Watershed

December 2018

Mississippi River Reno Stressor Identification Report

A study of local stressors limiting the biotic communities in the Mississippi River-Reno Watershed.

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Key terms and abbreviations

AUID	Assessment Unit ID
BOD	biological oxygen demand
CADDIS	Causal Analysis/Diagnosis Decision Information System
CBI	Coldwater biotic index
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	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
µg/L	Microgram per liter
µS/cm	Microsiemens per centimeter
MIBI	Macroinvertebrate Index of Biological integrity
mg/L	Milligrams per liter
MPCA	Minnesota Pollution Control Agency
MR	Mississippi River
MSHA	MPCA Stream Habitat Assessment
SID	Stressor Identification
SOE	Strength of Evidence
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
TSVS	Total Suspended Volatile Solids
WARSSS	Watershed Assessment of River Stability and Sediment Supply
WRAPS	Watershed Restoration and Protection Strategy

Executive summary

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

Stressor identification (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. Stressor identification is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act.

This report summarizes stressor identification work in the Mississippi River (MR) Reno Watershed. A total of 11 streams assessed for biology in the MR-Reno Watershed (Table 2) There were **four** biological impairments identified in this watershed, that are further described in Section 4.

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

- Crooked Creek (519) and Clear Creek (524)
    - Habitat
- South Fork Crooked Creek (574)
    - Temperature
    - Dissolved oxygen/eutrophication
- Winnebago Creek (693)
    - Total suspended solids

A summary of recommendations, in addition to protection considerations, are found at the end of this document in Section 5.

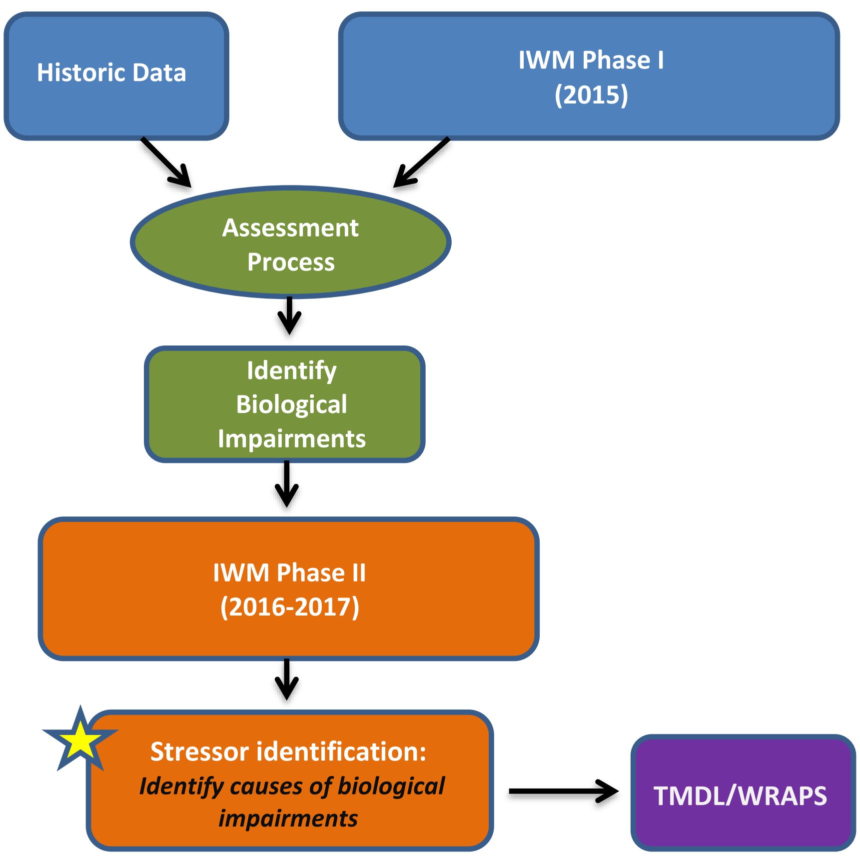
1. Introduction

1.1. Monitoring and assessment

As part of the MPCA's Intensive Watershed Monitoring (IWM) approach, monitoring activities increased in rigor and intensity during the years of 2015-2016, 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 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 IWM, Assessment, SID and TMDL processes.

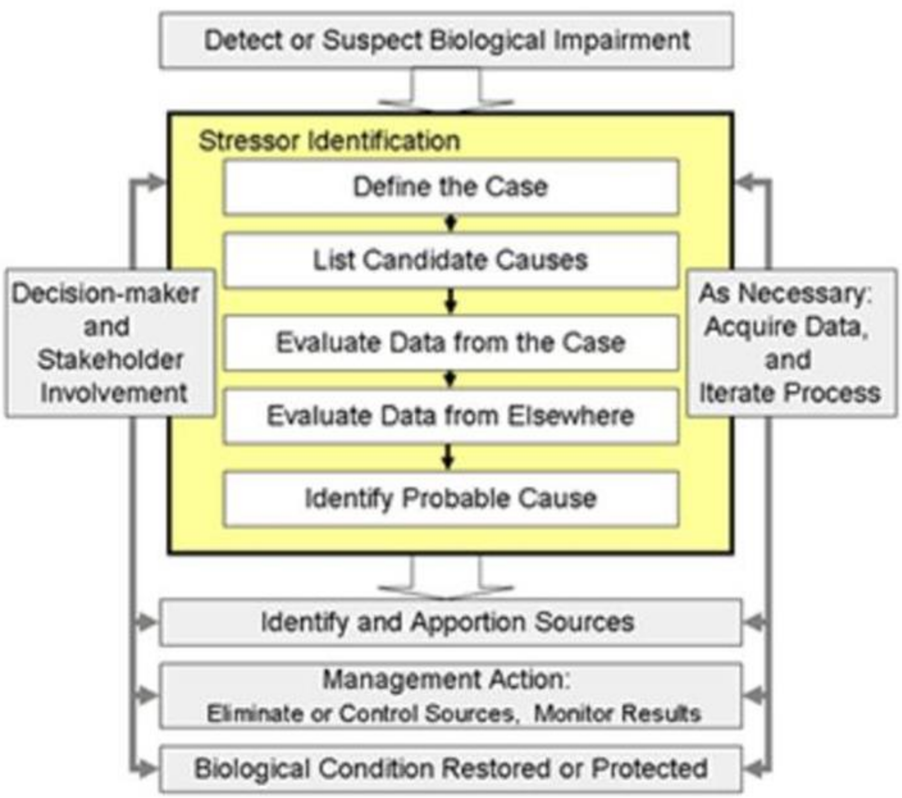


1.2. Stressor identification process

The MPCA follows the U.S. Environmental Protection Agency's (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: http://www.epa.gov/caddis/

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 SID 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 (Table A1). A narrative description of how the scores were obtained from the evidence should be discussed as well. The SOE table allows for organization of all of the evidence, provides a checklist to ensure each type has been carefully evaluated and offers transparency to the determination process.

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

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

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

2. Overview of the Mississippi River-Reno Watershed

2.1. Background

The MR-Reno Watershed is located in eastern Houston County, along the Mississippi River. The watershed drains 184 square miles in Minnesota. There is no main river in the watershed, just a collection of tributaries that flow directly into the Mississippi River. Two of the larger streams are Crooked Creek and Winnebago Creek. Both flow from west to east in the watershed and have a complex system of springs, coldwater and warmwater streams.

The MR-Reno Watershed is found entirely in the Driftless Area ecoregion, which is an area of the state that was missed in the last glaciation. The area is known for its karst features, deep limestone lined valleys, and coldwater streams. Soils are well to moderately well drained and consist of silty soils over bedrock. This area is also characterized by alternating hills and valleys with steep slopes are often forested. The watershed contains a number of popular trout fisheries. Rainbow trout, brown trout and brook trout can all be found in the watershed. Brook trout are the only native trout species in southern Minnesota.

Caledonia is the largest town in the watershed with a population of 2,868. Other cities include Brownsville, Eitzen and Jefferson. The overall population of the watershed is only 5,372. More details can be found at the Mississippi River – Reno watershed webpage.

2.2. Monitoring overview

Ten stream AUIDs in the MR-Reno Watershed were assessed for aquatic life use, aquatic recreational use or both. Of the assessed streams, six streams were considered to be fully supporting of aquatic life. Four AUIDs are considered non-supporting for aquatic life and recreation and are discussed further in this report.

The biological monitoring stations that led to aquatic life listing and are included in this report are mapped in Figure 3. Additional information can be found in subsequent sections of this report, in addition to the comprehensive Mississippi River Reno Monitoring and Assessment Report.

2.3. Summary of biological impairments

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

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 as expected. Confidence limits 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 **MR-Reno Watershed**, **four** AUIDs have biological impairments (Table 2).

Table 2. All biologically assessed AUIDs in the MR-Reno Watershed. Those highlighted in "red" indicate biological impairments and are discussed further in section 4. MTS = Meets standards for fish and macroinvertebrates.

			Impairments	
Stream Name	AUID #	Reach Description	Biological	Water Quality
Crooked Creek	07060001-507	South Fork Crooked Creek to T102 R4W S28, east line	None; MTS	
Winnebago Creek	07060001-508	Unnamed creek to T101 R4W S28, east line	None; MTS	
Wildcat Creek	07060001-516	Unnamed creek to Mississippi R	None; MTS	
Crooked Creek Tributary	07060001-518	Unnamed creek to Crooked Cr	None; MTS	
North Fork Crooked	07060001-520	T102 R5W S21, north line to Crooked Cr	None; MTS	
Winnebago Creek Tributary	07060001-685	T101 R6W S12, west line to Unnamed creek	None; MTS	
Crooked Creek	07060001-519	T102 R4W S27, west line to Bluff Slough	Macroinvertebrate	E. Coli
Winnebago Creek	07060001-693	T101 R4W S27, west line to south line	Macroinvertebrate	TSS, E.Coli
South Fork Crooked	07060001-574	T102 R5W S26, west line to Crooked Cr	Fish and Macroinvertebrate	
Clear Creek	07060001-524	T102 R4W S34, south line to Bluff Slough	Macroinvertebrate	

The Fish Index of Biological Integrity (FIBI) and Macroinvertebrate Index of Biological integrity (MIBI) scores for each of the biological monitoring stations are included in Table 3. A total of 12 biological stations were sampled in the watershed, with four scoring below impairment threshold for fish or macroinvertebrates. These stations' average scores are included in the table, and those which resulted in impairments are highlighted red. Most stations were visited once in 2015, but some had multiple visits and were averaged.

Table 3. Summary of FIBI and MIBI scores for biological monitoring stations in the MR-Reno Watershed. Scores below impairment threshold and assessed as impaired are in red. If there were multiple visits from the same year, the mean is presented.

Location		Fish				Macroinvertebrate		
Stream Name	AUID suffix	Station	FIBI Class[1] (Use[3])	FIBI impairment threshold	FIBI score (mean)	MIBI Class[2] (Use[3])	MIBI impairment threshold	MIBI score (mean)
Winnebago Tributary	687	04LM030	Southern Coldwater	50	77	Southern Coldwater	43	52
Crooked Tributary	518	10EM162	Southern Coldwater	50	51	Southern Coldwater	43	78
Wildcat Creek	516	15LM038	Southern Coldwater	50	57	Southern Coldwater	43	46
Crooked Creek	507	15LM027	Southern Coldwater	50	66	Southern Coldwater	43	66
South Fork Crooked	574	15LM033	Southern Coldwater	50	50	Southern Coldwater	43	38
North Fork Crooked	520	15LM034	Southern Coldwater	50	69	Southern Coldwater	43	56
North Fork Crooked	520	15LM035	Southern Coldwater	50	59	Southern Coldwater	43	41
Winnebago Trib	685	15LM031	Southern Coldwater	50	87	Southern Coldwater	43	44
Winnebago Creek	508	15LM030	Southern Coldwater	50	85	Southern Coldwater	43	35
Winnebago Creek	693	15LM028	Southern Coldwater	50	58	Southern Coldwater	43	30
Clear Creek	524	15LM036	Southern Headwaters	55	33	Southern Forest Streams GP	43	30
Crooked Creek	519	15LM037	Southern Streams	50	57	Southern Forest Streams GP	43	20

The biological monitoring stations and assessment determinations for each stream are mapped in Figure 3. Additionally, any stations with chemical monitoring are also shown in the map for reference. Overall, the fish scores across the watershed are considered good, with only one biological impairment identified on the South Fork Crooked Creek. A few of the sites could not be assessed for fish due to proximity to the Mississippi River. Macroinvertebrates show variability among the different sites in the watershed and are likely responding to multiple stressors that are detailed in this report. Additional information on assessment and background can be found Mississippi River Reno Monitoring and Assessment Report.

Figure 3. Map of MR-Reno Watershed, impairments, and monitoring stations.

3. Possible stressors to biological communities

A candidate cause is defined as a "hypothesized cause of an environmental impairment that is sufficiently credible to be analyzed" (EPA, 2012). Identification of a set of candidate causes is an important early step in the SID process and provides the framework for gathering key data for causal analysis. A more detailed description of possible candidate causes or stressors is provided in the document *Stressors to Biological Communities in Minnesota's Rivers and Streams* (MPCA, 2017). This information provides an overview of the pathway and effects of each candidate stressor considered in the biological stressor identification 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.

Table 5 shows 11 candidate causes that were selected as possible drivers of biological impairment in the MR-Reno Watershed. The list was developed based upon the results of the MR-Reno monitoring and assessment process and other completed SID reports in the state. The credibility of each candidate cause as a possible stressor to the fish and/or macroinvertebrate community of the biologically impaired reaches in the watershed was then evaluated through a comprehensive review of available information, including water quality and quantity data, as well as existing plans and reports. Based upon the results of this evaluation, six candidate causes were identified to undergo causal analysis (Section 4).

Table 5. Summary of stressors evaluated as potential candidate causes for the biologically impaired reaches of the MR-Reno Watershed.

Stressor	Candidate cause identification	
	Summary of available information	Candidate cause (Yes/No/Inconclusive)
Connectivity/Fish Passage	This watershed has documented connectivity barriers (e.g., dams and private road crossings and beaver dams) that are potential obstructions to fish passage.	Yes
Temperature	Current data and DNR reports suggest some of the coldwater streams in the watershed experience higher than normal temperature values.	Yes
Physical habitat	The watershed and impaired reaches shows visual indications of insufficient instream habitat, bank erosion, and sedimentation.	Yes
TSS (Total Suspended Solids)	Several samples from the watershed have discrete total suspended solids (TSS) values that exceed the applicable state standard with multiple sediment sources that could contribute to TSS related issues.	Yes
Low dissolved oxygen and/or Eutrophication	Samples show discrete and/or continuous dissolved oxygen (DO) values that were near the applicable state standard (5 mg/L for warmwater and 7 mg/L for coldwater). Several instances of total phosphorus values exceed the proposed river eutrophication standard values for the central region (0.100 mg/L) which may or may not be linked to DO values observed. Further analysis needed.	Yes
Nitrate	Nitrate-nitrite concentrations in the watershed are generally low but vary across the watershed. Given the spatial prevalence of high nitrate stress in surrounding watersheds, further analysis was needed.	Yes
pH	The vast majority of the pH values within the watershed were within the state standard range (Coldwater Streams: 6.5-8.5 and Warmwater Streams: 6.5-9.0) and pH was meeting aquatic life use for the streams assessed.	No

Chloride	Chloride is low and meeting aquatic life use standards for the two streams assessed (Crooked-519 and Winnebago-693 had 11 samples each in 2015)	No
Ammonia	Unionized ammonia is meeting aquatic life use over the assessment period (Crooked-519 and Winnebago-693 had 11 samples each in 2015).	No
Flow Alteration	This entire watershed, among others in SE MN have a naturally flashy hydrology. Overall, there is little suggestion that flows (peak and low flow) have been altered significantly beyond what is considered typical in the region and are driving the biological impairments. It is not clear how much climate change and/or other land practices may be affecting flows generally in the region. More specific information is needed before flow alteration can be considered further as a stressor.	Inconclusive
Pesticides	The limited pesticide sampling in this watershed (2010; one site) indicate that at this time there are no pesticide concentrations exceeding an applicable standard for aquatic toxicity. This does not mean that pesticides are not acting as stressors, only that the existing monitoring data does not implicate a pesticide as a likely stressor at this time. Additional sampling across the watershed and information regarding aquatic toxicity, duration, and responses to pesticide exposure is needed before stressor determinations can be made specific to pesticides.	Inconclusive

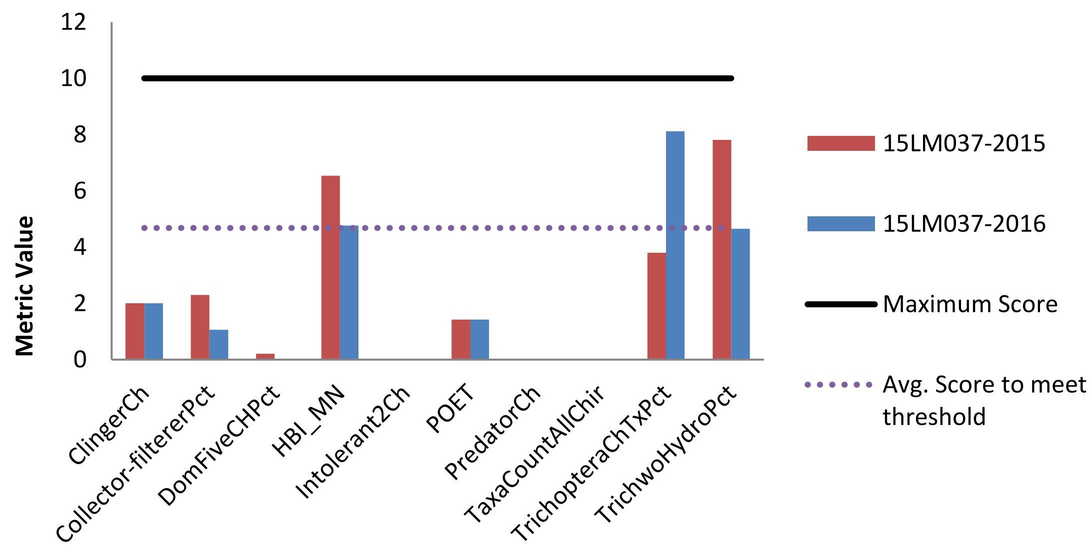
4. Evaluation of candidate causes to biological impairments in the Mississippi River-Reno

4.1. Crooked Creek 07060001-519

Biological and background information

This lower section of Crooked Creek is impaired for macroinvertebrates. Two macroinvertebrate samples were collected at one station (15LM037; Figure 3 in 2015 and 2016. The stream is designated macroinvertebrates Class 6 (Southern Forest Streams Gilde/Pool) with an impairment threshold of 43. Both scores were below impairment threshold, and the lower confidence interval (scored between 15 and 24). This site had relatively cold temperatures, and very poor in-stream habitat. The top two abundant macroinvertebrates sampled in all three visits were G*ammarus* and C*aecidotea*, both which are types of crustaceans. The samples also had some other coldwater individuals, like *Brachycentrus occidentalis* and *Baetis brunneicolor* suggesting the possibility of a stream that is transitional between warm and coldwater. All the stream reaches upstream of this one are considered coldwater. The diverse warmwater fish community also had coldwater taxa present (brown trout). However, at time of assessment, there was not temperature evidence to assess this reach as a coldwater stream. Additionally, with close proximity to the larger Mississippi River, a coldwater assessment may not be appropriate. The fish collected in this reach had many river species including emerald shiner, mimic shiner, weed shiner, yellow perch, walleye, pumpkinseed and warmouth. The fish IBI scores were all above warmwater impairment thresholds. When looking closer at the macroinvertebrate community metrics, most scored below the average needed to meet the impairment threshold (Figure 4).

Figure 4. Macroinvertebrate metrics for Crooked Creek 0704006-519, from one station, two different sampling years.



Temperature

In the summer of 2015 and 2016, a temperature logger was placed at 15LM037 to gather temperature data (Figure 5 and Figure 6). While this is currently considered a warmwater reach, the temperature data shows fairly cool temperatures. The maximum temperature measured during 2015 was 22.5°C. The July and August temperature averages were 17.3°C and 17.8°C respectively. These averages are in line with a coolwater stream and look very comparable to the station just upstream 15LM027 (which is considered coldwater). In 2017, the maximum temperature measured was 21.2°C, with July and August averages of 17.2°C (both months).

Figure 5. Continuous temperature data from 15LM037 collected in 2015.

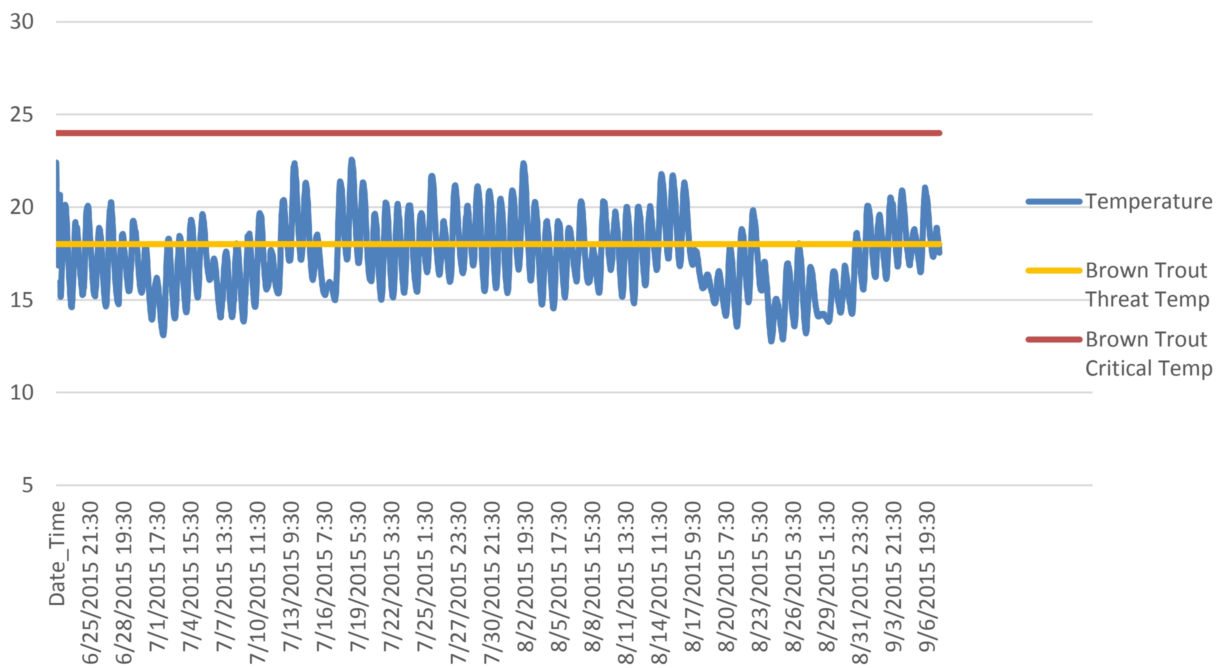
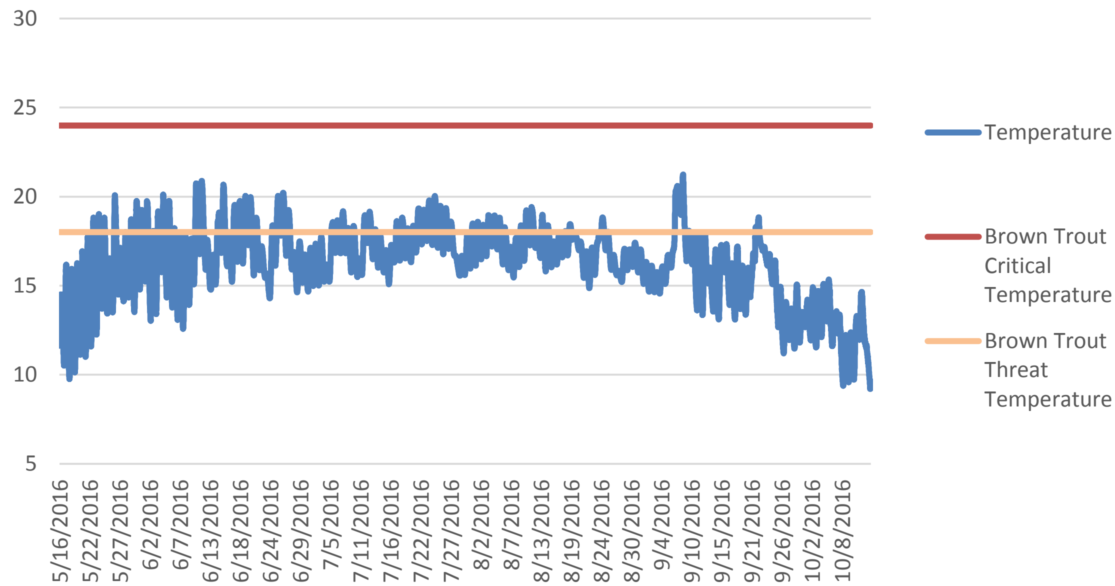


Figure 6. Continuous temperature data from 15LM037 collected in 2016.



There are not indications that temperatures are too warm for this stream. However, it is important for future work to understand these thermal regimes and assessment considerations. If anything, the thermal regime is much more like a coolwater/coldwater stream and temperatures are not a limiting factor or stressor at this time.

Nitrate

Nitrate concentrations in this section of Crooked Creek are some of the lowest in the region. There were 32 nitrate samples taken in 2015, 2016 and 2017. The samples represented a range of conditions, and were evenly distributed over the 2015, 2016 and 2017 monitoring periods. Of those samples, the average nitrate concentration was 1.8 mg/L, with a maximum of 2.2 mg/L.

The macroinvertebrate metrics for Crooked Creek show false indications of potential nitrate related stress (Table 4).Within the impaired reach, there was a mixed response of Trichoptera (caddisfly) taxa, who are often considered sensitive to elevated nitrate, but also commonly respond to other stressors like habitat degradation (TrichopteraCh). Non-hydropsychid Trichoptera (TricwoHydroPct) metric showed a mix of response between the two years; this may be due to higher flows that had occurred just before sampling in 2016. The non-hydropsychid Trichoptera are generally more sensitive, especially to nitrate, so their decline in 2016 may be due to higher flows just before the sample. However, the nitrate index score, which is meant to characterize the overall community's tolerance to high nitrate, is greater than average at most sites, indicating a tolerant community overall. While the nitrate tolerant taxa did not vary much across years, it shows low numbers of tolerant taxa overall. However, the abundance metric (Nitrate Tolerant Pct) did indicate they were quite abundant making up almost the entire community. There were zero nitrate intolerant taxa present as well.

The biological response does seem to point to some nitrate related stress, yet the chemical samples do not confirm nitrate is elevated in this reach. It is more likely that other stressors, instead of high nitrate, explain the responses seen in Table 4. Nitrate is not a stressor to Crooked Creek.

Table 4. Macroinvertebrate metrics that respond to nitrate stress in Crooked Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM037 (2015)	**4.48**	**0**	10	**94.44**	**1**	5.8
15LM037 (2016)	**4.33**	**0**	11	**98.10**	**1**	**0.6**
15LM037 (2016 Replicate)	**3.98**	**0**	10	**96.63**	**2**	**2.1**
Southern Forest Streams Median	*3.0*	*2*	*18*	*67.3*	*4*	*2.3*
Expected response to stress	↑	↓	↑	↑	↓	↓

Total suspended solids

The grab sample results during fish sampling were both well below the total suspended solids (TSS) standard (65 mg/L) in Crooked Creek (10 mg/L and 14 mg/L). There were 25 additional samples for TSS taken from the impaired reach during monitoring in 2015, 2016 and 2017. The maximum concentration was 740 mg/L, taken at 15LM037 on September 7, 2016. Only three samples (of the 25) exceeded the southern warmwater standard of 65 mg/L. However, these exceedances occurred when the stream was sampled during or immediately following a significant rainfall event. Overall, regular sampling over the course of the three year period, samples show minimal exceedence of the standard and do not suggest the stream sees long periods of time where the standard is exceeded and turbidity doesn't appear to be a chronic issue.

Biologically, the TSS index score is slightly higher than average in 2015, which demonstrate a higher tolerance to TSS based on the macroinvertebrate community composition (Table 5). However, the results in 2016 were better (lower) than average, which conflicts with the 2015 results. Overall, there are no TSS intolerant taxa during any visit. However, the abundance and number of tolerant taxa are not high. These results provide a mixed response among biological evidence, and do not strongly implicate TSS as a stressor. Since the water levels in 2016 were actually slightly above normal, and less of a response is observed that year compared to 2015 (when water levels were normal) it provides further indication that TSS is not the likely cause of impairment. It is more likely the responses seen are due to other stressors. TSS is not a stressor in Crooked Creek.

Table 5. Macroinvertebrate metrics relevant to TSS for stations in Crooked Creek compared to statewide median for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
15LM037 (2015)	**15.82**	**0**	7	19.8
15LM037 (2016)	14.94	**0**	5	14.2
15LM037 (2016 Replicate)	13.8	**0**	4	10.4
Southern Forest Streams Median	*15.13*	*2.0*	*11*	*26.7*
Expected response to stress	↑	↓	↑	↑

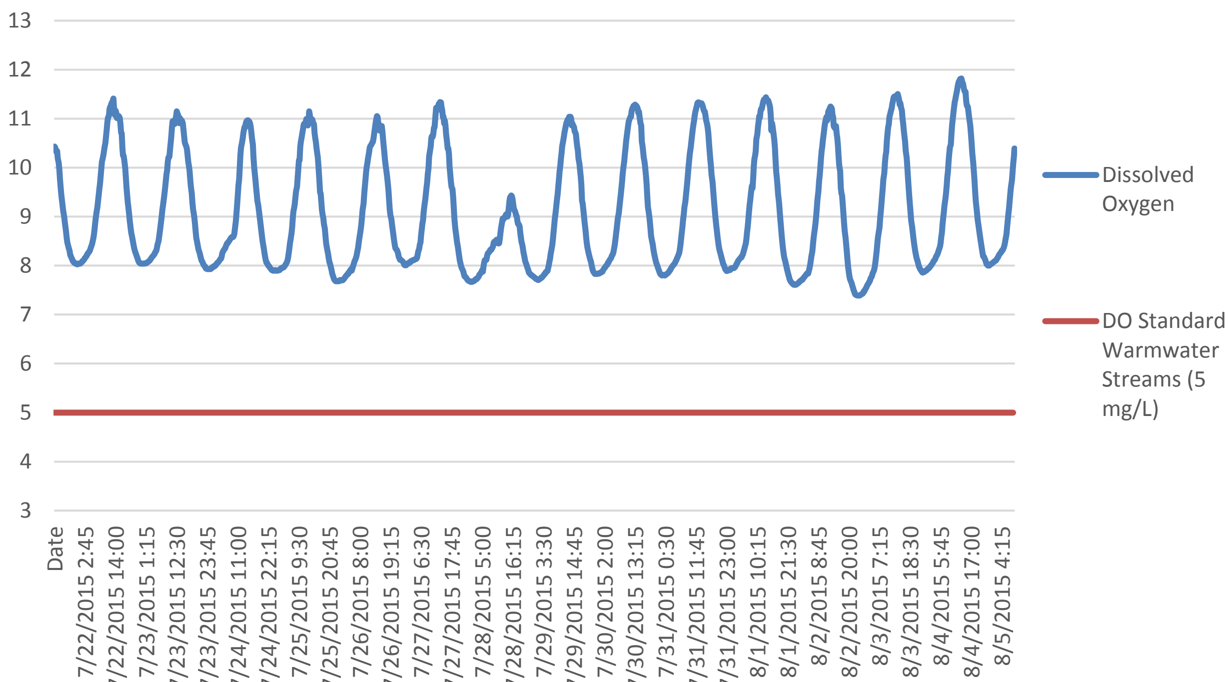
Dissolved oxygen/eutrophication

In 2015, 2016, and 2017, Crooked Creek had a number of grab samples taken at 15LM037 (S008-436). No samples of them exceeded the warmwater dissolved oxygen (DO) standard of 5 mg/L. However, only three of these samples were early morning samples (before 9 am; when DO levels are typically lowest). The lowest concentration observed during grab sampling was 6.36 mg/L from September 7, 2016, which was a storm event sample. In 2015, a multiparameter sonde was deployed at 15LM037 from July 22, 2015 to August 5, 2015. Dissolved oxygen levels from that deployment were normal, with no values exceeding the warmwater low DO standard of 5 mg/L. The majority of the early morning samples were from a sonde deployment in 2015, the lowest daily minimum during this deployment was 7.39 mg/L. DO flux was also normal, at an average of about 3 mg/L (Figure 7).

Total phosphorus (TP), DO flux, chlorophyll-a and biochemical oxygen demand (BOD) data can be used when looking closer at the potential for eutrophication and related DO issues. Total phosphorus concentrations exceeded the Central River Nutrient standard (0.100 mg/L) twice with an average concentration of 0.08 mg/L for 27 samples collected in 2015, 2016 and 2017. Both of the TP exceedances occurred following a storm event in September 2016.

Chlorophyll-a data was limited to 9 summer samples on this reach from 2015 and 2016. The concentrations ranged from 1.49-5.26 μg/L, which is very low compared to the standard of 18 μg/L and does not suggest suspended algae and eutrophication are a concern. Only one BOD sample was available in 2016 (1.2 mg/L), which was also normal (i.e. meeting standards).

Figure 7. Dissolved oxygen concentrations at 15LM037 from, 7/22/15-8/5/15.



The biology in Crooked Creek shows minimal response to DO/eutrophication (Table 6). While there were only three low DO intolerant taxa sampled, they make up a large percentage of the overall community. That coupled with few taxa and low DO tolerant individuals, are good indications that DO is sufficient here. This is also reflected in the higher DO index score, which is considered good or better than average for both visits. Taxa richness of collector-filterers (Collector-filtererCh), collector-gatherers (Collector-gathererCh) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) were below the median for this type of stream.

Table 6. Macroinvertebrate metrics that respond to DO/eutrophication related stress in Crooked Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

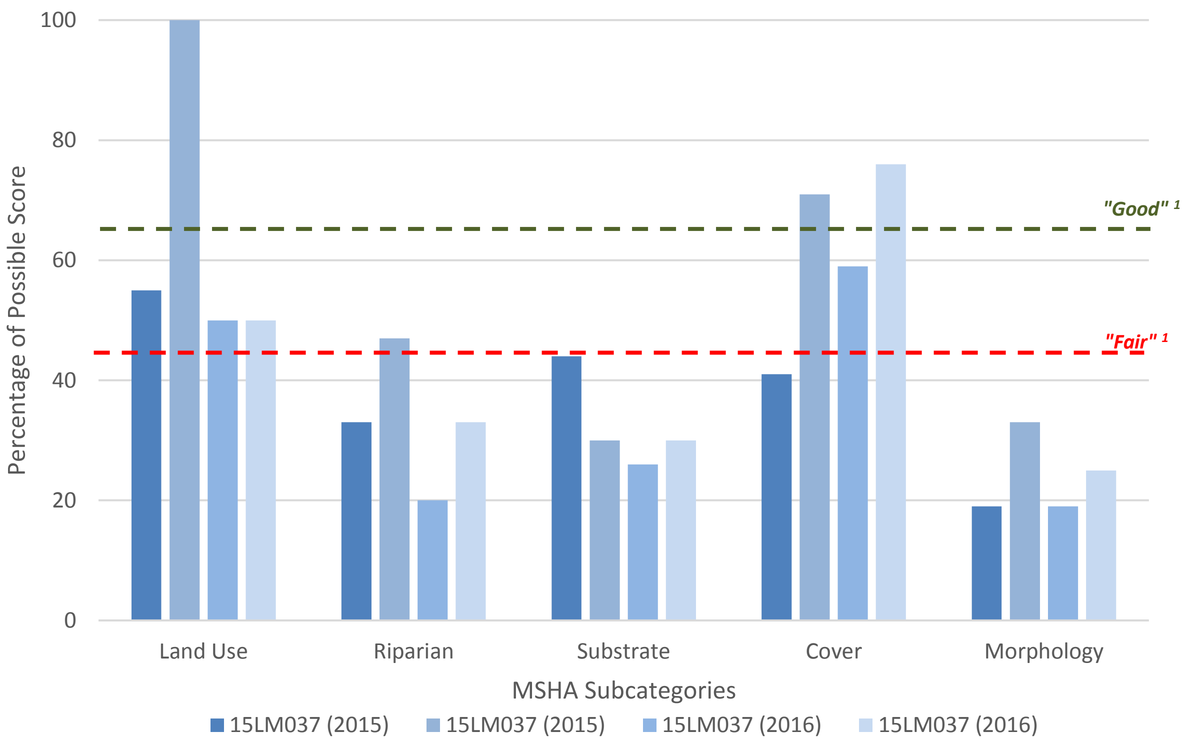
Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT	Phosphorus Index Score	Phosphorus Tolerant Pct	Collector FiltererCh	Collector GathererCh
15LM037 (2015)	7.7	**3**	58	1	0.6	**3**	0.127	**20.1**	**5**	**5**
15LM037 (2016)	7.6	**3**	49	1	0.3	**3**	**0.142**	**35.3**	**3**	**5**
Southern Forest Streams Median	*6.9*	*5*	*9.4*	*6*	*9.0*	*8*	*0.127*	*18.7*	*6*	*14*
Expected response to stress	↓	↓	↓	↑	↑	↓	↑	↑	↓	↓

Considering all of the DO evidence and the corresponding response variables the data and biological response do not provide any strong evidence that eutrophication or low DO is occurring in this part of Crooked Creek and contributing to biological impairment. Therefore, low DO and eutrophication are not considered stressors at this time.

Habitat

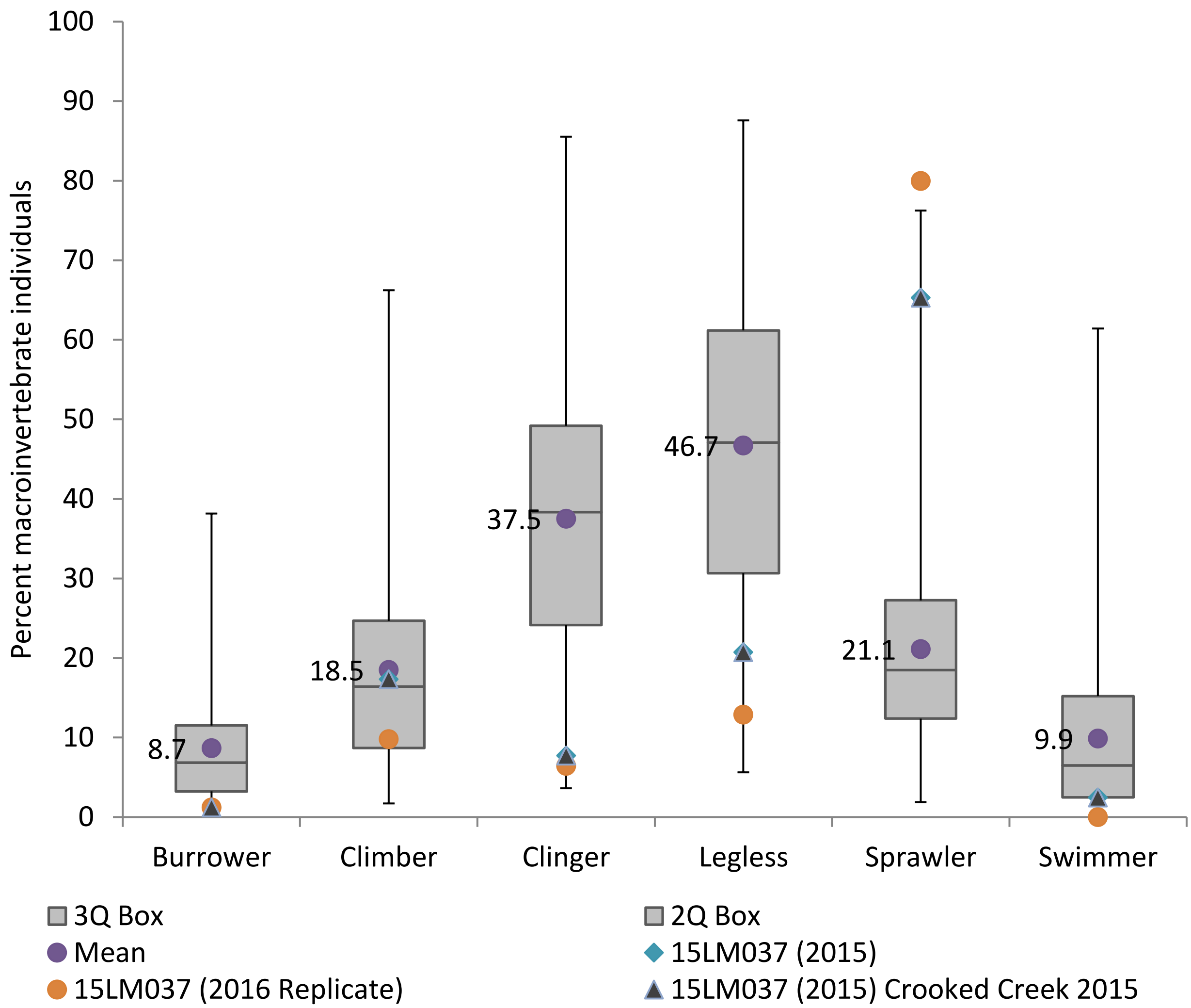
The MPCA Stream Habitat Assessment (MSHA) scores for Crooked Creek, 15LM037 were all considered "poor". There were four visits, with a total score ranging from 29-44. The subcategory metrics of the MSHA that scored poorly were substrate, riparian, and morphology (Figure 8). Land use and cover scored in the moderate or fair range and varied depending on the visit. The dominant substrate noted within the entire reach, including the pools and runs, was sand. There was no coarse substrate. The dominant channel type during most visits was "run" (85-100%), with poor channel development. Submerged aquatic vegetation was noted as well. Generally, there was little riparian width, little to moderate bank erosion, and little shade.

Figure 8. MSHA subcategory scores for four visits at 15LM037 in 2015 and 2016. [1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.



The dominant macroinvertebrate habitat noted during biological surveys was aquatic macrophytes and overhanging vegetation. This sample showed that the macroinvertebrate community had few burrowers and swimmers, while also having near average amounts of climbers that would likely be found on the macrophytes and vegetation (Figure 9). However, there were reduced clinger individuals, which are typically found in streams with ample amounts of woody debris and course substrates. Both of these habitat types are limited in this reach and the community certainly reflects that. The site did have a macroinvertebrate community consisting of an overabundance of sprawlers, which often can increase with fine sedimentation. Sprawlers are macroinvertebrates which sprawl on top of fine sediments and can correlate to poor substrate conditions in streams. The two dominant macroinvertebrates at this site are both sprawlers; Gammarus and Caecidotea. In addition, a tolerant snail (Physa) was also common in the samples and they can tolerate very poor habitat conditions, among other stressors. In addition, the percentage of EPT individuals was lower than average. EPT taxa are commonly used to measure overall health of ecosystems, due to their sensitivity to many stressors including habitat. The quality and diversity of habitat types are limited in this reach and the biological metrics match, signaling a community being negatively impacted by the poor substrate and lack of diverse habitat types.

Figure 9. A comparison box plot of macroinvertebrate habit metrics representing the average macroinvertebrate class 6 stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.



The Minnesota Department of Natural Resources (DNR) completed multiple geomorphology surveys and a larger scale WARSSS (Watershed Assessment of River Stability and Sediment Supply) study on the entire Crooked Creek drainage. Erosion rates and sediment contributions for the entire Crooked Creek Watershed show that streambanks make up 36% of the sediment supply while surface erosion (estimated with HSPF) make up 64% of the total sediment supply. The majority of unstable stream banks occur in the lower end of Crooked Creek and correspond with station 15LM037. At the geomorphic sampling location, the reach is considered a sand dominated F channel. This stream type does not typically provide good diversity of habitat for macroinvertebrates. At the biological site (15LM027) upstream of 15LM037, channel conditions are similar; however, the upstream site also contains downed woody debris that likely contribute to more diversity of habitat for macroinvertebrates keeping them from being impaired there. Both of these areas have a channel dominated by course and fine sand. The stream in this area is entrenched, which means flood flows are often contained in the channel banks, causing higher stream bank erosion rates. While the streambanks are a bit lower in the biological reach, the grazing intensity in that location exposes more bare streambanks leading to a higher predicted rate of erosion as well.

Macroinvertebrate habitat could be improved by limiting upstream sources of excess sediment causing systemic issues. It is also possible that recovery of the channel or restoration could also improve the efficiency of sediment transport, as current dimensions are leading to sediment aggradation. The Mississippi River backwater may also have an effect on the biological reach and this aggradation, however. A LiDAR profile of Crooked Creek shows the stream naturally flattens out significantly, and loses power to transport sediment in this part of the stream (lower section). For more detailed geomorphology information, refer to the DNR WARSSS study. Overall, the evidence points to lack of habitat as a stressor to the macroinvertebrate community in Crooked Creek.

Figure 10. Photo taken during August 31 2016 macroinvertebrate sample, displaying a wide, slow velocity stream with lack of woody debris and coarse substrates.

Connectivity/fish passage

While fish are not impaired in this reach, a potential fish barrier was identified upstream of 15LM037 (Figure and Figure 12). The barrier is a velocity barrier at most flows. It is likely some fish can migrate up on occasion, most likely during flood flows.

Figure 11. Fish barrier identified upstream of 15LM037.

Figure 12. Aerial photo and location of fish barrier in relation to 15LM027 (upstream road; S009-025) and 15LM037 (downstream road; S008-436). The Mississippi River backwaters are downstream of 15LM037.

The majority of migratory fish species are found upstream of the identified fish barrier (Table 7). These are mainly coldwater fish. Upstream habitat may be better than downstream, and the downstream community (15LM037) is more reflective of proximity to the Mississippi River backwaters. The fish barrier and the backwater area are large drivers of the fish community composition at these two stations, which are only 1.9 river miles apart.

Table 7. Numbers of fish collected at two stations in lower Crooked Creek, 15LM027 and 15LM037 in 2015. A fish barrier was identified in-between the two stations, in addition to the proximity to the Mississippi river, both of which are driving the community composition at these stations. Migratory fish species are in bold.

	Upstream→Downstream			
Fish Species Present in Sample	15LM027		15LM037	
	2015		2015	
Brown trout	70	Fish Barrier		Mississippi River Backwaters
White sucker	23		68	
Central mudminnow	3		8	
Golden shiner	3			
American brook lamprey	2			
Rainbow trout	2			
Common shiner	1			
Walleye	1		1	
Weed shiner			205	
Spotfin shiner			13	
Emerald Shiner			5	
Largemouth Bass			5	
Pumpkinseed			5	
Bluegill			3	
Northern Pike			3	
Yellow Perch			3	
Shorthead redhorse			2	
Yellow bullhead			2	
Brook stickleback			1	
Burbot			1	
Common Carp			1	
Green Sunfish			1	
Warmouth			1	

While barriers can alter fish movement, fish are not currently impaired in this reach and therefore it is of less concern. Migratory fish are found at stations upstream and downstream of the barrier. At this time, connectivity and fish passage are not considered stressors to the impaired macroinvertebrate community, but may need to be evaluated later if future issues arise related to fish.

Summary

The main stressor contributing to the macroinvertebrate impairment in Crooked Creek is lack of habitat. The dominant substrate in the reach was sand, with no coarse substrate. Generally, there was little riparian width, some bank erosion, and sparse shade. These limitations do not provide quality, diverse habitat conditions that macroinvertebrates need to thrive.

Macroinvertebrate habitat could possibly be improved by limiting upstream sources of excess sediment. It is also possible that recovery of the channel or restoration could also improve the efficiency of sediment transport, as current channel dimensions are leading to sediment aggradation (accumulation). The Mississippi River backwater may also have an effect on the biological reach and this aggradation, however. A LiDAR profile of Crooked Creek shows the stream naturally flattens out significantly, and loses power to transport sediment in this part of the stream (the lower section). Therefore, habitat overall may just be naturally limited in this section of stream due to these natural characteristics. Any potential projects would need to consider if it is appropriate to do habitat restoration due to these natural limitations.

Temperatures in this reach do appear to give a bit of a coldwater signal, in addition to the presence of some coldwater macroinvertebrates. While the stream was assessed as warmwater, and the fish community certainly reflects that, there are suggestions it may support coldwater/coolwater communities or at least a mix of species. This should be considered in any future assessments.

Nitrate, TSS, eutrophication, and DO all showed adequate levels and no clear biological response which would implicate them as stressors at this time.

4.2. South Fork Crooked Creek 07060001-574

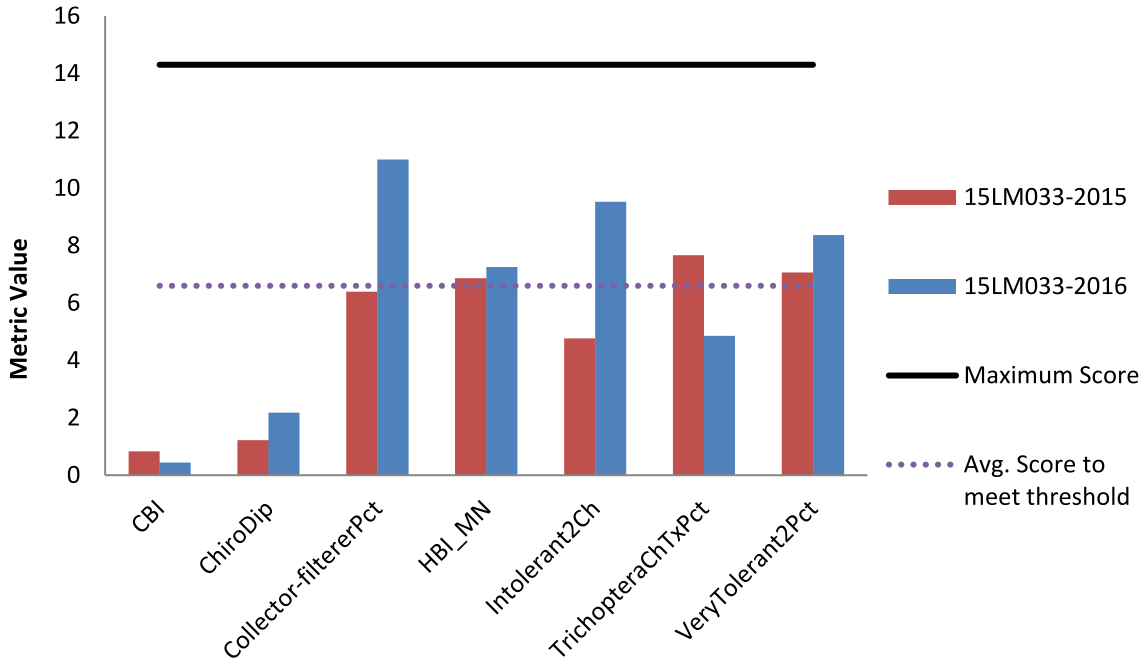
Biological and background information

The South Fork Crooked Creek (15LM033) is impaired for fish and macroinvertebrates. There is a large reservoir upstream of this station (R-3), which is located at stream mile 1.42 and was built in 1971. This reservoir has changed the character of this coldwater stream and has a large impact on the fish and macroinvertebrate communities present. The R-3 reservoir is managed by the DNR and provides a warmwater fishery to the area. Upstream of the reservoir there have been documented brook trout reproduction and downstream there is a DNR trout fishing easement that provides good angling opportunities.

Figure 13. South Fork Crooked Creek and R-3 reservoir.

There were two macroinvertebrate samples at 15LM033 (See location in Figure 3), one each in 2015 and 2016. The sample in 2015 scored 10 points below the southern coldwater threshold (33) and just above impairment threshold in 2016 (Score of 43.6 with a threshold of 43). The coldwater taxa at this station were very low in abundance, 11 or fewer total individuals, which is shown in a low CBI (Coldwater Biotic Index) score. The other low scoring metric was the ratio of Chironomidae abundance to total Dipteran abundance (ChiroDip). The remaining metrics all scored near the average needed to meet the impairment threshold (Figure 14).

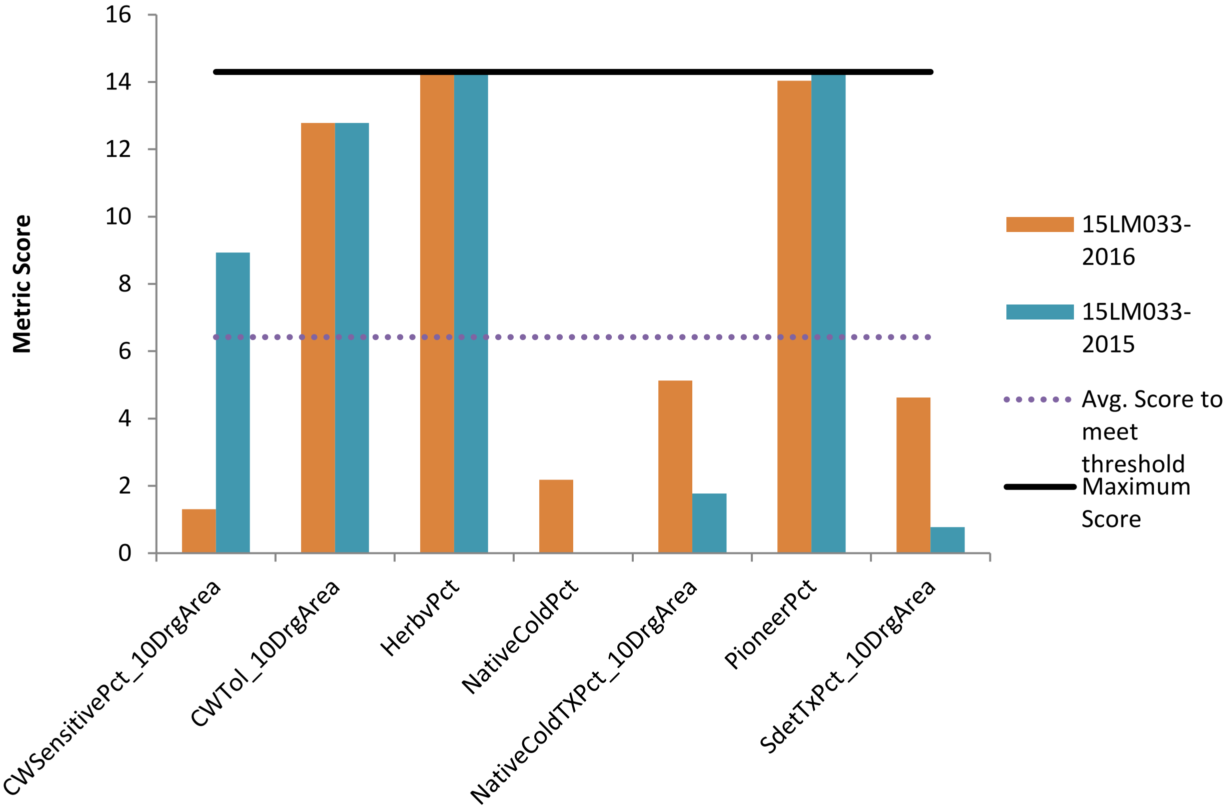
Figure 14. Macroinvertebrate metrics for South Fork Crooked Creek 0704006-574, from one station, two different sampling years.



There were also two fish visits at 15LM033 in 2015 and 2016 (Figure 15). The 2015 sample scored below the southern coldwater impairment threshold only by two points (FIBI of 48, threshold of 50). Rainbow and brown trout were both sampled, in addition to a number of white sucker and yellow bullhead. The water temperature from this sample was 24.6, which is very high for a coldwater stream. The second sample was above the threshold but only by four points (FIBI of 54). During this sample, brown trout and a single brook trout were sampled. This single brook trout likely increased the FIBI score, despite a weak coldwater community present. White Sucker and Largemouth Bass accounted for the majority of the fish captured. The water temperature at the time of the 2016 sample was 21.7, which is still high for a trout stream.

The relative abundance of individuals that are sensitive in coldwater streams (CWSensitivePct_10DrgArea), varied between the two samples with 2015 scoring better than 2016. Additionally, the relative abundance of individuals that are native coldwater species (NativeColdPct), relative abundance of taxa that are native coldwater species (NativeColdTXPct_10DrgArea), and the relative abundance of taxa that are detritivorous (SdetTXPct_10DrgArea) were below average. The taxa richness of tolerant species in coldwater streams (CWTol_10DrgArea), the relative abundance of individuals that are herbivorous (HerbvPct), and the relative abundance of individuals that are pioneer species (PioneerPct) were the only FIBI metrics with above average scores (Figure 15). There was one brown trout that resulted in a 5 point DELT deduction in the 2015 sample (DELT=deformities, eroded fins, lesions, or tumors).

Figure 15. Fish metrics for South Fork Crooked Creek 0704006-574, from one station, two different sampling years.



Temperature

In the summer of 2015 and 2017, a temperature logger was placed at 15LM033 (downstream of the R-3 reservoir) to gather temperature data throughout the season (Figure 16 and Figure 17). The maximum temperature measured during the 2015 season was 26.4°C. The maximum temperature measured at 15LM033 in 2017 was 26.7°C. These both exceed critical and threat temperatures for trout.

Temperature taken at multiple locations throughout the South Fork clearly demonstrate impacts the R-3 reservoir has on the stream (Figure 18). Temperature loggers were placed in 2017 upstream of the reservoir, just downstream of the outlet (in the tailwater), and farther downstream at the biological station (15LM033). The summer maximum temperature upstream of the reservoir was 20.5°C, compared to the biological station that was 26.7°C. On average, comparing all the upstream temperature measurements to downstream of the reservoir, the stream is 7°C warmer due to the reservoir. The maximum increase in temperature observed was 12°C. Comparing the upstream to the biological station (which is slightly farther downstream), the stream warms on average 5°C with a maximum increase in temperature of 10°C. This less dramatic temperature difference is likely due to the springs and tributaries that enter the stream downstream of the R-3 outlet and before the biological station. In other words, without the R-3 reservoir, the stream at the biological station would be on average 5°C (and up to 10°C) cooler depending on the time of year.

Figure 16. Continuous temperature data collected at 15LM033 in 2015.

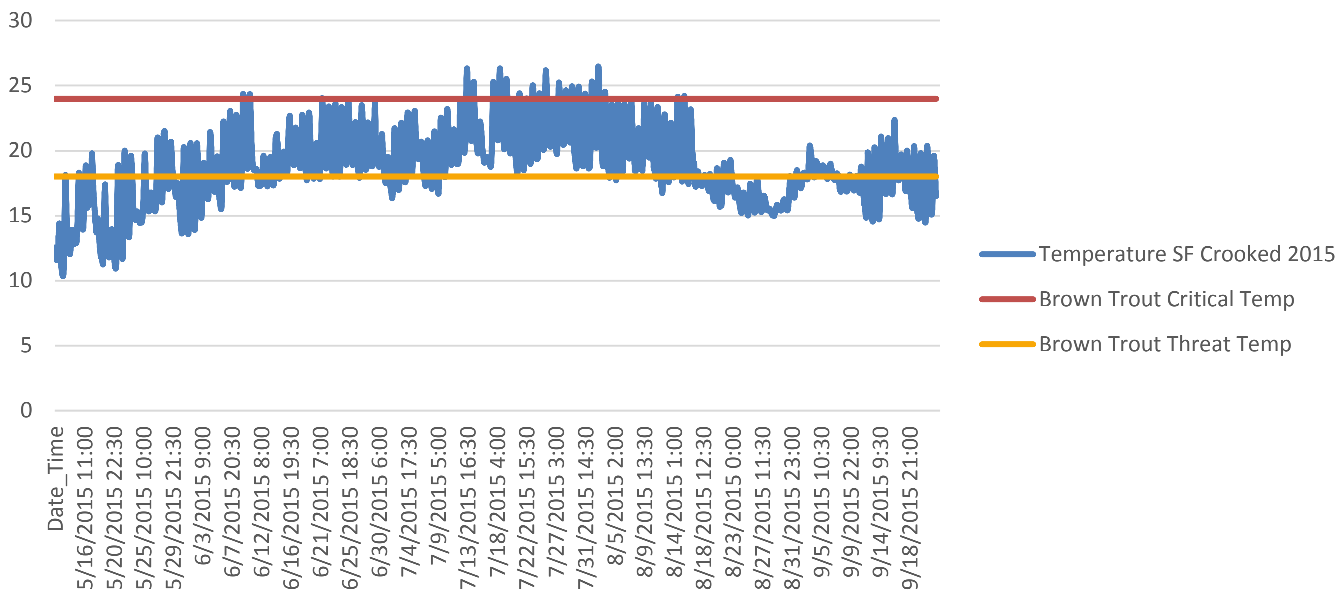


Figure 17. Continuous temperature data collected at 15LM033 in 2017.

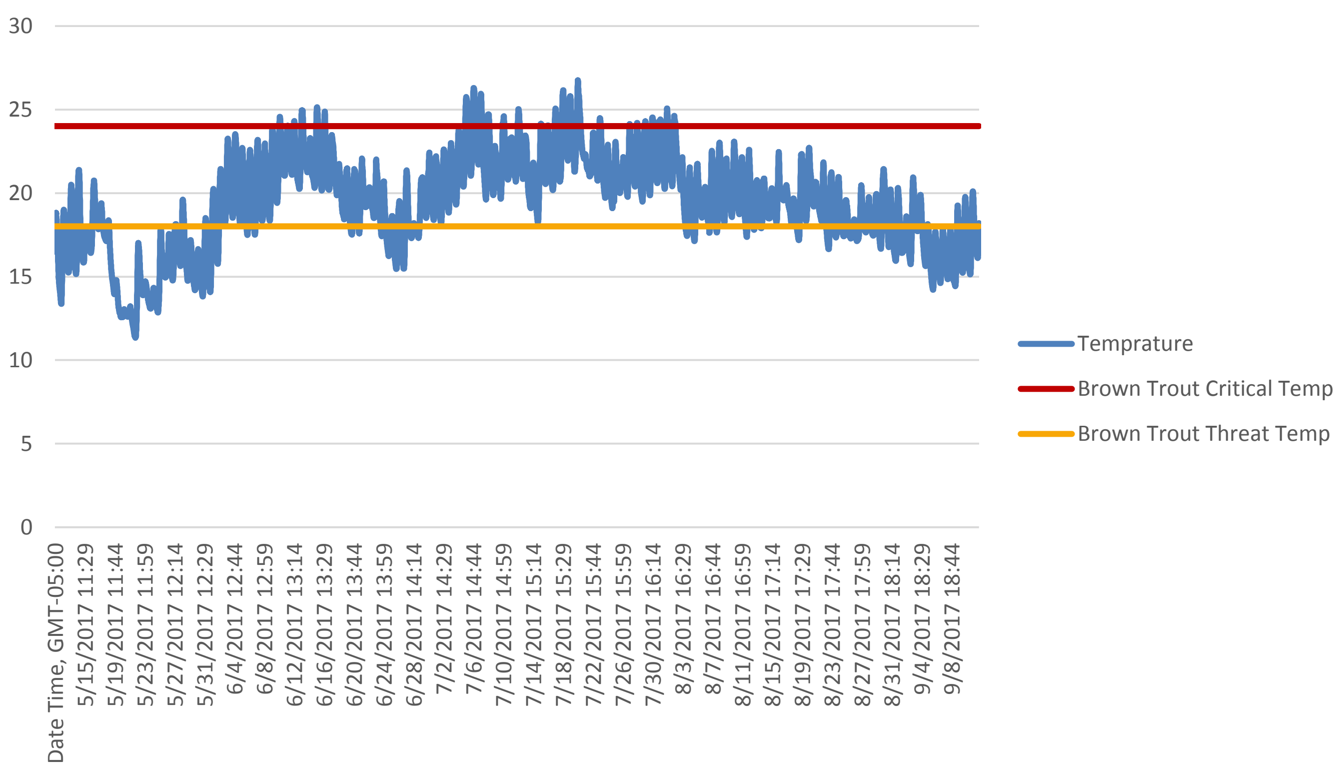
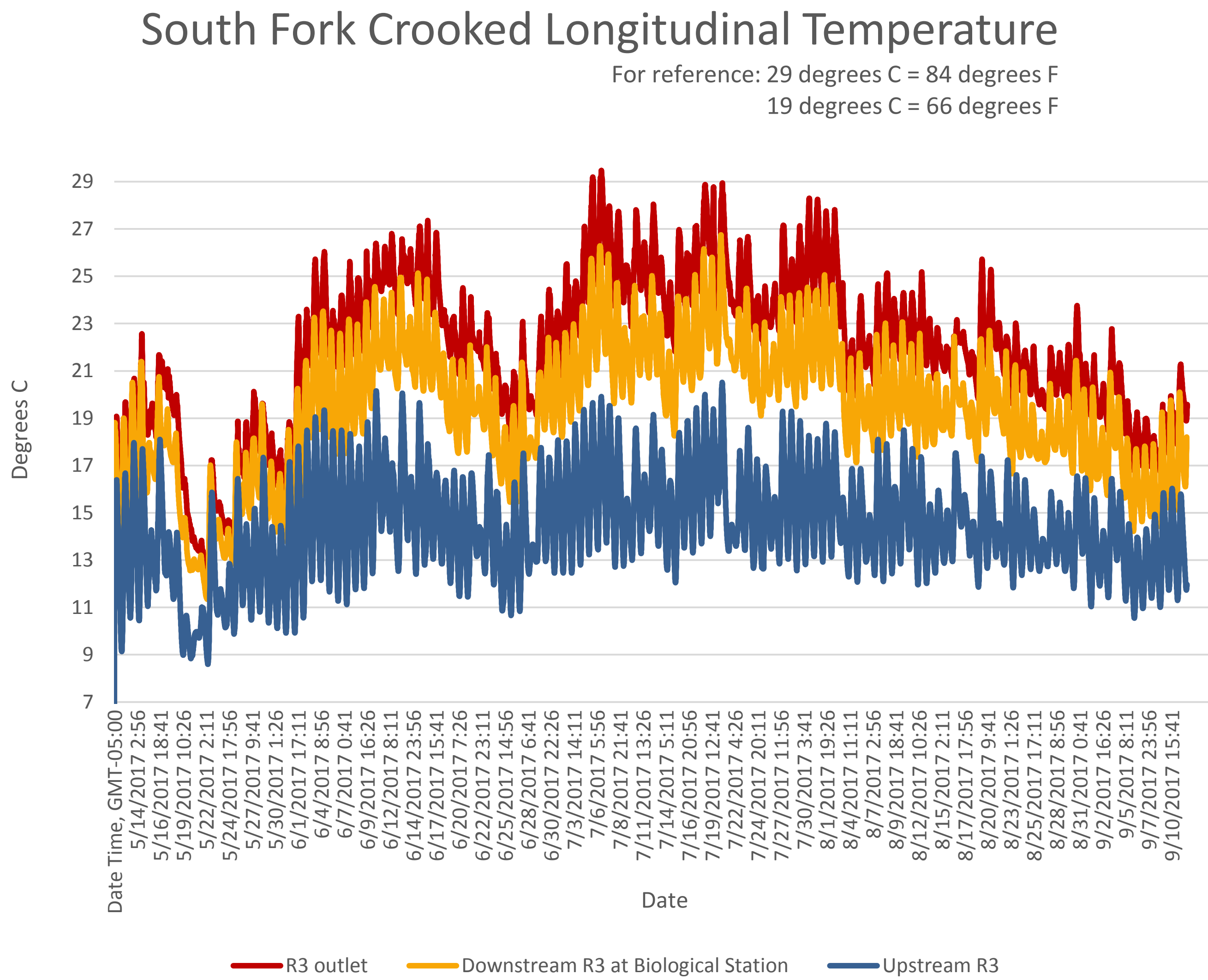


Figure 18. Continuous temperature data collected longitudinally on the South Fork Crooked Creek in 2017. One station was located upstream of the R-3 reservoir, one just downstream of the R-3 reservoir discharge point, and one farther downstream at biological station 15LM033. This comparison was used to assess temperature changes and impacts from the reservoir and coldwater tributary springs just downstream of the R-3 outlet.



After review with DNR and agency staff, it was decided to keep the stream coldwater instead of changing it to warmwater. There is enough evidence that the stream did function as a coldwater trout stream and the DNR still manages South Fork Crooked as a trout stream with fishing easements. This site had much warmer temperatures than a typical coldwater stream, and the presence of coldwater taxa is likely due to either localized springs near the station, contributions from upstream coldwater feeder tributaries, or proximity to Crooked Creek at the downstream outlet.

Biologically, the fish community in the South Fork Crooked Creek has fewer coldwater fish species than expected compared to other coldwater streams. Their abundance can indicate thermal degradation among other stressors. The percentage of coldwater fish species at 15LM033 was 36% in 2015 and only 11% in 2016. Most coldwater streams in the area have around 50% coldwater fish species present, with many nearing 100%. Similarly, coldwater sensitive fish species and native coldwater fish species were not abundant. The fish community does also show an interesting mix of species, likely due to the upstream reservoir. While trout were found in both samples, they were not overly abundant, and additional tolerant/warmwater species (white sucker, yellow bullhead, largemouth bass) were present.

The bullhead and bass are likely coming from the reservoir upstream. While fish often provide a good indication of thermal regime in a stream, coldwater macroinvertebrates and their abundance are also an important consideration. The CBI score (coldwater biotic index) metric for macroinvertebrates was well below the average needed to meet the IBI threshold (Figure 14). This shows that coldwater macroinvertebrates were not abundant nor diverse. This is important because macroinvertebrates do not have the ability to move to seek refuge from warm temperatures as fish do. In the South Fork Crooked Creek, it is likely that fish are not only coming from the reservoir, but can also migrate downstream and seek refuge in the cooler temperatures of Crooked Creek as 15LM033 is close to the watershed outlet. Additionally, there are a few significant spring tributaries where coldwater fish can also likely seek some refuge during the hot summer months.

Temperature data shows a marginal coldwater thermal regime, with the stream spending a good amount of time exceeding the trout threat and critical temperatures. Both coldwater macroinvertebrate and fish communities show signs of temperature related stress. Overall, the negative impacts that the reservoir has on the thermal regime of the South Fork Crooked Creek are clear and temperature is a stressor.

Nitrate

Nitrate concentrations in South Fork Crooked Creek are fairly low. There were 14 nitrate samples overall, from 2016 and 2017. The samples represented a range of conditions, and most were evenly distributed over the 2016 and 2017 summer monitoring periods. Of those samples, the average nitrate concentration was 2.1 mg/L, with a maximum of 3.0 mg/L. Samples taken upstream of this reach (above R-3) were actually higher by about 2 mg/L (around 4.3 mg/L for an average; from five paired samples upstream and downstream R-3 in 2017) suggesting possible dilution from groundwater sources lower in nitrate, or denitrification/plant uptake from R-3. Therefore, the most significant nitrate contributions to this reach are sourced from upstream headwater areas of the watershed.

Biological response to nitrate varies and is different for warmwater streams compared to coldwater streams. Overall, fish lack strong biological response evidence in relation to elevated nitrate in coldwater streams and therefore are not good indicators of nitrate degradation. Better relationships have been made with macroinvertebrate impairment and nitrate concentration. The macroinvertebrate metrics for South Fork Crooked Creek do not show strong indications of nitrate related stress (Table 8). Within the impaired reach, there was some response of Trichoptera (caddisfly) taxa, who are often considered sensitive to elevated nitrate, but also commonly respond to other stressors (TrichopteraChTxPct). However, the nitrate index score, which is meant to characterize the overall community's tolerance to high nitrate is lower than average at both visits. While the nitrate tolerant taxa did vary between visits, the abundance metric (Nitrate Tolerant Pct) did not indicate they were abundant. There were two to three nitrate intolerant taxa present, which is better than average. These results are good evidence that nitrate is not likely making an impact to the macroinvertebrates in South Fork Crooked Creek, and the small responses seen are due to other stressors.

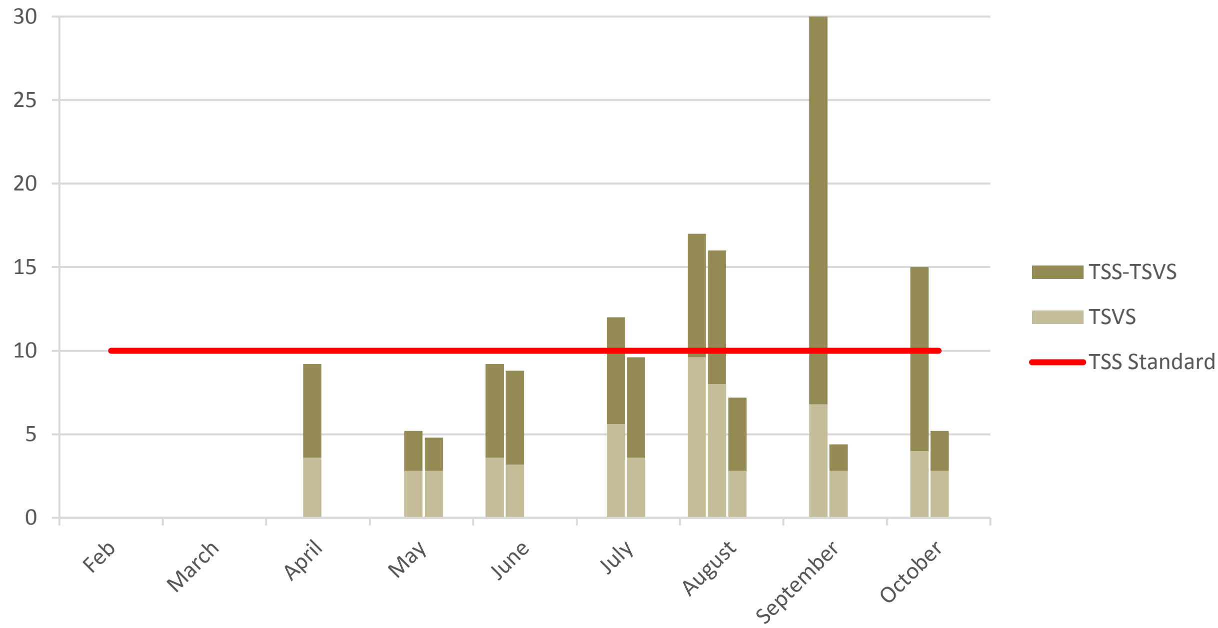
Table 8. Macroinvertebrate metrics that respond to nitrate stress in South Fork Crooked Creek compared to the statewide average of visits meeting the coldwater biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraChTxPct	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
15LM033 (2015)	**15.6**	2.58	2	14	39.49
15LM033 (2016)	**12.2**	2.60	3	**17**	33.54
Southern Coldwater Average	*17.3*	*3.04*	*1.35*	*14.29*	*60.79*
Expected response to stress	↓	↑	↓	↑	↑

Total suspended solids

The grab sample results during fish sampling at 15LM033 had one result below the TSS standard (10 mg/L) and one above (2.4 mg/L and 16 mg/L). There were 14 additional samples for TSS taken from the impaired reach during monitoring in 2016 and 2017. The average TSS concentration of those samples was 12 mg/L, just above the standard of 10 mg/L for coldwater streams. The maximum concentration was 40 mg/L, taken at 15LM033 on September 14, 2016. Five samples (of the 14) exceeded the standard of 10 mg/L. However, these exceedances occurred in the later summer months of 2016 (July-October). During this time, Total Suspended Volatile Solids (TSVS) (organics) made up a larger portion of the TSS sample (about 40%) which point to the influence of upstream reservoir R-3 and production transferring downstream to this reach (Figure 19). Typically, higher TSS is the result of sediment in streams and not algal production, but in this case, TSS increased during these baseflow conditions and when temperatures warm the reservoir. Another potential source of higher volatile solids is the Caledonia Wastewater Treatment Plant; however, DMR data during the monitoring time frame show maximum effluent concentrations of TSS that are very low (Average 2.1 mg/L and max 3.8 mg/L) Some of the elevated TSS observed in 2016 corresponds to higher chl-a, and late summer production of R-3 reservoir. All three chlorophyll-a exceedances measured in 2016 also exceeded the TSS standard. For more related information, see the DO/eutrophication section of the report.

Figure 19. Sampling for TSS/TSVS from months in 2016 and 2017. Lighter colors respresent the proportion of TSS that is TSVS in any given sample. For each month, the left column corresponds to a 2016 sample, while a right column is the 2017 sample. August 2016 showed the highest amounts of TSVS, almost violating the 10 mg/L standard alone. This corresponds to data shown in other sections of the report that indicate high summer production in R-3 during that time frame. A large storm event in 2016 was also captured in September.



Overall, the majority of fish metrics showed a response to elevated TSS (Table 9). The percentage of carnivores, which often respond negatively to increases in TSS, were just below average. The probability of meeting the TSS standard, based on the fish community present, was also just below average for southern coldwater stations. This reveals a community that is moderately tolerant of high TSS. However, the TSS index score for fish does show a mixed result between the two years. Overall, it appears that more response is demonstrated in 2016 compared to 2015, which may be attributed to the conditions of the stream and production in the R-3 reservoir.

Table 9. Fish metrics and data that correspond to TSS stress in South Fork Crooked Creek. *TSS concentration is shown as 10 mg/L, which is the standard for coldwater streams (not the southern coldwater average).

Station (Year sampled)	TSS Index Score	Conditional probability for TSS (%)	% Carnivores	TSS concentration at time of fish sample (mg/L)
15LM033 (2015)	11.0	**59**	**51**	*2.4*
15LM033 (2016)	**13.0**	**56**	**54**	***16***
Southern Coldwater Averages and Standards	*12.45*	*60%*	*56%*	*10 mg/L**
Expected response to stress	↑	↓	↓	↑

The macroinvertebrate TSS index score is slightly higher than average in the 2016 sample, which demonstrates a higher tolerance to TSS based on the macroinvertebrate community composition. Similarly, the abundance and number of tolerant taxa are higher than average. Yet, the number of intolerant taxa are better than average, which show some sensitivity within the community. These results provide a mixed response among biological evidence, and do not strongly implicate TSS as a stressor. Again, the 2016 data seem to point to TSS being higher overall compared to 2015. Much of the chemical evidence presented in this section of the report corroborates those metric responses.

Table 10. Macroinvertebrate metrics relevant to TSS for stations in South Fork Crooked Creek compared to statewide median for southern coldwater stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
15LM033 (2015)	13.19	3	**9**	**18.49**
15LM033 (2016)	**13.95**	2	**9**	**23.29**
Southern Coldwater Median	*13.42*	*2.0*	*5*	*8.34*
Expected response to stress	↑	↓	↑	↑

While it appears that all the biological and chemical response points to TSS related stress, especially in 2016, the lower MIBI and FIBI scores actually occur in 2015. It is not clear at this point how much of the responses and impairment is driven by TSS issues or other stressors, as these can be highly variable from year to year and dependent on conditions of the reservoir. Due to the conflicting results, it is difficult to confirm or rule out TSS as stressor. TSS in the form of organic matter/algae is significant at times, relative to that from sediment sources. Evidence collected during a DNR geomorphology survey in 2015 confirms that the reach is in stable condition, which supports this theory as well. Additional information across multiple years may help tease apart the variable TSS dynamics in this reach and how it corresponds to biological responses. As a result, TSS is inconclusive as a stressor to the South Fork Crooked Creek.

Dissolved oxygen/eutrophication

In 2016 and 2017, the South Fork Crooked Creek had a number of grab samples (13) taken at 15LM033 (S003-796). All of them met the coldwater DO standard of 7 mg/L. However, these particular samples were not early morning samples (before 9 am; when DO levels are typically lowest). The lowest concentration observed during grab sampling was 8.01 mg/L from July 13, 2017.

In 2016 and 2017, sondes were deployed at 15LM033 (Figure 21 and Figure 22) to try to capture the early morning DO ranges and get additional high resolution DO information. In 2017 a sonde was placed both upstream and downstream of R-3 reservoir, to compare DO levels. Dissolved oxygen levels from both years showed multiple violations of the 7 mg/L standard (Figure 21 and Figure 22). The minimum DO in 2016 was 5.32 mg/L and in 2017 was 5.11 mg/L. Upstream of the reservoir, DO met the standard during sonde deployment and low DO was not observed. This highlights the oxygen impact and change the reservoir has on the downstream water (Figure 22). Regular sampling also revealed high amounts of aquatic vegetation in the stream channel as well (Figure 20).

Figure 20. Photo of submerged aquatic vegetation taken just upstream 15LM033 on July 19 2016.

Figure 21. Continuous DO measurements for 15LM033 in 2016. The chlorophyll a reading was 85 μg/L at start of deployment 8/10; and 92 μg/L at end of deployment 8/29.

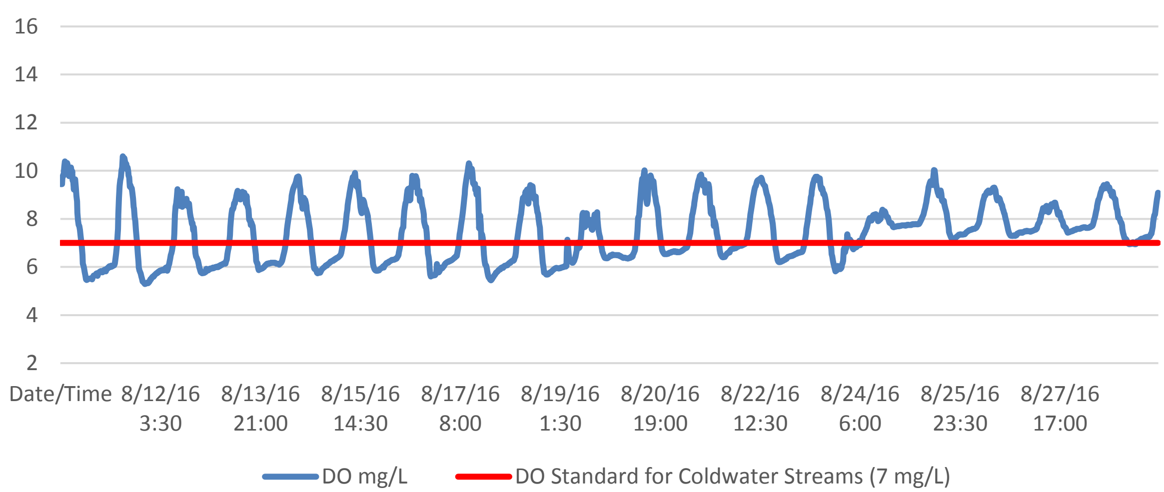
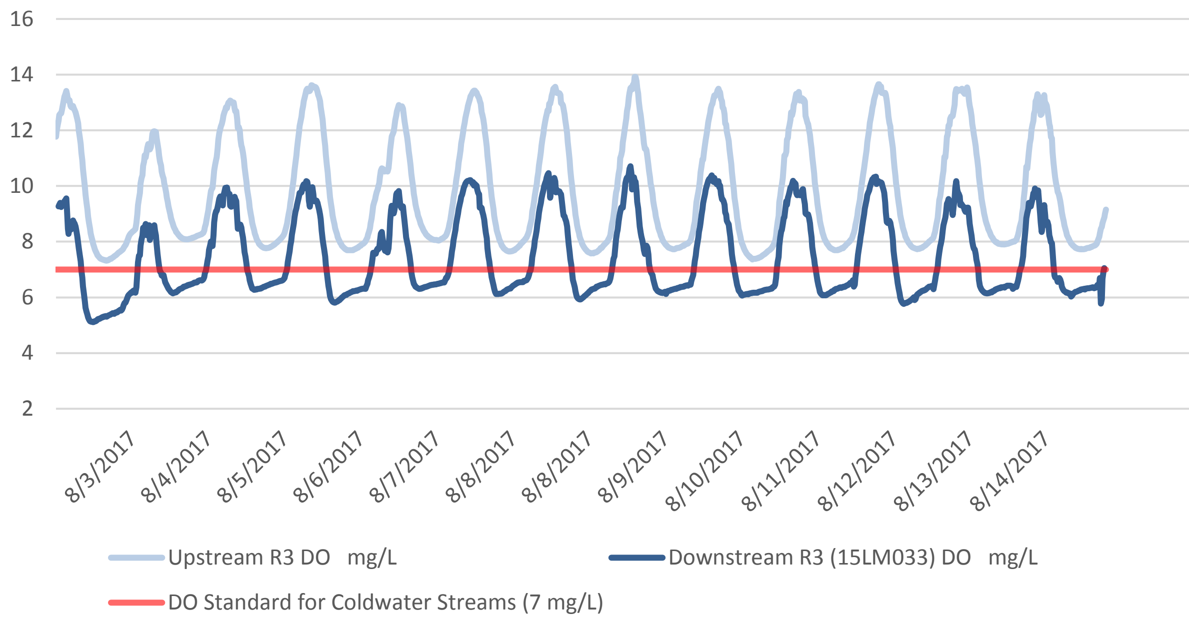


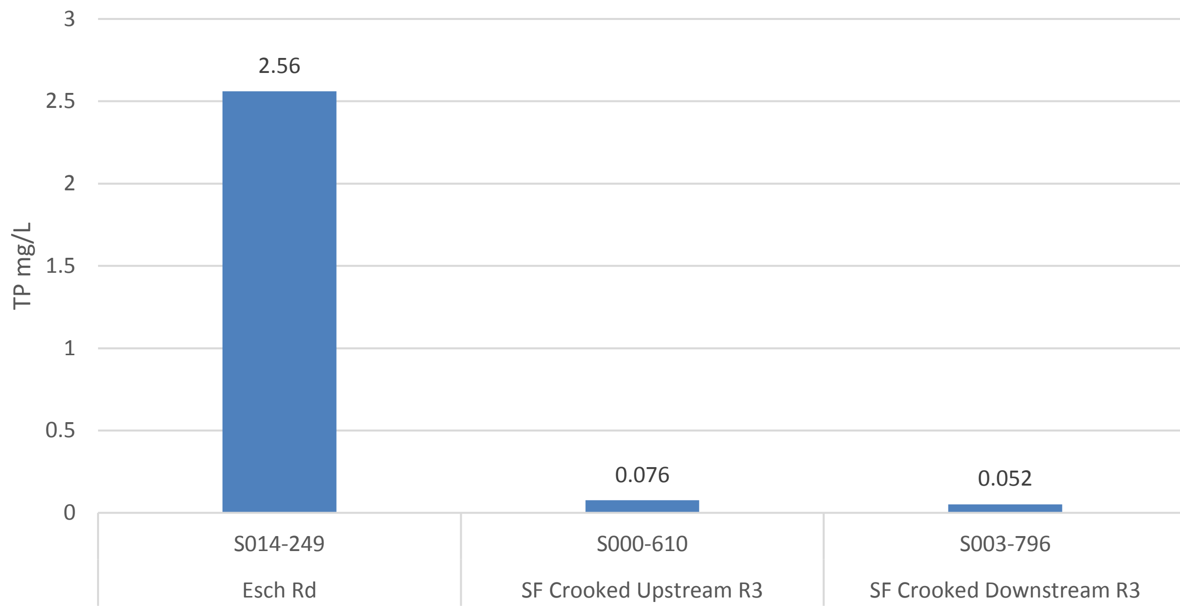
Figure 22. Continuous DO measurements for 15LM033 compared to upstream R-3 reservoir in 2017. Chlorophyll-a was 1.67 μg/L upstream on 8/2 and 9.68 μg/L downstream on 8/2. This was likely a result of cool summer and lack of production in R-3 compared to 2016.



Total phosphorus, DO flux, chlorophyll-a and BOD data are often used when looking closer at the potential for eutrophication and related DO issues. These values are used as benchmarks to help assess the potential for river eutrophication. In this particular reach, a river eutrophication assessment could not be completed due to lack of a full dataset at time of assessment in 2016. However, in 2017, additional data was collected, but revealed different results compared to 2016. Overall, TP concentrations were higher than the Central River Nutrient standard (0.100 mg/L) four times during sampling. The average concentration from all 14 samples collected from April-October in 2016 and 2017 was 0.09 mg/L. If only the 9 summer average samples are included (RES applicability period June-September) the average does increase to 0.118 mg/L, which is just the standard of 0.100 mg/L. However, 12 samples are needed for a full river eutrophication assessment. The four elevated TP samples occurred in August, September, and October of 2016 (October is outside the river eutrophication standard applicability period). The September result of high phosphorus was likely from sediment due from a storm event. However, the other high phosphorus values occurred when the water levels were normal, but again only in 2016. In addition, there were no exceedances of the phosphorus standard at any time in 2017 (monthly sampling occurring May through October). These varying conditions do point to a very dynamic system driven by the climate and the conditions of the R-3 reservoir.

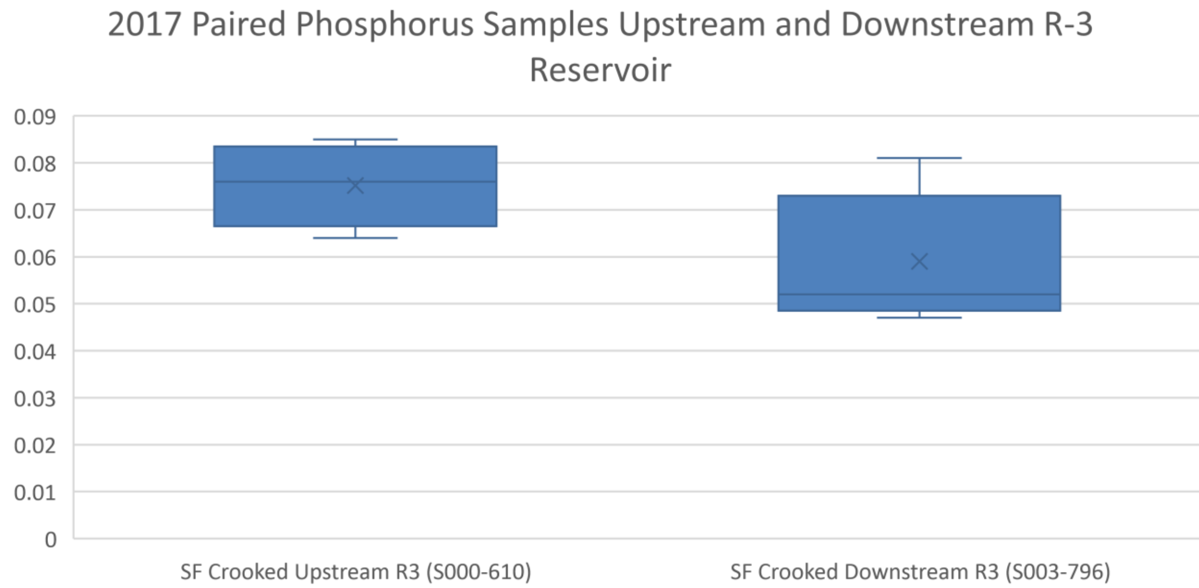
There are relatively high concentrations of TP coming from the wastewater treatment plant in Caledonia, but it is not clear how much it is affecting the reservoir and areas downstream. Based on longitudinal sampling, it appears as is if the phosphorus concentration is significantly reduced (likely dilution by springs/groundwater) before it reaches the reservoir (Figure 23). Sampling occurred at Esch Road, which is closest to the treatment plant discharge. Additional samples were taken just above the reservoir and downstream of the reservoir on the same day for comparison. The Esch Road site could only be sampled in May of 2017 since during the other sampling events the road crossing was completely dry (it is assumed the wastewater was sinking underground before reaching that road crossing).

Figure 23. Longitudinal phosphorus sampling on the South Fork Crooked Creek from one sample on 5/11/2017 showing high concentrations near the wastewater effluent discharge and dramatic decrease in concentrations when the stream reaches the R-3 reservoir.



Additional paired sampling from upstream and downstream of the reservoir in 2017 shows a slightly higher phosphorus concentration upstream of the reservoir compared to downstream of the reservoir (Figure 24). Additionally, all of those sample pairs (five total) were lower than the TP standard concentration (0.100 mg/L). Currently it is assumed that the groundwater inputs downstream of the wastewater discharge are resulting in dilution. It is not clear where the wastewater discharge sinks underground and how it can vary depending on the hydrologic conditions, but it is likely that it resurfaces in some of the springs or groundwater inputs farther downstream. However, without dye tracing to confirm, it is difficult to know for sure if all of the effluent is staying within the watershed and/or resurfacing in the downstream springs. It is possible it could be following groundwater flow paths and being discharged into neighboring watersheds. According to DNR reports, downstream of where the springs begin and perennial flow begins, there is a reproducing brook trout population. This indicates the water quality in this area must be fairly good.

Figure 24. Box plot of five paired phosphorus samples taken upstream and downstream of the R-3 reservoir from 5 months of sampling in the spring and summer of 2017.



Chlorophyll-a data was limited to six summer samples on the South Fork Crooked (15LM033) from late summer 2016 and 2017. The concentrations ranged from 3.9 μg/L to 92.4 μg/L, with three exceedances of the standard of 18 μg/L. Those exceedances occurred in August of 2016 (two samples) and October of 2016. All four available BOD samples exceeded the standard for the central region (2 mg/L). The range of BOD concentrations was 3.1 mg/L to 9.9 mg/L. The three samples that exceeded chlorophyll-a standards also exceeded BOD standards. The other BOD exceedence occurred in August of 2017. The river eutrophication impairment criteria would not apply to the October sample, but it is included here for information.

The mean DO flux from 2016 was 3.35 mg/L, which falls just below the river eutrophication standard. However, in 2017 the mean DO flux was slightly higher and closer to 3.5 mg/L. Both years showed abundant aquatic vegetation in the stream channel (Figure 20). As the chlorophyll-a results show, there was much more suspended algae present in 2016 compared to 2017. However, the stream never had a very "green" appearance, despite some of the high chlorophyll-a concentrations. It is possible that diatoms or other types of algae contributed to the condition observed. It is also likely that we did not see the same response in 2017 due to the mild summer and lack of production in the R-3 reservoir compared to 2016. However, the DO flux was slightly higher in 2017, which may be due to more aquatic macrophytes driving those DO conditions during that year.

Biologically, the percentage of sensitive fish species (SensitivePct) and tolerant species (TolPct) can be correlated to low DO, but also other stressors. There is response to these metrics for all the visits. The abundance of fish individuals where the females mature at greater than three years in age decreases with low DO conditions as well, and show a response for both visits. Similarly, the DO TIV scores were lower than the southern coldwater average for both visits, which indicate the community is generally more tolerant to low DO. Interestingly there is a difference in the serial spawning individuals (SSpnPct) between the two years. Serial spawning fish will often increase in low DO conditions. The opposite years responded when looking at the conditional probability for DO, with more favorable scores in 2015 compared to 2016 (Table 11).

Table 11. Fish metrics that respond to low DO/eutrophication compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	MA>3Pct	SSpnPct	TolPct	DO Index Score	Cond Prob for DO early AM (%)
15LM033 (June 10 2015)	**64**	**57**	**14.9**	21	**8.2**	95
15LM033 (June 28 2016)	**13**	**55**	1	**45**	**7.1**	**45**
Southern Coldwater Average	72	75	1.79	24	8.8	93
Expected response to stress	↓	↓	↑	↑	↓	↓

The macroinvertebrate metrics show a mixed response to low DO/eutrophication (Figure 25). While there were 7 and 10 low DO intolerant taxa in the samples, they did not make up a large percentage of the overall community. The number of low DO tolerant taxa varied between the years, but the number of individuals were abundant for both (Low DO Tolerant Pct). This is also reflected in the low DO index score, which is less than average for both visits. Taxa richness of collector-filterers (Collector-filtererCh), collector-gatherers (Collector-gathererCh) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) were showing minimal response. The phosphorus index score and tolerant percent were also above average for both visits, meaning the macroinvertebrate community was made up of many individuals that often sampled in streams with higher phosphorus level and tolerant to high phosphorus.

Figure 25. Macroinvertebrate metrics that respond to DO/eutrophication stress in South Fork Crooked Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT	Phosphorus Index Score	Phosphorus Tolerant Pct	Collector FiltererCh	Collector GathererCh
15LM033 (2015)	**6.6**	**7**	**30.4**	1	**6.3**	9	**0.106**	**5.9**	9	**10**
15LM033 (2016)	**7.1**	10	**29.1**	**4**	**10.9**	9	**0.112**	**7.7**	9	15
Southern Coldwater Streams Median	*7.6*	*10*	*56.1*	*1*	*0.6*	*6*	*0.102*	*4.7*	*5*	*11*
Expected response to stress	↓	↓	↓	↑	↑	↓	↑	↑	↓	↓

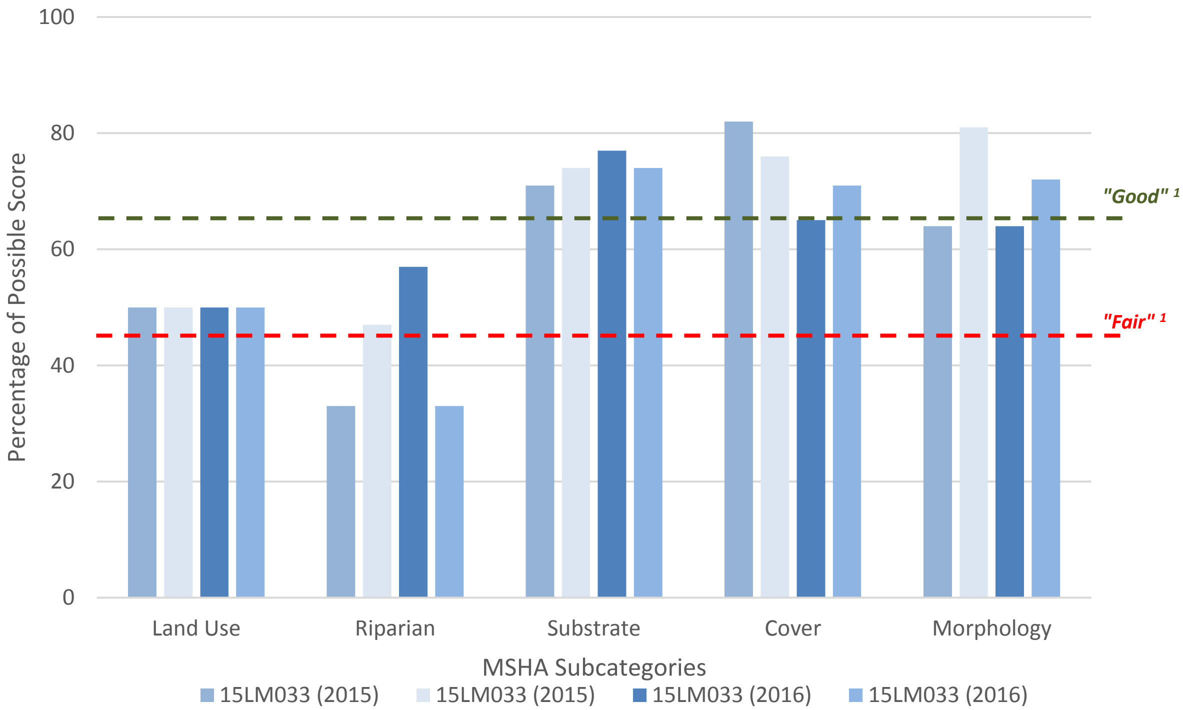
Overall, multiple lines of evidence point to low DO/eutrophication related stress in the South Fork Crooked Creek. The R-3 reservoir drives the oxygen dynamics, phosphorus/chlorophyll/BOD concentrations, and vegetation growth in the channel (Figure 26). Additionally, the biological response shows consistency among both fish and macroinvertebrate communities. Low DO and eutrophication are stressors to the South Fork Crooked Creek.

Figure 26. Photo of vegetation and algae at 15LM033, during fish sample on June 10, 2015.

Habitat

There were four visits that measured MSHA at 15LM033 (Figure 27). Three of the four scored “good”, with one scoring “fair”. Overall, the majority of the subcategory metrics scored well, with land use and riparian with the lowest scores. The open pasture, adjacent field, and some bank erosion are likely the reasons for the somewhat lower land use and riparian scores. Overall, the channel morphology was considered good, and the stream had multiple velocity types, good depth variability and channel stability. Light embeddedness was noted, but there was extensive cover and multiple substrate and channel types. Curly leaf pondweed was noted during the visits and is likely a result of the R-3 reservoir just upstream.

Figure 27. MSHA subcategory scores for four visits at 15LM033 in 2015 and 201



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Insectivores (e.g., darters and sculpins), simple lithophilic spawners, and riffle dwelling species require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes. The impaired reach shows decent percentages of simple lithophilic spawners, which is due to the presence of some more tolerant warmwater fish (Table 12). However, the only coldwater fish that are simple lithophilic spawners are sculpin, and they are not present in this location.

Detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006). The species richness of fish that are detritivores is represented as DetNWQPct (Table 12). All visits had a higher percentage of fish individuals that were detritivores. It is possible that due to the R-3 reservoir, with abundant algae and plant production, that decomposing organic matter is a common and available food source for these fish, thus increasing their abundance.

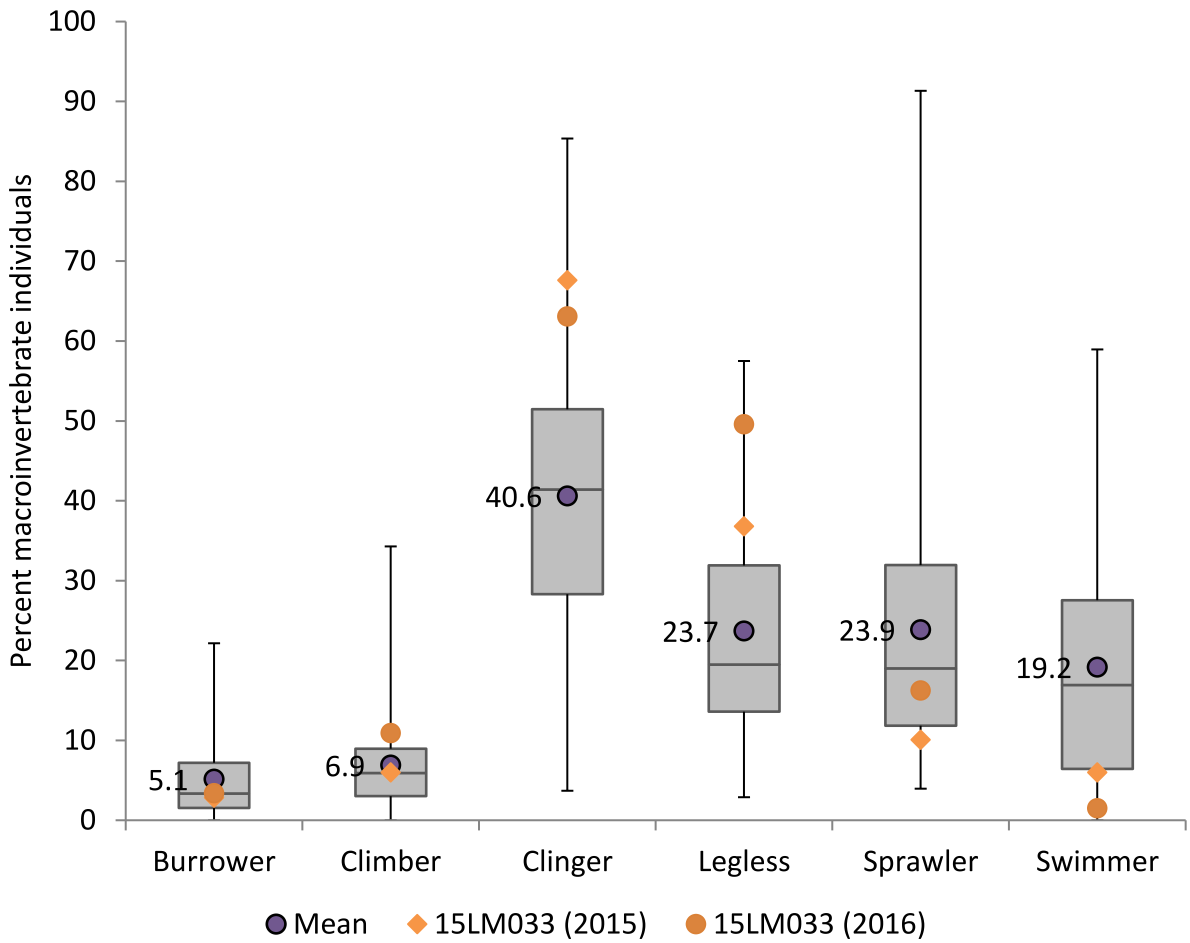
Pioneer fish species thrive in unstable environments, and are the first to invade a stream after disturbance. They were found to be low in abundance in this reach, which is considered good. However, Piscivores were found in somewhat reduced abundance at these two visits compared to the statewide average of 50%. Piscivores generally require good substrate, and good pool habitats for predator-prey relationships. Their reduction could be explained by other stressors, like temperature. Riffle dwelling species had percentages above the average for both visits.

Table 12. Fish metrics that can respond to habitat stress for station 15LM033.

Station (Year Sampled)	SLithopPct	PioneerPct	DetNWQPct	PiscivorePct	RifflePct
15LM033 (2015)	48.9	0	**21.3**	36.2	51.1
15LM033 (2016)	46.0	1	**44.0**	52.0	46.0
Southern Coldwater Average	*21.1*	*4.79*	*15.4*	*53.5*	*34.8*
Expected response to stress	↓	↑	↑	↓	↓

The dominant macroinvertebrate habitat noted during biological surveys was riffles and overhanging vegetation/macrophytes. Burrowers and climbers were found near averages; while swimmers and sprawlers were slightly lower than average (Figure 28). There was an abundance of clingers (good) and legless individuals in the sample (not good). Legless individuals are often tolerant midges that would be common in a stream with low DO/eutrophication issues. Additionally, the number of EPT taxa in this reach is higher than average. EPT taxa are commonly examined due to their sensitivity to many stressors including habitat. Overall most of the macroinvertebrate metrics do not point to habitat causing stress (with the exception of legless individuals) and their relative abundance can likely be attributed to other stressors (DO/eutrophication).

Figure 28. A comparison box plot of macroinvertebrate habit metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.



The DNR completed a geomorphology survey at 15LM033 in 2015. Evidence collected during that survey points to the reach being in a geomorphic stable condition. Riffles and pools of this reach, along with large particles and aquatic vegetation aid in channel stability while also providing good habitat. The upstream R-3 reservoir is estimated to reduce 1,400 tons of sediment per year to this reach.

Overall, the available habitat in this reach appears to be suitable. The geomorphology survey supports a stable stream condition with good habitat overall. Overall, there is very little suggestion in the habitat metrics for fish and macroinvertebrates that habitat is the reason for the impairment, and therefore lack of habitat is not a stressor to the South Fork Crooked Creek.

Connectivity/fish passage

A reservoir (called R-3) is located at stream mile 1.42 on the South Fork Crooked Creek and was built in 1971 (Figure 29). The reservoir warms the lower end of the South Fork but also provides a warmwater fishery in the reservoir for those interested in largemouth bass, black crappie, bluegill and channel catfish. R-3 has its own management plan by DNR. Fish in the lower end of the South Fork Crooked have access to smaller spring tributaries, in addition to the mainstem of Crooked Creek. Over half of the community found at 15LM033 are considered migratory species. Overall, fish would be restricted to the smaller reach only downstream of the reservoir (1.42 miles) and do not have free access to the entire stream length and other habitats due to the reservoir. It appears the main impacts from R-3 are temperature and chemical changes, which together are stressing the biology and causing impairment downstream.

The R-3 reservoir is making impacts to the reach via multiple stressors and the overall impacts to related to fish passage aren't clear. Connectivity is inconclusive as a stressor since it cannot be confirmed nor completely ruled out.

Figure 29. Photo of R-3 reservoir taken in October 2017.

Summary

The stressors contributing to the fish and macroinvertebrate impairment in the South Fork Crooked Creek are temperature and DO/eutrophication. Overall, the evidence points to the R-3 reservoir as the main cause. Higher stream temperature and low DO/eutrophication are significant impacts, all caused by the reservoir. Simultaneous monitoring upstream and downstream of the reservoir show that without the R-3 reservoir, the stream at the biological station would be on average 5°C, and up to 10°C cooler depending on the time of year. Similarly, low DO was not observed upstream of the reservoir in the same monitoring period it was observed downstream of the reservoir. These all support significant effects the R-3 reservoir has on the stream. Additionally, the R-3 reservoir alters stream flow to the South Fork Crooked Creek, but it is not clear what impacts that flow alteration directly has on the biology; it is more likely showing itself in the other stressors identified. The DNR management plan for the South Fork Crooked Creek shows that overall trout populations **above** the R-3 reservoir have been doing well and brook trout stocking has been successful in establishing natural reproduction. In 2015, brook trout were not present downstream at the biological station, and in 2016, one brook trout was sampled. It is assumed the brook trout migrated from a nearby spring tributary. It does not appear that brook trout are reproducing nor flourishing downstream of the reservoir in the impaired reach, while they seem to be doing well upstream of the reservoir.

The reservoir also affects the DO regime of the South Fork Crooked Creek. DO concentrations were consistently found below the coldwater standard downstream of the reservoir while monitoring during the same period upstream of the reservoir, did not see the same results. In 2017, it appears production of suspended algae was lower in the R-3 reservoir compared to 2016 (lower concentrations of chlorophyll-a in samples from 2017), but macrophytes and aquatic vegetation were still abundant throughout the stream. Temperature differences between the upstream and downstream sites are the likely reason for the low DO observed downstream since cold water upstream can hold more oxygen. Overall, there were large differences between the 2016 and 2017 monitoring data for oxygen, phosphorus, and chlorophyll-a. These all suggest chemistry downstream is highly dependent on conditions of the reservoir and overall climate/hydrologic conditions. In addition, overall the phosphorus concentrations were much higher in 2016. At this time, this stream does not have enough information to forward with a river eutrophication assessment (the available data shows conflicting results across the two sampling years and would require additional samples to complete an assessment). The data does show that the conditions are highly variable due to the reservoir, and are contributing to biological stress on the downstream reach. Additional information to understand this seasonal and yearly variability would be helpful.

The Caledonia Wastewater Treatment Plant that discharges in the headwater area of this stream, which sinks underground after the discharge point. Sampling at Esch Road confirmed this is the case; the streambed was dry during most months of sampling, except for early spring. When flowing water was present, sampling showed a definite wastewater signature (i.e. high conductivity). However, sampling downstream showed that most of the wastewater had been diluted and was not contributing high concentrations of nutrients to the reservoir. It would be beneficial to understand where the wastewater is sinking underground and resurfacing (via dye tracing). Farther downstream, there are many springs that begin the perennial flow of the South Fork Crooked and DNR has documented a reproducing brook trout population as well, which does indicate good water quality. It would also be useful to get more information on the eutrophic conditions within the reservoir itself. Overall, additional information are needed to understand nutrient sources and dynamics in the South Fork Crooked Creek and the R-3 reservoir as current data shows they can be highly variable.

Despite the stressors present on this stream, the coldwater fish community is close to meeting the fish IBI goal, scoring just a couple points below impairment threshold. The macroinvertebrates did show more of a response during one of two sampling years. Climate and the varying condition (i.e. degree of eutrophication from year to year and temperatures) of the upstream reservoir are likely influencing the variability of the biological sample results.

Nitrate and habitat do not appear to be causing stress to biology in the South Fork Crooked Creek. Additionally, TSS and connectivity could not be confirmed nor ruled out as stressors, and are inconclusive.

4.3. Clear Creek 07060001-524

Biological and background information

Clear Creek is impaired for macroinvertebrates. There was one macroinvertebrate sample taken at station 15LM036 in 2015 (See location in Figure 3).The stream is designated macroinvertebrates class 6 (Southern Forest Streams Glide/Pool) with an impairment threshold of 43. The sample scored below the general use threshold, within the lower confidence interval (score of 30.1). Both in-stream habitat, as well as riparian conditions were relatively poor at this location and upstream (Figure 31). The stream bed was primarily sand and silt. Physella (snail) was the dominant taxa present. The presence of a few coldwater taxa suggests the influence of springs on this station. The majority of MIBI metrics scored poorly, indicating a degraded community is present (Figure 30). Taxa richness of clingers (ClingerCh), relative abundance of dominant five taxa in subsample (DomFiveChPct), taxa richness of macroinvertebrates with tolerance values less than or equal to 2 using MN TVs (Intolerant2Ch), taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET), taxa richness of predators (PredatorCh), total taxa richness (TaxaCountAllChir), and relative abundance of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct) all scored below the average needed to meet the threshold (Figure 30). The only metric that scored well was the relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct). The fish community, with only two species sampled (spottail shiner and central mudminnow) also characterizes degradation. However, the fish community was not officially assessed due to proximity to the Mississippi River and its potential influence.

Figure 30. Macroinvertebrate metrics for Clear Creek 0704006-524, from one station in 2015.

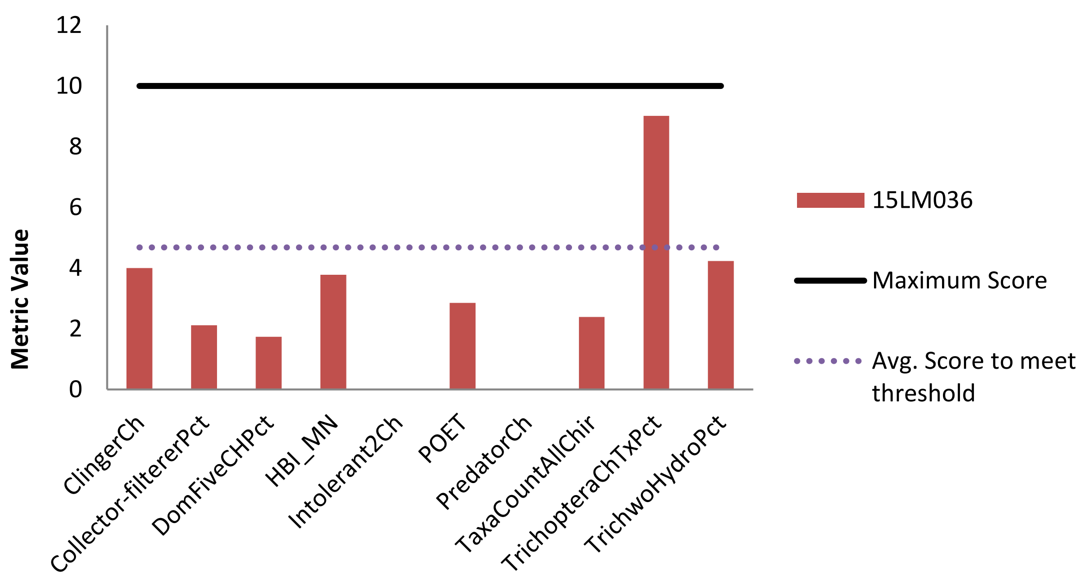


Figure 31. Pasture upstream of 15LM036 on April 17, 2017, looking upstream into the small and steep watershed valley.

Temperature

In the summer of 2015 and 2017, a temperature logger was placed at 15LM036 to gather temperature data throughout the season (Figure 32 and Figure 33). The maximum temperature measured during the 2015 season was 24.2 °C. The July and August temperature averages were 16.5°C and 15.9°C respectively. The maximum temperature measured during the 2017 season was 23.1 °C. The July and August temperature averages were 16.4°C and 14.9°C respectively.

Figure 32. Temperature data collected at 15LM036 in 2015.

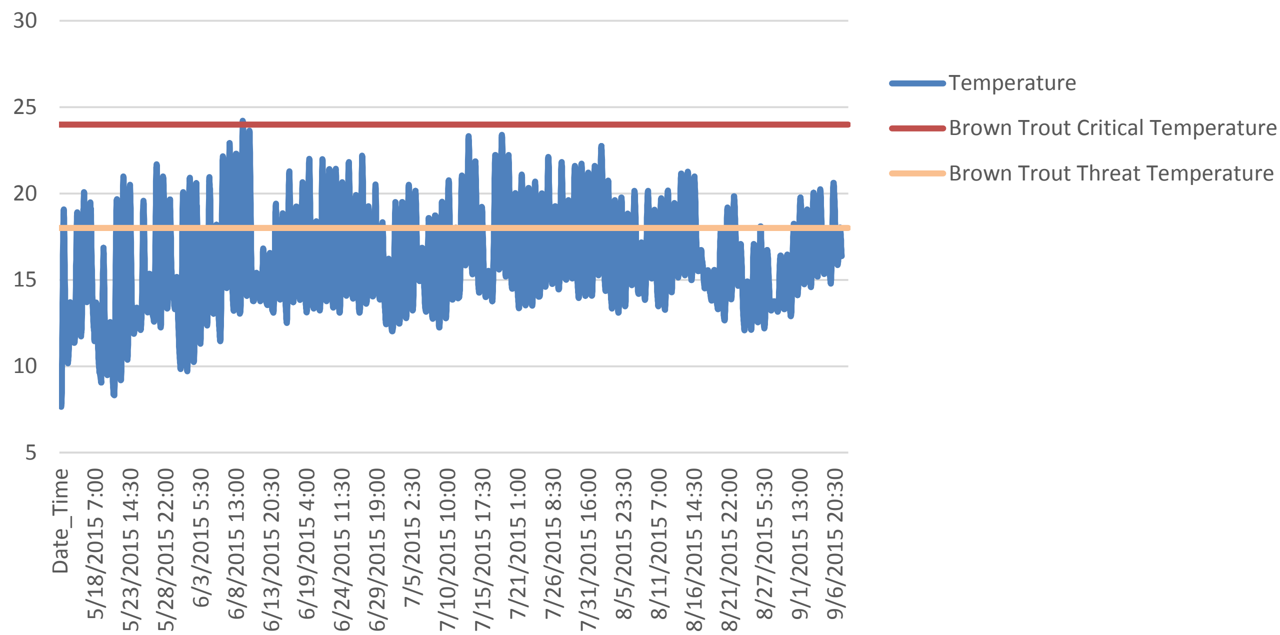
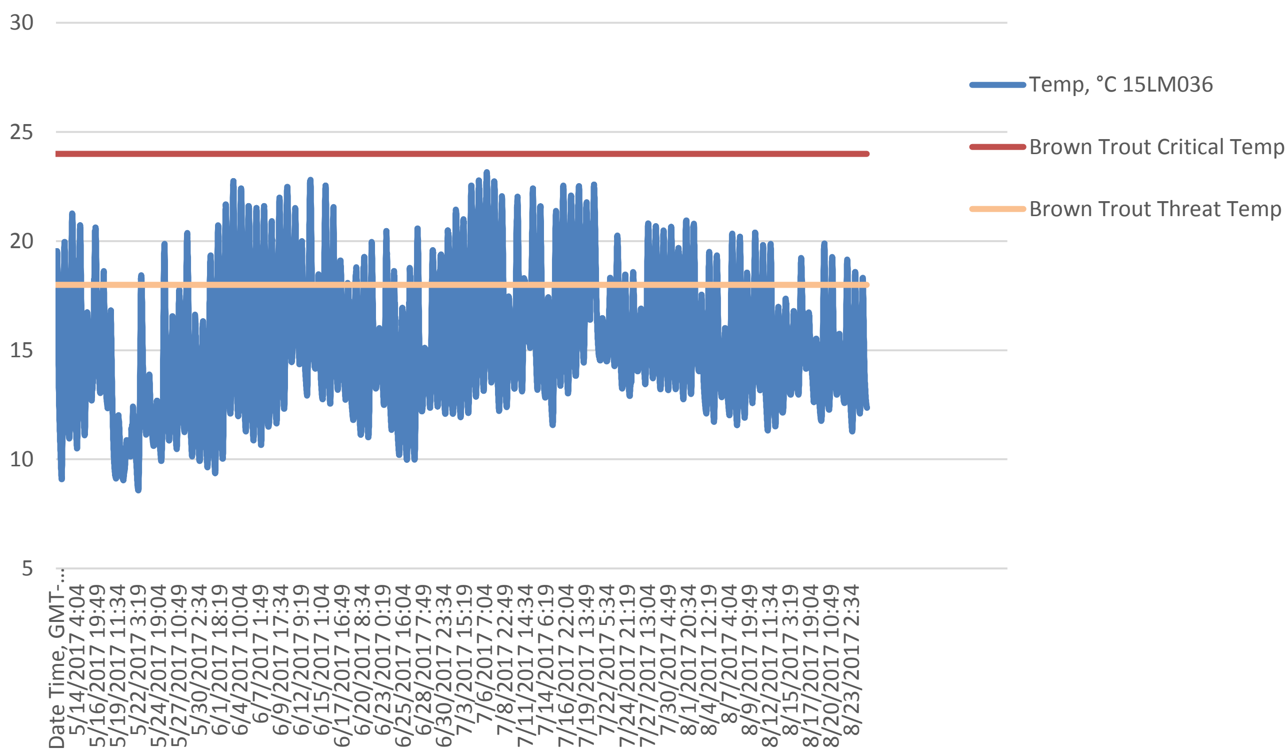


Figure 33. Continuous temperature data collected at 15LM036 in 2017.



DNR characterizes this stream as a "coldwater feeder" and the long range goal is to protect it as such. They sampled trout in their surveys from 1990, 2000 and 2016 (albeit only a few young of year). MPCA did not have trout in the biological sample from 2015. DNR measured temperatures in August, and noted summer max temperatures were adequate for trout but physical habitat was severely limited. Temperatures were limited by ponds, beaver dams, and lack of cover. There were 693 brook trout stocked in this stream in 1981. Beaver dams were also noted on 2015 google earth imagery approximately 1 mile upstream of the biological monitoring site. These same beaver dams were blown out in 2016 (Figurer 41). It is possible beaver dams were impacting the temperature logger readings for the 2015 season. The 2017 data did show lower temperatures overall, but air temperatures were generally lower too. The maximum temperature from the 2017 deployment was 23.1 degrees C on July 6, 2017. The July average temperature from 2017 was 16.4 degrees C, which is in line with many other coldwater streams in SE MN. There wasn't information to confidently make a change to coldwater during this assessment, but this stream shows all the signs it has coldwater potential yet is severely degraded.

Figure 34. Headwater seeps/springs, April 2015

Figure 35. Photo from August 2016 at 15LM036 showing significant watercress and vegetation growth in stream channel.

Currently, there are many factors that indicate this stream has coldwater potential and could be assessed as such. The headwater area does appear to be sourced by springs/seeps (Figure 34), and farther downstream abundant watercress is found at the monitoring station (Figure 35), which also indicate coldwater inputs. With more shade to the stream channel and better riparian management, it is possible the temperature could be improved. The evidence indicates that there are coldwater inputs that can likely sustain a coldwater thermal regime in this stream. At this time, temperature cannot be confirmed or ruled out as a stressor given the current question in its classification and is inconclusive as stressor.

Nitrate

Nitrate concentrations in Clear Creek are some of the lowest in the region. There were 16 nitrate samples overall, from 2016 and 2017. The samples represented a range of conditions, and most were evenly distributed over the 2016 and 2017 summer monitoring periods. Of those samples, the average nitrate concentration was 0.8 mg/L, with a maximum of 1.1 mg/L.

The macroinvertebrate metrics in Clear Creek show false indications of nitrate related stress (Table 13). Within the impaired reach, there was an average number of Trichoptera (caddisfly) taxa, who are often considered sensitive to elevated nitrate, but also commonly respond to other stressors like habitat degradation (TrichopteraCh). Non-hydropsychid Trichoptera (TricwoHydroPct metric) showed a response as these are often more sensitive caddisflies. The nitrate index score, which is meant to characterize the overall community's tolerance to high nitrate, is significantly higher than average at 6.57. Nitrate tolerant taxa were right at the average. However, the abundance metric (Nitrate Tolerant Pct) did indicate they were quite abundant making up almost the entire community. There was zero nitrate intolerant taxa present as well.

The dramatic biological response to nitrate makes it appear as if the macroinvertebrates are responding to nitrate. However, the nitrate concentrations simply do not corroborate those conditions. The biological response in nitrate is likely explained by over half of the community being Physella (snails) that are very tolerant to high nitrate among many other stressors like poor habitat. The reality is that the biology is responding to other stressors, and has created a false response due to the domination of snails. Nitrate is not a stressor to Clear Creek.

Table 13. Macroinvertebrate metrics that respond to nitrate stress in Clear Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct	TrichopteraCh	TrichwoHydroPct
15LM036 (2015)	**6.57**	**0**	18	**89.26**	4	**1.8**
Southern Forest Streams Median	*3.0*	*2*	*18*	*67.3*	*4*	*2.3*
Expected response to stress	↑	↓	↑	↑	↓	↓

Total suspended solids

The grab sample result during fish sampling (7.6 mg/L) was well below the TSS standard for the southern region (65 mg/L). There were 16 additional samples for TSS taken from the impaired reach during monitoring in 2016 and 2017. The average TSS concentration of those samples was 52 mg/L, below the standard of 65 mg/L for warmwater streams in the central region. The maximum concentration was 250 mg/L, taken on September 7, 2016. Only 3 samples (of the 16) exceeded the standard of 65 mg/L. However, these exceedances occurred when the stream was sampled during or immediately following a significant rainfall event. If this stream were assessed as coldwater, with a TSS standard of 10 mg/L, all but 2 samples exceed the standard.

Biologically, the TSS index score is much higher than average, which demonstrates a higher tolerance to TSS based on the macroinvertebrate community composition (Table 14). Similarly, there are no intolerant taxa. However, the abundance of TSS tolerant species is high, making up 58% of the community. Physically, sedimentation does appear to be an issue in this stream, but given the current standards (warmwater, 65 mg/L) TSS does not show strong evidence as a driving stressor (chemically). Given the inconsistency within all the evidence, and possible use classification questions, TSS is inconclusive as a stressor to Clear Creek.

Table 14. Macroinvertebrate metrics relevant to TSS for stations in Clear Creek compared to statewide median for southern Forest Streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
15LM036 (2015)	**19.79**	**0**	**7**	**58.2**
Southern Forest Streams Median	*15.13*	*2.0*	*11*	*26.7*
Expected response to stress	↑	↓	↑	↑

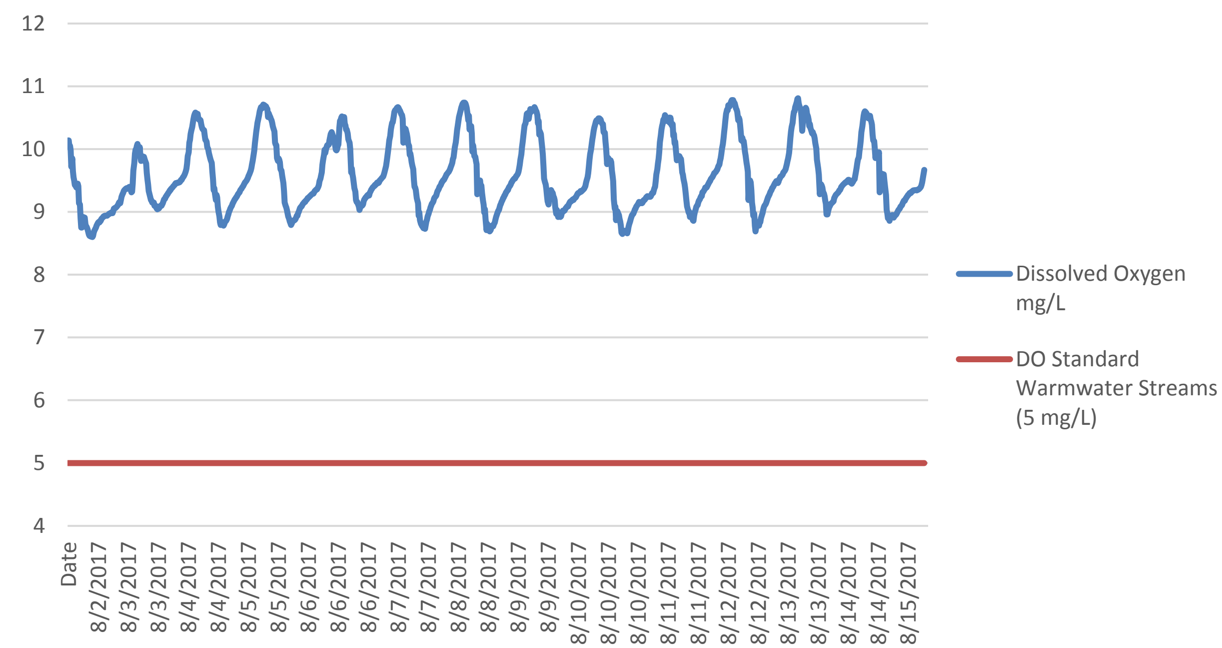
Dissolved oxygen/eutrophication

In 2016 and 2017, Clear Creek had a number of grab samples taken at 15LM036 (S009-026). None of them exceeded the warmwater DO minimum standard of 5 mg/L. However, these samples were not early morning samples (before 9 am; when DO levels are typically lowest). The lowest concentration observed during grab sampling was 9.50 mg/L from June 13, 2016. In 2017, a sonde was deployed at 15LM036 (8/2/17-8/15/17). Dissolved oxygen levels from that deployment were normal; no values exceeded the low DO standard of 5 mg/L (Figure 36).

Total phosphorus, DO flux, chlorophyll-a and BOD data can be used when looking closer at the potential for eutrophication and related DO issues. Total phosphorus concentrations exceeded the Central River Nutrient standard (0.100 mg/L) only once with an average concentration of 0.06 mg/L for 16 samples collected in 2016 and 2017. The sole TP exceedance occurred following a storm event in September 2016. DO flux was also normal, at an average of about 3 mg/L (Figure 36).

Chlorophyll-a data was limited to two summer samples on this reach from 2016 and 2017. The concentrations ranged from 1.64-5.99 μg/L, which is very low compared to the standard of 18 μg/L and does not suggest suspended algae and eutrophication are a concern. On the same day as chlorophyll samples, BOD samples were also taken (1 mg/L in 2016 and 3.5 mg/L in 2017), which does show one exceedence (i.e. >2 mg/L is the standard for the central region). At the time of the second sample the stream was cloudy with slightly elevated TSS. Nitrates and phosphorus were both very low. Its possible grazing from upstream may have affected that particular sample.

Figure 36. Sonde deployment from August 2017 showing oxygen concentrations collected at 15LM036.



The macroinvertebrates in Clear Creek show minimal response related to DO/eutrophication stress (Figure 37). There are many low DO intolerant taxa and individuals and few taxa and low DO tolerant individuals, which are good indications that DO is likely sufficient here. This is also reflected in the higher DO index score, which is considered good or better than average. Taxa richness of collector-gatherers (Collector-gathererCh) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) were below the median for this type of stream, which may be explained by other stressors.

Figure 37. Macroinvertebrate metrics that respond to low DO and eutrophication stress in Unnamed Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

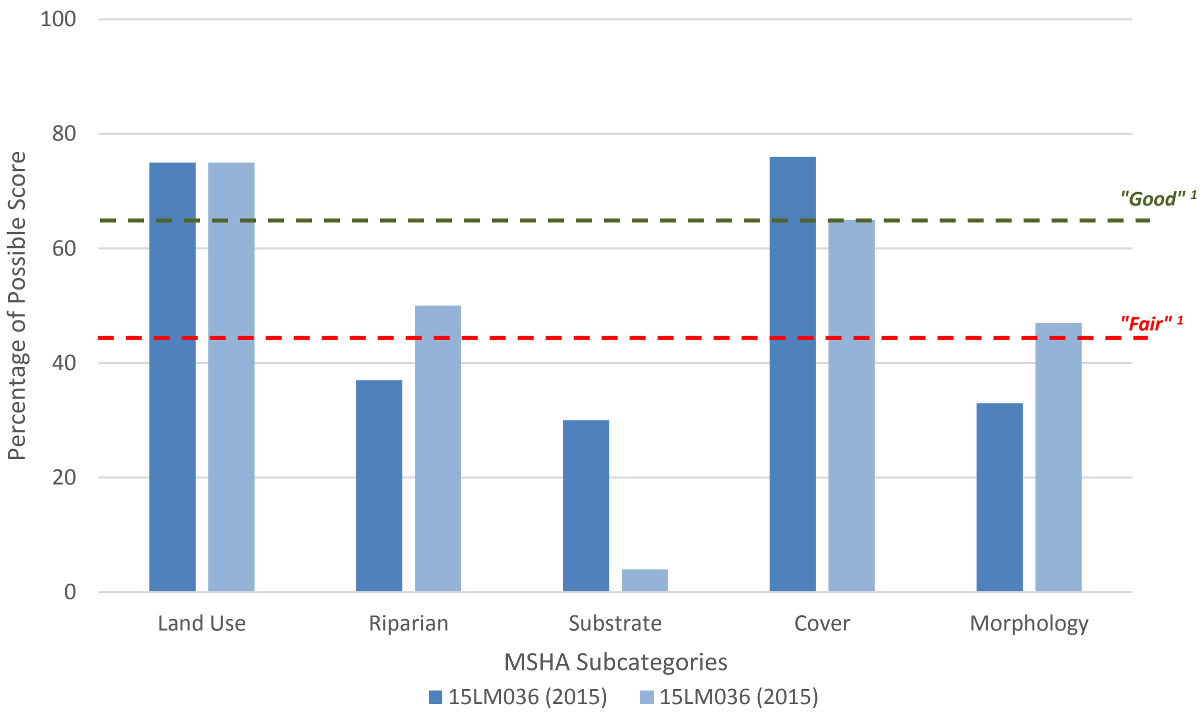
Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT	Phosphorus Index Score	Phosphorus Tolerant Pct	Collector FiltererCh	Collector GathererCh
15LM036 (2015)	7.2	5	16.3	4	2.1	**6**	**0.146**	**14.7**	6	**11**
Southern Forest Streams Median	*6.9*	*5*	*9.4*	*6*	*9.0*	*8*	*0.127*	*18.7*	*6*	*14*
Expected response to stress	↓	↓	↓	↑	↑	↓	↑	↑	↓	↓

Considering all of the DO evidence and the corresponding response variables, the data do not suggest eutrophication or low DO is occurring. The small amount of biological response is likely due to other stressors. Therefore, low DO and eutrophication are not stressors in Clear Creek.

Habitat

The MSHA scores for 15LM036 were both considered “poor”, scoring 42 and 40 in June and August of 2015. The subcategory metrics which scored the lowest were riparian and substrate (Figure 38). The stream was noted as having no course substrate or riffle, and was considered 80% run, 20% pool in June, and 100% run in August. Sand and silt were the two available substrate types, and heavy siltation was noted.

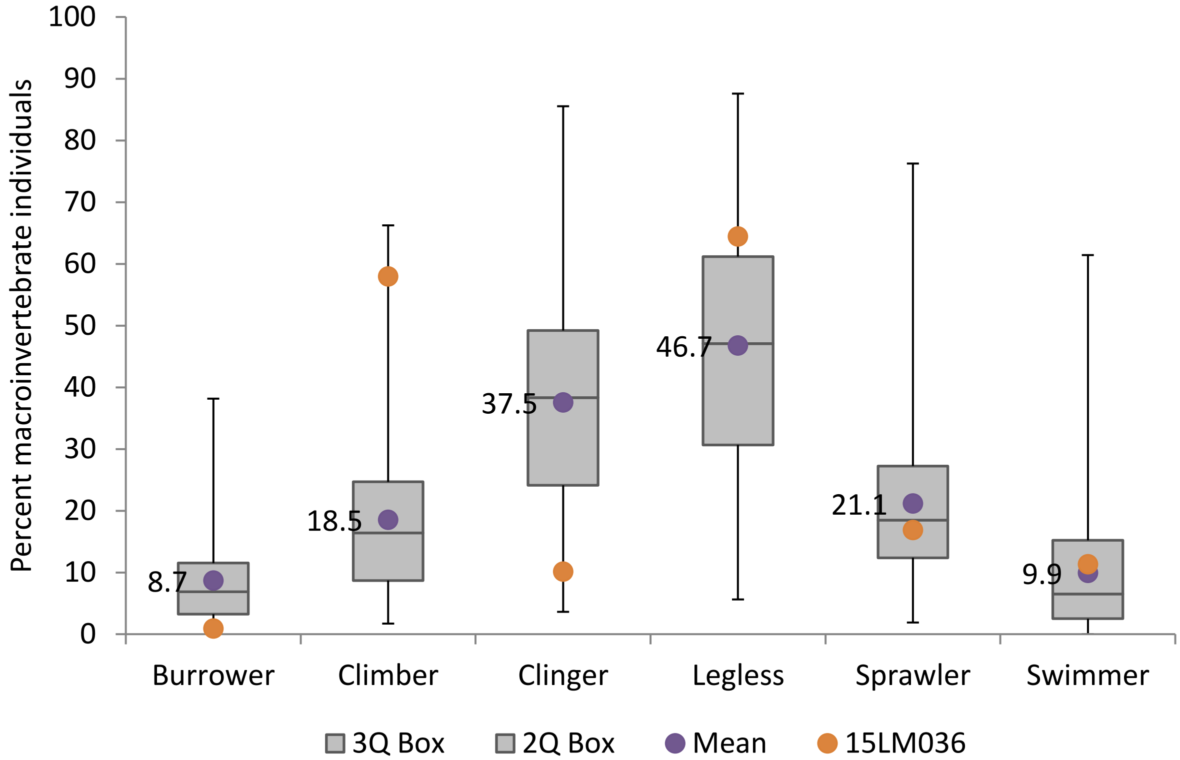
Figure 38. MSHA subcategory scores for two visits at 15LM036 in 2015



[1] The minimum percentage of each subcategory score needed for the station to achieve a “fair” and “good” MSHA rating.

The dominant macroinvertebrate habitat noted during biological surveys was aquatic macrophytes and overhanging vegetation. This sample showed that the macroinvertebrate community had few burrowers, while also having near average amounts of sprawlers and swimmers (Figure 39). However, there were reduced clinger individuals that are typically found in streams with ample amounts of woody debris and course substrates, which were not available at this site. The site did have a macroinvertebrate community consisting of an overabundance of legless and climber individuals. This is explained by the dominant invert *physella,* a tolerant snail. The quality and diversity of habitat types are limited in this reach and the biological metrics match, signaling a community being negatively impacted by the poor substrate and lack of diverse habitat. In addition, the percentage of EPT individuals was lower than average. EPT taxa are commonly used to measure overall health of ecosystems, due to their sensitivity to many stressors including habitat.

Figure 39. A comparison box plot of macroinvertebrate habit metrics representing the average macroinvertebrate class 6 stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.



The DNR completed a geomorphology survey downstream of the sampling location and road crossing. In that location the stream channel bed was dominated by the natural soil materials of fine sand and silt, which minimizes the habitat diversity for macroinvertebrates. In between the MPCA and DNR site is County 249, a four culvert crossing with the upstream side concreted in. The overall width of the crossing is 35 feet, while the bankfull width of the channel is around 11 feet, leading to over widening of the channel near the crossing (Figure 40). This crossing may cause sediment transport issues in the future and further impact habitat. Overall, the evidence strongly supports lack of habitat as a stressor in Clear Creek.

Figure 40. Over wide culvert at road crossing. MPCA image taken 5/10/15.

Connectivity/fish passage

Barriers like beaver dams can alter fish movement, but currently fish have not been assessed in this reach. Beaver dams have been documented in Clear Creek in the past, including one recent large beaver dam that was blown out in 2016 (Figure 41). Overall, there were very few fish found at this station, but it is not clear if that is due to a fish passage issue or other stressors. At this time, connectivity and fish passage are not stressors to the biology or contributing to the macroinvertebrate impairment. However, if fish are assessed later on, fish passage should be assessed to ensure it is adequate.

Figure 41. MPCA photo taken from 10/13/2016. Evidence of beaver dams that were blown out upstream following rain event in September.

Summary

The main stressor contributing to the macroinvertebrate impairment in Clear Creek is lack of habitat. The dominant substrate in the reach was silt and sand, with no coarse substrate. The quality and diversity of habitat types are limited in this reach and the biological metrics match, signaling a community being negatively impacted by the poor substrate, sedimentation, and lack of diverse habitat. Excessive pasturing throughout this stream is likely contributing to the poor habitat conditions and stream bank instability.

Both TSS and temperature were inconclusive because they require additional information and both suggest they could be important factors in the future health of this stream. TSS concentrations were moderate, but not exceeding the warmwater standard significantly. There was a mixed biological response pointing to high TSS as a possible stressor. This is also likely due to the heavy sedimentation and siltation noted in the reach. The link between the habitat issues and TSS may be needed for future consideration, especially if the stream changes its thermal classification to coldwater as coldwater species would be more sensitive to the TSS concentrations.

Temperatures do show suggestion of coldwater potential in this stream. The DNR characterizes this stream as a “coldwater feeder” and the long-range goal is to protect it as such. They sampled trout in their surveys from 1990, 2000 and 2016 (albeit only a few young of year). With more shade to the stream channel and better grazing management, this streams temperature could be improved. It appears that coldwater inputs are sufficient to sustain a decent thermal regime in this stream.

Nitrate concentrations are very low in this stream, and DO levels are adequate and do not suggest low DO or eutrophication stress. Connectivity issues are not currently an issue for the macroinvertebrate community, but the over wide crossing near the biological station could be a future issue for connectivity and sediment transport and may need additional consideration especially if the fish are assessed or impaired later on.

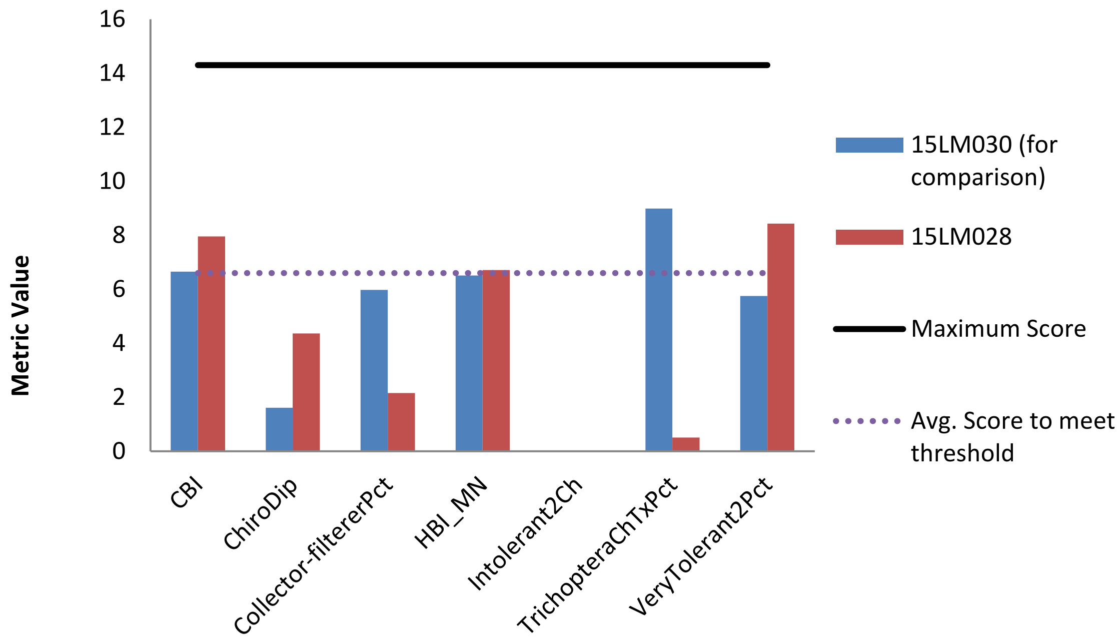
4.4 Winnebago Creek 07060001-693

Biological and background information

Winnebago Creek is impaired for macroinvertebrates. There was one macroinvertebrate sample at 15LM028 in 2015, which is at the lower end of the watershed (location in Figure 3). The sample scored below the southern coldwater general use threshold (MIBI of 30, threshold of 41). Low diversity of coldwater taxa likely had an impact on the low MIBI score at this location. The relatively poor in-stream habitat (namely lack of coarse substrate), does not lend itself to high quality macroinvertebrate communities. Given the location of this station in the watershed, it is likely that coarse substrates are uncommon, and locations upstream have more course substrate. This is the case at 15LM030 which had a slightly higher MIBI score and many more coldwater species present. Additionally, the presence of woody debris would likely also boost the score at 15LM028.

Overall, the IBI metrics all had average to low scores (Figure 42). Taxa richness of macroinvertebrates with tolerance values less than or equal to two using Minnesota TVs (Intolerant2Ch) scored zero, indicating few intolerant taxa were present. Similarly, the ratio of Chironomidae abundance to total Dipteran abundance (ChiroDip), and percentage of collector filterers (Collecter-FiltererPct) scored low. The Coldwater Biotic Index score (CBI), a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), the relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct), and the relative abundance of macroinvertebrate individuals with tolerance values equal to or greater than eight using MN TVs (VeryTolerant2Pct) all scored near the average needed to meet the MIBI threshold.

Figure 42. Macroinvertebrate metrics for Winnebago Creek 0704006-693, from two stations, using upstream station (15LM030) to compare to downstream impaired station 15LM028.

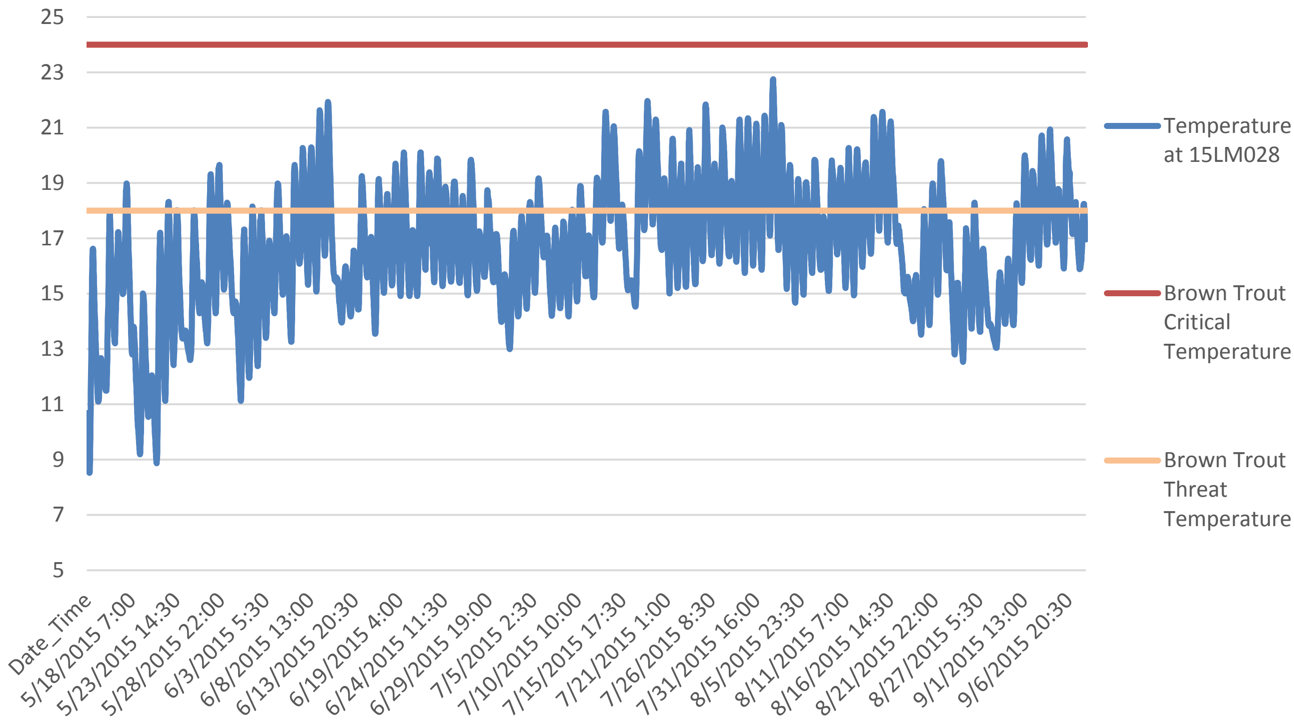


The fish at this station score above coldwater impairment thresholds and are not impaired. Brown trout were the second most abundant fish in the sample with 39 individuals. Longnose dace and a rainbow trout were also collected. Some river species were collected, but overall they were not in high abundance. It is not surprising to see larger river species at this lower site due to its proximity to the Mississippi River. In contrast, station 15LM030 in the upper part of the watershed (not in the impaired reach) was dominated by brown trout and slimy sculpin.

Temperature

In the summer of 2015, a temperature logger was placed at 15LM028 to gather temperature data throughout the season (Figure 43). The maximum temperature measured during that period was 22.7 °C. The July and August temperature averages were 17.4°C and 16.8°C respectively. These averages are typical for a stream with this drainage area and do not strongly suggest thermal stress.

Figure 43. Continuous temperature data collected at 15LM028 in 2015.



Biologically, the fish community in Winnebago Creek shows few coldwater fish species, but at the outlet of the watershed, and with a larger drainage area, we would naturally expect fewer coldwater fish species. Trout abundance (or lack thereof) can indicate thermal degradation among other stressors. The percentage of coldwater fish species at 15LM028 was only 10%, while most coldwater streams in the area have around 50% coldwater fish species present. Similarly, coldwater sensitive fish species and native coldwater fish species were not abundant. The fish community does also show a mix of species due to proximity to the Mississippi River and a dominance of white sucker. While fish often provide a good indication of thermal regime in a stream, coldwater macroinvertebrates are also an important consideration, especially in this case because macroinvertebrates are impaired. The CBI score (coldwater biotic index) metric for macroinvertebrates was near the average needed to meet the IBI threshold (Figure 42). This shows that coldwater macroinvertebrates were moderately abundant and diverse. Given the temperature data which shows a good thermal regime, and fairly abundant coldwater macroinvertebrates, temperature is not limiting the biology in this location and they are responding to other stressors present.

Nitrate

Nitrate concentrations in this section of Winnebago Creek are fairly low compared to others in the region. There were 82 nitrate samples overall, taken from 2009, 2015, 2016 and 2017. The samples represented a range of conditions, and most were evenly distributed over the 2009, 2015, 2016 and 2017 monitoring periods. Of those samples, the average nitrate concentration was 2.8 mg/L, with a maximum of 3.6 mg/L. Samples taken upstream of this reach near 15LM030 were actually higher (around 5.4 mg/L for an average; 20 samples in 2016/2017) suggesting possible dilution from groundwater sources lower in nitrate when moving downstream into this impaired reach. Therefore, it is likely the nitrate contributions to this reach are mainly sourced from upstream headwater areas and springsheds where there are more cultivated crops.

The macroinvertebrate metrics for Winnebago Creek do show consistent indications of nitrate related stress (Table 15). Within the impaired reach, there was reduced Trichoptera (caddisfly) taxa, which are often considered sensitive to elevated nitrate, but also commonly respond to other stressors like habitat degradation (TrichopteraChTxPct). The nitrate index score, which is meant to characterize the overall community's tolerance to high nitrate, is higher than average, which indicates stress. Similarly, nitrate tolerant taxa and abundance were both greater than average, demonstrating many nitrate tolerant taxa and individuals in the sample. There was zero nitrate intolerant taxa present.

There is a strong biological response to nitrate concentrations, but chemical data shows fairly low concentrations. Upstream, where macroinvertebrates are not impaired, nitrate concentrations are higher and a similar biological response is occurring (See Table 15 for comparison; 15LM030). It is likely the better habitat conditions in that reach are helping the community thrive despite higher nitrate concentrations.

In the impaired reach of Winnebago Creek, the macroinvertebrates are potentially subjected to multiple stressors that are having a cumulative impact on the community. Nitrate may be making some impacts on the community in this reach, but it is not likely the driving stressor. It is difficult to rule out completely given the amount of biological response observed. It is not clear if the response could be attributed to the other stressors or if nitrate is causing the response. Due to the mix of response compared to chemistry data, nitrate is inconclusive as a stressor to Winnebago Creek.

Table 15. Macroinvertebrate metrics that respond to nitrate stress in Winnebago Creek compared to the statewide average of visits meeting the coldwater biocriteria. Bold indicates metric value indicative of stress. Station 15LM030 is not impaired but included for comparison purposes.

Station (Year sampled)	TrichopteraChTxPct	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
15LM028 (2015)	**6.89**	**3.79**	**0**	**16**	**79.75**
15LM030 (2015)	**17.2**	**3.84**	**0**	**20**	**65.20**
Southern Coldwater Average	*17.3*	*3.04*	*1.35*	*14.29*	*60.79*
Expected response to stress	↓	↑	↓	↑	↑

Total suspended solids

The grab sample results during fish sampling at 15LM028 had one result below the TSS standard (8 mg/L). There were 29 additional samples for TSS taken from the impaired reach during monitoring in 2009, 2015, 2016, and 2017. The average TSS concentration of those samples was 20 mg/L, which is above the standard of 10 mg/L for coldwater streams. The maximum concentration was 98 mg/L, taken at 15LM028 in June of 2009. Twenty-two samples (of the 29) exceeded the standard of 10 mg/L. During assessment, TSS was determined as non-supporting aquatic life use and listed as impaired. Additional longitudinal sampling took place in Winnebago Creek in 2016 and 2017 to understand relative concentrations of TSS throughout the watershed. Samples taken on the same days, at three sites throughout the watershed, show dramatic differences in sediment concentrations (Figure 44 and Figure 45). The farthest site downstream (S005-495; 15LM028) represents the impaired AUID in this report and shows many more exceedances of the TSS standard compared to the other sites upstream when sampled on the same day.

Figure 44. Longitudinal TSS sampling from three sites in Winnebago Creek in 2016 and 2017. Samples for each of the three sites were taken on the same day for comparison purposes.

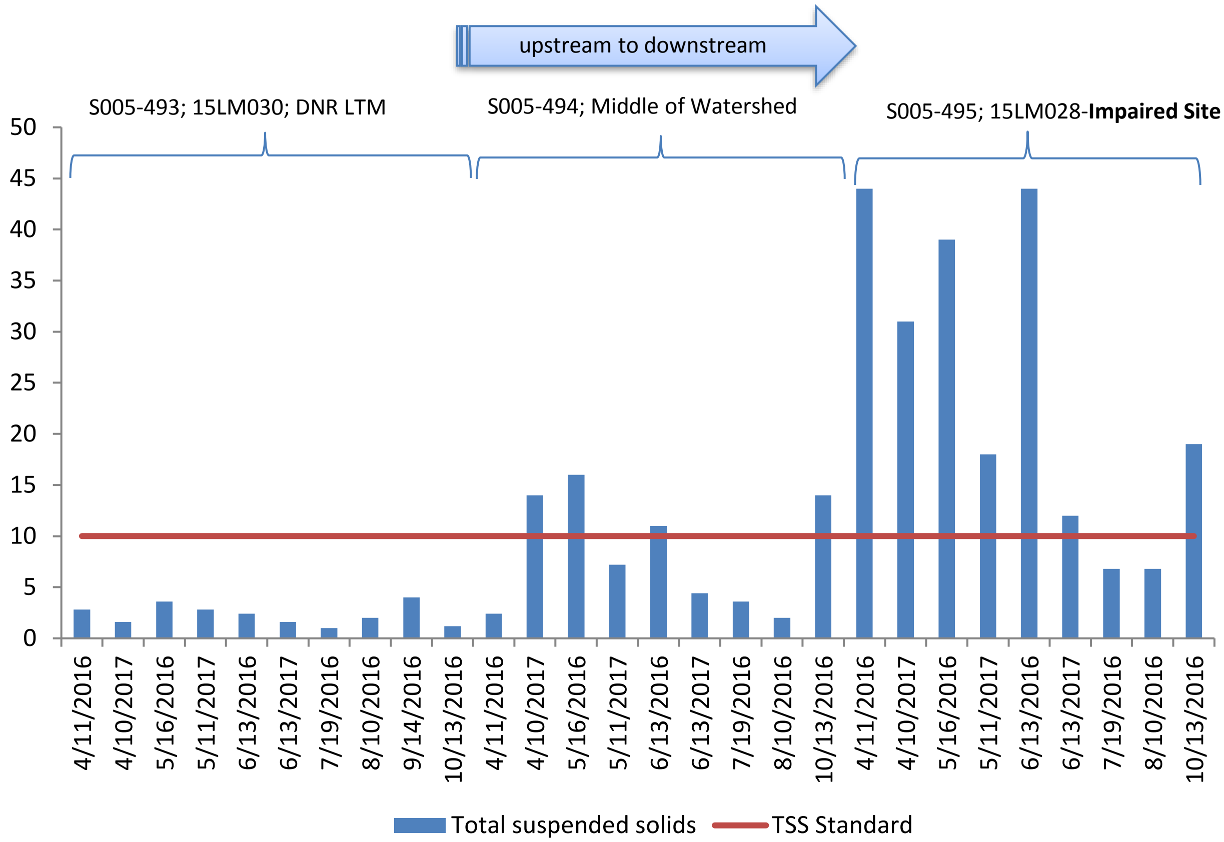
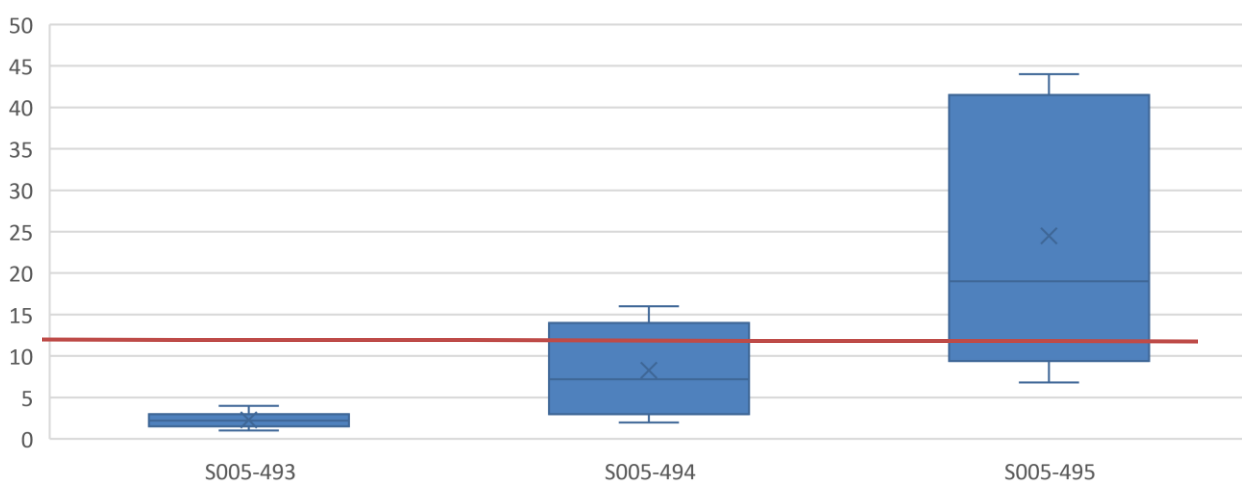


Figure 45. TSS concentrations (mg/L) from 27 samples taken longitudinally (upstream to downstream) at 3 sites in Winnebago Creek in 2016 and 2017. Samples were collected during both years, mainly baseflow conditions. Stations are organized upstream to downstream, which shows increases in TSS moving downstream in the impaired AUID (S005-495). The red line (10 mg/L) indicates the TSS standard for coldwater streams. S005-495=15LM028; Impaired Site, S005-493=15LM030; DNR LTM Site, not impaired.



Biologically, the TSS index scores demonstrate a higher tolerance to TSS based on the macroinvertebrate community composition at both sites in Winnebago Creek. Similarly, there are fewer intolerant taxa at the impaired downstream station (15LM028) compared to the non-impaired station (15LM030) and more tolerant taxa and individuals moving downstream. These results provide consistency in the evidence and shows macroinvertebrates are showing response to elevated TSS throughout Winnebago Creek with the more prominent response in the impaired reach. When moving downstream into the impaired reach, bank erosion becomes common and could be a large source of the additional sediment (Figure 46 and Figure 47). TSS is a stressor to Winnebago Creek and actions should be taken to reduce TSS throughout the Creek.

Table 16. Macroinvertebrate metrics relevant to TSS for stations in Winnebago Creek compared to statewide averages for southern coldwater stations meeting impairment threshold. Station 15LM030 is not impaired, bur father upstream and included for comparison purposes. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress. Red line indicates TSS standard of 10 mg/L.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
15LM028 (2015)	**16.92**	**1**	**9**	**28.97**
15LM030 (2015)	**14.69**	**3**	**4**	**15.98**
Southern Coldwater Median	*13.42*	*2.0*	*5*	*8.34*
Expected response to stress	↑	↓	↑	↑

Figure 46. Photo of stream bank erosion upstream of 15LM028 on 4/14/2017.

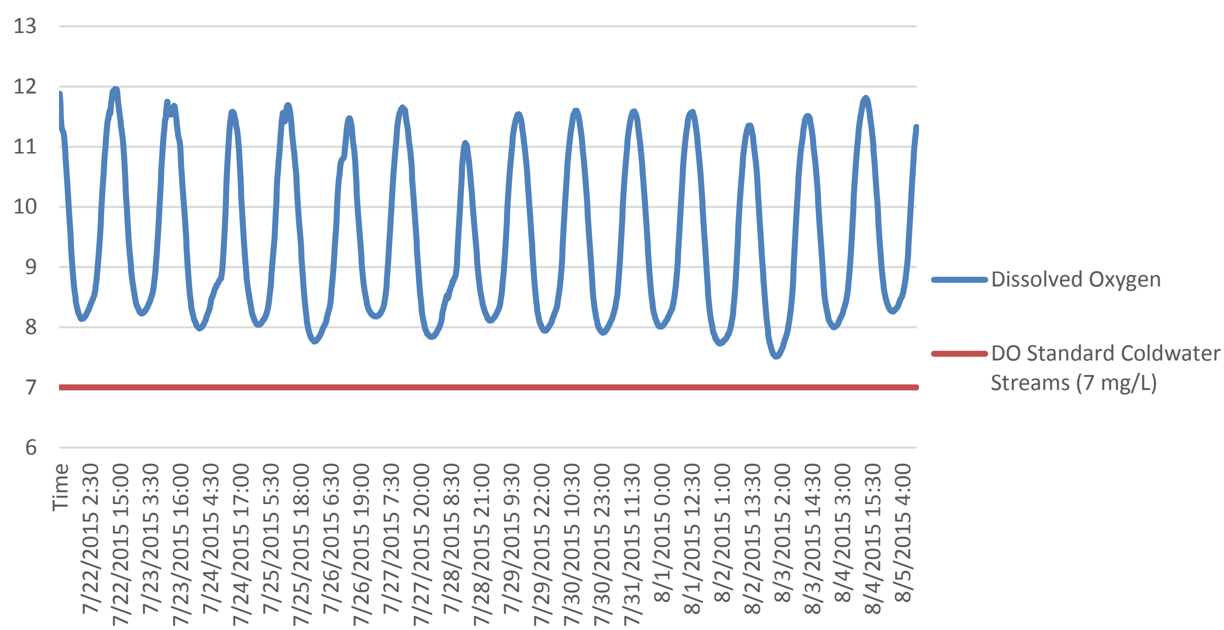
Figure 47. Photo of stream bank erosion and lack of buffer upstream of 15LM028 on 9/14/16. This is common upstream of 15LM028 and seen throughout the watershed.

Dissolved oxygen/eutrophication

In 2015, 2016 and 2017, Winnebago Creek had a number of grab samples (30) taken at 15LM028 (S005-495). None of them exceeded the coldwater DO standard of 7 mg/L. Seven of these samples were early morning samples (before 9 am; when DO levels are typically lowest). The lowest concentration observed during grab sampling was 8.7 mg/L from September 2, 2015. In 2015, a sonde was deployed at 15LM028 (7/22/15-8/5/15). Dissolved oxygen levels from that deployment were normal; no values exceeded the low DO standard of 7 mg/L. Additional early morning samples were available from a sonde deployment in 2015, and the lowest daily minimum during this deployment was 7.5 mg/L (Figure 48).

Total phosphorus, DO flux, chlorophyll-a and BOD data can be used when looking closer at the potential for eutrophication and related DO issues. Total phosphorus concentrations exceeded the Central River Nutrient standard (0.100 mg/L) once with an average concentration of 0.03 mg/L for 29 samples collected in 2009, 2015, 2016 and 2017. Chlorophyll-a data and BOD data were not available on this reach. DO flux was slightly elevated, at an average of about 3.7 mg/L (Figure 48). The DO standard flux for streams in the Central region is 3.5 mg/L.

Figure 48. Sonde deployment from July 2015 showing oxygen concentrations collected at 15LM028.



The macroinvertebrate metrics were mixed and don't show much difference compared to the site that isn't impaired farther upstream (Figure 49). Taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) was above the median both years. There were a few less low DO intolerant taxa at the impared site, but still comprised half of the community at both stations. There were two low DO tolerant taxa making up 2% of the community. The macroinvertebrate low DO index score was above the median while the non-impaired site had a low DO index score below the median. These results seem very comparable across the two monitoring sites.

Figure 49. Macroinvertebrate metrics that respond to DO stress in South Fork Crooked Creek compared to the statewide median of visits meeting the biocriteria. Bold indicates metric value indicative of stress. 15LM028 is the impaired site, while 15LM030 is farther upstream and not impaired; used here for comparison purposes.

Station (Year Sampled)	Low DO Index Score	Low DO Intolerant Taxa	Low DO Intolerant Pct	Low DO Tolerant Taxa	Low DO Tolerant Pct	EPT	Phosphorus Index Score	Phosphorus Tolerant Pct	Collector FiltererCh	Collector GathererCh
15LM028 (2015)	7.8	**7**	**50.1**	**2**	**1.9**	6	**0.110**	**8.4**	6	12
15LM030 (2015)	**7.4**	12	**50.8**	1	**11.6**	8	**0.113**	**14.1**	6	12
Southern Coldwater Streams Median	*7.6*	*10*	*56.1*	*1*	*0.6*	*6*	*0.102*	*4.7*	*5*	*11*
Expected response to stress	↓	↓	↓	↑	↑	↓	↑	↑	↓	↓

Considering all of the DO evidence and the corresponding response variables the data do not strongly suggest eutrophication or low DO is occurring. The biological response is more likely the result of other stressors. Therefore, low DO and eutrophication are not stressors in Winnebago Creek.

Habitat

The overall MSHA scores for Winnebago Creek, 15LM028 were both “fair”, with scores of 55 and 45. The subcategory metrics that scored poorly were the substrate and cover (Figure 50). The stream was noted as having no coarse substrate, and was considered 80%-100% run. Sand, clay and silt were noted as the substrate types (Figure 51). In August 2015 when the site was also sampled, it was noted as having no riffle or pool, had poor channel development and was noted as having adequate flow for riffle organism, but not suitable coarse substrate to support these organisms.

Figure 50. MSHA subcategory scores for 15LM028, Winnebago Creek (2 visits from 2015) [1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

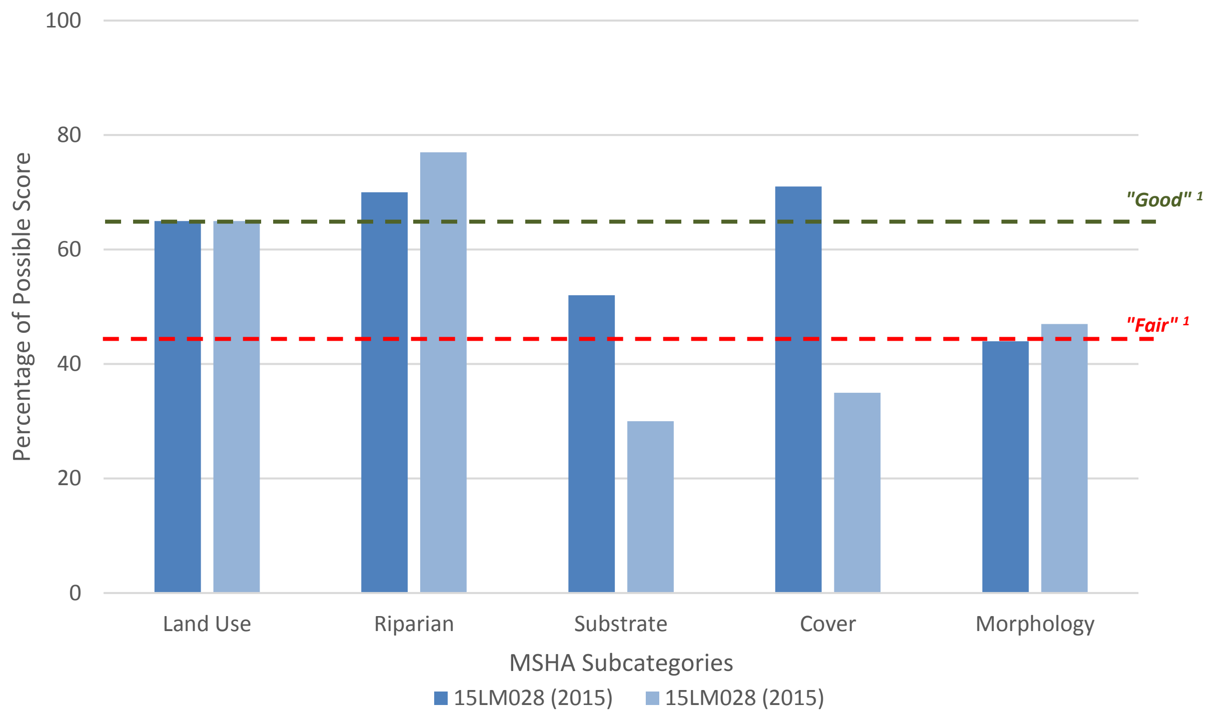
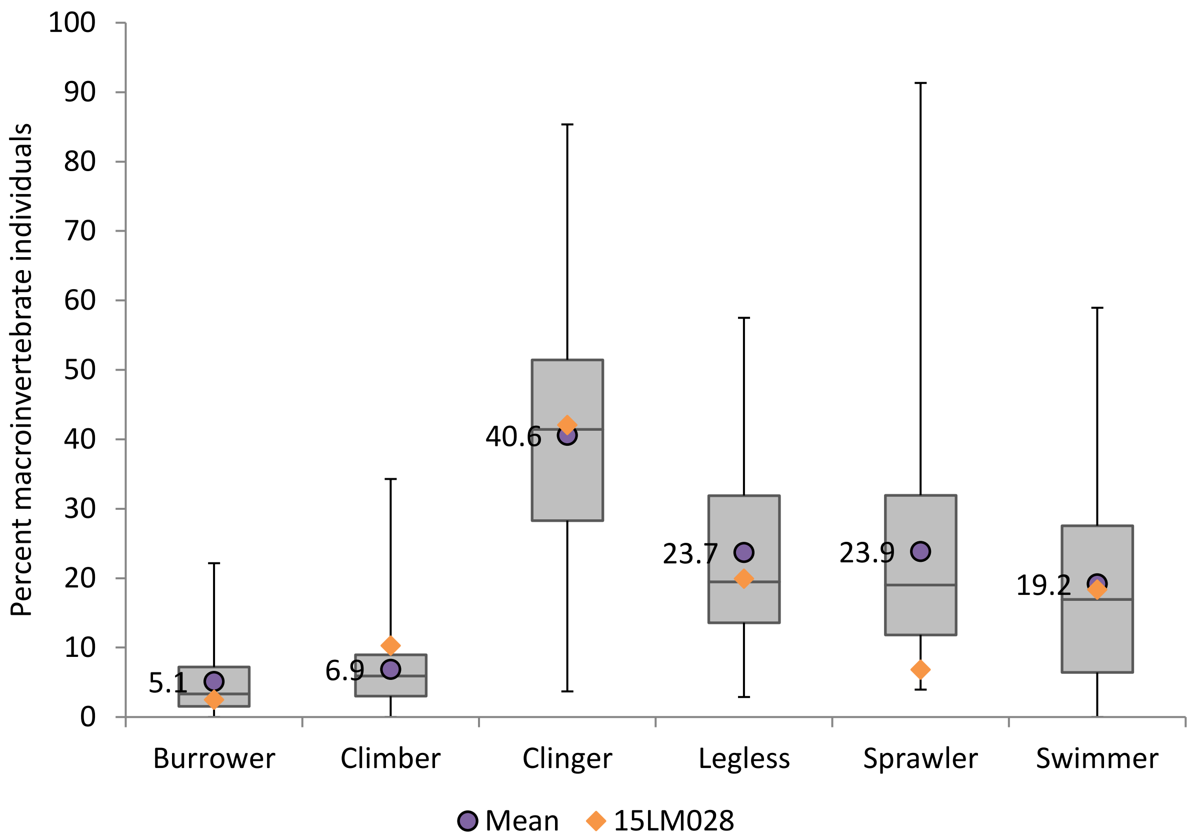


Figure 51. Photo upstream of bridge at lower end of biological station 15LM028, July 21, 2015.

The dominant macroinvertebrate habitat noted during biological surveys was overhanging vegetation and aquatic macrophytes. Burrowers, clingers, and swimmers were found near averages; while legless and sprawler individuals were slightly lower than average (Figure 52). Climbers were just above average. Additionally, the number of EPT taxa in this reach is right at the average. EPT taxa are commonly looked at due to their sensitivity to many stressors including habitat.

Figure 52. A comparison box plot of macroinvertebrate habit metrics representing the average class 9 (Coldwater) stations statewide, for stations above impairment threshold. The range of data is displayed for this stream class, with the median line inside the box plot and mean number displayed. Station specific information is represented by colored points.



According to DNR geomorphology surveys, Winnebago Creek is entrenched and contributes disproportionate amounts of sediment from streambanks and channel beds due to high shear stress. Riparian vegetation is considered dense with no obstructions to flow, and abundant aquatic vegetation resulted in an observed Pfankuch rating of fair. The largest factor negatively affecting the score was extensive deposits of fine sediment easily moved at most flows.

Additionally, the entire Winnebago Watershed was assessed by DNR to determine its geomorphic stream type. It revealed an extensive length of F stream type (62% of total). F stream types are incised and entrenched with high width to depth channels associated with higher sediment supply. Because of high width to depth ratios, they usually have increased streambank erosion, leading to mid-channel and transverse bars. As this reach is in a wildlife management area, the lack of direct impacts to the stream and vegetation are minimizing erosion. However, aerial photos reveal very large eroding banks throughout the system upstream.

Utilizing LiDAR interpolation, DNR found the stream is displaying signs of incision beginning roughly 7 stream miles upstream of 15LM028. A large contributor to the incision is a 1 mile long straightened segment of stream created prior to 1937, likely causing a head cut upstream and degradation downstream. Historical photo comparison below the straight section reveals significant movements of the stream channel (Figure 53). Between 1937 and 1952, the stream lost about 2,300 feet in length (22% reduction). Another 500 feet of stream length was lost between 1952 and 2015. Considering the broad valley and high sinuosity prior to straightening, the stable stream is most likely an E stream type.

Figure 53. Current and historical stream line locations, based off aerial photos.

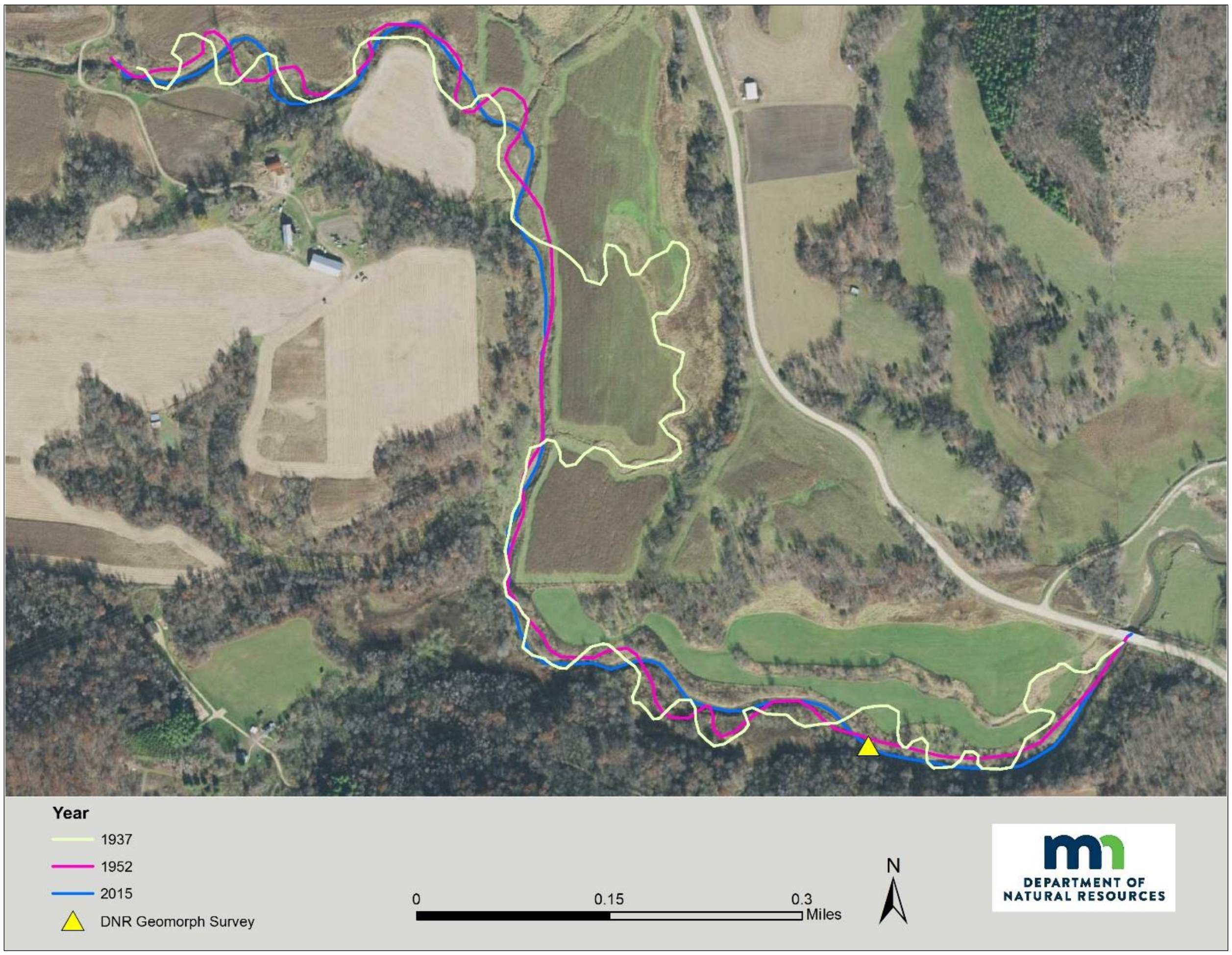


Figure 54. Photo taken downstream of the biological monitoring site (15LM028) showing extensive deposition of sand on the stream bed and pasturing downstream.

Overall, the macroinvertebrate metrics do not strongly point to habitat stress. The physical data does point strongly to the likelihood that lack of habitat is playing a role in the macroinvertebrate impairment. Clearly, having no riffle habitat or coarse substrates limits habitat in this coldwater reach. The sediment transport due to the bank erosion upstream is causing issues in the form of TSS and likely habitat (bedload) as well. At this point with very little biological signal, it is difficult to conclude habitat as a stressor. Regardless, sedimentation (Figure 54) and bank erosion is an issue in this watershed (as noted in the TSS section as well) and should be addressed. At this time, lack of habitat is inconclusive as a stressor to Winnebago Creek.

Connectivity/fish passage

While barriers can alter fish movement, fish are not impaired in this reach and therefore it is of less concern at this particular location. At this time, connectivity and fish passage are not a stressor or contributor to the macroinvertebrate impairment in Winnebago Creek.

Summary

The main stressor contributing to the macroinvertebrate impairment in Winnebago Creek is high TSS. The TSS listing is supported by the biological response that indicating the biology is responding to elevated TSS. The upstream area of Winnebago Creek does not show the same stress as the downstream impaired reach. Moving downstream, poor land use in the riparian corridor and extreme bank erosion all contribute to increased sediment deposition and loss of stream habitat features.

According to the DNR geomorphology information collected, the stream channel needs to narrow within its current channel to reach stability. It is possible for the current walls of the channel (roughly 58 feet wide) to become the new floodplain. This means the bankfull channel needs to narrow 12 feet to reach the minimum entrenchment ratio for an E stream type, and subsequent width to depth. Management recommendations include a reduction of heavy grazing of livestock and row crop near the stream channel, and stream restoration using natural channel design principles on the straightened channel segment, in addition to the other high erosion sites throughout the watershed.

Macroinvertebrates are not currently showing signs of habitat stress, but sediment is clearly impacting habitat quality in this reach and needs to be addressed. While habitat stress seems likely given the lack of coarse substrates and shifting sand streambed, the biological response could not confirm stress and therefore considered inconclusive as a stressor. Sediment is certainly a problem in this watershed, but it seems to be revealing itself in mostly the form of TSS at this time.

Nitrate is moderate at this location of Winnebago Creek, but not as high as the upstream (not impaired site). While the biological response seems to point to nitrate as a stressor, the chemical information is not as strong, and therefore it is inconclusive as a stressor. It seems more likely the response could be attributed to other stressors. Nonetheless, nitrate concentrations should be monitored. Any increase could result in impairment upstream or further degradation of the macroinvertebrates overall in Winnebago Creek.

Temperature and DO levels are considered normal and are not contributing to any biological stress at this time.

5. Conclusions and recommendations for the Mississippi River-Reno Watershed

Table 17. Table summary of probable stressors in MR-Reno Watershed.

Stream Name	AUID	Biological Impairment	Stressors: Temperature	Nitrate	TSS	Dissolved Oxygen/Eutrophication	Lack of Habitat	Connectivity/Fish Passage
Crooked Creek	519	Macroinvertebrates					●	
South Fork Crooked Creek	574	Fish and Macroinvertebrates	●		o	●		o
Clear Creek	524	Macroinvertebrates	o		o		●	
Winnebago Creek	693	Macroinvertebrates		o	●		o	

● = stressor; o = inconclusive stressor; blank = not a stressor

Recommendations

The stressors and recommended actions for the biological impairments in the MR-Reno Watershed are shown in Table 17 and Table 18. The recommended actions listed below, as well as those included in The Aquatic Biota Stressor and Best Management Practice Selection Guide, will help to reduce the influence of the stressors that are limiting the biology in the entire watershed.

Table 18. Recommended actions relative to the stressors contributing to the biological impairments in the MR-Reno Watershed.

Stressor	Priority	Comment
TSS	High	Focus on reducing sediment input from riparian corridor (cattle pastures/row crops/increased fencing) and immediate stream channel (including possible stream bank restoration). Address gullies that may be contributing sediment to the stream. Control runoff from upland areas. Use soil conservation practices; practices that reduce flows, include CRP, grassed waterways, WASCOBs, etc
Temperature and Habitat	High	Aim to re-establish quality riparian corridor buffers to increase woody debris, CPOM inputs, and stream shading.
Temperature	High	Protect spring sources; etc. Improve near channel riparian cover and reduce sedimentation (see above)
Nitrate	Low	Reduce leaching loss of nitrates from row crop acres using source control (rate, timing of application) and vegetative changes (e.g. cover crops)
DO and Eutrophication	Low	Improve nutrient management and reduce soil erosion through implementation of BMP's. Collect additional information on DO and eutrophication where necessary. Consider studying eutrophication dynamics of R-3 reservoir to better understand impacts and sources of nutrients to the reservoir

Protection

In the MR-Reno watershed, there were six other streams sampled that were not discussed in this report since they were not considered biologically impaired (Table 2). All of these streams, except Wildcat Creek, are upstream tributaries to the impaired reaches that are already addressed in this report. Wildcat Creek, which is located in the far northern edge of this watershed, has both FIBI and MIBI scores close to impairment threshold. This stream may be at risk of future impairment and should be protected.

Wildcat Creek

Wildcat Creek is a small direct tributary to this Mississippi River near Brownsville (Figure 3). It is a designated trout stream, and has a fishing easement through the biological station. The stream scored near impairment thresholds for both fish and macroinvertebrates and may be **at risk of impairment**. In 2015, the site scored three points above impairment threshold for macroinvertebrates (46.5 with a threshold of 43). There were two fish samples, scoring 54 and 61 in 2015 and 2016 (impairment threshold of 50). Blacknose dace were the most common fish sampled in 2015, while brown trout were the most common fish sampled in 2016. Both samples had some brook trout in the sample as well, amongst other more tolerant species like white sucker and creek chub.

Nitrate concentrations are consistently 2 mg/L or below, which was measured during biological sampling in 2015, and for multiple samples taken in 2016 upstream and downstream of the biological station (14 total samples taken at Cork Hollow Road and CR 3). Phosphorus was generally low and meeting standards for these samples as well.

TSS was also generally low at both locations but did show consistently that the downstream location had more suspended sediment compared to the upstream site during baseflows. From the paired sampling upstream and downstream (Cork Hollow Road to CR-3) suspended sediment concentrations during baseflow sampling increased on average 73% (or 7 mg/L). While overall the concentrations were all below 15 mg/L, some did exceed the standard of 10 mg/L for coldwater streams at the downstream station on CR-3. Erosion within the stream channel, active pasturing, and deposited sediment that is resuspended from the streambed could be sources of this sediment in these samples. Storm event samples may have different sources of sediment and related to active channel erosion and upstream sources like stream bank failures (Figure 55). Additionally, a dry run tributary just upstream of the Cork Hollow Road crossing seems to be contributing a lot of sediment to Wildcat Creek (Figure 56).

Figure 55. Large bank failure just upstream of the biological station in Wildcat Creek Watershed.

Figure 56. A dry run tributary upstream of the biological station that could be suppling a large amount of sediment to the stream during storm events.

A DNR geomorphology survey of the site showed stream incision and fine sediment build up, all indications of instability. Incision may be a result of past land use changes, but the effects are mitigated by the access to a narrow floodplain and dense vegetation protecting banks in that particular location. Fine sediments are likely from upstream sources, as the reaches above and below the surveyed site have little streambank erosion. Potential sources are areas upstream with intense grazing along the channel that show signatures of higher sediment input (Figure 57). Protection efforts would likely be most effective by focusing on reducing the number and intensity of grazed areas to maintain and improve riparian vegetation and improve channel stability where active erosion is taking place.

Figure 57. Example of an upstream grazed area of the stream with signatures of erosion

Multiparameter sondes were deployed at two stations from July 27, 2016 to August 10, 2016, which showed adequate DO concentrations, and minimal DO flux at both sites (2-3 mg/L average). It was noted that periphyton and aquatic vegetation were much more prominent at the upper site on Cork Hollow Road.

Similarly, temperatures were fairly cold and considered normal with a summer average around 16 degrees C at the biological station in 2016. Temperature loggers were also placed upstream (Cork Hollow Road) and downstream (CR-3) and revealed cooler summer averages at both locations (15.4 and 15.3 degrees C). The summer maximum temperature at CR-3 was 21.1 degrees C while the summer maximum at the upstream site on Cork Hollow Road was 23.7 degrees C. The warmer summer averages at the biological station, in the middle of the watershed, may be due to the beaver dam just upstream influencing temperatures (Figure 58).

Overall, sedimentation and habitat issues are likely the largest limiting factors to biology Wildcat Creek. These stressors are exacerbated by flash flooding which is common to the area. Temperatures seem ok but may be at risk due to the riparian land use practices that limit shade and increase sedimentation/erosion. Good pasture management, restricting cattle access to the stream, and soil conservation practices in the uplands controlling flow and flooding would all help ensure excess sediment in the watershed does not end up causing fish or macroinvertebrate impairments in Wildcat Creek in the future.

Figure 58. Beaver dam just upstream of sampling site May 10, 2016.

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7. Appendix

7.1 Pesticides

The Minnesota Department of Agriculture (MDA) has been conducting pesticide monitoring in surface waters since 1991. Annually, the MDA completes approximately 1,000 sample collection events from rivers, streams, lakes, wetlands, and groundwater across the state. In general, MDA analyzes water samples for pesticides that are widely used and/or pose the greatest risk to water resources. The purpose of MDA's pesticide monitoring program is to determine the presence and concentration of pesticides in Minnesota waters. Samples are collected statewide during the late spring and throughout the summer when the potential for pesticide movement is the greatest.

The MDA conducted a single pesticide monitoring event in the MR-Reno Watershed on June 8, 2010. The monitoring was conducted in an unnamed stream adjacent to Meadowbrook Road, 5.5 miles southwest of Brownsville, Minnesota (S006-643; -91.35449, 43.62895). For more information regarding MDA's monitoring, please refer to: http://www.mda.state.mn.us/monitoring .

Pesticides (including herbicides, fungicides, and insecticides) are considered potential stressors in the MR-Reno Watershed due to the surrounding land use. In 2010, one herbicide and three herbicide degradates were detected at very low concentrations (Table 1). When comparing water quality pesticide results to standards and reference values, duration of pesticide occurrence in a water body must be assessed in conjunction with the numeric result. For example, MPCA Class 2Bd Chronic Standards are developed with a duration exposure of 4 days (aquatic toxicity) or 30 (human health). Therefore, concentration data cannot solely be used for assessment. All of the data collected by MDA is reviewed annually by MPCA for the assessment of water quality standards. The monitoring conducted in 2010 did not result in a pesticide water quality impairment.

MDA will continue to conduct statewide pesticide monitoring in the future and will provide additional information related to the occurrence of pesticides in Minnesota surface waters.

Table 1. MR–Reno Watershed Pesticide Water Quality Data (2010)

Pesticide Name	Pesticide Type	Concentration (ng/L)	Pesticide Type			
			MPCA Class 2Bd[5] Chronic Standard[3]	MPCA Maximum Standard[4]	EPA Acute Value Aquatic Life Benchmark (ng/L)[2]	EPA Chronic Value Aquatic Life Benchmark (ng/L)[2]
Alachlor ESA	Degradate	61.2	--	--	>52,000,000(f)	–
Atrazine	Herbicide	50	3,400 H; 10,000 T	323,000T	na	na
Desethylatrazine	Degradate	60	--	--	–	1,000,000(n)
Metolachlor ESA	Degradate	10.6	--	--	24,000,000 (f)	>95,100,000(v)

Key to value types and symbols in surface water reference values

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

na – not applicable

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

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

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

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

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

T – "T" Chronic Standard values are toxicity-based for aquatic organisms and protective for an exposure duration of 4 days.

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

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

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

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

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

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

Minnesota water quality standards

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

Surface water reference values (text from MDA, 2010)

The MPCA has developed toxicity-based (for aquatic life) or human health-based enforceable chronic standards for pollutants detected in surface water. The toxicity-based standard is designed to be protective of aquatic life exposure, and is typically based on exposure duration of four days. The human health-based standard (protective for drinking water plus fish consumption) is based on exposure duration of 30 days. For the most current MPCA water quality rules see Chapter 7050: Standards for Protection of Waters of the State (www.revisor.leg.state.mn.us/rules/?id=7050). A summary of MPCA's chronic and maximum standard values for common pesticides used in Minnesota are shown in Table 2. Additionally, MDA uses the EPA Office of Pesticide Programs aquatic life benchmarks for detected pesticides without an established Minnesota standard.

Table 2. Summary of MPCA Toxicity Based Surface Water Standards Associated with Target Pesticide Analytes – Chronic[1] and Maximum[2] Standards

Pesticide Analyte	Class 2A[1] (ng/L)	Class 2B[1] (ng/L)	Maximum Standard[2] (ng/L)
Acetochlor	3,600	3,600	86,000
Alachlor	59,000	59,000	800,000
Atrazine	10,000	10,000	323,000
Chlorpyrifos	41	41	83
Metolachlor	23,000	23,000	271,000

Pesticides as a biological stressor in Minnesota watersheds

The presence and concentrations of pesticides detected in a Minnesota watershed have been presented in the above tables. The presence and detection frequency of pesticides in surface waters is reason for concern. Although individual pesticide toxicity has been determined for many pesticides, there is concern that the biological effects of various combinations of pesticides under varying environmental conditions are less understood.

The results above indicate that at this time there are no pesticide concentrations exceeding an applicable standard for aquatic toxicity and therefore no direct evidence that concentrations are high enough to cause known impacts to sensitive aquatic life. This does not mean that pesticides are not acting as stressors, only that the existing monitoring data does not implicate a pesticide as a likely stressor.

The MDA monitoring program targets watersheds with land uses dominated by agriculture and collects samples during storm flow periods when pesticide concentrations are likely to be highest. The MDA operates one of the largest state level pesticide monitoring efforts in the nation. With this said, in order to document the potential contribution of pesticides to stream biology impacts, one would have to design a site-specific study that, among other factors, simultaneously looked at pesticide application timetables while measuring pesticide concentration in adjacent water bodies, complete water chemistry (including the presence of other toxins), water temperature, and fluctuations in hydrology and biological diversity. The study would need to ascertain how the chemical is entering the water, the exposure time, and look for impacts to sensitive organisms. This work has not been performed and is not currently anticipated.