Freshwater Ecology Field School 2017
Fleming College - Fish and Wildlife
Fleetwood Creek

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Summary Report

Report prepared by:

Craig Paterson, B.Sc.

Fish & Wildlife Technician

School of Environmental & Natural Resource Sciences

Sir Sandford Fleming College, Frost Campus

January 2018

Acknowledgments

Field work for the Freshwater Ecology Field School, Fleetwood Creek 2017, was overseen by Brian Round (Professor Fisheries Science, Frost Campus), Fish and Wildlife Technician Craig Paterson, Brett Tregunno (Aquatic Biologist, Kawartha Conservation), and Michael Cook (Assistant Biologist, Kawartha Land Trust). Round and Tregunno were invaluable as advisors and editors for this report.

The Fish and Wildlife Technician/Technologist program is very grateful for the support provided by partner agencies and individuals in making this field school the success that it is. That crucial support includes any or all of providing financial assistance for buses, equipment, and Technicians wages, providing assistance in-field, and of course the ever-important access to private property. Thank you to Fisheries and Oceans Canada, Kawartha Conservation, Ontario Heritage Trust, John McLaughlin and Kate Arthur, Danielle French and South Pond Farms, Ralph McKim and Jean Garsonnin (Ballyduff Trails – Kawartha Land Trust), Michael R. W. Longfield, Roy Graves, and James and Mark Wilford.

And of course, thanks are due to the large number of keen and eager Fish and Wildlife students who participated with diligence that helped make collected data useable by these and other partners.

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Introduction

"Cold water fish species are akin to the "canary in the coal mine". Cold water species are more sensitive to habitat changes than fishes found in
warmer waters, and when the health of cold water species is threatened, it is a symptom of change that will trickle down and affect all other associated ecosystems." (MNRF 2004)

The Freshwater Ecology Field School at Fleming College derives much of its inspiration from the Ministry of Natural Resources and Forestry (MNRF) Peterborough District Coldwater Stream Strategy. Following the inexorable sprawl of urban development and the changing climate, education promoting sustainability and habitat protection are paramount.

At Fleming College, students enrolled in third semester of the Fish & Wildlife Technician program are submersed in five challenging weeks of infield studies. A portion of the curriculum is dedicated to the Fresh Water Ecology Field School. This field school is structured to enhance student exposure to cold water stream surveys. To achieve this, students participate in five days of intensive training whilst utilizing the Ontario Stream Assessment Protocol (OSAP) And Ontario Benthos Biomonitoring Network (OBBN) protocol. Both protocols contain a series of standardized methodologies for identifying sites, evaluating benthic macroinvertebrates, fish communities, physical habitat, hydrology and water temperature in wadable streams.

Skills acquired through participation in this field school provide students with data collection and assessment techniques that mirror industry standards. To further enhance value, the data collected and presented in this report is entered into the Flowing Water Information System (FWIS) database. Thus, providing access to partners and stakeholders of the field school.

The purpose of this report is to present a summary of data collected from previously un-sampled sites on a cold water stream originating from the Oak Ridges Moraine. Full datasets are available on The Flowing Waters Information System (FWIS). Additionally, the findings presented are intended to be used as a point of reference for comparative analysis with future sites, exploring chemical, hydrological, morphological and biological components.

Completion of the 2017 field school has revealed a collective 125 hours of field work and teaching, sampling 1600 m^2 of stream habitat. A total of 107 transects were measured with 510 observation points examined and quantified. Biological sampling saw the successful processing of 276 individual fish and the identification of 3000 benthic invertebrates at the OBBN 27 group resolution.

Twelve sites were sampled, although data were collected for any one parameter at 10 sites only.

Study Area: Fleetwood Creek

The Fleetwood Creek Watershed encompasses an area of 7,291 ha, located in the extreme south-eastern area of the Kawartha Conservation (KRCA) watershed (KRCA 2009). Meandering through the watershed is the 100km watercourse known as Fleetwood Creek. The headwaters of this stream system are fed by natural springs, seeps and overland flows (Barrett & Silhanek 1991). Much of its groundwater intake is a direct result of it's landmass residing within the Oak Ridges Moraine (Figure 3). The Moraine is one of the most significant geological landforms in Southern Ontario and plays a pivotal role in groundwater recharge.

The 20km main channel navigates predominately through mixed wood forests and agricultural fields. A series of 3 on-stream ponds are present, the largest, McKinnon Pond with a surface area of 94,200 m^2 (Barrett & Silhanek 1991). KRCA defines approximately 30% of the watercourse as a cold-water system. Fleetwood Creek is located within Area B (Oak Ridges Moraine, Iroquois Plane North & East) of the Cold Water Stream Strategy management zones, (Figure 2).

A substantial portion of Fleetwood Creek is designated as a Provincially Significant Earth and Life Science Area of Natural and Scientific Interest (ANSI).

Sites were primarily selected to ensure sampling was completed in or around watercourses contained in the Fleetwood Creek Conservation Area. Sites residing beyond the CA boundary were accessed with property owner permission. Considerations regarding large student groups further influenced site selection.

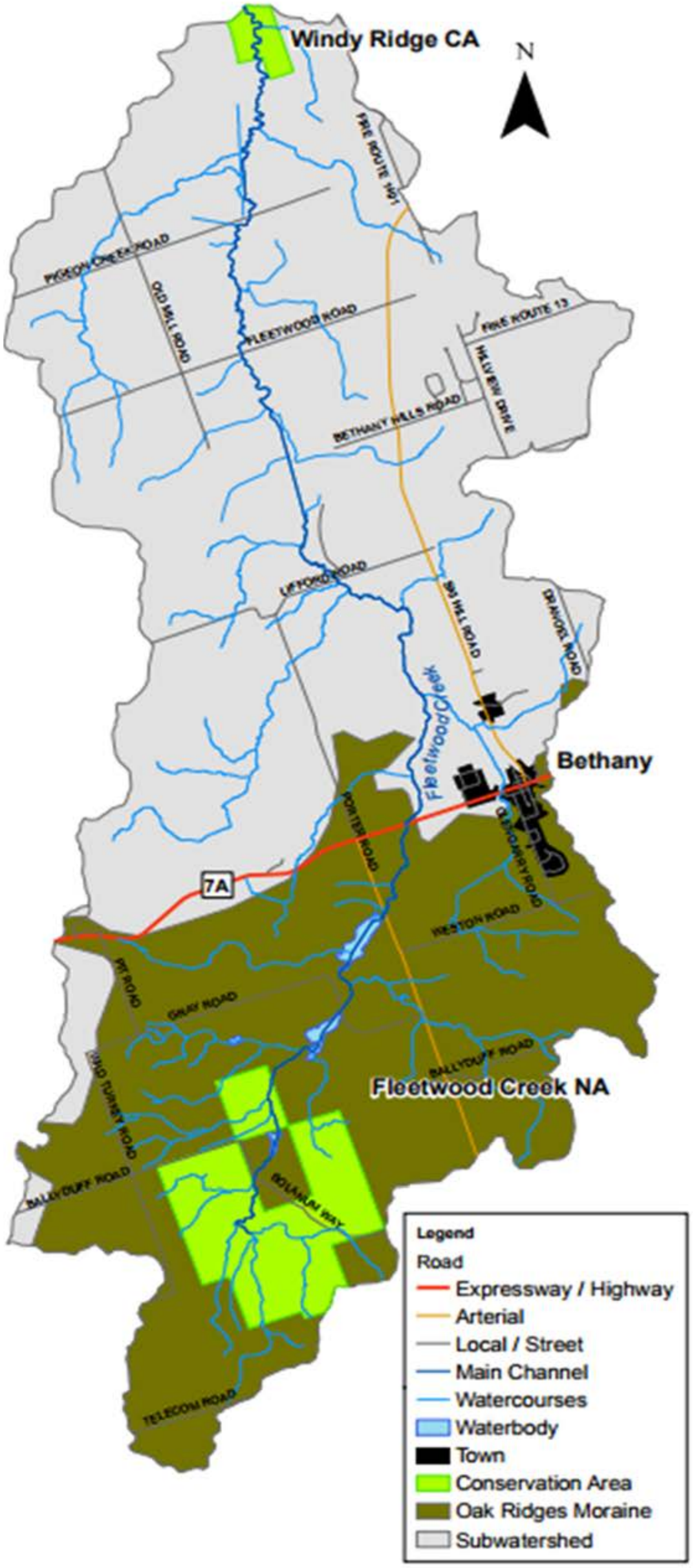

Figure 1: Fleetwood Creek Watershed, Kawartha Conservation Watershed Atlas 2009

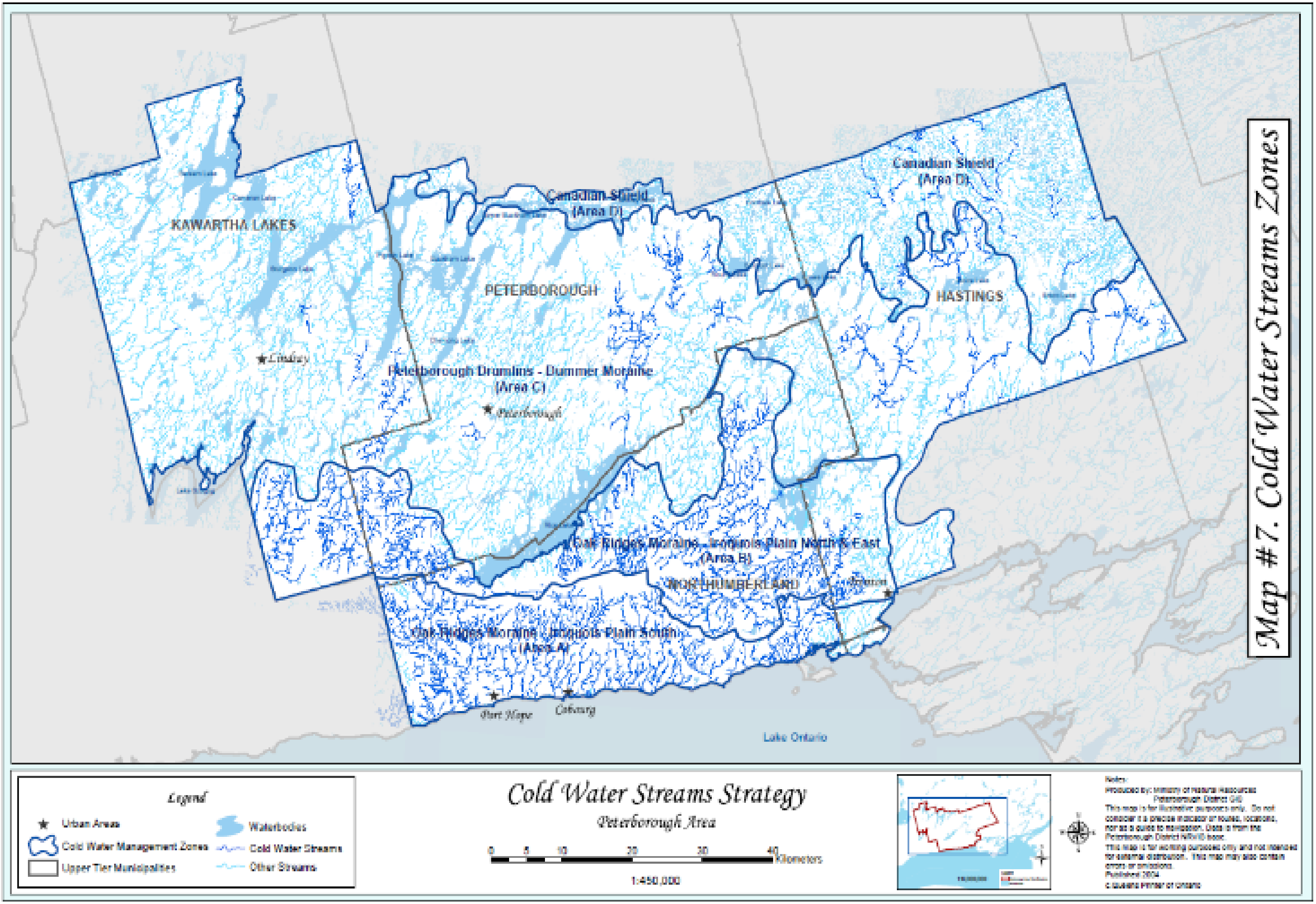

Figure 2: Cold-Water Strategy Management Zones

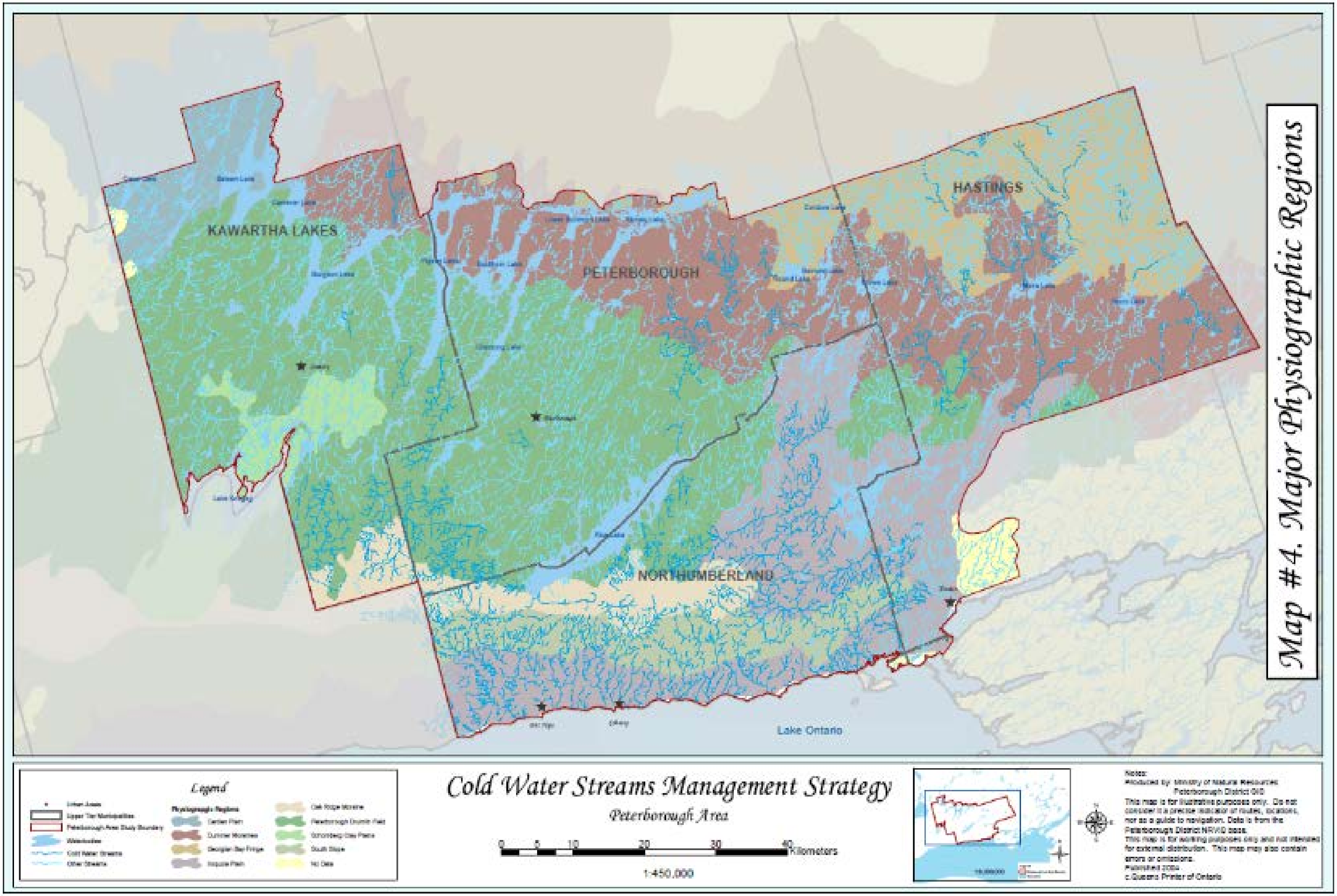

Figure 3: Physiographical Regions

Methodology

Abiotic Measurements

Identification of Site Boundaries

Sample site boundaries were defined according to Ontario Stream Assessment Protocol (OSAP) in which the minimum site length is 40 m, and the upstream and downstream limits occur where the thalweg crosses over from one side to the other.

Channel Morphology

Morphology measurements were made in accordance with Section 4: Module 2; Point-Transect Sampling for Channel Structure, Substrate and Bank Conditions, OSAP Manual. The number of transects and observation points per transect were determined through the measurement of stream minimum width; If >3 m, 10 transects with 6 observation points each. If 1.5 - 3.0 m, 12 transects and 5 observation points. If 1.0 - 1.5 m, 15 transects and 3 observation points, and if <1.0 m, 20 transects with 2 observation points each.

Transect spacing was calculated with the following formula; $\frac{Site\ Length}{(Number\ of\ Transects - 1)}$

At each transect students completed the following measurements; compass bearing, active channel width, water depth (negative height for island and protruding features), hydraulic head, particle sizes, instream cover, aquatic vegetation types, Bank angle profile & particle median diameters, dominant terrestrial vegetation and bank stability. All measurements were conducted under the supervision of field school staff & partnership biologist.

Hydraulic head measurements were used to calculate percent riffle, run and pool habitat. Criteria for each was adapted from the OSAP Manual 2017; Pool/Glides 0 <= 7 mm, Run >= 8 <= 17 mm and Riffle >17 mm. Additionally, similar criteria were adapted from the manual to calculate percent substrate type. Substrate type was defined with the following parameters; Bedrock >1000 mm, Cobble 101 to 1000 mm, Gravel 2 to 100 mm, Sand 0.1 mm, Silt 0.05 mm, Consolidated Clay 0.011 mm, and Unconsolidated Clay 0.01 mm.

Bank measurements were achieved with the use of bank angle profile tools as described in the OSAP Manual. Constructed tools differed from the specifications in that vertical risers were increased from 150cm to 200cm.

Water Chemistry

Students completed water chemistry testing through a variety of Hach & LaMotte titration kits and instrument measurements. Student involvement consisted of 3 - 4 member teams each completing a full chemistry profile. Air and water temperatures were measured with Enviro-Safe, Non-Mercury, 0 to 300° F glass bulb thermometers. Dissolved oxygen readings were obtained through a modified Winkler titration (as per EPA standard), and with YSI Model 55 DO meter. Saturation of oxygen as a percentage was achieved with a saturation nomogram. Further analysis consisted of measuring pH using Bromthymol Blue titration kit, and alkalinity with T.F.E Alkalinity test. PO4 Phosphorus and NO3 Nitrogen values were recorded using LaMotte Phosphate 0.5 - 10 ppm and LaMotte Nitrate, Nitrogen Table Kit 0 - 15 ppm. PO4 Phosphorus and NO3 Nitrogen testing was added to this field school in 2017 to provide greater insight on chemical stressors in the cold-water system. Conductivity was determined using YSI Model 30 Conductivity Meter, and Total Dissolved Solids (T.D.S.) calculated using the following formula;

$$TDS = \frac{(Conductivity\ in\ \mu s) \times 0.666}{1 + (0.02(cell\ temp\ C^{\circ} - 25))}$$

Discharge, Slope & Sinuosity

Discharge measurement at each sample site were partly based in compliance with Section 4: module 4; Rapid Assessment Surveys for Stream Discharge and Perched Culverts, OSAP manual. A single transect demonstration was performed by field school Technicians with several student volunteers. It should be noted; bias was shown in transect selection to provide students with a more productive and engaging output. Velocity data was collected with Pygmy Gurley Flow Velocity Indicator Model 1100. Channel width at 70% of sites constricted deployment of ten survey panels, resulting in deployment of five panels.

Slope measurements were performed at each site where channel structure surveys were completed. Foresight was measured using an Abney Hand level, and horizontal distance measured with a 30m tape. Measurements for sinuosity were obtained by using a 50m chain to measure both valley length and channel length.

Temperature

A series of five temperature data loggers (Onset HOBO TidbiTv2), were strategically situated at five separate locations. Data logger HOBO1 was placed below a large shallow impoundment exiting at Gray Road. HOBO5 resided on the main channel upstream of that same shallow impoundment. The remaining three data loggers were placed on tributaries upstream of that impoundment, and to the west. HOBO3 was situated directly below the dam at the South Pond Farms property. HOBO4 was placed approximately 200 m downstream of HOBO3. Finally, HOBO2 was strategically positioned in a small tributary located on the Ballyduff Trails property, with a source that can be tracked to a groundwater upwelling. Temperature data was recorded at 30-minute intervals from August 8th 2017, through to October 10th 2017. Deployment of the temperature loggers was conducted by the course lead; retrieval of each unit was independent and strategic in that units were removed before electrofishing of that portion of stream.

Thermal classification of the data was defined using a thermal classification nomogram outlined in Chu et al (2009). Daily maximum water and air temperatures from the three hottest consecutive days during baseflow conditions were used to achieve each classification.

Biotic Measurements

Macroinvertebrate Survey

Student participation in Benthic surveying heavily mirrored OBBN standards described in Section2; Module 3; Transect Travelling kick and sweep Survey for Macroinvertebrates. Collection areas were selected following the two riffle one pool standard. Water depth, hydraulic head and wetted width were all recorded. Knowledge of benthos abundance at sample sites was unknown, therefore students were directed to sample a 10 m linear area for approximately 3 minutes of effort, to reach the desired saturation of 100 organisms. The Travelling Kick & Sweep method with a 500 µm mesh D-net and a stopwatch were used to collect each sample.

Sub-samples were extracted and examined, organisms were documented to the accepted taxonomic resolution (OBBN 27 group level). To ensure accuracy, all individual specimens were confirmed by the course lead and technicians before preservation. Hilsenhoff Biotic Indices were adapted from the FWIS database and calculated as follows;

$$HBI = \frac{\sum n_i \, a_i}{N}$$

Where n_i represents the total number of individual organisms in a given taxa, a_i represents the tolerance value for that taxa and N represents the total number of individuals. The adapted coefficients are presented in Table 2.

Fish Sampling

Fish community was assessed using a Smith-Root LR-24 Electrofisher. Survey sites were fished using techniques that ensured complete coverage of all habitats. A streamside sampling station operated concurrently while the electrofisher operator and netters were actively fishing. Due to time restrictions and less experienced operators, sites that were dominated by coarse woody material causing poor mobility were sampled with single pass electrofishing. SOPO2 and SOPO4 were the only sites that provided an opportunity for triple pass protocol, which is the standard for this field school.

Result Tables

Table 1: Habitat characteristics for study sites.

		Site Code											
		SSRSOPO2	SSRSOPO4	SSRSOPO6	SSRSOPO8	SSRBADU2A	SSRBADU5	SSRBADU6	SSRSOLA5	SSRSOLA7	Avg	Min	Max
Site ID	Sample Date (YYYY/MM/DD)	17/09/14	17/09/14	17/10/05	17/10/05	17/09/28	17/10/13	17/10/13	17/09/21	17/09/21			
	Easting (UTM Zone17T)	691545	691503	691471	691440	691689	691729	691734	691559	691538			
	Northing (UTM Zone 17T)	4891994	4892004	4892014	4892017	4891238	4891125	4891078	4890516	4890475			
Channel Morphology	Site Length (m)	49.9	46.7	48.6	51.8	45.2	49.8	49.2	54.6	43.0	48.8	43	54.6
	Site Width (Avg)	1.77	1.73	2.02	2	5.88	6.2	4.54	4.7	5.3	3.8	1.73	6.2
	Site Area (m^2)	88.3	80.8	98.2	103.6	265.8	308.8	223.4	256.6	227.9	183.7	80.8	308.76
	Site Depth (Avg)	110.2	105.9	101.4	81.2	209.2	278.5	265.2	422.8	405.8	220.0	81.2	422.8
	Riffle %	6.7	3.3	8.9	15.6	13.3	13.3	15.0	0.0	0.0	8.45	0	15.60
	Run %	11.1	20.0	28.9	31.1	31.7	30.0	40.0	5.0	1.7	22.16	1.7	40.00
	Pool %	82.2	75.0	62.2	51.1	55.0	55.0	41.7	95.0	98.3	68.39	41.7	98.33
	Substrate Bedrock %	0	0	0	0	0	0	0	0	0	0	0	0
	Substrate Cobble %	0	1.7	2.3	4.4	0	3.3	0	0	0	1.30	0	4.44
	Substrate Gravel %	13.3	38.3	70.5	71.1	25.0	23.3	6.7	0	0	27.58	0	71.11
	Substrate Sand %	48.9	46.7	6.8	11.1	71.7	66.7	88.3	38.3	68.3	49.65	6.8	88.33
	Substrate Silt %	37.8	8.3	20.5	8.9	3.3	6.7	5.0	61.7	31.7	20.42	3.3	61.67
	Substrate Consolidated Clay %	0	0	0	2.2	0	0	0	0	0	0.25	0	2.22
	Substrate Unconsolidated Clay %	0	5.0	0	2.2	0	0	0	0	0	0.80	0	5.00
	Cover Wood %	37.8	16.7	20.0	2.2	63.3	36.7	43.3	31.7	30.0	31.30	2.2	63.33
	Cover Round Rock %	0	31.7	6.7	40.0	6.7	13.3	6.7	0	1.7	11.85	0	40.00
	Cover Flat Rock %	2.2	10.0	0	6.7	1.7	6.7	1.7	0	1.7	3.40	0	10.00
	Cover Macrophyte %	6.7	3.3	6.7	6.7	0	0	0	10.0	11.7	5.00	0	11.67
	Cover Bank %	20.0	21.7	2.2	4.4	6.7	1.7	8.3	3.3	5.0	8.15	1.7	21.67
	No Cover %	51.1	41.7	68.9	46.7	28.3	41.7	46.7	60.0	58.3	49.26	28.3	68.89
	Vegetation	30.0	111.7	26.7	6.7	11.7	21.7	5.0	43.3	58.3	35.00	5.0	111.67
Flow	Discharge (m^3 / sec)	0.0079	0.0114	-	-	0.5451	0.2147	0.1891	0.2228	0.1707	0.1945	0.0079	0.5451
Water Chemistry	Air Temperature C°	19	14	-	19	22	7	8	20	17	15.8	7.0	22.0
	Water Temperature C°	14	12	-	16	15	9	7.8	12	11	12.1	7.8	16.0
	Dissolved Oxygen (mg/l)	9.2	14.4	-	10.8	9.6	13.8	10.8	12	10.4	11.4	9.2	14.4
	pH	8.5	8	-	7.5	8	8	7.8	8.4	8	8.0	7.5	8.5
	Conductivity (µs)	338.3	317.9	-	345.2	317.5	266.4	258.4	290.6	385.8	315.0	258.4	385.8
	Phosphates PO_4 (ppm)	-	-	-	0.5	0	0	0.5	-	-	0.3	0.0	0.5
	Nitrates NO_3 (ppm)	-	-	-	0.5	0	0	0	0	0	0.1	0.0	0.5

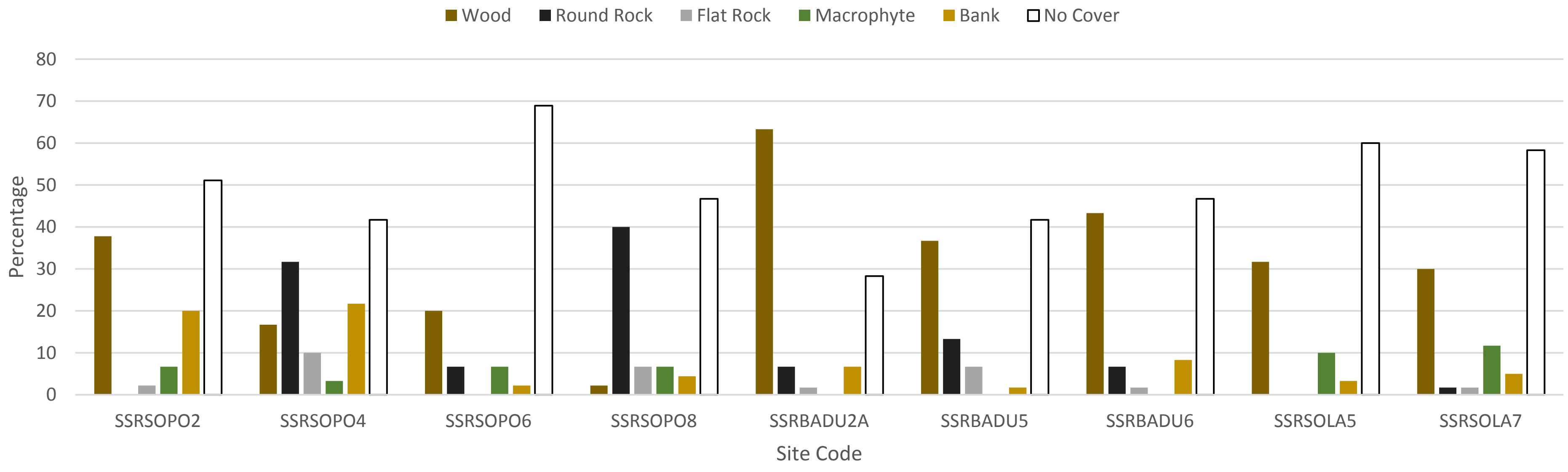

Figure 4: Instream cover types as a percent total for each site, including embedded and unembedded cover.

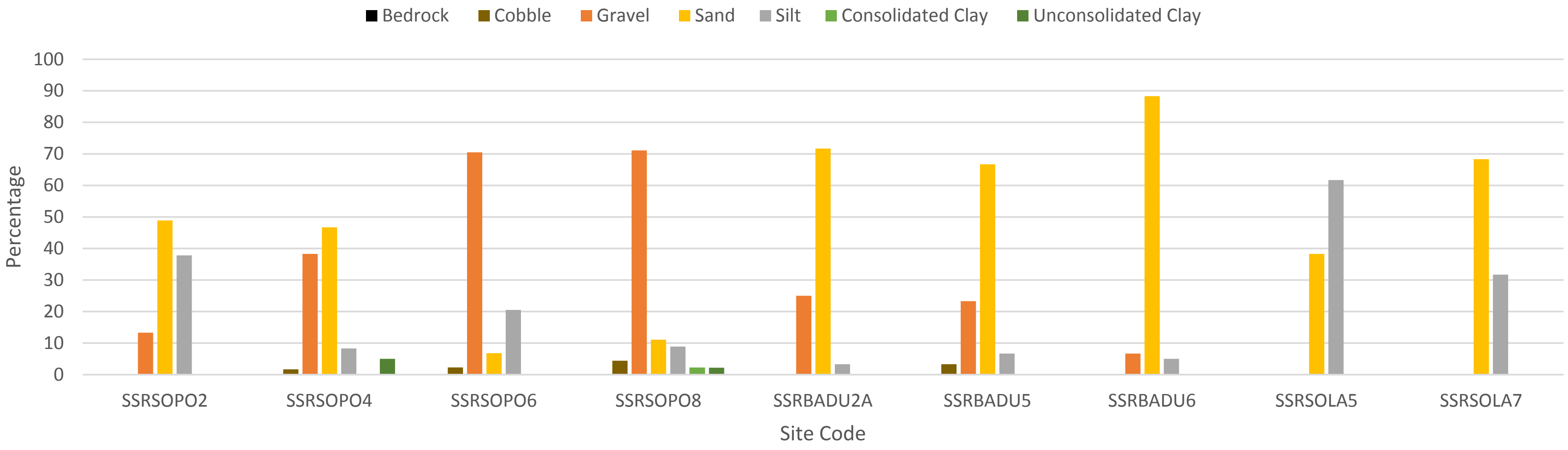

Figure 5: Substrate composition as a percent total for each site.

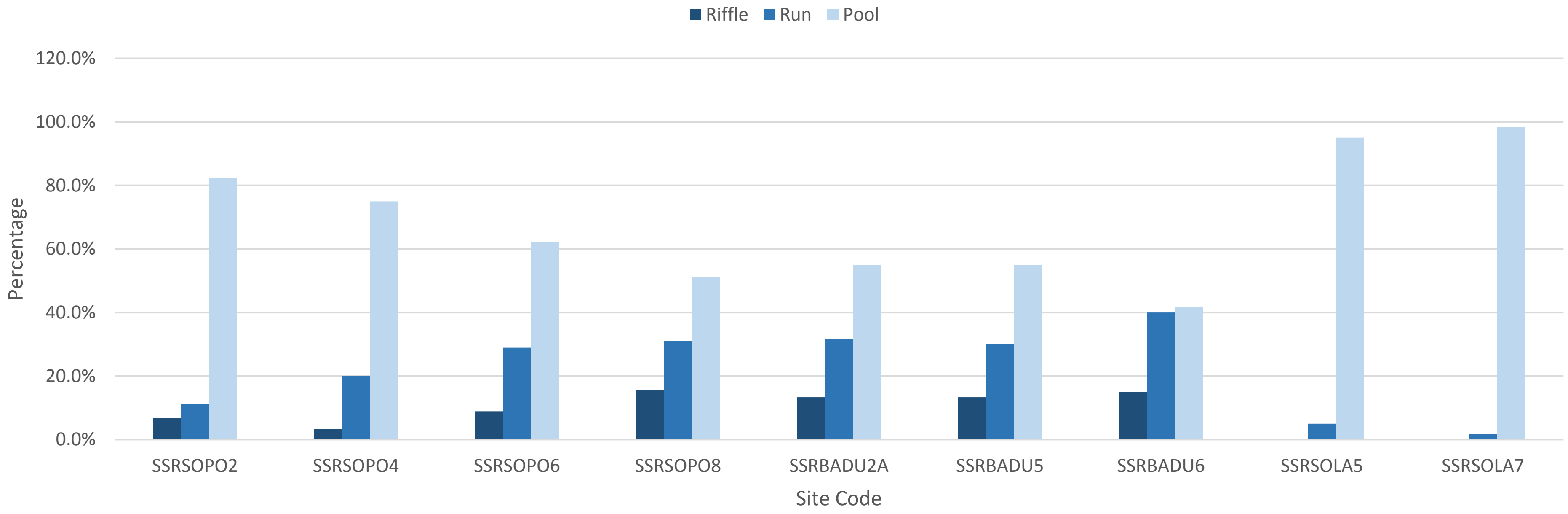

Figure 6: Percent Riffle, Run & Pool composition incorporating adapted hydraulic head classifications outlined in Ontario Streams Assessment Protocol.

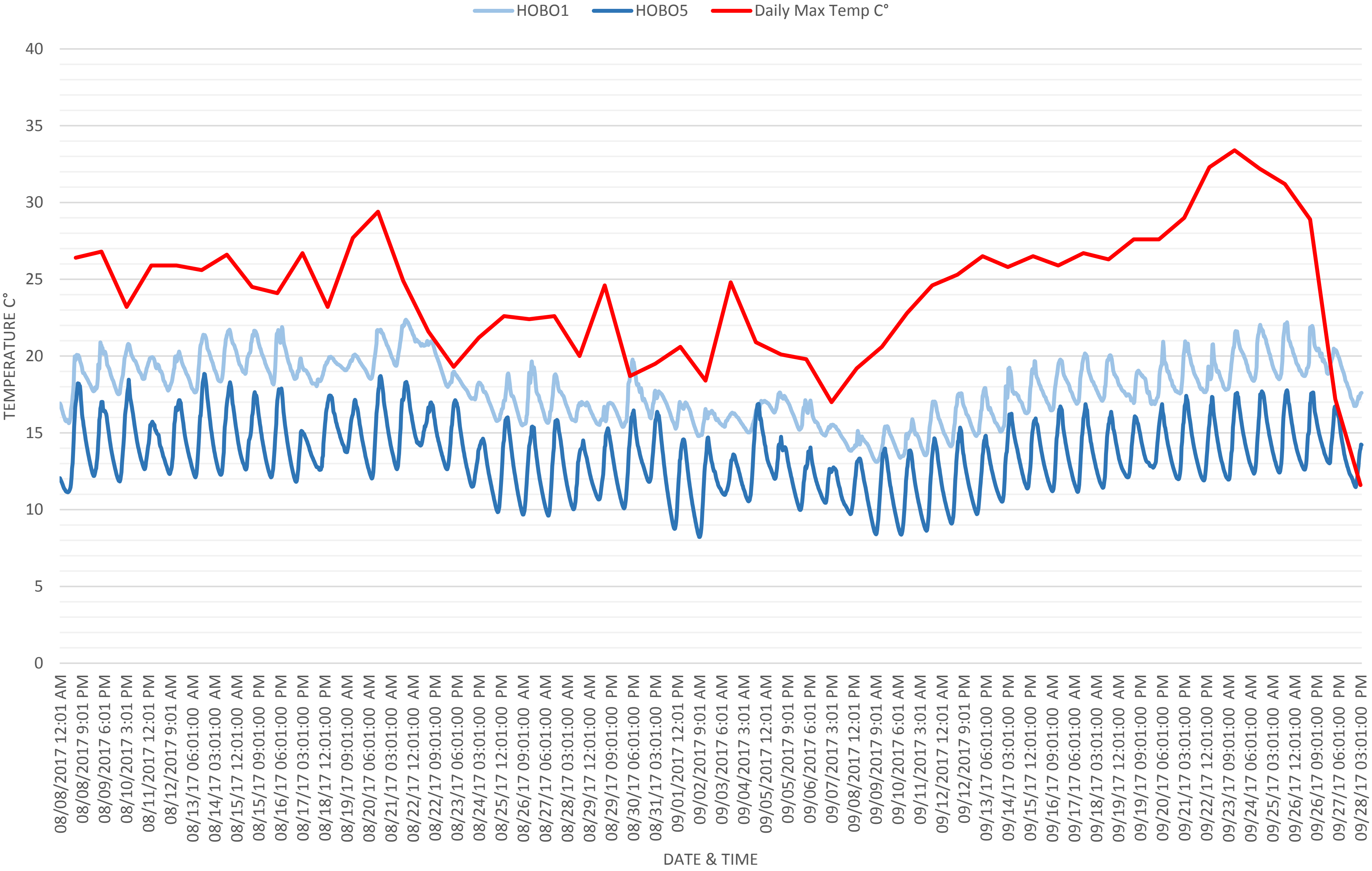

Figure 7: Fleetwood Creek temperatures, main channel, August 8 to September 28, 2017

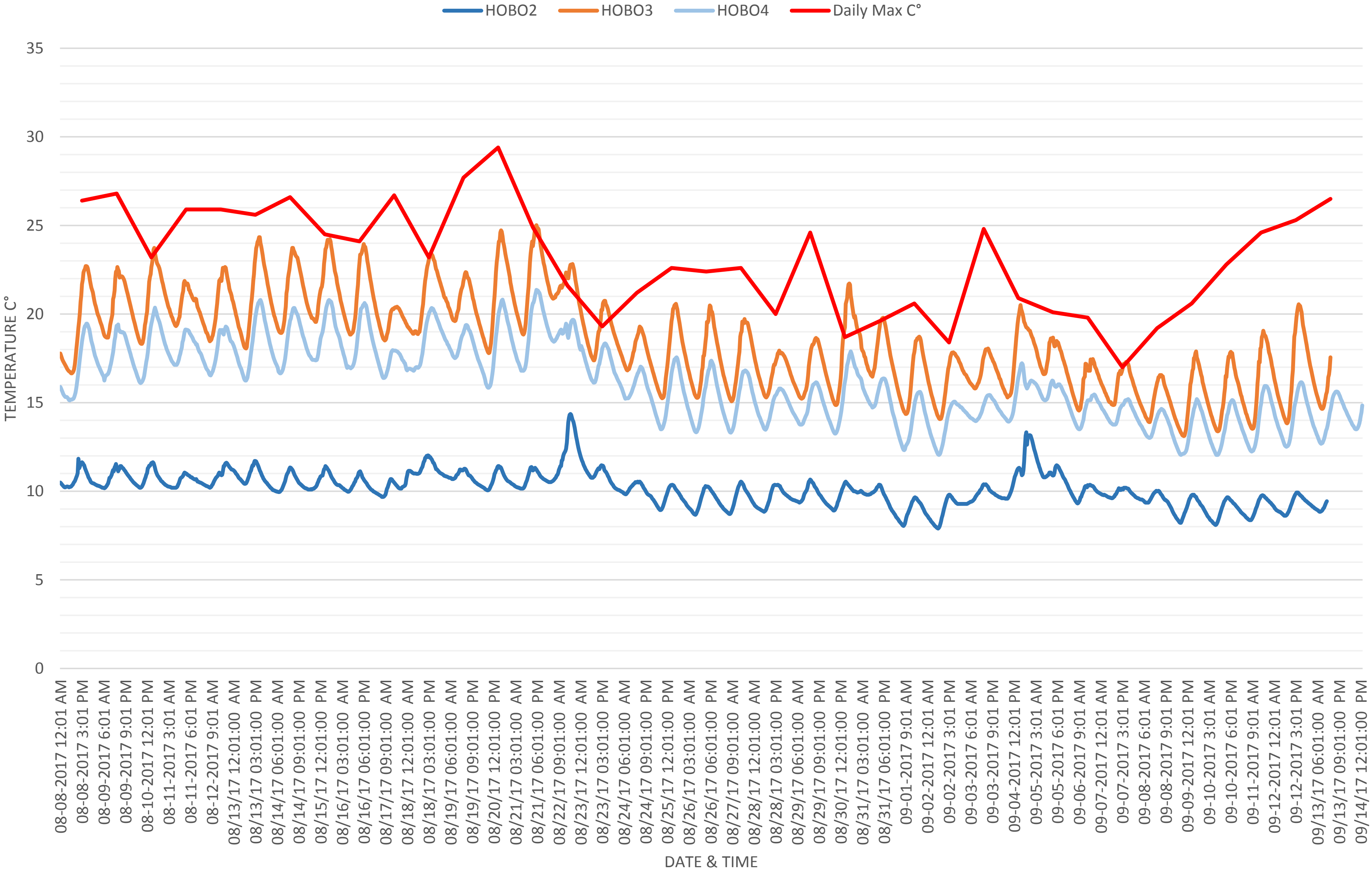

Figure 8: Fleetwood Creek temperatures, South Pond and Ballyduff Trails tributaries, August 8 to September 14, 2017

Table 2: Macroinvertebrate community represented as a percent total, displaying Hilsenhoff Biotic Index values adapted from Freshwater Information System database (FWIS)

			Site Code											
Scientific Name	Common Name	Hilsenhoff Value	SSRSOPO2	SSRSOPO4	SSRSOPO6	SSRSOPO8	SSRBADU2A	SSRBADU3A	SSRBADU5	SSRBADU6	SSRSOLA5	Avg	Min	Max
			4.7	4.2	3.8	4.7	4.9	3.9	4.3	4.5	5.0			
Hydrozoa	Hydra	6	0	0	0	0	0	0.3	0	0	0	0	0	0.3
Platyhelminthes	Flatworms	6	0	0.2	0	5.1	0	0	0	0	0	0.6	0	5.1
Nemata	Roundworms	5	0.7	0.2	0	0.6	0	0	0	0	6.3	0.9	0	6.3
Oligochaeta	Annelid worms	8	3.6	1.7	1.0	2.3	1.0	0.3	0.6	2.6	0.6	1.5	0.3	3.6
Hirudinea	Leeches	8	0	0	0.6	0.8	0	0.3	0	0	0	0.2	0	0.8
Isopoda	Aquatic Sowbugs	8	0	0	0	0	0	0.3	0	0	0	0	0	0.3
Bivalvia	Clams	8	1.0	1.0	0.3	0	1.4	0	4.4	0	0.6	1	0	4.4
Amphipoda	Scuds	6	0	0	0	1.1	0	1.3	0	0	0	0.3	0	1.3
Decapoda	Crayfish	6	0	0	0	0	0	0	0	0	0	0	0	0
Acari	Aquatic Mites	6	0	0	0.3	0	0.5	0.6	0.3	0	1.3	0.3	0	1.3
Ephemeroptera	Mayflies	5	0.3	4.0	1.0	2.8	31.4	19.4	23.7	25.2	7.5	13	0.3	31.4
Anisoptera	Dragonflies	5	7.8	1.5	0.6	0.3	1.4	0.6	3.1	9.6	0.6	2.8	0.3	9.6
Zygoptera	Damselflies	7	0.7	0.2	0.6	0	0.5	0	0	0	0	0.2	0	0.7
Plecoptera	Stoneflies	1	3.6	8.4	14.7	0.3	1.4	19.4	9.0	1.7	13.8	8	0.3	19.4
Hemiptera	True Bugs	5	2.0	0	0.3	0	0	0	1.2	0	0	0.4	0	2
Megaloptera	Fishflies	4	1.3	4.5	0.3	0	0.5	0.3	0.9	0	0	0.9	0	4.5
Trichoptera	Caddisflies	4	33.9	37.2	59.4	53.2	35.7	40.3	40.5	38.3	10.1	39	10	59.4
Lepidoptera	Aquatic Moths	4	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Beetles	4	17.3	21.8	15.7	15.8	19.0	10	2.5	5.2	0.6	12	0.3	21.8
Gastropoda	Snails	7	8.1	5.0	1.6	0.3	1.0	2.3	2.8	0.9	0	2.4	0	8.1
Chironomidae	Midges	7	7.2	5.5	0	0.8	4.3	2.6	2.8	3.5	47.8	8.3	0	47.8
Tabanidae	Horse & Deer Flies	3	0.7	1.2	0.3	0	0.5	0.3	3.1	4.3	0.6	1.2	0	4.3
Culicidae	Mosquitoes	4	0	0	0	0	0	0	0	0	0.0	0	0	0
Ceratopogonidae	No-see-ums	4	8.5	3.0	0	1.1	0.5	1.3	1.6	6.1	8.8	3.4	0	8.8
Tipulidae	Crane Flies	3	0.3	1.2	0	0	0	0	1.2	2.6	0.0	0.6	0	2.6
Simulidae	Black Flies	6	2.6	0.2	1.6	15.2	1.0	0.3	0	0	1.3	2.5	0	15.2
Misc Diptera	Misc Flies	5	0.7	3.0	1.6	0.3	0	0	2.2	0	0.0	0.9	0	3

Table 3: Fish community represented by species accounts during electrofishing protocols.

		Site Code														
Scientific Name	Common Name	SSRSOPO1	SRRSOPO2	SSRSOPO4	SSRLONG3	SSRBADU2A	SSRBADU3A	SSRBADU5	SSRBADU6	SSRSOLA5	SSRSOLA7	Abundance #	Avg	Min	Max	
Umbra limi	Central Mudminnow	0	0	0	0	0	0	0	1	0	0	1	0.1	0	1	
Salvelinus fontinalis	Brook Trout	9	13	7	21	26	43	55	24	27	31	256	25.6	7	55	
Culaea inconstans	Brook Stickleback	0	0	0	1	0	0	0	0	0	0	1	0.1	0	1	
Cottidae	Sculpin	0	0	0	0	0	0	0	0	6	2	8	0.8	0	6	
Cottus Bairdii	Mottled sculpin	0	0	0	1	1	0	1	1	1	5	10	1	0	5	
		9	13	7	23	27	43	56	26	34	38	276				Totals

Table 4: Brook Trout population estimates and catch per unit effort (CPUE) by site.

	Site Code												
	SSRSOPO2	SSRSOPO4	SSRSOPO1	SSRLONG3	SSRBADU2A	SSRBADU3A	SSRBADU5	SSRBADU6	SSRSOLA5	SSRSOLA7	Avg	Min	Max
Site Length (m)	49.9	46.7	50.6	44.1	45.2	55.1	49.8	49.2	54.6	43	48.8	43.0	55.1
Site Width (Avg)	1.77	1.73	1.42	1.52	5.88	4.56	6.2	4.54	4.7	5.3	3.8	1.4	6.2
Site Area (m^2)	88.3	80.8	71.9	67.0	265.8	251.4	308.8	223.4	256.6	227.9	184.2	67.0	308.8
Fishing Effort (s/m^2)													
Run 1	8	11	26	22	12	13	12	16	11	15	14.6	8.0	26.0
Run 2	9	10	–	–	–	–	–	–	–	–	9.5	9.0	10.0
Run 3	6	8	–	–	–	–	–	–	–	–	7.0	6.0	8.0
CPUE (#/s)	0.006	0.003	0.005	0.015	0.008	0.013	0.015	0.007	0.010	0.009	0.0091	0.003	0.015
Abundance (#)	13	7	9	22	26	43	55	24	27	31	25.7	7.0	55.0
Relative Abundance (%)	100	100	100	95.7	96.3	100	98.2	92.3	79.4	81.6	94.4	79.4	100.0
Relative Biomass (%)	100	100	100	99	96.5	100	99	94.5	94.6	89	97.3	89.0	100.0
Average Weight (g)	17.5	17.3	22.8	8.4	8.6	10.5	16.4	18.2	7.1	9.6	13.6	7.1	22.8
Length Min (mm)	91	89	98	65	59	67	61	60	60	62	71.2	59.0	98.0
Length Max (mm)	170	144	181	168	153	187	282	210	142	162	179.9	142.0	282.0
Population Estimate (#)	14.5	7.3	20.5	48.7	60.5	101.1	129.9	55.8	62.9	72.4	57.4	7.3	129.9
Population Per Unit Area ($\#/m^2$)	0.16	0.09	0.29	0.73	0.23	0.41	0.42	0.25	0.25	0.32	0.32	0.09	0.73
Biomass Estimate (g)	253.8	126.5	466.7	407.1	520.5	1065.9	2130.4	1014.9	449.4	695.8	713.1	126.5	2130.4
Biomass Per Unit Area (g/m^2)	2.9	1.6	6.5	6.1	2.0	4.2	6.9	4.5	1.8	3.1	4.0	1.6	6.9

Discussion & Results

Habitat suitability and productive capacity require an assemblage of components, including food sources, instream cover & stable temperatures. Waterbodies providing clear, cool, well-oxygenated waters are essential in supporting Brook Trout (*Salvelinus fontinalis*) populations (Scott & Crossman 1998). Furthermore, research performed by Stoneman & Jones (2000) revealed the four crucial determinants for trout biomass; cold water, percentage of pools, food, and cover. Attention toward these four distinguished criteria can aid in determining the overall Brook Trout productivity for the sites sampled within the Fleetwood Creek watershed.

Channel Morphology

The richness and availability of pools for all life stages of Brook Trout, particularly, Young of Year (YOY) is of fundamental importance (Stoneman Et al 1996). Brook Trout Habitat Suitability Models presented by (Stoneman Et al 1996) indicate “sites containing at least 20% pools is optimal for YOY Brook Trout.” Figure 6 displaying riffle, run & pool percentages, expressed a high percentage of pools that surpassed the stated threshold, with an average percent of 68.4.

It is well documented that stream dwelling Brook Trout require gravelly shallows of headwater streams with strong springwater flow for spawning (Scott & Crossman 1998). Mean values for sand and gravel were the highest of all substrates. Sand dominated most of the study sites with an average of 49.65%. Gravel encompassed 27.58% of substrate composition.

Cover quality is one of the most significant influences on aquatic biota. The quality is distinguished by embeddedness. Unembedded cover provides overhead and velocity refuge for small fish, whereas embedded cover provides only velocity refuge. Fundamentally, unembedded cover has at minimum a 4 cm overhang, providing suitable burrowing habitat for fish. The mean value for unembedded cover across all sites was 43.7%. The highest values were witnessed at BADU2A (77.8%) and SOPO4 (60.0%), with the lowest at SOPO8 (13.3%). Figure 9.

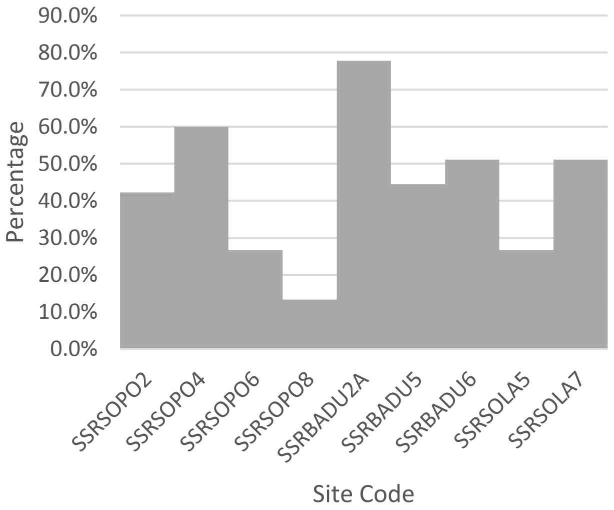

Figure 9: Unembedded Cover as a percent total for each site.

Water Chemistry

Data collected by chemical analysis exhibited overall values that align with provincial guidelines. The Ministry of the Environment (OMOE) 1994 publication documenting the Provincial Water Quality Objectives (PWQO) indicate dissolved oxygen levels for cold water biota, ranging from 10 - 15° C, should not drop below 6 mg/L. Regarding sample sites, no site presented DO levels lower than 9.2 mg/L. The average DO level was 11.2 mg/L (Table 1).

pH levels that support aquatic biota are outlined by the Canadian Council of Ministers of the Environment (CCME). pH concentrations should reside within a range of 6.5 - 9.0. Values recorded throughout sample sites spanned 7.5 - 8.5, with an average of 8.0 (Table 1). Evidently, all sites resided within the stated guidelines and exhibited a neutral to basic environment.

Current and accurate scientific Phosphorous concentration guidelines are insufficient (OMOE 2017). However, PWQO provides a general guideline, avowing “Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L. Phosphate PO_4 readings were only obtained at 4 sites, SOPO8, BADU2A, BADU5 and BADU6. The highest readings obtained, 0.5 ppm (500 µg/L) recorded at SOPO8 & BADU6, are higher than the provincial general values.

Current safe Nitrate (NO_3) levels for the protection of aquatic biota should not exceed 550 mg/l or 550,000 µg/l (CCME 2017). Nitrate measurements measured at BADU2A, BADU5, BADU6, SOLA5 & SOLA7 were 0.0 mg/L. SOPO8 generated a value of 0.5 ppm (500 µg/L), a reading well below the safe Nitrate threshold.

Temperature

(Stoneman & Jones 2000) suggest that water temperature is the single most important determinant of trout biomass and that cold water must be available for trout species to flourish. Optimal water temperature for Brook Trout is defined as 16° C, supporting a cold water classification (Corker et al 2001). The upper thermal limit has been defined as 24° C (Meisner 1990). Results from thermal analysis classified the stream exiting the shallow impoundment upstream of Gray Road (HOBO1) as cool water. The main channel flowing into this shallow impoundment at BADU5 (HOBO5) was classified as cold water to cold-cool water.

Data collected directly below South Pond Farms dam (HOBO3) produced the highest thermal classification of the dataset. Water in this area was defined as cool-warm water. Approximately 200 m downstream HOBO4 was located between SOPO1 and SOPO2, water temperatures here exhibited a cool water classification. This decrease in temperature is likely the result of groundwater inputs from the Oak Ridges Moraine, and results in a more suitable temperature regime for Brook Trout. Finally, the small groundwater tributary (HOBO2) produced the coldest results with a thermal classification of cold water. Temperatures in this tributary did not exceed 16° C during the sampling period, and only for several days did it exceed 12° C. However, this data displays suitable temperatures for Brook Trout with the exception of the cool-warm water regime immediately downstream from the South Pond Farms dam. (See figure 7 & 8 for complete temperature data)

Macroinvertebrate Survey

Presenting percentages for *Ephemeroptera*, *Plecoptera* and *Trichoptera* can be a useful index when expressing water quality, as these species exhibit a low tolerance to stressors relating to pollution (Brisbois et al 2008). Observing the percent abundance reveals EPT were the most abundant taxa within the OBBN 27 group resolution throughout the study sites

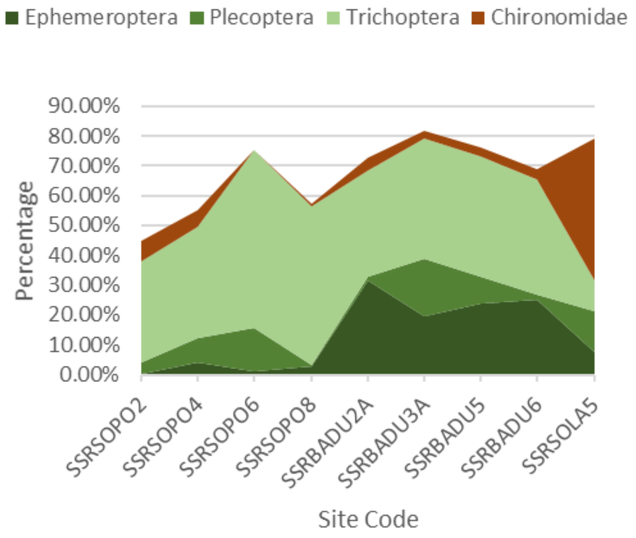

Figure 10: Percent totals comparing Ephemeroptera, Plecoptera & Trichoptera (EPT) with Chironomidae.

Conversely, "*Chironomidae* are often abundant in streams experiencing pollution and are identified as pollution tolerant" (Brisbois 2008). Thus, streams with a high abundance can be described as impaired or impacted. The percent abundance of *Chironomidae* is shown in figure 10 alongside EPT abundance. With an average percent of 8.3 (table 1) chironomid abundance was low, except for SOLA5, where 48.7% of the sites benthic invertebrate community was compromised of chironomids.

Hilsenhoff Biotic Index

Classifying sites with a HBI value can provide an instantaneous evaluation regarding water quality. Although it is no longer the accepted practice to compare Hilsenhoff values derived from the OBBN 27 group level, to the original Hilsenhoff interpretation. If done, the sites sampled range from very good to good. Results derived from (Mackie 2008) interpretation reveals the sites ranged from non-impacted to slightly-impacted. BADU2A and SOLA5 denoted the highest tolerance values. Considering the correlation between the abundance of Chironomidae and the increased level of pollution, SOLA5's tolerance value would predictably, be elevated due to the high abundance of Chironomids (47.8%).

Fish Sampling

Community Assessment

Table 3 presents the fish community data collected at each site. Species diversity was low with *Salvelinus fontinalis* representing 92.8% of all species documented. Further species accounts included Sculpin (Cottidae), Central Mudminnow (*Umbra limi)* and Brook Stickleback (*Culaea inconstans)*. It should be noted that the tributary below the South Pond Farms Dam, between the dam and the perched culvert located upstream of LONG3; based on sampling protocols exhibited a total catch consisting of 100% Brook Trout. However, the presence of Gasterosteidae (Stickleback) and Chrosomus (Dace) species were discovered in the pool immediately below the dam by way of a quick screening survey.

Population Summary Brook Trout

Table 4 presents a summary of abundance, biomass and population estimates for *Salvelinus fontinalis*. The mean relative abundance of Brook Trout (94.4%) and the mean relative biomass of Brook Trout (97.3%), revealed a fish community heavily dominated by Brook Trout. Within each site average weights of Brook Trout catch varied, SOPO1 hosting the biggest individuals at 22.8 g and SOLA5 hosting the smallest at 7.1 g. Similarly, biomass estimates varied significantly, with BADU5 supporting 2130.4 g and SOPO4 supporting a 126.5 g. However, these statistics do not accurately portray Brook Trout densities at each site. In order to achieve representative Brook Trout densities, the statistics must be standardized.

Biomass per unit area (g/m2) was calculated to produce a consistent value that could be used to categorized Brook Trout densities. (Stoneman and Jones 2000) devised four groups to indicate Brook Trout densities ranging from low to high. The presented groups are low biomass density (<1.25 g/m^2), moderate (1.25 - 5.0 g/m^2), high (5.0 - 10.0 g/m^2), and very high (>10.0 g/m^2).

Considering all sampled sites, no sites reached Stoneman and Jones' very high distinction (>10.0 g/m2). However, BADU5, SOPO1 & LONG3 met the criteria for high Brook Trout densities. The remaining seven sites were characterized with a moderate density rating as no site fell below the 1.25 g/m2 threshold. Figure 11 represents these findings in decreasing order of abundance.

Figure 11:Brook Trout densities presented as biomass per unit area.

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Appendices

Appendix A Site Maps

Appendix B Temperature Data loggers

BADU and SOLA study sites, FWIS Mapping Tool, 2017.

SOPO and LONG study sites, FWIS mapping Tool, 2017.

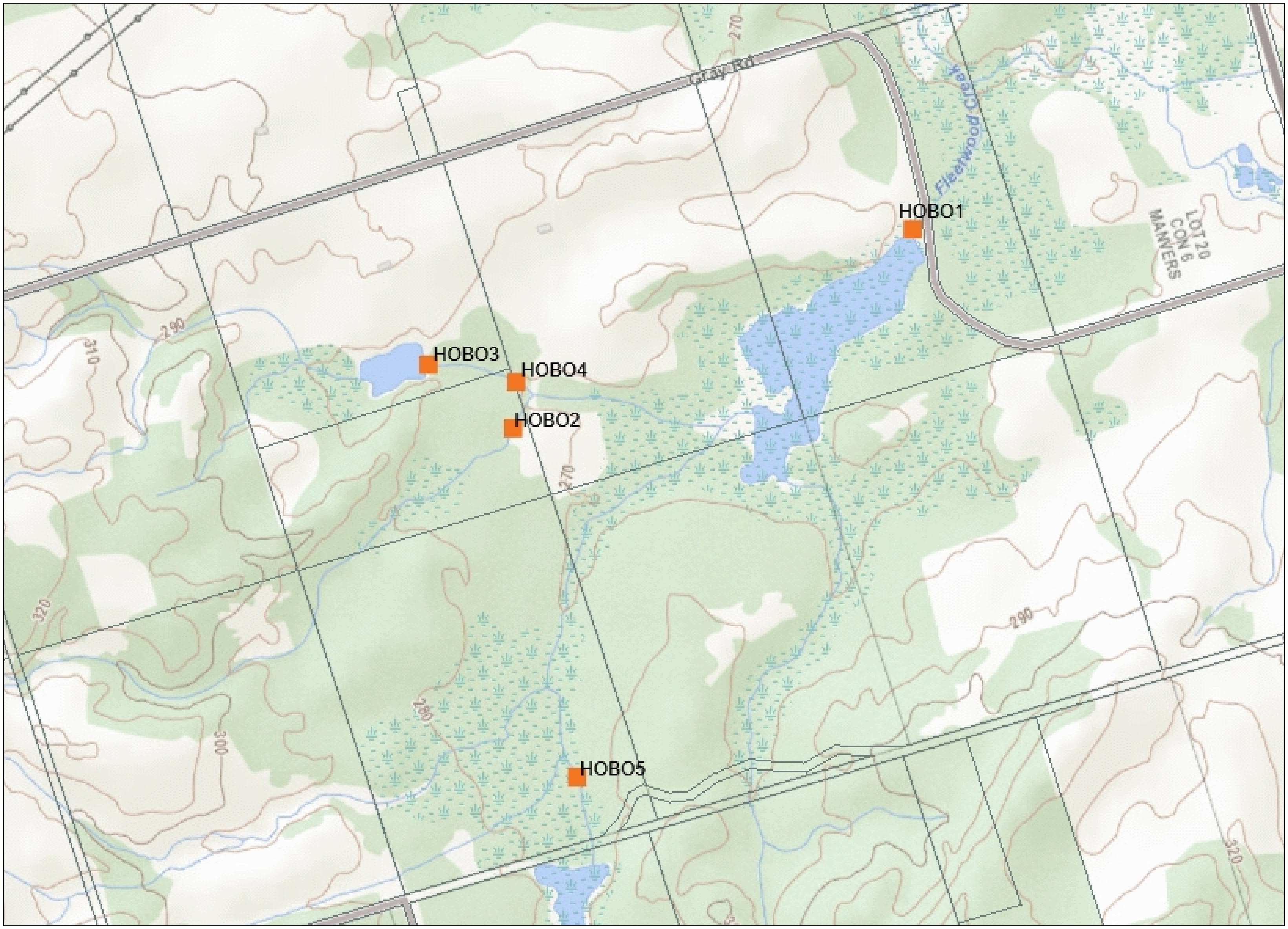
Ontario MINISTRY OF NATURAL RESOURCES AND FORESTRY

Make a Topographic Map

Temperature Data Logger Locations

Notes:

Fleming College - Fish and Wildlife Freshwater Ecology Field School 2017



Legend

- Building as Symbol
- Building to Scale
- Airport
- Heliport \ Hospital Heliport
- Seaplane Base
- Ferry Route
- Trail Head \ Trail
- Railway \ Train Station
- Railway with Bridge
- Railway with Tunnel
- Road (Major → Minor)
- Winter Road
- Road with Bridge
- Road with Tunnel
- 7 Primary, Kings or 400 Series Highway
- 524 Secondary Highway
- 801 Tertiary Highway
- 28 District, County, Regional or Municipal Road
- 407 Toll Highway
- One Way Road
- Road with Permanent Blocked Passage
- 420 500 421 499 Road with Address Ranges
- Hydro Line, Communication Line or Unknown Transmission Line
- Natural Gas Pipeline, Water Pipeline or Unknown Pipeline
- .208 Spot Height
- 200 Index Contour
- Contour
- Wooded Area
- Wetland
- Waterbody
- 184 Waterbody Elevation
- Watercourse
- Falls
- Rapids
- Rapids \ Falls
- Rapids
- Rocks
- Lock Gate
- Dam \ Hydro Wall
- Dam \ Hydro Wall
- Provincial \ State Boundary
- International Boundary
- Upper Tier \ District Municipal Boundary
- Lower Tier \ Single Tier Municipal Boundary
- Lot Line
- Indian Reserve
- Provincial Park
- National Park
- Conservation Reserve
- Military Lands

0 0.7 km

Projection: Web Mercator

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