RESULTS FROM THE 2016 POST-REMEDIATION ASSESSMENT OF NEWTON CREEK AND HOG ISLAND INLET:

WATER QUALITY AND BIOLOGICAL COMMUNITIES

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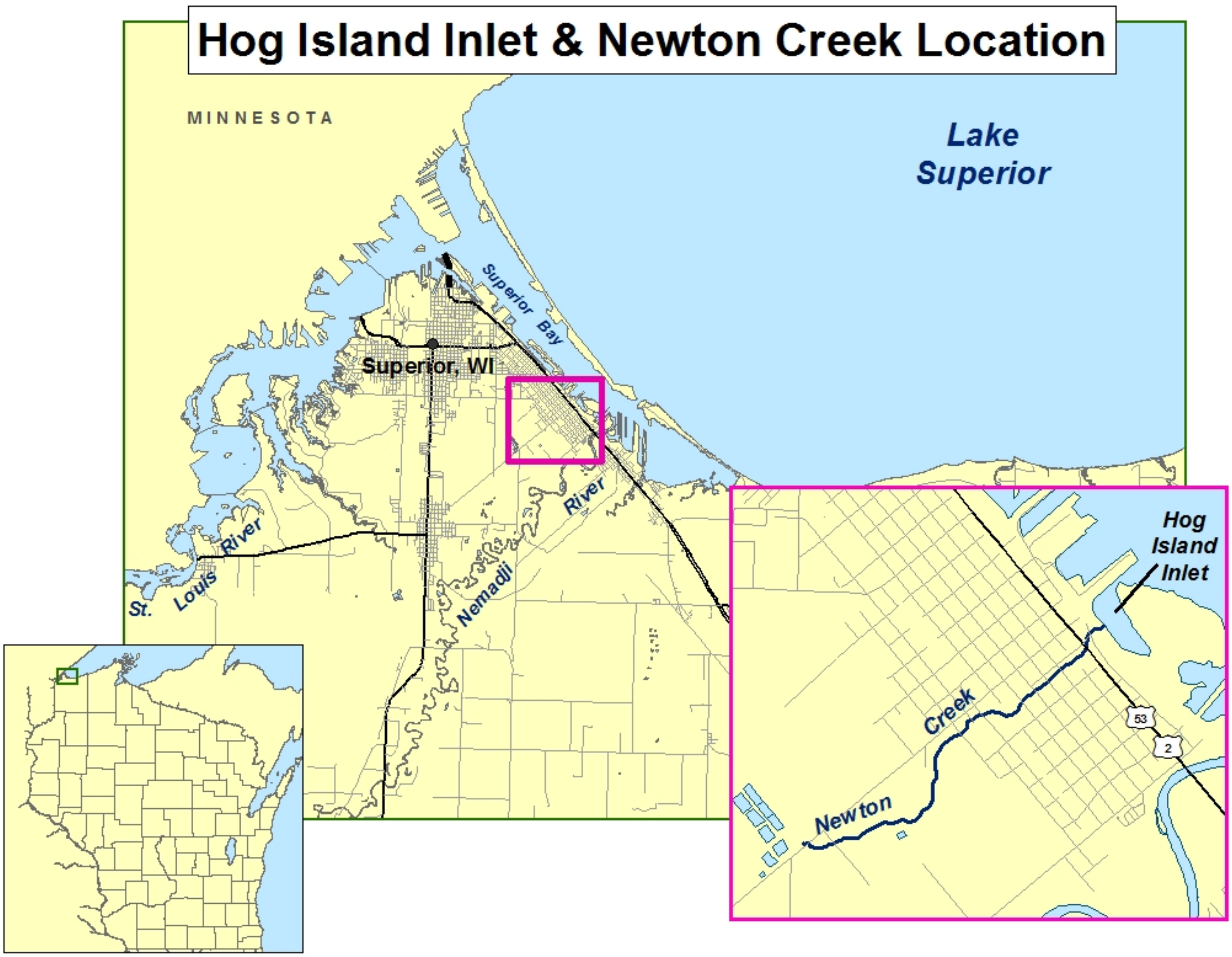
Introduction

Newton Creek is a small (1.8 mile long) stream located in the City of Superior. It flows into Hog Island Inlet which is a shallow 18 acre bay and wetland area connected to Superior Bay (Figure 1). Base flow in Newton Creek is primarily maintained by wastewater effluent discharge from the Calumet oil refinery, which averages 0.4 cfs. The creek also receives runoff from industrial and residential areas. The watershed for Newton Creek is shown in Appendix A.

Removal of contaminated sediment in Newton Creek was largely completed by 2003. Contaminated sediment removal from Hog Island Inlet was conducted in 2005. A variety of post-remediation monitoring has been conducted since that time.

Figure 1. Locations of Hog Island Inlet and Newton Creek.



A 2015 review of post-remediation monitoring (Graham and Roesler 2015) identified some ongoing concerns regarding the environmental health of Newton Creek and Hog Island Inlet including:

- Fish populations in Newton Creek that commonly had biotic index ratings of poor.
- Macroinvertebrate population in Newton Creek that commonly had biotic index ratings of poor and appeared to have declined in recent years.
- A 91% decline in aquatic plant abundance in Hog Island Inlet between 2010 and 2014.
- Observations of petroleum-like odors released from disturbed sediment in both Newton Creek and Hog Island Inlet.
- Observations of petroleum-like odors emanating from the undisturbed water of Newton Creek.
- Observations of chronic foaming in Newton Creek.
- Indications of possible sediment toxicity in Newton Creek.

These concerns prompted additional assessment work in Newton Creek and Hog Island Inlet in 2016. Components of the 2016 assessment work included:

<u>Newton Creek</u>

- Water chemistry sampling
- Water toxicity testing
- Fish surveys
- Fish abnormalities assessment
- Macroinvertebrate sampling
- Sediment chemistry sampling
- Sediment toxicity testing

<u>Hog Island Inlet</u>

- Aquatic plant survey
- Soft sediment depth survey
- Sediment odor survey
- Benthic macroinvertebrate sampling
- Fish survey
- Sediment chemistry sampling
- Sediment toxicity testing

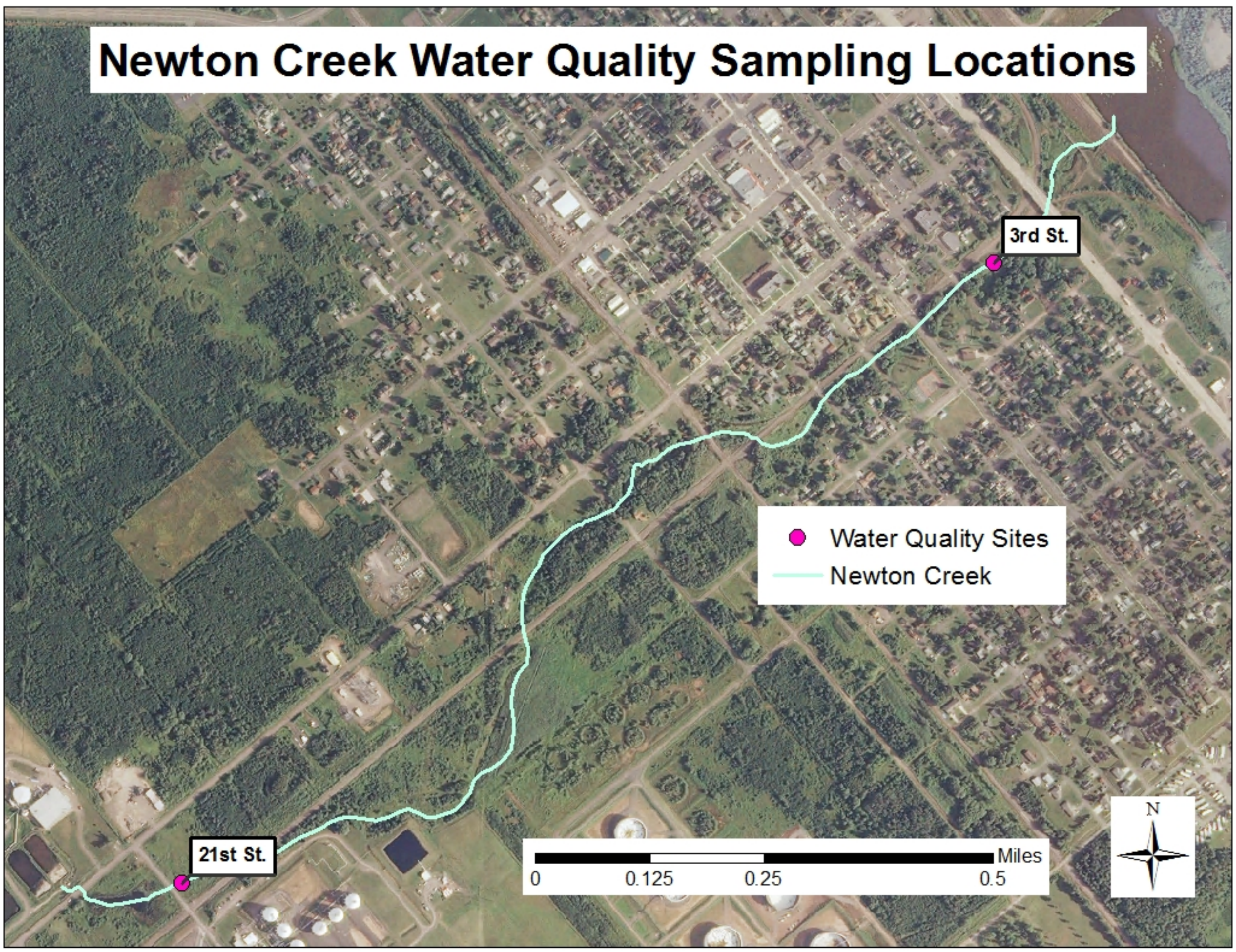
Water quality and biological community results are presented in this report. A companion report presents results for sediment chemistry and sediment toxicity testing.

Newton Creek

Newton Creek Water Chemistry Sampling

Newton Creek water samples were collected from two sites (Figure 2) on two dates. The 21st St. site is just downstream of the Calumet oil refinery. The 3rd St. site is near the creek mouth and is influenced by additional inputs to the creek such as urban residential runoff and storm sewer outfalls. Samples were tested for a range of total petroleum hydrocarbons (TPH's), oil and grease, polycyclic aromatic hydrocarbons (PAH's), volatile organic compounds (VOC's), metals, dioxins/furans, total phenolics, chloride, sulfate, and ammonia. One Newton Creek site (21st St.) was also sampled during January of 2017. The parameter list was reduced for that sample (no VOC's or dioxins/furans). Samples collected during January of 2017 were also tested for naphthenic acids.

Figure 2. Water Quality Sampling Locations for Newton Creek



Parameters with detects found are listed in Table 1. Diesel range organics (DRO TPH; C_{10}-C_{20}) and oil range organics (ORO TPH; C_{20}-C_{34}) were present in all samples, with combined concentrations ranging from 1.00-2.85 mg/l. Concentrations were higher at the 21st St site (upper) than the 3rd St. site (lower). Gasoline range organics (GRO TPH; C_6-C_{10}) were detected in the October samples, with a concentration at the 21st St. site of 0.568 mg/l, and a concentration at the 3rd St. site of 0.102 mg/l. Complete parameter results are presented in Appendices B, C, and D.

Three PAH compounds were detected in August, six were detected in October, and two were detected in January. Estimated TPAH18 concentrations ranged from 0.21 – 0.48 ug/l. Estimated TPAH36 concentrations ranged from 0.26 – 0.65 ug/l. Naphthenic acids were found at a concentration of 2.9 mg/l at the 21st St. site. VOC's were not detected in any of the samples.

Total phenolics were detected at low levels in the August samples (12-38.3 ug/l). Molybdenum and vanadium were metals detected in October. Vanadium was also detected in January.

A freshwater chronic toxicity screening threshold concentration for molybdenum of 34 ug/l has been reported (NOAA 2008). Eisler (1989) reported that adverse effects on growth and survival of aquatic organisms usually only appear at molybdenum concentratons > 50 **mg**/l. For vanadium, a freshwater chronic toxicity screening threshold concentration of 19 ug/l has been reported (NOAA 2008). Sprague et al. (1978) reported that 80 ug/l of vanadium was the threshold for chronic toxicity for fish. It seems unlikely that molybdenum and vanadium concentrations in Newton Creek are high enough to cause toxicity.

The dioxin/furan results show several detects, all of which are qualified as being above the LOD but below the LOQ ("J"). Most detects are further qualified as having interference ("I") or having less than optimal separation from blank concentrations ("B"). OctaCDD was detected above the LOD in both samples (4.4 -6.8 pg/l). This was also the most abundant dioxin compound present in sediment samples, so it is likely to be present in the stream water. 1,2,3,4,6,7,8-HeptaCDF was also detected above the LOD, but below the LOQ in one sample.

Newton Creek sample results for nutrients, suspended solids, and field parameters are shown in Table 2. Total phosphorus concentrations (TP) at 21st St. prior to 2015 averaged 278 ug/l (Graham and Roesler 2015). In 2015, TP averaged <75ug/l, Wisconsin's stream TP standard, in six monthly May to October samples. TP in 2016 increased with concentrations ranging from 86-164 ug/l. TP increases downstream of the 21st St. site, are likely due to urban runoff influences.

The nitrate plus nitrite concentration was very high in June at the 21st St. site (27 mg/l). Nitrate plus nitrite concentrations at this site have been highly variable in past years, ranging from 0.1-17.5 mg/l. The total suspended solids concentration (TSS) in June at the 21st St. site was very low (2 mg/l). TSS averaged 10.1 mg/l at this site in past years. TSS increases downstream of the 21st St. site, are likely due to urban runoff influences.

Table 1. Newton Creek Water Chemistry Sampling Parameters with at Least One Detect.

	21st Street			3rd Street	
Parameter	17-Aug-16	31-Oct-16	9-Jan-17*	17-Aug-16	31-Oct-16
GRO TPH (C6-C10) mg/L	< 0.0741	**0.568**	< 0.0741	< 0.0741	**0.102**
DRO TPH (C10-C20) mg/L	**0.97**	**1.7**	**1.9**	**0.65**	**1.6**
ORO TPH (C20-C34) mg/L	**0.55**	**0.79**	**0.95**	**0.35**	**0.7**
Total TPH (ΣGRO+DRO+ORO) mg/L	1.5941	3.058	2.9241	1.0741	2.402
Total Phenolics (ug/L)	**38.3**	< 3.4	< 3.4	**12**	< 3.4
PAH's					
TPAH18 (ug/L)[1]	0.2996	0.32595	0.28975	0.32075	0.4769
TPAH36 (ug/L)[2]	0.4711	0.49735	1.77125	0.59475	0.6483
2-Methylnaphthalene (ug/L)	< 0.011	**0.042**	< 0.011	< 0.011	**0.035 J**
Acenaphthene (ug/L)	**0.098**	< 0.010	**0.089**	**0.089**	**0.17**
Acenaphthylene (ug/L)	**0.053**	**0.053**	< 0.0093	< 0.0093	**0.073**
Anthracene (ug/L)	< 0.010	**0.017 J**	< 0.010	< 0.010	**0.017 J**
Benzo(b)fluoranthene (ug/L)	**0.050**	< 0.016	< 0.016	**0.086**	< 0.016
Benzo(e)pyrene (ug/L)	< 0.010	< 0.0098	< 0.010	**0.071**	< 0.0098
C1-Fluoranthenes/Pyrenes (ug/L)	<0.020	<0.020	**0.13**	<0.020	<0.020
C4-Naphthalenes (ug/L)	<0.020	<0.020	**1.2**	<0.020	<0.020
Fluoranthene (ug/L)	< 0.011	< 0.011	< 0.011	**0.048**	< 0.011
Fluorene (ug/L)	< 0.0090	**0.086**	**0.094**	< 0.0090	**0.084**
Perylene (ug/L)	< 0.013	< 0.013	< 0.013	**0.043**	< 0.013
Phenanthrene (ug/L)	< 0.0081	**0.02 J**	< 0.0081	< 0.0081	< 0.0079
Pyrene (ug/L)	< 0.011	**0.021 J**	< 0.011	< 0.011	**0.012 J**
Anions					
Chloride (mg/L)	**178**	**274**	**317**	**156**	**265**
Sulfate (mg/L)	**81.5**	**147**	**138**	**69.1**	**144**
Metals					
Molybdenum (ug/L)	< 2.5	**13.8**	< 1.4	< 2.5	**11.8**
Vanadium (ug/L)	< 2.5	**19.4**	**14.8**	< 2.5	**11.6**
Dioxins and Furans					
1,2,3,4,6,7,8-HeptaCDD (pg/L)	**5.0 BJ**	**0.75 IJ**	NA	**7.9 BJ**	**1.0 J**
OctaCDD (pg/L)	**39.0 BJ**	**4.4 J**	NA	**57.0 BJ**	**6.8 J**
1,2,3,4,6,7,8-HeptaCDF (pg/L)	< 1.20	< 0.29	NA	**1.9 IJ**	< 0.40
OctaCDF (pg/L)	**16 IJ**	< 0.73	NA	**24.0 IJ**	< 0.86

[1]TPAH18 (ug/kg) was calculated by summing 1-Methylnaphthalene, 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene. Any nondetects had the detection level used for the value when nondetects were <40%. When nondetects were >40%, half of the detection level was used for nondetects. Any data with qualifiers used the number reported.

[2]TPAH36 (ug/kg) was calculated by summing all measured PAH's. C2-Fluoranthenes/Pyrenes and C3-Fluoranthenes/Pyrenes were not analyzed for water samples. Any nondetects had the detection level used for the value when nondetects were <40%. When nondetects were >40%, half of the detection level was used for nondetects. Any data with qualifiers used the number reported.

*Sample was received without ice present and at 19°C.

B-less than 10X higher than method blank level

I-Interference present

J-Estimated concentration at or above the level of detection and below the level of quantitation

Table 2. Nutrient, Suspended Solids, and Field Parameter Data for Newton Creek.

	21st Street			11st Street				3rd Street			Floodplain park	NC-B
Lab Parameter	13-Jun-16	28-Oct-16	5-Dec-16	13-Jun-16	8-Sep-16	17-Oct-16	28-Oct-16	13-Jun-16	8-Sep-16	28-Oct-16	17-Oct-16	17-Oct-16
Ammonia (mg/L)	0.091			0.107				0.115				
Nitrate + Nitrite (mg/L)	27			26.3				24.2				
Nitrogen Kjeldahl Total (mg/L)	1.41			1.62				1.26				
Total Phosphorus (ug/L)	86		164	122				116				
Total Suspended Solids (mg/L)	2			25.7				15				
Field Parameter												
Temperature (°C)	14.5	9.9		13.6	18.3	11.5	9.4	12.8	18.0	8.6	11.7	11.9
Dissolved Oxygen (mg/L)	8	8.5		8.1	6.7	8.8	10.1	6.7	7.0	10.2	9	9.1
pH (SU)	7.6			7.6				7.5				
Conductivity (umhos/cm)	1365	1574		1333	452	692	1538	1266	484	1516	1093	667
Transparency (cm)	>120			25	19	21		28	15		29	21
Flow (cfs)	0.75			0.6	4.3			0.5	4.5			
Stream velocity (ft/sec)						1.2					1	1.1

Chronic foaming of Newton Creek water was observed during 2016 monitoring (Figures 3 and 4) as well as in previous years. Foaming was most noticeable where the stream was aerated, such as below culver drops. Foam could be generated throughout the length of the stream by briskly agitating the water.

Figure 3. Foaming Downstream of Culvert at 21st St. Crossing on June 13, 2016.

Figure 4. Foaming Downstream of Culvert at 21st St. Crossing on December 5, 2016.

Newton Creek Water Toxicity Testing

Newton Creek stream water from two sites (Figure 2; the same sites where water quality testing was done) was tested for toxicity on two dates (May and October of 2016). Tests were conducted by the Biomonitoring Lab of the Wisconsin State Lab of Hygiene. Testing included:

- Fathead minnow growth and survival test
- *Ceriodaphnia dubia* (a zooplankton) reproduction and survival test
- *Selenastrum capricornutum* (an algae) growth test

Results are summarized in Table 3. For the May 2nd samples, fathead minnow growth and *C. dubia* reproduction were not significantly different than the lab water control (Figure 5). The growth of *S. capricornutum* was significantly less for both of the Newton Creek samples than for the lab water control. The *S. capricornutum* growth reduction in the 21st St. sample (-32.1%) was also significantly greater than the reduction in the 3rd St. sample (-18.8%).

For the October 31st samples, fathead minnow growth was significantly less (-43.5%) for the 21st St. sample than for the lab water control. *C. dubia* reproduction was also significantly less (-33.3%) for the 21st St. sample than for the lab water control. Fathead minnow growth for the 3rd St. sample was not significantly different than for the lab water control. *C. dubia* reproduction for the 3rd St. sample was also not significantly different than for the lab water control.

Also for the October 31st samples, the growth of *S. capricornutum* was significantly less for both of the Newton Creek samples than for the lab water control. Growth reductions were greater than those observed in the May samples. The *S. capricornutum* growth reduction in the 21st St. sample (-92.8%) was also significantly greater than the reduction in the 3rd St. sample (-85.9%).

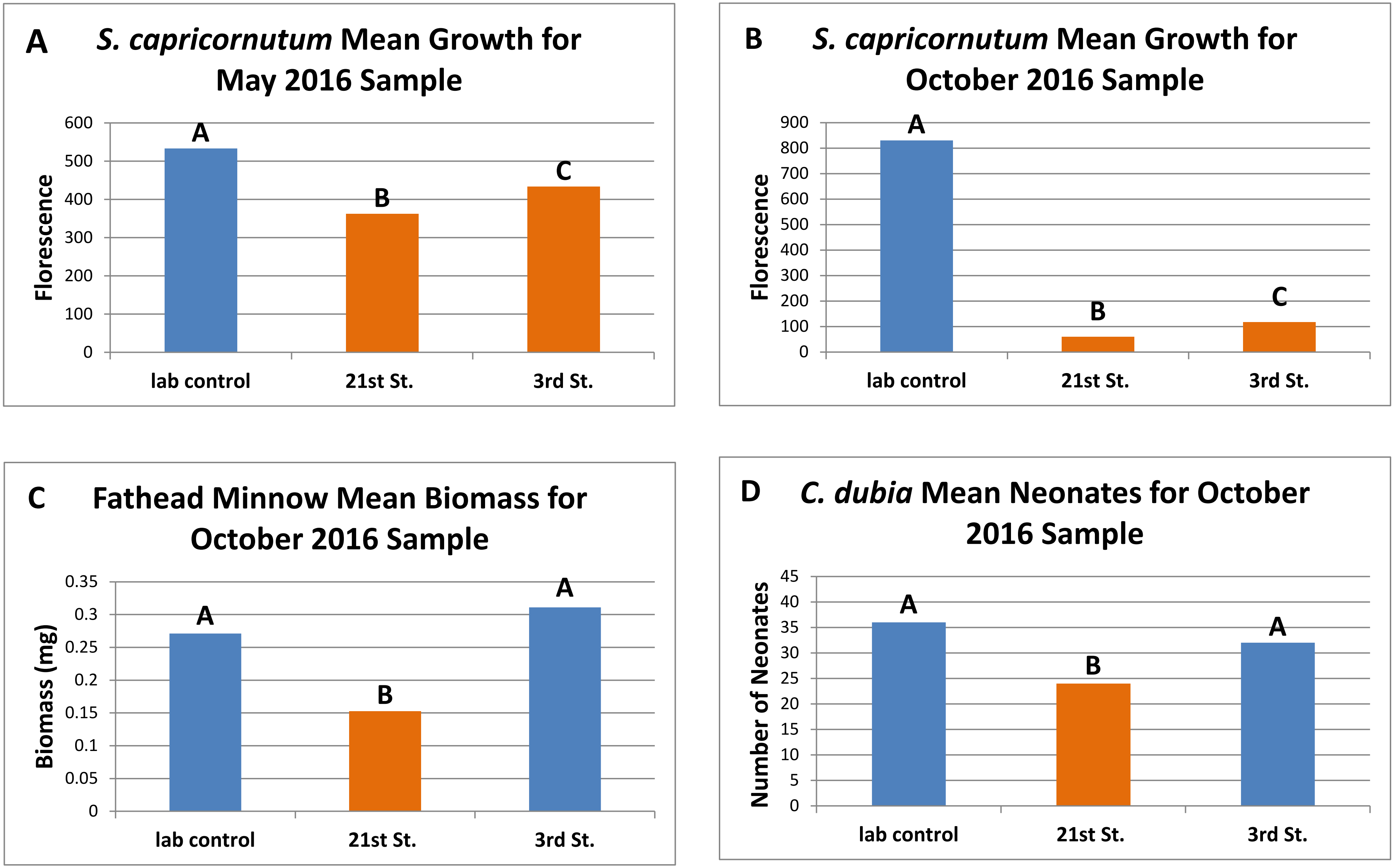
Table 3. Summarized Toxicity Test Results for Newton Creek Water Samples.

	May 2, 2016			**October 31, 2016**		
	Control	21st St.	3rd St.	Control	21st St.	3rd St.
Fathead minnow mean biomass (mg)	0.277	0.28	0.279	0.271	0.153	0.311
% difference from lab control water	NA	1.1	0.7	NA	-43.5	14.8
Statistically significant?	NA	NO	NO	NA	YES	NO
***C. dubia* mean neonates (no.)**	39	36	35	36	24	32
% difference from lab control water	NA	-7.7	-10.3	NA	-33.3	-11.1
Statistically significant?	NA	NO	NO	NA	YES	NO
***S. capricornutum* mean growth (fluorescence)**	533	362	433	830	60	117
% difference from lab control water	NA	-32.1	-18.8	NA	-92.8	-85.9
Statistically significant?	NA	YES	YES	NA	YES	YES

Other water testing done on October 31st found various contaminants present at the time (Table 1) including gasoline range organics, diesel range organics, oil range organics, PAH's, molybdenum, and vanadium. Comparable water testing was not done in conjunction with the May 2nd toxicity test due to delayed funding approval.

The suppression of algal growth shown in the toxicity tests may be reflected in field observations of filamentous algae growth in Newton Creek. The presence of filamentous algae growth was highly variable. Of particular note was the absence of filamentous algae during the June 13th fish surveys. Moderate growth of filamentous algae was noted on December 5th. Variations in the quality of water being discharged to Newton Creek might be influencing filamentous algae growth in Newton Creek.

Figure 5. Significant Newton Creek Water Toxicity Test Results for *S. capricornutum* (A,B), Fathead Minnow (C), and *C. dubia* (D).



Newton Creek Fish Surveys

Fish surveys were conducted at three sites (Figure 6) on three dates during 2016 for Newton Creek. Results are summarized in Table 4. A total of seventeen fish species were found. The most frequently occurring species were brook sticklebacks, white suckers, and creek chubs. Fish communities found indicate a cool-warm headwater is the best fitting natural community for the creek. More fish and more fish species were found at the furthest downstream site (3rd St.) since it is closer to a source of ongoing recruitment (Hog Island Inlet and the St. Louis River estuary) and it has better pool habitat. The fish index of biotic integrity (IBI) ratings for the 2016 surveys ranged from poor to fair (Table 5).

Figure 6. Fish Survey Locations for Newton Creek.

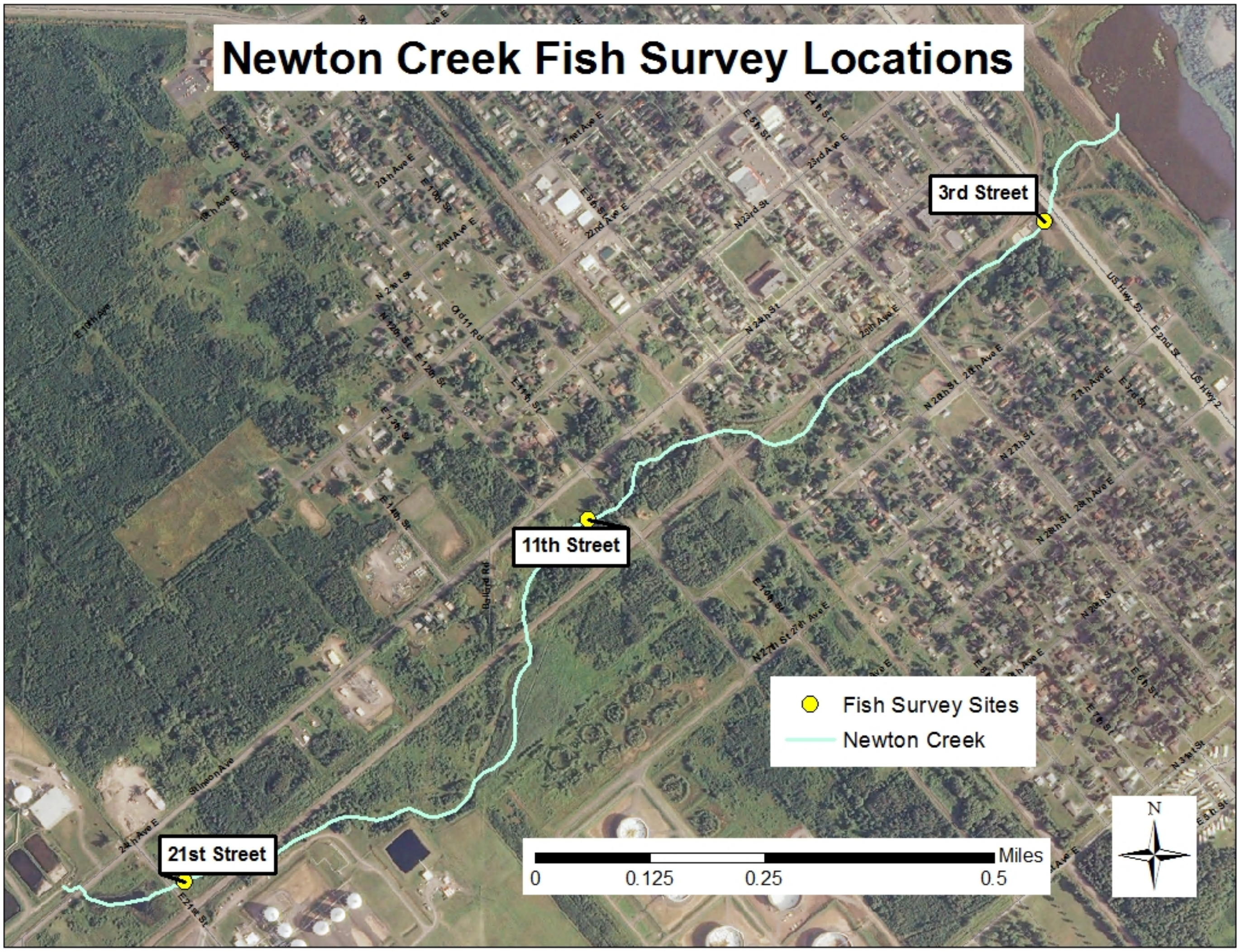


Table 5 also summarizes fish IBI's for all past fish surveys for Newton Creek. Nearly all IBI ratings ranged from poor to fair, with a single survey having an IBI rating of good (3rd St., 2008). The 11th St. site has the worst IBI ratings which are consistently poor.

Table 4. Newton Creek Fish Survey Data.

	21st Street			11st Street			3rd Street					
Fish Species	14-Jun-16	15-Sep-16	28-Oct-16	13-Jun-16	15-Sep-16	28-Oct-16	13-Jun-16	08-Sep-16	19-Sep-16	28-Oct-16	Species Total No.	No. of Occurrences
White Sucker	1	3	6	10	5	1	13	18	28	42	127	10
Brook Stickleback	24	43	37	15	17	17	33	2	6	3	197	10
Creek Chub			1		3	3	1	2	2	1	13	7
Fathead Minnow	1					1		1	4	7	14	5
Central Mudminnow			2				2			1	5	3
Bluegill		1	1						2	5	9	4
BluegillxPumpkinseed Hybrid										1	1	1
Black Bullhead			3						1		4	2
Round Goby							1		5	1	7	3
Troutperch							18				18	1
Shorthead Redhorse									3	11	14	2
Longnose Sucker								1			1	1
Johnny Darter									1		1	1
Logperch									1		1	1
Common Shiner								2	2		4	2
Golden Shiner						1				2	3	2
Spottail shiner							1				1	1
Small Stream IBI Score	30	10	20	20	10	30	50	40	40	40		
IBI Rating	Poor	Poor	Poor	Poor	Poor	Poor	Fair	Fair	Fair	Fair		
% Tolerant Individuals	100	97.9	98	100	100	100	71.0	88.5	74.5	75.7		
Qualifier						<25 fish						
Total species	3	3	6	2	3	5	7	6	11	10		
Total fish	26	47	50	25	25	23	69	26	55	74		

Table 5. Fish IBI Scores for all Surveys on Newton Creek.

	Date Sampled	FIBI score	FIBI Rating	Qualifier	DELTs[1] present
	3rd St. (NC-29)				
2008	(Sept 17, 2008)	70	Good		
2009	(Sept 10, 2009)	30	Poor		yes
2010	(July 26, 2010)	30	Poor		yes
2011	(May 24, 2011)	50	Fair		
2012	(May 16, 2012)	40	Fair		
2016	(June 13, 2016)	50	Fair		yes
2016	(Sept 8, 2016)	40	Fair		yes
2016	(Sept 19, 2016)	40	Fair		yes
2016	(Oct 28, 2016)	40	Fair		yes
	E. 11th St.				
2008	(Sept 17, 2008)	30	Poor		
2009	(Sept 10, 2009)	20	Poor		
2010	(July 26, 2010)	0	Poor	< 25 fish	
2011	(May 24, 2011)	10	Poor	< 25 fish	
2012	(May 16, 2012)	20	Poor		
2016	(June 13, 2016)	20	Poor		
2016	(Sept 15, 2016)	10	Poor		yes
2016	(Oct 28, 2016)	30	Poor	< 25 fish	yes
	21st St. (below Murphy Oil)				
2008	(Sept 19, 2008)	40	Fair		
2010	(July 26, 2010)	40	Fair		
2011	(May 24, 2011)	60	Fair		
2012	(May 16, 2012)	50	Fair		
2016	(June 14, 2016)	30	Poor		
2016	(Sept 15, 2016)	10	Poor		yes
2016	(Oct 28, 2016)	20	Poor		yes

[1]DELTS stands for external deformities, eroded fins, lesions, and tumors

Newton Creek Fish Abnormalities

Fish Survey Observations

Fish surveys were conducted at three sites on Newton Creek (Figure 5), on three dates in 2016. During the initial survey on June 13th, a nearly fin-less white sucker was collected. All fins were reduced to basal nubs (Figure 7). No other obvious abnormalities were noted for the rest of the fish collected on that date.

Figure 7. Nearly Fin-less White Sucker Collected from Newton Creek 3rd St. Site on June 13, 2016.

In following surveys, more detailed observations of fin erosion and other abnormalities were made. White suckers were the fish observed to most frequently have fin erosion (Figure 8). Rates of white sucker fin erosion for the three survey dates are shown in Table 6. While only one of the twenty-four white suckers collected during the June 13-14, 2016 surveys had fin erosion, larger numbers of fin-eroded suckers (1 or more fins with $\geq$ 5% loss) were found on September 15-19, 2016 (27of 36) and October 28, 2016 (20 of 49)(Table 6 and Figure 9).

Figure 8. Fin-eroded White Suckers Collected from Newton Creek on September 15, 2016.

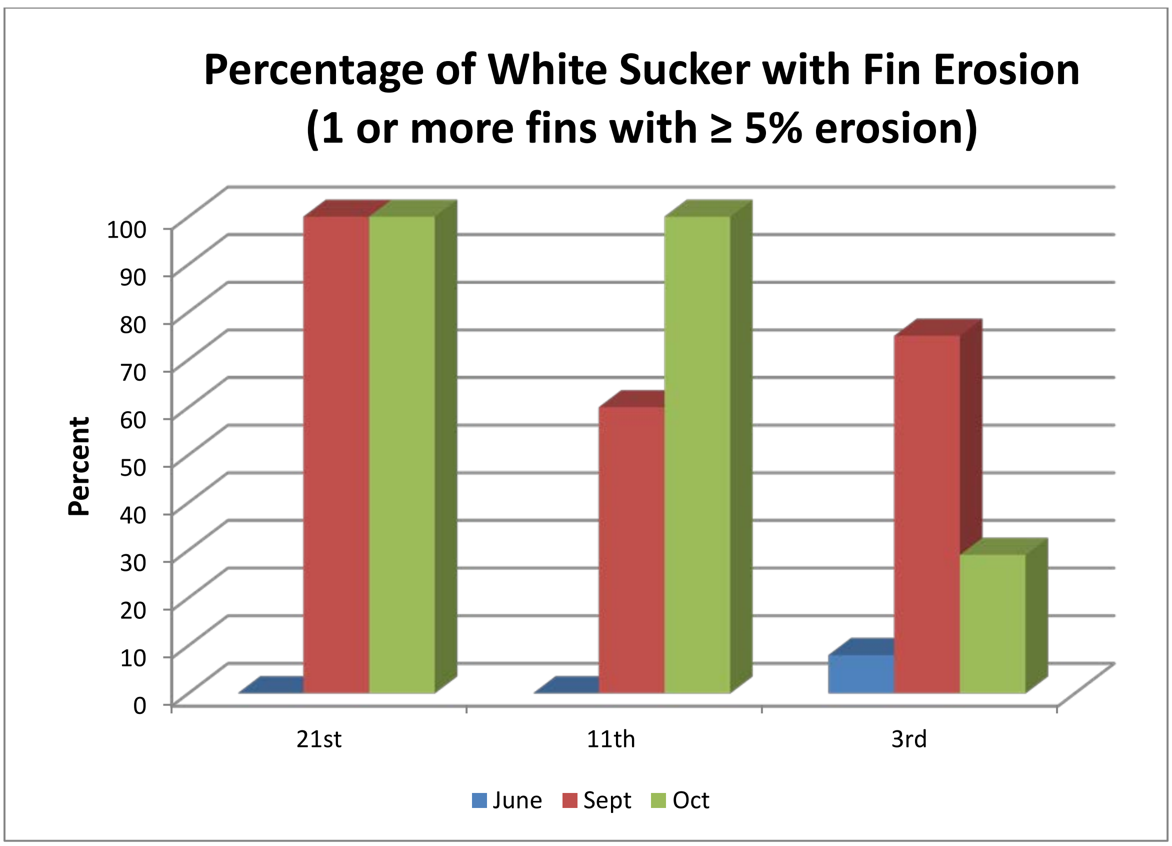
A longer duration of exposure may account for increased fin erosion rates later in the year. The high variability in fin erosion rates at the 3rd St. site may be due to a greater exchange of fish between the creek and the nearby Hog Island Inlet.

Table 6. Newton Creek White Sucker Fin Erosion Observations.

Site	Fin erosion*	Survey Dates 06/13-14/2016	09/15-19/2016	10/28/2016
21st St.	≥ 50%	0/1=0%	3/3=100%	5/6=83%
	≥ 5%	0/1=0%	3/3=100%	6/6=100%
11th St.	≥ 50%	0/10=0%	3/5=60%	0/1=0%
	≥ 5%	0/10=0%	3/5=60%	1/1=100%
3rd St.	≥ 50%	1/13=8%	20/28=71%	6/42=14%
	≥ 5%	1/13=8%	21/28=75%	13/42=31%

*fin erosion categories are based on 1 or more fins with ≥ 50% loss, and 1 or more fins with ≥ 5% loss

Figure 9. Newton Creek White Suckers with greater than 5% Fin Erosion.



Fin erosion was observed to a lesser extent in other fish species, including creek chub (Figure 10), central mudminnow, fathead minnow, bluegill, golden shiner, and black bullhead.

Figure 10. Creek Chub with Eroded Dorsal and Pelvic Fins Collected from Newton Creek on September 15, 2016.

Other abnormalities observed in some Newton Creek fish specimens during the October 28, 2016 survey included (also see Appendix E):

- White sucker – reddened areas on fins and sides
- Central mudminnow – reddened areas on gill covers, jaws, and dorsal fin
- Fathead minnow – 1 deformed snout
- Creek chub – body cavity and/or digestive tract bloated with gas
- Bluegill – reddened areas on head and fin, abnormally thickened body cavities
- Brook stickleback – reddened pectoral fin bases, gill covers, 1 tumor between pectoral fins
- Black bullhead – partial barbel loss

A fish survey was also conducted at Faxon Creek on October 31, 2016 to allow a comparison to October 28, 2016 Newton Creek fish surveys (Appendix F). Faxon Creek is a similar-sized nearby stream in the City of Superior. Much of its watershed is urbanized. A 100 m segment of Faxon Creek yielded 108 fish, including 34 white suckers. Only one fish, a white sucker, had any abnormalities. These consisted of small red spots on one side (Appendix E).

Pathology Exam

Newton Creek white sucker specimens with fin erosion were submitted to Vicki Blazer, a USGS fish pathologist. In addition to fin erosion, the examination found inflamed nerve endings, inflamed gut linings, and abnormal thyroid glands. Bacterial infection was not contributing to fin erosion.

Caged White Sucker Test

A caged white sucker test was conducted from November 21st to December 5th 2016 to provide some additional preliminary information before the onset of freezing winter temperatures. Three four inch white suckers were caged in each of two modified minnow traps. Vinyl coated wire minnow traps (16” length, 7-9” diameter) were modified by bending funnel ends outward and closing the openings. Suckers were obtained from a local bait shop.

One trap was placed in Newton Creek, just downstream of 21st St. The second trap was placed in Faxon Creek to serve as a control. Traps were retrieved after the two week exposure period. Only one sucker in each trap survived, with starvation probably causing the mortality. Demand for bait at that time of year is low, so the suckers had probably been held at the bait shop for an extended period and had depleted much of their energy reserves.

The surviving sucker from each creek are compared below (Figures 11 and 12):

Newton Creek white sucker (4.1 in. length). Notable abnormalities were:

- Caudal fin somewhat stiffened and easily split (2 splits visible in photo)
- Dorsal fin appears contracted
- Left pelvic fin 50% eroded
- Reddened areas on caudal, dorsal, anal, left pelvic and right pectoral (not visible in photo) fins, left gill cover, and ventral skin surface between anal and pelvic fins (mostly not visible in photo)

Figure 11. Caged White Sucker after 2 Weeks Exposure in Newton Creek.

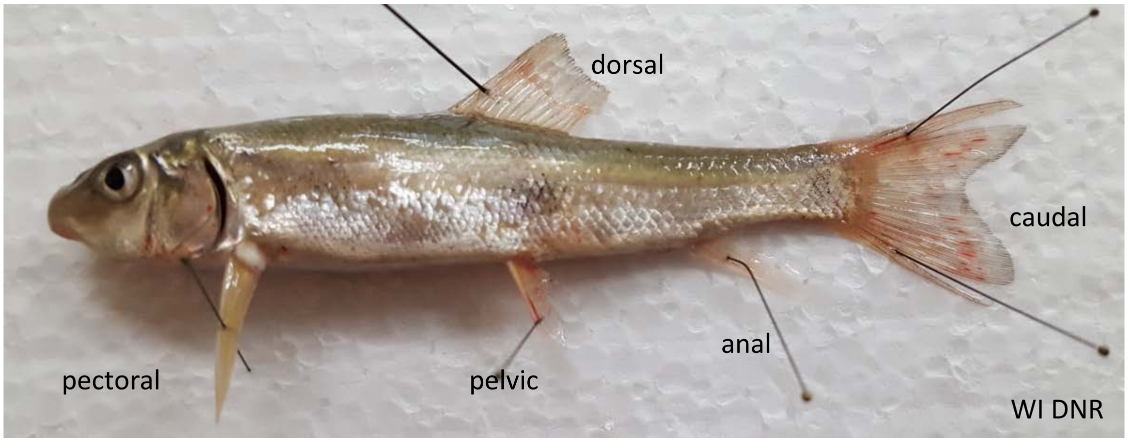
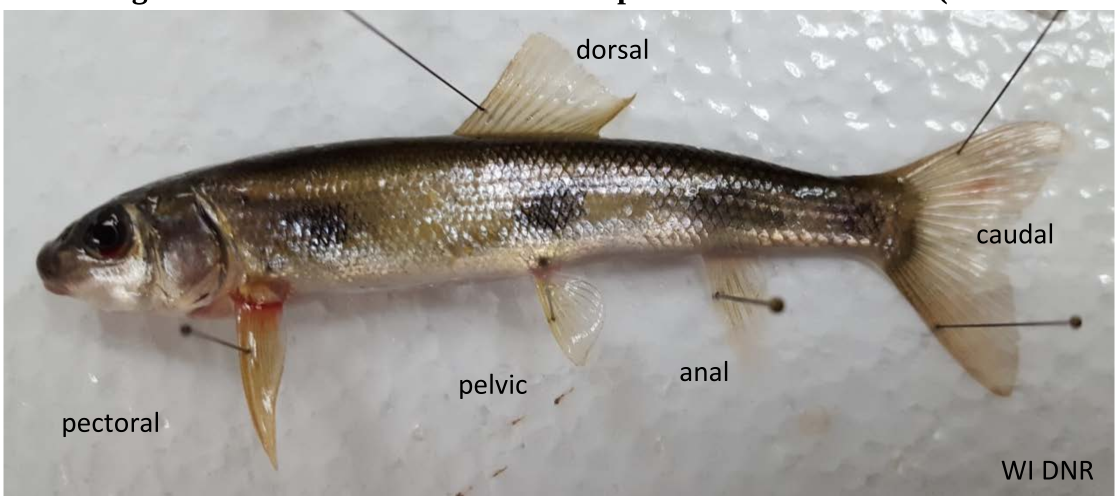


Figure 12. Caged White Sucker after 2 Weeks Exposure in Faxon Creek (Control Stream).



Faxon Creek (control stream) white sucker (4.1 in. length). Notable characteristics/abnormalities were:

- Caudal and dorsal fins very flexible
- Reddened area at base of left pectoral fin; small reddened area on caudal fin

The Newton Creek sucker had numerous abnormalities. The erosion of the left pelvic fin, the deterioration of the caudal fin and the numerous reddened areas are consistent with abnormalities observed in wild fish in Newton Creek. This strongly suggests that creek water contaminants present at the 21st St. site are causing abnormalities.

The Faxon Creek sucker had relatively minor abnormalities (2 reddened areas). These may have been due to handling, cage stress, or exposure to contaminants in Faxon Creek water. Oil sheens were observed on Faxon Creek on two dates in the fall of 2016.

Possible Causes of Fin Erosion

A literature review was conducted to determine potential causes of the fin erosion (Appendix G). The scientific research available indicated that fin erosion can result from both natural and anthropogenic causes. Natural causes of fin erosion and fin rot include aggressive behavior by other fish, exposure to extreme temperatures, and nutritional deficiencies. While fin erosion can be associated with a bacterial infection, the fish in Newton Creek that were examined by Vicki Blazer did not display any signs of a bacterial infection. The main anthropogenic cause is poor water quality. Fin erosion is often seen in polluted waters and has been observed in fish exposed to water contaminated with crude oil, pulp and paper mill effluent, mining tailings, heavy metals, and various organic pollutants (PAH's, PCB's, dioxin, DDT)(Appendix G).

Petroleum related compounds, heavy metals, PAH's and dioxin-furan congeners were found at varying levels in Newton Creek sediments and water. In Newton Creek sediments, PAH levels were generally below remediation goals for all sites, though elevated levels of petroleum hydrocarbons and invertebrate toxicity were evident in the 21st St. impoundment (see companion sediment report). This site is located at the uppermost section of the creek. Moles and Norcross (1998) associated fin erosion in juvenile flatfishes with oil contaminated sediment.

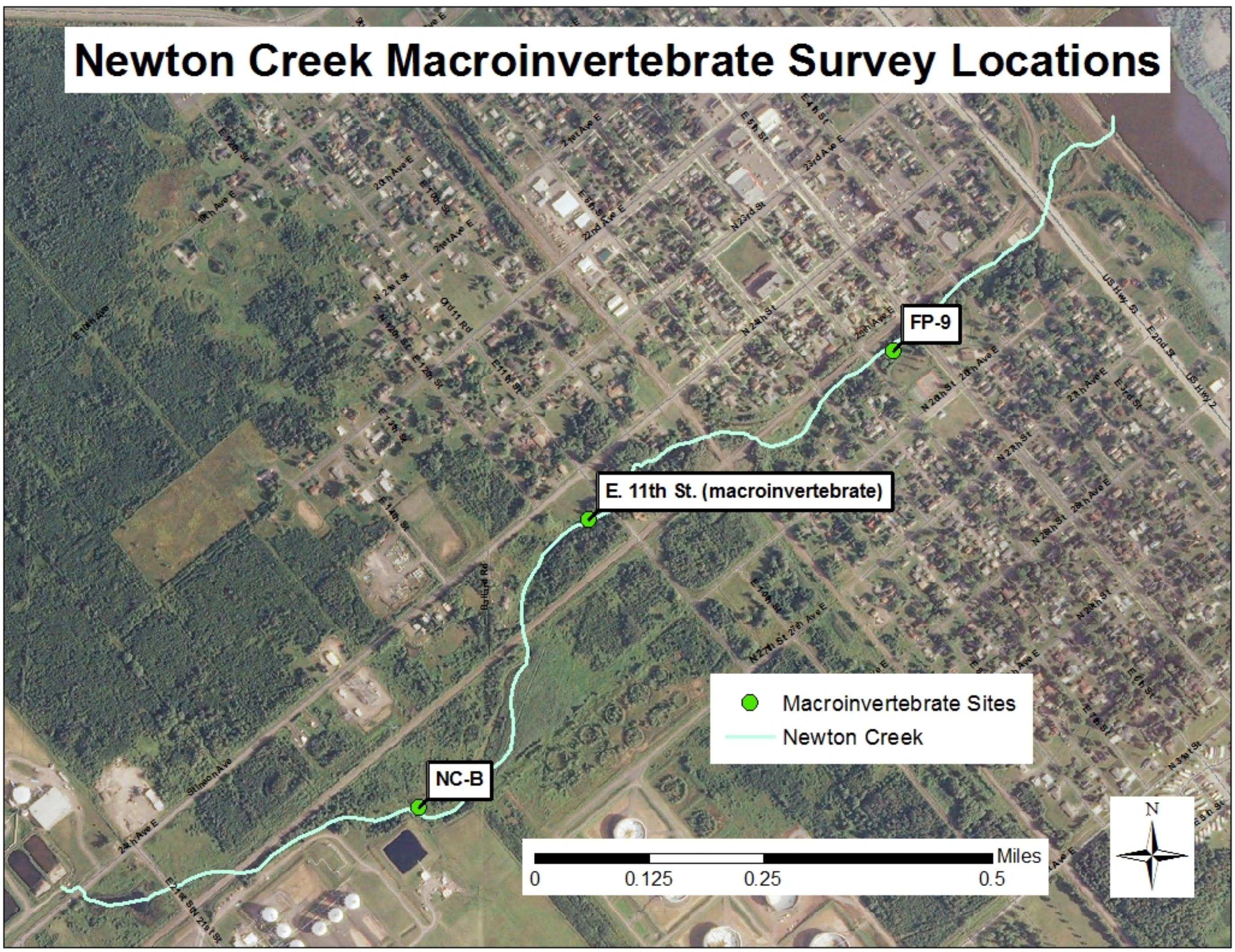
Petroleum related compounds were also present in Newton Creek water at 21st St., including diesel range organics, oil range organics, gasoline range organics, PAH's, naphthenic acids, molybdenum, and vanadium (table 1). Some or all of these substances may be contributing to fin erosion. Cutthroat trout exposed to an oil-water mixture in a laboratory experiment exhibited increased fin erosion with increased oil concentration (Woodward et al. 1981). A study done in the Alberta oil sands area found a correlation between naphthenic acids and fin erosion (Hogan et al.). Allen (2008) concluded that naphthenic acids are the primary source of acute toxicity in Canadian oil sands tailings pond water. A single sample collected from Newton Creek at 21st St. had a naphthenic acids concentration of 2.9 mg/l/. Further work is needed to ascertain the cause of fin erosion observed in Newton Creek.

Newton Creek Macroinvertebrate Samples

Macroinvertebrate samples were collected at three sites during October of 2016 (Figure 13). These sites were previously selected to evaluate macroinvertebrate samples in the creek following remediation actions. They were previously sampled during 2003-2010.

Table 7 lists the macroinvertebrate index of biotic integrity (MIBI) results from the 2016 samples along with past results for 2003-2010 fall-collected samples. In 2016, the furthest upstream site (NC-B) had an MIBI rating of fair while the two downstream sites (E. 11th St., Fp-9) had ratings of poor. Urban runoff probably contributes toward lower MIBIs. Site Fp-9 has the poorest mean MIBI; this site is the furthest downstream and is more likely influenced by the cumulative effects of urban runoff. While annual patterns in MIBIs are somewhat erratic, there is a trend towards lower mean MIBI values in recent years. Average MIBI values for the three most recent years of sampling (2009, 2010, 2016) were poor for all three sites. Average MIBI values for 2003-2008 samples were higher (Table 7).

Figure 13. Macroinvertebrate Sampling Locations on Newton Creek.



Net sweeps of overhanging vegetation in Newton Creek downstream of 21st St. found Odonates (dragonfly and damselfly nymphs) to be common. Virile crayfish (*Orconectes virilis*) were observed to be present in low numbers at the three fish survey sites. Bank burrows of devil crawfish (*Cambarus diogenes*) were observed downstream of 21st St. and one dead specimen was found in the creek, so this crayfish species is also present.

Table 7. Newton Creek Fall Macroinvertebrate IBI values for 2003-2016.

	NC-B		**E 11th St**		**Fp-9**	
Year	MIBI	Rating	MIBI	Rating	MIBI	Rating
2003	4.715	Fair	4.375	Fair	3.135	Fair
2004	4.37	Fair	2.635	Fair	3.81	Fair
2005	2.925	Fair	2.875	Fair	-0.425	Poor
2006	2.335	Poor	3.155	Fair	0.175	Poor
2007	6.725	Good	7.785	Excellent	2.115	Poor
2008	1.545	Poor	6.115	Good	2.065	Poor
2009	2.475	Poor	2.21	Poor	-0.265	Poor
2010	0.06	Poor	1.26	Poor	1.05	Poor
2011						
2012						
2013						
2014						
2015						
2016	3.75	Fair	1.38	Poor	1.415	Poor
2003-16 Mean	3.21	Fair	3.53	Fair	1.45	Poor
2009-16 Mean	2.10	Poor	1.62	Poor	0.73	Poor

Hog Island Inlet Aquatic Plant Survey

Point Intercept Survey

An aquatic plant (macrophyte) point intercept survey and meander survey were conducted on July 18-19, 2016. The point intercept survey consisted of sampling aquatic plants with a double sided rake on a pole at 100 predetermined locations set 25m apart. The meander survey followed an irregular path throughout the inlet looking for all potential plant species.

A list of plant species found and their relative abundance is shown in Table 8. A total of 56 species were found. Only 14 species were found in rake samples with the remainder found visually at point intercept sites or during the meander survey. Coontail (*Ceratophyllum demersum*) was the most frequently occurring species (30.8%) followed by small pondweed (*Potamogeton pusillus*)(21.2%).

Rising water levels in Lake Superior have been causing a landward shift in aquatic plant zones in recent years. In 2014, a landward shift in the zone of cattail growth was observed (Figure 14). In 2016, a die-off of speckled alders was observed, presumably also due to rising water levels (Figure 15).

Table 8. Hog Island Inlet Aquatic Plant Species and Abundance

Species	Common Name	Frequency of Occurrence (%)[1]
Acorus calamus	sweet flag	ND
Alnus rugose	speckled alder	ND
Asclepias ircarnata	swamp milkweed	ND
Bidens vulgatus	beggar-ticks	ND
Bolboschoenus fluviatilis	river bulrush	ND
Calamagrostis canadensis	canada bluejoint grass	ND
Carex pseudocyperus	cypress-like sedge	3.85
Carex pseudocyperus	cypress-like sedge	ND
Ceratophyllum demersum	coontail	30.77
Cicuta bulbifera	bulb-bearing water hemlock	ND
Eleocharis palustris	common spikerush	ND
Elodea canadensis	common waterweed	1.92
(Filamentous algae)	filamentous algae	1.92
Iris pseudacorus	yellow iris	ND
Iris versicolor	northern blue flag	ND
Juncus arcticus	arctic rush	ND
Lemna minor	small duckweed	ND
Lemna minor	small duckweed	ND
Lythrum salicaria	purple loosestrife	ND
Myrica gale	sweetgale	ND
Myriophullum sibiricum	northern water milfoil	ND
Myriophyllum spicatum	eurasian water milfoil	ND
Najas flexilis	slender naiad	1.92

Nitella sp.	nitella	3.85
Nuphar variegata	spatterdock	ND
Nymphaea odorata	white water lily	1.92
Phalaris arundinacea	reed canary grass	1.92
Phragmites australis americanus	native common reed	ND
Agrostis gigantea	redtop	ND
Potamogeton crispus	curly-leaf pondweed	ND
Potamogeton epihydrus	ribbon-leaf pondweed	1.92
Potamogeton nodosus	longleaf pondweed	ND
Potamogeton praelongus	white-stem pondweed	ND
Potamogeton pusillus	small pondweed	21.15
Potamogeton richardsonii	clasping pondweed	ND
Potamogeton spirillus	spiral-fruited pondweed	ND
Potamogeton zosteriformis	flat-stem pondweed	ND
Potentilla palustris	marsh cinquefoil	ND
Riccia fluitans	slender riccia	ND
Sagittaria cuneata	arumleaf arrowhead	ND
Sagittaria latifolia	common arrowhead	ND
Salix exigua	narrowleaf willow	ND
Salix petiolaris	meadow willow	ND
Scirpus cyperinus	woolgrass	ND
Scirpus tabernaemontans	soft stemmed bulrush	ND
Sium suave	water parsnip	ND
Sparganium eurycarpum	common bur-reed	ND
Sparganium fluctuans	floating bur-reed	1.92
Spirodela polyrhiza	large duckweed	ND
Stuckenia pectinata	sago pondweed	1.92
Typha angustifolia	narrow-leaved cattail	ND
Typha angustifolia x latifolia	hybrid cattail	1.92
Typha latifolia	broad leaved cattail	ND
Utricularia vulgaris	common bladderwort	ND
Vallisneria americana	wild celery	1.92

[1]Calculated at Sites Shallower than Maximum Depth of Plant Growth. ND = not collected in rake samples.

Figure 14. Shifting Emergent Plant Zone Edge in 2014 at Hog Island Inlet.

Figure 15. Die-off of Speckled Alders in 2016 at Hog Island Inlet.

Plant distribution and abundance is shown in Figure 16. The distribution and density of aquatic plants in 2016 has increased since 2014. Of the 100 sites visited in 2016, 52 were in the littoral zone (depths ≤5.1 feet; maximum depth of pant growth). Through rake sampling, 21 (40.4%) of the littoral sites were found to have plants. Density of plants was low with a mean rake density of 1.29. A rake fullness of 1 is the lowest possible rake density and indicates one to a few plants on the rake (Figure 16). Plant abundance between surveys can be roughly compared by multiplying the number of sites with aquatic plants present times the average rake fullness rating (Table 9).

Figure 16. Hog Island Inlet Aquatic Plant Abundance.

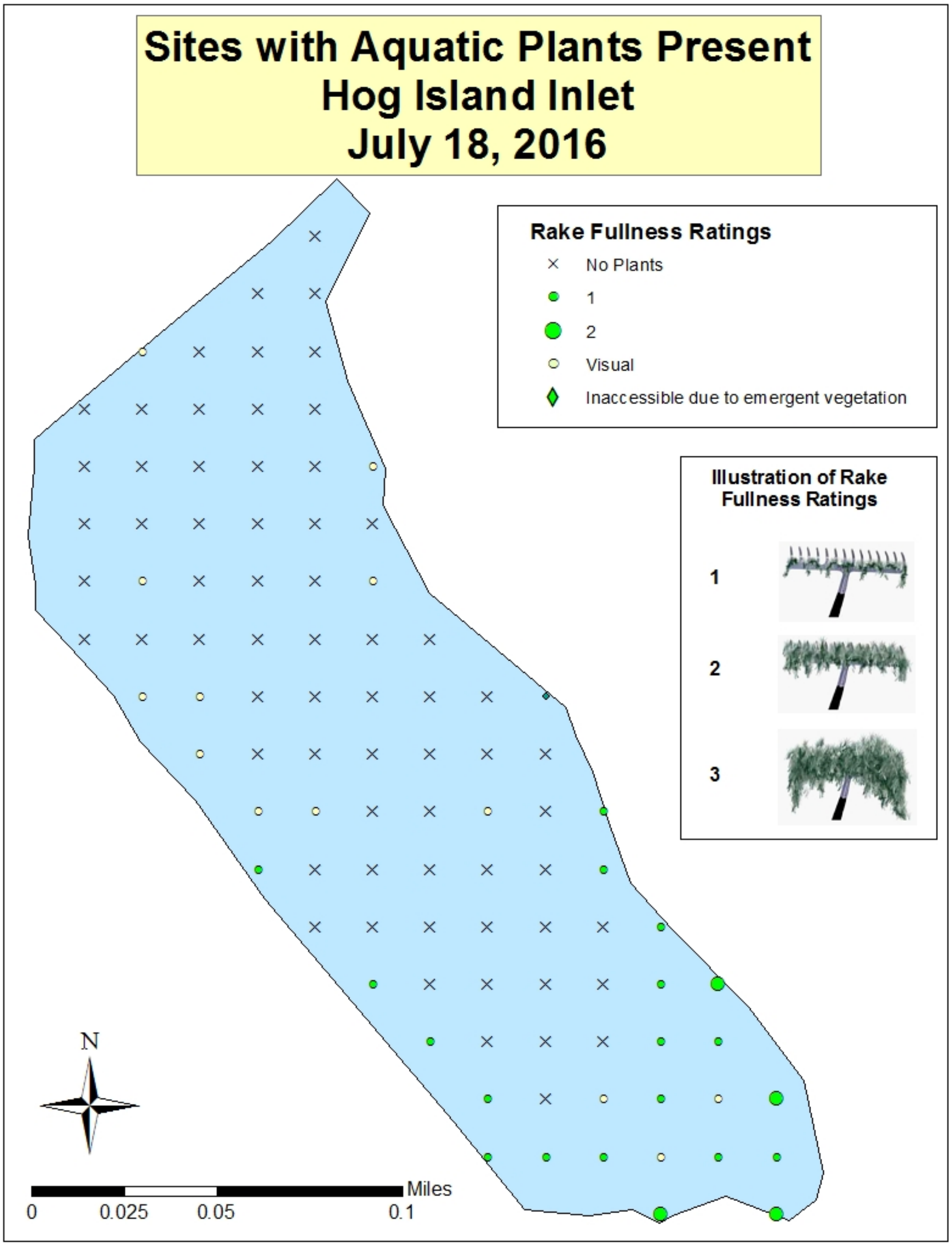


Table 9. Plant Abundance in Hog Island Inlet for all Survey Years.

Year	No. of Littoral Sites with Plants	Average Rake Fullness	No. Sites x Rake Fullness
2008	10	1.11	11.1
2010	40	2.24	89.6
2014	7	1.14	8.0
2016	21	1.29	27.1

Plant abundance in 2008 was believed to be low because dredging took place in 2005, which left a hard clay substrate across much of the inlet. Increasing deposition of fine sediment may have allowed improved plant abundance in 2010. A major flood event occurred in 2012 and plant burial by heavy deposition of fine sediment may have suppressed plant abundance in 2014. Increased plant abundance is seen in 2016, but field observations suggest there may still be limitations to optimal plant growth in the inlet.

There is a small bay to the southeast of the inlet by Loon's Foot Landing referred to as Loon's Foot Bay (Figure 17). It is separated from the inlet by an emergent wetland isthmus. It has been used as a reference site for the inlet for various comparisons since site investigations began in 1994. Transparency measurements in this bay were identical to those in the inlet on multiple summer dates. Water depths range from 0-4.6 ft, which is close to the littoral zone depth for Hog Island Inlet (0-5.1 ft). Photos comparing sites of maximum aquatic plant density for the inlet and the bay are shown in Figures 18 and 19. Photos comparing sites of maximum *Vallisneria americana* (wild celery) density for the inlet and the bay are shown in Figures 20 and 21.

Figure 17. Locations of Hog Island Inlet and Loon's Foot Bay.

Figure 18. Maximum Density of Aquatic Plants in Hog Island Inlet.

Figure 19. Maximum Density of Aquatic Plants in Loon's Foot Bay.

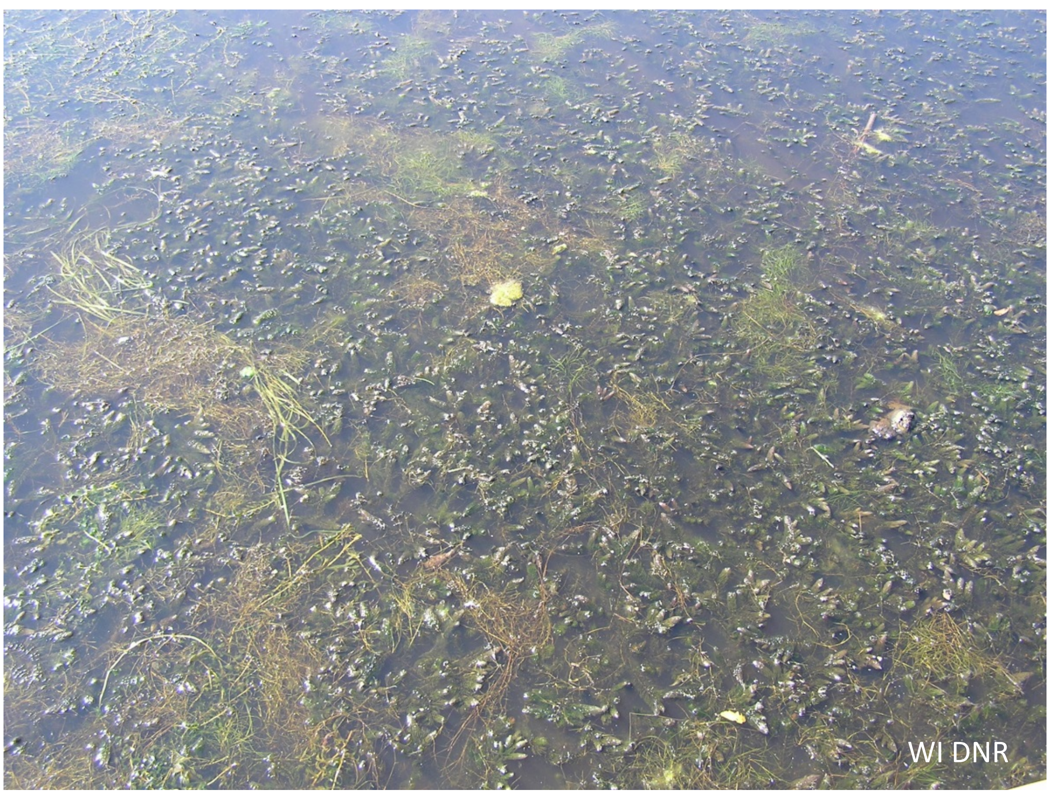


Figure 20. Maximum Density of *Vallisneria americana* in Hog Island Inlet.

Figure 21. Maximum Density of *Vallisneria americana* in Loon's Foot Bay.

The cause of potentially sub-optimal macrophyte growth in Hog Island Inlet is uncertain. The observed toxicity to algal growth in Newton Creek samples suggests phytotoxic compounds may be present in the water column. The sediment in Hog Island Inlet has higher concentrations of polycyclic aromatic hydrocarbon (PAH) compounds and total petroleum hydrocarbon (TPH) compounds than the sediment in Loon's Foot Bay (see companion sediment report). These might also affect plant growth.

Alternatively, higher nutrient concentrations in Hog Island Inlet may support increased growth of epiphytic diatoms on macrophytes. This could reduce the vigor of macrophytes by reducing photosynthesis.

Substrate Physical Characteristics Observed During Aquatic Plant Survey

Substrate composition and distribution is described below:

- Silt (or sandy silt, silty sand) at 90% of sites
- Sand at 4% of sites
- Clay at 0% of sites
- Fibric organic matter (or coarse detritus) at 4% of sites
- Partial to full presence of woody material at 6% of sites
- Partial to full presence of gravel or cobble at 10% of sites

Percentages do not total 100% since woody material and gravel/cobble were mixed with other substrates at some sites.

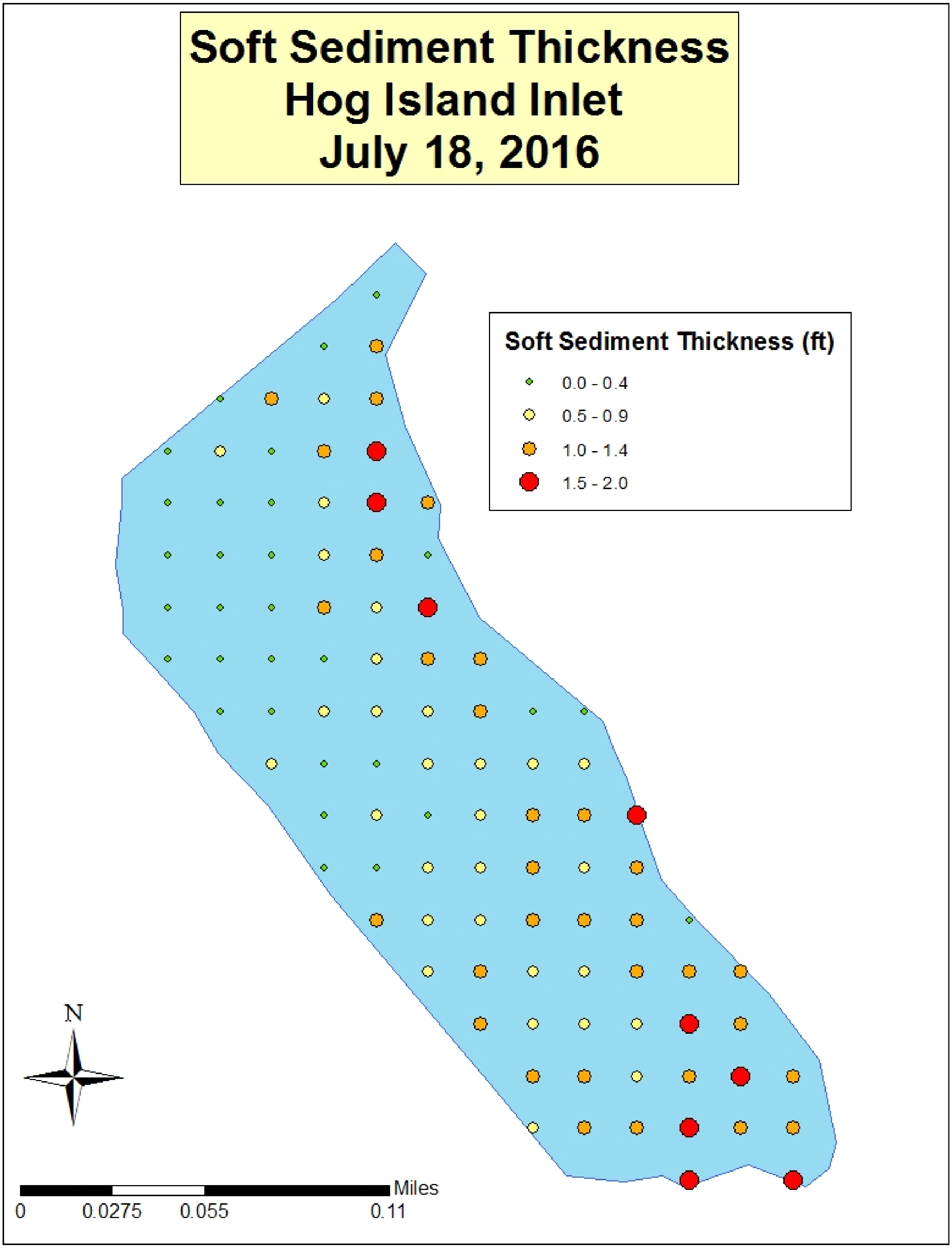
Deposition of fine sediment and organic matter has been ongoing since the inlet was dredged in 2005, which left a hard clay substrate in most areas. In 2008, 57% of sites were described as clay substrate and 18% of the sites had hard material substrates (sand, gravel, rock). By 2014, only 20% of sites were described as clay substrate. In 2016, 0% of sites were described as clay substrates. The silty material that now dominates the inlet's substrate appears to be physically suitable for supporting rooted aquatic plants.

The substrate in Loon's Foot Bay appeared similar to that in Hog Island Inlet. One sediment sample collected in Loon's Foot Bay had a higher silt content and lower clay content than the samples from Hog Island Inlet (see companion sediment report).

Hog Island Inlet Soft Sediment Thickness Survey

Soft sediment thickness was measured by probing with a 1.75 in. diameter aluminum pole at point intercept plant survey sites. Sediment thickness is shown in Figure 22. A sediment thickness of $\geq$ 0.5 ft is present at most locations in the inlet. This is adequate to support aquatic plant growth. Sediment is generally thinnest between the mouth of Newton Creek and the outlet that connects the inlet to the rest of the St. Louis River estuary. Seiche-driven inflow and outflow and flood flows from Newton Creek produce enough current velocity to minimize sediment deposition in this area.

Figure 22. Soft Sediment Thickness in Hog Island Inlet.

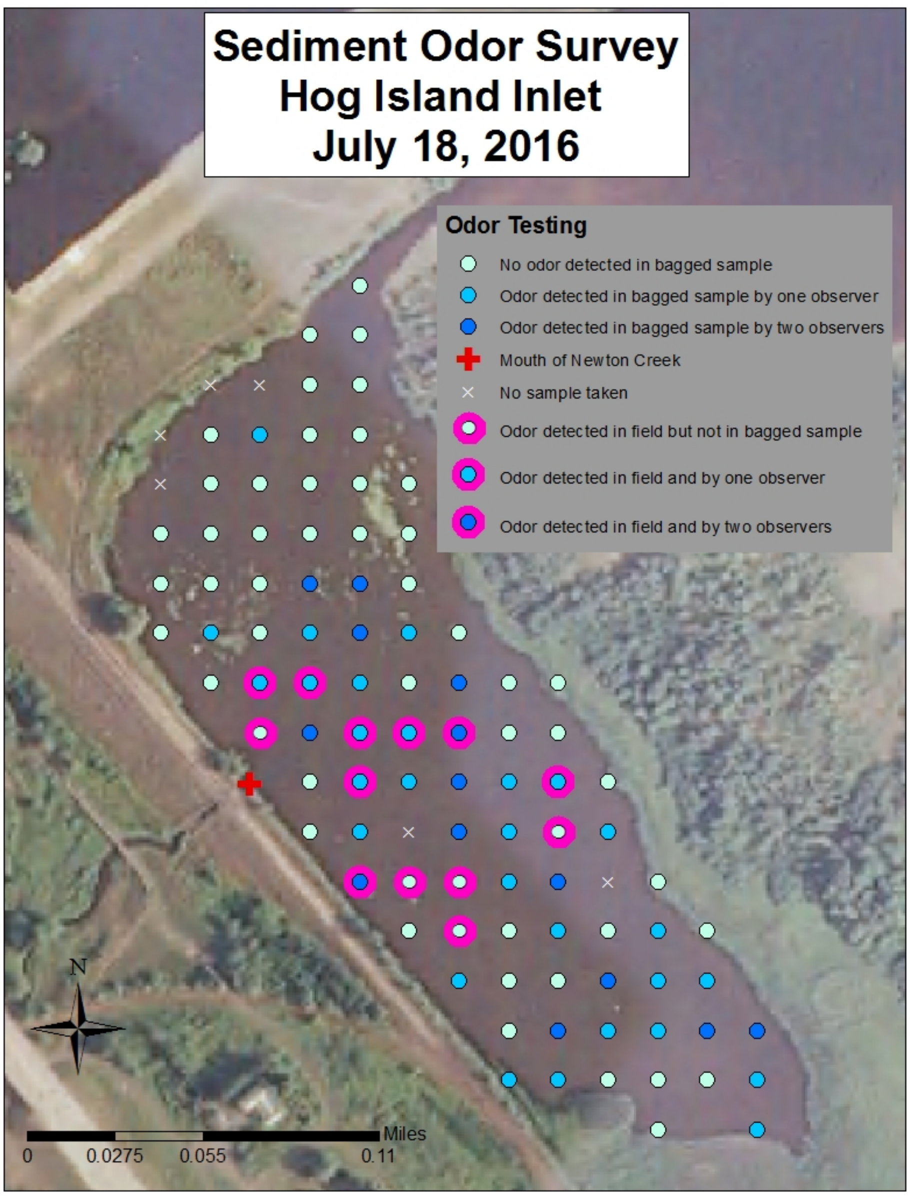


Hog Island Inlet Sediment Odor Survey

A petroleum-like odor was noted at several sites in the field during rake collection of aquatic macrophytes. Soft sediment samples were also collected in zipper-seal type plastic bags that were later opened and smelled by two observers. This approach had limitations, since the small air space in the bag was quickly flushed upon opening. The first observer detected odor more frequently than the second observer. However, it did provide some additional qualitative information on the presence of odor in the sediment. Observations of sediment odor are shown in Figure 23.

Field-observed odor was most frequently noted in depositional areas near the mouth of Newton Creek. The northwest end of the inlet had the least odor noted. Sediment flushing and mixing of St. Louis River estuary water is most pronounced in this area.

Figure 23. Hog Island Inlet Sediment Odor Survey.



Hog Island Inlet Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate samples were collected with a petite ponar at nine sites in Hog Island Inlet and three sites in the Loon's Foot Bay reference area (Figure 24). Complete sample results are shown in Appendix F. A recently developed trimetric index for the St. Louis River Estuary (Angradi et al. 2016) was used to judge the quality of the benthic macroinvertebrate community relative to other estuary sites. Trimetric index values along with the associated ephemerid index values are shown in Table 10.

Figure 24. Macroinvertebrate Sampling Sites for Hog Island Inlet (HI and HOG sites) and Loon's Foot Bay (WI sites).

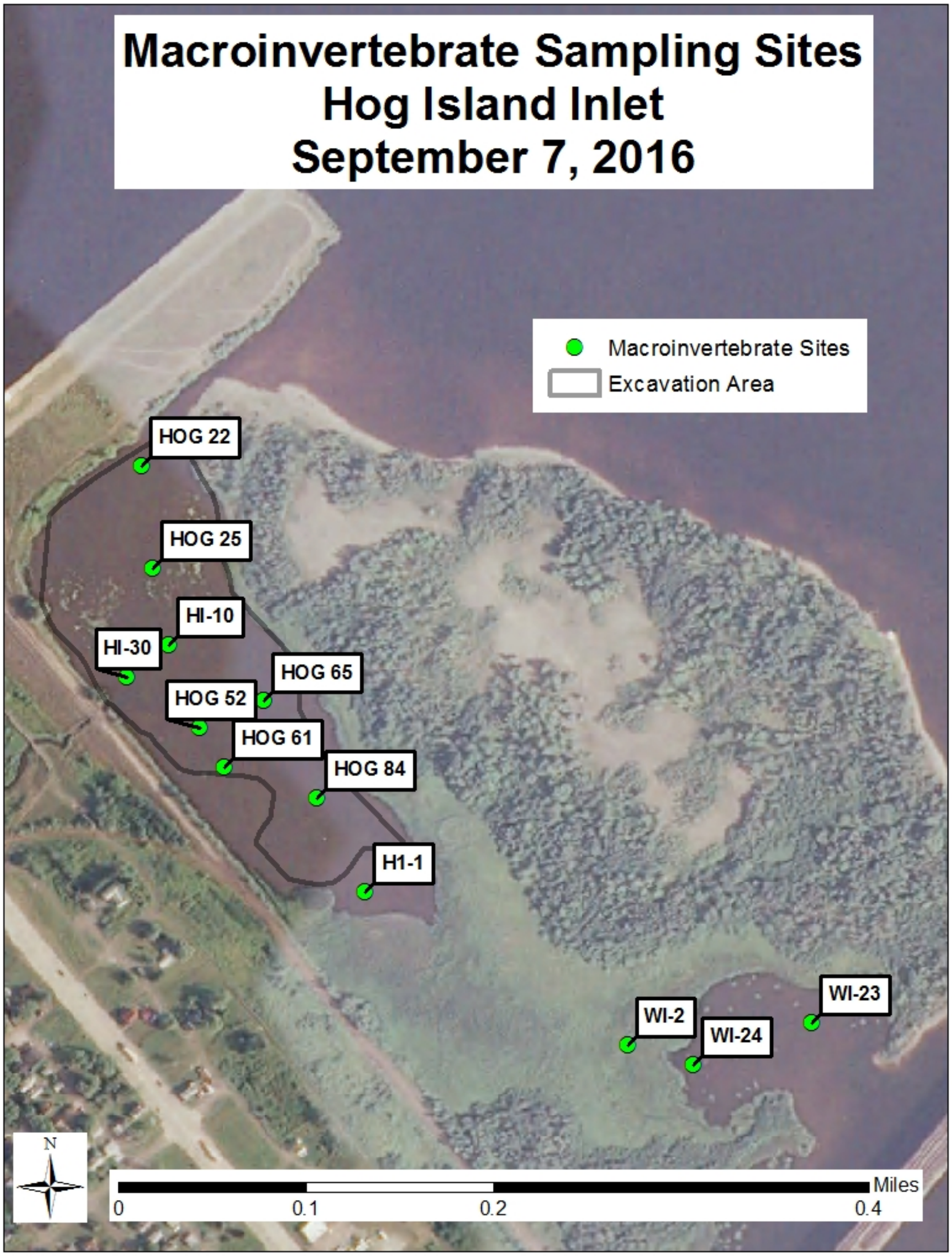


Table 10. Trimetric Conditions and Ephemerid Density Conditions for Benthic Macroinvertebrate Samples from Hog Island Inlet (HI and HOG sites) and the Loon's Foot Bay Reference Area (WI sites).

Site	Scaled Trimetric Index	Superior Bay* Depth Adjusted Trimetric Condition	Spirit Lake* Depth Adjusted Trimetric Condition	Superior Bay Epemerid Density Depth Adjusted Condition	Spirit Lake Epemerid Density Depth Adjusted Condition	Depth (m)
WI-2	0.542	Good	Good	Poor	Poor	0.70
WI-23	0.573	Excellent	Good	Poor	Poor	1.28
WI-24	0.431	Good	Poor	Poor	Poor	0.98
H1-1	0.544	Excellent	Good	Poor	Poor	0.88
HI-10	0.577	Excellent	Excellent	Good	Excellent	1.77
HOG 22	0.511	Excellent	Excellent	Excellent	Excellent	3.05
HOG 25	0.482	Good	Good	Good	Good	2.23
HI-30	0.475	Good	Good	Poor	Poor	1.74
HOG 52	0.449	Good	Fair	Poor	Poor	1.83
HOG 61	0.531	Good	Good	Good	Good	0.98
HOG 65	0.364	Fair	Poor	Poor	Poor	1.86
HOG 65-DUP	0.311	Poor	Poor	Poor	Poor	1.86
HOG 84	0.278	Poor	Poor	Poor	Poor	2.10
					Mean depth of Hog Island sites	1.83

*For the SLRE trimetric index, condition thresholds are lowest for Superior Bay and highest for Spirit Lake
Sites used for index development had mean depths of 5.0 m for Superior Bay and 1.8 m for Spirit Lake

Trimetric condition at most sites scored good to excellent when the Superior Bay zone condition thresholds are applied. The site with duplicate samples (HOG 65, HOG 65-DUP) straddled the fair/poor threshold, but the average of the two values indicates a fair condition. Site HOG 84 scored poor. Hog Island Inlet is located in the Superior Bay zone as defined for the trimetric index. However, the mean depth of samples used to develop the Superior Bay zone trimetric index was 5.0 m. The mean depth of samples used to develop the Spirit Lake zone trimetric index was 1.8 m, which is close to the mean depth of samples from Hog Island Inlet (1.83 m). The Spirit Lake zone trimetric index may be more reflective of the characteristics of Hog Island Inlet. Applying the Spirit Lake zone trimetric index still results in most sites scoring fair to excellent. However, one additional Hog Island Inlet site and one Loon's Foot Bay site change to a poor condition.

Absence of ephemerids (*Hexagenia* mayfly nymphs) resulted in poor condition ratings for Superior Bay ephemerid density condition at five of the nine sites in Hog Island Inlet. Four sites in Hog Island Inlet had good to excellent ephemerid density condition ratings. All three Loon's Foot Bay area sites were also lacking ephemerids. The reason for the limited distribution of ephemerids in these areas is unknown. Application of Spirit Lake zone ephemerid density conditions raises the rating for one Hog Island Inlet site from good to excellent.

Overall, average conditions in Hog Island Inlet indicate reasonably good benthic macroinvertebrate communities relative to other sites in the St. Louis River Estuary including the Loon's Foot Bay reference area.

Hog Island Inlet Fish Survey

An electrofishing survey was conducted at Hog Island Inlet on July 12, 2016. A mini boom shocker traveled around the near shore perimeter (1.84 km). Standard protocols for large river fish surveys were followed. Runoff from heavy rain the night before reduced water clarity and probably limited fish capture. All fish observed were targeted for capture. Fish captured are listed below in Table 11.

Table 11. Hog Island Inlet Electrofishing Survey Results July 12, 2016.

Fish species	No. caught	Net weight (g or kg)
Carp	4	24.97 kg
Spottail shiner	5	10 g
Shorthead redhorse	2	2.01 kg
Silver redhorse	1	1.61 kg
Yellow perch	6	147 g
Emerald shiner	9	23 g
Golden shiner	27	102 g
White sucker	1	10 g
Common shiner	3	4 g
Bluegill x pumpkinseed	3	18 g

Number of species captured = 10 (2 additional species observed, 2 small muskellunge and 1 black crappie)

Ten fish species were captured, and two additional species were observed. Golden shiners were the most abundant species. Due to the unique characteristics of Hog Island Inlet (a sheltered bay in an estuary) there is not a fish index of biotic integrity that is appropriate to apply. The fish community observed indicates reasonably good conditions and is fairly typical of fish communities found elsewhere in the lower St. Louis River Estuary (Piszczek, pers. comm. 2017).

References

Allen, E.W. (2008). Process water treatment in Canada's oil sands industry: I. Target pollutants and treatment objectives. *Journal of Environmental Engineering Science.* 7: 123-138

Angradi, T.R., Bartsch, W.M., Trebitz, A.S., Brady, V.J., Launspach, J.L. (2016). A depth-adjusted distribution approach for setting numeric removal targets for a Great Lakes Area of Concern beneficial use impairment: Degraded benthos. *Journal of Great Lakes Research.* http//dx.doi.org/10.1016/j.jglr.2016.11.006

Eisler, R. (1989). Molybdenum hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv., Biol. Rep 85 (1.19). 61 pp.

Graham, J.R. and Roesler, C.P. (2015). Newton Creek and Hog Island Inlet post-remediation assessment. Unpublished Wisconsin Dept. of Natural Resources report. 45 pp.

Hogan, N.S. et al. Opportunistic disease in yellow perch in response to decadal changes in the chemistry of oil sands-affected water, unpublished

Moles, A. et al. (1998) Effects of oil-laden sediments on growth and health of juvenile flatfishes. *Canadian Journal of Fish and Aquatic Sciences.* 55: 605-610

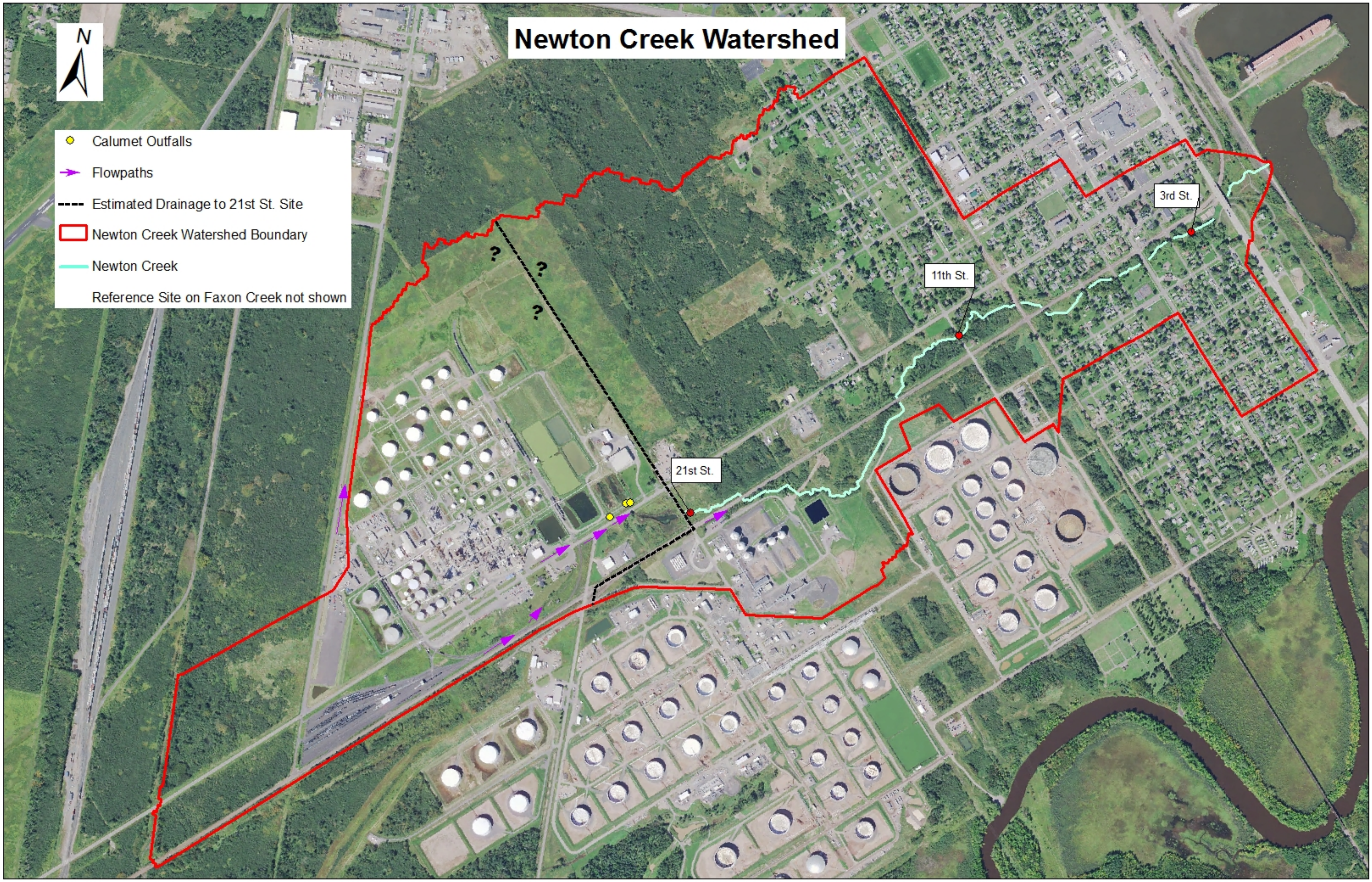
NOAA. (2008). Screening quick reference tables. http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html

Piszczek, P. (2017). Personal communication. Wisconsin Dept. of Natural Resources Fisheries Manager. Superior, WI.

Schwalb, A.N. et al. (2015) Changes in migratory fish communities and their health, hydrology, and water chemistry in rivers of the Athabasca oil sands region: a review of histological and current data. *Environmental Review.* 23: 133-150

Sprague, J.B., Holdway, D.A., Stendahl, D. (1978). Acute and chronic toxicity of vanadium to fish. Alberta Oil Sands Env. Res. Program. Project AF 3.5.1.

Appendix A. Newton Creek Watershed Map.



Appendix B. Newton Creek Water Chemistry Results for Metals, TPH's, VOC's and Other Parameters.

	21st Street			3rd Street	
Parameter	17-Aug-16	31-Oct-16	9-Jan-17*	17-Aug-16	31-Oct-16
Oil and Grease (mg/L)	< 1.1	< 1.1	< 1.1	< 1.1	< 1.1
Chloride (mg/L)	178	274	317	156	265
Sulfate (mg/L)	81.5	147	138	69.1	144
Nitrogen, Ammonia (mg/L)	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Phenol (ug/L)	38.3	< 3.4	< 3.4	12.0	< 3.4
TPH (C06-C10) (mg/L)	< 0.0741	0.568	< 0.0741	< 0.0741	0.102
TPH (C10-C20) (mg/L)	0.97	1.7	1.9	0.65	1.6
TPH (C20-C34) (mg/L)	0.55	0.79	0.95	0.35	0.70
Total TPH (ΣGRO+DRO+ORO) (mg/L)	1.5941	3.058	2.9241	1.0741	2.402
Antimony (ug/L)	< 7.3	< 7.6	< 7.6	< 7.3	< 7.6
Beryllium (ug/L)	< 0.68	< 1.2	< 1.2	< 0.68	< 1.2
Cadmium (ug/L)	< 1.0	< 1.3	< 1.3	< 1.0	< 1.3
Chromium (ug/L)	< 1.5	< 2.5	< 2.5	< 1.5	< 2.5
Copper (ug/L)	< 3.4	< 6.3	< 6.3	< 3.4	< 6.3
Lead (ug/L)	< 1.6	< 4.3	< 4.3	< 1.6	< 4.3
Molybdenum (ug/L)	< 2.5	13.8	< 1.4	< 2.5	11.8
Nickel (ug/L)	< 1.3	< 2.6	< 2.6	< 1.3	< 2.6
Vanadium (ug/L)	< 2.5	19.4	14.8	< 2.5	11.6
Zinc (ug/L)	< 5.8	< 9.3	< 9.3	< 5.8	< 9.3
Mercury (ug/L)	< 0.13	< 0.13	< 0.13	< 0.13	< 0.13
1,2,4-Trichlorobenzene (ug/L)	< 2.2	< 2.2	NA	< 2.2	< 2.2
1,2-Dichlorobenzene (ug/L)	< 0.50	< 0.50	NA	< 0.50	< 0.50
1,4-Dichlorobenzene (ug/L)	< 0.50	< 0.50	NA	< 0.50	< 0.50
Benzene (ug/L)	< 0.50	< 0.50	NA	< 0.50	< 0.50
Cyclohexane (ug/L)	< 0.88	< 0.88	NA	< 0.88	< 0.88
Ethylbenzene (ug/L)	< 0.50	< 0.50	NA	< 0.50	< 0.50
Isopropylbenzene (Cumene) (ug/L)	< 0.14	< 0.14	NA	< 0.14	< 0.14
Methylcyclohexane (ug/L)	< 2.3	< 2.3	NA	< 2.3	< 2.3
Toluene (ug/L)	< 0.50	< 0.50	NA	< 0.50	< 0.50
m&p-Xylene (ug/L)	< 1.0	< 1.0	NA	< 1.0	< 1.0
o-Xylene (ug/L)	< 0.50	< 0.50	NA	< 0.50	< 0.50

*Sample was received without ice present and at 19°C. VOC's were not tested.

Appendix C. Newton Creek Water Chemistry Results for individual PAH compounds.

	21st Street					3rd Street		
PAH's (ug/L)	17-Aug-16	31-Oct-16		9-Jan-17*		17-Aug-16	31-Oct-16	
1-Methylnaphthalene [(a)]	< 0.0091	< 0.0089		< 0.0091		< 0.0091	< 0.0089	
2-Methylnaphthalene [(a)]	< 0.011	0.042		< 0.011		< 0.011	0.035	J
Acenaphthene[(a)]	0.098	< 0.010		0.089		0.089	0.17	
Acenaphthylene[(a)]	0.053	0.053		< 0.0093		< 0.0093	0.073	
Anthracene[(a)]	< 0.010	0.017	J	< 0.010		< 0.010	0.017	J
Benzo(a)anthracene[(a)]	< 0.013	< 0.013		< 0.013		< 0.013	< 0.013	
Benzo(a)pyrene[(a)]	< 0.013	< 0.013		< 0.013		< 0.013	< 0.013	
Benzo(b)fluoranthene[(a)]	0.050	< 0.016		< 0.016		0.086	< 0.016	
Benzo(e)pyrene	< 0.010	< 0.0098		< 0.010		0.071	< 0.0098	
Benzo(g,h,i)perylene[(a)]	< 0.019	< 0.019		< 0.019		< 0.019	< 0.019	
Benzo(k)fluoranthene[(a)]	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C1-Chrysenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C1-Fluoranthenes/Pyrenes	< 0.020	< 0.020		0.13		< 0.020	< 0.020	
C1-Fluorenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C1-Naphthalenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C1-Phenanthrenes/Anthracenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C2-Chrysenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C2-Fluorenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C2-Naphthalenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C2-Phenanthrenes/Anthracenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C3-Chrysenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C3-Fluorenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C3-Naphthalenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C3-Phenanthrenes/Anthracenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	
C4-Chrysenes	< 0.020	< 0.020		< 0.020		< 0.020	< 0.020	

C4-Naphthalenes	< 0.020		< 0.020		1.2		< 0.020		< 0.020	
C4-Phenanthrenes/Anthracenes	< 0.020		< 0.020		< 0.020		< 0.020		< 0.020	
Chrysene[a]	< 0.014		< 0.014		< 0.014		< 0.014		< 0.014	
Dibenz(a,h)anthracene[a]	< 0.017		< 0.017		< 0.017		< 0.017		< 0.017	
Fluoranthene[a]	< 0.011		< 0.011		< 0.011		0.048		< 0.011	
Fluorene[a]	< 0.0090		0.086		0.094		< 0.0090		0.084	
Indeno(1,2,3-cd)pyrene[a]	< 0.020		< 0.020		< 0.020		< 0.020		< 0.020	
Naphthalene[a]	< 0.012		< 0.012		< 0.012		< 0.012		< 0.012	
Perylene	< 0.013		< 0.013		< 0.013		0.043		< 0.013	
Phenanthrene[a]	< 0.0081		0.020	J	< 0.0081		< 0.0081		< 0.0079	
Pyrene[a]	< 0.011		0.021	J	< 0.011		< 0.011		0.012	J
TPAH18[1]	0.2996		0.32595		0.28975		0.32075		0.4769	
TPAH36[2]	0.4711		0.49735		1.77125		0.59475		0.6483	

(a) compounds included in the TPAH18

1 TPAH18 (ug/kg) summation done using same 18 individual compounds as the sediment chemistry. Any nondetects had the detection level used instead when nondetects were <40%. When nondetects were >40%, half of the detection level was used for nondetects. Any data with qualifiers used the number reported.

2 TPAH36 (ug/kg) was calculated by summing all measured PAHs. C2-Fluoranthenes/Pyrenes and C3-Fluoranthenes/Pyrenes were not analyzed for water samples. Any nondetects had the detection level used instead when nondetects were <40%. When nondetects were >40%, half of the detection level was used for nondetects. Any data with qualifiers used the number reported.

*Sample was received without ice present and at 19°C.

J-Estimated concentration at or above the level of detection and below the level of quantitation.

Appendix D. Newton Creek Water Chemistry Results for Dioxin Furan Congeners.

	21st Street*				3rd Street			
Dioxins (pg/L)	17-Aug-16		31-Oct-16		17-Aug-16		31-Oct-16	
2,3,7,8-TetraCDD	< 0.84		< 0.68		< 0.77		< 0.61	
1,2,3,7,8-PentaCDD	< 0.57		< 0.74		< 0.87		< 0.84	
1,2,3,4,7,8-HexaCDD	< 0.64		< 0.46		< 0.95		< 0.68	
1,2,3,6,7,8-HexaCDD	< 0.69		< 0.47		< 1.20		< 0.82	
1,2,3,7,8,9-HexaCDD	< 0.94		< 0.40		< 0.88		< 0.64	
1,2,3,4,6,7,8-HeptaCDD	5.0	BJ	0.75	IJ	7.9	BJ	1.0	J
OctaCDD	39.0	BJ	4.4	J	57.0	BJ	6.8	J
Furans (pg/L)								
2,3,7,8-TetraCDF	< 0.51		< 0.57		< 0.67		< 0.61	
2,3,4,7,8-PentaCDF	< 0.32		< 0.52		< 0.43		< 0.56	
1,2,3,7,8-PentaCDF	< 0.50		< 1.00		< 0.79		< 0.99	
1,2,3,4,7,8-HexaCDF	< 0.55		< 0.36		< 1.40		< 0.41	
1,2,3,6,7,8-HexaCDF	< 0.65		< 0.29		< 1.00		< 0.39	
2,3,4,6,7,8-HexaCDF	< 0.55		< 0.28		< 0.97		< 0.36	
1,2,3,7,8,9-HexaCDF	< 0.64		< 0.44		< 1.10		< 0.46	
1,2,3,4,6,7,8-HeptaCDF	< 1.20		< 0.29		1.9	IJ	< 0.40	
1,2,3,4,7,8,9-HeptaCDF	< 2.00		< 0.58		< 2.80		< 0.57	
OctaCDF	16	IJ	< 0.73		24.0	IJ	< 0.86	

B-less than 10X higher than method blank level

I-Interference present

J-Estimated concentration at or above the level of detection and below the level of quantitation.

*January 9, 2017 water sample from 21st Street was not analyzed for dioxins and furans.

Appendix E. Newton Creek Fin Loss Observations.

date	site	species	Length (in)	count	% FIN LOSS caudal	anal	dorsal	pelvic	pectoral	other irregularities	Comments
06/13/2016	3rd St.	white sucker	-	1	X	X	X	X	X		Fins reduced to nubs. Only fish noticed with fin erosion in the June sampling for all three sites
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	X	0	0	0	X		15% fin erosion
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	brook stickleback	-	1	0	0	0	0	0		
09/15/2016	11th St.	white sucker	-	1	X	X	X	X	X		all fins 75-90% eroded
09/15/2016	11th St.	white sucker	-	1	X	X	X	1 fin	0		50-90% eroded
09/15/2016	11th St.	white sucker	-	1	X	X	X	1 fin	1 fin		50-80% eroded
09/15/2016	11th St.	white sucker	-	1	0	0	0	0	0		smaller fish
09/15/2016	11th St.	white sucker	-	1	0	0	0	0	0		smaller fish
09/15/2016	11th St.	creek chub	-	1	50	0	0	0	0	only caudal fin noted	creek chubs seemed to have internal gas (body cavity or gastrointestinal)
09/15/2016	11th St.	creek chub	-	1	20	0	50	0	30	anal, pelvic, pectoral, and under jaw reddened	
09/15/2016	11th St.	creek chub	-	1	0	0	80	75	70	lower jaw, pectoral, pelvic, anal and caudal reddened	
09/15/2016	21st St.	brook stickleback	-	1	15	0	0	0	15	red spots on gill plates and pectoral fin bases	
09/15/2016	21st St.	brook stickleback	-	43	0	0	0	0	0	half of sticklebacks have red at base of pectoral fins; normal?	
09/15/2016	21st St.	white sucker	-	3	X	X	X	X	X	heavy fin erosion on all fins for all 3 fish	
09/15/2016	21st St.	bluegill	1.1	1	0	0	0	0	0		
09/19/2016	3rd St.	creek chub	-	1	-	-	-	-	-	bloated	
09/19/2016	3rd St.	creek chub	-	1	-	-	-	-	-	minor red spots on fins	
09/19/2016	3rd St.	white sucker	-	1	30	0	90	50	0		
09/19/2016	3rd St.	white sucker	-	1	0	0	0	0	0		
09/19/2016	3rd St.	white sucker	-	1	0	10	10	0	0		

09/19/2016	3rd St.	white sucker	-	1	0	0	0	0	0		
09/19/2016	3rd St.	white sucker	-	1	10	30	90	80	30		
09/19/2016	3rd St.	white sucker	2.4	1	10	20	80	10	0		
09/19/2016	3rd St.	white sucker	-	1	20	10	70	50	0		
09/19/2016	3rd St.	white sucker	-	1	50	80	70	90	0		
09/19/2016	3rd St.	white sucker	-	1	30	10	70	10	10		one of the largest
09/19/2016	3rd St.	white sucker	-	1	80	80	90	90	30		
09/19/2016	3rd St.	white sucker	-	1	20	10	60	30	0		
09/19/2016	3rd St.	white sucker	-	1	0	0	0	0	0		
09/19/2016	3rd St.	white sucker	-	1	10	20	50	0	0		
09/19/2016	3rd St.	white sucker	-	1	10	0	50	0	0		
09/19/2016	3rd St.	white sucker	-	1	20	40	70	10	0		
09/19/2016	3rd St.	white sucker	-	1	30	20	70	30	0		
09/19/2016	3rd St.	white sucker	-	1	50	50	90	90	20		
09/19/2016	3rd St.	white sucker	-	1	0	0	0	0	0		
09/19/2016	3rd St.	white sucker	-	1	0	0	0	0	0		
09/19/2016	3rd St.	white sucker	-	1	0	0	0	0	0		
09/19/2016	3rd St.	white sucker	-	1	10	0	80	10	0		
09/19/2016	3rd St.	white sucker	1.8	1	30	30	80	100	10		
09/19/2016	3rd St.	white sucker	-	1	30	70	80	80	10		
09/19/2016	3rd St.	white sucker	-	1	X	X	X	X	X		1 of 4 with most severe fin erosion preserved for later evaluation. % erosion not conducted
09/19/2016	3rd St.	white sucker	-	1	X	X	X	X	X		1 of 4 with most severe fin erosion preserved for later evaluation. % erosion not conducted
09/19/2016	3rd St.	white sucker	-	1	X	X	X	X	X		1 of 4 with most severe fin erosion preserved for later evaluation. % erosion not conducted
09/19/2016	3rd St.	white sucker	-	1	X	X	X	X	X		1 of 4 with most severe fin erosion preserved for later evaluation. % erosion not conducted
09/19/2016	3rd St.	white sucker	-	1	UNK	UNK	UNK	UNK	UNK		fish released prior to fin evaluation
10/28/2016	21st St.	white sucker	2.5+	1	60	60	80	20	20		
10/28/2016	21st St.	white sucker	3.3	1	20	40	30	30	30		
10/28/2016	21st St.	white sucker	3.4+	1	90	90	90	80	80		
10/28/2016	21st St.	white sucker	3.9	1	50	60	70	60	20		
10/28/2016	21st St.	white sucker	4.4+	1	50	30	70	70	80		
10/28/2016	21st St.	white sucker	5.8+	1	40	70	50	80	30		
10/28/2016	21st St.	creek chub	6.2	1	10	20	80	20	10	body cavity and/or digestive tract bloated with gas	
10/28/2016	21st St.	central mudminnow	3.8	1	0	0	0	0	0		
10/28/2016	21st St.	central mudminnow	4.0	1	10	0	0	0	10		
10/28/2016	21st St.	bluegill	1.6	1	10	0	0	0	0		
10/28/2016	21st St.	black bullhead	2.9	1	30	30	10	50	10		
10/28/2016	21st St.	black bullhead	3.0	1	50	40	10	40	10		
10/28/2016	21st St.	black bullhead	3.0	1	60	30	10	20	10	partial barbel loss	
10/28/2016	21st St.	brook stickleback	1.5	1	0	0	0	0	0		

10/28/2016	21st St.	brook stickleback	1.6	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	1.7	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	1.7	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	1.8	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	1.8	1	0	0	0	0	0	red areas on gill cover
10/28/2016	21st St.	brook stickleback	1.9	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	1.9	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	1.9	1	0	0	0	0	0	red at pectoral fin bases; tumor between pectoral fins
10/28/2016	21st St.	brook stickleback	2.0	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.0	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.0	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	21st St.	brook stickleback	2.0	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.0	1	0	0	0	0	0	red areas on gill cover
10/28/2016	21st St.	brook stickleback	2.0	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.0	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.0	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.1	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.1	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.1	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	21st St.	brook stickleback	2.1	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.1	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.1	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.2	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.2	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.2	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.2	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	21st St.	brook stickleback	2.2	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.2	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	21st St.	brook stickleback	2.2	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.3	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.3	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	21st St.	brook stickleback	2.3	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.3	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.3	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.5	1	0	0	0	0	0	
10/28/2016	21st St.	brook stickleback	2.8	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	1.6	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	1.6	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	1.8	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	11th St.	brook stickleback	1.8	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	1.8	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	1.9	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	1.9	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	2.2	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	11th St.	brook stickleback	2.2	1	0	0	0	0	0	

10/28/2016	11th St.	brook stickleback	2.2	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	2.3	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	2.3	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	2.3	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	11th St.	brook stickleback	2.3	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	2.4	1	0	0	0	0	0	
10/28/2016	11th St.	brook stickleback	2.5	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	11th St.	brook stickleback	2.7	1	0	0	0	0	0	red at pectoral fin bases
10/28/2016	11th St.	creek chub	3.5	1	5	10	60	0	0	body cavity and/or digestive tract bloated with gas
10/28/2016	11th St.	creek chub	3.7	1	15	30	60	30	40	body cavity and/or digestive tract bloated with gas
10/28/2016	11th St.	creek chub	4.3	1	5	10	80	20	30	body cavity and/or digestive tract bloated with gas
10/28/2016	11th St.	white sucker	4.2	1	20	30	30	20	0	
10/28/2016	11th St.	fathead minnow	2.1	1	30	90	40	30	10	
10/28/2016	11th St.	golden shiner	2.2	1	10	0	0	0	0	
10/28/2016	3rd St.	white sucker	1.9	1	10	80	40	0	0	
10/28/2016	3rd St.	white sucker	2.2	1	50	70	0	0	0	
10/28/2016	3rd St.	white sucker	2.6	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	2.8	1	0	0	0	0	0	red spots above anal fin
10/28/2016	3rd St.	white sucker	2.8	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	2.8	1	0	0	0	0	0	red spots above pelvic fins on sides
10/28/2016	3rd St.	white sucker	3.1	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.1	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.1	1	5	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.1	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.1	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.1	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.1	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.1	1	10	0	0	0	0	red spots above pelvic fins on sides
10/28/2016	3rd St.	white sucker	3.2	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.2	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.2	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.3	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.3	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.3	1	20	60	10	20	0	
10/28/2016	3rd St.	white sucker	3.3+	1	60	80	80	90	10	
10/28/2016	3rd St.	white sucker	3.3+	1	70	80	90	40	0	
10/28/2016	3rd St.	white sucker	3.5	1	5	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.5	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.5	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.5	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.5	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.6	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.6	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.6	1	0	0	0	0	0	

10/28/2016	3rd St.	white sucker	3.6	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.7	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.7	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	3.9	1	20	70	50	20	0	
10/28/2016	3rd St.	white sucker	3.9	1	5	0	0	0	0	
10/28/2016	3rd St.	white sucker	4.1	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	4.2	1	0	0	0	0	0	
10/28/2016	3rd St.	white sucker	4.2	1	0	0	0	0	0	red spots above anal fin and in caudal fin
10/28/2016	3rd St.	white sucker	4.3	1	20	30	10	10	20	
10/28/2016	3rd St.	white sucker	4.7	1	15	30	40	0	0	
10/28/2016	3rd St.	white sucker	5.2	1	10	20	10	10	0	
10/28/2016	3rd St.	white sucker	5.7	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.3	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.3	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.3	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.4	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.5	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.5	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.6	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.6	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.6	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	2.9	1	0	0	0	0	0	
10/28/2016	3rd St.	shorthead redhorse	3.0	1	0	0	0	0	0	
10/28/2016	3rd St.	central mudminnow	4.7	1	0	0	0	0	0	reddened areas on gill covers, jaws, and dorsal fin
10/28/2016	3rd St.	creek chub	4.9	1	5	10	0	0	0	body cavity and/or digestive tract bloated with gas
10/28/2016	3rd St.	fathead minnow	1.4	1	80	90	60	unk	30	deformed snout
10/28/2016	3rd St.	fathead minnow	2.1	1	0	0	0	0	0	
10/28/2016	3rd St.	fathead minnow	2.2	1	0	0	0	0	0	
10/28/2016	3rd St.	fathead minnow	2.2	1	50	80	0	0	0	
10/28/2016	3rd St.	fathead minnow	2.4	1	0	0	0	0	0	
10/28/2016	3rd St.	fathead minnow	2.6	1	0	0	0	0	0	
10/28/2016	3rd St.	fathead minnow	2.7	1	0	0	0	0	0	reddened areas near bases of pectorals and pelvic fins
10/28/2016	3rd St.	golden shiner	2.2	1	0	0	0	0	0	
10/28/2016	3rd St.	golden shiner	2.3	1	0	0	0	0	0	
10/28/2016	3rd St.	brook stickleback	2.2	1	0	0	0	0	0	
10/28/2016	3rd St.	brook stickleback	2.2	1	0	0	0	0	0	
10/28/2016	3rd St.	brook stickleback	2.6	1	10	0	0	0	0	
10/28/2016	3rd St.	round goby	2.3	1	50	30	20	10	20	
10/28/2016	3rd St.	bluegill x pumpkinseed	1.5	1	0	0	0	0	0	
10/28/2016	3rd St.	bluegill	1.5	1	0	0	0	0	0	
10/28/2016	3rd St.	bluegill	1.5	1	0	0	0	0	0	

10/28/2016	3rd St.	bluegill	1.5	1	0	0	0	0	0	red spots in caudal fin and throat; thickened body cavity	
10/28/2016	3rd St.	bluegill	1.5	1	0	0	0	0	0	red areas on lower head and eyes; thickened body cavity	
10/28/2016	3rd St.	bluegill	1.6	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	2.9	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.0	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.1	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.1	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.2	1	0	0	0	0	0	small red spots on the side	
10/31/2016	Faxon	white sucker	3.2	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.2	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.3	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.4	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.4	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.5	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.5	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.7	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.7	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.7	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.7	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.8	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.8	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	3.9	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	4.0	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	4.0	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	4.2	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	4.4	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	4.4	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	4.7	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	5.0	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	5.5	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	5.5	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	6.4	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	8.7	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	11.5	1	0	0	0	0	0		
10/31/2016	Faxon	white sucker	1.7	1	0	0	0	0	0		young of year
10/31/2016	Faxon	white sucker	1.8	1	0	0	0	0	0		young of year
10/31/2016	Faxon	white sucker	2.1	1	0	0	0	0	0		young of year
10/31/2016	Faxon	creek chub	2.8	1	0	0	0	0	0		
10/31/2016	Faxon	creek chub	2.9	1	0	0	0	0	0		
10/31/2016	Faxon	creek chub	3.0	1	0	0	0	0	0		
10/31/2016	Faxon	creek chub	3.3	1	0	0	0	0	0		
10/31/2016	Faxon	creek chub	3.3	1	0	0	0	0	0		
10/31/2016	Faxon	creek chub	3.4	1	0	0	0	0	0		
10/31/2016	Faxon	creek chub	3.6	1	0	0	0	0	0		
10/31/2016	Faxon	creek chub	3.6	1	0	0	0	0	0		

10/31/2016	Faxon	creek chub	3.6	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	3.7	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	3.8	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	3.8	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	3.9	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	4.0	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	4.5	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	4.7	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	4.8	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	5.3	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	6.5	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	6.8	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	7.8	1	0	0	0	0	0	
10/31/2016	Faxon	creek chub	1.4	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	1.4	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	1.5	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	1.5	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	1.5	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	1.9	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	2.0	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year

10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	creek chub	-	1	0	0	0	0	0	young of year
10/31/2016	Faxon	common shiner	3.2	1	0	0	0	0	0	
10/31/2016	Faxon	logperch	3.5	1	0	0	0	0	0	

Appendix F. Fish Survey Data for Faxon Creek.

Species	Count
white sucker	34
creek chub	72
common shiner	1
logperch	1
Small Stream IBI Score	30
IBI Rating	Poor
% Tolerant Individuals	99.1
Qualifier	
Total species	4
Total fish	108

Fin Erosion and Water Quality

Sarah Yang, PhD

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Introduction

Fin erosion is defined as the condition where fins are degraded, frayed, or reduced in size. Fin erosion is typically distinguished from fin rot in that fin erosion is defined as fin damage in which there is no demonstrable microbial involvement. Fin rot is defined as fin lesions that are associated with the presence of one or more microbial agent. Fin rot is the resultant condition from fin necrosis, where fin necrosis is the process of fins becoming abraded and frayed via infection from a variety of bacteria.

There are both natural and anthropogenic causes of fin erosion and fin rot. These causes can lead to fin erosion either directly, such as through irritation of the skin epithelium, or indirectly, such as through a weakened immune system allowing for bacterial infection. Natural causes of fin erosion and fin rot include aggressive behavior by other fish, exposure to extreme temperatures, and nutritional deficiencies. Anthropogenic causes include degraded habitat and poor water quality.

Fin Erosion and Water Quality

Fin erosion is a fairly common, non-specific response to poor water quality. In fact, one publication noted that "fin erosion is probably the most frequently encountered anomaly of fishes from polluted waters" (Reash, 1998). Fin erosion has been observed in fish exposed to waters contaminated with crude oil, pulp and paper mill effluent, mining tailings, heavy metals, and various organic pollutants (PAHs, PCBs, dioxin, DDT). Below are summaries from publications evaluating the impact of some of these pollutants on fin erosion in freshwater fish.

Literature Review

Incidence of fin erosion and anomalous fishes in a polluted stream and a nearby clean stream

In one of the first studies on fin erosion conducted in fresh water, researchers evaluated the incidence of fin erosion in fish in two Ohio streams: one in a watershed dominated by agriculture and forest (i.e., the "clean" stream) and the other in an urban watershed receiving both industrial and municipal effluents (i.e., the "polluted" stream). They found that the incidence of fin erosion was more than twenty times greater in the polluted stream than in the clean stream. The species that experienced the highest incidence of fin erosion were white sucker, gizzard shad, stoneroller, and green sunfish. They also observed that fin erosion in the polluted stream varied by month and was inversely correlated with water temperature. The causative agent of the increased incidence of fin erosion in the polluted stream was not evaluated.

Contaminated Sediments from Tributaries of the Great Lakes: Chemical Characterization and Carcinogenic Effects in Medaka (Oryzias latipes)

In this study, the researchers collected sediment from four contaminated sites within the Great Lakes (Black River – OH, Cuyahoga River – OH, Menominee River – MI, and Fox River – WI). The model organism, Japanese medaka (*Oryzias latipes)* were exposed to these sediments in a pulse-dose format in which 24-h exposures were conducted at weekly intervals for a total of 4 exposures during the 360 day test. The impact of contaminated sediment on survival and the incidence of fin erosion, liver abnormalities, and neoplasms was evaluated. Contaminated sediments contained varying levels of numerous organic pollutants including polycyclic aromatic compounds (PACs), alkylated PACs, oxidized PACs, and PCBs.

Contaminated sediment caused a dose-dependent decrease in survival. The incidences of liver abnormalities were more prevalent in fish exposed to contaminated sediment than those exposed to sediment from a reference site and contaminated sediment from Black River and Fox River caused tumor formation in exposed fish. In addition, exposure to contaminated sediment resulted in significantly higher frequencies of caudal fin and pectoral fin erosion than exposure to reference sediment or control. Additional analysis to identify the causative agent of this effect was not conducted.

Accumulation, Sublethal Effects, and Safe Concentration of a Refined Oil as Evaluated with Cutthroat Trout

In this study, the researchers exposed cutthroat trout to 5 concentrations of refined oil for 90 days and evaluated survival, growth, gill and liver pathology, caudal fin erosion and pathology, and swimming performance. These endpoints were correlated to water and tissue concentrations of petroleum hydrocarbons. Chemical analysis indicated the oil contained branched chain and cyclic hydrocarbons with the dominant aromatic compound being naphthalenes.

Significant decrease in survival was observed at the highest concentration. Reductions in fish growth and weight, changes to gills and liver, and alterations to swimming performance occurred in a dose-dependent manner. The incidence of gross fin erosion increased as total oil concentration increased with the two highest concentrations causing erosion in all surviving fish. Although histological examination of the fins indicated hemorrhaging in the muscle tissues and twisting of muscle fibers, no evidence of bacterial infection was observed and the mechanism for the fin erosion was not investigated.

Changes in migratory fish communities and their health, hydrology, and water chemistry in rivers of the Athabasca oil sands region: a review of historical and current data

In this study, the researchers evaluated existing data to determine whether community composition and health of migratory fish in the lower Athabasca river region has changed over the past 40 years and whether changes in hydrology or water chemistry could explain these changes. They evaluated the body condition and incidence of fin erosion in Artic grayling, mountain whitefish, northern pike, longnose sucker, and white sucker to determine impacts on fish health and attempted to correlate these effects to changes in hydrology, precipitation, and water chemistry.

The researchers found that fin erosion was the most commonly occurring abnormality and its incidence correlated with other external abnormalities including deformities, lesions, and parasites. The species with the highest incidence of fin erosion were white suckers, northern pike, and walleye. The incidence and severity varied between months and species. The location of the fin erosion also varied by species with the caudal fin the most affected for suckers and pike and the dorsal fin the most affected in walleye. Size was a significant factor with larger fish experiencing more incidences of fin erosion than smaller fish. The authors evaluated a variety of potential causes for the high incidences of fin erosion including contamination, aggressive behavior, extreme temperatures/weather, high discharge, increased turbidity, and changes in water quality, but were unable to establish a causal relationship.

*Opportunistic disease in yellow perch in response to decadal changes in the chemistry of oil sands-affected waters**

In this study, the researchers evaluated the temporal association of disease states in yellow perch stocked in experimental ponds containing oil-sands materials. The objectives of the study were to 1) associate fish lesions that occur due to exposure of oil sands-influenced water to specific pathogens; and 2) associate observed disease states with classes of compounds. To do this, they evaluated the incidence of disease, identification of pathogens, indicators of organic contaminant exposure (i.e., bile metabolites, CYP1A activity), and water quality parameters (i.e., temperature, pH, conductivity, dissolved oxygen, and naphthenic acids) in two experimental ponds, a reservoir used for extraction water, and two reference lakes.

The authors observed increased white nodular lesions and fin erosion in fish from the oil sands-affected ponds. They determined that the lesions were caused by a lymphocystis disease virus infection. They suspected that the fin erosion was caused by a bacterial infection as a high prevalence of *Acinetobacter lwoffii* was observed on the fins of affected fish.

Water quality impacts were observed in the two experimental ponds. In one pond (Demonstration Pond), an increase in total naphthenic acid (NA) concentration, pH and conductivity over last 15 years was observed while a decrease in total NA concentration and no change in pH and conductivity was observed in the other pond (South Bison Pond). They also observed higher levels of CYP1A activity and bile metabolites in fish from the experimental ponds which indicate exposure to aromatic compounds.

While a causative agent was not identified in this study, the authors conjectured that PAHs may cause immunosuppression leading to infection and fin erosion. A number of studies have shown that PAHs can reduce leukocytes, decrease antibody production, and lower disease resistance. However, similar effects were not observed in fish exposed to naphthenic acids isolated from one of the experimental ponds.

*Note: this document is an unpublished manuscript that has not gone through the rigorous peer review process. As such, caution must be taken when interpreting the results.

Summary

The studies summarized above highlight the connection between poor water quality and fin erosion. Direct causal relationships are difficult to establish as both natural and anthropogenic factors can contribute to this response. Fin erosion can be considered an indicator of stress and a signal that further investigation is needed.

References

Allen, E.W. (2008). Process water treatment in Canada's oil sands industry: I. Target pollutants and treatment objectives. *Journal of Environmental Engineering Science.* 7: 123-138

Arens, C.J. et al. (2015) Sublethal effects of aged oil sands-affected water on white sucker (*Catostomus commersonii) Environmental Toxicology and Chemistry.* 34 (3): 589-599

Au, DWT. (2004) The application of histo-cytopathological biomarkers in marine pollution monitoring: a review. *Marine Pollution Bulletin*. 48 (9-10): 817-834

Hogan, N.S. et al. Opportunistic disease in yellow perch in response to decadal changes in the chemistry of oil sands-affected water, unpublished†

Latremouille, DN. (2003) Fin erosion in aquaculture and natural environments. *Reviews in Fisheries Science*. 11 (4): 315-335

Lockhart, W.L. et al. (1996) Chronic Toxicity of the 'Water-soluble Fraction' of Norman Wells Crude Oil to Juvenile Fish. *Spill Science & Technology Bulletin.* 3 (4): 259-262

Fabacher, D.L. et al. (1991) Contaminated sediments from tributaries of the Great-Lakes - chemical characterization and carcinogenic effects in Medaka (*Oryzias latipes*). *Archives of Environmental Contamination and Toxicology*. 21 (1): 17-34†

Moles, A. et al. (1998) Effects of oil-laden sediments on growth and health of juvenile flatfishes. *Canadian Journal of Fish and Aquatic Sciences.* 55: 605-610

Reach, R.J. et al. (1989) Incidence of fin erosion and anomalous fishes in a polluted stream and a nearby clean stream. *Water Air and Soil Pollution.* 47 (1-2): 47-63†

Schwalb, A.N. et al. (2015) Changes in migratory fish communities and their health, hydrology, and water chemistry in rivers of the Athabasca oil sands region: a review of histological and current data. *Environmental Review.* 23: 133-150†

Sharples, A. D. et al. (1996) Pathology of fin erosion in goldfish *Carassius auratus. Diseases in Aquatic Organisms.* 24: 81-91

Sindermann, C.J. (1978) Pollution-associated disease and abnormalities of fish and shellfish: A review. *Fishery Bulletin*. 76 (4): 717-749

Wake, H. (2005). Oil refineries: A review of their ecological impacts on the aquatic environment. *Estuarine, Coastal and Shelf Science.* 62: 131-140

Woodward, D.F. et al. Accumulation, sublethal effects, and safe concentration of a refined oil as evaluated with Cutthroat Trout. *Archives of Environmental Contamination and Toxicology.* 12 (4): 455-464

† Note: these references are summarized in the literature review

Appendix H. Hog Island Inlet Macroinvertebrate Data by Site.

Table 1. Macroinvertebrate raw number by taxon.

	Loon's Foot Bay (Reference)			Hog Island Inlet									
Taxon (number)	**WI-2**	**WI-23**	**WI-24**	**HI-1**	**HOG 10**	**HOG 22**	**HOG 25**	**HI-30**	**HOG 52**	**HOG 61**	**HOG 65**	**HOG 65 Duplicate**	**HOG 84**
CHIRONOMIDAE													
Chironomini													
Chironomus	4	4	4	4			2	4		6			
Cryptochironomus	8	6	16	4	28	4	6	6	4	8	6	6	2
Cryptotendipes			4	8		4							
Dicrotendipes		4		12				2					
Einfeldia natchitocheae			8	8									
Endochironomus subtendens grp.	4				4								
Harnischia										2			
Glyptotendipes sp. group B					4						2		
Microchironomus					8	80	2	14		16			
Microtendipes pedellus grp.	4												
Pagastiella ostansa		2			4	120	12	22	2	8	4		
Parachironomus							2				2		
Paracladopelma								2					
Paralauterborniella nigrohalterale						8							
Paratendipes						4							
Polypedilum halterale grp.		2	40	24	8	28		8	10	2	2		
Potthastia longimanna grp.					4								
Stictochironomus					28								
Tribelos		4			4		10	6	2				
TOTAL CHIRONOMINI	20	22	72	60	92	248	34	64	18	42	16	6	2
Cladotanytarsus				4	4	4							
Stempellina sp. A (Epler)			4							4			
Tanytarsus		6	64	24		12		12	2	36			
TOTAL TANYTARSINI		6	68	28	4	16	0	12	2	40	0	0	0
Epoicocladius flavens										2			
TOTAL ORTHOCLADIINAE										2			
Tanypodinae (too immature)	4				4	4		4					
Ablabesmyia			4	4					2				
Ablabesmyia annulata						4	4			4			
Clinotanypus		6		4				4					
Procladius	28	14	16	80	40	160	28	48	18	16	10	4	8
TOTAL TANYPODINAE	32	20	20	88	44	168	32	56	20	20	10	4	8
TOTAL CHIRONOMIDAE	52	48	160	176	140	432	66	132	40	102	26	10	10
CHAOBORIDAE													
Chaoborus punctipennis				4		1	4		10	2	12	14	8

CERATOPOGONIDAE													
Ceratopogoninae		8	4				4		2	4	2	4	4
TRICHOPTERA (caddisflies)													
Phylocentropus placidus		2		4	2					2	2		
Oecetis	4	4	4	8			8			2			
EPHEMEROPTERA													
Caenis		2		4	8	4	2			2		2	
Hexagenia					4	36							
Hexagenia limbata							2			4			
POLYCHAETA													
Manayunkia speciosa		40	52		80								
OLIGOCHAETA													
Naidinae													
Arcteonais lomondi										2			
Dero	60	2	76	16						106	24	22	6
Ophidonais serpentina	16			8									
Stylaria lacustris	4												
Vejdovskyella intermedia										18			
Tubificinae													
immature tubificids w/o hairs	68	48	388	152	48	168	86	60	26	36	108	214	124
immature tubificids with hairs	32		72	20	8	152	10	8	2	24	6	12	
Aulodrilus limnobius	12			4	36					4			
Aulodrilus pigueti		12								2	6	14	
Aulodrilus pluriseta		6											
Limnodrilus cervix		2			4								
Limnodrilus hoffmeisteri	4		8								8	4	6
Potamothrix vejdovskyi					4								
Quistadrilus multisetosus	12												
Spirosperma ferox		2											
TOTAL OLIGOCHAETA	208	72	544	200	100	320	96	68	28	192	152	266	136
Sphaeriidae (too immature)	24												
Pisidium (clam)	4	50	52	100	12	4		6		6			
Sphaerium (clam)									2				
Dreissenia (zebra mussel)					16								
Hydrobiidae (snail)	28	2								6			
Gyraulus (snail)	8												
Valvata piscinalis/sincera (snail)	4	6											
TOTAL MOLLUSCA	68	58	52	100	28	4	0	6	2	12	0	0	0
Caecidotea sp. (sowbug - females)	44												
Caecidotea communis	20												
Caecidotea racovitzai	104			16									
Gammarus sp. (scud)	4												
Hydrachnida (mites)													

Hygrobates (mite)					4		2						
Krendowskia (mite)				4									
Limnesia (mite)		2	4						2				
Piona (mite)			4									2	
Unionicola (mite)	4	2					4				6	10	2
Hydra	4												
Helobdella stagnalis (leech)	4												
TURBELLARIA	4												
Total Organisms	900	464	1740	1168	774	1985	416	544	194	734	404	594	316
EPT Taxa Richness	1	3	1	3	3	2	3	0	0	4	1	1	0
Taxa Richness	27	25	19	23	24	18	17	15	13	26	15	12	8

Table 2. Macroinvertebrate number per square meter by taxon.

	Loonsfoot Landing (Reference)			**Hog Island Inlet**									
Taxon (No. per m^2)	**WI-2**	**WI-23**	**WI-24**	**HI-1**	**HOG 10**	**HOG 22**	**HOG 25**	**HI-30**	**HOG 52**	**HOG 61**	**HOG 65**	**HOG 65 Duplicate**	**HOG 84**
CHIRONOMIDAE													
Chironomini													
Chironomus	172.2	172.2	172.2	172.2			86.1	172.2		258.3			
Cryptochironomus	344.4	258.3	688.8	172.2	1205.4	172.2	258.3	258.3	172.2	344.4	258.3	258.3	86.1
Cryptotendipes			172.2	344.4		172.2							
Dicrotendipes		172.2		516.6				86.1					
Einfeldia natchitocheae			344.4	344.4									
Endochironomus subtendens grp.	172.2	0			172.2								
Harnischia										86.1			
Glyptotendipes sp. group B					172.2								
Microchironomus					344.4	3444	86.1	602.7		688.8			
Microtendipes pedellus grp.	172.2												
Pagastiella ostansa		86.1			172.2	5166	516.6	947.1	86.1	344.4	172.2		
Parachironomus							86.1						
Paracladopelma								86.1					
Paralauterborniella nigrohalterale						344.4							
Paratendipes						172.2							
Polypedilum halterale grp.		86.1	1722	1033.2	344.4	1205.4		344.4	430.5	86.1			
Potthastia longimanna grp.					172.2								
Stictochironomus					1205.4								
Tribelos		172.2			172.2		430.5	258.3	86.1				
TOTAL CHIRONOMINI	861	947	3099.6	2583	3960.6	10676.4	1463.7	2755.2	774.9	1808.1	430.5	258.3	86.1
Cladotanytarsus				172.2	172.2	172.2							
Stempellina sp. A (Epler)			172.2							172.2			
Tanytarsus		258.3	2755.2	1033.2		516.6		516.6	86.1	1549.8			
TOTAL TANYTARSINI		258	2927.4	1205.4	172.2	688.8	0	516.6	86.1	1722	0	0	0
Epoicocladius flavens										86.1			

TOTAL ORTHOCLADIINAE										86			
Tanypodinae (too immature)	172.2				172.2	172.2		172.2					
Ablabesmyia			172.2	172.2					86.1				
Ablabesmyia annulata						172.2	172.2			172.2			
Clinotanypus		258.3		172.2				172.2					
Procladius	1205.4	602.7	688.8	3444	1722	6888	1205.4	2066.4	774.9	688.8	430.5	172.2	344.4
TOTAL TANYPODINAE	1377.6	861	861	3788.4	1894.2	7232.4	1377.6	2410.8	861	861	430.5	172.2	344.4
TOTAL CHIRONOMIDAE	2238.6	2066.4	6888	7576.8	6027	18597.6	2841.3	5682.6	1722	4391.1	861	430.5	430.5
CHAOBORIDAE													
Chaoborus punctipennis				172.2		43.05	172.2		430.5	86.1	516.6	602.7	344.4
CERATOPOGONIDAE													
Ceratopogoninae		344.4	172.2				172.2		86.1	172.2	86.1	172.2	172.2
TRICHOPTERA (caddisflies)													
Phylocentropus placidus		86.1		172.2	86.1					86.1	86.1		
Oecetis	172.2	172.2	172.2	344.4			344.4			86.1			
EPHEMEROPTERA													
Caenis		86.1		172.2	344.4	172.2	86.1			86.1		86.1	
Hexagenia					172.2	1549.8							
Hexagenia limbata							86.1			172.2			
POLYCHAETA													
Manayunkia speciosa		1722	2238.6		3444								
OLIGOCHAETA													
Naidinae													
Arcteonais lomondi										86.1			
Dero	2583	86.1	3271.8	688.8						4563.3	1033.2	947.1	258.3
Ophidonais serpentina	688.8			344.4									
Stylaria lacustris	172.2												
Vejdovskyella intermedia										774.9			
Tubificinae													
immature tubificids w/o hairs	2927.4	2066.4	16703.4	6543.6	2066.4	7232.4	3702.3	2583	1119.3	1549.8	4649.4	9212.7	5338.2
immature tubificids with hairs	1377.6		3099.6	861	344.4	6543.6	430.5	344.4	86.1	1033.2	258.3	516.6	
Aulodrilus limnobius	516.6			172.2	1549.8					172.2			
Aulodrilus pigueti		516.6								86.1	258.3	602.7	
Aulodrilus pluriseta		258.3											
Limnodrilus cervix		86.1			172.2								
Limnodrilus hoffmeisteri	172.2		344.4								344.4	172.2	258.3
Potamothrix vejdovskyi					172.2								
Quistadrilus multisetosus	516.6												
Spirosperma ferox		86.1											
TOTAL OLIGOCHAETA	8954.4	3099.6	23419.2	8610	4305	13776	4132.8	2927.4	1205.4	8265.6	6543.6	11451.3	5854.8
Sphaeriidae (too immature)	1033.2												
Pisidium (clam)	172.2	2152.5	2238.6	4305	516.6	172.2		258.3		258.3			
Sphaerium (clam)									86.1				
Dreissenia (zebra mussel)					688.8								
Hydrobiidae (snail)	1205.4	86.1								258.3			
Gyraulus (snail)	344.4												

Valvata piscinalis/sincera (snail)	172.2	258.3											
TOTAL MOLLUSCA	2927.4	2496.9	2238.6	4305	1205.4	172.2	0	258.3	86.1	516.6	0	0	0
Caecidotea sp. (sowbug - females)	1894.2												
Caecidotea communis	861												
Caecidotea racovitzai	4477.2			688.8									
Gammarus sp. (scud)	172.2												
Hydrachnida (mites)													
Hygrobates (mite)					172.2		86.1						
Krendowskia (mite)				172.2									
Limnesia (mite)		86.1							86.1				
Piona (mite)												86.1	
Unionicola (mite)	172.2	86.1					172.2				258.3	430.5	86.1
Hydra	172.2												
Helobdella stagnalis (leech)	172.2												
TURBELLARIA	172.2												
TOTAL ORGANISMS	38745	19975	74563	50282	33321	85454	17909	23419	8352	31599	16617	25572	13604

Table 3. Macronivertebrate Trimetric Index and Ephemerid Density Components.

Site	Taxa Richness	% ETO Individuals	Total/(m^2) Organisms	Ephemeroptera/m^2	Trichoptera/m^2	Odonata/m^2	ETO/m^2	Oligochaete/m^2	% Non-oligochaete Individuals
WI-2	27	0.44	38745	0	172	0	172.2	8954.4	76.9
WI-23	25	1.72	19975	86	258	0	344.4	3099.6	84.5
WI-24	19	0.23	74563	0	172	0	172.2	23419.2	68.6
H1-1	23	1.37	50282	172	517	0	688.8	8610	82.9
HI-10	24	1.81	33321	517	86	0	602.7	4305	87.1
HOG 22	18	2.02	85454	1722	0	0	1722	13776	83.9
HOG 25	17	2.88	17909	172	344	0	516.6	4132.8	76.9
HI-30	15	0.00	23419	0	0	0	0	2927.4	87.5
HOG 52	13	0.00	8352	0	0	0	0	1205.4	85.6
HOG 61	26	1.36	31599	258	172	0	430.5	8265.6	73.8
HOG 65	15	0.52	16617	0	86	0	86.1	6543.6	60.6
HOG 65-DUP	12	0.34	25572	86	0	0	86.1	11451.3	55.2
HOG 84	8	0	13604	0	0	0	0	5854.8	57.0

Table 4. Macroinvertebrate Trimetric Index Components.

Site	Ephemerid Density (No./m^2)	Taxa Richness Scaled Metric Value	%ETO Scaled Metric Value	Non-Oligochaete Scaled Metric Value	Scaled Trimetric Index	Depth (m)	Field Measured Latitude	Field Measured Longitude
WI-2	0	0.485	0.012	0.719	0.542	0.70	46.70214	92.03578
WI-23	0	0.446	0.045	0.790	0.573	1.28	46.70325	92.03372
WI-24	0	0.331	0.006	0.641	0.431	0.98	46.702	92.03503
H1-1	0	0.408	0.036	0.775	0.544	0.88	46.70327	92.03876
HI-10	172.2	0.427	0.047	0.814	0.577	1.77	46.70513	92.04103
HOG 22	1549.8	0.312	0.053	0.784	0.511	3.05	46.70651	92.04139
HOG 25	86.1	0.293	0.075	0.719	0.482	2.23	46.70572	92.04124
HI-30	0	0.255	0.000	0.818	0.475	1.74	46.70488	92.0415
HOG 52	0	0.216	0.000	0.800	0.449	1.83	46.7045	92.04066
HOG 61	172.2	0.466	0.036	0.690	0.531	0.98	46.7042	92.04038
HOG 65	0	0.255	0.014	0.567	0.364	1.86	46.70472	92.03996
HOG 65-DUP	0	0.197	0.009	0.516	0.311	1.86	46.70472	92.03996
HOG 84	0	0.121	0.000	0.532	0.278	2.10	46.70398	92.03933