Lower St. Croix Watershed Biotic Stressor Identification Report

A study of local stressors limiting the biotic communities.

Minnesota Pollution Control Agency

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Acronyms

AUID – Assessment Unit ID

CADDIS – Causal Analysis/Diagnosis Decision Information System

DELT – Deformities, eroded fins, lesions, and tumors

DO – Dissolved oxygen

DNR – Minnesota Department of Natural Resources

EDA – Environmental data access

EPA – U.S. Environmental Protection Agency

EPT – Ephemeroptera, Plecoptera, and Trichoptera

FIBI – Fish Index of Biotic Integrity

FWC – Flow weighted concentration

HUC – Hydrologic unit code

IBI – Index of biotic integrity

mg/L – milligrams per Liter

MIBI – Macroinvertebrate index of biotic integrity

MPCA – Minnesota Pollution Control Agency

MSHA – Minnesota Stream Habitat Assessment

SID – Stressor Identification

SOE – Strength of evidence

TIV – Tolerance indicator value

TMDL – Total Maximum Daily Load

TP – Total phosphorus

TSS – Total suspended solids

TSVS – Total suspended volatile solids

USGS – U.S. Geological Survey

WRAPS – Watershed Restoration and Protection Strategies

Executive summary

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 rivers and streams. The basic approach is to evaluate fish and aquatic macroinvertebrates (mostly insects), and related habitat conditions, at sites throughout a major watershed. The resulting information is used to produce an index of biological integrity (IBI). IBI scores can then be compared to standards. Segments of streams and rivers with low IBI scores are deemed impaired. The purpose of Stressor Identification (SID) is to interpret the data collected during the biological monitoring and assessment process.

The objective of this report was to evaluate the environmental data available for the Lower St. Croix River Watershed to diagnose the probable causes of biological impairments. Numerous candidate causes for impairment were evaluated using U.S. Environmental Protection Agency's (EPA's) Causal Analysis/Diagnosis Decision Information System (CADDIS), and weight of evidence analysis. SID is a formal step by step approach that identifies stressors causing biological impairment of aquatic ecosystems, and provides a structure for organizing the scientific evidence supporting the conclusions. In simpler terms, it is the process of identifying the major factors causing harm to fish, macroinvertebrates and other stream life. SID is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Land and Legacy Amendment. After an analysis of biological, chemical, and physical data, a list of probable stressors were identified.

The results of the SID analysis pointed to probable stressors in each of the impaired reaches which include:

Rush Creek (07030005-509)

- Lack of habitat
- Dissolved oxygen
- Lack of connectivity

Goose Creek (07030005-510)

- Phosphorus
- Nitrate
- Lack of habitat
- Altered hydrology
- Dissolved oxygen

North Branch Sunrise River (07030005-501)

- Lack of habitat
- Phosphorus
- Lack of connectivity

Sunrise River (07030005-539, 540)

- Lack of habitat
- Lack of connectivity
- Dissolved oxygen

Bloomquist Creek (07030005-723)

- Lack of habitat
- Phosphorus
- Ammonia
- Dissolved oxygen

Unnamed (07030005-601)

- Dissolved oxygen
- Phosphorus
- Lack of habitat
- Suspended sediment
- Lack of connectivity

West Branch Sunrise River (07030005-529)

- Dissolved oxygen
- Lack of habitat
- Phosphorus
- Suspended sediment

The eight stressors identified and their connections to biological impairments in the Lower St. Croix River Watershed will be evaluated in this report. The initial list of candidate causes was reduced after additional data analysis leaving five candidate causes for final analysis in this report. The stressors with strong evidence of their impacts on the biological communities were found to be the main stressors. The main stressors to the Lower St. Croix River Watershed are lack of habitat, dissolved oxygen (DO), and nutrients. Increased nutrients in the West Branch Sunrise River are of chief concern, as well as the resulting diurnal DO fluctuations. Several impoundment structures located on the Sunrise River, Rush Creek, and Unnamed Creek may be altering stream flow and/or impeding fish passage. The effect of pesticides is unclear.

Loss of habitat due to deposited and bedded sedimentation appears to be problematic in each of the impaired reaches. Many of the upper reaches of the streams are lower in gradient and serve as depositional areas for sediment from upstream sources. Sediment deposition reduced pool and riffle habitat quality. This sediment deposition affects fish species dependent on coarse substrates for feeding and reproduction. A lack of riffle-run-pool combinations is also affecting the available habitat. Stream dominated by runs and with high width to depth ratio leads to few refuge areas for fish, particularly during dry years. The low gradient nature of the stream creates low stream power, and the flow is not enough to move the fine sediments once they are deposited. Prevention of stream bank erosion is important to limit further deposition of fine sediments to the stream bed. Addressing areas of erosion in the North Branch Sunrise River would help prevent future bedded sediment deposition.

Introduction

Organization framework of Stressor Identification

The SID is prompted by biological assessment data indicating that a biological impairment has occurred. Through a review of available data, stressor scenarios are developed that may accurately characterize the impairment, the cause, and the sources/pathways of the various stressors. Confidence in the results often depends on the quality of data available to the SID process. In some cases, additional data collection may be necessary to accurately identify the stressors (Figure 1).

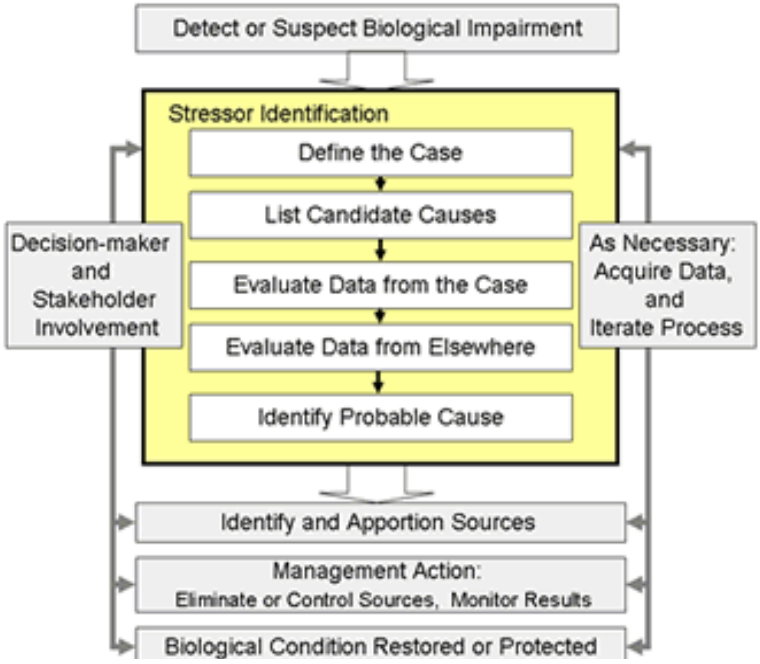

Figure 1. Conceptual model of SID process

SID draws upon a broad variety of disciplines, such as aquatic ecology, geology, geomorphology, chemistry, land-use analysis, and toxicology. Strength of evidence (SOE) analysis is used to develop cases in support of, or against various candidate causes. Typically, the majority of the information used in the SOE analysis is from the study watershed, although evidence from other case studies or scientific literature can also be drawn upon in the SID process.

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 load allocation will 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.

Elements of stream health

The elements of a healthy stream consist of five main components (Figure 2); stream connections, hydrology, stream channel assessment, water chemistry, and stream biology. The following flowchart shows the five components of a healthy stream. If one or more of the components are unbalanced the stream ecosystem fails to function properly and is listed as an impaired water body.

The Elements of Stream Health

Stream Health is linked to the 5 main categories below. The MPCA and local partners examine many interrelated factors to identify stressors

Stream Connections
Examples: dams, culverts and drainage tiles

Hydrology
Examples: stream flow and runoff

Stream Channel Assessment
Example: Bank erosion and Channel Stability

Water Chemistry
Example: Dissolved oxygen, nutrients and temperature

Stream Biology
Example: fish and macroinvertebrates

What conditions stress our streams?

Several factors can stress the biological condition within streams.

Too much sediment
Soil and other particles in water can make it difficult for fish and invert to breathe, feed and reproduce. Sediment can fill pools and smoother gravel and rock habitat

Low Oxygen
Fish and macro invertebrates need dissolved oxygen in the water to breathe and survive.

Temperature
Stream temperature affects metabolism of fish, especially cold water fish species and also influences oxygen content in water.

Lack or Loss of Habitat
Habitat affects all aspects of survival for fish and macro invertebrates. Habitat encompasses places to live, food to eat, places to reproduce and means of protection.

Increased nutrients
Excess nutrients, such as phosphorus and nitrogen, cause excessive algal blooms which can lead to high daily fluctuations in dissolved oxygen concentrations. High amounts of nitrogen can be toxic to fish and macro invertebrates.

Figure 2. Five components of stream health and conditions that stress streams

Lower St. Croix River Watershed

The Lower St. Croix Watershed is comprised of a series of tributaries that flow into the St. Croix River. It is the furthest downstream of the 8-digit hydrologic unit code (HUC) watersheds that flow into the St. Croix River. The watershed is comprised of higher gradient streams that are located along the St. Croix River, and lower gradient headwater streams that flow through numerous lakes and wetlands in the western part of the watershed on the way to the Sunrise River system (Figure 3).

Figure 3. Sunrise River at Highway 14

The Sunrise River is the largest system in the watershed. The watershed was monitored in 2009 and assessed in 2011. As described in the Lower St. Croix Monitoring and Assessment Report (MPCA, 2012), all data collected during a 10-year window was used for assessment. SID work began in 2011 with the aim of identifying the main stressors affecting the biological communities. While there are E. coli impairments in this watershed, E. coli impairments do not have a strong or direct linkage to the biotic impairments and are not covered in this report. Browns Creek, which already has a completed SID and TMDL, was not addressed in this study. Data is included on the South Branch Sunrise River, Valley Creek, and Lawrence Creek although there are not biological impairments on those streams to help with protection efforts. The report is divided into minor watersheds from north to south along the St. Croix and includes Goose Creek, Rush Creek, North Branch Sunrise River, South Branch Sunrise River, West Branch Sunrise River, Sunrise River, Tributary to Lake Carnelian, Bloomquist Creek, Valley, and Lawrence Creeks.

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. There are nine fish and nine macroinvertebrate classes in the state, each with an individual threshold. Each class has a high score of 100. The metrics included in each class is in Appendix A. Other metrics besides just those used in the IBI will also be discussed in this report, as they are often more closely tied to individual stressors. While only data from 2000 to 2010 was used during the assessment, where available, older biological sampling information is used in this report.

The fish and macroinvertebrate IBI metrics, thresholds, and confidence intervals are shown in Appendix A. IBI scores higher than the impairment threshold generally indicate that the stream reach supports aquatic life. Contrarily, scores below the impairment threshold indicate that the stream reach does not support aquatic life. 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 waterbody condition involves consideration of potential stressors, and draws upon additional information regarding water chemistry, physical habitat, land use activities, etc.

Summary of biological impairments

Prior to the watershed work in 2009, there were existing fish impairments on Rush Creek, Goose Creek, the North Branch Sunrise River, and the West Branch Sunrise River, with corresponding macroinvertebrate impairments on all but the West Branch Sunrise River. Coming out of the 2011 assessment cycle, the new biological impairments breakdown were four fish, one macroinvertebrate, and one reach with a fish and macroinvertebrate impairment for aquatic life (Figure 4). The macroinvertebrate impairments on the North Branch Sunrise River and Goose Creek were removed as corrections for macroinvertebrate impairments based on new IBI information. This report will focus on stressors to the biological community impairments.

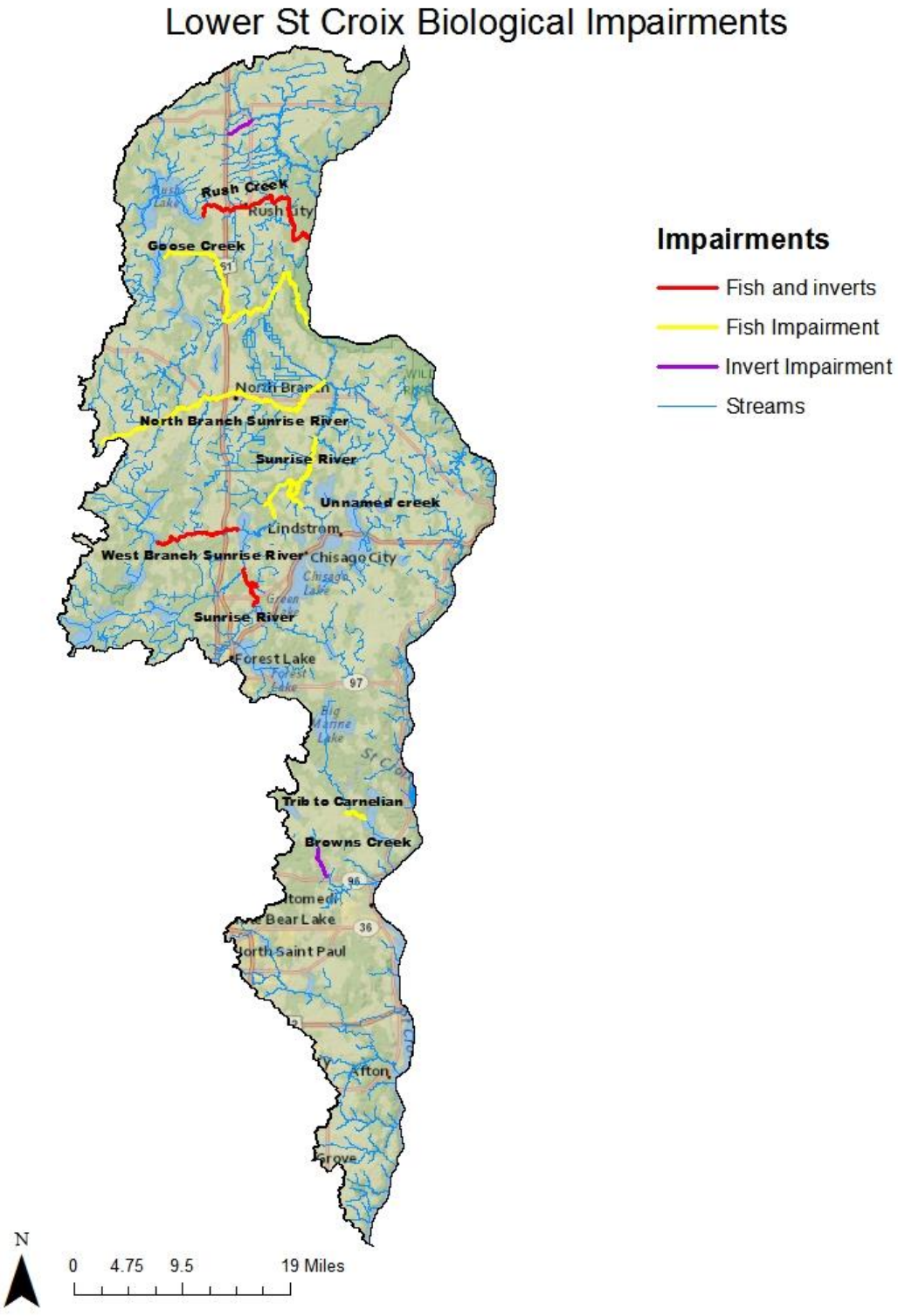

Figure 4. Biological impairments in the Lower St. Croix Watershed

Overview of candidate causes

A list of candidate causes was formed at the start of the SID process. The original list included:

- Dissolved oxygen (DO) regime alteration
- Hydrologic regime alteration (includes flow or depth conditions; timing, duration, frequency, etc.)
- Nutrient regime alteration
- pH regime alteration
- Suspended solids and/or turbidity alteration
- Water temperature regime alteration
- Habitat destruction
- Bed sediment load changes, including siltation
- Habitat fragmentation (e.g., barriers to movement, exclusion from habitat)
- Physical crushing and trampling
- Toxic substances
    - Herbicides and fungicides
    - Chloride
    - Insecticides
    - Metals

Candidate causes ruled out

Some candidate causes were ruled out as unlikely candidates. The potential causes ruled out included:

- Water temperature regime alteration
- Physical crushing and trampling

Water temperature regime alteration
All of the streams that this report explores, that are impaired for lack of biotic assemblage, are considered warmwater. The highest temperature found in the biological impaired reaches was 28.8 degrees Celsius. The temperature data falls within an expected range for warmwater reaches. With the available data, temperature is an unlikely stressor to the biological community.

Candidate causes without enough information (Inconclusive)

Some candidate causes were unable to be considered further due to the lack of connecting data between the potential stressor and the biological community; and/or there was not enough data available. The potential causes that were inconclusive included:

- Chloride
- Toxic substances
    - Metals
    - Pesticides (herbicides, insecticides, and fungicides)

Ionic strength/Chloride

The highest chloride value in the watershed was 588 mg/L at a tributary to the headwaters of the Sunrise River. The standard is 230 mg/L. Less than 1% of chloride were greater than 230 mg/L. The highest value on an impaired reach was 468 mg/L in the headwaters of the Sunrise at station S004-465. The rest of the values over 230 mg/L were taken at a tributary to Long Lake and a tributary to the headwaters of the Sunrise River.

The highest specific conductance value in the watershed was 1909, also located at the tributary to the headwaters of the Sunrise River. The highest specific conductance value in the impaired reaches in the watershed was 1074 at station 09SC025. The headwaters of the Sunrise River (-526) had a value of 1034. The 75% of ecoregion expectation for the Central Hardwood Forest from data from 1970-1992 annual is 330.

As salinity increases, macroinvertebrate taxa richness and Ephemeroptera has been found to decrease (Piscart et al., 2005; Echols et. al, 2009) also found a reduction in Ephemeroptera, Plecoptera, and Trichoptera (EPT) abundance as conductivity values increased. There is no macroinvertebrate data on the reaches with elevated values, making ionic strength and chloride inconclusive as a stressor.

Physical crushing and trampling

Little of the land use in the Lower St. Croix River Watershed is pasture. Pastured animals in the stream or river would be the most likely process in which crushing or trampling may take place. While there is a lack of evidence of this occurring, it is inconclusive as a stressor to the biologically impaired reaches in the Lower St. Croix Watershed.

Metals

Five stations in the Lower St. Croix River Watershed had measurements of the metals of cadmium, nickel, copper, lead, or zinc. The water quality standards could not be calculated for any of these samples due to the lack of hardness data which is required to calculate the standard. It is recommended to continue monitoring of these metals including hardness to ensure that they are below the standard and to increase metals monitoring to locations that do not have any data at this time.

Pesticides

Minimal monitoring of pesticides samples were taken on Rush Creek, Goose Creek, and the West Branch Sunrise River Watershed. More intense sampling has occurred on the North Branch Sunrise River, and the samples meet relevant standards. In many of the samples, although numerous pesticides were present, none were above the state or federal standards. With the limited data available, the effects of pesticides on the biological community within this reach are inconclusive. Currently, the additive effect of pesticides on aquatic organisms at levels below state or federal standards is unknown. More research needs to be developed to characterize this potential effect.

Additional monitoring is recommended to further understand the presence of pesticides and their potential impacts to the biological community. Given the current gaps in understanding of the additive effects, it is difficult to rule out pesticide toxicity as a possible stressor or conclude that it may be a stressor.

Candidate cause: Dissolved oxygen

Dissolved oxygen (DO) measures the concentration of oxygen in the water. DO concentrations change seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column. DO concentrations and fluctuations are affected by shifts in ambient air and water temperature, precipitation, stream flow,

atmospheric pressure, plant/algal growth and decomposition, salinity, and ammonia concentrations. Low concentrations or highly fluctuating concentrations of DO can have detrimental effects on many fish and macroinvertebrate species (Davis, 1975; Nebeker et al., 1991). DO concentrations change seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column.

Fish require oxygen for respiration. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995). Some macroinvertebrates that are intolerant to low levels of DO include mayflies, stoneflies and caddisflies (Marcy, 2007). Many species of fish avoid areas where DO concentrations are below 5 mg/L (Raleigh et al., 1986). Additionally, fish growth rates can be significantly affected by low DO levels (Doudoroff and Warren, 1965).

In most streams and rivers, the critical conditions for stream DO usually occur during the late summer season when water temperatures are high and stream flows are reduced to baseflow. As temperatures increase, the saturation levels of DO decrease. Increased water temperature also raises the DO needs for many species of fish (Raleigh et al., 1986). Low DO can be an issue in streams with slow currents, excessive temperatures, high biological oxygen demand (BOD), and/or high groundwater seepage (Hansen, 1975). Heiskary et al. (2013) observed several strong negative relationships between fish and macroinvertebrate metrics and DO flux. Wide fluctuations in one day are also very stressful to aquatic communities. This results in a shift from functional assemblages of aquatic communities to tolerant or generalist species (Heiskary et al. 2013).

Water quality standards

The standard for Class 2B (warmwater) streams in the state of Minnesota for DO is 5.0 mg/L as a daily minimum (Minn. Stat. § 7050.0222 subp. 4). The standard for coldwater streams is 7.0 mg/L.

The stream water quality standard for eutrophication in the central region of the state for daily DO fluctuations (max-min) is 3.5 mg/L.

Dissolved oxygen in the Lower St. Croix River Watershed

Instantaneous DO measurements were collected throughout the watershed and can be used as an initial screening tool. While cold-water streams can often have elevated DO readings due to colder water holding more DO, values over 14 mg/L are often tied to nutrients and daily DO fluctuations. Elevated daily fluxes (up to 9.57 mg/L) were recorded on Rush Creek, Goose Creek, the West Branch Sunrise, and Sunrise River. These streams all also experienced daily minimum values below the 5.0 mg/L standard for Class 2B waters.

Sources and causal pathways for dissolved oxygen

Dissolved oxygen concentrations in lotic environments are driven by a combination of natural and anthropogenic factors. Natural background characteristics of a watershed, such as topography, hydrology, climate, and biological productivity define the DO regime of a waterbody. Agricultural and urban land-uses, impoundments (dams), and point-source discharges are just some of the anthropogenic factors that can cause unnaturally high, low, or volatile DO concentrations. The conceptual model for low DO as a candidate stressor is modeled at EPA's CADDIS Dissolved Oxygen webpage.

Nutrient inputs from, agricultural runoff, and other point sources are upsetting the natural dynamics by increasing algae and macrophyte production, which in turn increases photosynthesis, respiration, and decomposition. This cycle creates fluctuations in DO levels.

Candidate cause: Nitrogen

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

Water quality standards

Streams classified as Class 1 waters of the state, designated for domestic consumption, in Minnesota have a nitrate water quality standard of 10.0 mg/L (Minn. Stat. § 7050.0222 subp. 3). At this time, Rush Creek and the West Branch of the Sunrise River are both impaired for biota and are classified as Class 1B streams. Minnesota currently does not have a nitrate standard for other waters of the state except for Class 1; however, an aquatic life nitrate standard is being drafted.

Nitrogen in the Lower St. Croix River Watershed

Water chemistry samples have been taken throughout the watershed, and total nitrate (Nitrate + Nitrite) values on range from less than 0.05 up to 4.2 mg/L. Values were highest on the North Branch Sunrise River, Goose Creek, and Unnamed Creek. Unionized ammonia is another form of nitrogen, and Bloomquist Creek is impaired for ammonia.

Sources and causal pathways for nitrogen

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

Candidate cause: Phosphorus

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

Water quality standards

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

Phosphorus in the Lower St. Croix River Watershed

Modeling done in the St. Croix basin showed a large proportion of phosphorus in the St. Croix River coming from the Sunrise River (Lenz et al. 2003). Over 35% of the available water chemistry data values in the watershed were over the water quality standard for phosphorus (0.100 mg/L). Phosphorus values were highest on Bloomquist Creek and Unnamed Creek with values up to 1.63 mg/L.

Sources and causal pathways for excess phosphorus

Increased phosphorus levels lead to increased algal and macrophyte growth which in turn leads to increased decomposition and respiration rates. Increased plant and algal growth causes increased oxygen production through photosynthesis during the day. The excess plant material eventually dies, and bacterial activity during decomposition strips oxygen from the water. This leads to low early morning DO readings in streams, and high readings in the afternoon. Streams dominated with submerged macrophytes experience the largest swings in DO and pH (Wilcox and Nagels 2001). Phosphorus is delivered to streams by wastewater treatment facilities, urban stormwater, agricultural runoff, and direct discharges of sewage. Phosphorus bound to sediments in the river channel could be contributing to concentrations; however, there is no data available. Orthophosphorus is the form of phosphorus that is readily available for plant and algal uptake, and can influence excess algae growth. While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from wastewater treatment plants, noncompliant septic systems, and fertilizers in urban and agricultural runoff. The causes and potential sources for excess phosphorus are modeled at EPA's CADDIS Phosphorus webpage.

Candidate cause: pH

The term pH is a measure of acidity or basicity, with a scale ranging from 0 to 14. As described by EPA, pH values are considered high when they are above 9.0 for a prolonged amount of time or frequency (U.S. EPA. 2013). Photosynthesis from elevated rates of eutrophication creates an increase in pH values. High pH values also influence elevated ionic strength and the toxicity of other chemicals such as ammonia. As pH increases, unionized ammonia becomes the predominant form, which can lead to ammonia toxicity (U.S. EPA. 2013). Values of pH outside the range of 6.5-9.0 or highly fluctuating values are stressful to aquatic life.

Water quality standards

The standard for Class 2B (warm-water) streams in the state of Minnesota for pH is range of 6.5 as a daily minimum and 9.0 as a daily maximum (Minn. Stat. § 7050.0222 subp. 4).

pH in the Lower St. Croix Watershed

Values of pH in the watershed had a high value of 9.21. The highest values in the watershed are on the North Branch Sunrise River. Elevated values and/or elevated pH flux were found on Rush Creek, Goose Creek, West Branch Sunrise, North Branch Sunrise, and Sunrise River.

Sources and causal pathways for pH

The conceptual model for pH as a candidate stressor is modelled at EPA's CADDIS pH webpage. Human effects on pH values can result from agricultural runoff, urbanization, and industrial discharges. Some geology has naturally high hydrogen ions that can leach into surface water, but it would be rare for this to be the only cause. Photosynthesis of overabundant macrophytes and algae can remove carbon dioxide from the water, causing a higher pH. Effects on biology include decreased growth and reproduction, decreased biodiversity, and damage to skin, gills, eyes, and organs. Concentrations of nutrients (especially nitrogen) also play a significant part in pH dynamics, as nitrification and respiration both produce hydrogen ions (U.S. EPA. 2013).

Candidate cause: Total suspended solids

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

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

Water quality standards

The water quality standard for turbidity is 25 Nephelometric Turbidity Units (NTUs) for Class 2B waters for protection of aquatic life (Minn. Stat. § 7050.0222 subp. 4). TSS and transparency tube measurements can be used as surrogate standard. A strong correlation exists between the measurements of TSS concentration and turbidity. In 2010, MPCA released comment new TSS criteria are stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The TSS standard for the central region of the state which includes the Lower St. Croix River Watershed, has been set at 30 mg/L. There is currently no standard for TSVS.

Turbidity in the Lower St. Croix Watershed

Unnamed Creek is currently impaired for turbidity, and has the highest average TSS values in the watershed. Values of TSS range from 1.0 to 824.0 mg/L in the watershed. Values were also elevated on the West Branch Sunrise River and the Sunrise River.

Sources and causal pathways for turbidity/total suspended solids

High turbidity occurs when heavy rains fall on unprotected soils, dislodging the soil particles which are transported by surface runoff into rivers and streams (MPCA and Minnesota State University Mankato [MSUM], 2009). The soil may be unprotected for a variety of reasons, such as construction, mining, agriculture, or insufficiently vegetated pastures. Bank erosion also plays a role in stream turbidity. The causes and potential sources for sediment are modeled at EPA's CADDIS Sediments webpage.

Sources of organic matter include the breakdown and decay of plants and algae. High nutrient loads increase the amount of plants and algae present in the stream. Nutrients are delivered to streams by wastewater treatment facilities, urban stormwater, agricultural runoff, and direct discharges of sewage.

Candidate cause: Lack of habitat

Excess fine sediment deposition on benthic habitat has been proven to adversely impact fish and macroinvertebrate species that depend on clean, coarse stream substrates for feeding, refugia, and/or reproduction (Newcombe et al., 1991). Aquatic macroinvertebrates are generally affected in several ways: (1) loss of certain taxa due to changes in substrate composition (Erman and Ligon, 1988); (2) increase in drift (avoidance by movement with current) due to sediment deposition or substrate instability (Rosenberg and Wiens 1978); and (3) changes in the quality and abundance of food sources such as periphyton and other prey items (Pekarsky 1984). Fish communities are typically influenced through: (1) a reduction in spawning habitat or egg survival (Chapman, 1988) and (2) a reduction in prey items as a result of decreases in primary production and benthic productivity (Bruton, 1985; Gray and Ward, 1982). Fish species that are simple lithophilic spawners require clean, coarse substrate for reproduction. These fish do not construct nests for depositing eggs, but rather broadcast them over the substrate. Eggs often find their way into interstitial spaces among gravel and other coarse particles in the stream bed. Increased sedimentation can reduce reproductive success for simple lithophilic spawning fish, as eggs become smothered by sediment and become oxygen deprived. The sediments primarily responsible for causing an embedded condition in southern Minnesota streams are sand and silt particles, which can be transported in the water column under higher flows, or as a bedload component. When stream velocities decrease, these sediments can "settle out" into a coarser bottom substrate area, thus causing an embedded condition.

Water quality standards

There currently is no applicable standard for lack of habitat due to deposited and bedded sediment for biotic communities.

Lack of habitat in the Lower St. Croix Watershed

Sand and silt are the dominant substrates in the Lower St. Croix Watershed. Fine sediments are a natural part of stream substrate; they become a problem when they cover and fill in the gaps between coarse substrate, limiting the habitat availability for fish and macroinvertebrates. Lack of habitat is a stressor on all of the impaired reaches in the watershed.

Sources and causal pathways for lack of habitat

Bedded and deposited sediments are closely related to suspended sediments. Decreases in bank stability lead to sediment loss from the stream-banks, causing sediment loads in the water column. Bank instability is often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, and increases in impervious surfaces.

Candidate cause: Connectivity

Connectivity in river ecosystems refers to how waterbodies and waterways are linked to each other on the landscape and how matter, energy, and organisms move throughout the system (Pringle, 2003). Both dams and culverts will be addressed in this paper. The presence of impoundment structures on river systems are known to alter steamflow, water temperature regime, and sediment transport processes – each of which can drastically alter fish and macroinvertebrate assemblages (Cummins, 1979; Waters 1995). Dams also regularly limit or impede fish migrations and can greatly reduce or even extirpate local populations (Brooker, 1981; Tiemann et al., 2004).

Water quality standards

There is currently no water quality standard for stream connectivity.

Connectivity in the Lower St. Croix Watershed

There are a series of dams in the Sunrise River system as well as dams on lakes flowing into Goose Creek and the West Branch Sunrise River. A dam has been removed from Rush Creek, but no restoration work was done. Miss-sized culverts are placed on Rush Creek and Unnamed Creek, and one was recently replaced on the North Branch Sunrise River.

Sources and causal pathways for connectivity

The causes and potential sources for lack of connectivity as a result of channel alteration are modeled at EPA's CADDIS Physical habitat webpage.

Candidate cause: Altered hydrology/channelization

Habitat availability can be scarce when flows are interrupted, low for a prolonged duration, or extremely low, leading to a decreased wetted width, cross sectional area, and water volume. Ditching and drain tile can lead to increased rates of runoff into and increased high and low flow periods. As areas of the landscape are drained, they lose the ability to store water and slowly release it over time. This leads to flashy streams that have peak discharge immediately following rain events, and have little or no baseflow. This flashy nature leads to extreme stress on channels and on aquatic life. When the delivery of water is quick, the stream organisms are exposed to very fast velocities and may have limited places to find refuge. Increasing surface water runoff and seasonal variability in stream flow have the potential for both indirect and direct effects on fish populations (Schlosser, 1990). Indirect effects include alteration in habitat suitability, nutrient cycling, production processes, and food availability. Direct effects include decreased survival of early life stages and potentially lethal temperature and oxygen stress on adult fish (Bell, 2006). Flow conditions can have an effect on the type of fish species that are present. Active swimmers, such as the green sunfish, contend better under low velocity conditions (Carlisle et al., 2010).

The nature of the rapid rise and fall of the stream flow places the stream banks at risk of eroding and contributing sediment which, in turn, fills the gravel and rocky substrate with fine material. This can lead to a loss of available habitat for gravel spawning fish and EPT taxa. When high flows become more frequent, species that do not manage well under those conditions will be reduced, leading to altered population. Macroinvertebrates may shift from those of long life cycles to short life cycles needing to complete their life history within the bounds of the recurrence interval of flow conditions (U.S. EPA. 2012). Aquatic organisms require adequate living space and when flows are reduced beyond normal baseflow, competition for resources increases. Pollutant concentrations often increase when flows are lower than normal, making it more difficult for populations to maintain a healthy diversity. Often tolerant individuals that can out-compete in limiting situations will thrive. Low flows of prolonged duration tend to lead to invertebrate and fish communities that have preference for standing water or are comprised of generalist species (U.S. EPA. 2012).

Water quality standards

There currently is no applicable standard for flow alteration.

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

Point and nonpoint sources of water pollution shall be controlled so that the water quality standards will be maintained at all stream flows that are equal to or greater than the 7Q10 [the lowest streamflow for 7 consecutive days that occurs on average once every 10 years] *for the critical month or months, unless another flow condition is specifically stated as applicable in this chapter*.

Altered hydrology in the Lower St. Croix watershed
The intensive channelization throughout the Goose Creek Watershed is affecting the biological communities.

Sources and causal pathways model for flow alteration
The causes and potential sources for lack of connectivity as a result of channel alteration are modeled at EPA's CADDIS Flow Alteration webpage.

Candidate cause: Ammonia (NH_3)

Ammonia (NH_3) is a common toxicant derived from animal waste, fertilizers, and natural processes. Ammonia nitrogen contains both the ionized form (ammonium, NH_4^+) and the unionized form (ammonia, NH_3). An increase in pH favors formation of the more toxic unionized ammonia (NH_3).

Water quality standards
The standard for Class 2B (warm-water) streams in the state of Minnesota for unionized ammonia is a chronic standard of 40 µg/L. Unionized ammonia is calculated using temperature and pH (Minn. Stat. § 7050.0222 subp. 4). Temperature and pH values are both needed to calculate the unionized ammonia value.

Ammonia in the Lower St. Croix Watershed
Bloomquist Creek is impaired for ammonia, and is a stressor to the biological community.

Sources and causal pathways model for ammonia
Many human activities and associated sources can contribute to high ammonia concentrations in aquatic systems, which can lead to lethal and sub-lethal effects on aquatic organisms. Channel alteration can result in decreased nitrogen uptake within the stream, while decreases in riparian and watershed vegetation associated with agriculture and urbanization can reduce nitrogen uptake in the surrounding landscape. Channel alteration and water withdrawals can reduce ammonia volatilization due to changes in water velocities and depths. Sources associated with agriculture, urbanization, industry and aquaculture also can directly increase ammonia inputs to aquatic systems via four main transport pathways (or transport-defined sources): stormwater runoff, leakage or leachate into groundwater sources, atmospheric emissions and deposition, or direct effluent discharges (U.S.EPA, CADDIS Volume 2 Sources, Stressors & Responses, 2012). For a more detailed explanation of ammonia sources and pathways visit EPA's CADDIS Ammonia webpage.

Impaired reaches in the Lower St. Croix River Watershed

Tributary to Rock Creek

The 1.77-mile stream segment (Assessment Unit Identification [AUID] 07030005-555) is a tributary to Rock Creek. The stream was channelized sometime after 1939. Aerial photos in 1939 show a stream with numerous natural bends. The stream is currently straight and did not meet the macroinvertebrate threshold with data taken in 1998, and was listed as impaired in 2004. Tiered aquatic life standards have since been created for channelized streams, and the data would meet the new modified stream channel threshold.

Rush Creek

The 15 mile reach of Rush Creek (Figure 5) from Rush Lake to the St. Croix River (AUID 07030005-509) is impaired for fish and macroinvertebrates. The river flows out of Rush Lake, where both bays are impaired for nutrients. The majority of biological scores fall at or below the threshold supporting the previous designation of impairment of aquatic life use. Communities improve at the outlet station (98SC004) of the watershed, possibly signaling the improved water quality in downstream reaches as a result of higher gradient and better substrate (MPCA 2011). Since 1996, Rush Creek has been sampled 29 times for fish and 27 times for macroinvertebrates at seven different locations. Only sites sampled after 2000 were included in the 10 year assessment window, however for the purposes of SID all data was used in this report. A dam was recently removed upstream of Rush City. Chemical and biological information is available throughout the watershed through sampling done by the MPCA, the Minnesota Department of Natural Resources (DNR), local counties, and citizens. A comprehensive review of biological, chemical, and physical data was performed (Figure 5).

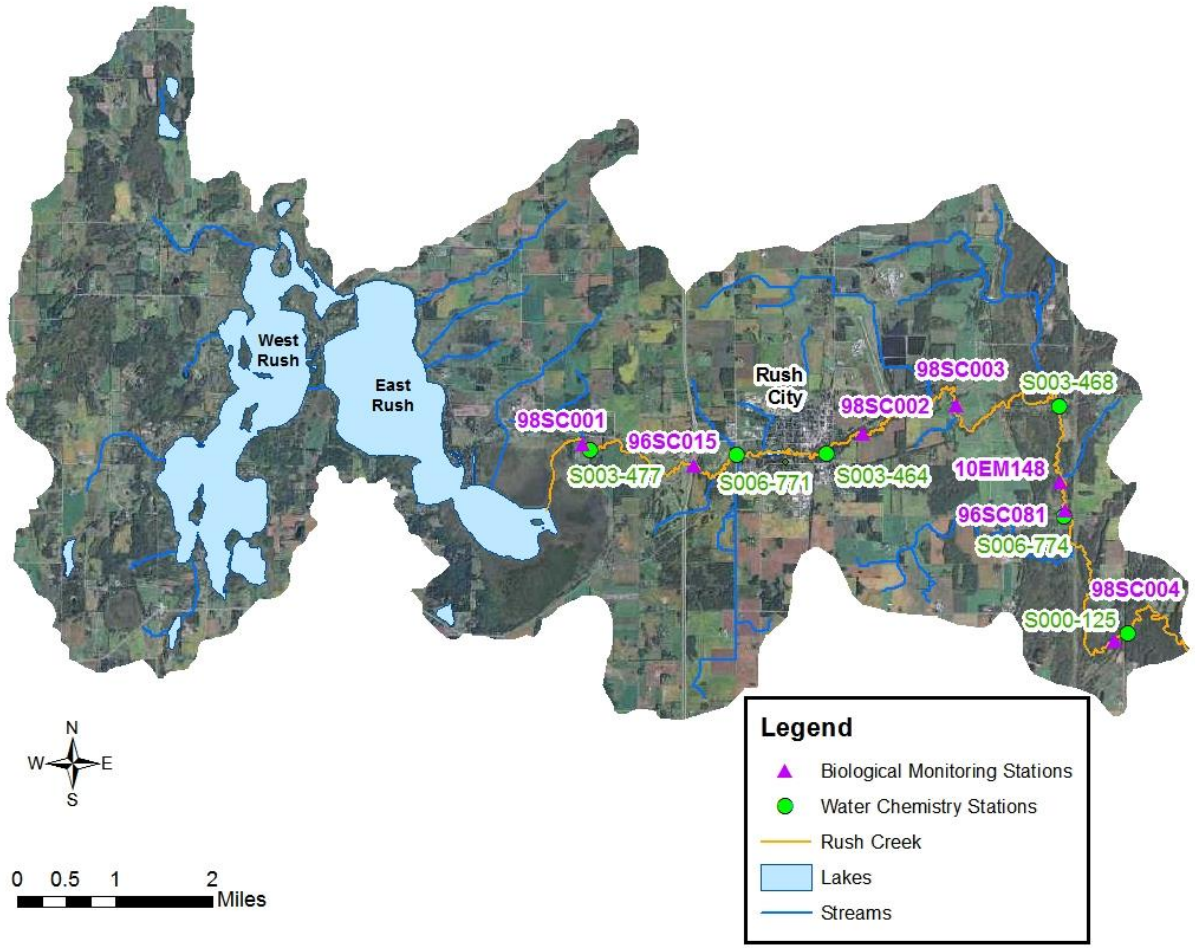

Figure 5. Rush Creek sampling locations

Metric scores cumulatively make up the IBI score for fish and macroinvertebrates. Each metric definition is located in Appendix A. There are not individual standards for each metric, but using a target score provides a method of identifying problem metrics for a stream or individual monitoring site. The target of the average score needed to meet the threshold is calculated by taking the IBI impairment threshold and dividing it by the total number of metrics (i.e. all metrics are weighted the same). For fish, this does not take into consideration the deduction that deformities, eroded fins, lesion, and tumors (DELTs) bring

to the IBI. The presence of DELTs is a metric that is part of each of the fish classes. If these indicators of poor fish health are present, five points are subtracted from the IBI score. If they are not present, the site gets a score of zero. Visits at stations 98SC001, 98SC002 and 98SC003 had DELT deductions due to lesions, eroded fins, and deformities.

Fish in Rush Creek were assessed using both the northern streams fish class (sites in northern Minnesota where watershed area is greater than 50 square miles but less than 500 square miles) and the northern headwaters fish class (for those stations where watershed area is less than 50 square miles and gradient is greater than 0.5 m/km). The four upstream stations in the northern headwaters fish class (fish class 6) scored low in the fish captured per meter (Figure 6). The taxa richness of the sensitive and headwater species was also low at these stations. These stations did score well for both tolerant taxa present and insectivorous taxa. The three downstream stations located in the northern stream fish class (fish class 5) score poorly for percentages of intolerant and mature age fish individuals (Figure 7). Two of the three most downstream sites (10EM148 and 98SC004) do have better sensitive taxa metric scores than the upstream stations.

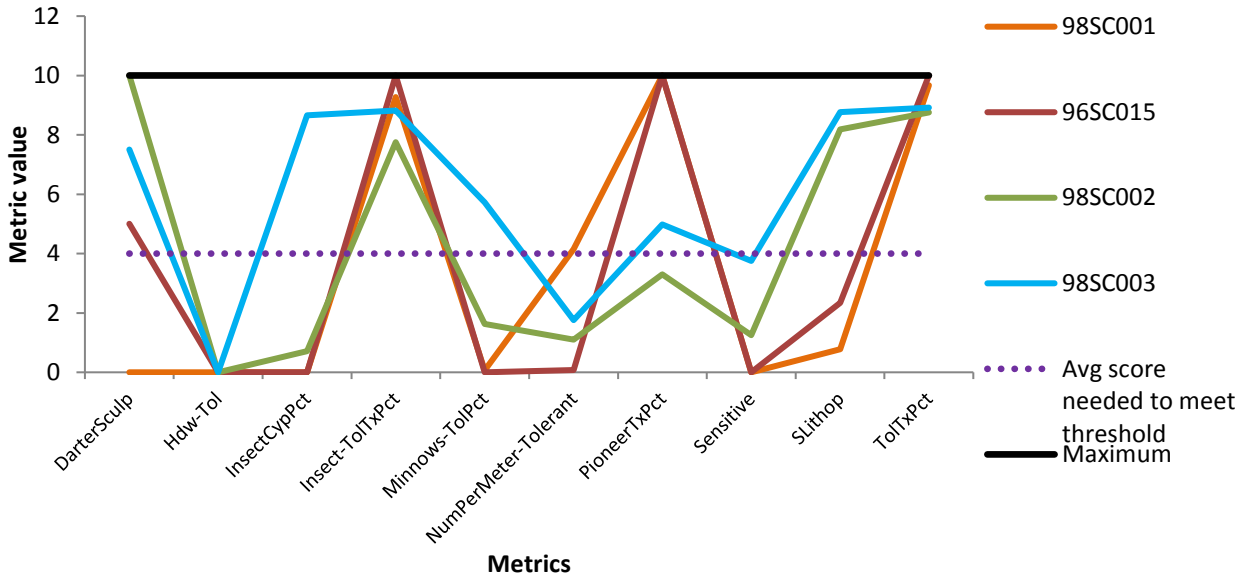

Figure 6. Rush Creek fish class 6 metric scores

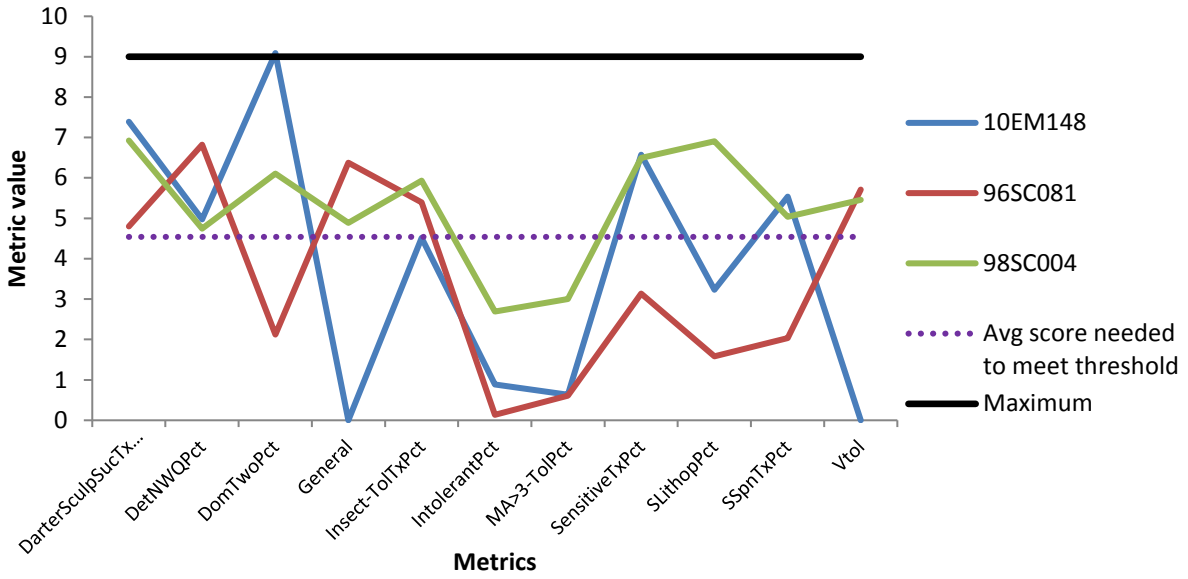

Figure 7. Rush Creek fish class 5 metric scores

Station 98SC001, the most upstream site, located near the outlet of Rush lake has been sampled seven times between 1999 and 2009 (Figure 8), and metrics have scored consistently over time. Sensitive, simple lithophilic spawner, headwater, and darter and sculpin taxa and individual percentages of minnow species have scored zero at every visit though the years. The 2009 visit saw improvements in the number of fish collected per meter.

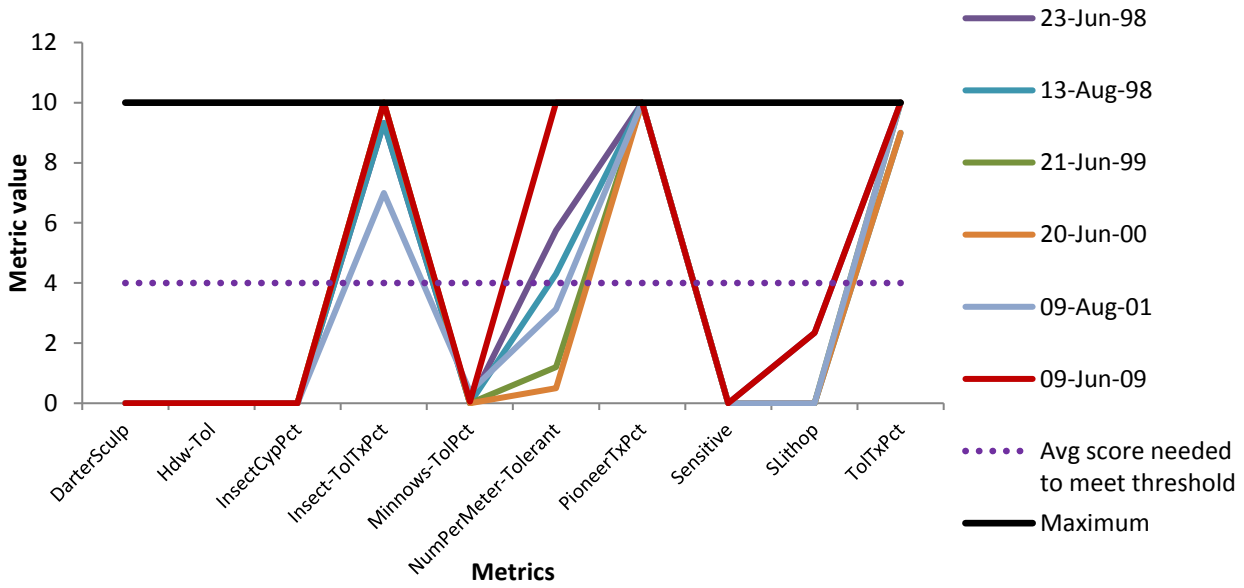

Figure 8. Station 98SC001 fish metrics over time

Stations on Rush Creek were also assessed using two macroinvertebrate classes; those with run and riffle habitats and those with glide and pool habitats. The three stations in the southern forest streams glide/pool class (macroinvertebrate class 6) have uniformly low scores in the collector-filterer and intolerant metrics (Figure 9). The four sites in the southern streams riffle/run class (macroinvertebrate class 5) do not have any metric uniformly scoring poorly station. Station 98SC001 was the lowest scoring site (Figure 10). Only 4 of the 10 metric scores for station 98SC001 are above the score needed to meet

the threshold. On average across the four stations, the Plecoptera, Trichoptera, and macroinvertebrate taxa percent are the lowest scoring metrics. The macroinvertebrate impairment is concentrated at stations 98SC001 and 96SC081, at the two ends of the AUID.

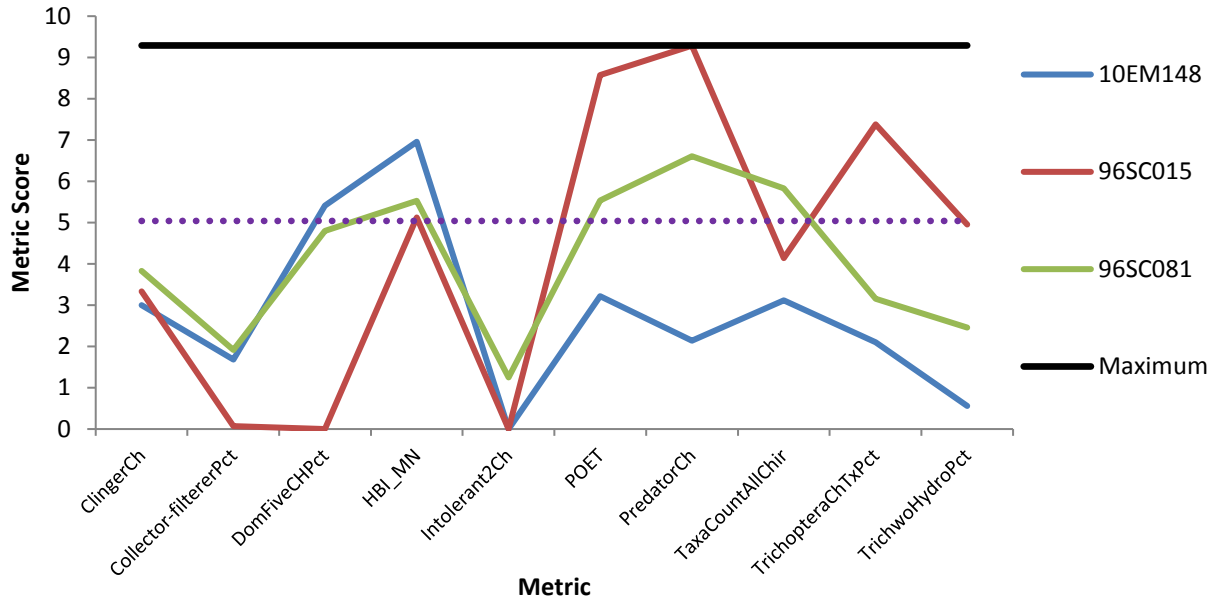

Figure 9. Rush Creek macroinvertebrate class 6 metric scores

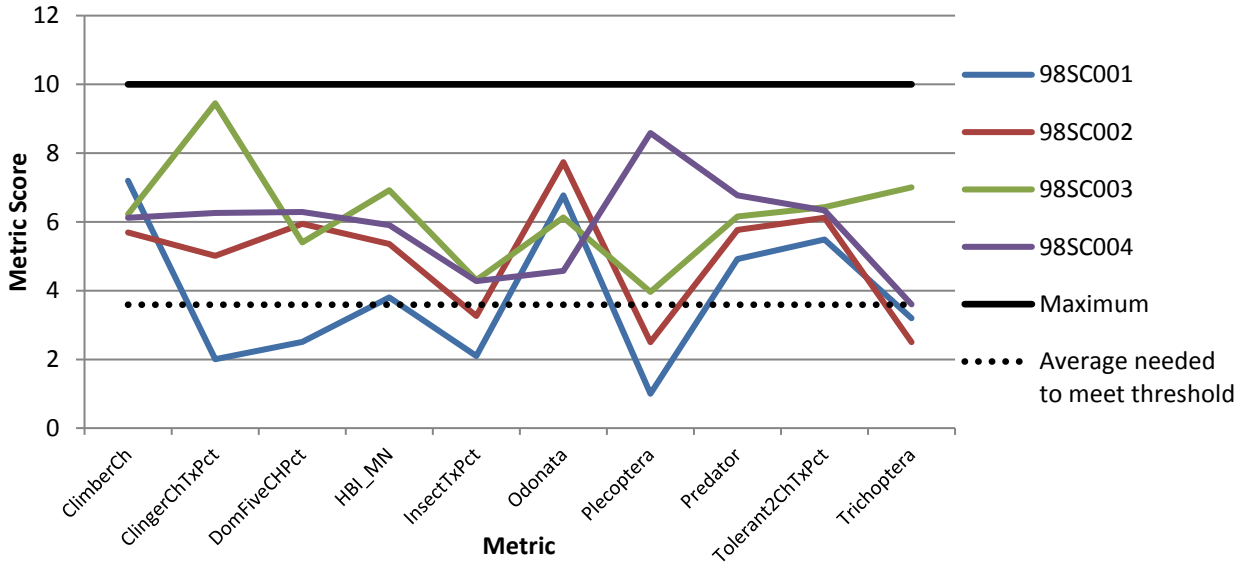

Figure 10. Rush Creek macroinvertebrate class 5 metric scores

Candidate cause: Dissolved oxygen

The stream is surrounded by riparian wetlands downstream of Rush Lake (Figure 11), with increased gradient downstream of Rush City. Early morning DO readings (Figure 12) taken in August 2012, show DO does not rise above the standard of 5 mg/L until Blueberry Trail, three miles east of Rush City. Gradient likely has an impact on this as the gradient changes from 0.79 at station 96SC015 to 1.52 at station 98SC004.

Figure 11. Rush Creek in Rush City

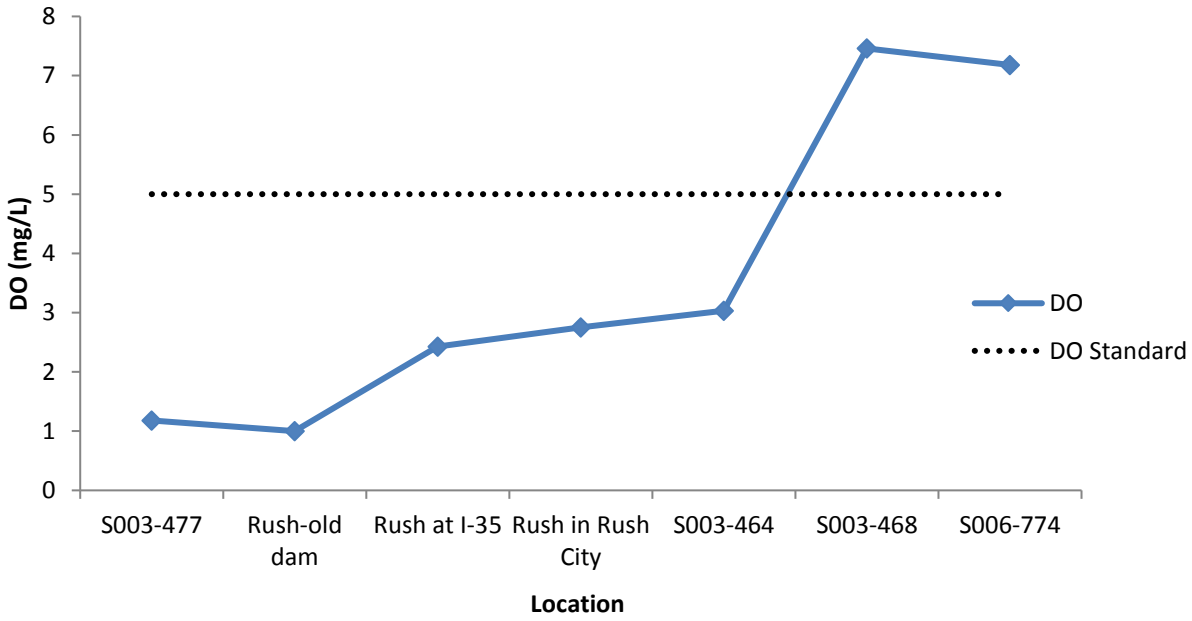

Figure 12. Longitudinal survey of DO values on Rush Creek prior to 9 AM

Continuous DO data was collected in Rush City in August 2011 (Figure 13). This data showed values that daily dipped below the standard of 5.0 mg/L, with daily fluxes up to 5.84 mg/L. The central regional eutrophication standard of daily DO flux is 3.5 mg/L. While Rush Creek is influenced by wetlands which naturally experience DO fluctuations, DO flux values between 2.0 to 4.0 are typical in a 24-hour period (Heiskary et al, 2010). Daily DO fluctuations are a measure of stress on the aquatic community. Algal respiration and photosynthesis are considered primary drivers of daily flux in DO, and high daily fluctuations of DO are connected to nutrient concentrations.

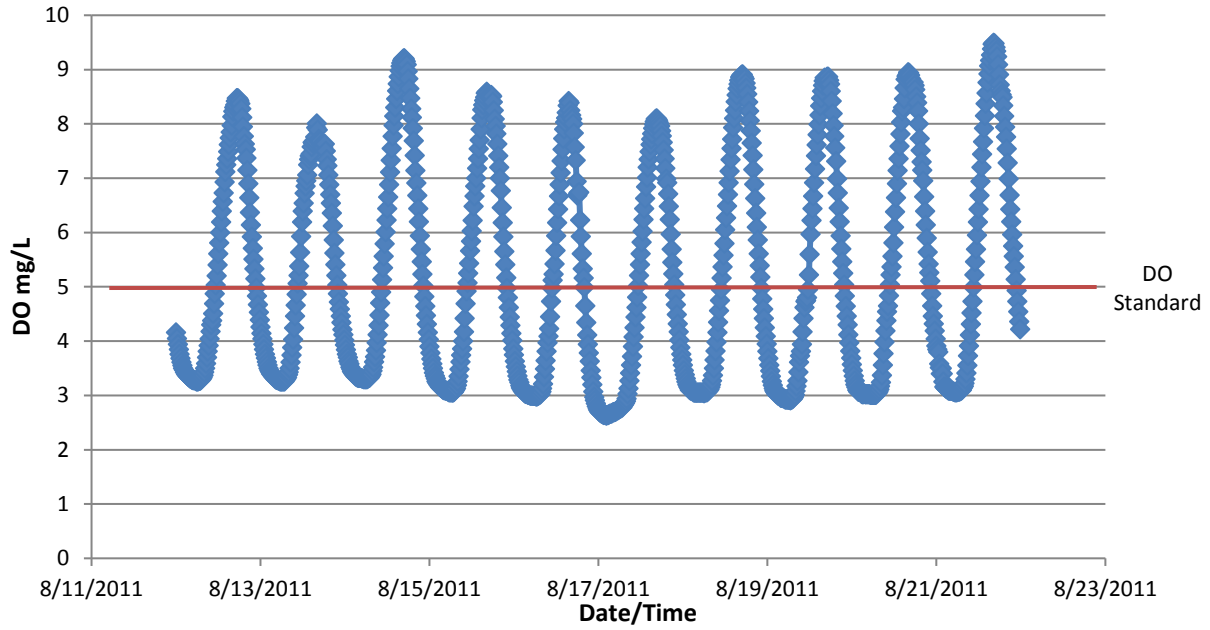

Figure 13. Continuous DO data on Rush Creek in Rush City

Recent DO data show concentrations that range up to 14.75 mg/L during the hottest months of the summer (Figure 14). The highest DO concentrations have been recorded at station S000-125. Riffle habitat which is present at station S000-125 increase flow and DO concentrations, however elevated concentrations can also be tied to elevated nutrient values. The lowest concentrations have been recorded at stations S003-477 and S006-771.

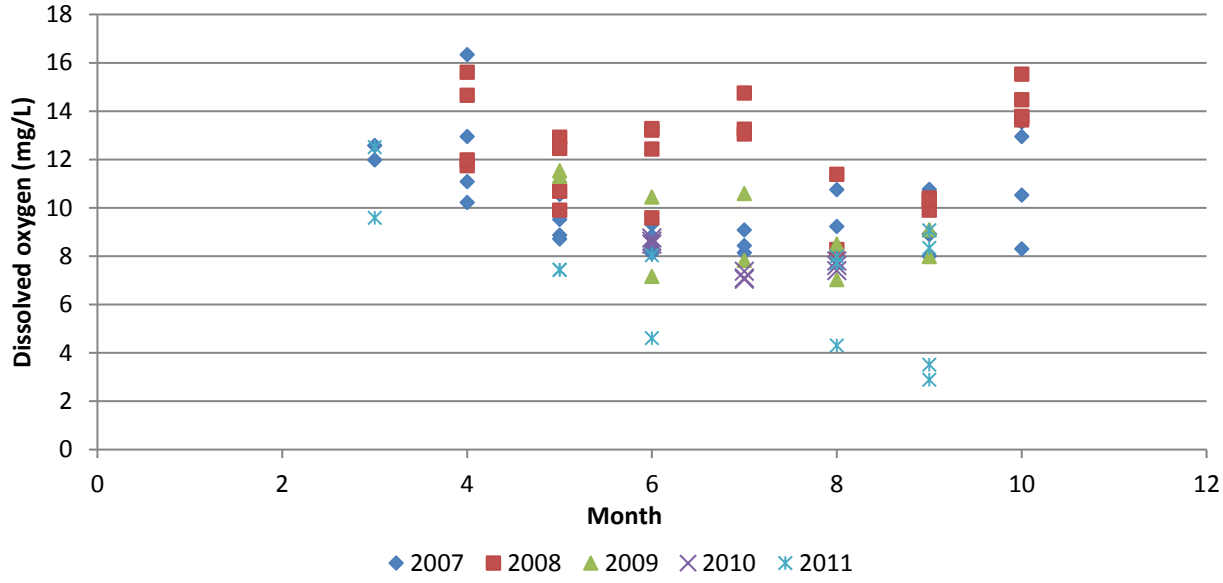

Figure 14. DO readings by month

Biotic response

Low DO values correspond with increased tolerant species and decreased sensitive species. The average sensitive fish percentages statewide for fish classes 5 and 6 are 22.32% and 15.11% respectively. Sensitive individual percentage at the upstream sites ranged from zero at station 98SC001 to six at station 98SC002. The range at downstream stations 98SC003 to 98SC004 was 16.83% to 50.99%.

Stations 98SC001, 96SC015, 98SC002, 10EM148, and 96SC081 all had visits with sensitive percentages under the statewide average. Station 96SC081 had a visit in 1997 with 20.99% sensitive fish but all subsequent visits were less than 9%. Tolerant fish taxa percentages in fish classes 5 and 6 statewide average 36.15% and 66.62%. Tolerant percentages ranged from 1.72 to 99.37 and averaged 37.47%. The stations with the highest tolerant numbers were 96SC015 (99.37%) and 98SC001 (83.08%). Fish that mature at greater than three years of age are inversely correlated with low DO values. The average percentage of fish that mature greater than three years of age statewide for fish classes 5 and 6 is 12.38% and 2.83%. The range of fish that mature at greater than three years of age percentages ranged from 0 to 27.82%.%. Stations 98SC001, 96SC015, 98SC002, 98SC003, 10EM148, 96SC081, and four of the five visits at station 09SC004 were below the statewide average.

Longitudinally from upstream to downstream along Rush Creek, the early morning DO tolerance indicator values (TIVs) were calculated for the seven sample sites (Figure 15). Fish data collected were placed into quartiles (i.e. 0-25%; 25-50%; 51-75%; and 76-100%) depending on their tolerance to low DO values, and then the number of fish in each quartile was added together for each site. The biological community on Rush Creek is dominated by early morning low DO tolerant species, particularly in the upstream section of the stream where 634 mudminnows were collected at station 96SC015.

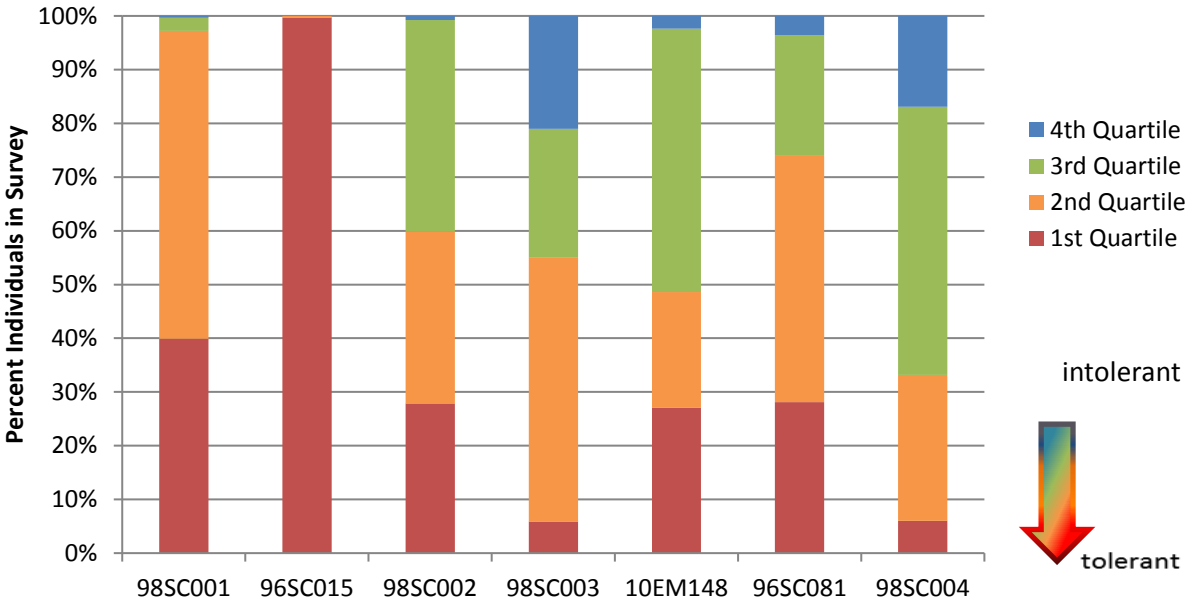

Figure 15. The percentage of fish individuals by tolerance quartile on Rush Creek

EPT communities are also inversely correlated with low DO values and high DO flux. The average statewide for classes 5 and 6 were 38.30% and 19.01% respectively. EPT individual percentages on Rush Creek range from 1.3 to 44.5% and average 32.8%. Station 98SC004 had the highest recorded values of phosphorus and DO; the EPT percentage has decreased over the years from 1998 to 2009 (declining from 54.6 to 19.9%). Total taxa richness has been shown to decrease with an increase in DO flux. The number of macroinvertebrate taxa in macroinvertebrate classes 5 and 6 average 25 and 23 statewide. The values for macroinvertebrate taxa richness range from 21 to 54 species, averaging 39.

The number of macroinvertebrate taxa that are intolerant to low DO at ranged from 0 to 13 on Rush Creek, with the lowest numbers at station 98SC001 (0 taxa), station 96SC015 (1 taxon), and station 96SC081 (2 taxa). The sites with the highest numbers of species intolerant to low DO were stations 98SC003 (12 taxa) and 98SC004 (13 taxa). The average number of low DO intolerant taxa in the St. Croix basin was 7.55. Stations 98SC001, 96SC015, 3 of the four visits at station 98SC002, 10EM148, and

96SC081 are all below the St. Croix basin average. The percentage of low DO tolerant species ranged from 2.53% (station 98SC003) to 92.05% (station 96SC015). The average in the St. Croix was 19.73%. Stations 98SC001, 96SC015, two of the four visits at station 98SC002, and three of the four visits at station 96SC081 had percentages of DO tolerant species higher than the St. Croix basin average.

While the effects of low DO values seem to be most extreme in the upper section of the stream, station 96SC081 is also being affected. The effects of DO flux should also be considered due to the large decrease in EPT percentages at station 98SC004 and the corresponding high DO values. Continuous DO data was not collected at station 98SC004, taking this in the future would help to define the flux occurring. Based on increased tolerant percentages, lowered sensitive and mature age percentages, predominance of low DO tolerant species and percentages, and the low numbers of DO intolerant species DO should be considered to be a main stressor on Rush Creek.

Candidate cause: Phosphorus

Both West Rush and East Rush lakes are impaired for excess nutrients. Phosphorus concentrations in recent years along Rush Creek were analyzed by month (Figure 16). The highest phosphorus concentrations were collected in June and October. Of the five highest phosphorus values (0.347-0.484 mg/L), only one of them correlated to increased suspended sediment (90 mg/L). Values are highest at station S000-125, the most downstream sampling location (Figure 17). There are areas of dense macrophyte growth on the creek, which is often tied to excess nutrients (Figure 18). During a longitudinal survey of phosphorus data on September 13, 2011 (Figure 19), values steadily increased from upstream to downstream and the two downstream sites both had values over the standard of 0.100 mg/L. These values were taken during base flow conditions. The highest value from Rush Creek was recorded at 0.484 mg/L, and was collected in June after 1.25 inches of rain.

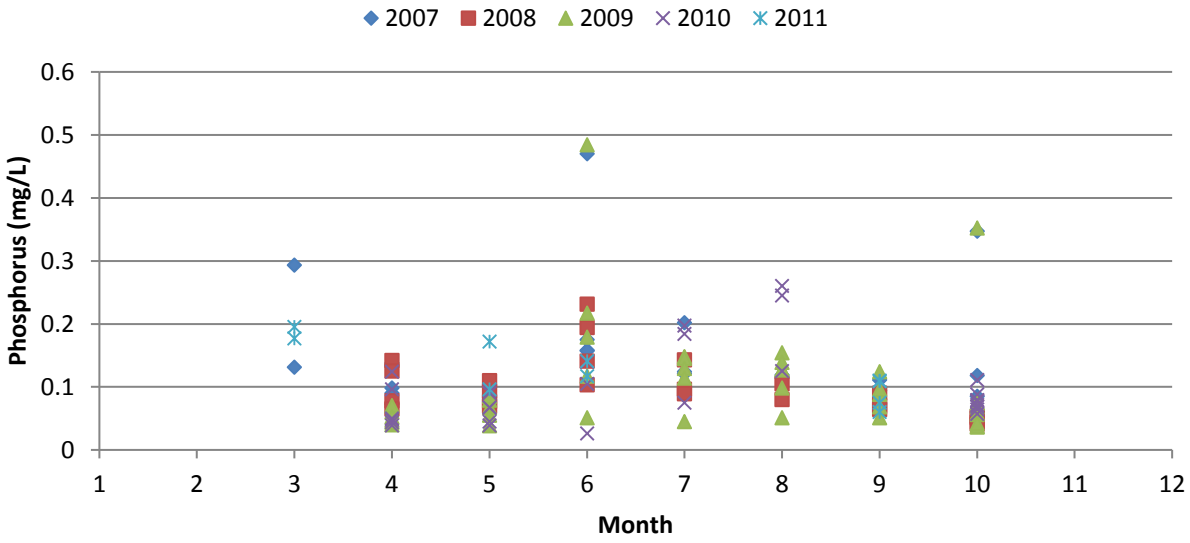

Figure 16. Phosphorus concentrations by month and year on Rush Creek

Orthophosphorus is the form of phosphorus that is readily available for plant and algal uptake, and can influence excess algae growth. Three paired phosphorus and orthophosphorus readings were taken in 2011 at station S003-477, with orthophosphorus making up from 30 to 53% of the phosphorus concentrations. Numerous paired orthophosphorus and phosphorus concentrations have been sampled at station S000-125 from 2006 to 2011, with orthophosphorus ranging from 13 to 100% of the phosphorus concentrations, and averaging 54%.

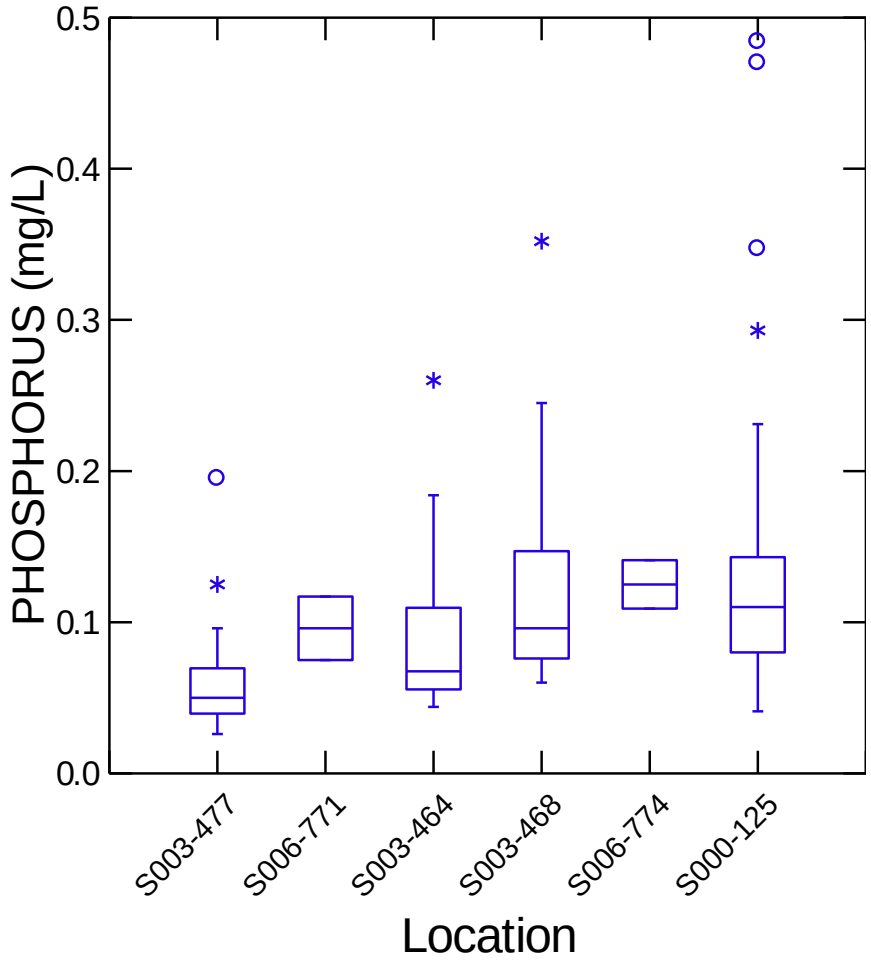

Figure 17. Phosphorus concentrations at stations along Rush Creek

Figure 18. Rush Creek in Rush City (September 13, 2011)

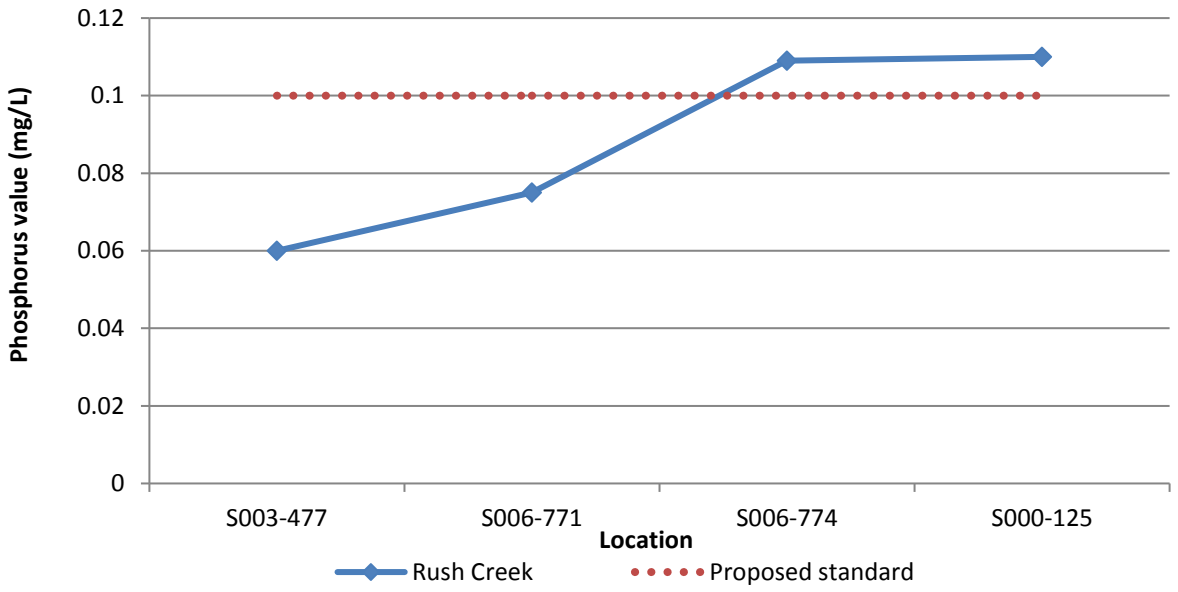

Figure 19. Longitudinal phosphorus readings on Rush Creek

Biotic response

Increased phosphorus levels have an inverse relationship with sensitive individual fish percentages and an increase in tolerant percentages of fish. The average sensitive fish percentages statewide for fish classes 5 and 6 were 22.32% and 15.11% respectively. Sensitive individual fish percentages range from 0 to 50.99% and average 13.42% on Rush Creek. The amount of sensitive individuals at station has been zero at all six visits at station 98SC001 and at stations 96SC015 and 98SC002. Tolerant fish percentage on Rush Creek ranged from 1.72 to 99.37%, averaging 35.24%. Tolerant fish taxa percentages in fish classes 5 and 6 statewide average 36.15% and 66.62%. Darter percentages are also inversely correlated with phosphorus. The percentage of darter individuals has decreased over time at station 98SC004. The lowest numbers were during the two 2009 samples (8.89 and 11.63%), decreased from 19.25% in 1999. The average statewide for class 5 streams is 13.48%

Effects of phosphorus are also seen through a decrease in macroinvertebrate taxa, and an increase in tolerant percentages. The number of macroinvertebrate taxa range from 21 to 54, and averaged 31 at sites on Rush Creek. The percent tolerant macroinvertebrate individuals ranged from 15.75 to 94.61%. The number of macroinvertebrate taxa in macroinvertebrate classes 5 and 6 average 25 and 23 statewide, and tolerant percent average 57.5% and 74.5%. Stations 98SC001 and 96SC015 had the highest number of tolerant individual macroinvertebrates (92.83 and 94.61%).

The percentages of sensitive individual fish species are less than seven percent at the three upstream stations which are below the statewide average while the downstream stations have averages above the statewide average for fish classes 5 and 6. The two upstream sites both have tolerant macroinvertebrate percentages much higher than other class 5 and 6 streams in the state, while this is not the case for fish. The average number of macroinvertebrate taxa was higher on Rush Creek than the averages of class 5 and 6 statewide. The high levels of phosphorus, especially at station S000-125 are likely contributing to photosynthesis and algal respiration, which in turn are effecting the daily oxygen production and oxygen demand. Phosphorus is a contributing stressor as it relates to low DO.

Candidate cause: Nitrate

Nitrate concentrations in recent years on Rush Creek range from less than 0.05 to 0.9 mg/L, and average 0.24 mg/L. The majority of samples were taken at station S000-125. A few samples were also collected upstream at station S003-477 where all samples were less than 0.01 mg/L. The highest values from Rush Creek were taken in April and June. The average nitrate value on Rush Creek was 0.14 mg/L during biological sampling, values measured during biological visits ranged from 0.17 to 0.323 mg/L.

Biotic response

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams (class 6) MIBI. The samples taken in the southern forest stream class (stations 10EM148 and 96SC015) had nitrate tolerant percentages of 66.45 and 71.88 respectively. The number of nitrate tolerant species collected was 15 during both samples.

The remainder of the stations on Rush Creek are in the southern streams macroinvertebrate class. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams (class 5) MIBI, and at 68.7% nitrate tolerant individuals there is a 50% probability of meeting the MIBI. Station 98SC001 ranged from 12.14 to 61.18% nitrate tolerant individuals, and averaged 33.46%. The highest percentage was during a visit in 2001, and corresponded with the lowest IBI score. Station 98SC002 ranged from 25.75 to 49.53% nitrate tolerant individuals, and averaged 43.62% with the highest value during 2000. Station 98SC003 ranged from 32.49 to 43.10% nitrate tolerant individuals, and averaged 39.24%. The highest percentage was in 1999. Station 98SC004 ranged from 21.62 to 56.11% nitrate tolerant individuals, and averaged 39%. The highest percentage was in 2009. The number of nitrogen tolerant taxa ranged from 3 to 22, and averaged 12.9. The highest number of tolerant taxa was collected at station 98SC004 in 2009. The 2009 visit also had the lowest IBI at this location. Additionally, there was higher abundance of nitrate intolerant taxa, ranging up to eight nitrate intolerant taxa at station 98SC001 (in 1998) and 98SC004 (in 1999 and 2000). Station 98SC001 also had six nitrate very intolerant taxa in 1998.

Increasing nitrate concentrations also have a relationship with a decrease in non-hydropsychid Trichoptera (caddisfly) individual percentages. Non-hydropsychid Trichoptera are all caddisflies that do not spin nets. The individual percentages on Rush Creek sites range from 0 to 26.64%, and average 5.2%. Sites in classes 5 and 6 averaged 3.76% and 1.99% of caddisflies statewide.

This biological evidence is not suggestive of nitrate as a stressor, as the nitrate tolerant individuals were much less than would be expected with nitrate stress, there is presence of nitrate intolerant taxa, and the non-hydropsychid caddisflies are found in greater percentages in some locations. Where they are reduced may be due to other stressor(s) present at those locations. In combination with low nitrate concentrations and lack of biological response to nitrate, nitrate is not found to be a stressor at this time. Continued monitoring and protection would be recommended so that nitrate does not become a stressor in this watershed.

Candidate cause: pH

High pH values have been recorded at stations 98SC001 and 98SC004 (9.1 and 9.08 respectively). Continuous data collected in three locations on Rush Creek during 2011 recorded a high value of 8.16, and a maximum flux of 0.9 (Figure 20). Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013). High fluctuations reflect excessive in-stream primary production, as algae and aquatic plants drive up pH during the daytime.

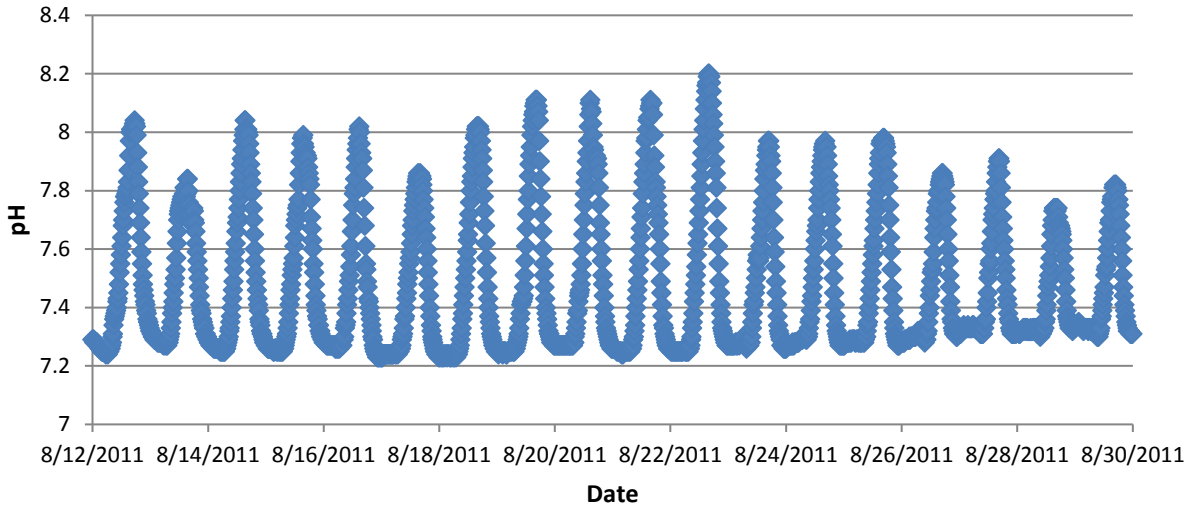

Figure 20. Continuous pH data on Rush Creek

Biotic response

EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (U.S. EPA. 2013). The fish sample taken at station 98SC001 during 2009 included 616 bluegills and 4 yellow perch with the pH value recorded at 9.1. While these are both lake species, and station 98SC001 is located downstream of Rush Lake, the elevated pH values do not seem to be directly affecting the fish community based on the very high number of bluegills collected.

Candidate cause: Lack of habitat

In Rush Creek, surrounding land uses were row crop and residential with some forest, wetland, and prairie land use Minnesota Stream Habitat Assessment (MSHA) scores taken during biological sampling ranged from 52.4 to 79.2 on the six locations on Rush Creek, all ranking in the fair category except for the furthest downstream station 98SC004. Differences in scores were due mainly to low substrate and channel morphology scores. The channel morphology scores on Rush Creek ranged from 14 to 35 (out of 36). This was primarily due to lack of riffles, depth variability, and of channel development. The substrate scores ranged from 7 to 23.75 (out of 27). Light to severe embeddedness was recorded, with severe embeddedness recorded at stations 98SC001 and 98SC002. No coarse substrate (gravel, cobble, boulder, etc.) was found at station 96SC015 or 96SC081. Coarse substrate is important for habitat and spawning. No riffles were present at stations 96SC081, 98SC001, and 98SC002.

Biotic response

Benthic insectivores, darter, sculpin, and sucker, riffle dwelling species, and simple lithophilic spawners require coarse substrate that is not embedded in fine substrate. Lack of coarse substrate or embeddedness of coarse substrate seems to be having a direct impact on biology, particularly in the upstream section of the stream (Figure 21). Where the depth of fines is greater there are fewer simple lithophilic spawners (Figure 22). Tolerant species are shown to increase with a lack of habitat availability. In Rush Creek, the tolerant species do not follow the trend expected, but the habitat dependent fish are located where coarse substrates are available and are not embedded with fine substrate.

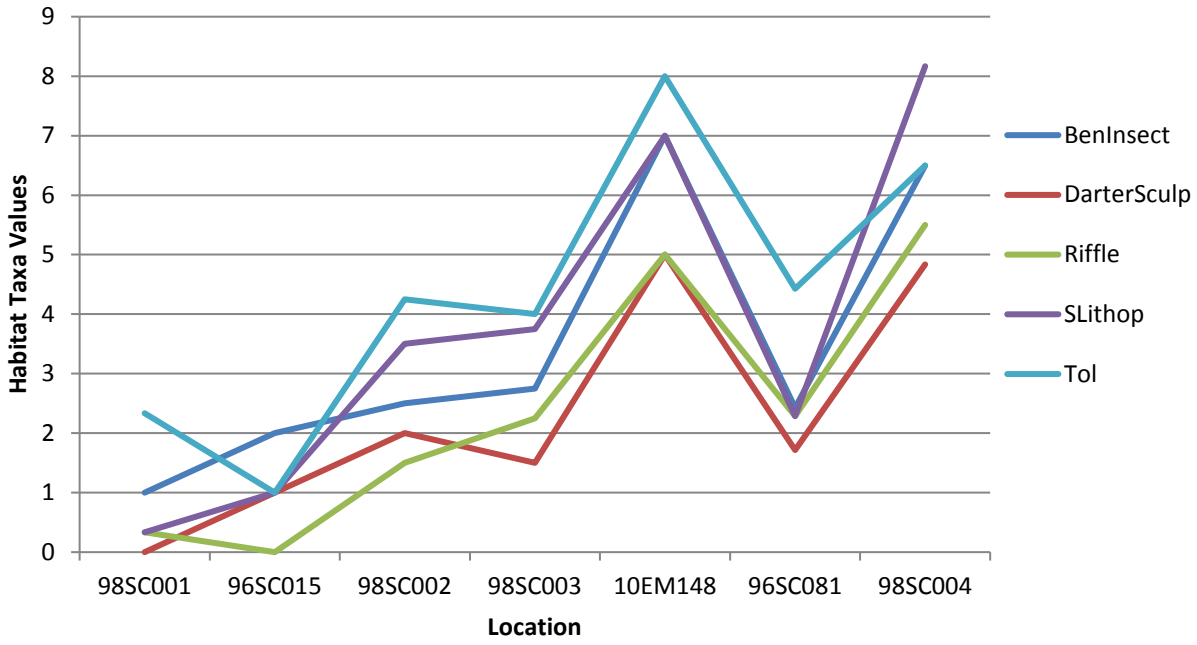

Figure 21. Habitat metrics in Rush Creek

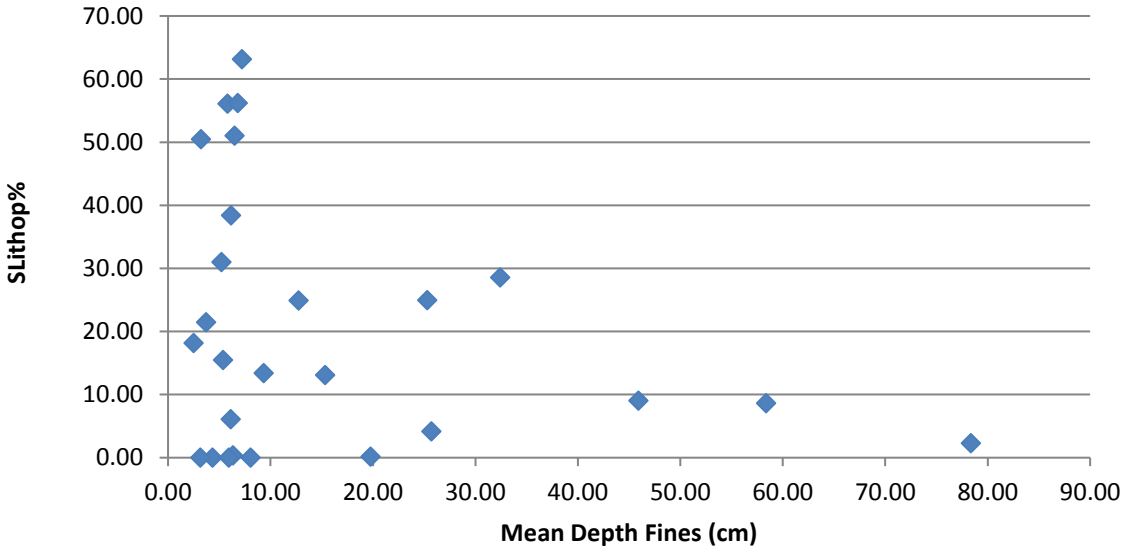

Figure 22. Simple lithophilic spawner percentage and mean depth of fine sediment

As the percentage of fine sediments increase, macroinvertebrate clinger and climber taxa tend to decrease and burrowers increase. Clingers live on firm substrates and climbers live on plant debris, as these materials become covered in fines the macroinvertebrate community decreases (Figure 23). Limited habitat availability, consisting of lack of riffles and an excess of bedded sediment, are stressors to the fish and macroinvertebrate communities.

While fine substrates in the river include muck and silt, sand is the predominant fine substrate. The underlying sand substrate (Figure 24) could be natural due to geologic influences, however the amount of embeddedness is likely influenced by erosion (Figure 25) and deposition. Sediment influences need to be addressed to prevent further filling in of pool and riffle areas.

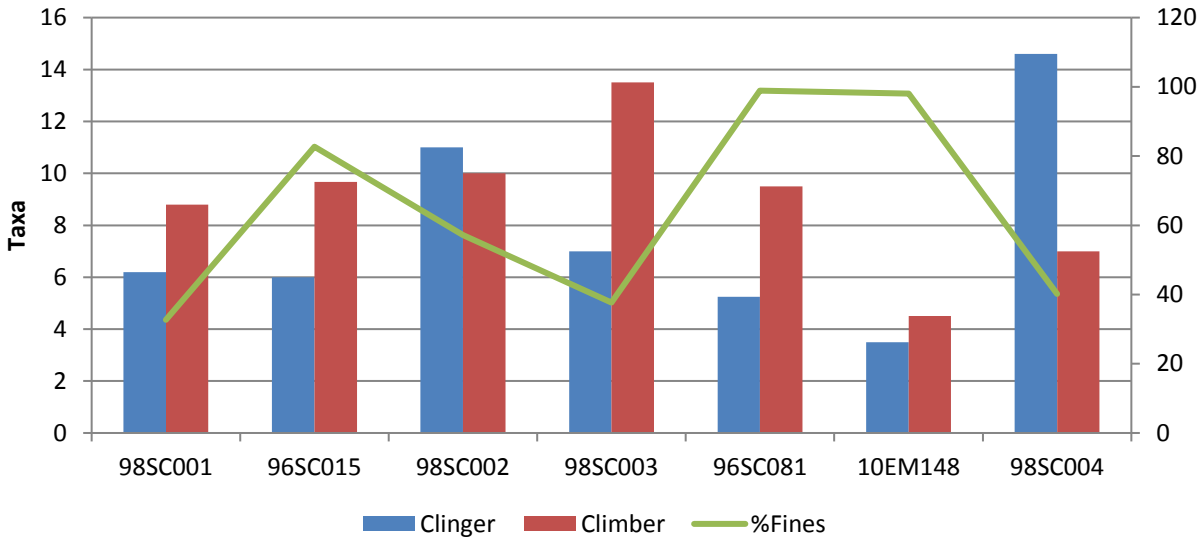

Figure 23. Macroinvertebrate taxa and percentage of fines

Figure 24. Sand substrate on Rush Creek

Figure 25. Streambank erosion on Rush Creek

Candidate cause: Suspended sediment

TSS values from the Rush Creek in recent years were analyzed by month (Figure 26). The majority of samples were taken at station S000-125. The standard for TSS for the central region of the state is 30 mg/L. The values were highest stations S000-125 and S003-468, with four values over 30 mg/L (90 mg/L the highest).

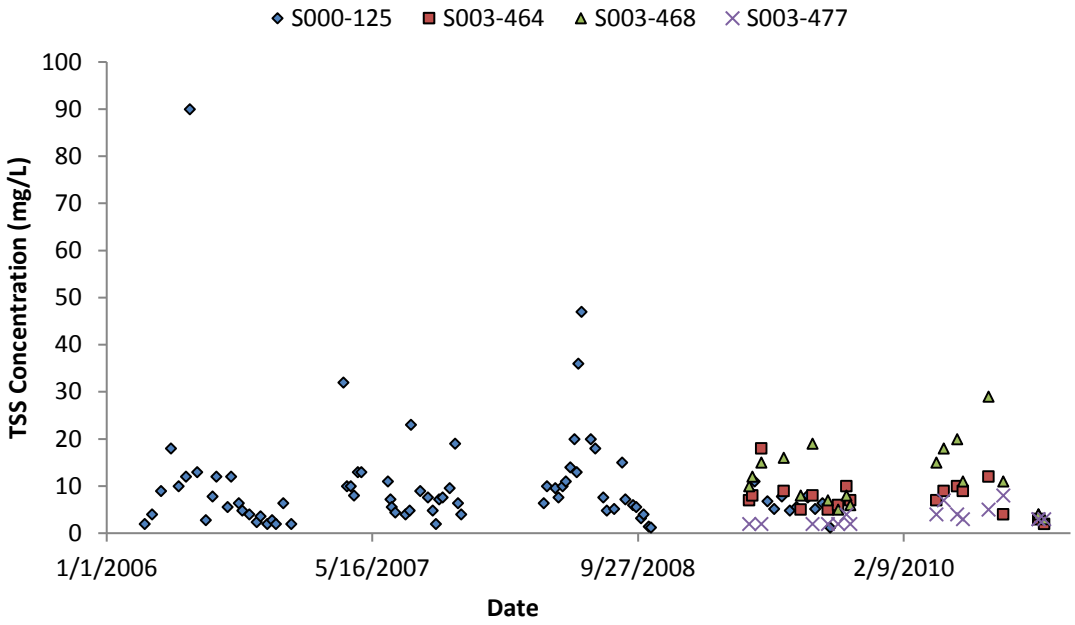

Figure 26. TSS values on Rush Creek

Biotic response

Herbivore species of fish decrease as TSS values increase. The individual herbivore percentages on Rush Creek are low, ranging from 0 (98SC003) to 7.52 (98SC004), and averaging 0.34%. The highest percentage was at station 98SC004 in 2001, but the percentage fell to 0.33% in 2009. The average statewide for fish classes 5 and 6 were 6.37% and 4.69% respectively. The average statewide for fish classes 5 and 6 were 2.07 and 5.67% respectively. TSS can also affect both the number and growth of smallmouth bass. While smallmouth bass were not collected at each visit, 22 smallmouth bass were sampled at one visit in 2009 at station 98SC004 alone. A range of sizes were collected. TIVs show that the fish communities on Rush Creek are predominantly comprised of species in quartiles 3 and 4, which are most intolerant to TSS (Figure 27).

The number of macroinvertebrate taxa collected that are intolerant to TSS ranged from 1 (station 96SC081) to 11 (station 98SC001), and average 4. Collector-filter percentages ranged from 2.55% (station 96SC081) to 39.32% (98SC001) with an average of 18.23%. The average collector-filterer percentage statewide in class 5 and 6 were 26% and 16% respectively. The percentage of long-lived individuals decrease as TSS values increase. Stations had a percentage of long-lived macroinvertebrates ranging from 0.31 (98SC001) to 11.04% (98SC004). The long-lived macroinvertebrate percentage increases from up to downstream. While the presence of TSS intolerant macroinvertebrate and fish taxa points to suspended sediments not affecting the biological communities, the herbivore and long-lived individuals both decreased over time. This points to possible degraded conditions. While TSS is inconclusive as a stressor, conditions should continue to be monitored particularily in the upstream section.

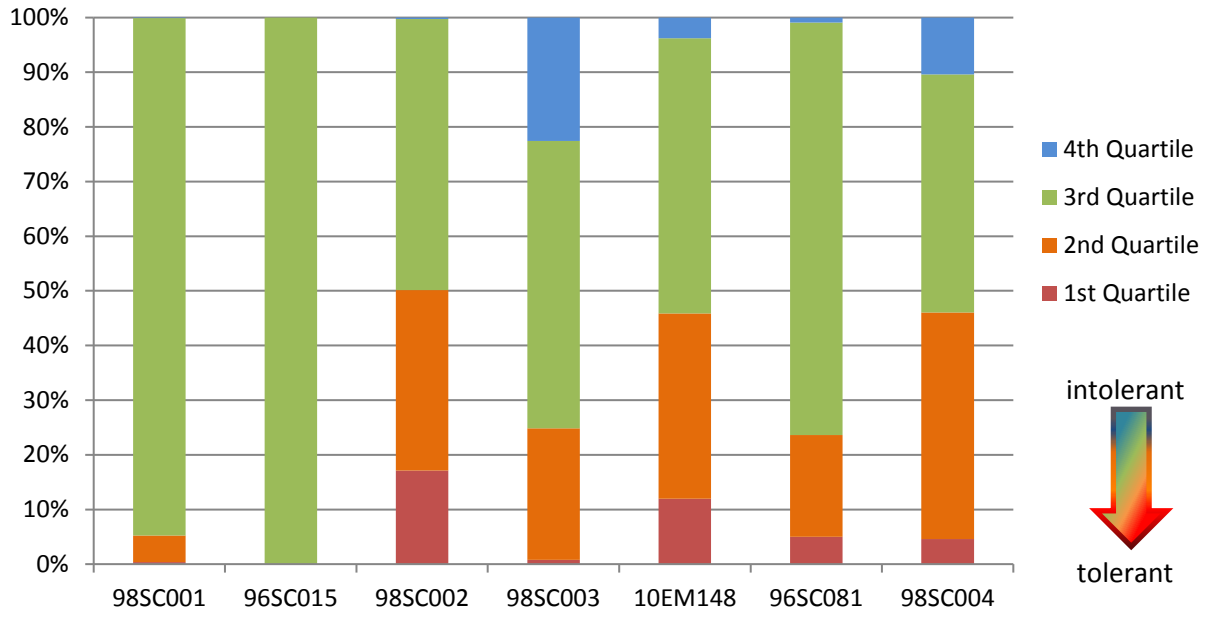

Figure 27. TSS TIV fish on Rush Creek

Candidate cause: Physical connectivity

Fish migration is dependent on stream connectivity. Former dams were located both downstream of Rush Lake where boards were removed allowing water to pass through, but the dam structure remains (Figure 28) and in Rush City where the dam failed in 2003. A culvert located on Government Road is perched (Figure 29), creating a gradient that makes it difficult for fish to move upstream.

Figure 28. Old dam structure on Rush Creek

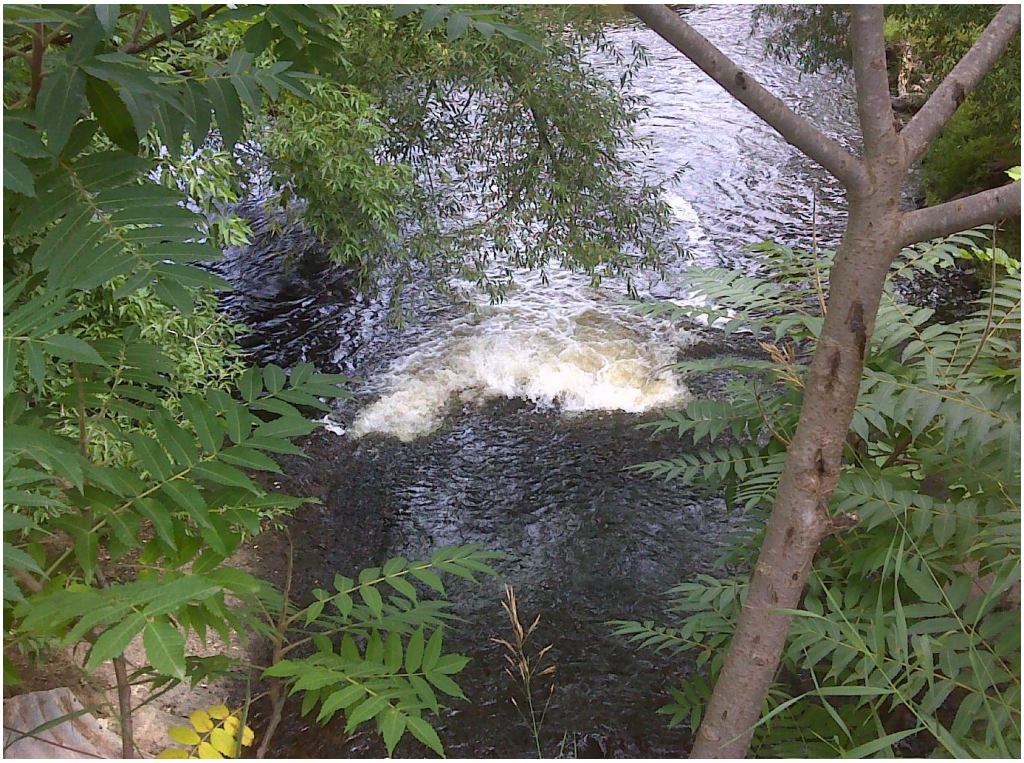

Figure 29. Perched culvert on Rush Creek

Biotic response

Looking at the fish captured during biological sampling shows a difference among migratory fish sampled upstream and downstream of the culvert (Table 4). The differences between the two areas are redhorse species, Iowa darters, and brown trout. The downstream sites do have larger drainages and higher gradient however; the biological differences start between station 98SC003 and station 10EM148 which are similar in drainage and gradient. Samples were taken prior to the removal of the dam; it is expected that the removal of the barrier would increase fish migration. The culvert is still creating a barrier and is considered a main stressor to the biological community that should be resized.

Table 1. Migratory fish collected on Rush Creek

Common name	98SC001	96SC015	Old dam	98SC002	98SC003	Culvert	10EM148	96SC081	98SC004
Blackside darter		X		X	X		X	X	X
Brown trout									X
Golden redhorse									X
Iowa darter							X		
Shorthead redhorse							X		X
Silver redhorse								X	X
Walleye				X			X	X	X
White sucker	X			X	X		X	X	X

AUID summary

The main stressors to Rush Creek were DO, phosphorus, lack of habitat, and physical connectivity.

Goose Creek

The 22-mile stretch of Goose Creek from Goose Lake to the St. Croix River (AUID 0703000-510) is impaired for fish. Goose Creek was impaired for macroinvertebrates in 2004, and was corrected in 2011 based on the new IBI. Goose Lake (South Bay and North Bay) is impaired for nutrients, along with Horseshoe Lake which is connected through a tributary to Goose Creek. There are eight biological stations on Goose Creek, which have been sampled 16 times for fish since 1996. Only sites sampled after 2000 were included in the 10 year assessment window, however for the purposes of SID all data was used in this report. Chemical and biological information is available throughout the watershed through sampling done by the MPCA, the DNR, local counties, and citizens. A comprehensive review of biological, chemical, and physical data was performed (Figure 30).

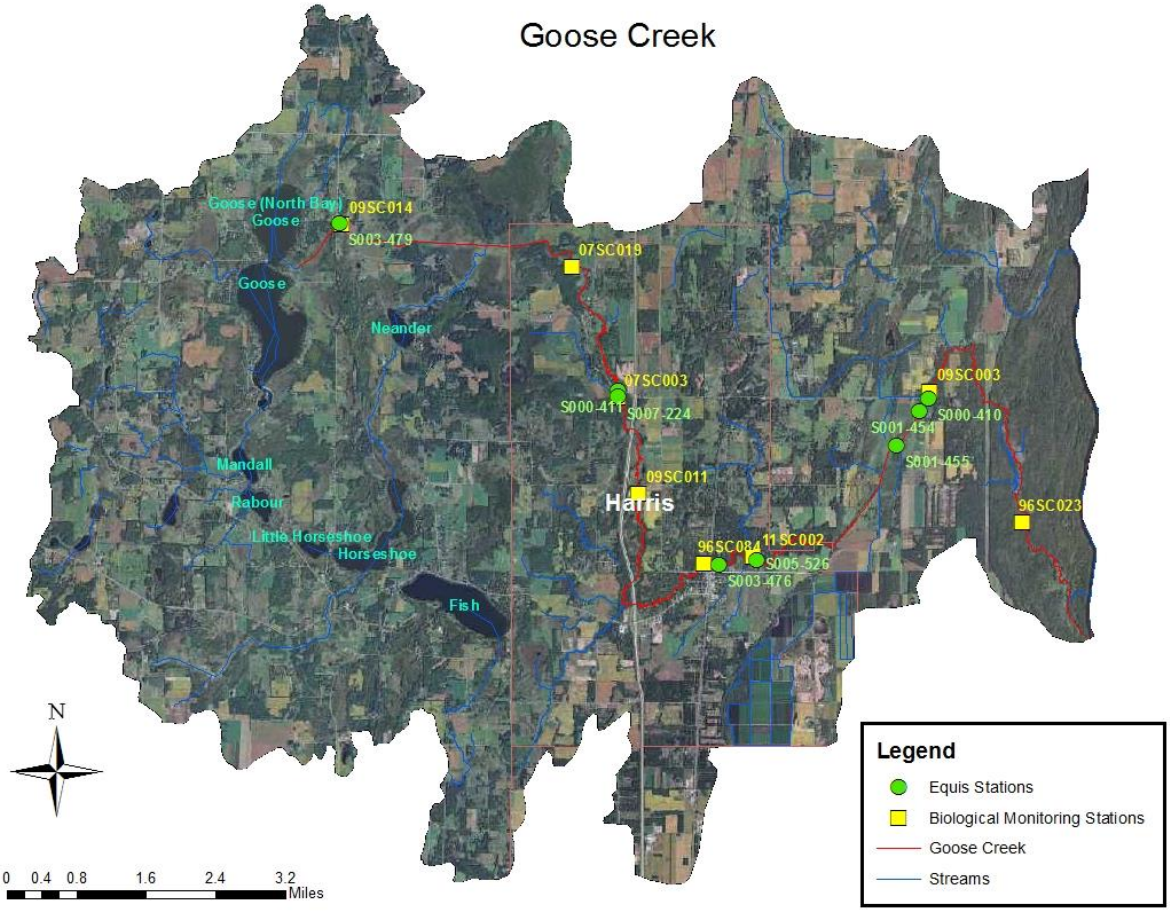

Figure 30. Goose Creek sampling locations

The eight stations were scored in three different fish classes (northern headwaters, northern streams, and low gradient). The two sites (07SC003 and 09SC003) that score below the threshold are spread throughout the AUID between higher scoring sites. The two most upstream sites are both channelized but are both above the threshold and confidence interval. Station 07SC003 is where the impairment begins (Figure 31). This site scores poorly for sensitive species, individual percentages of minnows, wetland species, simple lithophilic spawner species, and the number of fish caught per meter. All six upstream sites score a zero for headwater species minus tolerant species but score well for tolerant taxa percent (Figure 32). Stations 96SC084 and 11SC002 both scored highly, but scores drop again at station 09SC003. Station 09SC003 scores particularly poorly for intolerant and the percent of individuals that mature at greater than three years of age (Figure 33).

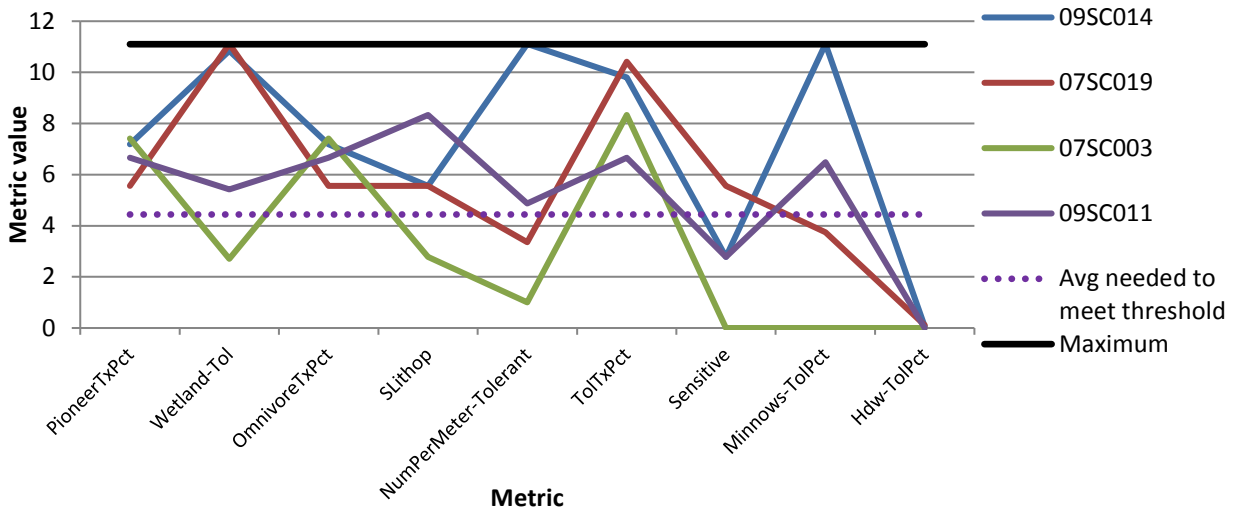

Figure 31. Fish metric scores for low gradient sites on Goose Creek

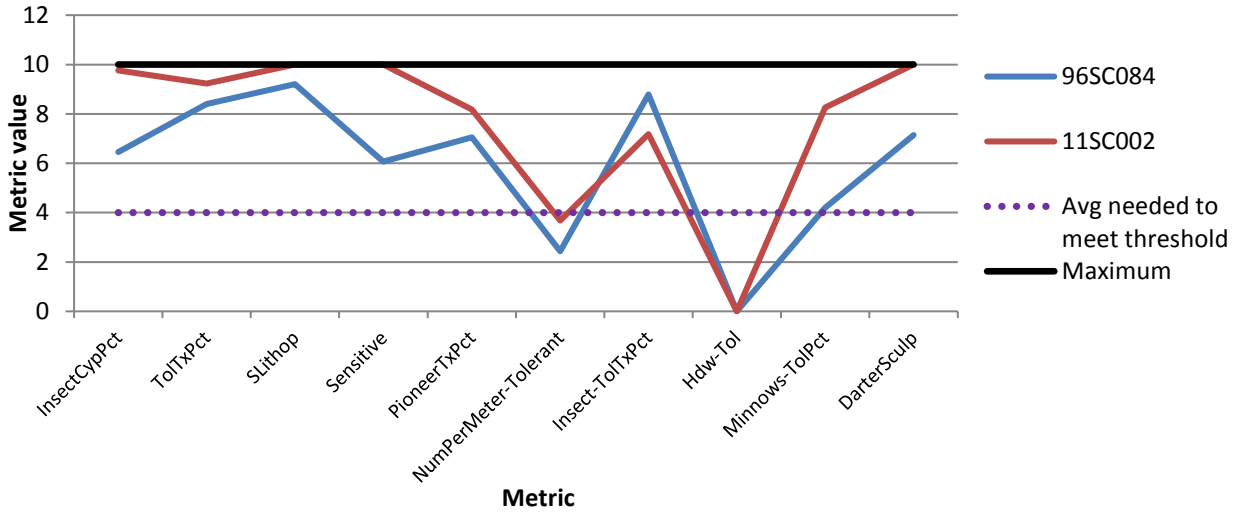

Figure 32. Fish metric scores for northern headwater sites on Goose Creek

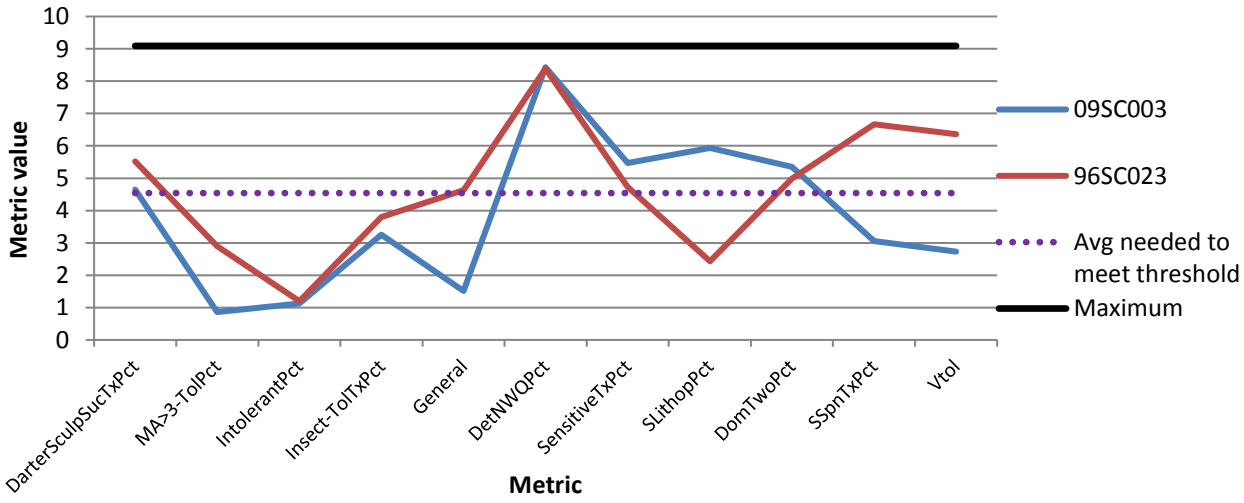

Figure 33. Fish metric scores for northern streams in Goose Creek

Seven visits have occurred on 96SC084 between 1996 and 2007 (Figure 34). The scores steadily increased from 1996 to 2007, with the exception of the visit in 2000. The highest scoring samples were in 2007 and was well above the threshold. The headwater taxa have consistently scored poorly over time, as have the number per minute metric, except for the most recent visit in 2007. The site has consistently had high metric scores of insectivore and simple lithophilic taxa percent.

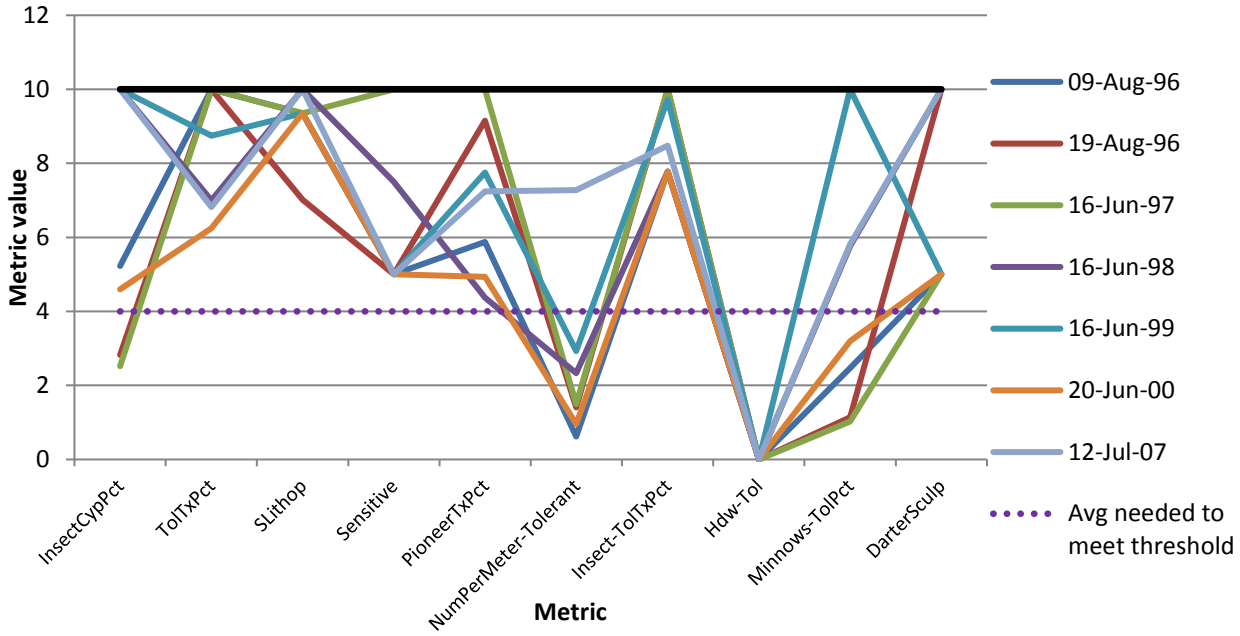

Figure 34. Site 96SC084 over time

Candidate cause: Dissolved oxygen

The headwater section of Goose Creek is low gradient with increasing gradient just upstream of the city of Harris (Figure 35). Early morning DO readings in 2012 show values not rising above the standard of 5 mg/L until Harris City Park (Figure 36). Afternoon re-readings at the upstream sites showed a large difference between the morning and afternoon DO values indicating likely elevated daily DO fluctuations.

Figure 35. Station 07SC003 (August 3, 2012)

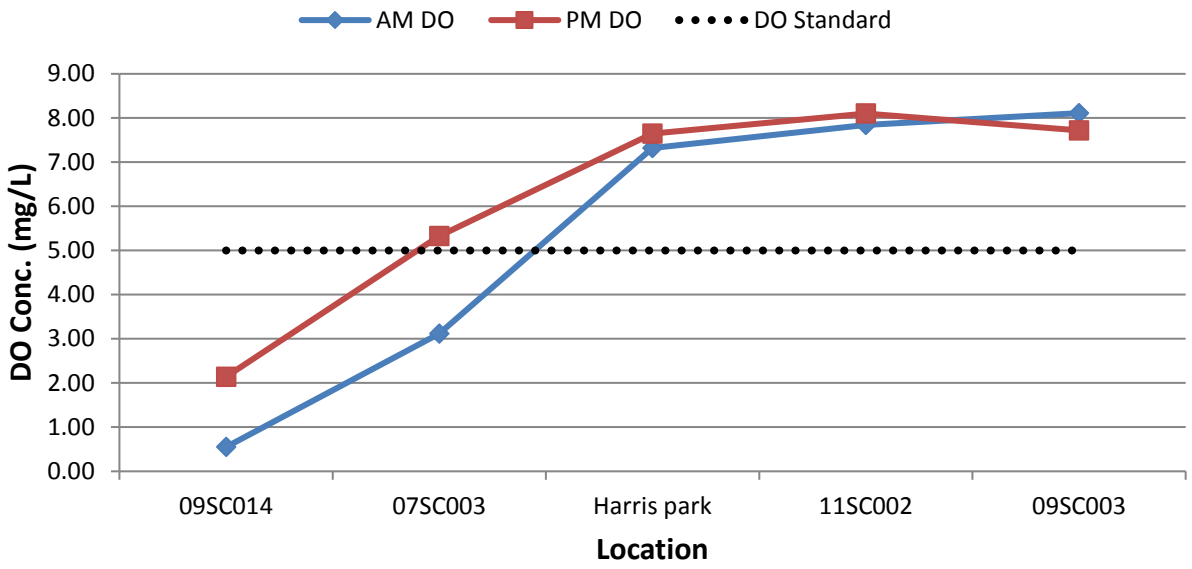

Figure 36. Longitudinal DO on July 19, 2012

Continuous DO data was collected in Goose Creek, at station 07SC003, in August 2012 (Figure 37). This data showed values that daily dipped below the standard of 5.0 mg/L, with daily fluxes up to 7.12 mg/L (Figure 38). The central regional standard of daily DO flux is 3.5 mg/L. All of the daily DO flux values were above this value except for one. While Goose Creek is a low gradient system influenced by wetlands which naturally experience DO fluctuations, DO flux values between 2.0 to 4.0 are typical in a 24-hour period (Heiskary et al, 2010). Daily DO fluctuations are a measure of stress on the aquatic community. Algal respiration and photosynthesis are considered primary drivers of daily flux in DO, and high daily fluctuations of DO are connected to nutrient concentrations.

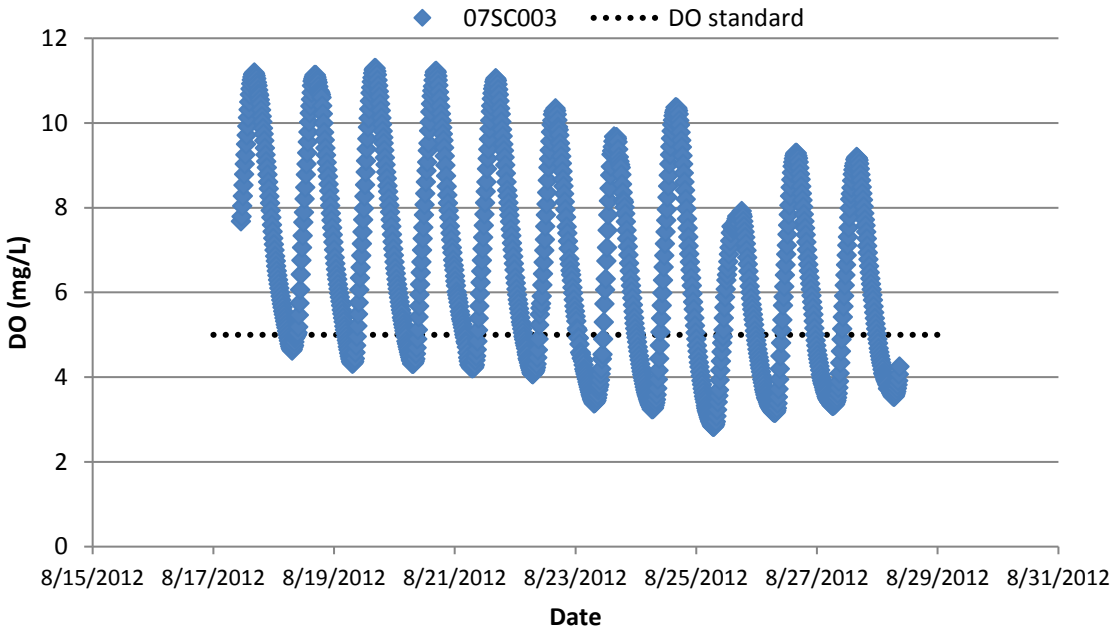

Figure 37. Continuous DO values at station 07SC003

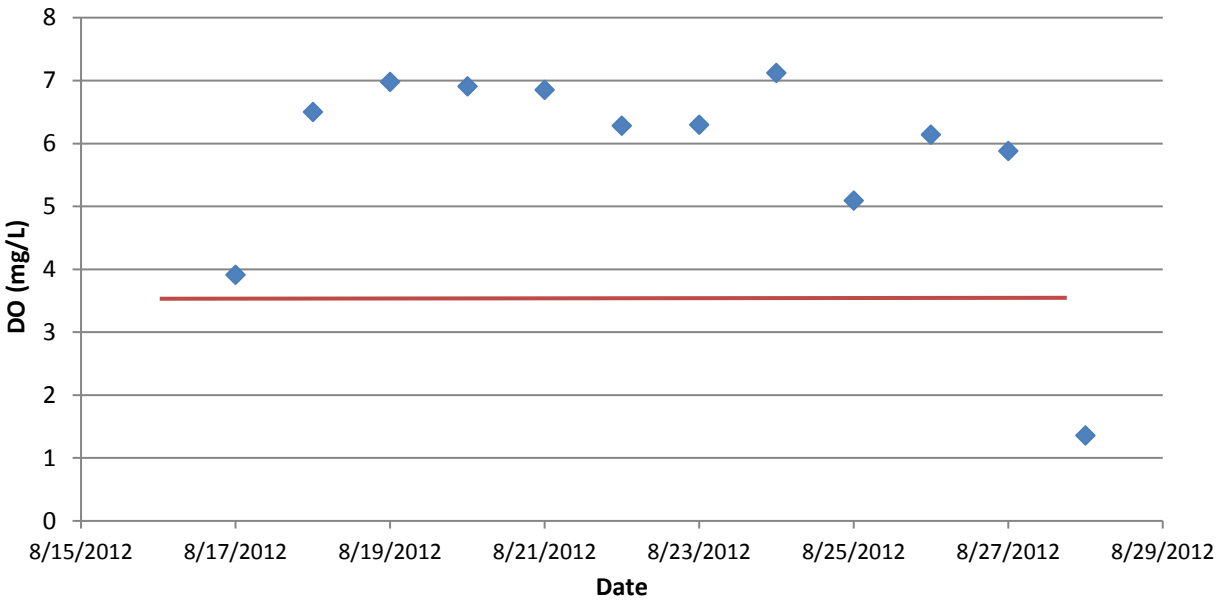

Figure 38. DO flux values at station 07SC003

Biotic response

Low DO values correspond with increased tolerant species and decreased sensitive species. The average sensitive fish percentage statewide for fish classes 5, 6, and 7 were 22.32, 15.11, and 8.14%. Sensitive individual percentages ranged from 0% at station 07SC003 (class 7) to 28.10% at station 09SC003 (class 5). Stations 09SC014, 07SC019, 07SC003, four of the seven visits at station 98SC084 all had visits with sensitive percentages below the statewide averages. Tolerant percentages ranged from 18.05% to 76.47% and averaged 46.22%. The average statewide in classes 5, 6, and 7 were 36.15, 66.62, and 70.61%. The station with the highest tolerant percentage was 07SC003 (76.47%). Species that mature at greater than three years of age are inversely correlated with low DO values. The range of mature age species percentages ranged from 0% to 16.8%. The percentage was highest at station 96SC023, but the percentage decreased over time from 16.8% in 1996 to 5.5% in 2007. The average percentage statewide in classes 5, 6, and 7 were 12.38, 2.83, and 4.44%. Stations 09SC014, 07SC019, 07SC003, 09SC011, 96SC084, 11SC002, and one visit at 96SC023 were below the statewide average.

Moving from upstream to downstream along Goose Creek (Figure 39), the early morning DO tolerance indicator values for fish were calculated at the eight Goose Creek sites. The headwater of the creek is predominantly comprised of species in the first and second quartiles of low early morning DO tolerance. Station 07SC003 had the highest percentages of fish in the first quartile, which are most tolerant to low DO conditions. This corresponds with the low DO concentrations collected at 07SC003. Downstream of station 09SC011, the majority of the fish communities are in the third and fourth quartiles, which means that species less tolerant to low DO conditions comprise most of the community. The presence of species that are sensitive to low DO conditions means that low DO conditions are likely not present.

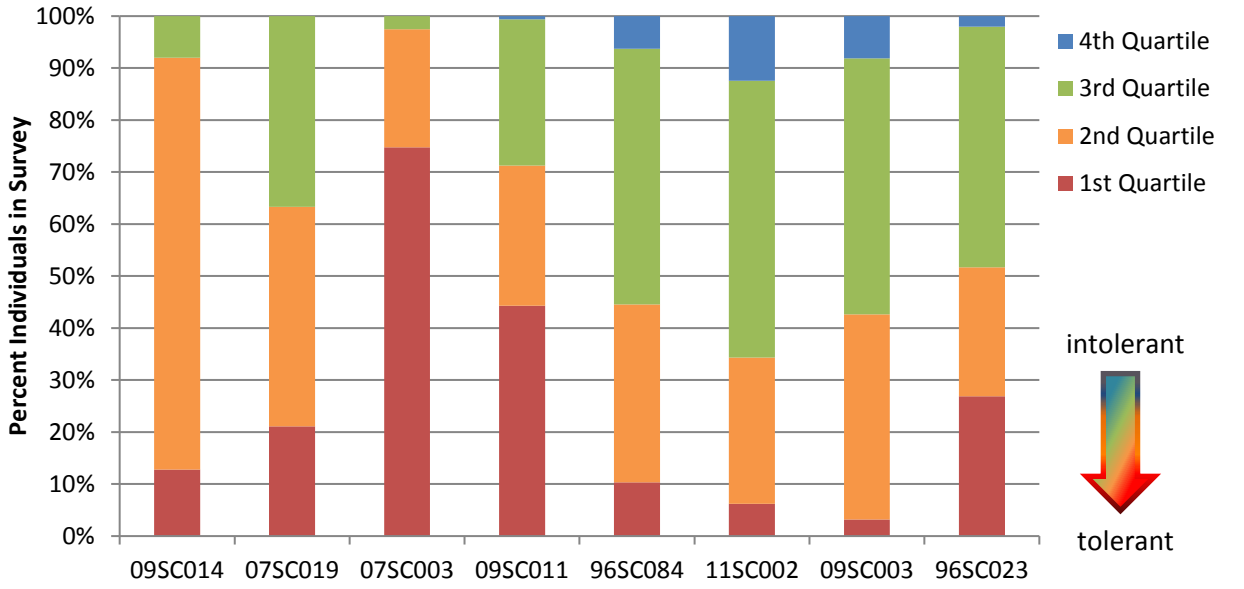

Figure 39. DO TIV values for stations on Goose Creek

As DO flux increases above 4.0 mg/L per day, the sensitive fish population falls to less than 10% (Heiskary, 2008). Sensitive fish individuals ranged from 0 to 38.35% on Goose Creek. The three upstream stations (07SC019, 09SC014, and 09SC003) all had less than 10% sensitive individuals, as did three visits at station 96SC084. The tolerant species percentages in the upper reach were also elevated and the mature age species percentages were low throughout the reach. The lower section of Goose Creek has increased gradient, is comprised of species more sensitive to low DO, and has higher number of sensitive species. Based on the low DO values recorded in the headwaters, the presence of low DO tolerant fish in the headwaters of the stream, and the low number of sensitive species low DO is a localized stressor in the upstream portion of the stream

Candidate cause: Phosphorus

Upstream of Goose Creek, both the bays of Goose Lake are impaired for excess nutrients. In Goose Creek, the highest phosphorus concentrations were collected in June (Figure 40). Values were highest at station S000-410, with a maximum of 0.306 mg/L, which is three times higher than the central region standard of 0.100 mg/L. There were areas of dense algae growth on Goose Creek, which is often tied to excess nutrients (Figure 41). Dense algae both in the living form and dead can affect habitat availability by covering access to substrate.

Chlorophyll-a and BOD values are proximate measurements of eutrophication and have more direct impacts on biology than phosphorus. There is no current available data for these parameters during the summer months when values are highest. Two chlorophyll-a samples were collected in March of 2006 with values of 2.8 and 16 µg/L. The standard for the central region is 18 µg/L.

County Ditch 9, which flows into Goose Creek just upstream of station 09SC003 (S000-410) where phosphorus values were highest, had concentrations ranging from 0.188 to 0.227 mg/L in 2011. Orthophosphorus is the form of phosphorus that is readily available for plant and algal uptake, and can influence excess algae growth. Orthophosphorus made up 50% of the phosphorus concentrations of each of the three samples on CD 9 and averaged 46% on station S000-410 on Goose Creek, ranging from 24 to 100%.

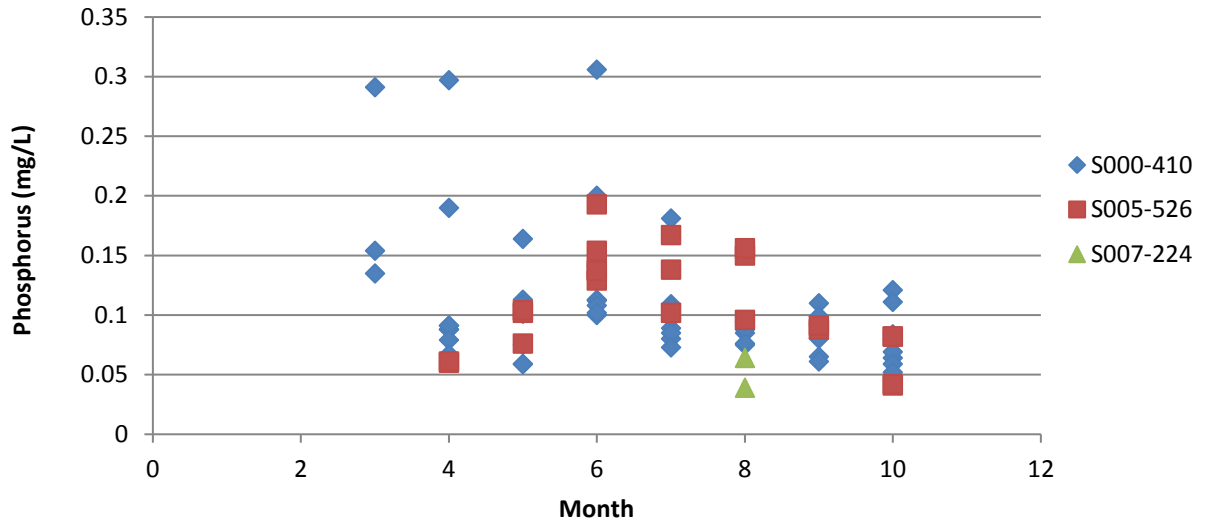

Figure 40. Phosphorus concentrations along Goose Creek

Figure 41. Algae at 07SC003 (August 17, 2012)

Biotic response

Increased phosphorus levels have an inverse relationship with sensitive individual fish percentages and an increase in tolerant taxa percentages of fish. Sensitive individual fish percentages ranged from 0 to 38.35, the sites with the smallest percentages are the three upstream stations 07SC019, 07SC003, and 09SC014 (0 to 1.04%). These stations are all in fish class 7. The average percent of sensitive species in fish class 7 streams statewide is 9.48. Darter percentages are also inversely correlated with phosphorus. Stations ranged from 0.91 to 33.70%. The stations with the lowest values (and which are all below their respective class averages) were station 09SC014 (0.91%) just downstream of Goose Lake and stations 11SC002 (5.71%) and 09SC003 downstream of Harris. Darter percentages were low at station 09SC003 (7.69 and 7.95%) where phosphorus is highest.

Tolerant fish percent on Goose Creek ranged from 18.04 to 76.03%, averaging 46.22%. The stations with the highest tolerant percent were 07SC003, 96SC084, and 96SC023. Tolerant fish taxa percent in fish classes 5, 6, and 7 were 36.11, 66.59, and 70.59%. The percentages of sensitive individual fish species are lower on the headwaters of Goose Creek than in the other class 7 streams in statewide. There are a range of tolerant fish percentages; some are above statewide averages while most are close to or below.

Low DO and DO flux is a stressor in the upper part of the watershed, where the individual sensitive percentages are also lowest. Phosphorus is likely contributing to the elevated DO fluctuations, particularly in the upstream part of the stream, and is a stressor to the biological community. Phosphorus mitigation is important to prevent further eutrophication of the stream.

Candidate cause: Nitrate

Nitrate concentrations in recent years on Goose Creek range from less than 0.05 to 2.3 mg/L, and average 0.38 mg/L. The majority of samples were taken at station S000-410. A few samples were also collected upstream at station S007-224 where concentrations were 0.42 and 0.57 mg/L respectively. The highest values taken during biological sampling were at stations 09SC003 and 98SC084. The 75% percentile of the North Central Hardwood Forests ecoregion norm is 0.26 mg/L. The unnamed ditch that flows into Goose Creek just upstream of station 09SC003 had a nitrate concentration of 1.3 mg/L after snowmelt in 2011 and 0.1 mg/L after a rain event.

Biotic response

Macroinvertebrates have stronger responses to nitrate, so while macroinvertebrates are not impaired on this stream nitrate intolerant macroinvertebrates were looked at to see if nitrate is affecting the community. Sensitive fish species have a negative relationship with nitrate, but sensitive species are also affected by DO and phosphorus. Nitrate intolerant macroinvertebrate taxa range from 1 to 8 and average 4.25. The nitrogen index value for sites in the St. Croix River basin averaged 2.48, while sites on Goose Creek range from 1.83 to 3.01.

Fish tolerance indicator values were used to determine how tolerant the fish community was at each biological station. This can provide clues to the effects of a pollutant, by looking to see if the majority of the community is tolerant or intolerant to the pollutant. If the majority of the community is tolerant, this is an indication that the pollutant is affecting the biological community. The majority of fish at five of the biological stations is comprised of fish in quadrants one and two. Stations 07SC003 and 09SC011 are primarily comprised of fish from quartiles three and four; indicating nitrate is not affecting the fish in this section of the creek (Figure 42). While stations 96SC084 and 09SC003 were averaged, the most downstream station, 96SC023 was not averaged in order to show the transition from less tolerant to more tolerant fish species between the samples in 1996 and 2007.

Nitrate concentrations on Goose Creek are not high, but are above background levels. Nitrate does not seem to be affecting the macroinvertebrate community. There does seem to be a localized effect on fish communities in areas of the stream, particularly at station 09SC003. The effects seen to biology are likely a combination of stressors and are inconclusive to whether it is attributable to nitrate.

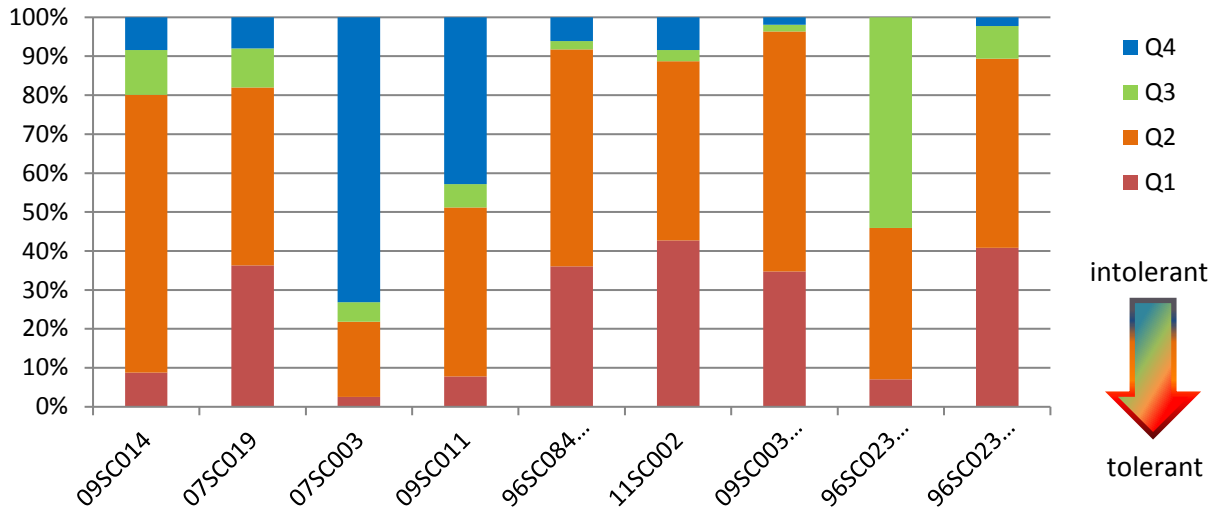

Figure 42. Nitrate fish TIVs on Goose Creek

Candidate cause: pH

The standard for pH in surface waters is a range of 6.5-8.5, values over 8.5 and large daily pH fluctuations are tied to nutrient enrichment. Fluctuations in pH, similar to those with DO, are due to photosynthesis and respiration. High pH values have been recorded at stations S005-526, S001-454, and S000-410 (9.13 and 9.15 respectively). All of the high values were collected in 2010 and were collected in the downstream portion of the creek, located downstream of Harris. Continuous data collected during 2012 recorded a high value of 8.33, and a maximum flux of 0.72. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013). High fluctuations reflect excessive in-stream primary production, as algae and aquatic plants drive up pH during the daytime.

Biotic response

EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (U.S. EPA. 2013). Bluegill and yellow perch were common species collected during fish samples at stations on Goose Creek, including in the lower portion where elevated pH values were found. The elevated pH values are not currently a stressor to the fish community.

Candidate cause: Lack of habitat

Goose Creek is wide and shallow, with a general lack of pools and riffles, which are important fish habitat and spawning areas. Additionally, there were high percentages of fine sediments during biological visits. MSHA scores taken during biological sampling ranged from 42 to 75.05 on the seven locations on Goose Creek. The two downstream sites scored in the good category, station 07SC019 scored in the poor category, while the rest were in the fair category. This was due mainly to difference in channel morphology, substrate, and cover scores. The channel morphology scores on Goose Creek ranged from 9 to 31 (out of 36). These scores were low due to lack of riffles, depth variability, sinuosity, and channel development. The substrate scores ranged from 12.3 to 20.3 (out of 27). The cover scores ranged from 7 to 15 (out of 17). Differences in substrate scores were due mainly to lack of coarse substrate at station 96SC023, small riffle percentages, severe embeddedness at station 07SC019, and low pool percentage at station 09SC003.

Quantitative habitat data showed the percentage of fines ranging from 13.46 to 92.31, averaging 50.64% (Figure 43). Where coarse substrates were present, embeddedness of fine sediments ranged from 31.25 to 96.4%, and averaged 50.15%. There was a lack of riffles, pools, and deep and/or wide pools that fish need for habitat. A diversity of run, riffles, and pools are necessary to create habit and nesting areas for different species. The percentage of run stream type ranged from 49.73 (station 11SC002) to 94.93 (station 96SC084). Station 09SC003 did not have any deep pools. Station 11SC002 was the only one to have significant percent of riffle, with station 07SC003 only having 1.28%.

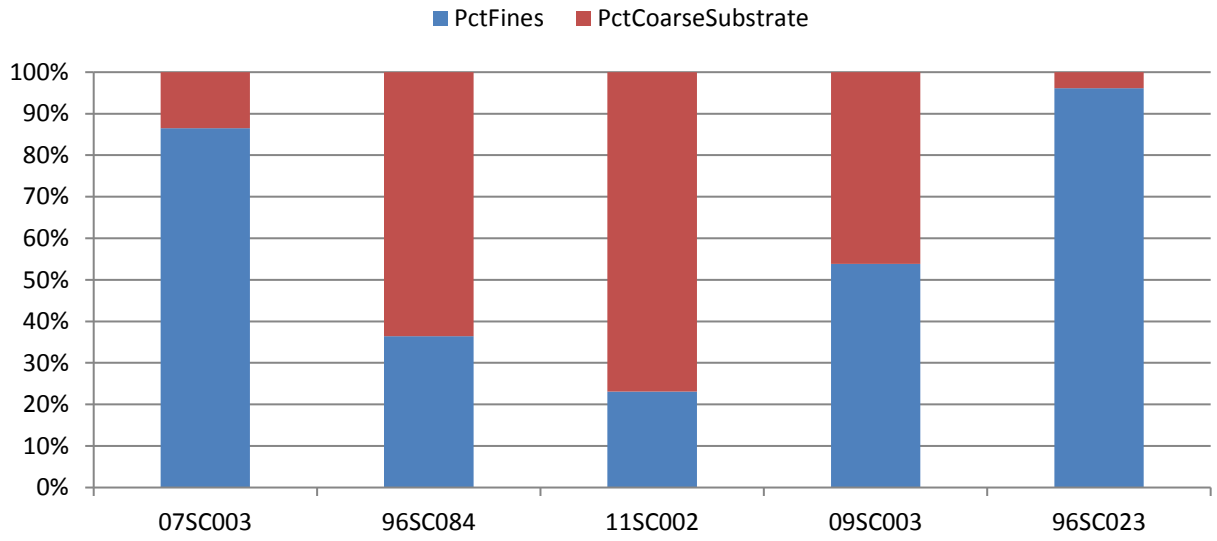

Figure 43. Percentage of fines and coarse substrate on Goose Creek

Sand substrate occurs throughout the stream (Figure 44), with thick deposition in some areas. Measurements with a copper rod ranged from 17-28 cm of sand at station 07SC003. Sand shelves and thick areas of dense, very fine sand are present. Further downstream in Harris, the stream still has thick sand deposition but also areas of gravel and good sized cobble. The sand deposition has a natural component, with the surficial geology being comprised of floodplain alluvium. The river and surrounding land use of the river is comprised of soils dominated by greater than 85% of sand substrate, represented in orange in the map to follow (Figure 45).

Figure 44. Sand deposition on Goose Creek (August 17, 2012)

Figure 45. Sand features in Goose Creek

Biotic response

The sand dominated substrate and lack of coarse substrates seems to be having a direct impact on biology, particularly in the upstream section of the stream (Figure 46). Benthic insectivores, darter, sculpin, and sucker, riffle dwelling species, and simple lithophilic spawners require coarse substrate that is not embedded in fine substrate. Tolerant species are shown to increase with a lack of habitat availability. Tolerant species do not follow the trend expected, but the habitat dependent fish are located where coarse substrates are available and are not embedded with fine substrate.

Where full qualitative habitat information is available at biological sampling sites, there is a clear relationship between an increase in depth of fines resulting in a low percentage of simple lithophilic spawners collected (Figure 46).

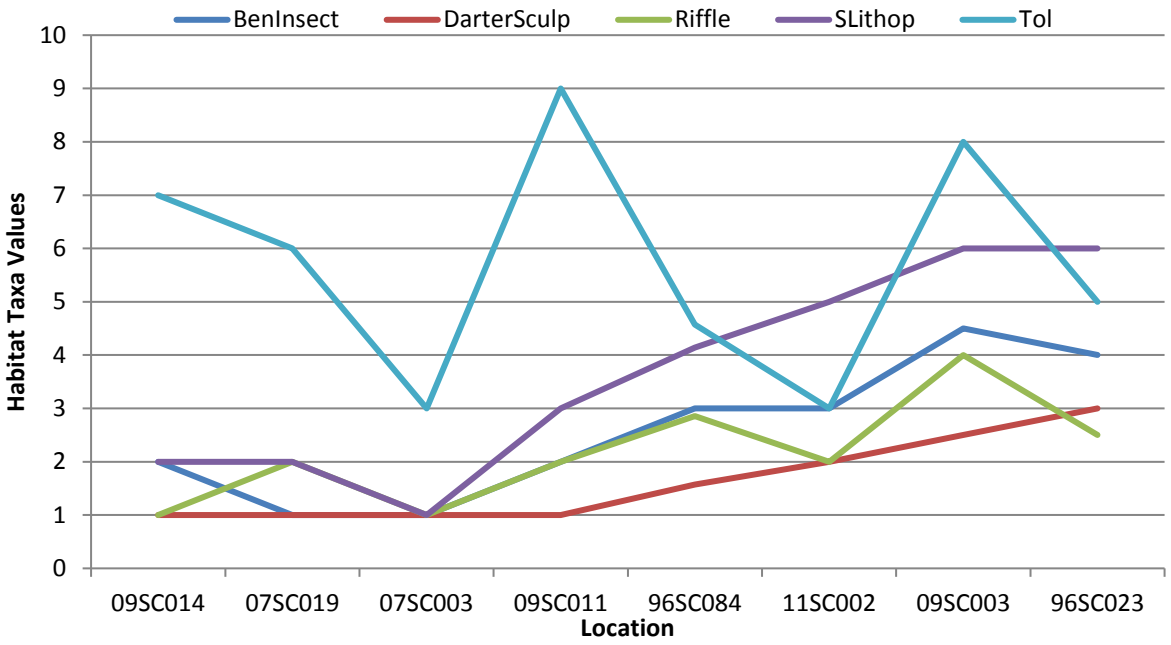

Figure 46. Habitat related metrics in Goose Creek

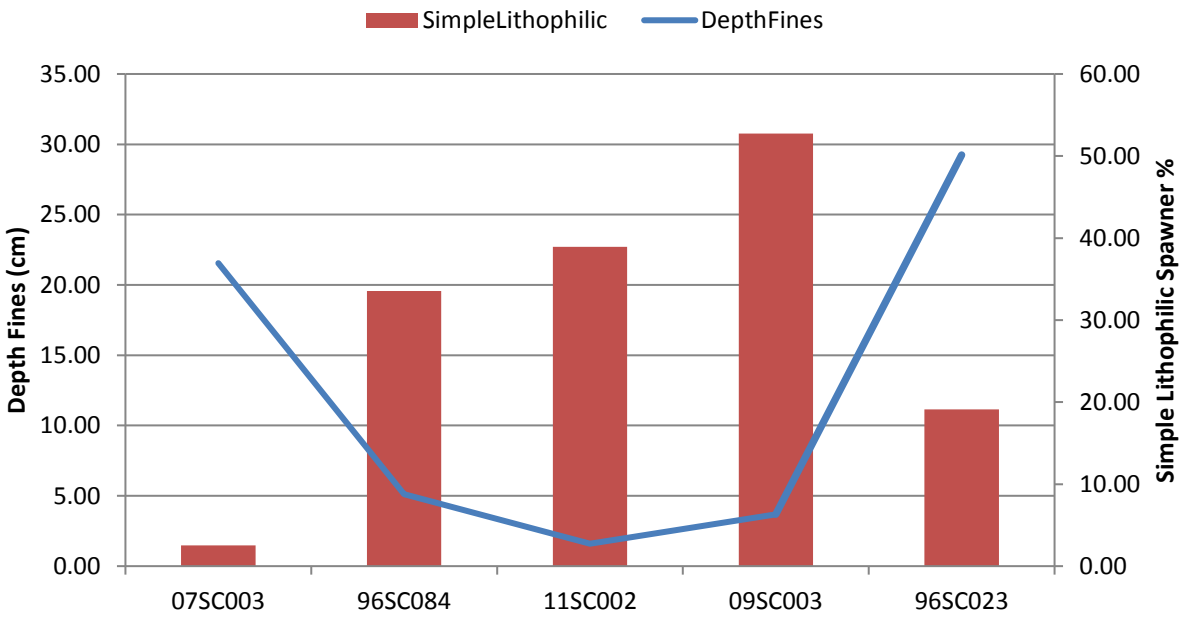

Figure 47. Depth of fines and simple lithophilic spawner

The lack of a diversity of pools and riffles and the presence of fine sediments in the stream bed are impacting the biological community. The lack of depth variability and pool width is found throughout the stream, while the limiting factor of fine sediment is most pronounced in the upper section of the stream. Lack of habitat and excess fine sediments should be considered as a stressor to both the fish and macroinvertebrate communities. Sediment influences need to be addressed to prevent further filling in of pool and riffle areas.

Candidate cause: Suspended sediment

In Goose Creek, TSS values were available at stations S005-526 and S000-410, with values up to 84 mg/L (Figure 48). The standard for TSS for the central region of the state is 30 mg/L. There were 6% of values over 30 mg/L. The highest values were recorded in March, June, and August. Three transparency tube values were below 25 cm, which is the equivalent of 30 mg/L. The values of 23 and 18 cm were taken in July and August.

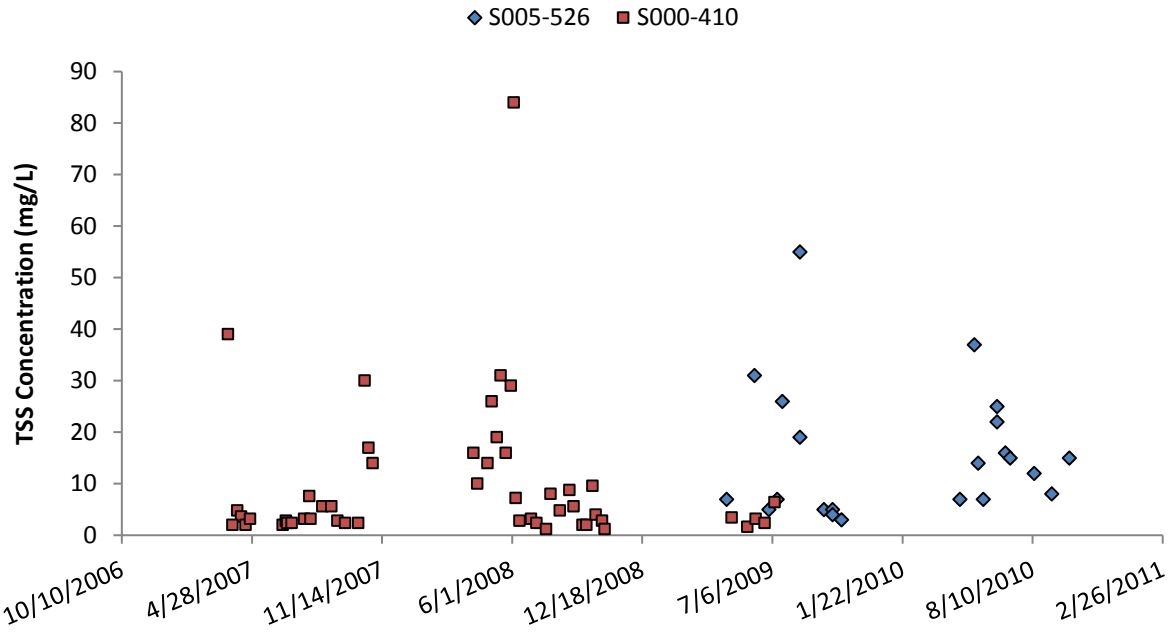

Figure 48. TSS values on Goose Creek

Biotic response

Herbivore species of fish decrease as TSS values increase. The individual herbivore percentages on Goose Creek were low, ranging from 0 to 0.97%, and averaging 0.12%. The average statewide for fish classes 5, 6, and 7 were 2.07, 4.38, and 4.01%. TSS can also affect both the number and growth of smallmouth bass. Smallmouth bass were only sampled at downstream stations with nine sampled at station 96SC023. TIVs show that the fish communities on Goose Creek are predominantly comprised of species in quadrants three and four, which are most intolerant to TSS (Figure 49), except for station 07SC019 which is comprised of 50% quadrants three and four and 50% quadrants one and two.

The number of macroinvertebrate taxa collected that were intolerant to TSS ranged from one (station 96SC084) to seven (station 09SC003), and averaged four. The average for classes 5 and 6 streams were 1.2 and 1.08. The percentage of long-lived individuals decrease as TSS values increase. Stations had a percentage of long-lived macroinvertebrates ranging from 0 (07SC019) to 17.48% (09SC003). The average percentages statewide in class 5 and 6 were 6.37% and 4.69% respectively. Collector-filter percentages ranged from 5.57% (station 07SC003) to 47.85% (09SC003). The average collector-filterer percentage statewide in class 5 and 6 were 26.49% and 16.64% respectively.

The presence of TSS intolerant macroinvertebrate and fish taxa intolerant point to TSS not being a stressor to Goose Creek, however the upstream section does have some low numbers of long-lived individuals and collector-filterers. Herbivore species were low throughout the stream. TSS is inconclusive as a stressor, but the upstream section in particular should continue to be mointored.

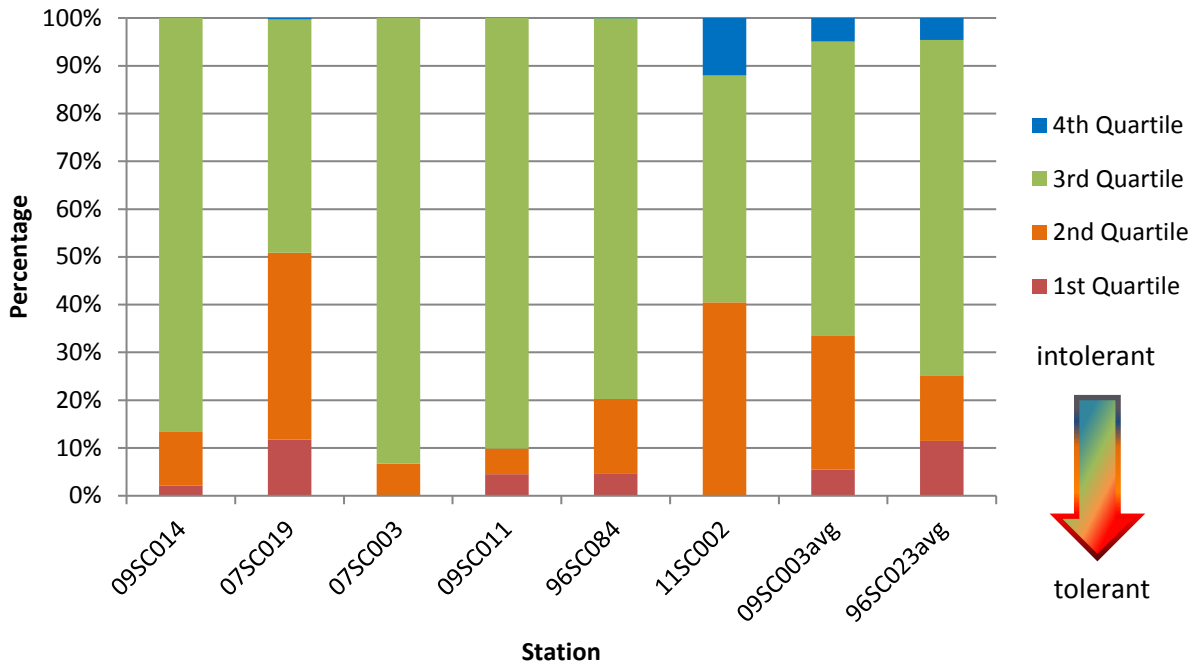

Figure 49. TSS fish TIV on Goose Creek

Candidate cause: Altered hydrology

Both the headwaters of Goose Creek and the section just upstream of station 09SC003 are channelized. The tributary just upstream of station 09SC003 is also extensively channelized (Figure 50). Channelization affects both high and low flow values. There is limited flow information taken in the city of Harris by U.S. Geological Survey (USGS). Flow information is available from 1986 to present, however the data is mainly limited to one or two values per year so determining any trend is not possible.

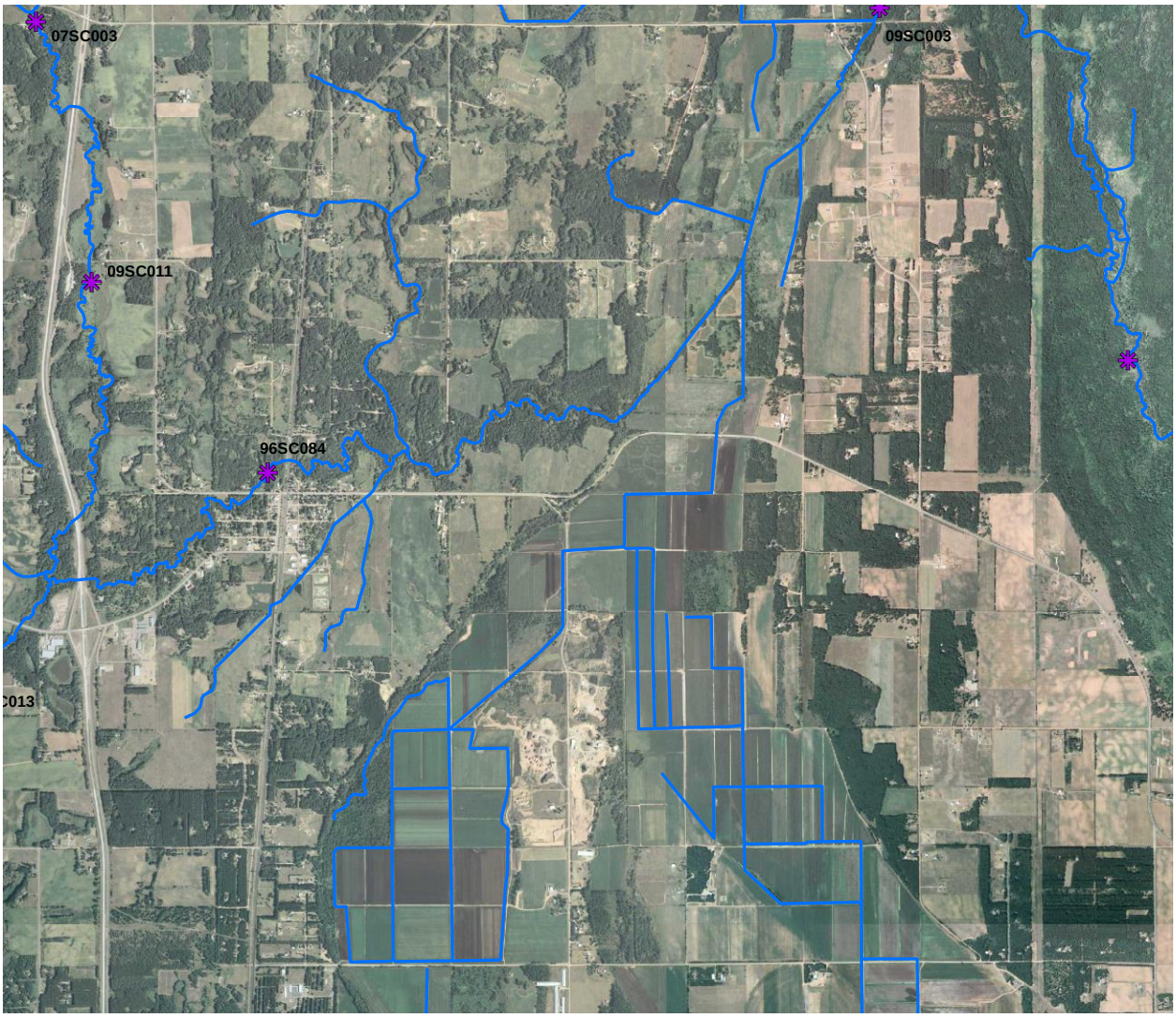

Figure 50. Channelization in Goose Creek

Biotic response

Channelization and tile drainage alters the natural flow regime by moving water through the system at a higher frequency, increasing the impact of high flow events and increasing the intensity of low flow periods, both of which affect biological communities. Increased flow events can cause increased bank erosion and bedload sedimentation, affecting fish species that rely on clean substrate for habitat.

Benthic insectivore and simple lithophilic species can decrease with channelization as bedload increases. Stations 09SC014 and 07SC019 are both channelized and have the lowest benthic insectivore and simple lithophilic taxa percent (11.76 and 6.25 and 11.76 and 12.5). Generalized fish species, which are adaptable to different habitats through generalized food preferences, are also correlated with channelization. The highest numbers of generalized individual percentages are found at stations 09SC014 and 07SC019 (77.01 and 64.71 respectively). Station 09SC003 is located just downstream of a channelized section and also has a high score of general individuals (60.18%). Station 11SC002 also has a high score of general individual percent (63.93) and is not channelized or downstream of a channelized reach, so the high number could be due to other contributing factors.

Benthic insectivore and simple lithophilic spawners taxa percentages are lowest at the channelized sites on Goose Creek, which are correlated to the lack of habitat and course substrates.

Channelization is contributing to the lack of habitat. The effects of altered hydrology could be contributing to the increase of generalized fish percentages, which are more adaptable to changing conditions and food sources, but this would not explain the high percentage at station 11SC002. Other contributing factors are likely affecting the high percentage of general fish species. Altered hydrology is a contributing stressor to lack of habitat.

AUID summary

The main stressors to Goose Creek were DO, phosphorus, lack of habitat, and altered hydrology.

North Branch Sunrise River

The North Branch River spans 24 miles from the headwaters to the St. Croix River (07030005-501), and is impaired for fish. There are nine biological stations, which have been sampled 13 times for fish since 1996. There are a range of fish IBI scores on this river, with the two most downstream sites scoring well, however as a whole the river is not supporting a healthy fish population. The river was impaired for macroinvertebrates but was corrected during the 2011 assessment cycle, when the new IBI showed scores above the threshold. Only sites sampled after 2000 were included in the 10-year assessment window, however for the purposes of SID all data was used in this report. Chemical and biological information is available throughout the watershed through sampling done by the MPCA, the DNR, local counties, and citizens. A comprehensive review of biological, chemical, and physical data was performed (Figure 51).

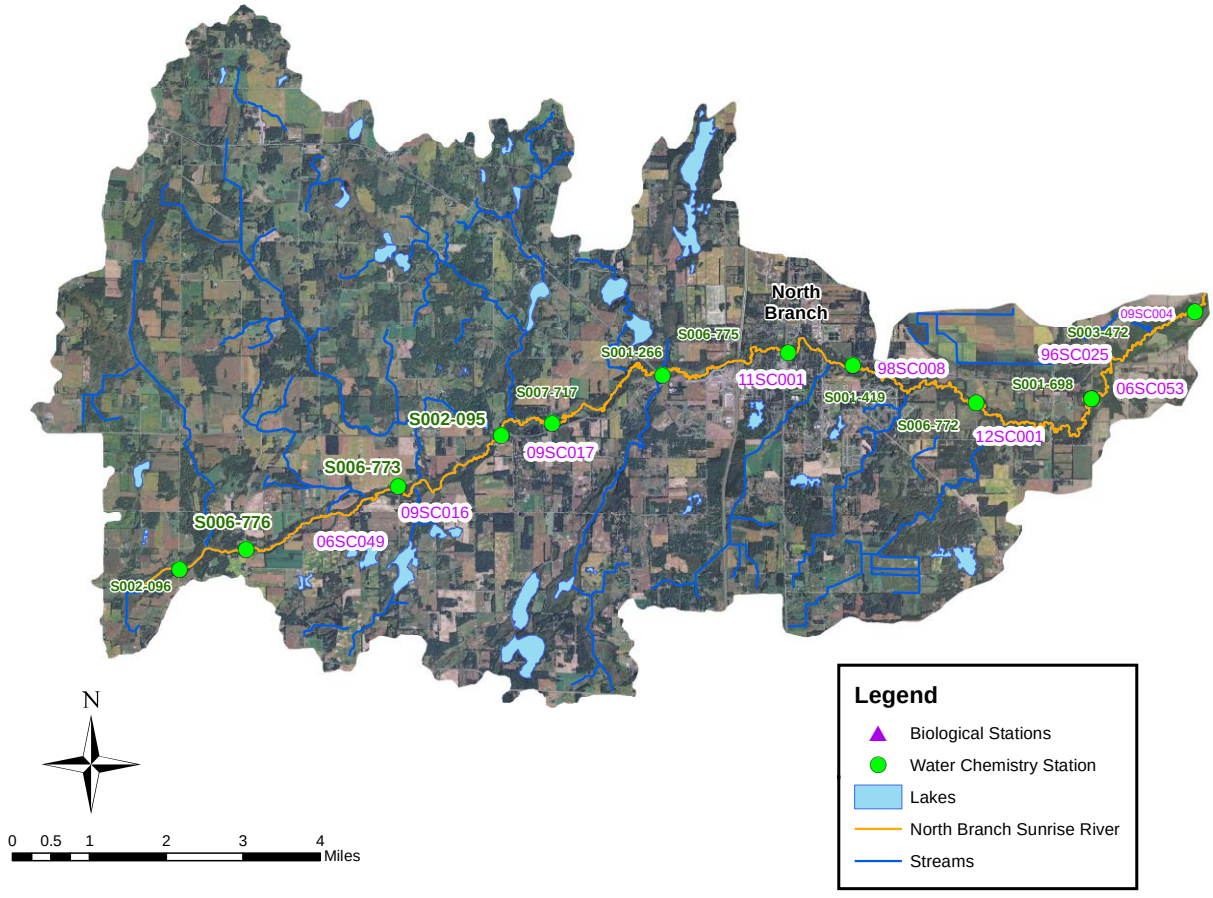

Figure 51. Sampling locations on the North Branch Sunrise River

The nine stations were scored in two different fish classes (northern streams, and low gradient). The upstream sites are in the low gradient streams class (class 7) and the downstream sites are in the northern streams class (class 5). The three sites in the low gradient class are all located upstream of the city of North Branch. The remaining sites are downstream of the city. They are in two different classes due to differences in stream gradient. The most upstream site (09SC049) scored well, and then IBI scores drop off until stations 06SC053 and 09SC004. Station 09SC017 was re-sampled in 2011 and scored better with sensitive and tolerant species than in 2009. All three upstream sites all score poorly for the number of individual percentage of minnows captured (Figure 52). Although the minnow metric is not a part of the class 5 IBI, the number of minnow species collected in the downstream section of the river are similar to those in the upstream section. Station 98SC008, located just downstream of the city of North Branch has been sampled three sites between 1998 and 2009, and the percentage of insectivore species scores have been near zero at all three visits. The downstream sites have low scoring simple lithophilic spawners and mature age species metrics. The downstream sites score better for sensitive taxa (Figure 53).

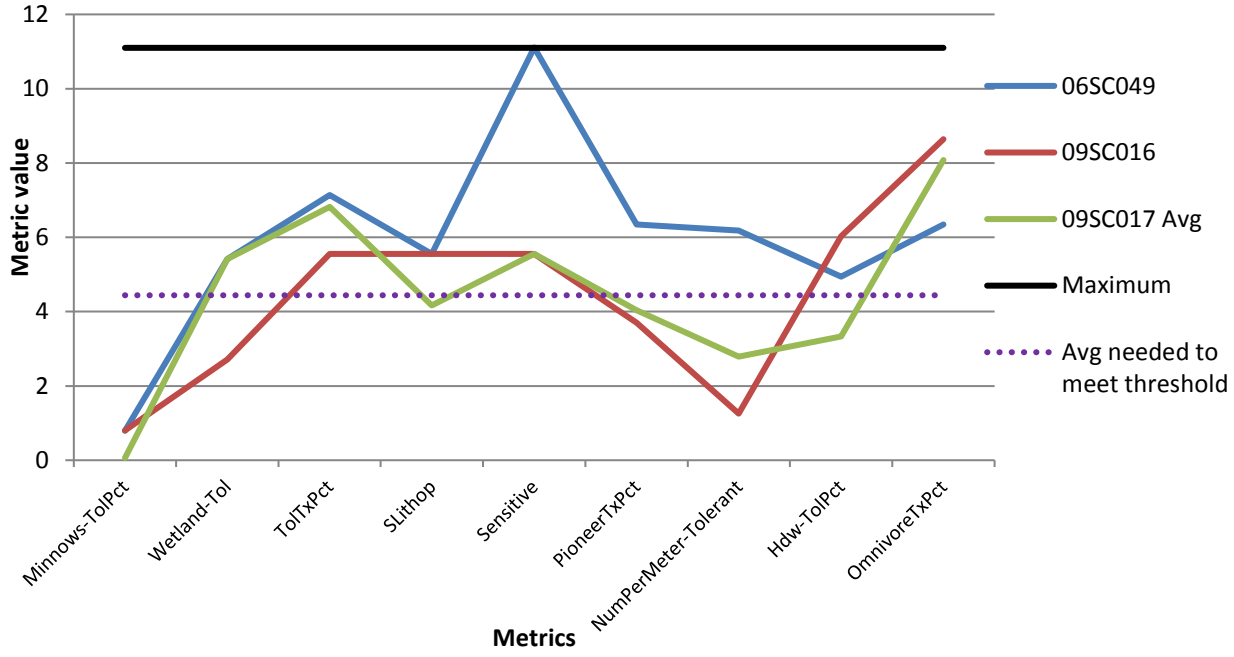

Figure 52. North Branch fish class 7 metric scores

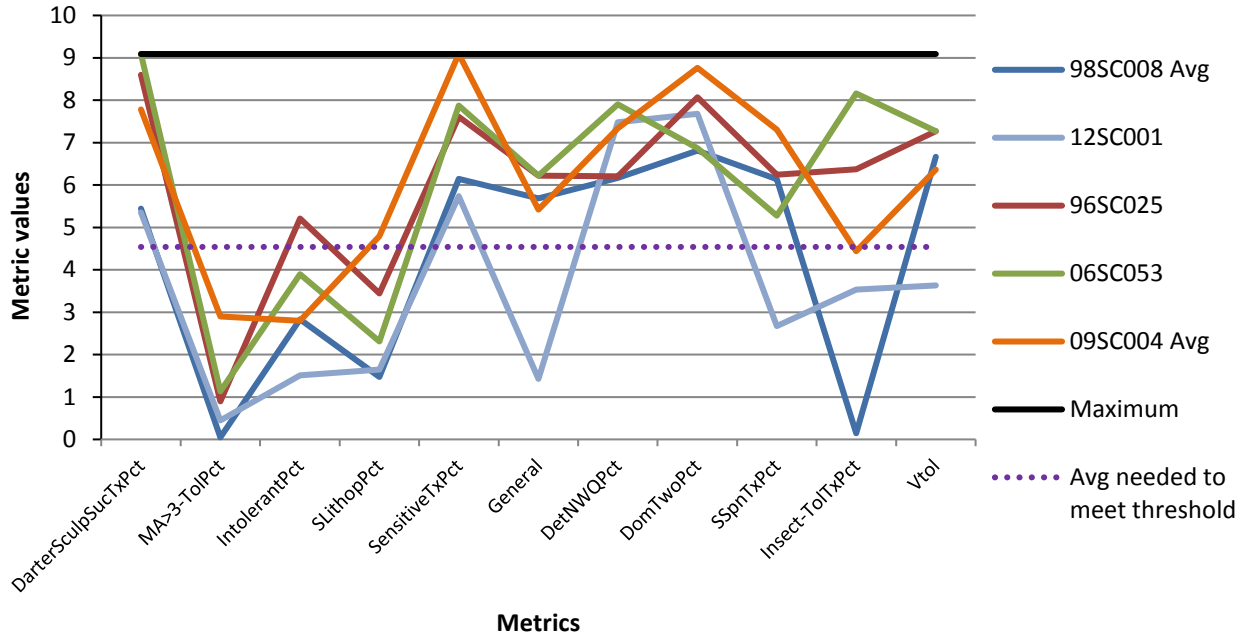

Figure 53. North Branch fish class 5 metric scores

Candidate cause: Dissolved oxygen

Similar to other streams in the watershed, the headwater section of the North Branch Sunrise River is low gradient with riparian wetlands (Figure 54). Gradient increases just upstream of the city of North Branch. Low DO readings have been recorded in the upstream portion of the stream. Afternoon readings at the same locations show a wide gap between morning and afternoon values at the upstream sites.

Figure 54. North Branch Sunrise River riparian wetlands

All values taken on July 12, 2012, were higher than 6 mg/L during a longitudinal morning run except near the headwaters on Highway 12 (Figure 55). On a longitudinal survey in the early afternoon after one inch rainfall on July 23, 2012, all locations upstream of North Branch had values below the standard of 5 mg/L. There are numerous wetlands in the headwaters of the stream, and with the low DO values corresponding with observations of tannic water; it is assumed that wetland influence was driving down the DO.

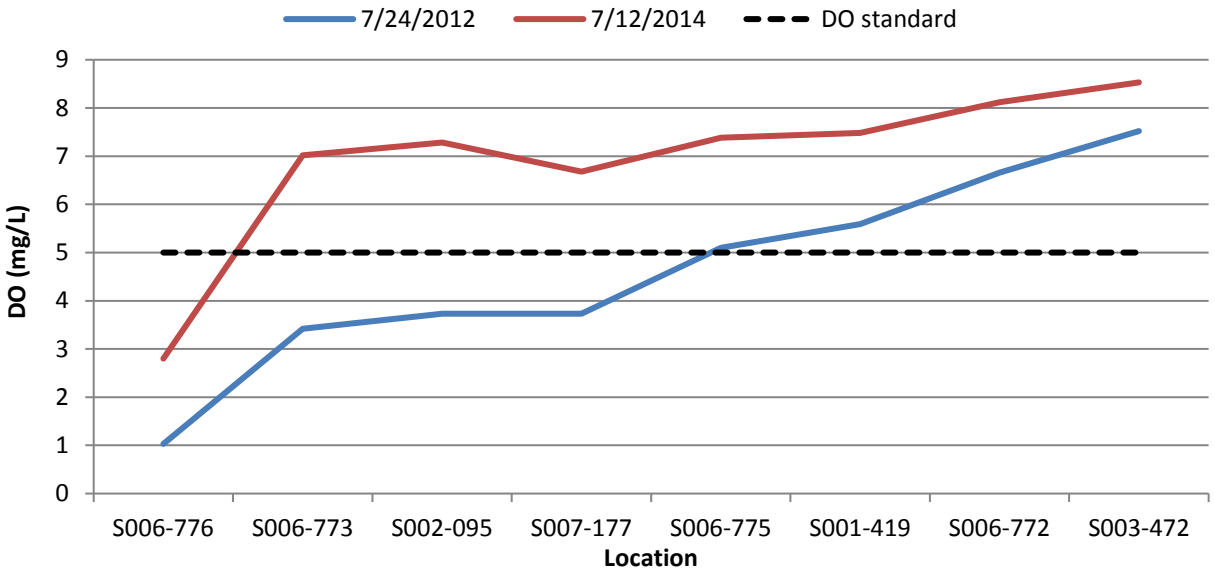

Figure 55. Longitudinal DO values

DO values along the river show highest values at station S004-033 and the lowest values were recorded at stations S002-095 and S006-776 (Figure 56). The lowest vales were recorded in August and September with the lowest value 2.47 mg/L. The highest values were recorded in June and July with the highest value 17.16 mg/L.

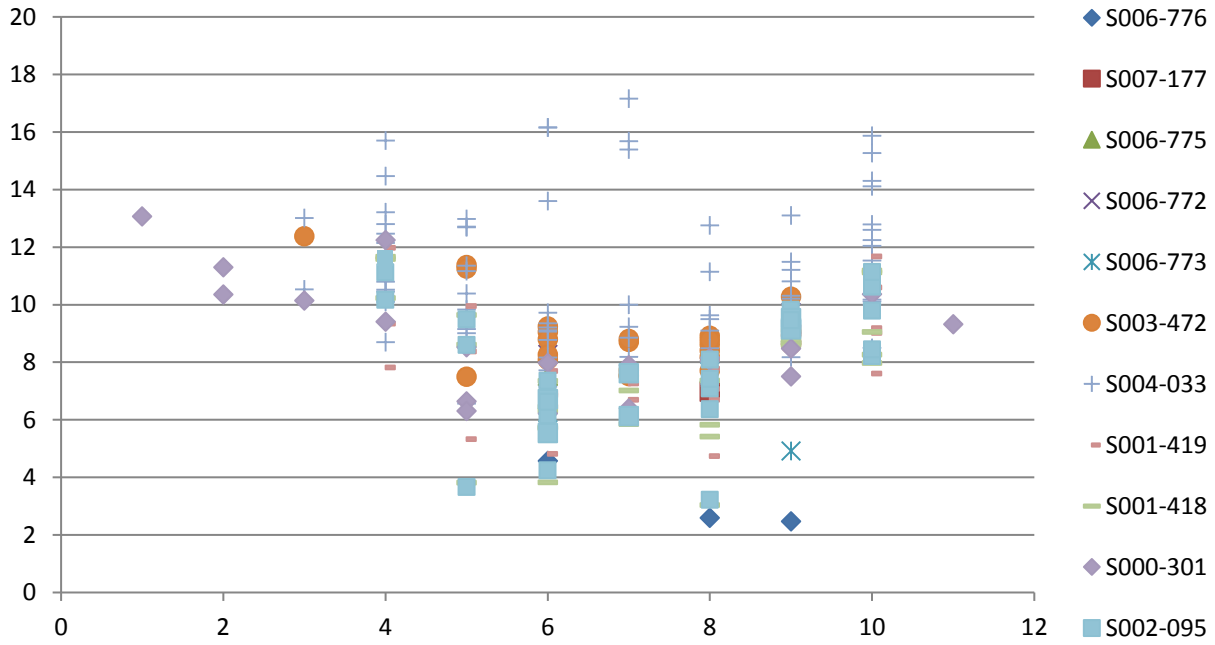

Figure 56. DO values on North Branch River

Biotic response

Low DO values correspond with increased tolerant species and decreased sensitive species. The average sensitive fish percentages statewide for fish classes 5 and 7 were 22.31% and 8.16% respectively. The percentage of sensitive individuals collected on the North Branch Sunrise River ranged from 6.36% to 47.71%, with the lowest percentages in the upper part of the stream (stations 09SC016 and 09SC017) and the highest in the downstream portion (stations 98SC008 and 09SC004). Tolerant percentages ranged from 28.75 to 66.11. The average in the statewide for fish classes 5 and 7 were 36.11% and 70.59%. Fish that mature at greater than three years of age are negatively correlated with low DO values. The range of mature age species percentages ranged from 0 to 12.39. The average percentages statewide for classes 5 and 7 were 13.46 and 4.62.

Similarly, the early morning low DO TIV values show a majority of the upstream sites (through 12SC001) are comprised of fish species in the first and second quartiles, which are most tolerant to low DO (Figure 57). Stations 09SC017 and 11SC001 had the highest percentages of fish in the first quartile, which are most tolerant to low DO conditions. Based on the low DO values recorded in the headwaters, the low percentages of sensitive species, species that mature at greater than three years of age, and tolerant percentages DO is a localized stressor in the upper section of the stream. It is unknown to what extent this is natural flushing of the wetlands, and what might be affected by human influence.

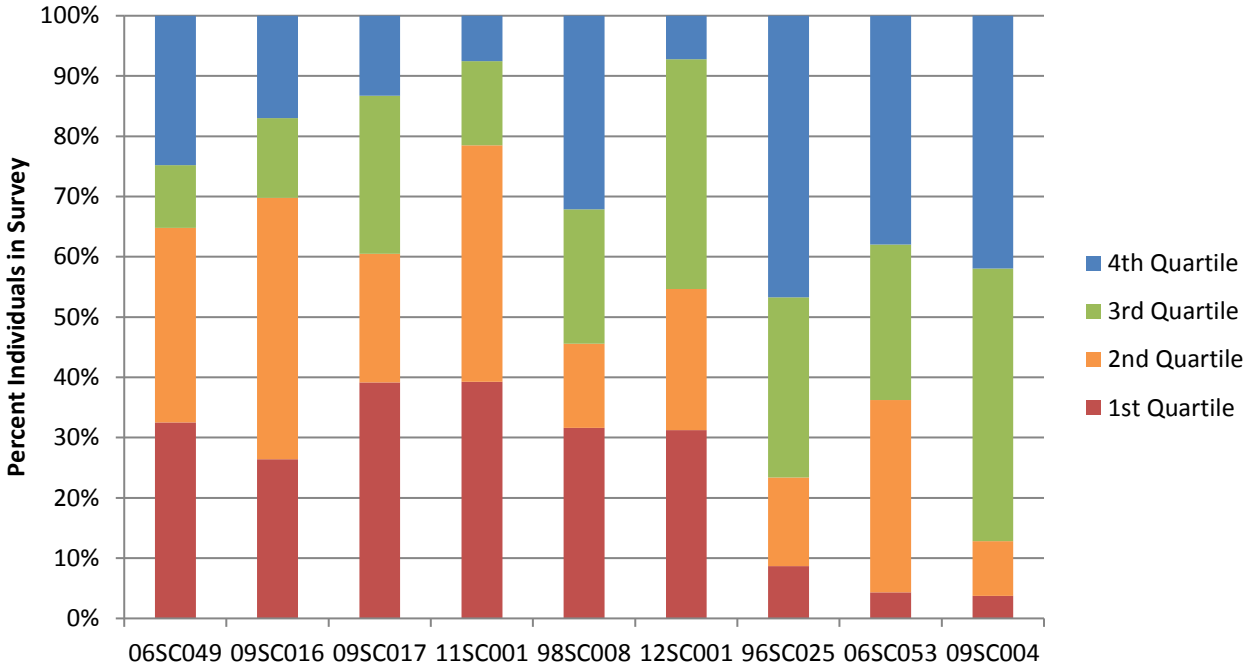

Figure 57. DO TIV fish values

Candidate cause: Phosphorus

Phosphorus concentrations in recent years along the north branch of the Sunrise River were analyzed by month (Figure 58). Values ranged from 0.04 to 0.386 mg/L. The highest phosphorus concentrations were collected on average in June. The highest concentration collected was at station S002-095. The summer average of all stations on the North Branch Sunrise River was 0.158 mg/L.

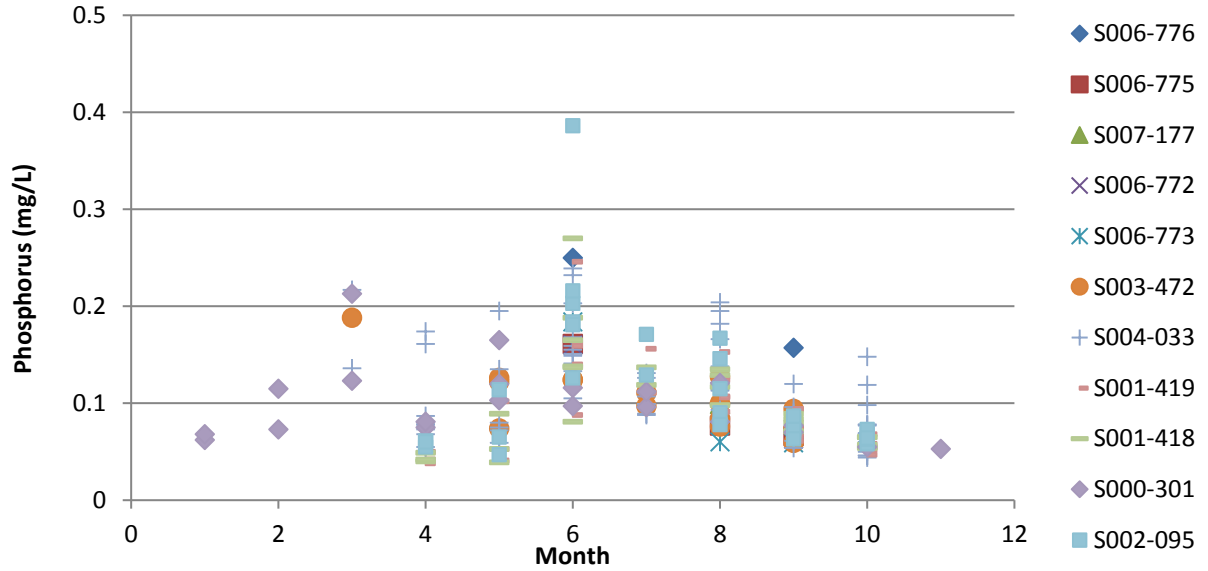

Figure 58. Phosphorus concentrations by month on the North Branch Sunrise River

Longitudinal surveys on June 16 and September 20, 2011, show phosphorus concentrations highest at station S006-776 (CSAH 12) on both dates and then leveling off downstream (Figure 59). All of the values on June 16 were above the phosphorus standard of 0.100 mg/L. The only value above the standard on during the September sampling event was at station S006-776. Both the longitudinal data and the complete data set show seasonally driven elevated values. Three values in 2002 at station S000-301 were above the BOD standard of 2 (2.1-4.9 mg/L), but all values since have ranged from 0.5-1.4 mg/L. Chlorophyll-a values ranged from 1.07 to 18.3 mg/L. The central region standard is 18 mg/L, with only one value above at station S004-033.

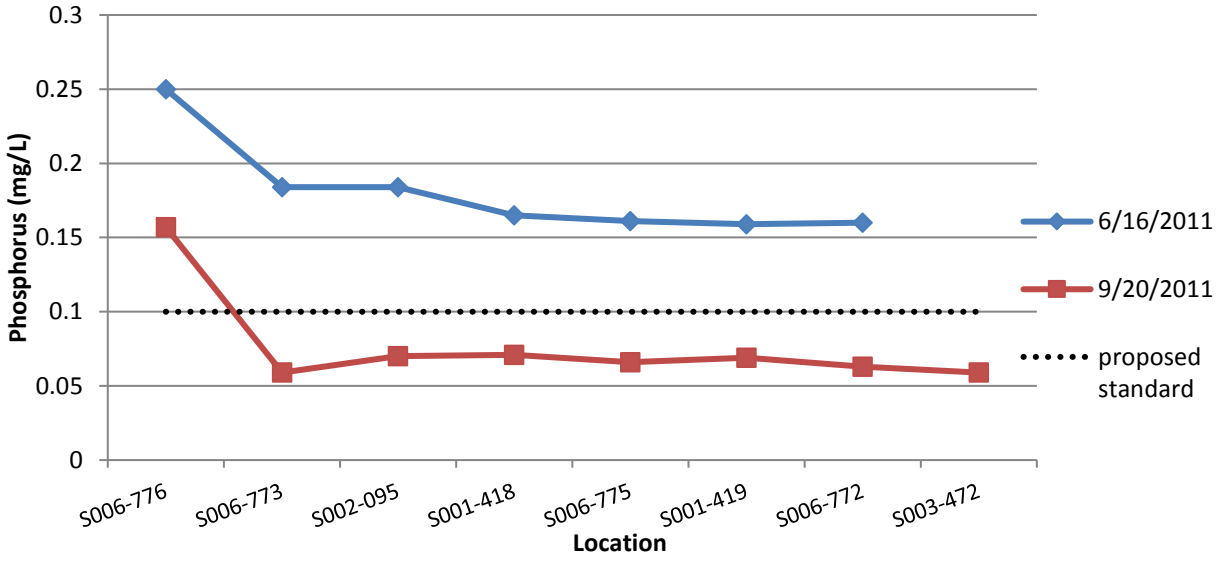

Figure 59. Phosphorus values during longitudinal surveys

Biotic response

The percent tolerant fish increase and percent sensitive fish decrease with increases in phosphorus levels. The percent of tolerant species range from 28 to 77% on the North Branch River. The average in the statewide for fish classes 5 and 7 were 36.11% and 70.59%. The percentage of sensitive fish sampled on the stream range from 6.36 to 54%. The average sensitive fish percentages statewide for fish classes 5 and 7 were 22.31% and 8.16% respectively The highest number of tolerant species (77%, which is very high)

and the lowest number of sensitive species (6.36 % which is very low) in the headwaters at station 09SC017 in 2011 corresponds with the highest phosphorus concentrations. Darter percentages are also inversely correlated with phosphorus. The darter percentages are above the statewide average except for the two visits at the mouth at station 09SC004.

Elevated phosphorus levels could be contributing to the depressed fish communities but does not seem to be a driving stressor. Phosphorus is an inconclusive stressor, and could be contributing to these values along with habitat conditions. Due to all values recorded over the standard in June of 2011 nutrient management would help to eliminate any effects phosphorus might be having.

Candidate cause: Nitrate

Nitrate concentrations in recent years ranged from less than 0.05 to 4.2 mg/L (Figure 60). High nitrate values have been recorded in wet years. The highest values were collected at stations S006-773 and S002-095 during August and September. The 75% percentile of the North Central Hardwood Forests ecoregion norm is 0.26 mg/L. Longitudinal surveys in June and September 2011 show that nitrate values are highest at station S006-773 (Figure 61).

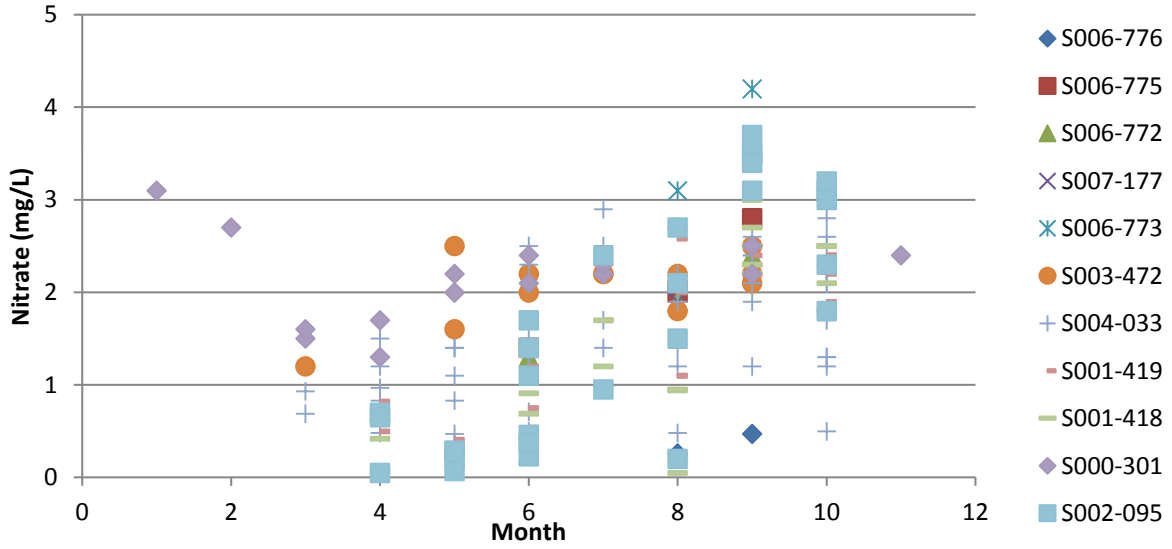

Figure 60. Nitrate concentrations on the North Branch Sunrise River by month

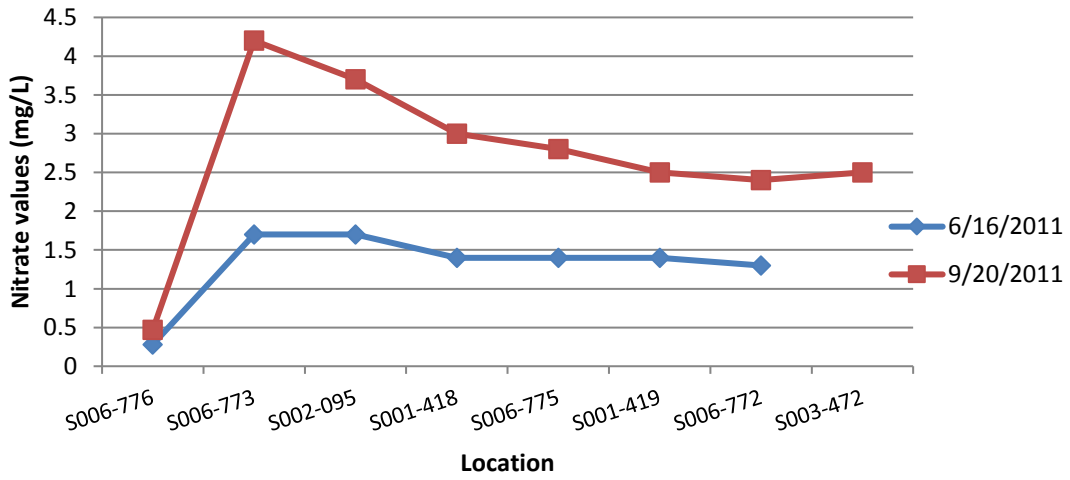

Figure 61. Longitudinal nitrate values

Biotic response

Macroinvertebrates have stronger responses to nitrate, so while macroinvertebrates are not impaired on this stream nitrate intolerant macroinvertebrates were looked at to see if nitrate is affecting the community. Nitrate intolerant macroinvertebrate taxa ranged from 1 to 5 and averaged 2.5. Sensitive fish species have a negative relationship with nitrate, but sensitive species are also affected by DO and phosphorus.

Fish tolerance indicator values were used to determine how tolerant the fish community was at each biological station. This can provide clues to the effects of a pollutant, by looking to see if the majority of the community is tolerant or intolerant to the pollutant. If the majority of the community is tolerant, this is an indication that the pollutant is affecting the biological community. The majority of fish at eight of the biological stations was comprised of fish in quadrants one and two. While stations 09SC004 and 09SC017 were averaged, the most downstream station, 98SC008 was not averaged in order to show the small increase from less tolerant to more tolerant fish species between the samples in 1998 and 2009 (Figure 62).

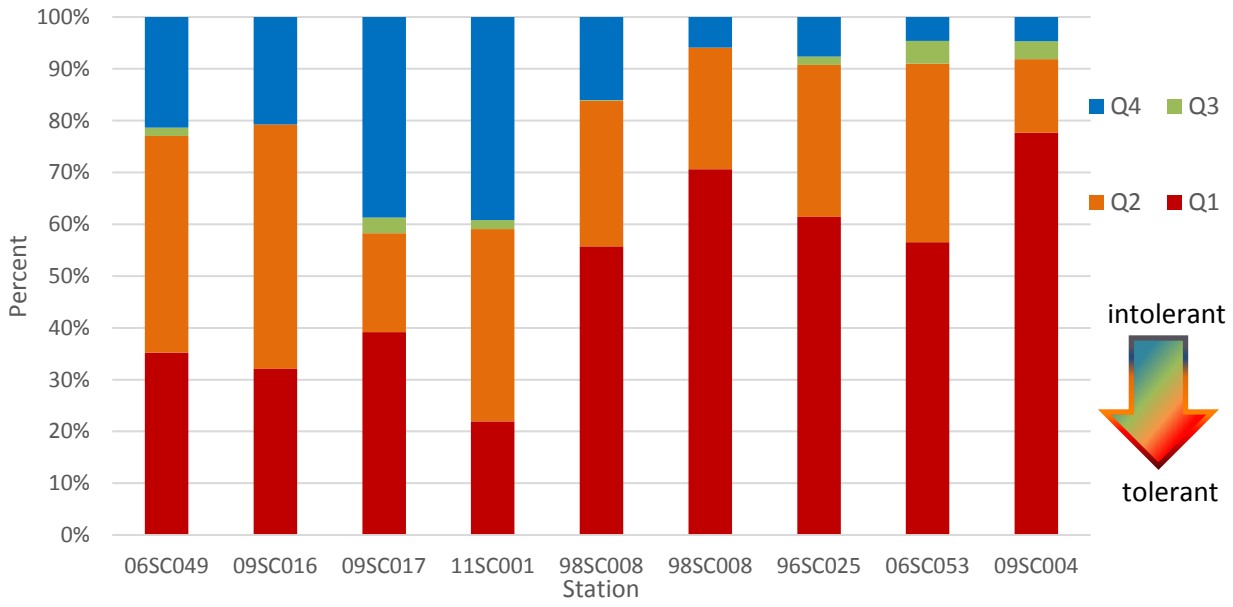

Figure 62. Nitrate TIV quads on North Branch Sunrise River

All stations in the North Branch Sunrise River were in macroinvertebrate class 6, and had a range of nitrate tolerant percentages from 37.72 to 63.49. The average statewide for class 6 is 53.16%. The number of nitrate tolerant species ranged from 12 to 24 and averaged 17.5. The average statewide for class 6 streams is 15.76. The highest number of individuals was collected during 2009 at station 09SC004, with the next highest percentages at stations 06SC053 and 09SC017. Nitrate intolerant taxa ranged from one to five taxa. The statewide average for class 6 streams was 4.60.

This biological evidence is not suggestive of nitrate as a stressor, as nitrate tolerant individuals are less than would be expected with nitrate stress, as well as the presence of nitrate intolerant taxa. In combination with low nitrate concentrations and lack of strong biological response to nitrate, nitrate is not found to be a stressor at this time. Continued monitoring and nutrient management would be recommended so that nitrate does not become a stressor in this watershed.

Candidate cause: pH

The standard for pH in surface waters is a range of 6.5-8.5, values over 8.5 and large daily pH fluctuations are tied to nutrient enrichment. Fluctuations in pH, similar to those with DO, are due to photosynthesis and respiration. Eight elevated pH values have been recorded at stations S003-472 and S000-301 (ranging from 8.54-9.21). All of the high values were collected in the downstream portion of the creek, located downstream of North Branch. Continuous pH data is not available in this portion of the stream. Low values have also been recorded, at stations S004-033 (3.1) and at station 06SC049 (5.32). Station S004-033 is in the downstream portion of the stream, while station 06SC049 is located in the upstream portion.

Biotic response

EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (U.S. EPA. 2012). Yellow perch were not collected on the North Branch, and bluegills were only collected at two stations (06SC053 and 11SC001). Since the bluegills were collected both up and downstream of the elevated pH values, they do not seem to be affecting the fish community. There are less bluegills and yellow perch than at some of the streams in the area but the pH values are not conclusive.

Candidate cause: Lack of habitat

MSHA scores ranged from 48.75 to 65.3, with station 09SC004 the only site to score a good rating. Station 09SC004 scored higher in the substrate and channel morphology subcategories. On a whole, sites in the North Branch Sunrise River had little depth variability and stream feature variability, and were mostly run stream features with limited riffles and pools. Many portions of the stream are wide and shallow, leaving little refuge for fish. Coarse substrate is lacking, especially in the upper part of the stream, and there is a prevalence of fine sediment (Figure 63). D50 is the average particle size located in the stream bed, and the values the US Army Corps of Engineers report (2010) collected confirms fine and coarse sand are the predominant sediment (Table 2). Moving sand makes it hard for species to nest. Where gravel was present, it was often embedded with sand.

Figure 63. Sand and clay substrate

Table 2. Substrate data on the North Branch Sunrise River

Field number	Embeddedness	Habitat rating	Substrate	Depth of fines	D50 (mm)
06SC049	No coarse substrate	Fair	100% sand		
09SC016	No coarse substrate	Fair	Sand and silt		0.84
09SC017	No coarse substrate	Fair	Sand and silt		0.33
11SC001	Moderate	Fair	Sand and cobble	40 cm	0.20
98SC008	No coarse substrate	Fair	Sand		
12SC001	Moderate	Fair	Sand		0.06
96SC025	None	Fair	Sand, gravel, clay, and cobble		
06SC053	Moderate	Fair	Sand and gravel		
09SC004	Light	Good	Sand, gravel, clay, and cobble		

- As described by EPA, 0.063–0.250 mm: fine sands that are suspended during times of high velocity but typically settle as water velocities decrease
- 0.250–2 mm: small bedload, medium to coarse sands (U.S. EPA. 2013)

The Chisago County geological atlas shows floodplain alluvium along the North Branch Sunrise River (2010). The sand substrate is natural, to what extent is unknown. There also seems to be human component as evidenced by the lack of depth variability. Healthy streams should have run-riffle-pool complexes. Other evidence of excess sedimentation included sand bars that have accumulated mid-channel (Figure 64) and culverts that have filled with sand (Highway 95). Bedded sediment seems to be more of a stressor than suspended sediment but sediment does become suspended at times as evidenced by TSS readings after snowmelt and rainfall. A sediment plume can be seen at the mouth of the North Branch as it enters the Sunrise River.

Figure 64. Mid-channel bar at station 98SC008

Biotic response

CADDIS shows a relationship between change in physical habitat availability and quality in an increase in tolerant taxa. Benthic insectivore, simple lithophilic spawners, riffle dwelling species, and darter, sculpin and sucker taxa richness metrics are all also related to habitat conditions (Figure 65). All of the metrics that are dependent upon habitat increase from upstream to downstream, as coarse substrate increases, while the tolerant taxa metric decreases. Downstream sites were found to have coarse substrate, such as gravel and cobble where the upstream sites were predominantly sand and silt. Lithophilic spawners reproduce by broadcasting eggs across gravel or coarse sand substrate, and without this substrate available these taxa would not be expected.

The lack of a diversity of habitat types and the presence of fine sediments in the stream bed seems to be impacting the biological community through a lack of lithophilic spawners, riffle dwelling species, benthic insectivores, and darter, sculpin, and sucker species, and an increase in tolerant species. Lack of habitat should be considered as a contributing stressor to the fish community. Sediment influences need to be addressed to prevent further filling in of pool and riffle areas.

The natural aspect of the sand substrate should be taken into consideration, but the increased bedload that is accumulating from eroding banks might be what is pushing the stream over the edge and filling in pools. A first step in addressing the areas of erosion will help prevent further accumulation and filling in of fish habitat. There are numerous areas of erosion (Figure 66) that can be addressed to prevent further fine sediments from eroding from banks and depositing in the stream bed. Areas of erosion observed are indicated in purple on the map below. Areas of mowing to the edge of the river are indicated in orange (Figure 67).

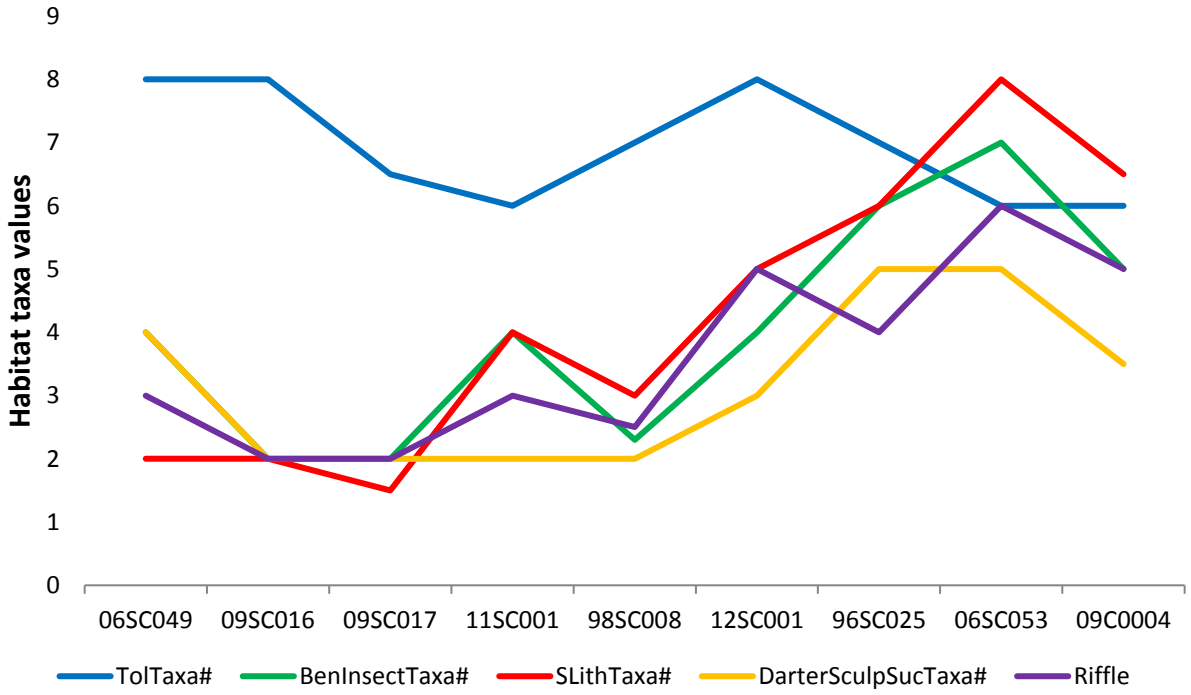

Figure 65. Habitat metrics in the North Branch

Figure 66. Eroding banks

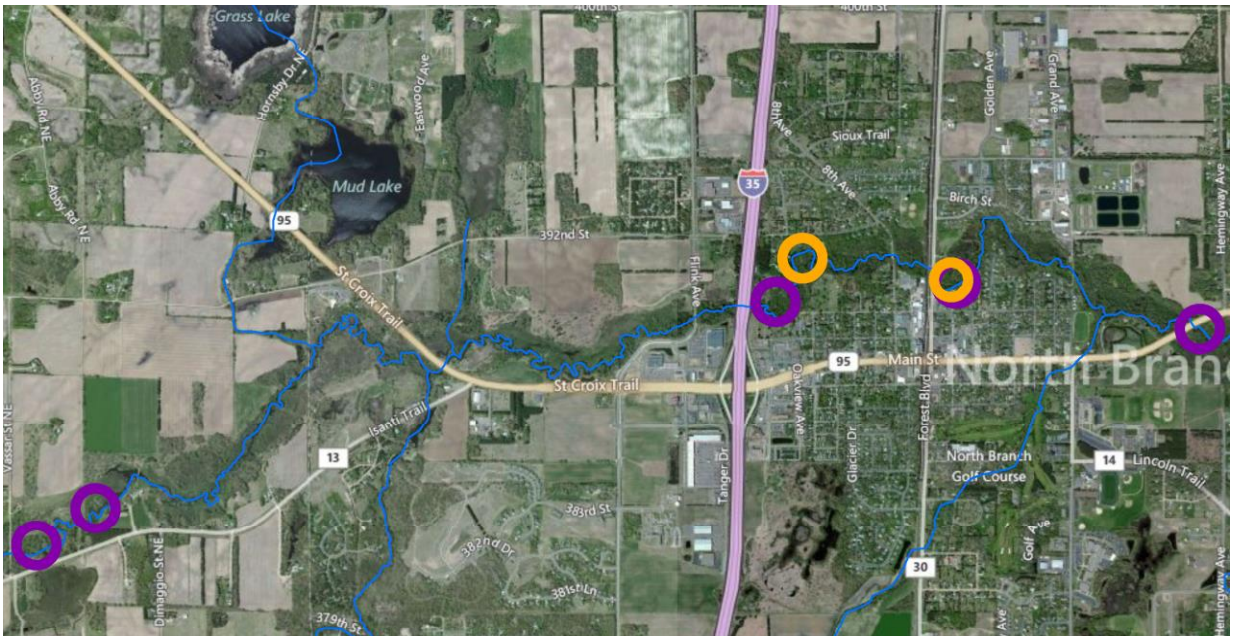

Figure 67. Areas of erosion and lack of riparian

Candidate cause: Suspended sediment

TSS values from the North Branch Sunrise River in recent years were analyzed by month (Figure 68). Values ranged from 1 to 49 mg/L. The standard for TSS for the central region of the state is 30 mg/L, but only 3% of values were above 30 mg/L. The highest values were recorded in June at station S004-033.

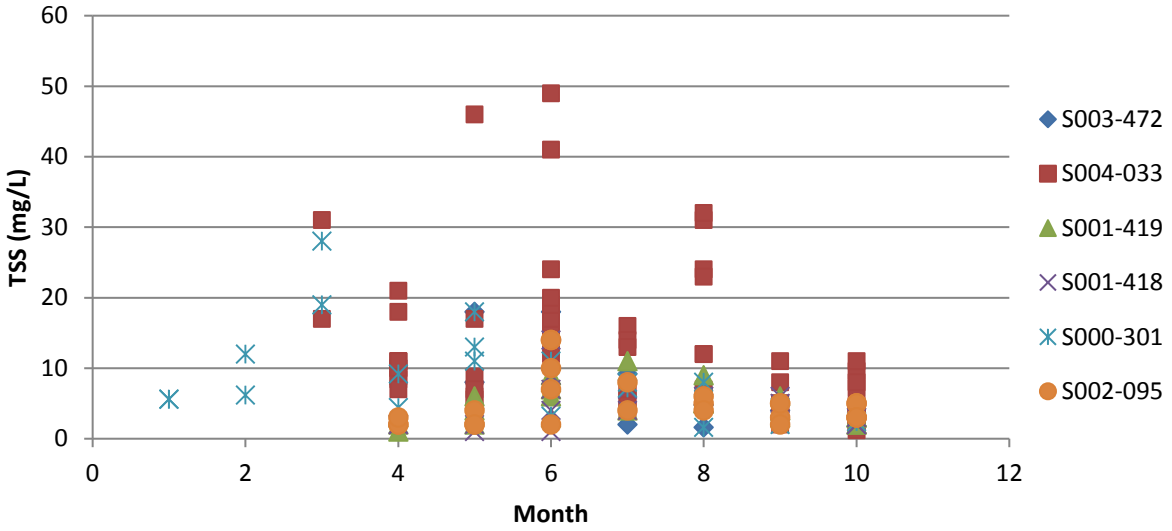

Figure 68. TSS values

Biotic response

Herbivore species of fish decrease as TSS values increase. The individual herbivore percentages ranged from zero (09SC017, 09SC004, and 11SC001) to 8.74% (98SC008), and averaged 1.97% Station 98SC008 had a decrease in herbivore percentages from 8.74% in 1998 to 0% in 2009. The average statewide for fish classes 5 and 7 was 2.07 and 4.01%. TSS can also affect both the number and growth of smallmouth bass. Smallmouth bass were sampled at downstream stations 96SC025, 06SC053, and 09SC004 which were all below station S004-033 which had the highest recorded TSS values. TIVs show that the fish communities on Goose Creek are predominantly comprised of species in quadrants three and four, which are most intolerant to TSS (Figure 69).

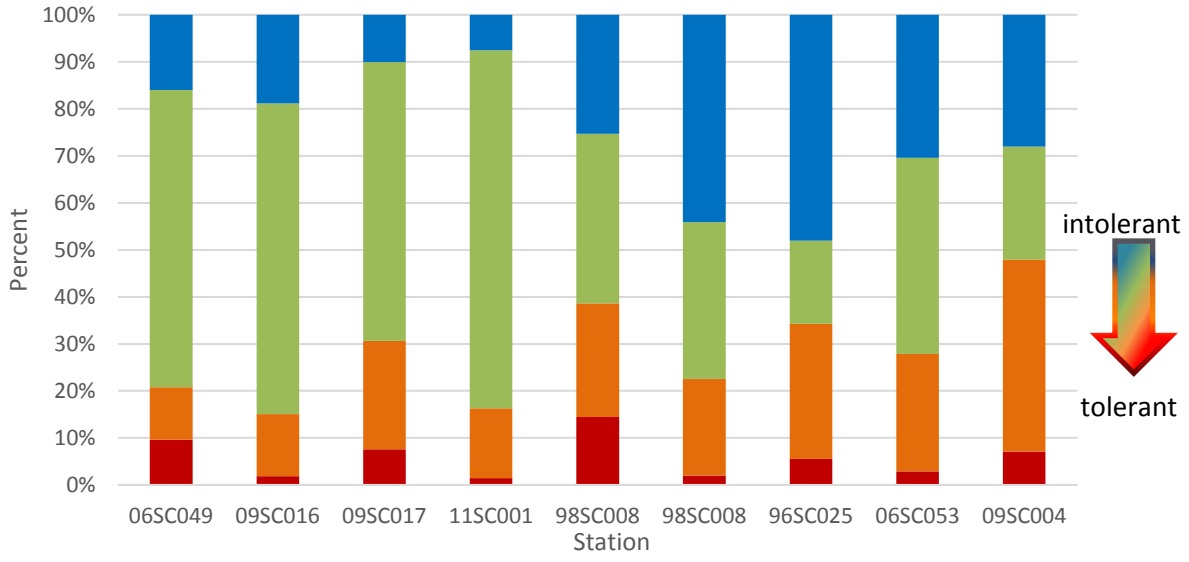

Figure 69. TSS TIVs for fish

The number of macroinvertebrate taxa collected that are intolerant to TSS ranged from zero (station 09SC017) to five (visits from 1998 and 1996 at stations 98CS008 and 96SC025 respectively), and average 2.6. The highest intolerant number of taxa collected in 2009 was at station 09SC004, and was four. The average for class 6 streams is 1.08. The percentage of long-lived individuals decrease as TSS values increase. Stations had a percentage of long-lived macroinvertebrates ranging from 1.64% (09SC016) to 9.40% (98SC008). The average percentages statewide in class 6 was 4.69%. Collector-filter percentages ranged from 22.73% (06SC053) to 54.67% (06SC049). The average collector-filterer percentage statewide in class 6 was 16.64% respectively.

While the herbivore percentages are very low, the presence of TSS intolerant macroinvertebrate, high percentages of collector-filterer individuals and fish tolerance indicator values point to suspended sediments not being a main stressor to the stream. The herbivore species could be low based on other contributing factors.

Candidate cause: Physical connectivity

A review of all road crossings and culverts would be helpful, especially with the amount of fine sediment that is moving through the system. The box culvert at Highway 95 just downstream of the city of North Branch (located at biological station 98SC008) is partially filled with sand. The culverts at Keystone Avenue which have since been replaced were creating a gradient difference (Figure 70). Upstream of St. Croix Trail is another mis-sized that is incorrectly placed and too small (Figure 71).

Figure 70. Former culverts at Keystone Avenue

Figure 71. Undersized culvert upstream of St. Croix Trail

Biotic response

The culverts at Keystone Avenue were having an impact on migration as migratory species were found downstream of the culvert at higher amounts than those found upstream (Table 2). While there are differences in gradient that could be contributing to the differences in fish species, the culvert does seem to be having an effect on fish migration. Taking a new biological sample now that the culverts have been replaced with a bridge to see if the fish distribution has changed would be beneficial.

Table 3. Migratory fish species on North Branch

	06SC049	09SC016	09SC017 (2009 & 2011)	11SC001	98SC008 (three visits)	12SC001	Culvert	96SC025	06SC053	09SC004 (both 2009 visits)
Blackside darter								X	X	X
Iowa darter	X									
Shorthead redhorse								X	X	
Walleye									X	
White sucker	X	X	X	X	X	X		X	X	X

AUID summary

The main stressors to the North Branch Sunrise River were DO and physical connectivity.

West Branch Sunrise River

Downstream of Martin Lake, the West Branch Sunrise River (07030005-529) is listed for both fish and macroinvertebrate biological impairments (Figure 72). This section, as well as the connection between Typo and Martin Lake is impaired for turbidity. Typo and Martin Lakes are both impaired for nutrients.

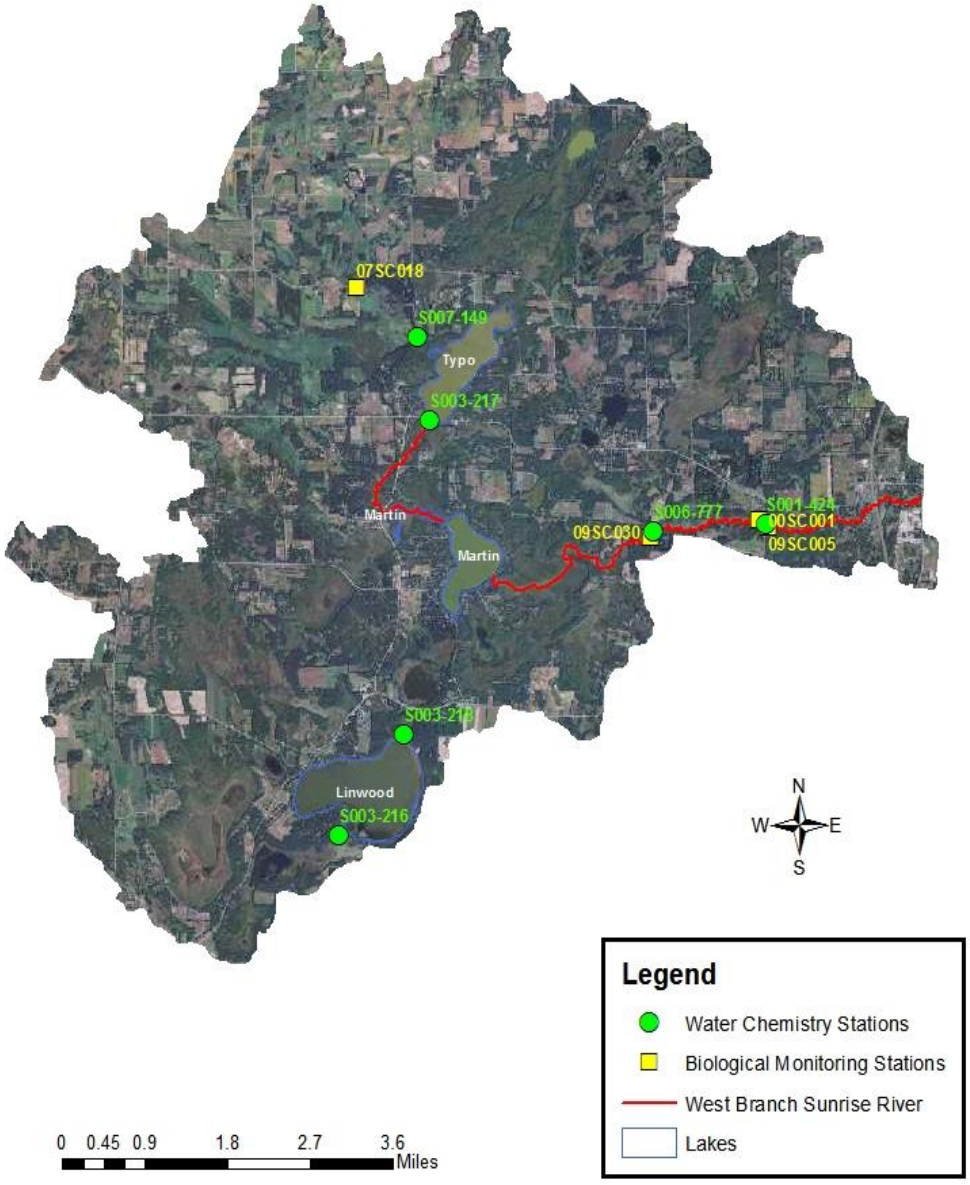

Figure 72. Sampling locations on the West Branch Sunrise River

Three fish visits and one macroinvertebrate sample occurred on the West Branch Sunrise River downstream of Martin Lake. Metric scores cumulatively made up the IBI score. The fish IBI scores were all calculated using the low gradient IBI (class 7), and the macroinvertebrate score was calculated using the southern forest streams glide pool IBI (class 6). There are not individual standards for each metric, but using a target score provides a method of identifying problem metrics for a stream or individual monitoring site.

Three fish visits occurred on the West Branch Sunrise River. Station 09SC005 is the lowest scoring site. The fish metrics have uniformly low scores of simple lithophilic spawners, sensitive species, and headwater species (not including tolerant species) (Figure 73). Sensitive or pollution intolerant fish species are typically the first to disappear when conditions become increasingly unfavorable. The simple lithophilic spawner species and headwater individual percentage was zero at each visit. The one macroinvertebrate visit was just below the IBI threshold (43) with five metrics below the average needed to meet the threshold, and five above (Figure 74). The intolerant metric was the lowest scoring, with a score of zero. The clinger and Trichoptera metrics also scored poorly.

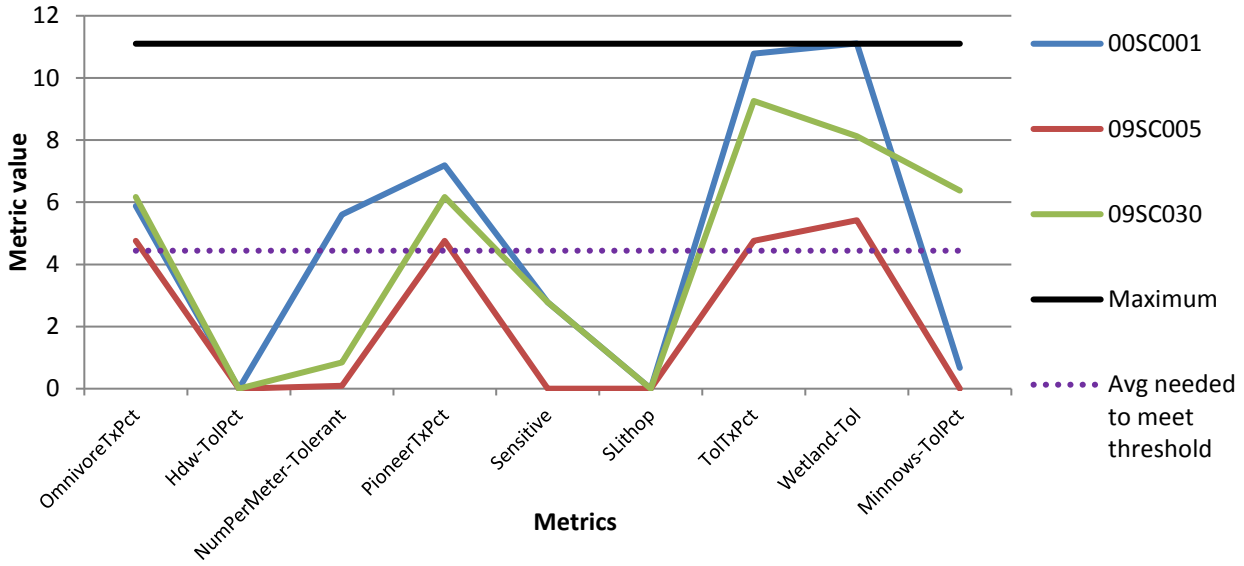

Figure 73. Fish metrics

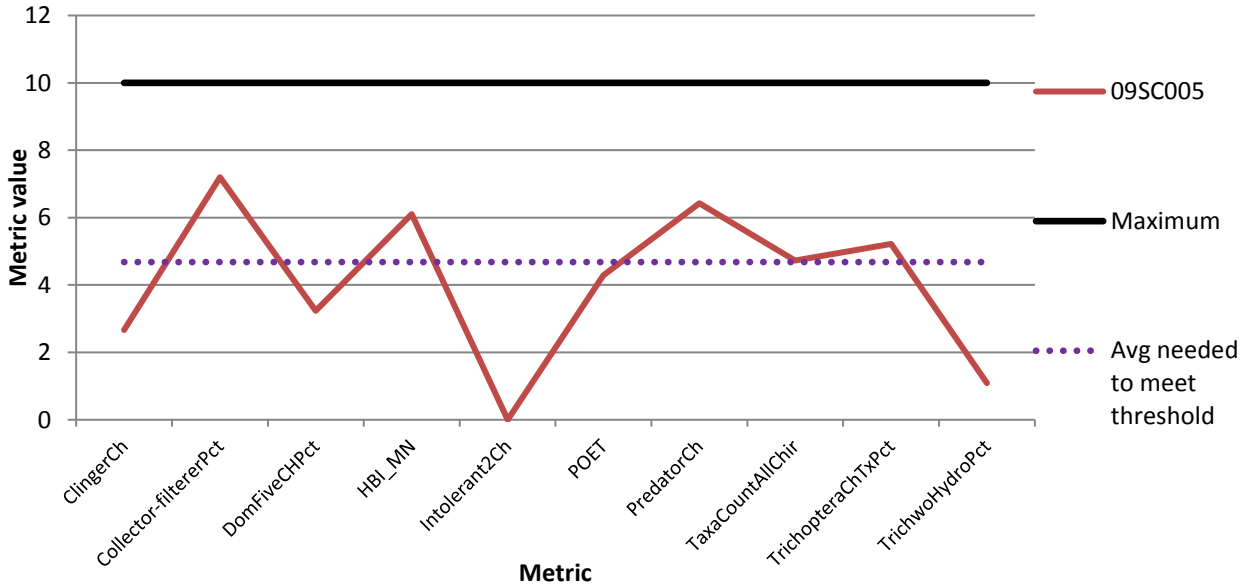

Figure 74. Macroinvertebrate metric scores

Candidate cause: Dissolved oxygen

DO values from recent years were analyzed by month, ranging from 2.42 and 17.76 mg/L. The lowest DO readings along AUID -529 were recorded at station S001-424 with a value of 2.42 mg/L in June and 2.97 mg/L at station S001-600 in August. 11% of values on the West Branch Sunrise River were below 5 mg/L. DO readings taken in 2012 after 0.35 inches of rain show DO readings right around the standard of 5 mg/L at all stations except right below Martin Lake (Figure 75). Of values below 5 mg/L some were taken after rain events, but others were taken without preceding rain, so low DO is not solely the result of rain events.

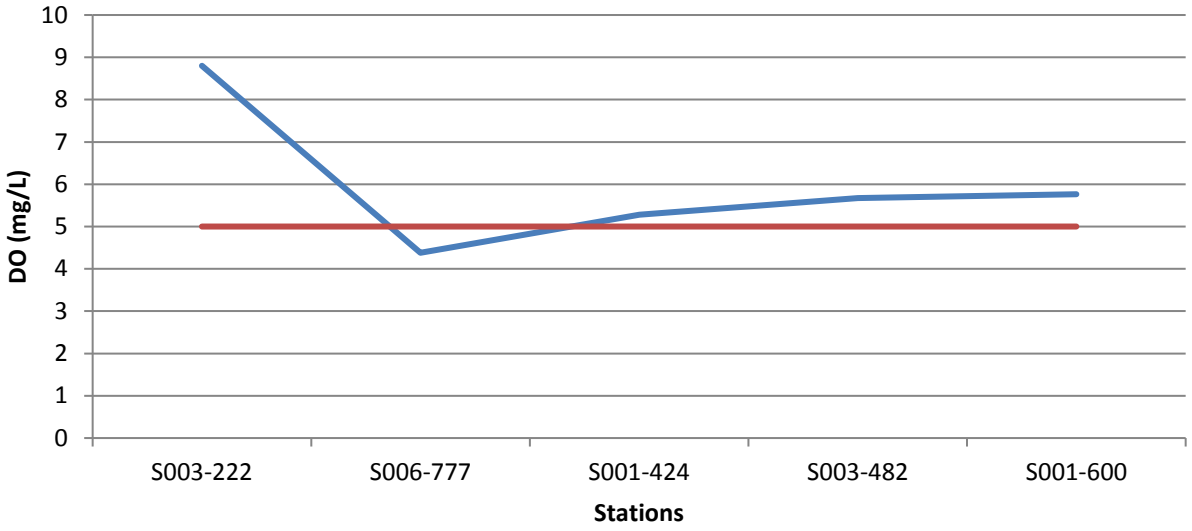

Figure 75. DO on West Branch Sunrise River (July 24, 2012)

Continuous DO values were taken at station S006-777 in 2012, where values dropped below the water quality standard of 5 mg/L all but two days over a two week deployment window (Figure 76). The standard for DO flux is 3.5 mg/L, and flux at this location ranged up to 5.31 mg/L. Algal respiration and photosynthesis are considered the primary drivers of daily flux in DO (Figure 77).

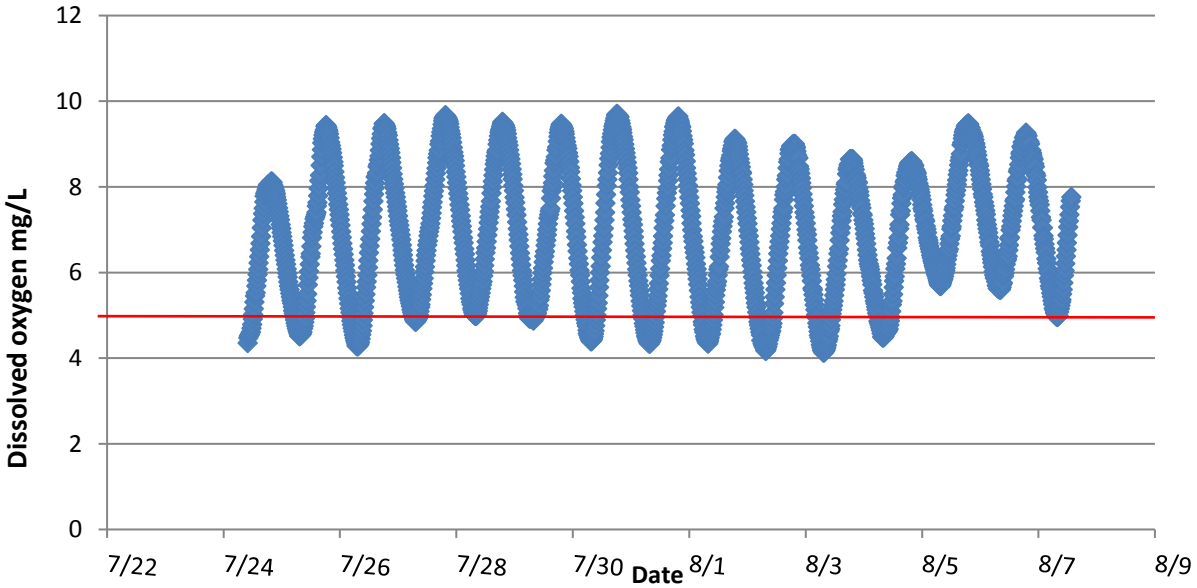

Figure 76. Continuous DO at station S006-777 in 2012

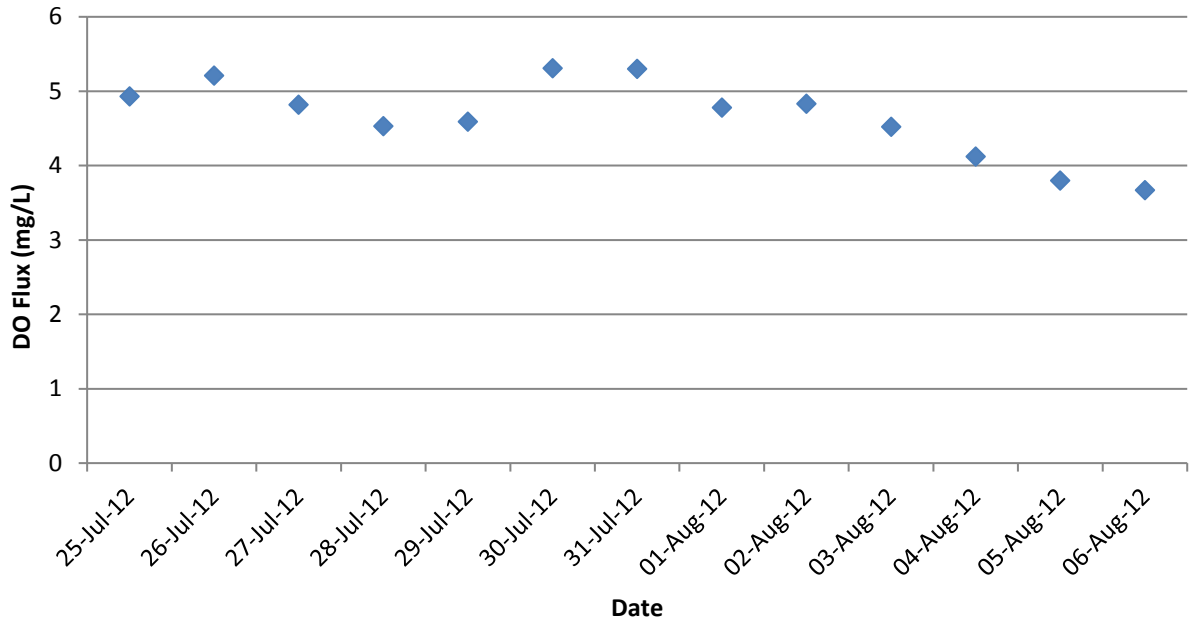

Figure 77. DO flux at station S006-777

Biotic response

Low DO values correspond with increased tolerant species and decreased sensitive species. Along with low DO values, wide daily fluctuations can also stress aquatic organisms. There is an inverse correlation between DO flux and sensitive fish species. As DO flux increases above 4.0 mg/L per day, the sensitive fish population falls to less than 10% (Heiskary, 2008). The average sensitive fish percentage statewide for fish class 7 is 9.48%. The percentage of sensitive individuals collected on the West Branch Sunrise River ranged from 0% at station 09SC005 to 9.97% at station 00SC001. Stations 00SC001 and 09SC005 are right across the road from each other but the visits were taken nine years apart.

Wetlands are likely having an influence on DO in the West Branch Sunrise River, however DO flux in undisturbed naturally low DO systems is typically 2-4 mg/L in a 24-hour period (Heiskary). Disturbed stream systems are more likely to exhibit higher diurnal flux. Tolerant percentages ranged from 40 to 86.36. The average in the statewide for fish class 7 was 70.60. Fish that mature at greater than three years of age are negatively correlated with low DO values. The range of mature age species percentages ranged from 0 to 2.56. The average percentage statewide for class 7 was 4.45. Sites on the West Branch Sunrise River are dominated by species that are in the first and second quartile of species most tolerant to low DO values, with station 09SC005 comprised of 73% of fish in the first quartile (Figure 78).

Based on the low DO values and daily DO fluctuations, the presence of low DO tolerant, the lack of sensitive fish and species that mature at greater than three years of age, low DO is a stressor to the fish in the stream. It is unknown to what extent this is natural flushing of the wetlands, and what might be affected by human influence.

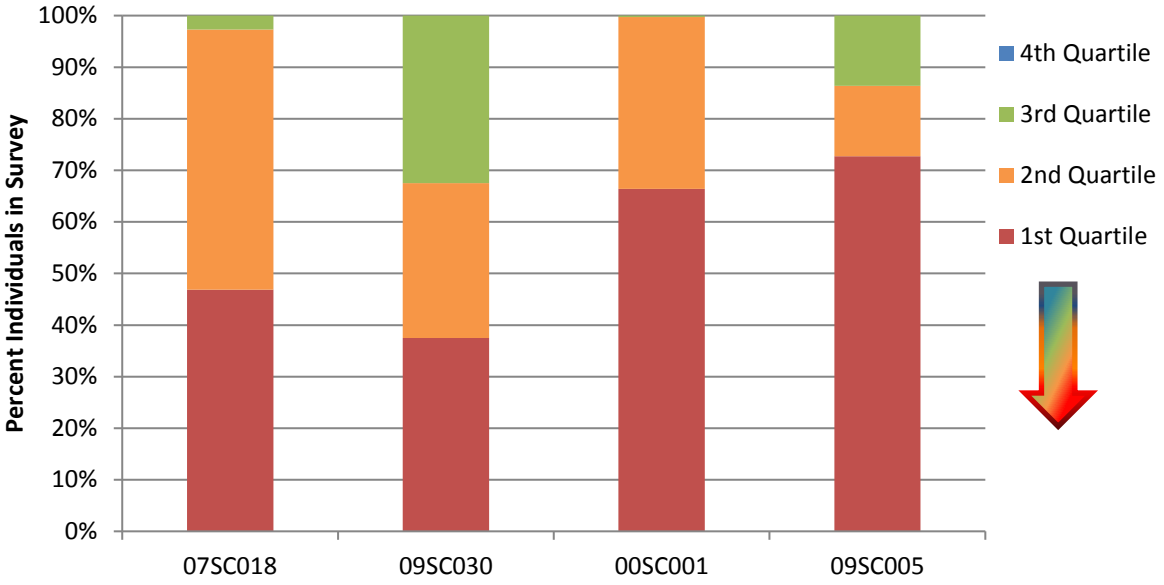

Figure 78. Low DO TIV

EPT communities are also inversely correlated with low DO values and high DO flux. The average statewide for class 6 is 18.58%. The EPT individual percentage at station 09SC005 was 20.62%, however the species collected can signify degraded conditions. Total taxa richness has been shown to decrease with an increase in DO flux. The average total taxa statewide for class 6 is 21.43. The values for macroinvertebrate taxa richness at station 09SC005 was 26 species.

The number of macroinvertebrate taxa that are intolerant to low DO was three on the West Branch Sunrise River. The average in class 6 streams statewide was 3.89. The percentage of DO tolerant species was higher in the West Branch Sunrise River (41.85%) than the average in statewide class 6 streams (24.88%). However, station 09SC005 only had 0.92% very tolerant DO species present in the sample.

The EPT percentage and taxa richness at station 09SC005 were slightly above statewide averages. The number of DO intolerant taxa was just below average, while the percentage of DO tolerant species was above average. Macroinvertebrate data is only available at one station along the impaired reach and does not have the same strong signature that the fish data has. DO is inconclusive as a macroinvertebrate stressor.

Candidate cause: Phosphorus

The West Branch Sunrise River has high levels of sestonic algae as it flows out of Martin Lake (Figure 79). The Typo and Martin Lakes TMDL allocates the phosphorus loads to Martin Lake as 67% from Typo Lake, 25% from watershed runoff, and 5.7% from the Island Lake Watershed (Schurbon 2012). This is supported by data collected in 2011 and 2012 where the highest phosphorus concentrations in the watershed were located at two sites on Data Creek and at the outlet of Typo Lake. The highest chlorophyll-a concentrations were also located at the outlet of Typo Lake. While concentrations out of Typo Lake are the highest, all values taken during a longitudinal survey in 2012 have values above the standard. Values are highest out of Martin Lake, and then decrease downstream (Figure 80).

Figure 79. Martin Lake dam

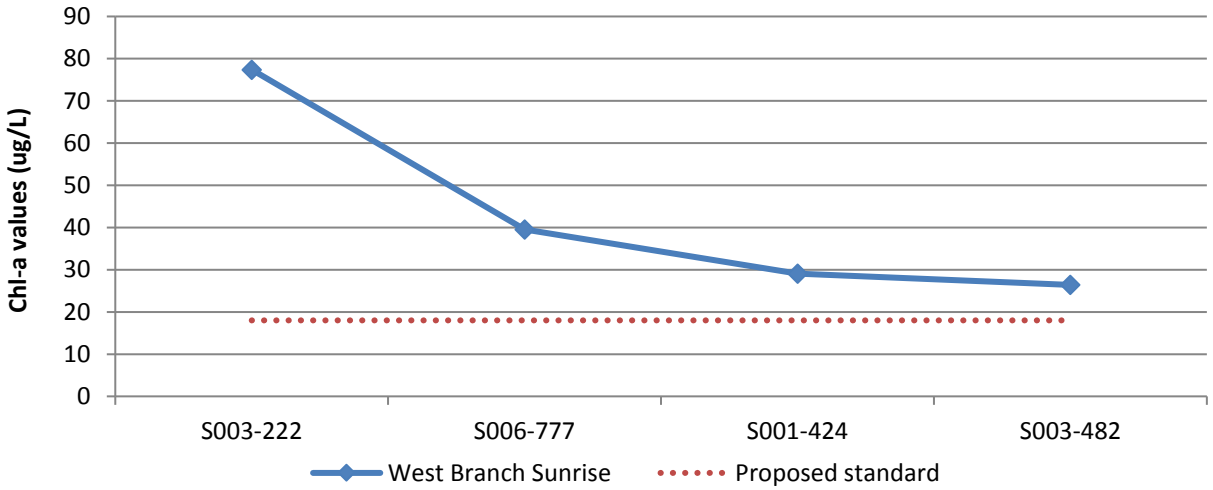

Figure 80. Chlorophyll-a longitudinal values on the West Branch Sunrise

The phosphorus levels downstream of Martin Lake were highest on Lyons Street (S001-424) (Figure 81); this is also where the largest concentration of samples was taken. Values up to 0.254 mg/L were recorded, which is 2.5 times the standard of 0.100 mg/L. Station S001-424 was observed to have high amounts of sestonic algae in 2009 and 2010 (Figure 82), and elevated DO flux was recorded just upstream.

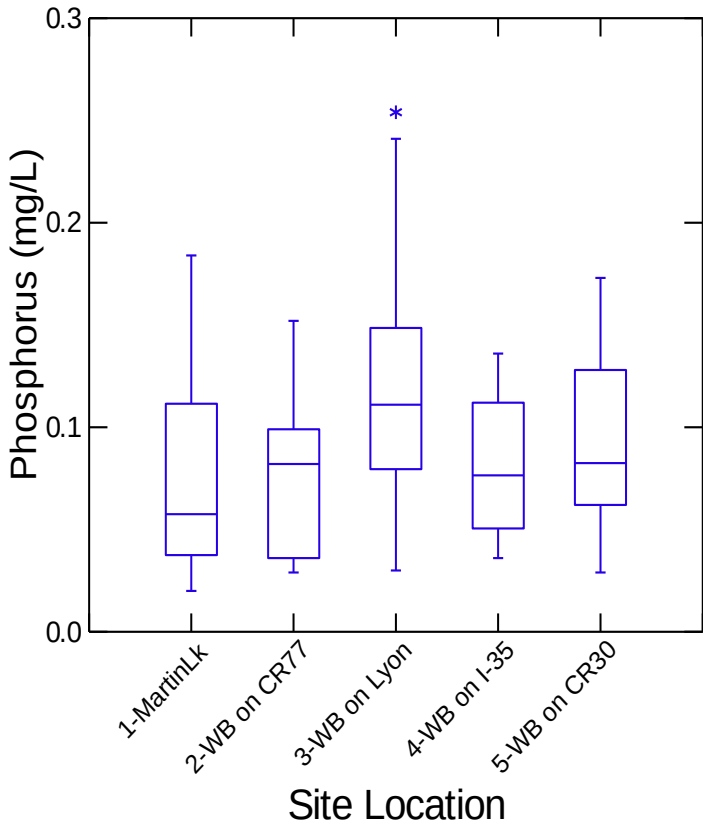

Figure 81. Phosphorus concentrations

Figure 82. Green color of station 09SC005

Biotic response

The effects of nutrients on aquatic life are more directly impacted by proximate stressors, as they have a direct influence on the composition and health of biological communities. DO flux, chlorophyll-a, and BOD are proximate stressors for phosphorus. Nutrient loading can create an increase in phytoplankton (measured as sestonic chlorophyll); along with temperature, light, and residence time (Heiskary 2010). Sensitive fish percentages, intolerant and tolerant fish and macroinvertebrates, total taxa macroinvertebrates and EPT percentage are correlated with high eutrophication levels. At TP of 0.1 mg/L or more, percent sensitive fish comprised 10% or less of the catch (Heiskary et. al. 2010).

The sites sampled on the West Branch Sunrise River downstream of Martin Lake had values of 0, 2.5, and 9.97% sensitive fish respectively. Figure 83 shows these sensitive fish percentages values in relation to other sites in the St. Croix basin. As chlorophyll-values increases above 33-40 ug/L the number of macroinvertebrate taxa diminishes below 32 (Heiskary 2012). The total number of macroinvertebrate taxa was 26.

There were no intolerant fish at either of the visits in the West Branch Sunrise River. There was a small percentage of intolerant macroinvertebrates (1.8%). The percentage of tolerant fish ranged from 40 to 86%, and the percentage of tolerant macroinvertebrates was 83%. Heiskary et al. found that the number of macroinvertebrate taxa decrease with increased TP, when TP increases above ~ 0.130 mg/L, total taxa tend to fall below 32. The total taxa of macroinvertebrates found during the one macroinvertebrate visit were 26. The EPT percentage was 21%.

While the EPT percentages were higher than might be expected, the intolerant, tolerant, and sensitive values on the West Branch Sunrise lead toward phosphorus and chlorophyll-a being main stressor to the fish and macroinvertebrate populations.

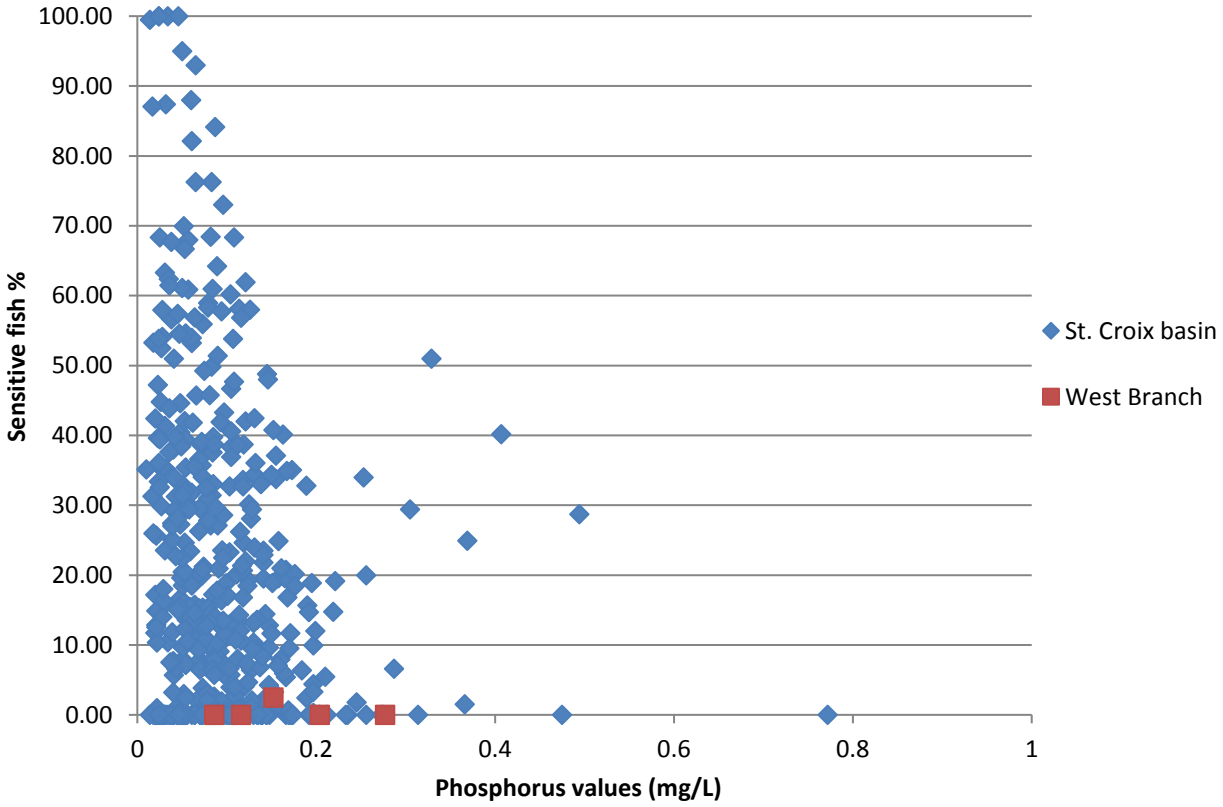

Figure 83. Sensitive fish in the West Branch

Candidate cause: Nitrate

Nitrate concentrations taken from 2008 to 2012 ranged from less than 0.05 to 0.39 mg/L throughout the stream reach (Figure 84). The highest values were collected during April and August. The 75% percentile of the North Central Hardwood Forests ecoregion norm is 0.26 mg/L. Nitrate values were highest at station S006-773, the most downstream station.

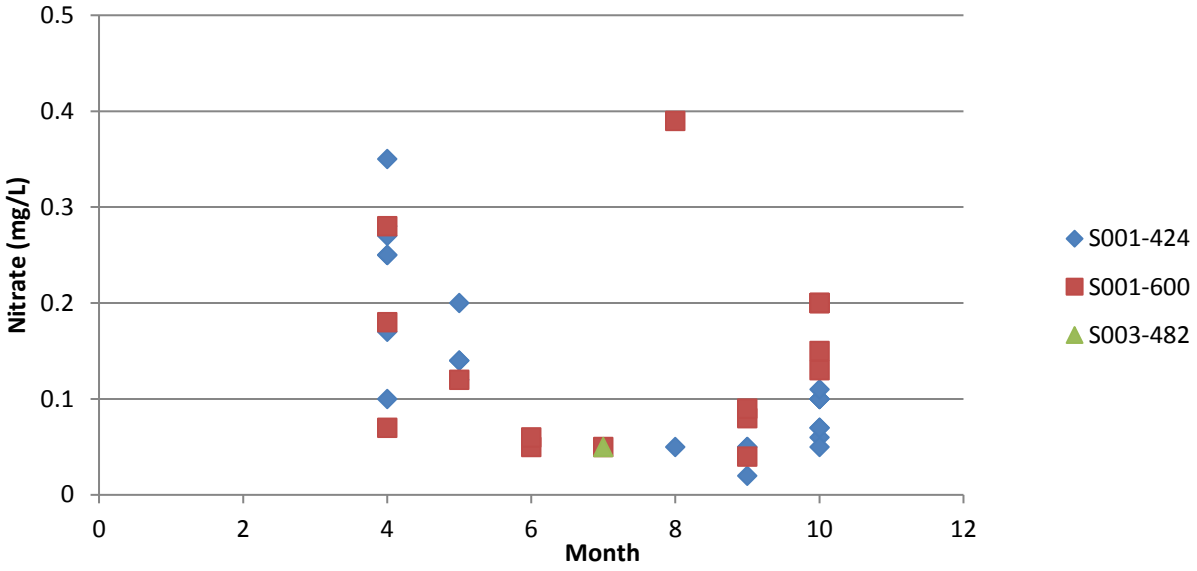

Figure 84. Nitrate values

Biotic response

Macroinvertebrates have stronger responses to nitrate, so while macroinvertebrates are not impaired on this stream nitrate intolerant macroinvertebrates were looked at to see if nitrate is affecting the community. Nitrate intolerant macroinvertebrate taxa ranged from 1 to 5 and averaged 2.5. Sensitive fish species have a negative relationship with nitrate, but sensitive species are also affected by DO and phosphorus.

Fish tolerance indicator values were used to determine how tolerant the fish community was at each biological station. This can provide clues to the effects of a pollutant, by looking to see if the majority of the community is tolerant or intolerant to the pollutant. If the majority of the community is tolerant, this is an indication that the pollutant is affecting the biological community. The majority of fish at four of the biological stations was comprised of fish in quadrants three and four (Figure 85).

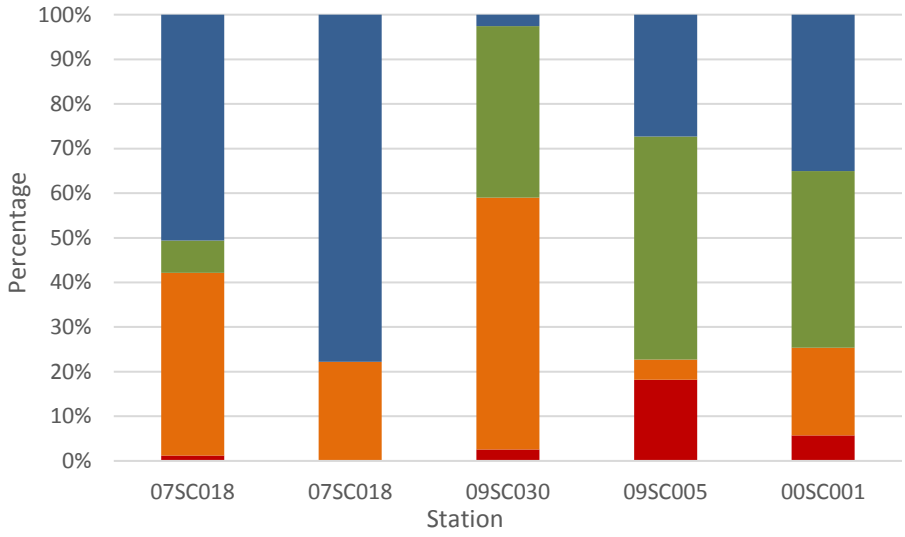

Figure 85. Nitrate TIVs on West Branch Sunrise River

Station 07SC018 was not averaged in order to show the increase to more intolerant fish species between the samples in 2007 and 2009.

Station 09SC005 had a nitrate tolerant percentage of 17.23. The average statewide for class 6 is 53.16%. The number of nitrate tolerant species was 12. The average statewide for class 6 streams is 15.76. There were three nitrate intolerant taxa. The statewide average for class 6 streams was 4.60. Increasing nitrate concentrations also have a relationship with a decrease in non-hydropsychid Trichoptera (caddisfly) individual percentages. Non-hydropsychid Trichoptera are all caddisflies that do not spin nets. The individual percentage on the West Branch Sunrise River was 0.31%. Sites in the class 6 statewide averaged 2.07.

While Trichoptera individual percentages were low, nitrate tolerant individuals were less than would be expected with nitrate stress. In combination with low nitrate concentrations, nitrate is not found to be a stressor at this time. Continued monitoring and nutrient management would be recommended so that nitrate does not become a stressor in this watershed.

Candidate cause: pH

The AUID between Typo and Martin lakes is impaired for pH. The standard for pH in surface waters is a range of 6.5-9, values over 8.5 and large daily pH fluctuations are tied to nutrient enrichment. Fluctuations in pH, similar to those with DO, are due to photosynthesis and respiration. High pH values have been recorded at stations S001-424 and S003-222 (ranging from 8.55 to 8.92). Longitudinal data taken in 2012 shows the highest pH value was located just downstream of Martin Lake which is impaired for nutrients and values steadily decline downstream of the lake. Continuous data collected during 2012 recorded a high value of 8.85, and a range of daily flux from 0.61 to 0.91. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013). High fluctuations reflect excessive in-stream primary production, as algae and aquatic plants drive up pH during the daytime.

Biotic response

EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (U.S. EPA. 2013). Bluegill and yellow perch were collected at station 00SC001 in 2000 but not at stations 09SC005 or 09SC030 in 2009. Flows were lower in 2009 than in 2000 so this could be the reason for the difference in the fish captured. Due to elevated pH values, pH flux, and lack of fish in 2009 pH as a stressor is inconclusive. Further data collection would be useful.

Candidate cause: Lack of habitat

There was a lack of riffles on sites on the West Branch of the Sunrise River and pools were only documented at station 09SC030. The dominant substrate on the river is sand, but there are areas of gravel and cobble embedded underneath sand. Excess sedimentation and detritus on top of the sand were found (Figure 86). Fine sediment up to 15 inches was recorded at station 09SC030. Both stations 09SC005 and 09SC030 had poor channel development. A geomorphic survey showed that the stream is moderately entrenched (USACE 2010), which could be the cause of the undercutting banks observed during sampling.

Figure 86. Detritus and sand at station 09SC005

MSHA scores taken during biological sampling ranged from 43 to 44.8. Both stations scored in the poor category. Scores were low across all the categories, but particularly in substrate and channel morphology. The channel morphology scores were 13 and 16 (out of 36). The channel morphology scores were low due to lack of riffles, moderate channel stability, and lack of channel development. The substrate scores were 8.5 and 10 (out of 27). The fish cover scores were 5 and 8 (out of 17). Low substrate scores were due mainly to lack of coarse substrate at both stations and lack of any pools at station 09SC005. A diversity of run, riffles, and pools are necessary to create habit and nesting areas for different species.

Biotic response

Benthic insectivores, darter, sculpin, and sucker, riffle dwelling species, and simple lithophilic spawners require coarse substrate. Tolerant species are shown to increase with a lack of habitat availability. Lithophilic spawners reproduce by broadcasting eggs across gravel or coarse sand substrate, and without this substrate available these taxa would not be expected. The number of benthic insectivores ranged from 0 to 3, and averaged 1.67, simple lithophilic spawners and riffle dwelling species collected were all zero, and darter sculpin, and sucker species ranged from 0 to 2 and averaged 1.3. These values are all very low and show that the fish community is being impacted by the limited habitat at the site (Figure 87). Lack of habitat should be considered as a contributing stressor to the fish community.

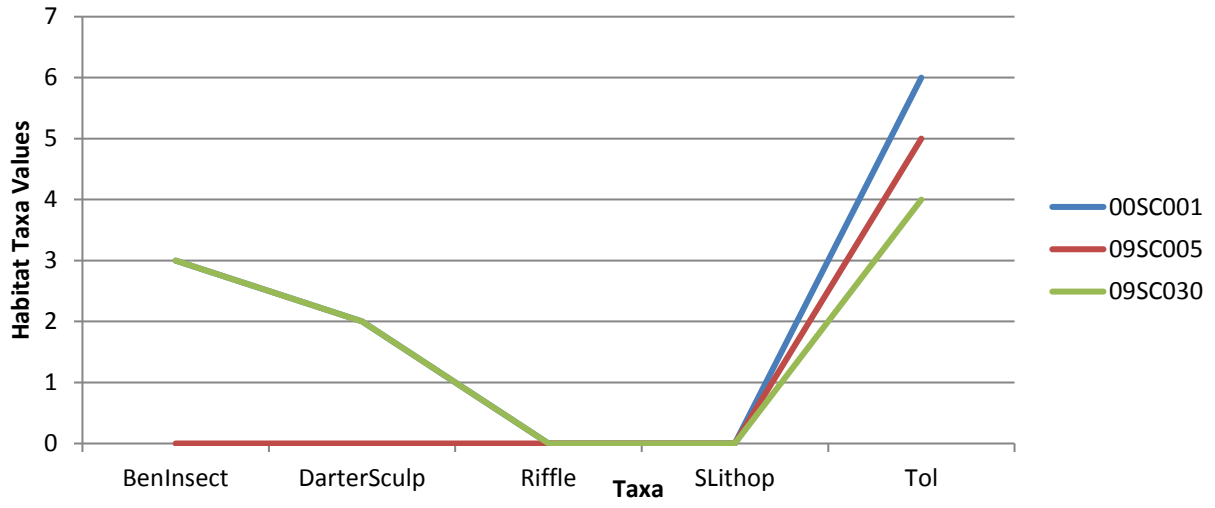

Figure 87. Habitat related fish metrics

As the percentage of fine sediments increase, clinger and climber taxa tend to decrease, and burrowers increase. Clingers live on firm substrates and climbers live on plant debris, as these materials become covered in fines the macroinvertebrate community decreases. Burrowers live in fine sediments. Six taxa of both clinger and climbers were collected at station 09SC005. This equaled 4.31% of climber individuals and 19.08% clinger individuals. The average class 6 percentages for climber and clingers were 24.3% and 27.3% of the community. The percentage of burrowers was 11.38% while the state average was 14.98%. Habitat availability seems to be having an effect on the biological community, but currently macroinvertebrates as a stressor is inconclusive.

Candidate cause: Suspended sediment

The West Branch Sunrise River is also impaired for turbidity. To determine if the turbidity impairment is driven by organic (algae) or inorganic (silt) particles, paired samples of organic solids (TSVS) and inorganic solids (TSS) samples were taken on the river. (Table 4). The majority of suspended solids were comprised of organic or algal particles. This corresponds with the high chlorophyll values in the stream.

Table 4. TSS and TSVS

Location	Range of values	# of values	Average of TSVS to TSS ratios
Martin Lake outlet	90-93%	2	92%
West Branch at Ryan Lake Drive	68-85%	3	77%
West Branch at Lyons Street	57-100%	56	73%
West Branch at I-35	66-75%	2	71%
West Branch at Highway 30	33-92%	28	65%

TSS values from 2007 to 2012 were analyzed (Figure 88). Values ranged from 2 to 55 mg/L. The standard for TSS for the central region of the state is 30 mg/L. Values above 30 mg/L made up 20% of the dataset. The majority of the highest values were recorded in June and July with the highest value in September.

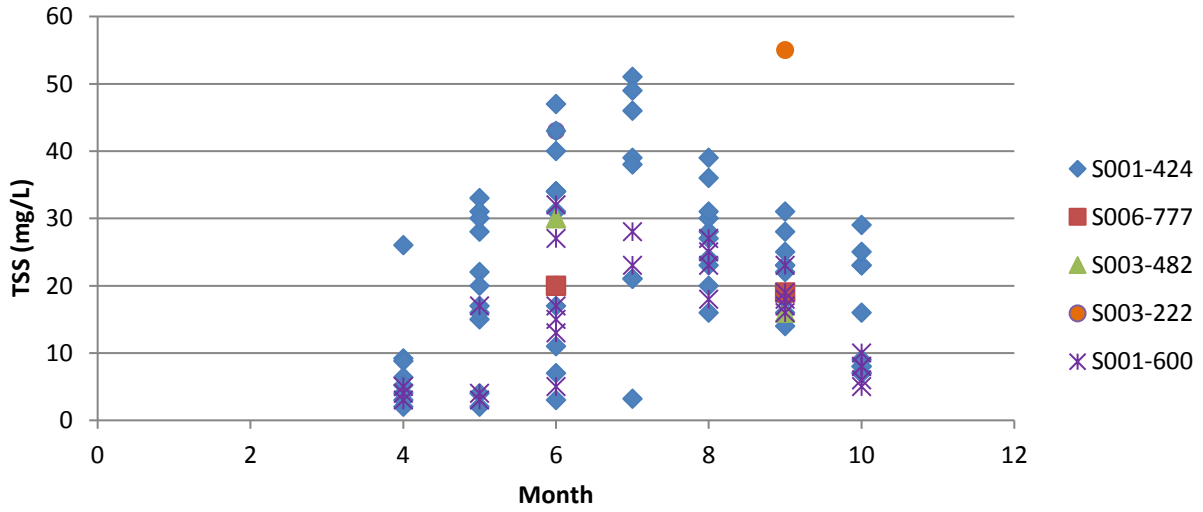

Figure 88. TSS values on the West Branch Sunrise River

Biotic response

Herbivore species of fish decrease as TSS values increase. Herbivores are fish species that consume plant material. These species are negatively impacted by the loss of vegetation which can be caused by sedimentation (Markus 2010). The individual herbivore percentages were zero at all three stations.

The average statewide for fish class 7 is 4.28. All stations were dominated by fish that were moderately tolerant of elevated TSS values. The most common fish include central mudminnow, spotfin shiners, and black bullhead, and johnny darters. Suspended sedimentation can also affect both the number and growth of smallmouth bass. Smallmouth bass were not collected at any of the stations. Heiskary et al (2010) found a relationship with lowered intolerant percentages when TSS concentrations rise over 33. There were zero intolerant fish collected on the West Branch Sunrise River (Figure 89).

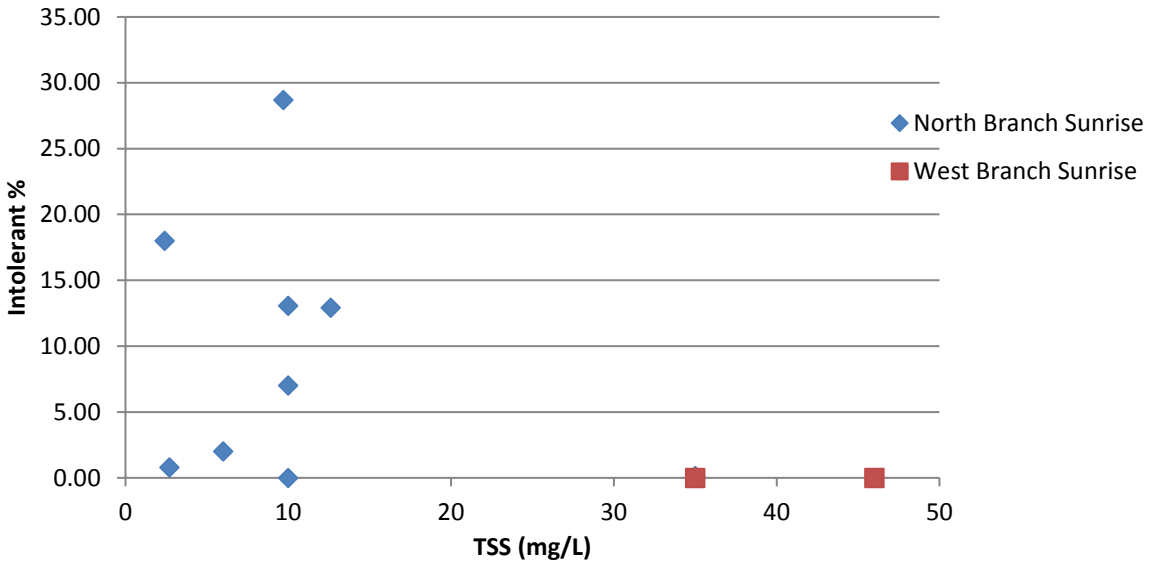

Figure 89. Intolerant fish

The one station with a macroinvertebrate visit had one taxa collected that is intolerant to TSS. The average for class 6 streams is 1.08. 12.62 percent TSS tolerant individuals were present. The average for class 6 streams statewide was 23.72. Station 09SC005 also had a low percentage of long-lived macroinvertebrates (0.92%), indicating conditions are not amenable to macroinvertebrates having a long life.

Organic sediment seems to be the driving factor with suspended sediments in the river, which are having an effect on the number of intolerant fish and herbivore species collected. While the TSS intolerant taxa are right at the class average, the tolerant percentage was lower than average leading to the conclusion that suspended sediments are a main stressor to the fish but not the macroinvertebrate community.

AUID summary

The main stressors to the West Branch Sunrise River were DO, phosphorus, lack of habitat, and suspended sediments.

South Branch Sunrise River

Due to the stream reach being predominantly channelized, the South Branch Sunrise River was not assessed for biology. The stream was assessed for DO and found to be impaired. The system is a large wetland complex with significant ditching. The color of the stream has been observed as a brownish orange color periodically over the last five years. Chemistry samples were taken at these locations to try and determine the source of the color. Phosphorus values above the standard were taken at Hornsby Street, Pool 8, and Pool 10 (Figure 90). The color is captured in the pictures (Figure 91), and show the river at Hornsby Street in the two pictures located on the left, at Pool 10 in the top right, and in Wyoming at Highway 30 on the bottom right.

Chlorophyll-a values was also high at Pool 10. Chlorophyll-a levels above 30 are considered to constitute an algae bloom, and the concentration at Pool 10 was 61 mg/L. TSVS make up the majority of the TSS samples, at Pool 10 and Pool 8, although TSS values are well below the standard. Carbon was 26 mg/L, and color had a value of 100. A color value of 100 or greater has an effect on water clarity. The color was strongest at Pool 10, which also had the highest chlorophyll and phosphorus values. This occurrence does not seem to be flow related as it has occurred in both low and high flow years.

A high organic content in streams and waterways leads to an increase in microorganisms, such as algae, which deplete the oxygen levels in the water to the detriment of other inhabitants of that ecosystem. This organic matter is introduced on a daily basis. It comes from decaying natural organic sources such as plants, animals and the environment. Iron rich soils could also be a source as discussed in the 2012 South Branch Sunrise River Stream Water Quality Monitoring Report.

Figure 90. South Branch Sunrise River

Figure 91. Orange color on the South Branch Sunrise River

Sunrise River

The Sunrise River is the largest tributary to the St. Croix River in the watershed. There are nine biological stations, which have been sampled 18 times for fish since 1996 and 17 times for macroinvertebrates. Only sites sampled after 2000 were included in the 10-year assessment window, however for the purposes of SID all data was used in this report. Chemical and biological information is available throughout the watershed through sampling done by the MPCA, the DNR, local counties, and citizens. A comprehensive review of biological, chemical, and physical data was performed (Figure 92).

The Sunrise River from Comfort Lake to Pool 1 (-527) with stations 09SC006 and 96SC024 was impaired for fish, macroinvertebrates, and DO. Headwater lakes Bone, Moody, Birch, and Comfort are impaired for nutrients. Pool 3 (-539) with station 09SC024 is impaired for fish, and the reach from Pool 3 to the Kost dam (-540) with stations 06SC009 and 09SC035 is impaired for fish and DO. AUIDs -542 and -543, the two most downstream AUIDs of Sunrise River were not impaired for biology and are used here for comparison to impaired areas.

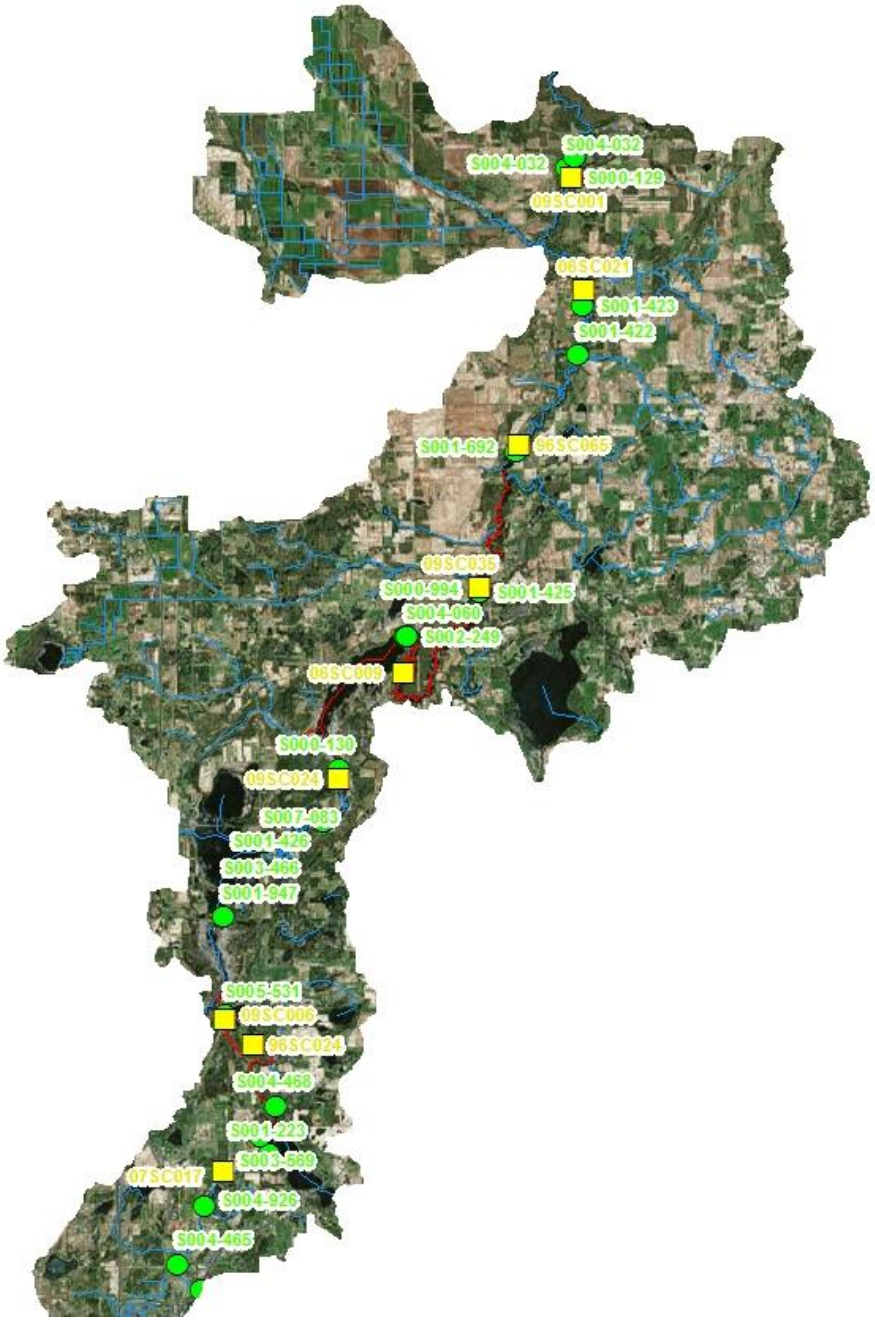

Figure 92. Sunrise River

Metric scores cumulatively made up the IBI score. The fish IBI scores were calculated using the northern streams (class 5) and low gradient IBI (class 7), and the macroinvertebrate score was calculated using the southern forest streams glide pool IBI (class 6). There are not individual standards for each metric, but using a target score provides a method of identifying problem metrics for a stream or individual monitoring site.

Station 96SC024 is the lowest scoring site. The fish metrics have uniformly low scores of intolerant percent, serial spawners, sensitive species, and simple lithophilic spawners (Figure 93). Sensitive or pollution intolerant fish species are typically the first to disappear when conditions become increasingly unfavorable. The serial spawner metrics is also very low at the upstream sites showing that fish that spawn several times a year are present. This is of interest, because serially spawning fish are reacting to disturbance. The intolerant percentage was zero at each visit. In comparison, the three visits on the

unimpaired downstream reaches (**-542** and **-543**) scored better, particularly in the simple lithophilic spawners and intolerant metrics (Figure 94). Station 96SC065 was sampled five times between 1996 and 2000 and scored consistently over time.

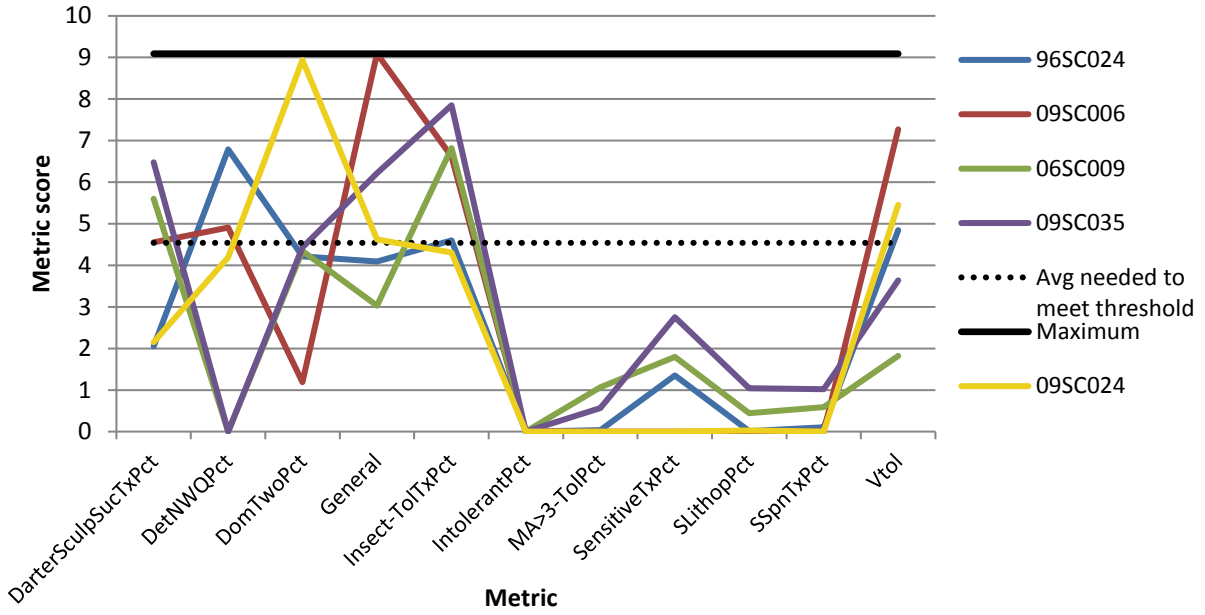

Figure 93. Sunrise River sites on impaired reaches

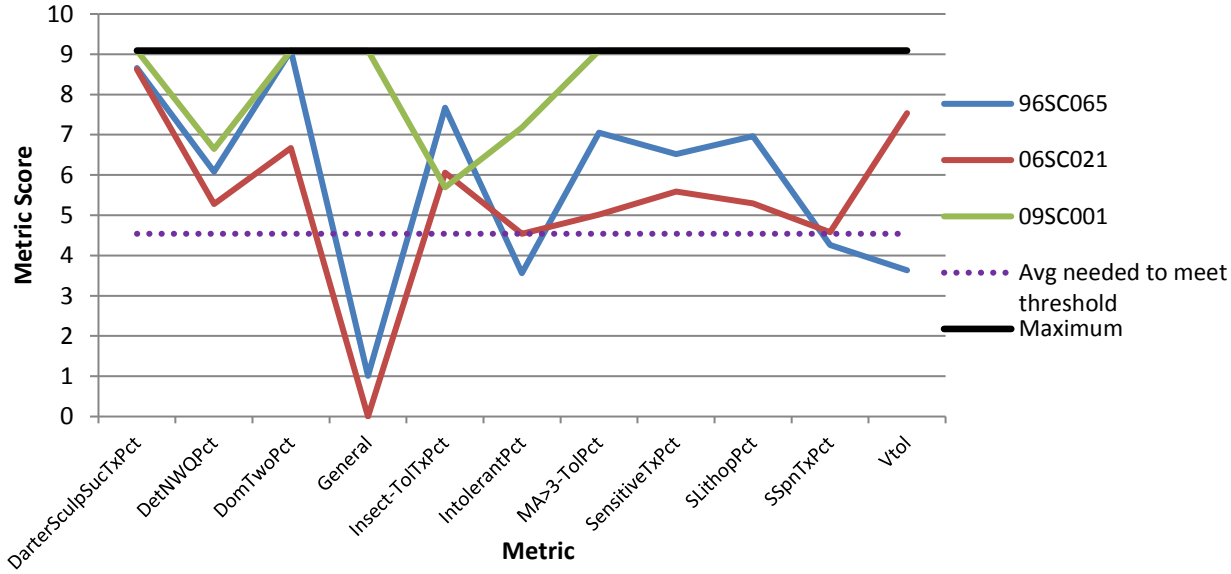

Figure 94. Sites on unimpaired reaches

Stations on the Sunrise River were also assessed using two macroinvertebrate classes; those with run and riffle habitats and those with glide and pool habitats. The three sites in the southern streams riffle/run class (macroinvertebrate class 5) are in the unimpaired reach of the stream and while this IBI uses different metrics, most all of the scores are above the average needed to meet the threshold (Figure 95). The four stations in the southern forest streams glide/pool class (macroinvertebrate class 6) have uniformly low scores in the intolerant metric and three of the four stations had low collector-filterer and clinger scores (Figure 96).

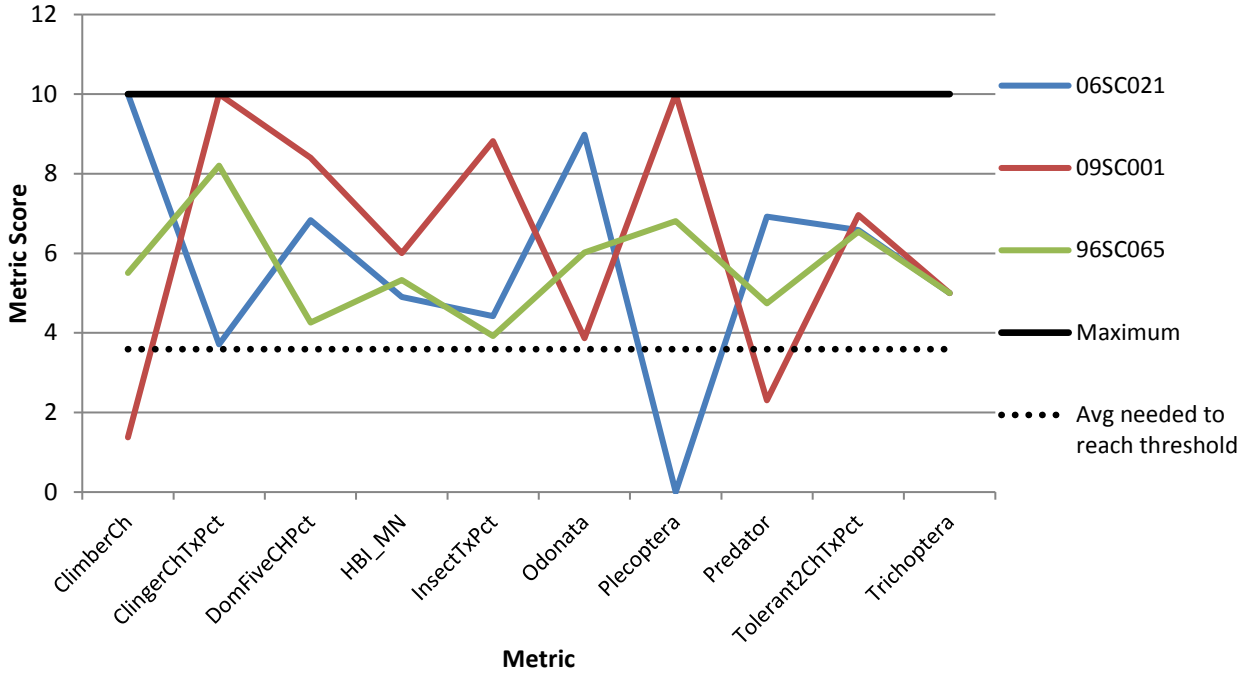

Figure 95. Class 5 Macroinvertebrates

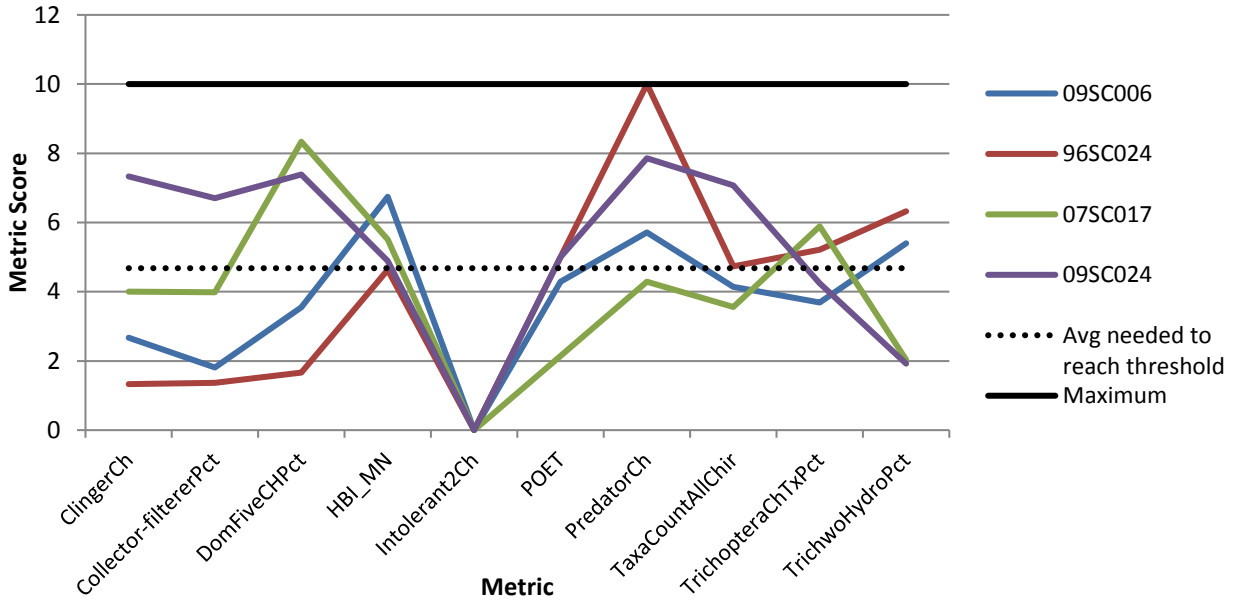

Figure 96. Class 6 Macroinvertebrates

Candidate cause: Dissolved oxygen

AUID **-527 and -540** are impaired for DO. Riparian wetlands are common in the upper (Figure 97) and middle (Figure 98) sections of the watershed. This area of the river is a low gradient and is controlled by dams, further changing the flow. Longitudinal DO readings (Figure 99) taken in May and August 2012, show DO does not consistency rise above the standard of 5 mg/L until station S000-994 which is located about five miles downstream of Pool 3. Gradient likely has an impact on this as the gradient changes from at 0.316 at station 09SC006 on AUID -527 to 0.917 at station 96SC065 on unimpaired AUID **-542**.

Figure 97. Sunrise River at County Road 19 (09SC024 on May 25, 2012)

Figure 98. Sunrise River at 295th (May 25, 2012)

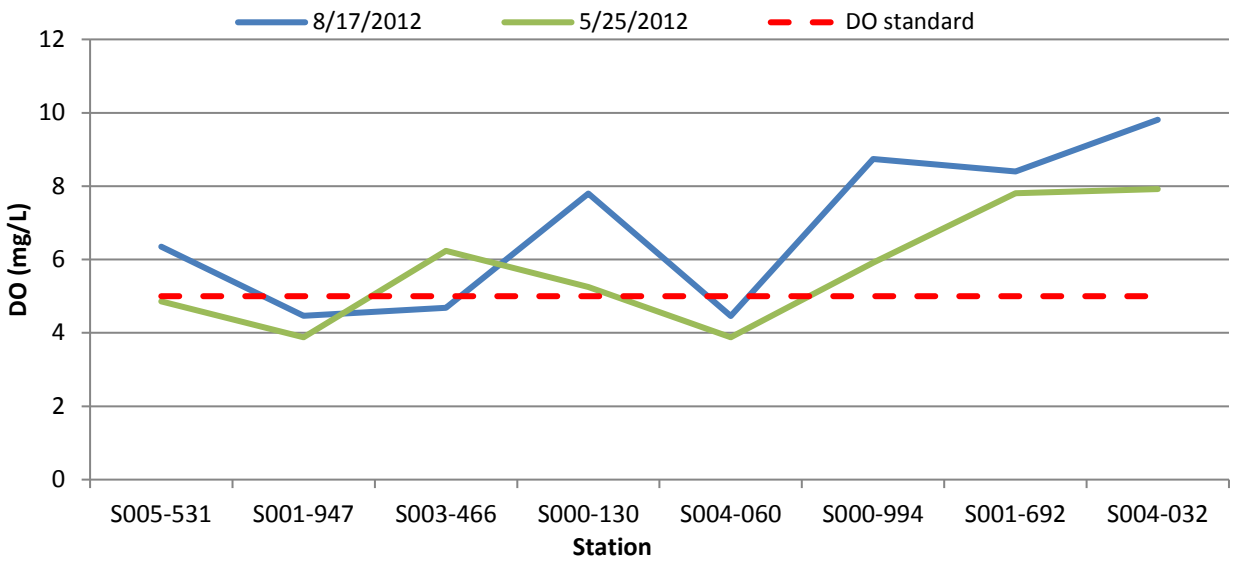

Figure 99. Longitudinal DO on Sunrise River

DO values on **-527** shows a range of values from 0.84 to 15.07 mg/L, with both the lowest and highest values occurring at station S005-531 (Figure 100). The lowest values were recorded in July, with numerous values below the DO standard. The highest values were recorded in May and June, and the extent of the elevated values points to eutrophication.

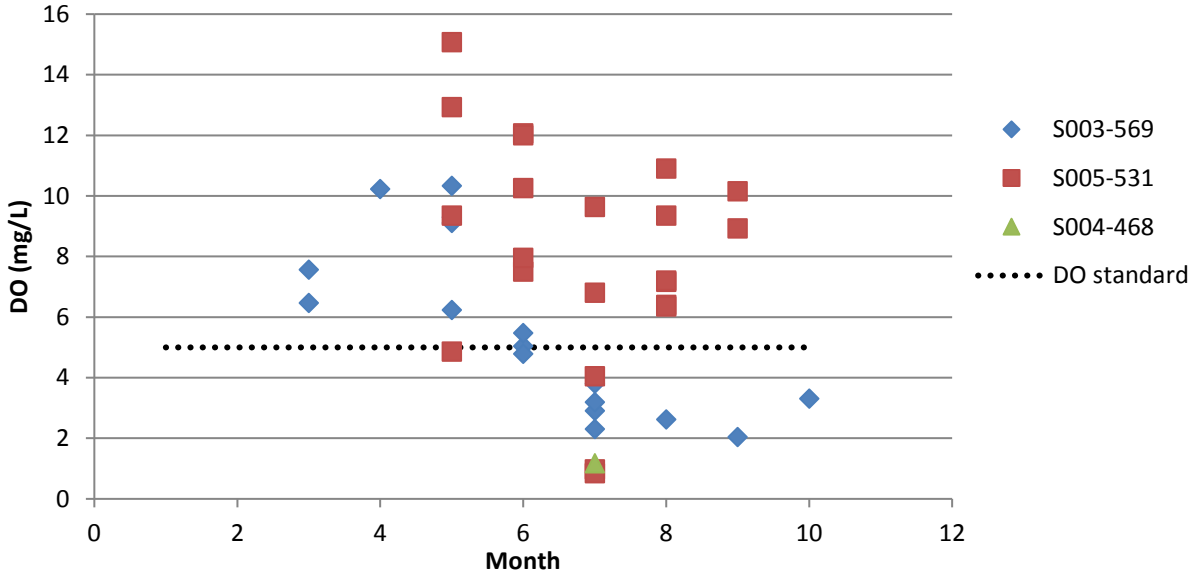

Figure 100. DO values on AUID 07030005-527

Continuous DO data was collected on the Sunrise River on **-527** in July and August 2012 (Figure 101). This data shows the DO daily dipped below the standard of 5.0 mg/L, with values as low as 0.39 mg/L. Daily fluxes were as high as 9.57 mg/L. The central regional eutrophication standard of daily DO flux is 3.5 mg/L. While portions of the Sunrise River are influenced by wetlands which naturally experience DO fluctuations, DO flux values between 2.0 to 4.0 are typical in a 24-hour period (Heiskary et al, 2010). Daily DO fluctuations are a measure of stress on the aquatic community. Algal respiration and photosynthesis are considered primary drivers of daily flux in DO, and high daily fluctuations of DO are connected to nutrient concentrations.

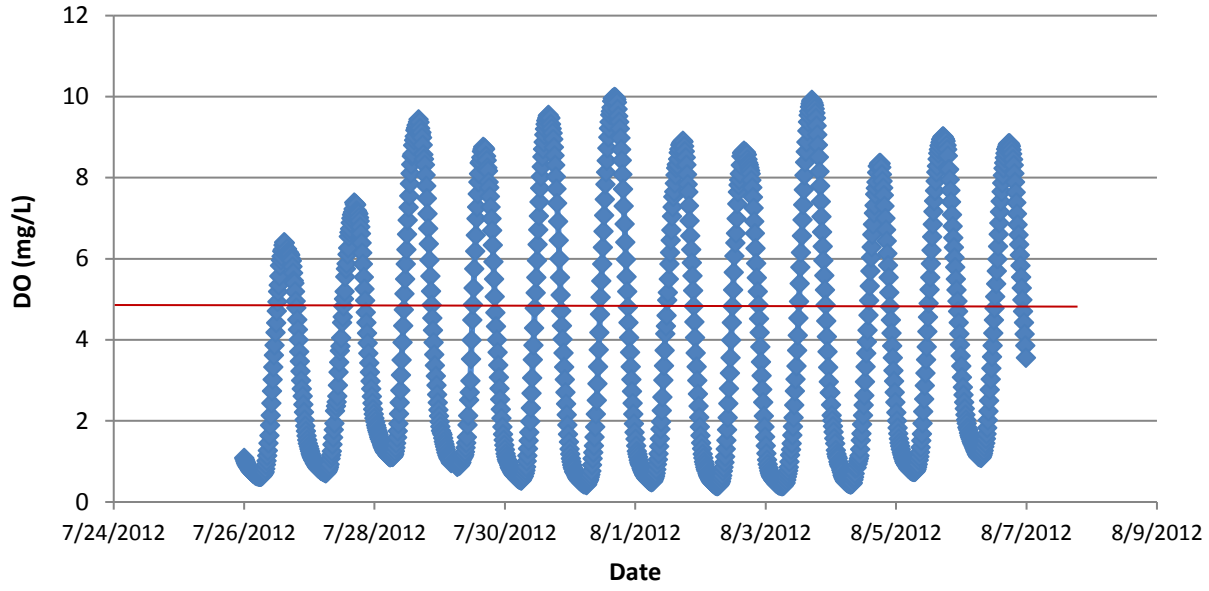

Figure 101. Continuous DO at station 09SC006

DO values on **-539** show a range of values from 0.53 to 13.80 mg/L during the years of 2006-2012, with both the lowest and highest values occurring in January when temperature are low and snow are ice are present on the river (Figure 102). The values taken at station S004-060 were both below the DO standard of 5 mg/L. DO values are lowest prior to 9 AM, but both values were taken later in the day when DO is expected to be higher. Continuous DO data is not available on this reach, but should be measured in the future to further available DO knowledge.

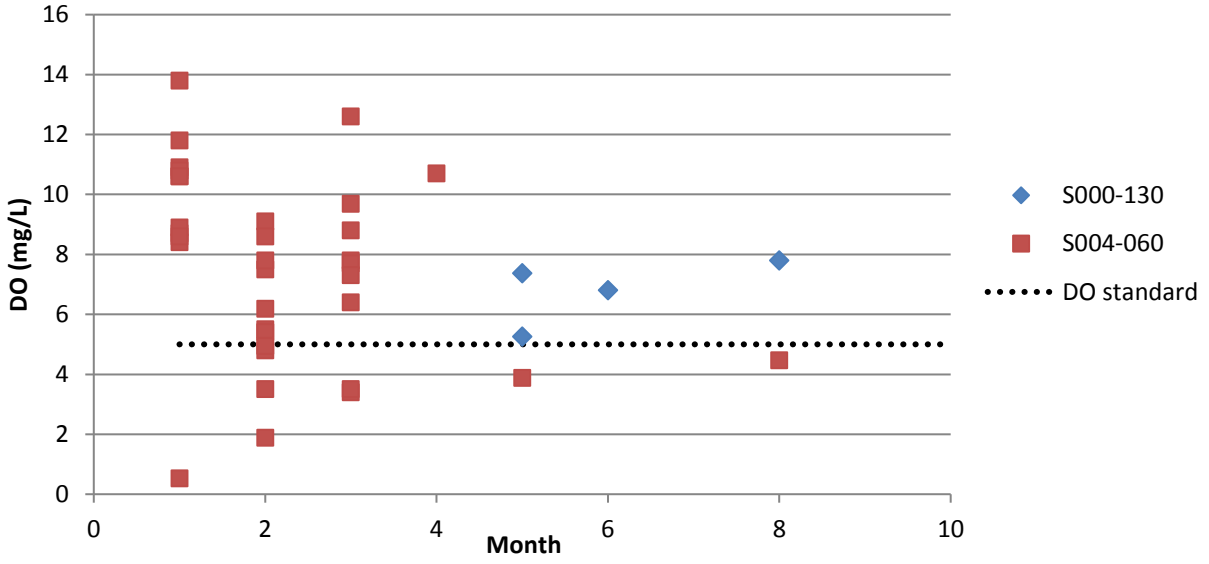

Figure 102. DO values on AUID 07030005-539

DO values on **-540** shows a range of values from 2.5 to 15.4 mg/L during the years of 2004-2012, with few samples taken during the summer months (Figure 103). The lowest values were recorded during the winter months when temperatures were lowest and snow and ice were present on the river.

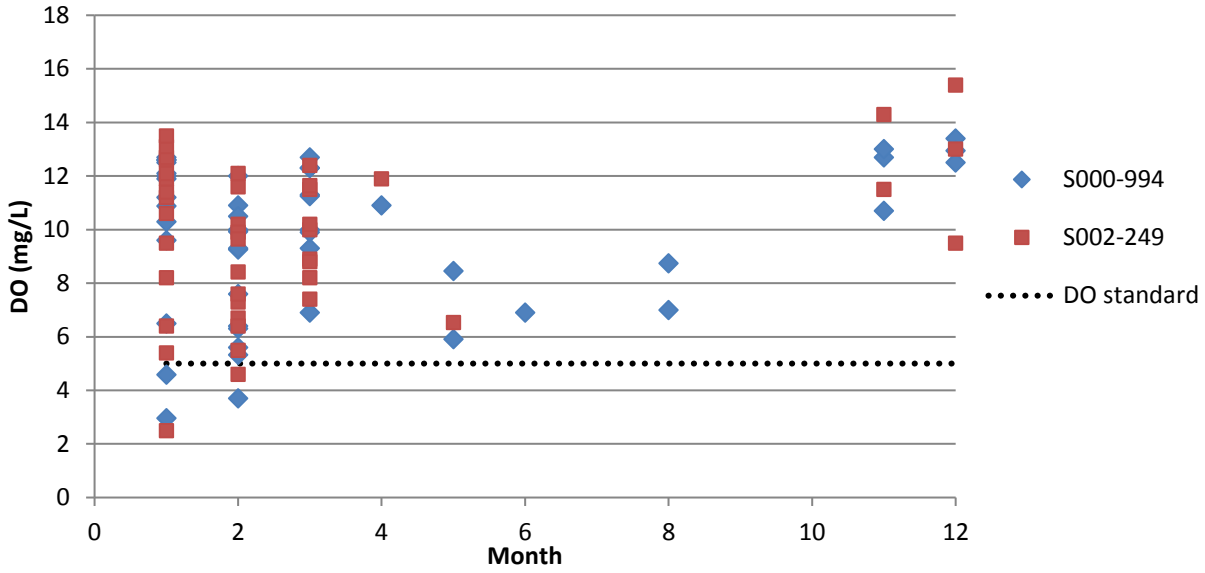

Figure 103. DO values on AUID 07030005-540

Continuous DO data was collected in July and August 2012 (Figure 104). This data shows the DO daily above the standard of 5.0 mg/L throughout the deployment. Only two daily flux values were above the eutrophication standard of 3.5 mg/L.

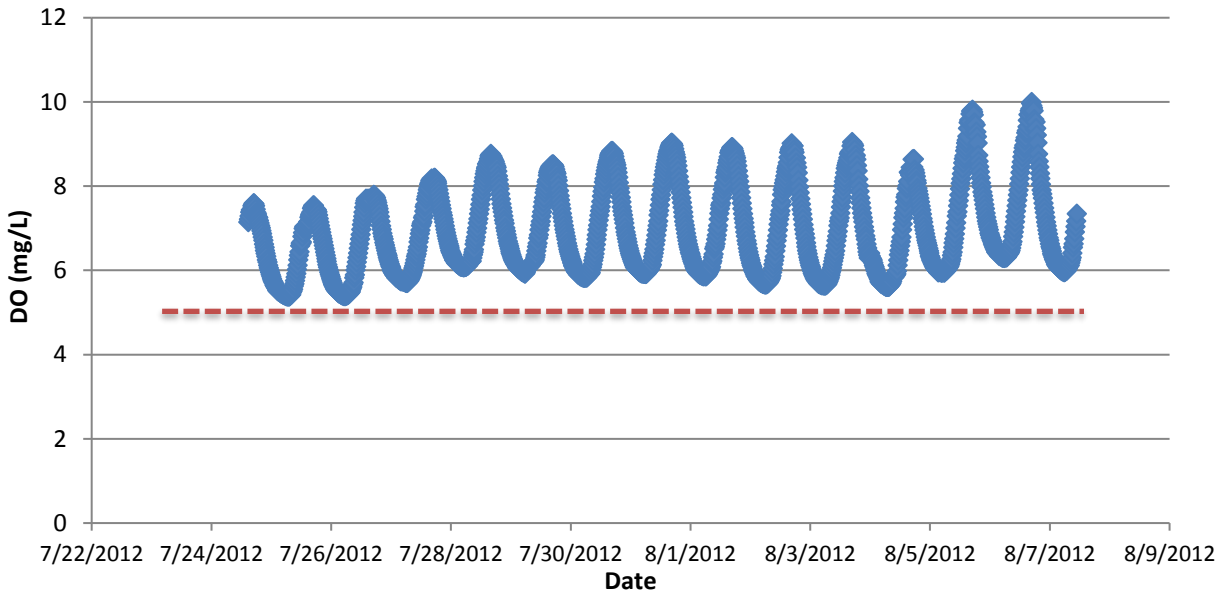

Figure 104. Continuous DO at station 09SC035

Biotic response

Low DO values correspond with increased tolerant species and decreased sensitive species. The average sensitive fish percentage statewide for fish classes 5 is 22.69%. The percentage of sensitive individuals collected on **-527** ranged from 0% to 0.97%. Tolerant percentages ranged from 38.04 to 89.50. The average in the statewide for fish classes 5 was 36.26%. Fish that mature at greater than three years of age are negatively correlated with low DO values. The range of species that mature at greater than three years of age percentages ranged from 0 to 0.41. The average percentage statewide for class 5 was 11.75%.

The numbers of macroinvertebrate taxa that are intolerant to low DO ranged from zero to two. The average statewide for stations in macroinvertebrate class 6 was 3.75 taxa. The percentage of DO tolerant species ranged from 30.16 to 84.12. The average percentage of DO tolerant species in macroinvertebrate class 6 statewide was 24.88%.

The percentage of sensitive individuals collected on **-539** was 0% at station 09SC024. The average sensitive fish percentage statewide for fish classes 5 is 22.69%. The tolerant percentage was 33.04. The average statewide for fish classes 5 was 36.26. Fish that mature at greater than three years of age are negatively correlated with low DO values. The percentage of species that mature at greater than three years of age percentages was 0%. The average percentage statewide for class 5 was 11.75%.

The number of macroinvertebrate taxa that are intolerant to low DO on **-539** was one taxa at station 09SC024. The average statewide for stations in macroinvertebrate class 6 was 3.75 taxa. The percentage of DO tolerant species was 33.13%. The average percentage of DO tolerant species in macroinvertebrate class 6 statewide was 24.88%.

The percentage of sensitive individuals collected on **-540** ranged from 2.09% to 7.36%. The average sensitive fish percentage statewide for fish classes 5 is 22.69%. The tolerant percentage ranged from 25.71 to 38.09. The average statewide for fish classes 5 was 36.26. Fish that mature at greater than three years of age are negatively correlated with low DO values. The percentage of species that mature at greater than three years of age percentages ranged from 2.13% to 5.63%. The average percentage statewide for class 5 streams was 11.75%.

The numbers of macroinvertebrate taxa that are intolerant to low DO on **-540** ranged from zero to five. The average statewide for stations in macroinvertebrate class 6 was 3.75 taxa. The percentage of DO tolerant species ranged from 8.02 to 25.09% The average percentage of DO tolerant species in macroinvertebrate class 6 statewide was 24.88%.

The early morning low DO TIV values along the entirety of the Sunrise River show a majority of the upstream sites (through 12SC001) are comprised of fish species in the first and second quartiles, which are most tolerant to low DO (Figure 105). Stations 96SC024 **(-527**) and 09SC024 **(-539)** had the highest percentages of fish in the first quartile, which are most tolerant to low DO conditions. A shift in predominance from the first and second quartiles occurs between stations 09SC024 **(-539)** and 06SC009 **(-540)** where the pool 3 dam is located. The most downstream sections of the river which were not impaired **(-542 and -543)** were predominantly comprised of species in the third and fourth quartiles, which are most intolerant to low DO.

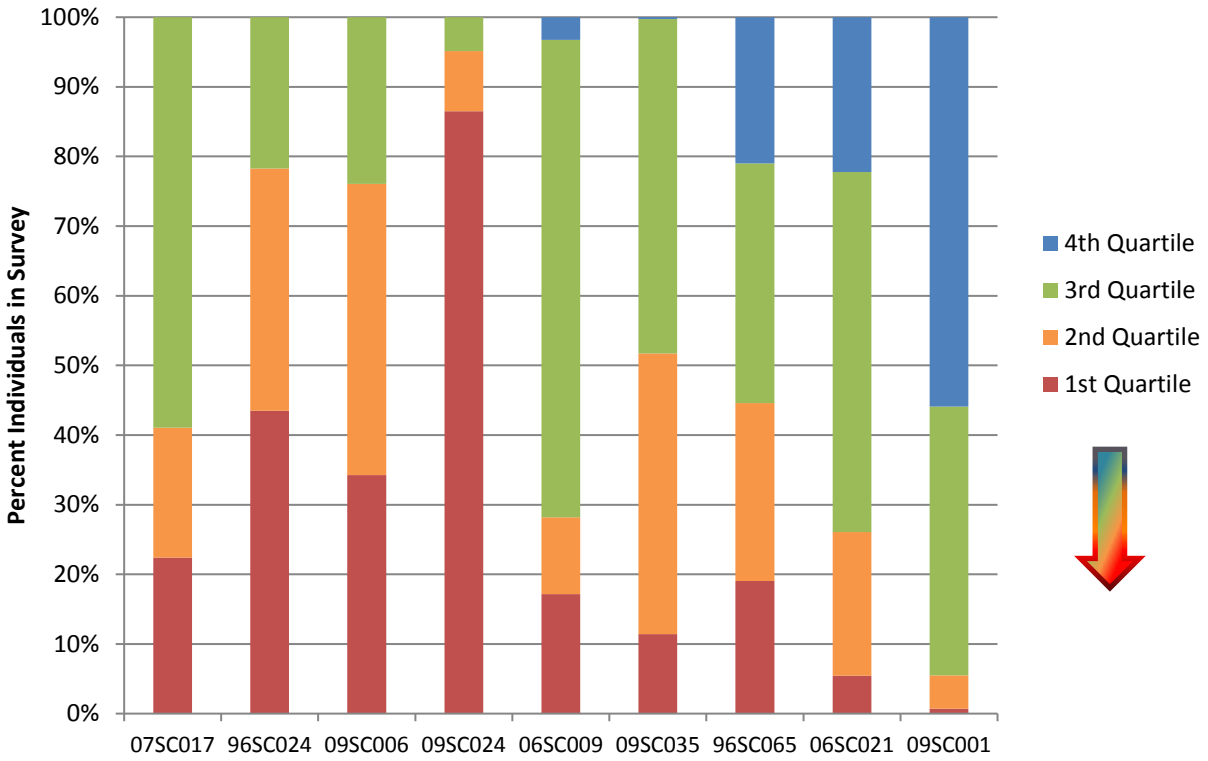

Figure 105. Low DO TIV on the Sunrise River

Low DO levels and high daily fluctuations are having an impact on the biological community, to what extent the wetland community is playing a role is unknown, but the presence of a dams at Pool 1 and 3 and the inflow of the South Branch and West Branch seems to be having a in impact on the amount of DO tolerant fish between 09SC006 and 09SC024. Based on the low DO values recorded in the headwaters, the low percentages of sensitive species, species that mature at greater than three years of age, and tolerant percentages DO is a localized stressor in the upper section of the stream on sections **-527** and **-539**. It is unknown to what extent this is natural flushing of the wetlands, and what might be affected by human influence. While the stations on **-540** also had lowered sensitive and tolerant percentages, this could be due to other stressors as the low DO TIV values were comprised of fish in the second and third quartile. This was in combination with the lack of DO values below the threshold during the continuous deployment, thus DO currently inconclusive as a stressor on this segment of the river.

Candidate cause: Phosphorus

AUID **-527** flows out of Comfort Lake which is impaired for elevated nutrients. Longitudinal studies occurred on May 25, 2012 and August 17, 2012 (Figure 106) along the entirety of the Sunrise River. Values were below the standard until the Kost dam in May and all values were below in August. Chlorophyll-a and BOD values are proximate measurements of eutrophication and have more direct impacts on biology than phosphorus, however there is no current available data for these parameters.

Of the three biologically impaired AUIDs only **-527** had a significant phosphorus dataset during 2009-2012 (Figure 107). The highest values were collected July-September and ranged from 0.01 to 0.231 mg/L. There were only three phosphorus values on -540 and two on -539. Values ranged from 0.037 to 0.138 mg/L on **-539** and 0.078 to 0.122 mg/L on **-540**.

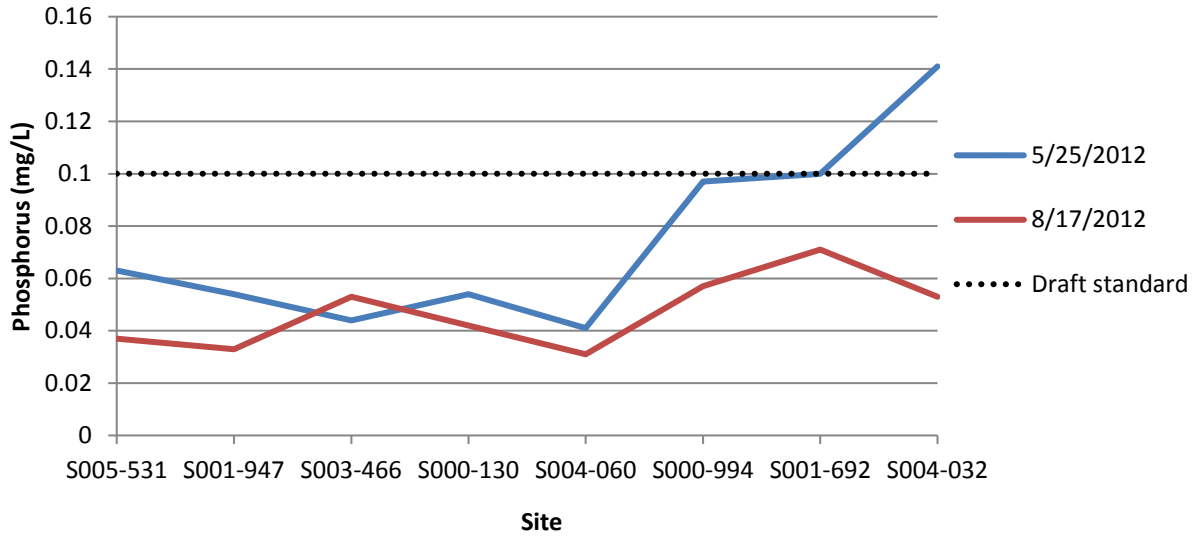

Figure 106. Phosphorus values along the Sunrise River

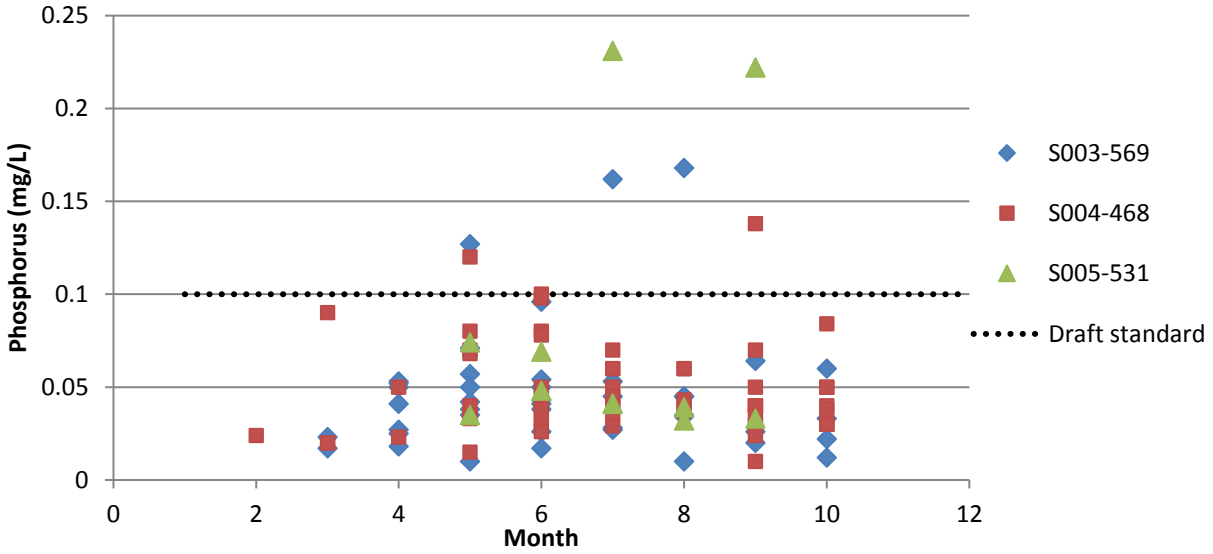

Figure 107. Phosphorus values on 07030005-527

Continuous DO data at station 09SC006 on **-527** showed daily values below the standard and DO flux values above the standard. This coincided with a channel filled with macrophytes and algae (Figure 108). Increased nutrients are tied to excess macrophyte and algae growth, increased photosynthesis and respiration and DO fluctuations.

Figure 108. Macrophytes and algae at station 09SC006

Biotic response

Increased phosphorus levels have an inverse relationship with sensitive individual fish percentages and an increase in tolerant percentages of fish. The average sensitive fish percentage statewide for fish class 5 is 22.69%. The percentage of sensitive individuals collected on **-527** ranged from 0% to 0.97%. Tolerant percentages ranged from 38.04 to 89.50. The average in the statewide for fish classes 5 was 36.2%. Darter percentages are also inversely correlated with phosphorus. The percentage of darter individuals has ranged from 0.08 to 41.85%. The average in the statewide for fish classes 5 was 18.03%. Johnny darters were the predominant species collected, increasing the darter percentage. However, Johnny darters are one of the most tolerant of the darter species and one of the first species to move into a disturbed environment (pioneer species).

Effects of phosphorus are also seen through a decrease in macroinvertebrate taxa, and an increase in tolerant percentage. The number of macroinvertebrate taxa ranged from 20 to 28, and tolerant percentages ranged from 78.57 to 92.73. The number of macroinvertebrate taxa in macroinvertebrate class 6 averaged 21.43 statewide, and tolerant percent averaged 74.27%.

The percentage of sensitive individuals collected on **-539** was 0% at station 09SC024. The average sensitive fish percentage statewide for fish classes 5 is 22.69%. The tolerant percentage was 33.04. The average statewide for fish classes 5 was 36.26. Darter percentages are also inversely correlated with phosphorus. The percentage of darter individuals was 11.30%. The average in the statewide for fish classes 5 was 18.03%.

Effects of phosphorus are also seen through a decrease in macroinvertebrate taxa, and an increase in tolerant percentage. The number of macroinvertebrate taxa on **-539** was 30 at station 09SC024, and tolerant percentages was 73.56%. The number of macroinvertebrate taxa in macroinvertebrate class 6 averaged 21.43 statewide, and tolerant percent averaged 74.27%.

The percentage of sensitive individuals collected on **-540** ranged from 2.09% to 7.36%. The average sensitive fish percentage statewide for fish classes 5 is 22.69%. The tolerant percentage ranged from 25.71 to 38.09. The average statewide for fish classes 5 was 36.26. Darter percentages are also inversely correlated with phosphorus. The percentage of darter individuals ranged from 4.57 to 28.49%. The average in the statewide for fish classes 5 was 18.03%.

Effects of phosphorus are also seen through a decrease in macroinvertebrate taxa, and an increase in tolerant percentage. The number of macroinvertebrate taxa on **-540** ranged from 28 to 32, and tolerant percentages ranged from 31.09 to 72.06%. The number of macroinvertebrate taxa in macroinvertebrate class 6 averaged 21.43 statewide, and tolerant percent averaged 74.27%.

Decreased sensitive and increased tolerant individuals along with high levels of phosphorus on **-527** are contributing to photosynthesis and algal respiration, which in turn are effecting the daily oxygen production and oxygen demand. Phosphorus is a stressor on this reach. Phosphorus data was limited on **-539** and **-540**. Lowered sensitive and increased tolerant individuals on **-539** are tied to low DO as a stressor, phosphorus could be influencing this stressor but it is inconclusive at this time. Similar to DO, metric responses are mixed on **-540** and phosphorus is not currently a stressor.

Candidate cause: Nitrate

Longitudinal studies occurred on May 25, 2012 and August 17, 2012 (Figure 109) along the entirety of the Sunrise River. Concentrations did not rise above 0.3 until station S001-692 below Kost dam. Nitrate concentrations collected in 2009 and 2012on **-527** ranged from <0.05 to 0.24 mg/L. The highest values were collected during July and August. The 75% percentile of the North Central Hardwood Forests ecoregion norm is 0.26 mg/L.

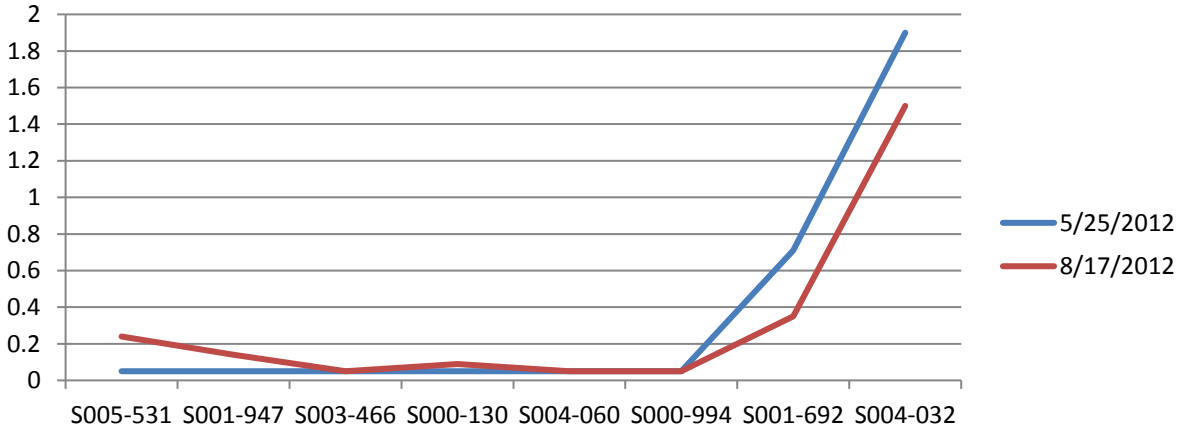

Figure 109. Longitudinal nitrate sampling on the Sunrise River

There was a limited nitrate dataset on **-539** with seven values ranging from <0.05 to 0.18 mg/L. Data was from 2006-2012. All of the values were below the 75% percentile of the North Central Hardwood Forests ecoregion norm of 0.26 mg/L, although the dataset is very small.

There was also a limited nitrate dataset on **-540** with seven values ranging from <0.05 to 0.15mg/L. Data was available from 2000-2012. All of the values were below the 75% percentile of the North Central Hardwood Forests ecoregion norm of 0.26 mg/L, although the dataset is very small.

Biotic response

Fish lack strong biological response evidence in relation to elevated nitrate. Macroinvertebrates have stronger responses to nitrate, so while macroinvertebrates are only impaired on **-527** stream nitrate intolerant and tolerant macroinvertebrates were looked at on all three AUIDs to see if nitrate is affecting the community.

Nitrate intolerant macroinvertebrate taxa ranged from 4 to 6 on **-527** and averaged 4.75. The statewide average for class 6 streams was 4.60. The two stations on **-527** had a nitrate tolerant percentage range of 10.36 to 24.34%. The average statewide for class 6 is 53.16%. The range of nitrate tolerant species was from 10 to 12. The average statewide for class 6 streams is 15.76. Increasing nitrate concentrations also have a relationship with a decrease in non-hydropsychid Trichoptera (caddisfly) individual percentages.

Non-hydropsychid Trichoptera are all caddisflies that do not spin nets. The individual percentages ranged from 1.52 to 3.48%, and averaged 2.6. Sites in class 6 statewide averaged 2.07.

Nitrate intolerant macroinvertebrate taxon was 4 on **-539**. The statewide average for class 6 streams was 4.60 taxa. Station 09SC024 had a nitrate tolerant percentage of 31.48%. The average statewide for class 6 is 53.16%. The number of nitrate tolerant species was 15. The average statewide for class 6 streams is 15.76.

Nitrate intolerant macroinvertebrate taxa ranged from 4 to 7 on **-540** and averaged 5.5. The statewide average for class 6 streams was 4.60. The two stations on **-540** had a nitrate tolerant percentage range of 34.77 to 62.96%. The average statewide for class 6 is 53.16%. The range of nitrate tolerant species was from 17 to 18. The average statewide for class 6 streams is 15.76.

This biological evidence is not suggestive of nitrate as a stressor, as nitrate tolerant individuals are less than would be expected with nitrate stress, as well as the presence of nitrate intolerant taxa. In combination with low nitrate concentrations and lack of biological response to nitrate, nitrate is not found to be a stressor at this time. Continued monitoring and nutrient management would be recommended so that nitrate does not become a stressor in this watershed. AUID **-540** and station 09SC035 is most in need of monitoring and protection with the highest nitrate tolerant percentage macroinvertebrate community.

Candidate cause: pH

The standard for pH in surface waters is a range of 6.5-9, values over 8.5 and large daily pH fluctuations are tied to nutrient enrichment. Fluctuations in pH, similar to those with DO, are due to photosynthesis and respiration. Values on **-539** ranged from 7.3-8.05. Values on **-540** ranged from 7.32-8.37. High pH values have been recorded on **-527** at stations S003-569 and S005-531 (8.82 and 9.14 respectively). Continuous data collected during 2012 recorded a high value of 8.1 on station 09SC006 at **-527**, and a high value of 8.29 at station 09SC035 on **-540.** There was a range of pH flux values of 0.16 to 0.82 at station 09SC006 with an average of 0.58 and a range of 0.26 to 0.52 at station 09SC035 with an average of 0.39. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013). High fluctuations reflect excessive in-stream primary production, as algae and aquatic plants drive up pH during the daytime.

Biotic response

EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (U.S. EPA. 2013). Bluegill and yellow perch were both collected on **-527** including 69 bluegills at station 96SC024; however, neither were collected at station 09SC006 where pH flux was elevated. Bluegills were also collected on **-539** and both bluegill and yellow perch were collected on **-540**. There were a few elevated pH values on **-527** but pH flux was of more concern, with 10 of the 13 days with flux over 0.5. The pH flux is likely tied to the phosphorus stressor and increased eutrophication on this reach, however pH itself is not a stressor on this or the downstream reaches of the Sunrise River.

Candidate cause: Lack of habitat

The Sunrise River is low gradient and sinuous with low slopes and low stream power (USACE). MSHA scores ranged from 53 to 63 on **-527**, with station 09SC006 in the fair category and station 96SC024 in the good category. Scores were limited at both stations by a lack of riffles, dominance of fine sediments,

and poor channel development. The MSHA score at station 09SC024 on **-539** was 53.5, and were also limited by absence of riffles, channel development, and any coarse substrates. Stations on **-540** had a range of MSHA scores of 57 to 65.5, which are in the fair category. Station 06SC009 had no riffles or coarse substrates and poor channel development, while stations also lacked riffles and channel development, gravel and cobbles were present. The average particle size located in the stream bed collected by the US Army Corps of Engineers confirms that very fine and medium sand are the predominant sediments (Table 5). Moving sand makes it hard for species to nest. Excess sedimentation in runs was recorded at station 06SC009. Station 06SC009 was also reported to be moderately entrenched by the DNR (2008). Scores were also limited by minimal stream shade (Figure 110), which can affect stream temperature. Stations 09SC006 and 09SC035 both had continuous temperatures in excess of 28 degrees Celsius.

Table 5. Habitat characteristics

Field number	Embeddedness	Habitat rating	Substrate	Depth of fines	D50 (mm)
96SC024	No coarse substrate	Good	Sand and silt (100% fines)	13 inches	
09SC006	Light	Fair	Sand and silt dominant		0.07
09SC024	No coarse substrate	Fair	Sand and silt		0.07
06SC009	No coarse substrate	Fair	Sand and silt (100% fines)	17 inches	0.5
09SC035	75% embedded	Fair	Sand, gravel, and cobble		0.4

Figure 110. Station 06SC009

A bankpin was placed in the upper bank at station 09SC035 for one year. The soil around the pin eroded 35.75 cm, or 14 inches. This station also had numerous mid-channel bars (Figure 111), indicating a surplus of sediment moving through the stream. Stream bank stabilization efforts would be useful.

Figure 111. Erosion and mid-channel bars at station 09SC035

Biotic response

CADDIS shows a relationship between change in physical habitat availability and quality in an increase in tolerant taxa. Benthic insectivores, darter, sculpin, and sucker, riffle dwelling species, and simple lithophilic spawners all require coarse substrate. Lithophilic spawners reproduce by broadcasting eggs across gravel or coarse sand substrate, and without this substrate available this taxa would not be expected. The metrics effected by fine sediments and a lack of riffle are lower in the upstream section of the river, where the river is low gradient and is comprised of fine sediments. The downstream section of the stream which is not impaired (stations 96SC065, 06SC021, and 09SC001) is higher gradient and has coarse substrates available (Figure 112). Habitat availability is a stressor to the fish biological community.

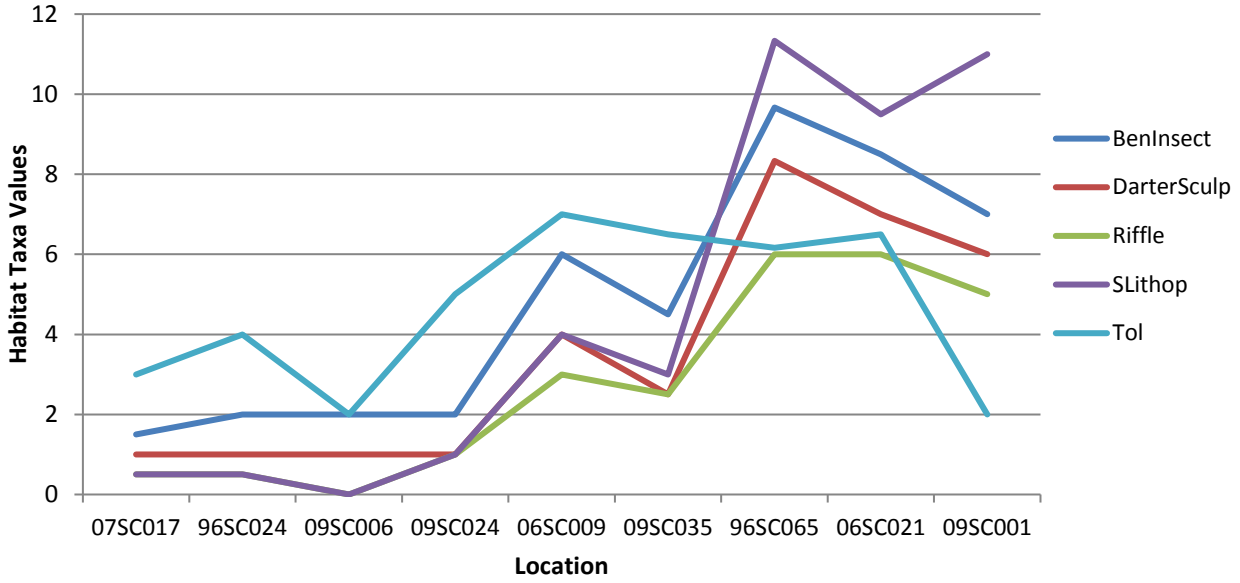

Figure 112. Habitat metrics on the Sunrise River

As the percentage of fine sediments increase, clinger and climber taxa tend to decrease, and burrowers increase. Clingers live on firm substrates and climbers live on plant debris, as these materials become covered in fines the macroinvertebrate community decreases. Burrowers live in fine sediments. There was a range of 3 (09SC035) to 11 (96SC024) of climber taxa and 4 (96SC024) to 23 (96SC065) clinger taxa. Stations 96SC065 and 06SC021 were located on unimpaired reaches and had the highest numbers of clingers, which were also the locations of lowest percentage fines (Figure 113).

The number of burrower taxa ranged from 0 (09SC035) to 4 (07SC017). While there is a relationship between the percentage fines and number of clinger taxa along the Sunrise River, there is not a clear relationship between climber and burrower taxa. Habitat availability seems to be having an effect on the biological community, but currently habitat as a stressor for macroinvertebrates is inconclusive.

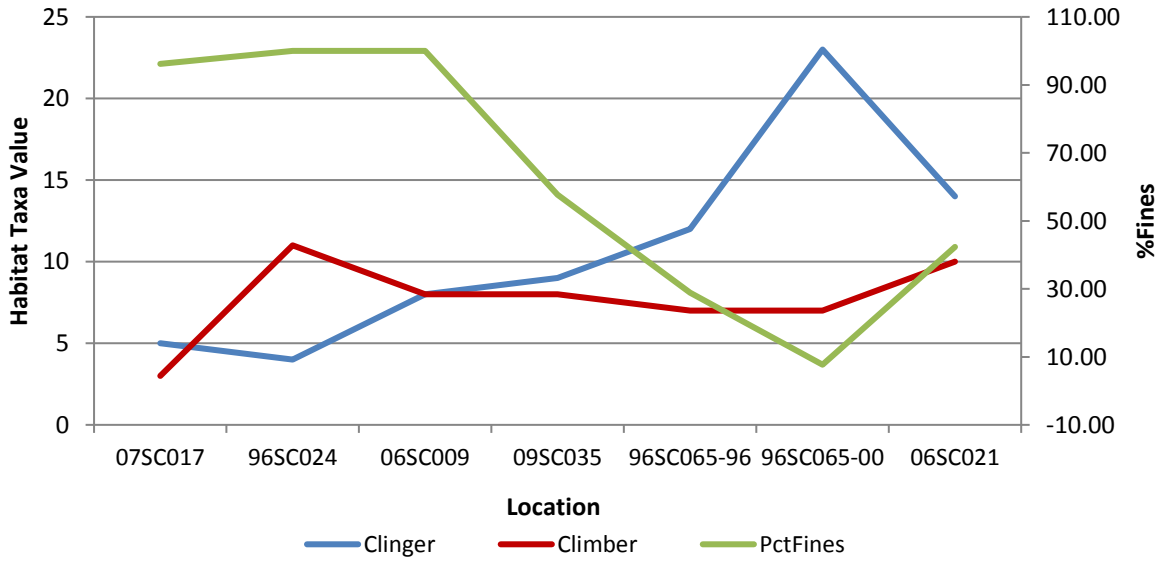

Figure 113. Macroinvertebrate taxa and percentage of fines

The natural aspect of the sand substrate should be taken into consideration. However, the lack of canopy cover, lack of coarse substrate, lack of riffles, channel development, and lack of habitat as a whole is limiting the fish and macroinvertebrate community particularly on **-527** and **-539**. There are areas of erosion that should be addressed to ensure that fine sediments are not accumulating.

Candidate cause: Suspended sediment

Based on low slopes and impoundments in the upper watershed, the Army Corp of Engineers concluded that the upper watershed does not have a large contribution to the sediment load in the Sunrise Watershed (USACE 2010). TSS values on the Sunrise River from 2007 to 2012 were analyzed by month on **-527** (Figure 114). Values ranged from 1 to 210 mg/L. The value of 210 was taken in 2009 after about an inch of rain at station S005-531. Three values were recorded over 30 mg/L, equating to 9% of the dataset. The standard for TSS for the central region of the state is 30 mg/L. The highest values were recorded in May and June at stations S003-569 and S004-468. There were no transparency tube values less than 44 cm, all above the standard of 25 cm.

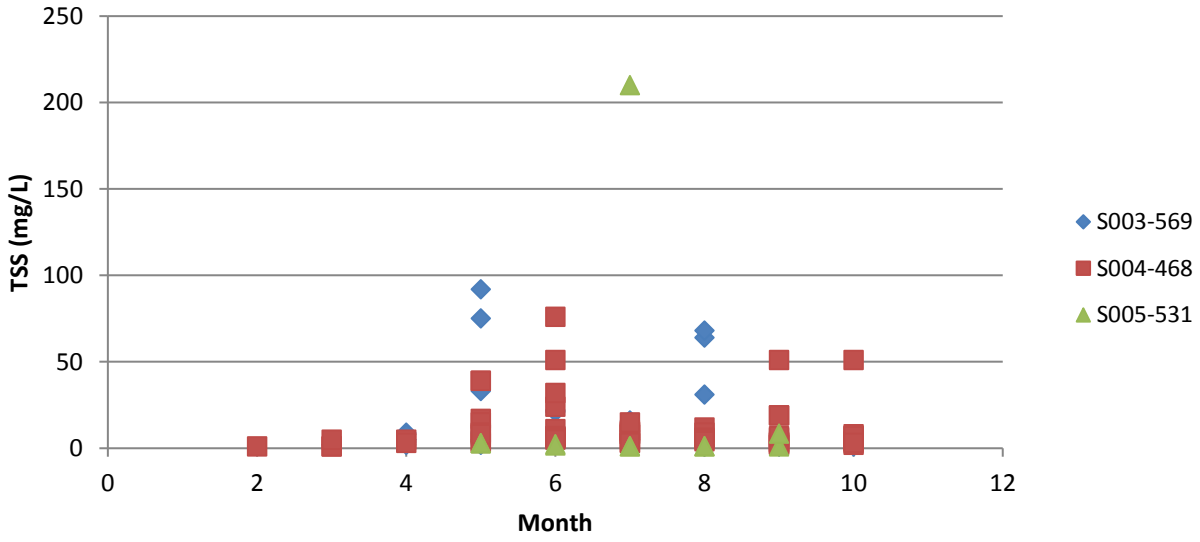

Figure 114. TSS values on -527

There were only two TSS values available on **-539**. The values were taken in 2009 and 2010 and are 20 and 6 mg/L respectively. There were also six transparency tube data points more available on this reach, ranging from 32 to >100 cm.

There were only three TSS values available on **-540**. The values were taken from 2006-2012 and were 1.2, 4.6, and 82 mg/L respectively. The standard for TSS for the central region of the state is 30 mg/L. Transparency tube data is more abundant on this reach with data ranging from 43 to >100.

Biotic response

Herbivore species of fish decrease as TSS values increase. The individual herbivore percentages were zero at all stations on **-527, -539, and -540**. The average statewide for fish in class 5 is 1.97. TSS can also affect both the number and growth of smallmouth bass. Smallmouth bass were not collected at any of the visits on any of these reaches.

The number of macroinvertebrate taxa that are intolerant to TSS ranged from 2 to 4 on reach **-527** and averaged 3. The average statewide for was 1.08. While there were not macroinvertebrate impairments on reaches **-539** and **-540**, there were 1 and 2-4 TSS intolerant taxa respectively. The range of TSS tolerant individuals was 7.76 to 29.91% on reach **-527**. The average statewide for fish in class 5 is 23.72.

The range on reaches **-539** and **-540** was 25.49 to 37.96. Collector-filterers are negatively correlated with TSS. There was a range of 2.12 to 37.97 on **-527** with an average of 20.02. The collector-filterer percentage on **-539** was 25.53. The range of percentages on **-540** was 13.49 to 23.17%. The average number of collector-filterer percentage in class 6 streams statewide is 16.45%.

The herbivore percentages were zero at all stations on the Sunrise River, and there were no smallmouth bass collected. The lack of these species indicates that sediments are influencing the fish community. The number of TSS intolerant taxa was above average, and the TSS tolerant percentage was near average on **-527** and above on **-540**, and the collector-filterer percentages were also near average, indicating that sediments are not affecting the macroinvertebrate community. Due to the very small TSS dataset, and the possibility that smallmouth bass and herbivore percentages could be affected by others stressors TSS as a stressor is inconclusive at this time. Further data should be collected. Based on the elevated value taken after a rain event, it is important to collect data under different flow conditions.

Candidate cause: Physical connectivity

Fish migration is dependent on stream connectivity. The Sunrise River system has a number of structures controlling water levels with three major dams on the river (Figure 115). The dams on the Sunrise River includes those on Pool 1 (South Pool), Pool 3 (North Pool), and the Kost Dam.

Figure 115. Pool 1 Dam

Biotic response

The dams on the river seem to be having an impact on the presence of migratory fish. The upstream most sites have very few migratory species in comparison to the downstream stations since they are separated from connection to the St Croix River by three dams (Table 6). Connectivity is a stressor on the Sunrise River on all three AUIDs.

Table 6. Migratory fish on the Sunrise River

	96SC024	09SC006		09SC024		06SC009	09SC035		96SC065	06SC021	09SC001
Common name			Pool 1 Dam		Pool 3 Dam			Kost Dam			
Blackside darter									X	X	X
Brook trout									X		
Brown trout									X		X
Golden redhorse						X	X		X		X
Greater redhorse									X		
Iowa darter	X					X					
Shorthead redhorse						X	X		X	X	X
Silver lamprey									X		
Silver redhorse									X	X	X
Slenderhead darter									X	X	
Walleye						X			X	X	X
White sucker	X			X		X	X		X	X	X

AUID Summaries

The main stressors to the Sunrise River on **-527** and **-539** were DO and lack of habitat, and lack of habitat on **-540**. Phosphorus is also a stressor to **-527**. Connectivity is a stressor to all three sections of Sunrise River.

Bloomquist Creek

Unnamed ditch (Bloomquist Creek AUID 07030005-723) is a direct tributary to the Sunrise River (Figure 116). This tributary is a warmwater (2B) stream but is just downstream from a class 7 stream (AUID 07030005-722). It is impaired for ammonia, DO, and fish.

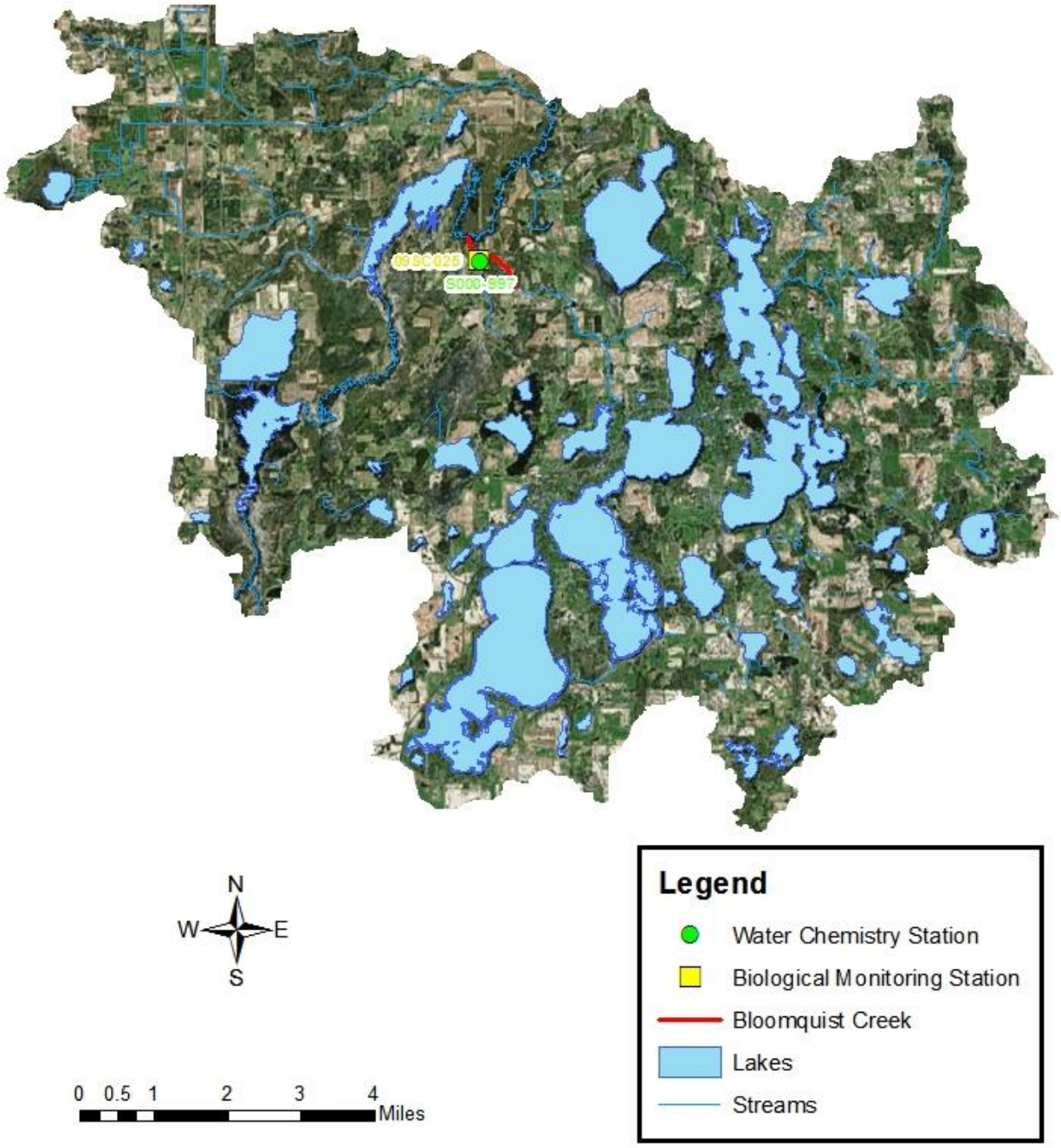

Figure 116. Map of Bloomquist Creek

Metric scores cumulatively made up the IBI score. The fish IBI scores were calculated using the northern streams (class 5). There are not individual standards for each metric, but using a target score provides a method of identifying problem metrics for a stream or individual monitoring site. The fish metrics have a uniform score of zero across all metrics to create a F-IBI score of 0 out of 100. One northern pike was collected and 18 central mudminnows were collected. Central mudminnows are very tolerant to human disturbance. Stations with less than 25 fish collected are indicative of unhealthy communities. Macroinvertebrates were not sampled at this station.

Candidate cause: Dissolved oxygen

This stream is impaired for low DO. DO collected from 2007 to 2010 show numerous values below the standard of 5 mg/L during the summer months, with values as low as 0.09 mg/L (Figure 117). Continuous data was collected during the fall of 2012. The data was collected late in the year when temperatures were lower and days were shorter, but DO still dropped below the standard.

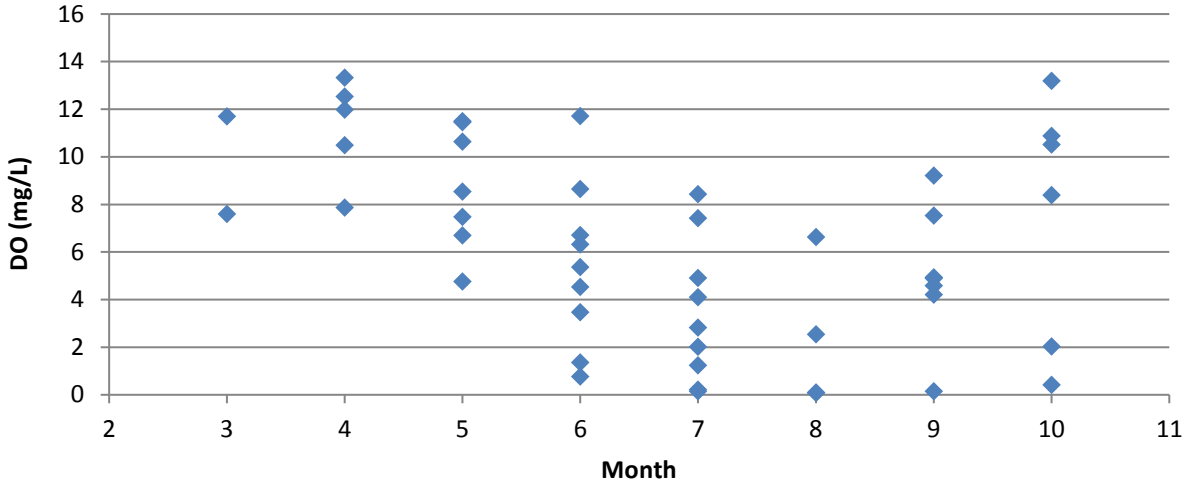

Figure 117. DO values at station S000-997

Biotic response

Low DO values correspond with increased tolerant species and decreased sensitive species. The average sensitive fish percentage statewide for fish class 5 is 22.69%. The percentage of sensitive individuals at station 09SC025 was 0%. The average statewide in classes 5 was 36.26%. The percentage of tolerant individuals was 94.74%. Species that mature at greater than three years of age are inversely correlated with low DO values. The percentage of mature age species was 0%. The average percentage statewide in classes 5 was 11.75%.

The early morning DO tolerance indicator values for fish were calculated for Bloomquist Creek (Figure 118). The creek is predominantly comprised of species in the first quartile of low early morning DO tolerance. This corresponds with the low DO concentrations observed and the DO impairment. Low DO is a stressor to the fish community on Bloomquist Creek.

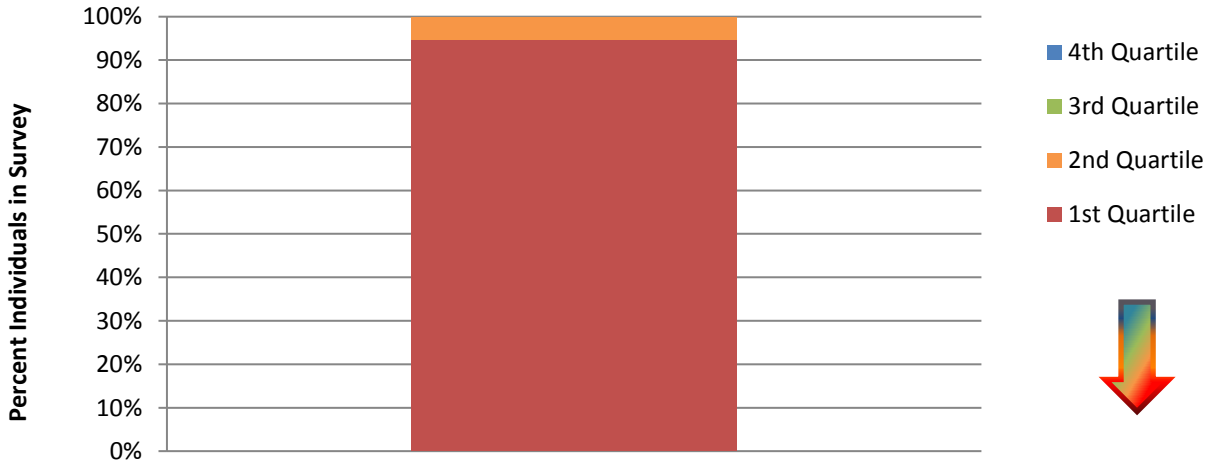

Figure 118. DO TIVs at station 09SC025

Candidate cause: Phosphorus

Phosphorus concentrations from 2008 to 2012 were analyzed by month (Figure 119). The highest phosphorus concentrations were collected in August. Values ranged from 0.116 to 1.63 mg/L, all over the nutrient standard of 0.100 mg/L. Chlorophyll-a and BOD values are proximate measurements of eutrophication and have more direct impacts on biology than phosphorus, however there is no current available data for these parameters.

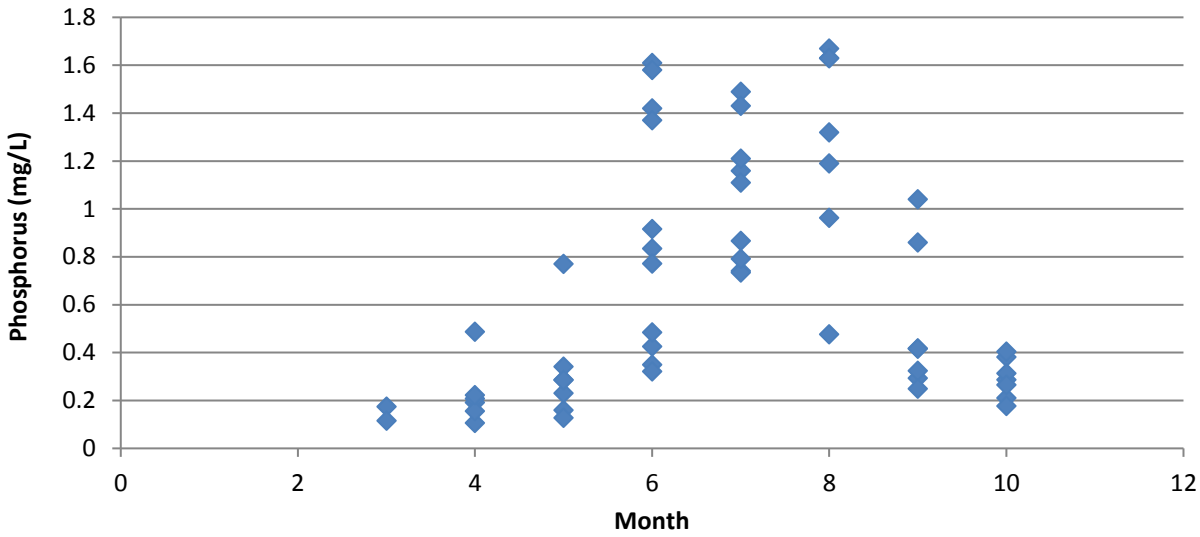

Figure 119. Phosphorus values on Bloomquist Creek

Biotic response

Increased phosphorus levels have an inverse relationship with sensitive individual fish percentages and an increase in tolerant percentages of fish. The average sensitive fish percentage statewide for fish class 5 is 22.69%. The percentage of sensitive individuals collected was 0%. The percentage of tolerant individuals was 94.74%. The average in the statewide for fish class 5 was 36.2%. Darter percentages are also inversely correlated with phosphorus. The percentage of darter individuals was 0%. The average in the statewide for fish classes 5 was 18.03%. Based on 100% of the phosphorus values being over the nutrient standard, the complete lack of sensitive or darter individuals and the high percentage of tolerant individuals, phosphorus is a stressor to Bloomquist Creek.

Candidate cause: Nitrate

Nitrate concentrations in recent years ranged from less than 0.07 to 0.53 mg/L (Figure 120). The highest values were collected during May. The 75% percentile of the North Central Hardwood Forests ecoregion norm is 0.26 mg/L.

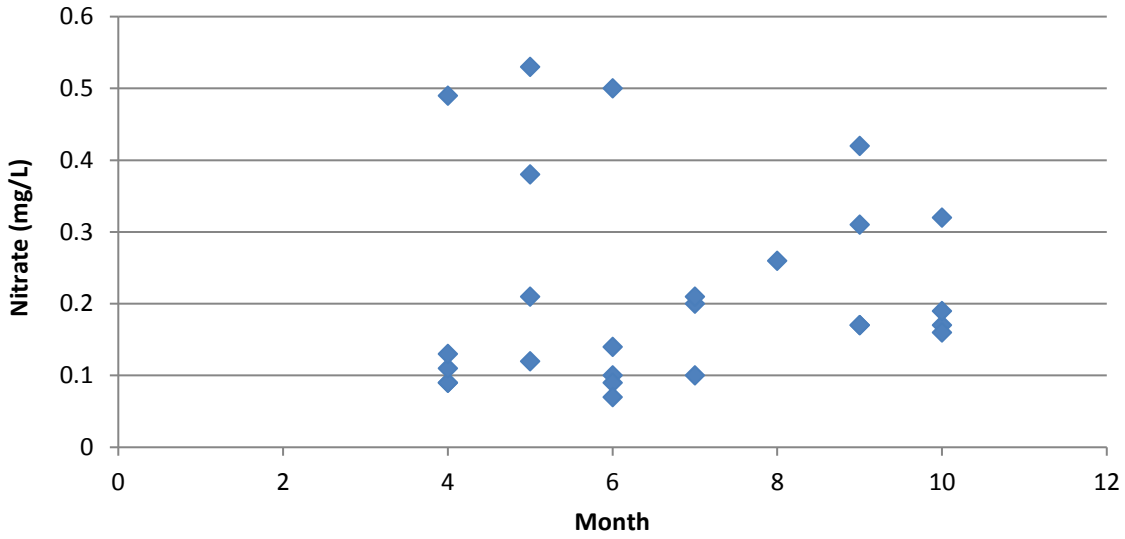

Figure 120. Nitrate values on Bloomquist Creek

Biotic response

Macroinvertebrates have stronger responses to nitrate, but macroinvertebrates were not sampled on this reach due to low flows. Negative correlations do exist between nitrate values and sensitive fish species and taxa richness. Two taxa were collected station 09SC025, of which zero were sensitive. The average taxa count statewide in class 5 streams is 16.4.

Fish tolerance indicator values were used to determine how tolerant the fish community was at each biological station. This can provide clues to the effects of a pollutant, by looking to see if the majority of the community is tolerant or intolerant to the pollutant. If the majority of the community is tolerant, this is an indication that the pollutant is affecting the biological community. Of the nineteen fish collected, all were located in the middle of the tolerant to intolerant range. While taxa richness and sensitive individual percentage were both low, these metrics are also influenced by other stressors. Based on the relatively low values of nitrate and without strong biological connections, nitrate as a stressor should be considered inconclusive at this time.

Candidate cause: Lack of habitat

The MSHA habitat score at station 09SC025 was 57.25, a fair score. Limiting factors include a lack of shade, no coarse substrates, and fair channel development. Dominant substrates were sand, silt, and detritus with excess sedimentation in pools recorded. The mean depth of fines was 21.48 cm. The channel was predominantly run habitat with only 1.25% of the channel riffle habitat.

Biotic response

Benthic insectivores, darter, sculpin, and sucker, riffle dwelling species, and simple lithophilic spawners require coarse substrate. Tolerant species are shown to increase with a lack of habitat availability. There was only one tolerant taxon. Lithophilic spawners reproduce by broadcasting eggs across gravel or coarse sand substrate, and without this substrate available this taxa would not be expected. The number of benthic insectivores was zero, simple lithophilic spawners, riffle dwelling species, and darter sculpin, and sucker species collected were all zero. These values are all very low and indicate that the fish community is being impacted by the abundance of fines and lack of coarse substrates at the site. Lack of habitat is a stressor.

Candidate cause: Suspended sediment

TSS values in from 2008 to 2010 at station S000-997 recent years were analyzed by month (Figure 121). The values ranged from 2 to 60 mg/L. The standard for TSS for the central region of the state is 30 mg/L. Two values were recorded over the standard (47 and 60 mg/L respectively). There were no transparency tube data below 25 cm, the value equivalent of 30 mg/L TSS.

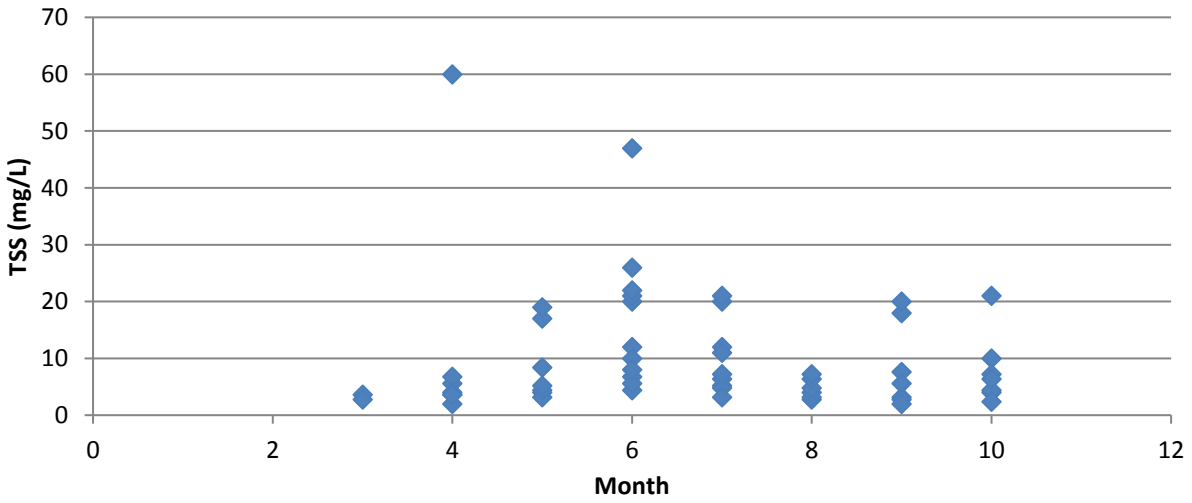

Figure 121. TSS values on Bloomquist Creek

Biotic response

Herbivore species of fish decrease as TSS values increase. The individual herbivore percentage at station 09SC025 was zero. The average statewide for fish class 5 is 1.97. The fish collected were in the middle of the TSS tolerance range. The two fish species collected were central mudminnows and northern pike. TSS can also affect both the number and growth of smallmouth bass. Smallmouth bass were not collected on Bloomquist Creek. While herbivore and smallmouth bass presence were both zero, the majority of TSS values were not elevated. The fish community could be affected by other stressors, TSS as a stressor is inconclusive at this time.

Candidate cause: Ammonia

Bloomquist Creek is impaired for unionized ammonia. The chronic standard for unionized ammonia is 0.04 mg/L. Values taken in 2008-2012 ranged from 0.00023 to 0.18 mg/L, with 20% of 59 values exceeding the standard at station S000-997 (09SC025). The highest values were in June and July.

Biotic response

Unionized ammonia is the most toxic form of ammonia to biota (U.S. EPA. 2012). As pH increases, so does the proportion of ammonia in its unionized form. Elevated pH levels have not been found on this stream. Increases in unionized ammonia correspond with decreases in fish, decreases in diversity, increases in tolerant species, and decreases in sensitive taxa. The fish community has very low diversity and a very highly tolerant population (94%). While these metrics are also affected by other stressors the increased percentage of ammonia values indicates ammonia is also contributing stress to Bloomquist Creek.

AUID summary

The main stressors were DO, phosphorus, lack of habitat, and ammonia.

Unnamed Creek

Unnamed creek (AUID 07030005-601) is a tributary to Big Carnelian Lake (Figure 122). This tributary is a warmwater (2B) stream. It is impaired for turbidity and fish.

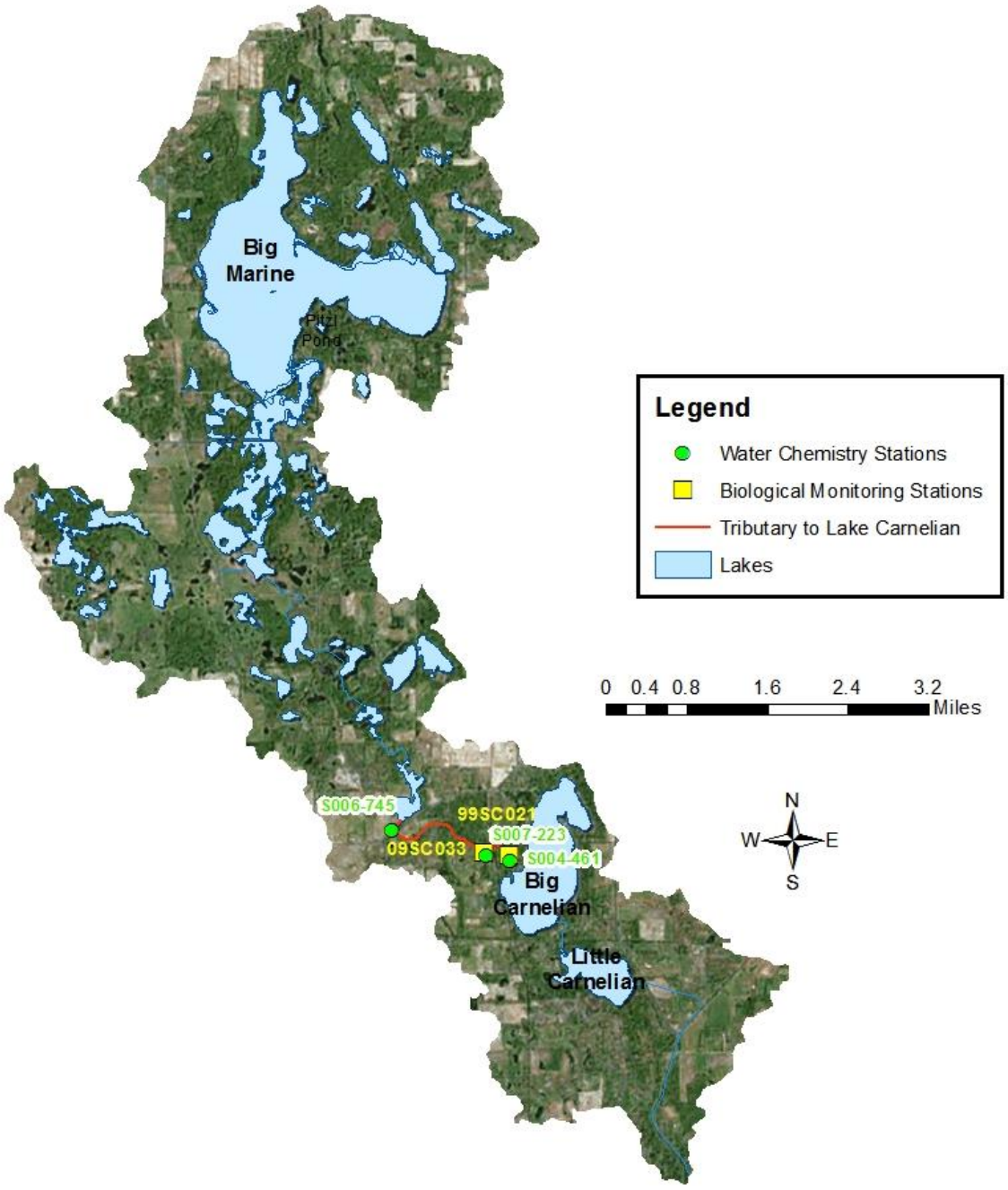

Figure 122. Unnamed Creek

Metric scores cumulatively made up the IBI score. The fish IBI scores were calculated using the low gradient classification (class 7). There are not individual standards for each metric, but using a target score provides a method of identifying problem metrics for a stream or individual monitoring site.

The fish metrics have a score of zero across five of the nine metrics (Figure 123) to create a F-IBI score of 22.2 out of 100 during a 2009 visit. The only metrics above the average needed to meet the threshold were pioneer and tolerant taxa, which both increase with human disturbance. A follow up visit in 2011 produced an IBI score of 0 with only 25 central mudminnows being collected. During the 2009 visit, 273 central mudminnows were collected along with 10 black bullheads, 1 bluegill, and 1 yellow bullhead. Central mudminnows are very tolerant to human disturbance. Macroinvertebrates were not sampled at this station.

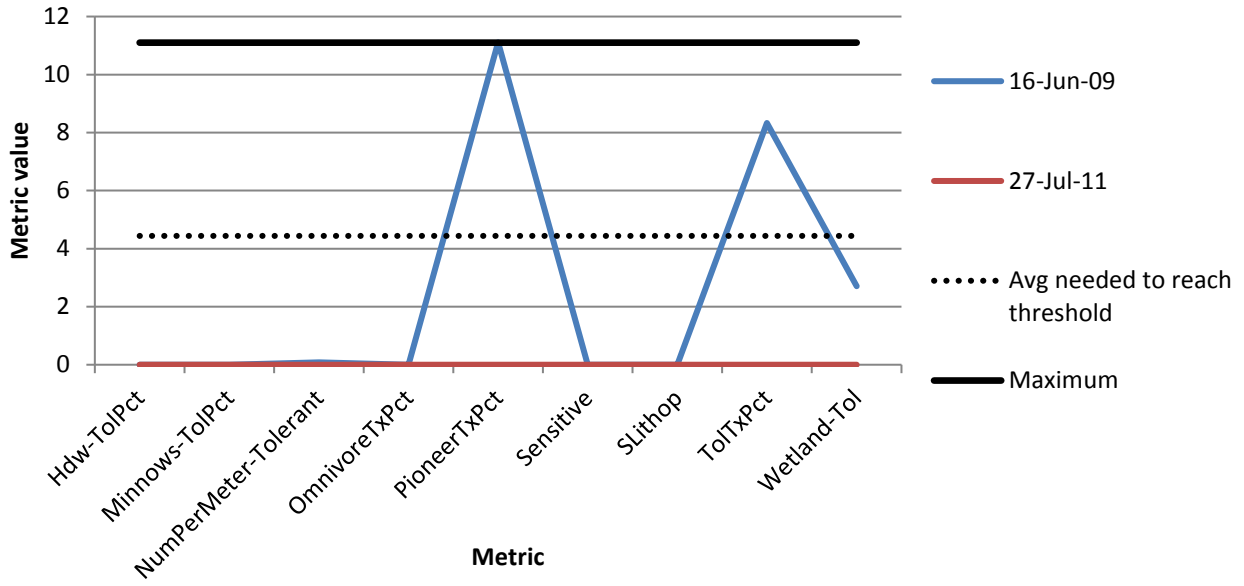

Figure 123. Metric scores of station 09SC033

Candidate cause: Dissolved oxygen

DO collected from 2007 to 2012 show a few values below the standard of 5 mg/L, particularly at station S006-745, with values as low as 1.72 mg/L (Figure 124). Continuous data was collected during the fall of 2012. The data was collected late in the year when temperatures were lower and days were shorter, DO values ranged between 7.26 and 10 mg/L and did not drop below the standard. However, the two values taken during biological monitoring were 5.07 and 15.17 mg/L indicating that DO flux is likely occurring and that continuous data might have been collected too late in the year.

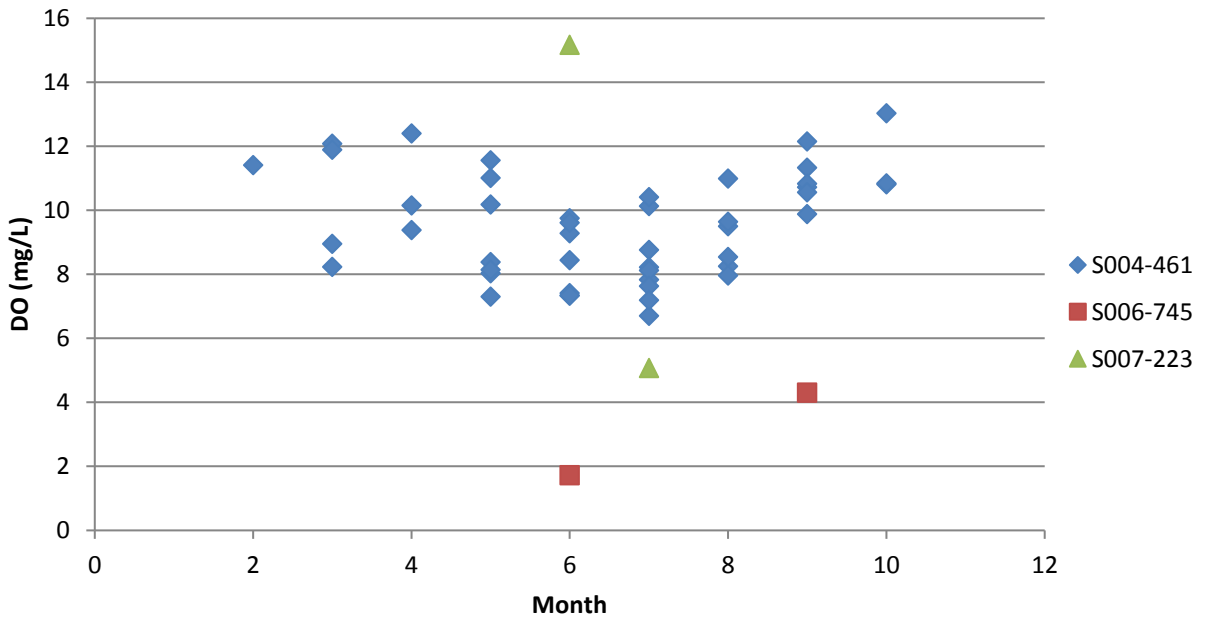

Figure 124. DO values

Biotic response

Low DO values correspond with increased tolerant species and decreased sensitive species. The average sensitive fish percentage statewide for fish class 7 is 9.48%. The percentage of sensitive individuals at station 09SC033 was zero percent during both visits. The percentage of tolerant individuals was 94.74% in 2009 and 100% in 2011. The average statewide in class 7 streams was 70.60%. Species that mature at greater than three years of age are inversely correlated with low DO values. The percentage of species that mature at greater than three years of age was zero percent at both visits. The average percentage statewide in class 7 streams was 4.45%.

The early morning DO tolerance indicator values for fish were calculated for Unnamed Creek (Figure 125). The creek is almost completely comprised of tolerant to low DO species in the first quartile. In comparison to downstream station 99SC021, where 66.67% of the fish community is in the first quartile, while the rest is in the second quartile. While there are only four DO values below the DO standard of 5 mg/L, there were nine values over 12 mg/L which is indicative of DO flux. The lack of sensitive species and species that mature at greater than three years of age, the very high percentage of tolerant species, and the high DO TIVs indicate that DO is a stressor. It would be helpful to take continuous data during the summer months to confirm that DO flux is occurring.

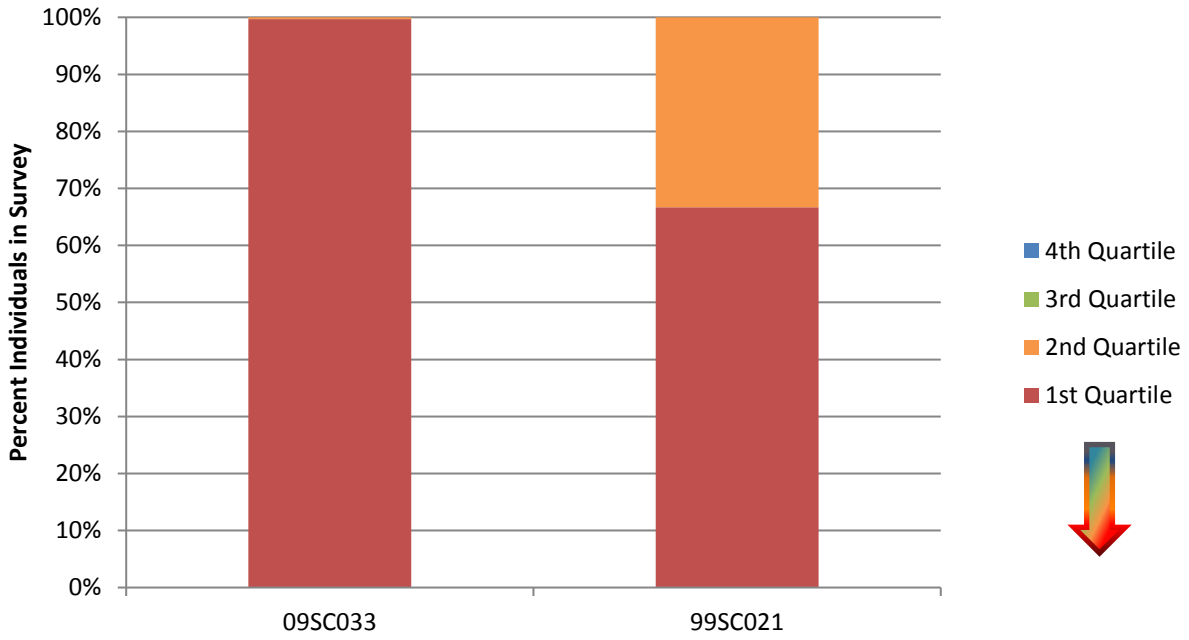

Figure 125. DO TIVs at station 09SC033

Candidate cause: Phosphorus

Phosphorus concentrations from 2007-2012 were analyzed by month (Figure 126). The highest phosphorus concentrations were collected in February and May. Values ranged from 0.01 to 1.01 mg/L, with over 42% of values over the nutrient standard of 0.100 mg/L. The highest value was collected in February. The average summer values over the years was 0.18 mg/L. Chlorophyll-a and BOD values are proximate measurements of eutrophication and have more direct impacts on biology than phosphorus, however there is only one BOD value of 1.8 mg/L.

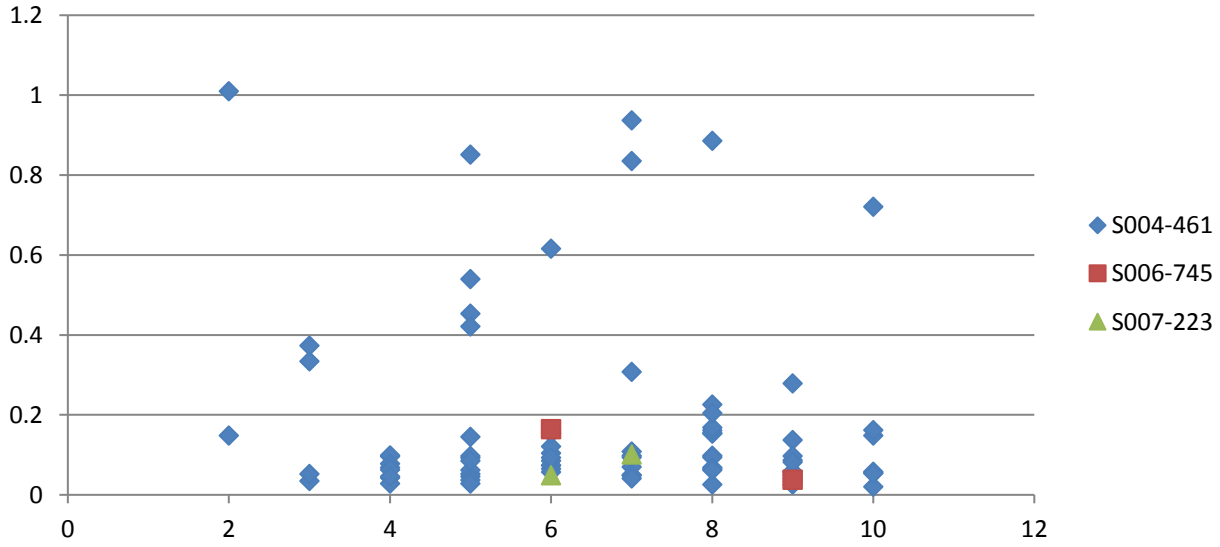

Figure 126. Phosphorus values on unnamed creek

Biotic response

Increased phosphorus levels have an inverse relationship with sensitive individual fish percentages and an increase in tolerant percentages of fish. The average sensitive fish percentage statewide for fish class 7 is 9.48%. The percentage of sensitive individuals at station 09SC033 was zero percent during both visits. The percentage of tolerant individuals was 94.74% in 2009 and 100% in 2011. The average statewide in class 7 streams was 70.60%. Darter percentages are also inversely correlated with phosphorus. The percentage of darter individuals was zero percent during both visits. The average in the statewide for fish class 7 was 4.52%. Based on a high proportion of the phosphorus samples exceeding the nutrient standard, the complete lack of sensitive or darter individuals and the high percentage of tolerant individuals, phosphorus is a stressor to unnamed creek. This correlates with the DO flux indicators that were observed.

Candidate cause: Nitrate

There is very limited nitrate information on this reach, with only six values available. Values range from less than 0.05 to 2.9 mg/L. The 75% percentile of the North Central Hardwood Forests ecoregion norm is 0.26 mg/L. The four values taken at the downstream station, S007-723 and S004-461 are all above the ecoregion norm while the one value taken upstream at station S006-745 is below the ecoregion norm.

Biotic response

Macroinvertebrates have stronger responses to nitrate, but macroinvertebrates were not sampled on this reach due to low flows. Negative correlations do exist between nitrate values and sensitive fish species and taxa richness. During the 2009 visit four taxa were collected at station 09SC033, of which zero were sensitive. During the 2011 visit one fish taxon was collected, which is not sensitive. The average taxa count statewide in class 7 streams is 8.3. Both visits had a TIV index score in the quadrant least tolerant to nitrate for all low gradient sites in the state. The two visits were comprised of fish that are not strongly tolerant or intolerant to nitrate. While taxa richness and sensitive individual percentage were both low, these metrics are also influenced by other stressors. Based on the relatively low values of nitrate and without strong biological connections, nitrate as a stressor should be considered inconclusive at this time.

Candidate cause: pH

Values of pH ranged from 6.5 to 8.6. The standard for pH in surface waters is a range of 6.5-9. Values over 8.5 and large daily pH fluctuations are tied to nutrient enrichment. Three values on the stream were recorded over 8.5. Continuous data collected during 2012 ranged from 7.24 to 8.09. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013). The pH fluctuations recorded ranged from 0.04 to 0.17.

Biotic response

EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (U.S. EPA. 2103). A bluegill was collected during the 2009 visit. Neither pH values nor pH flux were elevated, pH should not be considered as a stressor.

Candidate cause: Lack of habitat

Unnamed creek is a low gradient stream with MSHA scores of 53 and 62, both in the fair category. Scores during both visits were limited at both visits by a lack of riffles, no coarse substrates, lack of depth variability, and poor channel development. The entire reach was recorded as a run without any riffles or pools. While the stream had good sinuosity, excessive sedimentation was noted as a problem during a fish visit. Coarse substrate (gravel, cobble, boulder, etc.) was lacking, and is important for habitat and spawning. The only substrates found were fines; silt, sand, and detritus. The average depth of the sand and silt substrate was 13.04 cm. A high value of 32 cm of fines was recorded. Flow was also very slow at station 09SC033.

Biotic response

Benthic insectivores, darter, sculpin, and sucker, riffle dwelling species, and simple lithophilic spawners require coarse substrate. The number of benthic insectivores, simple lithophilic spawners, riffle dwelling species, and darter sculpin, and sucker species collected were all zero on both visits. Tolerant species are shown to increase with a lack of habitat availability. The tolerant taxa were two in 2009 and one in 2011. Lithophilic spawners reproduce by broadcasting eggs across gravel or coarse sand substrate, and without this substrate available this taxa would not be expected. The absence of these fish taxa indicate that the fish community is being impacted by the abundance of fines and lack of coarse substrates at the site, however it is hard to know what percentage of the sand is natural. A low gradient, slow stream naturally has some fine sediments. Lack of habitat is inconclusive as a stressor.

Candidate cause: Suspended sediment

TSS values from 2007 to 2012 were analyzed by month (Figure 127). The values ranged from 1 to 824 mg/L. The standard for TSS in the central region of the state is 30 mg/L. Values were very high with 31% over 30 mg/L, corresponding with the turbidity impairment. Values were highest in April and May.

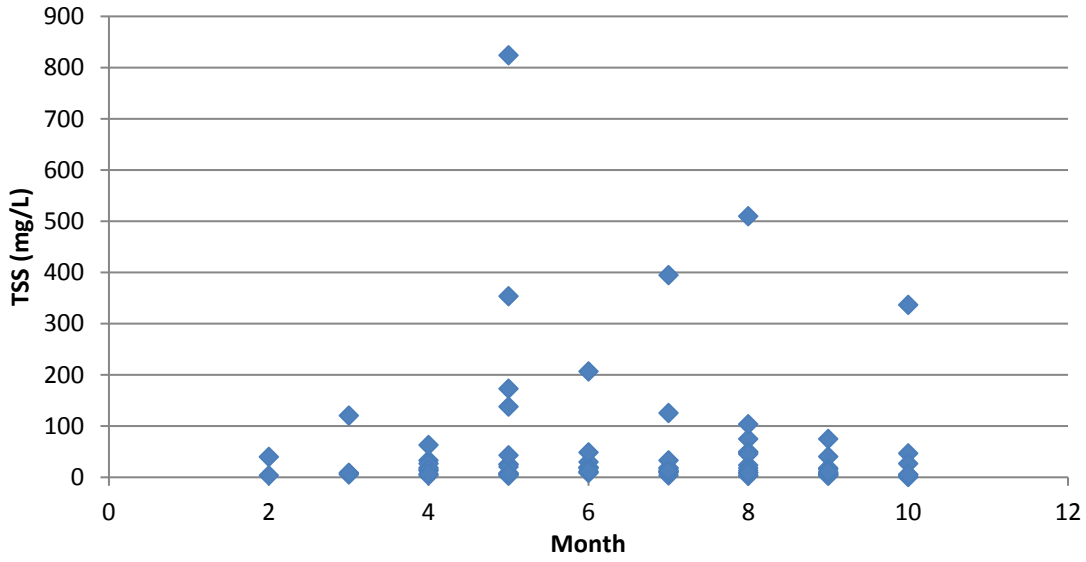

Figure 127. TSS values on Unnamed Creek

Biotic response

Herbivore species of fish decrease as TSS values increase. The individual herbivore percentages during both visits at station 09SC033 were zero. The average statewide for fish class 7 is 4.28%. TSS can also affect both the number and growth of smallmouth bass. Smallmouth bass were not collected on Unnamed Creek. Herbivore and smallmouth bass presence were both zero; in conjunction with 11 TSS values above 100 mg/L. The station was dominated by fish that were moderately tolerant of elevated TSS values. The fish collected were central mudminnows, yellow bullhead, black bullheads, and bluegill. TSS is inconclusive as a stressor to the fish community.

Candidate cause: Physical connectivity

Fish migration is dependent on stream connectivity. Large rocks were placed downstream of the culvert at Ozark Trail (Figure 128). During low flow these rocks will make fish migration from Big Carnelian Lake impossible. Small streams like Unnamed Creek depend on larger streams and lakes to restock their fish population through migration.

Figure 128. Large rocks preventing fish migration at Ozark Trail

Biotic response

The three visits available on Unnamed Creek are all upstream of the culvert and oversized rocks on Ozark Trail. A downstream sample is not available to compare the number of migratory fish species both up and downstream of the culvert. There is a lack of migratory fish upstream of Ozark Trail however (Table 7). Based on the lack of migratory fish and the visual evidence of the difficulty in fish moving upstream of the rock, physical connectivity is a stressor on this stream. Replacing the culvert and removing the rocks that are impacting fish migration would eliminate this stressor.

Table 7. Migratory fish on Unnamed Creek

	09SC033 (2009)	09SC033(2011)	99SC021	Culvert
Blackside darter				
Iowa darter				
Shorthead redhorse				
Walleye				
White sucker			X	

AUID summary

The main stressors were DO, phosphorus, and connectivity.

Summary and recommendations

Nine stream reaches are impaired for aquatic life due to their biological communities. A summary of the stressors to aquatic life in the Lower St. Croix Watershed are found in Table 8. Strength of evidence analysis is available by request. DO, fine sedimentation, and changes to stream connectivity are the main stressors to the aquatic communities and should be the primary focus of efforts in the watershed.

Agricultural land use in the watershed creates 86% of the sediment and 55% of the phosphorus nonpoint-source loads in the Sunrise River watershed (Almendinger et. al 2012). Phosphorus is an indirect stressor which effects both eutrophication and the resulting DO fluctuations. Eutrophication is of particular concern on the West Branch Sunrise River (07030005-529) where DO values have been elevated as high as 17.76 mg/L. Any restoration efforts would also have to address Martin Lake at the same time. Intercepting and removing nutrient inputs as much as possible should be pursued throughout the entire watershed.

Extreme low and high conditions, along with the large daily differences are stressful to the biological communities. DO values routinely fall below 5.0 mg/L and have been measured as low as 1.72 mg/L at the unnamed creek (07030005-601). The headwaters of Rush Creek (AUID 07030005-509), Goose Creek (0703000-510), and the Sunrise River (0703000-527) were all recorded having extended periods of low DO during continuous monitoring. These areas are low gradient and are heavily influenced by wetlands.

The aquatic communities would benefit from a decrease in fine sediment. As would be expected, suspended sediment concentrations are highest after rain events; protection from further fine sediment accumulation suspended no-till agricultural practices and grass waterways are recommended (Almendinger et. al 2012).

The dams and perched culverts on the Sunrise River, North Branch Sunrise River, Rush Creek, and the unnamed creek change flow regimes and the ability for organisms to migrate. Perched culverts cut off upstream migration and cut off stream flow during low flow periods. The dams on the Sunrise River also limit migration as well as changing habitat characteristics and flow regimes. More consistent flow would be beneficial to aquatic life, especially during periods of low precipitation. The culvert replacement on Keystone Avenue on the North Branch Sunrise River (07030005-501) should be pursued in other problem areas.

Table 8. Stressors to streams in the Lower St. Croix Watershed

Watershed	Watershed name	AUID	Biological impairment	Stressors						
				Ammonia	Dissolved oxygen	Nitrate	Total suspended solids (TSS)	Habitat	Connectivity/Altered hydrology	Phosphorus/ Eutrophication
Sunrise	Sunrise	527	Fish and macroinvertebrates		•		o	•	•	•
	Sunrise	539	Fish		•		o	•	•	o
	Sunrise	540	Fish		o		o	•	•	
North Branch	Sunrise	501	Fish		•			•	•	o
West Branch	Sunrise	529	Fish and macroinvertebrates		•		•	•		•
Tributaries to St. Croix River	Bloomquist Creek	723	Fish	•	•			•		•
	Unnamed Creek	610	Fish		•		o	o	•	•
	Rush Creek	509	Fish and macroinvertebrates		•		o	•	•	•
	Goose Creek	510	Fish		•	o	o	•	•	•

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

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Appendix A. Metric fact sheets applicable to the Lower St. Croix Watershed

Northern Streams –fish class 5 (Threshold 47, Confidence Interval 9)

Metric name	Category	Response	Metric_Desc_tech
DarterSculpSucTXPct	composition	positive	Relative abundance (%) of taxa that are darters, sculpins, and round-bodied suckers
DetNWQPct	trophic	negative	Relative abundance (%) of individuals that are detritivorous
General	trophic	negative	Taxa richness of generalist species
Insect-TolTXPct	trophic	positive	Relative abundance (%) of taxa that are insectivorous (excludes tolerant species)
IntolerantPct	tolerance	positive	Relative abundance (%) of individuals that are intolerant
MA>3-TolPct	reproductive	positive	Relative abundance (%) of individuals with a female mature age >=three (excludes tolerant taxa)
SensitiveTXPct	tolerance	positive	Relative abundance (%) of taxa that are sensitive
SLithopPct	reproductive	positive	Relative abundance (%) of individuals that are simple lithophilic spawners
SSpnTXPct	reproductive	negative	Relative abundance (%) of taxa that are serial spawners (multiple times per year)
Vtol	tolerance	negative	Number of taxa that are very tolerant
DomTwoPct	dominance	negative	Combined relative abundance of two most abundant taxa
FishDELTPct	tolerance	negative	Relative abundance (%) of individuals with Deformities, Eroded fins, Lesions, or Tumors

Low gradient –fish class 7 (Threshold 42, Confidence Interval 10)

Metric name	Category	Response	Metric_Desc_tech
Hdw-TolPct	habitat	positive	Relative abundance (%) of individuals that are headwater species (excludes tolerant species)
Minnows-TolPct	composition	positive	Relative abundance (%) of individuals that are Cyprinids (excludes tolerant species)
NumPerMeter-Tolerant	composition	positive	Number of individuals per meter of stream sampled (excludes tolerant species)
OmnivoreTXPct	trophic	negative	Relative abundance (%) of taxa that are omnivorous
PioneerTXPct	lifehistory	negative	Relative abundance (%) of taxa that are pioneers
Sensitive	tolerance	positive	Taxa richness of sensitive species
SLithop	reproductive	positive	Taxa richness of simple lithophilic spawning species
TolTXPct	tolerance	negative	Relative abundance (%) of taxa that are tolerant
Wetland-Tol	habitat	positive	Taxa richness of wetland species (excludes tolerant species)
FishDELTPct	tolerance	negative	Relative abundance (%) of individuals with Deformities, Eroded fins, Lesions, or Tumors

Northern Headwaters –fish class 6 (Threshold 42, Confidence Interval 16)

Metric name	Category	Response	Metric_Desc_tech
DarterSculp	richness	positive	Taxa richness of darter and sculpin species
Hdw-Tol	habitat	positive	Taxa richness of headwater species (excludes tolerant species)
InsectCypPct	trophic	positive	Relative abundance (%) of individuals that are insectivorous Cyprinids
Insect-TolTXPct	trophic	positive	Relative abundance (%) of taxa that are insectivorous (excludes tolerants)
Minnows-TolPct	composition	positive	Relative abundance (%) of individuals that are Cyprinids (excludes tolerant species)
NumPerMeter-Tolerant	composition	positive	Number of individuals per meter of stream sampled (excludes tolerant species)
PioneerTXPct	life history	negative	Relative abundance (%) of taxa that are pioneers
Sensitive	tolerance	positive	Taxa richness of sensitive species
SLithop	reproductive	positive	Taxa richness of simple lithophilic spawning species
TolTXPct	tolerance	negative	Relative abundance (%) of taxa that are tolerant
FishDELTPct	tolerance	negative	Relative abundance (%) of individuals with Deformities, Eroded fins, Lesions, or Tumors

Appendix B.1 – Values used to score evidence in the stressor identification process developed by EPA

Rank	Meaning	Caveat
+++	*Convincingly supports*	*but other possible factors*
++	*Strongly supports*	*but potential confounding factors*
+	*Some support*	*but association is not necessarily causal*
0	*Neither supports nor weakens*	*(ambiguous evidence)*
-	*Somewhat weakens support*	*but association does not necessarily reject as a cause*
--	*Strongly weakens*	*but exposure or mechanism possible missed*
---	*Convincingly weakens*	*but other possible factors*
R	*Refutes*	*findings refute the case unequivocally*
NE	*No evidence available*	
NA	*Evidence not applicable*	
D	*Evidence is diagnostic of cause*	

Appendix B.2 – Strength of evidence scores for various types of evidence used in SID analysis

Types of Evidence	Possible values, high to low
Evidence using data from case	
Spatial / temporal co-occurrence	+, 0, ---, R
Evidence of exposure, biological mechanism	++, +, 0, --, R
Causal pathway	++, +, 0, -, ---
Field evidence of stressor-response	++, +, 0, -, --
Field experiments / manipulation of exposure	+++, 0, ---, R
Laboratory analysis of site media	++, +, 0, -
Temporal sequence	+, 0, ---, R
Verified or tested predictions	+++, +, 0, -, ---, R
Symptoms	D, +, 0, ---, R
Evidence using data from other systems	
Mechanistically plausible cause	+, 0, --
Stressor-response relationships in other field studies	++, +, 0, -, --
Stressor-response relationships in other lab studies	++, +, 0, -, --
Stressor-response relationships in ecological models	+, 0, -
Manipulation of exposure experiments at other sites	+++, +, 0, --
Analogous stressors	++, +, -, --
Multiple lines of evidence	
Consistency of evidence	+++, +, 0, -, --
Explanatory power of evidence	++, 0, -