Integrated Ecological Research

Assessing and enhancing wetland species in the West Kootenays, 2016-2018

Three-year summary of trends
(COL-F19-W-2710)

Prepared for:
Fish and Wildlife Compensation Program

Prepared by:

Darcie Quamme, MSc., R.P.Bio., Integrated Ecological Research
Rhia MacKenzie, BArch., BIT, Slocan River Streamkeepers
Gregoire Lamoureux, Slocan River Streamkeepers Society
Ryan Durand, R.P.Bio., Durand Ecological Ltd., Crescent Valley
And Richard Johnson, P.Eng., Opus Petroleum Engineering

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ABSTRACT

We used both quantitative abiotic and biotic indicators to monitor wetland recovery over a three-year period following wetland restoration. These indicators serve as benchmarks to provide alerts to adaptive management and the iterative decisions making process with regards to management of the progress of wetland restoration sites.

We also 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 and provides a baseline for future comparisons.

An important component of this project is private landowner engagement by participation in our wetland science and enhancement projects fostering stewardship and eventually restoration of private wetlands.

This work aligns with the Fish and Wildlife Compensation Programs FWCP Riparian and Wetlands Action Plan for monitoring and evaluation and habitat-based actions. 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.

In addition, the project helps to support increased knowledge of the ecology of wetlands in the West Kootenays with important management outcomes for the community, funders and supporters.

Recommendations from this project include actions that encourage the development of a diverse macroinvertebrate community providing a prey base for higher trophic levels in wetland ecosystems. Restoration or enhancement actions that increase the biodiversity of macroinvertebrates include: (1) Maintain a native plants and healthy riparian buffer around aquatic ecosystems on public, conservation and private lands, (2) Increase communications with the community and the Regional Districts on nuisance mosquito control, (3) Improve messaging regarding the fact that restored wetlands are a net benefit to the community because of the high percentage of invertebrate predators present in wetlands dominated by sedges and a diverse plant community, and (4) Conserve existing natural wetlands in the Columbia Basin.

Actions that can improve the design and maintenance of constructed wetlands with respect to macroinvertebrates include: (1) Increase the establishment of wetland soils and diverse plant

community, (2) Ensuring that soil is not overly compacted to encourage incorporation of organics, microbial activity and root development, (3) Reconstruct rooting depth by replacement of topsoil, (4), Use of peat overlying compacted soils or clay seal, (5) Planting a diversity of native species during wetland creation and (6) Encourage the colonization of invertebrate predators by ensuring a variety of water levels.

Funding of long-term monitoring, and small improvements to restored wetlands over time is needed to extend the benefits of restoration and enhancement actions within an adaptive management framework. In community-level collaborations, identifying win-win scenarios is crucial to promote effective communication, data sharing and collaboration between community groups, private landowners and stakeholders in the conservation of wetlands, securement of wetland riparian buffers and cost-efficient Integrated Management Plans for mosquitos.

1 Introduction

This project uses the Environment Canada's Canadian Aquatic Monitoring Protocols (CABIN) for wetlands (Env. Canada 2018) to assess previously funded by Fish and Wildlife Compensation Program (FWCP) as the Wetland Invertebrate Assessment Tool (W-F16-10). The goals of the project Assessing and enhancing wetland species in the West Kootenays were 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 through enhancement. The Wetland Invertebrate Assessment Tool was used to monitor restoration recovery in a three-year project at conservation lands in Meadow Creek (The Nature Trust Lands/private lands) and private land at Crooked Horn Farm (COL-F17W-1438) in collaboration with the BC Ministry of Forest, Lands and Natural Resources and Rural Development (FLNRORD), Slocan River Streamkeepers and Slocan Solutions.

The current project has been developed through multi-year funding from the FWCP including projects (Quamme et al. 2018, Quamme et al. 2016 and Quamme 2015) as well as matching funding from the Environment Canada's National Wetland Conservation Program (NWCF), the Columbia Basin Trust (CBT), Columbia Basin Watershed Network (CBWN), in-kind contributions from the Royal BC Museum (RBCM), the FWCP Community Engagement Grant and collaborations with FLNRORD. The project also overlaps with other FWCP-funded projects including: Crooked Horn Farm Restoration (Slocan River Streamkeepers, SRS), Meadow Creek conservation lands (FLNRORD), Snk'mip/Bonanza wetland (Valhalla Wilderness Society) and the Goulden-Thurston Property (SRS).

This project aligns with the FWCP Riparian and Wetlands Action Plan (2012) including: (1) monitoring and Evaluation of the effectiveness of completed wetland and riparian restoration projects (Action No. 11. Obj. 1 Priority 1) and (2) habitat-based actions for the Slocan Valley that strengthen available habitat by creating habitat structures including nest-boxes in this focal area. (Action priorities for the Slocan Valley Action 1. Priority 1).

In addition, the 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 enhancement planning.

2 CABIN wetland sampling procedures

CABIN methods for wetlands (Environment Canada 2018) is a National Canadian protocol developed in Quebec (Tall et al. 2016 and 2008), the Yukon (Baily and Reynoldson 2009), and prairie provinces including Saskatchewan and Alberta (pers com. Adam Martens 2019).

Macroinvertebrates are important indicators of anthropogenic-induced stresses such as habitat degradation, development and contaminants and have been successfully used in bioassessment (Kovalenko 2014, Mazzacano 2011, Uzarski et al. 2017, Archer et al. 2010, U.S EPA 2002 and Apfelbeck 2000).

However, studies of wetland macroinvertebrates in British Columbia are fewer in number except for Adama et al. (2013) and Miller and Hawkes (2013). This study is the first to field test CABIN methodologies for wetlands in British Columbia.

Macroinvertebrate sampling in this study focused on characterizing the macroinvertebrate community that inhabit the emergent zone of the wetlands because macroinvertebrate diversity is often highest in the emergent and submergent vegetation zones of wetlands (De Szalay and Resh 2000).

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.

The objectives of constructed wetlands in Meadow Creek and the Slocan Valley were to provide benefits to amphibians, wetland plants and mosquito predators, and diverse invertebrate and vertebrate communities and designed as wetlands with drawdown rates of 29-73% (McGlynn 2017 and 2018, and data from G. Lamoureux). Our goal was to track constructed wetlands over three years in order to assess wetland recovery relative to reference wetlands. We compared constructed wetlands to previously sampled reference wetlands 2014-2016 and paired wetlands (2017-2018).

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[3]	10
2017	1			4[3]	4[3]	9
2018	1			4[3]	4[3]	9
Total	**9**	**5**	**10[4]**	**18**	**7**	**52**

[1] Wetland classifications from Hansen et al. 2000.[2] Wetland classifications from Env Canada 2018. [3] Repeat visits.
[4] Four sites affected by historical mining not included in the present study.

Clockwise. (1) Dragonfly larvae.(2) Inspecting collection screen. (3) Mosquito sampler (4) Quadrat at Crooked Horn Farm, (5) Collecting a water sample, (6) Collection net.

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

We monitored four constructed sites over a three-year period from 2016-2018 in Meadow Creek (3 sites) and a site in the Slocan Valley near Winlaw to assess trend in biodiversity over time relative to natural or established wetlands also on floodplain areas.

The three constructed wetlands 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. In the Slocan Valley we monitored a wetland constructed by the Slocan River Streamkeepers at Crooked Horn Farm, this included one-year pre-restoration and 2-years post- restoration. The goal was to monitor trend in invertebrate biodiversity in a descriptive manner relative to reference sites. All constructed wetlands were repeat sampled in 2017 and 2018 for a total of two- or three-years post-construction.

A total of 38 reference samples were collected over four years from 2014-2018 (Table 1) from the Slocan Valley and Meadow Creek areas. Reference sites were collected as funding allowed in testing of CABIN for wetland methods. Thus, the first year of the project in 2014 served as a pilot effort to test developing methods. While in 2015 and 2016, sites were selected throughout the Slocan Valley to capture the variance in wetland type. In 2017 and 2018 riverine-floodplain reference sites were selected to pair with constructed sites.

The experimental design of this project was limited by funding levels and changing community-oriented goals over time. However, the primary focus of current analyses was to aid in making adaptive management decisions and planning in regard to wetland restoration projects in the Columbia Basin.

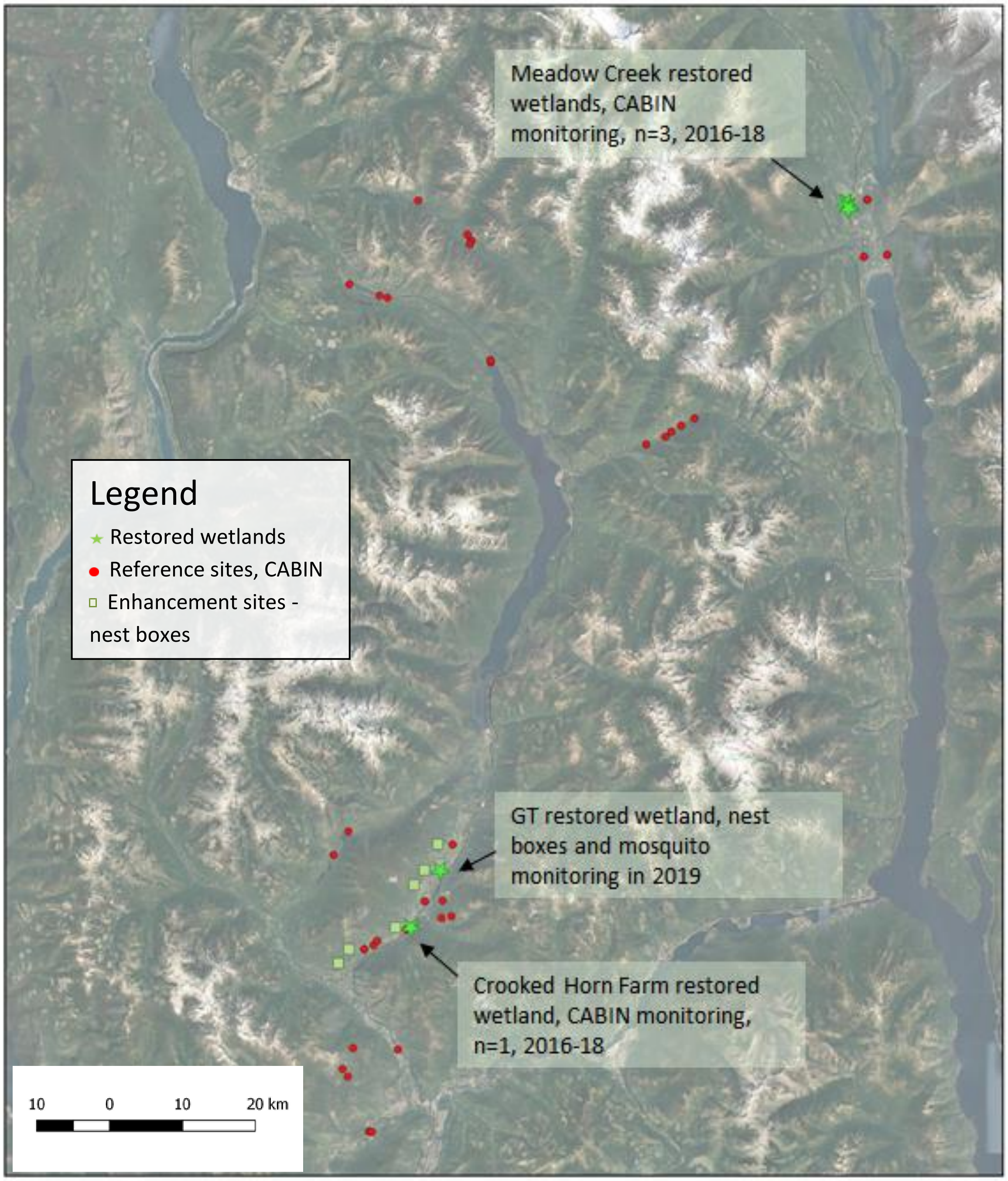

Figure 1: Location of monitoring of constructed wetlands at Crooked Horn Farm and Meadow Creek sites. Red circles indicate CABIN for wetland reference sites. Nest box placement occurred on private lands (green square) as well as Crooked Horn Farm (2017) and GT restoration sites (2019) by Gregoire Lamoureux of Slocan River Streamkeepers Society.

2.1.1 Macroinvertebrate collection

Macroinvertebrates were sampled from the near shore of the emergent zone 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). Emergent plants represented at least 50% of the plot area.

The samples were collected from a 25m^2 m area in a timed three-minute sweep sample (Environment Canada 2018). This technique involves a gentle disturbance of bottom sediments and sweep in a zig-zag pattern within the water column quadrat at each site. Sampling was timed for mid-July where possible to coincide with optimal water levels prior to draw-down and the presence of mature macrophytes at temporary, seasonal wetlands and permanent wetlands. Estimates of the relative proportion of vegetation were made within the quadrat within 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.

Field sheets provided by Environment Canada's CABIN program were used as a basis for field measurements (Environment Canada 2018) 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 as well as other estimates.

2.1.2 Wetland sample processing

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. The sampling net, cup and sieve were carefully check for macroinvertebrates clinging to equipment. Large pieces of plant material were inspected and rinsed and then removed from the net.

In addition, all amphibians were quickly removed from nets following sampling according to 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 wide mouth Nalgene jars with 80% ethanol used as a preservative as recommended by the Royal BC Museum. Sample material comprised no more than 50% of the jar. Ethanol was replaced with fresh 80% ethanol at least once before shipping because water from unsorted organics tends to dilute the preservative over time (Mazzacano 2011, Jepsen et al. 2007). Prior to shipping large piece of vegetation were inspected, rinse and removed in the laboratory if necessary to reduce samples. All samples were checked with a hydrometer to verify preservation at 80% ethanol prior to shipping and Rhithron Associates Inc. (taxonomist) reported that the samples were well preserved when they arrived and reassessed with a hydrometer.

For shipping, all wide mouth Nalgene sample jars were sealed with electrical tape and 'Glad Stretch and Seal'. In addition, the samples were place inside separate zip lock bags to prevent leaks and sample loss in case of breakage. Samples were shipped in coolers with a Chain-of-Custody form.

Clockwise. (1) Blue-listed twelve-spotted skimmer (*Libellula pulchella*) from Crooked Horn Farm. Photo credit Tyson Ehlers.(2) Rhia MacKenzie with a sediment sample. (3) Water chemistry bottles. (4) Darcie Quamme and Jen Yeow collecting a sample. Floating plants within quadrat, Potamagean sp.

Photo 2: Sampling of wetlands in the Slocan River Watershed and Meadow Creek Areas.

Samples collected for the CABIN database were sent to a certified taxonomist that follow procedures outlined in Environment Canada (2012). Rhithron Associates Inc, 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 (See Appendix 6.1.2) were carried out according to CABIN methods (Environment Canada 2018 and 2012). Preservative levels within the sample were maintained at the laboratory until sorting and samples were processed within a few months to prevent accidental degradation of the sample.

In addition, voucher specimens were shipped to the Royal BC Museum in 80% ethanol following identification by taxonomist 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 (Environment Canada 2018, 2012 and 2007).

2.2 Water and sediment physiochemistry

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.

Field measurements of water quality and surface water samples were collected prior to other sampling using methods of Environmental Canada (2018), Duncan and Duncan (2012), Clark (2013) and Cavanagh et al (1997). Metering of water quality included: temperature, pH, conductivity, and dissolved oxygen carried out using field meters.

Surface water and sediment were collected at each site. Samples were taken wearing latex gloves in a non-disturbed area free of large amounts of vegetation prior to completing invertebrate sampling. Surface water samples were collected immediately after field measurements for the following parameters including, low level nutrients (total phosphorus, total Keldhal nitrogen, nitrate, nitrite, and ammonia), alkalinity, major ions (Ca, Mg, Na, K), total suspended solids, sulfate, chlorine, and dissolved organic carbon. A subset of these parameters was monitored in the 2014 pilot study when funding was limited. Grab samples of surface sediment were collected following invertebrate sampling in an undisturbed location using methods described in Environment Canada (2018), Duncan and Duncan (2012), Marvin-DiPasquale (2009), and Clark (2013). Total metals were measured in sediment only in 2014 and in both water and sediment from 2015-2018.

The sample jars were wrapped in bubble wrap and immediately put in a cooler with ice packs and sent to laboratories within 24 hours of collection. Maxxam Analytics Inc. was used to analyse water and sediment samples in 2014 and CARO Analytical Services was used from 2015-2018.

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 field blanks were collected to assess any possible contamination from sample containers, collection at the site, and transport (Clark 2003).

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 Associates Inc. (Section 7.2.1).

2.4 Geospatial measures of landcover

Base orthophotos were collected from DataBC Imagery Web Map Service (DataBC 2019) with a resolution of one-meter ranging in date from 1995-2004 of the Slocan Valley and north Kootenay Lake area. Interpretations of landscape features were limited by a lack of sterio-imagery was not available for these locations. Mapping was completed in ESRI ArcMap 9.3 using heads up delineation adjusted to fit natural features as needed. Mapping procedures followed provincial methods including Ecosystem Classification Methods (Province of BC 2016 and 2010), Terrestrial Ecosystem Mapping (TEM) (RISC 1998), BC Ministry of Environment, Lands and Parks and Ministry of Forests (1998), Standard for Mapping Ecosystems At Risk in British Columbia (RISC 2006), and Mackenzie and Moran (2004). Other sources of information include; BC Vegetation Resources Inventory Mapping, BC Bio geoclimatic Ecosystem Classification, Provincial base layers for lakes, streams, contours and roads.

2.5 Site descriptions and land cover

2.5.1 Reference wetland descriptions

Reference wetlands included wetlands of 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 in order to track the wetland recovery relative to reference wetlands (Table 1).

Lacustrine wetland (n=9) 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 5). Total Kjeldhahl nitrogen (median=0.237 mg/L) was relatively high compared to other habitat types (Table 5).

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 5).

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 5).

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). We used the subset of floodplain wetlands to compare to constructed wetlands created in the lower valley bottoms because of similar elevations.

Reference sites in this study are defined as least-impacted sites with moderate levels of human impacts rather than "in-reference condition". Four sites affected by historical mining were not included in the present study because they were highly impacted. Low to moderate impacts to sites included historical agriculture, forestry, impoundment, nearby roads, residential. But also included possible impacts from road salt at one floodplain site in the Slocan Valley and aerial or ground spraying of Bacillus thuringiensis subspecies israelensis, BTi, for mosquitoes at the six locations in Meadow Creek.

Table 1: Description and classification of reference sites.

	n	Elevation (m)	Dominant emergent	Classification[1]	Locations
Lacustrine	9	534-1515	Sedges, grasses, cattail, horsetail	Marsh (Wm01), Shallow water (OW)	Little Slocan Lakes, Summit Lake, Snk'mip/Bonanza Marsh, Little Wilson Lake, Cooley Lake
Palustrine	5	976-1580	Sedges, grasses, cattail, horsetail	Marsh (Wm01, Wm02, Wm05 and Wm06) or Shallow water (OW).	Mid-bench wetlands in Winlaw Creek woodlot, private land Paradise Road, Goose Creek FSR above Cooley Lake
Riverine, Stream	6	567-1080	Sedges, cattails and grasses	Marsh (Wm01, Wm02) or shallow water (OW)	Pass Creek wetland, Beaver Lakes complex, Bear Lake outflow
Riverine, Floodplain	18	470-558	Sedges, cattails and grasses	Marsh (Wm01, Wm02) or shallow water (OW)	Small ponds and side-channels on the floodplain of the Slocan or Duncan Rivers

[1] Wetland classification, MacKenzie W. and J. Moran (2004)

2.5.1 Constructed wetlands

Floodplain reference sites were more variable in marginal zone vegetation than constructed sites and at times had a higher percentage of *Typha* sp. (mean percent = 32.9) and/or woody riparian (mean=25.7%). The constructed sites were created in open old fields dominated by canary reed grass and planted with sedges (91.1% grass/sedge). The marginal zone vegetation at floodplain reference sites was 41.2% grass/sedge on average

In addition, open water was greater within constructed wetlands (54.4% of wetland zone and quadrat 35.6%) than reference sites (11.8% of overall wetland and 12.9% of quadrat). This was largely due to greater development of the emergent zone at reference sites (80% on average) than at constructed sites (45.6%). Reference sites were also slightly higher in periphyton (16.9% reference, 2.4% constructed) and submerged vegetation (46.1% reference and 27.3% constructed) within quadrats (Table 4).

Floodplain reference sites also likely represented a greater diversity of wetland sizes and hydrology than constructed sites. For instance, two of the reference sites were drawn down in early July (SCH001 and MC005 particularly in 2018) while, for example, larger lacustrine wetlands had more permanent water through to October.

All constructed sites retained water throughout the year (McGlynn 2017 and 2018, data from G. Lamoureux). Two staff gauges on conservation lands at the constructed sites at Meadow Creek indicated that draw down rates at constructed sites were 75% and 77% near approximate time of sampling (July 19, 2017) and 73% and 56% by July 16 in 2018 (for MC002 and MC003, respectively). The lower drawdown, particularly at MC003 in 2018, was due to a higher full pond and flooding in April 2018. At Crooked Horn Farm, draw down rates of 51% by June 29 in 2017 and 29% July 2, 2018 were observed (data from G. Lamoureux).

However, we did observe the development of the emergent zone over the three-year period at constructed sites over time from a thin <1-1m in 2016 to approximately 1-2 m in 2017 and 2->2 m zone in 2018 at Meadow Creek with a similar trend at Crooked Horn Farm.

As well, soils started to develop over the three-year period of monitoring. This was evident particularly at the constructed wetland with the clay liner (MC002) where organics were very low in the center of the wetland in the first two-years, but decomposing plants and soil began to roll into the wetland along the edges and new “lumps” of organic materials were colonized by plants by the third year. There was also an increase % submergent plants within the quadrat from 5% the first season to 25% in year two and then 90% in year three at this site. Likely because the initial starting point was quite low at MC002 relative to the three-year point, it was clear to see the large increase over time.

However, we were unable to document other trends in visual assessments, perhaps, because in part we chose to standardize the plot area but not the plot shape. Our assessment of plant composition and the CABIN protocol were prioritized to characterize macroinvertebrate habitat. In other words, we sampled the best habitat in the first year of sampling due to a thin emergent zone but did not include areas of bare ground. In addition, the variability in observer methods, standardization or locations may have been too high relative to trends. Improvements to the visual assessments of composition within the CABIN protocol are suggested in the recommendations section.

Overall reference floodplain wetlands were higher in conductivity and hardness than upper elevation wetlands (palustrine and riverine) and lacustrine sites. Natural floodplain wetlands had neutral pH (7.6), and median values of conductivity (208 uS/sec) and hardness (96 mg/L).

Constructed floodplain wetlands had neutral pH (7.6) with a median conductivity of 181.5 uS/sec and hardness values of 99.0 mg/L (Table 5). The median of dissolved organic carbon (26.8 mg/L) for constructed floodplain wetlands was higher in than all other habitat types reflective of recent disturbance during the process of restoration (Table 5). Soil phosphorus was the highest at floodplain wetlands (915 mg/kg, natural and 920 mg/kg constructed) relative to other wetland types. Total Kjeldhahl nitrogen (median=0.77 mg/L and 1.46 mg/L at natural and constructed) were also relatively high compared to other habitat types (Table 5).

2.5.1 Land cover

Sensitive Ecosystem Inventory Mapping was carried out previously for 42 sites and mapping products are available for all sites (for example see Figure 2 and 3, Quamme et al. 2018).

In 2019 we carried out mapping of landcover for a subset of five out of 42 of the sites including the four restoration sites and one reference site. We explored the use of the disturbance coding within the provincial Terrestrial Ecosystem Monitoring (TEM) protocols to quantify landcover classes at a site level for these wetlands.

Buffer zones of 100 m and 500 m around each site are available as mapping products because these scales have been shown to be most predictive of biotic indices for plants and birds by Rooney et al. (2012) who assessed scales of 1-6 km. In addition, previous work by Environment Canada CABIN for wetlands (Tall et al. 2008 and 2016) used scales of 100 m for landscape variables. However, in contrast to this work, the influences of wetland cover and impervious cover on wetland quality and benthic invertebrates were found to be important at larger scales of 0.8–1.8 km (Patenaude et al. 2015).

Multi-scale habitat models that select variables at different scales based on predictive power of each habitat layer may also be useful in the future in studies with greater sample size and address some of these issues. For example, foraging bats were most strongly associated with variables measured at smaller spatial scales of 100-500 m although variables were evaluated up to 6 km and some of these were incorporated into the model to improve performance (Bellamy et al. 2012 and 2013). In previous work (Durand 2013, 2014, Quamme et al. 2018), the disturbance variables or stressors were simply categorized as "non-sensitive" or coded as NS. However, this type of coding does not categorize the type of stressors which has been shown to be more predictive of biotic indices than total disturbance (Rooney et al 2012).

Presently, we found that the disturbance codes in the Terrestrial Ecosystem mapping protocol (RISC 1998) could function to quantify stressors at these scales (Figures 4 and 5). Absolute areas in hectares were also converted to percentages to compare between wetlands. In addition, we propose that these disturbance categories could be used to create additional variables used to identify reference sites versus test sites and other purposes required by CABIN. For instance, some of the variables developed by CABIN for streams protocols (see BCMOE 2012) could be calculated from Ecosystem Classification and TEM methods (Section 5.1) and could be adapted for wetlands at the required scale. Additional notes for residential or urban development or other needed codes (X. Miscellaneous, See Appendix 2) were made where required. See RISC (2006) and Durand (2014a, 2014b) for list of codes used to categorize other landcover features under Sensitive Ecosystem Inventory methods (Section 5.1, Table 2).

Constructed sites were confirmed to be designed to minimize mosquito colonization: (1) the slope angle was found to be tapered to prevent pockets of standing water, (2) <20% of the basin was covered by emergent vegetation and that (3) open water was present to minimize mosquito colonization (SWS 2009).

Table 2. Selected disturbance codes from Terrestrial Ecosystem Mapping Protocol

Disturbance	Disturbance codes		
Biotic effects	B	b	b. beaver tree cutting
		d	d. domestic grazing/browsing
Forest Harvesting	L	l	l. land clearing (includes abandoned agriculture)
Plant or site modification effects	M.	g	g. seeded or planted to grasses
		i	i. irrigation
Soil disturbance	S	a	a. cultivation (agricultural)
		f	f. sidecast/fill
		r	r. road bed, abandoned
		t	t. railway, abandoned
		e	e. excavation
Water-related effects	W	d	d. water table control (diking, damming) ** project specific code to include ditching
		i	i. inundation (including temporary inundation resulting from beaver activity)
		s	s. temporary seepage (artificially induced; excludes intermittent seepage from climatic conditions)
Miscellaneous	X		undefined (just X)
		.r	road * project specific code
		.b	buildings (residential, farm, etc.) Lawn and out-buildings *project specific

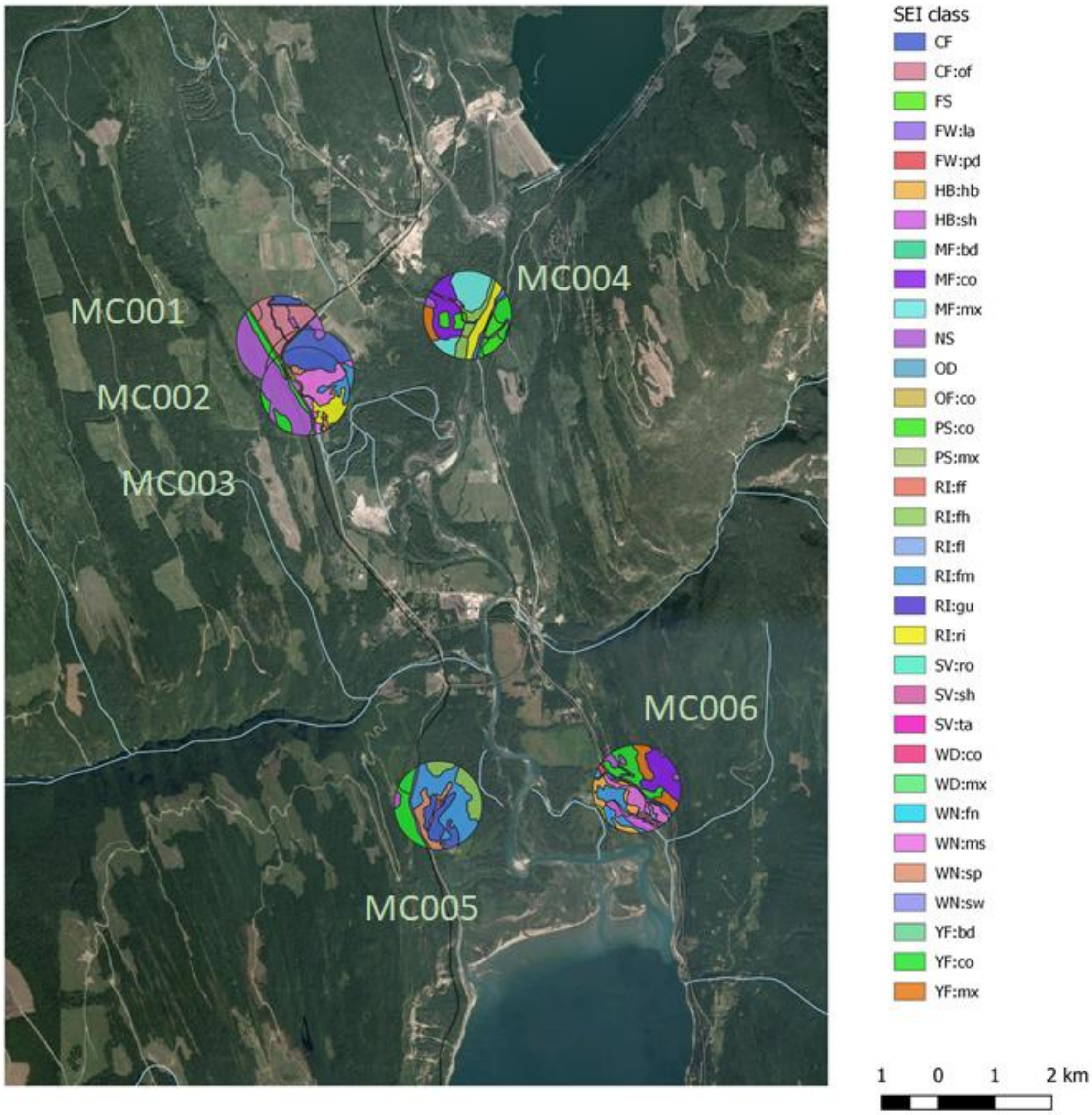

Figure 2. Sensitive Ecosystem Inventory Mapping (SEI) of 500m buffer zones around plot centers in the Meadow Creek area. Restored sites are clustered points (MC001, MC002, MC003) and natural sites/reference sites are MC004-MC006. SEI mapping was carried out for all wetland sites. Scale is in kilometers. See Section 5.1 for Terrestrial Ecosystem Mapping codes.

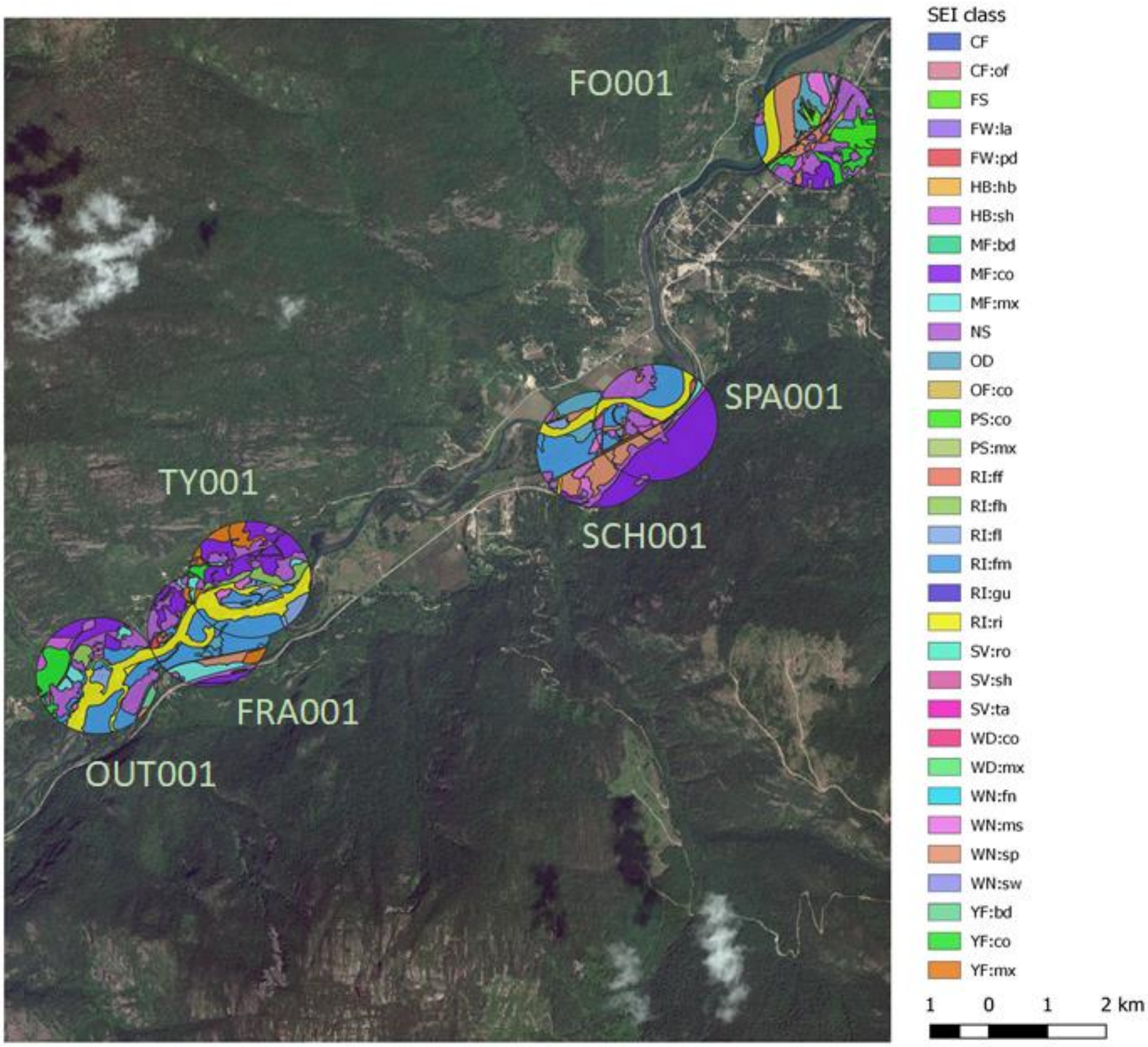

Figure 3. Sensitive Ecosystem Mapping of 500m buffer zones around CABIN plots centers in the Slocan Valley, near Winlaw surrounding the Crooked Horn restoration site (SPA001). Some examples of the natural Riverine_Floodplan wetland sites include SPA001 (Constructed wetland), OUT001, FRA001, TY001, SCH001, FO001 (Reference sites). SEI mapping products are available for all sites. Scale is in kilometers. See Section 5.1 for Terrestrial Ecosystem Mapping codes.

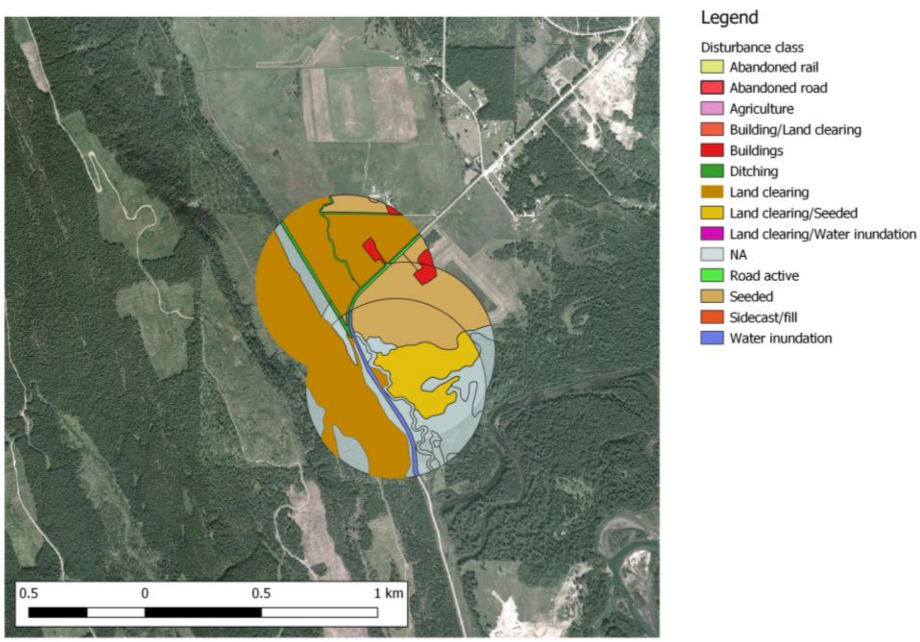

Figure 4. Disturbance coding of 500m buffer zones around plot centers of the constructed sites in the Meadow Creek area. Restored sites on private land (MC001, northernly site) and conservation lands (Sites MC002, MC003 north to south, respectively) are clustered with over lapping areas. See Table 2 for Disturbance codes.

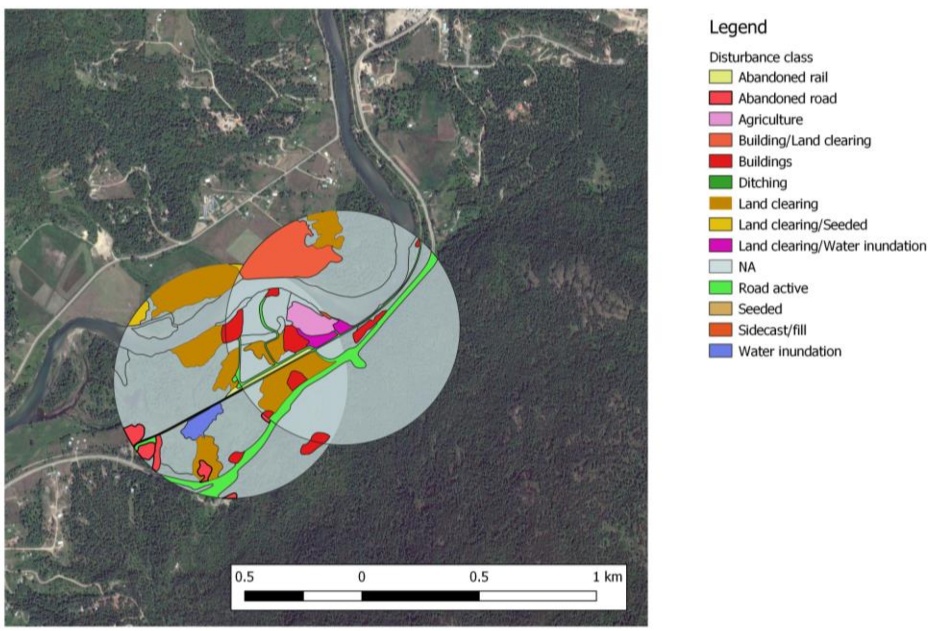

Figure 5. Disturbance coding of 500m buffer zones around plot centers of the constructed sites in near Winlaw BC. The restored site, Crooked Horn Farm (SPA001) is to the east of reference site (SCH001). See Table 2 for Disturbance codes.

Table 3. Summary of percent land use of 500m buffer zones around plot centers of constructed wetlands as a pilot evaluation of use of these metrics.

% Land use		Meadow Creek			Slocan	
		Constructed MC001[1]	Constructed MC002[1]	Constructed MC003[1]	Constructed SPA001[1]	Reference SCH001[2]
Linear	Abandoned road	0.0	0.0	0.0	0.0	30.0
	Abandoned rail	0.0	0.0	0.0	0.6	0.3
	Soil disturbance	0.0	0.0	0.0	0.1	0.0
	Ditching	4.2	1.3	0.4	0.0	0.0
	Active road	1.7	2.4	0.0	5.3	10.0
Forest harvesting	Land clearing	55.4	39.5	29.3	7.5	7.5
Agriculture	Old field	25.0	32.3	33.1	0.0	0.7
	Agriculture, active	0.0	0.0	0.0	2.3	1.0
Urban	Buildings	2.9	1.2	0.0	11.6	20.2
Undisturbed		10.7	23.3	32.4	69.1	28.0

[1]Constructed site, [2]Reference site included because of overlapping buffer

Table 4: Selected site characteristics from Canadian Aquatic Monitoring Protocol for Wetlands, Field Sheet 2014-2018.

Variables in percent area	Lotic_Floodplain Constructed		Lotic_Floodplain Reference		Lentic_Lacustrine Reference		Lentic_Palustrine Reference		Lotic_Riverine Reference	
	Mean	Min-max	Mean	Min-max	Mean	Min-max	Mean	Min-max	Mean	Min-max
% Zones of wetland										
Emergent vegetation -Visual	45.6	10-70	80.0	30-100	46.1	1-90	51.0	25-70	57.9	10-95
Submergent vegetation- Visual	32.3	1-75	34.6	0-85	23.7	0-80	29.0	0-75	27.9	1-50
Open Water- Visual	54.4	30-90	11.8	0-40	17.0	0-80	24.0	0-60	11.4	0-40
% Margin Disturbance (0-50 m)										
Disturbance - none	18.9	0-60	46.2	0-100	61.0	20-100	76.0	50-100	55.7	0-100
Disturbance - filling	48.9	20-60	3.5	0-25	2.0	0-20	0.0	0-0	0.0	0-0
Disturbance - grazing	3.3	0-10	6.9	0-90	0.0	0-0	0.0	0-0	0.0	0.0
Disturbance - road	20.0	10-50	30.4	0-50	30.0	0-60	24.0	0-50	35.7	0-100
Disturbance - farm yard	8.9	0-20	8.1	0-50	0.0	0-0	0.0	0-0	0.0	0.0
Disturbance - urban	0.0	0-0	5.0	0-40	7.0	0-30	0.0	0-0	1.4	0-10
Disturbance - mining	0.0	0-0	0.0	0-0	0.0	0-0	0.0	0-0	7.1	0-50
Percentage of marginal zone vegetation (0-50 m)										
Woody riparian	8.3	0-30	32.9	0-90	28.5	0-80	66.0	20-95	28.7	1-90
Typha	0.6	0-5	25.7	0-100	9.0	0-80	0.0	0-0	0.1	0.0
Scirpus	0.0	0-0	0.4	0-5	12.3	0-60	0.0	0-0	4.4	0-30
Grass/sedge	91.1	70-100	41.1	1-90	50.3	18-90	34.0	5-80	53.0	1-90
Percentage of quadrat vegetation (25m^2)										
Emergent	63.9	35-80	79.6	50-100	73.3	50-98	56.0	30-80	61.4	45-100
Floating plants	0.1	0-1	2.5	0-15	4.8	0-25	16.2	1 to 30	11.6	0-25
Open water	35.6	20-65	12.9	1 to 30	21.0	0-40	29.0	5-55	27.3	1-55
Periphyton	2.4	0-10	16.9	0-90	13.2	0-40	1.2	0-5	27.3	0-80
Submergent plants	27.3	1-90	46.1	0-90	22.8	0-90	19.2	0-65	33.7	0-100
Woody debris	2.1	0-5	3.4	0-15	0.8	0-5	12.8	0-60	13.7	0-20

Historical Mine sites were excluded n=4

Table 5: Selected physiochemical variables from water and sediment by habitat type 2014-2018.

		Lotic_Floodplain Reference		Lotic_Floodplain Constructed		Lentic_Palustrine Reference		Lentic_Lacustrine Reference		Lotic_Riverine Reference		
Variables	**MRL**	**Median**	**Min-max**	**Median**	**Min-max**	**Median**	**Min-max**	**Median**	**Min-max**	**Median**	**Min-max**	**Units**
Water												
Chloride	0.1	1.645	<0.10-14.8	0.75	<0.10-6.13	1.855	<0.10-2.29	2.44	<0.10-5.89	4.97	0.34-76.9	**mg/L**
Sulfate	1	5.75	1.1-18.5	4.3	2.1-21.5	3.1	<1.0-5.2	11	<1.0-79.3	3.6	<1.0-11.1	**mg/L**
Alkalinity, Total as CaCO3		96.8	3.23-427	81.65	71-167	27	13.7-34.2	61.55	16-184.7	34	20.52-175	**mg/L**
Carbon, Dissolved Organic	0.5	9.7	0.029-20	26.8	5.9-126	7.3	3.2-35	2.4	1.2-5.2	5.12	1-11.8	**mg/L**
Nitrogen, Total Kjeldahl	0.05	0.77	<0.050-2.9	1.46	0.433-9.48	0.73	0.35-10.5	0.27	<0.05-0.97	0.24	0.18-1.78	**mg/L**
Phosphorus, Total as P	0.002	0.088	0.0023-0.426	0.0334	0.0201-0.102	0.04	0.011-0.82	0.014	<0.002-0.021	0.023	<0.002-0.129	**mg/L**
Solids, Total Suspended	2	24.5	<2-80	8.6	<3.3-20.5	102	<2-186	3.5	<2-8	11	4-42	**mg/L**
Turbidity		1.7	0.45-19.3	7.41	2.63-61.1	1.5	0.65-47.4	0.7	0.33-1.8	1.8	0.4-4.9	**NTU**
pH		7.625	6.8-8.29	7.61	7.11-7.87	6.5	6-7.58	7.46	6.7-8.18	7.2	6.73-8.2	**pH units**
Conductivity (EC)		208	79.9-738	181.5	155-326	39.3	8.6-165	140	16.4-431	82	38.9-620	**uS/cm**
Hardness, Total (Total as CaCO3)	5	96	41-417	98.95	73.3-176	33.8	<5.0-86.7	77	<5.0-261	31.8	17.1-204	**mg/L**
Calcium, total	2	31.3	12.9-97.9	30.4	21.2-58.8	10.4	<2.0-23.5	26.4	<2.0-68.8	9.9	6.3-55.4	**mg/L**
Magnesium, total	0.1	3.6	1.65-26.3	5.835	4.29-7	0.8	0.1-6.8	2.8	0.4-21.7	2	0.6-15.9	**mg/L**
Potassium, total	0.2	1.45	<0.2-5.4	1.35	0.22-4.1	1.1	<0.2-1.5	0.535	<0.2-0.9	2.85	<0.2-5.1	**mg/L**
Sodium, total	0.2	2.3	0.652-9.79	0.97	0.21-3.95	1.35	<0.2-2.9	2.6	0.5-5.56	1.4	0.5-46.5	**mg/L**
Sediment												
>75um	0.1	12.5	2.8-81.9	6.8	0.6-58.7	17.5	11.2-52.6	42.6	27.6-82.9	27.8	16.3-60.6	
Size class	Fine/Coarse	Fine		Fine		Fine		Fine		Fine		
Phosphorus	10	915	282-1580	920	697-1180	639	262-1090	680	397-1110	500	394-1070	**mg/kg**
Metals Concentrations in sediment												
Antimony (Sb)	0.1	0.49	<0.1-2.24	0.3	0.2-0.55	0.9	0.2-4.4	1.05	0.13-4.8	1.15	<0.1-3.04	**mg/kg**
Arsenic (As)	0.4	3.56	1.5-15.8	8.64	5.98-10.2	2.2	0.8-4.2	4.7	<0.4-8.06	1.2	0.6-10.4	**mg/kg**
Cadmium (Cd)	0.04	2.12	0.373-7.28	0.333	0.14-0.97	0.89	0.38-5.82	2.085	0.15-7.29	1.45	0.08-4.44	**mg/kg**
Chromium (Cr),	1	29.5	5.8-61.5	98.15	10.1-186	7.5	2.5-14.3	29.65	3.1-69.8	23.5	11.5-29.7	**mg/kg**
Cobalt (Co)	0.1	7.8	2.8-16.3	20.05	3.27-41.1	1.2	0.4-2.9	5.45	0.8-14	2.98	1.3-11	**mg/kg**
Copper (Cu),	0.2	28.9	3.7-69.1	57.85	14.1-69	19.6	2-61	15.15	5.7-63.1	11.4	5.77-45.9	**mg/kg**
Lead (Pb)	0.2	22.3	5.9-145	21.45	5.2-25.4	26.8	7.4-61.3	16.05	7-204	36.7	3.8-77.4	**mg/kg**
Nickel (Ni),	0.4	21.4	5.9-52.3	74.8	13.6-106	7.5	1.1-16.1	17.35	3.5-50	9.9	7.7-47.9	**mg/kg**
Silver (Ag)	0.2	0.22	<0.10-0.5	0.19	<0.10-0.3	<0.2	<0.2-<0.2	0.27	<0.050-0.4	0.7545	<0.050-1.4	**mg/kg**
Tin (Sn)	0.2	0.44	0.25-1.5	0.4	0.3-0.83	0.5	0.3-1.3	0.85	0.23-1.6	0.7	0.29-1.4	**mg/kg**
Vanadium (V)	0.4	29.3	12.3-43.9	54.35	10.7-98.6	15.6	3.5-18.5	32.5	3-105	20.4	9.7-23	**mg/kg**
Zinc (Zn)	2	131	100-494	99.45	4-136	33	5-63	88.5	41-298	77	25-275	mg/kg

2.6 Descriptive statistics of constructed versus reference wetlands

We used a descriptive approach to document macroinvertebrates colonizing four constructed wetlands relative to reference sites in order to track the recovery of constructed wetland ponds over a three-year period. The total abundance of Chironomidae (midges), Other Diptera (flies), Segmented worms (Annelida), Arachnids (aquatic mites), Odonata (dragonflies), Ephemeroptera (mayflies), Trichoptera (caddisflies), Amphipods (freshwater shrimp), Gastropod (snails) and Bivalves (Figure 6) at constructed wetlands was compared graphically to reference sites over a three year period at individual constructed wetlands.

Dipterans (flies) were the most abundant group at 78% (n=45) of the sites across all wetland types while 20% (n=10) of the sites were dominated by Amphipods, Gastropods or Bivalves. The sites dominated by Amphipods and Gastropods were and were floodplain reference sites (n=8) or constructed wetlands (n=2). In addition, one upper bench palustrine site was dominated by bivalves and one constructed wetland sample was dominated by Ephemeroptera in the first year.

The total abundance of invertebrates increased exponentially over three years at individual constructed sites (Figure 6) largely due to increases in chironomids, other Diptera, Odonata, and Ephemeropterans and Arachnids (aquatic mites).

Some taxonomic groups were slightly lower in occurrence at constructed wetlands over the three-years of monitoring compared to floodplain reference sites. For example, no trichopterans colonized the constructed wetlands (n=12 samples) over the three-year period while 23% of reference sites documented the presence of trichopterans. In addition, twenty-five percent of samples collected at constructed wetlands (n=12) showed the presence of amphipods in comparison to 50% of floodplain reference sites (n=14). The presence of gastropods was found at 75% of the samples from constructed wetlands in contrast to 100% of the floodplain references sites (n=14). Finally, forty-one percent of samples (n=12) from constructed wetlands showed the presence of bivalves while 71% of the floodplain references samples showed the presence of bivalves (n=14).

MC005 was drawn down in 2018 and perhaps should be considered an outlier. We could not collect an unaffected water quality sample at the time of collection, so this water sample was flagged.

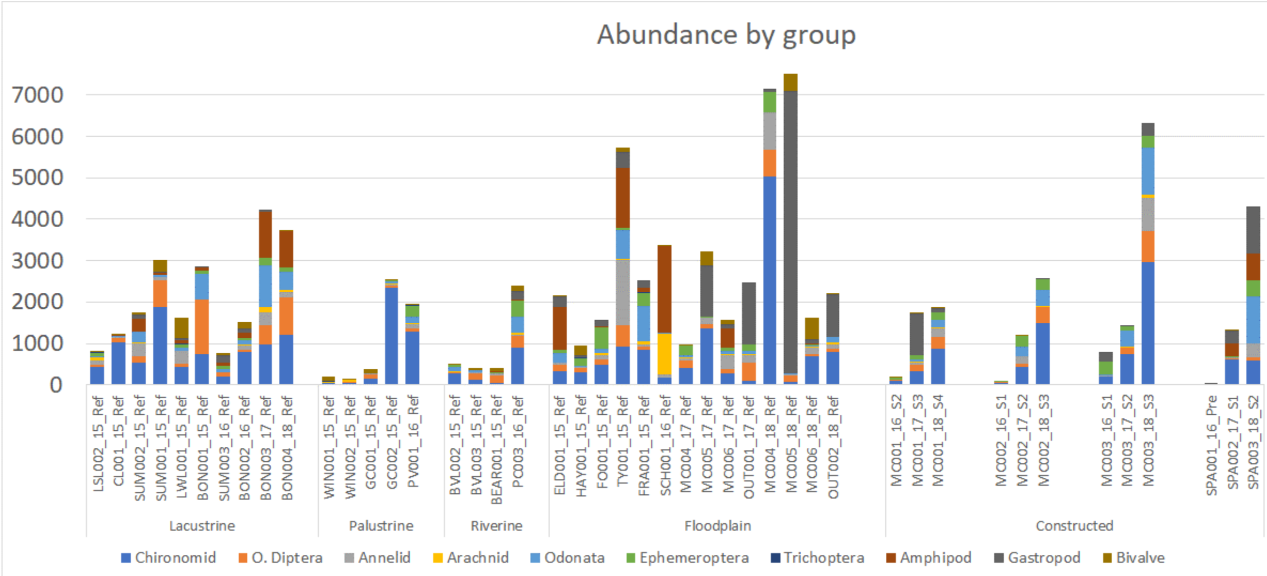

Figure 6. Abundance at wetlands monitored from 2015-18 in Meadow Creek and Slocan area. Chironomidae (midges) is indicated by medium blue, Other Diptera (flies) indicated by orange, Segmented worms (Annelida) indicated by grey, Arachnids (aquatic mites) indicated by yellow, Odonata (dragonflies) indicated by light blue, Ephemeroptera (mayflies) indicated by green, Trichoptera (caddisflies) indicated by dark blue, Amphipods (freshwater shrimp) indicated by red, Gastropod (snails) indicated by dark grey and Bivalve by brown. Site name is followed by year monitored. Ref =Reference site.

Total richness increased over the 3-year monitoring period at all constructed wetlands by 1.1 - 2.4 fold at the Meadow Creek wetlands and 2.7-fold from pre-restoration monitoring at Crooked Horn Farm (Figure 8). Among the Meadow Creek sites, mean genus richness increased from 18.3 (SE=5.36) in 2016 to 28 (2.51) in 2017 and 30.7 (SE=1.86) in 2018 at the Meadow Creek sites. Richness at the Crooked Horn Farm increased from 9 genera in 2016 (pre-restoration) to 18 in 2017 and 25 in 2018 (post-restoration). This compares to the mean richness of 31.2 (SE=2.2) for floodplain reference sites and 30 (SE=1.3) for all reference sites for all wetland types.

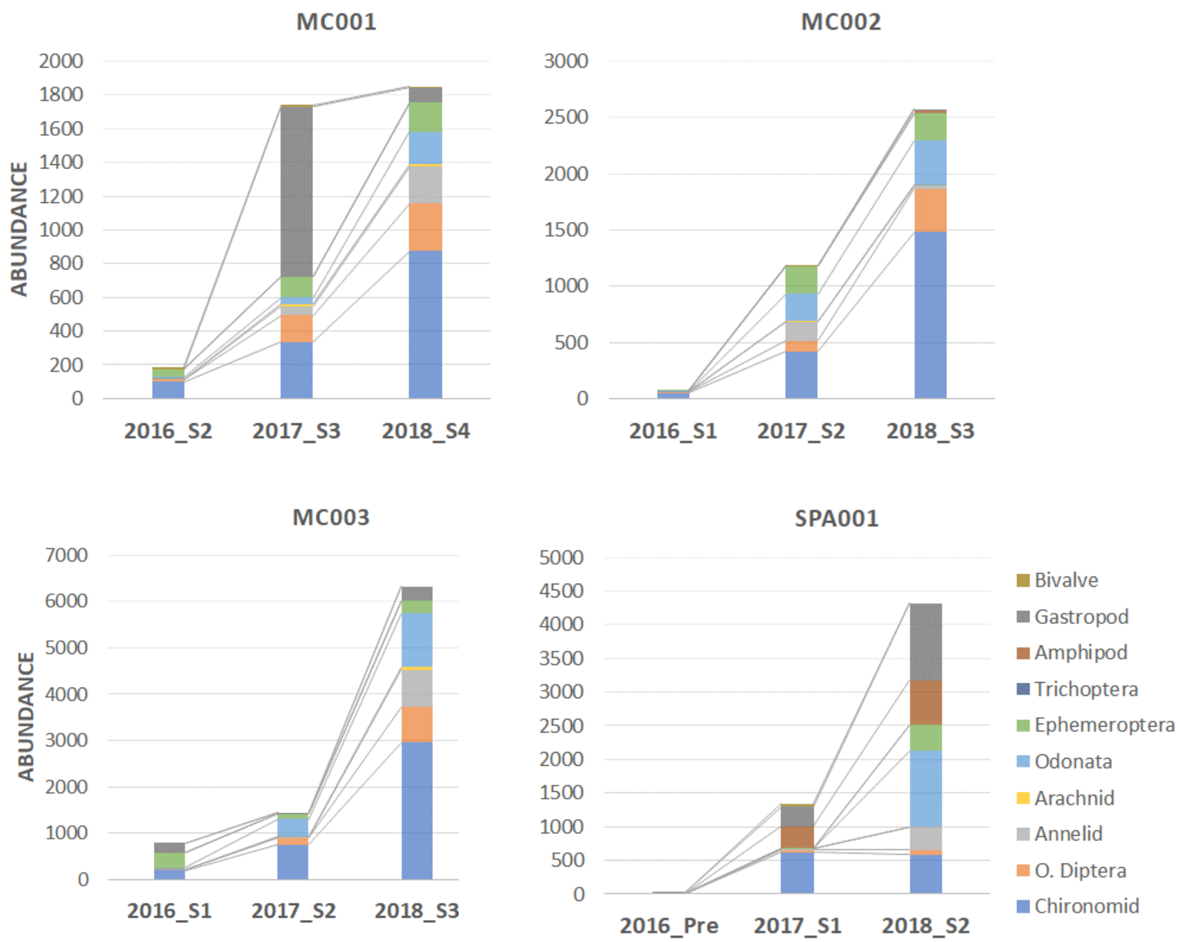

Figure 7. Abundance by group at four constructed wetland sites monitored from 2016-18 in the Meadow Creek and Slocan areas. S1, S2 and S3 indicate Season 1, 2, 3, respectively. Pre indicates pre-restoration. O.Diptera = Other Diptera. Chironomidae or midges is indicated by medium blue, Other Diptera (flies) indicated by orange, Segmented worms (Annelida) indicated by grey, Arachnids (aquatic mites) indicated by yellow, Odonata (dragonflies) indicated by light blue, Ephemeroptera (mayflies) indicated by green, Trichoptera (caddisflies) indicated by dark blue, Amphipods (freshwater shrimp) indicated by red, Gastropod (snails) indicated by dark grey and Bivalve by brown. Site name is followed by year monitored. Ref =Reference site.

Richness (count of genus) were grouped as metrics by (1) Bivalves, gastropods and amphipods (BGA), (2) Annelida (annelids or segmented worms), (3) Other Diptera, (4) Chironomidae (chironomids or midges), 5) Odonata, Ephemeroptera and Trichoptera (OET, dragonflies, mayflies and caddisflies) (Figure 8).

Chironomids were the most diverse group at the genus level comprising 21-53% of the number of genus across all wetland types among these groups while total dipterans (flies including chironomids) comprised 39-75%. Other groups combined comprised 25-61% of the total number of genus across all wetland, respectively.

At the subset of floodplain reference sites, counts of the number of total dipteran genus (chironomids plus other dipterans) comprised 39-72% of the total counts relative to constructed sites 50-75% of total counts were dipteran on average. Other groups including OET, annelids and BGA, together, comprised 28-61% of total counts at reference sites and 25-50% at constructed sites over the 3-years.

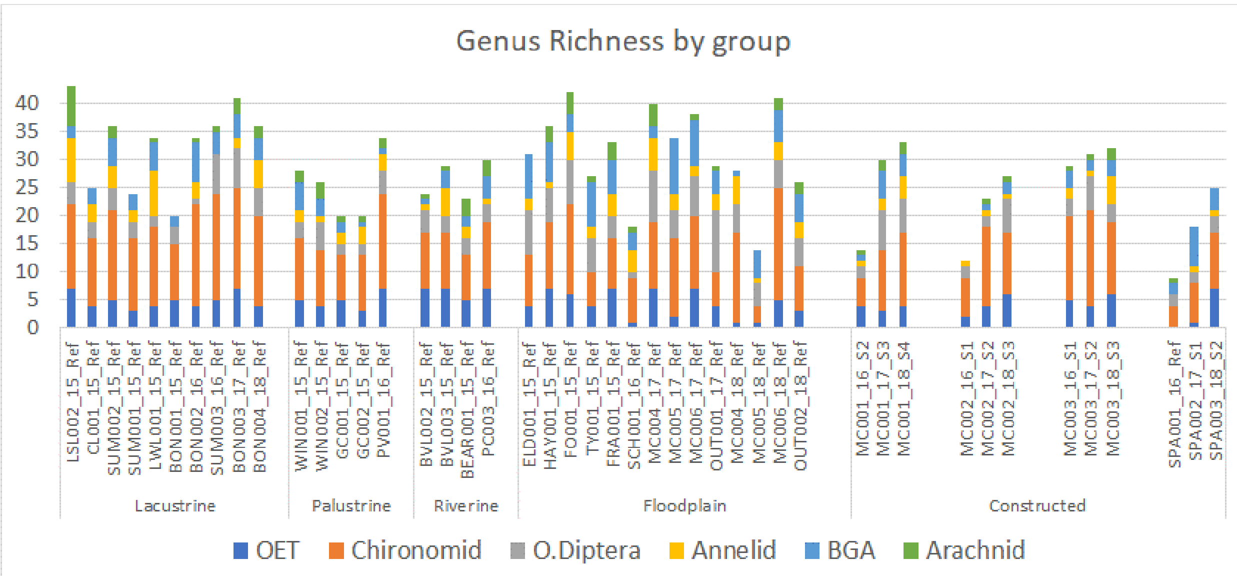

Figure 8. Richness (total count of genus) at wetlands monitored from 2015-18 in Meadow Creek and Slocan areas. OET (dark blue) = Odonata, Ephemeroptera and Trichoptera (dragonflies, mayflies and caddisflies), Annelid (grey)= segmented worms and Annelid (yellow), BGA (light blue) = Bivalves, gastropods plus amphipods and Arachnid (green)= Aquatic mites. Site name is followed by year monitored. Ref =Reference site.

Total richness increased over the monitoring period at all constructed wetlands by 1.1 - 2.4 fold at the Meadow Creek wetlands and 2.7-fold from pre-restoration monitoring at Crooked Horn Farm (Figure 8 and 9). Among the Meadow Creek sites, mean genus richness increased from 18.3 (SE=5.36) in 2016 to 28 (2.51) in 2017 and 30.7 (SE=1.86) in 2018 at the Meadow Creek sites. Richness at the Crooked Horn Farm increased from 9 genera in 2016 (pre-restoration) to 18 in 2017 and 25 in 2018 (post-restoration). This compares to the mean richness of 31.2 (SE=2.2) for floodplain reference sites and 30 (SE=1.3) for all reference sites for all wetland types.

The rate of colonization of by macroinvertebrate groups varied among wetlands. For instance, MC003 was colonized by 29 genera by the time we sampled in July of the first season which was over double the other two wetlands in Meadow Creek in the first year of sampling. Variations in colonization rates at the genus level could result from (1) variations of macroinvertebrate habitat quality at the time of sampling, (2) variations in the recovery of emergent vegetation recovery (such as plantings which may speed recovery or the presence or absence of a clay liner which may compact rooting material and delay recovery), (3) a bias toward sampling the best habitat in the first year because of bare ground in some locations and non-random site choice, and (4) differences in distance from source of colonizing macroinvertebrates.

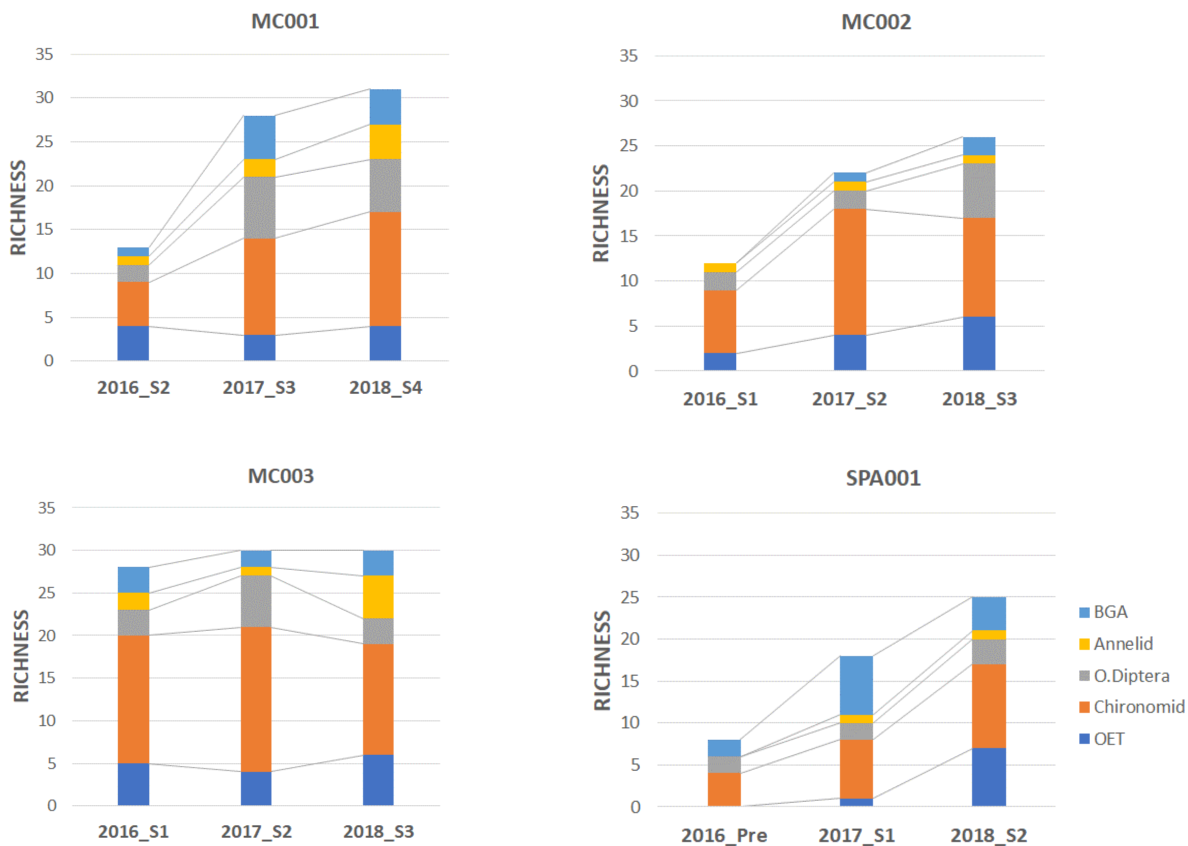

Figure 9. Genus richness by group at four constructed wetland sites monitored from 2016-18 in the Meadow Creek and Slocan areas. S1, S2 and S3 indicate Season 1, 2, 3, respectively. "Pre" indicates pre-restoration. O.Diptera = Other Diptera. OET (dark blue) = Odonata, Ephemeroptera and Trichoptera (dragonflies, mayflies and caddisflies), Annelid (grey)= segmented worms and Annelid (yellow), BGA (light blue) = Bivalves, gastropods plus amphipods and Arachnid (green)= Aquatic mites

The abundance and total richness (count of genus) of constructed wetland sites in Meadow Creek and Winlaw (Crooked Horn Farm) were plotted against reference site data for the subset of Lotic_Floodplain wetland sites collected from 2015-2018. Total abundance and richness showed increases at all restored wetland sites over the period of 2016-2018. Sampling at Crooked Horn Farm constructed wetland (SPA001) included pre-restoration monitoring in 2016 and post-restoration monitoring in the first two years of the project.

At Meadow Creek, the total abundance of invertebrates increased by 10-fold on average (n=3) with mean values increasing from 396 (standard error, SE=243) in 2016, the first year of monitoring, to 1599 (SE=135) in 2017 and 4160 (SE =1668) in 2018 (Figure 10). As a benchmark, total abundances varied from 785-7480 in all reference samples (mean= 2756.2, n=17, SE=1102.6). There was a 10-fold increase at MC001, 30-fold increase at MC002 and 8.5-fold increase at MC003 over three years. The community wetland at Crooked Horn Farm restored by Slocan River Streamkeepers Society showed similar trends including a 144-fold increase in total abundance in 2018 relative to 2016 (pre-restoration) and 3.4-fold increase from 2017 to 2018.

From 2016-2018, the total richness of macroinvertebrates increased by 1.6-fold on average with mean values over this time period of 16 (standard deviation, SE=5.0) in 2016, 23 (SE=1.2) in 2017 and 26 (SE=2.4) in 2018 (Figure 10). This response included a 2.3-fold increase at MC001, 2.1-fold increase at MC002 and 1.1-fold increase at MC003 over three years. Crooked Horn Farm (n=1) showed similar trends 3.1-fold increase in total abundance in 2018 relative to 2016 (pre-restoration) and 1.3-fold increase from 2017 to 2018. The number of total genus varied from 10-36 in all reference samples as a benchmark (mean= 26.1, n=17, SE=4.0).

Individual constructed wetlands varied in response rate in total abundance and richness in part due to (1) the magnitude of trend from the time of construction to the time of monitoring in July 2016 as well as (2) the trend over the three-year period. The wetlands were created in old fields and there were no macroinvertebrates present at the time of construction, in the case of Meadow Creek wetlands and few at the pre-restoration site at Crooked Horn Farm (Figure 10).

MC003, for example, showed an early response from the time of construction to July in the first year and tended to show a higher response over three years. The other wetlands monitored including MC001 and MC002 showed slower colonization rates but nearly caught up to MC003 over time (Figure 7). However, the magnitude of the response was lower because of the response in the first season by early colonizers.

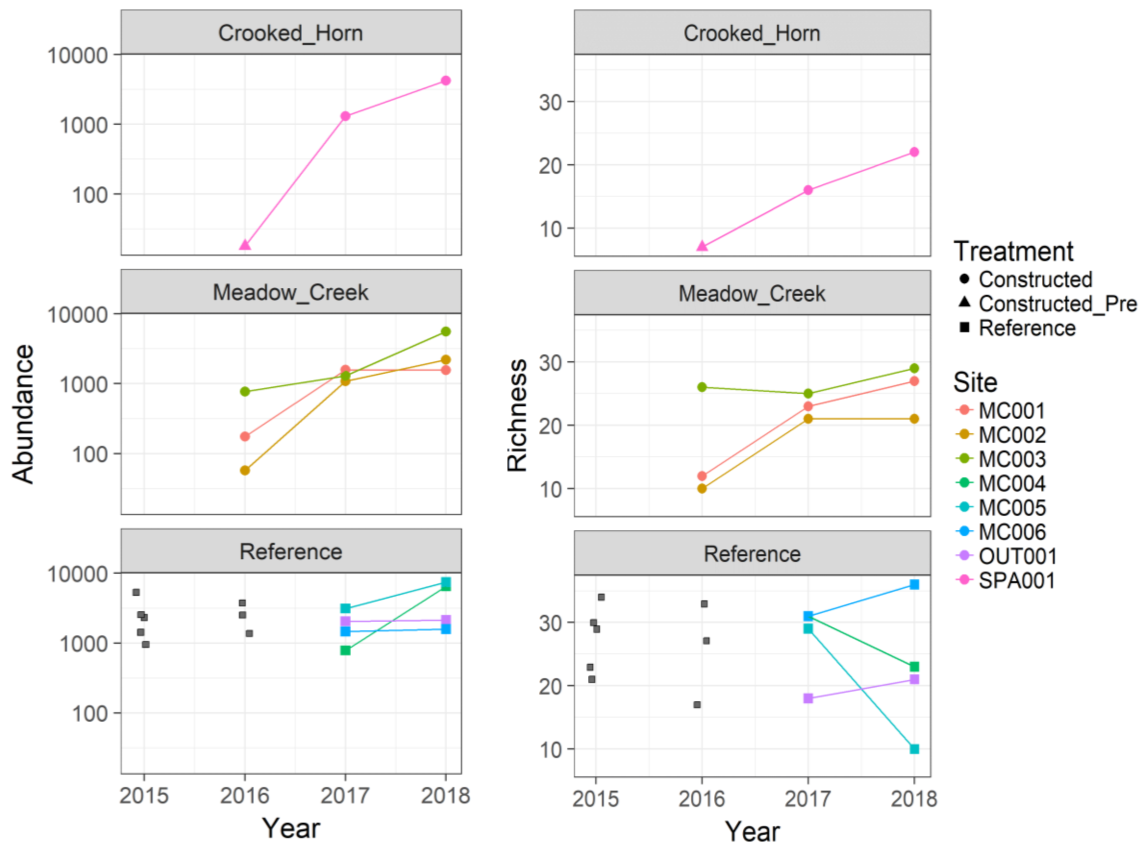

Figure 10. Total abundance (log10()) and total richness at restored wetland sites relative to reference sites in the Slocan Valley and Meadow Creek areas. MC001 was located on private lands in Meadow Creek and MC002 and MC003 were located on The Nature Trust properties. In 2016 monitoring at Crooked Horn Farm (SPA001 on private land) was pre-restoration. Note: log base 10 scale on abundance only.

The total abundance of chironomids increased at restored sites in Meadow Creek (n=3) increase by 16-fold in 2018 relative to the first year of monitoring on average. Mean values in abundance increased from 112.7 (SE=42.0) in 2016, to 502.3 (SE=126.1) in 2017 and 1773 (SE=619.1) in 2018 (Figure 11). At MC001 the increase resulted in an 8.8-fold increase, while at the other wetlands there were increases of 31.5-fold at MC002 and 15.5-fold at MC003 over the three-year monitoring period. In addition, there was an early response in the first year following restoration at Crooked Horn Farm which showed increases of 124.6 and 116.8 times the abundance in 2017 and 2018, respectively, relative to pre-restoration monitoring (2016). The number of chironomids varied from 80-5020 in all reference samples combined (mean=864.5, n=17, SE=275.7).

The total richness of chironomids increased at restored sites in Meadow Creek (n=3) to a maximum of 1.5-fold relative to the first year of monitoring on average. Wetlands were colonized on average by eight types of chironomid genus in 2016 (standard deviation, SE=1.0), to 12 (SE=0.54) in 2017 and 14 (SE=0.21) in 2018 (Figure 11). By wetland, this resulted in a 2.6-fold increase at MC001, 1.6-fold increase at MC002 and 0.9-fold increase at MC003 over three years. The site at Crooked Horn Farm showed similar trends including a 2.5-fold increase in total abundance in 2018 relative to 2016 (pre-restoration) and 1.4-fold increase from 2017 to 2018 within the wetland. The number of chironomid genera varied from 3-20 in all reference samples combined (mean= 11.6, n=17, SE=1.1).

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. This could potentially depress the abundance of insect Dipterans (Nematocerans) within the restored wetland and natural reference sites. Despite this issue, we observed increases in chironomid abundance and richness within the restored wetlands (Figure 11). However, we did not evaluate the effect of BTi on the wetlands nor the extent of any reduction that may or may not have occurred due to BTi. With regards to mosquitos, the only mosquito genus present was *Anopheles sp*. at all 48 project site locations (reference and constructed). This is likely because of the site selection, habitat sampled and timing of sampling. We sampled habitats which were dominated by sedge, cattail, horsetail during the monitoring period of late June to July. Nuisance mosquitos (*Aedes sp*.) are known to dominate the leading edge of inundation of floodwater grasses, reed canary grass (*Phalaris arundinacea*) from April-June (pers com Dirk Lewis).

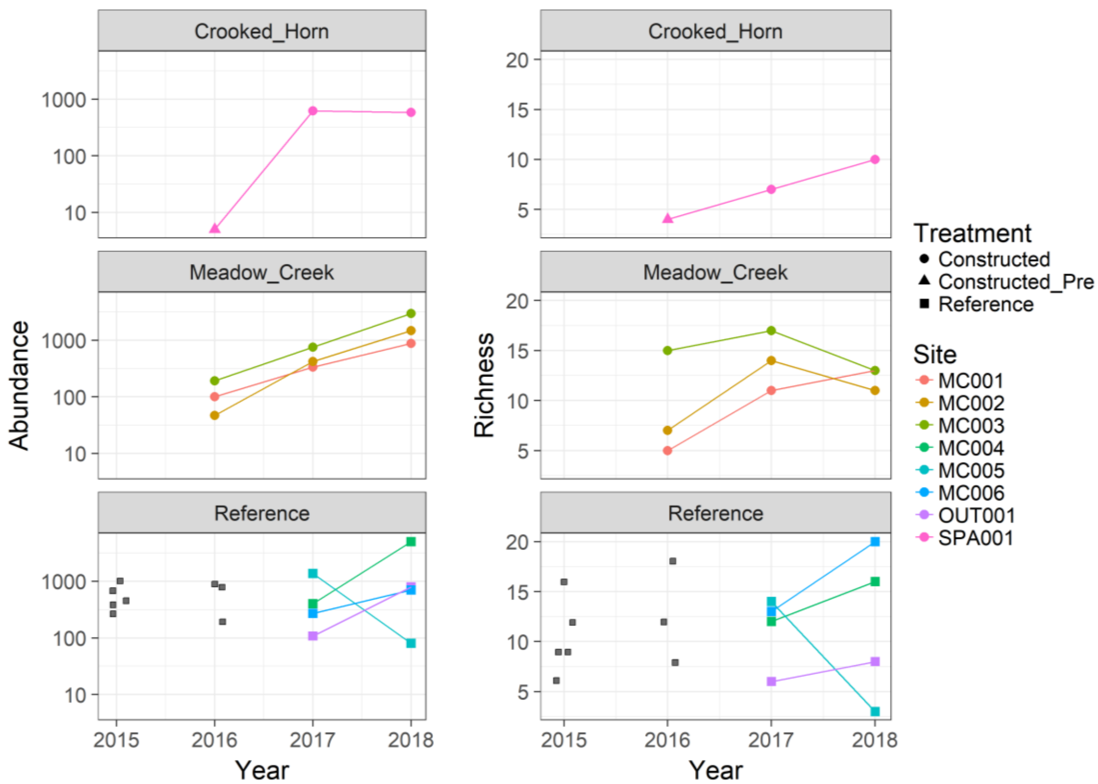

Figure 11. Total abundance (log10()) and total richness of chironomids at restored wetland sites relative to reference sites in the Slocan Valley and Meadow Creek areas. MC001 was located on private lands in Meadow Creek and MC002 and MC003

were located on The Nature Trust properties. In 2016 monitoring at Crooked Horn Farm (SPA001 on private land) was pre-restoration. Note: log base 10 scale on abundance only.

The total abundance of non-chironomids increased at restored sites by 6.0-fold in 2018 relative to the first year of monitoring on average. Mean values in abundance increased from 221 (SE=179.5) in 2016 to 819 (SE=217.4) in 2017 and 1334.3 (SE=632) in 2018 (Figure 8). The number of non-chironomids varied from 385-7400 in all reference samples combined (mean= 1891.6, n=17, SE=988.3) (Figure 12).

At MC001 the increase resulted in a 16-fold (2017) and 9-fold (2018) increases relative to the first year of monitoring, while at the other wetlands there were increases of 70.9-fold at MC002 and 4.5-fold at MC003 over the three years monitoring period. There was an early response in the first year following restoration at Crooked Horn Farm which showed increases of 281-fold relative to pre-restoration monitoring and 5.3 times the abundance from 2017 to 2018.

The total richness of non-chironomids increased at restored sites by 1.6-fold and 1.4-fold (2018, SE=0.6) relative to the first year of monitoring on average. Mean values over this time period increased beginning in 2016 from 8 types of chironomid genus (standard error, SE=27), to 12 (SE=1.2) in 2017 and 11 (SE=0.6) in 2018 (Figure 8). The number of chironomid genus varied from 7-20 in all reference samples (mean= 14.5, n=17, SE=2.2).

By wetland, there was a 2-fold increase at MC001, 3.3-fold increase at MC002 and 1.5-fold increase at MC003 at the end of three years of non-chironomid macroinvertebrates. The unreplicated site at Crooked Horn Farm showed similar trends 4-fold increase in total abundance in 2018 relative to 2016 (pre-restoration) and 1.3-fold increase from 2017 to 2018 within the wetland.

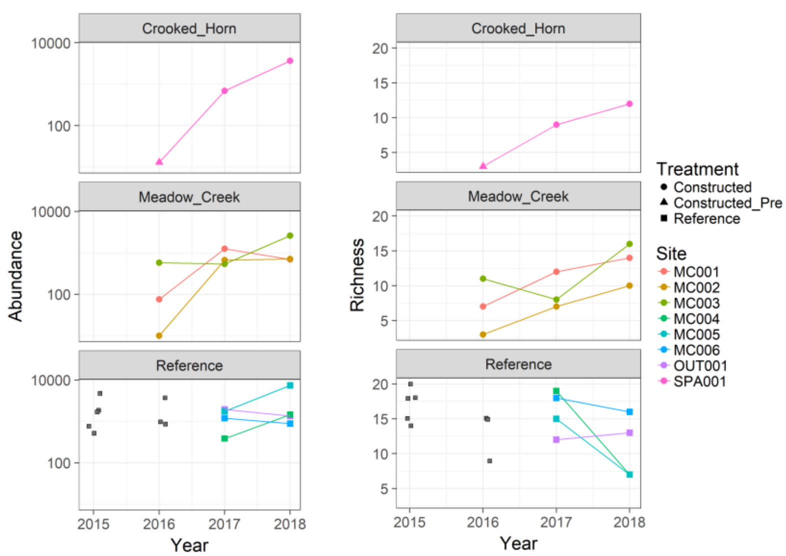

Figure 12. Total abundance (log10()) and total richness of non-chironomids at restored wetland sites relative to reference sites in the Slocan Valley and Meadow Creek areas. MC001 was located on private lands in Meadow Creek and MC002 and

MC003 were located on The Nature Trust properties. In 2016 monitoring at Crooked Horn Farm (SPA001 on private land) was pre-restoration. Note: log base 10 scale on abundance only.

The details of the OET metric (abundance of dragonflies, mayflies and caddisflies) were also plotted because these taxa are an important outreach tool to community members. As a metric the abundance of OET genus showed increases at restored wetland sites relative to references sites at floodplain wetlands from 2016-2018. The abundance of OET groups was dominated by the mayfly genus (*Callisbaetis sp*.), damselfly families Coenagrionidae (narrow-winged damselflies or the pond damselflies) and Lestidae (spread-winged damselflies). Note that there were no caddisflies contributing to the metric at constructed wetlands.

From 2016-2018, the abundance of OET groups at the Meadow Creek sites increased by 6-fold on average with mean values over this time period of 139 (standard error, SE,=106) in 2016, 385 (SE=111) in 2017 and 815 (SE=322) in 2018 (Figure 13). However, this increase varied by wetland with a 6-fold increase at MC001, 71-fold increase at MC002 and 4-fold increase at MC003. The wetland at site MC003 showed early colonization by the mayfly, *Callibaetis sp*. (Figure 13) relative to slower colonization rates at MC001 and MC002. The community wetland at Crooked Horn Farm showed similar trends 303-fold increase in OET abundance in 2018 relative to 2017.

Varying colonization rates between constructed wetlands suggests that it is important to monitor individual wetlands in the early phase of wetland creation and follow over time in order to assess the rate of response and end points during the colonization phase of wetland creation. Colonization rates can depend on dispersal strategy, habitat connectivity and complexity. For example, strong flyers such as hemipterans, dipterans, and coleopterans are known early colonizers (Rhui et al. 2016).

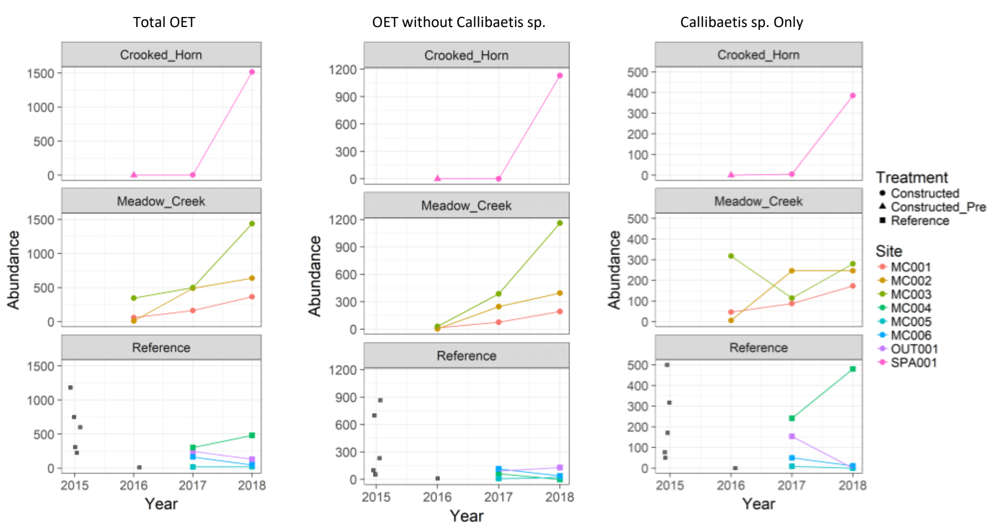

Figure 13. Plots of total abundance of dragonfly (O), mayfly (E) and caddisfly groups (T) at restored wetlands at Meadow Creek and Crooked Horn Farm relative to Lotic_Flood plain wetland reference sites. Black squares represent sites sampled that we unpaired reference sites. Sites connected by line represent sites with repeated sampling.

2.7 Extending the benefits of FWCP restoration through enhancement

Enhancement activities were carried at four new locations in 2019 on private lands as well as the Goulden Thurston (GT) wetland restoration site created by the Slocan River Streamkeepers Society in 2019. This follows previous enhancements in 2018 on two locations on private lands and those placed at Crooked Horn Farm wetland restoration in 2017 for a total of eight locations on private lands with wetland restoration or enhancements with nest boxes.

The landowners at seven of these sites also previously participated in the wetland science program with invertebrate monitoring and/or riparian planting treatments provided by the Slocan River Streamkeepers Riparian Restoration Program. Enhancement activities were highly popular with private landowners and served as powerful outreach tools.

In 2019, a total of 40 boxes were placed on private lands at the five locations (Figures 14). Twenty boxes were placed on four enhancement sites (5 boxes/site) and twenty boxes were placed at the Goulden Thurston wetland restoration site. The small nest boxes were appropriate for small cavity nesting birds such as swallows or chickadees. Currently, most of the 40 boxes placed on private lands and at the Goulden Thurston wetland restoration site created in 2019 are occupied by swallows.

Observations of breeding or colonization success at current FWCP restoration and enhancement sites have been used to inform further restoration and enhancement work in an adaptive management approach. During the first and second seasons at Crooked Horn Farm restoration site, eight out of thirty (2017) and four (2017) small bird boxes were successfully utilized for breeding by violet-green swallows (*Tachycineta thalassina*) and tree swallows (Tac*hycineta bicolor*) while other posts and boxes were used for perching (Figure 14). In early spring 2019 these boxes were cleaned and maintained prior to the breeding season. This primarily included cleaning out wasps' nests from the boxes which may have prevented breeding in 2018. Long-term maintenance, monitoring and adaptive management options were reviewed with landowners.

Larger bird boxes have not been colonized to date; thus, swallow boxes were the focus of community outreach in 2019. The bat box at Crooked Horn Farm was inspected during the Kootenay Conservation Program fall tour in October 2018 and a new location or removal was considered. However, recent observations demonstrated that Little Brown Myotis (*Myotis lucifugus*) or Yuma Myotis (*Myotis yumanensis*) may be utilizing the bat box. The boxes in place will continue to be monitored in 2019-2020 and new locations or removal will be considered if not utilized in the upcoming season. The Slocan River Streamkeeper Society placed an additional multichambered bat box was placed at Goulden Thurston wetland under separate funding for the restoration site.

A review of box placement at Slocan sites was requested from the Kootenay Community Bat Program. Further expertise, outreach and messaging that can be used by the Slocan River Streamkeepers for the lower Slocan River has been requested with respect to these enhancements. Continued enhancement with small nest boxes is also recommended as a useful outreach tool particularly for landowners with mosquito problems. However, evaluation of swallow nest box location, position and density is recommended as a small citizen science project or directed studies thesis.

Figure 14. Photos of 40 boxes placed at five private landowner properties placed in April and May 2019 with nearly full occupation in June 2019.

3 Conclusions and recommendations

Monitoring of restored or constructed wetland sites is crucial to informing the process of adaptive management for organizations who carry out stewardship and long-term management of conservation, private or public lands (Stelk et. al 2017, McGlynn 2017). We tracked wetland recovery on conservation and private lands and collaborated with FLNRORD and the Slocan River Streamkeepers Society over three years to assess the recovery of constructed wetlands relative to natural wetlands.

We documented increases in abundance and genus richness of macroinvertebrates over the three-year period coinciding with an increase in the development of emergent and submergent vegetation (see McGlynn 2017 and SRS website for photos). We submitted and inspected voucher samples at the Royal BC Museum in Victoria.

We helped to further the development of GIS metrics of sensitive habitats and disturbance indicators to characterize point observations of wetland species including macroinvertebrates, birds, bats, and amphibians using already existing provincial methods at appropriate scales (100m and 500m buffer around point observations).

We did not document the presence of floodwater nuisance mosquitos *Aedes sp*., the target of Bti control program in Meadow Creek, at any of the 48 reference or control sites in habitats dominated by sedge, horsetail or cattail during the monitoring period of late June and July.

Recommendations from this project include actions that encourage the development of a diverse macroinvertebrate community providing a prey base for higher trophic levels in wetland ecosystems. Restoration or enhancement actions that increase the biodiversity of macroinvertebrates include:

- Maintain a native plants and healthy riparian buffer around aquatic ecosystems on public, conservation and private lands
- Increase communications with the community and the Regional Districts on nuisance mosquito control.
- Improve messaging regarding the fact that restored wetlands are a net benefit to the community because of the high percentage of invertebrate predators present in wetlands dominated by sedges and lack of nuisance mosquitos.
- Conserve existing natural wetlands in the Columbia Basin.

Actions that can improve the design and maintenance of constructed wetlands with respect to macroinvertebrates include:

- Increase the establishment of wetland soils and diverse plant community
    a. Ensuring that soil is not overly compacted to encourage incorporation of organics, microbial activity and root development (Rip and loosen graded subsoils, Stelk et al 2017)
    b. Reconstruct rooting depth by replacement of topsoil (Stelk et al. 2017)
    c. Use of peat overlying compacted soils or clay seal (pers. com. D. Polster, 2019)
    d. Planting a diversity of native species during wetland creation
- Encourage the colonization of invertebrate predators by ensuring a variety of water levels (Biebighauser 2011).
- Long term investment to continue improve restored wetlands over time as needed. Some wetland professionals recommend 5-20 years of post-restoration monitoring and 10% of implementation costs per year for maintenance (Stelk et al. 2017).
- Looking for win-win scenarios through effective communication and data sharing in a cost-efficient Integrated Management Plan for mosquitos.

3.1.1 Recommendations on methodology

The use of the CABIN protocol successfully documented the early colonization of four constructed wetlands in the first two-four years post-construction. This standardized protocol can then be used to compare the late successional macroinvertebrate community at a later point in time. We would recommend three years of continued monitoring for these wetlands after leaving them for 2-3 years.

Macroinvertebrate diversity is tied to the diversity of the plant community within wetlands and the micro-habitats that a community of varied plants create (Ruhi et al. 2016). Thus, it is important to have an understand of how the plant community changes over time.

We were able to describe using how the percent composition of the plant community changed over the three-year period using visual estimates of percent cover primarily developed to describe macroinvertebrate habitat. However, improvements to assessing or quantifying the plant community could be increased by greater standardization from year to year, increased replicates for plants with standard plot shape, double-observer methods, or inclusion of other measurement methods such as an estimate of bare ground (Fletcher 2019). Quantification of the emergent zone using drones in open areas, or standardized photo plot monitoring (example, McGlynn 2017), or LIDAR would provide supplemental information in some appropriate areas in addition to GIS metrics.

Recommendations from Environment Canada CABIN on useful metrics or analyses are in development (EC 2018). We have tested a few possible metrics within this report. We have not focussed on traits because of a lack of a trait database for wetlands in North America. But trophic level traits including percent predators (which may be useful for evaluations of mosquitos) have been summarized for this project in spreadsheet format. Further work could be done to summarize this information for each site. In addition, multivariate methods may be useful for further comparisons in the future. Finally, side by side collection of macroinvertebrate samples for traditional taxonomy and DNA analysis were completed in 2019 field season in the Creston area which may add to the development of metrics for wetlands over time.

Provincial standard GIS methods of sensitive habitats and disturbance indicators reviewed in this report could be used to characterize point observations of wetland species both throughout the Columbia Basin and provincially at varying scales. These pilot methods have been sent to Environment Canada for review for the CABIN protocol for wetlands.

3.1.2 Recommendations to Slocan River Streamkeepers Society

A four-page document was provided to the Slocan River Streamkeepers with a prioritized list of completed and recommended wetland monitoring that could feed into an adaptive management approach for restored wetlands and enhancements. High priorities included:

- Further CABIN monitoring recommended if in collaboration with a larger project and collection of reference sites
- Enhancements: nest and bat box placement, an evaluation of the location and height of boxes after a designated time period is recommended
- Hydrology and temperature: water level monitoring using staff gauges and temperature recorders placed
- Summary of wildlife observations and upload to Conservation Data Center
- Amphibian and turtle observations, no systematic surveys to date, possible citizen science project

- Data management, housing and summary required
  - Water levels
  - Temperature recorder
  - Bird recorders placed in breeding season, currently deployed, data processing
  - Visual aids including drone photos, video and standardized ground photos.
- Long-term monitoring and application of adaptive management principles

Finally, this work supports increased information on the ecological processes of wetlands in the Slocan Valley and North Kootenay Lake leading and important 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 addresses community concerns.

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.

3.2 Outreach

We participated in participated in numerous events in the past year (2018-2019) including:

- Inspected voucher samples housed at the Royal BC Museum, September 2019.
- Initiated a youth Environmental Ambassador and water testing program with the Nelson Paddling Club, June 2019
- Slocan River Streamkeepers Gap analysis survey, May 2019
- Participation in RDCK Mosquito Control Program (MCP) meeting, April 2019
- Wetland Restoration Monitoring and Adaptive Management: Overview for Slocan River Streamkeepers Society, March 2019.
- Provided mentoring to Columbia Basin Watershed Network on Loblaws grant, Dec. 2018
- Tour of Crooked Horn Farm restoration site, October 13, 2018 for Kootenay Conservation Program Fall Gathering.
- Outreach to Naksup and Area Community Forest on (1) bat enhancement with Cori Lausen August 2018 and (2) planning around migratory bird monitoring
- Toadfest, August 22 and 23, 2018, Slocan Streamkeepers Society presented invertebrate monitoring to youth
- Post-restoration monitoring of constructed wetlands in the Slocan Valley and Meadow Creek, July 2018
- Citizen science, Song Bird/Bull Frog Monitoring, May-July 2018
- Planning around wetland restoration 2018 in the Slocan Valley and Bonanza Biodiversity corridor
- Tour of Slocan River Streamkeepers Society. Crooked Horn Farm Restored Wetland, October 2018

- Implementation of Private landowner small enhancements/wetland science, May-ongoing 2018
- Steering Committee meeting, March 2018

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6 Appendices

6.1 Quality Assurance

6.1.1 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.

6.1.2 Technical Report, Rhithron: Macroinvertebrate quality assurance procedures

by
W. Bollman, Chief Biologist
Rhithron Associates, Inc.
Missoula, Montana

METHODS

Sample processing

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 cladocerans 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 varied from 96-100%. Taxonomic precision for identification and enumeration ranged from 96-99% (Bray-Curtis), with a range of 0.6-4% for percent taxonomic disagreement and 0-1.2% for percent difference in enumeration 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 2015-2018.

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				
IER18DQ001	SPA003	7/9/2018				
IER18DQ002	BON003	7/11/2018	0.9761	0.97.40	0.0323	0.0065
IER18DQ003	OUT001	7/11/2018				
IER18DQ004	MC001	7/16/2018	0.9969	0.9889	0.0193	0.0084
IER18DQ005	MC002	7/16/2018	1	0.9796	0.0349	0.0150
IER18DQ006	MC003	7/16/2018				
IER18DQ007	MC004	7/18/2018		0.9728	0.0272	0
IER18DQ008	MC005	7/18/2018				
IER18DQ009	MC006	7/18/2018				

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6.2 Codes for terrestrial ecosystem mapping (RISC 1998)

Table 1. SEI Classes and Subclasses (from Durand, 2013).

SEI Class	SEI Subclass	Brief Description
Sensitive Ecosystems		
OF: Old Forest*		Forests > 140 yrs
OF	co: coniferous	Conifer > 75% of stand
OF	mx: mixed	Stand composition > 25% conifer and > 25% broadleaf
RI: Riparian		Ecosystems associated with and influenced by freshwater
RI	fh: high bench	High bench floodplain terraces
RI	fm: medium bench	Medium bench floodplain terraces
RI	fl: low bench	Low bench floodplain terraces
RI	ff: fringe	Narrow, linear community along watercourses that generally lack floodplains and floodplain communities
RI	ri: river	River and creeks, including gravel bars
WN: Wetland		Terrestrial – freshwater transitional areas.
WN	ms: marsh	Graminoid or forb-dominated nutrient-rich wetlands
WN	sp: swamp	Shrub or tree-dominated wetlands
WN	ow: shallow water	Permanently flooded, water less than 2m deep at mid-summer

FW: Freshwater		
FW	pd: pond	Open water > 2 m deep and generally < 50 ha.
FW	La: lake	Open water > 2 m deep and generally > 50 ha.
SV: Sparsely Vegetated		Areas with 5 – 10% vascular vegetation.
SV	cl: cliff	Steep slopes, often with exposed bedrock.
SV	ro: rock outcrop	Rock outcrops – areas of bedrock exposure.
SV	ta: talus	Dominated by rubbly blocks of rock.
SV	es: exposed soil	Any area of exposed soil that is not in other definitions.
Other Important Ecosystems (OIE)		
MF: Mature Forest		Forests > 80 yrs, < 140 yrs
MF	co: coniferous	Conifer-dominated (> 75% of stand composition)
MF	mx: mixed	Stand composition > 25% conifer and > 25% broadleaf
MF	bd: broadleaf	Broad-leaf dominated (> 75% of stand composition)
WD: Woodland		Dry site, open stands with between 10 and 25% tree cover
WD	co: coniferous	Conifer > 75% of stand
WD	mx: mixed	Conifer > 25% and broadleaf > 25% of composition
Not Sensitive (NS)		
NS: Not Sensitive		Disturbed and permanently developed/modified areas.
YF: Young Forest		Patches of forest – stands > 30 yrs, < 80 yrs
YF	co: coniferous	Conifer-dominated (> 75% of stand composition)
YF	mx: mixed	Stand composition > 25% conifer and > 25% broadleaf
YF	bd: broadleaf	Broad-leaf dominated (> 75% of stand composition)
PS: Pole Sapling		Trees > 10 m tall, usually 10 - 15 yrs
PS	co: coniferous	Conifer-dominated (> 75% of stand composition)
PS	mx: mixed	Stand composition > 25% conifer and > 25% broadleaf
PS	bd: broadleaf	Broad-leaf dominated (> 75% of stand composition)
HB: Herbaceous		Non-forested ecosystems; usually shallow soils, often with bedrock outcrops.
HB	hb: herbaceous	Non-forested, often shallow soils, lichens, moss, or grass/herb dominated.
HB	sh: shrub	Dominated by shrubby vegetation (<10m in height)
FS: Seasonally Flooded Fields		Annually flooded cultivated fields, hay fields, range land, or old fields.
OD: Old Field		Large, old field ecosystems.

6.3 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

6.4 Appendix 2. Disturbance codes, terrestrial ecosystem mapping

34. **Site Disturbance**
Note any events that have caused vegetation and soil characteristics to differ from those expected at climax for the site. Be as specific as possible, including codes for the category and specific types of disturbance separated by periods. Record up to three different types of disturbance, separated by slashes. For example, enter L.c./ F.l.bb for a clearcut that has been broadcast burned. If existing codes are inadequate, enter an “X” here and explain under "Notes."

A. Atmosphere-related effects
Use these codes if causative factors are no longer in effect or are isolated incidents. If effects are ongoing, code as an "Exposure Type" (Item 32).
e. climatic extremes
co extreme cold
ht extreme heat
gl glaze ice
ha severe hail
sn heavy snow
p. atmospheric pollution
ac acid rain
to toxic gases
w. windthrow

B. Biotic effects
b. beaver tree cutting
d. domestic grazing/browsing
w. wildlife grazing/browsing
e. excrement accumulation (other than that normally associated with grazing/browsing)
i. insects
ki insect kill
in infestation
p. disease
t. turbation (soil)
v. aggressive vegetation

D. Disposals
c. chemical spill or disposal
e. effluent disposal
g. domestic garbage disposal
o. oil spill or disposal
r. radioactive waste disposal or exposure

F. Fires
c. overstorey crown fire
g. light surface (ground) fire
r. repeated light surface fires
s. severe surface fire
i. repeated severe surface fires
l. burning of logging slash
bb broadcast burn
pb piled and burned
wb burned windrows

L. Forest harvesting
l. land clearing (includes abandoned agriculture)
a. patch cut system
wr with reserves
c. clearcut system (if slashburned, see also "Fires")
wrwith reserves (patch retention)
d. seed tree system
un uniform
gr grouped
e. selection system
gr group selection
si single tree
st strip
s. shelterwood system
un uniform
gr group
st strip
ir irregular
na natural
nu nurse tree
o. coppice

M. Plant or site modification effects
c. herbicide use (chemical)
f. fertilization (specify type under "Notes")
i. irrigation
g. seeded or planted to grasses
h. seeded or planted to herbs
s. planted or seeded to shrubs
t. planted or seeded to trees

P. Gathering or removal of plant products
f. firewood gathering
m. mushrooms
o. moss

s. shrubs (e.g., salal, falsebox)
x. other (specify under "Notes")

S. Soil disturbance
a. cultivation (agricultural)
c. compaction
g. gouging (> 5 cm into mineral soil)
s. scalping (forest floor removed)
f. sidecast/fill
r. road bed, abandoned
t. railway, abandoned
e. excavation
m. mining effects
pt placer tailings
rq rock quarrying (including open pit mines)
ta tailings
p. mechanical site preparation
bb brush blading
ds drag scarification (anchor chain or shark fin)
dt disc trenching
md mounding
ps patch scarification
vp V-plowing
xx other (specify under "Notes")

T. Terrain-related effects
a. avalanche
d. recent deglaciation
e. eolian (active deflation or deposition)
s. terrain failures (active/recent slumps, slides, solifluction, etc.)
v. volcanic activity

W. Water-related effects
i. inundation (including temporary inundation resulting from beaver activity)
s. temporary seepage (usually artificially induced; excludes intermittent seepage resulting from climatic conditions)
d. water table control (diking, damming)
e. water table depression (associated with extensive water extraction from wells)

X. Miscellaneous
(For other disturbance types, enter "X" and describe under "Notes")