Upper Iowa River Watershed Stressor Identification Report

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

Minnesota Pollution Control Agency

September 2018

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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.

HIST: 1995 c 247 art 1 s 36; 2001 c 187 s 3

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Contents

List of Tables

List of Figures

Key Terms and Abbreviations

AUID	Assessment Unit ID
BOD	Biological Oxygen Demand
CADDIS	Causal Analysis/Diagnosis Decision Information System
Cfs	Cubic feet per second
CL	Confidence limits
cm	Centimeter
DELT	Deformities, Eroded fins, Lesions, and Tumors
DNR	Minnesota Department of Natural Resources
DO	Dissolved Oxygen
DOP	Dissolved Orthophosphate Phosphorus
EPA	U. S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
FIBI	Fish Index of Biological Integrity
GP	Glide/Pool
HUC	Hydrologic Unit Code
HSPF	Hydrological Simulation Program – FORTRAN
IBI	Index of Biotic Integrity
IWM	Intensive Watershed Monitoring
MIBI	Macroinvertebrate Index of Biological integrity
mg/L	Milligrams per liter
MPCA	Minnesota Pollution Control Agency
MSHA	MPCA Stream Habitat Assessment
P	Phosphorus
SID	Stressor Identification
SOE	Strength of Evidence
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
TSVS	Total Suspended Volatile Solids

Executive Summary

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

Stressor identification (SID) 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. The SID 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 SID work in the Upper Iowa River Watershed. There are seven AUIDs currently impaired for a lack of biological assemblage. After examining many candidate causes for the biological impairments, the following stressors were identified as probable causes of stress to aquatic life:

- Nitrate
- Total Suspended Solids (TSS)
- Habitat
- Fish Passage
- Flow Alteration

1. Introduction

1.1. Monitoring and Assessment

Water quality and biological monitoring in the Upper Iowa River Watershed has been ongoing. As part of the MPCA's Intensive Watershed Monitoring (IWM) approach, monitoring activities increased in rigor and intensity during 2015, 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 2015, 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 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.

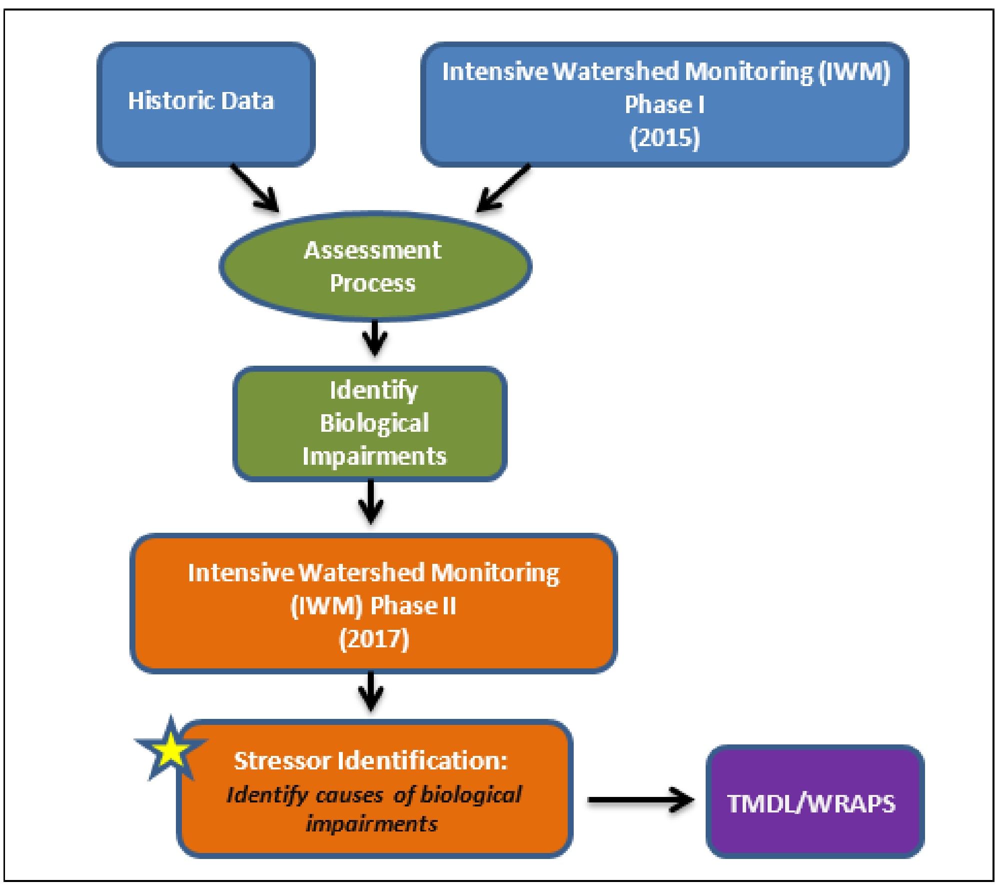


Figure 1: Process map of Intensive Watershed Monitoring, Assessment, Stressor Identification and TMDL processes.

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 SID (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 SID. Additional information on the SID process using CADDIS can be found here: https://www.epa.gov/caddis-vol1.

The SID 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.

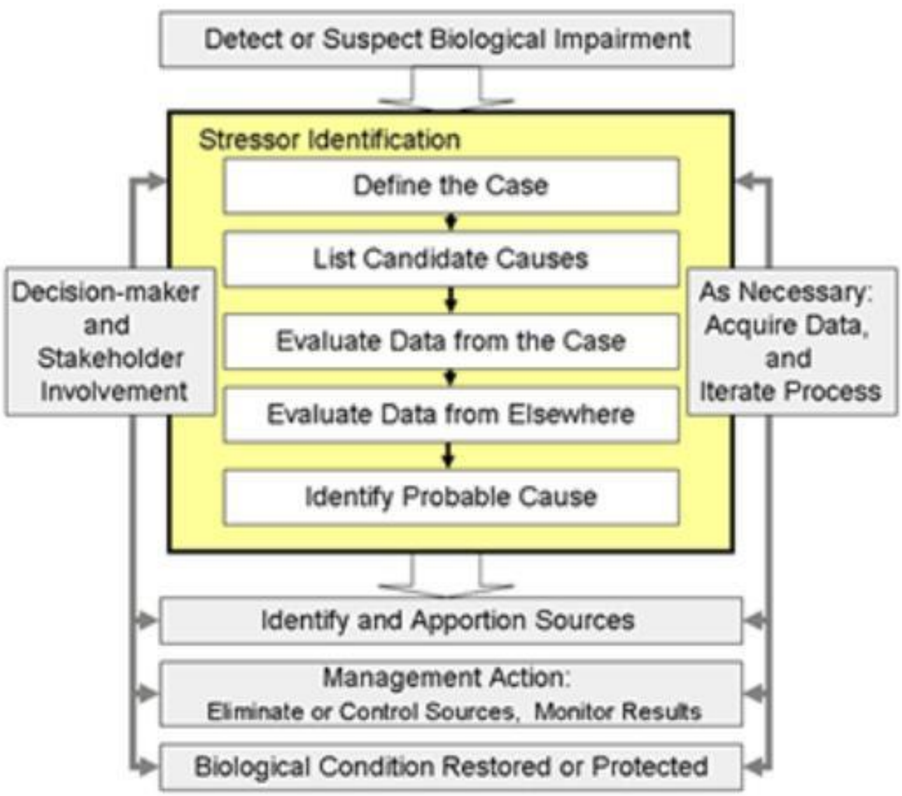


Figure 2: Conceptual model of Stressor Identification process (Cormier et al. 2000).

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

Developed by the EPA, a standard scoring system is used to tabulate the results of the SOE analysis for the available evidence. 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. 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: https://www.epa.gov/caddis-vol1/caddis-volume-1-stressor-identification-summary-tables-types-evidence.

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 Wooded riparian cover • Lack of naturally connected habitats/ causing fragmented habitats	Fish and macroinvertebrates cannot freely move throughout system. Stream temperatures also become elevated due to lack of shade.
Hydrology	**Altered Hydrology** **Loss of habitat due to channelization** **Elevated Levels of TSS** • Channelization • Peak discharge (flashy) • Transport of chemicals	Unstable flow regime within the stream can cause a lack of habitat, unstable stream banks, filling of pools and riffle habitat, and affect the fate and transport of chemicals.
Stream Channel Assessment	**Loss of Habitat due to excess sediment** **Elevated levels of TSS** • Loss of dimension/pattern/profile • Bank erosion from instability • Loss of riffles due to accumulation of fine sediment • Increased turbidity and or TSS	Habitat is degraded due to excess sediment moving through system. There is a loss of clean rock substrate from embeddedness of fine material and a loss of intolerant species.

Water Chemistry	**Low Dissolved Oxygen Concentrations** **Elevated levels of Nutrients** • Increased nutrients from human influence • Widely variable dissolved oxygen (DO) levels during the daily cycle • Increased algal and or periphyton growth in stream • Increased nonpoint pollution from urban and agricultural practices • Increased point source pollution from urban treatment facilities	There is a loss of intolerant species and a loss of diversity of species, which tends to favor species that can breathe air or survive under low DO conditions. Biology tends to be dominated by a few tolerant species.
Stream Biology	Fish and macroinvertebrate communities are affected by all of the above listed stressors	If one or more of the above stressors are affecting the fish and macroinvertebrate community, the IBI scores will not meet expectations and the stream will be listed as impaired.

1.4. Report Format

This SID report follows a format to first summarize candidate causes of stress to the biological communities at the 8-digit Hydrologic Unit Code (HUC) scale. Within the summary (Section 3), there is information about how the stressor relates broadly to the Upper Iowa River Watershed, water quality standards and general effects on biology. Section 4 is organized into three geographic sections (western, central, and eastern Upper Iowa River Watershed); each section discusses the available data and relationship to fish and macroinvertebrate metrics in more detail.

2. Overview of the Upper Iowa River Watershed

2.1. Background

See Upper Iowa River Watershed Monitoring and Assessment Report and [Upper Iowa River homepage](#) for background information.

2.2. Monitoring Overview

The Upper Iowa River Watershed was sampled intensively for fish and macroinvertebrates in 2015 (Figure 3). Detailed information regarding the biological monitoring process and impairment decisions can be found in the Upper Iowa River Watershed Monitoring and Assessment Report.

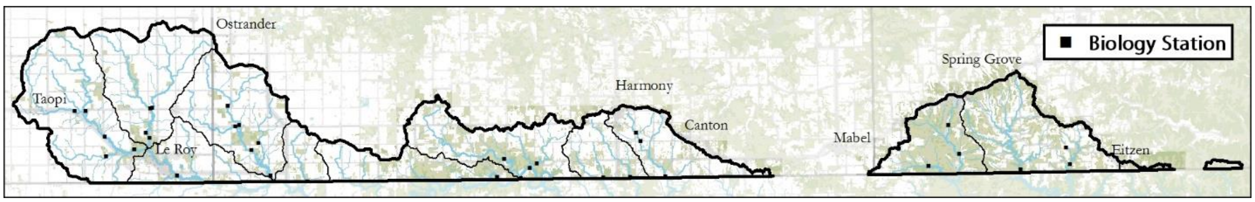


Figure 3: Biology monitoring stations for streams in the Upper Iowa River Watershed.

2.3. Summary of Biological Impairments

The approach used to identify biological impairments includes assessment of fish and aquatic macroinvertebrate communities and related habitat conditions at sites throughout a watershed. The resulting information is used to calculate a specific Index of Biotic Integrity (IBI) for that reach. The IBI scores can then be compared to a range of thresholds (MPCA 2016).

The fish and macroinvertebrates within each Assessment Unit Identification (AUID) were compared to a regionally developed threshold and confidence interval and utilized a weight of evidence approach. The water quality standards call 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. Confidence limits (CL) around the impairment threshold help to ascertain where additional information may be considered to help inform the impairment decision. When IBI scores fall within the confidence interval, interpretation and assessment of the waterbody condition involves consideration of potential stressors, and draws upon additional information regarding water chemistry, physical habitat, and land use, etc.

In the Upper Iowa River Watershed, seven AUIDs are currently impaired for a lack of biological assemblage (Table 2). Two AUIDs (503 and 512) are Class 7, and therefore not assessed. AUIDs 505 and 521 were also not assessed due to their small drainage area.

Table 2: Biologically impaired AUIDs in the Upper Iowa River Watershed.

			Impairments	
Stream Name	**AUID #**	**Reach Description**	**Biological**	**Water Quality**
Deer Creek	520	Unnamed cr to MN/IA border	Fish	
Unnamed Creek	535	Unnamed cr to MN/IA border	Macroinvertebrates	
Unnamed Creek	537	Unnamed cr to Beaver Cr	Macroinvertebrates	
Unnamed Creek	540	Unnamed cr to Little Iowa R	Macroinvertebrates	
Unnamed Creek	544	Unnamed cr to Upper Iowa R	Macroinvertebrates	
Beaver Creek	546	Mower-Fillmore Rd to Upper Iowa R	Macroinvertebrates	Bacteria
Upper Iowa River	550	-92.5901, 43.5985 to Little Iowa R	Macroinvertebrates	Bacteria

The general use IBI thresholds for stream classes sampled in the Upper Iowa River Watershed can be found below in Table 3 and Table 4. Additional information can be found in the Upper Iowa River Watershed Monitoring and Assessment Report.

Table 3: Fish classes with respective general use IBI thresholds and upper/lower CL found in the Upper Iowa River Watershed.

Class	Class Name	IBI Thresholds	Upper CL	Lower CL
2	Southern Streams	50	59	41
3	Southern Headwaters	55	62	48
10	Southern Coldwater	50	63	37

Table 4: Macroinvertebrate classes with respective general use IBI thresholds and upper/lower CL found in the Upper Iowa River Watershed.

Class	Class Name	IBI Thresholds	Upper CL	Lower CL
5	Southern Streams RR	37	49.6	24.4
6	Southern Forest Streams GP	43	56.6	29.4
9	Southern Coldwater	43	56.8	29.2

The purpose of SID is to interpret data collected during the biological monitoring and assessment process. Trends in the IBI scores can help to identify causal factors for biological impairments. A summary of the macroinvertebrate and fish IBI scores can be found in the Upper Iowa River Watershed Monitoring and Assessment Report.

3. Possible Stressors to Biological Communities

A comprehensive list of potential stressors to aquatic biological communities compiled by the EPA can be found here (https://www.epa.gov/caddis-vol2/caddis-volume-2-sources-stressors-and-responses-learn-about-stressors). This comprehensive list serves two purposes. First, it can serve as a checklist for investigators to consider all possible options for impairment in the watershed of interest. Second, it can be used to identify potential stressors that can be eliminated from further evaluation. In some cases, the data may be inconclusive and limit the ability to confidently determine if a stressor is causing impairment to aquatic life. It is imperative to document if a candidate cause was suspected, but there was not enough information to make a scientific determination of whether or not it is causing harm to aquatic life. In this case, management decisions can include modification of sampling plans and future evaluation of the inconclusive case. Alternatively, there may be enough information to conclude that a candidate cause is not causing biological impairment and therefore can be eliminated. The inconclusive or eliminated causes will be discussed in more detail in the following section.

3.1. Eliminated Causes

There were no causes eliminated from the Upper Iowa River Watershed.

3.2. Inconclusive Causes (insufficient information)

Some candidate causes were unable to be considered further and therefore were determined inconclusive. These causes were inconclusive due to lack of information, lack of biological connection, and/or mixed results (water quality and/or biological). The potential causes that were inconclusive in the Upper Iowa River Watershed were pesticides, ammonia, pH, chloride, metals, and conductivity. These causes are discussed in more detail below.

3.2.1. Overview of Pesticides in the Upper Iowa River Watershed

There is no pesticide data available in the Upper Iowa River Watershed.

3.2.2. Overview of Ammonia in the Upper Iowa River Watershed

Minimal ammonia data is available in the Upper Iowa River Watershed. Twenty-nine samples were collected in 2015, ranging from 0.05 to 0.12 mg/L. There are zero ammonia impairments in the watershed; all AUIDs are meeting standards or have insufficient information.

3.2.3. Overview of pH in the Upper Iowa River Watershed

Several instantaneous pH samples (712) were collected across the watershed from 2015 through 2017, ranging from 5.0 to 8.8. Minimal exceedances were observed, and all AUIDs are meeting standards or have insufficient information.

3.2.4. Overview of Chloride in the Upper Iowa River Watershed

Thirty-five chloride samples were collected across the watershed in 2015. Concentrations ranged from 15.3 to 40.8 mg/L (average of 20.7 mg/L); all samples were well below the chronic standard (230 mg/L).

3.2.5. Overview of Metals in the Upper Iowa River Watershed

Arsenic, Calcium, Cadmium, Chromium, Copper, Magnesium, Molybdenum, Lead, Selenium, Zinc, and Nickel were sampled at stations S001-415 (co-located with station 15LM020), S008-437 (co-located with station 15LM006), S008-439 (co-located with station 15LM001), and S008-668 (co-located with station 15LM004) on August 2, 2016. Flow conditions during sampling were near baseflow, and all concentrations were below the standard (Table 5).

Table 5: Metal concentrations in the Upper Iowa River Watershed on 8/2/16.

	S001-415 (15LM020)	S008-437 (15LM006)	S008-439 (15LM001)	S008-668 (15LM004)
Arsenic (µg/L)	<1	<1	<1	<1
Calcium (mg/L)	75	82	76	82
Cadmium (µg/L)	<0.1	<0.1	<0.1	<0.1
Chromium (µg/L)	<1	<1	<1	<1
Copper (µg/L)	<10	<10	<10	<10
Magnesium (mg/L)	18.2	22.3	21.7	27.7
Molybdenum (µg/L)	<1	<1	<1	<1
Lead (µg/L)	<1	<1	<1	<1
Selenium (µg/L)	<1	<1	<1	<1
Zinc (µg/L)	<10	<10	<10	<10
Nickel (µg/L)	<5	<5	<5	<5

3.2.6. Overview of Conductivity in the Upper Iowa River Watershed

Several instantaneous conductivity samples (737) were collected across the watershed from 2015 through 2017. Concentrations ranged from 99 to 785 uS/cm (average of 534 uS/cm). The average concentration is lower than the ecoregion average for the Western Corn Belt Plains (698 uS/cm) (McCollor et al. 1993). Although this average for the Western Corn Belt Plains was derived using an older data set (1970 through 1992), it provides some context to the concentrations documented in the Upper Iowa River Watershed.

3.3. Summary of Candidate Causes in the Upper Iowa River Watershed

Fourteen candidate causes were selected as possible drivers of biological impairments in the Upper Iowa River Watershed. The initial list of candidate/potential causes was narrowed down after the initial data evaluation/data analysis resulting in eight for final analysis in this report. The eight remaining candidate causes are:

- Temperature
- Nitrate
- Eutrophication
- DO

- TSS
- Habitat
- Fish Passage
- Flow Alteration

Background information specific to candidate causes/stressors in Minnesota can be found here. This information provides an overview of the pathway and effects of each candidate stressor considered in the biological SID process with relevant data and water quality standards specific to Minnesota. The EPA has additional information, conceptual diagrams of sources and causal pathways, and publication references for numerous stressors on its CADDIS website.

4. Evaluation of Candidate Causes

Candidate causes were evaluated in the Upper Iowa River Watershed by individual AUID. Each AUID is discussed below, and organized geographically from west to east. This report only covers the Minnesota portion of the watershed.

4.1. Western Upper Iowa - Upper Iowa River (550), Beaver Creek (546), and Unnamed Creek (544, 540, and 537)

This section encompasses biotic impairments in the western portion of the Upper Iowa River Watershed (Figure 4). There are five AUIDs with macroinvertebrate impairments; these stream reaches are located on the Upper Iowa River (AUID 550), Beaver Creek (AUID 546), and three unnamed creeks (AUIDs 544, 540, and 537). All AUIDs are warmwater (2B) and general use.

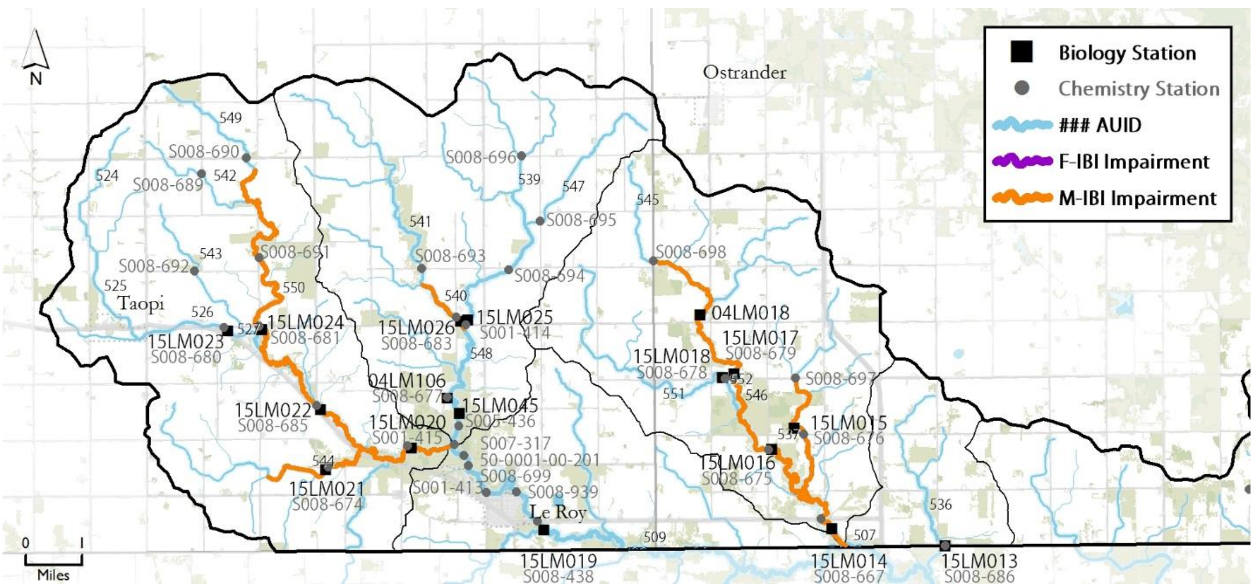


Figure 4: Upper Iowa River Watershed (western portion) biota impairments, biology stations, and chemistry stations.

4.1.1. Upper Iowa River (550)

Biological Communities

Upper Iowa River (07060002-550) is a 12.9 mile long stream segment starting in the headwaters of the Upper Iowa River, and ending in Lake Louise State Park (at Louise Mill Pond). This is a warmwater reach with macroinvertebrate and bacteria impairments. Biological monitoring stations in this AUID include 15LM020, 15LM022, and 15LM024; all stations were sampled for fish and macroinvertebrates in 2015 (except fish at station 15LM022, which was sampled in 2016).

The fish community is “supporting” the aquatic life use, and not currently impaired. Fish Index of Biological Integrity (FIBI) scores for stations 15LM020, 15LM022, and 15LM024 were 62, 80, and 63 respectively. All stations were above their general use thresholds and confidence intervals; station 15LM022 was above the exceptional use threshold. Station 15LM020 is Southern Streams (class 2), and stations 15LM022 and 15LM024 are Southern Headwaters (class 3). Several fish species were collected at each site.

The macroinvertebrate community is impaired and “not supporting” the aquatic life use. MIBI scores for stations 15LM020, 15LM022, and 15LM024 were 40, 30, and 29 respectively. Station 15LM020 was above the general use threshold, and stations 15LM022 and 15LM024 were below the threshold; all stations were within the confidence interval. All stations are Southern Streams RR (class 5). In general, pollution scores based on tolerance values (HBI_MN), taxa richness of Plecoptera (Plecoptera), taxa richness of predators (Predator), tolerant taxa (Tolerant2ChTxPct), and taxa richness of Trichoptera (Trichoptera) scored poorly and contributed to the low MIBI scores (Figure 5).

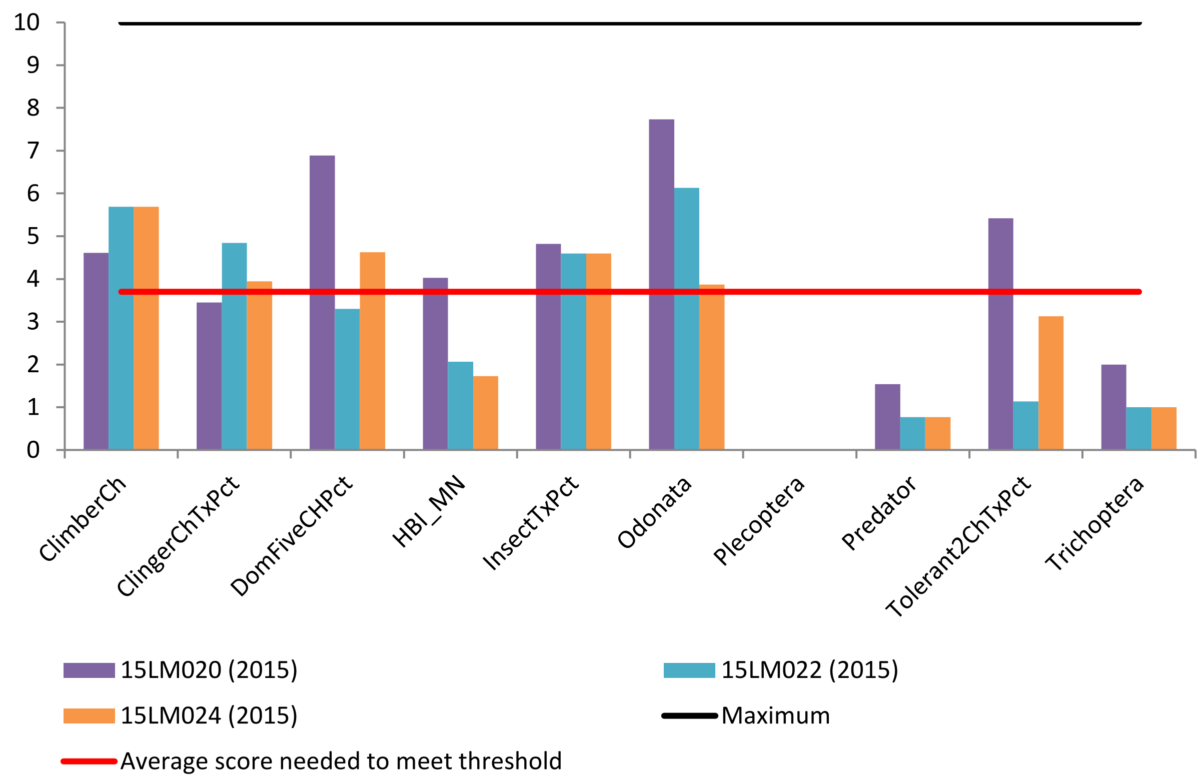


Figure 5: Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for the Upper Iowa River, stations 15LM020, 15LM022, and 15LM024.

Data Evaluation for each Candidate Cause

Temperature

Sonde deployments at stations 15LM020 (2017), 15LM022 (2017), and 15LM024 (2016) had maximum temperature values of 21.8 °C, 25.8 °C, and 21.3 °C respectively. All values were below the daily average warmwater standard (30 °C). Instantaneous samples from 1999 through 2017 had a maximum value of

21.1 °C (115 samples). Temperature appears suitable for warmwater macroinvertebrates and is not a stressor in this AUID.

Nitrate

Nitrate concentrations during fish sampling at stations 15LM020, 15LM022, and 15LM024 were 11 mg/L, 9 mg/L, and 14 mg/L respectively. Additional samples were collected at four stations (S008-691, S008-681, S008-685, and S001-415) as part of SID from 2015 through 2017, with a goal to sample various flow conditions and establish a range of nitrate concentrations (Figure 6). Concentrations ranged from 2.1 to 21 mg/L (average of 10 mg/L), and 44% of the 100 samples were above 10 mg/L. Elevated concentrations were documented at all sites during various months.

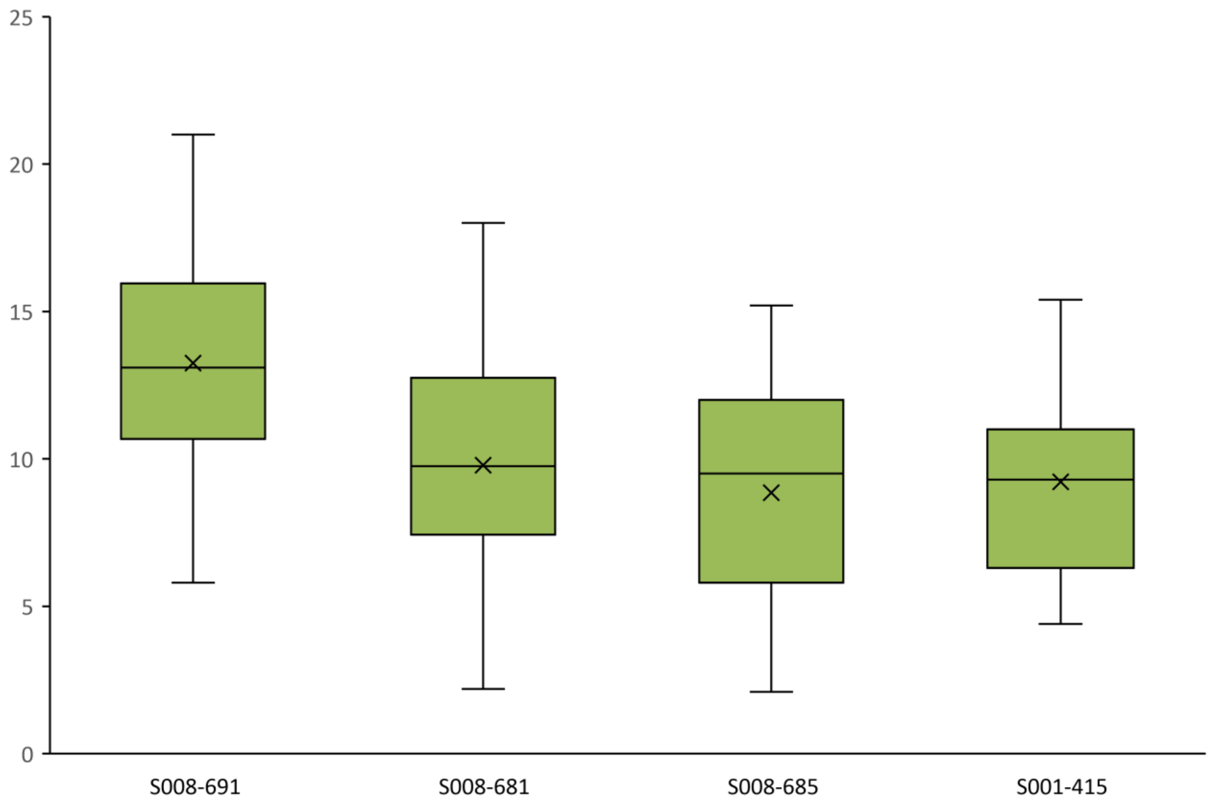


Figure 6: Nitrate concentrations (mg/L) at stations S008-691, 15LM024 (co-located with station S008-681), 15LM022 (co-located with station S008-685), and 15LM020 (co-located with station S001-415) from 2015 – 2017.

TrichopteraCh and relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were below the statewide median of stations meeting the MIBI threshold at all stations (Table 6). There were 0 to 2 nitrate intolerant taxa, and 23 to 29 nitrate tolerant taxa comprising 63% to 75% of the community. The macroinvertebrate nitrate index scores were worse than the median, ranging from 3.3 to 4.6. Overall, a majority of the macroinvertebrate metrics are indicative of nitrate stress.

Table 6: Macroinvertebrate metrics that respond to nitrate stress in the Upper Iowa River compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Intolerant Pct	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM024 (2015)	**4.6**	2	**0.6**	**23**	**70.5**	**3**	**0.6**
15LM022 (2015)	**3.8**	**0**	**0.0**	**29**	**75.2**	**3**	**0.3**
15LM020 (2015)	**3.3**	**0**	**0.0**	**24**	**62.7**	**4**	**0.3**
Southern Streams Median	*3.0*	*2*	*1.0*	*19*	*49.6*	*5*	*3.6*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Elevated nitrate concentrations have been documented in the Upper Iowa River, and the macroinvertebrate community shows signs of nitrate stress. The nitrate index scores were worse than the median, there were minimal nitrate intolerant taxa, and nitrate tolerant taxa dominated the community. Nitrate is a stressor in this AUID.

Eutrophication

Total phosphorus (TP) concentrations during fish sampling at stations 15LM020, 15LM022, and 15LM024 were 0.041 mg/L, 0.085 mg/L, and 0.024 mg/L respectively. Additional samples were collected at these stations as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TP concentrations (Figure 7). Concentrations ranged from 0.016 to 0.596 mg/L (average of 0.080 mg/L), and six (11%) of the 55 samples exceeded the river eutrophication standard for the South Region (0.150 mg/L). All stations had at least one exceedance, and exceedances occurred in February (3), July, August, and September with most during elevated flow conditions. Dissolved Orthophosphate Phosphorus (DOP) concentrations ranged from 0.007 through 0.320 mg/L.

Chlorophyll-a (Chl-*a*), Biological Oxygen Demand (BOD), DO flux, and pH flux are also considered when evaluating eutrophication stress. Three chl-*a* and BOD samples were collected at each station in July and August of 2017. Chl-*a* concentrations ranged from 1.7 to 14.5 µg/L, and BOD concentrations ranged from 0.7 to 1.7 mg/L. There were no exceedances of the chl-*a* standard (35 µg/L) or BOD standard (3 mg/L). Daily DO flux at stations 15LM020, 15LM022, and 15LM024 ranged from 3.5 to 5.5 mg/L, 0.7 to 2.9 mg/L, and 1.0 to 3.1 mg/L respectively; the only exceedances of the standard (4.5 mg/L) occurred at station 15LM020 (four days exceeded the standard). The pH flux at stations 15LM020, 15LM022, and 15LM024 ranged from 0.25 to 0.51 (average of 0.36), 0.10 to 0.63 (average of 0.24), and 0.14 to 0.25 (average of 0.18) respectively. Typical daily pH fluctuations are 0.2 to 0.3 (Heiskary et al. 2013).

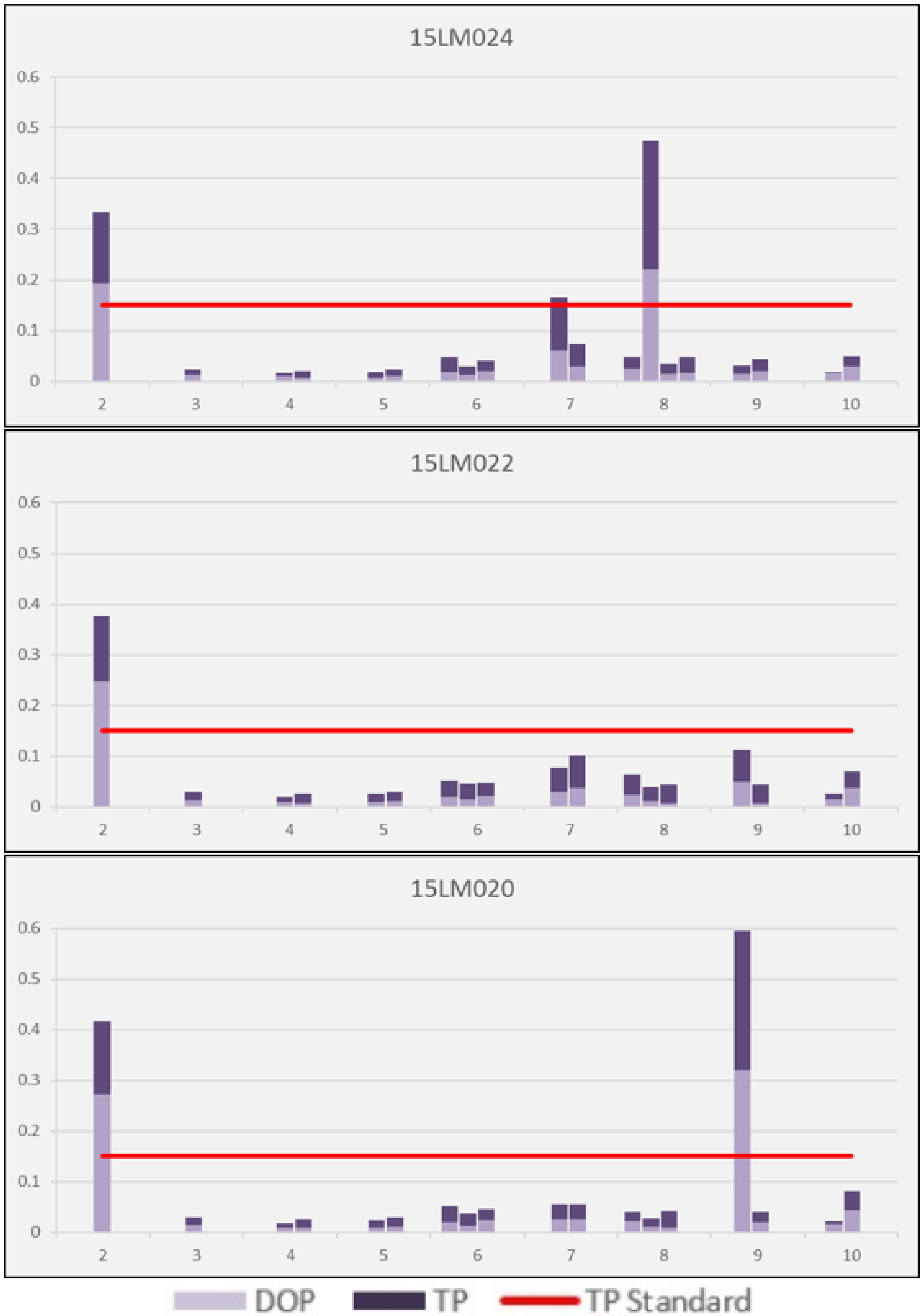


Figure 7: TP and DOP concentrations (mg/L) in the Upper Iowa River in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were better than the statewide median of stations meeting the MIBI threshold (Table 7). Taxa richness of collector-filterers (Collector-filtererCh) and collector-gatherers (Collector-gathererCh) were at or above the median at all stations. Taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) was below the median at all stations. There were 1 to 5 phosphorus (P) intolerant taxa comprising 0% to 12% of the community, and 5 to 9 P tolerant taxa comprising 2% to 12% of the community. All stations had relatively low phosphorus intolerant and tolerant individuals. The macroinvertebrate phosphorus index scores were worse than the median at stations 15LM022 and 15LM024, and better than the median at station 15LM020; phosphorus index scores ranged from 0.116 to 0.134. Although a majority of the macroinvertebrate metrics are better than the median, most metrics at stations with low MIBI scores (15LM022 and 15LM024) are worse than the median.

Table 7: Macroinvertebrate metrics that respond to eutrophication stress in the Upper Iowa River compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Phosphorus Index Score	Phosphorus Intolerant Taxa	Phosphorus Intolerant Pct	Phosphorus Tolerant Taxa	Phosphorus Tolerant Pct	Collector-filtererCh	Collector-gathererCh	EPT
15LM024 (2015)	**0.134**	**3**	**1.3**	7	12.1	6	19	**5**
15LM022 (2015)	**0.132**	**1**	**0.3**	**9**	5.3	8	17	**8**
15LM020 (2015)	0.116	5	11.9	5	2.4	7	15	**5**
Southern Streams Median	*0.122*	*4*	*3.2*	*8*	*14.2*	*6*	*15*	*11*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓	↓

TP and DO flux exceedances have been documented, but limited chl-*a* and BOD data is meeting standards. The macroinvertebrate metrics don't display a strong signal for eutrophication stress; eutrophication is inconclusive as a stressor.

Dissolved Oxygen

Continuous DO data was collected at stations 15LM020 (2017), 15LM022 (2017), and 15LM024 (2016); concentrations ranged from 6.8 to 12.5 mg/L, 5.2 to 9.8 mg/L, and 7.1 to 10.8 mg/L respectively (Figure 8). All values were above the warmwater DO standard (5 mg/L). Daily DO flux at stations 15LM020, 15LM022, and 15LM024 ranged from 3.5 to 5.5 mg/L, 0.7 to 2.9 mg/L, and 1.0 to 3.1 mg/L respectively; the only exceedances of the standard (4.5 mg/L) occurred at station 15LM020 (four days exceeded the standard). Instantaneous samples from 2015 through 2017 ranged from 2.4 to 12.7 mg/L, with two (2%) of the 103 samples below the low DO standard. These exceedances occurred in the upper end of the

AUID in September 2015; two samples collected downstream in the lower end of the reach on the same day were above the standard.

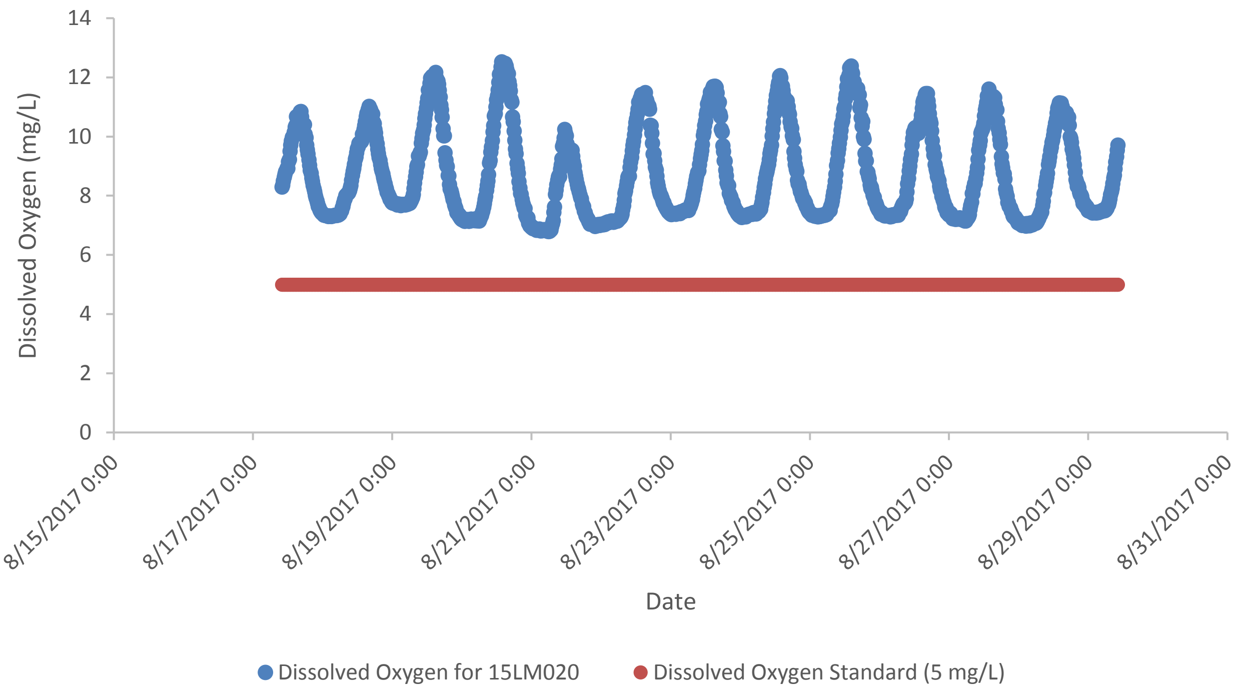


Figure 8: Example of DO conditions in the Upper Iowa River. This data is from a sonde deployment at station 15LM020 in 2017.

The macroinvertebrate metrics were mixed, with some worse than the statewide median of stations meeting the MIBI threshold and some better (Table 8). Taxa richness of EPT was below the median at all stations. There were 8 to 14 low DO intolerant taxa comprising 13% to 42% of the community, and 2 to 6 low DO tolerant taxa comprising 1% to 4% of the community. The macroinvertebrate low DO index score was worse than the median at station 15LM024, and better than the median at stations 15LM020 and 15LM022. Low DO index scores ranged from 6.9 to 7.6. Although a majority of the macroinvertebrate metrics at stations with low MIBI scores (15LM022 and 15LM024) were worse than the median, there does not appear to be a strong signal for low DO stress.

Table 8: Macroinvertebrate metrics that respond to DO stress in the Upper Iowa River compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT
15LM024 (2015)	**6.9**	11	**12.7**	3	2.9	**5**
15LM022 (2015)	7.3	**8**	**20.7**	**6**	4.3	**8**
15LM020 (2015)	7.6	14	42.2	2	0.6	**5**
Southern Streams Median	*7.1*	*9*	*21.2*	*4*	*5.6*	*11*
Expected response to stress	↓	↓	↓	↑	↑	↓

DO concentrations appear adequate, and the macroinvertebrates don't display a strong signal for low DO stress. DO is not a stressor in this AUID.

TSS

TSS concentrations during fish sampling at stations 15LM020, 15LM022, and 15LM024 were 4.4 mg/L, 8.8 mg/L, and 6.4 mg/L respectively. Additional samples were collected at these stations as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TSS concentrations (Figure 9). Concentrations ranged from 2.8 through 110 mg/L (average of 18.2 mg/L), and three (6%) of the 55 samples exceeded the TSS standard for the South Region (65 mg/L). Exceedances occurred in February (15LM024), August (15LM024), and September (15LM020) during elevated flow conditions. Total Suspended Volatile Solids (TSVS) concentrations ranged from 1.6 to 20 mg/L.

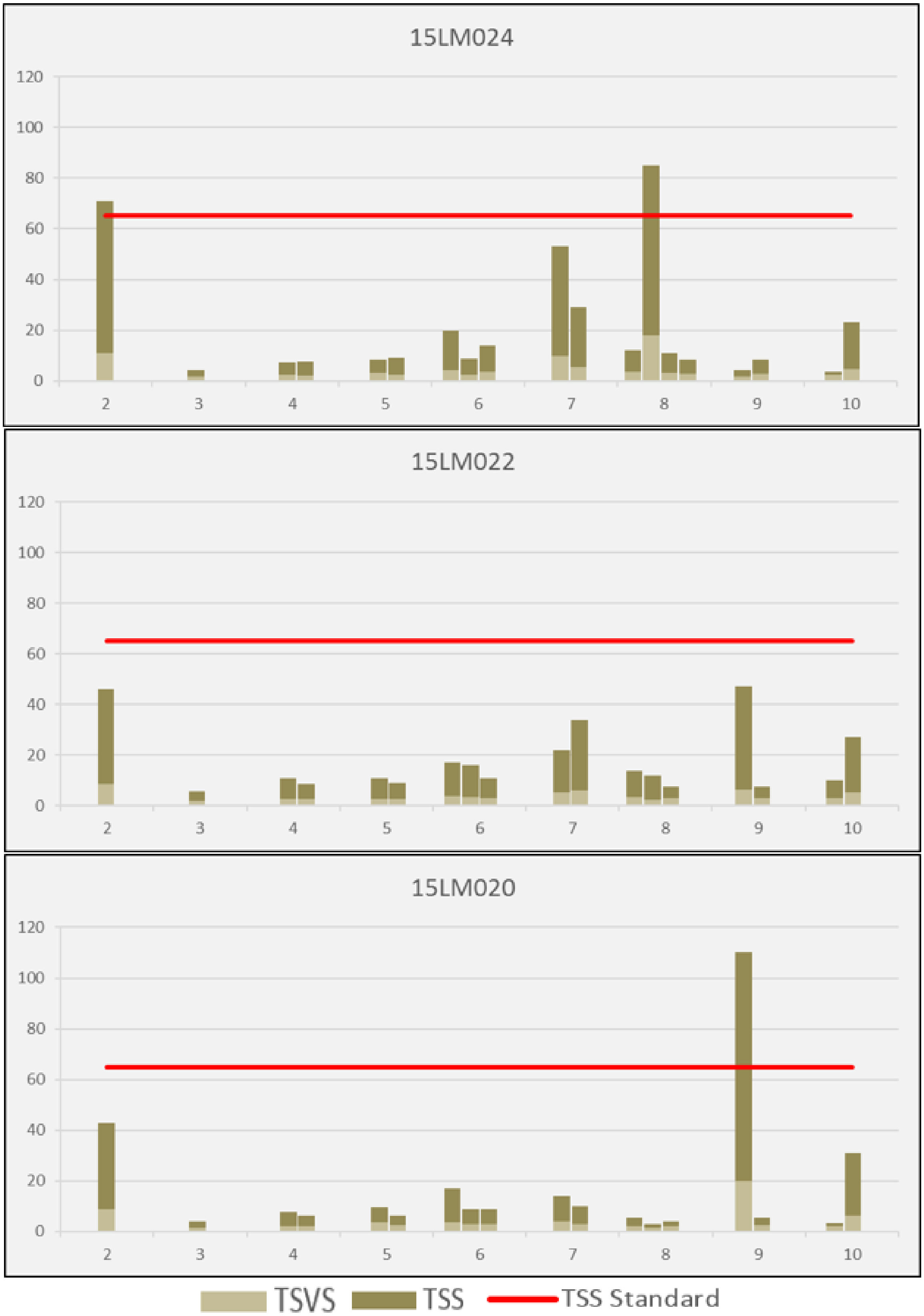


Figure 9: TSS and TSVS concentrations (mg/L) in the Upper Iowa River in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 9). Relative abundance of collector-filterer individuals (Collector-filtererPct) was below the median at stations 15LM022 and 15LM024, and above the median at station 15LM020. Relative abundance of Plecoptera individuals (PlecopteraPct) was zero at all stations. There were 0 to 1 TSS intolerant taxa comprising 0% of the community, and 8 to 12 TSS tolerant taxa comprising 30% to 51% of the community. The macroinvertebrate TSS index scores were worse than the median at stations 15LM022 and 15LM024, and better than the median at station 15LM020. TSS index scores ranged from 15.2 to 17.4. TSS tolerant individuals are highest at the farthest upstream station, and decrease going downstream. Stations with low MIBI scores (15LM022 and 15LM024) have signals of TSS stress.

Table 9: Macroinvertebrate metrics that respond to TSS stress in the Upper Iowa River compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Intolerant Pct	TSS Tolerant Taxa	TSS Tolerant Pct	Collector-filtererPct	PlecopteraPct
15LM024 (2015)	**17.4**	**1**	**0.3**	8	**51.4**	**20.0**	0.0
15LM022 (2015)	**16.9**	**0**	**0.0**	12	**43.3**	**18.8**	0.0
15LM020 (2015)	15.2	**1**	**0.3**	11	29.7	37.1	0.0
Southern Streams Median	*15.5*	*2*	*1.8*	*12*	*33.7*	*23.7*	*0.0*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Minimal TSS exceedances have been documented, but the macroinvertebrate community shows signs of TSS stress. It's possible the macroinvertebrate stress is due to other stressors as a majority of the TSS concentrations are below the standard. TSS is inconclusive as a stressor.

Lack of Habitat

The MPCA Stream Habitat Assessment (MSHA) scores ranged from 34 to 63 ("poor" to "fair") in 2015 and 2016. Channel features consisted of runs (55% to 80%), pools (15% to 30%), and riffles (5% to 15%). In general, dominant substrate was gravel, sand, and silt in runs, sand and silt in pools, and cobble, gravel, and sand in riffles. Light to severe embeddedness was noted, and bank erosion varied between visits and stations (little to severe). Channel stability ranged from low to moderate. Multiple cover types were present, with cover amount ranging from sparse to moderate.

The macroinvertebrate metrics are suggestive of habitat stress (Figure 10). Climbers were present in good numbers at all stations, but burrowers (station 15LM024) and legless (stations 15LM024 and 15LM022) were elevated and clingers (stations 15LM024 and 15LM022) were reduced. Burrowers burrow in fine sediment, legless are tolerant species that can withstand degraded habitat conditions, and clingers attach to rock or woody debris. The upper end of the AUID appears to be experiencing more habitat stress, which is also where the low MIBI scores occurred.

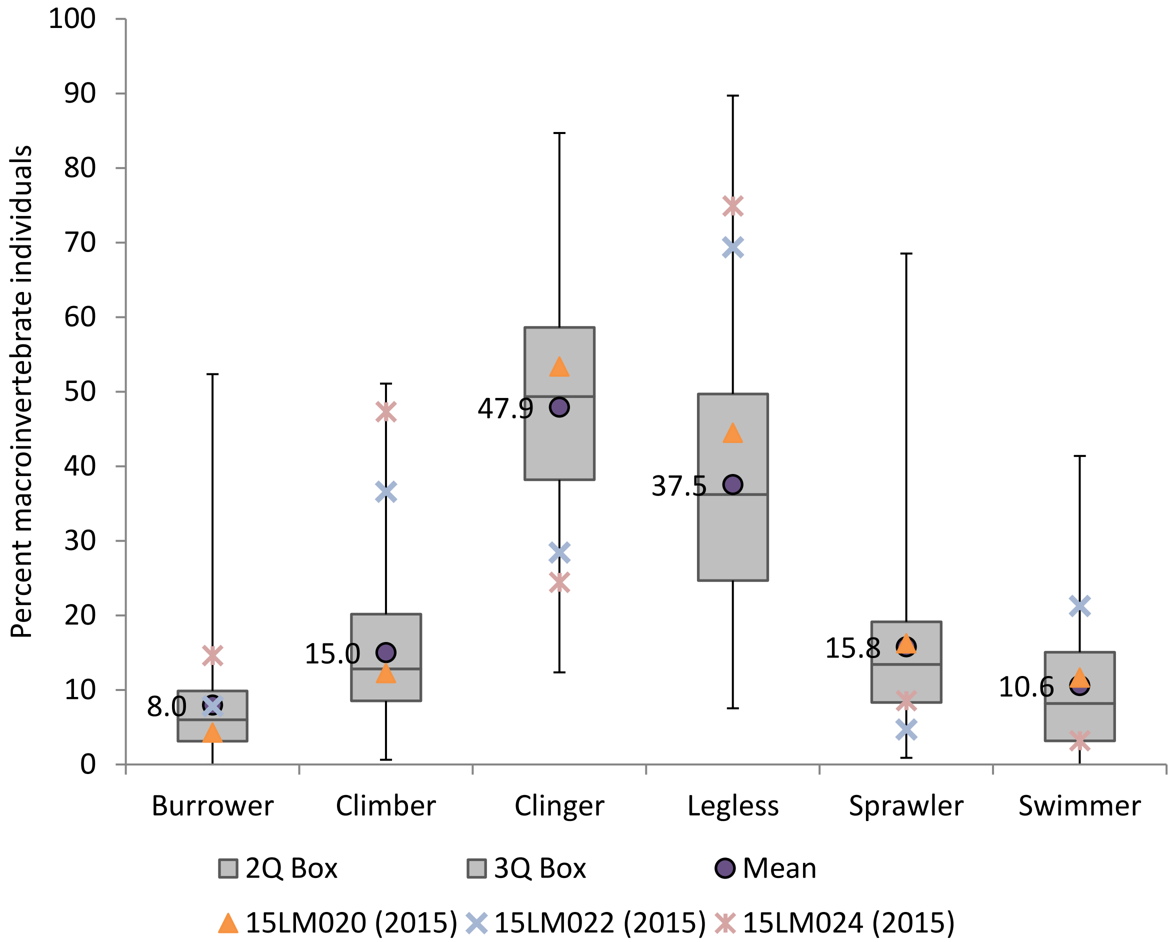


Figure 10: Macroinvertebrate habitat metrics with box plot showing range of values from Southern Streams RR (class 5) stations meeting the bio criteria, mean of those stations, and metric values from Upper Iowa River stations.

Geomorphology work completed by the DNR in 2016 at station 15LM024 documented slight to moderate incision, which creates higher shear stress and streambank erosion (Figure 11). Five eroding banks were observed during the survey, which resulted in an estimated erosion rate categorized as highly unstable. The DNR staff noted that “although there is an excess sediment supply, diverse habitat is seen with pools that are well defined and relatively deep, while riffles show a range of depths”; it was also mentioned that “excess sediment deposition is likely limiting macroinvertebrate habitat.” It may be the case that habitat is suitable for fish, but limited for macroinvertebrates. In addition, the box culverts at the road crossing upstream of the station are creating channel instability and reducing sediment transport (DNR 2017).

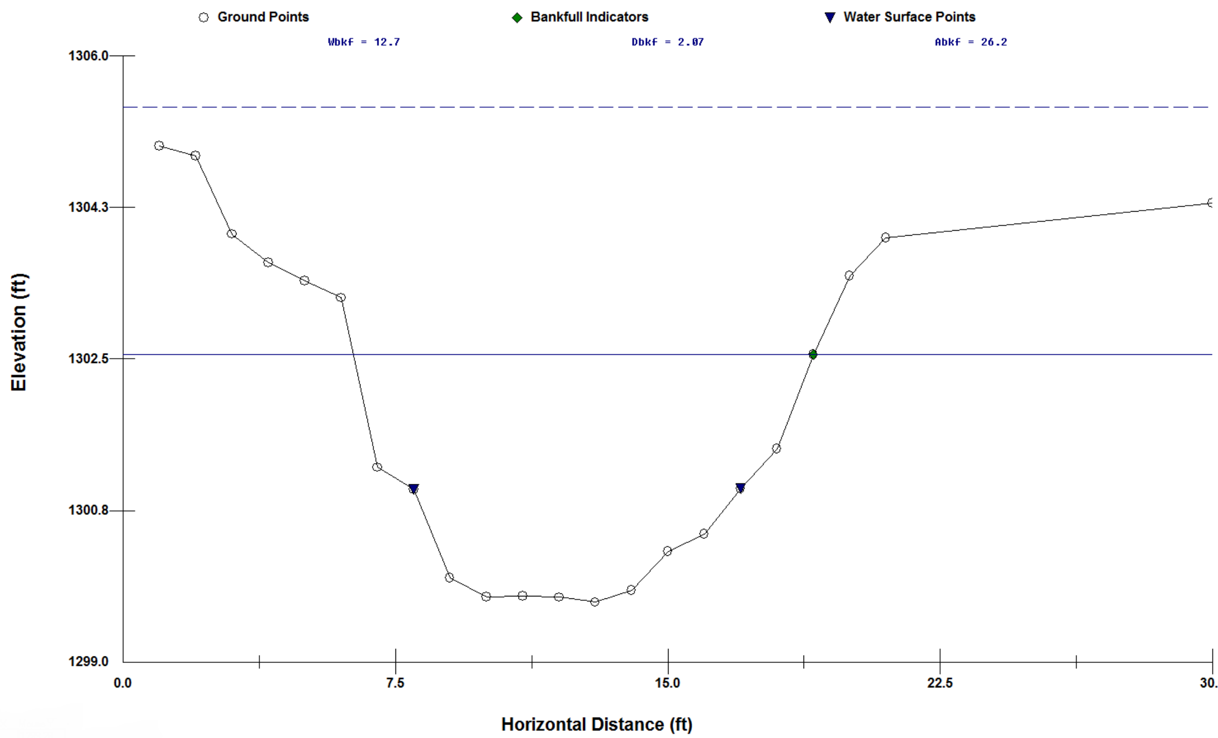


Figure 11: Cross section of riffle at station 15LM024 showing bankfull (solid line) and flood prone elevations (dashed line). Bankfull flows are contained within the channel, increasing shear stress and streambank erosion. Figure provided by the DNR.

The MSHA scores were "poor" to "fair", fine substrates were abundant, embeddedness and erosion were present, and the macroinvertebrate community shows signs of habitat stress (elevated burrowers and legless and reduced clingers). Lack of habitat and fine substrate are stressing the macroinvertebrate community.

Flow Alteration

There are currently no stream gaging stations in the watershed, but modeled flows via the Hydrological Simulation Program – FORTRAN (HSPF) model are available for the watershed from 1993 through 2015 (Tetra Tech 2018). Modeled flows at the mouth of this AUID ranged from 0.8 to 1,793.9 cubic feet per second (cfs) (average of 32.9 cfs).

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 10). Relative abundance of long-lived individuals (LongLivedPct) and non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were worse than the median at all stations. Relative abundance of EPTPct, tolerant taxa (Tolerant2ChTxPct), and total taxa richness (TaxaCountAllChir) were mixed; some stations were better than the median and some were worse. Also, a beaver dam was noted near station 15LM022; beaver dams can impact hydrology as well as other variables. Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of EPT, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al. 2002; Poff and Zimmerman 2010; EPA 2012).

Table 10: Macroinvertebrate metrics that respond to flow alteration stress in the Upper Iowa River compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	EPTPct	LongLivedPct	TrichwoHydroPct	TaxaCountAllChir	Tolerant2ChTxPct
15LM024 (2015)	**15.2**	**4.8**	**0.6**	43	**79.1**
15LM022 (2015)	**25.9**	**0.9**	**0.3**	43	**88.4**
15LM020 (2015)	45.1	**4.3**	**0.3**	**38**	68.4
Southern Streams Median	*41.8*	*7.0*	*3.6*	*43*	*73.1*
Expected response to stress	↓	↓	↓	↓	↑

Flow alteration is a stressor in the Upper Iowa River, and is contributing to nitrate and habitat stressors. Altered (channelized) watercourses and agricultural tile drainage are common in this part of the watershed (Figure 63). Channelized reaches have direct impacts on hydrology and habitat (as well as other variables), and although tile drainage can increase agricultural productivity it has negative impacts on hydrology (e.g. increasing peak flows and reducing base flows) and water quality (e.g. increasing nitrogen loading). See Section 5 (Conclusions in the Upper Iowa River Watershed) for more information on flow alteration.

Conclusion

Nitrate, habitat, and flow alteration are stressing the macroinvertebrate community in the Upper Iowa River. Eutrophication and TSS are inconclusive, while temperature, DO, and fish passage are not stressors.

4.1.2. Beaver Creek (546)

Biological Communities

Beaver Creek (07060002-546) is a 9.4 mile long stream segment starting near the headwaters of Beaver Creek, and ending at the Minnesota/Iowa border. This is a warmwater reach with macroinvertebrate and bacteria impairments. Biological monitoring stations in this AUID include 04LM018, 15LM014, 15LM016, and 15LM017; all stations were sampled for fish and macroinvertebrates in 2015, except station 04LM018 which was sampled in 2004. Data from station 04LM018 is expired for assessment purposes, and not included in any analysis for this AUID.

The fish community is “supporting” the aquatic life use, and not currently impaired. FIBI scores for stations 15LM014, 15LM016, and 15LM017 were 79, 66, and 66 respectively. All stations were above the general use threshold and confidence interval; station 15LM014 was above the exceptional use threshold. All stations are Southern Headwaters (class 3). Several fish species were collected at each site.

The macroinvertebrate community is impaired and “not supporting” the aquatic life use. MIBI scores for stations 15LM014, 15LM016, and 15LM017 were 42, 44, and 27 respectively. Stations 15LM014 and 15LM016 were above the general use threshold, and station 15LM017 was below the threshold; all stations were within the confidence interval. All stations are Southern Streams RR (class 5). Taxa richness of climbers (ClimberCh), pollution scores based on tolerance values (HBI_MN), relative abundance of insect taxa (InsectTxPct), taxa richness of Odonata (Odonata), Plecoptera, taxa richness of predators (Predator), tolerant taxa (Tolerant2ChTxPct), and Trichoptera scored below average at station 15LM017 and contributed to the low MIBI score (Figure 12).

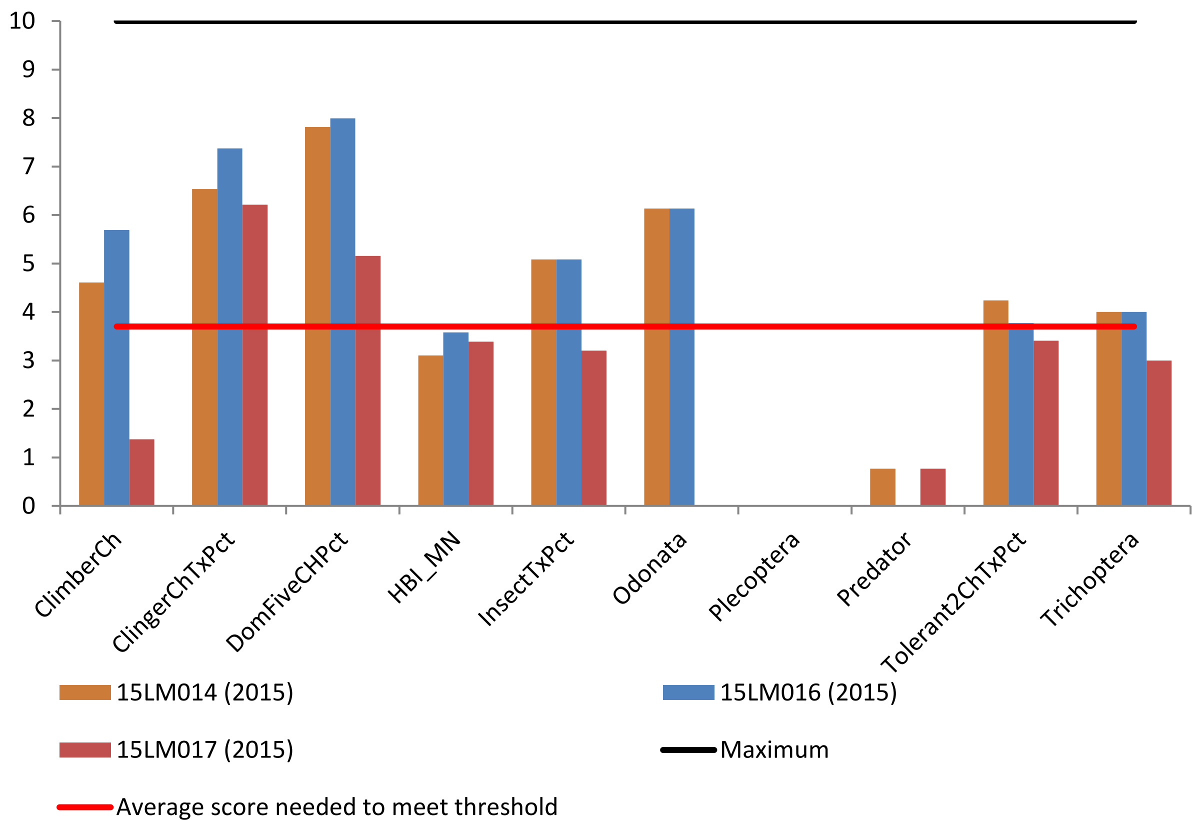


Figure 12: Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for Beaver Creek, stations 15LM014, 15LM016, and 15LM017.

Data Evaluation for each Candidate Cause

Temperature

A continuous temperature sensor was deployed at station 15LM017 in 2015 with a maximum value of 27.9 °C (Figure 13). All values were below the daily average warmwater standard (30 °C). Sonde deployments at stations 15LM014 (2016), 15LM016 (2017), and 15LM017 (2016) had maximum temperature values of 26.9 °C, 27.7 °C, and 26.5 °C respectively. Instantaneous samples from 2015 through 2017 had a maximum value of 24.8 °C (86 samples). Temperature appears suitable for warmwater macroinvertebrates and is not a stressor in this AUID.

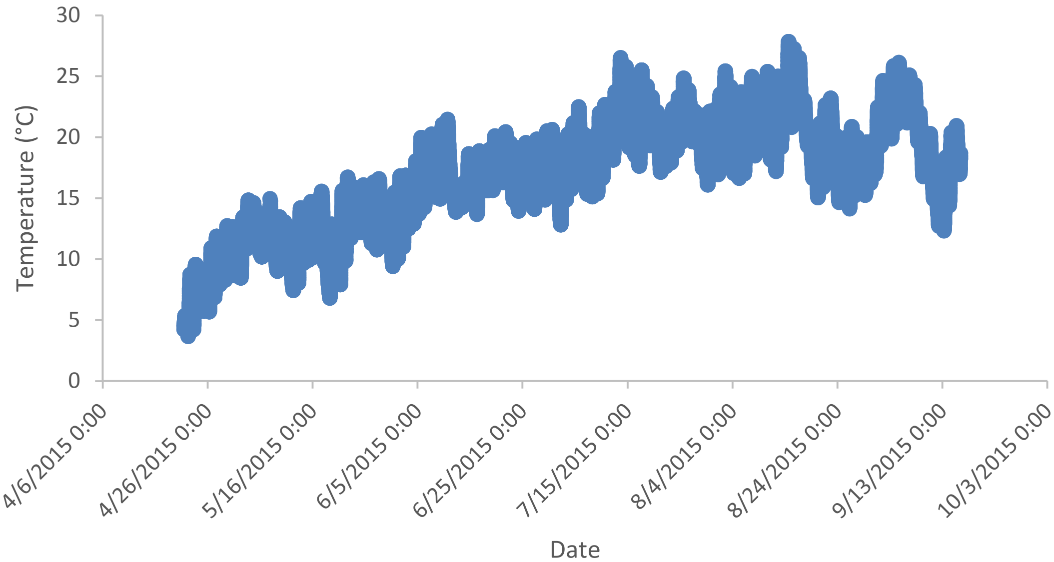


Figure 13: Continuous temperature data at station 15LM017 in 2015; all values were below 30 °C.

Nitrate

Nitrate concentrations during fish sampling at stations 15LM014, 15LM016, and 15LM017 were 2.4 mg/L, 11 mg/L, and 12 mg/L respectively. Additional samples were collected at three stations (S008-679, S008-675, and S008-667) as part of SID from 2015 through 2017, with a goal to sample various flow conditions and establish a range of nitrate concentrations (Figure 14). Concentrations ranged from 0.9 to 14 mg/L (average of 8.2 mg/L), and 24 (28%) of the 87 samples were above 10 mg/L. Elevated concentrations were documented at all sites during various months.

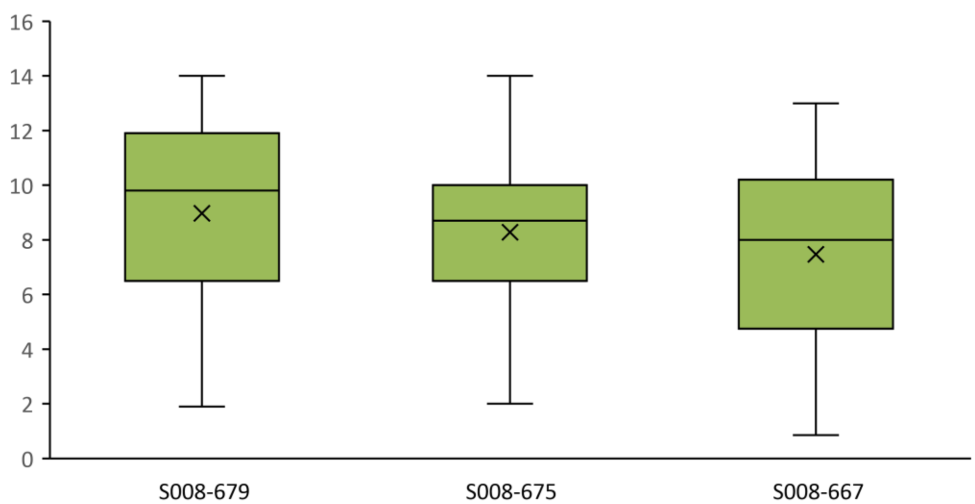


Figure 14: Nitrate concentrations (mg/L) at stations 15LM017 (co-located with station S008-679), 15LM016 (co-located with station S008-675), and 15LM014 (co-located with station S008-667) from 2015 – 2017.

TrichopteraCh and relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were at or above the statewide median of stations meeting the MIBI threshold at all stations (Table 11). There were zero nitrate intolerant taxa, and 22 to 29 nitrate tolerant taxa comprising 58% to 62% of the community. The macroinvertebrate nitrate index scores were worse than the median, ranging from 3.3 to 3.4. Overall, a majority of the macroinvertebrate metrics are indicative of nitrate stress.

Table 11: Macroinvertebrate metrics that respond to nitrate stress in Beaver Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Intolerant Pct	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM017 (2015)	**3.4**	**0**	**0.0**	**22**	**62.4**	5	9.7
15LM016 (2015)	**3.3**	**0**	**0.0**	**29**	**58.7**	6	11.1
15LM014 (2015)	**3.4**	**0**	**0.0**	**29**	**58.0**	6	5.9
Southern Streams Median	*3.0*	*2*	*1.0*	*19*	*49.6*	*5*	*3.6*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Elevated nitrate concentrations have been documented in Beaver Creek, and the macroinvertebrate community shows signs of nitrate stress. The nitrate index scores were worse than the median, there were zero nitrate intolerant taxa, and nitrate tolerant taxa dominated the community. Nitrate is a stressor in this AUID.

Eutrophication

TP concentrations during fish sampling at stations 15LM014, 15LM016, and 15LM017 were 0.057 mg/L, 0.030 mg/L, and 0.034 mg/L respectively. Additional samples were collected at these stations as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TP concentrations (Figure 15). Concentrations ranged from 0.008 to 0.502 mg/L (average of 0.089 mg/L), and seven (12%) of the 57 samples exceeded the river eutrophication standard for the South Region (0.150 mg/L). All stations had at least one exceedance, and exceedances occurred in February (3), August, and September (3) during elevated flow conditions. DOP concentrations ranged from 0.005 to 0.265 mg/L.

Chl-*a*, BOD, DO flux, and pH flux are also considered when evaluating eutrophication stress. Three chl-*a* and BOD samples were collected at each station in July and August of 2017. Chl-*a* concentrations ranged from 3.1 to 10.7 µg/L, and BOD concentrations ranged from 1.1 to 2.2 mg/L. There were no exceedances of the chl-*a* standard (35 µg/L) or BOD standard (3 mg/L). Daily DO flux at stations 15LM014, 15LM016, and 15LM017 ranged from 1.0 to 4.2 mg/L, 0.7 to 4.0 mg/L, and 1.0 to 3.9 mg/L respectively; there were no exceedances of the standard (4.5 mg/L). The pH flux at stations 15LM014, 15LM016, and 15LM017 ranged from 0.11 to 0.37 (average of 0.26), 0.13 to 0.79 (average of 0.28), and 0.13 to 0.42 (average of

0.32) respectively. Typical daily pH fluctuations are 0.2 to 0.3 (Heiskary et al. 2013).

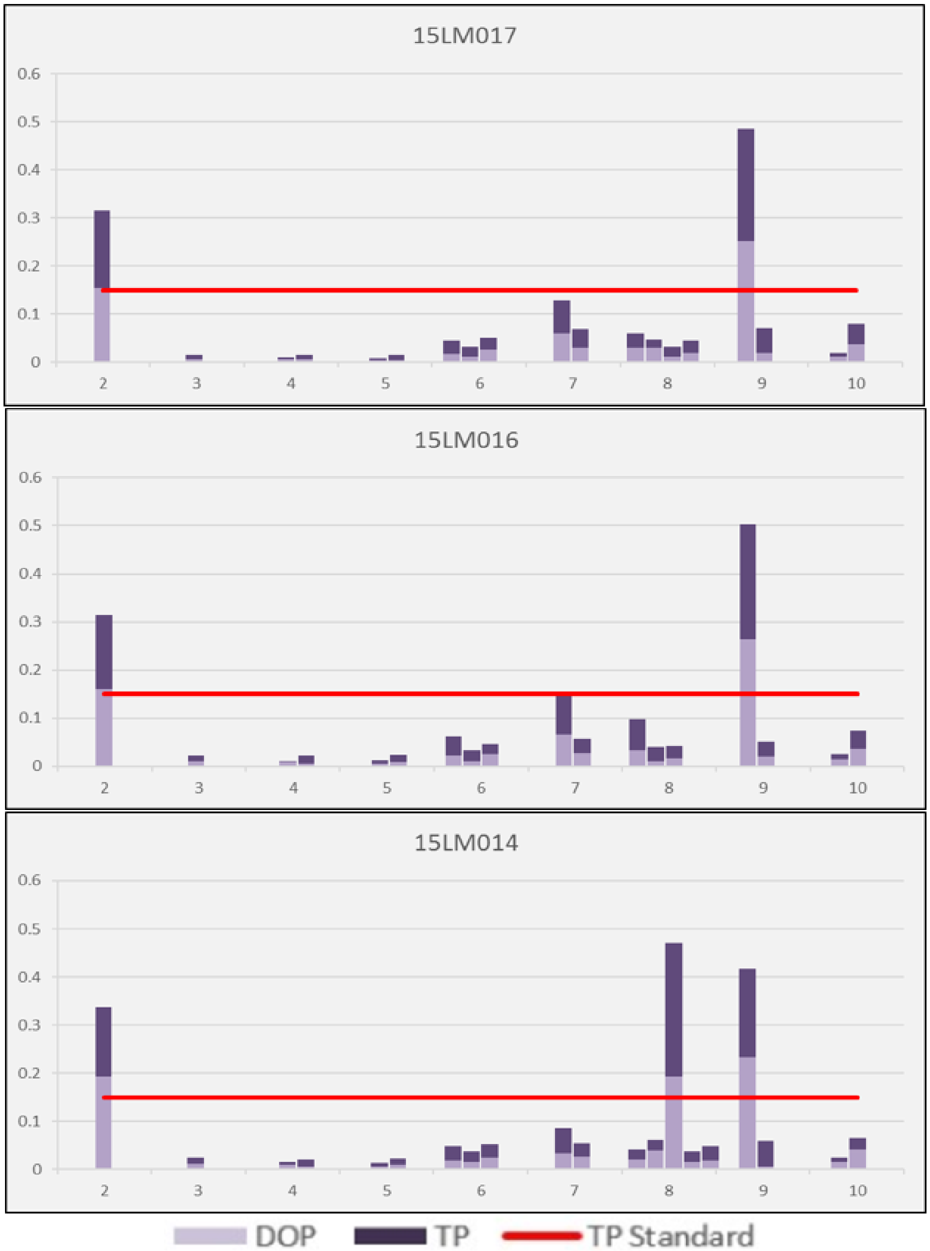


Figure 15: TP and DOP concentrations (mg/L) in Beaver Creek in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were better than the statewide median of stations meeting the MIBI threshold (Table 12). Taxa richness of collector-filterers (Collector-filtererCh) was at or above the median at all stations, while taxa richness of EPT was below the median at all stations. Taxa richness of collector-gatherers (Collector-gathererCh) was above and below the median. There were 3 to 4 P intolerant taxa comprising 2% to 7% of the community, and 7 to 9 P tolerant taxa comprising 3% to 11% of the community. All stations had relatively low P intolerant and tolerant individuals. The macroinvertebrate phosphorus index scores were worse than the median at stations 15LM014 and

15LM016, and better than the median at station 15LM017; phosphorus index scores ranged from 0.118 to 0.130.

Table 12: Macroinvertebrate metrics that respond to eutrophication stress in Beaver Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Phosphorus Index Score	Phosphorus Intolerant Taxa	Phosphorus Intolerant Pct	Phosphorus Tolerant Taxa	Phosphorus Tolerant Pct	Collector-filtererCh	Collector-gathererCh	EPT
15LM017 (2015)	0.118	**3**	7.2	7	2.8	6	**14**	**6**
15LM016 (2015)	**0.123**	4	**2.5**	8	7.6	8	20	**10**
15LM014 (2015)	**0.130**	4	**2.1**	**9**	11.3	7	18	**8**
Southern Streams Median	*0.122*	*4*	*3.2*	*8*	*14.2*	*6*	*15*	*11*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓	↓

TP exceedances have been documented during elevated flows, but the limited chl-*a*, BOD, and DO flux data is meeting standards. The macroinvertebrate metrics don't display a strong signal for eutrophication stress; eutrophication is inconclusive as a stressor.

Dissolved Oxygen

Continuous DO data was collected at stations 15LM014 (2016), 15LM016 (2017), and 15LM017 (2016); concentrations ranged from 6.2 to 10.8 mg/L, 6.2 to 10.7 mg/L, and 6.2 to 10.3 mg/L respectively (Figure 16). All values were above the warmwater DO standard (5 mg/L). Daily DO flux at stations 15LM014, 15LM016, and 15LM017 ranged from 1.0 to 4.2 mg/L, 0.7 to 4.0 mg/L, and 1.0 to 3.9 mg/L respectively; there were no exceedances of the standard (4.5 mg/L). Instantaneous samples from 2015 through 2017 ranged from 0.2 to 14.0 mg/L, with three (4%) of the 85 samples below the low DO standard. These exceedances occurred at stations S008-675 (November 16, 2015) and S008-679 (August 2, 2016 and September 14, 2017); station S008-675 is co-located with station 15LM016 and station S008-679 is co-located with station 15LM017. A beaver dam was located just downstream of station S008-679, creating a more stagnant condition that could be affecting DO concentrations (as well as other parameters).

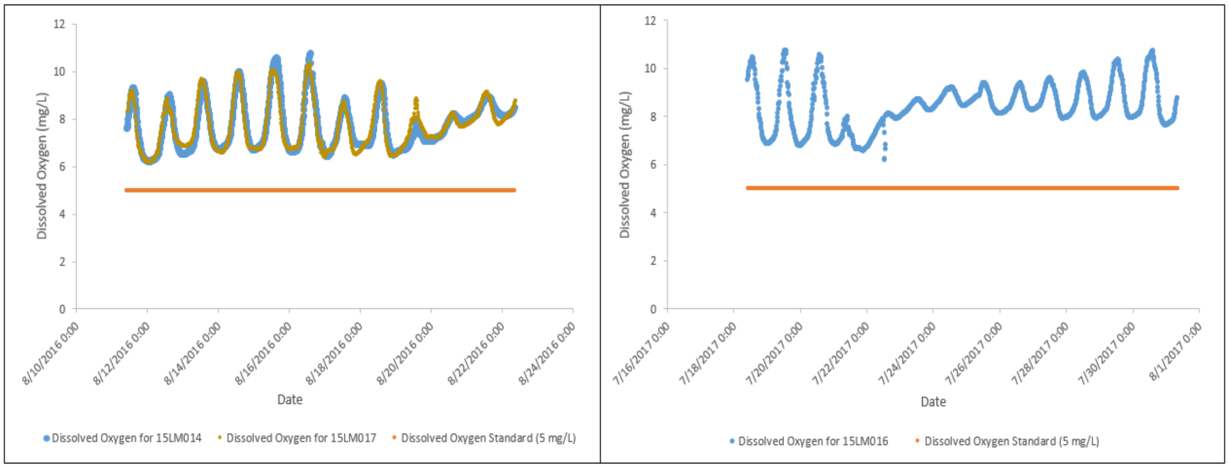


Figure 16: DO conditions during sonde deployments at stations 15LM014 and 15LM017 in 2016 (left), and station 15LM016 in 2017 (right).

A majority of the macroinvertebrate metrics were better than the statewide median of stations meeting the MIBI threshold (Table 13). Taxa richness of EPT was below the median at all stations. There were 9 to 15 low DO intolerant taxa comprising 21% to 27% of the community, and 1 to 5 low DO tolerant taxa comprising 0% to 9% of the community. The macroinvertebrate low DO index scores were at or above the median at all stations, ranging from 7.1 to 7.4. There is not a strong signal for low DO stress.

Table 13: Macroinvertebrate metrics that respond to DO stress in Beaver Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT
15LM017 (2015)	7.1	9	27.3	1	0.3	**6**
15LM016 (2015)	7.1	15	**20.6**	**5**	4.8	**10**
15LM014 (2015)	7.4	15	**20.9**	3	**8.6**	**8**
Southern Streams Median	*7.1*	*9*	*21.2*	*4*	*5.6*	*11*
Expected response to stress	↓	↓	↓	↑	↑	↓

DO concentrations appear adequate, and the macroinvertebrates don't display a strong signal for low DO stress. DO is not a stressor in this AUID.

TSS

TSS concentrations during fish sampling at stations 15LM014, 15LM016, and 15LM017 were 15 mg/L, 11 mg/L, and 8 mg/L respectively. Additional samples were collected at these stations as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TSS concentrations

(Figure 17). Concentrations ranged from 2 to 110 mg/L (average of 19.6 mg/L), and 5 (9%) of the 57 samples exceeded the TSS standard for the South Region (65 mg/L). All stations had at least one exceedance, and exceedances occurred in February (2), August, and September (2) during elevated flow conditions. TSVS concentrations ranged from 1.2 to 22 mg/L.

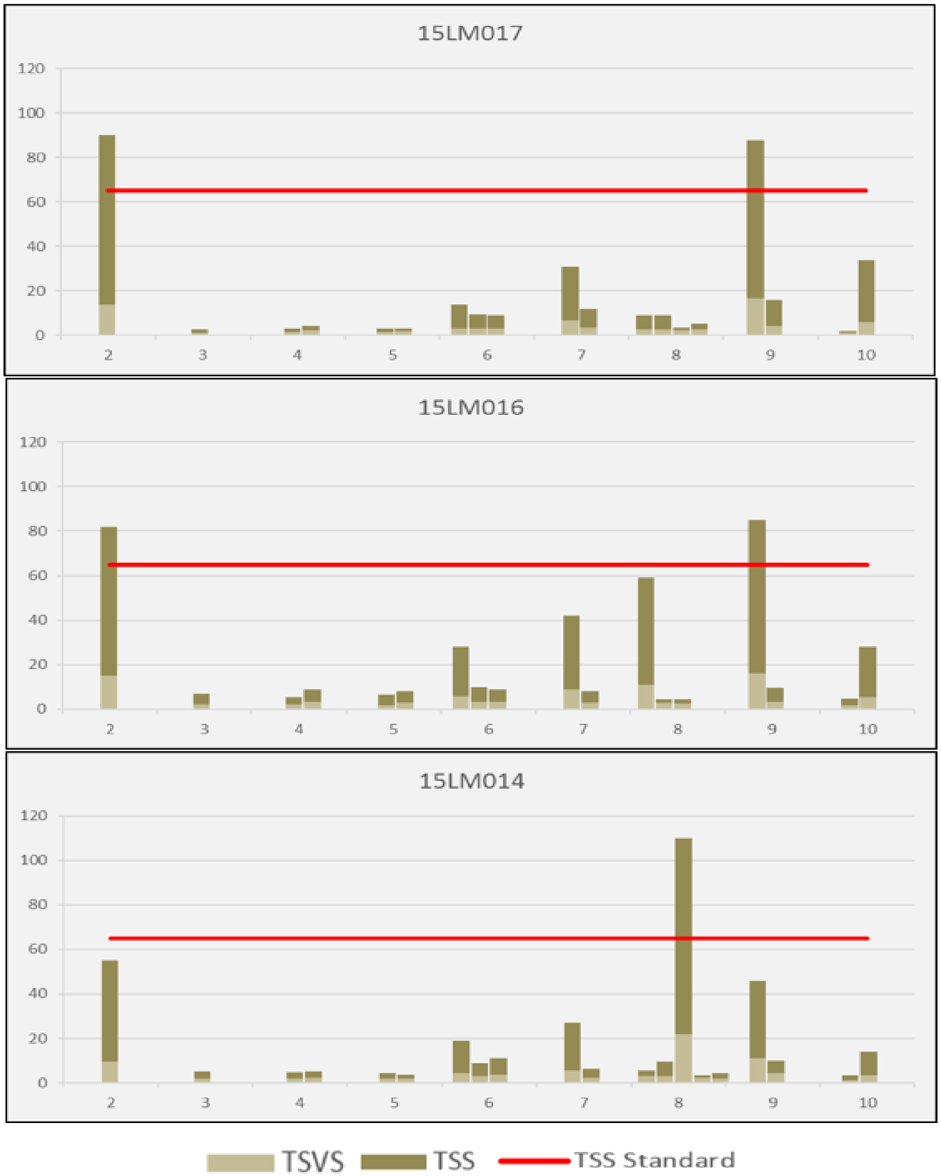


Figure 17: TSS and TSVS concentrations (mg/L) in Beaver Creek in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were better than the statewide median of stations meeting the MIBI threshold (Table 14). Relative abundance of collector-filterer individuals (Collector-filtererPct) was below the median at station 15LM016, and above the median at stations 15LM014 and 15LM017. Relative abundance of Plecoptera individuals (PlecopteraPct) was zero at all stations. There was one TSS intolerant taxa comprising 3% to 8% of the community, and 10 to 14 TSS tolerant taxa comprising 33% to 47% of the community. The macroinvertebrate TSS index scores were worse than the median at stations 15LM014 and 15LM017, and better than the median at station 15LM016. TSS index scores ranged from 15.5 to 16.2. TSS tolerant individuals are highest at the farthest upstream station, and decrease going downstream.

Table 14: Macroinvertebrate metrics that respond to TSS stress in Beaver Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Intolerant Pct	TSS Tolerant Taxa	TSS Tolerant Pct	Collector-filtererPct	PlecopteraPct
15LM017 (2015)	**15.6**	**1**	4.7	10	**47.0**	26.7	0.0
15LM016 (2015)	15.5	**1**	8.3	11	**37.1**	**22.9**	0.0
15LM014 (2015)	**16.2**	**1**	2.8	**14**	33.1	38.9	0.0
Southern Streams Median	*15.5*	*2*	*1.8*	*12*	*33.7*	*23.7*	*0.0*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

TSS exceedances have been documented, but a majority of the macroinvertebrate metrics were better than the median. TSS is inconclusive as a stressor.

Lack of Habitat

The MSHA scores ranged from 22 to 65 (“poor” to “fair”) in 2015. Channel features consisted of runs (70% to 95%), pools (0% to 20%), and riffles (5% to 15%). In general, dominant substrate was gravel, sand, and silt in runs, sand and silt in pools, and cobble, gravel, and sand in riffles. Some pools also contained gravel and detritus, while some riffles had clay. Light to severe embeddedness was noted, and bank erosion varied between visits and stations (none to heavy). Channel stability ranged from moderate to high. Multiple cover types were present, with cover amount ranging from sparse to moderate.

The macroinvertebrate metrics don’t display strong signals of habitat stress (Figure 18). A majority of the metrics are within an expected range, with most in the middle quartiles. Although the metrics aren’t suggestive of habitat stress, station 15LM017 (which is responsible for the impairment) was dominated by silt with moderate to severe embeddedness (Figure 19). This station also had the lowest MSHA scores in the reach (22 and 47), and a beaver dam that may be impacting habitat conditions.

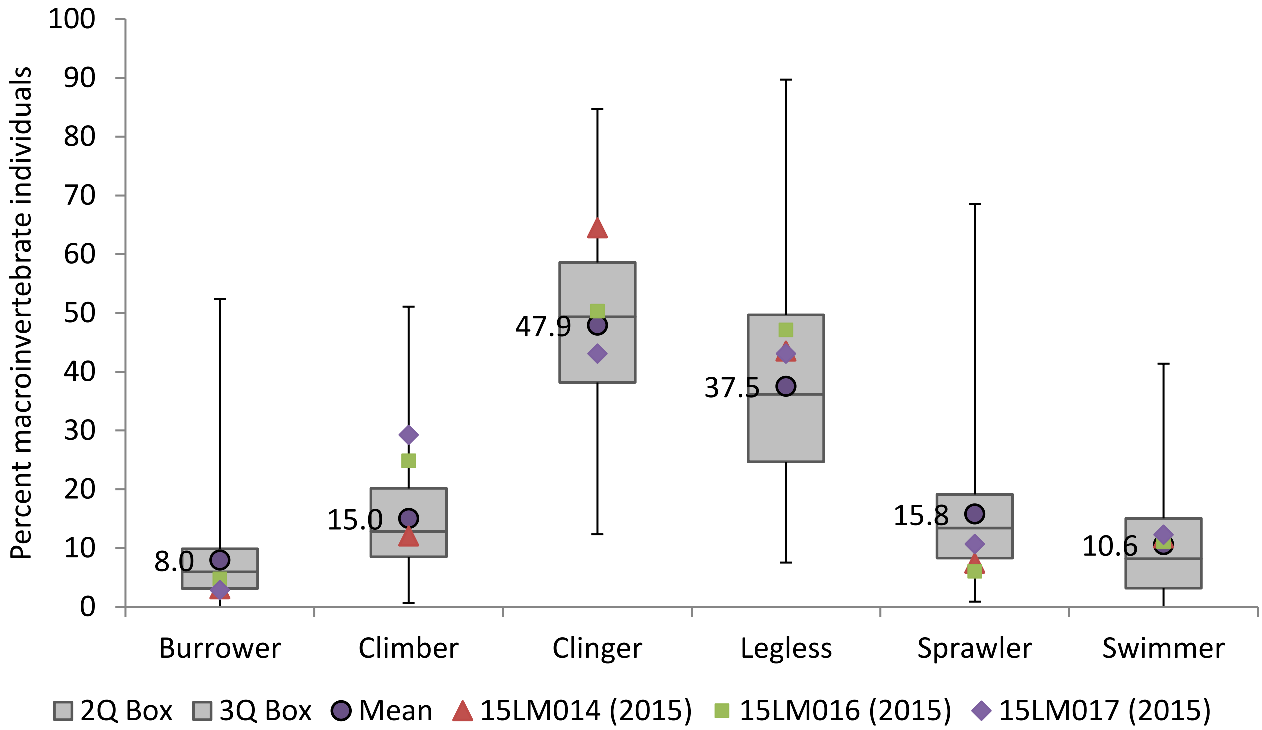


Figure 18: Macroinvertebrate habitat metrics with box plot showing range of values from Southern Streams RR (class 5) stations meeting the bio criteria, mean of those stations, and metric values from Beaver Creek stations.

Figure 19: Habitat and fine substrate conditions during sonde deployment at station 15LM017 (8/11/16).

Geomorphology work completed by the DNR in 2016 at station 15LM016 noted the following:

> *"Geomorphic evidence of a stable reach supports the initial biological monitoring showing no impairment. E4 stream types have low width to depth ratios resulting in high sediment transport abilities. These stream types are also resistant to change unless vegetation, sediment supply, or streamflow alterations occur. In this case, dense vegetation is aiding the stream in maintaining a low width to depth. Although Pfankuch Stability Rating and pebble counts show signatures of fine sediments, the stream reach contains deep pools and has no build-up of bars. As long as vegetation remains intact, and streamflow and sediment supply remain static, this stream reach should remain stable to moderately stable"* (DNR 2017).

MSHA scores were “poor” to “fair”, multiple substrates were present with fines often dominating, embeddedness and bank erosion were severe at times, but the macroinvertebrate community wasn’t suggestive of habitat stress. It seems likely that poor habitat conditions and fine substrate are impacting the macroinvertebrate community at station 15LM017, but habitat is inconclusive as a stressor at this time due to mixed results.

Flow Alteration

There are currently no stream gaging stations in the watershed, but modeled flows via the HSPF model are available for the watershed from 1993 through 2015 (Tetra Tech 2018). Modeled flows at the mouth of this AUID ranged from 0.3 to 1,033 cfs (average of 13.9 cfs).

A majority of the macroinvertebrate metrics were better than the statewide median of stations meeting the MIBI threshold (Table 15); however, a majority of metrics at station 15LM017 (which is the station responsible for the impairment) were worse than the median. Relative abundance of EPTPct and non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were better than the median at all stations. Relative abundance of long-lived individuals (LongLivedPct), tolerant taxa (Tolerant2ChTxPct), and total taxa richness (TaxaCountAllChir) were mixed; some stations were better than the median and some were worse. Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of EPT, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al. 2002; Poff and Zimmerman 2010; EPA 2012).

Table 15: Macroinvertebrate metrics that respond to flow alteration stress in Beaver Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	EPTPct	LongLivedPct	TrichwoHydroPct	TaxaCountAllChir	Tolerant2ChTxPct
15LM017 (2015)	48.7	**1.9**	9.7	**36**	**77.8**
15LM016 (2015)	42.7	**6.4**	11.1	46	**76.1**
15LM014 (2015)	42.0	9.6	5.9	46	**73.9**
Southern Streams Median	*41.8*	*7.0*	*3.6*	*43*	*73.1*
Expected response to stress	↓	↓	↓	↓	↑

Although a majority of the macroinvertebrate metrics were better than the statewide median, flow alteration is a stressor in Beaver Creek and is contributing to nitrate and habitat stress. Altered (channelized) watercourses and agricultural tile drainage are common in this part of the watershed (Figure 63). Channelized reaches have direct impacts on hydrology and habitat (as well as other variables), and although tile drainage can increase agricultural productivity it has negative impacts on hydrology (e.g. increasing peak flows and reducing base flows) and water quality (e.g. increasing nitrogen loading). See Section 5 (Conclusions in the Upper Iowa River Watershed) for more information on flow alteration.

Conclusion

Nitrate and flow alteration are stressing the macroinvertebrate community in Beaver Creek. Eutrophication, TSS, and habitat are inconclusive, while temperature, DO, and fish passage are not stressors.

4.1.3. Unnamed Creek (544)

Biological Communities

Unnamed Creek (07060002-544) is a 2.7 mile long tributary to the Upper Iowa River. This is a warmwater reach with a macroinvertebrate impairment. The only biological monitoring station in this AUID is 15LM021; this station was sampled for fish and macroinvertebrates in 2015.

The fish community is "supporting" the aquatic life use, and not currently impaired. The FIBI score for station 15LM021 was 65, which is above the general use threshold and confidence interval. This station is Southern Headwaters (class 3). Several fish species were collected; creek chub, johnny darter, and white sucker were the top three species.

The macroinvertebrate community is impaired and "not supporting" the aquatic life use. The MIBI score for station 15LM021 was 33, which is below the general use threshold but within the confidence interval. This station is Southern Forest Streams Glide/Pool (GP) (class 6). Pollution scores based on tolerance values (HBI_MN), intolerant taxa (Intolerant2Ch), Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET), taxa richness of predators (PredatorCh), macroinvertebrate taxa richness (TaxaCountAllChir), and relative abundance of Trichoptera taxa (TrichopteraChTxPct) scored below average and contributed to the low MIBI score (Figure 20).

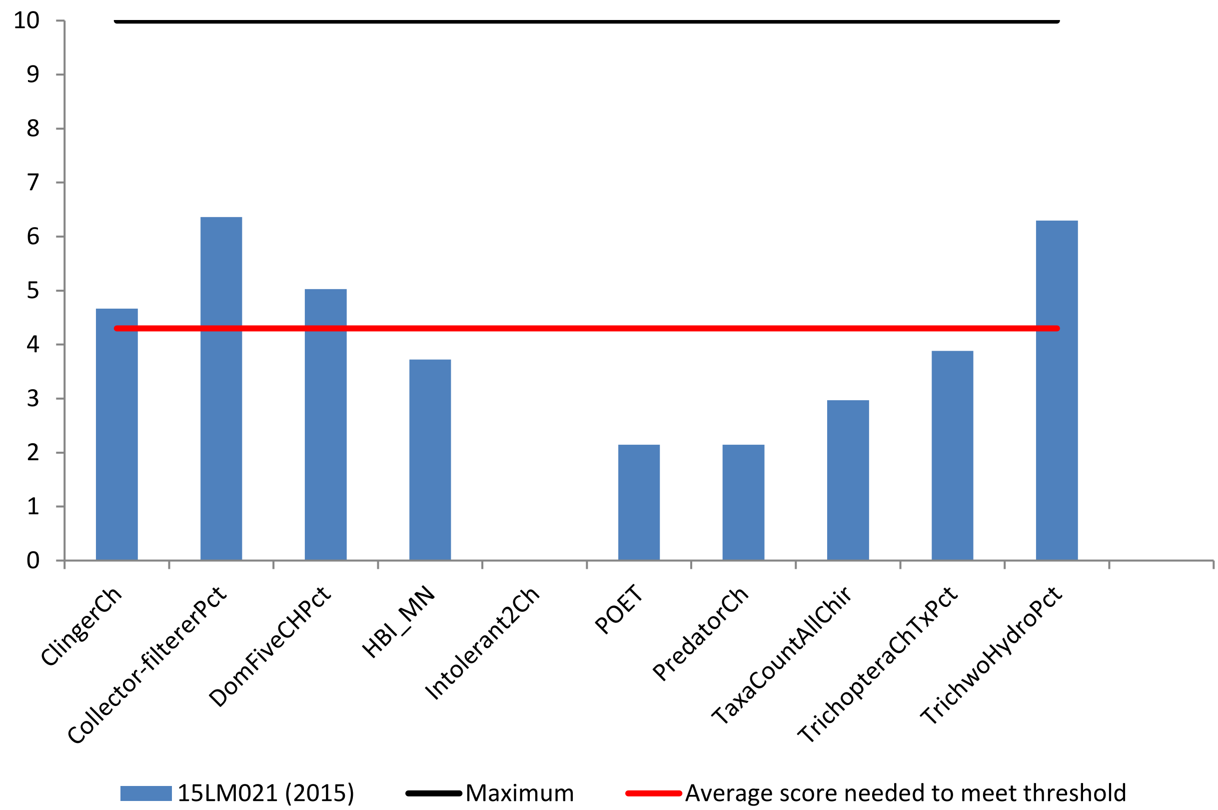


Figure 20: Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for station 15LM021.

Data Evaluation for each Candidate Cause

Temperature

Temperature ranged from 14.7 to 20.4 °C at station 15LM021 during sonde deployment from August 29, 2016 to September 6, 2016. All values were below the daily average warmwater standard (30 °C). Instantaneous samples from 2015 to 2017 had a maximum value of 20.2 °C (30 samples). Temperature is suitable for warmwater macroinvertebrates and is not a stressor in this AUID.

Nitrate

Nitrate concentration during fish sampling in 2015 was 18 mg/L. Additional samples were collected as part of SID from 2015 through 2017, with a goal to sample various flow conditions and establish a range of nitrate concentrations (Figure 21). Concentrations ranged from 6.5 to 23 mg/L (average of 13.9 mg/L). 23 (74%) of the 31 samples were above 10 mg/L; elevated concentrations were documented throughout the year.

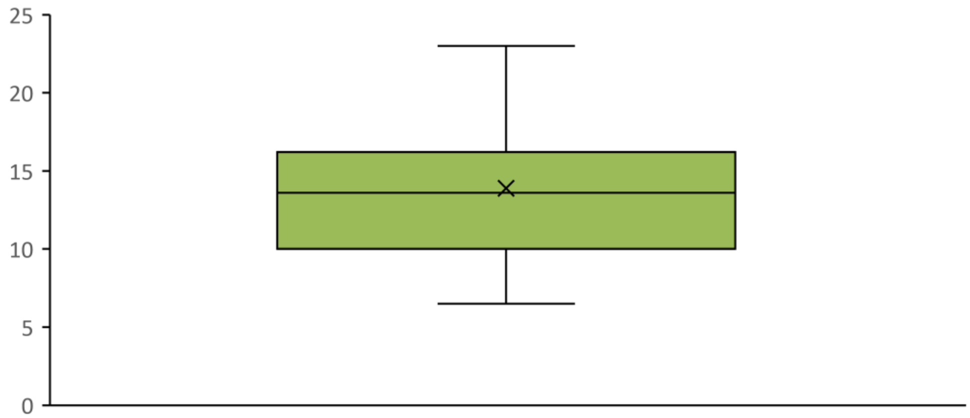


Figure 21: Nitrate concentrations (mg/L) at station 15LM021 from 2015 through 2017.

TrichopteraCh and relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were below the statewide median of stations meeting the MIBI threshold (Table 16). There were zero nitrate intolerant taxa, and twenty-two nitrate tolerant taxa comprising 79% of the community. The macroinvertebrate nitrate index score was worse than the median, and all of the macroinvertebrate metrics are indicative of nitrate stress.

Table 16: Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Intolerant Pct	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM021 (2015)	**5.2**	**0**	**0.0**	**22**	**79.1**	**3**	**0.0**
Southern Forest Streams Median	*3.0*	*2*	*1.0*	*18*	*49.1*	*4*	*2.3*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Elevated nitrate concentrations have been documented in this stream, and the macroinvertebrate community shows signs of nitrate stress. The nitrate index score was worse than the median, there were zero nitrate intolerant taxa, and nitrate tolerant taxa dominated the community. Nitrate is a stressor in this AUID.

Eutrophication

TP concentration during fish sampling in 2015 was 0.03 mg/L. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TP concentrations (Figure 22). Concentrations ranged from 0.007 to 0.628 mg/L (average of 0.097 mg/L). Three (15%) of the 20 samples exceeded the river eutrophication standard for the South Region (0.150

mg/L). Exceedances occurred in February, August, and September during elevated flow conditions. DOP concentrations ranged from 0.007 to 0.344 mg/L.

Chl-*a*, BOD, DO flux, and pH flux are also considered when evaluating eutrophication stress. Three chl-*a* and BOD samples were collected in July and August of 2017. Chl-*a* concentrations ranged from 1.8 to 19.6 µg/L, and BOD concentrations ranged from 0.5 to 1.9 mg/L. There were no exceedances of the chl-*a* standard (35 µg/L) or BOD standard (3 mg/L). Daily DO flux was minimal (maximum of 2.1 mg/L) and no low DO exceedances were observed during sonde deployment in 2016. pH flux ranged from 0.07 to 0.74 (average of 0.24). Typical daily pH fluctuations are 0.2 to 0.3 (Heiskary et al. 2013).

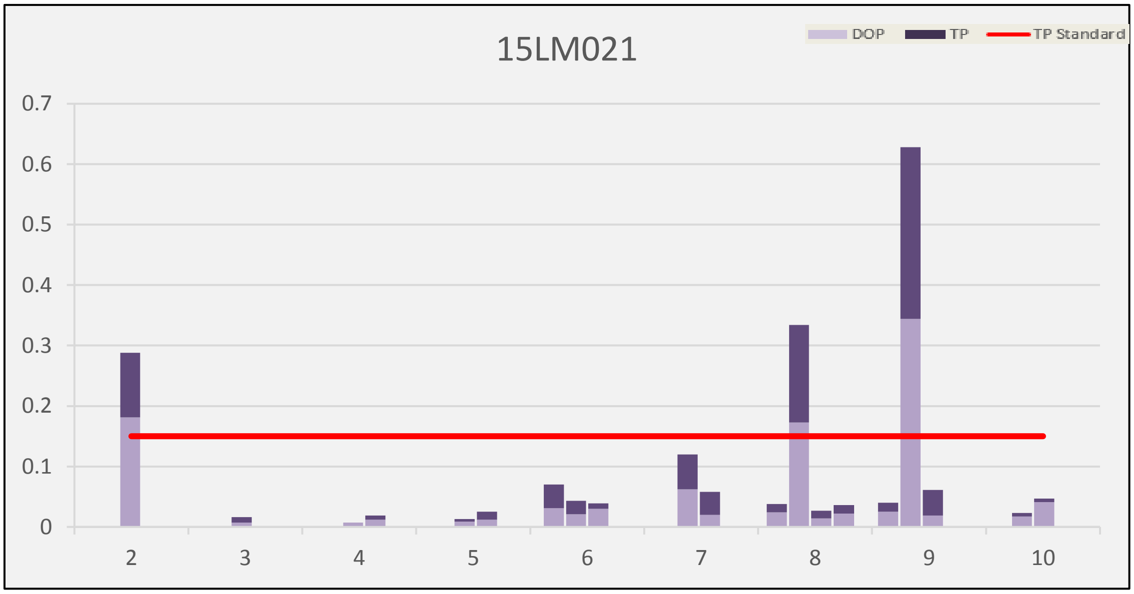


Figure 22: TP and DOP concentrations (mg/L) at station 15LM021 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 17). Taxa richness of collector-filterers (Collector-filtererCh), collector-gatherers (Collector-gathererCh), and EPT were below the median. There was one phosphorus intolerant taxa comprising 7% of the community, and eight phosphorus tolerant taxa comprising 5% of the community. The macroinvertebrate phosphorus index score was worse than the median.

Table 17: Macroinvertebrate metrics that respond to eutrophication stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Phosphorus Index Score	Phosphorus Intolerant Taxa	Phosphorus Intolerant Pct	Phosphorus Tolerant Taxa	Phosphorus Tolerant Pct	Collector-filtererCh	Collector-gathererCh	EPT
15LM021 (2015)	**0.134**	**1**	7.1	8	4.6	**5**	**9**	**4**
Southern Forest Streams Median	*0.127*	*2*	*1.9*	*10*	*18.7*	*6*	*14*	*8*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓	↓

TP exceedances have been documented during elevated flow conditions, but limited chl-*a*, BOD, and DO flux data is meeting standards. The macroinvertebrate metrics don't display a strong signal for eutrophication stress, but eutrophication is inconclusive as a stressor. Additional monitoring is recommended to strengthen the data set.

Dissolved Oxygen

Continuous DO data was collected in 2016 at station 15LM021; concentrations ranged from 6.9 to 9.5 mg/L (Figure 23). All values were above the warmwater DO standard (5 mg/L), and daily DO flux was minimal (maximum of 2.1 mg/L). Instantaneous samples from 2015 through 2017 ranged from 5.5 to 13.2 mg/L (30 samples) with no exceedances of the low DO standard.

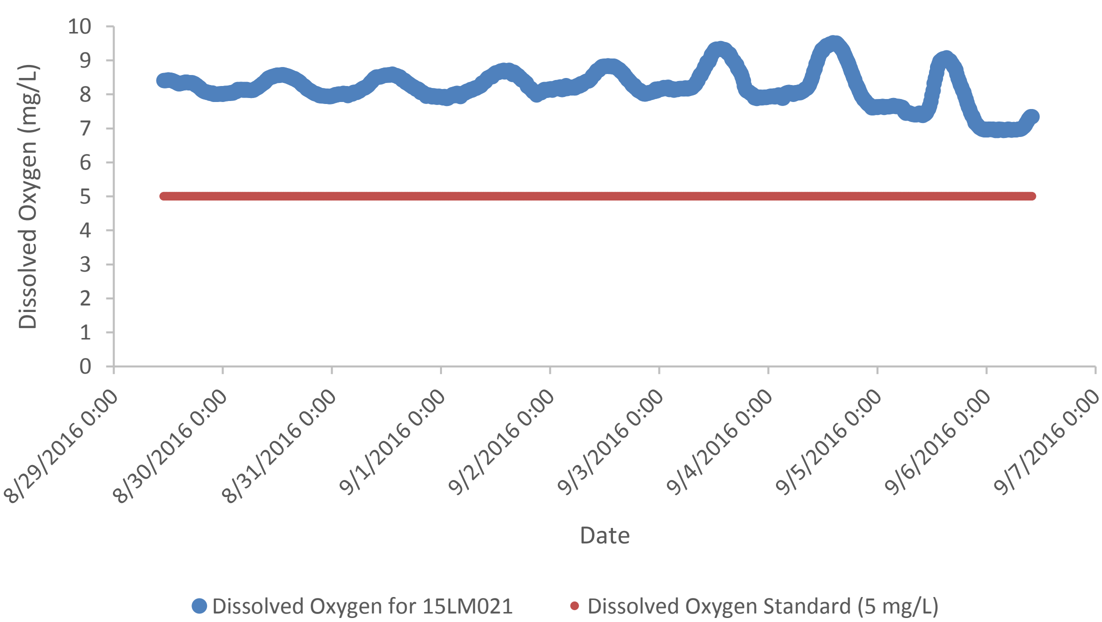


Figure 23: DO conditions during sonde deployment at station 15LM021 in 2016.

A majority of the macroinvertebrate metrics were better than the statewide median of stations meeting the MIBI threshold (Table 18). Taxa richness of EPT was below the median. There was seven low DO intolerant taxa comprising 19% of the community, and four low DO tolerant taxa comprising 2% of the community. The macroinvertebrate low DO index score was above the median and there does not appear to be a strong signal for low DO stress.

Table 18: Macroinvertebrate metrics that respond to DO stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT
15LM021 (2015)	7.2	7	19.3	4	1.5	**4**
Southern Forest Streams Median	*6.9*	*5*	*9.4*	*6*	*9.0*	*8*
Expected response to stress	↓	↓	↓	↑	↑	↓

DO concentrations are adequate, and the macroinvertebrates don't appear stressed by low DO. DO is not a stressor in this AUID.

TSS

TSS concentration during fish sampling in 2015 was 6.4 mg/L. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TSS concentrations (Figure 24). Concentrations ranged from 2.8 to 150 mg/L (average of 19.1 mg/L). One (5%) of the 20 samples exceeded the TSS standard for the South Region (65 mg/L). The exceedance occurred in September during elevated flow conditions. TSVS concentrations ranged from 1.6 to 28 mg/L.

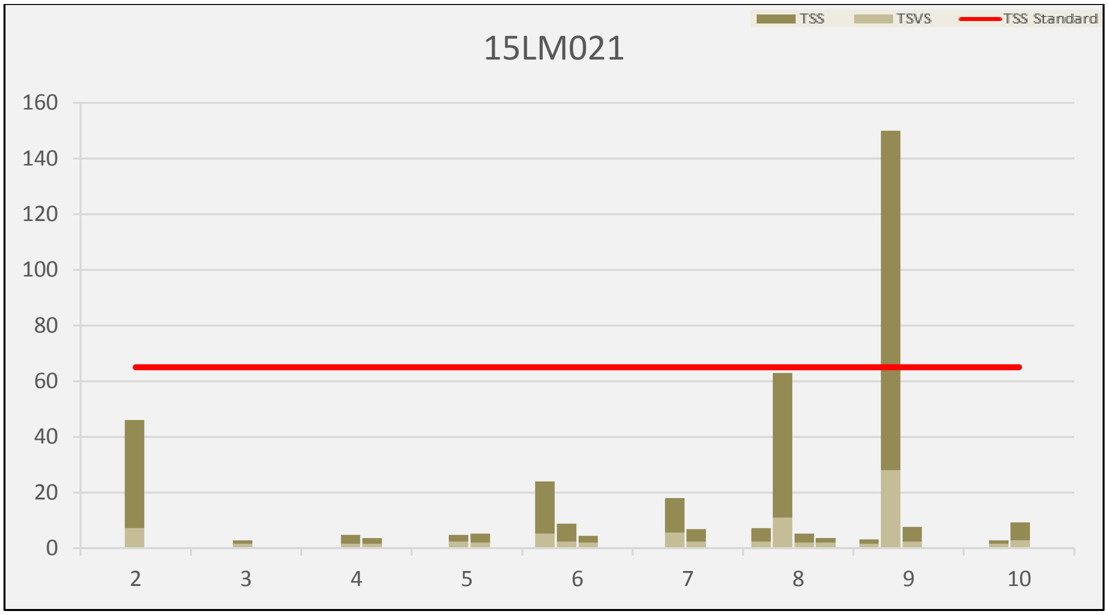


Figure 24: TSS and TSVS concentrations (mg/L) at station 15LM021 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 19). Relative abundance of collector-filterer individuals (Collector-filtererPct) was above the median, while relative abundance of Plecoptera individuals (PlecopteraPct) was zero. There were zero TSS intolerant taxa, and seven TSS tolerant taxa comprising 64% of the community. The macroinvertebrate TSS index score was worse than the median, and station 15LM021 is showing signs of TSS stress.

Table 19: Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Intolerant Pct	TSS Tolerant Taxa	TSS Tolerant Pct	Collector-filtererPct	PlecopteraPct
15LM021 (2015)	**18.5**	**0**	**0.0**	7	**64.1**	24.2	0.0
Southern Forest Streams Median	*15.1*	*1*	*0.9*	*11*	*26.8*	*23.3*	*0.0*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Only one TSS exceedance has been documented, but the macroinvertebrate metrics show signs of TSS stress. It’s possible the macroinvertebrate stress is due to other stressors as a majority of the TSS concentrations are below the standard. TSS is inconclusive as a stressor due to mixed results.

Lack of Habitat

The MSHA scores were 54 (“fair”) and 38 (“poor”) in 2015 (June and August). Runs were the main channel type (70% to 75%), with minimal pools (20%) and riffles (5% to 10%). Sand, silt, and muck dominated the runs and pools, while sand, gravel, and cobble was the primary substrate in riffles. Moderate embeddedness was noted, and bank erosion varied between visits (little to heavy) (Figure 26). Channel stability ranged from low to moderate. Multiple cover types were present, with cover amount ranging from sparse to moderate.

In general, the macroinvertebrate metrics don’t display a strong signal for habitat stress (Figure 25). Burrowers and clingers are within the middle quartiles, and climbers (who require habitat such as overhanging vegetation or woody debris) were abundant. However, there are elevated legless individuals, which are expected to increase with habitat stress. In addition to the tolerant legless individuals, *Physella* and *Polypedilum* were the top two species. Indicator values for fine substrates for *Physa* and *Polypedilum*, developed by Carlisle et al (2007), are eight; the scoring system is based on a scale from 1 to 10, with 10 being the most tolerant.

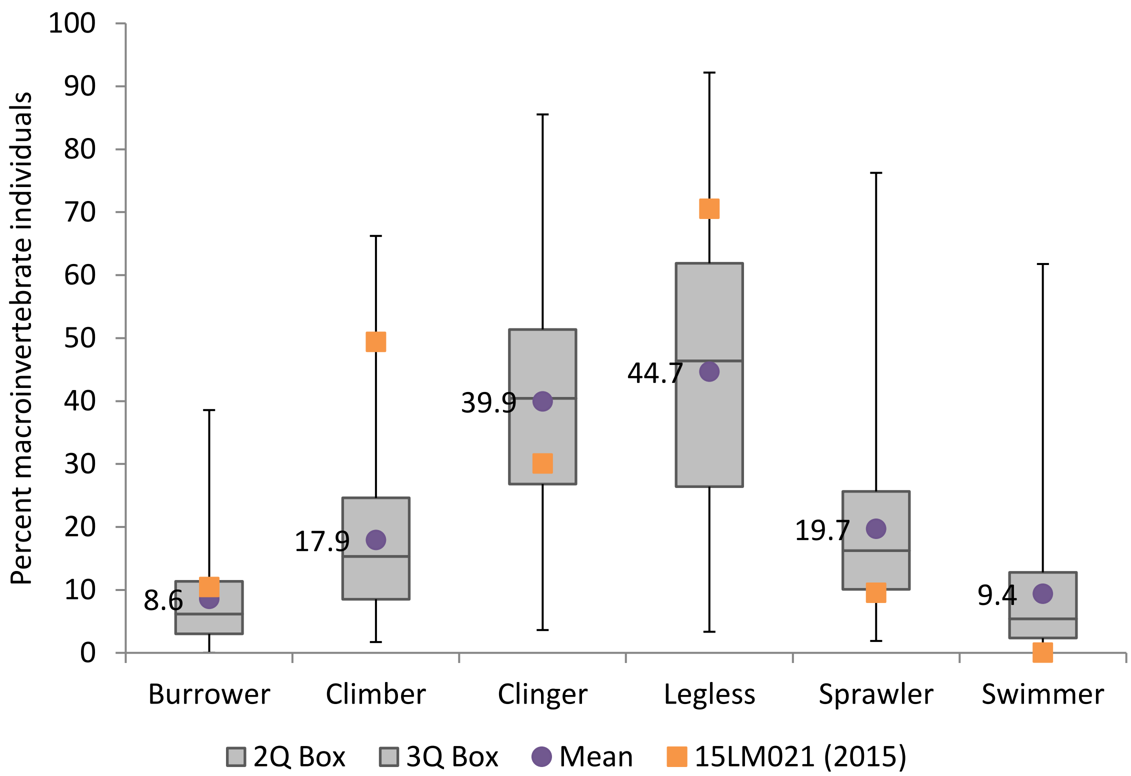


Figure 25: Macroinvertebrate habitat metrics with box plot showing range of values from Southern Forest Streams GP (class 6) stations meeting the bio criteria, mean of those stations, and metric values from station 15LM021.


Figure 26: Station 15LM021 on June 10, 2015.

MSHA scores were “poor” to “fair”, fine substrates were abundant, embeddedness and erosion were present, and tolerant macroinvertebrates were elevated. Lack of habitat and fine substrate are stressing the macroinvertebrate community.

Flow Alteration

There are currently no stream gaging stations in the watershed, but modeled flows via the HSPF model are available for the watershed from 1993 through 2015 (Tetra Tech 2018). Modeled flows at the mouth of this AUID ranged from 0.2 to 326.7 cfs (average of 6.3 cfs). Flows were less than one cfs approximately 11% of the time.

All macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 20). Relative abundance of EPTPct, non-hydropsychid Trichoptera individuals (TrichwoHydroPct), long-lived individuals (LongLivedPct), tolerant taxa (Tolerant2ChTxPct), and total taxa richness (TaxaCountAllChir) were all worse than the median. Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of EPT, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al. 2002; Poff and Zimmerman 2010; EPA 2012).

Table 20: Macroinvertebrate metrics that respond to flow alteration stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	EPTPct	LongLivedPct	TrichwoHydroPct	TaxaCountAllChir	Tolerant2ChTxPct
15LM021 (2015)	**25.5**	**2.1**	**0.0**	**29**	**93.1**
Southern Forest Streams Median	*27.4*	*3.9*	*2.3*	*40*	*75.9*
Expected response to stress	↓	↓	↓	↓	↑

Flow alteration is a stressor in Unnamed Creek, and is contributing to nitrate and habitat stressors. Altered (channelized) watercourses and agricultural tile drainage are common in this part of the watershed (Figure 63). Channelized reaches have direct impacts on hydrology and habitat (as well as other variables), and although tile drainage can increase agricultural productivity it has negative impacts on hydrology (e.g. increasing peak flows and reducing base flows) and water quality (e.g. increasing nitrogen loading). See Section 5 (Conclusions in the Upper Iowa River Watershed) for more information on flow alteration.

Conclusion

Nitrate, habitat, and flow alteration are stressing the macroinvertebrate community in Unnamed Creek. Eutrophication and TSS are inconclusive, while temperature, DO, and fish passage are not stressors.

4.1.4. Unnamed Creek (540)

Biological Communities

Unnamed Creek (07060002-540) is a 1.3 mile long tributary to the Little Iowa River. This is a warmwater reach with a macroinvertebrate impairment. The only biological monitoring station in this AUID is 15LM026; this station was sampled for fish and macroinvertebrates in 2015.

The fish community is "supporting" the aquatic life use, and not currently impaired. The FIBI score for station 15LM026 was 83, which is above the general use threshold and confidence interval. The FIBI score was also above the exceptional use threshold. This station is Southern Headwaters (class 3). Several fish species were collected; central stoneroller, white sucker, and common shiner were the top three species.

The macroinvertebrate community is impaired and "not supporting" the aquatic life use. The MIBI score for station 15LM026 was 32, which is below the general use threshold but within the confidence interval. This station is Southern Streams RR (class 5). Taxa richness of climbers (ClimberCh), pollution scores based on tolerance values (HBI_MN), Plecoptera, Predator, tolerant taxa (Tolerant2ChTxPct), and Trichoptera scored below average and contributed to the low MIBI score (Figure 27).

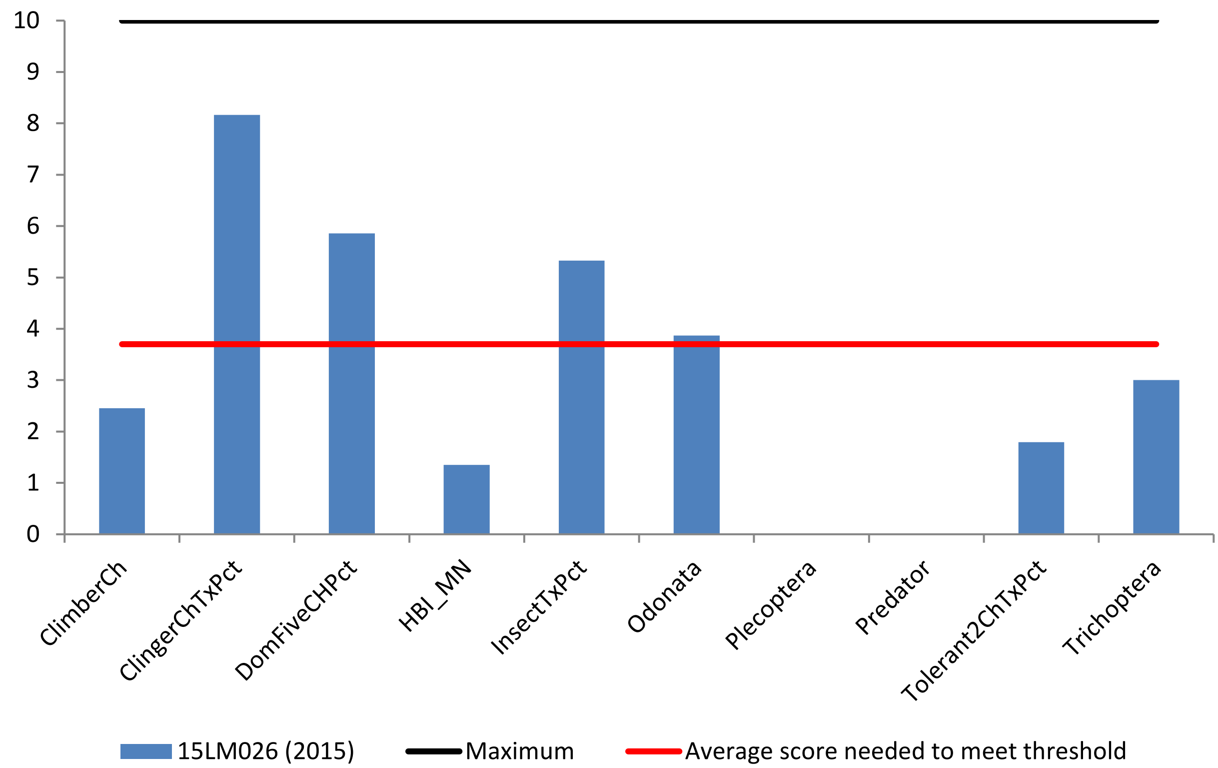


Figure 27: Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for station 15LM026.

Data Evaluation for each Candidate Cause

Temperature

Temperature ranged from 15.7 to 22.0 °C at station 15LM026 during sonde deployment from August 29, 2016 through September 6, 2016. All values were below the daily average warmwater standard (30 °C). Instantaneous samples from 2015 through 2017 had a maximum value of 20.6 °C (29 samples). Temperature appears suitable for warmwater macroinvertebrates and is not a stressor in this AUID.

Nitrate

Nitrate concentration during fish sampling in 2015 was 9.5 mg/L. Additional samples were collected as part of SID from 2015 through 2017, with a goal to sample various flow conditions and establish a range of nitrate concentrations (Figure 28). Concentrations ranged from 1.3 to 13 mg/L (average of 7.1 mg/L). Five (17%) of the 30 samples were above 10 mg/L; these concentrations occurred in March, April, May, and June (2).

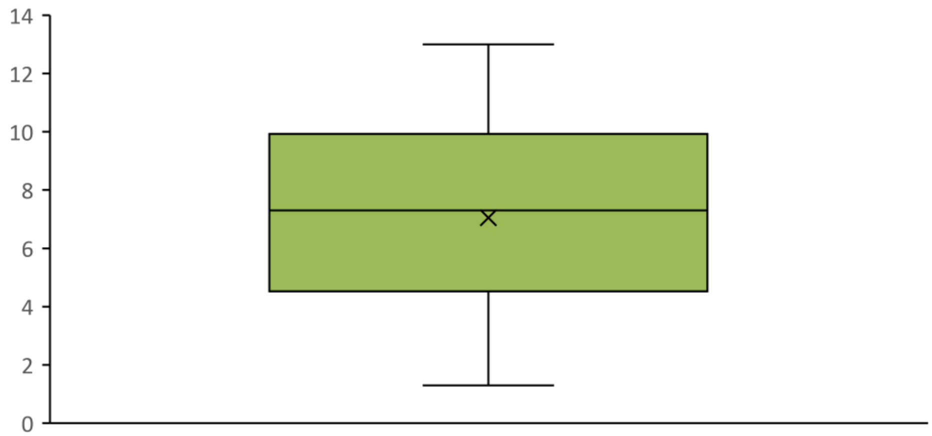


Figure 28: Nitrate concentrations (mg/L) at station 15LM026 from 2015 – 2017.

TrichopteraCh and relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were at or below the statewide median of stations meeting the MIBI threshold (Table 21). There were zero nitrate intolerant taxa, and 22 nitrate tolerant taxa comprising 76% of the community. The macroinvertebrate nitrate index score was worse than the median, and a majority of the macroinvertebrate metrics are indicative of nitrate stress.

Table 21: Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Intolerant Pct	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM026 (2015)	**4.1**	**0**	**0.0**	**22**	**76.4**	5	**1.3**
Southern Streams Median	*3.0*	*2*	*1.0*	*19*	*49.6*	*5*	*3.6*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Elevated nitrate concentrations have been documented, and the macroinvertebrate community shows signs of nitrate stress. The nitrate index score was worse than the median, there were zero nitrate intolerant taxa, and nitrate tolerant individuals dominated the community. Nitrate is a stressor in this AUID.

Eutrophication

TP concentration during fish sampling in 2015 was 0.028 mg/L. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TP concentrations (Figure 29). Concentrations ranged from 0.015 to 0.378 mg/L (average of 0.066 mg/L).

Two (11%) of the nineteen samples exceeded the river eutrophication standard for the South Region (0.150 mg/L). Exceedances occurred in February and August during elevated flow conditions. DOP concentrations ranged from 0.005 to 0.177 mg/L.

Chl-*a*, BOD, DO flux, and pH flux are also considered when evaluating eutrophication stress. Three chl-*a* and BOD samples were collected in July and August of 2017. Chl-*a* concentrations ranged from 1.9 to 8.4 µg/L, and BOD concentrations ranged from 0.6 to 1.2 mg/L. There were no exceedances of the chl-*a* standard (35 µg/L) or BOD standard (3 mg/L). Daily DO flux was minimal (maximum of 2.7 mg/L) and no low DO exceedances were observed during sonde deployment in 2016. The pH flux ranged from 0.2 to 0.3; typical daily pH fluctuations are 0.2 to 0.3 (Heiskary et al. 2013).

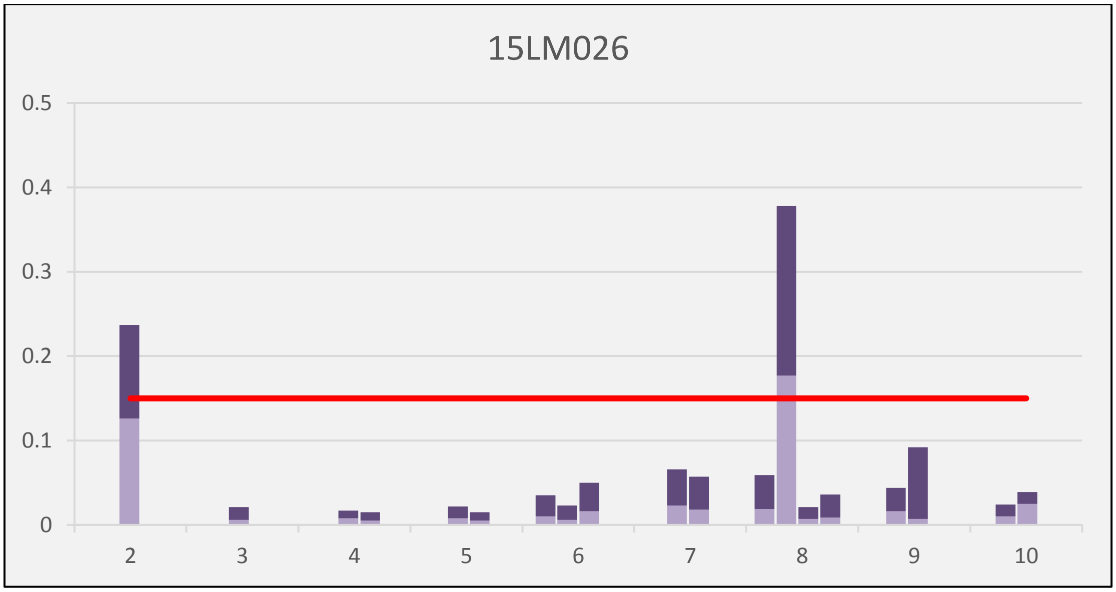


Figure 29: TP and DOP concentrations (mg/L) at station 15LM026 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 22). Taxa richness of collector-filterers (Collector-filtererCh), collector-gatherers (Collector-gathererCh), and EPT were at or below the median. There was one phosphorus intolerant taxa comprising 0% of the community, and nine phosphorus tolerant taxa comprising 13% of the community. The macroinvertebrate phosphorus index score was worse than the median.

Table 22: Macroinvertebrate metrics that respond to eutrophication stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Phosphorus Index Score	Phosphorus Intolerant Taxa	Phosphorus Intolerant Pct	Phosphorus Tolerant Taxa	Phosphorus Tolerant Pct	Collector-filtererCh	Collector-gathererCh	EPT
15LM026 (2015)	**0.139**	**1**	**0.3**	**9**	13.4	6	**11**	**8**
Southern Streams Median	*0.122*	*4*	*3.2*	*8*	*14.2*	*6*	*15*	*11*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓	↓

TP exceedances have been documented during elevated flow conditions, but limited chl-*a*, BOD, and DO flux data is meeting standards. In addition, there has been no low DO documented. Macroinvertebrate metrics are suggestive of eutrophication stress, but eutrophication is inconclusive as a stressor due to mixed results.

Dissolved Oxygen

Continuous DO data was collected in 2016 at station 15LM026; concentrations ranged from 6.5 to 10.3 mg/L (Figure 30). All values were above the warmwater DO standard (5 mg/L), and daily DO flux was minimal (maximum of 2.7 mg/L). Instantaneous samples from 2015 through 2017 ranged from 5.8 to 12.4 mg/L (28 samples) with no exceedances of the low DO standard.

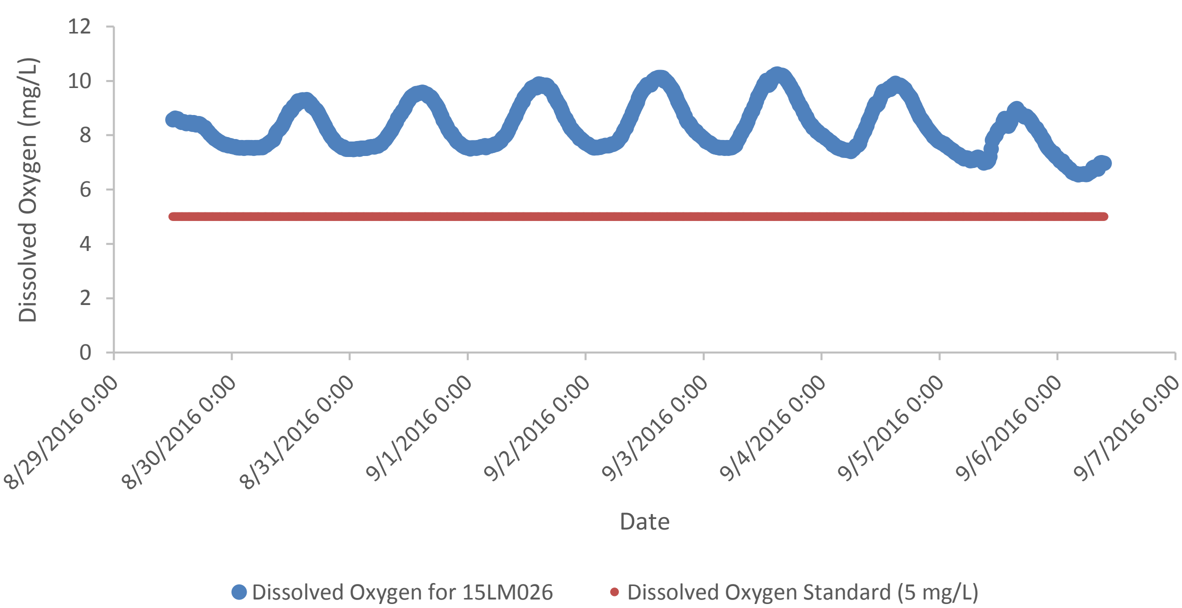


Figure 30: DO conditions during sonde deployment at station 15LM026 in 2016.

All of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 23). Taxa richness of EPT was below the median. There were four low DO intolerant taxa comprising 7% of the community, and six low DO tolerant taxa comprising 8% of the community. The macroinvertebrate low DO index score was below the median.

Table 23: Macroinvertebrate metrics that respond to DO stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT
15LM026 (2015)	**7.0**	**4**	**6.9**	**6**	**7.5**	**8**
Southern Streams Median	*7.1*	*9*	*21.2*	*4*	*5.6*	*11*
Expected response to stress	↓	↓	↓	↑	↑	↓

DO concentrations appear adequate, but the macroinvertebrates show signs of low DO stress. It's possible this response is due to other stressors as all DO concentrations are above the standard. DO is inconclusive as a stressor due to mixed results.

TSS

TSS concentration during fish sampling in 2015 was 8.8 mg/L. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TSS concentrations (Figure 31). Concentrations ranged from 3.2 to 50 mg/L (average of 13.2 mg/L). Zero of the 19 samples exceeded the TSS standard for the South Region (65 mg/L). TSVS concentrations ranged from 1.2 to 12 mg/L.

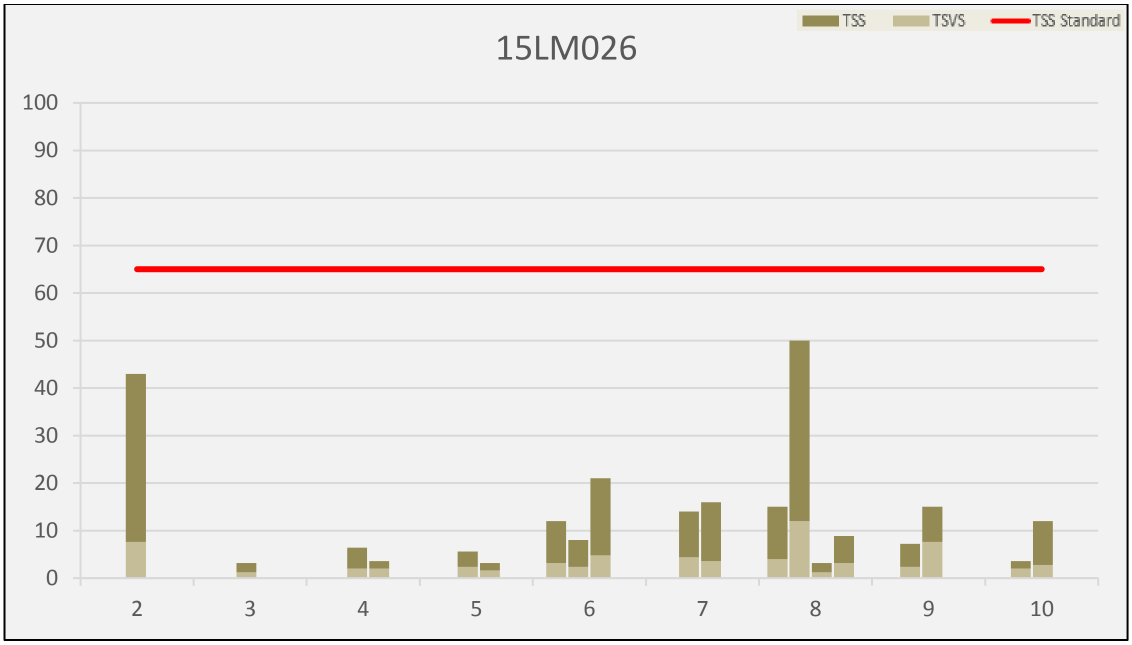


Figure 31: TSS and TSVS concentrations (mg/L) at station 15LM026 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 24). Relative abundance of collector-filterer individuals (Collector-filtererPct) was below the median, and relative abundance of Plecoptera individuals (PlecopteraPct) was zero. There were two TSS intolerant taxa comprising 1% of the community, and nine TSS tolerant taxa comprising 51% of the community. The macroinvertebrate TSS index score was worse than the median, and station 15LM026 is showing signs of TSS stress.

Table 24: Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Intolerant Pct	TSS Tolerant Taxa	TSS Tolerant Pct	Collector-filtererPct	PlecopteraPct
15LM026 (2015)	**17.3**	2	**1.0**	9	**50.8**	**18.0**	0.0
Southern Streams Median	*15.5*	*2*	*1.8*	*12*	*33.7*	*23.7*	*0.0*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

There have been zero TSS exceedances documented, but the macroinvertebrates show signs of TSS stress. It's possible this response is due to other stressors as all TSS concentrations are below the standard. TSS is inconclusive as a stressor due to mixed results.

Lack of Habitat

The MSHA scores were 61 ("fair") and 54 ("fair") in 2015 (June and August). Channel features consisted of runs (40% to 50%), pools (15% to 40%), and riffles (20% to 35%). Runs and riffles were dominated by sand, gravel, and cobble, while pools were primarily sand and silt. Light embeddedness was noted, and bank erosion varied between visits (little to heavy). Channel stability ranged from moderate to high. Multiple cover types were present, and cover amount was moderate.

The macroinvertebrate metrics display signals of habitat stress (Figure 32). Although climbers are abundant, the elevated burrowers and legless and reduced clingers are often symptoms of habitat stress. Also, the sample was dominated by *Polypedilum*. Indicator values for suspended sediment and fine substrates for *Polypedilum*, developed by Carlisle et al (2007), are seven and eight respectively. The scoring system is based on a scale from 1 to 10, with 10 being the most tolerant.

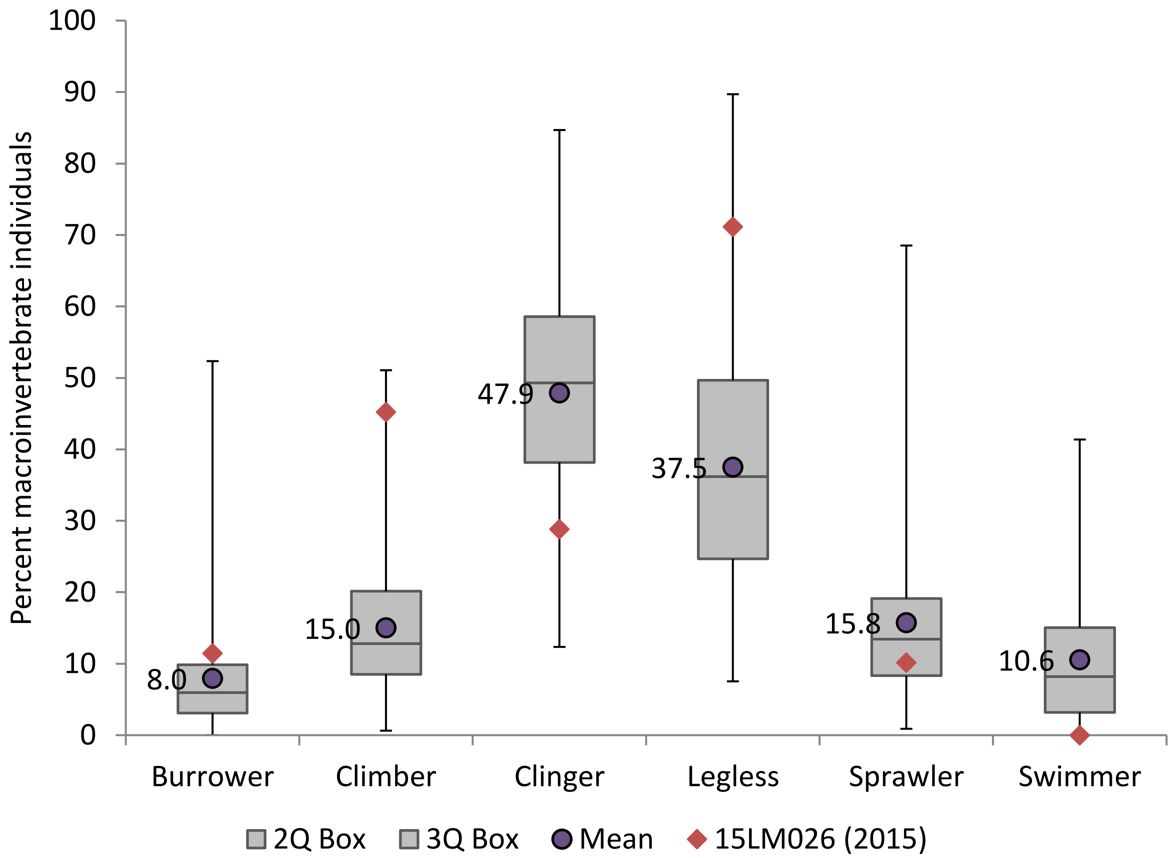


Figure 32: Macroinvertebrate habitat metrics with box plot showing range of values from Southern Streams RR (class 5) stations meeting the bio criteria, mean of those stations, and metric values from station 15LM026.

Geomorphology work completed by the DNR in 2016 just upstream of station 15LM026 noted the following:

> *"Information gathered from the survey show signs of stability, however preliminary IBI scores show invertebrates not meeting thresholds. Although the surveys are showing measures of*

channel stability, concerns over incision exists. As seen in Figure 3, bankfull elevation is below low bank elevation, a 1.15 average bank-height ratio categorized as slightly incised. Also seen in Figure 3, there is an elongated steep riffle, indicative of a head cut. Below this head-cut is a higher bank-height ratio, indicating that the source is downstream and advancing head ward. Incision is a lowering of the water level, leading to an abandonment of the floodplain. Flows above bankfull would be contained within the channel leading to increased bank erosion. Aerial photos, Pfankuch rating and low erosion points to the stream having potential resiliency to change, with the possibility of improvement."

"A potential localized stressor on the reach is the crossing located 250ft. downstream of the survey. The crossing measures about 25ft across while the bankfull width of the stream is 15ft. From Figure 6, there is a clear downstream pool and upstream widening of the stream, likely from road prism reducing floodplain. The effect of the overwide channel crossing is a reduction in sediment transport capability. In addition, it's likely the cause of the head-cut moving upstream captured in the longitudinal profile. Another localized stressor is livestock. The biological site is in an actively pastured reach, while the geomorphic site was upstream and no longer in pasture" (DNR 2017).

The MSHA scores were "fair", multiple substrates were present, embeddedness and bank erosion were documented, and the macroinvertebrates display signs of habitat stress. Lack of habitat is stressing the macroinvertebrate community.

Flow Alteration

There are currently no stream gaging stations in the watershed, but modeled flows via the HSPF model are available for the watershed from 1993 through 2015 (Tetra Tech 2018). Modeled flows at the mouth of this AUID ranged from 0.2 to 484.5 cfs (average of 9.2 cfs). Flows were less than one cfs approximately 5% of the time.

All macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 25). Relative abundance of EPTPct, non-hydropsychid Trichoptera individuals (TrichwoHydroPct), long-lived individuals (LongLivedPct), tolerant taxa (Tolerant2ChTxPct), and total taxa richness (TaxaCountAllChir) were all worse than the median. Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of EPT, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al. 2002; Poff and Zimmerman 2010; EPA 2012).

Table 25: Macroinvertebrate metrics that respond to flow alteration stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	EPTPct	LongLivedPct	TrichwoHydroPct	TaxaCountAllChir	Tolerant2ChTxPct
15LM026 (2015)	**16.4**	**6.2**	**1.3**	**34**	**85.3**
Southern Streams Median	*41.8*	*7.0*	*3.6*	*43*	*73.1*
Expected response to stress	↓	↓	↓	↓	↑

Flow alteration is a stressor in Unnamed Creek, and is contributing to nitrate and habitat stressors. Altered (channelized) watercourses and agricultural tile drainage are common in this part of the watershed (Figure 63). Channelized reaches have direct impacts on hydrology and habitat (as well as other variables), and although tile drainage can increase agricultural productivity it has negative impacts on hydrology (e.g. increasing peak flows and reducing base flows) and water quality (e.g. increasing nitrogen loading). See Section 5 (Conclusions in the Upper Iowa River Watershed) for more information on flow alteration.

Conclusion

Nitrate, habitat, and flow alteration are stressing the macroinvertebrate community in Unnamed Creek. Eutrophication, DO, and TSS are inconclusive, while temperature and fish passage are not stressors.

4.1.5. Unnamed Creek (537)

Biological Communities

Unnamed Creek (07060002-537) is a 3.1 mile long tributary to Beaver Creek. This is a warmwater reach with a macroinvertebrate impairment. The only biological monitoring station in this AUID is 15LM015; this station was sampled for fish and macroinvertebrates in 2015 and 2016 (fish only).

The fish community is "supporting" the aquatic life use, and not currently impaired. The FIBI scores for station 15LM015 were 62 (2015) and 67 (2016), which are above the general use threshold and at or above the confidence interval. This station is Southern Headwaters (class 3). Several fish species were collected both years.

The macroinvertebrate community is impaired and "not supporting" the aquatic life use. The MIBI score for station 15LM015 was 25, which is below the general use threshold and confidence interval. This station is Southern Forest Streams GP (class 6). Taxa richness of clingers (ClingerCh), relative abundance of dominant five taxa (DomFiveCHPct), pollution scores based on tolerance values (HBI_MN), intolerant taxa (Intolerant2Ch), Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET), PredatorCh, macroinvertebrate taxa richness (TaxaCountAllChir), relative abundance of Trichoptera taxa

(TrichopteraChTxPct), and relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) scored below average and contributed to the low MIBI score (Figure 33).

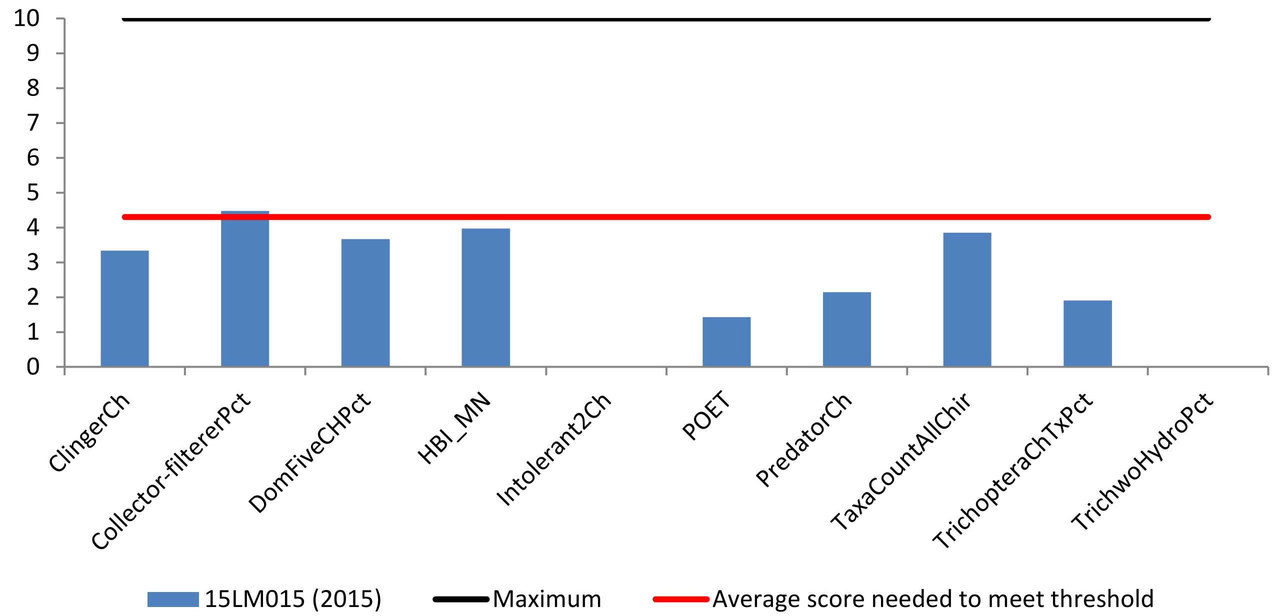


Figure 33: Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for station 15LM015.

Data Evaluation for each Candidate Cause

Temperature

Temperature ranged from 15.3°C to 24.2°C at station 15LM015 during sonde deployment from August 11, 2016 through August 22, 2016. All values were below the daily average warmwater standard (30 °C). Instantaneous samples from 2015 to 2017 had a maximum value of 21.5 °C (46 samples). Temperature appears suitable for warmwater macroinvertebrates and is not a stressor in this AUID.

Nitrate

Nitrate concentration during fish sampling in 2015 and 2016 was 8.8 mg/L and 6.8 mg/L respectively. Additional samples were collected as part of SID from 2015 through 2017, with a goal to sample various flow conditions and establish a range of nitrate concentrations (Figure 34). Samples were collected from two stations (S008-676 and S008-697), and concentrations ranged from 1.9 to 19.1 mg/L (average of 8.7 mg/L). Thirteen (28%) of the 46 samples were above 10 mg/L. Elevated concentrations were documented at both sites during various months.

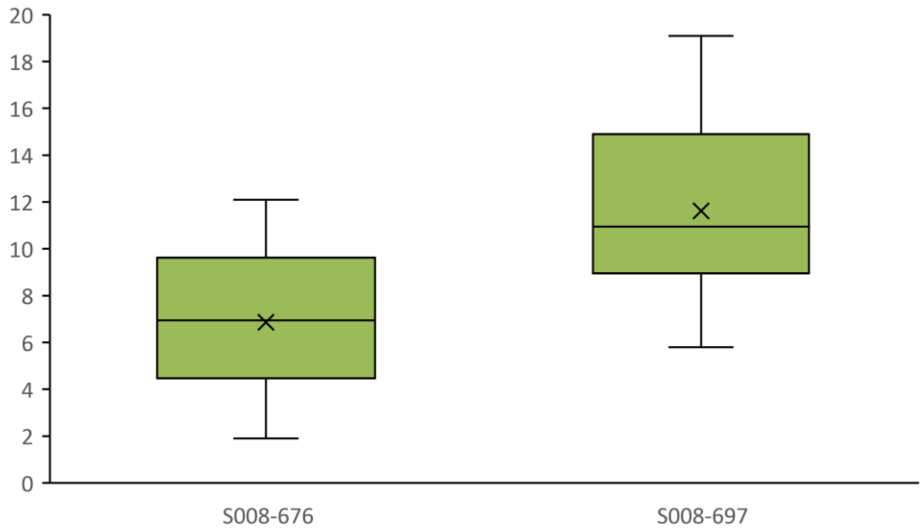


Figure 34: Nitrate concentrations (mg/L) at station 15LM015 (co-located with station S008-676) and station S008-697 from 2015 – 2017.

TrichopteraCh and relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were below the statewide median of stations meeting the MIBI threshold (Table 26). There were zero nitrate intolerant taxa, and 23 nitrate tolerant taxa comprising 88% of the community. The macroinvertebrate nitrate index score was worse than the median, and all of the macroinvertebrate metrics are indicative of nitrate stress.

Table 26: Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Intolerant Pct	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM015 (2015)	**5.5**	**0**	**0.0**	**23**	**87.6**	**1**	**0.0**
Southern Forest Streams Median	*3.0*	*2*	*1.0*	*18*	*49.1*	*4*	*2.3*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Elevated nitrate concentrations have been documented, and the macroinvertebrate community shows signs of nitrate stress. The nitrate index score was worse than the median, there were zero nitrate intolerant taxa, and nitrate tolerant individuals dominated the community. Nitrate is a stressor in this AUID.

Eutrophication

TP concentration during fish sampling in 2015 and 2016 was 0.037 mg/L and 0.092 mg/L respectively. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TP concentrations (Figure 35). Concentrations ranged from 0.014 to 0.504 mg/L (average of 0.101 mg/L). Three (15%) of the twenty samples exceeded the river eutrophication standard for the South Region (0.150 mg/L). Exceedances occurred in February, August, and September during elevated flow conditions. DOP concentrations ranged from 0.010 to 0.246 mg/L.

Chl-*a*, BOD, DO flux, and pH flux are also considered when evaluating eutrophication stress. Three chl-*a* and BOD samples were collected in July and August of 2017. Chl-*a* concentrations ranged from 1.5 to 3.1 µg/L, and BOD concentrations ranged from 0.9 to 1.6 mg/L. There were no exceedances of the chl-*a* standard (35 µg/L) or BOD standard (3 mg/L). Daily DO flux was below the standard of 4.5 mg/L (maximum of 3.5 mg/L) and no low DO exceedances were observed during sonde deployment in 2016. pH flux ranged from 0.1 to 0.7 (average of 0.3); typical daily pH fluctuations are 0.2 to 0.3 (Heiskary et al. 2013).

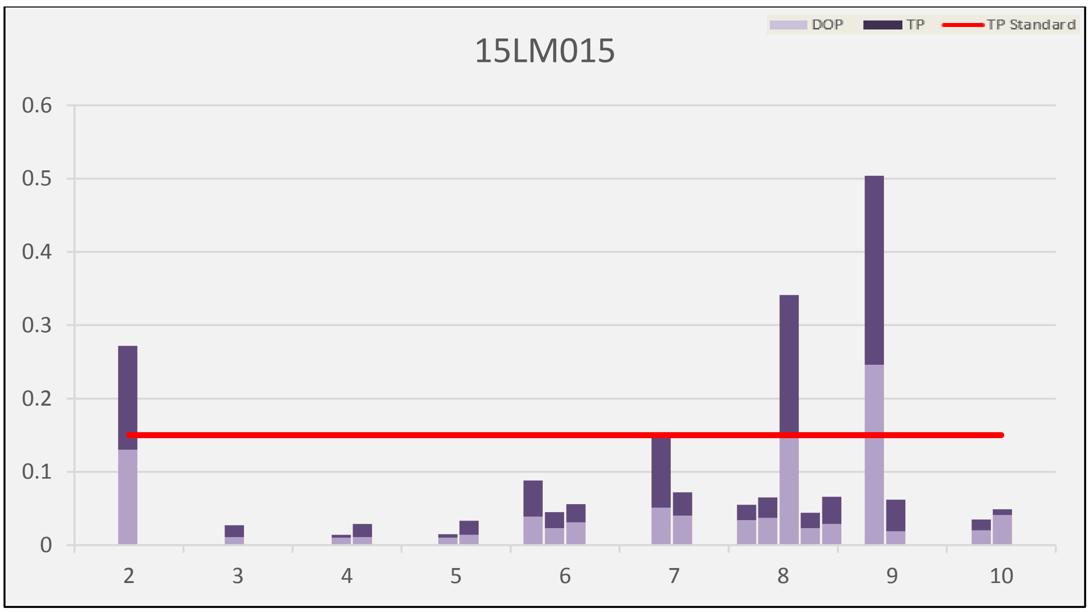


Figure 35: TP and DOP concentrations (mg/L) at station 15LM015 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 27). Taxa richness of collector-filterers (Collector-filtererCh), collector-gatherers (Collector-gathererCh), and EPT were at or below the median. There was one phosphorus intolerant taxa comprising 2% of the community, and five phosphorus tolerant taxa comprising 5% of the community. The macroinvertebrate phosphorus index score was worse than the median.

Table 27: Macroinvertebrate metrics that respond to eutrophication stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Phosphorus Index Score	Phosphorus Intolerant Taxa	Phosphorus Intolerant Pct	Phosphorus Tolerant Taxa	Phosphorus Tolerant Pct	Collector-filtererCh	Collector-gathererCh	EPT
15LM015 (2015)	**0.138**	**1**	**1.6**	5	5.4	**4**	14	**4**
Southern Forest Streams Median	*0.127*	*2*	*1.9*	*10*	*18.7*	*6*	*14*	*8*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓	↓

TP exceedances have been documented during elevated flow conditions, but limited chl-*a*, BOD, and DO flux data is meeting standards. In addition, minimal low DO has been documented. A majority of the macroinvertebrate metrics were worse than the median, but eutrophication is inconclusive as a stressor due to mixed results.

Dissolved Oxygen

Continuous DO data was collected in 2016 at station 15LM015; concentrations ranged from 6.6 to 10.4 mg/L (Figure 36). All values were above the warmwater DO standard (5 mg/L), and daily DO flux was below the standard of 4.5 mg/L (maximum of 3.5 mg/L). Instantaneous samples from 2015 through 2017 ranged from 4.7 to 12.8 mg/L (46 samples) with one (2%) exceedance of the low DO standard.

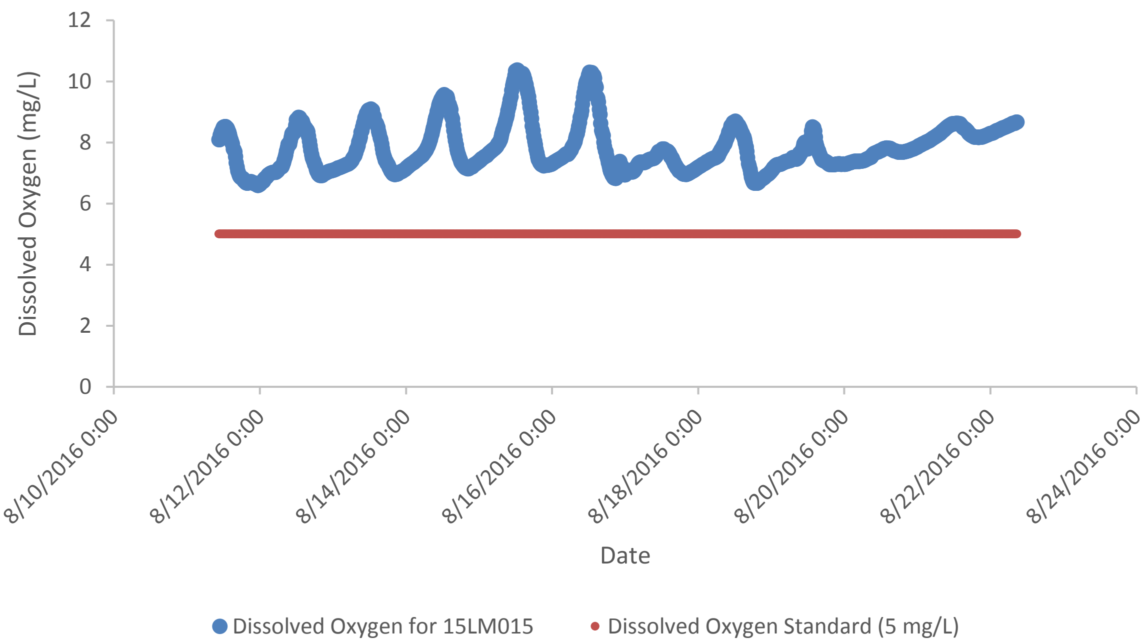


Figure 36: DO conditions during sonde deployment at station 15LM015 in 2016.

A majority of the macroinvertebrate metrics were better than the statewide median of stations meeting the MIBI threshold (Table 28). Taxa richness of EPT was below the median. There were nine low DO intolerant taxa comprising 24% of the community, and two low DO tolerant taxa comprising 1% of the community. The macroinvertebrate low DO index score was above the median and there does not appear to be a strong signal for low DO stress.

Table 28: Macroinvertebrate metrics that respond to DO stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT
15LM015 (2015)	7.4	9	23.5	2	1.0	**4**
Southern Forest Streams Median	*6.9*	*5*	*9.4*	*6*	*9.0*	*8*
Expected response to stress	↓	↓	↓	↑	↑	↓

DO concentrations are adequate, and the macroinvertebrates don't appear stressed by low DO. DO is not a stressor in this AUID.

TSS

TSS concentration during fish sampling in 2015 and 2016 was 4 mg/L and 17 mg/L respectively. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TSS concentrations (Figure 37). Concentrations ranged from 2 to 98 mg/L (average of 22.3 mg/L). Three (15%) of the twenty samples exceeded the TSS standard for the South Region (65 mg/L). The exceedances occurred in February, August, and September during elevated flow conditions. TSVS concentrations ranged from 1 to 20 mg/L.

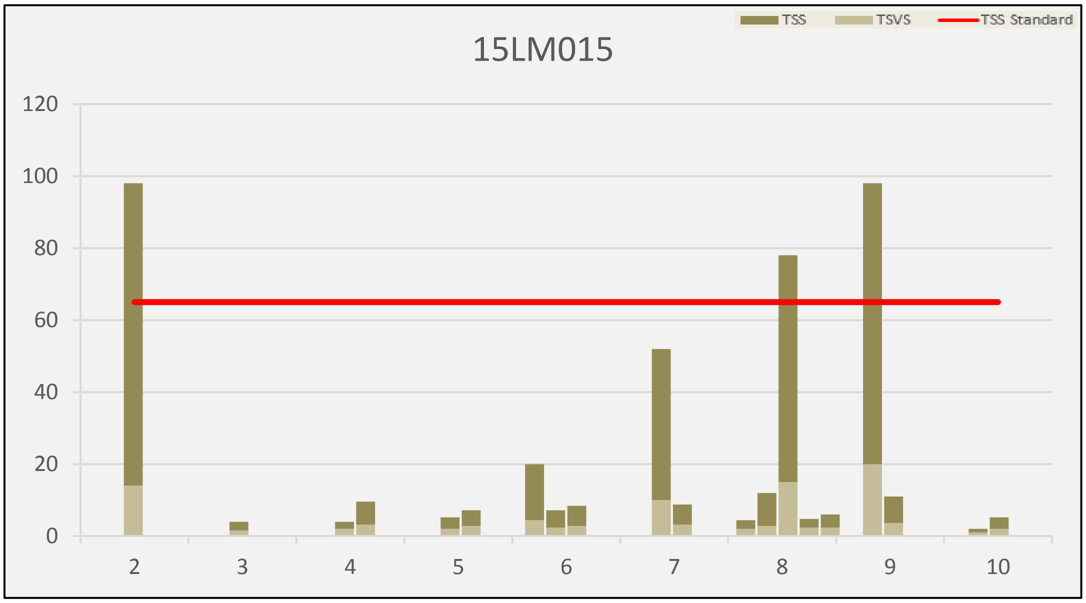


Figure 37: TSS and TSVS concentrations (mg/L) at station 15LM015 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 29). Relative abundance of collector-filterer individuals (Collector-filtererPct) was below the median, and relative abundance of Plecoptera individuals (PlecopteraPct) was zero. There were zero TSS intolerant taxa, and seven TSS tolerant taxa comprising 58% of the community. The macroinvertebrate TSS index score was worse than the median, and station 15LM015 is showing signs of TSS stress. However, the fish community (although not impaired), showed no indication of TSS stress; the probability of meeting the TSS standard based on the fish community was 74% and 83%.

Table 29: Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Intolerant Pct	TSS Tolerant Taxa	TSS Tolerant Pct	Collector-filtererPct	PlecopteraPct
15LM015 (2015)	**19.2**	**0**	**0.0**	7	**58.4**	**17.1**	0.0
Southern Forest Streams Median	*15.1*	*1*	*0.9*	*11*	*26.8*	*23.3*	*0.0*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

TSS exceedances have been documented during elevated flow conditions, and the macroinvertebrates show signs of TSS stress. The DNR has also documented channel incision and instability in this reach, which has an impact on sediment supply and transport (see habitat section below for more information). It's possible the macroinvertebrate response is due to other stressors, as the MPCA biologists noted inadequate flow for riffle organisms and very little sampleable habitat. Also, the fish community (although not impaired) doesn't appear stressed by TSS. TSS is inconclusive as a stressor at this time; additional sampling is recommended to gain better understanding of TSS dynamics in this reach and the impact to the macroinvertebrate community.

Lack of Habitat

The MSHA scores were 68 ("good") (June 2015), 38 ("poor") (August 2015), and 63 ("fair") (July 2016). Channel features consisted of runs (15% to 80%), pools (10% to 35%), and riffles (10% to 50%). Runs and pools were dominated by sand, silt, and gravel, while sand and gravel were the primary substrate in riffles. Light to moderate embeddedness was noted, and bank erosion varied between visits (little to severe). Channel stability ranged from low to high. Multiple cover types were present, with cover amount ranging from sparse to moderate (Figure 38). During macroinvertebrate sampling in August 2015, the MPCA biologists noted that there was very little flow and sampleable habitat.

Figure 38: Habitat conditions at station 15LM015 on July 13th, 2016.

The macroinvertebrate metrics don't display strong signals of habitat stress (Figure 39). Climbers are abundant, and burrowers and sprawlers are in the middle quartiles. The only suggestion of habitat stress is the slightly reduced clingers, and slightly elevated legless individuals. Clingers attach to rock or woody debris, and legless are tolerant species that can withstand degraded habitat conditions. Also, *Physella* and *Polypedilum* were the top two species. Indicator values for fine substrates for *Physa* and *Polypedilum*, developed by Carlisle et al (2007), are eight; the scoring system is based on a scale from 1 to 10, with 10 being the most tolerant.

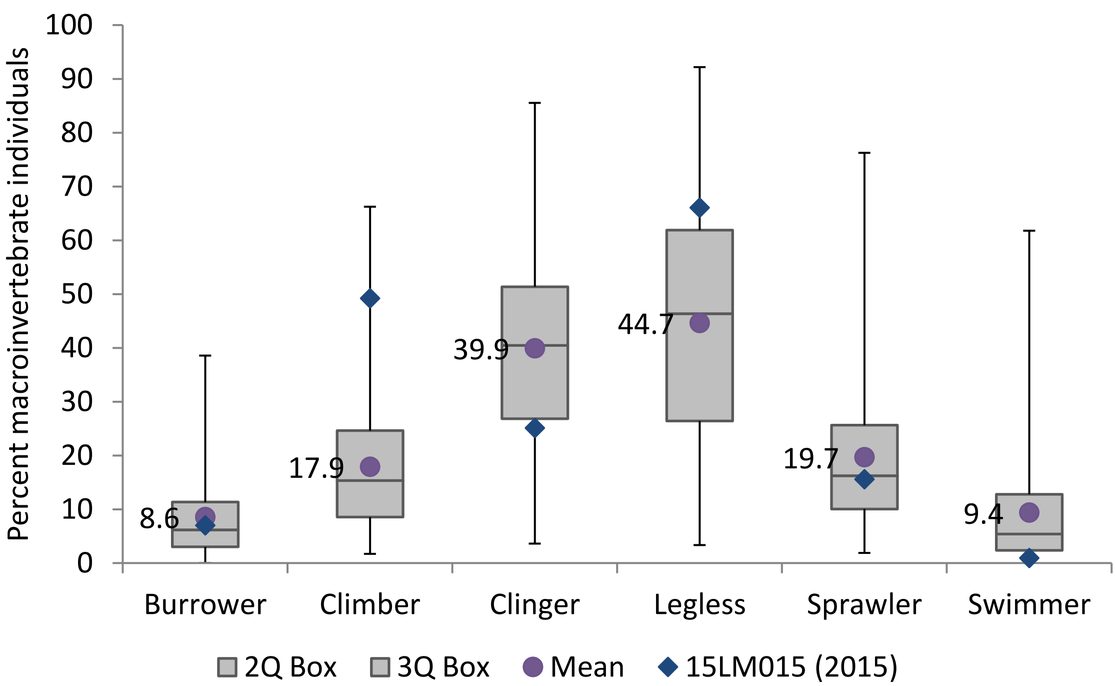


Figure 39: Macroinvertebrate habitat metrics with box plot showing range of values from Southern Forest Streams GP (class 6) stations meeting the bio criteria, mean of those stations, and metric values from station 15LM015.

Geomorphology work completed by the DNR in 2016 at station 15LM015 documented severe channel incision and lack of floodplain connection (Figure 40). It was also noted that the *"stream above the survey reach is possibly a stable E or C stream, then down cutting to the unstable F seen in the survey. Final stable stream type is an E or a C, but in either scenario the channel currently is in an unstable form. In this unstable form, as a function of width to depth, the channel is unable to effectively transport sediment. This causes fine sediment build-up, contributing to lack of habitat for macroinvertebrates"* (DNR 2017).

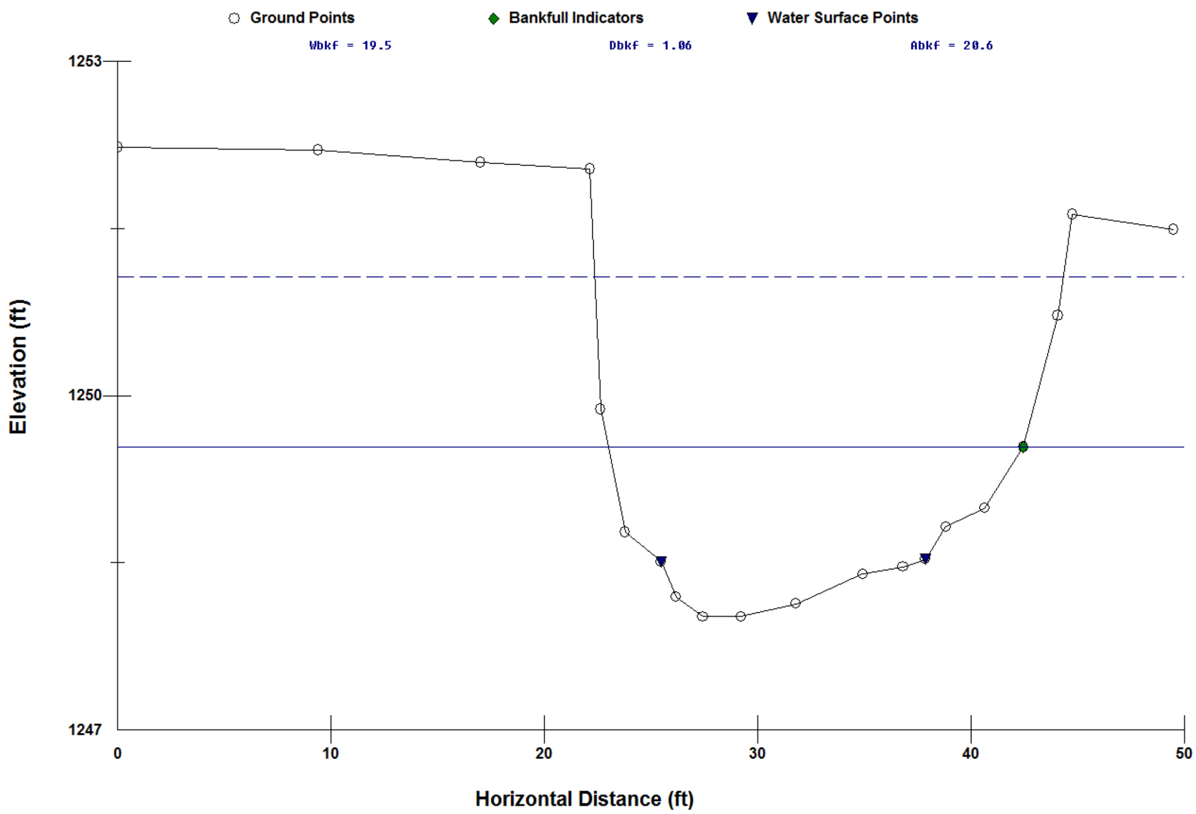


Figure 40: Cross section of riffle at station 15LM015 showing bankfull (solid line) and flood prone elevations (dashed line). Bankfull and flood flows are contained within the channel, increasing shear stress and streambank erosion; this reach lacks floodplain connection. Figure provided by the DNR.

The MSHA scores were "poor" to "good", fine substrates were abundant, embeddedness and erosion were present, and geomorphology work performed by DNR documented an unstable channel that is limiting macroinvertebrate habitat. Clingers were reduced, legless were elevated, and the dominant two species are tolerant of fine substrates. Lack of habitat and excess fine substrate are stressing the macroinvertebrate community.

Flow Alteration

There are currently no stream gaging stations in the watershed, but modeled flows via the HSPF model are available for the watershed from 1993 through 2015 (Tetra Tech 2018). Modeled flows at the mouth of this AUID ranged from 0.1 to 283.2 cfs (average of 5.1 cfs). Flows were less than one cfs approximately 15% of the time.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 30). Relative abundance of EPTPct, non-hydropsychid Trichoptera individuals (TrichwoHydroPct), tolerant taxa (Tolerant2ChTxPct), and total taxa richness (TaxaCountAllChir) were worse than the median. Relative abundance of long-lived individuals (LongLivedPct) was better than the median. Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of EPT, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al. 2002; Poff and Zimmerman 2010; EPA 2012). MPCA biologists noted inadequate flows during macroinvertebrate sampling in August 2015.

Table 30: Macroinvertebrate metrics that respond to flow alteration stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	EPTPct	LongLivedPct	TrichwoHydroPct	TaxaCountAllChir	Tolerant2ChTxPct
15LM015 (2015)	**14.9**	8.3	**0.0**	**32**	**81.3**
Southern Forest Streams Median	*27.4*	*3.9*	*2.3*	*40*	*75.9*
Expected response to stress	↓	↓	↓	↓	↑

Flow alteration is a stressor in Unnamed Creek, and is contributing to nitrate and habitat stressors. Altered (channelized) watercourses and agricultural tile drainage are common in this part of the watershed (Figure 63). Channelized reaches have direct impacts on hydrology and habitat (as well as other variables), and although tile drainage can increase agricultural productivity it has negative impacts on hydrology (e.g. increasing peak flows and reducing base flows) and water quality (e.g. increasing nitrogen loading). See Section 5 (Conclusions in the Upper Iowa River Watershed) for more information on flow alteration.

Conclusion

Nitrate, habitat, and flow alteration are stressing the macroinvertebrate community in Unnamed Creek. Eutrophication and TSS are inconclusive, while temperature, DO, and fish passage are not stressors.

4.2. Central Upper Iowa – Deer Creek (520)

This section encompasses biotic impairments in the central portion of the Upper Iowa River Watershed (Figure 41). There is only one biological impairment, which is for fish in Deer Creek (AUID 520). This AUID is warmwater (2B) and general use.

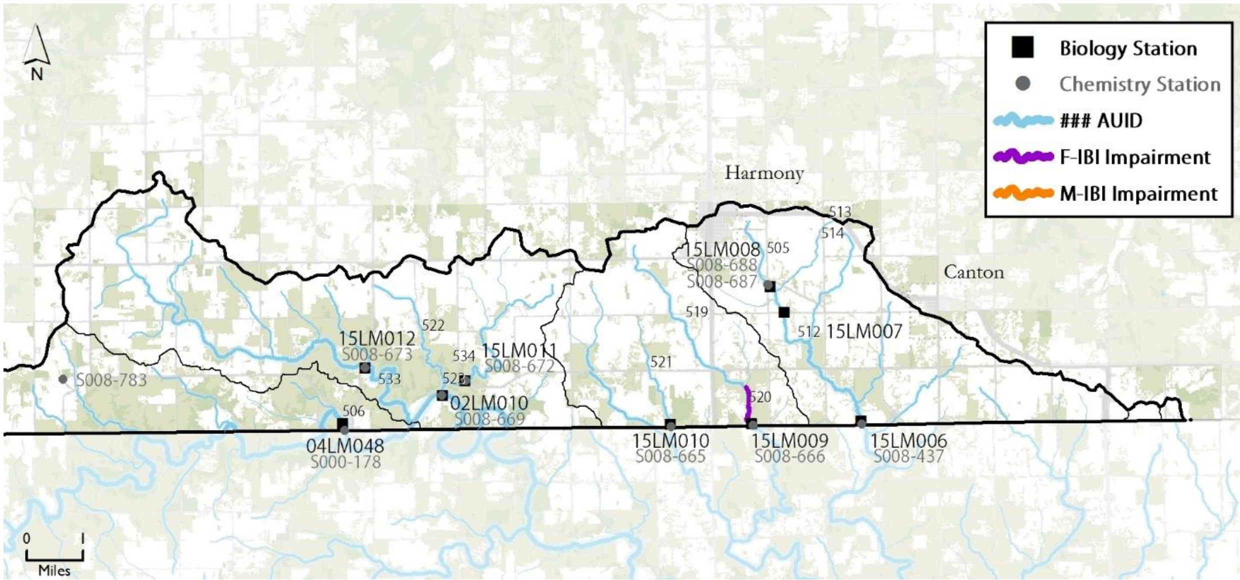


Figure 41: Upper Iowa River Watershed (central portion) biota impairments, biology stations, and chemistry stations.

Biological Communities

Deer Creek (07060002-520) is a 0.8 mile long stream segment that ends at the Minnesota/Iowa border south of Harmony. This is a warmwater reach with a fish impairment. Station 15LM009 is the only biological monitoring station in the AUID; this station was sampled for fish and macroinvertebrates in 2015 and 2016 (fish only).

The fish community is impaired and “not supporting” the aquatic life use. FIBI scores for station 15LM009 were 51 (2015) and 73 (2016). The 2015 sample was below the general use threshold but within the confidence interval; the 2016 sample was above the threshold and confidence interval. Station 15LM009 is Southern Headwaters (class 3). Relative abundance of detritivorous taxa (DetNWQTxPct), generalist taxa (GeneralTxPct), and taxa richness of sensitive species (Sensitive) scored poorly and contributed to the low FIBI score (Figure 42). There were no deformities, eroded fins, lesions, or tumors (DELTs) in either sample; these would negatively impact the FIBI score. Creek chubs and Johnny darters dominated both samples.

The macroinvertebrate community is “supporting” the aquatic life use, and not currently impaired. The MIBI score for station 15LM009 was 56.8, which is above the general use threshold and confidence interval. Station 15LM009 is Southern Forest Streams GP (class 6).

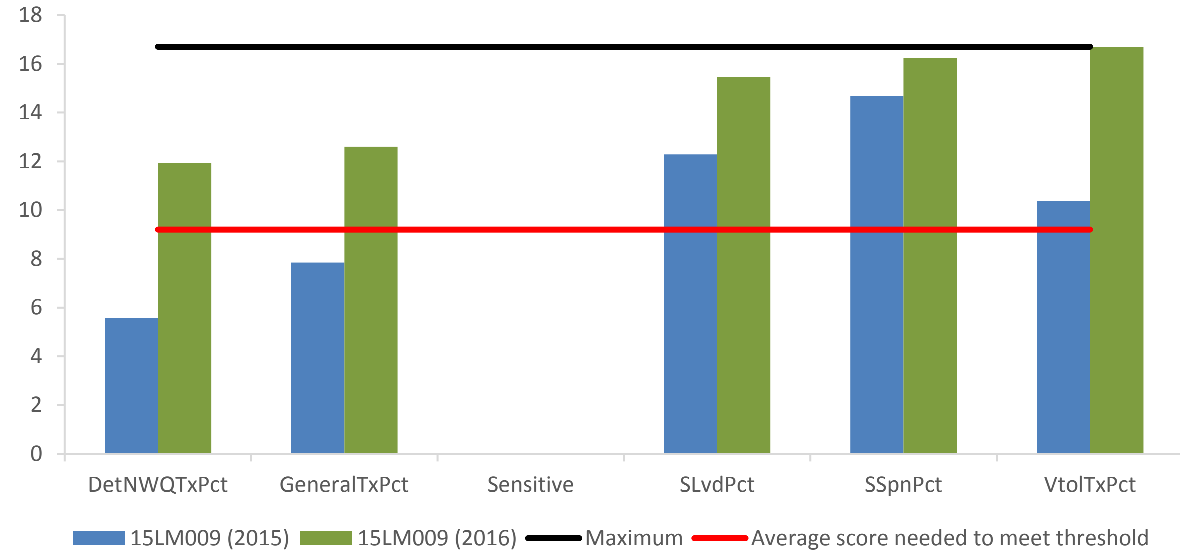


Figure 42: Fish metrics of the Southern Headwaters (class 3) IBI for station 15LM009.

Data Evaluation for each Candidate Cause

Temperature

A continuous temperature sensor was deployed at station 15LM009 in 2015 and 2016 (Figure 43). Maximum values were 22.8 °C (2015) and 21.1 °C (2016). All values were below the daily average warmwater standard (30 °C). Instantaneous samples from 2015 through 2017 had a maximum value of 19.7 °C (30 samples). A use class change to 2A (coldwater) was discussed, but the AUID remained warmwater. Temperature appears suitable, and is not a stressor in this AUID.

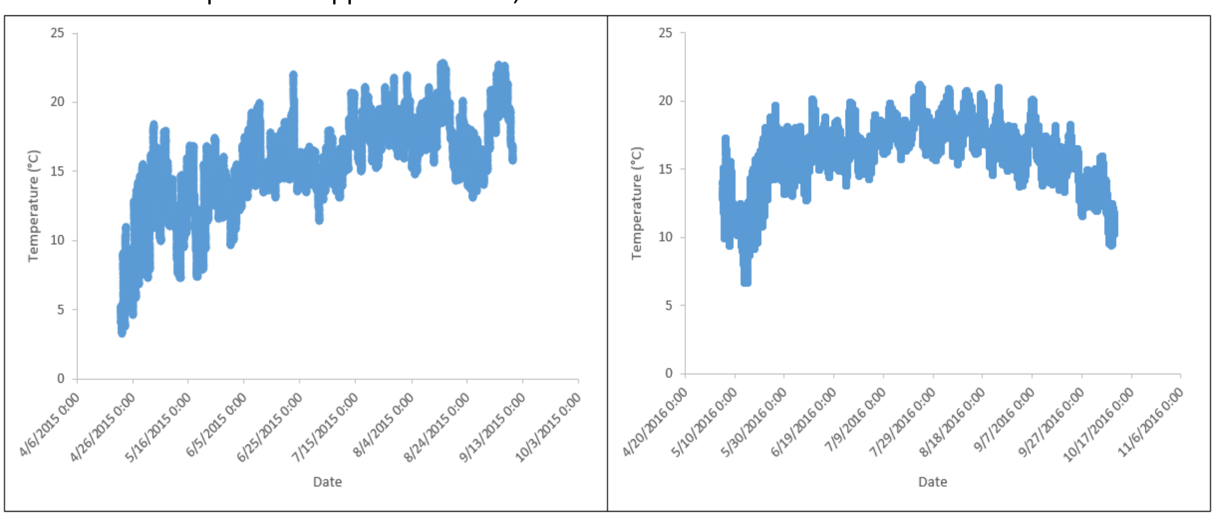


Figure 43: Continuous temperature data at station 15LM009 in 2015 (left) and 2016 (right).

Nitrate

Nitrate concentration during fish sampling in 2015 and 2016 was 7.9 mg/L and 7.4 mg/L respectively. Additional samples were collected as part of SID from 2015 through 2017, with a goal to sample various flow conditions and establish a range of nitrate concentrations (Figure 44). Concentrations ranged from

1.7 to 10.7 mg/L (average of 7.1 mg/L). One (4%) of the 28 samples was above 10 mg/L; this concentration occurred in June.

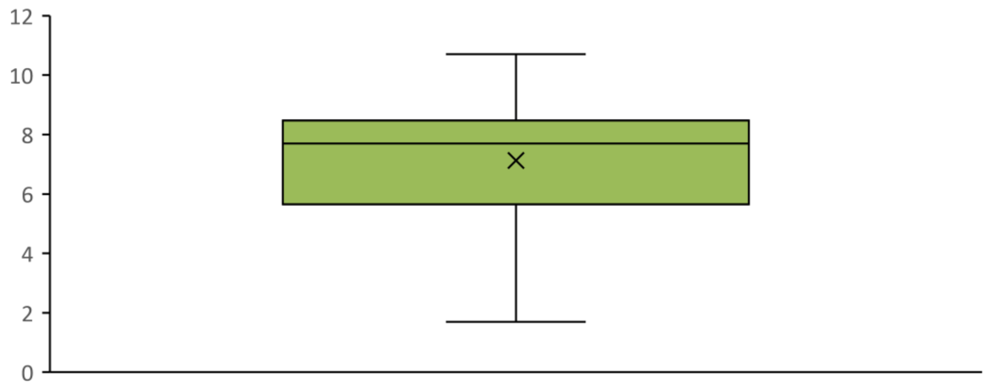


Figure 44: Nitrate concentrations (mg/L) at station 15LM009 from 2015 – 2017.

Although this reach has a fish impairment, better relationships have been made with respect to macroinvertebrates and nitrate concentration. TrichopteraCh and relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were above the statewide median of stations meeting the MIBI threshold (Table 31). There was one nitrate intolerant taxa, and 20 nitrate tolerant taxa comprising 54% of the community. The macroinvertebrate nitrate index score was worse than the median, and a majority of the macroinvertebrate metrics are indicative of nitrate stress.

Table 31: Macroinvertebrate metrics that respond to nitrate stress in Deer Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Intolerant Pct	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM009 (2015)	**3.1**	**1**	2.2	**20**	**54.3**	5	5.7
Southern Forest Streams Median	*3.0*	*2*	*1.0*	*18*	*49.1*	*4*	*2.3*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Elevated nitrate concentrations have been documented, and the macroinvertebrate community (although not currently impaired) shows signs of nitrate stress. Nitrate is inconclusive as a stressor in Deer Creek as the impacts to the fish community are unclear.

Eutrophication

TP concentration during fish sampling in 2015 and 2016 was 0.196 mg/L and 0.129 mg/L respectively. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TP concentrations (Figure 45). Concentrations ranged from 0.062 to 0.770 mg/L (average of 0.225 mg/L). Thirteen (72%) of the 18 samples exceeded the river eutrophication standard for the Central Region (0.100 mg/L). Exceedances occurred in February, May, June (3), July (2), August (3), September (2), and October during both low flow and elevated flow conditions. DOP concentrations ranged from 0.044 to 0.494 mg/L.

Chl-*a*, BOD, DO flux, and pH flux are also considered when evaluating eutrophication stress. Three chl-*a* and BOD samples were collected in July and August of 2017. Chl-*a* concentrations ranged from 4.1 to 19.4 µg/L, and BOD concentrations ranged from 0.8 to 16.0 mg/L. There was one exceedance of the chl-*a* standard (18 µg/L) and BOD standard (2 mg/L). There is no daily DO flux data available for this reach, but zero low DO exceedances were observed during instantaneous sampling. pH flux ranged from 0.2 to 0.4 (average of 0.3); typical daily pH fluctuations are 0.2 to 0.3 (Heiskary et al. 2013).

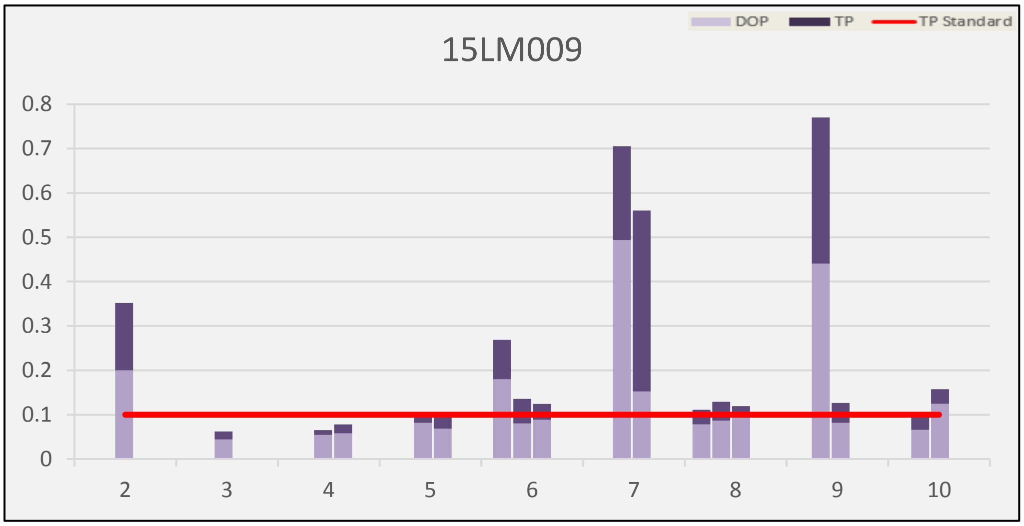


Figure 45: TP and DOP concentrations (mg/L) at station 15LM009 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the fish metrics were better than the statewide average of stations meeting the FIBI threshold (Table 32). Relative abundance of individuals that are darter species (DarterPct), omnivore species (OmnivorePct), and tolerant species (TolPct) were better than average both years. Relative abundance of individuals that are simple lithophilic spawners (SLithopPct) was worse than average both years. The fish community does not exhibit a strong signal for eutrophication stress.

Table 32: Fish metrics that respond to eutrophication stress in Deer Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with FIBI scores below the threshold are highlighted red.

Station (Year Sampled)	DarterPct	SLithopPct	OmnivorePct	TolPct
15LM009 (2015)	29.9	**15.0**	9.3	66.4
15LM009 (2016)	29.8	**6.4**	2.1	68.1
Southern Headwaters Average	*12.1*	*33.2*	*14.7*	*70.8*
Expected response to stress	↓	↓	↑	↑

TP exceedances have been documented during low flow and elevated flow conditions, and elevated chl-*a* and BOD have also been documented. There is no daily DO flux data available, but zero low DO exceedances were observed. A majority of the fish metrics were better than average and eutrophication is inconclusive as a stressor due to mixed results.

Dissolved Oxygen

Continuous DO data was collected in 2017 at station 15LM009, but due to potential equipment malfunction the data was discarded. Instantaneous samples from 2015 through 2017 ranged from 5.5 – 15.1 mg/L (30 samples) with no exceedances of the low DO standard (5 mg/L).

A majority of the fish metrics were better than the statewide average of stations meeting the FIBI threshold (Table 33). Relative abundance of individuals with a female mature age ≥ 3 (MA>3Pct) was worse than average both years, while relative abundance of individuals that are serial spawning species (SSpnPct) and tolerant species (TolPct) were better than average both years. Low DO index scores and probability of meeting the DO standard were at or above average both years, with the exception of the low DO index score in 2015. The fish community does not appear to have a strong signal for DO stress.

Table 33: Fish metrics that respond to DO stress in Deer Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with FIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Low DO Index Score (RA)	Probability of meeting DO std.	MA>3Pct	SSpnPct	TolPct
15LM009 (2015)	**7.1**	0.50	**6.5**	9.3	66.4
15LM009 (2016)	7.2	0.57	**2.1**	2.1	68.1
Southern Headwaters Average	*7.2*	*0.45*	*13.6*	*16.5*	*70.8*
Expected response to stress	↓	↓	↓	↑	↑

DO concentrations appear adequate, and the fish community doesn't display strong signs of low DO stress. It's hard to fully understand the DO regime without continuous data, making DO inconclusive as a stressor in Deer Creek. Additional monitoring (continuous data) is recommended in this reach.

TSS

TSS concentration during fish sampling in 2015 and 2016 was 64 mg/L and 27 mg/L respectively. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TSS concentrations (Figure 46). Concentrations ranged from 4 to 200 mg/L (average of 43.4 mg/L). Four (22%) of the 18 samples exceeded the TSS standard for the South Region (65 mg/L). The exceedances occurred in February, July (2), and September with most during elevated flow conditions. TSVS concentrations ranged from 1.2 – 38 mg/L.

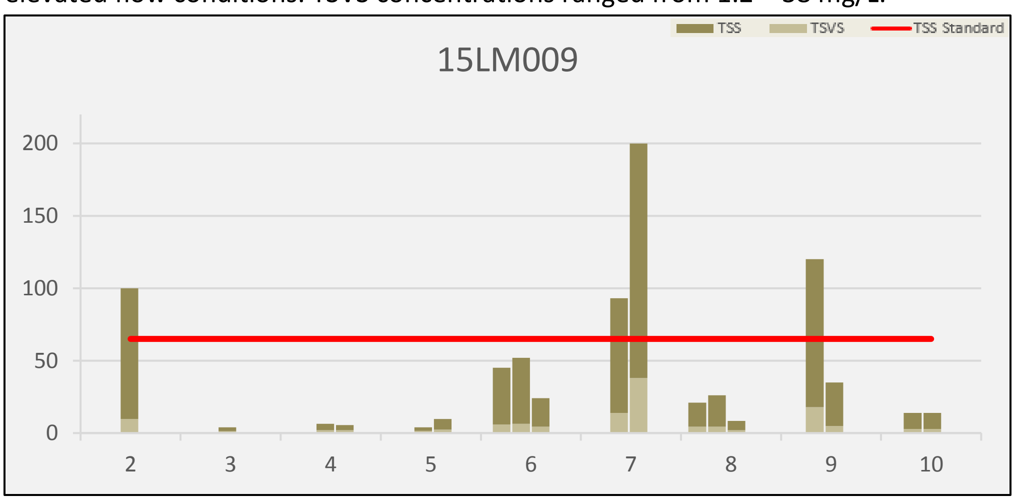


Figure 46: TSS and TSVS concentrations (mg/L) at station 15LM009 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the fish metrics were worse than the statewide average of stations meeting the FIBI threshold (Table 34). Relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), herbivore species (HrbNWQPct), intolerant species (IntolerantPct), long-lived (LLvdPct), riffle dwelling species (RifflePct), sensitive species (SensitivePct), and simple lithophilic spawners (SLithFrimPct) were worse than average both years. Non-tolerant Centrarchidae and intolerant, long-lived, and sensitive species were zero both years. Relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct) was above and below average, and relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct) was above average both years. TSS index scores and probability of meeting the TSS standard were better than average both years. The fish community shows signs of TSS stress.

Table 34: Fish metrics that respond to TSS stress in Deer Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with FIBI scores below the threshold are highlighted red.

Station (Year Sampled)	TSS Index Score (RA)	Probability of meeting TSS std.	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct
15LM009 (2015)	14.5	0.76	41.1	**0.0**	**7.5**	**0.0**	**0.0**	29.9	**7.5**	**0.0**	**10.3**
15LM009 (2016)	14.6	0.75	**36.2**	**0.0**	**4.3**	**0.0**	**0.0**	29.8	**4.3**	**0.0**	**4.3**
Southern Headwaters Average	*16.9*	*0.60*	*37.4*	*0.9*	*23.1*	*2.1*	*3.5*	*13.9*	*28.1*	*8.9*	*14.9*
Expected response to stress	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

TSS exceedances have been documented, and the fish community shows signs of TSS stress. Although there are signals of TSS stress, the TSS index scores and probability of meeting the TSS standard (based on the fish community) were better than average both years. It's possible the fish response is due to another stressor(s) (e.g. habitat and/or fish passage); TSS is inconclusive as a stressor.

Lack of Habitat

The MSHA scores were 41 ("poor") (June 2015), 25 ("poor") (August 2015), and 38 ("poor") (June 2016). Channel features consisted of runs (60% to 100%), pools (0% to 25%), and riffles (0% to 15%) (Figure 47). Silt and clay were the dominate substrate, and embeddedness ranged from severe to no coarse substrate. Bank erosion varied between visits (little to heavy), and channel stability ranged from low to moderate. Multiple cover types were present, with cover amount ranging from moderate to extensive. The MPCA biologists noted that the "stream is dominated by fine sediment and has limited habitat morphology" (MPCA CARL 2017).

Figure 47: Habitat conditions at station 15LM009 on June 28th, 2016.

A majority of the fish metrics were worse than the statewide average of stations meeting the FIBI threshold (Table 35). Relative abundance of individuals that are tolerant species (TolPct), benthic insectivore species (BenInsectPct), and darter, sculpin, and round bodied sucker species (DarterSculpSucPct) were better than average both years. Relative abundance of individuals that are lithophilic spawners (LithFrimPct), dominant two species (DomTwoPct), riffle-dwelling species (RifflePct), and simple lithophilic spawners (SLithopPct) were worse than average both years. The fish community shows signs of habitat stress.

Table 35: Fish metrics that respond to habitat stress in Deer Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with FIBI scores below the threshold are highlighted red.

Station (Year Sampled)	TolPct	BenInsectPct	LithFrimPct	DarterSculpSucPct	DomTwoPct	RifflePct	SLithopPct
15LM009 (2015)	66.4	29.9	**52.3**	29.9	**66.4**	**7.5**	**15.0**
15LM009 (2016)	68.1	29.8	**67.0**	29.8	**88.3**	**4.3**	**6.4**
Southern Headwaters Average	*70.8*	*16.8*	*68.3*	*12.8*	*58.6*	*28.1*	*33.2*
Expected response to stress	↑	↓	↓	↓	↑	↓	↓

The MSHA scores were “poor”, fine substrates were abundant, severe embeddedness and bank erosion were present, and the fish community shows signs of habitat stress. Lack of habitat and fine substrate are stressing the fish community.

Fish Passage

Deer Creek has barriers that limit fish migration just downstream from station 15LM009 in Iowa (Figure 48). A perched culvert (approximately six inches) exists at County Road A14; minimal flow was also noted at this road crossing. At the next road crossing downstream (370th Street) the streambed is completely dry, prohibiting any migration upstream.

Figure 48: Perched culvert (left) and dry streambed (right) from November 22, 2017, reconnaissance visit; both are located just south of the MN/IA border.

Relative abundance of migratory taxa (MgrTxPct) and individuals (MgrPct) ranged from 22% to 29% and 4% to 7% respectively. Migratory taxa were above the statewide average (20%), but migratory individuals were well below average (23%).

Deer Creek disappears underground just south of the Minnesota/Iowa border, eliminating fish migration upstream. Very few migratory fish were present during sampling, and fish passage is a stressor in this AUID.

Flow Alteration

There are currently no stream gaging stations in the watershed, but modeled flows via the HSPF model are available for the watershed from 1993 through 2015 (Tetra Tech 2018). Modeled flows at the mouth of this AUID ranged from 0.1 to 170.7 cfs (average of 2.6 cfs). Flows were less than one cfs approximately 38% of the time.

A majority of the fish metrics were worse than the statewide average of stations meeting the FIBI threshold (Table 36). Relative abundance of individuals of the dominant two species (DomTwoPct), individuals with a female mature age less than or equal to two (MA<2Pct), pioneer species (PioneerPct), and the number of individuals per meter of stream sampled excluding tolerant species (NumPerMeter-Tol) were worse than average both years. Relative abundance of generalist species (GeneralPct) and short-lived individuals (SLvdPct) were mixed (above and below average). Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al. 2005; Poff and Zimmerman 2010).

Table 36: Fish metrics that respond to flow alteration stress in Deer Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with FIBI scores below the threshold are highlighted red.

Station (Year Sampled)	DomTwoPct	GeneralPct	MA<2Pct	NumPerMeter-Tol	PioneerPct	SLvdPct
15LM009 (2015)	**66.4**	53.3	**92.5**	**0.2**	**72.0**	**26.2**
15LM009 (2016)	**88.3**	**62.8**	**95.7**	**0.2**	**88.3**	7.4
Southern Headwaters Average	*58.6*	*59.0*	*73.9*	*0.7*	*37.9*	*24.3*
Expected response to stress	↑	↑	↑	↓	↑	↑

Although a majority of fish metrics were worse than average, flow alteration is inconclusive as a stressor in Deer Creek. Altered (channelized) watercourses and agricultural tile drainage decrease as you move east in the watershed (Figure 63). Channelized reaches have direct impacts on hydrology and habitat (as well as other variables), and although tile drainage can increase agricultural productivity it has negative impacts on hydrology (e.g. increasing peak flows and reducing base flows) and water quality (e.g. increasing nitrogen loading). See Section 5 (Conclusions in the Upper Iowa River Watershed) for more information on flow alteration.

Conclusion

Habitat and fish passage are stressing the fish community in Deer Creek. Nitrate, eutrophication, DO, TSS, and flow alteration are inconclusive, while temperature is not a stressor.

4.3. Eastern Upper Iowa – Unnamed Creek (535)

This section encompasses biotic impairments in the eastern portion of the Upper Iowa River Watershed (Figure 49). There is only one biological impairment, which is for macroinvertebrates in Unnamed Creek (AUID 535). This AUID is coldwater (2A) and general use.

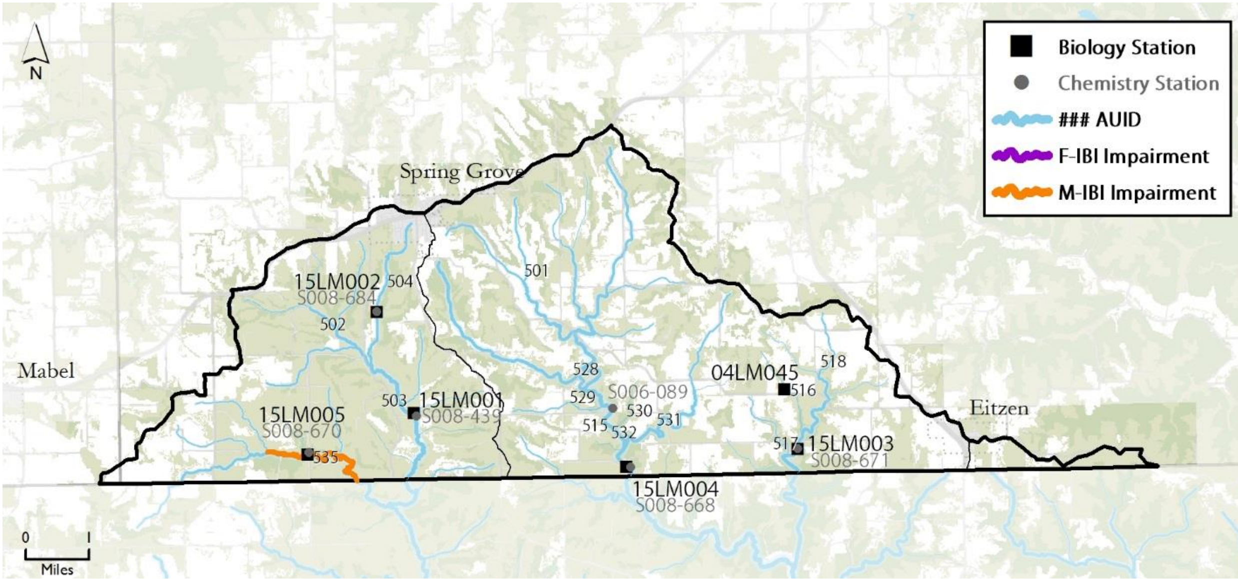


Figure 49: Upper Iowa River Watershed (eastern portion) biota impairments, biology stations, and chemistry stations.

Biological Communities

Unnamed Creek (07060002-535) is a 2.4 mile long tributary to North Bear Creek. This is a coldwater reach with a macroinvertebrate impairment. The only biological monitoring station in this AUID is 15LM005; this station was sampled for fish and macroinvertebrates in 2015 and 2016 (macroinvertebrates only).

The fish community is “supporting” the aquatic life use, and not currently impaired. The FIBI score for station 15LM005 was 57, which is above the general use threshold and within the confidence interval. This station is Southern Coldwater (class 10). Six fish species were collected, including mottled sculpin (73), white sucker (39), brook stickleback (27), creek chub (18), fathead minnow (4), and brook trout (1).

The macroinvertebrate community is impaired and “not supporting” the aquatic life use. The MIBI scores for station 15LM005 were 37 (2015) and 34 (2016); both scores are below the general use threshold but within the confidence interval. This station is Southern Coldwater (class 9). Coldwater Biotic Index scores (CBI), ratio of chironomid abundance to total dipteran abundance (ChiroDip), pollution scores based on tolerance values (HBI_MN), intolerant taxa (Intolerant2Ch), and relative abundance of very tolerant individuals (VeryTolerant2Pct) scored poorly and contributed to the low MIBI scores (Figure 50).

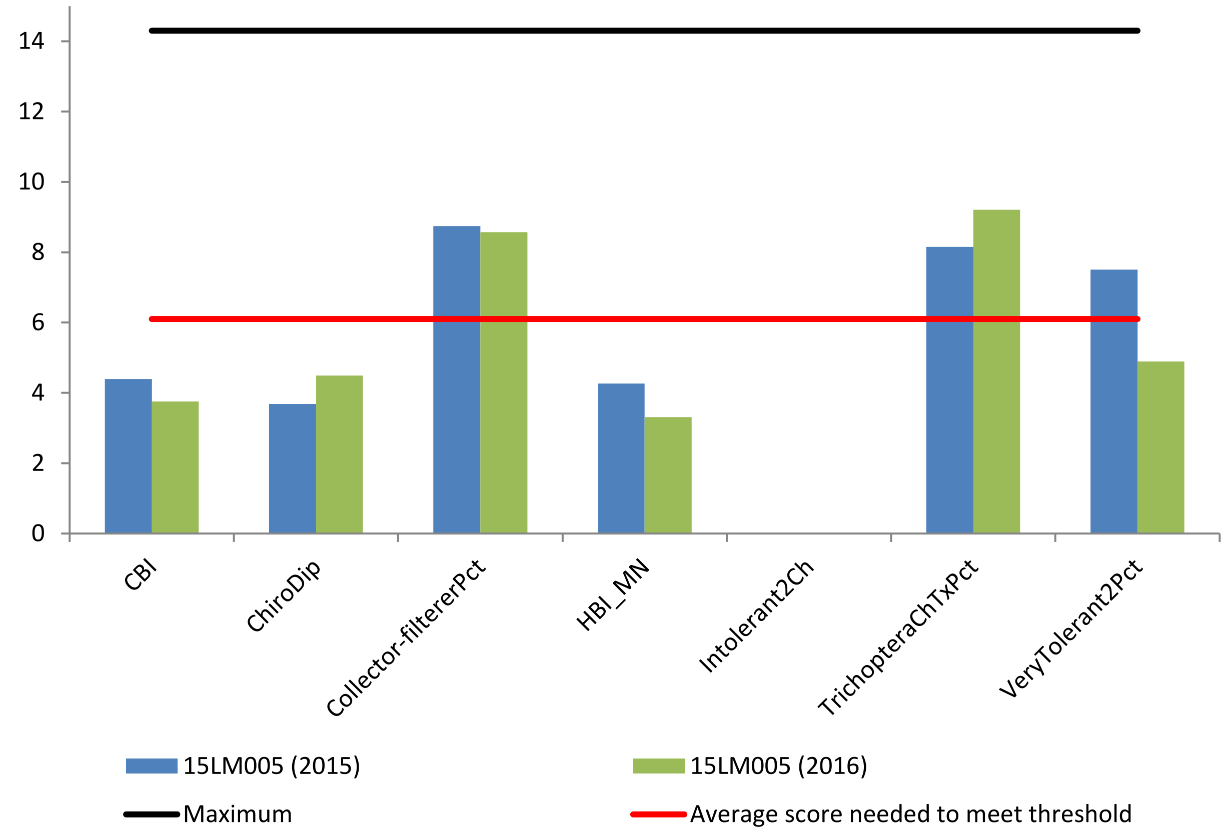


Figure 50: Macroinvertebrate metrics of the Southern Coldwater (class 9) IBI for station 15LM005.

Data Evaluation for each Candidate Cause

Temperature

A continuous temperature sensor was deployed at station 15LM005 in 2015 and 2016 (Figure 51). Maximum values were 21.8 °C (2015) and 21.1 °C (2016). There were zero samples above 22 °C; brown trout may be physiologically stressed from 19-22 °C (Bell 2006). Instantaneous samples from 2015 through 2017 had a maximum value of 20.3 °C (31 samples).

The CBI MIBI metric scores, which are based on coldwater tolerance values derived from Minnesota taxa and temperature data, were below the average metric score needed to meet the MIBI threshold both years (Figure 50). Although these scores were below average, temperature appears suitable for coldwater macroinvertebrates and is not a stressor in this AUID. Also, the fish community (although not impaired) was dominated by mottled sculpin, providing supporting evidence of an adequate temperature regime.

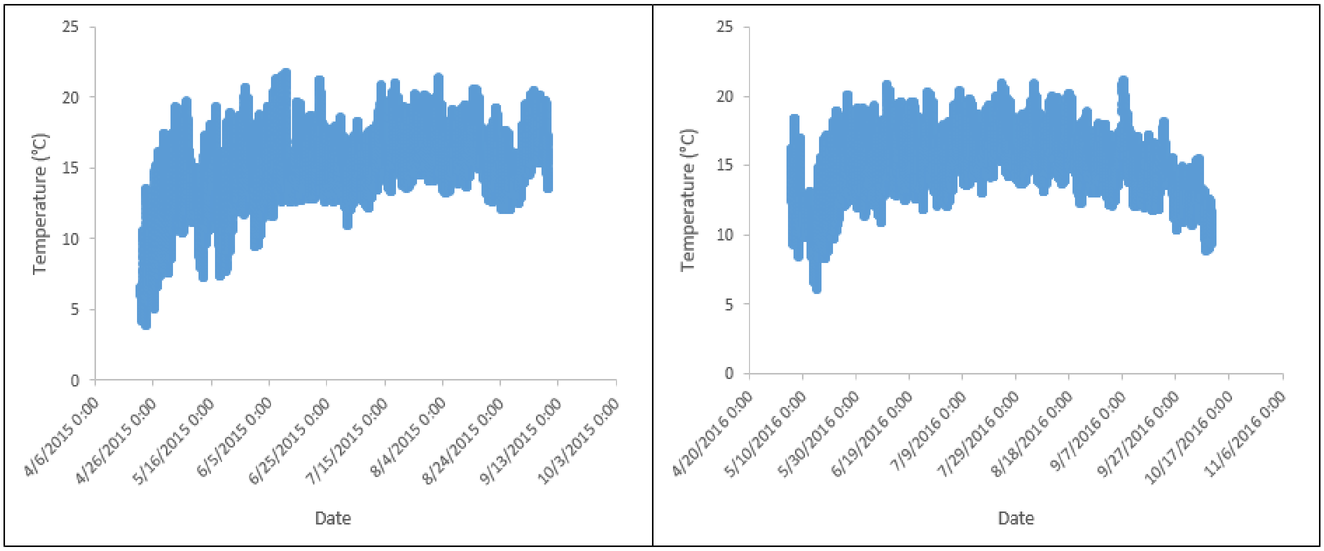


Figure 51: Continuous temperature data at station 15LM005 in 2015 (left) and 2016 (right); all values were below 22 °C.

Nitrate

Nitrate concentration during fish sampling in 2015 was 6.8 mg/L. Additional samples were collected as part of SID from 2015 through 2017, with a goal to sample various flow conditions and establish a range of nitrate concentrations (Figure 52). Concentrations ranged from 1.7 to 8.3 mg/L (average of 7.1 mg/L). All 30 samples were below 10 mg/L.

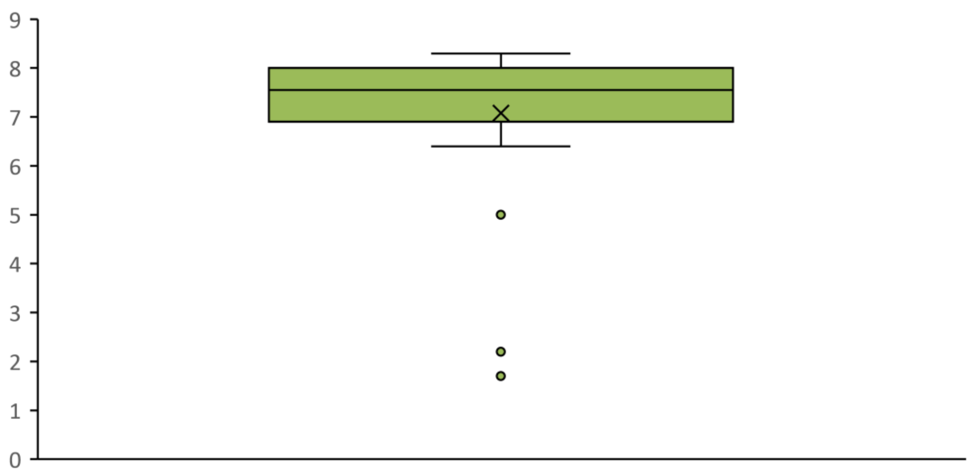


Figure 52: Nitrate concentrations (mg/L) at station 15LM005 from 2015 – 2017.

TrichopteraCh was above the statewide median of stations meeting the MIBI threshold both years, and relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) was below the median both years (Table 37). There was one nitrate intolerant taxa, and 19 to 25 nitrate tolerant taxa comprising 56% to 58% of the community. The macroinvertebrate nitrate index scores were worse than the median. The MPCA biologists noted that nitrogen tolerant taxa were in the 90th percentile for similar streams (MPCA CARL 2017). Overall, the macroinvertebrate metrics are providing a mixed response to nitrate stress.

Table 37: Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Intolerant Pct	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM005 (2015)	**3.3**	1	0.6	**25**	57.8	6	**2.9**
15LM005 (2016)	**3.7**	1	**0.3**	**19**	56.3	7	**3.1**
Southern Coldwater Streams Median	*3.1*	*1*	*0.6*	*14*	*60.9*	*4*	*6.7*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

Moderate nitrate concentrations have been documented, and the macroinvertebrate community provides a mixed response to nitrate stress. Nitrate is inconclusive as a stressor in this AUID.

Eutrophication

TP concentration during fish sampling in 2015 was 0.068 mg/L. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TP concentrations (Figure 53). Concentrations ranged from 0.046 to 1.22 mg/L (average of 0.226 mg/L). Eight (44%) of the 18 samples exceeded the river eutrophication standard for the Central Region (0.100 mg/L). Exceedances occurred in February, May, June, July (2), August, September, and October during both low flow and elevated flow conditions. DOP concentrations ranged from 0.031 to 0.369 mg/L.

Chl-*a*, BOD, DO flux, and pH flux are also considered when evaluating eutrophication stress. Three chl-*a* and BOD samples were collected in July and August of 2017. Chl-*a* concentrations ranged from 1.2 to 2.4 µg/L, and BOD concentrations ranged from 0.8 to 1.2 mg/L. There were no exceedances of the chl-*a* standard (18 µg/L) or BOD standard (2 mg/L). Daily DO flux exceeded the standard (3.5 mg/L) for the entire deployment (ranging from 3.6 to 5.4 mg/L), and minimal low DO exceedances were observed during sonde deployment in 2017. pH flux ranged from 0.2 to 0.4 (average of 0.3); typical daily pH fluctuations are 0.2 to 0.3 (Heiskary et al. 2013).

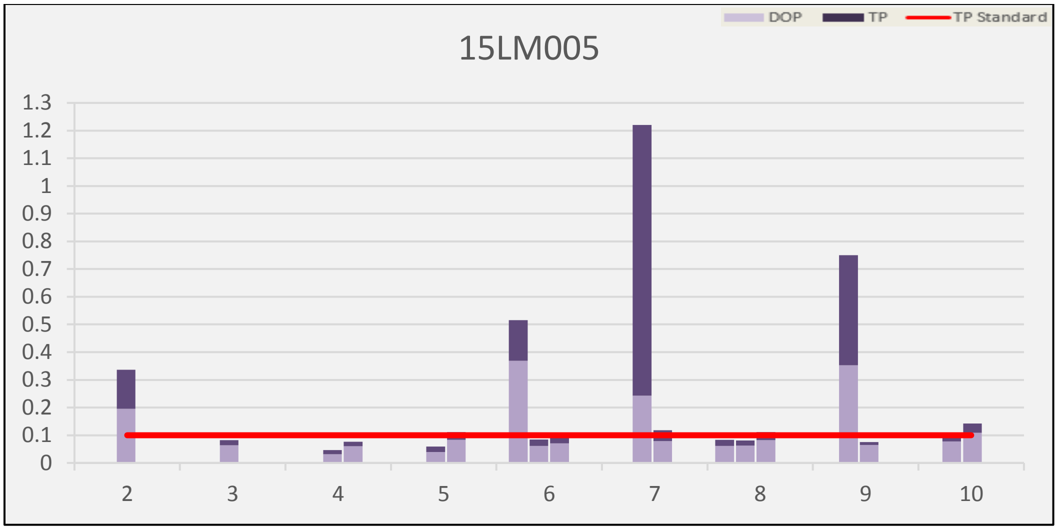


Figure 53: TP and DOP concentrations (mg/L) at station 15LM005 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 38). Taxa richness of collector-filterers (Collector-filtererCh), collector-gatherers (Collector-gathererCh), and EPT were at or above the median. There were 2 to 3 P intolerant taxa comprising 4% of the community, and 6 to 9 phosphorus tolerant taxa comprising 4% to 6% of the community. The macroinvertebrate phosphorus index scores were worse than the median.

Table 38: Macroinvertebrate metrics that respond to eutrophication stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Phosphorus Index Score	Phosphorus Intolerant Taxa	Phosphorus Intolerant Pct	Phosphorus Tolerant Taxa	Phosphorus Tolerant Pct	Collector-filtererCh	Collector-gathererCh	EPT
15LM005 (2015)	**0.110**	**2**	**3.8**	**9**	**6.3**	5	15	8
15LM005 (2016)	**0.110**	**3**	**4.3**	**6**	3.7	9	12	8
Southern Coldwater Streams Median	*0.102*	*4*	*5.1*	*4*	*4.7*	*5*	*11*	*6*
Expected response to stress	↑	↓	↓	↑	↑	↓	↓	↓

TP exceedances have been documented during low flow and elevated flow conditions, but limited chl-*a* and BOD data is meeting standards. Daily DO flux exceeded the standard for the entire sonde deployment, but minimal low DO was documented. A majority of the macroinvertebrate metrics were worse than the median, but eutrophication is inconclusive as a stressor due to mixed results.

Dissolved Oxygen

Continuous DO data was collected in 2017 at station 15LM005; concentrations ranged from 6.9 to 13.0 mg/L (Figure 54). There were minimal exceedances (2%) of the coldwater DO standard (7 mg/L), but daily DO flux exceeded the standard (3.5 mg/L) for the entire deployment (ranging from 3.6 to 5.4 mg/L). Instantaneous samples from 2015 to 2017 ranged from 5.1 to 17.8 mg/L (31 samples) with one (3%) exceedance of the low DO standard (which occurred during a storm event in July 2016).

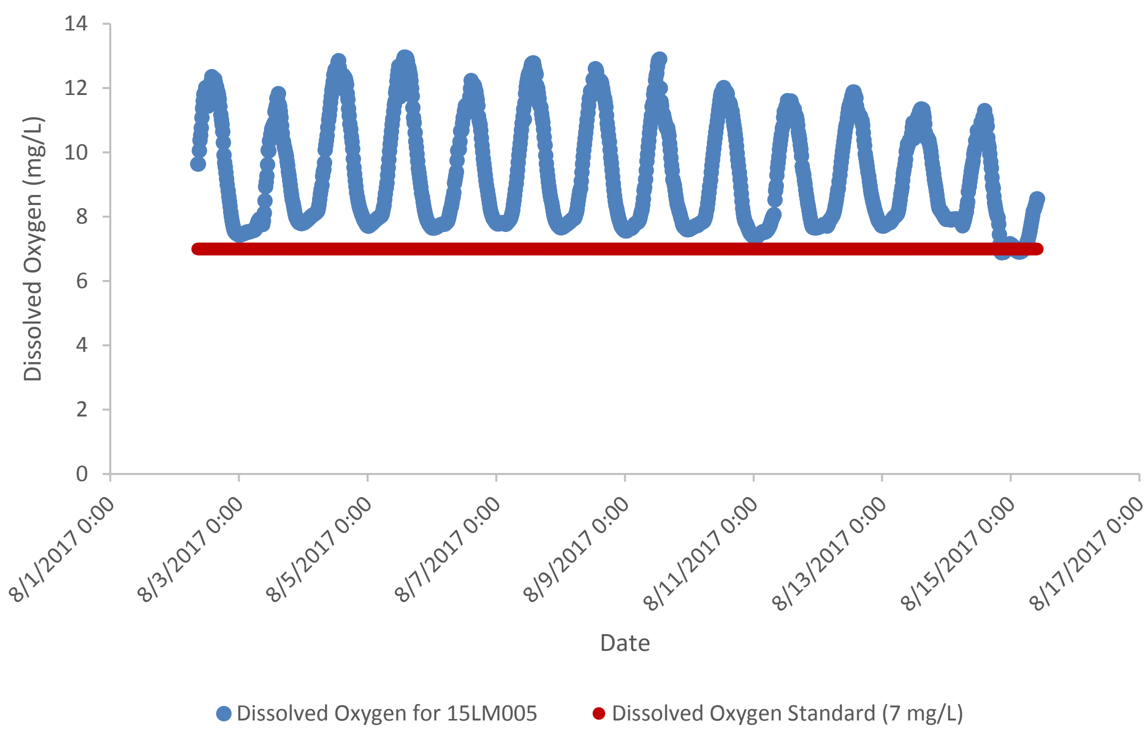


Figure 54: DO conditions during sonde deployment at station 15LM005 in 2017.

The macroinvertebrate metrics were mixed; half were better than the statewide median of stations meeting the MIBI threshold and half were worse (Table 39). Taxa richness of EPT was above the median both years. There were 10 low DO intolerant taxa comprising 39% to 58% of the community, and two low DO tolerant taxa comprising 2% to 3% of the community. The macroinvertebrate low DO index score was at or below the median.

Table 39: Macroinvertebrate metrics that respond to DO stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT
15LM005 (2015)	7.6	10	57.8	**2**	**2.9**	8
15LM005 (2016)	**7.0**	10	**39.4**	**2**	**1.5**	8
Southern Coldwater Streams Median	*7.6*	*10*	*56.1*	*1*	*0.6*	*6*
Expected response to stress	↓	↓	↓	↑	↑	↓

DO concentrations appear adequate, but low DO has been documented and the macroinvertebrate community displays a mixed response to low DO stress. It's possible the macroinvertebrate response is due to another stressor as DO concentrations seem sufficient, but DO is inconclusive as a stressor at this time.

TSS

TSS concentration during fish sampling in 2015 was 10 mg/L. Additional samples were collected as part of SID in 2016 and 2017, with a goal to sample various flow conditions and establish a range of TSS concentrations (Figure 55). Concentrations ranged from 2.4 to 540 mg/L (average of 51.9 mg/L). Seven (39%) of the 18 samples exceeded the coldwater TSS standard (10 mg/L) (Figure 56). The exceedances occurred in February, June, July (2), August, September, and October with most during elevated flow conditions. TSVS concentrations ranged from 1.2 – 84 mg/L.

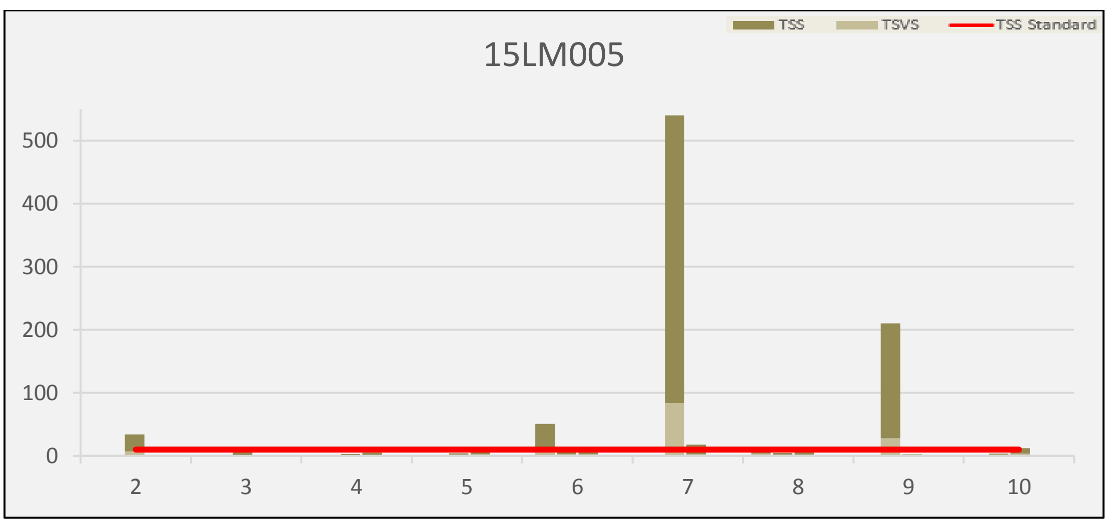


Figure 55: TSS and TSVS concentrations (mg/L) at station 15LM005 in 2016 and 2017. Numbers along the x-axis represent the month in which the sample was collected.


Figure 56: Station 15LM005 after a rain event on 9/7/16; TSS concentration was 210 mg/L.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 40). Relative abundance of collector-filterer individuals (Collector-filtererPct) and longlived individuals (LongLivedPct) were at or above the median. There were 0 to 1 TSS intolerant taxa comprising 0% to 1% of the community, and 9 to 10 TSS tolerant taxa comprising 15% to 27% of the community. The MPCA biologists noted that TSS tolerant taxa were in the 90th percentile for similar streams (MPCA CARL 2017). The macroinvertebrate TSS index scores were worse than the median both years, and station 15LM005 is showing signs of TSS stress. Indicator values for suspended sediment for *Baetis*, *Ceratopsyche*, *Simulium*, and *Physa*, developed by Carlisle et al (2007), are five; the scoring system is based on a scale from 1 to 10, with 10 being the most tolerant. The top three most abundant taxa each visit were comprised of these taxa.

Although not impaired, the fish community can provide supporting information in the SID process. The most abundant fish species was mottled sculpin, with white sucker, brook stickleback, and creek chub comprising a large portion of the remaining community. The probability of meeting the TSS standard based on the fish community (0.58) and fish TSS index score (11.7) were worse than the statewide average of visits meeting the biocriteria (0.60 and 11.3 respectively), indicating potential TSS stress.

Table 40: Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Intolerant Pct	TSS Tolerant Taxa	TSS Tolerant Pct	Collector-filtererPct	LongLivedPct
15LM005 (2015)	**14.7**	**0**	**0.0**	**9**	**15.2**	35.6	1.3
15LM005 (2016)	**14.8**	**1**	**0.6**	**10**	**27.1**	35.0	0.9
Southern Coldwater Streams Median	*13.4*	*2*	*1.6*	*5*	*8.4*	33.7	0.9
Expected response to stress	↑	↓	↓	↑	↑	↓	↓

TSS exceedances have been documented, and the macroinvertebrate community shows signs of TSS stress. TSS is a stressor in this AUID.

Lack of Habitat

The MSHA scores were 63 (“fair”) (July 2015), 58 (“fair”) (August 2015), and 59 (“fair”) (August 2016). Channel features consisted of runs (50% to 70%), pools (10% to 40%), and riffles (5% to 25%). Runs had multiple substrates (cobble, gravel, sand, clay, and silt), and riffles were dominated by cobble and gravel. Pools also had multiple substrates (cobble, gravel, sand, and silt). Light to moderate embeddedness was noted, and bank erosion varied between visits (none to heavy) (Figure 57). Channel stability ranged from moderate to high. Multiple cover types were present, with cover amount ranging from moderate to extensive. Also, low flow conditions (see Flow Alteration section below) may be impacting habitat availability.

Figure 57: Habitat conditions at station 15LM005 on July 23rd, 2015.

The macroinvertebrate metrics don't display strong signals of habitat stress (Figure 58). Most metrics were within an expected range, but the elevated legless individuals may be a result of habitat stress. Legless are tolerant species that can withstand degraded habitat conditions.

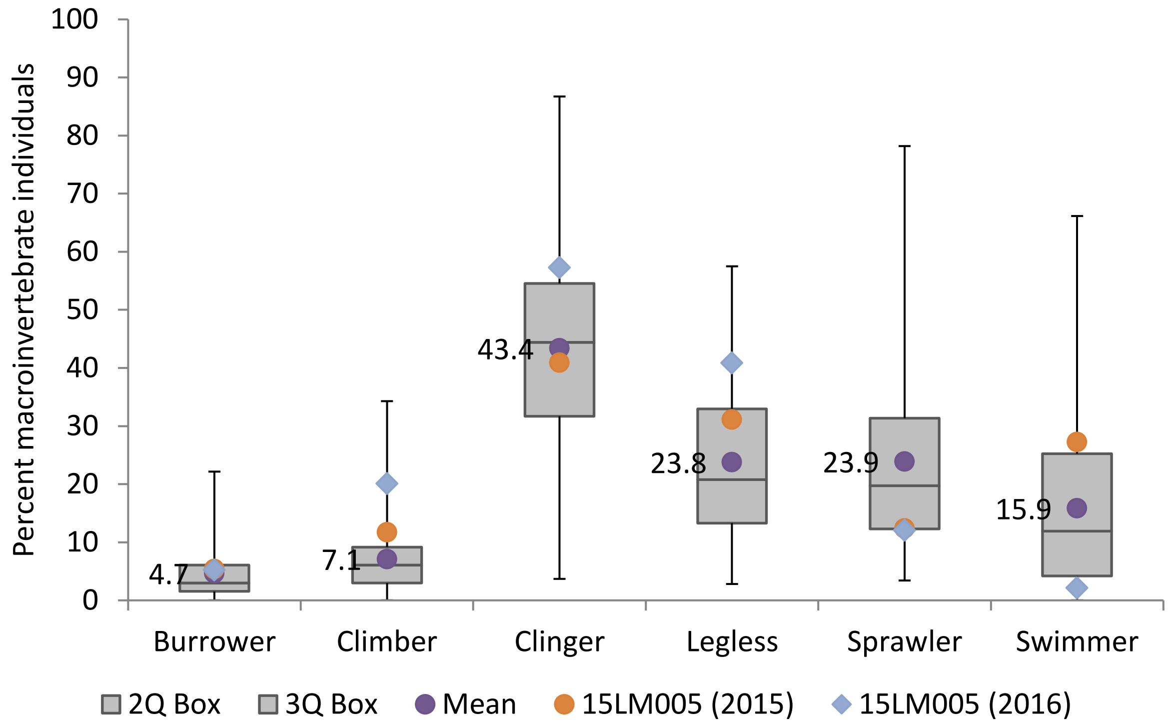


Figure 58: Macroinvertebrate habitat metrics with box plot showing range of values from Southern Coldwater Streams (class 9) stations meeting the bio criteria, mean of those stations, and metric values from station 15LM005.

MSHA scores were "fair", multiple substrates were present, embeddedness and bank erosion were documented, and the macroinvertebrate community displayed minimal signs of habitat stress. However, the elevated legless individuals may be indicative of degraded habitat conditions. Lack of habitat is inconclusive as a stressor.

Flow Alteration

There are currently no stream gaging stations in the watershed, but modeled flows via the HSPF model are available for the watershed from 1993 through 2015 (Tetra Tech 2018). Modeled flows at the mouth of this AUID ranged from 0.1 to 353.1 cfs (average of 3.5 cfs). Flows were less than one cfs approximately 29% of the time.

A majority of the macroinvertebrate metrics were worse than the statewide median of stations meeting the MIBI threshold (Table 41). Relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), tolerant taxa (Tolerant2ChTxPct), and total taxa richness (TaxaCountAllChir) were worse than the median both years, and relative abundance of long-lived individuals (LongLivedPct) was better than the median both years. Relative abundance of EPTPct was better than the median in 2015 and worse than the median in 2016. Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of EPT, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al. 2002; Poff and Zimmerman 2010; EPA 2012). Station 15LM005 appears to experience variable flow conditions, potentially going dry during low flow years (Figure 59). The water control structures/ponds in the upper end of the watershed (far left side of pictures in Figure 59) may be contributing to low stream flows during certain years.

Table 41: Macroinvertebrate metrics that respond to flow alteration stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. Stations with MIBI scores below the threshold are highlighted red.

Station (Year Sampled)	EPTPct	LongLivedPct	TrichwoHydroPct	TaxaCountAllChir	Tolerant2ChTxPct
15LM005 (2015)	54.9	1.3	**2.9**	**37**	**73.0**
15LM005 (2016)	**39.9**	0.9	**3.1**	**40**	**75.0**
Southern Coldwater Streams Median	*41.2*	*0.9*	*6.7*	*27*	*65.7*
Expected response to stress	↓	↓	↓	↑	↑

Figure 59: Historical photos of station 15LM005 documenting variable flow conditions. The stream appears to be dry or have very little flow in 2003 and 2006. Photos courtesy of Google Earth.

Although a majority of macroinvertebrate metrics were worse than the median, flow alteration is inconclusive as a stressor in Unnamed Creek. Altered (channelized) watercourses and agricultural tile drainage decrease as you move east in the watershed (Figure 63). Channelized reaches have direct impacts on hydrology and habitat (as well as other variables), and although tile drainage can increase agricultural productivity it has negative impacts on hydrology (e.g. increasing peak flows and reducing base flows) and water quality (e.g. increasing nitrogen loading). Unnamed Creek appears to experience very low flow conditions, but it's unclear how often they occur and what their impact is on the macroinvertebrate community. See Section 5 (Conclusions in the Upper Iowa River Watershed) for more information on flow alteration.

Conclusion

TSS is stressing the macroinvertebrate community in Unnamed Creek. Nitrate, eutrophication, DO, habitat, and flow alteration are inconclusive, while temperature and fish passage are not stressors. Based on the current chemistry and biology data, the impact of many stressors is unclear. One possibility is that the cumulative impact of elevated TSS, moderate nitrate concentrations, mediocre habitat, and low flow conditions are degrading the macroinvertebrate community and causing impairment. Although many stressors are ambiguous at this point, reducing TSS and nitrate loading, habitat improvement, and pasture management could be areas of focus for restoration efforts. Improvements in these areas will benefit water quality and the macroinvertebrate community in Unnamed Creek.

5. Conclusions in the Upper Iowa River Watershed

Nitrate, TSS, habitat, fish passage, and flow alteration are stressing the biology in the Upper Iowa River Watershed (Table 42 and Figure 64, Figure 65, and Figure 66). In general, nitrate concentrations are higher (and more variable) in the western portion of the watershed and decrease on a gradient to the east (Figure 60); some of the primary factors impacting nitrate concentrations in the watershed include agricultural tile drainage, karst features (springs, sinkholes, etc.), geology, soils, and land use (Figure 63). The elevated concentrations in the western portion of the watershed are stressing the macroinvertebrates. TSS exceedances have been documented across the watershed (with a majority occurring during elevated flow conditions) (Figure 61), but in most cases TSS is inconclusive due to mixed results. The only conclusive TSS stressor identified was located in the eastern part of the watershed on Unnamed Creek (535). Poor habitat conditions and fine substrate are common across the watershed; habitat is a stressor in all AUIDs except Unnamed Creek (535) and Beaver Creek (546). Fish passage is a stressor in Deer Creek (520) as the stream disappears underground just south of the Minnesota/Iowa border, eliminating fish migration upstream. A culvert inventory conducted by the DNR noted “75% of culverts are impacting stream channel stability while 31% are barriers to fish passage” (Figure 63) (DNR 2018); these impacts on stream channel stability also influence other variables such as sediment transport and habitat. Flow alteration is a stressor in the western portion of the watershed, and is contributing to nitrate and habitat stressors. Altered (channelized) watercourses and agricultural tile drainage are common in this part of the watershed (Figure 63). Channelized reaches have direct impacts on hydrology and habitat (as well as other variables), and although tile drainage can increase agricultural productivity it has negative impacts on hydrology (e.g. increasing peak flows and reducing base flows) and water quality (e.g. increasing nitrogen loading). Wetlands also impact hydrology by providing water storage and reducing peak flows; the lack of wetlands in the Upper Iowa River Watershed has negative impacts on hydrology (Figure 63).

Elevated TP has been documented across the watershed, but eutrophication is inconclusive as a stressor due to mixed results and limited data (Figure 62); it’s unclear at this time if the elevated TP is resulting in eutrophic conditions. In general, DO concentrations and stream temperatures are adequate in the Upper Iowa River Watershed and don’t appear to be stressing the biology.

In general, reducing nutrient and sediment loading, and improving in-stream habitat should be priorities for increasing biological health in the Upper Iowa River Watershed. In the western portion of the watershed, reducing nitrogen loading and improving habitat are key to healthier macroinvertebrate communities. Flow alteration is a source of stress in this part of the watershed, with agricultural tile drainage and channelization contributing to degraded macroinvertebrate communities. Although TSS is an inconclusive stressor in most cases, reducing the sediment load will benefit the biology and habitat conditions across the watershed. Although this report focuses primarily on biological impairments and their respective stressors, the Upper Iowa River Watershed does have areas in need of protection. Bee Creek, located southeast of Spring Grove, is classified as “Exceptional Use” for fish and macroinvertebrates. Bee Creek is a coldwater stream, and the MPCA biologists noted “excellent habitat and biological conditions." It is also a designated trout stream by the DNR. Protecting Bee Creek from degradation and impairment should be a priority in the Upper Iowa River Watershed.

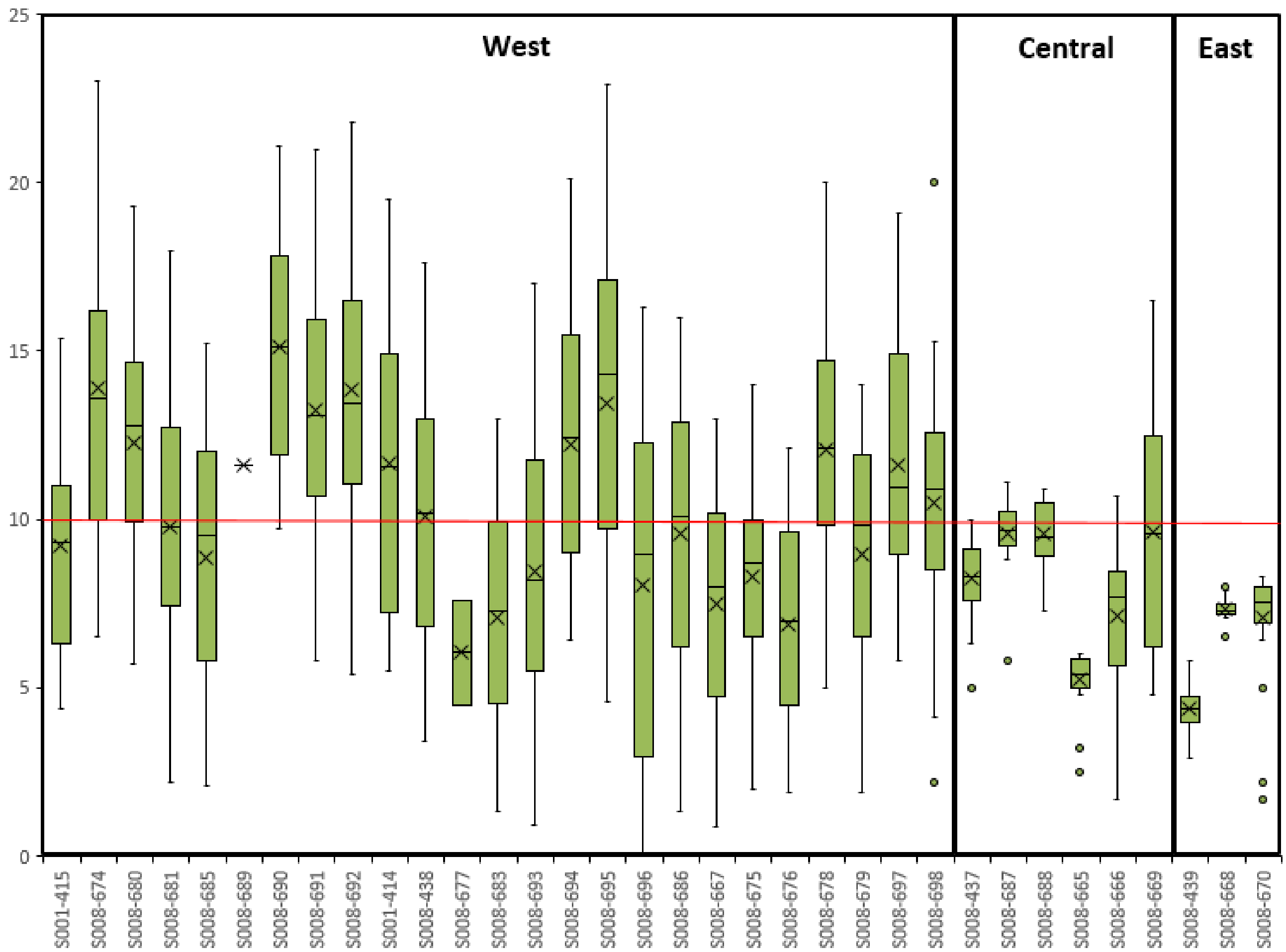


Figure 60: Nitrate concentrations (mg/L) across the Upper Iowa River Watershed from 2015 – 2017. Samples were collected during all seasons with a majority during baseflow conditions; this dataset represents 727 samples. Stations are organized geographically highlighting differences in concentration and variability from west to east. The red line (10 mg/L) indicates the drinking water standard.

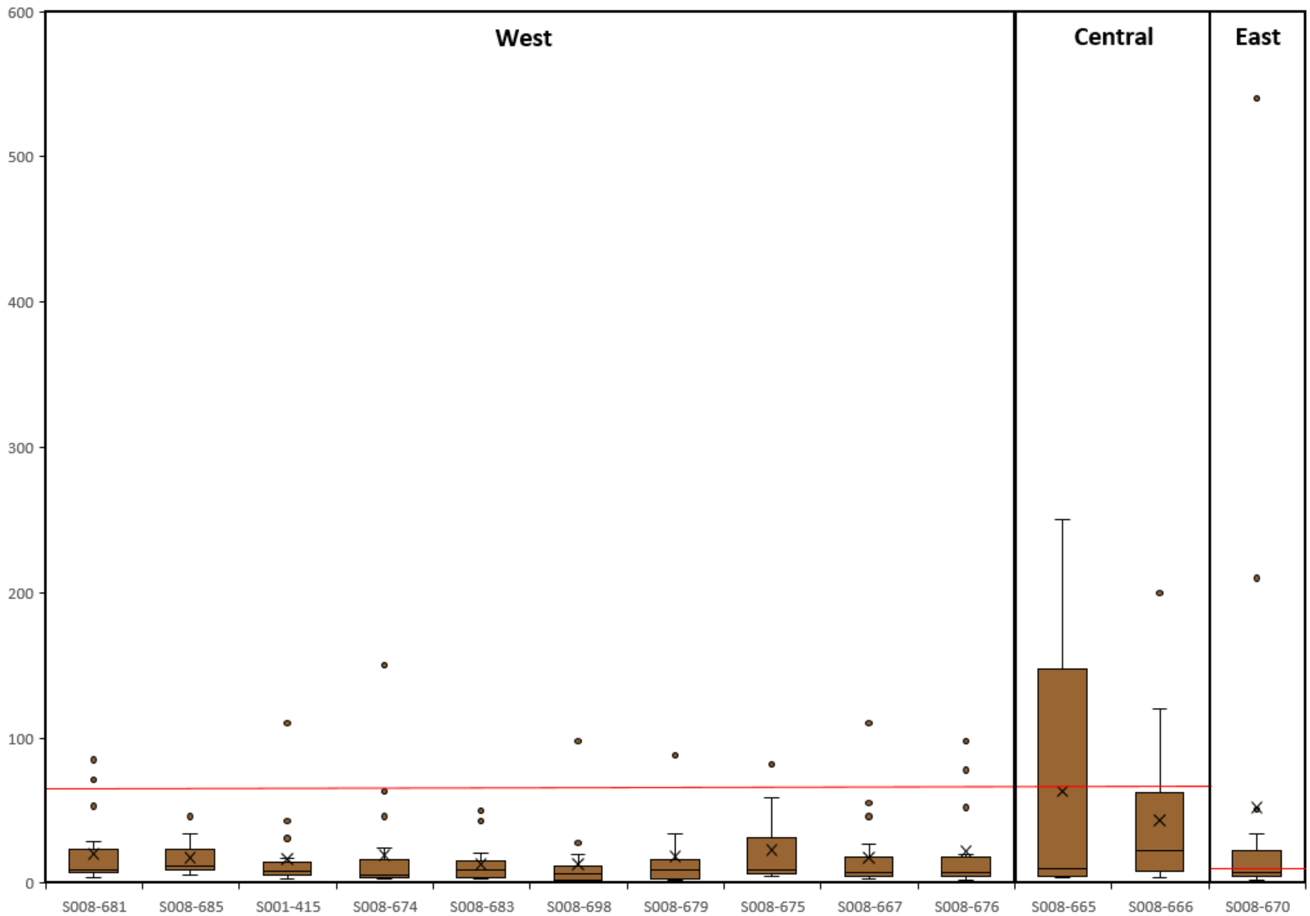


Figure 61: TSS concentrations (mg/L) across the Upper Iowa River Watershed from 2016 – 2017. Samples were collected throughout the years with a goal to sample various flow conditions and establish a range of TSS concentrations; this dataset represents 235 samples. Stations are organized geographically highlighting differences in concentration and variability from west to east. The red lines (65 mg/L and 10 mg/L) indicate the respective TSS standards.

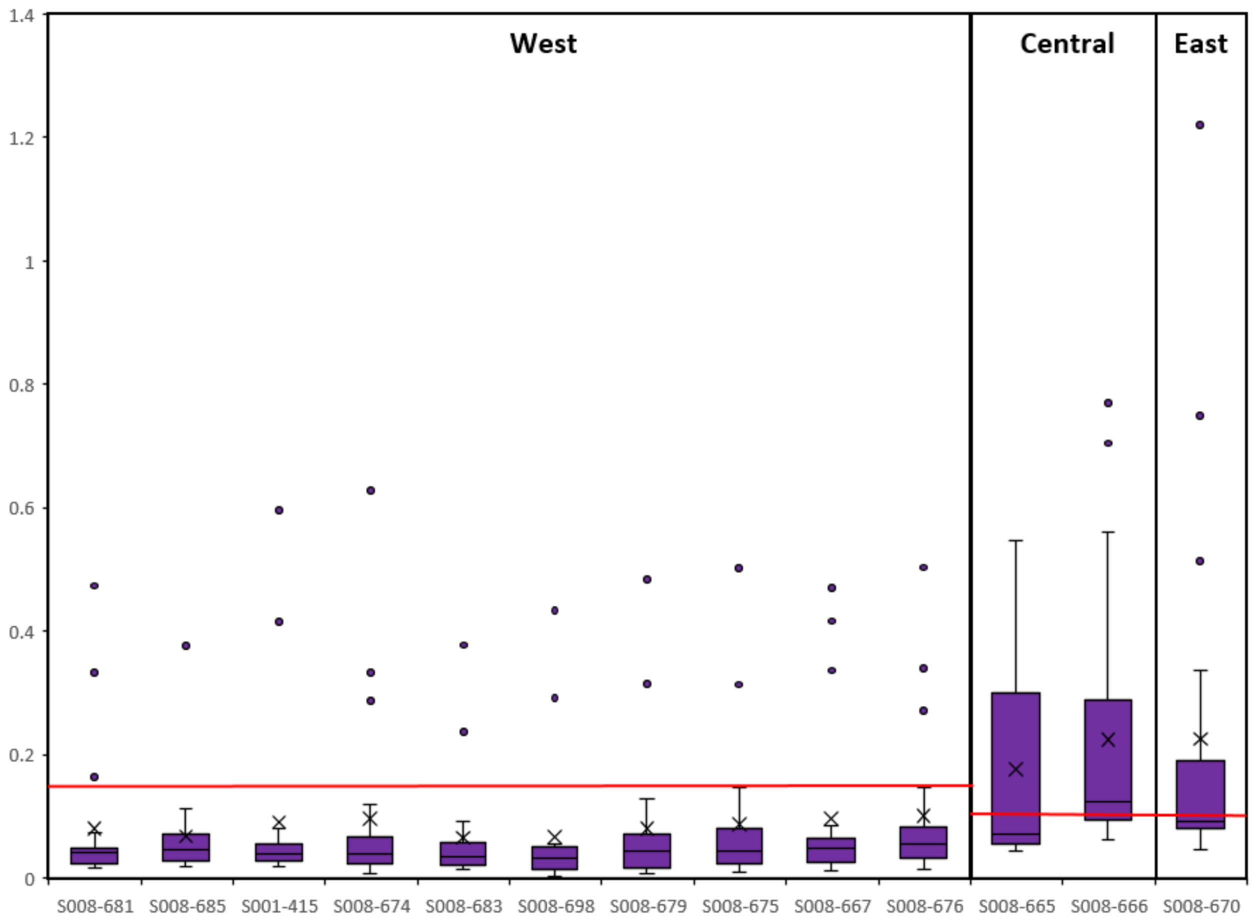


Figure 62: TP concentrations (mg/L) across the Upper Iowa River Watershed from 2016 – 2017. Samples were collected throughout the years with a goal to sample various flow conditions and establish a range of TP concentrations; this dataset represents 235 samples. Stations are organized geographically highlighting differences in concentration and variability from west to east. The red lines (0.15 mg/L and 0.1 mg/L) indicate the respective TP standards.

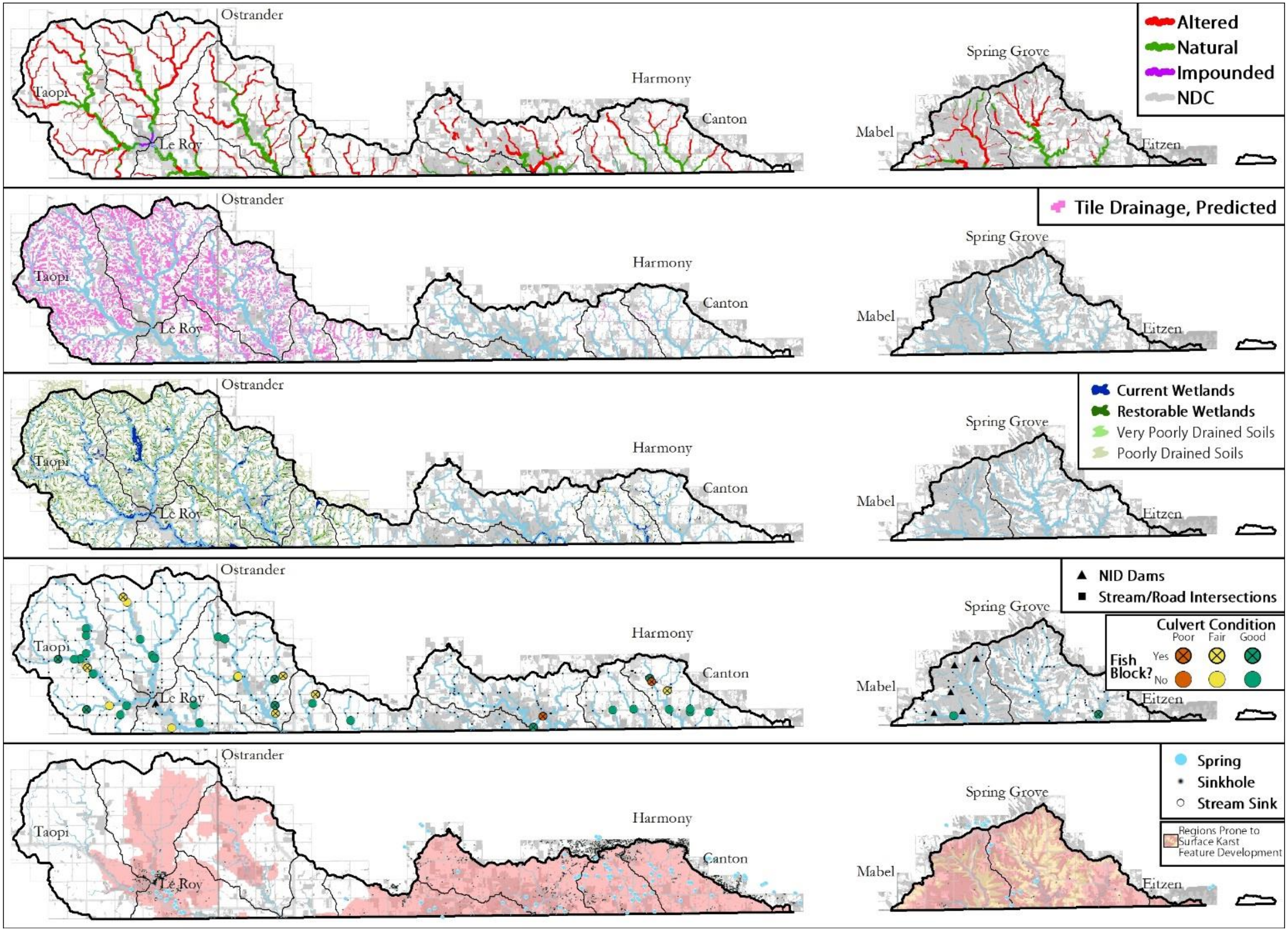
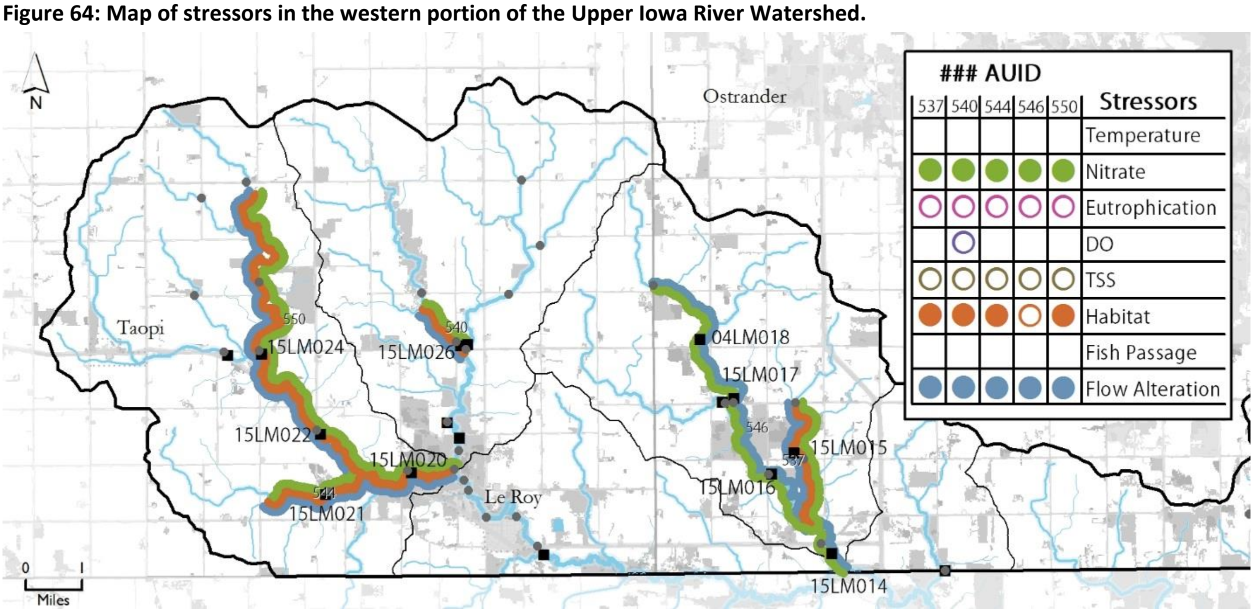


Figure 63: Altered, natural, impounded, and no definable channel watercourses, tile drainage estimates, current wetlands and potential wetland areas, fish barriers, and karst features in the Upper Iowa River Watershed. Fish barrier information provided by DNR.

Table 42: Summary of stressors in the Upper Iowa River Watershed (• = stressor, ○ = inconclusive stressor, blank = not a stressor).

	Waterbody	AUID	Stations	Biological Impairment	Class	Stressors: Temperature	Nitrate	Eutrophication	DO	TSS	Habitat	Fish Passage	Flow Alteration
Central Upper IA	Deer Creek	520	15LM009	Fish	2B		○	○	○	○	●	●	○
Eastern Upper IA	Unnamed Creek	535	15LM005	Macroinvertebrates	2A		○	○	○	●	○		○
Western Upper IA	Unnamed Creek	537	15LM015	Macroinvertebrates	2B		●	○		○	●		●
	Unnamed Creek	540	15LM026	Macroinvertebrates	2B		●	○	○	○	●		●
	Unnamed Creek	544	15LM021	Macroinvertebrates	2B		●	○		○	●		●
	Beaver Creek	546	15LM014,15LM016,15LM017	Macroinvertebrates	2B		●	○		○	○		●
	Upper Iowa River	550	15LM020,15LM022,15LM024	Macroinvertebrates	2B		●	○		○	●		●

Figure 64: Map of stressors in the western portion of the Upper Iowa River Watershed.



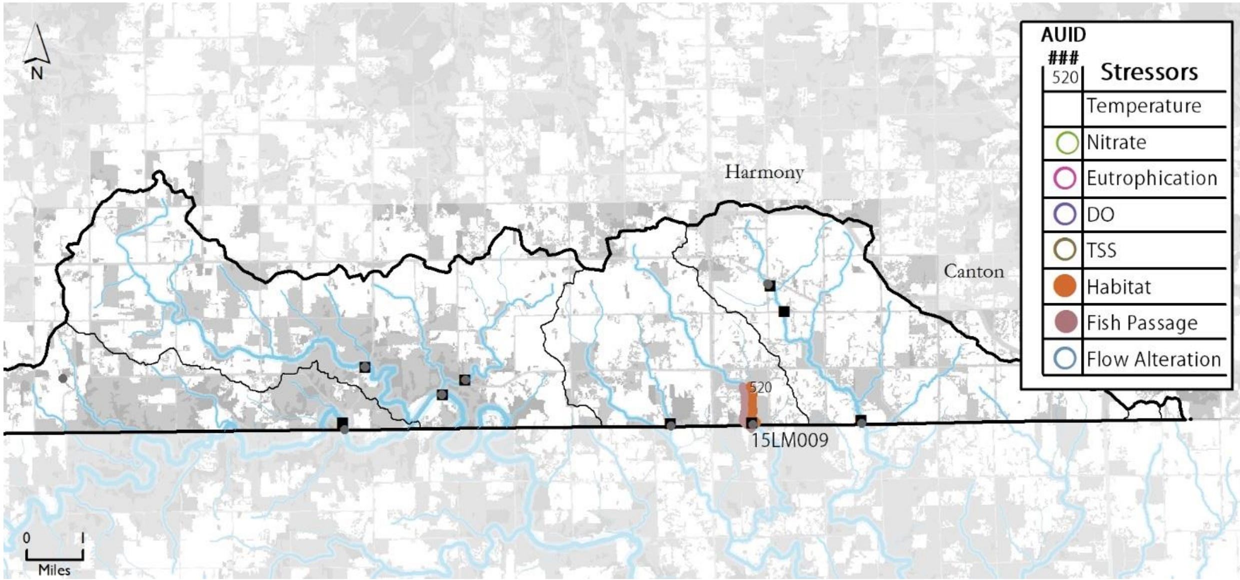


Figure 65: Map of stressors in the central portion of the Upper Iowa River Watershed.

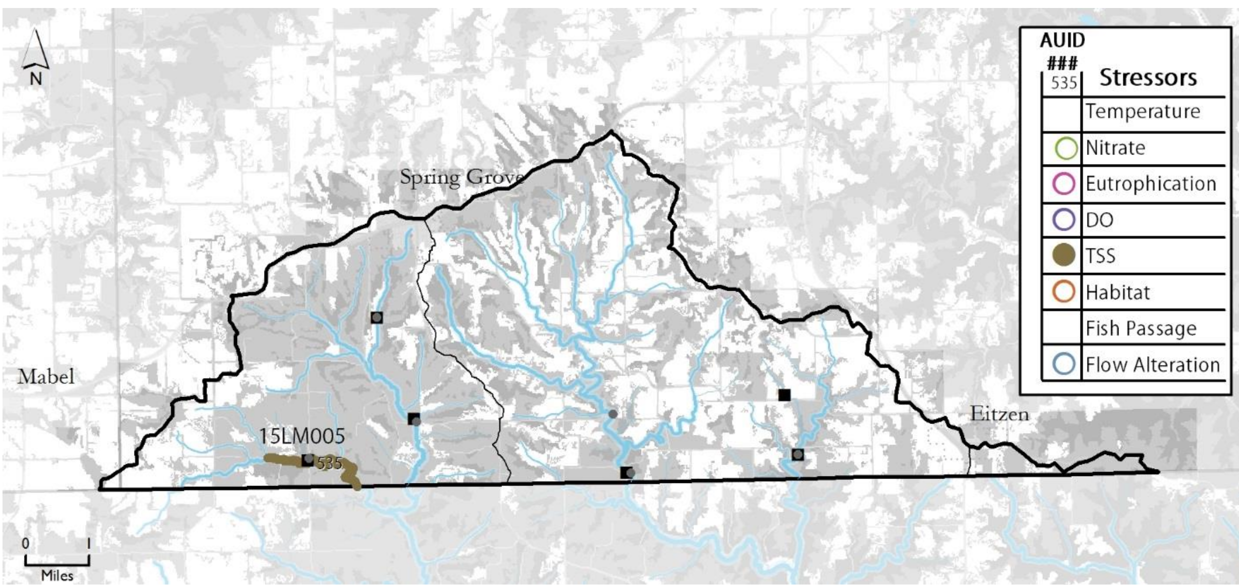


Figure 66: Map of stressors in the eastern portion of the Upper Iowa River Watershed.

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7. Appendix

Table 43: Fish and macroinvertebrate metrics used in stressor analysis in the Upper Iowa River Watershed.

Metric Name	Type	Metric Description
BenFdFrimPct	Fish	Relative abundance (%) of individuals that are exclusively benthic feeders (Frimpong)
BenInsectPct	Fish	Relative abundance (%) of individuals that are benthic insectivore species
Burrower	Macroinvertebrates	Taxa richness of burrowers (excluding chironomid burrower taxa)
CBI	Macroinvertebrates	Coldwater Biotic Index score based on coldwater tolerance values derived from Minnesota taxa/temperature data
Centr-TolPct	Fish	relative abundance (%) of individuals that are non-tolerant Centrarchidae
ChiroDip	Macroinvertebrates	Ratio of chironomid abundance to total dipteran abundance
Climber	Macroinvertebrates	Taxa richness of climbers (excluding chironomid climber taxa)
ClimberCh	Macroinvertebrates	Taxa richness of climbers
Clinger	Macroinvertebrates	Taxa richness of clingers (excluding chironomid clinger taxa)
ClingerCh	Macroinvertebrates	Taxa richness of clingers
ClingerChTxPct	Macroinvertebrates	Relative percentage of taxa adapted to cling to substrate in swift flowing water
Collector-filtererCh	Macroinvertebrates	Taxa richness of collector-filterers
Collector-filtererPct	Macroinvertebrates	Relative abundance (%) of collector-filterer individuals in subsample
Collector-gathererCh	Macroinvertebrates	Taxa richness of collector-gatherers
DarterPct	Fish	Relative abundance (%) of individuals that are darter species
DarterSculpSucPct	Fish	Relative abundance (%) of individuals that are darter, sculpin, and round bodied sucker species
DetNWQTXPct	Fish	relative abundance (%) of taxa that are detritivorous (NAWQA database)
DomFiveCHPct	Macroinvertebrates	Relative abundance (%) of dominant five taxa in subsample (chironomid genera treated individually)
DomTwoPct	Fish	Relative abundance (%) of individuals of the dominant two species

Metric Name	Type	Metric Description
EPT	Macroinvertebrates	Taxa richness of Ephemeroptera, Plecoptera & Trichoptera (baetid taxa treated as one taxon)
EPTPct	Macroinvertebrates	Relative abundance (%) of Ephemeroptera, Plecoptera & Trichoptera individuals in subsample
FishDELTPct	Fish	Relative abundance (%) of individuals with DELT anomalies (deformities, eroded fins, lesions, or tumors)
GeneralPct	Fish	Relative abundance (%) of individuals that are generalist species
GeneralTxPct	Fish	Relative abundance (%) of taxa that are generalists
HBI_MN	Macroinvertebrates	A measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart
HrbNWQPct	Fish	Relative abundance (%) of individuals that are herbivore species (NAWQA database)
InsectTxPct	Macroinvertebrates	Relative percentage of insect taxa
Intolerant2Ch	Macroinvertebrates	Taxa richness of macroinvertebrates with tolerance values less than or equal to 2, using MN TVs
IntolerantPct	Fish	Relative abundance (%) of individuals that are tolerant species
Legless	Macroinvertebrates	Taxa richness of legless macroinvertebrates (chironomid taxa treated as one taxon)
LithFrimPct	Fish	Relative abundance (%) of individuals that are lithophilic spawners
LLvdPct	Fish	Relative abundance (%) of individuals that are long-lived (Frimpong)
LongLivedPct	Macroinvertebrates	Relative abundance (%) of longlived individuals in subsample
Low DO Index Score	Macroinvertebrates	Low DO index score
Low DO Index Score (RA)	Fish	Low DO Index Score (RA)
Low DO Intolerant Pct	Macroinvertebrates	Relative abundance of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores
Low DO Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores
Low DO Tolerant Pct	Macroinvertebrates	Relative abundance of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores

Metric Name	Type	Metric Description
Low DO Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores
MA<2Pct	Fish	relative abundance (%) of individuals with a female mature age <=2 (Frimpong)
MA>3Pct	Fish	relative abundance of individuals with a female mature age >=3 (Frimpong)
MgrPct	Fish	Relative abundance (%) of individuals that are migratory species
MgrTxPct	Fish	Relative abundance (%) of taxa that are migratory
Nitrate Index Score	Macroinvertebrates	Nitrate index score
Nitrate Intolerant Pct	Macroinvertebrates	Relative abundance of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores
Nitrate Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores
Nitrate Tolerant Pct	Macroinvertebrates	Relative abundance of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores
Nitrate Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores
NumPerMeter-Tolerant	Fish	Number of individuals per meter of stream sampled (excludes individuals of tolerant species)
Odonata	Macroinvertebrates	Taxa richness of Odonata
OmnivorePct	Fish	Relative abundance (%) of individuals that are omnivore species
Percfm-TolPct	Fish	Relative abundance (%) of individuals of the Order Perciformes (excluding tolerant)
Phosphorus Index Score	Macroinvertebrates	Phosphorus Index Score
Phosphorus Intolerant Pct	Macroinvertebrates	Relative abundance of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores
Phosphorus Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores
Phosphorus Tolerant Pct	Macroinvertebrates	Relative abundance of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores
Phosphorus Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores

Metric Name	Type	Metric Description
PioneerPct	Fish	Relative abundance (%) of individuals that are pioneer species
Plecoptera	Macroinvertebrates	Taxa richness of Plecoptera
PlecopteraPct	Macroinvertebrates	Relative abundance (%) of Plecoptera individuals in subsample
POET	Macroinvertebrates	Taxa richness of Plecoptera, Odonata, Ephemeroptera, & Trichoptera (baetid taxa treated as one taxon)
Predator	Macroinvertebrates	Taxa richness of predators (excluding chironomid predator taxa)
PredatorCh	Macroinvertebrates	Taxa richness of predators
Probability of meeting DO std.	Fish	Probability of meeting DO std.
Probability of meeting TSS std.	Fish	Probability of meeting TSS std.
RifflePct	Fish	Relative abundance (%) of individuals that are riffle-dwelling species
Sensitive	Fish	Taxa richness of sensitive species
SensitivePct	Fish	Relative abundance (%) of individuals that are sensitive species
SlithFrimPct	Fish	Relative abundance (%) of individuals that are simple lithophilic spawners, as per Frimpong database
SlithopPct	Fish	Relative abundance (%) of individuals that are simple lithophilic spawners
SLvdPct	Fish	Relative abundance (%) of individuals that are short-lived
Sprawler	Macroinvertebrates	Taxa richness of sprawlers (excluding chironomid and baetid sprawler taxa)
SSpnPct	Fish	Relative 109bundance (%) of individuals that are serial spawning species
Swimmer	Macroinvertebrates	Taxa richness of swimmers (excluding chironomid, baetid taxa treated as one taxon)
TaxaCountAllChir	Macroinvertebrates	Total taxa richness of macroinvertebrates
Tolerant2ChTxPct	Macroinvertebrates	Relative percentage of taxa with tolerance values equal to or greater than 6, using MN TVs
TolPct	Fish	Relative abundance (%) of individuals that are tolerant species
Trichoptera	Macroinvertebrates	Taxa richness of Trichoptera
TrichopteraCh	Macroinvertebrates	Taxa richness of Trichoptera
TrichopteraChTxPct	Macroinvertebrates	Relative percentage of taxa belonging to Trichoptera

Metric Name	Type	Metric Description
TrichwoHydroPct	Macroinvertebrates	Relative abundance (%) of non-hydropsychid Trichoptera individuals in subsample
TSS Index Score	Macroinvertebrates	TSS index score
TSS Index Score (RA)	Fish	TSS index score (RA)
TSS Intolerant Pct	Macroinvertebrates	Relative abundance of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores
TSS Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores
TSS Tolerant Pct	Macroinvertebrates	Relative abundance of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores
TSS Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores
VeryTolerant2Pct	Macroinvertebrates	Relative abundance (%) of macroinvertebrate individuals in subsample with tolerance values equal to or greater than 8, Using MN TVs
VtolTxPct	Fish	Relative abundance (%) of taxa that are very tolerant species