Integrated Ecological Research

Assessing and enhancing wetland species in the West Kootenays

Wetland Invertebrate Assessment Tool
(COL-F18-W-2405)

Prepared for:
Fish and Wildlife Compensation Program

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May 31, 2018

This Project is funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

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ABSTRACT

We developed quantitative biotic benchmarks to track wetland recovery that can be used to assess wetlands in the Columbia Basin. These benchmarks along with an adaptive management approach can be used to make management decisions about restoration and conservation. We identified reference sites that can be used to compare to trends at restored wetland sites over time. This information will provide data on trends over time in wetland recovery following restoration. An important component of this project is private landowner engagement by participation in our invertebrate monitoring program and enhancement projects providing some first steps towards fostering stewardship and restoration of private wetlands. Data obtained during this study, will be used to inform new work on bat-insect trophic interactions and testing of bat enhancement methods centered within the Bonanza to Box Lake corridor. This work aligns with the Fish and Wildlife Compensation Programs FWCP Riparian and Wetlands Action Plan for monitoring and evaluation and habitat-based actions. In addition, the project helps to support increased information and knowledge on the ecological processes of wetlands in the Slocan Valley and North Kootenay Lake, leading to meaningful outcomes for the community, funders and supporters.

1 Introduction

In 2014 the Slocan Wetland Assessment and Monitoring Project (SWAMP) Steering Committee suggested that monitoring of wetland invertebrates could be integrated with ongoing wetland assessments in the Slocan Valley including mapping and classification of wetlands with the objective of developing a protocol for an assessment of wetland health using Environment Canada's Canadian Aquatic Monitoring Protocols (CABIN) previously funded by Fish and Wildlife Compensation Program (FWCP) as the *Wetland Invertebrate Assessment Tool*, W-F16-10. The project was initiated under SWAMP in collaboration with the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD), the Slocan River Streamkeeper's Society (SSS) and the Columbia Basin Watershed Network (CBWN).

The goals of the proposed project "*Assessing and enhancing wetland species in the West Kootenays*" are to (1) track restoration recovery of FWCP funded sites using quantitative measures of wetland stress and biological health and (2) strengthen restoration work at FWCP-funded sites with enhancements. The CABIN methods for sampling wetland invertebrates will be used to monitor restoration recovery in a 3-year context at FWCP-funded restoration sites including: Crooked Horn Farm (COL-F17W-1438) and Meadow Creek (The Nature Trust lands/Halleran property).

The current project builds on past funding streams from the FWCP which total 18% of total contributions for the Wetland Invertebrate Assessment Tool since as well as matching funding from the Environment Canada's National Wetland Conservation Program (NWCF), the Columbia Basin Trust (CBT), CBWN, in-kind contributions from the Royal BC Museum (RBCM), the FWCP Community Engagement Grant and collaborative efforts with FLNRORD (Meadow Creek Restoration sites). The

project also overlaps with other FWCP-funded projects or candidates including: Crooked Horn Farm Restoration, Meadow Creek conservation lands (FLNRORD), Bonanza wetland (Valhalla Wilderness Society) and the Goulden-Thurston Property (SSS). New this year is a developing relationship with Nakusp and Area Community Forest (NACFOR) to identify possible enhancement sites on their forest license.

This project aligns with the FWCP Riparian and Wetlands Action Plan (2012) including:

- **Monitoring and Evaluation:** (Action No. 11. Obj. 1 Priority 1). Compile, assess and document the effectiveness of completed wetland and riparian restoration projects.
- **Habitat-based Actions** (Action priorities for the Slocan Valley Action 1. Priority 1.) Strengthen available habitat by creating structures in this focal area including but not limited to nest boxes in wetland and riparian areas.

The present project is an application of this past work based upon methods under the Canadian Aquatic Biomonitoring Network, CABIN, (Tall et al. 2008, Bailey and Reynoldson 2009) and other programs in Canada (Adams et al. 2013, Miller and Hawkes 2013, Archer et al. 2010, Eaton 2005) and the United States (Kovalenko et al. 2014, Uzarski et al. 2011, Mazzancano 2011, Apfelbeck 2000). These methodologies have the potential to provide further inference about the status of wetlands and wetland restoration in the Slocan Valley and Meadow creek areas (Quamme et al. 2016, Quamme 2016a, Quamme 2016b and Quamme 2015).

The goals of the current project are:

- Quantify wetland water resources based on mapping, water/sediment quality and a biological monitoring to assess the health of wetlands in the Slocan and Meadow Creek areas.
- Support current wetland restoration work in these areas through monitoring and management recommendations.
- Engage and encourage private landowner enhancements and community involvement.
- Report findings to the Slocan and Meadow Creek Communities, the Kootenay Region and the Columbia Basin.

The objectives are:

- Track and improve restoration recovery of FWCP funded sites using quantitative environmental and biological indicators.
- Conduct follow-up monitoring and make recommendations on wetland restoration improvements.
- Strengthen environmental restoration work at the FWCP-funded Crooked Horn Farm using small enhancements and community engagement on nearby private lands.

2 Field and Laboratory Methods

2.1 Macroinvertebrate protocols

Macroinvertebrates are important wetland indicators of anthropogenic-induced stresses such as habitat degradation, development and contaminants (Kovalenko 2014, Mazzacano 2011, Uzarski et al. 2011, Archer et al. 2010, U.S EPA 2002 and Apfelbeck 2000). Bioassessments using macroinvertebrates in wetlands have been successfully carried out under the Canadian Aquatic Biomonitoring Network, CABIN, (Tall et al. 2016 and 2008, Bailey and Reynoldson 2009, Environment Canada 2018) and other programs in Canada (Adama et al. 2013, Miller and Hawkes 2013, Archer et al. 2010, Eaton 2005) and the United States (Kovalenko et al. 2014, Uzarski et al. 2011, Mazzancano 2011, Jepson et al. 2007, Apfelbeck 2000). However, studies of wetland macroinvertebrates in British Columbia are limited except for Adama et al. (2013) and Miller and Hawkes (2013).

This study is the first to field test CABIN methodologies for wetlands in B.C. However, CABIN methods have been developed in other areas of Canada including published work from Quebec (Tall et al. 2016 and 2008), protocols developed in the Yukon (Baily and Reynoldson 2009), and prairie provinces including Saskatchewan and Alberta. A national draft protocol was provided by Environment Canada, Vancouver office for our use in beta-testing of these methods in BC (pers. com. Adam Martens 2018).

Macroinvertebrate sampling in this study focused on characterizing the community that inhabits the emergent zone of the wetlands. In the past, macroinvertebrates collected from emergent vegetation have been used to differentiate reference sites from impacted sites in bioassessments of wetland habitats on the wetlands of the St. Lawrence River (Tall et al. 2008), Great Lakes coastal wetlands (Uzarski et al. 2011), marshes in the Niagara area (Archer et al. 2010) and wetlands in Montana (Apfelbeck 2000) and Oregon (Mazzacano 2011). The kick sampling procedure in wetlands involves a gentle disturbance of bottom sediments and three-minute sweeps of the water column in a zig-zag pattern over a 5 m by 5 m quadrat. Thus, macroinvertebrates are collected from the water column, bottom sediments and aquatic plants at each site within the emergent zone.

To date, a total of 43 samples at various sites have been collected from 2014-2017 (Figure 2). We sampled wetlands elevations from 470-1580 m associated with lentic (lacustrine and palustrine) and lotic (riverine/stream and floodplain) wetlands ranging from reference condition to wetlands impacted by mining, agriculture, forest operations, invasive species and development.

2.1.1 Emergent zone kick samples

Macroinvertebrates were sampled from the near shore of the emergent zone (≥10% emergent vegetation cover) at a depth of approximately 0.5-1 m using a CABIN kick-net of length 45.7 cm, width 25.4 cm, and depth 25.4 cm with a 500 µm mesh net (Environment Canada 2007, Tall et al 2008). The samples were collected in a 5 m by 5 m plot in a timed three-minute kick sample

(Environment Canada draft protocol 2016). This technique involves a gentle disturbance of bottom sediments and sweep in a zig-zag pattern within the water column quadrat at each site.

Estimates of the relative proportion of vegetation were made within the 5 x 5 m quadrat in the emergent zone. The $25m^2$ m quadrat was marked with cedar stakes following water collection, assessments of percent composition of wetland plants were made prior to macroinvertebrate collection so as not to disturb or damage emergent plants.

A field sheet was provided by Environment Canada's CABIN program (June 2015) from their draft field protocol and was used as a basis for field measurements (Environment Canada 2016).

2.1.2 Handling and preservation of macroinvertebrate samples

Following field sampling, the volume of sediment/vegetative matter in each sample was reduced by gently washing the nets in water well away from sampling area or sample can be taken back to the laboratory and further reduced. All amphibians were removed from nets following (Ministry of Environment, 2008) protocol for safe handling of amphibians. Material was gently poured through a 500 µm sieve and further rinsed.

Sample material was transferred to one litre jars with 80% ethanol used as a preservative. Sample material comprised no more than 50% of the jar. Ethanol was replaced with fresh 80% ethanol (Mazzacano 2011, Jepsen et al. 2007). All samples were checked with a hydrometer to verify preservation at 80% ethanol prior to shipping and Rhithron reported that the samples were well preserved when they arrived.

Photo 1: Field sampling of wetlands in the Slocan River Watershed and Meadow Creek Areas.

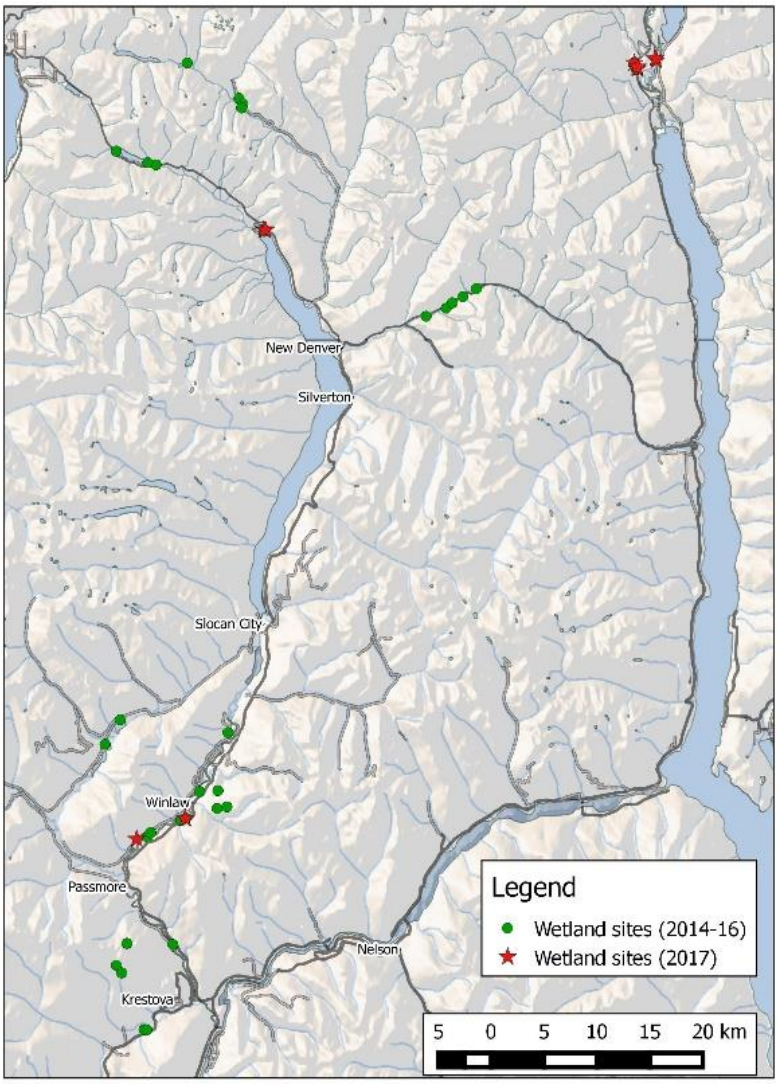

Figure 2. Overview of wetlands sampled in 2017 (red stars) using Wetland Assessment Tool Methods in 2014-16 (green dots).

2.1.3 Taxonomic identifications of macroinvertebrates

Samples collected for the CABIN database were sent to a certified taxonomist that follow procedures outlined in Environment Canada (2012). Rhithron Ltd, taxonomists based in Missoula, Montana specializing in identifying wetland invertebrates were used for the taxonomic work. Rhithron invertebrate taxonomists collectively hold 34 Level-II certifications from the Society for Freshwater Science. All laboratory techniques and quality control were carried out according to CABIN methods (Environment Canada 2012 and 2016).

In addition, voucher specimens were shipped to the Royal BC Museum following identification by taxonomist for id confirmation and to add to our understanding of wetlands in Interior BC where there are currently knowledge gaps. All project methods met museum specifications for collection, taxonomic identification and storage of specimens (CABIN 2007 and 2012).

2.2 Water and sediment physiochemistry

Field measurements of water quality and surface water samples were collected prior to other sampling to prevent contamination of samples using methods of Duncan and Duncan (2012), Uzarski et al. (2011), Bailey and Reynoldson (2009), Clark (2013) and Cavanagh et al (1997).

Metering of water quality included: temperature, pH, conductivity, and dissolved oxygen carried out using field meters or at Passmore Laboratories (2014-15). These parameters were taken at each of the emergent zone stations.

Surface water samples were collected for the following parameters including: Phosphorus (measured as total unfiltered Phosphorus), Nitrogen (Total Keldhal Nitrogen, Nitrate, Nitrite, and Ammonia), Alkalinity, Major ions (e.g. Ca, Mg, Na, and K), Total Suspended Solids (TSS), Sulfate, Chlorine, and Dissolved Organic Carbon. However, a subset of these parameters was monitored in 2014 when funding was very limited. Grab samples of surface sediment were collected using methods described in Duncan and Duncan (2012), Marvin-DiPasquale (2009), and Clark (2013). Total metals from the metals scan carried out by Maxxam (2014) and CARO Laboratories (2015-2017). From 2015-2017, metals concentrations were measured in water and sediment along with grain size, and carbon content for sediment.

Prior to sampling for water and sediment quality, all jars were labeled, packed and transported to sites in a field cooler in ziplock bags by site. At each site field personnel labeled all sample jars with site code, time and all other relevant information. Water surface samples were taken wearing latex gloves in a non-disturbed area prior to completing the full wetland invertebrate protocols. The sample jars were wrapped in bubble wrap and immediately put in a cooler with ice packs and sent to CARO and Passmore Laboratories within 24 hours of collection. After water quality samples were collected, sediment samples were taken in the same vicinity at all sites.

2.3 Quality Control

Duplicate sampling of five percent of the water and sediment samples was conducted for samples sent to CARO for water and sediment quality parameters. Duplicate sampling of ten percent of the water samples sent to Passmore Laboratories (2014-15) of was carried out for parameters that included turbidity (meter) and Hach kit measurements for alkalinity, conductivity, pH and acidity. All data was screened, and quality control measures were conducted to assess field and laboratory data collection methods according to quality assurance and quality control field sampling protocols in Clark (2013). Trip blanks were collected to assess any possible contamination from sample

containers, collection at the site, and transport. Field blanks were evaluated using the following equation (Clark 2003):

Blank x difference = Field Blank Value/Method Reporting Limit.

Field Duplicates were evaluated based on absolute relative percent difference (RPD) using the following equation:

RPD= (Abs. Difference of Duplicate 1 minus Duplicate 2)/(Average of Duplicate 1 plus Duplicate 2)*100.

Duplicate values that were greater than five times the method reporting limit (MRL) with RPD values of 20-50% (Clark 2013) were inspected and values of greater than 25% were further considered as alerts on possible contamination or lack of representativeness. All internal quality control for laboratory methods and results provided by the labs were reviewed and evaluated.

The quality control information on the macroinvertebrate sorting and subsampling is presented in the technical report by Rhithron (Section 7.2).

3 Results

3.1 Site descriptions

A total of 43 sites were sampled in emergent vegetation over four years from 2014-2017 (Table 1). Sampling sites were located in the Slocan Valley and Meadow Creek areas with the first year (2014) of the study served as a pilot effort to test developing methods. In 2015 and 2016, sites were selected throughout the Slocan Valley to capture the variance in wetland type. In 2016, trend monitoring of restored wetlands was initiated in early phase post-restoration to document recovery of restored wetlands on conservation lands in Meadow Creek and private lands in the lower Slocan Floodplain, south of Winlaw, relative to natural wetlands in these areas.

We sampled upper and lower elevation sites (470-1580 m) associated with lentic and lotic habitats (Hansen et al 2000) including: riverine (stream or floodplain), lacustrine and palustrine wetland types (Environment Canada 2016). Impacts to these sites included historical agriculture, forestry, impoundment, nearby roads, residential activities (Table 2). But also included possible impacts from road salt and spraying (Bacillus thuringiensis subspecies israelensis, BTi) for mosquitoes. Of the 43 sites, four sites were highly impacted by historical mining. However, the present paper does not include mine sites because the current work is focussed on summarizing data from the restored sites relative to natural sites.

Reference sites or natural sites in this study are defined as least-impacted sites with moderate levels of human impacts rather than “in-reference condition”.

Table 1: Number of samples collected.

	Lentic[1]		Lotic[1]			
Year	**Lacustrine[2]**	**Palustrine[2]**	**Riverine[2] Streams**	**Riverine[2] Floodplain**		**Total**
				Natural	**Constructed**	
2014	1		3			4
2015	5	4	5	6		20
2016	2	1	2	2	3	10
2017	1			4	4[3]	9
Total	**8**	**5**	**10[4]**	**12**	**7**	**43**

[1] Wetland classifications defined in Hansen et al. 2000.[2] Wetland classifications defined in CABIN Draft Protocol for wetlands, 2017 contact Adam Martens Env Canada. [3] Sites were repeat visits to document trend over time.
[4] Four out of 10 sites were affected by historical mining and not included in the present study.

We also used GIS methods map a 500 m buffer zone around quadrat centers for all 43 sites using Sensitive Ecosystem Mapping standards (RISC 2006, Durand 2013, Section 9.3) to begin to examine ecosystem attributes of each site. GIS methods regarding quantifying disturbance require further refinement, however. As a result, GIS measures will be updated as methods are developed and released by Environment Canada, CABIN. Examples of mapping products are provided in Figures 3 and 4.

A detailed sheet provided by Environment Canada's CABIN program (2016, see Table 2 below) was used as a basis for field measurements including: (1) percent disturbance of the margin within a 50m buffer around the site, (2) percent zones of wetland based on a visual estimate, (3) percentage of marginal zone vegetation, 50m buffer zone around quadrat and (4) percent composition of plant type, periphyton, open water and large woody debris within the $25m^2$ sampling quadrat. Invertebrates were sampled from emergent vegetation habitat along the edge of the wetlands. As a result, all assessments of the wetland margin were dominated by emergent vegetation and woody riparian (within 50 m of plot centers). Quadrats (5m x 5m) were dominated with emergent and submerged vegetation (Table 2).

In addition, representative emergent vegetation by wetland type is described below with respect to MacKenzie W. and J. Moran (2004) based on CABIN assessments and corresponding plots (400 m^2) by Ryan Durand within wetland complexes of the Slocan Valley (Durand 2016).

Lacustrine wetland (n=8) sites within the invertebrate study were associated with inflows and outflows of lake habitat at Little Slocan Lakes, Summit Lake, Bonanza wetland (Slocan lake), Little Wilson Lake, and Cooley Lake at elevations of 534 to 1515 m. The emergent vegetation at these sites ($25m^2$) was dominated by sedges, grasses, cattail, horsetail and these wetlands were classified primarily as Marsh (Wm01) or Shallow water (OW). These types of habitats were often associated with treed swamp habitats or fens (Durand 2016). Lacustrine wetlands had neutral pH (7.5),

conductivity (140 uS/sec) and hardness values (69.34 mg/L, median values from Table 3). Total Kjeldhahl nitrogen (median=0.237 mg/L) was relatively high compared to other habitat types (Table 3).

Palustrine wetland (n=5) sites occurred at mid-bench to upper elevations were from 976m to 1580 m. These locations were dominated by sedges, grasses, cattail, horsetail and were classified as marsh (Wm01, Wm02, Wm05 and Wm06) or shallow water (OW). Durand (2016) found that these habitat types were found in association with treed swamp habitats fens (Durand 2016). Palustrine wetlands in our study had the lowest median pH (6.5), conductivity (39.3 uS/sec) and hardness values (21.5 mg/L, Table 3).

Riverine wetlands (n=10) situated along streams or within river valleys were located at elevations of 567-1080 m. These sites were dominated by sedges, cattails and grasses and were classified as marsh (Wm01, Wm02) or shallow water (OW). Complexes of these types of habitats were typically associated with treed swamp habitats (Durand 2016). Upper elevation riverine wetlands had neutral pH (7.5), conductivity (75.3 uS/sec) and hardness values (29.7 mg/L, see Table 3).

Floodplain wetlands (n=16) in our study included small ponds or side-channels located at low elevations (470-558 m) on the floodplain of the Slocan or Duncan Rivers. Four of these sites were constructed wetlands. These wetland sites ($25m^2$) were dominated by sedges, cattails and grasses and were classified as marsh (Wm01, Wm02, Wm05) or shallow water (OW). Floodplain habitats were frequently dominated by canary reed grass and/or treed swamp habitats (Durand 2016).

Overall floodplain wetlands were higher in conductivity and hardness than upper elevation wetlands and lacustrine sites. Natural floodplain wetlands had neutral pH (7.6), and median values of conductivity (203.2 uS/sec) and hardness (103.5 mg/L). Constructed floodplain wetlands had neutral pH (7.8) with a median conductivity of 182 uS/sec and hardness values of 104 mg/L (Table 3). The median of dissolved organic carbon (24.6 mg/L) for constructed floodplain wetlands was higher in than all other habitat types, perhaps reflective of recent disturbance during the process of restoration (Table 3). Soil phosphorus was the highest at floodplain wetlands (826.5 mg/L, natural and 866 mg/L constructed). Total phosphorus (median=0.73mg/L and 1.46 mg/L at natural and constructed, respectively) and Total Kjeldhahl nitrogen (median=0.08 mg/L and 0.03 mg/L at natural and constructed) were also relatively high compared to other habitat types.

We monitored three constructed sites in the Meadow Creek area situated on floodplain habitat initiated in 2016 (FLNRORD) to assess trend in biodiversity over time relative to natural or established wetlands also on floodplain areas. These same sites were repeated in 2017 and will be monitored in 2018 for a total of three years post-construction. Also, in 2016 and 2017, we added a community wetland constructed by the Slocan River Streamkeepers at Crooked Horn Farm, pre and post- restoration. Again, the goal was to monitor trend in invertebrate biodiversity at this site over a three-year period in a descriptive manner.

Table 2: Selected site characteristics from Canadian Aquatic Monitoring Protocol for Wetlands, Field Sheet.

	Lentic_Lacustrine		Lentic_Palustrine		Lotic_Riverine		Lotic_Floodplain			
	Natural (n=10)		Natural (n=5)		Natural (n=7)		Natural (n=12)		Constructed (n=4)	
Variables	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max
% Margin Disturbance (0-50m)										
Disturbance - none	61.0	20-100	76.0	50-100	55.7	0-100	40.0	0-100	17.5	0-50
Disturbance - filling	2.0	0-20	0.0	0-0	0.0	0-0	4.5	0-25	43.8	20-55
Disturbance - grazing	0.0	0-0	0.0	0-0	0.0	0.0	9.0	0-90	0.0	0-0
Disturbance - road	30.0	0-60	24.0	0-50	35.7	0-100	29.5	0-50	25.0	10-50
Disturbance - farm yard	0.0	0-0	0.0	0-0	0.0	0.0	10.5	0-50	11.3	0-25
Disturbance - urban	7.0	0-30	0.0	0-0	1.4	0-10	6.5	0-40	0.0	0-0
Disturbance - mining	0.0	0-0	0.0	0-0	7.1	0-50	0.0	0-0	0.0	0-0
% Zones of wetland										
Emergent vegetation -Visual	46.1	1-90	51.0	25-70	57.9	10-95	77.0	30-95	36.3	10-65
Submergent vegetation- Visual	23.7	0-80	29.0	0-75	27.9	1-50	33.0	0-85	20.3	1 to 30
Open Water- Visual	17.0	0-80	24.0	0-60	11.4	0-40	12.0	0-40	55.0	20-90
% Marginal zone vegetation (0-50m)										
Woody riparian	28.5	0-80	66.0	20-95	28.7	1-90	28.5	0-90	8.3	0-30
Typha	9.0	0-80	0.0	0-0	0.1	0.0	26.0	0-100	0.0	0-00
Scirpus	12.3	0-60	0.0	0-0	4.4	0-30	0.6	0-5	0.0	0-0
Grass/sedge	50.3	18-90	34.0	5-80	53.0	1-90	45.1	1-90	67.1	48-100
% Quadrat vegetation										
Emergent	73.3	50-98	56.0	30-80	61.4	45-100	76.5	50-90	67.5	57.5-75
Floating plants	4.8	0-25	16.2	1 to 30	11.6	0-25	3.5	0-15	0.1	0-0.5
Open water	21.0	0-40	29.0	5-55	27.3	1-55	13.1	43130.0	31.9	25-42.5
Periphyton	13.2	0-40	1.2	0-5	27.3	0-80	21.6	0-90	2.6	0-5
Submergent plants	22.8	0-90	19.2	0-65	33.7	0-100	43.5	0-90	15.9	1-32.5
Woody debris	0.8	0-5	12.8	0-60	13.7	0-20	2.7	0-15	1.6	0-3

Historical Mine sites were excluded n=4

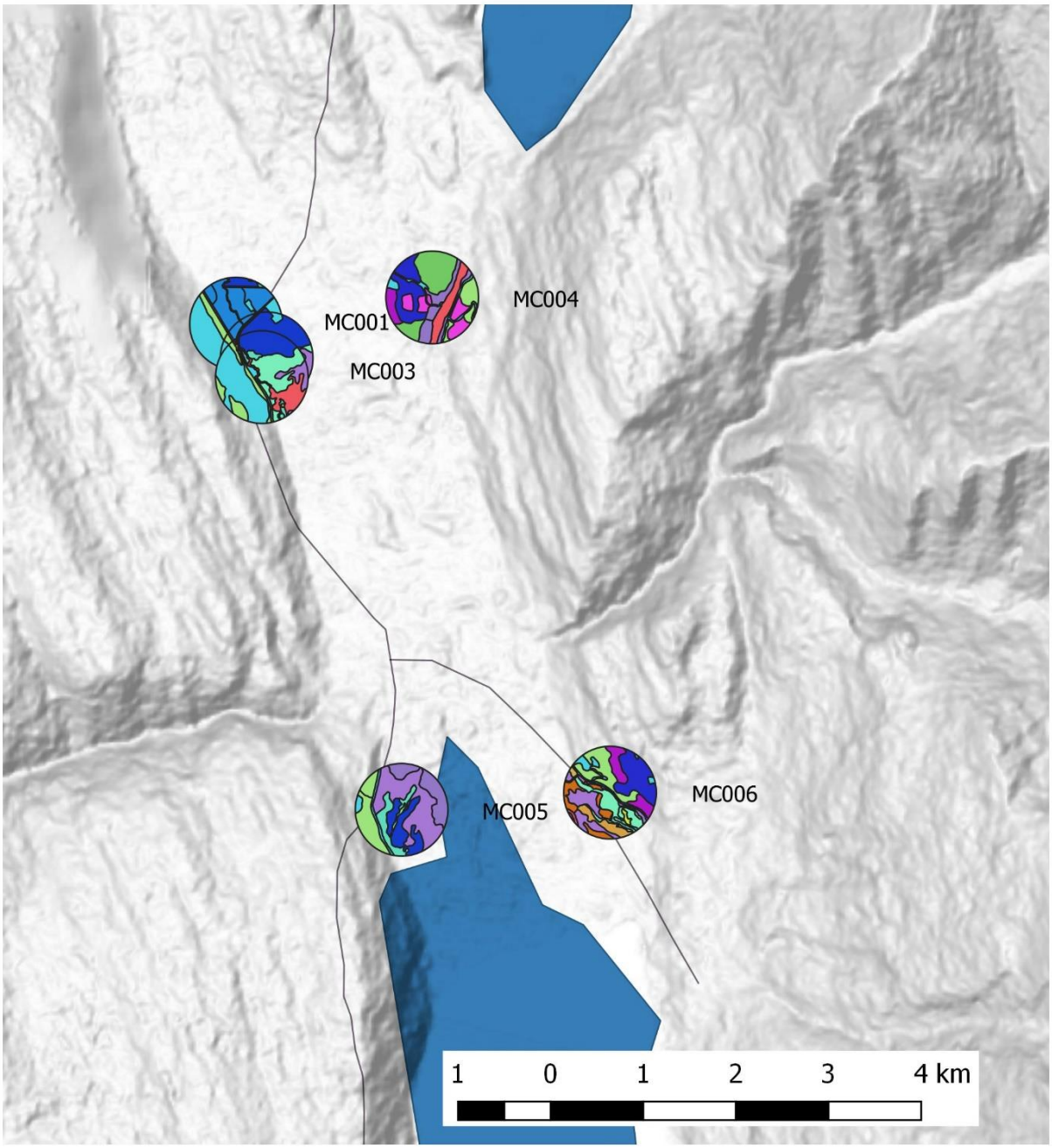

Figure 3. Sensitive Ecosystem Inventory Mapping (SEI) of 500m buffer zones around plot centers in the Meadow Creek area. Restored sites are clustered points (MC001-MC003) and natural sites/reference sites are MC004-MC006. SEI mapping was carried out for all wetland sites.

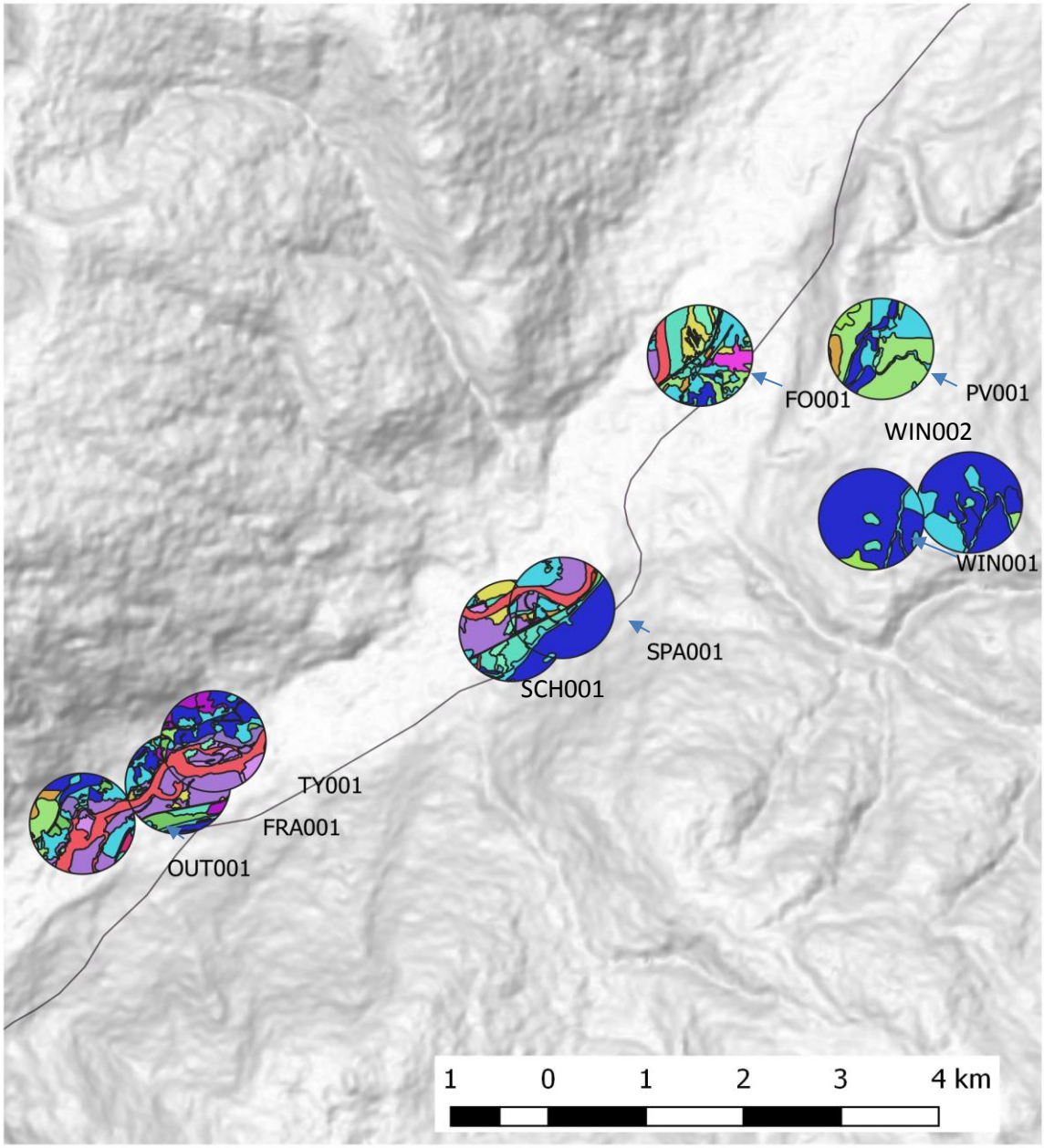

Figure 4. Sensitive Ecosystem Mapping of 500m buffer zones around CABIN plots centers in the Slocan Valley, near Winlaw surrounding the Crooked Horn restoration site (SPA001). Some examples of the natural Riverine_Floodplan wetland sites include OUT001, FRA001, TY001, SCH001, FO001. WIN001, WIN002 and PV001 are upper bench Palustrine sites. SEI mapping products are available for all 34 sites in the Slocan Valley and six locations in Meadow Creek.

Table 3: Selected physiochemical variables from water and sediment by habitat type 2014-2017.

		Lentic_Lacustrine		Lentic_Palustrine		Lotic_Riverine		Lotic_Floodplain		Lotic_Floodplain		
		Natural		Natural		Natural		Natural		Constructed		
Variables	**MRL**	Median	Min-max	Median	Min-max	Median	Min-max	Median	Min-max	Median	Min-max	**Units**
Water												
Chloride	0.1	1.25	<0.10-5.89	1.77	<0.10-2.29	3.285	0.34-5.24	1.08	<0.10-76.9	0.67	<0.10-6.13	mg/L
Sulfate	1	10.8	<1.0-79.3	0.5	<1.0-5.2	2.3	<1.0-11.1	5.75	1.1-18.5	6.2	4.2-21.5	mg/L
Alkalinity, Total as CaCO3		61.55	16-184.7	27	13.7-34.2	30.7	20.52-88.9	99.4	3.23-260	82.6	71-167	mg/L
Carbon, Dissolved Organic	0.5	2.25	1.2-5.18	7.3	3.2-35	4.46	1-9.6	9.7	<0.5-15.2	24.6	12.4-126	mg/L
Nitrogen, Total Kjeldahl	0.05	0.237	<0.05-0.237	0.73	0.35-10.5	0.225	0.18-0.93	0.73	<0.050-1.78	1.46	0.433-9.48	mg/L
Phosphorus, Total as P	0.002	0.014	<0.002-0.021	0.04	0.011-0.82	0.02	0.002-0.05	0.0805	0.0023-0.121	0.0283	.0201-0.10	mg/L
Solids, Total Suspended	2	2	<2-8	9.75	<2-186	8	4-42	6.5	<2-80	4.2	<3.3-16	mg/L
Turbidity		0.7	0.33-1.8	1.5	0.65-47.4	1.19	0.4-15	1.4	0.45-7.52	7.78	2.63-18	NTU
pH		7.46	6.7-8.18	6.5	6-7.58	7.05	6.73-8.2	7.64	6.8-8.29	7.71	7.11-7.87	pH units
Conductivity (EC)		140	16.4-431	39.3	8.6-165	75.3	38.9-169	203.15	79.9-620	182	172-326	uS/cm
Hardness, Total (Total as CaCO3)	5	69.35	<5.0-261	21.5	<5.0-86.7	29.65	17.1-95.7	103.5	41-289	104	90.4-176	mg/L
Calcium, total	2	26.2	<2.0-68.8	7.2	<2.0-23.5	9.7	6.3-26	32.55	12.9-80.7	31.3	27.1-58.8	mg/L
Magnesium, total	0.1	2.8	0.4-21.7	0.8	0.1-6.8	1.35	0.6-7.5	3.65	2.2-21.2	6.6	4.31-7	mg/L
Potassium, total	0.2	0.5	<0.2-0.9	0.3	<0.2-1.5	0.1	<0.2-0.6	1.45	<0.2-4.62	1.5	0.84-4.1	mg/L
Sodium, total	0.2	2.6	0.5-5.56	0.8	<0.2-2.9	1.1	0.5-2.8	3.175	0.8-46.5	1.2	0.51-3.95	mg/L
Sediment												
>75um	0.1	42.6	27.6-82.9	17.5	11.2-52.6	17.5	16.3-60.6	16.3	2.8-81.9	1.7	0.6-58.7	
Size class	Fine/Coarse	Fine		Fine		Fine		Fine		Fine		
Phosphorus	10	680	397-1110	639	262-1090	639	394-1070	826.5	282-1580	866	697-1180	mg/kg
Antimony (Sb)	0.1	1.05	0.13-4.8	0.9	0.2-4.4	0.9	<0.1-3.04	0.525	<0.1-2.24	0.28	0.2-0.55	mg/kg
Arsenic (As)	0.4	3.85	<0.4-8.06	2.2	0.8-4.2	2.2	0.6-10.4	3.425	1.5-15.8	8.31	7.1-9.42	mg/kg
Cadmium (Cd)	0.04	2.085	0.15-7.29	0.89	0.38-5.82	0.89	0.08-4.44	2.29	0.373-7.28	0.326	0.14-0.97	mg/kg
Chromium (Cr),	1	29.65	3.1-69.8	7.5	2.5-14.3	7.5	11.5-29.7	29.15	5.8-43.1	103	10.1-186	mg/kg
Cobalt (Co)	0.1	5.45	0.8-14	1.2	0.4-2.9	1.2	1.3-11	6.3	2.8-16.3	21.5	3.27-41.1	mg/kg
Copper (Cu),	0.2	15.15	5.7-63.1	19.6	2-61	15.15	5.77-45.9	25.15	3.7-38.9	55.4	14.1-69	mg/kg
Lead (Pb)	0.2	16.05	7-204	26.8	7.4-61.3	16.05	3.8-77.4	28.3	5.9-145	22.3	5.2-25.4	mg/kg
Nickel (Ni),	0.4	17.35	3.5-50	7.5	1.1-16.1	7.5	7.7-47.9	19	5.9-40.1	74.8	13.6-106	mg/kg
Silver (Ag)	0.2	0.1	<0.2-0.4	<0.2	<0.2-<0.2	0.15	<0.2-1.4	0.1	<0.20-0.5	0.1	<0.20-0.3	mg/kg
Tin (Sn)	0.2	0.85	0.23-1.6	0.5	0.3-1.3	0.5	0.29-1.4	0.75	0.36-1.5	0.4	0.3-0.83	mg/kg
Vanadium (V)	0.4	32.5	3-105	15.6	3.5-18.5	15.6	9.7-23	27.85	12.3-43.9	65.4	10.7-98.6	mg/kg
Zinc (Zn)	2	88.5	41-298	33	5-63	33	25-275	134	100-494	95.9	4-136	mg/kg

3.2 Macroinvertebrate community by reference habitat type

There were 45 families collected from 2014-2017 in 39 samples at natural sites collected in the Slocan Valley and Meadow Creek areas. Chironomid (midge) larvae were the dominant family and comprised 35% of the abundance on average among all sites collected from 2014-2017. Other dominant Families included: Baetidae (small minnow mayflies), Ceratopogonidae (sandflies), Hyalellidae (amphipod), Sphaeriidae (sphaerid clams), Coenagrionidae (narrow winged damselfly), Planorbididae (ram's horn snails), Dytiscidae (predaceous diving beetle), Lymenaeidae (pond snails) and Naididae (segmented worm). These families together comprised 73% of the abundance at all sites.

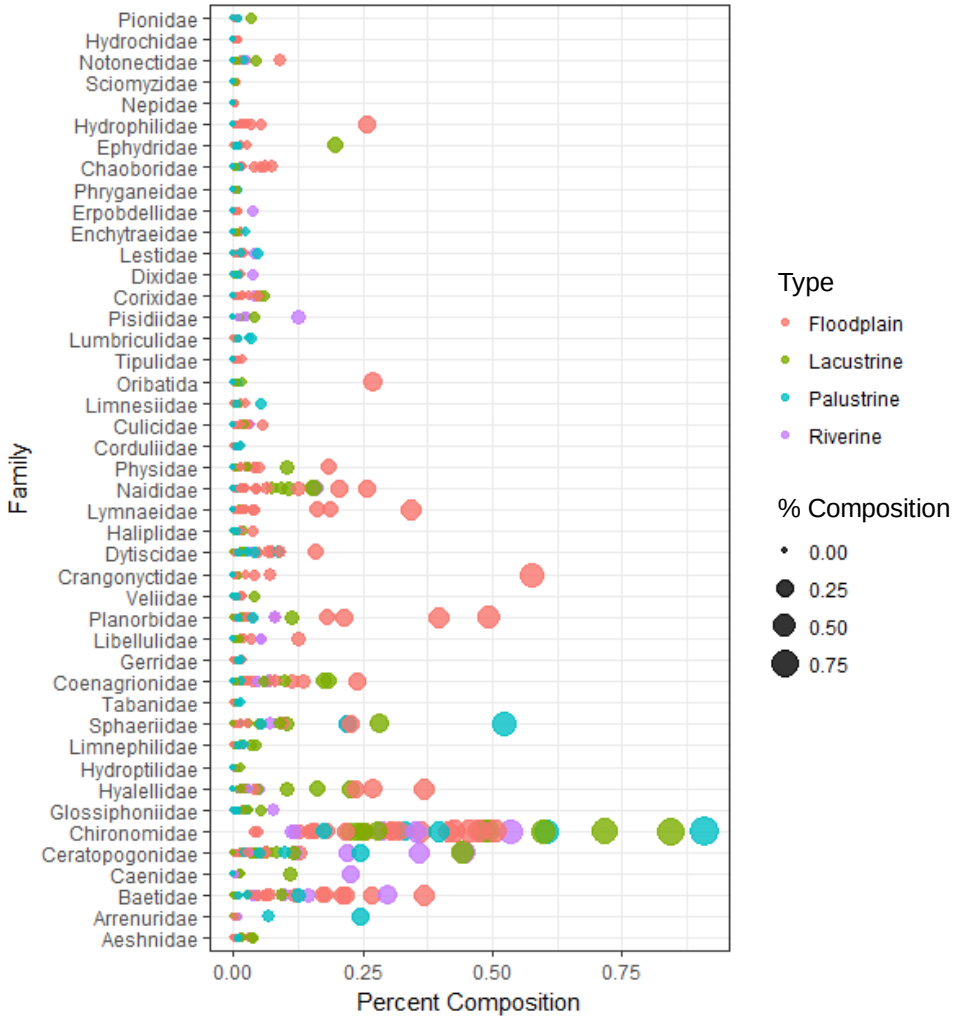

Figure 3. Percent composition of dominant families (occurrence > 5) by wetland type, Lotic_Floodplain (orange), Lentic_Lacustrine (green), Lentic_Palustrine (blue) and Lotic_Stream (purple).

Pirate plots (R Development Core Team. 2018) were used to display the total counts and richness of macroinvertebrates, graphically (Kampstra 2008).

Pirate Plots display 95% Highest Density Intervals (HDIs) of the mean of each group. HDIs indicate that there is a 95% probability that the true population mean falls within that interval. In the pirate plots, 95% HDIs are shown as solid bands around the sample mean. Non-overlapping HDIs provide inference that there is a 95% probability that Lentic_Palustrine sites were lower, sqrt(mean)=16.3, HDIs =4.7-23.1, in count than Lotic_Floodplain sites, sqrt(mean)=40.6, HDIs =27.7-40.6, for least impacted sites pooled from 2015-2017. Lentic_Lacustrine sites had a sqrt(mean) of 31.9 with HDIs of 21.2-40.7 and Lotic_Stream sites had a sqrt(mean) of 22.6 with an HDI of 0-33.6.

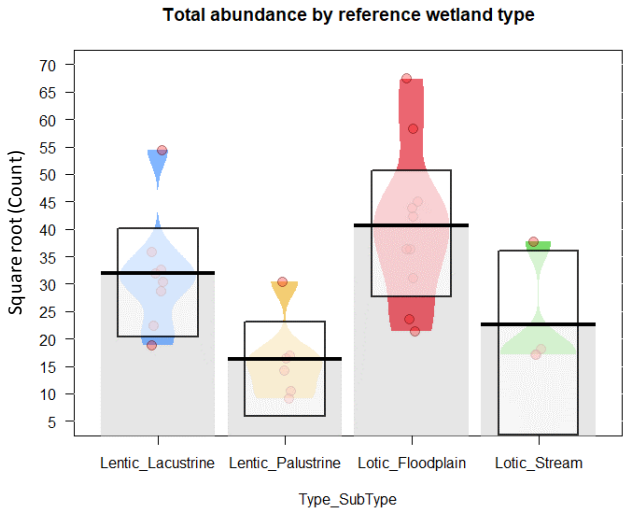

Figure 4. Pirate plots of total count by reference wetland type using BEST (Bayesian Estimation Supersedes the T-Test) with 95% Highest Density Intervals (HDIs) of the mean of each group. White boxes indicate that there is a 95% probability that the true population mean falls within that interval. Horizontal black lines indicate mean. (n= 8, 6, 10 and 4 for Lentic_Lacustrine, Lentic_Palustrine, Lotic_Floodplain and Lotic_Stream, respectively). All data was transformed using a square root transformation (Zar 1984).

Richness calculated from counts of number of total taxa at the genus level demonstrated that Lentic_Palustrine (20.6, HDIs =12.2-26.6) and Lotic_stream sites (21, HDIs =7.0-28.8)) had lower mean richness than Lotic_Floodplain sites (26.3, HDIs =21.6-30.4) and Lentic_Lacustrine sites (29.5, HDIs =23.6-34.6). Overlapping HDIs among all groups was indicative of a wide variation among sites.

Richness (count of genus) were grouped as metrics by (1) Odonata, Ephemeroptera and Trichoptera (OET, dragonflies, mayflies and caddisflies), (2) Chironomidae (chironomids or midges), (3) Annelida (annelids or segmented worms) and (4) Bivalves, gastropods and amphipods (BGA) for each habitat type for these reference wetlands (Figure 6). Chironomids were the most diverse group at the genus level. Counts of chironomid genus taxa comprised 34-69% of the total counts of genus taxa of these groups

among all sites. Other groups including OET, annelids and BGA, together, comprised 31-66% of total counts of genus taxa of this subset of groups at all sites.

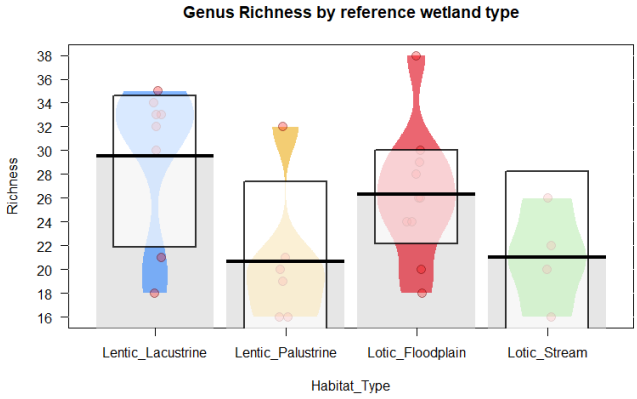

Figure 5. Pirate plots of total count by reference wetland type using BEST (Bayesian Estimation Supersedes the T-Test) with 95% Highest Density Intervals (HDIs) of the mean of each group. White boxes indicate that there is a 95% probability that the true population mean falls within that interval. Horizontal black lines indicate mean. (n= 8, 6, 10 and 4 for Lentic_Lacustrine, Lentic_Palustrine, Lotic_Floodplain and Lotic_Stream, respectively)

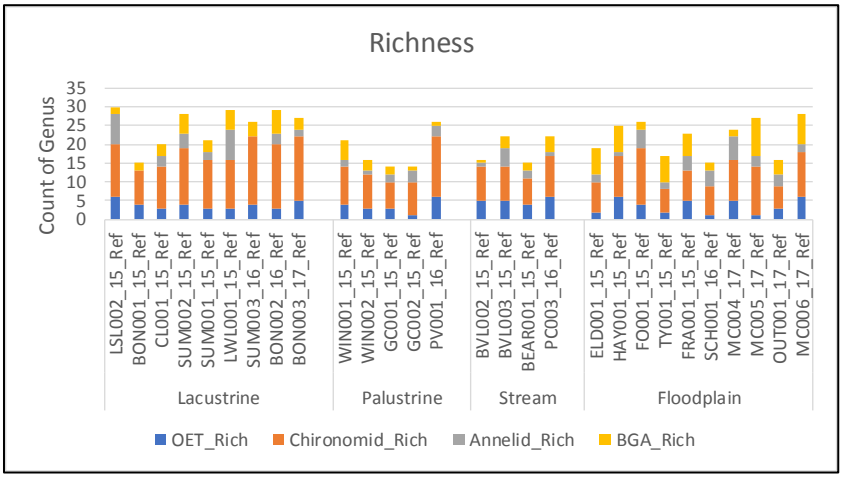

Figure 6. Richness (total count of genus) at all reference sites grouped by metrics monitored from 2015-17 in the Slocan Valley and Meadow Creek areas. OET (blue) = Odonata, Ephemeroptera and Trichoptera (dragonflies, mayflies and caddisflies), Chironomid (red) = Chironomidae (midges), Annelid (grey)= segmented worms and BGA (yellow) = Bivalves, gastropods plus amphipods. Site name is followed by year monitored. Ref =Reference site. Lacustrine =Lentic_Lacustrine, Palustrine=Lentic_Palustrine, Floodplain=Lotic_Floodplain.

3.3 Descriptive statistics of restored sites versus reference sites

Preliminary descriptive statistics of restoration sites (constructed) versus reference sites were examined in a pilot assessment to examine the potential of using the Canadian Aquatic Biomonitoring Protocol for wetlands. The sampling design for this assessment was strongly dictated by limited funding levels and multiple community-oriented goals that created limitations in power

and inference. As such, this assessment should be viewed as an initial assessment relative to large academic studies or governmental efforts. This data is intended for use in management decisions, future planning and discussion around post-restoration monitoring in the Columbia Basin.

Total abundance and richness (count of genus) generally showed increases at restored wetland sites relative to references sites at floodplain wetlands from 2016-2017. Sampling at Crooked Horn Farm restoration site (SPA001) included pre-restoration monitoring in 2016 and post- restoration monitoring in the first year of the project. Three sites in Meadow Creek included one site located on private lands (MC001) constructed in 2015 and two sites located on the Nature Trust Properties (MC002 and MC003) constructed in 2016.

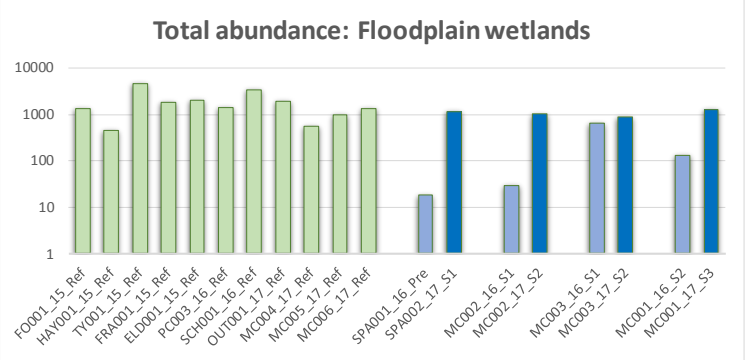

Figure 7. Total abundance at restored wetland sites monitored in 2016 (light blue) and 2017 (dark blue) relative to reference sites (green) in the Slocan Valley and Meadow Creek areas. In 2016 monitoring at Crooked Horn Farm (SPA001) was at a pre-restoration site. MC001 was located on private lands in Meadow Creek and MC002 and MC003 were located on The Nature Trust properties. Ref =Reference site, Pre=pre-restoration, S1, S2 and S3 indicate Season 1, 2, 3, respectively.

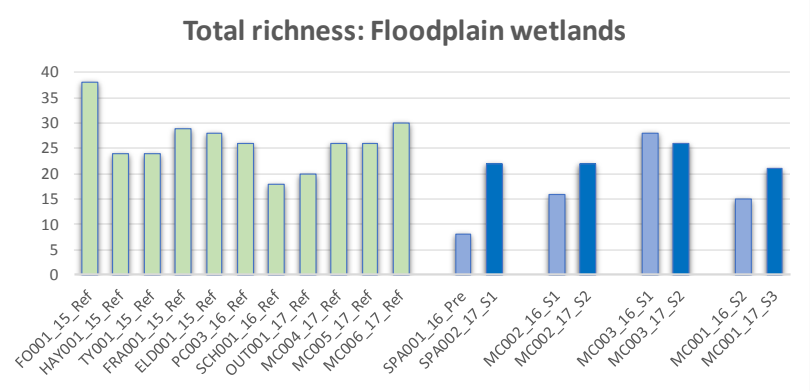

Figure 8. Richness (total count of genus) at restored wetland sites in 2016 (light blue) and 2017 (dark blue) relative to reference sites (green) in the Slocan Valley and Meadow Creek areas. Monitoring in 2016 at Crooked Horn Farm (SPA001) was pre-restoration monitoring. MC001 was located on private lands in Meadow Creek and MC002 and MC003 were located on The Nature Trust properties. Ref =Reference site, Pre=pre-restoration, S1, S2 and S3 indicate Season 1, 2, 3, respectively.

The following analyses were run as an exploration of data on samples collected from 2015-2017. Mean abundance and total richness of restored wetland sites in Meadow Creek and Winlaw (Crooked Horn Farm) were plotted against reference site data for Lotic_Floodplain wetland sites collected from 2015-2017 and displayed as benchmarks.

Highest Density Intervals (HDIs) of the mean of total abundance for each group were plotted for reference sites from 2015-2017, sqrt(mean)=40.6, HDIs =27.7-40.6. HDIs indicate that there is a 95% probability that the true population mean falls within that interval and 95% HDIs are shown as solid bands around the sample mean. Restored wetland sites at Meadow Creek (n=3) monitored in 2016 (sqrt(mean)=14.2 and HDI 0-31.8) and again in 2017 (sqrt(mean)=32.6 and HDI 13-50) showed increases in the total abundance over time.

Highest Density Intervals (HDIs) of the mean of richness (count of genus taxa) at the Meadow Creek restoration sites were plotted for reference sites from 2015-2017 (mean=26, HDIs =22.3-29.7. HDIs) indicate that there is a 95% probability that the true population mean falls within that interval and 95% HDIs are shown as solid bands around the sample mean. Three restored wetland sites monitored in 2016, mean=19.7 and HDI 0-35.1, and again in 2017 mean=23 and HDI 6.5-32.3, showed increases in the total abundance over time.

Sites within the Meadow Creek area may have been subjected to a spraying program using bacteria thuringiensis israelensis (BTi) for mosquito control. BTi is known to have direct negative effects on other insects within the order Diptera including chironomids with possible indirect trophic level effects on Odonata and avian species which rely on Dipterans as a food source. This could potentially depress the abundance of insect Dipterans (Nematocerans) within the restored wetland and natural reference sites. While this is a possible effect, the three reference sites from Meadow Creek monitored in 2017 were centered around the mean total abundance for all sites monitored from 2015-2017, sqrt(mean)=40.6 and within the HDI of 27.7-40.6 for this time.

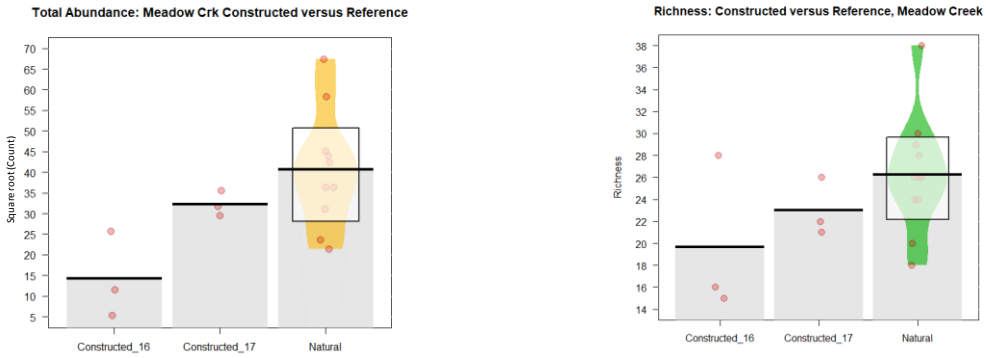

Figure 9. Plots of total abundance and total richness (counts of genus) at restored wetlands at Meadow Creek versus least impacted reference or natural sites using BEST (Bayesian Estimation Supersedes the T-Test) with 95% Highest Density Intervals (HDIs) of the mean of each group. The white box for natural sites indicates that there is a 95% probability that the true population mean falls within that interval. Horizontal black lines indicate mean (n= 3) for repeated sampling at restored wetland sites in 2016 & 2017 and bench mark for least impacted sites for Lotic_Floodplain monitored from 2015-2017 (n=10). Natural sites were pooled for all years (2015-2017) as a benchmark located in the Slocan Valley (n=10) and Meadow Creek (n=3).

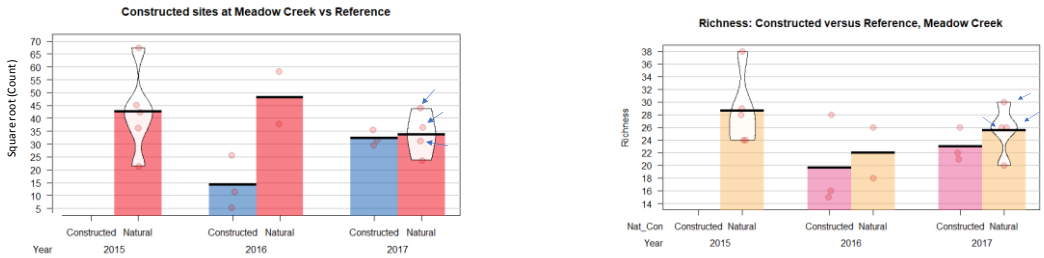

Figure 10. Bean plots of total abundance (sqrt (count)) and total richness (counts of genus) at restored wetland sites in Meadow Creek versus least impacted reference or natural sites. Horizontal black lines indicate mean for repeated sampling at restored wetland sites in 2016 & 2017 and bench mark for least impacted sites for Lotic_Floodplain monitored by year 2015-2017. Restored wetland sites (constructed) and natural sites in Meadow Creek (indicated by blue arrow) are potentially affected by the Meadow Creek mosquito control/BTi spraying program.

Initial sampling from Crooked Horn Farm restored wetland site in Winlaw (n=1) demonstrated an increase in total abundance of invertebrates in the first season of monitoring (sqrt(mean)=33.5 in 2017 relative to pre-restoration monitoring of a temporary canary reed grass dominated pond monitored in 2016 (sqrt(mean)=4.2 (Figure 11). This unreplicated point fell within the Highest Density Intervals (HDIs) of the mean of total abundance for reference sites from 2015-2017, sqrt(mean)=40.6, HDIs =27.7-40.6.

Preliminary results from unreplicated sampling at Crooked Horn Farm in 2017 (Figure 11) showed that richness of 22 genus was greater than pre-restoration sampling that occurred in 2016 (richness of 8 genus). The post-restoration count of genus (22) was at the lower HDI for reference sites from 2015-2017 (mean=26, HDIs =22.3-29.7. HDIs) indicate that there is a 95% probability that the true

population mean falls within that interval and 95% HDIs are shown as solid bands around the sample mean.

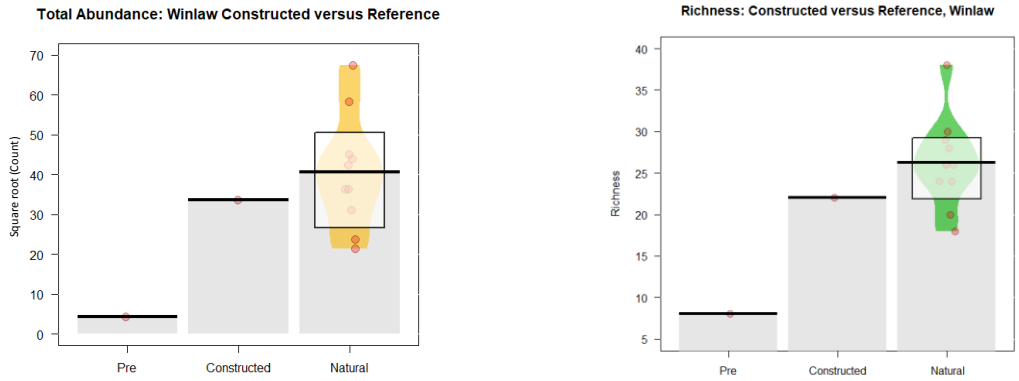

Figure 11. Richness (total count of genus) at restored wetland sites versus reference benchmarks monitored from 2015-17 in the Slocan Valley and Meadow Creek areas. OET plus chironomids = Odonata, Ephemeroptera and Trichoptera (dragonflies, mayflies and caddisflies) plus Chironomidae (midges). Site name is followed by year monitored. Ref =Reference site, Pre=pre-restoration, S1, S2 and S3 indicate Season 1, 2, 3, respectively. Restored wetland sites are indicated by orange (2016) and red (2017) and all other sites are reference sites (green).

Richness (count of genus) were grouped as metrics by (1) Odonata, Ephemeroptera and Trichoptera (OET, dragonflies, mayflies and caddisflies), (2) Chironomidae (chironomids or midges), (3) Annelida (annelids or segmented worms) and (4) Bivalves, gastropods and amphipods (BGA) for Lotic_Floodplain habitats (Figure 6). Chironomids were the most diverse group at the genus level. Counts of chironomid genus taxa comprised 35-57% of the total counts of genus taxa of these groups among at natural sites and 44-75% of total counts of genus taxa at constructed sites. Other groups including OET, annelids and BGA, together, comprised 33-65% of total counts of genus taxa of this subset of groups at natural sites and 25-56% at constructed sites.

Chironomids colonized the Meadow Creek restoration sites within a two-year period based on counts of genus. There was also a 1.7-fold increase in the richness of chironomid genus from 2016-2017 and mean counts of chironomid genus at restored sites monitored in Meadow Creek in 2016 (mean=8, HDI=0-13.6, n=3) and 2017 (mean=13.3, HDI=0.9-21.3, n=3) exceeded mean counts of natural sites mean=9.8, HDI= 7.4-12.1 n=10). In addition, the initial counts of chironomid taxa at the Crooked Horn Farm restored site in pre-restoration sampling of a temporary pond were 4 taxa (n=1) in 2016 and in the first post-restoration season were 7 taxa (n=1) in 2017. This colonization rate likely reflects aerial colonization and a rapid life cycle and dispersal rates of chironomid taxa (Figures 12 and 14-15).

In addition, the initial counts of OET, annelids and BGA taxa at the Crooked Horn Farm restored sites in the pre-restoration year of a temporary pond were 2 taxa (n=1) in 2016 and in the first post-restoration season were 7 taxa (n=1) in 2017. Mean counts of natural sites (mean=12.2, HDI= 9.9-14.0, n=10).

However, other taxa groups as indicated by counts of genus were slower to recover relative to natural wetlands (Figures 13 and 14-15) including: OET, annelids and BGA taxa. For instance, mean counts at restored sites monitored in Meadow Creek in 2016 (mean=5.3, HDI=0-9.9, n=3) were 2017 (mean=6.67, HDI=0-10.0, n=3) were 2.3 (2016) and 1.83 (2017) times lower than mean counts of natural sites (mean=12.2, HDI= 9.9-14.0, n=10). However, there was a 1.25-fold increase in the richness of these taxa from 2016-2017 at the constructed wetlands. In addition, the initial counts of OET, annelids and BGA taxa at the Crooked Horn Farm restored sites in the pre-restoration year of a temporary pond were 2 taxa (n=1) in 2016 and in the first post-restoration season were 7 taxa (n=1) in 2017. Mean counts of natural sites (mean=12.2, HDI= 9.9-14.0, n=10).

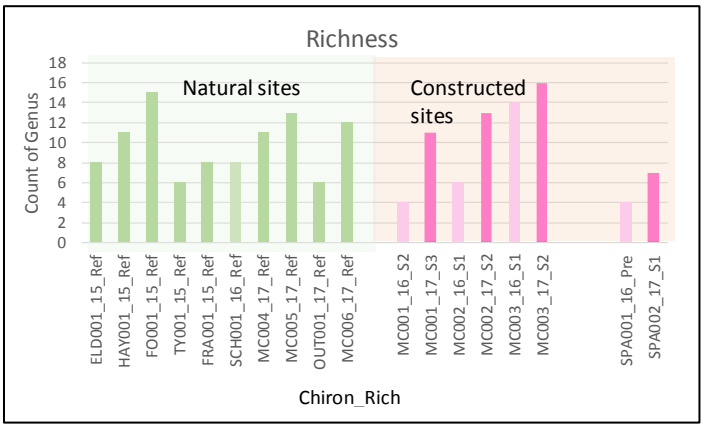

Figure 12. Richness (total count of genus) at Lotic_Floodplain wetland sites for the family Chironomidae (chironomids, midges) monitored from 2015-17 in the Slocan Valley and Meadow Creek areas. Site name is followed by year monitored. Ref =Reference site (green bars). Pre=pre-restoration, S1, S2 and S3 indicate Season 1, 2, 3, post-restoration indicated respectively, 2016 (light pink). 2017 (dark pink). Reference sites are indicated by light green shading and constructed sites are indicated by light orange shading.

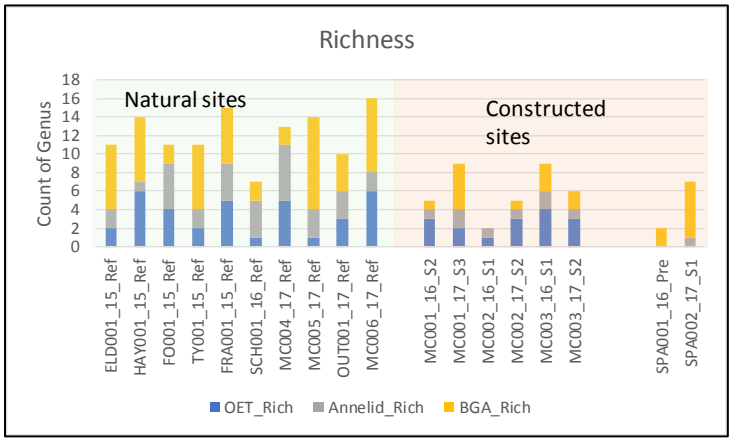

Figure 13. Richness (total count of genus) at Lotic_Floodplain wetlands (non-chironomid groups) monitored from 2015-17 in the Slocan Valley and Meadow Creek areas. OET (blue) = Odonata, Ephemeroptera and Trichoptera (dragonflies, mayflies and caddisflies), Annelid (grey)= segmented worms and BGA (yellow) = Bivalves, gastropods plus amphipods. Site name is followed by year monitored. Ref =Reference site. Reference sites are indicated by light green shading and constructed sites are indicated by light orange shading.

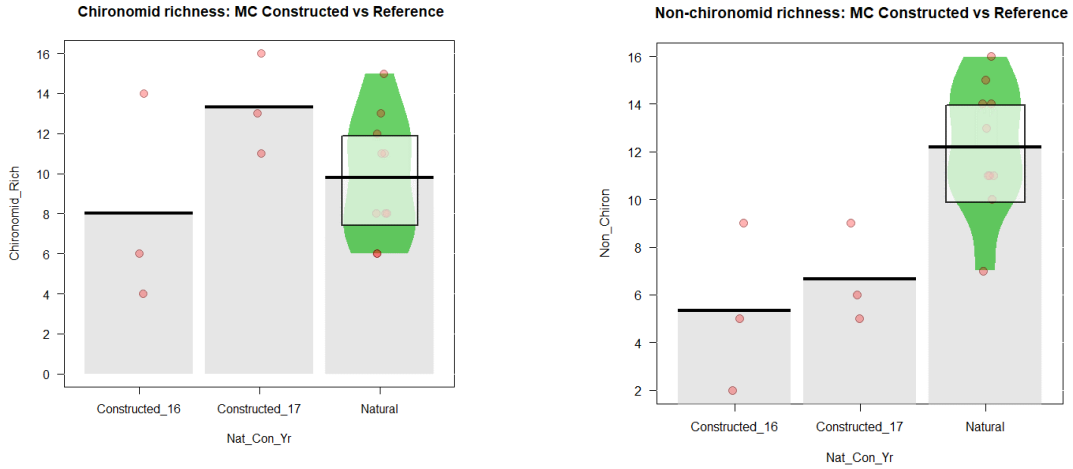

Figure 14. Plots of chironomid and non-chironomid (OET, BGA and annelids) richness (count of genus) at restored wetlands at Meadow Creek versus least impacted reference or natural sites using BEST with 95% HDIs of the mean of each group. The white box for natural sites indicates that there is a 95% probability that the true population mean falls within that interval. Horizontal black lines indicate mean (n= 3) for repeated sampling at restored wetland sites in 2016 & 2017 and bench mark for least impacted sites for Lotic_Floodplain monitored from 2015-2017 (n=10). Natural sites were pooled for all years (2015-2017) as a benchmark located in the Slocan Valley (n=10) and Meadow Creek (n=3).

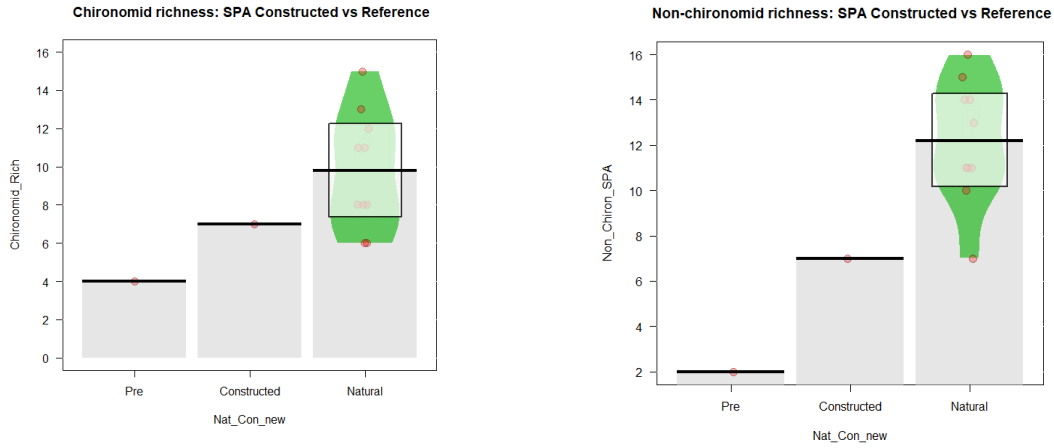

Figure 15. Plots of counts of genus taxa for chironomid and non-chironomid (OET, BGA and annelids) at the restored wetland at Crooked Horn/Spankie Farm (SPA) versus least impacted reference or natural sites using BEST with 95% HDIs of the mean of each group. The white box for natural sites indicates that there is a 95% probability that the true population mean falls within that interval. Horizontal black lines indicate mean (n= 3) bench mark for least impacted sites for Lotic_Floodplain monitored from 2015-2017 (n=10). Natural sites were pooled for all years (2015-2017) as a benchmark located in the Slocan Valley (n=10) and Meadow Creek (n=3).

3.4 Extending the benefits of FWCP restoration through enhancement

Private land owners were contacted and options for participation in wetland science, placing bird, bat boxes, riparian planting on their property were discussed under the current project (COL-F18-W-2405). Enhancement activities were carried at two locations in 2018 on private lands, in addition to, the

wetland enhancements previously carried out at Crooked Horn Farm in 2017 (COL-F17W-1438). The landowners at these sites also participated in the invertebrate sampling program.

This project built on relationships developed under the SSS Riparian Restoration Program and the "Wetland Invertebrate Assessment Tool" (W-F16-10). Maintenance and long-term monitoring were discussed in communications and meetings with landowners. Printed educational materials and brochures provided by BCWF for outreach materials were distributed.

Observations from the first season at Crooked Horn Farm restoration site demonstrated that eight out of thirty small bird boxes were successfully utilized for breeding by violet-green swallows (*Tachycineta thalassina)* and tree swallows (*Tachycineta bicolor*) while other posts and boxes were used for perching (Figure 11). Larger bird boxes and bat houses were not colonized in the first season (2017); however, late spring installation may have precluded use in the first year. These boxes will continue to be monitored in 2018 and new locations will be considered if not utilized in the upcoming season (2018). Observations of breeding or colonization success at current FWCP restoration and enhancement sites will be used to inform further restoration and enhancement work.

In 2018, private lands at two locations (Figures 12-13) were enhanced with posts for six bird boxes at each site appropriate for small cavity nesting birds such as swallows or chickadees and one bat box on each site. This follows riparian restoration work at each of the same locations (Figure 13) carried out from 2014-2015 by the Slocan River Streamkeepers and as well as nearby wetland restoration at Crooked Horn Farm.

Figure 11. Photos of post-restoration monitoring and enhancement at the restored wetland at Crooked Horn Farm near Winlaw, BC from 2017.

Figure 12. Photos of nest box enhancements at private landowner properties placed in May 2018.

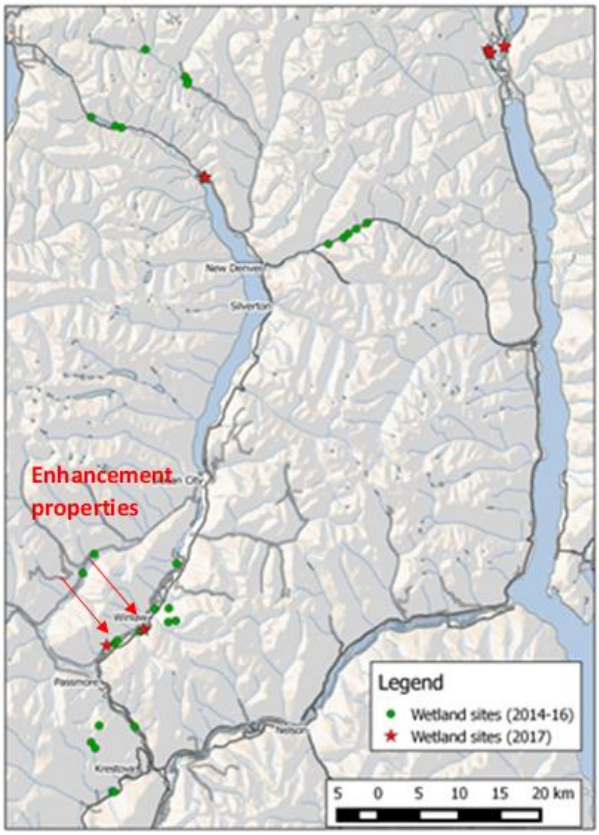

Figure 13. Private landowner enhancements are indicated with red arrows. Overview of wetlands sampled in 2017 (red stars) using Wetland Assessment Tool Methods in 2014-16 (green dots).

4 Conclusions and recommendations

Performance monitoring (pre and post tracking) through time of restored or constructed wetland sites is essential to determine whether additional management actions are required. Monitoring is key to informing the process of adaptive management (long-term improvements) and can inform other restoration efforts within the Columbia Basin.

We developed initial quantitative bench marks to track wetland recovery that can be used to assess wetlands in the Columbia Basin to make management decisions about restoration and conservation. In addition, establishment of reference conditions for wetland and riparian areas was identified in the Fish and Wildlife Conservation Program Columbia Basin Riparian Wetland Action Plan as one of the highest priorities for conservation and management planning. We identified reference sites that can be used as a comparison to restored wetland sites and provide preliminary data on tracking recovery time to reach bench marks following restoration.

Recommendations from this project include actions that encourage the development of a diverse invertebrate community dependent on a diverse plant community including emergent and submerged plants. For example, restoration or enhancement management actions that improve the biodiversity of invertebrates and encourage the development of emergent and submerged plants as habitat for invertebrates (Biebighauser 2011, Mazzacano et al. 2011) could include:

- Removal and replacement of topsoil during wetland creation to speed the recovery of wetland soils and plants.
- Ensuring that soil is not overly compacted to encourage root development of wetland plants.
- Placing woody debris, sticks and plantings within the restored wetlands that encourages nymphs to emerge and perch.
- Planting native species to encourage the speed of the vegetation process.
- Control of invasive plant species.
- Reduction in mowing to the bank or damage to emergent/submerged vegetation
- Communications with the community and the Regional Districts on mosquito control.
- Long term investment to continue improve restored wetlands over time as needed.

Finally, this work supports increased information on the ecological processes of wetlands in the Slocan Valley and North Kootenay Lake leading to meaningful outcomes for the community, funders and supporters. In addition, the Invertebrate Assessment Tool will be used as an early benchmark to evaluate wetland restoration relative to reference or least impacted sites and may address some community concerns (e.g. mosquito issues).

The enhancement and engagement work carried out under this project aids in education and encourages restoration and enhancement actions by private landowners. Ultimately this work will be available for use by community members and agencies who wish implement management

actions such as: wetland enhancement and restoration, land acquisition, forest management, and regional planning.

4.1 Outreach

We participated in participated in numerous community events in the past year (2017-2018) including:

- SWAMP Steering Committee meeting, April 2018
- Living Lakes: Open Source Water Data Hub, Invermere, November 29, 2017
- Tour of Box Lake wetland and poster session in Nakusp for community groups and public in collaboration with Columbia Basin Watershed Network supported by WWF and Loblaws Canada. October, 2017
- Outreach to Nakusp Elementary school in collaboration with Central Kootenay Invasive Species Society (CKISS), Columbia Basin Watershed Network (CBWN) supported by WWF and Loblaws Canada. October, 2017
- Implementation of Private landowner small enhancements/wetland science, June-Sept. 2017
- Slocan River Streamkeeper Society River Float and tour of restored sites, August 2017
- Toadfest, August 2017
- Post-restoration monitoring of restored wetlands in the Slocan Valley and Meadow Creek, July 2017
- BC Wildlife Federation Workshop, Lentic and Lotic Riparian Assessment, July 2017
- Citizen science, Song Bird/Bull Frog Monitoring, May-July 2017
- Wild Days, July-August 2017
- Tour of Slocan River Streamkeepers Society. Crooked Horn Farm Restored Wetland, June 2017
- Steering Committee meeting, May 2017

Figure 13. Outreach at Toadfest , CKISS/CBWN event for Nakusp Elementary School and Box Lake wetland tour in 2017.

4.2 2018 Field season planning

Continued monitoring of the Meadow Creek and Crooked Horn restoration sites in collaboration with FLNRORD is planned.

Matching funds for enhancement work included three successful applications to the Columbia Basin Trust and FWCP (Slocan River Streamkeepers Society and SWAMP) for 2018/2019.

In addition, a successful application was made to Habitat Conservation Trust Fund to examine bat-insect trophic interactions and review newer methods that facilitate the reproductive success of bats. This project will be a local pilot of some newer bat house designs that will be focused within the North American Bat Monitoring (NA Bat) cells around Bonanza wetland (with Meadow Creek as a future site) in collaboration with Valhalla Wilderness Society (VHS), CBWN (Columbia Basin Watershed Network) and Naskusp and Area Community Forest (NACFOR). NACFOR will provide a Co-op student time to help with the project.

We have worked with Copperhead Design, VWS and SSS to price the cost of BrandenBark (Copperhead Design). This enhancement also ties into an on-going effort in collaboration with the BC Bat Action Team and Cori Lausen on bat-insect trophic interactions.

Finally, an application by SWAMP to Wildlife Habitat Canada will be encouraged for maintenance of nest boxes in future years.

An expanded goal in 2018 is to improve habitat in Meadow Creek, Bonanza-Box Lake corridor and the Slocan Valley using small enhancements and community involvement.

Data from our sites will also be leveraged in a variety of other projects:

- Community engagement and education regarding wetland habitats in the Slocan, Meadow Creek and Nakusp Areas.
- Development of CABIN protocols and data sharing on a national level. For instance, feedback and updated information is exchanged with Environment Canada.
- Biodiversity of wetland invertebrates in the Slocan Valley and Meadow Creek areas in cooperation with the Royal BC Museum.
- Quantifying trophic-level interactions and ecological services provided by bats,
- Spatial information on water quantity and quality monitoring data within the Columbia basin with respect to climate change in a Columbia Basin Trust project led by Martin Carver.
- Support of other conservation and restoration work under SWAMP, CBWN, FLNRORD VWS, Wildlife Conservation Society.

5 Acknowledgements

With respect to the present report, Darcie Quamme of Integrated Ecological Research developed the invertebrate protocol design, and conducted field work, statistical analyses, reporting and presentations to community members. Rhia MacKenzie carried out grant applications, data analysis, reporting and outreach. Gregoire Lamoureux identified private landowners interested in enhancement activities and carried out enhancement work. Irene Manley acted as the contract monitor for the monitoring of the restoration sites in Meadow Creek. Richard Johnson of Slocan Solutions served as the contract administrator for FWCP funds and helped to communicate results to local community groups and members. John Boulanger of Integrated Ecological Research provided statistical advice and carried out the statistical analyses that were carried out using SAS. Tyson Ehlers and Ryan Durand carried out plant identifications and Ryan provided GIS site evaluations. Local streamkeepers, Verena Shaw, Mechelle Babic and Jennifer Yeow helped with field work in 2014.

We gratefully acknowledge the financial support of the Fish and Wildlife Compensation Program for its contribution to the Evaluating wetland restoration: Invertebrate Assessment Tool. www.fwcp.ca.

Funding, in-kind support or letters of support have been provided by the Fish and Wildlife Compensation Program, BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, BC Wildlife Federation, Columbia Basin Trust, Selkirk College, Regional District of Central Kootenay, Environment Canada's Canadian Aquatic Biomonitoring Network and Canadian Wildlife Service National Wetland Conservation Fund, the Columbia Basin Watershed Network, the Ministry of Environment, the Columbia Power Corporation and the Royal BC Museum.

The Slocan Wetlands Assessment and Mapping Project (SWAMP) is a collaboration of three societies, Slocan Solutions, Slocan River Streamkeepers and Slocan Lake Stewardship, working with the BC Wildlife Federation, the Fish and Wildlife Compensation Program, Columbia Basin Trust, Selkirk College, Regional District of Central Kootenay, Environment Canada's Canadian Aquatic Biomonitoring Network and Canadian Wildlife Service National Wetland Conservation Fund, the Columbia Basin Watershed Network, the Royal BC Museum.

Members of the SWAMP technical committee have provided valuable feedback and include: Jennifer Yeow, Rhia MacKenzie, Richard Johnson, Irene Manley, Margaret Hartley, Ann Meidinger, Bruce Cottingham, Amy Waterhouse, Doris Hausleitner, Gregoire Lamoureux, Marcy Mahr, Meeri Durand, Neil Fletcher, Terry Anderson, and Martin Carver.

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7 Appendices

7.1 Quality Assurance

7.1.1 Physiochemistry

Forty-five of the fifty parameters analysed by Caro in a duplicate sample collected at SEAT003 on August 16, 2015 were below the RPD limit of 25%. Five of the fifty parameters exceeded an RPD limit of 25% in some cases because one of the values was near detection. Of these, only two parameters including total lead and total manganese in water exceeded the additional criteria that the difference between duplicates should be less than two times the method detection limit when duplicates are less than five times detection (Clark 2013).

In 2016, 47 out 54 water quality parameters analysed from MC001 on July 13, 2016 were below the RPD limit of 25% in duplicate samples.

In 2017, 84 of the 94 parameters analysed by Caro in a duplicate sample collected at MC005 on July 10, 2017 were below the RPD limit of 25%. Of these, eight exceeded the additional criteria that the difference between duplicates should be less than two times the method detection limit when duplicates are less than five times detection (Clark 2013).

In 2016, forty-four of the fifty parameters analysed from a Field Blank collected at Bonanza Creek Marsh (BON001) and analysed by CARO for a full scan of metals and basic water quality parameters were below detection. Six of the parameters were above detection including: Dissolved Organic Carbon, Ammonia, TKN, Total P, Total Dissolved P and Total Nitrogen. Of these, only Total and Dissolved Phosphorus were greater than two times the Method Detection Limit.

In 2017, 14 parameters measured from a field blank collected from MC005 on July 11, 2017 were all below detection except for sulfate which measured 7.1mg/L.

Basic parameters/Field measurements

- Basic parameters only including alkalinity, total acidity, turbidity and specific conductance from 2014-2015 were measured at Passmore Laboratory Ltd.
- Two sets of duplicates collected on August 6, 2016 and analysed for alkalinity, total acidity, turbidity and specific conductance at Passmore laboratories were within the required RPD range of 20-50%.

- Two field blanks collected on July 21 and August 6, 2016 and analysed for alkalinity, total acidity, turbidity and specific conductance at Passmore laboratories were less than two times the method detection limit for all parameters.

These analytical discrepancies did not interfere with the main results. Additional blanks and replicates will be used to verify that there is no contamination during the sampling process.

7.1.2 Technical Report, Rhithron: Macroinvertebrate quality assurance procedures

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METHODS

Sample processing

Twenty macroinvertebrate samples collected for the Slocan Wetland Assessment & Mapping Project (SWAMP) were delivered to Rhithron's laboratory facility in Missoula, Montana on September 2, 2015. All samples arrived in good condition. A chain-of-custody document containing sample identification information was provided by the Integrated Ecological Research (IER) Project Manager. Upon arrival, samples were unpacked, examined, and checked against the IER chain-of-custody. An inventory spreadsheet was created which included project code and internal laboratory identification numbers and was uploaded into the Rhithron database prior to sample processing.

Sorting protocols consistent with CABIN standard operating procedures (Environment Canada: CABIN Laboratory Methods: Processing, Taxonomy, and Quality Control of Benthic Macroinvertebrate Samples: May 2014) were applied to achieve representative subsamples of a minimum of 300 organisms. A Marchant Box was used for subsampling and sorting. Subsampling of each sample began with a random selection of 5 Marchant Box cells. All ostracods, copepods and cladoerans were picked from the first selected cell and placed in a separate vial; these organisms were not assigned a count and did not contribute to the 300-organism target. Subsequent sorting did not include these organisms. The initial 5 cells were completely sorted of all organisms. The contents of each grid were examined under stereoscopic microscopes using 10x-30x magnification. All aquatic invertebrates from each selected grid were sorted from the substrate and placed in 80% ethanol for subsequent identification. Grid selection, examination, and sorting continued until at least 300 organisms were sorted. If more than 50% of the sample was required to obtain the minimum 300 organism count, the entire sample was sorted. All unsorted sample fractions were retained and stored at the Rhithron laboratory.

Organisms were individually examined by certified taxonomists, using 10x – 80x stereoscopic dissecting scopes (Leica S8E) and identified to target taxonomic levels specified by the IER Project Manager, using appropriate published taxonomic references and keys. Chironomids and oligochaetes were carefully morphotyped

using 10x – 80x stereoscopic dissecting microscopes (Leica S8E) and representative specimens were slide mounted and examined at 200x – 1000x magnification using an Olympus BX 51 or Leica DM 1000 compound microscope.

Identification, counts, life stages, and information about the condition of specimens were recorded on electronic bench sheets. Organisms that could not be identified to the taxonomic targets because of immaturity, poor condition, or lack of complete current regionally-applicable published keys were left at appropriate taxonomic levels that were coarser than those specified. Organisms designated as "unique" were those that could be definitively distinguished from other organisms in the sample. Identified organisms were preserved in 80% ethanol in voucher labeled vials (by taxon and life stage), and shipped to the Royal BC Museum in Victoria, British Columbia.

Quality control procedures

Quality control procedures for initial sample processing and subsampling involved checking sorting efficiency. These checks were conducted on 15% of the samples (minimum of 3 samples from the project) by independent observers who microscopically re-examined sorted substrate from each sample. Quality control procedures for each sample proceeded as follows: the quality control technician poured the sorted substrate from a processed sample out and all substrate was re-examined under 10x – 30x magnification. All organisms that were missed were counted and this number was added to the total number obtained in the original sort. Sorting efficiency was evaluated by applying the following calculation, where: SE is the sorting efficiency, expressed as a percentage, n_1 is the total number of specimens in the first sort, and n_2 is the total number of specimens in the second sort.

$$SE = \frac{n_1}{n_1 + n_2} \times 100$$

Quality control procedures for taxonomic determinations of invertebrates involved checking accuracy, precision and enumeration. Three samples were randomly selected, and all organisms re-identified and counted by an independent taxonomist. Taxa lists, and enumerations were compared by calculating a Bray-Curtis similarity statistic (Bray and Curtis 1957), Percent Taxonomic Disagreement (PTD) and Percent Difference in Enumeration (PDE). Routinely, discrepancies between the original identifications and the QC identifications are discussed among the taxonomists, and necessary rectifications to the data are made. Discrepancies that cannot be rectified by discussions are routinely sent out to taxonomic specialists for identification.

Data analysis

Taxa and counts for each sample were entered into Rhithron's customized database software. A taxonomic flat file including site information, taxonomic hierarchy, taxonomic identifications, counts, life stages and other information was formatted in Microsoft Excel.

RESULTS

Results of internal quality control procedures for subsampling and taxonomy are given in Table 1. Sorting efficiency averaged 99.50%. Taxonomic precision for identification and enumeration averaged 98.17% (Bray-Curtis), 2.20% PTD and 0.49% PDE for the randomly selected taxonomic QC samples, and data entry efficiency averaged 100% for the project. These similarity statistics fall within acceptable industry criteria (Stribling et al.

2003). An electronic spreadsheet was provided to the IER Project Manager via e-mail. Voucher labeled vials were shipped to the Royal BC Museum.

Table 1. Results of internal quality control procedures for subsampling and taxonomy 2015-2017.

Rhithron ID	Station ID	Date Collected	Sorting efficiency	Bray-Curtis similarity for taxonomy and enumeration	Percent Taxonomic Disagreement (PTD)	Percent Difference in Enumeration (PDE)
IER15DQ001	FO001	6/29/2015		0.9631	0.0428	0.0062
IER15DQ002	WIN001	6/30/2015				
IER15DQ003	WIN002	6/30/2015				
IER15DQ004	GC001	7/9/2015	0.994			
IER15DQ005	GC002	7/9/2015				
IER15DQ006	CL001	7/9/2015				
IER15DQ007	HAY001	7/10/2015				
IER15DQ008	TY001	7/10/2015		0.9903	0.0165	0.0069
IER15DQ009	FRA001	7/10/2015	0.9911			
IER15DQ010	ELD001	7/13/2015				
IER15DQ011	BEAR001	7/14/2015				
IER15DQ012	SEAT001	7/14/2015				
IER15DQ013	LSL002	7/15/2015	1			
IER15DQ014	SUM001	7/21/2015				
IER15DQ015	SUM002	7/21/2015				
IER15DQ016	BON001	7/21/2015				
IER15DQ017	LWL001	7/29/2015				
IER15DQ018	BVL002	7/29/2015		0.9918	0.0066	0.0016
IER15DQ019	BVL003	7/29/2015				
IER15DQ020	SEAT003	8/6/2015				
IER16DQ001	SPA001	6/2/2016	0.9744			
IER16DQ002	SCH001	6/2/2016				
IER16DQ003	PC003	6/21/2016				
IER16DQ004	SEAT004	6/22/2016				
IER16DQ005	SUM003	6/22/2016	0.9568	0.9877	0.0184	0.0062
IER16DQ006	PV001	6/23/2016	0.9971			
IER16DQ007	BON002	6/27/2016		0.9715	0.0299	0.0015
IER16DQ008	MC001	7/13/2016				
IER16DQ009	MC002	7/13/2016				
IER16DQ010	MC003	7/13/2016		0.9708	0.0405	0.0117
IER17DQ001	SPA002	7/5/2017	1			
IER17DQ002	BON003	7/13/2017	0.982	0.0196	0.0016	
IER17DQ003	OUT001	7/14/2017				
IER17DQ004	MC001	7/6/2017	0.9969	0.9889	0.0193	0.0084
IER17DQ005	MC002	7/6/2017				
IER17DQ006	MC003	7/6/2017	0.9912			
IER17DQ007	MC004	7/6/2017	0.9694	0.0306	0	
IER17DQ008	MC005	7/11/2017				
IER17DQ009	MC006	7/11/2017				

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7.2 Sensitive Ecosystem Mapping of 500m buffer zone

Example data from Sensitive Ecosystem Mapping of 500m buffer zone for constructed sites

Wtld_Name	Id	Area_ha	SE1p	SE1	SE1_area	SE2p	SE2	SE2_area	SE3p	SE3	SE3_area
MC001	19	4.63	10	NS	0.46	0		0.00	0		0.00
MC001	20	0.28	10	NS	0.03	0		0.00	0		0.00
MC001	21	1.97	10	RI:ri	0.20	0		0.00	0		0.00
MC001	22	20.95	10	NS	2.10	0		0.00	0		0.00
MC001	23	15.65	10	CF	1.57	0		0.00	0		0.00
MC001	24	0.20	10	RI:ri	0.02	0		0.00	0		0.00
MC001	25	2.71	10	CF	0.27	0		0.00	0		0.00
MC001	26	1.13	10	RI:ri	0.11	0		0.00	0		0.00
MC001	27	5.43	10	CF:of	0.54	0		0.00	0		0.00
MC001	28	1.66	10	CF:of	0.17	0		0.00	0		0.00
MC001	29	6.38	8	CF:of	0.51	2	WN:ms	0.13	0		0.00
MC001	30	9.08	8	CF:of	0.73	2	WN:ms	0.18	0		0.00
MC001	31	0.33	10	YF:co	0.03	0		0.00	0		0.00
MC001	32	5.01	10	YF:co	0.50	0		0.00	0		0.00
MC001	33	0.57	10	RI:ri	0.06	0		0.00	0		0.00
MC001	34	0.43	10	WN:sp	0.04	0		0.00	0		0.00
MC001	35	0.04	10	WN:ms	0.00	0		0.00	0		0.00
MC001	36	0.98	10	WN:sp	0.10	0		0.00	0		0.00
MC001	37	1.08	6	WN:ms	0.07	4	WN:sp	0.04	0		0.00
MC002	38	2.97	10	NS	0.30	0		0.00	0		0.00
MC002	39	5.62	10	RI:fm	0.56	0		0.00	0		0.00
MC002	40	14.63	6	WN:ms	0.88	4	WN:sp	0.59	0		0.00
MC002	41	25.22	10	CF	2.52	0		0.00	0		0.00
MC002	42	0.95	10	RI:ri	0.09	0		0.00	0		0.00
MC002	43	2.03	10	YF:co	0.20	0		0.00	0		0.00
MC002	44	1.53	10	YF:co	0.15	0		0.00	0		0.00
MC002	45	14.09	10	NS	1.41	0		0.00	0		0.00
MC002	46	1.58	10	RI:ri	0.16	0		0.00	0		0.00
MC002	47	0.08	10	WN:sp	0.01	0		0.00	0		0.00
MC002	48	4.19	8	WN:sp	0.34	2	WN:ms	0.08	0		0.00
MC002	49	1.32	6	WN:ms	0.08	4	WN:sp	0.05	0		0.00
MC002	50	0.55	10	WN:ms	0.05	0		0.00	0		0.00
MC002	51	0.00	10	RI:ri	0.00	0		0.00	0		0.00
MC002	52	0.04	10	RI:ri	0.00	0		0.00	0		0.00
MC002	53	0.70	8	CF:of	0.06	2	WN:ms	0.01	0		0.00
MC002	54	1.61	8	CF:of	0.13	2	WN:ms	0.03	0		0.00
MC002	55	0.43	10	WN:sp	0.04	0		0.00	0		0.00
MC002	56	0.98	10	WN:sp	0.10	0		0.00	0		0.00
MC003	57	2.41	10	NS	0.24	0		0.00	0		0.00
MC003	58	1.49	10	YF:co	0.15	0		0.00	0		0.00
MC003	59	2.82	10	YF:co	0.28	0		0.00	0		0.00
MC003	60	2.50	10	YF:co	0.25	0		0.00	0		0.00
MC003	61	4.00	10	RI:fm	0.40	0		0.00	0		0.00
MC003	62	0.16	10	RI:fm	0.02	0		0.00	0		0.00
MC003	63	9.52	10	RI:ri	0.95	0		0.00	0		0.00
MC003	64	0.70	10	WN:sp	0.07	0		0.00	0		0.00

Example data from Sensitive Ecosystem Mapping of 500m buffer zone for constructed sites, Continued

Wtld_Name	Id	Area_ha	SE1p	SE1	SE1_area	SE2p	SE2	SE2_area	SE3p	SE3	SE3_area
MC003	65	0.11	10	WN:sw	0.01	0		0.00	0		0.00
MC003	66	0.24	10	WN:sp	0.02	0		0.00	0		0.00
MC003	67	2.14	6	WN:ms	0.13	4	WN:sp	0.09	0		0.00
MC003	68	23.08	10	NS	2.31	0		0.00	0		0.00
MC003	69	13.89	6	WN:ms	0.83	4	WN:sp	0.56	0		0.00
MC003	70	12.64	10	CF	1.26	0		0.00	0		0.00
MC003	71	0.36	10	RI:ri	0.04	0		0.00	0		0.00
MC003	72	0.98	10	YF:co	0.10	0		0.00	0		0.00
MC003	73	0.43	10	WN:sp	0.04	0		0.00	0		0.00
MC003	74	0.98	10	WN:sp	0.10	0		0.00	0		0.00
MC003	75	0.09	8	CF:of	0.01	2	WN:ms	0.00	0		0.00
SPA001	323	7.59	10	RI:ri	0.76	0		0.00	0		0.00
SPA001	324	8.93	10	NS	0.89	0		0.00	0		0.00
SPA001	325	7.91	10	NS	0.79	0		0.00	0		0.00
SPA001	326	29.10	5	MF:co	1.46	4	YF:co	1.16	1	NS	0.29
SPA001	327	0.59	5	RI:ff	0.03	5	RI:fm	0.03	0		0.00
SPA001	328	9.01	9	RI:fm	0.81	1	RI:fl	0.09	0		0.00
SPA001	329	0.46	10	WN:sp	0.05	0		0.00	0		0.00
SPA001	330	1.24	10	WN:sp	0.12	0		0.00	0		0.00
SPA001	331	0.60	7	WN:sp	0.04	3	WN:ms	0.02	0		0.00
SPA001	332	0.21	4	RI:fm	0.01	4	WN:sp	0.01	2	WN:sw	0.00
SPA001	333	0.27	10	NS	0.03	0		0.00	0		0.00
SPA001	334	2.98	4	WN:sp	0.12	4	WN:ms	0.12	2	NS	0.06
SPA001	335	0.58	6	HB:sh	0.04	4	WN:sp	0.02	0		0.00
SPA001	336	0.18	10	YF:mx	0.02	0		0.00	0		0.00
SPA001	337	0.34	10	OD	0.03	0		0.00	0		0.00
SPA001	338	0.25	10	HB:sh	0.02	0		0.00	0		0.00
SPA001	339	0.51	7	HB:sh	0.04	3	HB:hb	0.02	0		0.00
SPA001	340	1.25	10	RI:fm	0.12	0		0.00	0		0.00
SPA001	341	0.51	10	WN:sp	0.05	0		0.00	0		0.00
SPA001	342	0.37	10	WN:sp	0.04	0		0.00	0		0.00
SPA001	343	0.17	10	WN:sp	0.02	0		0.00	0		0.00
SPA001	344	1.47	8	RI:fm	0.12	2	WN:sp	0.03	0		0.00
SPA001	345	0.26	5	RI:ff	0.01	5	RI:fl	0.01	0		0.00
SPA001	346	1.41	10	RI:fm	0.14	0		0.00	0		0.00
SPA001	347	0.48	5	WN:sp	0.02	5	YF:bd	0.02	0		0.00
SPA001	348	0.09	7	OD	0.01	3	WN:ms	0.00	0		0.00
SPA001	349	0.33	4	WN:ms	0.01	4	WN:sp	0.01	2	WN:sw	0.01
SPA001	350	1.08	5	MF:mx	0.05	5	YF:mx	0.05	0		0.00
SPA001	351	0.30	10	WN:ms	0.03	0		0.00	0		0.00
SPA001	352	0.07	5	RI:ff	0.00	5	RI:fm	0.00	0		0.00

7.3 All weather poster developed for outreach activities

Figure 14. New weather proof poster for outdoor education activities purchased in 2017.