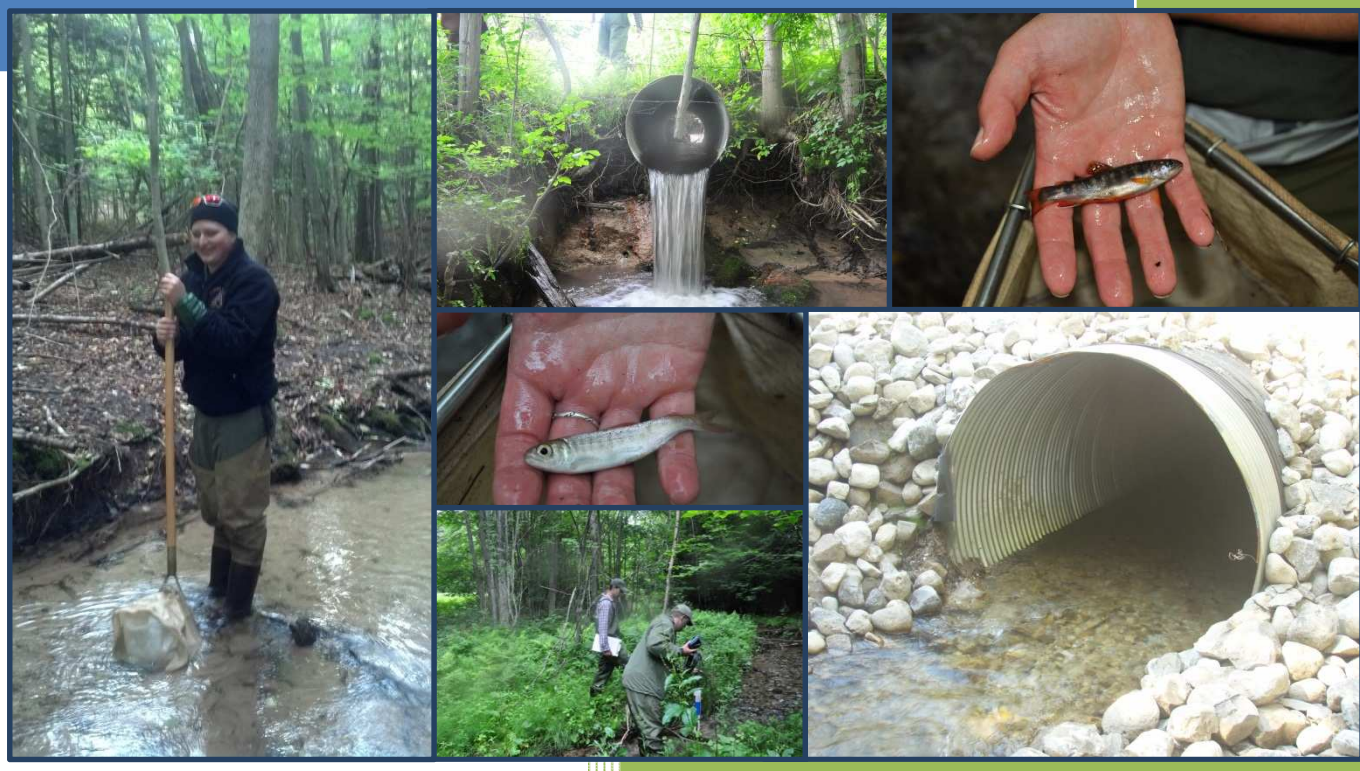
Final Technical Report -

Arcadia Marsh / Bowens Creek Restoration and Fish Passage



Little River Band of Ottawa Indians

Final Technical Report - 2013

Restoration Monitoring

Grant Number: 21470

Executive Summary: As a collaborator on the Arcadia Marsh Restoration Project, the Little River Band of Ottawa Indians (LRBOI) Natural Resources Department was contracted to monitor streams before and after restoration for biological parameters. The first part of this report covers the upper watershed of Bowens Creek, and focuses on the restoration of road stream-crossings among upper tributary streams. The second part of the report covers the lower watershed of Bowens Creek, and evaluates the impact of the restoration within Arcadia Marsh. Pre-restoration habitat, water quality and aquatic community data were collected during 2010 and 2011 sampling seasons in both the lower and upper portions of Bowens Creek watershed. In the upper watershed, monitoring was conducted upstream of road/stream crossing restoration sites in three separate tributary streams, as well as in a nearby control stream. In the lower watershed, where Bowens Creek flows through a 420 acre coastal emergent wetland complex (Arcadia Marsh), monitoring was conducted in stations within the historic channel and in the channelized segment. In 2012 and 2013 post restoration sampling was conducted at monitoring stations above improved road stream crossings as well as at control sites. Post restoration sampling of the lower watershed was conducted in 2013, following the completion of the re-routing of Bowens Creek.

Project Objectives:

1) **Evaluate Habitat Response**

- Transects were established near restoration sites as well as at control sites.
- Monitored stream width, depth, meso-habitat type (pool, riffle, run), substrate and habitat scores (RBP and GLEAS) to determine the effectiveness of the project.

2) **Evaluate Macroinvertebrate Response to Habitat Restoration Techniques**

- Established multiple transects for macroinvertebrate collection prior to and after restoration.
- Monitored macroinvertebrate communities through the restoration process to determine the effectiveness of the project.

3) **Evaluate Fish Community Response to Habitat Restoration Techniques**

- Established multiple transects for fishery evaluation prior to and after restoration.
- Fish community composition and relative abundance were monitored to determine effectiveness of the project.

Foreword

Despite the value of river and streams for drinking water, agriculture, recreation and food, human activities continue to disturb the natural structure and function of these systems (Karr 1995). During the last two decades, there has been a substantial attempt to improve the quality and integrity of freshwater ecosystems at both national and international levels (Frissell and Bayles 1996; Stanford et al., 1996; Baron et al., 2002); subsequently, river restoration has become a common management activity that is growing exponentially (Bernhardt et al., 2005). Unfortunately, much of this effort has proceeded without documentation of the relative successes and failures of individual activities (Reeves et al.,1991; Ham and Pearsons, 2000; Palmer et al., 2005). Even when success is noted there is often a lack of data to identify and support specific results or endpoints for the management activity (Bernhardt et al., 2005). As part of the National River Restoration Science Synthesis Alexander and Allan (2007) examined the results from Midwest (Michigan, Wisconsin and Ohio) restoration projects and found that some form of monitoring occurred in 79% of the projects but rarely documented biological improvements. In an effort to assess the benefit and success of these projects in the Bowens Creek watershed we quantified the biotic community pre and post restoration.

UPPER WATERSHED – ROAD STREAM CROSSINGS

Introduction

In 2009, Ducks Unlimited was awarded a National Fish and Wildlife Foundation – Sustain Our Great Lakes Stewardship Grant. Through this funding and the collaboration of many partners seven perched, undersized or misaligned culverts within Bowens Creek and its tributaries were replaced. The culverts were preventing access to upstream areas for many migratory and resident species of fish. Additionally, water quality was being negatively impacted due to streambank scouring occurring as a result of misaligned and perched culverts. The restoration of the upper watershed of Bowens Creek was designed to improve passage for fish and other aquatic organism re-connecting approximately ten miles of stream. The LRBOI Natural Resources department partnered in the project to monitor fish, macroinvertebrates and habitat throughout the restoration project.

Figure 1. Ware Creek (upper left) and Hull Creek (upper right).

Site Descriptions

Alkire Creek

Alkire Creek is a first order stream located approximately 2.6 km upstream of Bowens Creek (Figure 2). Alkire Creek watershed borders the northern edge of Bear Lake watershed, and extends north with a total catchment area of 19.3 km². Alkire Creek's watershed is dominated by forest (32.7%), grassland (29.2%) and cultivated crops (29.0%). Three 100 m sampling stations were established in the upper portion of Alkire Creek. Station 1 was located just upstream of the replaced culvert at Alkire Rd., Station 2 was located just upstream of the replaced culvert at Myers Rd., and Station 3 was located approximately 10-m upstream from Station 2. Station 1 is

shaded with cedar and hemlocks transitioning to a more open canopy in Stations 2 and 3 with grasses and forbes as the predominant riparian vegetation (Figure 3).

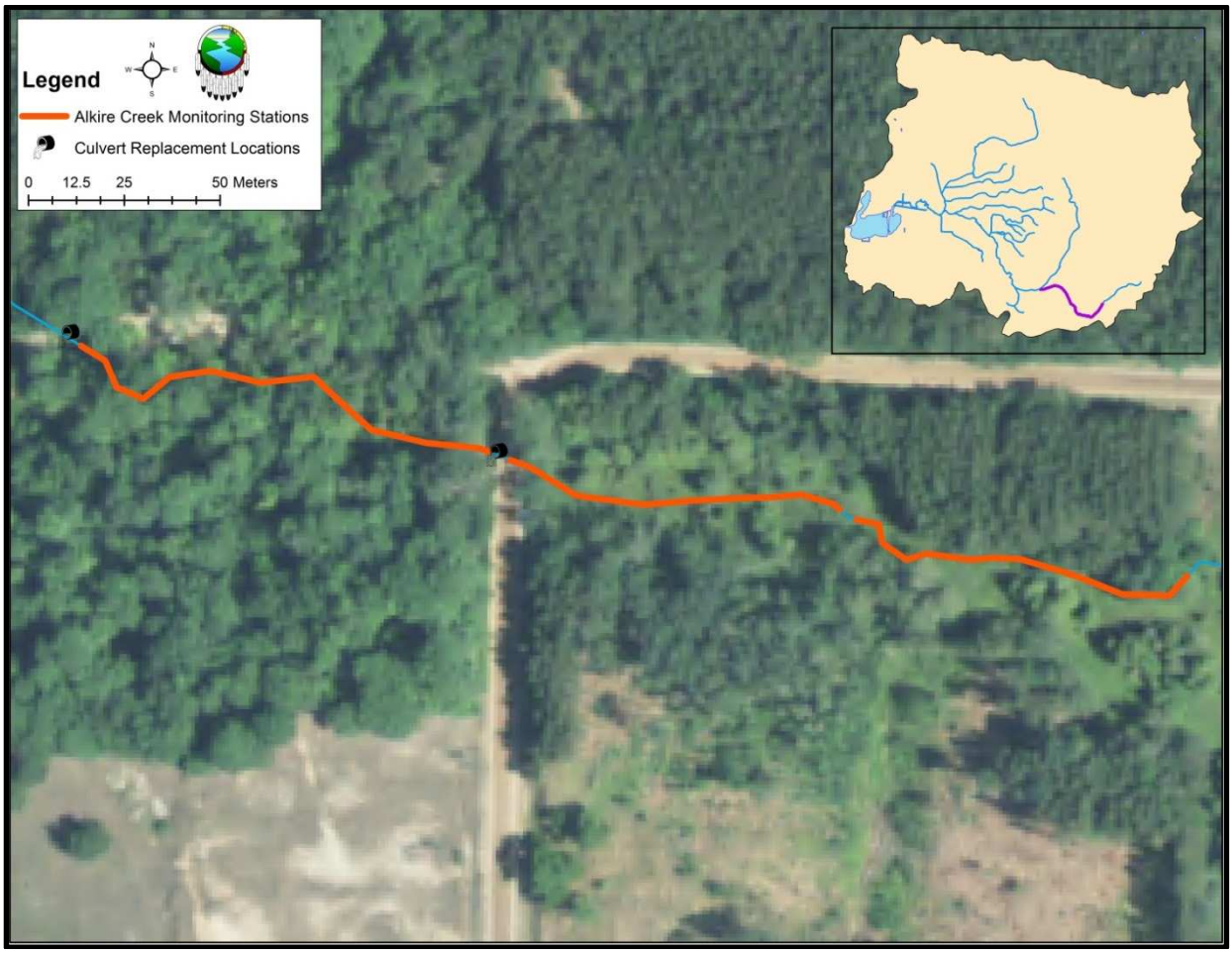


Figure 2. Alkire Creek Site Map.

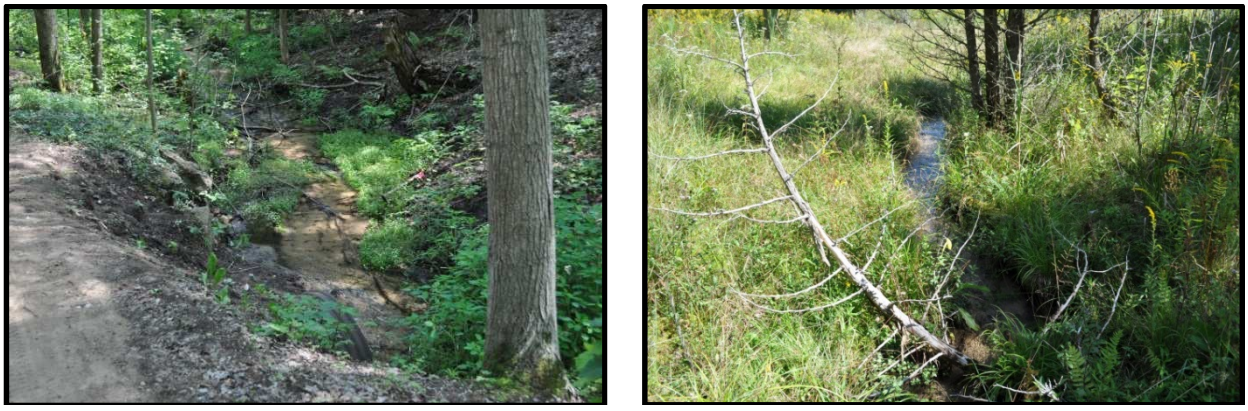


Figure 3. Alkire Creek - Station 1 (left) and 3 (right).

Hull Creek

Hull Creek is a spring fed first order stream draining a catchment area of approximately 0.89 km² (Figure 4). The stream is somewhat flashy due to clay in the watershed and the numerous gullies draining nearby agricultural land. Hull Creek's watershed is dominated by forest (48.6%) pasture/hay (25.0%), and cultivated crops (20.7%). Five 120 m sampling stations were established in Hull Creek. Spacing between stations was 100 m, and all stations were located upstream of the replaced culvert at Ware Rd.

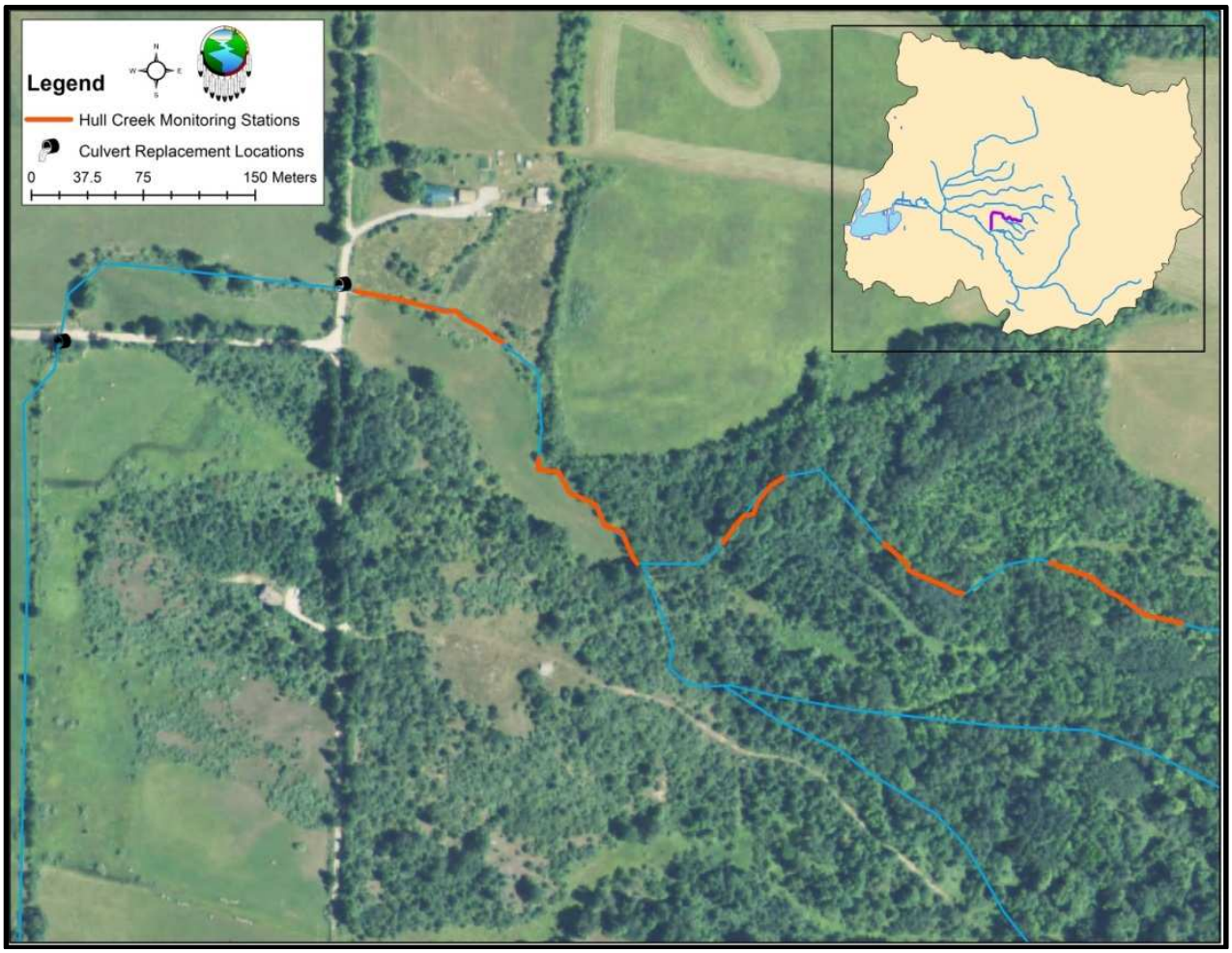


Figure 4. Hull Creek Site Map.

In Stations 1 and 2, the stream flows through pasture land shaded along the banks by grasses and shrubs. Station 3 is heavily shaded by abandoned orchard land providing a unique stream cover (Figure 5). Riparian vegetation transitions to mixed deciduous forest in Stations 4 and 5.


Figure 5. Hull Creek - Station 2 (left), 3 (upper right), and 4 (lower right).

Ware Creek

Ware Creek is a spring fed first order stream located upstream of Bowens Creek (Figure 6). Ware Creek watershed borders the northern edge of Hull Creek watershed draining an area slightly larger than Hull Creek. The catchment area for Ware Creek is 1.4 km² with land cover dominated by forest (82.6%) and to a lesser extent pasture/hay (10.1%). Three 120 m sampling stations were established in Hull Creek. Spacing between stations was 100 m, and all stations were located upstream of the replaced culvert at Ware Rd. Riparian vegetation was similar among the three stations with predominately mixed deciduous and coniferous forest (Figure 7).

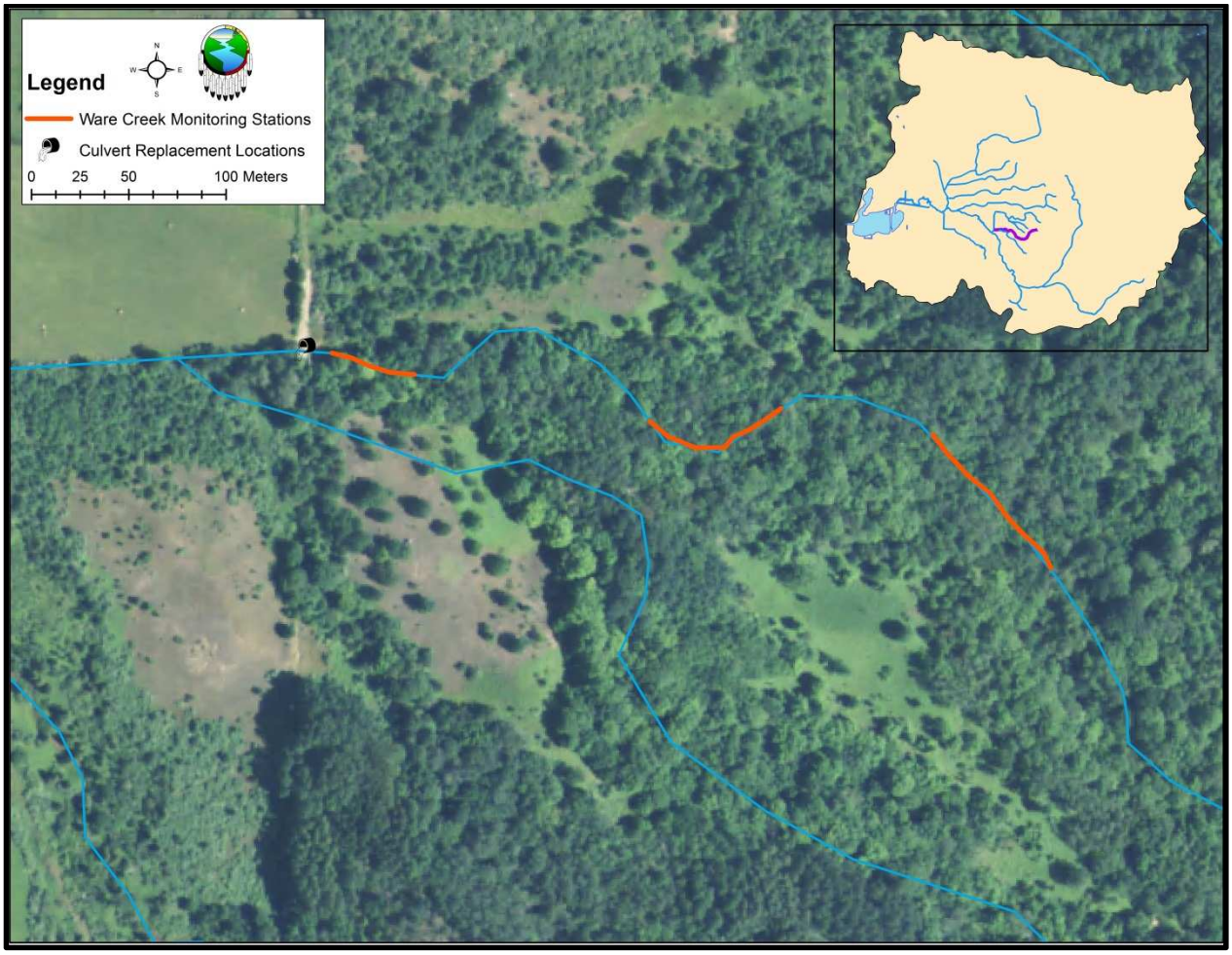


Figure 6. Ware Creek Site Map.


Figure 7. Ware Creek - Station 2 (left) and 3 (right).

Toohey Creek

Toohey Creek was used as the control site. Toohey Creek is a spring fed first order stream similar in size to Alkire, Hull, and Ware Creeks. Its watershed borders Alkire Creek watershed to the east and drains approximately 8.1 km² (Figure 8). Toohey Creek watershed is dominated by forest (67.1%) and to a lesser extent cultivated crops (16.1%). Three 120 m sampling stations were established in Toohey Creek. Spacing between stations was 100 m, and all stations were located just upstream of Gilbert Rd. Riparian vegetation was similar among the three stations with predominately mixed deciduous and coniferous forest (Figure 9). Toohey Creek has a natural barrier and is therefore impassible to migratory fish from Bowens Creek.

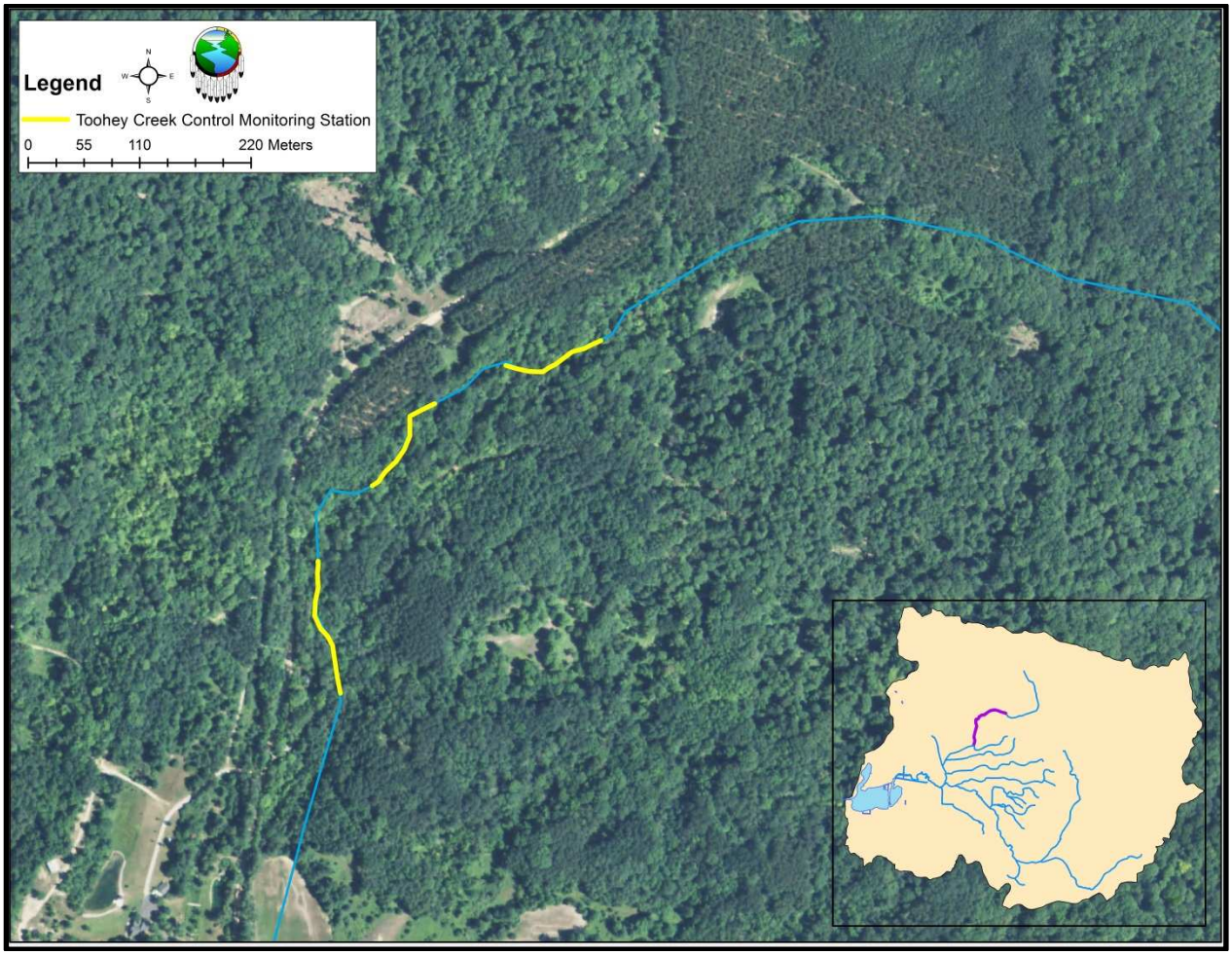


Figure 8. Toohey Creek Site Map.

Figure 9. Toohey Creek - Station 2 (left) and 3 (right).

Methods

Restoration monitoring of upper watershed tributary streams included annual assessments of water quality, in-stream habitat, fish and macroinvertebrate communities. Water quality was measured during backpack electro-fishing surveys in all stations during mid-summer from 2010-2013. Measurements were taken with a Hydrolab (Model DS 4A/5) and parameters included water temperature, dissolved oxygen, pH, conductivity, and turbidity. In-stream habitat variables were systematically sampled at equally spaced intervals (Wills et al. 2006) throughout each sampling station during mid-summer from 2010-2013. At each interval, stream widths (m) and depths (m) were measured and meso-habitat type was classified as pool, riffle, or run. Substrate classes were estimated using a modified pebble count (Wolman 1954) from 2010-2013. Habitat indices including EPA's Rapid Bioassessment Protocol and MDNR's Great Lakes and Environmental Assessment Section, Procedure #51, were conducted mid-summer from 2010-2013 (Barbour et al. 1999). Macroinvertebrate sampling was conducted during Spring and Fall from 2010-2013 using a multi-habitat approach (Barbour et al. 1999). Following field collection, macroinvertebrates were sub-sampled with a minimum sample size of 200 organisms ± 10% (Vinson and Hawkins, 1996) and identified to genus and indices calculated. Single pass backpack electro-fishing was conducted from 2010-2013 to characterize the composition of the fish community in each stream. All fish were identified and measured for total length (mm TL). Scale samples were taken from all salmonids ≥ 100mm TL. Scales were imaged and age estimates were performed and verified by multiple readers. Repeated Measures ANOVA was used to statistically analyze stream fish communities based on their Index of Biological Integrity (IBI). Stream stations were treated as a fixed factor, transects as replicates, and sample year (2010, 2011, 2012, 2013) as our repeated measure. Levene's test was used to assess equality of variance of scores taken from individual sampling stations within a particular stream.

Results

Water Quality

Water quality conditions were mostly stable among sampling sites and years (Table 1). Turbidity was more variable than other water quality parameters, but this is a common response to variations in summer precipitations events. In general, water temperatures were consistently cold and well oxygenated in all tributary streams and among all years sampled, suggesting water quality in each of these streams is suitable for cold-water fish and macroinvertebrate species.

Table 1. Average stream water quality from 2010-2013.

Waterbody	Temperature (ºC)	Dissolved Oxygen (ppm)	pH	Conductivity (mS/cm)	Turbidity (NTU)
Alkire Creek	14.5 (1.2)	8.4 (0.7)	7.7 (0.1)	0.2205 (0.03)	2.9 (4.3)
Hull Creek	11.1 (0.9)	10.5 (0.9)	7.9 (0.2)	0.3297 (0.02)	3.1 (4.0)
Ware Creek	10.3 (0.5)	11.3 (0.6)	7.9 (0.3)	0.3317 (0.02)	9.0 (8.8)
Toohey Creek*	11.1 (1.6)	10.6 (0.9)	7.8 (0.2)	0.3689 (0.01)	2.6 (4.3)

Numbers in parentheses represent standard deviations among stations and years. Control Site*

Habitat

Streams sampled were relatively small with widths typically less than 2.0 m and depths approximately 0.1 m (Table 2). Toohey Creek, the control site, was wider and shallower, with a higher proportion of riffle areas and fewer pools than other streams sampled. The predominant habitat in Alkire, Hull, and Ware Creeks were runs, with periodic pools and riffles.

Table 2. Average in-stream habitat characteristics from 2010-2013.

Waterbody	Width (m)	Depth (m)	% Pool	% Riffle	% Run
Alkire Creek	1.0 (0.4)	0.11 (0.06)	0.09 (0.10)	0.08 (0.12)	0.84 (0.12)
Hull Creek	1.4 (0.5)	0.10 (0.06)	0.13 (0.09)	0.34 (0.24)	0.53 (0.22)
Ware Creek	2.1 (0.5)	0.10 (0.06)	0.16 (0.08)	0.21 (0.16)	0.62 (0.17)
Toohey Creek*	3.1 (1.2)	0.06 (0.04)	0.06 (0.06)	0.53 (0.18)	0.41 (0.22)

Numbers in parentheses represent standard deviations among stations transects and years. Control Site*

Percentages of substrate classes were similar among sampling stations before and after restoration (Figure 10). Substrate in Alkire Creek was dominated by sand, Hull and Ware Creek were predominately sand and pebble, and the control site Toohey Creek, was a mixture of pebble, sand, and silt.

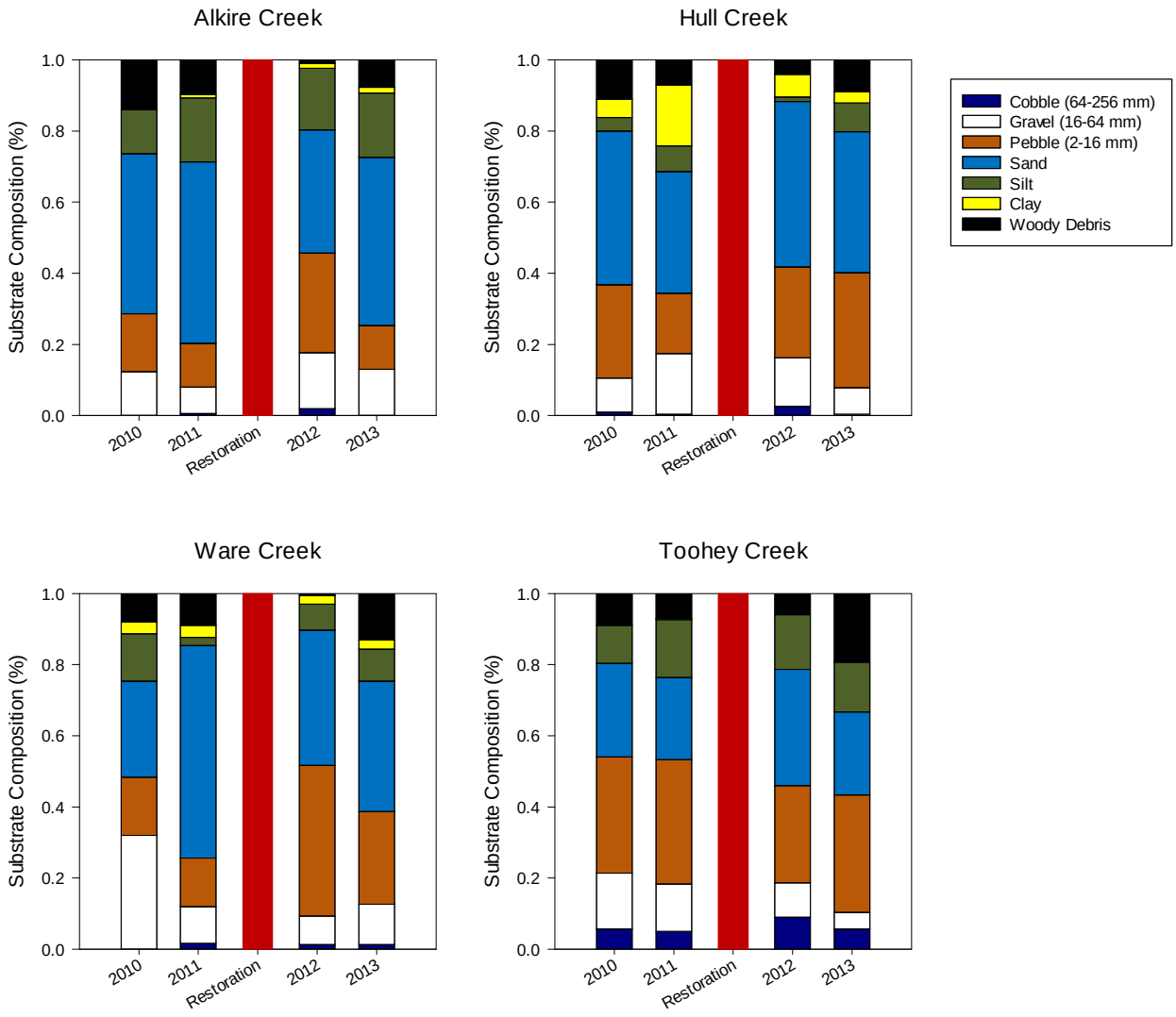


Figure 10. Substrate classes among four upper watershed streams, 2010-2013.

Results for Bowens Creek tributaries show little to no improvement in overall habitat score after replacement of culverts (Table 3). All sites were scored as sub-optimal (RBP) or good (GLEAS) except for the control site (Toohey Creek) which scored as optimal (RBP) or excellent (GLEAS). Since sampling stations were upstream of the replaced culverts, it may take multiple seasons for change in habitat scores to occur.

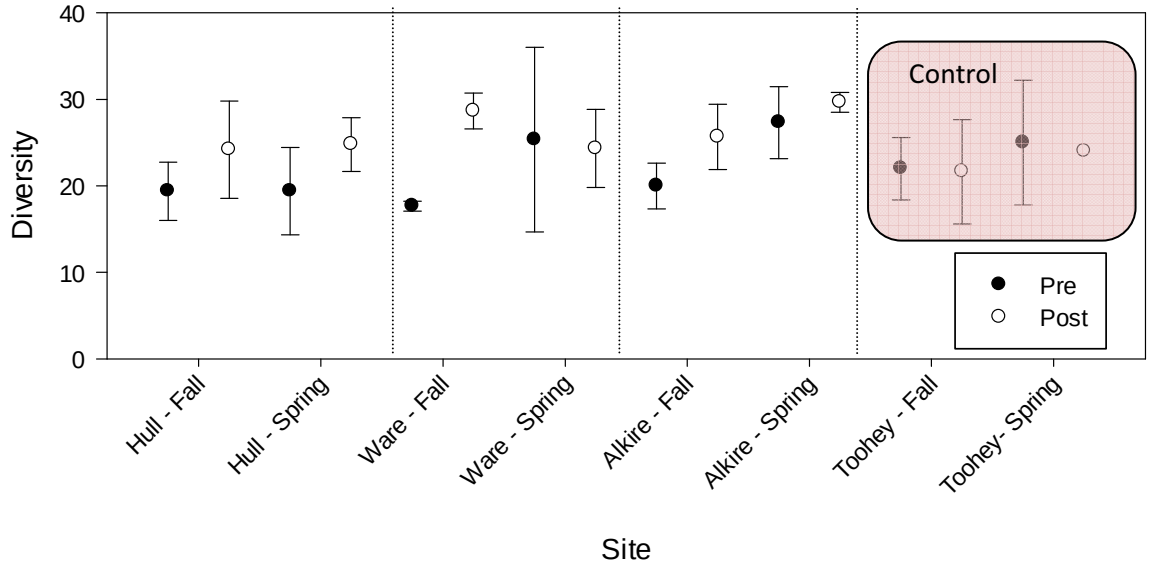
Table 3. RBP and GLEAS habitat scores for area tributaries.

	RBP		GLEAS	
	Pre	*Post*	*Pre*	*Post*
Alkire Creek	151	151	91	95
Hull Creek	133	139	79	83
Ware Creek	135	136	81	78
Toohey Creek*	171	181	110	118

** Control Site*

Macroinvertebrates

Results from macroinvertebrate data indicate that after replacement of road stream crossings diversity increases for taxa in most sampling sites (Figure 11). The control site maintained its level of diversity over the two years of sampling. This indicates communities shifted after restoration and there may be colonization of additional taxa post restoration. Alkire Creek, Hull Creek, and Ware Creek had construction occur in the summer of 2011. Toohey Creek (shaded box within Figure 11) had no construction and serves as a control site. Additional sampling may be needed to identify long term changes in macroinvertebrate communities.



Community composition metrics include the Hilsenhoff biotic index (HBI), the Great Lakes environmental assessment section (GLEAS), Procedure 51 and a benthic community index for macroinvertebrates (BCI). These three indicators score sites compared to a reference condition representing the best habitat and associated community composition available in this ecoregion. All three restoration streams as well as the control stream showed no significant change throughout the monitoring period ($p>0.05$, t-test) (Table 4). Alkire Creek generally scored the best with the other streams scoring lower but still in a "good" category. All site scores were similar to Toohey Creek which was the control system.

Table 4. Biotic index scores for streams pre- and post-restoration.

	Pre		Post		
	2010 Fall	2011 Spring	2011 Fall	2012 Spring	2012 Fall
Alkire					
HBI	3.999	5.062	4.719	4.870	4.114
GLEAS	5.3	3.3	4.0	4.3	2.7
BCI	32.7	30.7	34.7	30.0	30.7
Hull					
HBI	4.373	4.321	4.846	3.870	5.180
GLEAS	2.4	1.6	2.8	2.4	3.4
BCI	26.0	26.0	24.8	25.6	26.4
Ware					
HBI	4.547	4.478	4.916	4.244	5.617
GLEAS	2.3	1.0	2.0	2.3	2.0
BCI	26.7	28.0	28.0	28.0	27.3
Toohey					
HBI	4.117	4.040	3.477	3.648	4.546
GLEAS	1.7	1.3	1.0	0.3	-1.3
BCI	28.7	28.7	28.0	29.3	27.3

Fish

Alkire Creek

The fish community in Alkire Creek was predominately smaller trout (brook trout, *Salvelinus fontinalis;* brown trout, *Salmo trutta;* coho salmon, *Oncorhynchus kisutch;* and rainbow trout *Oncorhynchus mykiss*) and slimy sculpin (*Cottus cognatus*) (Figure 12.). Fish species observed were the same before and after restoration. Post-restoration, CPE and percent dominance of coho salmon showed a substantial increase (0.4 to 1.6 fish/min), while brown and brook trout decreased (3.0 to 1.5 and 0.7 to 0.2 fish/min, respectively). Rainbow trout and slimy sculpin remained fairly constant among years sampled.

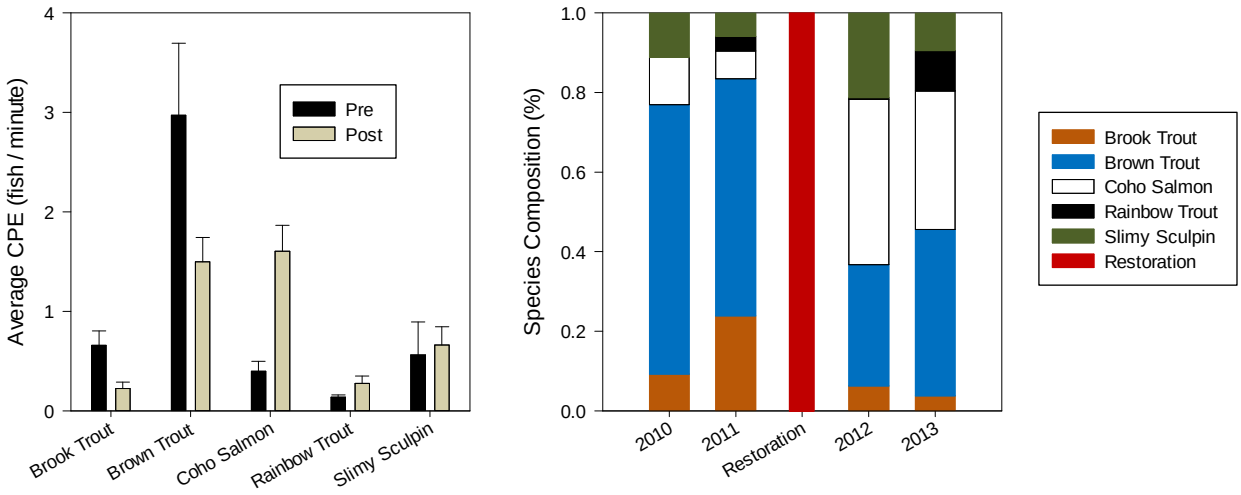


Figure 12. Alkire Creek Fish Community

Hull Creek

Prior to restoration, the fish community composition in Hull Creek was exclusively slimy sculpin while post-restoration, there was an increase of coho salmon (0 to 1.4 fish/min) and brown trout (0 to 0.4 fish/min) and a notable reduction in slimy sculpin (4.9 to 2.1 fish/min; Figure 13). The fish community seems to be shifting toward that of Alkire Creek, where coho salmon and brown trout are dominant and slimy sculpin compose a lesser proportion of the community.

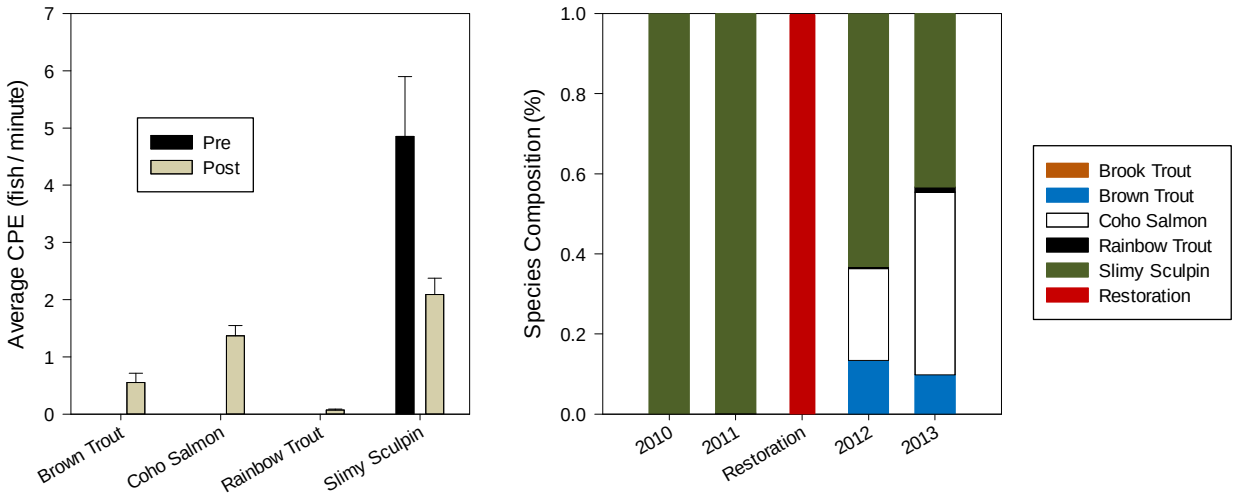


Figure 13. Hull Creek Fish Community

Ware Creek

Prior to restoration, fish community composition in Ware Creek was predominately slimy sculpin, brown trout, and rainbow trout (Figure 14.). Restoration led to an increase in coho salmon (0 to 1.5 fish/min), and to a lesser extent an increase in brown trout (2.2 to 3.5 fish/min). Reduced CPE's and percent dominance of slimy sculpin seem to have resulted from this shift. Rainbow trout appear to be unaffected by the influx of coho salmon and brown trout, at least in the two years observed post-restoration.

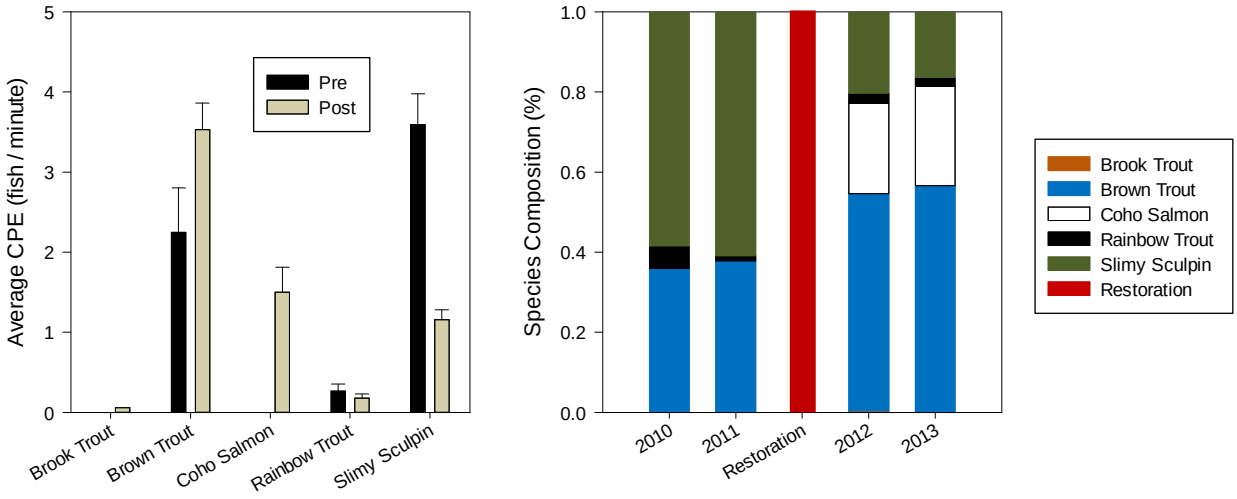


Figure 14. Ware Creek Fish Community

Toohey Creek

Fish community composition in Toohey Creek was predominately slimy sculpin, brook trout, and to a lesser extent rainbow trout (Figure 15.). The community was stable throughout the four years studied. Migratory salmon and trout were not observed in Toohey Creek because of a small impass just downstream from our study location.

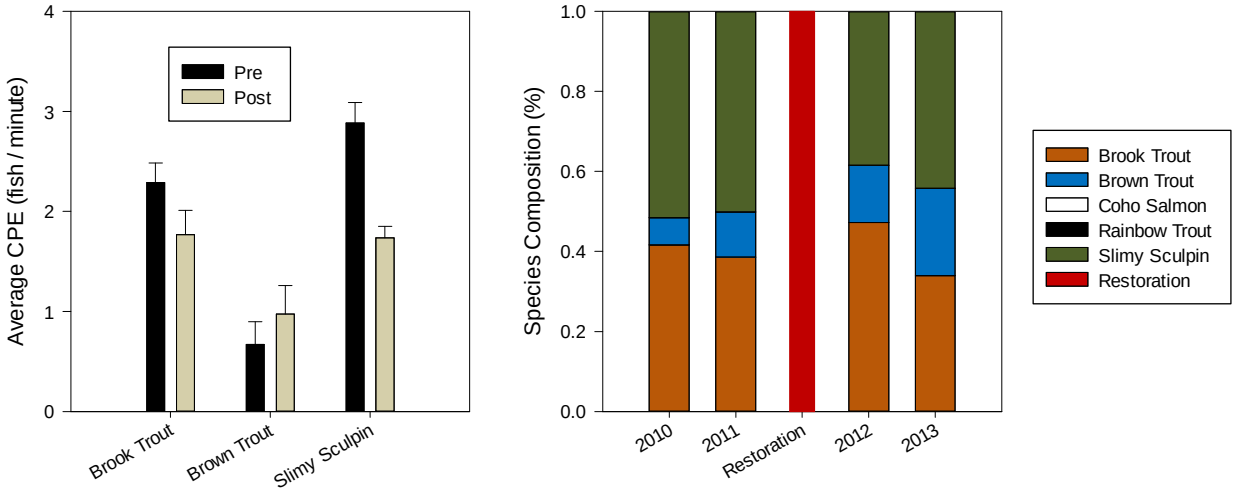
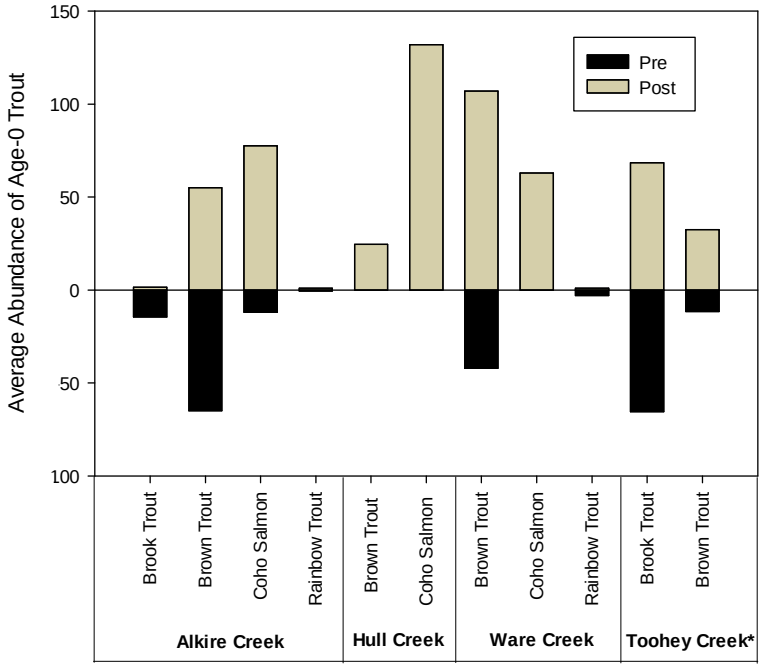


Figure 15. Toohey Creek Fish Community

An overall increase in age-0 trout and salmon was observed in all streams (with the exception of the control site) following restoration (Figure 15). Abundances of age-0 coho salmon were notably higher in each stream post-restoration, with the highest abundance in Hull Creek. Post-restoration abundances of age-0 brown trout were higher in Hull Creek and Ware Creek. Overall increases in age-0 trout and salmon indicate recruitment.



Fish IBI scores were calculated from metrics developed in Mundahl and Simon (1999) specifically for coldwater streams in our ecoregion. Fish IBI scores were significantly higher post restoration in Hull and Ware Creeks (Table 5). Both streams had higher fish species diversity and a higher percent dominance of trout and salmon post restoration. The control site showed no difference in fish IBI scores between pre and post restoration. Fish IBI scores in Alkire Creek were not significantly different between pre and post sampling events. Alkire Creek was the only stream which had salmon prior to restoration suggesting that fish passage may not have been as limited in Alkire Creek as other streams.

Table 5. Fish IBI scores (Mundahl and Simon, 1999) for area tributaries.

	Fish IBI		
	Pre	*Post*	*p-value*
Alkire Creek	100.8	96.7	0.120
Hull Creek	86.5	98.0	**<0.001**
Ware Creek	96.7	103.3	**0.047**
Toohey Creek*	106.7	106.7	0.378

** Control Site*

Discussion and Conclusion

Restoration of road stream crossings showed an immediate shift in fish communities. Coho salmon showed a substantial increase in each stream where road stream crossings were replaced. Other trout species, including brown and rainbow trout are now present in streams where they were not previously sampled. In general, streams where culverts were replaced had higher fish species diversity and a higher percent dominance of trout and salmon post restoration. Macroinvertebrate taxa richness improved although community index scores did not. These stream sites prior to restoration were already quality sites for macroinvertebrates so it would be difficult to improve scores. Maintaining quality scores is an indication that the culvert replacements did not have a negative impact to the hydrology of the system.

Fish communities in the control site Toohey Creek were stable throughout the four years of this study, indicating that over time climatic and environmental effects should have been similar among streams sampled. Water quality and habitat also remained similar before and after restoration suggesting that these shifts in fish communities were likely not a consequence of changes in water quality, habitat, or temporal climatic effects, but rather an increase in connectivity from the restoration. Overall, the replacement of road stream crossings improved stream continuity by re-connecting waters. The effects of this restoration have been immediately observed, but it is likely that the biological community will continue to change as it approaches a natural structure.

LOWER WATERSHED – ARCADIA MARSH

Introduction

Ducks Unlimited was awarded a National Fish and Wildlife Foundation – Sustain Our Great Lakes Stewardship Grant in 2009. Through this funding as well as the effort of numerous partners a one-mile section of channelized Bowens Creek that flows through Arcadia Marsh was redirected into its original watercourse by plugging five diversion ditches. These ditch plugs consisted of soil and rock, were designed to be long-lasting and withstand erosion, and should be maintenance free. This process will divert the entire creek flow back into its original meandering channel and allow natural hydrologic processes to return to the original Bowens Creek within Arcadia Marsh. The LRBOI Natural Resources department partnered in the project to specifically address pre- and post-monitoring of fish, macroinvertebrates and habitat throughout the restoration project.

Site Descriptions

Bowens Creek is a third order stream located in Manistee County near Arcadia, Michigan. The catchment area for Bowens Creek is 64.9 km² with land cover dominated by forest (48.7%), cultivated crops (19.0%), and grasslands (15.4%) (Figure 16). The lower section of Bowens Creek watershed is part of a unique and diverse ecosystem defined as Great Lakes coastal wetland. Below St Pierre Rd., Bowens Creek flows approximately 2 km through Arcadia Marsh into Arcadia Lake and eventually into Lake Michigan.

Five sampling stations were established in the lower watershed of Bowens Creek. Sampling locations included one station in the channelized segment, three stations in the historical channel below the diversion, and one just above the diversion serving as our control (Figure 16). Each station is described separately below.

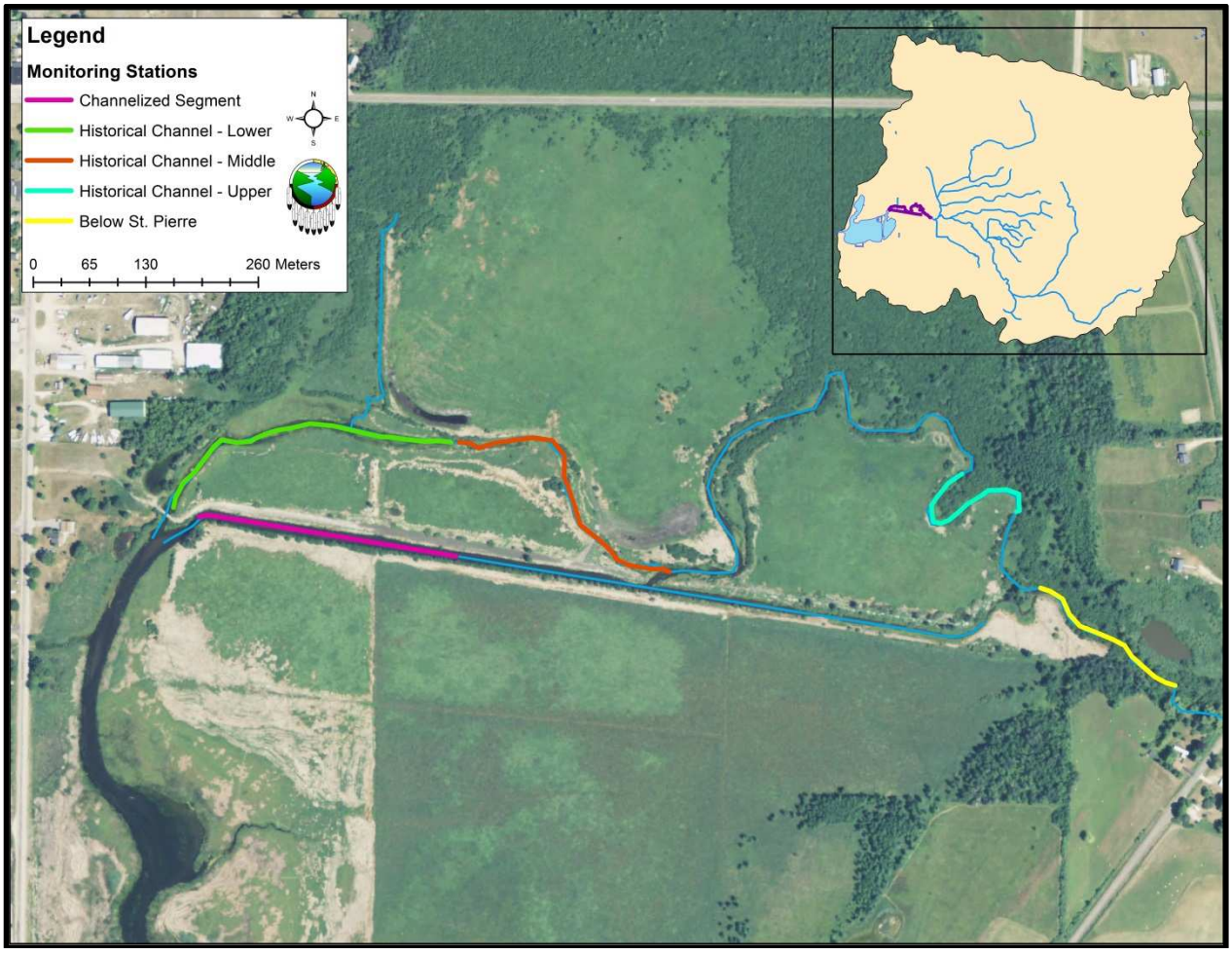


Figure 16. Lower Bowens Creek Watershed Site Map.

Channelized Segment

Bowens Creek was channelized along a railroad grade running through Arcadia Marsh and as a result of a host of additional anthropogenic disturbances the stream was nearly completely diverted. The channelized segment ran from just downstream of St. Pierre Rd. approximately 1 km to near its confluence with Arcadia Lake. A 300 m sampling station was established in the lower portion of the channel. The riparian vegetation within this station was predominately grasses and sedges with very little in-stream habitat or riparian cover (Figure 17). Sampling was conducted pre-restoration only. Once the stream was re-routed into the historical channel, the channelized segment filled in and no additional aquatic sampling was performed (Figure 17, right image).

Figure 17. Bowens Creek Channelized Segment – Pre (left) and Post Restoration (right).

Historical Channel Lower

Prior to restoration, the channelized segment bi-passed approximately 1.7 km of the natural stream channel. The lower sampling station in Bowens Creek's historical channel was located just upstream of where the channelized segment re-connected with the natural stream channel (Figure 16 above). Station length was 215 m, and riparian vegetation was predominately cattails, grasses and rushes (Figure 18).

Figure 18. Bowens Creek Historical Channel Lower – Pre (left) and Post Restoration (right).

Historical Channel Middle

The middle sampling station in Bowens Creek's historical channel was located just upstream of the lower station (Figure 16 above). This station had a relatively unconfined stream channel with sections that were too shallow to kayak (Figure 19). Station length was 215 m and riparian vegetation was predominately cattails and grasses.

Figure 19. Bowens Creek Historical Channel Middle – Pre (left) and Post Restoration (right).

Historical Channel Upper

The upper sampling station in Bowens Creek's historical channel was located upstream of the middle station and just downstream of the diversion (Figure 16 above). The upper sampling station was 200 m in length and riparian vegetation was alders, cattails and grasses. In-stream habitat was characterized by undercut banks and overhanging vegetation (Figure 20).


Figure 20. Bowens Creek Historical Channel Upper – Pre (left) and Post Restoration (right).

St. Pierre

St. Pierre Rd. sampling station was located downstream of St Pierre Rd. and ending at the diversion (Figure 16 above). This station was used as a control for the lower watershed because it was located upstream of the diversion. The station was 200 m in length and riparian vegetation was predominately mixed deciduous, alders, cattails and grasses. In-stream habitat was characterized by large bends, undercut banks, and overhanging vegetation (Figure 21).


Figure 21. Bowens Creek downstream of St. Pierre Rd. – Pre (left) and Post Restoration (right).

Methods

Restoration monitoring of the lower Bowens Creek system included annual assessments of water quality, in-stream habitat, fish and macroinvertebrate communities. Pre-restoration monitoring was conducted in 2010 and 2011. Since restoration was delayed until winter 2012-2013, post-restoration monitoring (with the exception of macroinvertebrate sampling) was conducted only during the 2013 field season. Water quality was measured during electro-fishing surveys in all stations during mid-summer. Measurements were taken with a Hydrolab (Model DS 4A/5) and parameters included water temperature, dissolved oxygen, pH, conductivity, and turbidity. In-stream habitat variables were systematically sampled at equally spaced intervals (Wills et al. 2006) throughout each sampling station during mid-summer. At each interval, stream widths and depths were measured and meso-habitat type was classified as pool, riffle, or run. Substrate classes were estimated using a modified pebble count (Wolman 1954). Habitat indices including EPA's Rapid Bioassessment Protocol and MDNR's Great Lakes and Environmental Assessment Section, Procedure #51 were conducted mid-summer (Barbour et al. 1999). Macroinvertebrate sampling was conducted during Spring and Fall from 2010-2013 using a multi-habitat approach (Barbour et al. 1999). Following field collection, macroinvertebrates were sub-sampled with a minimum sample size of 200 organisms ± 10% (Vinson and Hawkins, 1996) and identified to genus level. Single pass backpack electro-fishing was conducted during mid-summer to characterize the composition of the fish community in each stream station. Backpack electrofishing was done by canoe in the channelized segment, and in both lower and middle stations in the historical channel due to the inability to effectively wade the stream. All fish were identified and measured for total length (mm). Scale samples were taken from all salmonids ≥ 100mm TL. Scales were imaged and age estimates were performed and verified by multiple readers.

Results

Water Quality

Several water quality trends were observed in sites pre- and post-restoration. In general, St. Pierre and upper Bowens Creek sampling stations were colder, and had slightly lower dissolved oxygen levels than stations further downstream, both pre- and post-restoration (Table 6). In 2013 (post restoration) water temperature, dissolved oxygen, and pH were lower, while conductivity was higher than pre-restoration levels in lower, middle and upper Bowens Creek sampling stations. Water quality at the control site was fairly stable, remaining mostly unchanged throughout the study.

Table 6. Water Quality Parameters Pre- and Post-Restoration.

Station	Temperature (ºC)		Dissolved Oxygen (ppm)		pH		Conductivity (mS/cm)		Turbidity (NTU)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Channel	14.7 (1.7)	NA	11.5 (1.4)	NA	8.3 (0.2)	NA	0.3324 (0.00)	NA	9.8 (0.2)	NA
Lower	19.8 (3.8)	13.7	7.8 (6.6)	5.9	7.8 (0.5)	7.3	0.2752 (0.04)	0.3556	2.9 (0.9)	3.1
Middle	18.7 (3.7)	13.4	8.1 (6.5)	7.0	8.1 (0.3)	7.4	0.2892 (0.05)	0.3518	26.6 (26.4)	3.2
Upper	13.7 (0.8)	11.6	11.0 (0.8)	9.1	8.1 (0.1)	7.8	0.3250 (0.02)	0.3484	6.7 (8.2)	3.0
St. Pierre*	13.4 (0.4)	12.4	11.1 (0.7)	10.8	8.1 (0.1)	7.9	0.3216 (0.02)	0.3477	7.4 (2.6)	2.5

*Pre-restoration values were averaged from 2010, 2011 and 2012 mid-summer samplings. Numbers in parentheses represent standard errors among years. * Control Site*

Habitat

Below the St. Pierre Rd. sampling station and above the upper historical channel sampling station, Bowens Creek was diverted into the channel. The channel had limited habitat and was wide and deep with an average discharge of 0.53 m^3/s. Sampling stations within the historical channel had less water moving through them and were on average shallower than the sampling station above the diversion, as well as in the channelized segment. Discharge was higher in the upper historical channel, and gradually decreased further downstream where the historical channel slowed and widened out. In-stream habitat in historical channel stations was nearly completely slow-flowing runs, with an occasional pool further upstream. St. Pierre Rd. was similar to the upper station in the historical channel.

Following restoration, average depths increased for all stations, including the control. Widths were fairly similar with the exception of the lower station within the historical channel, which was much narrower (Table 7). Habitat was predominately runs both before and after restoration.

Table 7. In-Stream Habitat Parameters Pre- and Post-Restoration.

Station	Width		Depth		% Pool		% Riffle		% Run	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Channel	12.5 (0.9)	NA	0.49 (0.01)	NA	0.04 (0.05)	NA	0	NA	0.96 (0.05)	NA
Lower	14.2 (0.6)	6.4	0.32 (0.11)	0.49	0 (0)	0	0	0	1.0 (0)	1.0
Middle	4.4 (1.0)	5.1	0.25 (0.06)	0.55	0.04 (0.05)	0	0	0	0.96 (0.05)	1.0
Upper	4.7 (0.5)	4.1	0.31 (0.11)	0.85	0.15 (0)	0.08	0	0	0.85 (0)	0.92
St. Pierre*	5.7 (0.2)	5.8	0.45 (0.05)	0.74	0.12 (0.16)	0	0	0	0.88 (0.16)	1.0

*Pre-restoration values were averaged from 2010 and 2011 mid- summer samplings. Numbers in parentheses represent standard errors among station transects and years. * Control Site*

Percentages of substrate classes were similar among sampling stations during 2010 and 2011 (Figure 22). In general, sampling stations further upstream had higher percentages of sand and lower percentages of silt. Post restoration, percent silt was lower and percent sand and woody debris were higher in lower, middle, and to a lesser extent upper sampling stations. The channelized segment of Bowens Creek had nearly identical substrate compositions pre-restoration with 41% sand, 58% silt, and 1% woody debris in 2010, and 41% sand and 59% silt in 2011. Substrate in the channelized segment was not sampled following restoration. Percent substrate in the control site, St. Pierre, was predominately a mixture of sand and silt. The small percentages of cobble, pebble, and gravel were mainly located around an old road stream crossing. Percent substrate in the control site was similar both pre and post restoration.

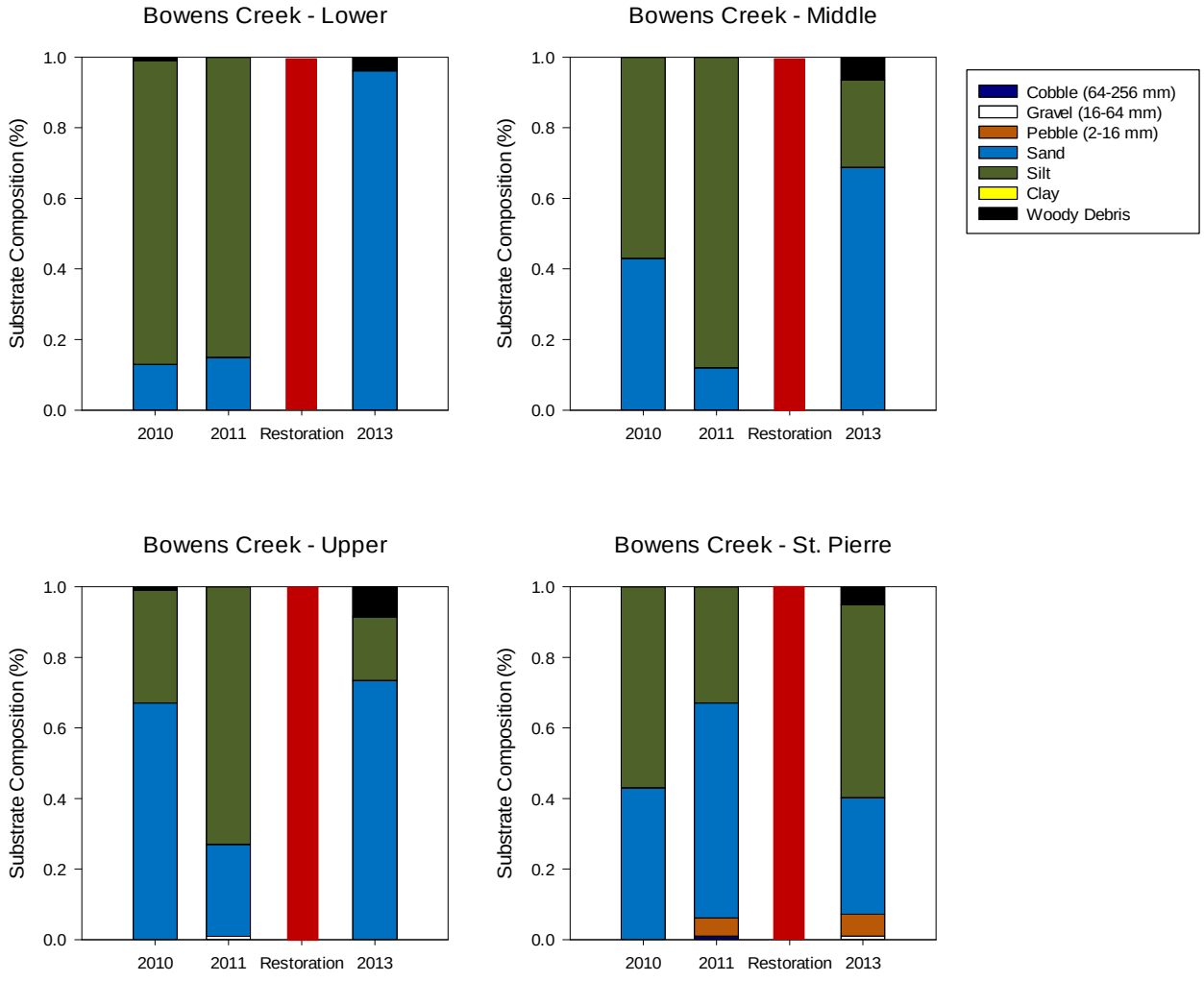


Figure 22. Substrate classes among four lower watershed sampling stations, 2010-2013.

Macroinvertebrates

The macroinvertebrate community below St. Pierre Road including the channelized section as well as the historic channel was rated "very poor" prior to any restoration activities. The Hilsenhoff (HBI) score indicated elevated levels of organic enrichment at numerous sampling stations. The Great Lakes and Environmental Section Assessment (GLEAS) score was considered "not acceptable" or in the lowest tier of classification in the channel sites and was only slightly better at the control site and the historic channel. The benthic community index (BCI) score was "poor", also the lowest index classification. After the stream was re-routed to the original channel (Summer 2013) only one sample was able to be collected for post monitoring (Fall 2013). This sample should be considered preliminary as the stream had not fully recovered from the restoration activity and monitoring should continue in future years to further evaluate the restoration effect. The post sample, taken three months after construction indicated a very similar community to pre-restoration with "very poor" scores in all indices (Table 8).

Table 8. Mean Macroinvertebrate Index Scores Pre- and Post- Restoration.

		Pre	Post
Channel			
	HBI	5.910	n/a
	GLEAS	-4	n/a
	BCI	18	n/a
Restored			
	HBI	5.966	6.811
	GLEAS	-3	-5
	BCI	20	17
Control			
	HBI	4.59	4.66
	GLEAS	-2	-5
	BCI	26	24

Fish

Bowens Creek – Lower

Prior to restoration, the fish community included brook stickleback (*Culaea inconstans*), central mudminnow (*Umbra limi*), yellow perch (*Perca flavescens*) and white sucker (*Catostomus commersonii).* Post restoration, the fish community shifted to predominately trout (64.5% rainbow trout, 35.5% brown trout), yellow perch, and northern pike (*Esox Lucius*) (Figure 23). Yellow perch was the only fish species that was observed both before and after restoration. Overall CPE was lower following restoration, with trout CPE's averaging less than 0.9 fish per minute.

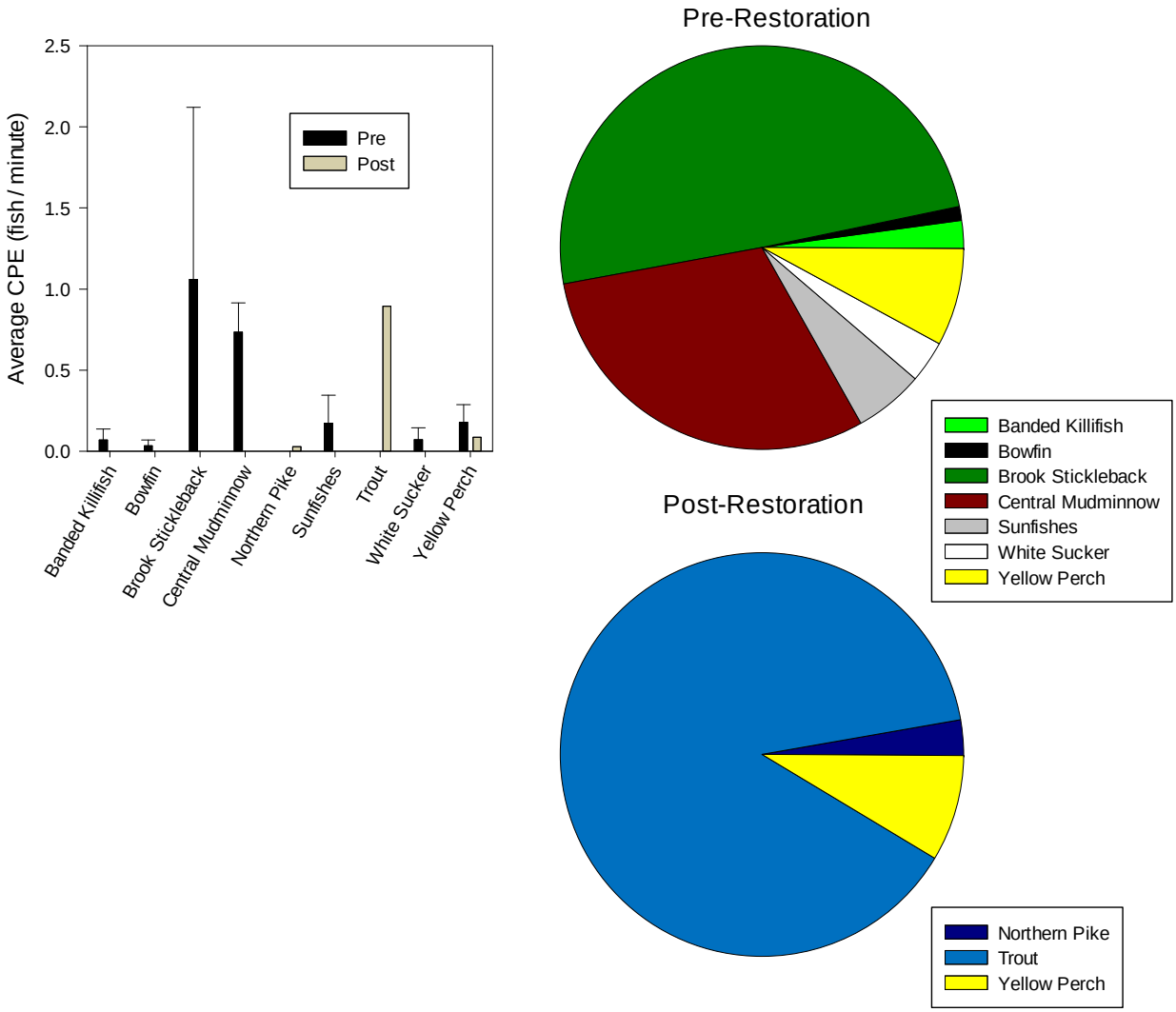


Figure 23. Bowens Creek – Lower Fish Community

Bowens Creek – Middle

Prior to restoration, the fish community included mainly brook stickleback, central mudminnow, and yellow perch. Post restoration, the fish community shifted to predominately trout (66.7% rainbow trout, 33.3% brown trout), yellow perch, and to a lesser extent white sucker (Figure 24). Yellow perch was the only fish species that was observed both before and after restoration. Overall CPE was higher following restoration, with trout CPE's averaging 3.5 fish per minute.

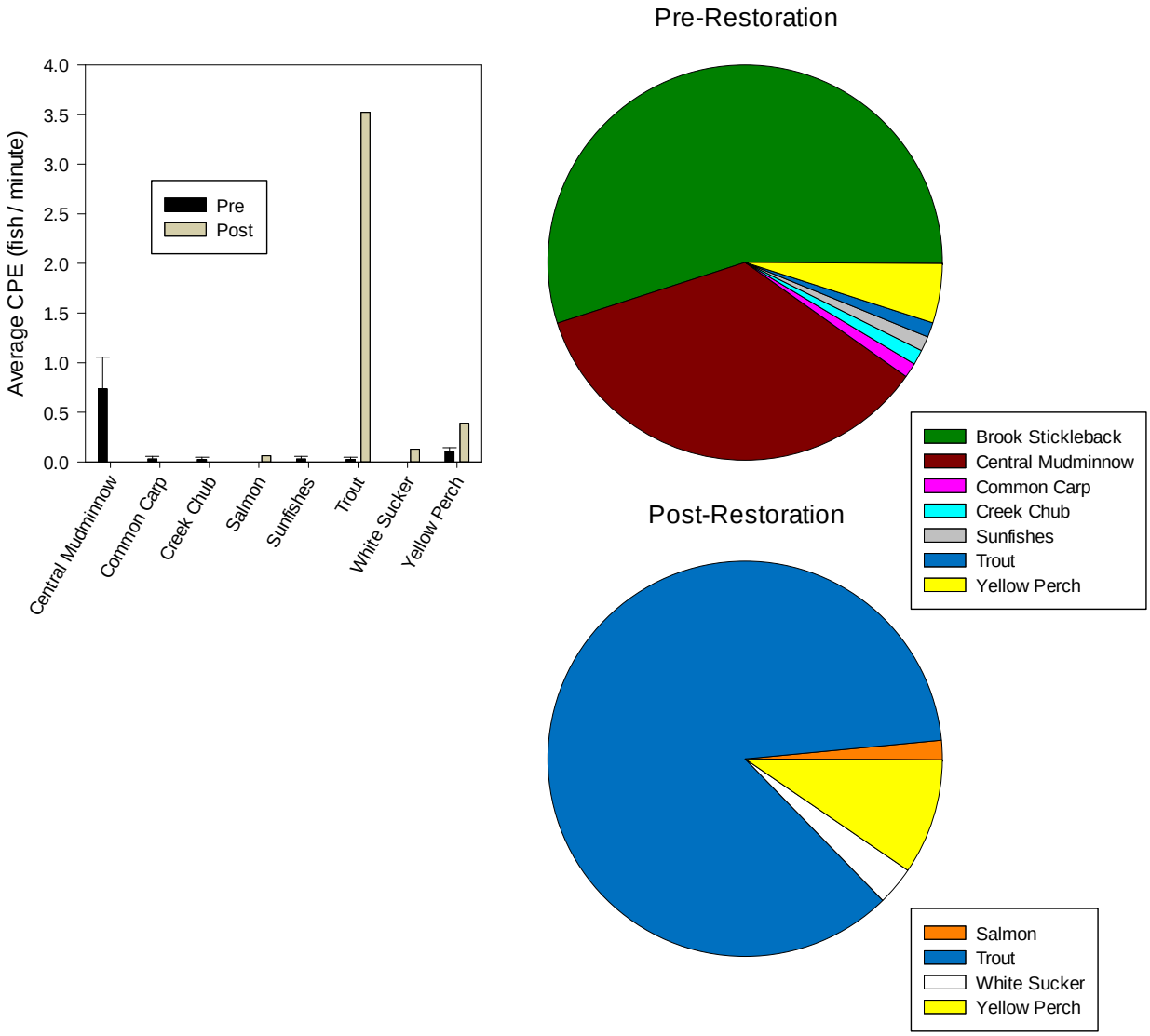


Figure 24. Bowens Creek – Middle Fish Community

Bowens Creek – Upper

Prior to restoration, fish community in Bowens Creek – Upper was predominately trout (2.1% brook trout, 41.0% brown trout, and 56.9% rainbow trout), slimy sculpin, central mudminnow, and brook stickleback (Figure 25). Post-restoration, diversity decreased from twelve species to four, with percent dominance of trout increasing from 60.8 to 90.0%. Percent dominance of rainbow trout was similar before and after restoration, while brown trout percent dominance increased from 24.9 to 56.7%. Overall CPE was lower following restoration, with trout CPE's averaging just over 1.2 fish per minute.

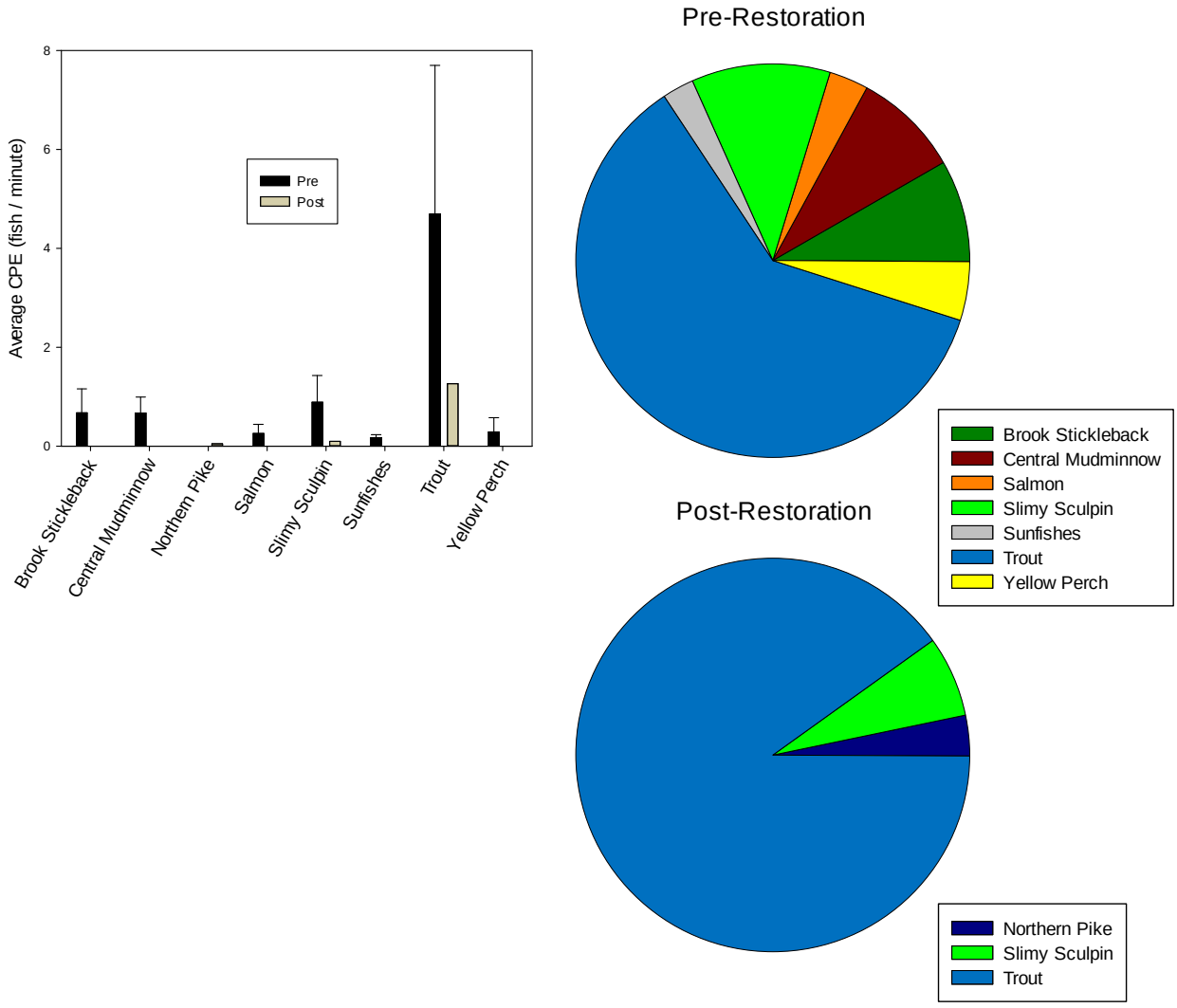


Figure 25. Bowens Creek – Upper Fish Community

Bowens Creek – St. Pierre

Prior to restoration, the fish community in Bowens Creek – St. Pierre was predominately trout (1.3% brook trout, 46.4% brown trout, and 52.3% rainbow trout), slimy sculpin, central mudminnow, and yellow perch (Figure 26). Post-restoration, species diversity decreased from ten species to three, with percent dominance of trout increasing from 59.2 to 94.4%. Percent dominance of slimy sculpin and rainbow trout decreased (31.0% to 8.3% and 23.1% to 5.6%, respectively), while brown trout increased (27.5% to 86.1%) following restoration. Overall CPE was lower following restoration, with trout CPE's averaging just over 1.0 fish per minute.

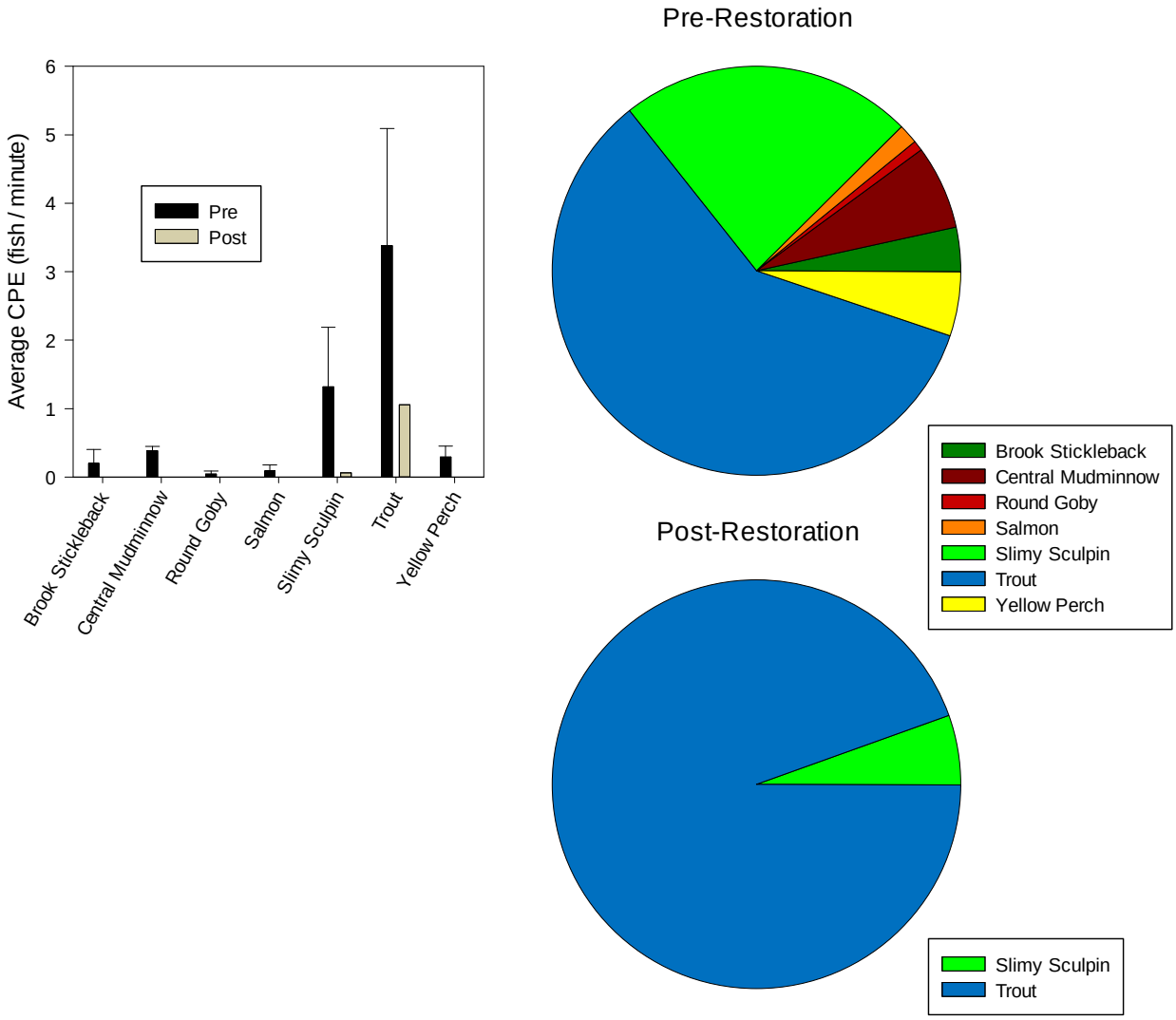


Figure 26. Bowens Creek – St. Pierre Fish Community

Bowens Creek – Channel

A total of nine species were collected in Bowens Creek – Channel with yellow perch, brook stickleback, and central mudminnow being the most dominant (Figure 27). Sampling was not conducted in the channel following restoration, since the channel filled in.

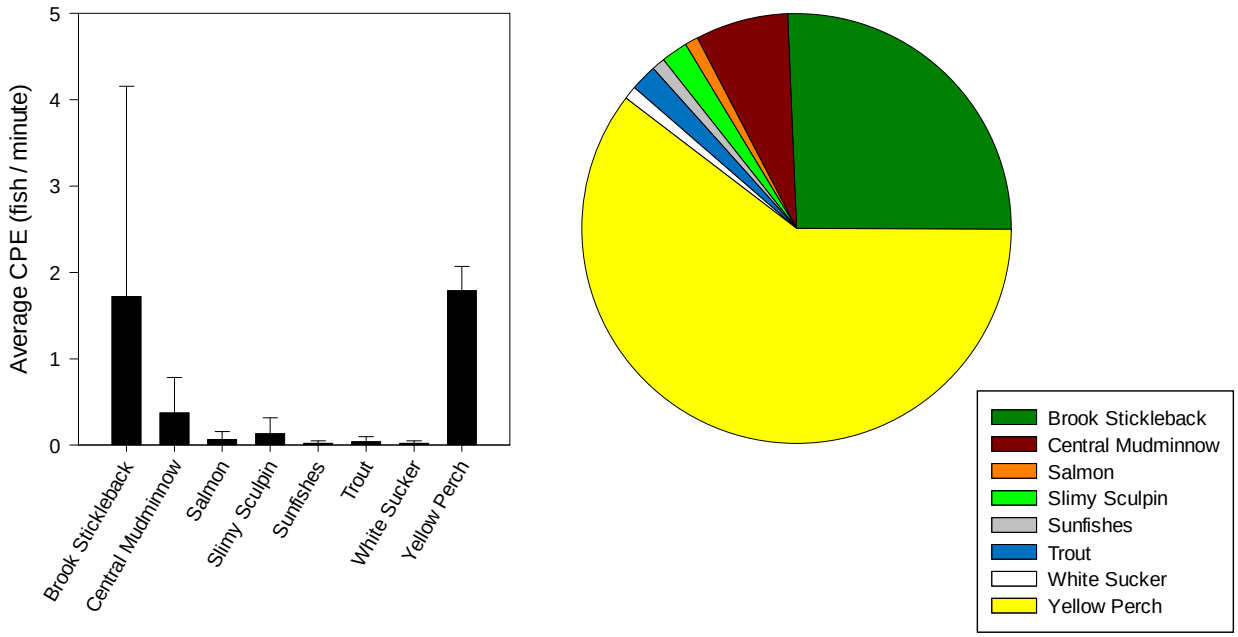


Figure 27. Bowens Creek – Channel Fish Community

Fish IBI scores were calculated from metrics developed in Mundahl and Simon (1999) specifically for coldwater streams in our ecoregion. Fish IBI scores were higher post restoration in Lower and Middle sampling stations (Table 9). Both streams had higher abundances of trout and fewer cooler water tolerant species post restoration. Upper and St. Pierre sampling stations showed very little difference in fish IBI scores between pre and post restoration. Although both sampling stations had fewer cooler water tolerant species, they also had fewer trout.

Table 9. Fish IBI scores (Mundahl and Simon, 1999).

	Fish IBI	
	Pre	*Post*
Channel	42.5	-
Lower	47.5	85
Middle	55	70
Upper	87.5	90
St. Pierre*	85	85

** Control Site*

Discussion and Conclusion

Restoration of Arcadia Marsh showed an immediate shift in fish communities. Following the re-routing of Bowens Creek into the historical channel fish communities shifted from cool water species such as brook stickleback, central mudminnows and sunfish to cold water species including, brown trout, rainbow trout and slimy sculpin. Lower and middle sampling stations showed a substantial increase in rainbow trout and to a lesser extent brown trout. Historical Channel – Upper and St. Pierre sampling stations saw a similar loss of cool water species such as central mudminnow and sunfishes, but also showed an unanticipated decrease in overall CPE of trout in 2013. St. Pierre, originally considered a control was affected by re-routing due to changing hydrology and impounding of water. St. Pierre and Historical Channel – Upper sampling stations were deep and over their banks in numerous locations. It is likely that the lower section of Bowens Creek, below the ditch plug, is still creating a new channel causing the upper stations to back up. Only one sample post-restoration (Fall 2013) was able to be collected for macroinvertebrates and this did not indicate any improvement in the community composition. Sampling should continue to evaluate the stream in the future. As the stream stabilizes and in-stream habitat types become more defined, biological communities will likely continue to shift. The re-connection of Bowens Creek has started a change in physical, chemical and biological components that will likely continue to change as this system stabilizes.

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