# Cedar, Pitch & Whitewood Creeks

## Benthic Invertebrate and Fish Community Assessment

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# Abstract

Aquatic assessments on three Whitefish River tributaries were conducted due to some concern over potential impacts from land use practices within the watersheds of Cedar, Pitch, and Whitewood creeks. The health of benthic invertebrate communities was assessed used the Ontario Benthos Biomonitoring Network (OBBN) protocol at three sites in 2010, which were compared to previously assessed reference sites on the same tributaries. Landscape habitat patterns were assessed using GIS and aerial reconnaissance, and were measured in the field at 25 sites using methods from the OBBN protocol as well as the Ontario Stream Assessment Protocol (OSAP). The fish communities at these 25 sites were sampled using 1-pass electrofishing with blocking nets. OBBN sites in the lower reaches of all three tributaries had good abundance of sensitive taxa such as EPT (Ephemeroptera-Plecoptera-Tricoptera), but showed increasing numbers of worms compared to upstream reference sites. This suggests increased algae and minor impairment of water quality, possibly due to nutrient inputs.

Fish abundance and biomass, particularly brook trout, varied significantly among sites mainly due to barriers to fish migration, changes in surficial geology, and other habitat factors. Brook trout were most abundant higher in the watershed and were less abundant or absent in the lower reaches of all three tributaries where rainbow trout were more abundant. The streams show higher than preferred maximum summer water temperatures in late summer and the possible lack of thermal refugia in lower reaches where the stream cut through fine-textured glaciolacustrine silts and clays may be limiting factor for brook trout. Localized impacts from land use practices such as livestock watering, dam building, and riparian vegetation removal may reduce the suitability of some sites for some fish species, particularly brook trout. As most of the lower watersheds of these three streams are on private lands, landowner outreach for stewardship is recommended.

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# 1 Introduction

Cedar (29.5 km), Pitch (31.5 km), and Whitewood (19.1 km) creeks are three tributaries of the Whitefish River whose watersheds encompass O'Connor, Marks, and other townships immediately west of Kakabeka Falls, Ontario (Figure 1). Forestry, agricultural use, and other human activities are widespread in much of their watersheds, and there has been some concern about potential impacts of these land use practices on aquatic ecosystems. For example, LRCA (1998) recorded *E. coli* levels exceeded provincial surface water quality guidelines on two occasions in 1998 on at Cedar Creek, and suggested it was due to runoff from agricultural use of the land upstream (LRCA 1998). Removal of riparian forests has been shown to have adverse impacts on water quality parameters such as water temperature, dissolved oxygen, phosphate, nitrate, and suspended sediments (Binkley and Brown 1993; Feller 1981) As a coldwater species, brook trout is particularly sensitive to disturbances in thermal regime since cool maximum summer water temperatures are crucial to stream resident brook trout populations (Scott and Crossman 1998).

The Thunder Bay District Stewardship Council decided to investigate the impact of land use practices on the water quality of streams within the Whitefish River watershed. Baseline data about aquatic benthic macroinvertebrates obtained during 2009 in three tributaries of Whitefish River —Cedar Creek, Whitewood Creek and Pitch Creek—indicated that these three sites were suitable for inclusion as Reference Condition sites in the Ontario Benthos Biomonitoring Network database (Deacon & Lavoie 2010). Three test sites located closer to the mouths of these three streams and more likely to be impaired were selected for study in 2010 to determine whether benthic macroinvertebrate communities were affected by land use practices.

Benthic macroinvertebrates respond to ecosystem changes faster than other members of the aquatic community and therefore are commonly used as indicator species to assess the health of aquatic ecosystems. Trends and changes in aquatic macroinvertebrate populations and in their community structure can serve as indicators of short-term stresses. EcoSuperior Environmental Programs has been acquiring baseline data about the macroinvertebrate communities in unimpaired streams on the north shore of Lake Superior and investigating the benthic community structure in possibly impaired sites (Deacon & Lavoie 2005; 2007; 2009; 2010 and 2011).

The purpose of this study was to assess the benthic invertebrate and fish communities in these watersheds, and to examine potential impacts on their habitats.

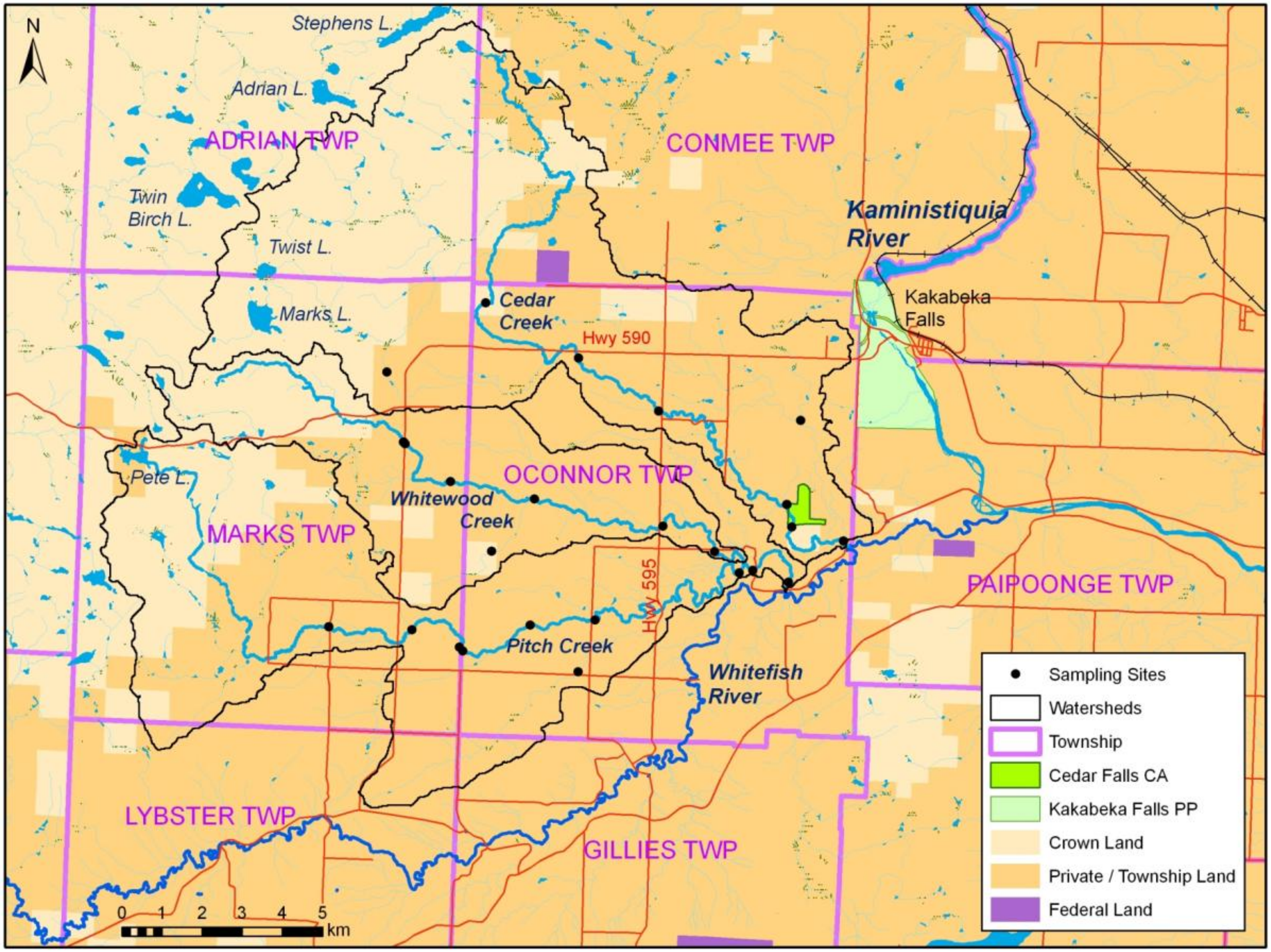



Figure 1. General location and land tenure of Whitefish tributaries 2010 study area.

# 2 Methods

Fieldwork was conducted July 15 to November 1, 2010. A reconnaissance flight was conducted by R. Foster, B. Raticliff, and D. Viebeck (OMNR) on July 29, 2010 to assess potential sampling locations, access, and adjacent land use practices.

## 2.1 Site Selection

Site selection and field methods generally followed the Ontario Stream Assessment Protocol (OSAP)(Stanfield 2002, 2005) and the Ontario Benthos Biomonitoring Network protocol (Jones et al. 2005). A total of 25 stations were sampled (Appendix 1, Figure 2). Sample site selection was primarily based on:

- potential impacts from land use practices,
- position in watershed,
- barriers to fish passage,
- access,
- land tenure,
- previous OBBN sampling sites, and
- 1998 and 2010 LRCA water quality sampling sites.

## 2.2 Water Temperature

A water temperature logger (HOBO Pendant Temperature Light data logger UA-002-08) was installed at one location in each stream (Figure 3, Table 1) on July 15 and removed November 1. Loggers were attached to a brick in at least 30 cm of water, and recorded water temperature hourly approximately 15 cm off the stream bottom. The logger at Whitewood Creek malfunctioned so no data are available for that location. Water temperatures were also taken during fish sampling using a hand-held thermometer.

Table 1. Temperature Logger Locations

| Logger | Stream | Easting | Northing |
|---|---|---|---|
| 1 | Whitewood | 293595 | 5361879 |
| 2 | Pitch | 291732 | 5357277 |
| 3 | Cedar | 302152 | 5360328 |

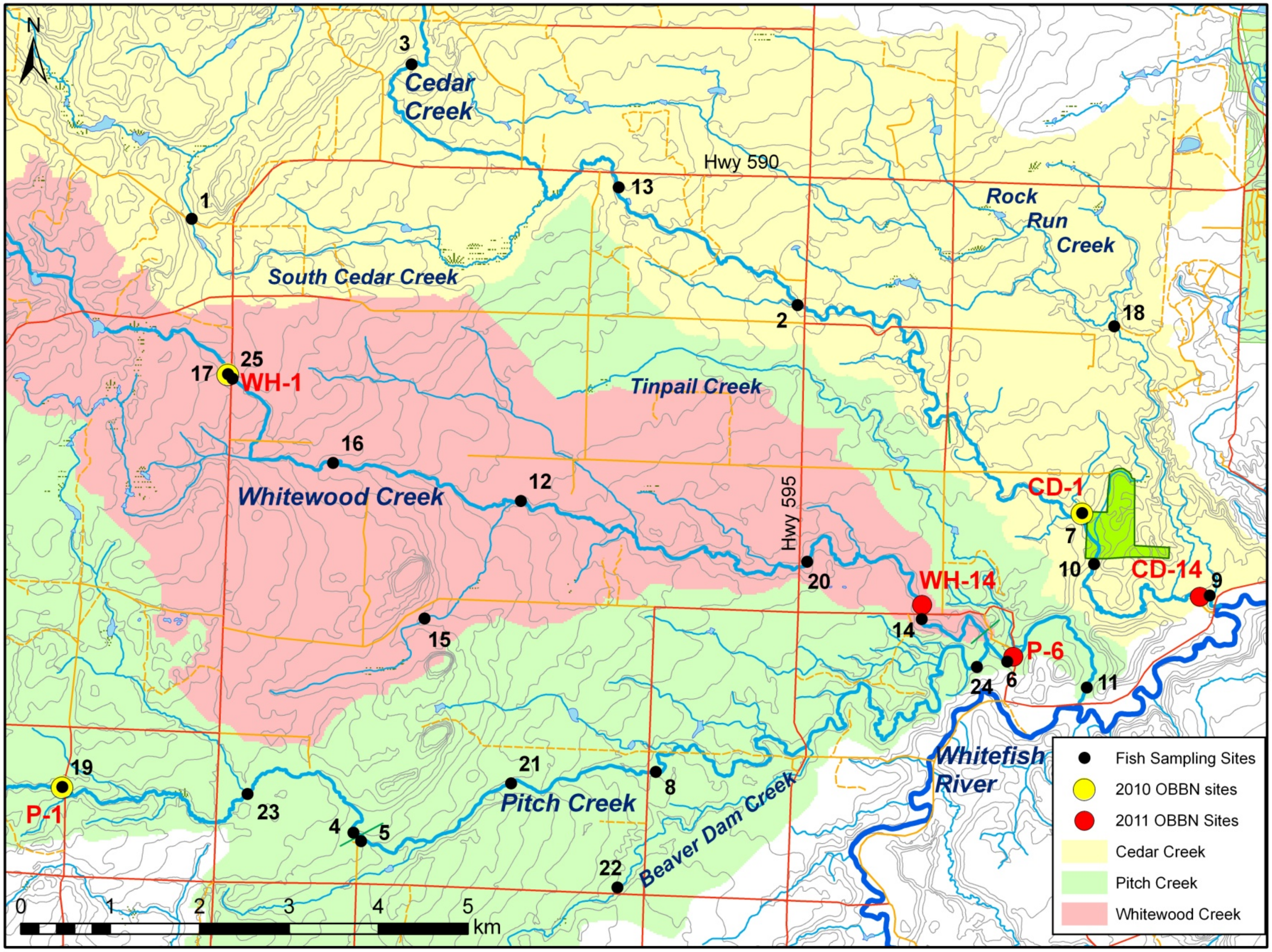



Figure 2. Location of 2009 and 2010 OBBN (red labels) and 2010 fish sampling sites in the Cedar, Pitch, and Whitewood Creek watersheds.


Figure 3. Water temperature logger (arrow) on Cedar Creek at Site 6 (L) and Pitch Creek at Site 19 (R).

## 2.3 Electrofishing

Fish community and fish habitat assessment was conducted from July 24, 2010 until October 5, 2010 under Licence to Collect Fish for Scientific Purpose No. 1058478.

Standard single pass electrofishing protocol for fish community sampling from the Ontario Stream Assessment Protocol (OSAP)(Stanfield 2002, 2005) was used. Single pass electrofishing is a more efficient use of sampling effort for fish community surveys than multi-pass surveys (Temple and Pearsons 2002; Reid et al. 2009). Electrofishing was conducted using a 2-person crew and a Smith-Root LR-24 backpack electrofisher and was consistent with OMNR (2002) in terms of safety guidelines. The Quick Setup function on the LR-24 was used to determine initial electrofisher settings: this function selects a voltage level necessary to achieve 25 watts average power output through the water between electrodes. Typical initial settings were 25% duty cycle, 4.2 m/s pulse width, 400 V and 60Hz. Voltage settings and frequency settings were adjusted as necessary (depending on the conductivity of the site) to achieve levels necessary for fish capture. At turbid sites e.g., Rock Run Creek, shocking was initially set at 200 V. At each site, at least one riffle-pool-riffle sequence was sampled; in some cases, additional pools and riffles were electrofished if the original sequence was fairly short (e.g., <600 sec).

Blocking (barrier) nets (1/4" mesh) were typically used at upstream and downstream of the sampling reach. A single pass of at least 1000 shocking seconds was used at each sampling site. All shocked fish were placed in streamside buckets with fresh water until they recovered and were processed after the completion of the electrofishing run. Water velocity was measured with a GlobalWater Flow Probe.

Figure 4. Downstream barrier net at Site 6 and electrofishing.

## 2.4 Data Collection and Analysis

Species were usually determined in the field and fish live-released on site. Where necessary, voucher specimens were retained to confirm identification in the lab using Holm et al. (2008), Scott and Crossman (1998), Stewart and Watkinson (2004) and Lagler et al. (2004). Total length (mm) and weight (g) were recorded individually for all salmonids, and for most adult fish of other species. Weights were recorded using an Ohaus Scout Pro scale (Figure 5) and rounded to the nearest 0.1 g. Where numbers were too great for individual measurements, particularly for young-of-the-year (YOY) cyprinids, total counts and batch sampling were used for weights. This allowed rapid sampling and return of fish to the stream without undue mortality, while permitting biomass estimates. Where necessary, missing weights were estimated from length data using the length-weight relationship derived from linear regression of LON-transformed total lengths and weights for that species.

Figure 5. Measuring length (L) and weight (R).

## 2.5 Habitat Survey

Habitat variables at each fish sampling station were collected according to OBBN methodology, with some additional variables collected following the OSAP. For each pool and riffle sampled, the mean length, width, and water depth were also measured to provide a rough value for the areal extent and volume of potential habitat electrofished. It is recognized that these are rough estimated that depend on discharge at the time of sampling, but provide a value for comparison with other published studies.

Results of the habitat survey are presented in Appendix 2 and Appendix 3. Representative photographs of each sample site are in Appendix 4.

## 2.6 OBBN Sampling

The aquatic benthic macroinvertebrate communities were sampled at three potentially impacted sites on Cedar Creek, Whitewood Creek and Pitch Creek during October 2010 according to OBBN protocols (Jones *et al.*, 2005), using a traveling kick-and-sweep with a 500-micron D-net. These three sites were adjacent to Sites 6, 9, 14 sampled for fisheries (Figure 2). Three sub-samples were collected at each of the sites and each sub-sample was preserved in the field in 96% ethanol, then the sub-samples were sorted in the laboratory. A minimum of 100 benthic macroinvertebrates were randomly picked from each of the sub-samples using a Nikon SMZ1500 at 10X magnification. The macroinvertebrates were identified using taxonomic keys by Clarke (1981), Peckarsky *et al.* (1990), Merritt *et al.* (2008), and Wiggins (1996). Most organisms were identified to Order or Family level to facilitate the determination of various biotic indices. Orders such as Ephemeroptera, Plecoptera, and Trichoptera are particularly sensitive to impaired water quality, and were therefore identified to the Genus level when possible.

The aquatic benthic macroinvertebrate community was assessed according to the 27-taxa Reference Condition Approach (RCA) as outlined in the Ontario Benthos Biomonitoring Network Protocol Manual (Jones *et al.* 2005). The OBBN is a partnership led by the Ontario Ministry of the Environment and Environment Canada's Ecological Monitoring and Assessment Network (EMAN). The 27-Taxa include: Amphipoda, Anisoptera, Bivalvia, Ceratopogonidae, Chironomidae, Coelenterata, Coleoptera, Culicidae, Decapoda, Ephemeroptera, Gastropoda, Hemiptera, Hirudinea, Isopoda, Lepidoptera, Megaloptera, Miscellaneous Diptera, Nematoda, Oligochaeta, Plecoptera, Simuliidae, Tabanidae, Tipulidae, Trichoptera, Trombidiformes, Turbellaria, and Zygoptera. The biotic indices used to characterize the benthic communities include: Total Abundance, Richness, Dipteran Richness, Insect Richness, Simpson's Index, Shannon's Diversity Index, Hilsenhoff Biotic Index (HBI), % Dominants, % Ephemeroptera Odonata Trichoptera (EOT), % Ephemeroptera Plecoptera Trichoptera (EPT), % Chironomids, %

Crustacea, % Dipterans, % Gastropods, % Mollusca, % Non-Dipteran Insects, % Odonates, % Pelecypods, and % Oligochaetes (Worms).

The OBBN biotic indices (Appendix 6)(Jones et al., 2005) used to analyse the 27-taxa identified from the candidate sites provide an insight into present and past conditions experienced by the aquatic macroinvertebrate communities. Some of the biotic indices (high % Worms, high % Chironomids) are useful for identifying sites that are heavily impacted by nutrient enrichment. Extreme enrichment will cause premature eutrophication resulting in low dissolved oxygen in the water, with consequent degradation of the habitat. Both worms and chironomids are tolerant of low-oxygen concentrations and become the dominant organisms in eutrophic ecosystems. Chironomids are also highly tolerant of toxic chemicals; therefore, they can survive and become dominant in conditions that kill other organisms, including worms. Other biotic indices (high % EPT, low Hilsenhoff Biotic Index) help to confirm high water quality at the site. Ephemeroptera, Plecoptera and Trichoptera (EPT) are intolerant of toxins and require oxygen concentrations that are close to saturation. The Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1988) is calculated using tolerance values assigned to the various macroinvertebrate taxa (Appendix 7). EPT have low HBI values, whereas worms and chironomids have high HBI values. HBI values above 6.0 are considered indicative of an impaired system, usually because of organic enrichment which can cause eutrophication. Each biotic index provides a separate insight into the quality of the habitat. The combination of several indices makes it possible to evaluate the relative, long-term health of the site. However, not all biotic indices are necessary to determine whether a site is impaired, or whether it should be considered a suitable reference condition site.

The selected biotic indices used to evaluate the sites were: Richness, Shannon's H' Diversity, Hilsenhoff Biotic Index, % Dominant, % EPT, % Chironomids, and % Worms. These biotic indices were compared with data from streams on the north shore of Lake Superior (Deacon & Lavoie, 2005; 2008; 2009; 2010 and 2011) to determine whether the values obtained for Cedar Creek, Whitewood Creek and Pitch Creek were high or low in relation to regional reference condition sites. General physiographic features (Table 3) combined with Biotic Indices (Appendix 6) provided sufficient means to evaluate whether the three test sites were impaired.

# 3 Study Area

## 3.1 Geology / Substrate

Most of the watersheds of the Cedar, Pitch, and Whitewood creeks is covered by morainal deposits, accounting for 59% overall (Figure 8). The vast majority (83%) of the Whitewood Creek watershed is underlain by silty or clayey till deposits of morainal origin. In contrast, only 48% of the Pitch Creek watershed is morainal deposits, and it has more finer-textured glaciolacustrine deposits in its lower reaches as well as further upstream (Figure 7). More than half (58%) of the Cedar Creek watershed is morainal deposits, but 15% of the watershed is coarse-grained sands and gravels of glaciofluvial deltaic deposits, particularly in the upper half of its watershed. The lower reaches of Cedar (3.1 km), Pitch (10.6 km), and Whitewood (1.0 km) creeks flow through silty glaciolacustrine delta or alluvial deposits (Figure 7). These largely correspond to Jarvis River soils that are characterized by calcareous reddish clay loam, clay or silty clay and varved lacustrine, and Nolalu soils that are non-calcareous fine sandy loam stony glacial till derived from shale (LRRI 1981). There are patches of bedrock and organic deposits in all watersheds, but alluvial deposits are restricted to the lowest reaches near the Whitefish River.

On a finer scale, there is considerable variation in dominant substrate type among and within sampling sites depending on stream gradient and energy. Coarser materials i.e., cobble and boulders are found in riffle sections where silts and clays remain in suspension (Figure 6). Finer sediments settle out in the deposition zones of pools and on inside point bars. Finer sediments were also found immediately below culverts and bridges, presumably from road-associated effects (e.g. gravel). Silts and clays were more abundant in the lower reaches of all three streams where they have cut through deep, fine-textured glaciolacustrine delta sediments, often leaving steep, slumping banks (Figure 6R). The predominant substrate in many pools in the upper reaches of all three tributaries were typically sands and gravels rather than silts and clays, and consequently less turbid.

Figure 6. Boulder and cobble riffle at Site 14 on Whitewood Creek (L) and corner pool with steep silty-clay bank at Site 6 on Pitch Creek (R).

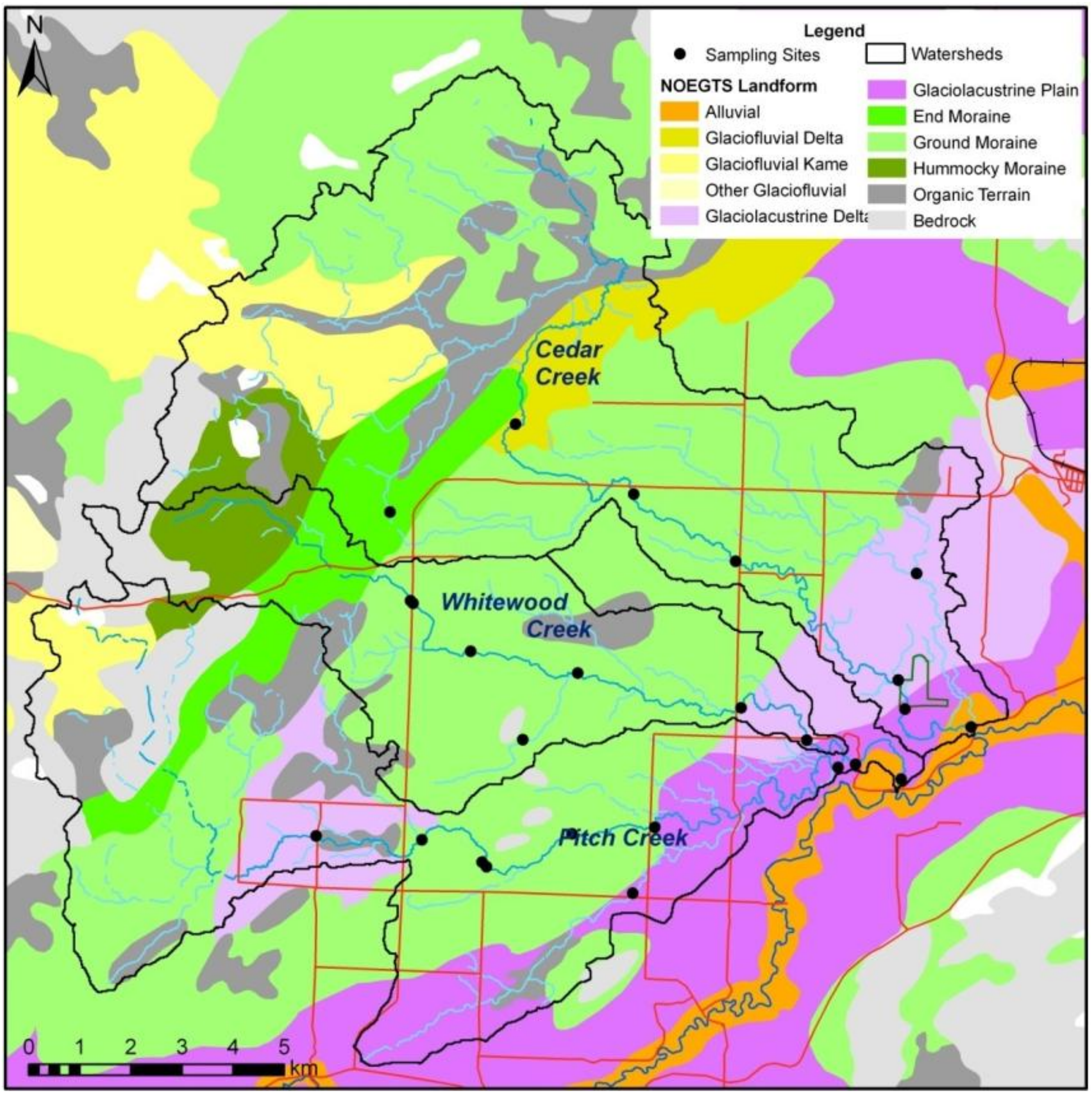



Figure 7. Surficial geology of study area based on NOEGTS (Mollard and Mollard 1980).

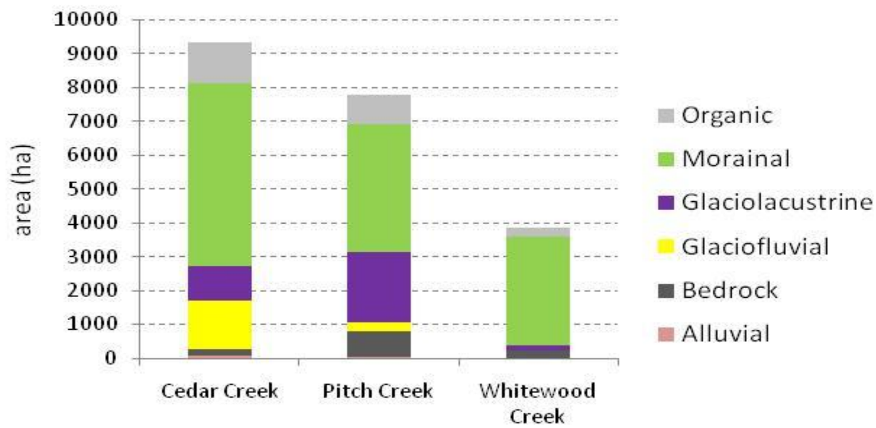



Figure 8. Area of landform types within each watershed of three Whitefish Creek tributaries.

## 3.2 Water Temperature

Hourly water temperatures on Cedar and Pitch creeks (no data available for Whitewood Cr.) showed very similar patterns of variation from July 15 through November 1, 2010 (Figure 9). Maximum water temperature of 26.6° C was recorded at Cedar Creek (August 3) and 24.5 °C at Pitch Creek (August 3, 9, 31). Water temperature fluctuated approximately 5°C between daytime highs and night-time lows during the warmer months. Cedar Creek site showed the greatest diel fluctuation, probably because the logger was in an exposed site rather than a heavily shaded site as at Pitch Creek.

After a relatively warm August with water temperatures well above 15°C in Pitch and Cedar, water temperature dropped dramatically in September in response to cooling air temperatures. Conditions in the Thunder Bay, and likely the study area, were warmer and drier in early 2010 than average. Mean daily air temperature in Thunder Bay Airport (WeatherStats 2011) was 19.7° C in July 2010 vs. 17.6° C for the long-term average, and was 2.4°C warmer than average in August (19.0° C vs. 16.6° C). Precipitation at the Thunder Bay Airport was much lower in spring and summer 2010 than normal, with only 265 mm of precipitation from March through August compared to 412 mm for the long-term average (Environment Canada 2011). Precipitation in the fall was slightly higher than average in 2010 however, and mean air temperatures returned to normal as well in September (10.7° C vs. 11.0° C). As a result, water levels in the streams were generally lower than expected during August sampling.

Picard (1995) found that in 1993 the mean and maximum summer water temperatures in Cedar Creek were 17.3°C and 22° C respectively, with Pitch Creek slightly warmer (mean 18.8° and max of 23°C). Barton et al. (1994) considered streams with maximum summer temperature greater than 22°C as marginal brook trout habitat, although 24°C has been used as the upper limit by others (Meisner 1990). Maximum temperatures on both the Pitch and Cedar creeks exceeded this value in 2010: however, brook trout were abundant at both logger locations. Picard (1995) considered streams in the Pitch, Cedar and other streams in the southwestern portion of his study area to have marginal thermal conditions for brook trout. Brook trout in these streams may rely on localized groundwater discharge points for coolwater refugia when streams become too warm (Picard 1995), as has been suggested for other systems (e.g. Gibson 1966; Nelsen et al. 1994). Groundwater discharge is related to surficial geology, and groundwater inputs are more likely in deep, coarse morainal or glaciofluvial deposits than the fine glaciolacustrine delta deposits found in the lower reaches of Cedar, Pitch, and Whitewood creeks.

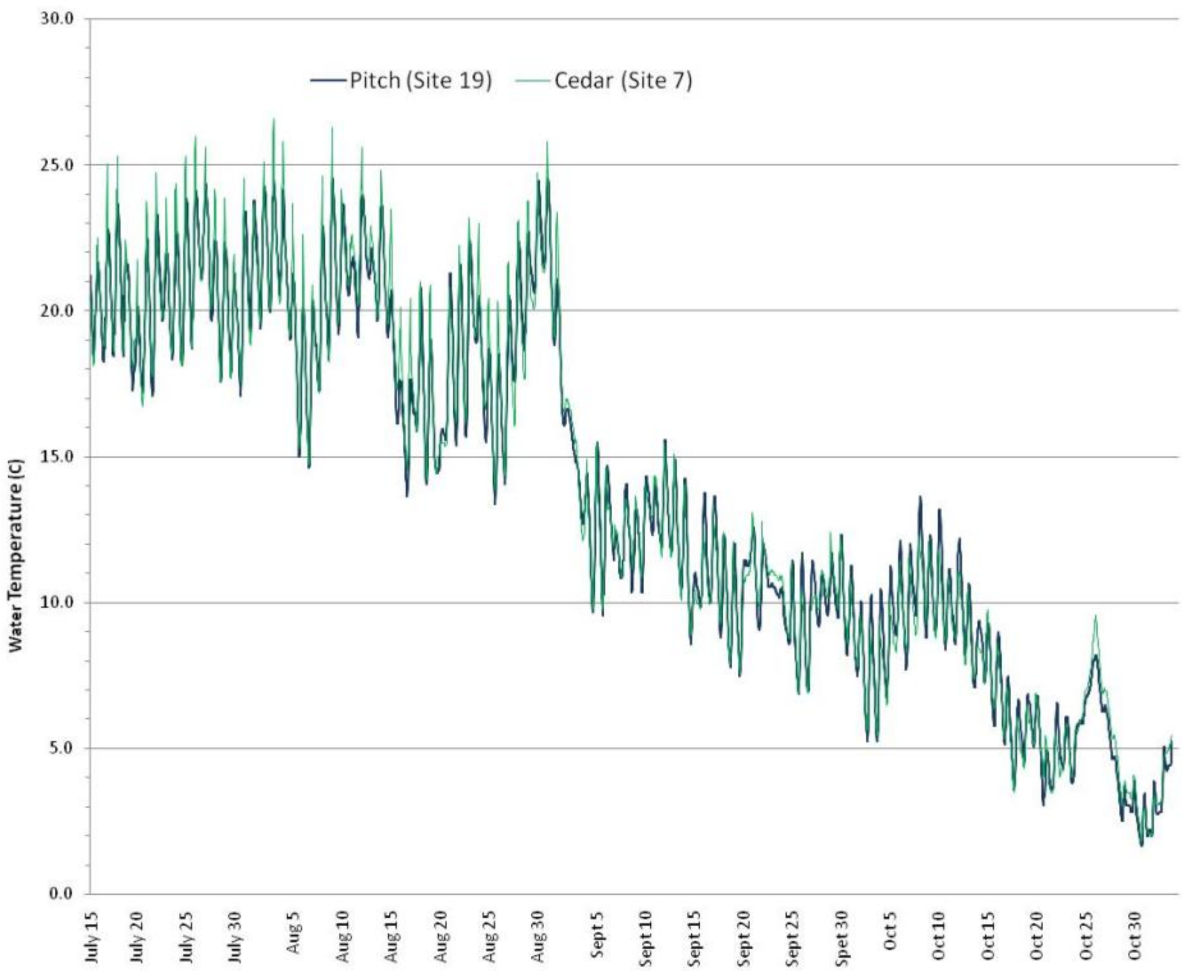



Figure 9. Hourly water temperature at Pitch and Cedar creeks, July 15 to November 1, 2010.

## 3.3 Aquatic Vegetation

The high gradient, rocky, substrate, and scouring effect of spring flows limits the growth of aquatic plants throughout much of the sampled portions of the watershed. Aquatic plants were sparse in sites in the three streams, and were limited to small patches in slow, sheltered portions of pools with soft sediments (e.g., clay or silt), although they are likely more abundant in established beaver pond environments in the watersheds that were not sampled. Dominant Pondweeds (*Potamogeton cf. pusillis*, *P. alba*) and water starwort (*Callitriche hermaphrodicitca*) were the most common submergents. Emergents included manna grass (*Glyceria grandis*), water plantain (*Alisma plantago-aquatica*), and arrowhead (*Sagitaria latifolia*) (Figure 10).

The aquatic moss, *Fontinalis novae-angliae* was abundant at several sites (e.g., Site 3,4,7) (Figure 10). Higher algae abundance was observed in pools downstream of water crossings, due to increased sunlight along the road corridor, and potential input of nutrients from roadside ditches. Effects appear to be minor and local however. Crustose algae was also abundant at Site 6 on Cedar Creek, and filamentous algae was also abundant at Site 5 where the cascading steps have a southern exposure promoting growth (Figure 11).

Figure 10. Submergents at Site 12 on Whitewood Creek (L) and aquatic moss on bedrock (L) at Site 4 on Pitch Creek.

Figure 11. Algae on cobble at Site 6 on Cedar Creek and (L) filamentous algae at Site 5 on Pitch Creek (R; mechanical pencil for scale).

# 4 Benthic Invertebrates

The Cedar Creek site (CD-9) had a high Richness (10.3) and Shannon's H' Diversity (1.81) (Table 2). The Hilsenhoff Biotic Index (5.54) was moderate. The % Dominants (34.0) was moderately low. The % Chironomids (21.8) was low. The % EPT (46.5) was moderate and the % Worms (18.8) was high. The high % Worms possibly indicates a community from a nutrient-rich habitat which supports an abundance of algae. The substrate at Cedar Creek was dominated by boulders, cobble and leaf packs (Table 3) which provide a somewhat stable substrate for a rich algal community. Worms thrive in an algal-rich habitat. Worms can also dominate a community when anaerobic conditions occur which differentially kill organisms with a high oxygen demand. The permanent nature of the flow at CD-9 and the high oxygen concentration recorded on 21 October (12.4 ppm) (Table 3) indicate anaerobic conditions are extremely unlikely in Cedar Creek. Worms are abundant at CD-9 probably because the algal-rich habitat is ideal for them. If toxins such as pesticides had entered the system, the worms would have been less abundant because of their sensitivity to toxic substances. The moderate HBI and the moderate % EPT indicate that site CD-9 was unimpaired at the time of sampling and should be included in the OBBN Reference Condition database, although it probably warrants reassessment because this site potentially is becoming impaired.

Table 2. Summary of selected mean Biotic Indices of the macroinvertebrate communities from Cedar Creek, Whitewood Creek and Pitch Creek, Ontario, 2009-2010.

Table 4. Summary of selected mean Biotic Indices of the macroinvertebrate communities from Pitch Creek, Whitew

| Site Name | Site Code | Sampling Date | Richness | H' Diversity | Hilsenhoff's Biotic Index | % EPT | % Chironomids | % Worms | % Dominants |
|---|---|---|---|---|---|---|---|---|---|
| Cedar Creek | CD-1 | 19-Oct-09 | 8.7 | 1.57 | 5.38 | 61.7 | 23.5 | 8.3 | 43.5 |
| | C-9 | 21-Oct-10 | 10.3 | 1.81 | 5.54 | 46.5 | 21.8 | 18.8 | 34.0 |
| Whitewood Creek | WH-1 | 29-Sep-09 | 8.7 | 1.77 | 5.22 | 57.2 | 19.9 | 14.5 | 30.1 |
| | WH-14 | 12-Oct-10 | 10.3 | 1.76 | 6.15 | 32.9 | 19.7 | 31.8 | 35.1 |
| Pitch Creek | P-1 | 06-Oct-09 | 11.0 | 1.59 | 5.10 | 71.5 | 13.8 | 4.8 | 46.8 |
| | P-6 | 17-Oct-10 | 9.7 | 1.48 | 6.37 | 21.8 | 50.1 | 18.3 | 50.1 |

The Whitewood Creek site (WH-14) had a high Richness (10.3) and Shannon's H' Diversity (1.76) (Table 2). The Hilsenhoff Biotic Index (6.15) was also high. The % Dominants (35.1) was moderately low. The % Chironomids (19.7) and the % EPT (32.9) were moderately low. The % Worms (31.8) was very high. The substrate at Whitewood Creek was dominated by boulders and cobble (Table 3) which support an algal community of slimes and crusts, as seen at Cedar Creek. Worms were abundant probably because of the presence of the algae. The high HBI and the moderately low % EPT indicate a possibly impaired community. Site WH-14 warrants reassessment.

The Pitch Creek site (P-6) had a moderate Richness (9.7) and Shannon's H' Diversity (1.48) (Table 2). The Hilsenhoff Biotic Index (6.37) was high and the % Dominants (50.1) was moderate. The % Chironomids (50.1) was moderate. The % EPT (21.8) was moderately low, whereas the % Worms (18.3) was high. The high HBI and the moderately low % EPT indicate an impaired community. Site P-6 warrants reassessment.

The upper reaches of Cedar Creek (CD-1), Whitewood Creek (WH-1) and Pitch Creek (P-1) (Fig. 1) were sampled during 2009. At that time, the sites were considered unimpaired and therefore recommended for inclusion in the OBBN Reference Condition site database (Deacon & Lavoie 2010). All three sites contained benthic macroinvertebrate communities with moderately low to moderate HBI values, and high to very high % EPT values which indicated high water quality (Deacon & Lavoie 2010). The three sites (CD-9, WH-14 & P-6) in the lower reaches of these creeks that were sampled during 2010 all contained macroinvertebrate communities that differed substantially from those communities found during 2009 at CD-1, WH-1 and P-1. The lower reach sites all had higher HBI and lower % EPT values than the upper reach sites. The % Chironomids remained similar in the Cedar and Whitewood sites; however, the value increased from 13.8% at P-1 to 50.1% at P-6. The % Worms was higher by more than a factor of two at all the lower reach sites of these creeks. Substrate was similar between the upper and lower reach sites, therefore, the change in the macroinvertebrate communities is possibly related to nutrient input and associated algal changes.

Table 3. Physiographic features of three tributary streams of the Whitefish River, Ontario, 2009 & 2010.

| Site Name | Site Code | Category | Hydraulic Head (mm) | Dissolved Oxygen (ppm) | Substrate | Overhead Cover | Algae | Woody Debris | Detritus |
|---|---|---|---|---|---|---|---|---|---|
| **2009** | | | | | | | | | |
| Cedar Creek (#7)* | CD-1-1 | Pool | 35 | 12.5 | boulder, cobble | 0-24 | filaments/attached/slimes/crusts | present | present |
| | CD-1-2 | Riffle | 15 | | gravel, silt | | slimes/crusts | abundant | present |
| | CD-1-3 | Riffle | 23 | | boulder, cobble | | slimes/crusts | abundant | present |
| Whitewood Creek (#17)* | WH-1-1 | Riffle | 25 | 8.9 | cobble, sand | 75-100 | slimes/crusts | present | abundant |
| | WH-1-2 | Pool | 4 | | sand, gravel | | absent | present | abundant |
| | WH-1-3 | Riffle | 13 | | gravel, boulder | | slimes/crusts | present | abundant |
| Pitch Creek (#19)* | P-1-1 | Riffle | 27 | 9.6 | cobble, sand | 50-74 | absent | abundant | abundant |
| | P-1-2 | Pool | 7 | | cobble, boulder | | absent | present | abundant |
| | P-1-3 | Riffle | 20 | | cobble, boulder | | absent | present | abundant |
| **2010** | | | | | | | | | |
| Cedar Creek (9)* | CD-9-1 | Pool | 10 | 12.4 | gravel, sand | 50-74 | slimes/crusts | absent | abundant |
| | CD-9-2 | Riffle | 15 | | gravel, sand | | slimes/crusts | absent | present |
| | CD-9-3 | Riffle | 90 | | cobble, gravel | | slimes/crusts | present | abundant |
| Whitewood Creek (14)* | WH-14-1 | Riffle | 15 | 12.4 | cobble, gravel | 0-24 | attached/slimes/crusts | absent | present |
| | WH-14-2 | Pool | 5 | | gravel, silt | | slimes/crusts | present | abundant |
| | WH-14-3 | Riffle | 20 | | boulder, cobble | | attached/slimes/crusts | absent | present |
| Pitch Creek (6)* | P-6-1 | Riffle | 7 | 11.7 | boulder, cobble | 0-24 | attached/slimes/crusts | present | present |
| | P-6-2 | Pool | 1 | | boulder, gravel | | attached/slimes/crusts | present | abundant |
| | P-6-3 | Riffle | 20 | | boulder, cobble | | attached/slimes/crusts | present | abundant |

*refers to site #s used for fisheries sampling

# 5 Fish Community

## 5.1 Species Diversity

A total of 18 species of fish were observed during 2010 sampling on the Cedar, Pitch, and Whitewood creeks (Table 4). An additional 13 species were recorded during previous sampling (2000, 2003, 2003, 2009, 2010) conducted by the Sea Lamprey Control Centre at 18 sites in the three watershed (DFO unpublished data), although one of these, spotfin shiner (*Cyprinella spiloptera*), is not known from Thunder Bay area or northern Ontario (Hartviksen and Momot 1987; Holm et al. 2009). In addition, native lamprey (*Ichthyomyzon* spp.) were historically recorded from Pitch Creek (e.g., 1960 pre-treatment surveys, DFO unpublished data), but it is not clear if they were northern brook lamprey (*I. fossor*) and/or silver lamprey (*I. unicupsis*). Of the approximately 32 species recorded for the three tributaries, the greatest species diversity (25 species) was observed in the lower reach of the Pitch Creek below its confluence with the Whitewood. Several species i.e., burbot, logperch, spottail shiner, and trout-perch, have only been recorded in the lower reach of Pitch/Whitewood, but this may reflect their low abundance rather than actual distribution. The fewest species (17) were recorded in Whitewood Creek. Cyprinids (minnows) were the most diverse group, with 14 species found in the three tributaries.

The sites with the most diverse fish communities in 2010 (8-10 species) were found on the lower reaches of Pitch Creek (Sites, 6, 8, 11, 24) and at Site 12 on Whitewood Creek (Table 5; see Figure 2 for location of sites). Based on DFO sampling additional species are also likely present, at least in some other seasons or years. Only one species, brook trout, was sampled at Site 17 and 25, two adjacent sites on the upper reach of Whitewood Creek, and several other sites on Cedar Creek or Pitch Creek had only brook trout with one other species (e.g., blacknose dace or sculpins).

### 5.1.1 Connectivity

There are two significant barriers to upstream fish passage, Cedar Falls on the Cedar Creek and an unnamed falls on Pitch Creek. No falls were identified on Whitewood Creek within the study area. No rainbow trout were observed above Cedar Falls suggesting it was a barrier during flow conditions experienced in at least last three years, assuming a maximum residence time of three years for smolts (Jon George pers. comm.) Chinook salmon have been recorded from Cedar Creek (DFO unpublished data), but it is not known if any were observed above Cedar Falls. They are capable leapers, and could likely jump the drop of approximately 1-2 m given the deep plunge (1 m) pool below the falls. The barrier on Pitch Creek is an approximately 3 m drop of cascading steps and ledges. It would be difficult for even jumping species to navigate upstream, although some brook trout were found in shallow pools on lower ledges (possibly from downstream movement).

Figure 12. Falls at Cedar Creek (L, LRCA photo) and Pitch Creek (R).

All three tributaries cross numerous roads from their headwaters to their confluence with the Whitefish River, but most are bridges or box culverts that have natural bottoms (Figure 13). The large-diameter culverts on these tributaries probably do not pose a barrier to upstream movement to fish, although they could potentially represent a velocity barrier for some species at high flows. Numerous beaver dams may hinder upstream and downstream passage of fish, but are natural features of these watersheds. Sea Lamprey Control Centre personnel routinely break up numerous beaver dams on Pitch Creek when conducting lampricide treatments every 3-4 four years to increase flow and reduce the wetted area during treatment.

Ponds and lakes farther upstream may serve as source of fish recruitment in the respective watersheds. For example, the 20 ha Pete Lake at the headwaters of Pitch Creek may have been the source of the juvenile white sucker (180 mm TL) sampled at Site 19. It is unlikely that white suckers could have moved past the barrier given the low flow conditions in the spring of 2010.

Figure 13. Box culvert on Cedar Cr. at Hwy 590 (L) and bridge over Whitewood Cr. at Smith Road (R).


Figure 14 double culvert on Whitewood Creek at Hwy 590 (L) and Beaver dam on Rock Run Creek above Site 18 (R).

## 5.2 Abundance

The numbers of individuals and biomass sampled at each site by species in 2010 are presented in Table 5 and Table 6. Of the 1882 fish sampled, approximately 39% were cyprinids (Minnow Family) and 35% were salmonids (Trout Family). Overall, the most common species was brook trout (397), followed by longnose dace (255), rainbow trout (252), and creek chub (247). Trout accounted for approximately 75% of the total fish biomass, with brook trout representing 58.1% and rainbow trout 17.4%. Although creek chub and longnose dace each accounted for approximately 15% of the individuals, they each represented only 5% of the biomass due to their small size. White suckers, although not common (1.4% of individuals), represented 3.4% of the biomass, since they tended to be fairly large individuals relative to other species.


Figure 15. Adult brook trout (L) and rainbow trout (R).

The number of fish per sampling location ranged from 29 to 189 individuals (Table 5), with a mean of 75 and a median of 65. There were few clear patterns in total abundance or biomass of all species combined based on watershed position (Figure 16). The highest numbers of fish were found at the Sites 1 and 3 farthest upstream on Cedar and South Cedar creeks where there were abundant brook trout, brook stickleback, longnose dace and sculpins, and near the mouths of Pitch and Cedar creeks where there were numerous rainbow trout, creek chub, and longnose dace. Numbers and biomass of fish in the middle reaches of all three tributaries was variable. Biomass was most closely related to trout abundance due to the typically greater size of brook and rainbow trout compared to cyprinids and other species.

Total abundance and biomass were also converted to density estimates based on length of sampled reach (km), area sampled (ha), and volume of water sampled ($m^3$), to account for differences in electrofishing effort and size of sample sites. These three density metrics were correlated and showed a slightly different pattern (Figure 17) than uncorrected total abundance or biomass, both for all species combined or for brook trout separately. For example, Site 25 had the highest abundance and biomass of brook trout and all species combined when converted into a density value with respect to sampled length, area, or volume (Appendix 3; Figure 17), despite having the lowest total uncorrected fish abundance. Site 25 was atypical in that it consisted of only a small (40 $m^2$) pool and no associated riffles, brook trout was the only species present, and the pool was electrofished for only 235 seconds (mean of all sites was 1147 sec). Although a small habitat patch, it obviously was preferred habitat, perhaps due to the greater mean depth (50 cm) and volume of the pool compared to Site 17 upstream (mean depth 20 cm) (Appendix 3). Site 22 on Beaver Dam Creek is a similar but more extreme example: despite average total abundance and biomass, the creek had a high density of fish since most were concentrated into one pool of this intermittent stream.

Of particular note is that biomass densities were comparatively low in the lower reaches of Pitch and Cedar creeks since the volume sampled at these sites was greater than elsewhere, and sites higher in the three watersheds (e.g., Sites 3, 4, 5, 16, 17) had higher biomass per stream volume sampled. Estimates of brook trout abundance and biomass in 2010 (Appendix 3) were broadly comparable to those found by Picard (1995) for 60 m-long reaches on Pitch and Cedar creeks (exact location unknown) sampled with 3-pass depletion/removal electrofishing in 1993. For example, Picard's estimates of 89 and 390 brook trout/km respectively for Cedar Creek and Pitch Creek fall within the ranges observed in 2010 i.e., 0 to 1075 BT/km for Cedar Creek (mean 325) and 16 to 667 BT/km for Pitch Creek(mean 170). His estimates for Pitch Creek were amongst the highest within 30 streams sampled in the Thunder Bay area in 1993-1994, which he suggested might be related to higher alkalinity of surfaces waters since Pitch Creek (and Cedar), is underlain by the limestone-rich Animikie bedrock formation.

In terms of brook trout biomass, 2010 estimates were approximately 10-40 kg/ha for upstream reaches on Cedar, Whitewood, and Pitch creeks where rainbow trout were absent but much lower where rainbow trout co-occurred. These values are broadly comparable to those observed by Picard (1995) for 30 Thunder Bay streams (mean 24.6 kg/ha) and are similar to those recorded for some streams in Quebec (12-53 kg/ha; O'Connor and Power 1976) and

Minnesota (35 kg/ha; Waters et al. 1990). This suggests that although upstream reaches of these streams have relatively healthy populations, lower reaches are marginal for brook trout, due to habitat, thermal regime, competitive interactions with rainbow trout, or other factors. The warmest water temperatures recorded during sampling was 21°C (at 10:30 am on August 31) on Cedar Creek at Site 9 near its mouth and also 3.4 km upstream at Site 7. There was no difference in water temperature between Sites 19 and 11on Pitch Creek on the morning of Sept 6 (despite the 11.3 km separating them) nor between Sites 19 and 8 on the afternoon of August 30. These observations indicate that there is no significant warming of stream temperatures in the lower portion of these creeks (at least in late summer / early fall), due to habitat changes such as overstory cover.

Brook trout were more abundant higher in the three watersheds and generally decreased towards their confluence with the Whitefish River, with rainbow trout showing a different trend. No brook trout were found in the lower portion of Cedar Creek itself, but a small (67 mm TL) brook trout was electrofished (160 sec), in a small side tributary as well as brook stickleback, central mudminnow, and several creek chub. Water temperature was the same (21°C) as the main stream, and this lone brook trout likely dispersed from upstream. Rainbow trout were not found above the falls on Pitch Creek or Cedar Creek. Rainbow trout were abundant at Site 16 on the Whitewood Creek, 16.4 km upstream from the confluence with the Whitefish River, but were absent from Site 17 only 2.1 km further upstream. There is a beaver dam between Site 16 and 17 which could potentially pose a barrier to upstream fish passage however.

The abundance of brook trout at Site 7 above Cedar Falls, 3.5 km from the Whitefish River, and the pattern of declining abundance/biomass where brook trout overlap with rainbow trout (and potentially salmon), suggest that interspecific competition may play a role in determining distribution and abundance on these tributaries. Brook trout may be at a competitive disadvantage with rainbow trout, although water temperature and preference for pool vs. riffle habitats appear to influence this interaction (e.g. Fausch 1988; Hearn 1987). Cedar, Pitch, and Whitewood creeks may be thermally marginal for brook trout and may depend on localized groundwater inputs for thermal refugia in the peak of the summer. These groundwater inputs are less likely in the lowest reaches of these creeks where they cut through fine glaciolacustrine silts and clays.

Table 4. Total number of individuals by species for streams sampled in 2010. "X" indicates species observed by DFO in previous sampling but not seen in 2010 (unpublished data).

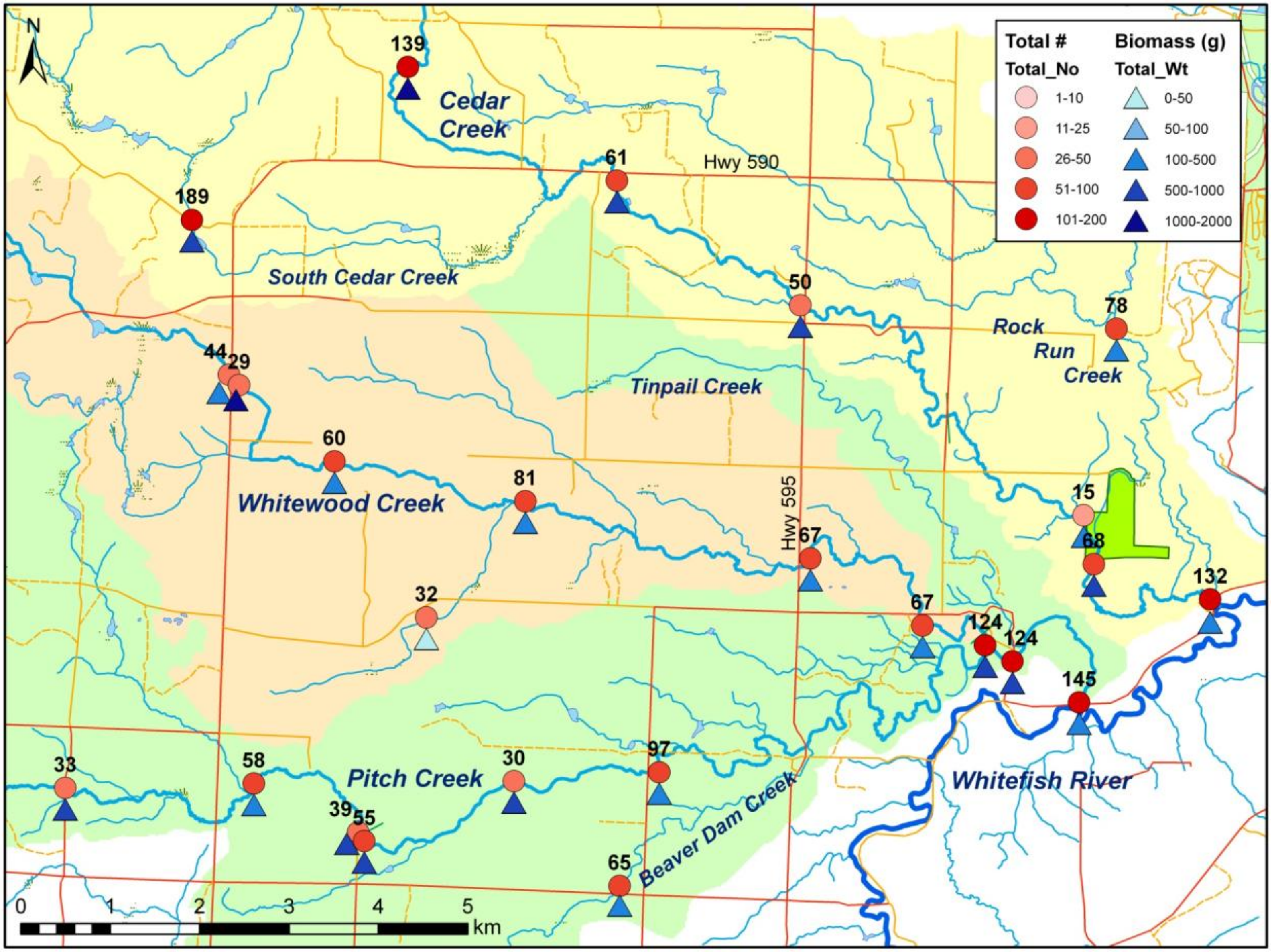
| Family | Common Name | Scientific Name | Cedar | Pitch | Whitewood | Pitch / Whitewood | Grand Total |
|---|---|---|---|---|---|---|---|
| Catostomidae | White Sucker | *Catostomus commersonii* | 9 | 10 | 5 | 3 | 27 |
| Centrarchidae | Rock Bass | *Amploplites rupestris* | X | | | | |
| Centrarchidae | Smallmouth Bass | *Micropterus dolomieu* | | 2 | | 16 | 18 |
| Cottidae | Mottled Sculpin | *Cottus bairdii* | X | X | | X | |
| Cottidae | Sculpin sp. | *Cottus* sp. | 30 | 4 | | | 34 |
| Cottidae | Slimy Sculpin | *Cottus cognatus* | 80 | 25 | | 18 | 123 |
| Cyprinidae | Blacknose Dace | *Rhinichthys atratulus* | 37 | 17 | 74 | 10 | 138 |
| Cyprinidae | Blacknose Shiner* | *Notropis heterolepis* | X | | | | |
| Cyprinidae | Bluntnose Minnow | *Pimephales notatus* | X | | | X | |
| Cyprinidae | Brassy Minnow | *Hybognathus hankinsoni* | X | | | X | |
| Cyprinidae | Common Shiner | *Luxilus cornutus* | X | 2 | 8 | X | 10 |
| Cyprinidae | Creek Chub | *Semotilus atromaculatus* | 49 | 58 | 78 | 62 | 247 |
| Cyprinidae | Cyprinid sp. | | 27 | 16 | 57 | 10 | 110 |
| Cyprinidae | Emerald Shiner | *Notropis atheroides* | | X | 11 | X | 11 |
| Cyprinidae | Fathead Minnow | *Pimephales promelas* | 5 | 2 | | X | 7 |
| Cyprinidae | Finescale Dace | *Chrosomus neogaeus* | 15 | 5 | 3 | X | 23 |
| Cyprinidae | Lake Chub | *Couesius plumbeus* | 1 | X | 5 | X | 6 |
| Cyprinidae | Longnose Dace | *Rhinichthys cataractae* | 133 | 54 | 7 | 61 | 255 |
| Cyprinidae | Northern Pearl Dace | *Margariscus nachtriebi* | X | | 2 | | 2 |
| Cyprinidae | Northern Redbelly Dace | *Chrosomus eos* | 10 | X | 18 | X | 28 |
| Cyprinidae | Spotfin Shiner | *Cyprinella spiloptera* | | | X | | |
| Cyprinidae | Spottail Shiner | *Notropis hudsonius* | | | | 10 | 10 |
| Gadidae | Burbot | *Lota lota* | | | | X | |
| Gasterosteidae | Brook Stickleback | *Culaea insonstans* | 69 | 20 | 42 | X | 131 |
| Gasterosteidae | Fourspine Stickleback | *Apeltes quadracus* | | X | | | |
| Percidae | Johnny Darter | *Ehteostoma nigrum* | 2 | | | 14 | 16 |
| Percidae | Logperch | *Percina caprodes* | | | | X | |
| Percopsidae | Trout-perch | *Percopsis omiscomaycus* | | | | 1 | 1 |
| Petromyzontidae | Sea Lamprey | *Petromyzon marinus* | X | X | X | X | |
| Petromyzontidae | Native lampreys spp. | *Icthyomyzon* | | X | | X | |
| Salmonidae | Brook Trout | *Salvelinus fontinalis* | 210 | 98 | 89 | | 397 |
| Salmonidae | Chinook Salmon | *Oncorhynchus tshawystscha* | | X | X | X | |
| Salmonidae | Rainbow Trout | *Oncorhynchus mykiss* | 34 | 59 | 97 | 62 | 252 |
| Umbridae | Central Mudminnow | *Umbra limi* | 21 | 13 | X | 2 | 36 |
| | | **Total** | **732** | **385** | **496** | **269** | **1882** |

Table 5. Total number of fish by species sampled at 2010 sampling sites on Cedar, Pitch, and Whitewood creeks.

| Common Name | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | Total # | % of Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blacknose Dace | | | | | | 1 | 3 | 3 | | 7 | 9 | 28 | 1 | 1 | | 9 | | 26 | 5 | 22 | 3 | 7 | 7 | 6 | | **138** | 7.3 |
| Brook Stickleback | 60 | | | | | | | | | | | 3 | | 2 | 21 | | | 9 | | | | 19 | 8 | 9 | | **131** | 7.0 |
| Brook Trout | 18 | 32 | 79 | 22 | 40 | | 7 | 3 | | 14 | | | 60 | | | 14 | 44 | | 18 | | 15 | | 1 | 1 | 29 | **397** | 21.1 |
| Central Mudminnow | 21 | | | | | | | | | | 2 | | | | | | | | | | | 13 | | | | **36** | 1.9 |
| Common Shiner | | | | | | | | 2 | | | | 5 | | 1 | | 2 | | | | | | | | | | **10** | 0.5 |
| Creek Chub | | | | 4 | 13 | 12 | | 37 | 21 | | 50 | 12 | | 2 | 2 | 5 | | 28 | 7 | 15 | | 8 | 21 | 10 | | **247** | 13.1 |
| Cyprinid sp. | | | | 13 | | | | 10 | 26 | 1 | 10 | | | 15 | | 2 | | | | | 1 | 6 | 20 | 6 | | **110** | 5.8 |
| Emerald Shiner | | | | | | | | | | | | | | | | | | | | 11 | | | | | | **11** | 0.6 |
| Fathead Minnow | | | | | | | | | | | | | | | | | | 5 | | | | 2 | | | | **7** | 0.4 |
| Finescale Dace | 14 | 1 | | | | | | | | | | 2 | | | 1 | | | | | | | 5 | | | | **23** | 1.2 |
| Johnny Darter | | | | | | 4 | | | 2 | | 10 | | | | | | | | | | | | | | | **16** | 0.9 |
| Lake Chub | | | | | | | | | 1 | | | | | | | 4 | | | | 1 | | | | | | **6** | 0.3 |
| Longnose Dace | 66 | 17 | | | 1 | 44 | 5 | 12 | 38 | 7 | 17 | 1 | | 1 | | 1 | | | 2 | 4 | 2 | | | 37 | | **255** | 13.5 |
| Northern Pearl Dace | | | | | | | | | | | | | | | 2 | | | | | | | | | | | **2** | 0.1 |
| N. Redbelly Dace | 10 | | | | | | | | | | | 5 | | | 6 | 7 | | | | | | | | | | **28** | 1.5 |
| Rainbow Trout | | | | | | 48 | | 14 | 13 | 17 | 14 | 25 | | 45 | | 15 | | 4 | | 12 | 9 | | | 36 | | **252** | 13.4 |
| Sculpin sp. | | | 20 | | | | | | 10 | | | | | | | | | | | | | | | 4 | | **34** | 1.8 |
| Slimy Sculpin | | | 40 | | | 3 | | 14 | 19 | 21 | 15 | | | | | | | | | | | | | 11 | | **123** | 6.5 |
| Smallmouth Bass | | | | | | 9 | | | | | 7 | | | | | | | | | | | | | 2 | | **18** | 1.0 |
| Spottail Shiner | | | | | | | | | | | 10 | | | | | | | | | | | | | | | **10** | 0.5 |
| Trout-perch | | | | | | | | | | | 1 | | | | | | | | | | | | | | | **1** | 0.1 |
| White Sucker | | | | | 1 | 3 | | 2 | 2 | 1 | | | | | | 1 | | 6 | 1 | 2 | | 5 | 1 | 2 | | **27** | 1.4 |
| **Total # Individuals** | **189** | **50** | **139** | **39** | **55** | **124** | **15** | **97** | **132** | **68** | **145** | **81** | **61** | **67** | **32** | **60** | **44** | **78** | **33** | **67** | **30** | **65** | **58** | **124** | **29** | **1882** | 100.0 |
| **# Species** | 6 | 3 | 2 | 2 | 4 | 8 | 3 | 8 | 7 | 6 | 10 | 8 | 2 | 6 | 5 | 9 | 1 | 6 | 5 | 7 | 4 | 7 | 5 | 9 | 1 | | |

Table 6. Total biomass (g) of fish by species sampled at 2010 sampling sites on Cedar, Pitch, and Whitewood creeks.font size changed below

| Common Name | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blacknose Dace | | | | | | 3 | 3 | 20 | | 18 | 14 | 27 | 0 | 90 | | 31 | | 87 | 7 | 27 | 20 | 10 | 37 | 20 | | **412** |
| Brook Stickleback | 64 | | | | | | | | | | | 2 | | 3 | 14 | | | 9 | | | | 18 | 8 | 14 | | **132** |
| Brook Trout | 704 | 616 | 1633 | 518 | 560 | | 362 | 13 | | 186 | | | 790 | | | 26 | 271 | | 638 | | 336 | | 76 | 28 | 1193 | **7950** |
| Central Mudminnow | 71 | | | | | | | | | | 2 | | | | | | | | | | | 45 | | | | **118** |
| Common Shiner | | | | | | | | 20 | | | | 15 | | 2 | | 4 | | | | | | | | | | **40** |
| Creek Chub | | | | 6 | 12 | 21 | | 32 | 12 | | 115 | 17 | | 68 | 8 | 34 | | 118 | 36 | 26 | | 167 | 42 | 25 | | **739** |
| Cyprinid sp. | | | | 2 | | | | | 21 | 2 | | | | | | | | | | | | | 8 | | | **34** |
| Emerald Shiner | | | | | | | | | | | | | | | | | | | | 23 | | | | | | **23** |
| Fathead Minnow | | | | | | | | | | | | | | | | | | 13 | | | | 7 | | | | **21** |
| Finescale Dace | 21 | 1 | | | | | | | | | | 3 | | | 1 | | | | | | | 7 | | | | **34** |
| Johnny Darter | | | | | | 9 | | | 6 | | 10 | | | | | | | | | | | | | | | **25** |
| Lake Chub | | | | | | | | | 1 | | | | | | | 23 | | | | 5 | | | | | | **28** |
| Longnose Dace | 123 | 26 | | | 5 | 115 | 19 | 49 | 83 | 22 | 26 | 8 | | 95 | | 3 | | | 10 | 11 | 2 | | | 85 | | **681** |
| Northern Pearl Dace | 8 | | | | | | | | | | | 8 | | | 9 | 11 | | | | | | | | | | **36** |
| Northern Redbelly Dace | | | | | | | | | | | | | | | 4 | | | | | | | | | | | **4** |
| Rainbow Trout | | | | | | 350 | | 115 | 25 | 574 | 19 | 349 | | 85 | | 209 | | 106 | | 104 | 188 | | | 256 | | **2378** |
| Slimy Sculpin | | | 119 | | | 17 | | 45 | 77 | 57 | 41 | | | | | | | | | | | | | 52 | | **408** |
| Smallmouth Bass | | | | | | 93 | | | | | 44 | | | | | | | | | | | | | 9 | | **146** |
| Spottail Shiner | | | | | | | | | | | 5 | | | | | | | | | | | | | | | **5** |
| Trout-perch | | | | | | | | | | | 2 | | | | | | | | | | | | | | | **2** |
| White Sucker | | | | | 50 | 11 | | 20 | 75 | 33 | | | | | | 11 | | 15 | | 22 | | 130 | 16 | 78 | | **462** |
| **Grand Total** | **993** | **643** | **1752** | **526** | **628** | **619** | **384** | **314** | **301** | **893** | **277** | **428** | **791** | **341** | **37** | **350** | **271** | **348** | **690** | **216** | **545** | **384** | **187** | **567** | **1193** | **13678** |



N
Total #
Total_No
1-10
11-25
26-50
51-100
101-200
Biomass (g)
Total_Wt
0-50
50-100
100-500
500-1000
1000-2000
Cedar Creek
South Cedar Creek
Hwy 590
Hwy 595
Rock Run Creek
Tinpail Creek
Whitewood Creek
Pitch Creek
Beaver Dam Creek
Whitefish River
139
61
189
50
78
44
29
60
81
15
68
67
132
32
67
124
124
145
33
58
30
97
39
55
65
0 1 2 3 4 5 km

Figure 16. Total number and biomass of all fish species at 25 sample sites on Whitefish River tributaries in 2010.

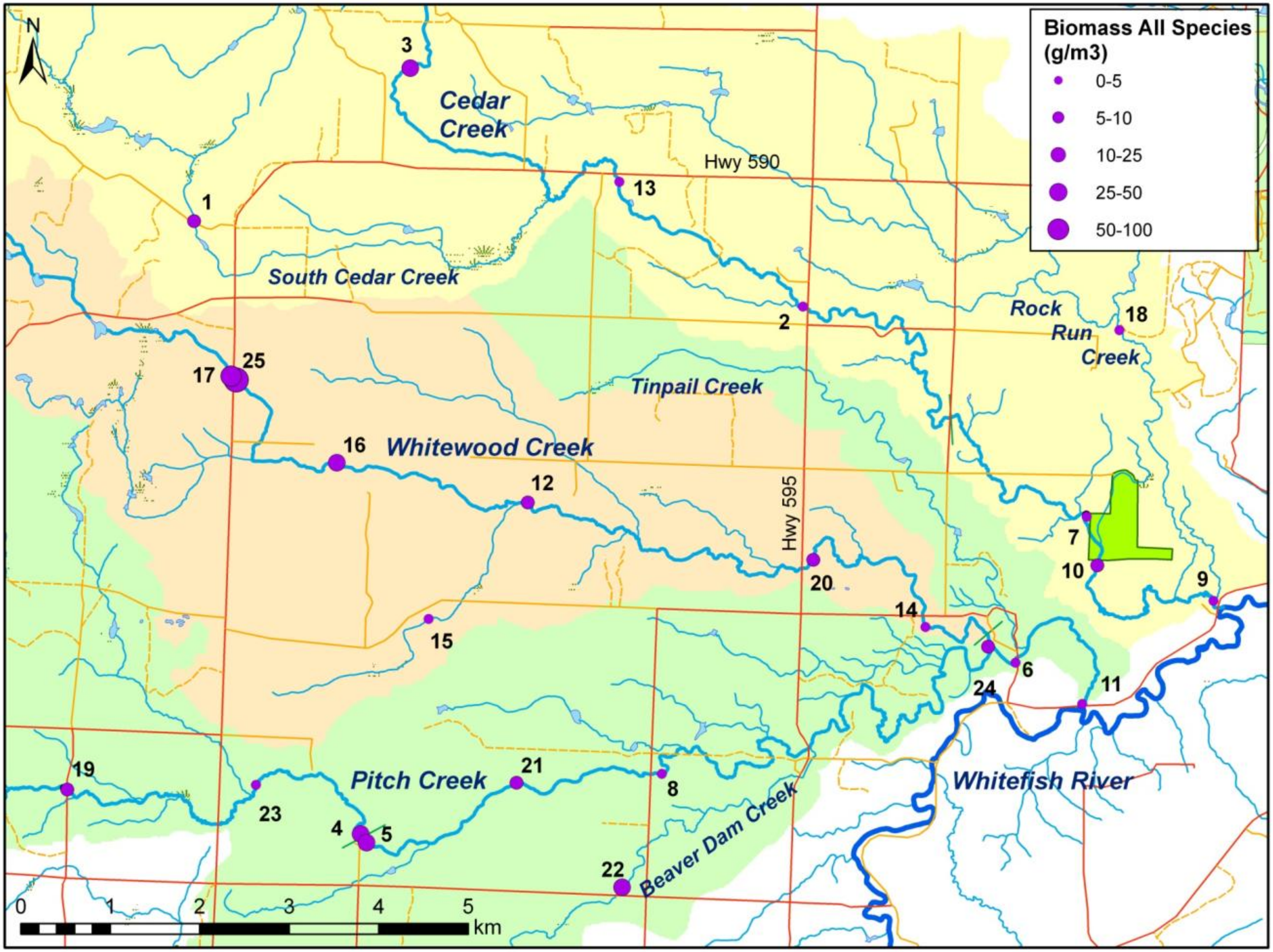


Figure 17. Biomass relative to sampled water volume ($m^3$) at 25 sample locations (labelled) on three Whitefish River tributaries, 2010.

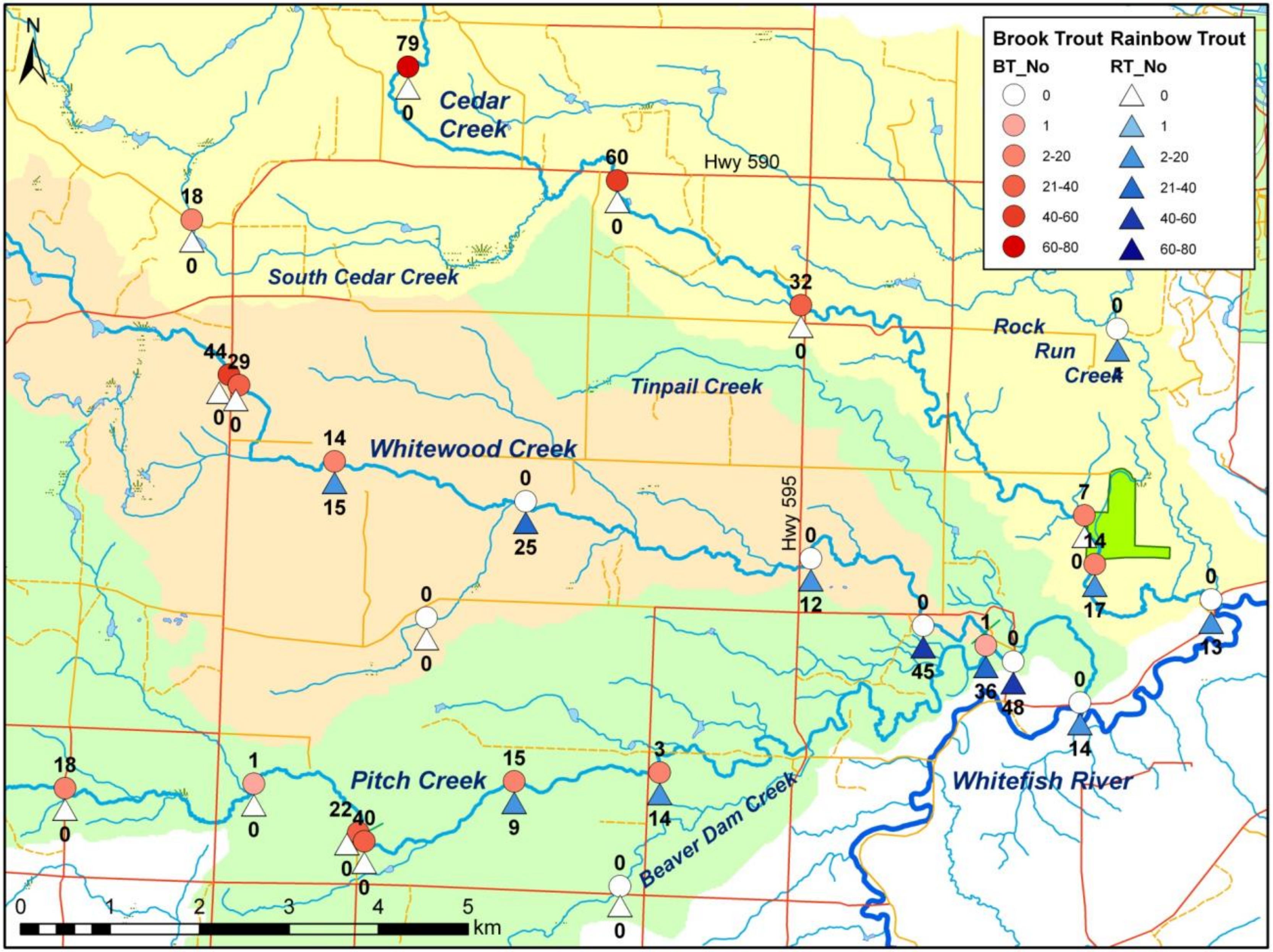



Figure 18. Total number brook and rainbow trout at 25 sample sites on Whitefish River tributaries in 2010.

## 5.3 Size Distribution

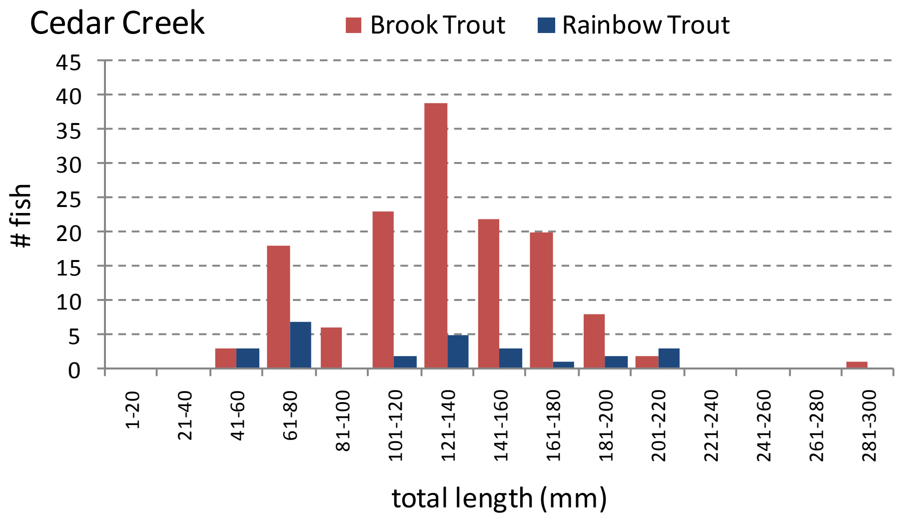
Length-frequency diagrams for rainbow trout and brook trout are presented in Figure 19. Brook trout in Cedar Creek exhibited a bell-shaped size distribution, with the 100-120 mm total length (TL) being the most common size class. In contrast, there were relatively few brook trout on Pitch and Whitewood Creeks in that size range, resulting in a roughly bimodal length-frequency distribution. A 133 mm TL brook trout sampled on September 17 from Site 25 had approximately 50 eggs and was 2 years of age, indicating that sexual maturity occurs at a relatively young age and small size on these systems. Another sampled male brook trout was 193 mm TL at 2 years of age.

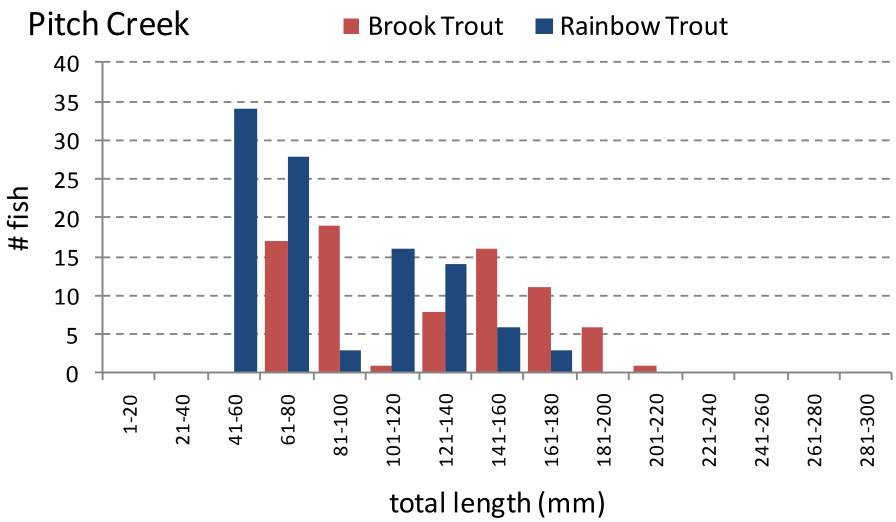
Mean total length was similar among the three tributaries ranging from 122.9 mm to 129.7 mm (

Table 7), with greater variation within each system than among tributaries. In 1993, Picard (1995) recorded a mean fork length of 176.8 ± 12.11 mm for brook trout from Cedar Creek and 124.6 ±10.14 from Pitch Creek. The locations of Picard's two sampling sites are not available however, but his values are roughly comparable to Site 7 at Cedar Falls (which is a likely sampling site due to ease of access and land tenure), and to several sites on Pitch Creek.

Table 7. Mean total length and live weight for brook trout and rainbow trout sampled at 21 stations on Whitefish River tributaries in 2010.

| | **Brook Trout** | | | **Rainbow Trout** | | |
|---|---|---|---|---|---|---|
| | **TL (mm)** | **Wt (g)** | **n** | **TL (mm)** | **Wt (g)** | **n** |
| **Cedar** | | | | | | |
| Site 1 | 139.4 | 39.1 | 18 | | | |
| Site 2 | 116.2 | 36.2 | 17 | | | |
| Site 3 | 135.9 | 33.3 | 49 | | | |
| Site 7 | 174.1 | 51.7 | 7 | | | |
| Site 9 | | | | 62.6 | 2.5 | 10 |
| Site 10 | 108.1 | 16.9 | 11 | 164.4 | 47.8 | 12 |
| Site 13 | 121.6 | 19.8 | 40 | | | |
| Site 18 | | | | 143.5 | 26.5 | 4 |
| Cedar All | 129.7 | 30.2 | 142 | 122.0 | 27.1 | 26 |
| **Pitch** | | | | | | |
| Site 4 | 113.0 | 23.5 | 22 | | | |
| Site 5 | 110.3 | 20.8 | 27 | | | |
| Site 6 | | | | 79.2 | 7.3 | 48 |
| Site 8 | 78.0 | 4.3 | 3 | 107.8 | 12.8 | 9 |
| Site 11 | | | | 55.0 | 1.7 | 11 |
| Site 19 | 159.8 | 48.8 | 13 | | | |
| Site 21 | 131.4 | 25.8 | 13 | 143.7 | 31.3 | 6 |
| Site 23 | 192.0 | 75.9 | 1 | | | |
| Site 24 | 158.0 | 27.8 | 1 | 89.3 | 8.5 | 30 |
| Pitch All | **122.9** | **27.1** | **80** | **85.8** | **8.9** | **104** |
| **Whitewood** | | | | | | |
| Site 12 | | | | 111.2 | 14.0 | 25 |
| Site 14 | | | | 59.5 | 2.6 | 33 |
| Site 16 | 64.0 | 2.4 | 11 | 121.7 | 19.0 | 11 |
| Site 17 | 86.6 | 8.5 | 32 | | | |
| Site 20 | | | | 97.4 | 8.7 | 12 |
| Site 25 | 153.7 | 41.1 | 29 | | | |
| Whitewood All | 110.2 | 20.7 | 72 | 89.5 | 9.2 | 81 |
| **Grand Mean** | **123.1** | **27.0** | **294** | **91.7** | **11.3** | **211** |


Cedar Creek
Brook Trout
Rainbow Trout
# fish
0
5
10
15
20
25
30
35
40
45
1-20
21-40
41-60
61-80
81-100
101-120
121-140
141-160
161-180
181-200
201-220
221-240
241-260
261-280
281-300
total length (mm)


Pitch Creek
Brook Trout
Rainbow Trout
# fish
0
5
10
15
20
25
30
35
40
1-20
21-40
41-60
61-80
81-100
101-120
121-140
141-160
161-180
181-200
201-220
221-240
241-260
261-280
281-300
total length (mm)

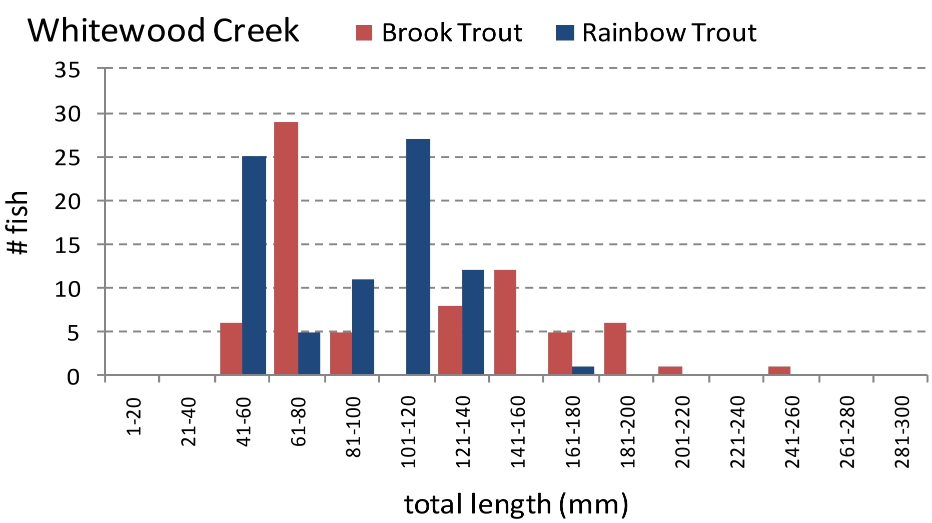

Whitewood Creek
Brook Trout
Rainbow Trout
# fish
0
5
10
15
20
25
30
35
1-20
21-40
41-60
61-80
81-100
101-120
121-140
141-160
161-180
181-200
201-220
221-240
241-260
261-280
281-300
total length (mm)

Figure 19. Length-frequency distribution for Cedar, Pitch, and Whitewood creeks sampled in 2010.

# 6 Anthropogenic Activities

## 6.1 Land Use

The primary land uses in the watersheds of the Cedar, Pitch, and Whitewood creeks are forestry and agriculture (Figure 23). However, based on 2000 interpreted Landsat satellite imagery (Spectranalysis 2004), approximately 3% of the combined watersheds was classed as recent cutovers and less than 1% was interpreted as cropland (Figure 20). It appears that much of the pasture and regenerating cutover (Figure 21 to Figure 23) in these three watersheds classed as sparse forest, and significant areas of pasture were misinterpreted and also included in this landcover class. Based on aerial reconnaissance and fieldwork, row crops (e.g. potato farm near Site 23) occupy only a minor proportion of the watershed, with pasture and hayfields being the primary agricultural use. Dense mixed or deciduous forests are the other significant land cover classes, representing approximately half the total watershed area according to 2000 interpreted Landsat imagery.

Aerial reconnaissance and GoogleEarth imagery (Figure 21, Figure 24) indicate that there is a greater proportion of the three watersheds in open land cover classes, particularly recent cutover and pasture on private lands, than indicated by the 2000 Landsat imagery. Based on digitized GoogleEarth imagery (date unknown, but more recent than 2000), approximately 30% of the land between Highway 590 and the Whitefish River is open habitat that is either recent cutover, pasture, cropland, lawns or gravel pits. The watershed of Whitewood Creek has the highest proportion of open lands (35%), followed by Cedar Creek (32%) and Pitch Creek (25%). There is some pasture west and north of Highway 590, but the predominant land use is forestry on Crown land.

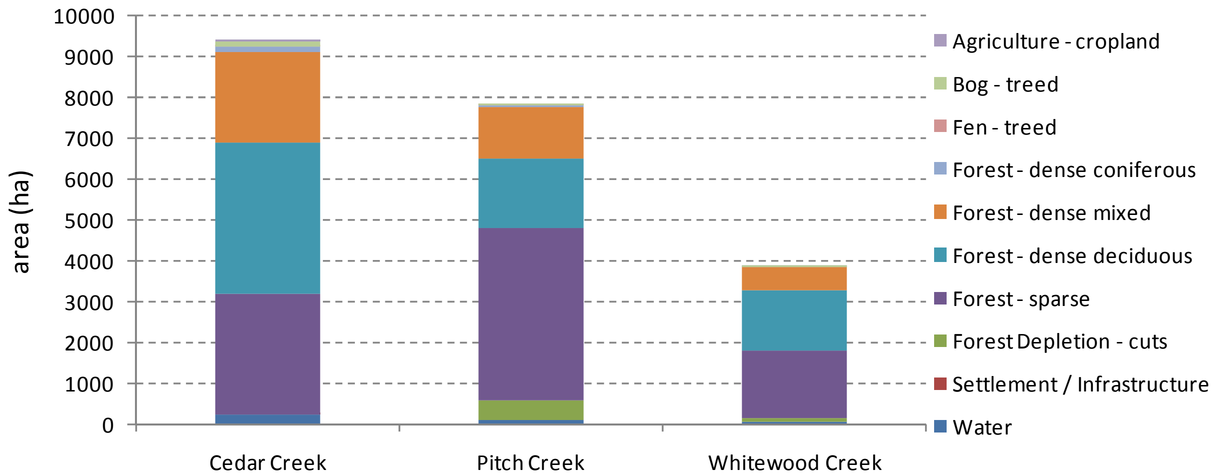



Figure 20. Area in different landcover classes (Spectranalysis 2004) in the watersheds of three Whitefish River tributaries.

Approximately 65% (13,600 ha) of the watershed area of the three Whitefish tributaries is on private land, and is therefore not covered by forest management guidelines for riparian areas and fish habitat (OMNR 1998). Nonetheless, the aerial reconnaissance survey, fieldwork, and examination of GoogleEarth imagery indicate that in most cases a treed, or at least vegetated, buffer is left adjacent to Cedar, Pitch, and Whitewood creeks. A discussion with one landowner indicated that logging companies operating on his land were instructed to leave a forested buffer from the top of the ridge along Whitewood Creek. No direct impacts on fish habitat from forestry were observed in the field in 2010.

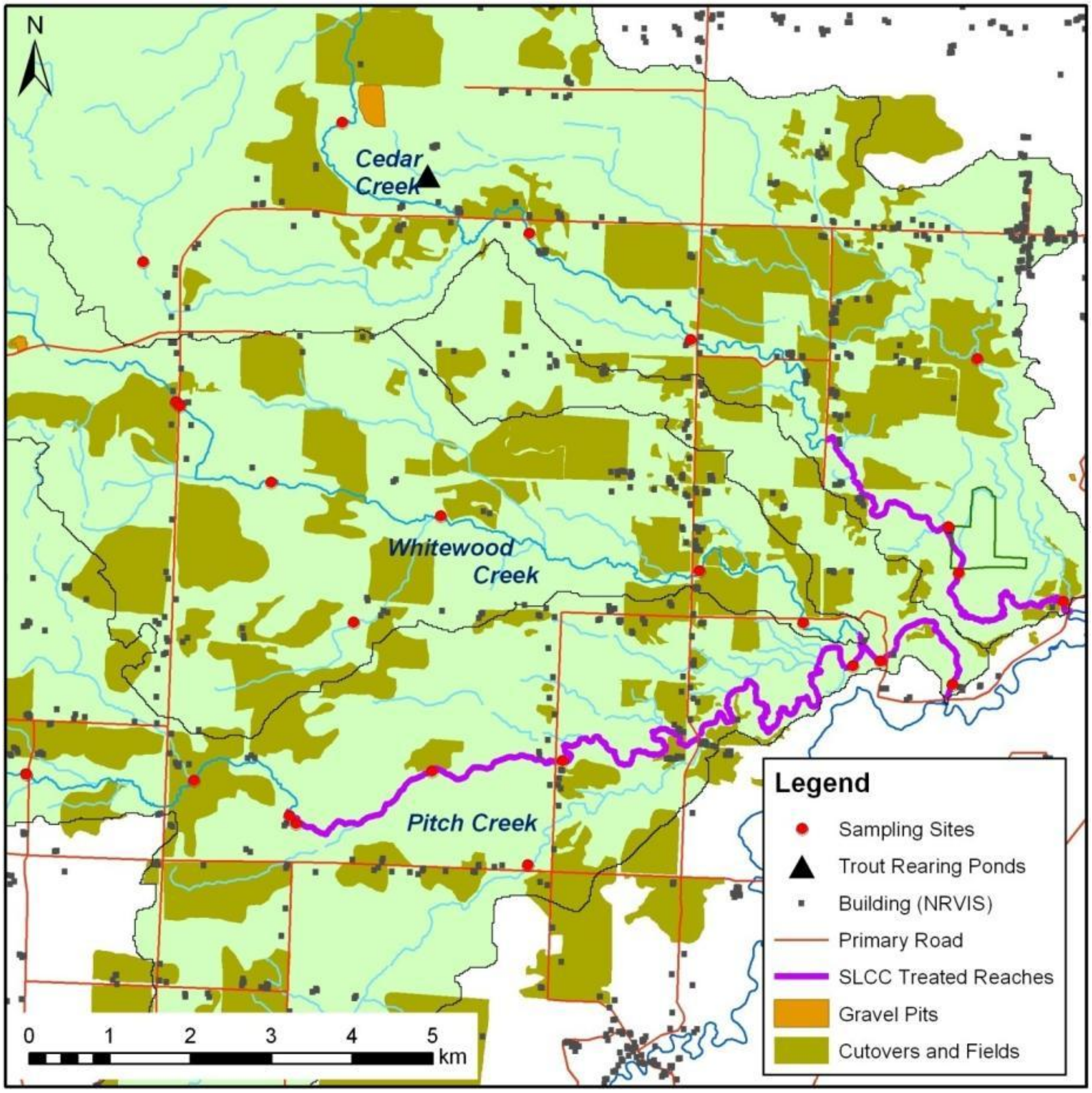



Figure 21. Main land use and potential anthropogenic impacts in the lower watershed of three Whitefish River tributaries. Recent cutovers and fields digitized from GoogleEarth imagery (unknown date).

Figure 22. Pasture and regenerating cutover near Site 12 on Whitewood Creek.

Figure 23. Hayfield and regenerating cutover adjacent to Pitch Creek and potato farming adjacent to Site 23 (arrow).

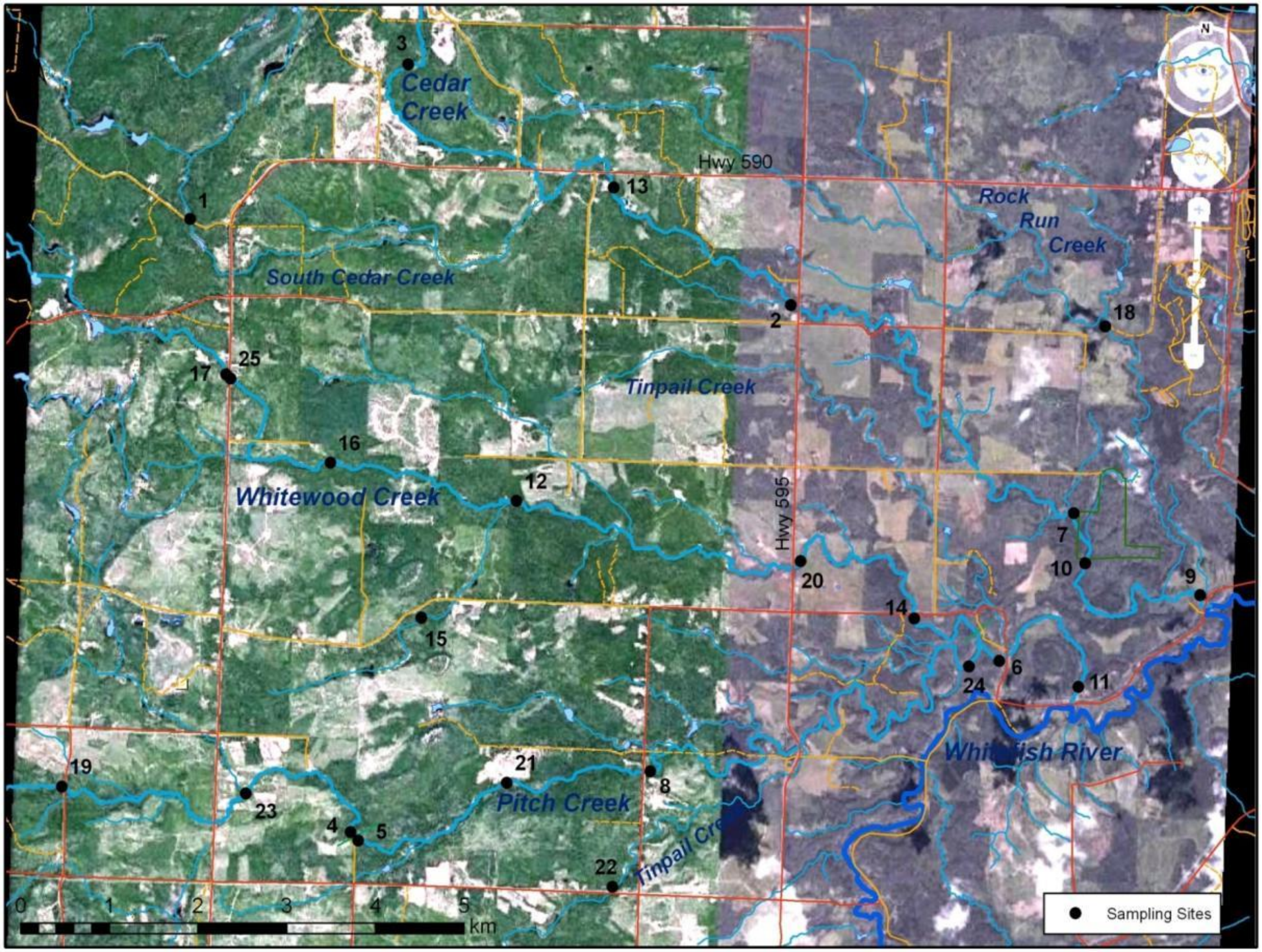



Figure 24. 2010 Sampling locations in relation to land use patterns (GoogleEarth imagery).

Most of the agricultural lands in the study watersheds are devoted to hayfields or pasture for cattle or horses. Although much of Cedar, Pitch and Whitewood creeks pass through forested landscape or have riparian buffers, portions of these watercourses or their tributaries pass through pastures. For example, the lower portion of Cedar Creek passes through a pasture that is used for cattle (Figure 25). No fencing prevents cattle from entering the stream, and as a result there are several cowpaths through the stream leading to bank erosion, reduced natural riparian vegetation, increased siltation, and widening of the channel at Site 6 (Figure 26).

Some erosion is a natural process as creeks cut through soft deposits, and there are other locations (e.g., Site 9) on the lower Pitch Creek with slumping silty clay banks similar to Site 6. These glaciolacustrine deposits are particularly susceptible to erosion which can be accelerated from improper land use practices, leading to siltation in Cedar Creek and farther downstream i.e., Whitefish River, Kaministiquia River. Siltation can have negative impacts on aquatic biota such as suffocating fish eggs (Kerr 1995), and may contribute to the lower fish biomass at Site 6. However, it is difficult to separate out direct or indirect farming-related impacts from natural habitat variability associated with landscape position. In particular, the streams become wider, shallower, slower, and more soft-bottomed on glaciolacustrine delta deposits in their lower reaches compared to on tills higher in the watershed.

Figure 25. Cattle trail and adjacent pasture at Site 9 on the lower reaches of Cedar Creek.

Figure 26. Lower reach of Cedar Creek with cow paths, streamside trampling, and eroding bank.

## 6.2 Aggregate Pits

A large (approximately 14 ha) gravel pit is located approximately 300 m northeast of Site 3 and adjacent to Cedar Creek (Figure 27) on a coarse glaciofluvial deposit. There are several other smaller aggregate pits associated with forest access roads in the western part of the study area. Although there was only a narrow riparian buffer adjacent to the gravel pit, no apparent effects of the gravel pit (e.g., siltation) were detected downstream at Site 3. Brook trout and sculpin were abundant at this site indicating no impairment of water quality.

Figure 27. Gravel pit near Cedar Creek (lower) and in relation to Site 8 (red arrow; upper right).

## 6.3 Roads and Trails

Trails created by all terrain vehicles (ATV) and informal footpaths, likely from anglers, were observed at several sites on private land (Sites 8, 15, 18, 20). In contrast, the snowmachine trail that crosses Cedar Creek at Site 8 on Crown land has a proper bridge structure. On an unnamed tributary of Whitewood Creek at Site 15, an ATV trail crosses at two locations (Figure 28). Boards have been placed to facilitate crossing and other boards have washed downstream into the next pool. There is erosion of silty-clay banks and siltation in the pool downstream. However, the impacts are localized to the first pool downstream, and pools farther downstream do not appear to be negatively impacted. Erosion at Site 8 on Rock Run Creek is extensive and has led to the development of multiple crossing points (Figure 29). Although there are fairly significant local impacts, they are less extensive or profound than the habitat changes associated with the beaver dam and pond immediately upstream. In contrast, there are minimal impacts to the watercourse at Site 8 where an ATV trail crosses the cobble bottom (Figure 28).

Figure 28. Quad trails crossing stream at Site 15 (L) and Site 8 (R).

Roadways can create pools by creating impoundments on the upstream end of improperly sized culverts, or when they are shallowly installed such as at Site 1 on Cedar Creek (see Appendix 4, Site 1). Scour pools can also develop on the downstream side of culverts such as at Site 25 on the Whitewood River (Figure 30) and above Site 20 (Figure 14). At Site 25, the silt-bottomed pool was approximately 8 m x 6 m with a maximum depth of 65 cm (mean 50 cm) with an associated small patch of pondweeds (*Potamogeton* sp.). The pool provides habitat for a relatively large number of good-sized brook trout; a total of 25 brook trout with a mean TL of 154 mm were sampled there in 235 seconds of electrofishing. A conversation with the adjacent landowner indicated that brook trout have traditionally been angled from this pool. The population was even larger in the past. In comparison, a shallow, silty culvert pool (average depth 70 cm) at Whitewood Creek above Site 20 (Figure 22) had only one rainbow trout in 75 seconds of sampling.

Figure 29. Quad trail through Rock Run Creek at Site 18 and resulting streambank erosion.

Figure 30. Muddy culvert pool below Site 17 on Whitewood River.

## 6.4 Residential Development and Associated Activities

A number of activities associated with residential development within the study watersheds may potentially have impacts, either positive or negative, on fish habitat and fish communities. The most commonly observed was the construction of small ponds or pools on private property. In several instances the pools appeared to have been created with the use of heavy machinery by excavation or creating a check dam (Figure 31). One pool was recent, whereas the other three large pools were created long ago judging by surrounding vegetation (Figure 32). One pond (0.2 ha) just downstream of Site 13 does not appear to be hydrologically connected to Cedar Creek. Riparian vegetation has been cleared around this pond and the adjacent residence (Figure 32L). A series of adjacent dug-out ponds along Rock Run Creek are apparently used for rearing rainbow trout (Figure 33L). No rainbow trout were observed at Site 18 km downstream on Rock Run Creek, indicating that no rainbow trout had escaped from the rearing ponds to establish a stream-resident population.

Several other pools have apparently been made by hand in an attempt to deepen them. Typically the pools consist of a small vortex weir or check dam made of rocks placed at the tail end of a pre-existing natural pool (Figure 33R, Figure 34). Such modifications can be difficult to distinguish from naturally-occurring rocks, but appear to have been made at Sites 2, 4, 5, 8, 13, 16, and 20. These modifications may enhance holding habitat to improve angling, particularly at easily accessible sites. Brook trout typically prefer pool to riffle habitats (Power 1980). The largest brook trout in the study was from a modified pool at Site 2. Discussions with landowners also indicate that some pools are modified to increase water depth for children to swim or play in during the summer. One pool has a pump and water line to provide water to the residence (Figure 35). Any impacts on the hydrology could not be assessed in the context of this study.

In at least two instances, coarse woody debris appears to have been removed from the modified pool presumably to facilitate swimming/bathing or to reduce snags when angling. Trees and other riparian vegetation have been partially or entirely removed adjacent to a number of these pools or residences (Figure 32, Figure 32, Figure 35) presumably for aesthetics, to increase sunlight, or to reduce biting insects. Nonetheless, the modified pool at Site 2 (Figure 36), held the largest brook trout observed during the 2010 study (291 mm TL, 293 g).

Attempted use of geotextile (filter cloth) to stabilize stream banks and prevent continued erosion was observed at three sites (Sites 8, 9, 11) (Figure 37). At all sites, the filter cloth had not actively been maintained in some time, and had pieces of geotextile blown out under high flow conditions which were observed on streambanks farther downstream.

Figure 31. Unauthorized earthen barrier on stream (L) and apparent man-made pool below water crossing on private road (R).

Figure 32. Man-made pond adjacent to Cedar Creek (L) and on upper reaches of Pitch Creek (R).

Figure 33. Rainbow trout rearing ponds near Rock Run Creek (R) and small check dam at outlet of culvert pool at Site 8 on Whitewood Creek.

Figure 34. Rock dam at Site 16 on Whitewood Creek.

Figure 35. Residential development adjacent to north Cedar Creek (L) and water intake pipe for residence on Pitch Creek (R).

Figure 36.  Modified pool at Site 2.

Figure 37. Geotextile used at Site 8 (L) and Site 9 (R; red arrow) to prevent erosion.

## 6.5 Sea Lamprey Control

The Kaministiquia River and a number of its tributaries, including the Whitefish River system, have been treated 15 times with the lampricide TFM for sea lamprey control since 1960, with the most recent treatment on July 14-18, 2010 (DFO unpublished data). The upstream lampricide application points used by Sea Lamprey Control Centre are:

- on Pitch Creek immediately above the falls, 15 km from its confluence with the Whitefish River;
- on Whitewood Creek just above the chutes, approximately 150 m above its confluence with the Pitch Creek; and
- on Cedar Creek (referred to as O'Connor Creek in SLCC records) immediately above Cedar Falls or at Garbutt Road (6.2 km from its mouth).

In the case of Pitch and Cedar creeks, these locations are thought to mark the upstream limit of sea lamprey ammocoete distribution, and the turbulence at all three sites helps ensure adequate mixing of the lampricide and stream water (DFO unpublished data).

Non-target mortality observed during sea lamprey control of Whitefish River tributaries on July 14-18, 2010 included central mudminnow, common shiner, emerald shiner, logperch, longnose dace, rainbow trout, and white sucker (DFO unpublished data). In July 30, 2006, Coho salmon (under 22.5 cm) were also recorded as non-target mortality on the Pitch Creek. Non-target mortality from the Whitefish River tributaries was often not reported separately from the rest of the Kaministiquia River treatment. Longnose Dace and trout-perch had moderate mortality during the 1992 treatment (501-100 individuals) on Whitefish Rivers tributaries (DFO unpublished data). Fish species that are bottom-oriented, such as longnose dace, trout-perch, and sculpins tend to be most adversely impacted by TFM treatments since the lampricide concentrations are highest near the streambottom. These species seek refuge in the substrate rather than by avoidance (Foster and Colby 2009). Fish community sampling in 2010, which occurred after SLCC treatment, found that sculpins and longnose dace were fairly abundant in portions of the treated reaches in Cedar and Pitch creeks. No pre-treatment data are available for comparison however.

According to Gilderhus and Johnson (1980) the long-term effects on benthic invertebrate communities from TFM treatments appear to be minimal. Although overall community composition and density are not significantly affected, some taxa are negatively impacted. The following taxa appear to be particularly sensitive to TFM and TFM/1% niclosamide mixtures at the concentrations applied for sea lamprey control (i.e., 1.3 to 1.5 MLC sea lamprey):

- mayflies *Hexagenia* and *Litobrancha* and to a lesser extent *Cloeon*, *Pseudocloeon*, *Baetis*

- and *Isonychia*;
- caddisflies *Chimarra*, *Dolophilodes* and *Glossosoma*;
- black fly family Simuliidae, especially *Prosimulium* and *Simulium*;
- aquatic worms (oligochaetes), and
- erpobdellid leeches.

Although significant mortality and drift of sensitive taxa may occur with individual treatments, it appears that pre-treatment densities of most taxa typically recover within several years due to inherent productivity of these communities and recolonization through downstream drift (Weisser et al. 2003). However, if streams are treated on a cycle of every 3-5 years, benthic communities may be in a near continuous state of recovery due to repeated applications of lampricide.

Lampricide treatments can impact aquatic invertebrates other than through direct mortality. Dramaticincreases in drift rates after lampricide treatments have been observed for the mayfly *Baetis*, caddisflies *Chimarra* and *Dolophilodes*, the blackfly *Simulium*, various oligochaete worms, leeches and scuds Gammarus (e.g., Maki 1980; Dermott and Spence 1984; Jeffrey et al. 1986; Kolton et al. 1986; McMahon et al. 1987; Dubois and Plaster 1993). TFM in lab studies immobilizes *Chironomus* at 1/6 the concentration required to produce 50% mortality for this genus (ACSCEQ 1985). Immobilization increases susceptibility of *Chironomus* to predation.

# 7 Summary and Recommendations

Landscape-level land use practices such as forestry and agriculture and more localized site-specific impacts may potentially impact the habitat of benthic invertebrate and fish communities of Cedar, Pitch, and Whitewood Creeks. These creeks flow through watersheds that support agricultural activity with probable nutrient inputs, either in the form of chemical fertilizers or organics, such as manure. Increased nutrients stimulate algal growth which in turn provides habitat favoured by worms. The macroinvertebrate communities at all three lower reach sites still retain taxa, such as Ephemeroptera, Plecoptera and Trichoptera, that require clean, well oxygenated water; however, the proportion of these taxa within the community has decreased while the proportion of worms has increased compared to the upper reach sites. The abundance of worms at all three lower benthic macroinvertebrates sites probably indicates that the communities were not affected significantly by the lampricide treatment, although pre-treatment data about macroinvertebrate community composition are not available for comparison. Reduction of nutrient inputs would probably reduce algal growth which would permit a rapid recovery of the EPT and benefit fish species that forage upon them.

Localized impacts which include increased rates of stream bank erosion and siltation, reduction in riparian vegetation, and changes to natural streamflows are caused by livestock trampling, ATV trails, dams, residential development and other anthropogenic activities. The impacts appear to be minor and/or localized, and do not appear to have had significant effects on overall benthic macroinvertebrate or fish communities at this time compared to habitat changes from natural processes such as beaver activity. However, cumulative impacts of these activities should be considered. Brook trout populations are particularly sensitive and may have a limited ability to recover their numbers following disturbance, especially since the creeks may be thermally marginal.

Discussions with landowners generally indicated a sincere concern for fish and fish habitat, particularly brook trout, on their properties. Given this interest, there is potential for stewardship outreach to address some of the land use concerns identified in 2010. Stewardship activities might focus on:

- Use of appropriate water crossing techniques for informal ATV trails such as cobble fords.
- Importance of coarse woody debris, particularly in natural or anthropogenic pools, as cover for trout and other fish species, as well as benthic macroinvertebrates.
- Importance of retaining overstory trees for maintenance of thermal stability and organic inputs (e.g., leaves, invertebrates) for the stream.
- Importance of retaining riparian vegetation as a barrier against sediment and nutrient input (e.g., fertilizers, pesticides) from adjacent lawns, pastures, and agricultural fields.
- Increased awareness of the Fisheries Act with respect to work in water.
- Livestock management e.g. fencing to prevent negative impacts on channel morphology, erosion, riparian vegetation.

# 8 Acknowledgments

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Appendix 1. Fish community sampling locations on Whitefish River tributaries, 2010 (*per=permanent; int=intermittent).

| Site No | Watercourse | Date Sampled | Observers | Land Tenure | Downstream Easting | Downstream Northing | Upstream Easting | Upstream Northing | River (per/int)* | Water Temp (°C) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cedar Creek | 05/10/2010 | RFF, BR, JH | Crown | 293182 | 5363609 | 293181 | 5363672 | per | 7.0 |
| 2 | Cedar Creek | 25/08/2010 | RFF, BR | Kydd | 299988 | 5362655 | 299942 | 5362673 | per | 15.5 |
| 3 | Cedar Creek | 05/10/2010 | BR, JH | Crown | 295598 | 5365318 | 295657 | 5365369 | per | 7.5 |
| 4 | Pitch Creek | 26/08/2010 | RRF, BR | Watson | 295043 | 5356764 | 295010 | 5356791 | per | 14.0 |
| 5 | Pitch Creek | 27/08/2010 | RRF, BR | Kramer | 295109 | 5356667 | 295085 | 5356696 | per | 19.0 |
| 6 | Pitch/Whitewood Creek | 28/08/2010 | RFF, BR, JH | Township | 302362 | 5358676 | 302296 | 5358684 | per | 10.0 |
| 7 | Cedar Creek | 29/08/2010 | AGH, RRF | LRCA | 303158 | 5360308 | 303110 | 5360343 | per | 21.0 |
| 8 | Pitch Creek | 30/08/2010 | RRF, BR | Arthur | 298411 | 5357436 | 298342 | 5357464 | per | 21.0 |
| 9 | Cedar Creek | 31/08/2010 | RRF, BR | Vaclav | 304575 | 5359368 | 304543 | 5359400 | per | 21.0 |
| 10 | Cedar Creek | 05/09/2010 | AGH, RRF | LRCA | 303273 | 5359763 | 303293 | 5359851 | per | 13.0 |
| 11 | Pitch/Whitewood Creek | 06/09/2010 | AGH, RRF | Baca | 303107 | 5358217 | 303221 | 5358451 | per | 10.0 |
| 12 | Whitewood Creek | 06/09/2010 | AGH, RRF | Travis | 296912 | 5360465 | 296880 | 5360469 | per | 14.0 |
| 13 | Cedar Creek | 08/09/2010 | RRF, BR | Wigley | 297936 | 5364048 | 297890 | 5364113 | per | 10.5 |
| 14 | Whitewood Creek | 08/09/2010 | RRF, BR | Township | 301356 | 5359077 | 301330 | 5359164 | per | 14.0 |
| 15 | Whitewood tributary | 16/09/2010 | RRF, BR | MNR/Cook | 295804 | 5359166 | 295759 | 5359129 | per | 8.0 |
| 16 | Whitewood Creek | 16/09/2010 | RRF, BR | Kukkee | 294778 | 5360911 | 294751 | 5360874 | per | 11.0 |
| 17 | Whitewood Creek | 17/09/2010 | RRF, JH | Vaillant | 293597 | 5361879 | 293573 | 5361900 | per | 11.5 |
| 18 | Rock Run Creek | 19/09/2010 | RRF, JH | Township | 303524 | 5362392 | 303502 | 5362452 | per | 9.0 |
| 19 | Pitch Creek | 19/09/2010 | RRF, JH | Bowyer | 291766 | 5357260 | 291728 | 5357298 | per | 9.5 |
| 20 | Whitewood Creek | 21/09/2010 | RRF, JH | Township | 300100 | 5359825 | 300007 | 5359735 | per | 10.5 |
| 21 | Pitch Creek | 22/09/2010 | RRF, JH | Flesherton | 296785 | 5357335 | 296709 | 5357303 | per | 9.5 |
| 22 | Beaver Dam Creek | 22/09/2010 | RRF, JH | Pogue | 297966 | 5356167 | 297919 | 5356125 | int | 10.0 |
| 23 | Whitewood Creek | 27/09/2010 | AGH, BR | Ray's Potato Farm | 293875 | 5357311 | 293850 | 5357252 | per | 7.5 |
| 24 | Pitch Creek | 28/09/2010 | BR, JH | Prentice | 302055 | 5358855 | 302079 | 5358805 | per | 10.0 |
| 25 | Whitewood Creek | 17/09/2010 | RRF, JH | Road Allowance | 293654 | 5361836 | 293623 | 5361839 | per | 11.5 |

Appendix 2. Characteristics of sampling locations on Whitefish River tributaries, 2010.

| Feature | Class | Sample # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Algae[1] | Attached | 1 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 3 | 1 | 2 | 3 | 3 | 1 | 2 | 2 | 3 |
| | | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 2 | 2 | |
| | | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | |
| | Filaments | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 2 | 2 | 3 | 2 |
| | | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | |
| | | 3 | 2 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | |
| | Floating | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 |
| | | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 2 |
| | | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | |
| | Slimes or Crusts | 1 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 2 | 2 | |
| | | 3 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |
| Macrophytes[1] | Emergents | 1 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2 |
| | | 2 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | |
| | | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 2 | 3 | |
| | Free-Floating | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | |
| | | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | |
| | Rooted | 1 | 2 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 |
| | | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | |
| | | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | |
| | Submergent | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 |
| | | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | |
| | | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | |
| Organic Matter[1] | Detritus | 1 | 1 | 2 | 2 | 3 | 2 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | 2 | 1 | 1 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |

| Feature | Class | Sample # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 1 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | |
| | Woody Debris | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | 2 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |
| | | 3 | 1 | 2 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | |
| Riparian Vegetation[2] | 1.5-10 m | Left | 4 | 4 | 6 | 6 | 6 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 6 | 6 | 6 | 4 | 4 | 4 | 6 | 6 | 4 | 4 | 3 |
| | | Right | 4 | 3 | 6 | 6 | 6 | 6 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 6 | 6 | 6 | 6 | 4 | 5 | 5 | 5 | 6 | 4 | 4 | 3 |
| | 10-30 m | Left | 5 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 4 | 4 | 3 |
| | | Right | 6 | 5 | 6 | 6 | 6 | 6 | 6 | 5 | 3 | 6 | 6 | 6 | 5 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 4 | 6 | 3 |
| | 30-100 m | Left | 5 | 6 | 6 | 5 | 6 | 6 | 6 | 5 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 6 | 4 | 6 | 6 | 2 | 6 | 6 |
| | | Right | 6 | 5 | 6 | 6 | 6 | 6 | 6 | 5 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 6 | 5 | 6 | 6 | 2 | 6 | 6 |
| Substrate[3] | Dominant | 1 | 2 | 5 | 5 | 5 | 6 | 6 | 5 | 6 | 5 | 5 | 4 | 5 | 6 | 5 | 2 | 5 | 4 | 5 | 5 | 6 | 5 | 6 | 1 | 4 | 2 |
| | | 2 | 2 | 2 | 5 | 7 | 7 | 1 | 4 | 2 | 2 | 2 | 4 | 3 | 5 | 1 | 5 | 5 | 3 | 2 | 5 | 4 | 4 | 7 | 1 | 4 | |
| | | 3 | 2 | 7 | 5 | 7 | 7 | 6 | 6 | 6 | 5 | 6 | 4 | 4 | 5 | 6 | 2 | 5 | 5 | 5 | 5 | 5 | 6 | 2 | 1 | 4 | |
| | Subdominant | 1 | 6 | 6 | 4 | 6 | 7 | 5 | 6 | 5 | 4 | 6 | 5 | 4 | 5 | 6 | 1 | 6 | 5 | 4 | 4 | 5 | 6 | 5 | 1 | 5 | 3 |
| | | 2 | 6 | 7 | 4 | 7 | 5 | 4 | 5 | 1 | 3 | 4 | 2 | 4 | 3 | 4 | 6 | 3 | 4 | 6 | 3 | 2 | 5 | 6 | 4 | 5 | |
| | | 3 | 6 | 6 | 4 | 7 | 6 | 5 | 4 | 5 | 4 | 5 | 5 | 1 | 6 | 5 | 1 | 6 | 4 | 2 | 4 | 2 | 5 | 5 | 4 | 5 | |
| Canopy Cover[4] | | | 1 | 1 | 3 | 4 | 3 | 1 | 2 | 4 | 1 | 1 | 1 | 2 | 1 | 1 | 4 | 3 | 3 | 1 | 4 | 2 | 2 | 1 | 2 | 1 | 1 |

[1] 1=abundant; 2=present; 3=absent

[2] 1=none; 2=cultivated; 3=meadow; 4=scrubland; 5=forest, mainly coniferous; 5=forest, mainly deciduous

[3] 1=clay (hard pan); 2=silt; 3=sand; 4=gravel; 5=cobble; 6=boulder; 7=bedrock

[4] 1=0-24%; 2=25-49%; 3=50-74%; 4=75-100%

Appendix 3. Site measurements and estimates of fish abundance for 25 sampling locations on Whitefish River tributaries, 2010.

| Site No | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Candidate Ref Site | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | No | No | Yes | No |
| Shocking Time (s) | 1206 | 1050 | 1406 | 811 | 1075 | 1761 | 1269 | 1247 | 1435 | 1380 | 1741 | 1025 | 1075 | 1778 | 635 | 966 | 852 | 1338 | 963 | 1053 | 1082 | 671 | 1017 | 1604 | 235 |
| Hyd. Head (mm) Riffle1 | 0 | 14 | 18 | 7 | 7 | 27 | 40 | 12 | 22 | 40 | 20 | 30 | 50 | 30 | 0 | 20 | 8 | 3 | 5 | 12 | 10 | 0 | 0 | 45 | |
| Hyd. Head (mm) Pool | 0 | 0 | 20 | 11 | 0 | 0 | 3 | 0 | 0 | 5 | 3 | 5 | 10 | 5 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| Hyd. Head (mm) Riffle2 | 0 | 20 | 14 | 16 | 6 | 19 | 3 | 13 | 20 | 40 | 50 | 20 | 20 | 10 | 0 | 15 | 18 | 2 | 15 | 8 | 7 | 0 | 0 | 50 | |
| Bankfull Width (m) | 15 | 9 | 6 | 6 | 7 | 10 | 17 | 6 | 9 | 15 | 14 | 10 | 6 | 10 | 5 | 5 | 4 | 3 | 7 | 5 | 7 | 8 | 7 | 19 | 15 |
| Total Pool Area (m3) | 88 | 228 | 32 | 80 | 77 | 238 | 70 | 175 | 207 | 210 | 205 | 120 | 85 | 387 | 114 | 82 | 8 | 185 | 119 | 44 | 90 | 61 | 308 | 117 | 45.0 |
| Total Pool Volume (m3) | 35 | 137 | 8 | 15 | 38 | 71 | 11 | 88 | 91 | 74 | 41 | 32 | 38 | 39 | 33 | 15 | 2 | 78 | 54 | 11 | 27 | 28 | 224 | 29 | 22.5 |
| Average Pool Depth (m) | 0.40 | 0.60 | 0.25 | 0.18 | 0.50 | 0.30 | 0.15 | 0.50 | 0.42 | 0.35 | 0.20 | 0.25 | 0.45 | 0.10 | 0.33 | 0.19 | 0.20 | 0.42 | 0.43 | 0.25 | 0.30 | 0.40 | 0.72 | 0.25 | 0.50 |
| Max. Pool Depth (m) | 0.51 | 0.12 | 0.50 | 0.33 | 0.78 | 0.51 | 0.23 | 0.92 | 0.94 | 0.55 | 0.28 | 0.50 | 0.68 | 0.42 | 0.73 | 0.42 | 0.23 | 0.65 | 0.80 | 0.40 | 0.37 | 0.74 | 1.10 | 0.43 | 0.65 |
| Total Site Length (m) | 66 | 98 | 74 | 63 | 60 | 78 | 67 | 98 | 84 | 98 | 106 | 100 | 88 | 98 | 47 | 53 | 52 | 55 | 62 | 73 | 64 | 53 | 57 | 63 | 9 |
| Total Site Area (m2) | 404 | 612 | 391 | 197 | 195 | 639 | 469 | 354 | 453 | 592 | 630 | 347 | 405 | 728 | 132 | 182 | 83 | 204 | 214 | 209 | 297 | 80 | 308 | 300 | 45 |
| Total Site Volume (m3) | 138 | 199 | 95 | 27 | 53 | 138 | 102 | 109 | 135 | 136 | 108 | 65 | 166 | 90 | 34 | 25 | 8 | 79 | 97 | 29 | 71 | 30 | 224 | 59 | 23 |
| BT Ave. Length (mm) | 139 | 116 | 136 | 113 | 110 | | 174 | 78 | | 108 | | | 122 | | | 64 | 87 | | 160 | | 131 | | 192 | 158 | 154 |
| RT Ave. Length (mm) | | | | | | 79 | | 108 | 63 | 164 | 55 | 111 | | 60 | | 122 | | 144 | | 97 | 144 | | | 89 | |
| BT Max TL | 215 | 291 | 203 | 185 | 179 | | 194 | 79 | | 176 | | | 173 | | | 73 | 157 | | 205 | | 182 | | 192 | 158 | 245 |

| Site No | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RT Max TL** | | | | | | 164 | | 128 | 74 | 216 | 65 | 136 | | 122 | | 173 | | 160 | | 125 | 173 | | | 152 | |
| **# Brook Trout (BT)** | 18 | 32 | 79 | 22 | 40 | 0 | 7 | 3 | 0 | 14 | 0 | 0 | 60 | 0 | 0 | 14 | 44 | 0 | 18 | 0 | 15 | 0 | 1 | 1 | 29 |
| **# Rainbow Trout (RT)** | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 14 | 13 | 17 | 14 | 25 | 0 | 45 | 0 | 15 | 0 | 4 | 0 | 12 | 9 | 0 | 0 | 36 | 0 |
| **# Fish (all spp.)** | 189 | 50 | 139 | 39 | 55 | 124 | 15 | 97 | 132 | 68 | 145 | 81 | 61 | 67 | 32 | 60 | 44 | 78 | 33 | 67 | 30 | 65 | 58 | 124 | 29 |
| **Wt (g) BT** | 704 | 616 | 1633 | 518 | 560 | 0 | 362 | 13 | 0 | 186 | 0 | 0 | 790 | 0 | 0 | 26 | 271 | 0 | 638 | 0 | 336 | 0 | 76 | 28 | 1193 |
| **Wt (g) RT** | 0 | 0 | 0 | 0 | 0 | 350 | 0 | 115 | 25 | 574 | 19 | 349 | 0 | 85 | 0 | 209 | 0 | 106 | 0 | 104 | 188 | 0 | 0 | 256 | 0 |
| **Wt (g) Fish (all spp.)** | 993 | 643 | 1752 | 526 | 628 | 619 | 384 | 314 | 301 | 893 | 277 | 428 | 791 | 341 | 37 | 350 | 271 | 348 | 690 | 216 | 545 | 384 | 187 | 567 | 1193 |
| **# BT/km** | 272 | 327 | 1075 | 347 | 667 | 0 | 104 | 31 | 0 | 143 | 0 | 0 | 682 | 0 | 0 | 264 | 854 | 0 | 290 | 0 | 234 | 0 | 18 | 16 | 3222 |
| **# All Fish/km** | 2859 | 510 | 1891 | 615 | 917 | 1600 | 224 | 990 | 1581 | 694 | 1368 | 810 | 693 | 684 | 681 | 1132 | 854 | 1418 | 532 | 918 | 469 | 1226 | 1018 | 1968 | 3222 |
| **# BT/ha** | 445 | 523 | 2023 | 1119 | 2057 | 0 | 149 | 85 | 0 | 236 | 0 | 0 | 1481 | 0 | 0 | 769 | 5273 | 0 | 841 | 0 | 505 | 0 | 32 | 33 | 6444 |
| **# All Fish/ha** | 4675 | 817 | 3559 | 1985 | 2828 | 1941 | 320 | 2740 | 2914 | 1148 | 2302 | 2334 | 1506 | 920 | 2424 | 3297 | 5273 | 3824 | 1542 | 3213 | 1010 | 8110 | 1881 | 4136 | 6444 |
| **# BT/100m3** | 13 | 16 | 83 | 82 | 76 | 0 | 7 | 3 | 0 | 10 | 0 | 0 | 36 | 0 | 0 | 57 | 572 | 0 | 19 | 0 | 21 | 0 | 0 | 2 | 129 |
| **# All Fish/ 100m3** | 137 | 25 | 146 | 145 | 104 | 90 | 15 | 89 | 98 | 50 | 134 | 125 | 37 | 75 | 93 | 244 | 572 | 99 | 34 | 230 | 42 | 218 | 26 | 210 | 129 |
| **BT kg/km** | 11 | 6 | 22 | 8 | 9 | 0 | 5 | 0 | 0 | 2 | 0 | 0 | 9 | 0 | 0 | 0 | 5 | 0 | 10 | 0 | 5 | 0 | 1 | 0 | 133 |
| **Wt (kg) All spp/km** | 15 | 7 | 24 | 8 | 10 | 8 | 6 | 3 | 4 | 9 | 3 | 4 | 9 | 3 | 1 | 7 | 5 | 6 | 11 | 3 | 9 | 7 | 3 | 9 | 133 |
| **BT kg/ha** | 17 | 10 | 42 | 26 | 29 | 0 | 8 | 0 | 0 | 3 | 0 | 0 | 20 | 0 | 0 | 1 | 33 | 0 | 30 | 0 | 11 | 0 | 2 | 1 | 265 |
| **Wt (kg) All spp/ha** | 25 | 11 | 45 | 27 | 32 | 10 | 8 | 9 | 7 | 15 | 4 | 12 | 20 | 5 | 3 | 19 | 33 | 17 | 32 | 10 | 18 | 48 | 6 | 19 | 265 |
| **BT kg/1000m3** | 5 | 3 | 17 | 19 | 11 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 5 | 0 | 0 | 1 | 35 | 0 | 7 | 0 | 5 | 0 | 0 | 0 | 53 |
| **Wt (kg) All spp/ 1000m3** | 7 | 3 | 18 | 20 | 12 | 4 | 4 | 3 | 2 | 7 | 3 | 7 | 5 | 4 | 1 | 14 | 35 | 4 | 7 | 7 | 8 | 13 | 1 | 10 | 53 |

# Appendix 4. Fish Sampling site photographs.

**Site 1**

Looking upstream from culvert, August 2010.

Middle reach looking upstream, October 2010.

**Site 2**


Lower riffle looking upstream (L) and downstream (R)


Pool from west bank (L) and looking downstream (R).


Upper riffle looking upstream (L) and downstream (R).

**Site 3**

Lower riffle looking upstream (L) and downstream (R)

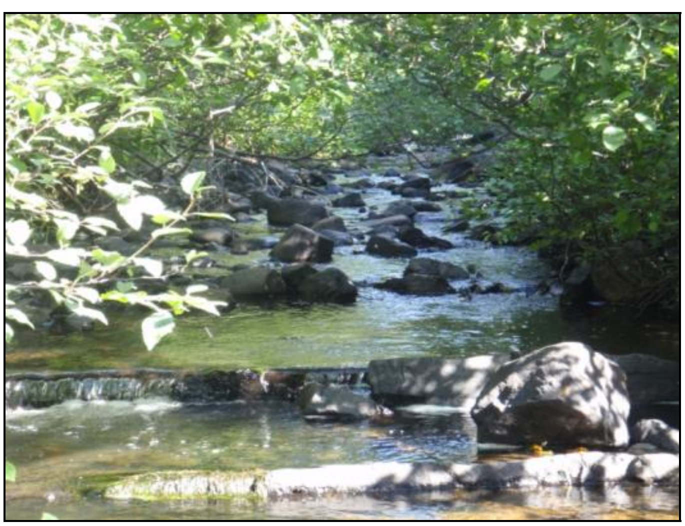
Pool looking downstream (L) and looking upstream (R).

Upper riffle looking upstream (L) and downstream (R).

**Site 4**


Lower riffle looking upstream (L) and lower pool looking downstream (R)


Middle riffle looking dowstream (L) and upper pool looking downstream (R).




Upstream riffle looking upstream (L) and downstream (R).

**Site 5**


Lower riffle looking upstream (L) and close-up at outlet of pool (R)


Pool looking downstream (L) and upstream R).


Upper riffle looking upstream (L) and stepped riffle farther upstream (R).

**Site 6**


Lower riffle looking upstream (L) and downstream (R).


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

**Site 7**


Lower riffle looking upstream (L) and downstream (R).


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

**Site 8**


Lower riffle looking upstream (L) and downstream (R)


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream.

**Site 9**



Lower riffle looking upstream (L) and downstream (R)



Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

**Site 10**


Lower riffle looking upstream (L) and downstream (R)


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

**Site 11**


Lower riffle looking upstream (L) and downstream (R)


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

**Site 12**


Lower riffle looking upstream (L) and middle riffle looking upstream (R)


Lower pool looking downstream (L) and middle riffle looking upstream (R).


Upper pool looking upstream (L) and upper riffle looking downstream(R).

**Site 13**


Lower riffle looking upstream (L) and downstream (R)


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

**Site 14**


Lower riffle looking upstream (L) and downstream (R)


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

**Site 15**




Lower pool looking upstream (L) and lower riffle looking upstream (M) and middle pool looking upstream (R)



Upper middle pool looking upstream (L) and middle riffle looking upstream R).


Upper riffle looking downstream (L) and pool looking upstream (R).

**Site 16**


Lower riffle looking upstream (L) and lower pool looking upwnstream (R)


Middle riffle looking upstream (L) and upper pool looking upstream R).


Upper pool looking downstream (L) and upper riffle looking downstream (R).

**Site 17**


Lower riffle looking upstream (L) and downstream (R)


Pool looking upstream (L) and detail of undercut bank R).


Upper riffle looking downstream (L) and upstream (R).

**Site 18**


Lower riffle looking upstream (L) and lower pool looking upstream (R).


Middle riffle looking upstream (L) and middle pool looking upstream R).


Upper middle pool (L) and upper pool (R) looking upstream.

**Site 19 Pitch Creek**


Lower riffle looking upstream (L) and downstream (R)

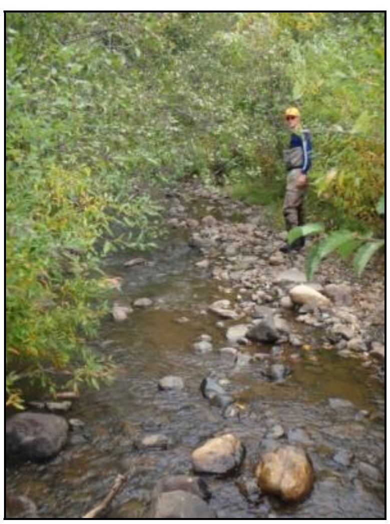

Pool looking downstream (L) and pool bottom( R).


Upper riffle looking downstream (L) and upper pool (R).

**Site 20 Whitewood Creek**


Lower riffle looking upstream (L) and downstream (R)


Pool looking downstream (L) and upstream R).




Upper riffle looking downstream (L) and upstream (R).

**Site 21**


Lower riffle looking upstream (L) and downstream (R)


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

**Site 22**

Lower pool looking upstream (L) and downstream (R)

Riffle looking downstream (L) and upstream R).

Looking downstream from box culvert (L) and upstream of box culvert (R).

**Site 23**


Pool


Pool


**Site 24**


Lower riffle looking upstream (L) and downstream (R)


Pool looking downstream (L) and upstream R).


Upper riffle looking downstream (L) and upstream (R).

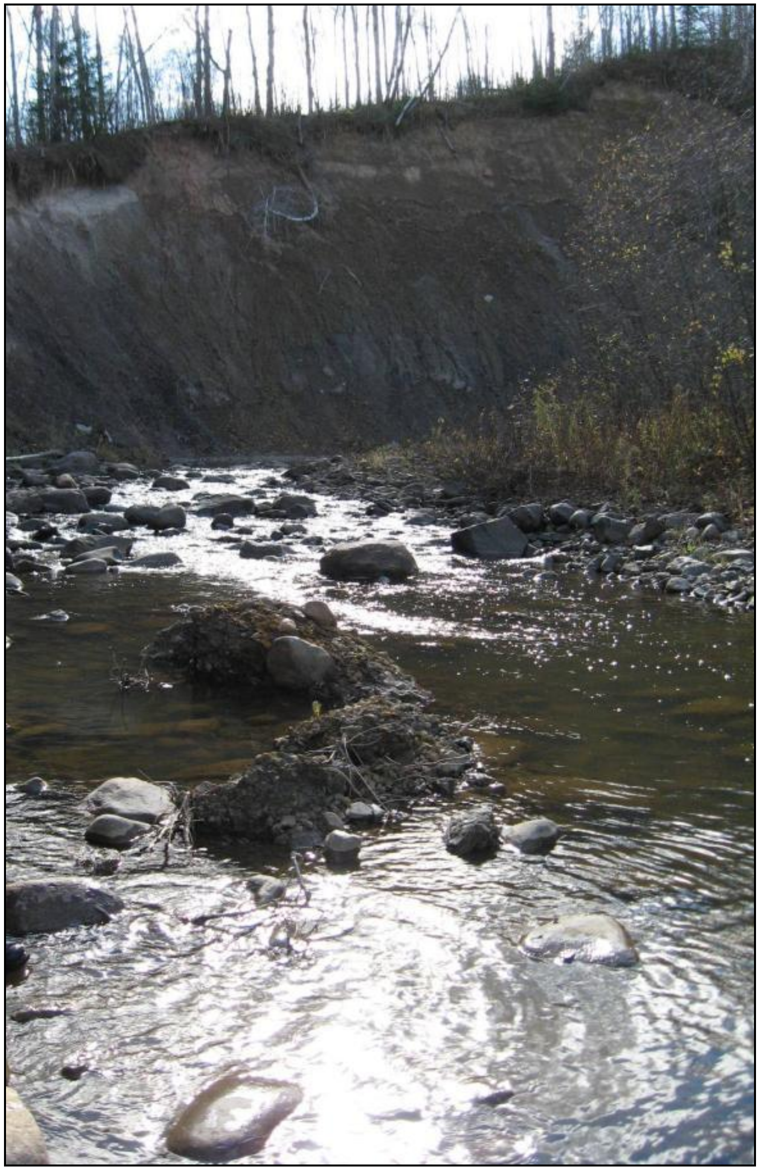
## Appendix 5. OBBN Sampling site photographs.

Cedar Creek (C-9) looking upstream from upper riffle.

Cedar Creek (C-9) looking downstream from upper riffle.

Whitewood Creek (WH-14) looking upstream from pool.

Whitewood Creek (WH-14) looking downstream from pool.




Pitch Creek (P-6) looking upstream (L) and downstream (R) from pool.

## Appendix 6. Biotic indices: Calculations and descriptions.

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| Subcatagory | Index | How to Calculate: | Indication |
|---|---|---|---|
| Richness/Diversity | ABUNDANCE | Sum of Organisms | possibly impaired if extremely low or high value |
| | RICHNESS | Count of taxa found in a sample | the greater the number of taxa the higher the quality of the habitat |
| | INSECT RICHNESS | Count of Chironomidae+Culicidae +Ceratopogonidae +Tipulidae +Tabanidae +Simuliidae+Odonates(Zygoptera and Anisoptera) + Coleoptera + Ephemeroptera + Hemiptera + Lepidoptera + Megaloptera + Plecoptera + Trichoptera + misc Dipterans | the greater the number of taxa the higher the quality of the habitat |
| | DIPTERIAN RICHNESS | Count of Chironomidae+Culicidae +Ceratopogonidae+Tipulidae+Tabanidae+ Simuliidae | the greater the number of taxa the higher the quality of the habitat |
| | SIMPSON'S INDEX | Proportion of species *i* relative to the total number of species ( $p_i$ ), squared Squared proportions for all the species summed, and the reciprocal is taken | probability that two individuals will belong to the same taxon |
| | SHANNON'S H' DIVERSITY | H'= -Sum($p_i$ * ln($p_i$) where $p_i$ =proportion of the count of each taxa | high values indicate increased evenness of the counts among the taxa and higher quality habitat |
| Composition | %AMPHIPODA | Sum of amphipoda /abundance *100 | asociated with eutrophic conditions |
| | %CHIRONOMIDAE | Sum of Chironomidae / Abundance*100 | extremely abundant in highly eutrophic situations, but present in all habitats |
| | %CRUSTACEANS and MOLLUSCA | (Sum of Amphipoda+Decapoda+Isopoda + Gastropoda + Pelecypoda) /Abundance*100 | associated with eutrophic conditions, but present in many habitats |
| | %CRUSTACEANS | (Sum of Amphipoda+Decapoda+Isopoda) /abundance*100 | associated with eutrophic conditions, but present in many habitats |
| | %EPHEMEROPTERA | Sum of Ephemeroptera /abundance*100 | the greater the value the higher the quality of the habitat |
| | %GASTROPODS | Sum of Gastropoda /abundance*100 | associated with eutrophic conditions, but present in many habitats |
| | %HIRUDINEA | Sum of Hirudinea /abundance*100 | associated with eutrophic conditions, but present in many habitats |
| | %ISOPODA | Sum of Isopoda /abundance*100 | asociated with eutrophic conditions |
| | %MOLLUSCA | (Sum of Gastropoda + Pelcypoda) /abundance*100 | associated with eutrophic conditions, but present in many habitats |
| | %ODONATES | (Sum of Anisoptera and Zygoptera) /abundance*100 | the greater the value the higher the quality of the habitat |
| | %OLIGOCHAETES | Sum of Oligochaetes /abundance*100 | abundant in highly eutrophic situations, but present in many habitats |
| | %PELECYPODA | Sum of Pelecypoda /abundance*100 | the greater the value the healthier the habitat |
| | %TIPULIDAE | Sum of Tipulidae /abundance*100 | possibly impaired if extremely high value, but present in many habitats |
| | %TABANIDAE | Sum of Tabanidae /abundance*100 | possibly impaired if extremely high value, but present in many habitats |
| | %SIMULIDAE | Sum of Simuliidae /abundance*100 | possibly impaired if extremely high value, but present in many habitats |
| | %DIPTERA | (Sum of Chironomidae+Culicidae +Ceratopogonidae +Tipulidae+Tabanidae+Simuliidae +misc Dipterans) / Total Abundance* 100 | possibly impaired if extremely low or high value |
| | %INSECTS | (Sum of abundance of Chironomidae+Culicidae +Ceratopogonidae +Tipulidae+Tabanidae+Simuliidae+Odonates (Zygoptera and Anisoptera) + Coleoptera + Ephemeroptera + Hemiptera + Lepidoptera + Megaloptera + Plecoptera + Trichoptera + misc Dipterans)/ Total Abundnce* 100% | possibly impaired if extremely low or high value |
| | %NON-DIPTERIAN INSECTS | (Sum of Zygoptera + Anisoptera + Coleoptera + Ephemeroptera + Hemiptera + Lepidoptera + Megaloptera + Plecoptera + Trichoptera)/Total Abundance* 100 | a high value indicates higher water quality than a lower value |
| | %EPT | (Sum of Ephemeroptera + Plecoptera + Trichoptera) / Abundance * 100 | a high value indicates higher water quality than a lower value |
| | %EOT | (Sum of Ephemeroptera + Anisoptera + Zygoptera + Trichoptera) / Total Abundance * 100 | a high value indicates higher water quality than a lower value |
| Tolerance | %DOMINANT | Abundance of the Most Common Taxon / abundance * 100 | the dominance of a pollution tolerant group indicates an impaired site |
| | HILSENHOFF'S BIOTIC INDEX | =SUM($x_i$.$t_i$)/Total abundance where $x_i$ =abundance of each taxa and $t_i$ = tolerance value for each taxa. | a low value implies low nutrient conditons. Values above 6.0 are of concern |

Appendix 7. Tolerance Values (Hilsenhoff 1988) used in the calculation of the Hilsenhoff Biotic Index.

| TAXON | TOLERANCE |
|---|---|
| **PLECOPTERA** | |
| Capniidae | 1 |
| Chloroperlidae | 1 |
| Leuctridae | 0 |
| Nemouridae | 2 |
| Peltoperlidae | ? |
| Perlidae | 1 |
| Perlodidae | 2 |
| Pteronarcyidae | 0 |
| Taeniopterygidae | 2 |
| **EPHEMEROPTERA** | |
| Baetidae | 4 |
| Baetiscidae | 3 |
| Capnidae | 7 |
| Ephemerellidae | 1 |
| Ephemeridae | 4 |
| Heptageniidae | 4 |
| Leptophlebiidae | 2 |
| Metretopodidae | 2 |
| Oligoneuriidae | 2 |
| Polymitarcyidae | 2 |
| Potomanthidae | 4 |
| Siphloneuridae | 7 |
| Trycorythidae | 4 |
| **ODONATA** | |
| Aeshnidae | 3 |
| Calopterygidae | 5 |
| Coenagrionidae | 9 |
| Cordulegastridae | 3 |
| Corduliiae | 5 |
| Gomphidae | 1 |
| Lestidae | 9 |
| Libellulidae | 9 |
| Macromiidae | 3 |
| **LEPIDOPTERA** | |
| Pyralidae | 5 |
| **COLEOPTERA** | |
| Dryopidae | 5 |
| Elmidae | 4 |

| TAXON | TOLERANCE |
|---|---|
| **TRICHOPTERA** | |
| Brachycentridae | 1 |
| Glossosomatidae | 0 |
| Helicopsychidae | 1 |
| Hydropsychidae | 4 |
| Hydroptilidae | 4 |
| Lepidostomatidae | 1 |
| Leptoceridae | 4 |
| Limnephilidae | 4 |
| Molannidae | 6 |
| Odontoceridae | 0 |
| Philopotamidae | 3 |
| Phryganeidae | 4 |
| Polycentropodidae | 6 |
| Psychomyiidae | 2 |
| Rhyacophiliidae | 0 |
| Sericostomatidae | 3 |
| **MEGALOPTERA** | |
| Corydalidae | 0 |
| Sialidae | 4 |
| **DIPTERA** | |
| Athericidae | 2 |
| Blephariceridae | 0 |
| Ceratopogonidae | 6 |
| Blood-red Chironomidae | 8 |
| other (including pink) Chironomidae | 6 |
| Dolochopodidae | 4 |
| Empididae | 6 |
| Ephydridae | 6 |
| Psychodidae | 10 |
| Simuliidae | 6 |
| Muscidae | 6 |
| Syrphidae | 10 |
| Tabanidae | 6 |
| Tipulidae | 3 |
| **AMPHIPODA** | |
| Gammaridae | 4 |
| Talitridae | 8 |
| **ISOPODA** | |

| | | | | |
|---|---|---|---|---|
| Psephenidae | 4 | | Asellidae | 8 |

Appendix 8. Benthic macroinvertebrates from Cedar Creek (C-9), Thunder Bay, Ontario, 2010.

| | | Cedar Creek C-9-2 Pool 21-Oct | Cedar Creek C-9-3 Riffle 21-Oct | Cedar Creek C-9-4 Riffle 21-Oct |
|---|---|---|---|---|
| **COELENTERATA** | | | | |
| **PLATYHELMINTHES** | | | | |
| **NEMATODA** | | | | |
| **MOLLUSCA** | | | | |
| **Gastropoda** | | | | |
| Ancylidae | | 3 | 1 | 1 |
| Lymnaeidae | | 1 | | |
| Physidae | | | 1 | |
| **Bivalvia** | | | | |
| Sphaeriidae | | 2 | | |
| **ANNELIDA** | | | | |
| **Oligochaeta** | | 9 | 14 | 43 |
| **ARTHROPODA** | | | | |
| **Hydracarina** | | 1 | 6 | 3 |
| **Insecta** | | | | |
| **Ephemeroptera** | | | | |
| Baetidae | Juvenile/damaged | 3 | 2 | 1 |
| | *Baetis* | 2 | | 1 |
| Heptageniidae | Juvenile/damaged | 1 | 6 | 7 |
| | *Leucrocuta* | | 3 | 2 |
| | *Maccaffertium* | | 1 | 1 |
| | *Rhithrogena* | | 3 | |
| Ephemerellidae | Juvenile/damaged | | | |
| | *Eurylophella* (s str.) | | | |
| | *Serratella* | 5 | 6 | 16 |
| Caenidae | *Caenis* | 1 | | |
| Baetiscidae | *Baetisca* | 2 | | |
| Leptophlebiidae | Juvenile/damaged | 2 | 3 | |
| | *Leptophlebia* | 2 | 6 | 9 |
| Ephemeridae | *Ephemera* | 1 | | |
| **Odonata** | | | | |
| Gomphidae | Juvenile/damaged | 1 | | 1 |
| | *Ophiogomphus* | | | |
| **Plecoptera** | | | | |
| Taeniopterygidae | *Oemopteryx* | | 3 | 1 |
| | *Taeniopteryx* | 1 | 2 | 1 |
| Nemouridae | *Nemoura* | | | |
| Leuctridae | *Leuctra* | | | |
| | *Paraleuctra* | 2 | | |
| Capniidae | Juvenile/damaged | | 10 | 1 |
| | *Paracapnia* | | 5 | 1 |
| Perlidae | Juvenile/damaged | | | 1 |
| | *Acroneuria* | 1 | 1 | |
| | *Claassenia* | | | |
| Perlodidae | Juvenile/damaged | | | |
| | *Isoperla* | | 1 | 2 |
| **Coleoptera** | | | | |
| Dryopidae | *Helichus* | | | |
| Elmidae | Juvenile/damaged | | | |
| | *Dubiraphia* | 3 | | |
| | *Optioservus* | 4 | 1 | 1 |
| **Trichoptera** | | | | |
| Philopotamidae | *Chimarra* | | | 1 |
| Polycentropodidae | *Polycentropus* | | | |
| Hydropsychidae | Juvenile | 6 | 4 | 8 |
| | *Cheumatopsyche* | 1 | | |
| | *Hydropsyche* | | 2 | 6 |
| Rhyacophilidae | *Rhyacophila* | | | |
| Glossosomatidae | *Glossosoma* | | 2 | 2 |
| Hydroptilidae | *Hydroptila* | | | |
| Lepidostomatidae | *Lepidostoma* | 1 | 1 | 2 |
| Limnephilidae | Juvenile/damaged | | | |
| **Diptera** | Damaged/pupa | | | |
| Ceratopogonidae | *Culicoides* | 1 | | |
| | *Probezzia* | 5 | 2 | |
| Chironomidae | | 40 | 16 | 14 |
| Simuliidae | *Simulium* | | | |
| Tipulidae | *Antocha* | | | |
| | *Dicronata* | 2 | | |
| Athericidae | *Atherix* | | | 1 |
| **Total number of individuals** | | 103 | 102 | 127 |
| **% Sorted (10m/3 min)** | | 3.4 | 5.7 | 1.6 |

Appendix 9. Benthic macroinvertebrates from Whitewood Creek (WH-14), Thunder Bay, Ontario, 2010.

| | | Whitewood Creek | Whitewood Creek | Whitewood Creek |
|---|---|---|---|---|
| | | W-14-1 | W-14-2 | W-14-3 |
| | | Riffle | Pool | Riffle |
| | | 12-Oct | 12-Oct | 12-Oct |
| **COELENTERATA** | | | | |
| **PLATYHELMINTHES** | | | | 1 |
| **NEMATODA** | | | 2 | |
| **MOLLUSCA** | | | | |
| **Gastropoda** | | | | |
| Ancylidae | | 4 | | 4 |
| Lymnaeidae | | | | |
| Physidae | | 1 | | |
| **Bivalvia** | | | | |
| Sphaeriidae | | | | |
| **ANNELIDA** | | | | |
| **Oligochaeta** | | 45 | 33 | 37 |
| **ARTHROPODA** | | | | |
| **Hydracarina** | | 3 | 1 | 1 |
| **Insecta** | | | | |
| **Ephemeroptera** | | | | |
| Baetidae | Juvenile/damaged | 1 | | 5 |
| | *Baetis* | | | 2 |
| Heptageniidae | Juvenile/damaged | 2 | | |
| | *Leucrocuta* | 3 | | |
| | *Maccaffertium* | 3 | 1 | 4 |
| | *Rhithrogena* | | | 1 |
| Ephemerellidae | Juvenile/damaged | | | |
| | *Eurylophella* (s str.) | | 1 | |
| | *Serratella* | | | |
| Caenidae | *Caenis* | 2 | 14 | |
| Baetiscidae | *Baetisca* | | | |
| Leptophlebiidae | Juvenile/damaged | | | 3 |
| | *Leptophlebia* | 1 | 16 | 11 |
| Ephemeridae | *Ephemera* | 1 | 5 | |
| **Odonata** | | | | |
| Gomphidae | Juvenile/damaged | 1 | 1 | |
| | *Ophiogomphus* | 2 | 1 | |
| **Plecoptera** | | | | |
| Taeniopterygidae | *Oemopteryx* | | | |
| | *Taeniopteryx* | 3 | | |
| Nemouridae | *Nemoura* | 2 | 3 | 4 |
| Leuctridae | *Leuctra* | | | |
| | *Paraleuctra* | | | |
| Capniidae | Juvenile/damaged | | | |
| | *Paracapnia* | | | |
| Perlidae | Juvenile/damaged | | | |
| | *Acroneuria* | | | 1 |
| | *Claassenia* | | | 1 |
| Perlodidae | Juvenile/damaged | | | 1 |
| | *Isoperla* | | | |
| **Coleoptera** | | | | |
| Dryopidae | *Helichus* | | | |
| Elmidae | Juvenile/damaged | | | 4 |
| | *Dubiraphia* | | | |
| | *Optioservus* | 4 | | 1 |
| **Trichoptera** | | | | |
| Philopotamidae | *Chimarra* | | | |
| Polycentropodidae | *Polycentropus* | 1 | | 2 |
| Hydropsychidae | Juvenile | | | 9 |
| | *Cheumatopsyche* | | | 1 |
| | *Hydropsyche* | | | 5 |
| Rhyacophilidae | *Rhyacophila* | | | |
| Glossosomatidae | *Glossosoma* | | | |
| Hydroptilidae | *Hydroptila* | 1 | | |
| Lepidostomatidae | *Lepidostoma* | 4 | | 2 |
| Limnephilidae | Juvenile/damaged | 1 | 2 | |
| **Diptera** | Damaged/pupa | | | |
| Ceratopogonidae | *Culicoides* | | | |
| | *Probezzia* | 8 | 14 | 2 |
| Chironomidae | | 24 | 47 | 6 |
| Simuliidae | *Simulium* | | | |
| Tipulidae | *Antocha* | | | |
| | *Dicronata* | 1 | | |
| Athericidae | *Atherix* | | | 1 |
| **Total number of individuals** | | 118 | 141 | 109 |
| **% Sorted (10m/3 min)** | | 2.9 | 2.1 | 5.0 |

Appendix 10. Benthic macroinvertebrates from Pitch Creek (P-6), Thunder Bay, Ontario, 2010.

| | | Pitch Creek | Pitch Creek | Pitch Creek |
|---|---|---|---|---|
| | | P-6-1 | P-6-2 | P-6-3 |
| | | Riffle | Pool | Riffle |
| | | 17-Oct | 17-Oct | 17-Oct |
| **COELENTERATA** | | | 1 | |
| **PLATYHELMINTHES** | | 1 | | |
| **NEMATODA** | | | 1 | |
| **MOLLUSCA** | | | | |
| **Gastropoda** | | | | |
| Ancylidae | | 2 | | |
| Lymnaeidae | | | | |
| Physidae | | | | |
| **Bivalvia** | | | | |
| Sphaeriidae | | | 1 | |
| **ANNELIDA** | | | | |
| **Oligochaeta** | | 20 | 27 | 12 |
| **ARTHROPODA** | | | | |
| **Hydracarina** | | | | 6 |
| **Insecta** | | | | |
| **Ephemeroptera** | | | | |
| Baetidae | Juvenile/damaged | | 2 | |
| | *Baetis* | 4 | 4 | |
| Heptageniidae | Juvenile/damaged | 4 | | |
| | *Leucrocuta* | 5 | | 5 |
| | *Maccaffertium* | 2 | 3 | |
| | *Rhithrogena* | | | |
| Ephemerellidae | Juvenile/damaged | | | 1 |
| | *Eurylophella* (s str.) | 1 | 1 | 2 |
| | *Serratella* | | | |
| Caenidae | *Caenis* | | 10 | |
| Baetiscidae | *Baetisca* | | | |
| Leptophlebiidae | Juvenile/damaged | | | 1 |
| | *Leptophlebia* | 2 | | |
| Ephemeridae | *Ephemera* | | 1 | |
| **Odonata** | | | | |
| Gomphidae | Juvenile/damaged | | | |
| | *Ophiogomphus* | | | 1 |
| **Plecoptera** | | | | |
| Taeniopterygidae | *Oemopteryx* | | 1 | 3 |
| | *Taeniopteryx* | 1 | 1 | 1 |
| Nemouridae | *Nemoura* | | | 1 |
| Leuctridae | *Leuctra* | 1 | 1 | |
| | *Paraleuctra* | | | |
| Capniidae | Juvenile/damaged | | | |
| | *Paracapnia* | 1 | | |
| Perlidae | Juvenile/damaged | | | |
| | *Acroneuria* | | | 1 |
| | *Claassenia* | | | |
| Perlodidae | Juvenile/damaged | | | |
| | *Isoperla* | | | |
| **Coleoptera** | | | | |
| Dryopidae | *Helichus* | | | 1 |
| Elmidae | Juvenile/damaged | 1 | | |
| | *Dubiraphia* | | 3 | |
| | *Optioservus* | 5 | | 1 |
| **Trichoptera** | | | | |
| Philopotamidae | *Chimarra* | | | |
| Polycentropodidae | *Polycentropus* | | | |
| Hydropsychidae | Juvenile | | | |
| | *Cheumatopsyche* | | | |
| | *Hydropsyche* | 1 | | 1 |
| Rhyacophilidae | *Rhyacophila* | | | |
| Glossosomatidae | *Glossosoma* | | | |
| Hydroptilidae | *Hydroptila* | 1 | | |
| Lepidostomatidae | *Lepidostoma* | 3 | | |
| Limnephilidae | Juvenile/damaged | 2 | 2 | |
| **Diptera** | Damaged/pupa | | | |
| Ceratopogonidae | *Culicoides* | | | |
| | *Probezzia* | 2 | 3 | |
| Chironomidae | | 46 | 48 | 65 |
| Simuliidae | *Simulium* | | | |
| Tipulidae | *Antocha* | 1 | | |
| | *Dicronata* | | | |
| Athericidae | *Atherix* | 1 | | |
| **Total number of individuals** | | 107 | 110 | 102 |
| **% Sorted** | | 4.5 | 4.8 | 2.8 |