habitat

Station 04LM105 had a MSHA score of 82.6, which is rated as good in 2004, and a score of 62.45 in 2012, which is rated as fair. There was a moderate amount of cover for fish in 2004, but it was nearly absent in 2012. Sand and gravel were the predominant substrate types with 46.3-55.26% embeddedness during the two visits (Figure 93). The station in 2004 was comprised of 16.88% riffle, 29.16% pool, and 54.29% run. In 2012, the riffle percentage was stable at 17.16%, while the pool percentage had decreased; likely due to pools filling in with fine sediment. The station had decreased to 14.73% pool and had increased to 68.24% run. A CCSI score was not available for station 04LM105, because the station was sampled in 2004, before the CCSI was being measured routinely.

Figure 93. Photos near 04LM105 showing sand, few course substrates and one natural riffle (photo on the right).

The macroinvertebrate community in Unnamed Creek shows some biological response consistent with degraded habitat. The community is sampled based on dominant habitat types found at each station. The habitats sampled in Unnamed Creek were riffle/runs, undercut banks/overhanging vegetation, and woody debris in 2004. However, in 2012 when the site was resampled, the habitat sampled was only undercut banks/overhanging vegetation. The macroinvertebrate metrics were compiled for Unnamed Creek, and then compared to statewide averages of this stream class (Southern Coldwater Class 9; Figure 94**.**). There was an abundance of more tolerant legless individuals in 2012 (47%) compared to 2004 when the percentage was only 29% (Figure 94). The percentage of climbers was higher in 2012 (36%) due to that habitat being sampled primarily that year, and they were lower in 2004 (8.5%). The percentage of clingers was near average in 2004 but below average in 2012 (39% in 2004 and only 11% in 2012). Clinger species attach to rocks or woody debris. Clingers can decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). EPT taxa are commonly used to measure overall health of ecosystems, due to their sensitivity to many stressors, including but not limited to habitat. The percentage of EPT individuals were below average for both years (21% and 39%, respectively).

Visual evidence confirms this reach is dominated by an unstable sand bottom. Photos of this reach shows erosion upstream and excess sand deposited in the floodplain. Habitat measurements in both years show that substrate is comprised of a high amount of fine sediments (63% in 2004 and 48% in 2012). This may explain changes in available habitat between 2004 and 2012 sampling, and a varied response between habitat metrics. Riffle/runs and woody debris were not sampled in 2012, which explains why clingers were reduced in numbers. Habitat is considered a stressor to the macroinvertebrate community due to low percentages of EPT individuals and clingers (2012). The increase in more tolerant legless macroinvertebrates in both years and burrowers in 2004 also show evidence that this reach is lacking quality habitat for macroinvertebrates.

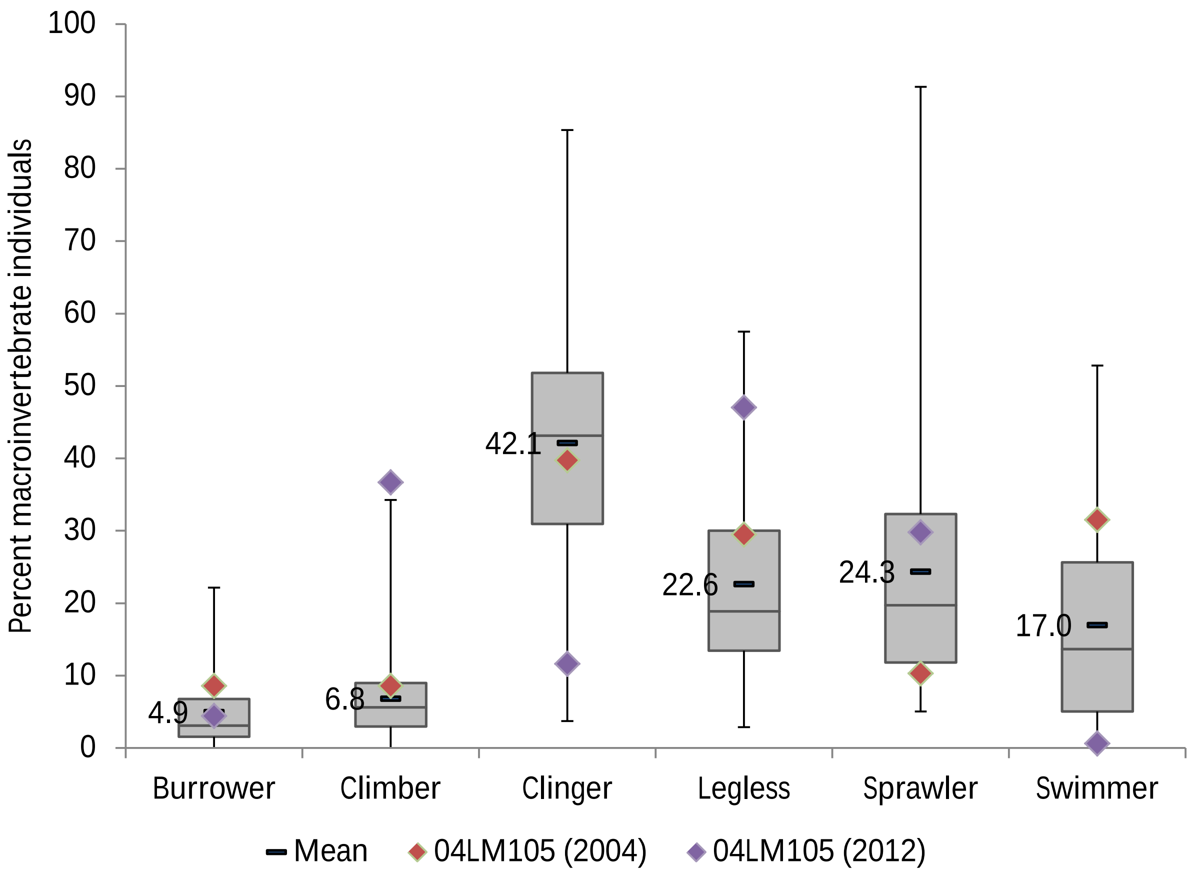

Figure 95. A comparison box plot of macroinvertebrate habitat metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the boxplot and mean number displayed. Station specific information is represented by colored points.

Conclusions and recommendations

The stressors found in this reach are summarized in Table 44. Lack of suitable habitat is the driving stressor to the macroinvertebrate community in Unnamed Creek. Two macroinvertebrate samples (2004 and 2012) demonstrate varying habitat conditions and biological response to habitat. A small coldwater stream like this is expected to have riffle habitats, which were not available in the 2012 sample. Visually, the stream is embedded with sand, and very wide and shallow for its size. There is excess sand being routed to this stream and being deposited in the streambed and on the floodplain. This sand is covering course substrates, and resulting in very unstable stream channel and habitat conditions. The riparian area in this entire watershed is excellent, and there are few areas for improvement since it exists mainly in a forested MDNR management area. However, slopes are very steep and water travel from the uplands is rapid, resulting in a very flashy system. A few large forested gullies were identified upstream of the biological monitoring location. These areas are thought to be contributing sand to the steam, as well as significant upstream streambank erosion. Exploring options for holding water back in the farmed uplands of this watershed may help mitigate potential affects from water moving down these steep ravines which is driving excess erosion.

Temperature in this stream is adequate, and supported by high resolution temperature data. DO, nitrate and TSS levels are adequate and do not appear to be affecting macroinvertebrates. However, the data is limited to a few samples and additional data to further characterize the water chemistry of this stream would be helpful. Connectivity should be explored further if the fish community is assessed on this reach.

Table 44. Summary of stressors found in Unnamed Creek (609).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:				
						Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat
07040003-609 Unnamed Creek, Unnamed Creek to Whitewater River	2.16	1B, 2A, 3B	04LM105	1mi. upstream of Hwy 74, in Whitewater State Park, 3 mi. N of Elba	Macroinvertebrate IBI (proposed)					●

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4.11 Gorman Creek (07040003-569)

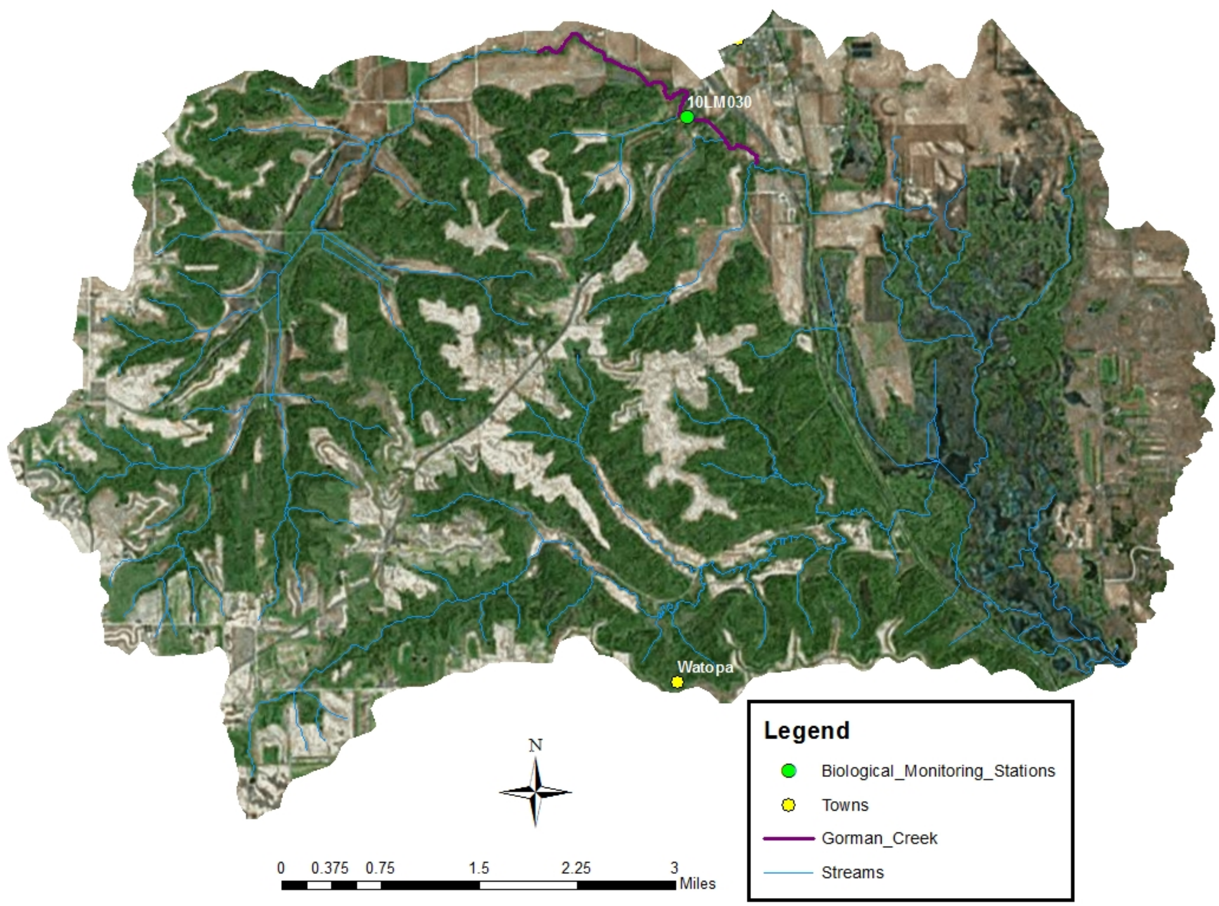

Figure 96. Map of Gorman Creek and biological stations.

Supporting Information

While biological monitoring visits occurred at a natural segment of Gorman Creek, a majority of the stream has been modified consistent with channelization (57.8%), thus an aquatic life use assessment was deferred. The MDNR considers Gorman Creek's upper coldwater reaches to be in good condition. The MPCA fish monitoring visit on the downstream warmwater results agreed with this, scoring slightly above the upper confidence interval at 10LM030. However, the community is beginning to demonstrate signs of stress, which is more evident in the poor macroinvertebrate results observed. The macroinvertebrate community was dominated by tolerant taxa which may be attributed to marginal habitat conditions observed at the biological station which include: sedimentation, erosion, cattle access to the stream, and a lack of sufficient habitat. Stressor identification was completed on this reach, prior to official aquatic life listing, in anticipation of macroinvertebrate impairment.

Station 10LM030 was sampled in 2010 (Figure 95) with a total macroinvertebrate IBI score of 36.4. The station is in the Southern Forest Streams GP macroinvertebrate class (class 6), with an impairment threshold of 46.8. Of the ten metrics, the clinger taxa, collector-filter percentage, dominant 5%and taxa count scores were the only metrics above the average score needed to meet the threshold. The number of intolerant taxa with chironomids identified to genus (Intolerant2Ch) had a score of zero. Intolerant taxa are sensitive to organic pollution/low oxygen levels in streams (Hilsenhoff 1987). The non-hydropsychid Trichoptera percentage score was also low.

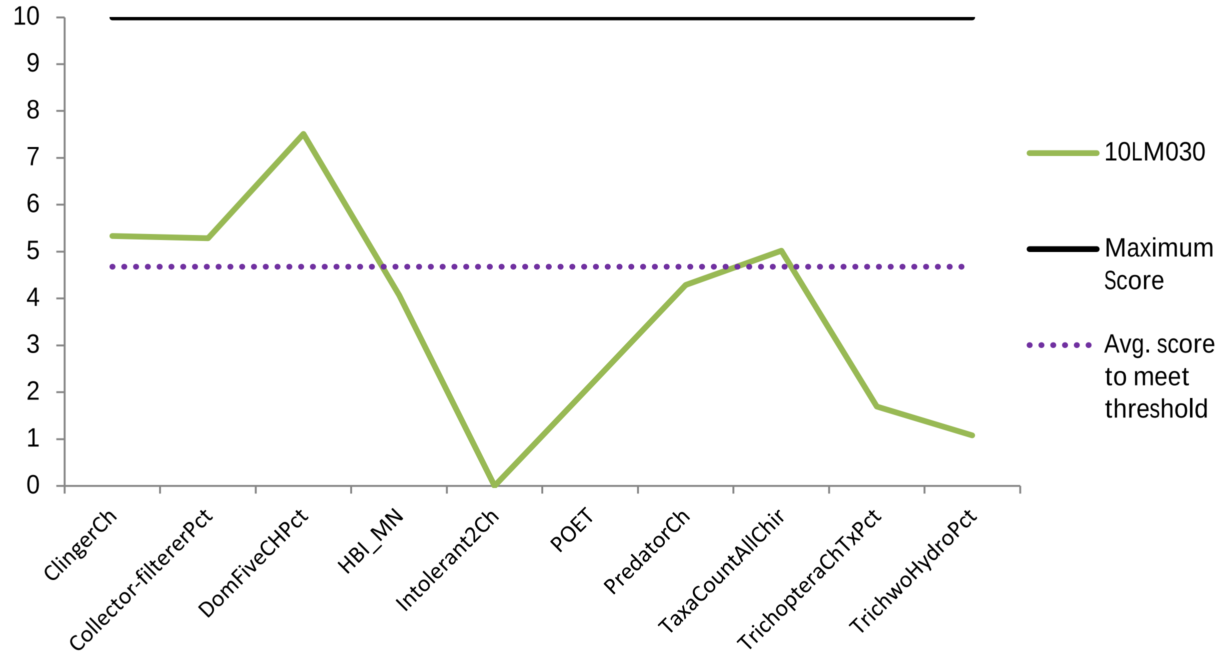

Figure 97. Macroinvertebrate IBI metric scores for Gorman Creek.

Temperature

Gorman Creek is currently classified warmwater in the lower reaches of the Creek. There was discussion and a decision to leave that lower section of creek warmwater given current information. The upper section of the creek remains a coldwater classification, where trout are managed by MDNR.

There was one temperature measurement (18.3°C) taken during fish sampling at station 10LM030 in June 2010. In addition, in 2012, continuous temperature was collected which confirms that temperatures are warm. The July and August average temperatures were 21.08°C and 17.8°C, respectively. The maximum temperature for those two months was 25.3°C and 22.5°C.

It is not completely clear if this reach in Gorman Creek was historically colder than it is currently. Given the current information, and warmwater classification, it has been determined that temperature is not considered a stressor to Gorman Creek at this time. The temperatures are considered normal for a warmwater stream. If the stream classification were switched to coldwater, then a temperature stressor would need to be reevaluated.

Dissolved oxygen

Low DO

The only DO data available on this stream reach was taken during biological sampling at station 10LM030 in June, 2010 at 1:20 pm and in August 2010 at 1:57 pm. The DO results were 8.57 mg/L and 8.37 mg/L respectively.

Macroinvertebrate species that are specifically tolerant and intolerant to DO were analyzed. The average number of low DO intolerant taxa in the warmwater sites in the Lower Mississippi basin was 7.31 and the average percentage of DO tolerant taxa was 10.79. There were six taxa intolerant to low

DO collected, and 7.56% DO tolerant taxa in the community. The number of DO intolerant taxa was slightly lower than the basin average for warmwater sites while the percentage of taxa tolerant to low DO was lower than the basin average. Low DO is not considered a stressor at this time. Further DO monitoring is recommended to better understand the DO regime of the system.

DO flux/Eutrophication

Phosphorus and pH are interacting eutrophication variables, along with DO flux. There is one phosphorus value available on this reach, taken during fish sampling, and the result was 0.145 mg/L. The phosphorus concentration was elevated for baseflow conditions, and is above the proposed standard of 0.100 mg/L for the central region of the state. There is one pH value available, taken during macroinvertebrate sampling, with a value of 8.3. BOD and chlorophyll-a data is not available on this reach.

EPT communities are inversely correlated with low DO and DO flux. The average EPT percentage in warmwater sites in the Lower Mississippi River basin was 28.6%. The percentage of EPT collected at station 10LM030 was 3.36%. While the percentage of EPT individuals was significantly lower than the basin average, EPT are also affected by other stressors. Phosphorus is also positively correlated with the percentage of tolerant taxa. The average percentage of tolerant macroinvertebrates in coldwater sites in the Lower Mississippi River basin was 42.68. The tolerant macroinvertebrates percentage at station 10LM030 was 82.57%. Until further information is collected including diurnal DO, chlorophyll-a, additional phosphorus and pH, DO flux and eutrophication is inconclusive at this time.

Nitrate

The nitrate concentration during fish sample at station 10LM030 on June 7th, 2010 was 2.7 mg/L. No additional nitrate data is available for analysis.

In 2010, station 10LM030 had better than average macroinvertebrate taxa count (TaxaCountAllChir; 36). The average taxa count for this macroinvertebrate class, (6; Southern Forest Streams GP) is 33. There was only one Trichoptera taxon, which is below the average for the Southern Forest Streams GP stations of the LMB. The macroinvertebrate sample had 65% nitrate tolerant individuals. At 65.71% nitrate tolerant individuals, there is a 50% probability of meeting the Southern Forest Streams GP (class 6) MIBI. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. There were no nitrate intolerant taxa found in the sample.

Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (caddisfly) individual percentages in warmwater streams. Non-hydropsychid Trichoptera are all caddisflies that do not spin nets. Gorman Creek had 0.3% non-hydropsychid Trichoptera, which is below the Lower Mississippi basin average of 3.39%.

There is some biological response to elevated nitrate in Gorman Creek, but a nitrate stressor is difficult to conclude, especially with the limited data available and generally low concentrations. The nitrate concentrations don't appear elevated based on grab sample results, and high nitrate is not likely in this location of the watershed (based on bedrock geology/contamination susceptibility). The biological response seen can likely be attributed to other stressors. Nitrate is not currently considered a stressor in this reach, but would benefit from further characterization of stream nitrate concentrations to rule out this stressor completely. Further, better understanding of biological response for fish and macroinvertebrates in this stream class would be helpful.

TSS

There was one TSS sample taken during fish sample at station 10LM030 in June, 2010, with a result of 13 mg/L. In addition, the transparency tube was measured at 47 cm. At station S001-704, transparency was measured 72 times between 2001 and 2007. The average transparency of those measurements was 38 cm, with a range of three cm to 60 cm.

In Gorman Creek, biological station 10LM030 had two macroinvertebrate related TSS metrics which are worse than average compared to the average for warmwater stations in the MR-Winona Watershed (Table 45). There were no TSS intolerant taxa present and a high percentage of TSS tolerant macroinvertebrate individuals. However, generally intolerant individuals and long-lived individuals were better than average. These two metrics often decrease with increases in TSS related stress.

The fish community shows some tolerance towards increased TSS. The dominant species captured was creek chub, which are considered tolerant to many stressors, including TSS. Increases in TSS have been correlated with reduced carnivore fish. Gorman Creek had 64.7% fish species which are considered carnivores, which is above average for the watershed (34%).

Overall, the biological response to elevated TSS is weak. The chemical information does not strongly suggest TSS issues, but the data is limited. At this time, TSS is not considered a stressor to Gorman Creek, but additional information on TSS in this reach may be beneficial in order to completely rule out this stressor.

Table 45. Macroinvertebrate metrics relevant to TSS for stations in Gorman Creek compared to averages for warmwater stations in the Mississippi River Winona 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	Intolerant Macroinvertebrate Taxa	Long-lived Macroinvertebrate Percent
10LM030	16.66	**0**	6	**39.86**	2	11.01
Expected response with increased TSS stress	↑	↓	↑	↑	↓	↓
Averages for Warmwater stations in the MR-Winona Watershed	16.92	0.61	7.66	28.95	1.75	3.36

Habitat

Station 10LM030 had a MSHA score of 52.7, which is rated as fair. The score was lowered due to the site being in a pasture and the lack of any riparian buffer, moderate embeddedness of fine sediments, and lack of channel development (Figure 97).

The channel stability ranking at station 10LM030 scored a 79 CCSI, which falls in the moderately unstable category. During site visits, an unconsolidated actively mobile streambed and excess deposition were noted in the reach.

Figure 98. Station 10LM030 in 2010; middle of reach, looking downstream.

The macroinvertebrate community in Gorman Creek shows some biological response consistent with degraded habitat. The community is sampled based on dominant habitat types found at each station. The habitats sampled in Gorman Creek were: undercut banks/overhanging vegetation, and woody debris. Riffle/runs were not sampled due to primarily glide/pool habitat of this stream class. The macroinvertebrate metrics were compiled for Gorman Creek, and then compared to statewide averages of this stream class (Southern Forest Streams GP; Class 6) (Figure 97). There was an abundance of more tolerant legless individuals (80%). The percentage of macroinvertebrates that are considered climbers was good (41%), due to that habitat being sampled. However, the percentage of clingers and EPT individuals (24% and 3.3%, respectively) were both low. Clinger species attach to rocks or woody debris. Clingers can also decrease in stream reaches with homogenous substrate composition, velocity, and depth (CADDIS). EPT taxa are commonly used to measure overall health of ecosystems, due to their sensitivity to many stressors. The percentages of sprawlers (species that require interstitial spaces within stable course gravel, cobble, or boulder substrate not embedded by fines) were also low in Gorman Creek (9.1%). A high percentage of burrower macroinvertebrates can indicate sedimentation in riffle habitats. Since riffles were not sampled, the burrow percentage is not as significant since burrower abundance can be due to the sampling of undercut banks. Habitat is considered a stressor in Gorman Creek due to the high percentage of legless individuals, and reduced percentages of clingers, EPT, and sprawler taxa.

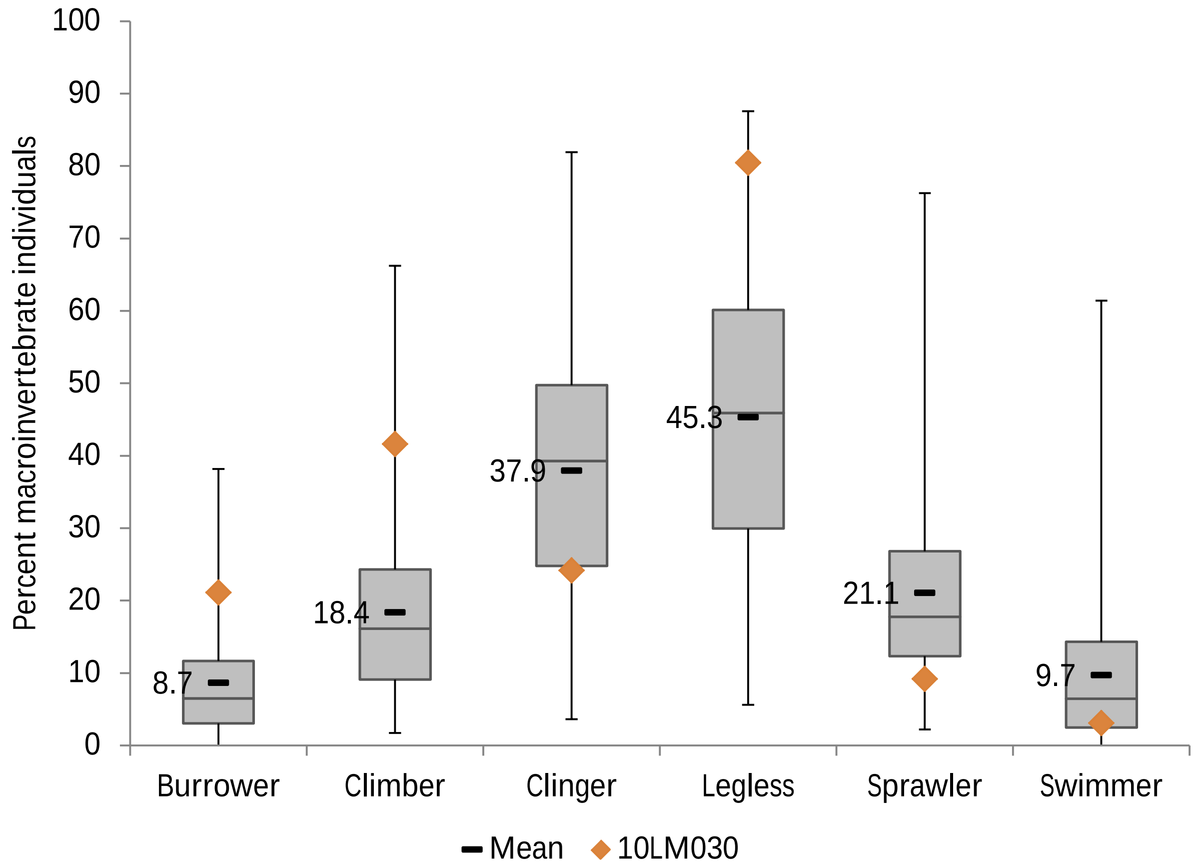

Figure 99. A comparison box plot of macroinvertebrate habitat metrics representing the average class 6 (Southern Streams GP) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.

Connectivity

Downstream of the biological station 10LM030 there are two small dams; one under the Highway 42 bridge (Figure 98) and the other on Highway 61 bridge (Figure 100). As noted in the previous section on habitat, excessive sediment deposition in this reach has been documented. These two dams are impacting the amount of sediment deposition at station 10LM030 by reducing water slope and velocity. It cannot be determined if connectivity is affecting fish passage (due to only one biological station upstream of the dams). Connectivity is considered a stressor to Gorman Creek's macroinvertebrate community as the dams are contributing to impacts on sedimentation and impacting habitat.

Figure 100. Dam under Highway 42 Bridge, downstream from 10LM030 (0.2 miles). Estimated 2 ft of vertical drop.

Figure 101. Dam by culvert under Highway 61 Bridge, downstream of 10LM030 (~1 mile). Estimated 6 feet of vertical drop.

Conclusions and recommendations

The stressors found in this reach are summarized in Table 46. The main stressor found contributing to macroinvertebrate impairment in Gorman Creek is habitat. The dams located on Highway 42 and Highway 61 are altering water slope and velocity, which contribute to the sedimentation and habitat loss found in this lower section of Gorman Creek. It's possible these dams are only affecting the far lower reaches of Gorman Creek. It is not known if the impacts reach farther than this area. Therefore, careful consideration would need to be made on whether or not any action (dam removal) would be warranted or necessary. Cost of dam removal may outweigh potential biological benefits gained.

Additional thermal monitoring was conducted in Gorman Creek, and its thermal regime is very characteristic of a warmwater stream. It is not completely clear if this reach in Gorman Creek was historically colder than it is currently. Little historical information exists on temperature in this lower section of stream because the Trout Stream designation is farther upstream. If the stream classification were switched to coldwater, then a temperature stressor would need to be reassessed. Additional monitoring for DO and TSS would be useful, as currently those datasets are very limited.

Those stressors are both inconclusive at this time.

Table 46. Summary of stressors found in Gorman Creek (569).

AUID Reach Name, Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Impairment(s)	Stressors:					
						Temperature	Dissolved Oxygen	Nitrate-Nitrite	Suspended Sediment	Habitat	Connectivity
07040003-569 Gorman Creek, T110 R10W S27, west line to Unnamed Creek	2.57	2B, 3C	10LM030	Downstream of 170th Ave (Lark Ln), 1.5 mi. SW of Kellogg	Macroinvertebrates (proposed)		o		o	●	●

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

4. Conclusions and recommendations for the MR-Winona Watershed

A summary of the stressors to aquatic life in the MR-Winona Watershed are found in Table 47. Strength of evidence analysis was conducted for each stream and parameter, and is available by request.

Table 47. Summary of Stressors found in the MR-Winona.

Watershed	Watershed Name	AUID	Biological Impairment	Stressors					
				Temperature	Dissolved Oxygen	Nitrate	Suspended Sediment (TSS)	Habitat	Connectivity
North Branch	North Branch Whitewater	553	Fish and Macroinvertebrates	o	o	•	•	•	
Middle Branch	Middle Branch Whitewater	515	Fish and Macroinvertebrates		•	•	•	•	
	Middle Branch Whitewater	F19	Macroinvertebrates			•	•		
	Crow Spring	611	Macroinvertebrates			•		•	
South Branch	South Branch Whitewater	F16	Fish and Macroinvertebrates		•	•	•	•	
	South Branch Whitewater	512	Macroinvertebrates			o	o	•	
	South Branch Whitewater	F17	Macroinvertebrates	•		•	•		
Tributaries	Beaver Creek	566	Macroinvertebrates					•	
	Bear Creek	581	Fish and Macroinvertebrates	•	•	•	o	•	
	Gorman Creek	569	Macroinvertebrates		o		o	•	•
	Unnamed Creek (Marnach)	609	Macroinvertebrates					•	
	Big Trout Creek (Pickwick Creek)	592	Macroinvertebrates		o			•	

● = stressor; o = inconclusive stressor; 'blank'-not an identified stressor

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6. Appendix

Appendix A

Table 48. Selected fish and macroinvertebrate metrics for analysis of habitat stress in the MR-Winona 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	EPT are a sensitive group of	*Decrease*

	Metric Description	Explanation	Expected Response to Habitat Stress
	Ephemeroptera, Plecoptera & Trichoptera individuals in subsample	macroinvertebrates commonly used to measure overall health of ecosystems	
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 live on the surface of floating plants or fine sediments. Many are adapted to keep respiratory surfaces free of silt	*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*

Appendix B

Pesticides:

Acetochlor has been detected above the chronic 4-day standard (3.6 ug/L), but these detections are very rare (Figure 101). The maximum concentration of 75 ug/L was detected in 1995, and the second highest level detected was 9.6 ug/L in 2002 (Figure 102). The 95th percentile of the entire dataset is 1.18 ug/L or approximately 33% of the chronic 4-day standard (3.6 ug/L). The annual median, 75th percentile, 90th percentile and 95th percentile concentrations have fallen since 2002. Since that time, the annual 95th percentile has been 1.08 ug/L or lower. The maximum annual concentration has fallen dramatically since 1995, and has been below 3.6 ug/L in nine of the last ten years.

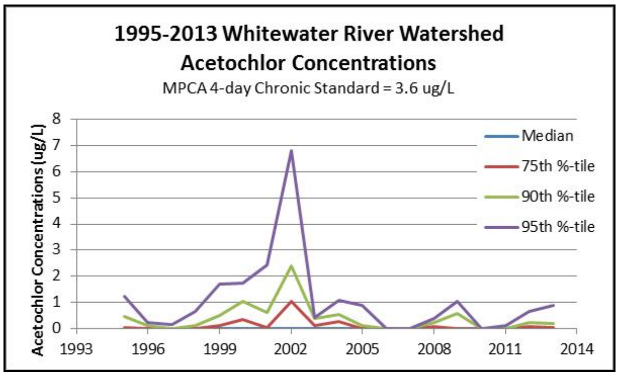

Figure 102. Acetochlor concentrations

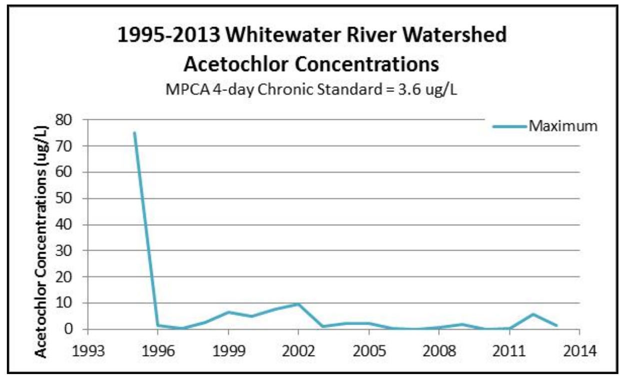

Figure 103. Acetochlor maximum concentrations

Alachlor was detected above the lower Class 2A standard (3.8 ug/L), in 1993 (Figure 103). Alachlor has not been detected in the Whitewater River Watershed since 2005, and has not been detected above 1.0 ug/L since 1998 (Figure 104).

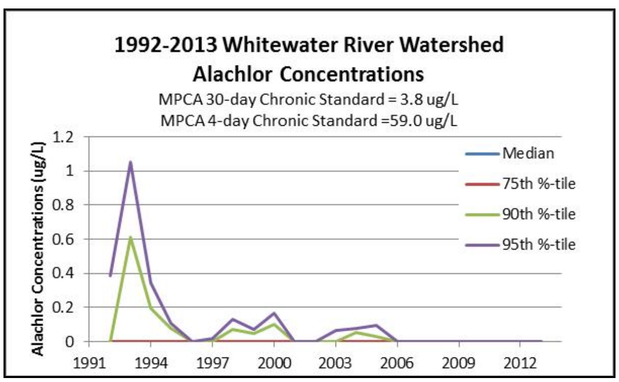

Figure 104. Alachlor concentrations

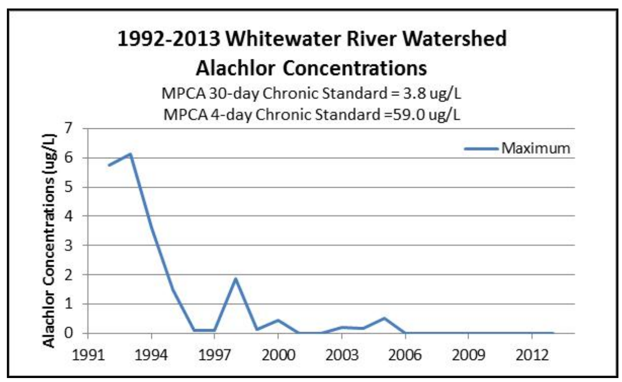

Figure 105. Alachlor maximum concentrations

Atrazine was detected above the chronic four-day standard (10 ug/L) 15 times from 2000-2004. Many of these samples were collected as short duration (hours) composite samples, and several of these samples came from the same events. The 95th percentile of the entire dataset is 3.34 ug/L or approximately 33% of the chronic four-day standard (10 ug/L).

In general, the annual median, 75th percentile, 90th percentile and 95th percentile concentrations since 2005 have been much lower than the levels observed from 2000-2004 (Figure 105). Since 2004, the annual 95th percentile has been below the 3.4 ug/L MPCA 30-day standard. The maximum annual concentration has been over the 3.4 ug/L MPCA 30-day chronic standard in two of the past nine years; however, the maximum annual concentration has not been above the MPCA four-day chronic standard of 10.0 ug/L in the past nine years (Figure 106).

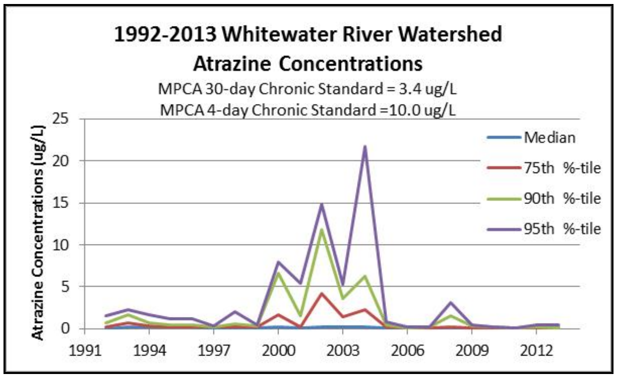

Figure 106. Atrazine concentrations

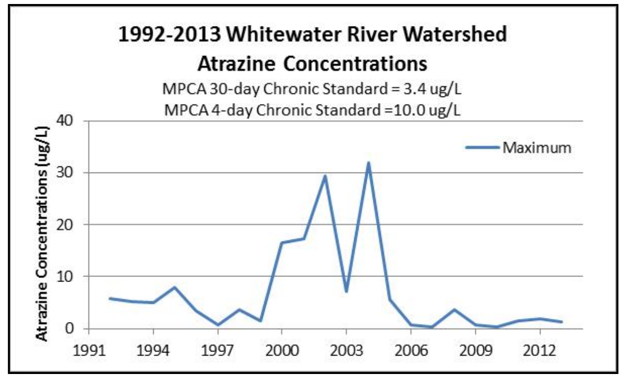

Figure 107. Atrazine maximum concentrations

Table 49. Whitewater River Watershed and Stream Pesticide Sampling, 1992-2013

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 2Bd5 Chronic Standard 3	MPCA Maximum Standard 4	EPA Acute Value Aquatic Life Benchmark 2	EPA Chronic Value Aquatic Life Benchmark 2
2,4-D	Herbicide	111	387	29%	nd	P(<0.2)	0.204	0.407	4.75	70 H	--	12,075 (f)	13.1 (v)
Acetochlor	Herbicide	290	871	33%	nd	P(<0.05)	0.39	1.18	75	3.6 T	86 T	na	na
Acetochlor ESA	Degradate	68	71	96%	0.11	0.17	0.305	0.393	0.549	--	--	> 62,500 (i)	9,900 (n)
Acetochlor OXA	Degradate	25	71	35%	nd	0.067	0.131	0.225	0.423	--	--	--	--
Alachlor	Herbicide	153	1118	14%	nd	nd	0.05	0.13	6.15	4.2 H; 59 T	800 T	na	na
Alachlor ESA	Degradate	67	71	94%	0.186	0.286	0.46	0.52	0.65	--	--	52,000 (f)(i)	–
Atrazine	Herbicide	994	1118	89%	0.14	0.26	1.413	3.344	32	3.4 H; 10 T	323 T	na	na
DEDI Atrazine	Degradate	26	50	52%	0.055	0.092	0.125	0.146	0.199	--	--	> 50,000 (f)(i)	--
Deisopropylatrazine	Degradate	105	979	11%	nd	nd	P(<0.2)	P (<0.2)	0.53	--	--	8,500 (f)	2,500 (n)
Desethylatrazine	Degradate	896	1118	80%	0.07	0.19	0.383	0.552	1.52	--	--	--	1,000 (n)
Hydroxyatrazine	Degradate	49	50	98%	0.046	0.067	0.089	0.122	0.210	--	--	> 1,500 (f)	>10,000 (n)
Azoxystrobin	Fungicide	3	49	6%	nd	nd	nd	0.012	0.055	--	--	130 (i)	44 (i)
Bentazon	Herbicide	9	88	10%	nd	nd	0.0003	0.002	4.69	--	--	> 50,000 (f)(i)	4,500 (n)
Clopyralid	Herbicide	17	163	10%	nd	nd	P(<0.2)	P (<0.2)	0.35	--	--	56,000 (i)	--
Clothianidin	Insecticide	1	30	3%	nd	nd	nd	nd	0.046	--	--	>46,800 (f)	120 (i)
Cyanazine	Herbicide	102	1096	9%	nd	nd	nd	0.45	8.25	--	--	--	--
Diazinon	Insecticide	4	730	1%	nd	nd	nd	nd	0.45	--	--	0.11 (i)	0.17 (i)
Dicamba	Herbicide	103	387	27%	nd	P(<0.2)	0.35	0.704	6.3	--	--	14,000 (f)	61 (n)
Dichlobenil	Herbicide	1	69	1%	nd	nd	nd	nd	P (<0.05)	--	--	1,850 (i)	30 (v)

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 2Bd5 Chronic Standard 3	MPCA Maximum Standard 4	EPA Acute Value Aquatic Life Benchmark 2	EPA Chronic Value Aquatic Life Benchmark 2
Dichlorvos	Insecticide	1	65	2%	nd	nd	nd	nd	0.1	--	--	0.035 (i)	0.0058 (i)
Dimethenamid	Herbicide	140	608	23%	nd	nd	0.08	0.23	6.05	--	--	3,150 (f)	5.1 (v)[6]
Dimethenamid ESA	Degradate	31	71	44%	nd	0.023	0.068	0.07	0.085	--	--	--	--
Dimethenamid OXA	Degradate	16	71	23%	nd	nd	0.021	0.032	0.056	--	--	--	--
Dimethoate	Insecticide	8	535	1%	nd	nd	nd	nd	1.38	--	--	21.5 (i)	0.50 (i)
Imazethapyr	Herbicide	21	50	42%	nd	0.008	0.020	0.033	0.305	--	--	> 55,000 (f)(i)	8.10 (v)
Imidacloprid	Insecticide	1	49	2%	nd	nd	nd	nd	0.030	--	--	35 (i)	1.05 (i)
MCPA	Herbicide	7	392	2%	nd	nd	nd	nd	0.28	--	--	90 (i)	20 (v)
MCPP	Herbicide	4	342	1%	nd	nd	nd	nd	P(<0.2)	--	--	45,500 (i)	14 (n)
Mesotrione	Herbicide	1	45	2%	nd	nd	nd	nd	0.055	--	--	> 60,000 (f)	9.8 (v)
Metalaxyl	Fungicide	1	50	2%	nd	nd	nd	nd	0.011	--	--	14,000 (i)	100 (i)
Metolachlor	Herbicide	586	1118	52%	P(<0.07)	0.128	0.606	1.4	9.84	23 T	271 T	na	na
Metolachlor ESA	Degradate	71	71	100%	0.914	1.215	1.49	1.75	2.31	--	--	24,000 (f)	> 95,100 (v)
Metolachlor OXA	Degradate	55	71	77%	0.050	0.158	0.377	0.507	0.74	--	--	7,700 (i)	57,100 (n)
Metribuzin	Herbicide	27	1082	2%	nd	nd	nd	nd	0.36	--	--	2,100 (i)	8.7 (n)
Metribuzin DK	Degradate	2	349	1%	nd	nd	nd	nd	P (<1)	--	--	--	--
Pendimethalin	Herbicide	3	532	1%	nd	nd	nd	nd	0.2	--	--	69 (f)	5.2 (n)
Prometon	Herbicide	2	331	1%	nd	nd	nd	nd	0.149	--	--	6,000 (f)	98 (n)
Propazine	Herbicide	21	333	6%	nd	nd	nd	P (<0.1)	P (<0.1)	--	--	>2,660 (i)	24.8 (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 2Bd5 Chronic Standard 3	MPCA Maximum Standard 4	EPA Acute Value Aquatic Life Benchmark 2	EPA Chronic Value Aquatic Life Benchmark 2
Propiconazole	Fungicide	1	352	0%	nd	nd	nd	nd	P(<0.2)	--	--	425 (f)	21 (n)
Saflufenacil	Herbicide	8	49	16%	nd	nd	0.027	0.069	0.119	--	--	> 49,000 (f)(i)	42 (n)
Tebuprimiphos	Fungicide	2	372	1%	nd	nd	nd	nd	P (<0.1)	4 H	--	500 (i)	36 (n)
Tembotrione	Herbicide	2	45	4%	nd	nd	nd	nd	0.078	--	--	915 (f)	310 (n)
Thiamethoxam	Insecticide	2	49	4%	nd	nd	nd	nd	0.130	--	--	17.5 (i)	20,000 (f)
Triclopyr	Herbicide	4	387	1%	nd	nd	nd	nd	P (<0.2)	--	--	180 (f)	100 (n)
Trifluralin	Herbicide	3	1112	0%	nd	nd	nd	nd	P (<0.17)	--	--	20.5 (f)	1.14 (f)

Table 50. Whitewater River Watershed Lake Pesticide Sampling, 2010-2011.

Pesticide Name 1	Pesticide Type	Detects	Total Samples	Detection Frequency	Detections (µg/L)		Water Quality Standards and/or Reference Values (µg/L)			
					Minimum	Maximum	MPCA Class 2Bd5 Chronic Standard 3	MPCA Maximum Standard 4	EPA Acute Value Aquatic Life Benchmark 2	EPA Chronic Value Aquatic Life Benchmark)2
2,4-D	Herbicide	2	2	100%	0.066	0.113	70 H	--	12,075 (f)	13.1 (v)
Atrazine	Herbicide	1	2	50%	nd	P (<0.05)	3.4 H; 10 T	323 T	na	na
Hydroxyatrazine	Degradate	2	2	100%	0.01	0.01	--	--	> 1,500 (f)	>10,000 (n)
Diuron	Herbicide	1	2	50%	nd	0.022	--	--	80 (i)	2.4 (n)
MCPA	Herbicide	1	2	50%	nd	0.006	--	--	90 (i)	20 (v)
Metolachlor	Herbicide	1	2	50%	nd	P(<0.07)	23 T	271 T	na	na

Key to value types and symbols in surface water reference values

– – For some analytes, reference values have not been identified or evaluated na – not applicable

(f) – USEPA/OPP benchmark value for fish.

(i) – USEPA/OPP benchmark value for invertebrates.

(n) – USEPA/OPP benchmark value for nonvascular plants

(v) – USEPA/OPP benchmark value for vascular plants.

H – “H” Chronic Standard values are human health-based and protective for an exposure duration of 30 days.

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* Ch. 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 and 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) and 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.