McDonald Creek: 2023 CABIN Monitoring Summary Report

In support of the Columbia Basin Water Monitoring Framework through Living Lakes Canada

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Table of Contents

Background information

Site

McDonald Creek watershed is located in the West Kootenay region of British Columbia, approximately 14km south of Nakusp along Highway 6. With a drainage area of 97.42km², the dominant land use within the sub-catchment is forestry and logging. Highway 6 runs parallel to Arrow Lakes with McDonald Creek Provincial Park sitting below Highway 6 and creating a buffer along the eastern shore of Arrow Lakes. A CABIN monitoring site, NEMCD01 (50.14500 N, -117.79389 W), was selected in the lower reach of McDonald Creek, above the Highway 6 bridge that travels over McDonald Creek. On August 17, 2023 the site was visited for field data collection following the nationally standardized CABIN protocol. NEMCD01 is classified as a stream order 4, and is located in a reach with intact riparian coverage. CABIN was used to assess the health of the stream and better understand the association between forestry and logging practices on the benthic macroinvertebrate community.

CABIN

The goal of using Environment and Climate Change Canada's (ECCC) Canadian Aquatic Biomonitoring Network (CABIN) protocols to monitor lotic systems is to understand the health of streams. CABIN uses standardized protocols to collect benthic macroinvertebrate samples which act as indicators of aquatic ecosystem health (Environment Canada, 2012). Benthic macroinvertebrates (BMI) are bottom dwelling organisms that are found in all freshwater ecosystems. With a lifespan from 1-3 years, these organisms are exposed to and respond differently to pollutants and disturbances in the aquatic environment. The presence and abundance of benthic macroinvertebrate species varies depending on exposure to pollutants and thus, are used to understand the cumulative effects of pollutants on aquatic ecosystem health.

The CABIN protocol uses a reference condition approach (RCA) to compare test sites to a group of reference sites. Descriptor data for land cover, climate, topography and hydrology are extracted for each test site watershed area using GIS tools. During site visits, field data is collected on the physical, biological, chemical and hydrological characteristics of a stream and its channel to characterize the stream reach. This data is input into the CABIN database where analysis is conducted to assess the stream health/condition.

When a reference model has been developed for an area of interest, the RCA approach can be applied. A BEAST analysis uses the derived habitat variables to determine which group of reference sites is most appropriate to compare the test site to, and then categorizes the test site to the most similar group of reference sites. The RIVPACS analysis then assesses a test site's observed benthic macroinvertebrate community compared to the expected BMI community for a group of reference sites. The Brays-Curtis analysis then assesses the degree of similarity between the test site and the median of the predicted reference sites. The deviation of the test site BMI community from the reference group expected BMI community results in the test site being assigned to one of four bands (confidence intervals/ellipses) of stream condition: reference, mildly divergent, divergent, and extremely divergent from reference condition.

Outside of the RCA analysis, ecological metrics for richness, abundance and diversity can be calculated from the BMI sample. These metrics are used to further understand and evaluate the community composition to better understand the condition of the site.

Benthic Macroinvertebrates

In aquatic systems, organisms are continuously exposed to fluctuations in their environment (ECCC, 2012). These fluctuations cause changes in the productivity of the aquatic environment, which influence the spatial and temporal distribution of species in both their composition and abundance (CCME 2008). BMI taxa in aquatic environments experience changes in their community structure, richness, abundance and diversity due to their exposure to water conditions throughout their life stages. Each taxa and Family group, and species, has a sensitivity or tolerance to various environmental conditions (DO%, pH, temperature, etc.). The richness, abundance and diversity of the community, along with taxa sensitivities and tolerances, can be used to understand the cumulative impacts of exposure to the environment on the BMI community. CABIN uses these ecological metrics to further understand impacts of disturbance on the BMI community to assess the stream health.

Taxon identified at the order level as Ephemeroptera, Plecoptera and Trichoptera (EPT) act as indicators of good water quality due to their sensitivity to pollution or degraded aquatic environments. The EPT index examines taxa richness within a sample, comparing the abundance of these 3 taxa to the total number of individuals in a sample. In contrast, the family Chironomidae (non-biting midges), in the order Diptera, are often more tolerant of degraded water quality. Therefore, determining the ratio of Diptera and Chironomidae to EPT species can be a good indicator of water quality. Monitoring the ratio over time can be used to determine whether the community is changing, and these changes may be associated with increased disturbance or climate change in the catchment area upstream of the site.

Metrics

Richness metrics measure the *number of different species* present in the sample. This can be measured as the total number of species at a site or within a taxon(s). Species richness does not take into account the number of individuals of each species present. Rather it gives as much weight to those species represented by very few individuals as to those represented by many individuals. Richness of a stream can decline with degradation of the water quality due to disturbance, with sensitive species replaced by more tolerant taxa.

Unlike richness, ***abundance*** is a measurement of the *sum of all organisms present in a sample at a selected taxonomic level or within a specified group* (ex. # of individuals per Family). The composition of the taxa within the sample population can be expressed numerically or as a percentage of the population also referred to as proportion. Shifts within the population's abundance, with certain species increasing or decreasing, can act as indicators of water quality and stream health. The abundance and compositional measures presented include but are not limited to:

%EPT: ∑EPT individuals / ∑sum of all individuals * 100
Where: the %EPT is expected to decrease with degradation

%Ephemeroptera that are Baetidae: ∑ Baetidae ind. / ∑ Ephemeroptera individuals * 100
Where: Baetidae are more tolerant of degraded conditions and expected to increase with degradation

%Trichoptera that are Hydropsychida: ∑ Hydropsychida ind. / ∑ Trichoptera individuals * 100
Where: Hydrophsychia are more tolerant of degraded conditions and are expected to increase with degradation

% Coleoptera: ∑ Coleoptera ind. / ∑ all individuals * 100
Where: Coleoptera are expected to decrease with disturbance and degraded conditions

% Chironomidae: ∑ Chironomidae ind. / ∑ all individuals * 100
Where: Chironomidae are generally more tolerant of pollution

#EPT individuals/Chironomidae + EPT individuals * 100
Where the ratio is expected to decrease with disturbance

Evenness is a richness metric that measures the *distribution of the relative abundance of various taxa across all taxa* in a community. When all species in a sample have the same abundance of individuals then evenness is highest. If the relative abundances vary between the taxa in a community, evenness gets closer to zero. Evenness can be applied as an indicator of water quality, with evenness decreasing in response to disturbances and decreased water quality. Species evenness can be described using metrics including Pielou's evenness or Simpson's Evenness.

Diversity takes into account the number of different species (richness) in a community, the abundance of the individuals in a species and how evenly the number of individuals is distributed among those species (evenness). Both richness and abundance measures function separately when calculating diversity. Diverse communities are a function of both high richness and high abundance, offering ecological opportunities and resilience within a community. Diverse communities act as indicators of "good" water quality and stream condition, where diversity is expected to decrease in response to disturbances and poor water quality (ECCC, 2024). Simpsons diversity and Shannon-Wiener diversity indices are used to assess diversity through the CABIN analysis.

RIVPACS measures the observed taxa found at the test site divided by the taxa predicted to be at the test site for all groups (p=0.70). The RIVPACS analysis uses only the taxa presence/absence data. A RIVPACS value of 1 indicates the site is in good condition with low values often meaning the site is in poor condition (closer to 0); whereas very high values above 1.0 can mean the site is enriched or a biodiversity hotspot.

The ***Bray-Curtis Index*** compares the degree of dissimilarity of the test site's community to the predicted reference group community. It takes into account the abundance of each taxa observed and compares the test site to the median of the predicted reference community, while not being influenced by the rarity of the species. 0 means there is no difference between the test site and median reference community, whereas a value of 1 means that the test site community is very different from the median of the reference community.

Functional Feeding Groups **(FFG)** are a classification of benthic macroinvertebrates based on the BMI'a primary method of obtaining food, with each group including several different taxa. Comparing FFGs at a site is a way to understand the productivity and inputs to the site in relation to the input of organic matter into the system as well as the productivity of the stream. The presence of FFGs depends on the type of food available such as; Coarse Particulate Organic Matter (CPOM), Fine Particulate Organic Matter (FPOM), algae, and vascular plants. These food types vary based on stream characteristics (substrate, flow, depth), photosynthetic active radiation (sunlight) and the inputs from vegetation (organic matter) adjacent to the stream. There are five main FFG (Cummins, 2021):

FFG	**Food Source**
Shredders	Leaf litter, rooted aquatic vascular plants, wood or other coarse particulate organic matter (CPOM; >1 mm)
Scrapers/grazers	Algae and other associated material
Collector/gatherers	Fine particulate organic matter (FPOM; #1 mm) on or in the stream sediments
Filterers	Filter fine particulate organic matter from the water column
Predators	Prey on other consumers

The River Continuum Concept describes how throughout a river system, from lower to higher stream orders, there are changing physical, chemical and biotic conditions that shift biological communities, including BMIs, in response to the change of the stream conditions. Variables such as slope, velocity, channel width, and sunlight exposure influence stream conditions and the availability of food sources within the stream, influencing FFGs along the stream continuum. The proportion of certain groups with respect to other groups has been shown to be related to stream health. In general, specialists such as shredders, are presumed to be more sensitive and therefore associated with healthy streams; whereas generalists (ex. gatherer and filterer species), with their broader diet, are presumed to be more tolerant to disturbance.

The ***Hilsenhoff Biotic Index*** (**HBI**) value estimates organic pollution using the proportion (abundance) of taxa at the genus/species level. Biotic tolerance values are assigned to each taxa based on their response to organic pollution. Index scores range from 0 to 10 (Table 1). Sensitive taxa have low scores while tolerant taxa are assigned high scores. Low HBI values reflect a higher abundance of sensitive groups inferring a lower level of pollution. While an increase in the index value suggests decreased water quality due to organic pollution (Hilsenhoff, 1987). The HBI is advantageous for evaluating the general status of organic pollution in streams to assist in decision making around which streams should be studied further (Hilsenhoff, 1987).

Table 1. Hilsenhoff Biotic Index (HBI) categories.

Biotic Index	Water Quality	Degree of Organic Pollution
0.00–3.50	Excellent	Organic pollution unlikely
3.51–4.50	Very Good	Possible slight organic pollution
4.51–5.50	Good	Some organic pollution probable
5.51–6.50	Fair	Fairly substantial pollution likely
6.51–7.50	Fairly Poor	Substantial pollution likely
7.51–8.50	Poor	Very substantial pollution likely
8.51–10.00	Very Poor	Severe organic pollution likely

For a complete list of metrics and calculations see Appendix A.

Field Site Visit

A site visit to McDonald Creek was conducted by PJ Butler and Paige Thurston on August 17, 2023 to collect data using the nationally recognized CABIN protocol. Benthic macroinvertebrate samples were sent to Biologica Consulting for taxonomic analysis. Water quality samples were sent for analysis to Caro Analytical Services in Kelowna, BC.

Results and Discussion

The BEAST analysis classified the site (MCD01) as divergent (for the full report, see Appendix B). NEMCD01 was categorized into reference group 6 (model reference group LM), with a group error rate of 29.4% and a probability of group membership of 39.3%. Group six was described as having a low abundance and a higher proportion of non-insects compared to other groups within the sample (ECCC, 2020).

With intact forest as the dominant land use in the sampled reach, the dominant substrate type at NEMCD01 was small cobble, with coarse sand occupying the interstitial spaces.

Total abundance at the site was 3,250, significantly higher than the reference group mean ($\bar{x}$ 214 ± SD 171.56). The proportion of EPT was 89.5%, with 77.3% Ephemeroptera (2 standard deviations from the predicted group mean). Among the Ephemeroptera, the more tolerant Baetidae family (73.6%) was the most dominant. The proportion of EPT in McDonald Creek was within one standard deviation of the predicted reference group mean. Diptera and other non-insects made up 9.2% of the sample. Together with a low proportion of Chironomidae (6.6%), these metrics indicate that the site is in relatively good condition, supporting sensitive species and reflecting good water quality.

The RIVPACS ratio was 0.99, indicating that the site was in good condition. The Bray-Curtis distance index for McDonald Creek was 0.93, suggesting that the test site community is very different (93% dissimilar) from the median of the reference group. The Simpson's Diversity Index was 0.6, indicating moderate diversity at the site. Pielou's Evenness Index was 0.6, suggesting a moderately even distribution of species.

The Hilsenhoff Family Index for Cottonwood Creek was 3.9, indicating very good water quality at the sampling site with the possibility of slight organic pollution. The dominant functional feeding group was scrapers (69.2%), which suggests that algae and associated material are the primary food sources at the site. Comparison of functional feeding groups and taxonomic richness shows that McDonald Creek has high abundance but low richness and evenness.

Water quality parameters measured in situ revealed that specific conductivity was higher (2 standard deviations) at the test site compared to the reference groups, while DO concentrations (9.93 mg/L) were within two standard deviations of the reference group mean (11.008 mg/L). Overall, the site was assessed as divergent from the reference group, with greater abundance and less evenness than expected. The benthic community composition metrics suggest a system experiencing potentially higher productivity, indicated by the dominant functional feeding group. This may point to disturbance and low levels of stress in the drainage area. These changes could be related to land-use practices and/or climate change, as the region has experienced periods of drought preceding forest fire activity. Forestry disturbances within the sub-watershed may have increased erosion and the transport of fine materials, including organic matter, shifting community structure at the site. Annual CABIN monitoring would help improve understanding of the variability within the system and how climate change and forestry activities relate to community composition in McDonald Creek.

Appendix A

Total number of taxa: number present at a selected taxonomic level.

EPT taxa: number present within each group; high numbers of EPTs generally indicate "good" water quality, as they are sensitive to habitat disturbance.

EPT individuals: the sum of all Ephemeroptera, Plecoptera and Trichoptera taxa which respond to most types of anthropogenic disturbance. A decline in abundance or richness of EPT individuals would suggest an environmental disturbance. These are compared to the Chironomidae taxa, expressed as a ratio using abundance or composition values (see Section 3.3.2. below).

RIVPACS: a ratio of the Observed taxa (O):Expected taxa (E) ratio where; O:E =1 are healthy, O:E ratio <1 are impaired, O:E ratio > 1 are biodiversity hotspots/enriched.

Pielou's Evenness measures between 0-1 with 0 indicating species are unevenly distributed among the community whereas, 1 indicates that the number of individuals within species is evenly distributed between species.

Diversity/evenness measurements: the richness, abundance and distribution among the taxa present (i.e., Simpson's Diversity/Evenness Index and Shannon-Weiner Index); these measurements provide a summary of the distribution of the taxa. Diverse communities are indicators of "good" water quality.

Simpson's Diversity Index (D): is a weighted arithmetic mean of the proportional abundance of species and gives more weight to dominant or common species.

Simpson's Diversity Index takes into account the number of species present, as well as the relative abundance of each species in each taxa, giving more weight to more abundant species. As the species richness and evenness increase, the diversity increases (ECCC, 2024). 0 represents no diversity whereas, 1 represents infinite diversity.

The formula for Simpson's Index is:

$D = 1 - \sum_{i=1}^{S} (n_i/N)^2$	where: n = the total number of organisms of a particular species N = the total number of organisms of all species

Site Description

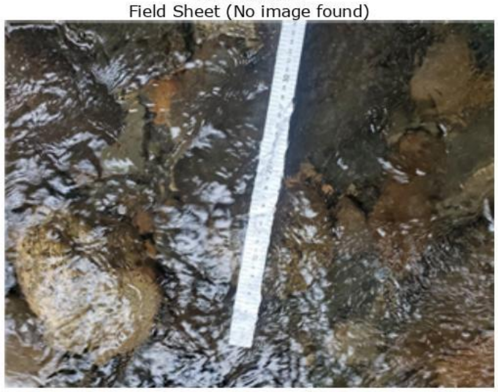
Study Name	BC NGO-Columbia Basin Water Monitoring Framework-LLC
Site	NEMCD01
Sampling Date	Aug 17 2023
Know Your Watershed Basin	Central Columbia
Province / Territory	British Columbia
Terrestrial Ecological Classification	Montane Cordillera EcoZone Columbia Mountains and Highlands EcoRegion
Coordinates (decimal degrees)	50.14500 N, 117.79389 W
Altitude	495
Local Basin Name	McDonald Creek
	Columbia River
Stream Order	

Figure 1. Location Map

Across Reach

Down Stream

Field Sheet (No image found)



Substrate

Up Stream

Cabin Assessment Results

Reference Model Summary	
Model	Columbia Basin 2020
Analysis Date	December 04, 2024
Taxonomic Level	Family

Cabin Assessment Results

Predictive Model Variables	Altitude Drainage-Area Longitude Natl-Grassland Natl-ShrubLow Natl-Water Precip10_Oct Reach-%CanopyCoverage Sedimentary Slope SlopeMax Temp12_DECmin

Reference Groups	**1**	**2**	**3**	**4**	**5**	**6**
Number of Reference Sites	13	24	28	35	32	15
Group Error Rate	53.8%	55.2%	34.1%	52.2%	23.1%	29.4%
Overall Model Error Rate	39.4%					
Probability of Group Membership	4.7%	20.7%	3.2%	31.4%	0.7%	39.3%
CABIN Assessment of NEMCD01 on Aug 17, 2023	Divergent					

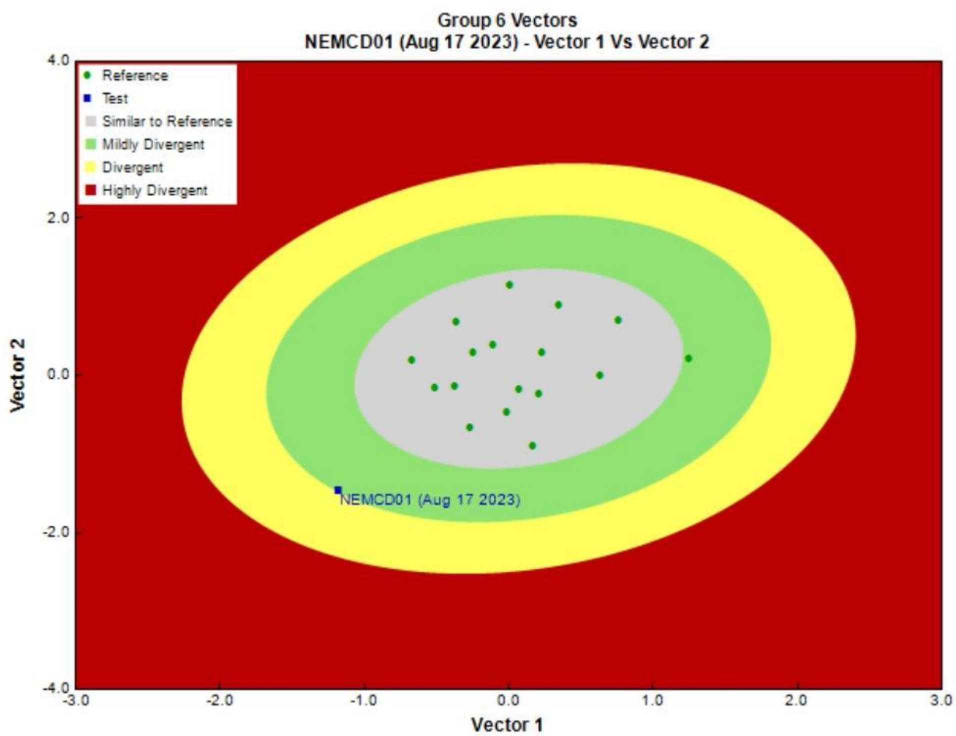


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3

Date: December 6, 2024 1:52 PM

Sample Information

Taxonomist	-
	-
Sub-Sample Proportion	10/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Lumbriculida	Lumbriculidae	1	10.0
Arthropoda	Arachnida			1	10.0
		Trombidiformes	Torrenticolidae	2	20.0
	Insecta	Coleoptera	Elmidae	4	40.0
		Diptera		2	20.0
			Chironomidae	20	200.0
			Psychodidae	4	40.0
			Tipulidae	1	10.0
		Ephemeroptera		9	90.0
			Baetidae	173	1,730.0
			Ephemerellidae	17	170.0
			Heptageniidae	44	440.0
			Leptophlebiidae	1	10.0
		Plecoptera		2	20.0
			Chloroperlidae	2	20.0
			Leuctridae	3	30.0
			Nemouridae	12	120.0
			Perlidae	3	30.0
			Perlodidae	4	40.0
			Taeniopterygidae	3	30.0
		Trichoptera		7	70.0
			Glossosomatidae	1	10.0
			Rhyacophilidae	9	90.0
			Total	325	3,250.0

Metrics

Name	NEMCD01	Predicted Group Reference Mean ±SD
Bray-Curtis Distance	0.93	0.5 ± 0.2
Biotic Indices		
Hilsenhoff Family index (Mid-Atlantic)	3.9	3.3 ± 0.7
Hilsenhoff Family index (North-West)	3.9	3.0 ± 0.6
Intolerant taxa	--	1.0 ± 0.0
Long-lived taxa	3.0	3.7 ± 2.5
Tolerant individuals (%)	--	
Functional Measures		
% Filterers	--	0.9
% Gatherers	19.4	45.5 ± 16.7
% Predatores	11.7	19.6 ± 9.1
% Scrapers	69.2	47.6 ± 19.0
% Shredder	7.1	33.9 ± 13.8
No. Clinger Taxa	24.0	16.4 ± 6.3
Number Of Individuals		
% Chironomidae	6.6	9.8 ± 10.2
% Coleoptera	1.3	1.8 ± 5.1
% Diptera + Non-insects	9.2	16.2 ± 13.7
% Ephemeroptera	77.3	38.6 ± 16.4
% Ephemeroptera that are Baetidae	73.6	25.0 ± 16.3
% EPT Individuals	89.5	81.5 ± 15.8
% Odonata	--	0.0 ± 0.0
% of 2 dominant taxa	71.4	53.0 ± 11.8
% of 5 dominant taxa	87.5	79.4 ± 9.4
% of dominant taxa	56.9	33.3 ± 9.9
% Plecoptera	8.9	37.6 ± 13.8
% Tribe Tanyatarisini	--	
% Trichoptera that are Hydropsychida	0.0	22.3 ± 35.7

Metrics

Name	NEMCD01	Predicted Group Reference Mean ±SD
% Tricoptera	3.3	5.3 ± 3.7
No. EPT individuals/Chironomids+EPT Individuals	0.9	0.9 ± 0.1
Total Abundance	3250.0	214.3 ± 171.5
Richness		
Chironomidae taxa (genus level only)	1.0	0.9 ± 0.3
Coleoptera taxa	1.0	0.1 ± 0.3
Diptera taxa	3.0	2.8 ± 1.2
Ephemeroptera taxa	4.0	3.7 ± 0.9
EPT Individuals (Sum)	2720.0	168.4 ± 119.3
EPT taxa (no)	12.0	11.1 ± 3.2
Odonata taxa	--	0.0 ± 0.0
Pielou's Evenness	0.6	0.8 ± 0.1
Plecoptera taxa	6.0	5.1 ± 1.2
Shannon-Wiener Diversity	1.6	2.1 ± 0.3
Simpson's Diversity	0.6	0.8 ± 0.1
Simpson's Evenness	0.2	0.4 ± 0.1
Total No. of Taxa	18.0	16.4 ± 6.1
Trichoptera taxa	2.0	2.3 ± 1.6

Frequency and Probability of Taxa Occurrence

Reference Model Taxa	Frequency of Occurrence in Reference Sites						Probability Of Occurrence at NEMCD01
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	

RIVPACS Ratios

RIVPACS : Expected taxa P>0.50	12.14
RIVPACS : Observed taxa P>0.50	10.00
RIVPACS : O:E (p > 0.5)	0.82
RIVPACS : Expected taxa P>0.70	9.13
RIVPACS : Observed taxa P>0.70	9.00
RIVPACS : O:E (p > 0.7)	0.99

Habitat Description

Variable	NEMCD01	Predicted Group Reference Mean ±SD
Bedrock Geology		
Sedimentary (%)	79.16000	82.88358 ± 30.75953
Channel		
Depth-BankfullMinusWetted (cm)	88.00	47.36 ± 27.19
Macrophyte (PercentRange)	1	0 ± 0
Reach-%CanopyCoverage (PercentRange)	1.00	1.12 ± 1.22
Reach-DomStreamsideVeg (Category(1-4))	3	3 ± 1
Reach-Pools (Binary)	0	1 ± 1
Reach-Rapids (Binary)	1	1 ± 0
Reach-Riffles (Binary)	1	1 ± 0
Reach-StraightRun (Binary)	0	1 ± 1
Slope (m/m)	0.0190000	0.0342024 ± 0.0245210
Veg-Coniferous (Binary)	1	1 ± 0
Veg-Deciduous (Binary)	1	1 ± 0
Veg-GrassesFerns (Binary)	1	1 ± 0
Veg-Shrubs (Binary)	1	1 ± 0
Width-Bankfull (m)	11.1	32.9 ± 57.4
Width-Wetted (m)	4.6	13.7 ± 9.2
XSEC-VelInstrumentDirect (Category(1-3))	2	2 ± 0
XSEC-VelMethod (Category(1-3))	3	2 ± 1
Climate		
Precip10_OCT (mm)	86.92000	93.20980 ± 34.74431
Temp12_DECmin (Degrees Celsius)	-10.10000	-13.22157 ± 2.49065
Hydrology		

Habitat Description

Variable	NEMCD01	Predicted Group Reference Mean ±SD
Drainage-Area (km^2)	97.42000	128.73316 ± 95.34698
Perimeter (Km)	47.25000	70.14529 ± 35.78518
Landcover		
Natl-Grassland (%)	6.18300	6.92953 ± 4.46178
Natl-ShrubLow (%)	0.00500	3.64474 ± 3.23210
Natl-Water (%)	0.00000	0.28041 ± 0.33747
Substrate Data		
%Bedrock (%)	0	0 ± 0
%Boulder (%)	2	7 ± 9
%Cobble (%)	67	56 ± 19
%Gravel (%)	4	4 ± 4
%Pebble (%)	27	33 ± 19
%Sand (%)	0	0 ± 1
%Silt+Clay (%)	0	0 ± 2
D50 (cm)	9.00	10.03 ± 5.73
Dg (cm)	8.2	8.6 ± 4.1
Dominant-1st (Category(0-9))	6	6 ± 1
Dominant-2nd (Category(0-9))	7	6 ± 1
Embeddedness (Category(1-5))	4	4 ± 1
PeriphytonCoverage (Category(1-5))	3	1 ± 0
SurroundingMaterial (Category(0-9))	2	3 ± 1
Topography		
SlopeMax (%)	218.98000	367.17555 ± 135.12349
Water Chemistry		
General-DO (mg/L)	9.9300000	11.0082353 ± 0.9760010
General-pH (pH)	7.8	8.1 ± 0.7
General-SpCond (µS/cm)	363.2000000	184.3705882 ± 121.7921629
General-TempAir (Degrees Celsius)	19.8	8.6 ± 4.0
General-TempWater (Degrees Celsius)	13.6000000	6.0976471 ± 2.0569897
General-Turbidity (NTU)	0.1700000	11.4600909 ± 16.4292847

References

Environment Canada. 2012. Canadian Aquatic Biomonitoring Network (CABIN) Field Manual for wadeable streams. 49pp.

Environment Canada. 2014. CABIN Processing, Taxonomy, and Quality Control of Benthic Macroinvertebrate Samples. May 2014.

Environment Canada. 2024. **Benthic macroinvertebrate metric reference guide.** Accessed December 10, 2024 from https://www.canada.ca/en/environment-climate-change/services/canadian-aquatic-biomonitoring-network/resources/benthic-macroinvertebrate-metric-reference-guide.html

Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist 20:31-39.

Strachan, S.A., Raggett, J., 2020. Reference Model Supporting Documentation for CABIN Analytical Tools: Columbia Basin, 2020. Retrieved on December 1, 2024, from https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-monitoring/biomonitoring