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MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER RESOURCES DIVISION
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STAFF REPORT

BIOLOGICAL SURVEYS OF AN UNNAMED TRIBUTARY TO PLATTE LAKE BENZIE COUNTY, MICHIGAN SEPTEMBER 2013

Watershed Information

The small unnamed tributary to Platte Lake is a cold, groundwater-fed stream that originates approximately two miles north and east of the lake. The watershed has an area of approximately 0.29 square miles and consists of two branches (west and east) that begin upstream of US-31, flow north, and merge upstream of Platte Road (Figure 1). Land use is dominated by forest (69%), followed by agriculture (18%), grass/pasture (10%), and water (3%) (Purdue University, 2013).

The watershed is located in the Manistee Subsection District Ecosystem (Albert, 1995). The Manistee District consists of sand dunes, sand lake plain, ground and end moraines, and outwash. The watershed originates in morainal bluffs and the soils consist of mostly well drained sand. All stations are located in the North Central Hardwood Forests (NCHF) ecoregion (Omernik and Gallant, 2010).

The unnamed tributary to Platte Lake was sampled in 2003 and 2008, and was visited in 2009 upstream of US-31. In 2003, staff from the Surface Water Assessment Section (SWAS) and Cadillac District Office conducted a chemical and biological survey of the tributary in response to a water quality complaint of strong odors and an unnatural orange color on the streambed. It was determined that the west branch of this groundwater-fed stream was impacted by contaminated groundwater venting from an illicit fruit waste disposal to a gravel pit located up-gradient of the stream (Wesener, 2011). The Other Indigenous Aquatic Life and Wildlife designated use is impaired in the west branch of the unnamed tributary due to poor macroinvertebrate scores (Goodwin et al., 2012). The fruit waste was at least partially removed from the gravel pit, but groundwater and soils were already contaminated. The east branch was not impacted by the contaminated venting groundwater and served as a control reach.

Poor macroinvertebrate conditions were found in 2003 and 2008 and degraded habitat conditions, consisting of orange bacterial slimes and accumulated organic matter that would not decompose, were found in 2003, 2008, and 2009. Macroinvertebrate surveys were not conducted in 2009 due to unchanged degraded habitat conditions since the 2008 survey. Additional reports (Walker, 2003 and Smith, 2003) were written as a result of the 2003 investigation and indicated elevated conductivity, total phosphorus metals concentrations, biochemical oxygen demand (BOD), and total organic carbon. Modeling indicates the dissolved oxygen (DO) concentrations did not meet water quality standards (WQS) further downstream in the unnamed tributary. Additional remediation has not occurred. Staff (Eric Chatterson and Janice Heuer) of the Michigan Department of Environmental Quality (MDEQ), Water Resources Division (WRD), indicate the facility has until January 2015 to remediate the site.

DO and BOD sampling were also conducted in 2013 to determine current attainment status of the WQS (Carpenter, 2013). Results indicated that DO was not meeting the 7 milligrams per liter (mg/l) minimum WQS in the west branch of the unnamed tributary to Platte Lake. In addition, data collected by Fishbeck, Thompson, Carr, and Huber in 2013 indicate that arsenic levels exceeded the chronic Human Cancer Valuefor non-drinking water (Fishbeck et al., 2013). Currently, a Total Maximum Daily Load is scheduled for 2016; however, it is not likely to be written until enforcement actions are complete and additional data are collected after remediation.

CHAPTER 1

BIOLOGICAL SURVEYS TO DETERMINE CURRENT STATUS AND CONDITION

Introduction

Biological and physical habitat conditions of an unnamed tributary to Platte Lake were assessed by SWAS staff on September 18 and 19, 2013. The primary objective was to assess the current status and condition of the water body and determine if Michigan WQS are being met.

The macroinvertebrate community and physical habitat was qualitatively assessed at each of three stations using the SWAS Procedure 51 (MDEQ, 1990; Creal et al., 1996) for wadeable streams (Table 1; Figure 1). Stations were sampled upstream of the road crossing. The macroinvertebrate communities were assessed and scored with metrics that rate water bodies from excellent (+5 to +9) to poor (-5 to -9). Scores from +4 to -4 are rated acceptable. Negative scores in the acceptable range are tending towards a poor rating, while positive scores in the acceptable range are tending towards an excellent rating. Habitat evaluations are based on 10 metrics, with a maximum total score of 200. A habitat score of >154 is characterized as having excellent habitat, 105-154 is good, 56-104 is marginal, and <56 is poor.

Table 1. Biological and Habitat results from the assessment conducted on September 18 and 19, 2013.

Station	Stream Name	Road Crossing	STORET #	County	TRS	Township	Latitude	Longitude	Habitat Evaluation		Macroinvertebrate Community		AUID#
									Rating	Score	Rating	Score	
P51a	East Branch Unnamed Tributary to	US-31	100252	Benzie	26N14WS07	Benzonia	44.664890	-86.051450	Good	145	Acceptable	3	040601040206-02
P51b	West Branch Unnamed Tributary to	Upstream of US-31	100192	Benzie	26N14WS07	Benzonia	42.663230	-86.054210	Good	135	Acceptable	-3	040601040206-01
P51c	Unnamed Tributary to Platte Lake	Platte Lake Rd.	100248	Benzie	26N14WS08	Benzonia	44.667830	-86.050070	Good	128	Acceptable	-2	040601040206-03

Habitat Scoring
Poor < 56 Marginal 56-104 Good 105-154 Excellent >154

Macroinvertebrate Scoring
Poor < -4 Acceptable -4 to +4 Excellent > +4

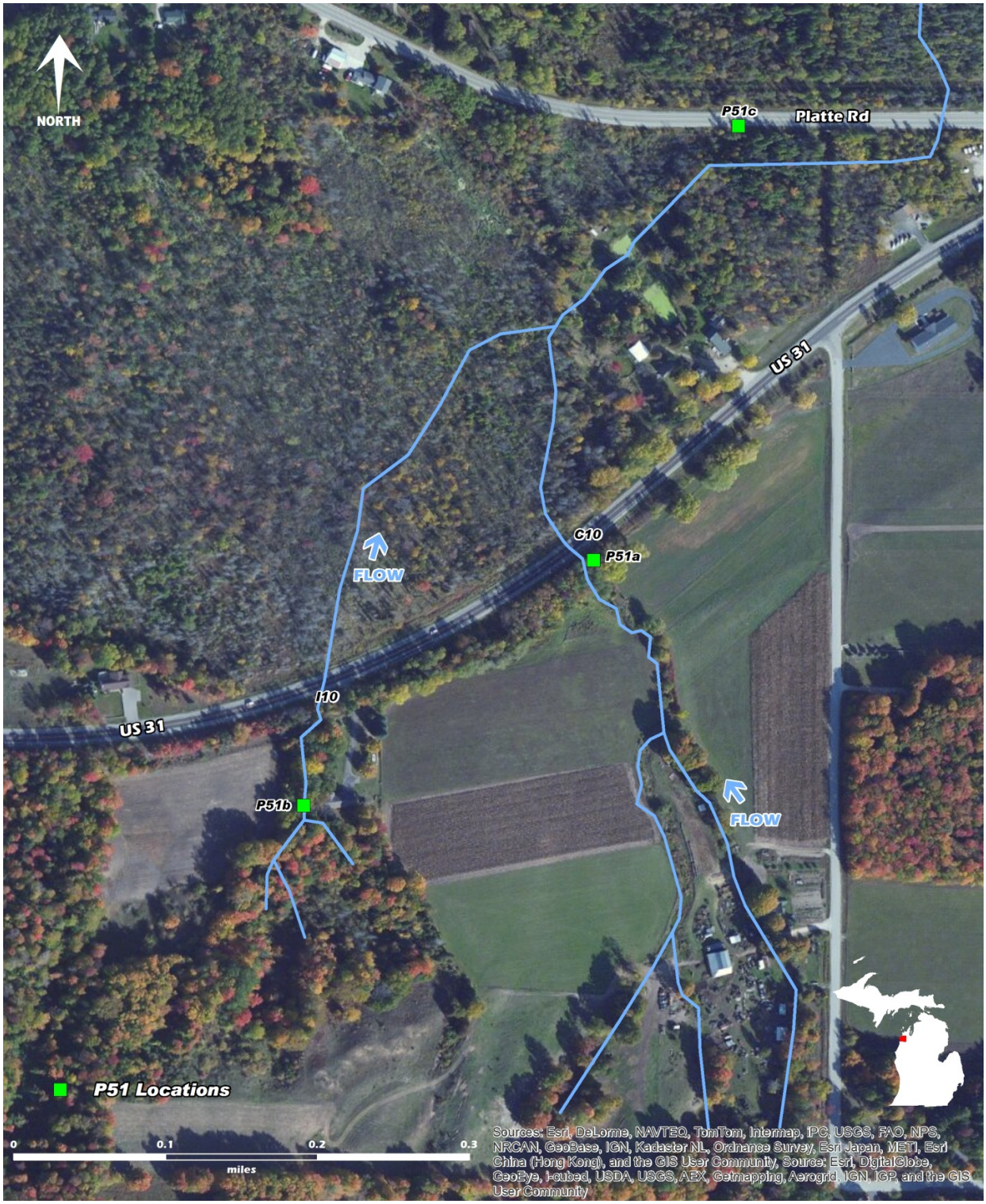

Figure 1. Locations of three biosurvey stations on the west branch, east branch, and confluence of the unnamed tributary to Platte Lake. September 18-19, 2013. Benzie County, Michigan. Stream flow direction for west branch downstream of US-31 is estimated through the wetland area.

2013 Sampling Results

The first station sampled (Station P51a; Figure 2) was on the unimpacted east branch of the unnamed tributary upstream of US-31. The riffle/run habitat was rated as good (145; slightly impaired; Table 2a). This branch is a small (mean width, 3 feet) coldwater, high gradient stream with substantial flow for the small size. Epifaunal substrate consisted of mostly gravel and sand. There was a small amount of undercut banks and woody debris and cobble. The substrate was fairly clean with some sand deposition evident (Figure 3). The stream is fairly straight, most likely due to historic (>50 years) drain work, and had an impacted riparian area due to agriculture land use. There were few large trees and a large amount of herbaceous vegetation and grasses. The macroinvertebrate community scored acceptable (3; Tables 2b and 2c). Four families of caddisfly, one family of mayfly, and one family of stonefly were found. Amphipods were the dominant taxa found at 42%.

Figure 2. Headwaters of the unimpacted east branch of an unnamed tributary to Platte Lake.

The impaired west branch of the unnamed tributary was sampled at one station approximately 300 feet upstream of US-31, behind a house (Station P51b). The riffle/run habitat was rated good (128; slightly impaired; Table 2a). The impaired west branch begins as groundwater seeps along the north facing slopes, approximately 300 feet upstream of this station. The groundwater seep areas are full of watercress and other herbaceous vegetation. The water is very cold and is a bright rusty orange color in areas (Figures 4 and 5). The stream is very narrow (1-3 feet on average) and has a steep gradient. The riparian area consists of many large trees and very little herbaceous vegetation due to the amount of shade provided by the mature trees. Many of the stream banks are raw, most likely due to the steep gradient of the stream. Tree roots help to hold the stream banks, but during high flows there is likely in-stream erosion. The stream did not appear flashy. The substrate at this station was a mix of gravel, cobble, undercut banks, and some woody debris. However, everything was covered with silt and an orange tinted biofilm and there was a fair amount of sediment deposition. The macroinvertebrate community scored acceptable (-2;

Figure 3. Bottom substrate of unimpacted east branch of an unnamed tributary to Platte Lake.

Tables 2b and 2c). This was an improvement from the 2008 score of -6 (poor) (Wesener, 2011; Tables 3a and 3b). Sensitive taxa were present in 2013 that were not present in 2008, including *Nemouridae* stoneflies and one *Limnephilidae* caddisfly. The inclusion of these two families improved the Procedure 51 score by two points. Fewer surface water breathers and one less isopod improved the score by two more points. *Chironomidae (86%)* still largely dominate the macroinvertebrate community, indicating that the stream is experiencing some environmental stress.

Figure 4. Groundwater seep in the impacted west branch of unnamed tributary to Platte Lake. Note orange/brown color of water and substrate.

Figure 5. Groundwater seep in the impacted west branch of unnamed tributary to Platte Lake.

In 2008 and 2009, the iron bacterial slime layer was much thicker than what was observed in 2013. However, the orange color of the ground water seeps (Figures 4 and 5) and the biofilm (Figure 6) indicate that conditions are still not what is normally observed in a small headwater stream in this watershed.

Figure 6. Orange biofilm found on much of the hard substrate in the impaired west branch of the unnamed tributary to Platte Lake. September 18-19, 2013.

Station P51c was sampled upstream of Platte Road. This station is downstream of where the west and east branches of the unnamed tributary combine in a wooded wetland area before a defined channel can be found upstream of Platte Lake Road. The glide/pool habitat was rated as good (135; slightly impaired; Table 2a). The stream gradient is very low and stream velocity is quite slow with a lot of sediment deposition due to the wetland nature of the stream. Epifaunal substrate is limited to a large amount of aquatic vegetation and large woody debris (LWD). The stream channel has been altered so that it flows along the side of the Platte Lake Road for a distance before crossing under it. Banks were stable and the riparian zone width was good except for the left bank where it flowed along the road. The macroinvertebrate community scored acceptable (-3; Tables 4b and 4c) This lower score was due to the lack of stonefly taxa and relatively low

density of caddisfly taxa (when compared to reference sites) and high density of isopods found; which was not surprising due to the wetland-like nature of the stream. It should be noted that 7 more caddisfly families and 41 more caddisfly individuals were found at this station than the impacted west branch. Indicating that it does have more sensitive taxa found than the lower score suggests.

Table 2a. Habitat evaluation for selected stations in an unnamed tributary to Platte Lake. Benzie County, September 18-19, 2013.

	East Branch Unnamed Tributary to Platte Lake @ US-31 RIFFLE/RUN	West Branch Unnamed Tributary to Platte Lake @ upstream US-31 RIFFLE/RUN	Unnamed Tributary to Platte Lake Platte Road GLIDE/POOL
	Station P51a	**Station P51b**	**Station P51c**
HABITAT METRIC			
Substrate and Instream Cover			
Epifaunal Substrate/ Available Cover (20)	15	10	8
Embeddedness (20)*	14	12	
Velocity/Depth Regime (20)*	10	10	
Pool Substrate Characterization (20)**			13
Pool Variability (20)**			10
Channel Morphology			
Sediment Deposition (20)	19	10	5
Flow Status - Maintenance Flow Volume (10)	9	8	10
Flow Status - Flashiness (10)	9	9	9
Channel Alteration (20)	15	17	13
Frequency of Riffles/Bends (20)*	18	18	
Channel Sinuosity (20)**			15
Riparian and Bank Structure			
Bank Stability (L) (10)	8	5	10
Bank Stability (R) (10)	8	5	10
Vegetative Protection (L) (10)	6	5	9
Vegetative Protection (R) (10)	6	5	9
Riparian Vegetative Zone Width (L) (10)	4	7	5
Riparian Vegetative Zone Width (R) (10)	4	7	9
TOTAL SCORE (200):	**145**	**128**	**135**
HABITAT RATING:	**GOOD (SLIGHTLY IMPAIRED)**	**GOOD (SLIGHTLY IMPAIRED)**	**GOOD (SLIGHTLY IMPAIRED)**
Date:	9/18/13	9/19/13	9/19/13
Weather:	Partly Cloudy	Partly Cloudy	Partly Cloudy
Air Temperature:	70 ºF	74 ºF	78ºF
Water Temperature:	50 ºF	52ºF	64 ºF
Average Stream Width:	3 Feet	3.3 Feet	9 Feet
Average Stream Depth:	0.25 Feet	0.16 Feet	0.5 Feet
Surface Velocity:	0.28 Ft./Sec.	1 Ft./Sec.	0.2 Ft./Sec.
Estimated Flow:	1.05 CFS	0.46992 CFS	1.89 CFS
Stream Modifications:	Canopy Removal	None	None
Nuisance Plants (Y/N):	N	N	N
STORET No.:	100188	100192	100248
Stream Name:	Unnamed Tributary to Platte Lake- East Branch	Unnamed Tributary to Platte Lake-West Branch	Unnamed Tributary to Platte Lake
Road Crossing/Location:	US-31	US-31	Platte Lake Road
County Code:	10	10	10
TRS:	26N14W07	26N14W07	26N14W07
Latitude (dd):	44.66214	44.66326	44.66783
Longitude (dd):	-86.04966	-86.05419	-86.05007
Ecoregion:	NCHF	NCHF	NCHF
Stream Type:	Coldwater	Coldwater	Coldwater
USGS Basin Code:	4060104	4060104	4060104

Table 2b. Qualitative macroinvertebrate community sampling results at selected stations in an unnamed tributary to Platte Lake. Benzie County, September 18-19, 2013.

	East Branch Unnamed Trib to Platte Lake US-31	West Branch Unnamed Trib to Platte Lake US-31	Unnamed Trib to Platte Lake @ upstream of Platte Rd.
	9/18/13	9/19/13	9/19/2013
TAXA	**STATION P51a**	**STATION P51b**	**STATION P51c**
ANNELIDA (segmented worms)			
Hirudinea (leeches)			1
Oligochaeta (worms)	11	2	
ARTHROPODA			
Crustacea			
Amphipoda (scuds)	132	9	8
Decapoda (crayfish)			1
Isopoda (sowbugs)	1	1	134
Arachnoidea			
Hydracarina		1	
Insecta			
Ephemeroptera (mayflies)			
Baetidae	142		
Leptophlebiidae			26
Odonata			
Anisoptera (dragonflies)			
Aeshnidae			4
Libellulidae			1
Zygoptera (damselflies)			
Calopterygidae			10
Coenagrionidae			2
Plecoptera (stoneflies)			
Nemouridae	20	11	
Hemiptera (true bugs)			
Gerridae	1	1	1
Notonectidae			1
Veliidae	1		1
Megaloptera			
Sialidae (alder flies)			1
Trichoptera (caddisflies)			
Glossosomatidae	1		
Hydropsychidae	1		14
Hydroptilidae			1
Lepidostomatidae	1		3
Limnephilidae		1	1
Molannidae	1		16
Philopotamidae			1
Phryganeidae			4
Polycentropodidae			2
Lepidoptera (moths)			
Pyralidae			1
Coleoptera (beetles)			
Dytiscidae (total)		1	
Haliplidae (adults)			1
Hydrophilidae (total)		1	
Dryopidae	2		
Elmidae	2		
Diptera (flies)			
Chironomidae	11	248	12

Table 2b. Qualitative macroinvertebrate community sampling results at selected stations in an unnamed tributary to Platte Lake. Benzie County, September 18-19, 2013.

	East Branch Unnamed Trib to Platte Lake US-31	**West Branch Unnamed Trib to Platte Lake US-31**	**Unnamed Trib to Platte Lake @ upstream of Platte Rd.**
	9/18/13	**9/19/13**	**9/19/2013**
TAXA	**STATION P51a**	**STATION P51b**	**STATION P51c**
Dixidae	9		
Ptychopteridae		1	
Simuliidae	2		1
Tabanidae		4	
Tipulidae	1	8	1
MOLLUSCA			
Gastropoda (snails)			
Physidae			2
Planorbidae	1	1	2
Pelecypoda (bivalves)			
Sphaeriidae (clams)			4
TOTAL INDIVIDUALS	340	290	257

Table 2c. Macroinvertebrate metric evaluation of selected stations in an unnamed tributary to Platte Lake. Benzie County, September 18-19, 2013.

	East Branch Unnamed Trib to Platte Lake @ US-31		**West Branch Unnamed Trib to Platte Lake @ US-31**		**Unnamed Trib to Platte Lake upstream of @ Platte Rd.**	
	9/18/13		**9/19/13**		**9/19/2013**	
	STATION P51a		**STATION P51b**		**STATION P51c**	
METRIC	Value	Score	Value	Score	Value	Score
TOTAL NUMBER OF TAXA	18	1	14	1	29	1
NUMBER OF MAYFLY TAXA	1	0	0	-1	1	-1
NUMBER OF CADDISFLY TAXA	4	1	1	0	8	1
NUMBER OF STONEFLY TAXA	1	0	1	0	0	-1
PERCENT MAYFLY COMPOSITION	41.76	1	0.00	-1	10.12	0
PERCENT CADDISFLY COMPOSTITION	1.18	-1	0.34	-1	16.34	-1
PERCENT DOMINANT TAXON	41.76	-1	85.52	-1	52.14	-1
PERCENT ISOPOD, SNAIL, LEECH	0.59	1	0.69	1	54.09	-1
PERCENT SURFACE AIR BREATHERS	0.59	1	1.38	0	1.56	0
TOTAL SCORE		3		-2		-3
MACROINVERTEBRATE COMMUNITY RATING	ACCEPTABLE		ACCEPTABLE		ACCEPTABLE	

Table 3a. Qualitative macroinvertebrate community sampling results for an unnamed tributary to Platte Lake. Benzie County, September 9, 2008.

	West Branch Unnamed Tributary to Platte Lake @ US-31
	9/9/2008
TAXA	
ANNELIDA (segmented worms)	
Oligochaeta (worms)	20
ARTHROPODA	
Crustacea	
Amphipoda (scuds)	4
Isopoda (sowbugs)	2
Insecta	
Hemiptera (true bugs)	
Gerridae	1
Veliidae	6
Megaloptera	
Sialidae (alder flies)	1
Coleoptera (beetles)	
Dytiscidae (total)	1
Diptera (flies)	
Ceratopogonidae	1
Chironomidae	245
Psychodidae	1
Tipulidae	8
MOLLUSCA	
Gastropoda (snails)	
Planorbidae	1
TOTAL INDIVIDUALS	291

Table 3b. Macroinvertebrate metric evaluation for an unnamed tributary to Platte Lake. Benzie County, September 9, 2008.

	West Branch Unnamed Tributary to Platte Lake @ US-31	
	9/9/2008	
METRIC	Value	Score
TOTAL NUMBER OF TAXA	12	1
NUMBER OF MAYFLY TAXA	0	-1
NUMBER OF CADDISFLY TAXA	0	-1
NUMBER OF STONEFLY TAXA	0	-1
PERCENT MAYFLY COMPOSITION	0.00	-1
PERCENT CADDISFLY COMPOSTITION	0.00	-1
PERCENT DOMINANT TAXON	84.19	-1
PERCENT ISOPOD, SNAIL, LEECH	1.03	0
PERCENT SURFACE AIR BREATHERS	2.75	-1
TOTAL SCORE		-6
MACROINVERTEBRATE COMMUNITY RATING	POOR	

CHAPTER 2

QUANTITATIVE BIOLOGICAL SURVEYS OF SELECTED STATIONS IN AN UNNAMED TRIBUTARY TO PLATTE LAKE

INTRODUCTION

Quantitative aquatic macroinvertebrate community, bacterial slime, and habitat assessments were conducted by SWAS staff on September 18 and 19, 2013, at 20 stations in the west and east branches of an unnamed tributary to Platte Lake, located just south of Honor, Michigan, Benzie County. All samples were taken upstream of US-31 and documented by GPS latitude and longitude coordinates (Table 4; Figure 7). The goal of the study was to compare the biological conditions of the west branch (impacted reach) to the biological conditions of the east branch (control reach).

STUDY OBJECTIVES

The objectives of the study are to:

1) Determine if and how the macroinvertebrate community in the impacted reach differs from that in the control reach.
2) Quantitatively assess the extent of the bacterial slime in the impacted reach and control reach.
3) Determine if habitat availability and flow conditions are similar in the impacted reach and control reach.

Table 4. Station locations of macroinvertebrate samples collected in the unnamed tributary to Platte Lake, Benzie County, Michigan. September 18-19, 2013. C = control (east branch); I = impacted (west branch).

Station #	Latitude	Longitude	Station #	Latitude	Longitude
C1	44.66227	-86.04971	I1	44.66311	-86.05403
C2	44.66257	-86.04993	I2	44.66276	-86.05456
C3	44.66351	-86.05061	I3	44.66253	-86.05457
C4	44.66379	-86.05078	I4	44.66265	-86.05435
C5	44.66402	-86.0508	I5	44.66286	-86.0545
C6	44.6643	-86.05096	I6	44.66313	-86.05421
C7	44.66446	-86.05111	I7	44.66338	-86.05419
C8	44.66475	-86.05145	I8	44.66369	-86.05424
C9	44.66489	-86.05145	I9	44.66381	-86.05405
C10	44.66496	-86.05152	I10	44.66388	-86.05408

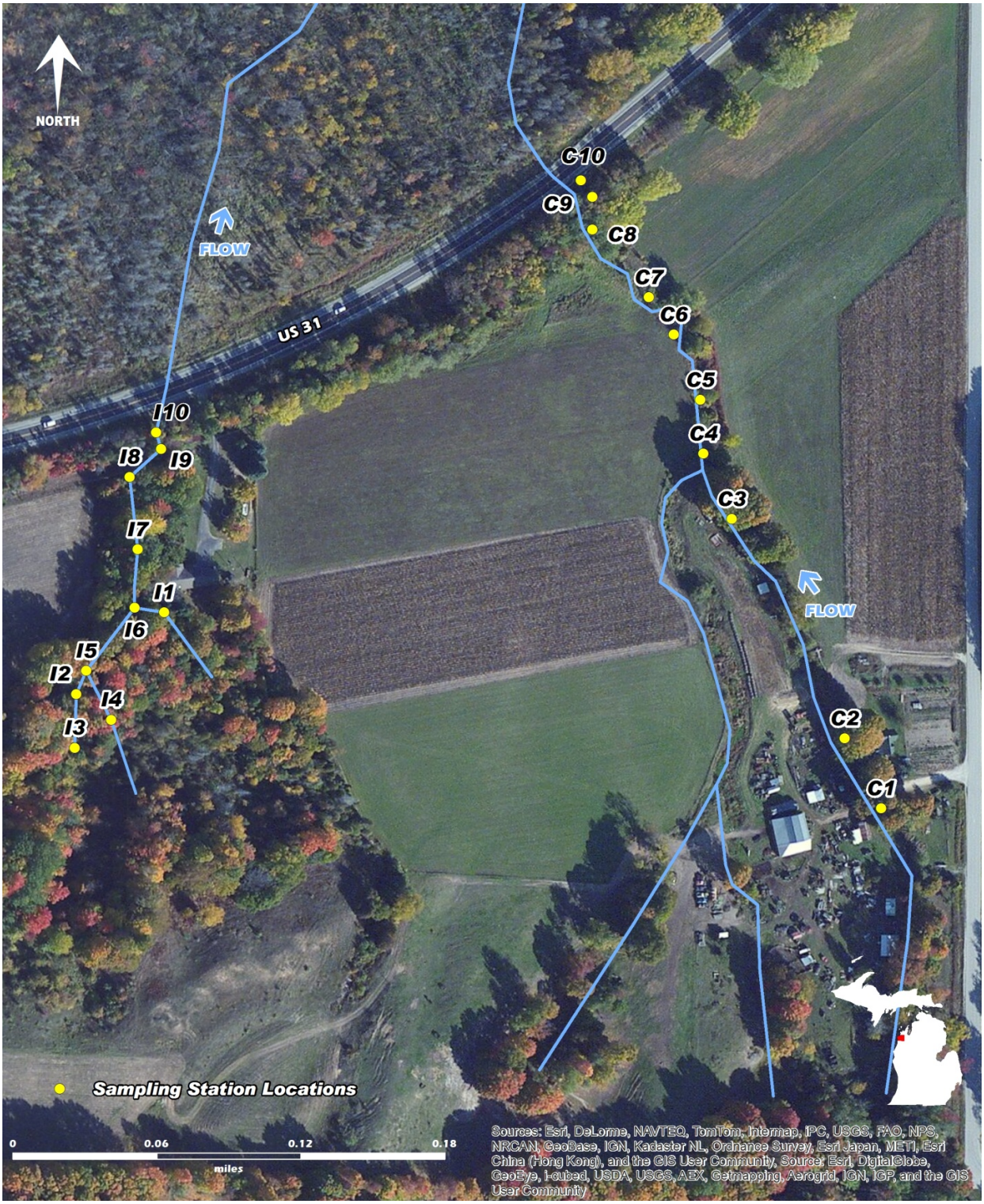

Figure 7. Surber sample stations surveyed September 18-19, 2013, in an unnamed tributary to Platte Lake. Benzie County, Michigan. C = control (east branch); I = impacted (west branch).

Field Sampling Methods and Analytical Procedures

A Quality Assurance Project Plan was developed and approved for this study prior to initiation, which includes specific sampling methodologies and analytical procedures (Lipsey, 2013).

Macroinvertebrates

The macroinvertebrate community was quantitatively assessed using a Surber sampling device (Fritz et al., 2006) to collect 10 macroinvertebrate samples from both the control and impacted reaches (20 samples total). The stream reach sampled was the entire impacted reach from upstream of US-31 to the initial groundwater seepage point (approximately 250 meters) and the entire control reach upstream of US-31 that was large enough to accommodate a Surber sampler (approximately 250 meters). Methodology included repeatedly (3 times) disturbing the streambed area inside the sampler's frame for 10 seconds to a depth of 10 centimeters (cm) (4 inches), dislodging and transferring invertebrates to a sample bottle, and preserving the contents with 70% ethanol. A label was placed inside the sample and affixed outside the sample container. Samples were transferred to the lab and one tablespoon of rose bengal solution was added until the samples could be identified.

In the lab, all individuals in a sample were identified to Family for 19 of the 20 samples. In 1 sample from the impacted west branch, there was an exceptionally large number of individuals collected (>9,200); therefore, 3 randomly selected cells were chosen from a grid and all individuals were identified to Family (n= 365). Estimates of total numbers in the sample were then made using proportions found in those 3 cells.

Metrics to describe and compare the macroinvertebrate communities between the impacted and control reaches were calculated. The metrics included:

- Number of Taxa
- The number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa
- Percentage of EPT taxa
- Density of EPT taxa
- Percent Dominance
- Percentage of Chironomidae
- Shannon Diversity Index
- Shannon Equitability Index
- Hilsenhoff Biotic Index
- Notations of particularly sensitive taxa found

In addition, one woody debris piece was sampled near each Surber sampler in an attempt to ensure all possible taxa were documented. The length and diameter of the woody debris piece was measured and scrubbed for one minute into a clean Surber sampler net. The woody debris samples collected at each station were composited for each reach (control versus impacted) for a total of two samples. All taxa were identified to Family in the lab.

Habitat and Stream Discharge

General observations of each reach including riparian area descriptions were recorded. General physical characteristics were measured and recorded at each site. Water velocity was measured using a velocity meter because sufficient depth was available. Wetted widths and

mean stream depth were measured at up to three cross sections and averaged. These measures along with stream velocity were used to calculate discharge.

Habitat type (riffle/run/glide/pool) was recorded. Riffle areas were targeted for sampling since a majority of sensitive taxa favor hard and well-oxygenated substrates. The dominant substrates and particle size distribution were noted for each station using the following size classifications (Thomson et al., 2005):

- % Boulder (>256 mm; larger than basketball)
- % Cobble (64-256 mm; apple-basketball)
- % Pebble (16-64 mm; dime to apple)
- % Gravel (2-16 mm; smaller than dime)
- % Sand/Silt (<2 mm)

Bacterial Slimes/Periphyton

A semi-quantitative assessment of the benthic algal/bacterial slime biomass was made using the United States Environmental Protection Agency (USEPA) Field-Based Rapid Periphyton Survey (Barbour et al., 1999). This method uses a viewing bucket marked with 50 dots on a transparent grid, and was altered slightly to accommodate the fact that bacterial slimes (not algae) was the community of concern. The original method includes characterizing both the macroalgae biomass and microalgae cover. A transect was established by placing the transparent grid of 50 dots over the habitat where the Surber sample was to be placed. If the stream was wide enough, up to three transects (grids) were measured, but this only occurred once in the east branch (control) and twice in the west branch (impacted) reach.

The numbers of dots were counted and recorded where macroalgae was present, and the maximum length of macroalgae was recorded. The number of dots were counted and recorded where substrate of suitable size was present for microalgal or bacterial accumulation (>2 cm in diameter). The number of dots covered by microalgae or bacterial slime and the thickness was also recorded.

Using this data, the following measurements were calculated:

- Number of dots evaluated per station
- Average percentage of the total suitable habitat (>2 cm in diameter) covered by the macroalgae, microalgae, or bacterial slimes
- Maximum length of macroalgae

The goal of these measurements was to get a more quantitative description of the types and quantity of biofilm and iron bacterial slimes observed on the substrate of both the impacted and control reaches.

Multiparameter Water Quality Probe Sampling

Monitoring of water temperature, DO, pH, and specific conductance was performed using a handheld multiparameter sonde at all stations using methods noted in the standard operating procedure for continuous monitoring of water quality (Carpenter, 2014; draft).

Water Chemistry

Water quality samples were collected in August 2013 and analyzed for ammonia and BOD (Carpenter, 2013).

RESULTS

Macroinvertebrates

Results of the Surber sampling are presented in Appendix 1. Summary statistics are presented in Table 5. Family metrics used to describe and compare the macroinvertebrate communities between the impacted and control reaches were calculated. The metrics included those in Table 5.

Table 5. Macroinvertebrate metrics used to compare macroinvertebrate communities between the impacted and control reaches of the unnamed tributary to Platte Lake.

Metric	Control (East Branch)	Impacted (West Branch)
Total Taxa	18	14
# EPT taxa	5	3
% EPT taxa	27%	21%
# EPT individuals	46	57
% EPT Individuals	12%	<1%
% Dominance	33%	90%
% Chironomidae	33%	90%
Shannon Diversity Index (higher number = more diversity)	1.88	0.47
Shannon Equitability Index (closer to one, the more even the species distribution and the less dominance)	0.64	0.15
Hilsenhoff Family Biotic Index (larger the number the more organic pollution)	5.79 (fairly poor; substantial organic pollution likely)	7.72 (very poor; severe organic pollution likely)
Very Sensitive taxa found (Pollution Tolerance Value =0)	Glossosomatidae and Rhyacophilidae	none

Diversity and Dominance

Healthy, stable, biological communities will have high species diversity. For the unnamed tributary to Platte Lake, the total number of taxa found across all sites was higher in the east branch (control reach) than the west branch (impacted reach; Table 5). The percent contribution of the dominant taxon is the ratio of the number of individuals in the most abundant taxon to the total number of organisms collected. A community dominated by relatively few taxa or by a large number of one or two taxa indicates an environmental stress (MDEQ, 1990). Percent Dominance and percentage of *Chironomidae* calculations for each station in each reach are shown graphically in Figures 8 and 9. *Chironomids*, which as a group tend to be more tolerant of environmental perturbation, dominated (90%) the macroinvertebrate community in

the impacted reach. They also were the dominant taxa found in the control reach, but at a much lower percentage (33%).

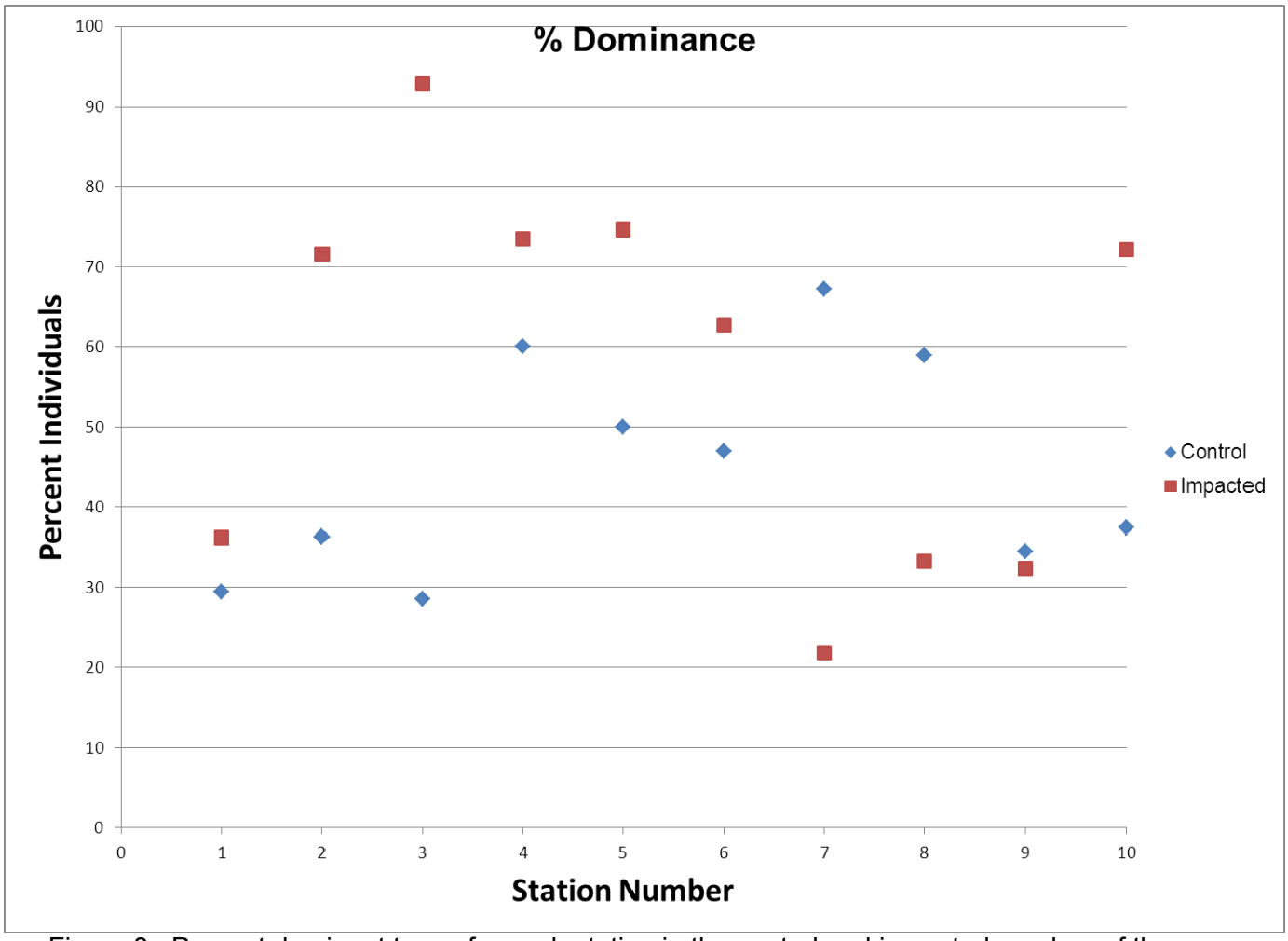

Figure 8. Percent dominant taxon for each station in the control and impacted reaches of the unnamed tributary to Platte Lake.

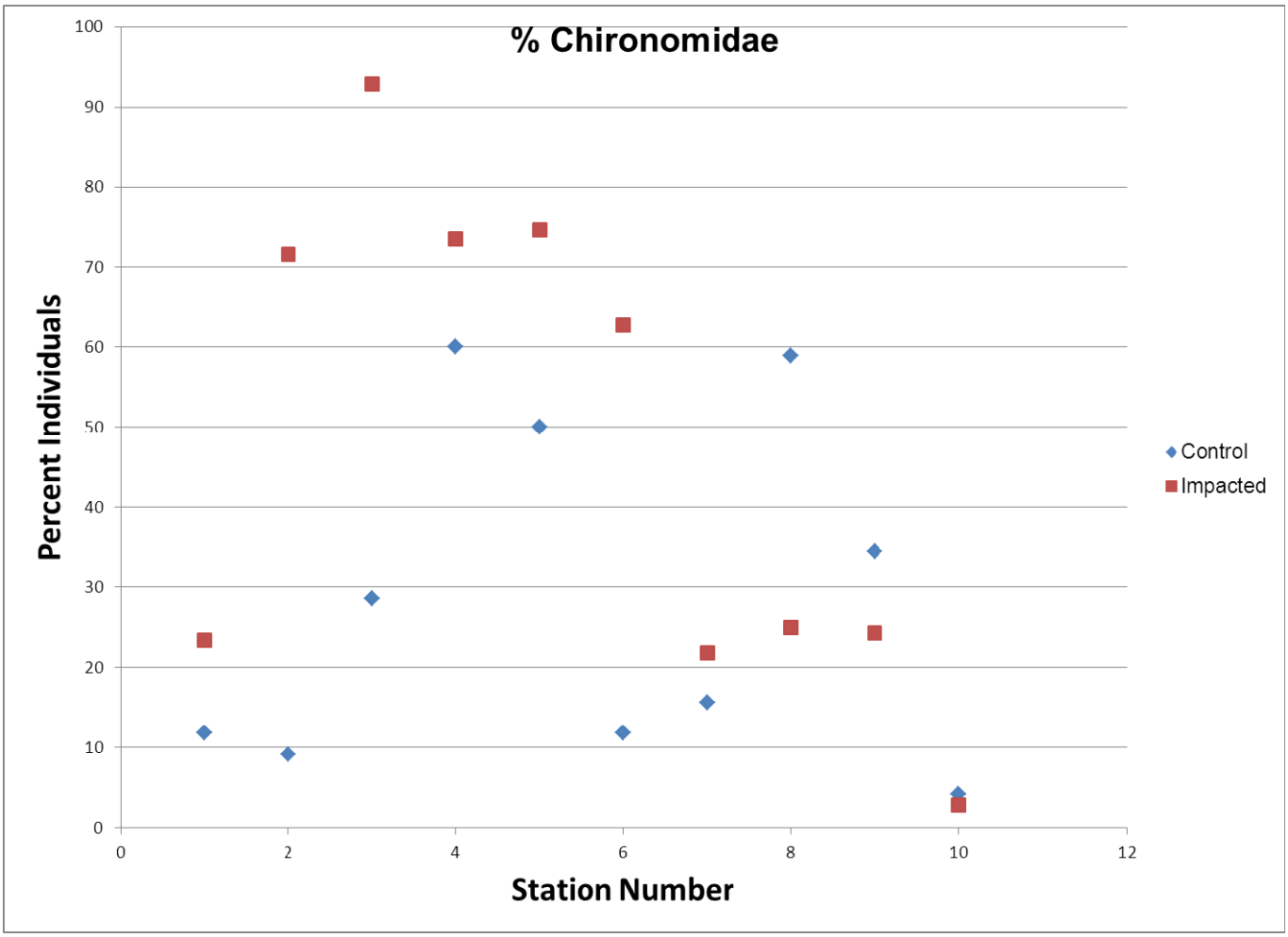

Figure 9. Percent *Chironomidae* found at each station in the control and impacted reaches of the unnamed tributary to Platte Lake.

The number of Families found that belong to Orders that are generally more sensitive to environmental perturbation (EPT) were similar between the impacted and control reaches (3 vs 5); however, 2 extremely sensitive Families of *Trichoptera* were only found in the control reach (*Glossosomatidae* and R*hyacophilidae*). The density of EPT taxa in the impacted stream (<1%) was much less than that of the control reach (12%; Table 5). The percentage of EPT taxa found at each station in each reach is graphically presented in Figure 10. Note that no EPT individuals were found at the sites that are closest to the area where the contaminated groundwater is venting (Stations I2, I3, I4, and I5). Station I1 is on a smaller side tributary to the impaired reach and had substrate that did not have the orange tinted biofilm noted at most of the other impaired stations. Stations I7-I10 are downstream of this side tributary.

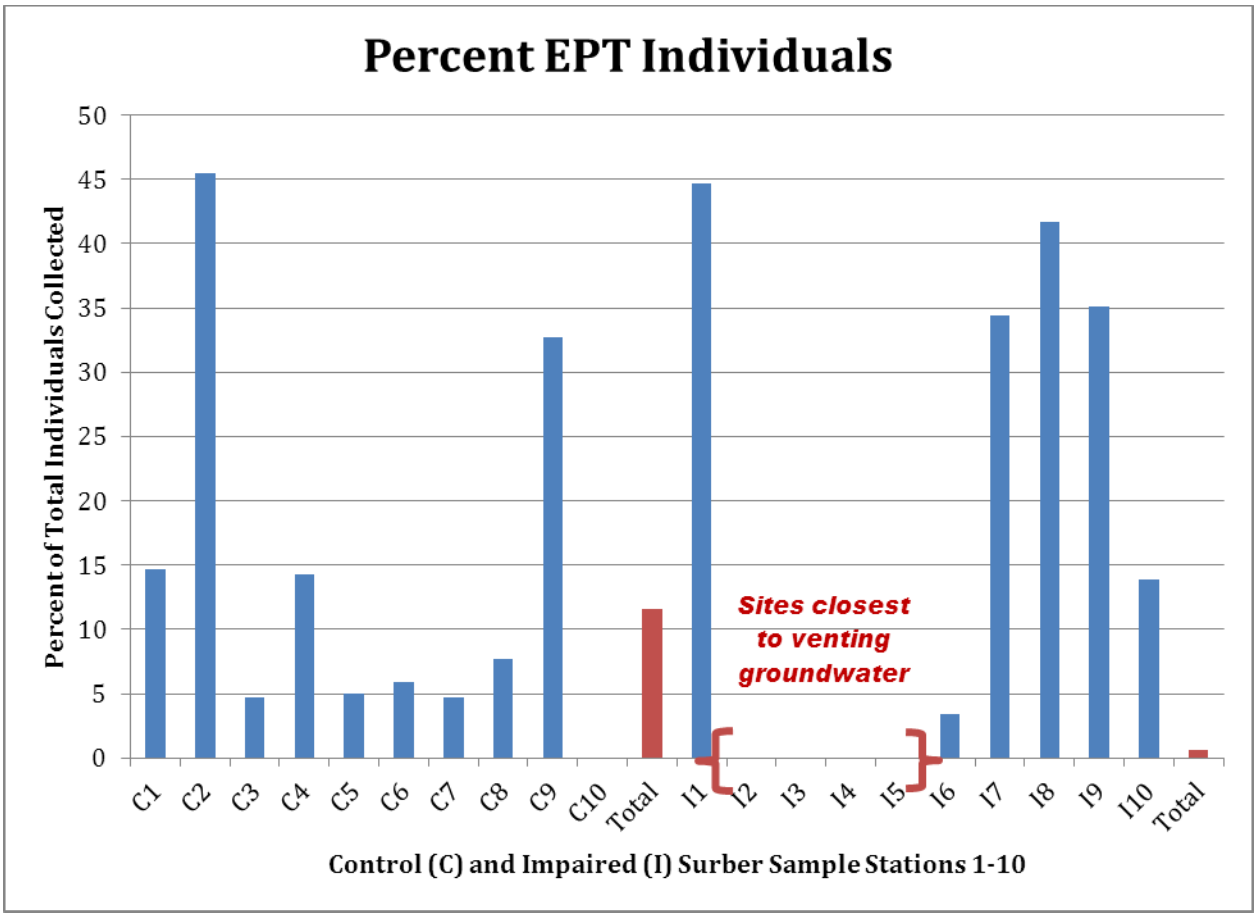

Figure 10. Percentage of EPT found at each station in the control (C) and impacted (I) reaches of the unnamed tributary to Platte Lake.

Shannon Diversity and Equitability Index

A Shannon Diversity Index (H), which is another index commonly used to characterize species diversity in a community, was calculated for the impacted and control reaches. It is calculated as follows:

$$H = - \sum (n_i/N \times \ln (n_i/N))$$

ni = number individuals of a taxa
N= total number individuals across all taxa

The higher the Shannon Diversity Index the higher the diversity of the sample. The Shannon Diversity Index was more than three times higher in the control reach compared to the impacted reach (Table 5). The Shannon Diversity Index was calculated for each individual Surber sample and for the woody debris samples as well. Impacted stations 2, 3, 4, and 5 had the lowest H scores and are closest to the area where the contaminated groundwater vents to the surface water (Figure 11).

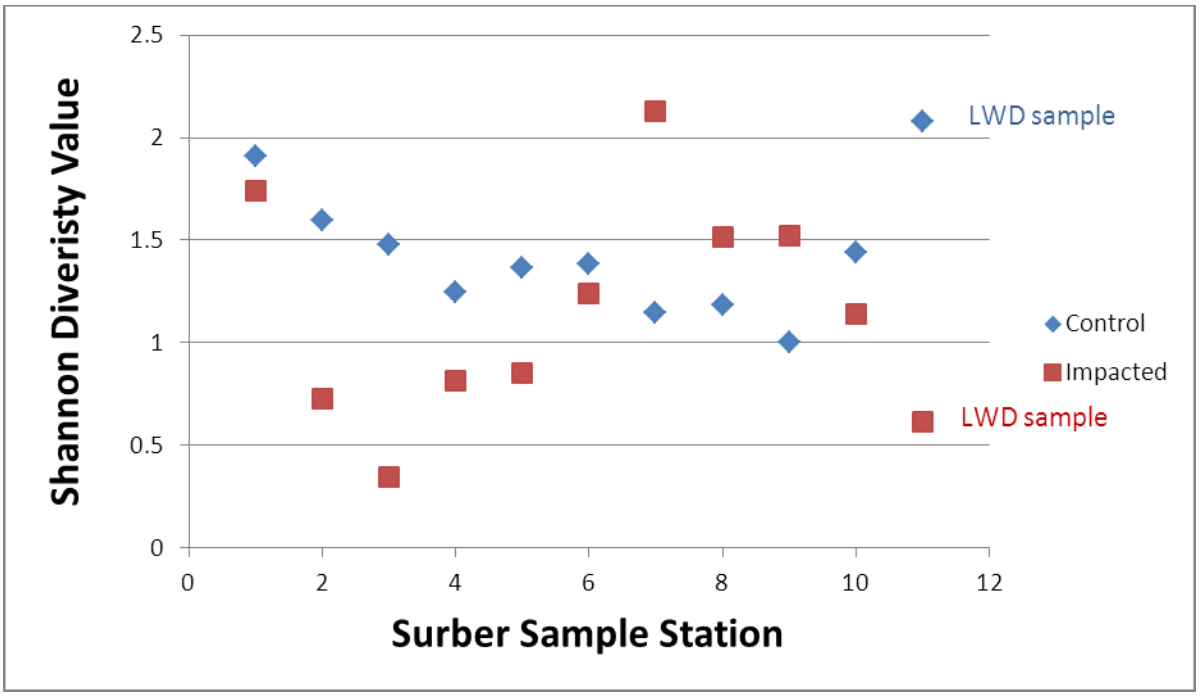

Figure 11. Shannon diversity values for each station sampled for macroinvertebrates in the impacted and control reaches of the unnamed tributary to Platte Lake.

Shannon Equitability Index (E_H) is a measure of the evenness. Evenness in this case is a measure of how close in numbers each taxa in a reach are. A higher score indicates less variation in numbers between the taxa. For example, if 90% of the individuals found are from only 3 families of the total 12 families found, then the evenness score would not be as high as if those individuals were spread more evenly among the 12 families found. The E_H was calculated as follows:

$E_H = H/\ln S$

S = Total number of taxa at a site (family was used)

The Shannon Equitability Index found in the control reach was more than three times the impacted reach (Table 5). The Shannon Equitability Index was calculated for each individual Surber and woody debris samples (Figure 12). Overall E_H was lower for the impacted reach stations; however, there was a lot of variability.

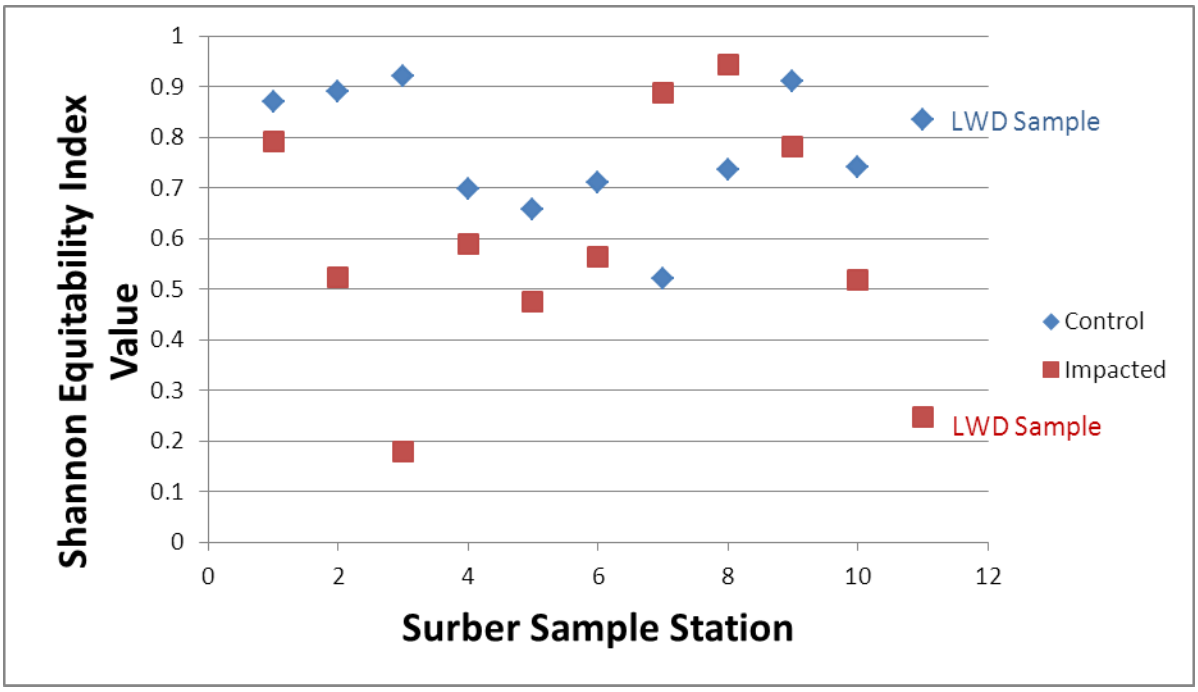

Figure 12. Shannon equitability index values for each station sampled for macroinvertebrates in the impacted and control reaches of the unnamed tributary to Platte Lake.

Hilsenhoff Family Biotic Index

A family level biotic index (FBI; Hilsenhoff, 1988) was calculated for the impacted and control reaches (all 10 sites from each reach combined).

$$FBI = (\sum (n_i * a_i))/N$$

n_i = number of individuals in each taxa
a_i = pollution tolerance levels (Appendix 1)
N = total number of organisms in a sample

Using the FBI scores, water quality is rated as follows:

(0.00-3.75) excellent
(3.76-4.25) very good
(4.26-5.00) good
(5.01-5.75) fair
(5.76-6.50) fairly poor
(6.51-7.25) poor
(7.26-10.00) very poor

Results indicate that the control reach with a score of 5.71 was in fairly poor condition where the impacted reach with a score of 7.72 was in very poor condition (Table 5).

Large Woody Debris Samples

Results of the LWD samples are similar to the Surber sampler results (Table 6). The number of taxa found in each reach was equal. The two very sensitive *Trichoptera* families found in the Surber samples in the control reach, but not the impaired reach, were again found only in the control reach. The percentage of EPT individuals in the LWD samples was three times as high as the Surber samples, but there was a 63 percentage point decrease in EPT numbers between the control and impaired reaches. The Hilsenhoff Family Biotic Index suggested a slightly higher quality rating of the control stream (good for LWD compared with fair from the Surber samples) but the impacted reach score remained very poor. One additional dipteran family was documented in the LWD impacted reach sample that was not found in the Surber samples. Psychodidae is a dipteran family with some species that can often live in low DO environments.

Table 6. Macroinvertebrate metrics used to compare macroinvertebrate communities between LWD samples collected from the impacted and control reaches of the unnamed tributary to Platte Lake.

Metric	LWD Control (East Branch)	LWD Impacted (West Branch)
Total Taxa	12	12
# EPT taxa	5	3
% EPT taxa	42%	25%
Total Individuals	219	517
# EPT individuals	79	16
% EPT Individuals	36%	3%
% Dominance	24%	88%
% Chironomidae	18%	88%
Shannon Diversity Index (higher number = more diversity)	2.07	0.62
Hilsenhoff Family Biotic Index (larger the number the more organic pollution)	4.40 (good; some organic pollution probable)	7.68 (very poor; severe organic pollution likely)
Shannon Equitability Index (closer to one, the more even the species distribution and the less dominance)	0.84	0.25
Very Sensitive taxa found (Pollution Tolerance Value =0)	Glossosomatidae and Rhyacophilidae	none
Additional Taxa Found (not in Surber samples for this reach)	none	Psychodidae

Habitat and Stream Discharge

Qualitative Procedure 51 habitat observations are described in Chapter 1. General habitat data recorded as a part of this study are available in Appendix 2. As can be seen in the aerial photo in Figure 7, the east branch (control reach) has a much narrower riparian area. In addition, although mature trees are present, they are not at the density found in the west branch (impacted reach). This is due to more agricultural land use in the immediate watershed surrounding the east branch.

Sampled habitats consisted almost entirely of riffle areas, which was the prevalent habitat type in both streams. One Surber sample was collected from a more depositional area (glides) in the control reach because a riffle was not available at that specific location. The dominant substrates and particle size distribution were noted for each station (Table 7 and Appendix 2).

Table 7. Qualitative assessment of dominant substrates observed in the control and impacted reaches of the unnamed tributary to Platte Lake.

	East Branch (Control)	West Branch (Impacted)
Particle Size	**Mean**	**Mean**
%Boulder	0	0
%Cobble	1	7
%Pebble	17	17
%Gravel	54	36
%Sand/Silt	29	39

The control reach was dominated by gravel, followed by sand or silt, and then pebbles. The impacted reach was dominated by nearly equal amounts of gravel and sand. The impacted branch did have a noticeably higher amount of sand/silt and cobble.

In addition to cobble, pebbles, and gravel available for macroinvertebrate colonization, other available epifaunal substrate was also qualitatively observed at each Surber sampling station (Table 8). Additional epifaunal substrate in the impacted reach was primarily limited to LWD. In the control reach, additional epifaunal substrate was primarily limited to overhanging vegetation and undercut banks.

Table 8. Overall availability of epifaunal substrate available for colonization in addition to the cobble, pebbles, and gravel noted in Table 8 for stations in control and impacted reaches of the unnamed tributary to Platte Lake.

Additional Epifuanal Substrate Type	**East Branch (Control)**	**West Branch (Impacted)**
Undercut Banks	sparse to moderate	almost none
Overhanging Veg	extensive	very sparse
LWD	Sparse	Moderate
Aquatic Macrophytes	Sparse	almost none
Rootwads	almost none	sparse to moderate

The mean stream width, depth, and velocity was slightly higher in the control reach, resulting in a higher mean discharge number (Table 9).

Table 9. Average width, depth, velocity measurements, and calculated discharge of control and impacted reaches of the unnamed tributary to Platte Lake.

	East Branch (Control)	West Branch (Impacted)
	Mean	Mean
Width (ft)	3.98	3.01
Depth (ft)	0.23	0.12
Velocity (ft)	1.38	0.71
Discharge (ft^3/s)	1.05	0.32

Bacterial Slimes/Periphyton

A semi-quantitative assessment of the benthic algal/bacterial slime community using the USEPA Field-Based Rapid Periphyton Survey (Barbour et al., 1999) usually resulted in 1 transect (50 dots on the grid) being surveyed at each Surber sample station. At 3 stations, the stream was wide enough to allow for 3 transects (150 dots; Appendix 3).

The numbers of dots that occur over macroalgae were counted and the maximum length of macroalgae was recorded. Macroalgae was only observed in the control reach. This was most likely due to the lack of sunlight that could penetrate the dense canopy cover in the impacted reach.

In the control reach, no bacterial slimes were observed and very few dots (3%) were observed over microalgae. In the impaired reach, bacterial slime biofilm and microalgae was discerned by the color of the biofilm. If it was more of a green color, it was recorded as microalgae; if it was an orange color we assumed it to be the iron bacteria causing the change in color. In the impaired reach 36% of the dots surveyed were observed over microalgae and 26% of the dots surveyed were over the bacterial slime biofilm. It should be noted that 100% of the bacterial slime biofilm was observed at impacted Stations 2, 3, 4, and 5, which were the stations closest to the contaminated venting groundwater (Table 10).

Table 10. Semi-quantitative assessment of the benthic algal/bacterial slime biomass in two reaches of the unnamed tributary to Platte Lake.

	East Branch (Control)	West Branch (Impacted)
Total dots evaluated in Surber sample area	600	700
Total dots over macroalgae	79	0
% dots over macroalgae	**13**	**0**
Total dots suitable (>2 cm diameter) for microalgae or bacterial slime	447	465
Total dots over thin layer microalgae	13	166
% dots with over thin microalgae layer	**3**	**36**
Total Dots over Bacterial Slime	0	119
% dots over bacterial slime	**0**	**26**
Total Dots over bacterial slime at Stations 2, 3, 4, and 5	0	26
% Dots over bacterial slime at Stations 2, 3, 4, and 5	**0**	**100**

Photographs of the observed bacterial slimes and biofilm were taken from the impacted stream. This can be compared to the cleaner substrate and no orange color observed in the control stream (Figures A-E: West [impacted] and East [control] branches of the Unnamed Tributary to Platte Lake, Benzie County, Michigan).

Figure A. Orange colored biofilm found on much of the hard substrates in the impacted reach.

Figure B. Substrate found in the control reach; note the lack of orange color.

Figure C. Area where orange colored groundwater vents to the surface in the impacted reach.

Figure D. Close-up photo of substrate in impacted stream.

Figure E. Station 2 in impacted stream.

Multiparameter Water Quality Probe Sampling

Measurement of water temperature, DO, pH, and specific conductance was performed using a handheld multiparameter sonde at all stations using methods noted in the standard operating procedure for continuous monitoring of water quality (Carpenter, 2014; draft).

Multiparameter water quality probe sampling data can be found in Appendix 2. Average stream temperature and DO (mg/L) were relatively the same for each branch. The conductivity was slightly higher and the pH and percent DO was slightly lower on average in the impacted reach (Table 11).

Table 11. Multiparameter probe and stream discharge calculations for two reaches of the unnamed tributary to Platte Lake.

	East Branch (Control)	West Branch (Impacted)
	Mean	Mean
Temperature*C	10.24	10.85
Conductivity	439	506
DO%	85.8	84.4
DO mg/L	9.57	9.26
pH	8.19	7.90
Width	1.21	0.92
Depth	6.90	3.79
Velocity	1.38	0.71
Discharge	9.76	2.94

DO monitoring results in August 2013 indicated that the coldwater 7 milligrams per liter (mg/l) minimum WQS was not being met in the west branch. The east branch did not have any violations of the WQS (Carpenter, 2013).

Water Chemistry

Water quality samples collected from the impaired reach for ammonia and BOD indicated that ammonia was detected and levels increased upstream towards the venting groundwater area; however, no WQS violations were found. BOD was below detection levels in both reaches (Carpenter, 2013).

CONCLUSION

Several metrics (Table 5) indicate a difference in the macroinvertebrate community between the impacted and control reaches of the unnamed tributary to Platte Lake. Total taxa, number of EPT taxa, and density of EPT taxa are all higher in the control reach, indicating that the conditions are more favorable for sensitive taxa. Although more individuals were found in the impacted reach, 90% of these individuals belong to a highly tolerant group (*Chironomidae*), and likely indicate there is an environmental stress in that system.

The Shannon Diversity and Equitability Indexes, which are measures of taxa diversity, are three times as high for the control reach when compared to the impacted reach. The Hilsenhoff Family Biotic Index, which is a measure of the likely amount of organic pollution in a system, rates the control reach as being in fairly poor condition compared to very poor in the impaired

reach. Finally, two families of caddisfly (*Glossomatidae* and *Rhyacophilidae*) that have very low (0) pollution tolerance values were found only in the control reach.

No bacterial slimes have been observed or documented in the control reach. This is one reason it was chosen as a control reach back in 2003 when the contamination in the west branch was first discovered. The semi-quantitative survey in this study indicates that bacterial slimes were found on 0% of the substrates that would be suitable for colonization. In the impacted reach, bacterial slimes covered 26% of the suitable substrate. All of the sampling locations that had bacterial slimes were located at the stations that are directly downstream of where the contaminated groundwater is venting, indicating the venting groundwater is causing the favorable conditions for unnatural iron bacteria growth.

Habitat availability for macroinvertebrate colonization was fairly similar between the impacted and control reaches. The streams had similar widths (one foot difference) and both were less than three inches deep on average. Both streams had a good amount of stable substrate (gravel, pebbles, and cobble). The impacted reach had more cobble substrate available, which can be favorable substrate for EPT taxa colonization. The control reach did have overhanging vegetation and undercut banks that were not available in the impacted reach; however, the impacted reach had much more woody debris available, which is excellent habitat for EPT taxa. Both streams had a fairly high gradient, which allowed for good stream velocity.

The slight differences in habitat between the control and impacted reaches cannot explain the differences in biological communities. The orange colored venting groundwater is certainly causing the growths of iron bacteria in the impacted reach. The amount of bacterial slimes has decreased since 2003 and even since 2009; however, a large amount of the impacted stream substrate has an orange biofilm covering it and this likely limits the amount of sensitive taxa that could potentially colonize the substrate. This orange biofilm is not typical of small streams in the Platte River watershed and is not found in the unimpacted reach. In addition, the low DO numbers found in the impacted stream in August 2013 (Carpenter, 2013) may be limiting the colonization of sensitive taxa and indicate that the stream is not meeting the DO WQS for coldwater streams.

As indicated in Chapter 1, the impacted stream is currently meeting WQS for the other indigenous aquatic life and wildlife designated use based on the macroinvertebrate community. Fish have not been sampled in either reach, but brook trout were observed in the control reach during this study and no fish were observed in the impacted reach. Finally R 323.1050 of Michigan's Part 4 Rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, addresses the following physical characteristics of a water body: turbidity, color, oil films, floating solids, foams, settleable solids, suspended solids, and deposits. Michigan does not have specific assessment methods or numeric standards for these physical characteristics; therefore, best professional judgement (including visual observation) in conjunction with other assessment types (e.g., biological) is used to determine whether the other indigenous aquatic life and wildlife designated use is supported based on this narrative standard (Goodwin et al., 2012). The orange colored substrates and bacterial slimes observed in the impacted reach are not considered normal for northern Michigan streams. Although the impacted reach's macroinvertebrate community and physical appearance have improved since 2003 when the illicit discharge of blueberry waste to the groundwater source of the impaired tributary was discovered, the impacted reach is still not meeting Michigan WQS and has not returned to background conditions.

Field Work By: Tamara Lipsey, Senior Aquatic Biologist
John Matousek, Aquatic Biologist
Surface Water Assessment Section
Water Resources Division

Report By: Tamara Lipsey, Senior Aquatic Biologist
Surface Water Assessment Section
Water Resources Division

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Appendix 1. Macroinvertebrate data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Station: C=control	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Total Numbers	Pollution Tolerance Values	Biotic Index Value	C(LWD)
TAXA														
Oligochaeta (worms)	7		5	2	14	16	5	8	10	3	70	8	560	5
Amphipoda (scuds)	5	4	3	6	17	10	43	2	3	9	102	4	408	53
Isopoda (sowbugs)										1	1	8	8	3
Baetidae	2	1					1		1		5	4	20	36
Nemouridae					2	1	1		1		5	2	10	28
Glossosomatidae	3	3	1	3	2	1		3	16		32	0	0	4
Hydropsychidae		1									1	4	4	2
Rhyacophilidae				2			1				3	0	0	9
Dytiscidae (total)												6	0	
Elmidae					2	1	1				4	4	16	3
Ceratopogonidae	1	1			1				1	1	5	6	30	
Chironomidae	4	1	6	21	40	4	10	23	19	1	129	8	1032	39
Dixidae	1							3	4	2	10	3	30	
Empididae					1						1	6	6	
Ephydridae												6	0	
Psychodidae												10	0	
Ptychopteridae												9	0	
Simuliidae	10		6	1			1				18	6	108	15
Tipulidae						1	1				2	3	6	22
Physidae	1										1	8	8	
Planorbidae										5	5	6	30	
Pisidiidae										2	2	8	16	
TOTAL INDIVIDUALS	34	11	21	35	79	34	64	39	55	24	396			219
Total Taxa	9	6	5	6	8	7	9	5	8	8	18			12
# EPT Taxa	2	3	1	2	2	2	3	1	3	0	5			5
# EPT individuals	5	5	1	5	4	2	3	3	18	0	46			79
% Dominance	29	36	29	60	51	47	67	59	35	38	33			24
% Chironomidae	12	9	29	60	51	12	16	59	35	4	33			18

Appendix 1. Macroinvertebrate data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Station: I=Impacted	I1	I2	I3*	I4	I5	I6	I7	I8	I9	I10	Total Numbers	Pollution Tolerance Values	Biotic Index Value	I(LWD)
TAXA														
Oligochaeta (worms)	3	49	186	28	4	1	2	2	1	1	277	8	2220	11
Amphipoda (scuds)	8		47	4	1	6	5	2	11	26	110	4	438	10
Isopoda (sowbugs)	2					1			2	1	6	8	48	2
Baetidae	1						2	4	12	3	22	4	88	2
Nemouridae	3					1	4		1	1	10	2	20	9
Glossosomatidae												0	0	
Hydropsychidae	17					1	5	1		1	25	4	100	5
Rhyacophilidae												0	0	
Dytiscidae (total)												6	0	2
Elmidae												4	0	
Ceratopogonidae			23								23	6	140	1
Chironomidae	11	144	7902	156	53	37	7	3	9	1	8323	8	66585	456
Dixidae							1				1	3	3	
Empididae			23		1	1	1				26	6	158	12
Ephydridae										1	1	6	6	
Psychodidae												10	0	3
Ptychopteridae			23								23	9	210	
Simuliidae	1				1		1		1		4	6	24	
Tipulidae	1	7	303	24	11	10	1			1	358	3	1074	4
Physidae												8	0	
Planorbidae												6	0	
Pisidiidae		1				1	2				4	8	32	
TOTAL INDIVIDUALS	47	201	8508	212	71	59	31	12	37	36	9214			517
Total Taxa	9	4	7	4	6	9	11	5	7	9	14			12
# EPT Taxa	3	0	0	0	0	2	3	2	2	3	3			3
# EPT individuals	21	0	0	0	0	2	11	5	13	5	57			16
% Dominance	36	72	93	74	75	63	22	33	32	72	90			88
% Chironomidae	23	72	93	74	75	63	22	25	24	3	90			88

Appendix 2. Location, habitat, and multiparameter probe data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Site #	Latitude	Longitude	Collection Date	Picture Taken?	LWD Length (cm)	LWD Width (cm)	LWD surface area (cm^2)	Temperature C	Conductivity	DO%	DO mg/L	pH
C1	44.66227	-86.04971	9/18/2013	Yes	15	2	30	10	433	84	9	8
C2	44.66257	-86.04993	9/18/2013	Yes	31	3	93	10.1	443	84	9.42	8.1
C3	44.66351	-86.05061	9/18/2013	Yes	23	1.5	34.5	10.28	439	84.5	9.44	8.2
C4	44.66379	-86.05078	9/18/2013	Yes	22	3.5	77	10.29	439	84.7	9.49	8.2
C5	44.66402	-86.0508	9/18/2013	Yes	90	1.5	135	10.51	439	84.6	9.39	8.2
C6	44.6643	-86.05096	9/18/2013	Yes	21.5	1.5	32.25	10.47	439	84.9	9.46	8.2
C7	44.66446	-86.05111	9/18/2013	Yes	22	4.5	99	10.39	439	83.4	9.37	8.3
C8	44.66475	-86.05145	9/18/2013	Yes	89	4	356	10.25	439	86.5	9.72	8.2
C9	44.66489	-86.05145	9/18/2013	Yes	32	3.5	112	10.09	439	88.6	9.97	8.2
C10	44.66496	-86.05152	9/18/2013	Yes	40	6	240	10.05	439	93	10.47	8.2

Appendix 2. Location, habitat, and multiparameter probe data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Site #	Latitude	Longitude	Collection Date	% Boulder	% Cobble	% Pebble	% Gravel	% Sand/Silt	Surber Habitat	Undercut Banks	Overhanging Vegetation	LWD	Aquatic Macrophytes	Rootwads
C1	44.66227	-86.04971	9/18/2013	0	1	10	39	50	Riffle	none	none	Sparse	Sparse	Sparse
C2	44.66257	-86.04993	9/18/2013	0	0	15	60	25	Riffle	none	sparse	Moderate	none	none
C3	44.66351	-86.05061	9/18/2013	0	3	20	62	15	Riffle	sparse	sparse	Moderate	none	Sparse
C4	44.66379	-86.05078	9/18/2013	0	1	20	70	10	Riffle	moderate	extensive	none	Sparse	none
C5	44.66402	-86.05080	9/18/2013	0	5	10	50	35	Riffle	extensive	extensive	Sparse	none	none
C6	44.66430	-86.05096	9/18/2013	0	1	20	70	10	Riffle	moderate	extensive	Sparse	Sparse	none
C7	44.66446	-86.05111	9/18/2013	0	0	25	65	10	Riffle	sparse	extensive	Sparse	Sparse	none
C8	44.66475	-86.05145	9/18/2013	0	0	20	70	10	Riffle	sparse	extensive	Sparse	Sparse	none
C9	44.66489	-86.05145	9/18/2013	0	1	30	49	20	Riffle	none	moderate	Moderate	Sparse	Sparse
C10	44.66496	-86.05152	9/18/2013	0	0	0	0	100	run	none	extensive	none	extensive	none

Appendix 2. Location, habitat, and multiparameter probe data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Site #	Latitude	Longitude	Collection Date	Mean Width (m)	Mean Depth (cm)	Velocity (ft/s)	Discharge (ft3/sec)	Notes
C1	44.66227	-86.04971	9/18/2013	0.80	10.60	1.1	1.00	Upstream of driveway, it looks more wetland-like. Upstream of this site is a very large maple tree and lots of metal junk. Ten-inch culvert under driveway.
C2	44.66257	-86.04993	9/18/2013	1.13	6.00	1.15	0.84	Right behind house, Japanese Knotweed extensive on right bank, fence/grass hay bales on the left. Large maple trees by house, very narrow to almost no riparian width.
C3	44.66351	-86.05061	9/18/2013	1.97	3.00	0.82	0.52	Maple tree canopy. Upstream of wagon cover (sheet metal) there is an extensive stand of Japanese Knotweed that is on right bank. The landowner cuts it, but it spreads. Cottonwood and maples.
C4	44.66379	-86.05078	9/18/2013	0.83	6.20	1.33	0.74	Upstream of small tributary (.5 m wide). The riparian was 10 m on right (one maple tree and grass) and 50 m on left (mostly grass).
C5	44.66402	-86.0508	9/18/2013	0.93	7.00	1.4	0.98	10 m riparian before corn, mostly shrubs and grass and some small trees, substrate noticeably larger.
C6	44.6643	-86.05096	9/18/2013	0.87	7.00	2.9	1.89	Young maples, ferns, banks very steep.
C7	44.66446	-86.05111	9/18/2013	0.67	8.00	2.43	1.40	No trees, but grass and willow shrubs, and herbaceous vegetation. Overhanging vegetation dense. Very fast current.
C8	44.66475	-86.05145	9/18/2013	1.23	8.40	1.12	1.25	Not many riparian trees, some young birch, 30-feet left, 45-feet right.
C9	44.66489	-86.05145	9/18/2013	1.87	4.60	0.94	0.87	Tons of tiny *Glossosomatidae* on the rocks. Riparian area fairly dense and about 100 feet wide.
C10	44.66496	-86.05152	9/18/2013	1.83	8.20	0.62	1.00	Small stream, fast flowing, narrow.

Appendix 2. Location, habitat, and multiparameter probe data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Site #	Latitude	Longitude	Collection Date	Picture Taken?	LWD Length (cm)	LWD Width (cm)	LWD surface area (cm^2)	Temperature C	Conductivity	DO%	DO mg/L	pH
I1	44.66311	-86.05403	9/19/2013	Yes	25	6	150	13.1	444	86.6	9.09	8.2
I2	44.66276	-86.05456	9/19/2013	Yes	21	4	84	10.4	526	72	8.03	7.7
I3	44.66253	-86.05457	9/19/2013	Yes	40	3	120	11.12	543	73.8	8.11	7.7
I4	44.66265	-86.05435	9/19/2013	Yes	33	4	132	10.22	513	82.8	9.29	7.8
I5	44.66286	-86.0545	9/19/2013	Yes	39	6	234	10.22	515	88.5	9.92	7.8
I6	44.66313	-86.05421	9/19/2013	Yes	32	6	192	10.19	515	87.4	9.81	7.8
I7	44.66338	-86.05419	9/19/2013	Yes	35	2	70	10.74	504	89.9	9.93	7.9
I8	44.66369	-86.05424	9/19/2013	Yes	37	3	111	10.79	499	90.5	10.02	8
I9	44.66381	-86.05405	9/19/2013	Yes	35	0.1	3.5	10.86	500	88.9	9.2	8
I10	44.66388	-86.05408	9/19/2013	Yes	20	0.2	4	10.86	502	83.4	9.21	8

Appendix 2. Location, habitat, and multiparameter probe data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Site #	% Boulder	% Cobble	% Pebble	% Gravel	% Sand/Silt	Surber Habitat	Undercut Banks	Overhanging Vegetation	LWD	Aquatic Macrophytes	Rootwads
I1	0	0	30	60	10	Riffle	none	none	Moderate	none	moderate
I2	1	5	5	10	80	Riffle	none	none	Sparse	none	moderate
I3	0	1	2	0	97	Riffle	none	none	Moderate	none	Sparse
I4	0	25	20	40	15	Riffle	sparse	sparse	Sparse	none	none
I5	0	30	25	35	10	Riffle	none	none	Moderate	none	none
I6	0	1	25	45	30	Riffle	none	none	Moderate	none	none
I7	0	2	10	8	70	Riffle	none	none	extensive	sparse	moderate
I8	0	3	30	47	20	Riffle	none	none	Sparse	none	moderate
I9	0	3	15	72	10	Riffle	none	sparse	Moderate	none	moderate
I10	0	0	5	45	50	Riffle	none	extensive	Sparse	Sparse	Sparse

Appendix 2. Location, habitat, and multiparameter probe data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Site #	Mean Width (m)	Mean Depth (cm)	Velocity (ft/s)	Discharge (ft3/sec)	Notes
I1	0.52	3.40	0.46	0.81	This side trib is more to the NW. Not as orange like other tribs. It does not seem as impacted by ground water. Riparian area on right bank is at backyard of house. Left bank is dense forest with little undergrowth.
I2	0.97	2.80	0.65	1.76	Same dense riparian/wet/muddy ground water seeps just at Surber and upstream a bit. Clay substrate.
I3	0.47	2.00	0.1	0.09	Small groundwater tributary, upwelling very orange upstream of this site. Dense canopy, little undergrowth because of shade and saturated soils.
I4	0.83	2.67	0.3	0.67	Dense riparian area, some herbaceous, soils very saturated upstream of here. Orange substrates due to thin layer of rusty colored biofilm.
I5	0.97	4.20	0.73	2.96	Dense forest. Naturally not much undergrowth. Steep banks highly eroded. Orange ground water seep just upstream of this site meets up with the tributary. The substrates are more orange in color downstream of this sight and GW seep.
I6	1.32	3.00	0.89	3.52	More odor in this branch than control branch. Bottom looks more rusty orange. Very dark periphyton on substrate. Not green.
I7	1.27	5.80	0.79	5.80	Upstream of footbridge, dense maple forest riparian zone >100-feet wide on left. Riparian area on right side is a yard mowed to the edge. Not much herbaceous or any grass. Bacterial slimes not apparent.
I8	1.10	3.80	0.79	3.30	Dark because of clouds and forest. Dense canopy, white cedar, popple, maple. Right bank with 30 m wide riparian zone, left with >100 feet wide riparian zone. No observable bacterial slimes.
I9	0.98	3.40	0.85	2.82	Thirty-foot riparian area on right bank, >300 foot on left bank. Moderate overhead cover, mostly maples, not as much herbaceous.
I10	0.75	6.83	1.5	7.69	Young trees, right bank riparian width is 75 feet, left bank is more than 300 feet, grasses and herbaceous vegetation dominant, black cherry tree, 30-feet upstream of open bottom concrete culvert.

Appendix 3. Periphyton and Bacterial Slime Data. Unnamed tributary to Platte Lake. Benzie, County, Michigan. September 18-19, 2013.

Site #	# Dots Macro-algae	# Dots bacterial slime	Max Length macro-algae (mm)	# Dots suitable for microalgae	# Dots no microalgae	# Dots thin layer microalgae
C1	7	0	310	25	25	0
C2	2	0	10	45	45	0
C3	0	0	0	49	49	0
C4	20	0	80	45	45	0
C5	15	0	230	49	49	0
C6	7	0	170	50	50	0
C7	5	0	220	49	49	0
C8	5	0	70	45	45	0
C9	18	0	230	40	32	8
C9	0	0	0	20	19	1
C9	0	0	0	30	26	4
C9 Total 150 dots surveyed	18	0	230	90	77	13
C10	0	0	0	0	0	0
Total	79	0	NA	447	434	13

Site #	# Dots Macro-algae	# Dots bacterial slime	% substrate with bacterial slime	Max Length macro-algae (mm)	# Dots suitable for microalgae	# Dots no microalgae	# Dots thin layer microalgae
I1	0	0	0	0	42	42	0
I2	0	14	100	0	14	0	0
I3	0	45	100	0	45	0	0
I4	0	43	100	0	43	0	0
I5	0	17	100	0	17	0	0
I6	0	0		0	40	40	0
I6	0	0		0	45	45	0
I6	0	0		0	45	45	0
I6 Total 150 dots surveyed	0	0	0	0	130	130	0
I7	0	0		0	0	0	0
	0	0		0	35	0	35
	0	0		0	3	0	3
I7 Total 150 dots surveyed	0	0	0	0	38	0	38
I8	0	0	0	0	43	0	43
I9	0	0	0	0	45	0	45
I10	0	0	0	0	48	8	40
Total	0	119			465	180	166