Coastal Action 2018 Water Quality and Sediment Review of the Petite Rivière Watershed

By

Coastal Action

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1. Introduction

1.1. Background

Located along the southern shore of Nova Scotia, the Petite Rivière watershed covers 244 km^2 (Figure 1). The watershed land is commonly used for forestry and agriculture, with the presence of urban and rural communities. The Petite Rivière provides habitat for various animals – especially the endangered Atlantic whitefish, which is only found in three lakes on Earth, all located within the Petite Rivière.

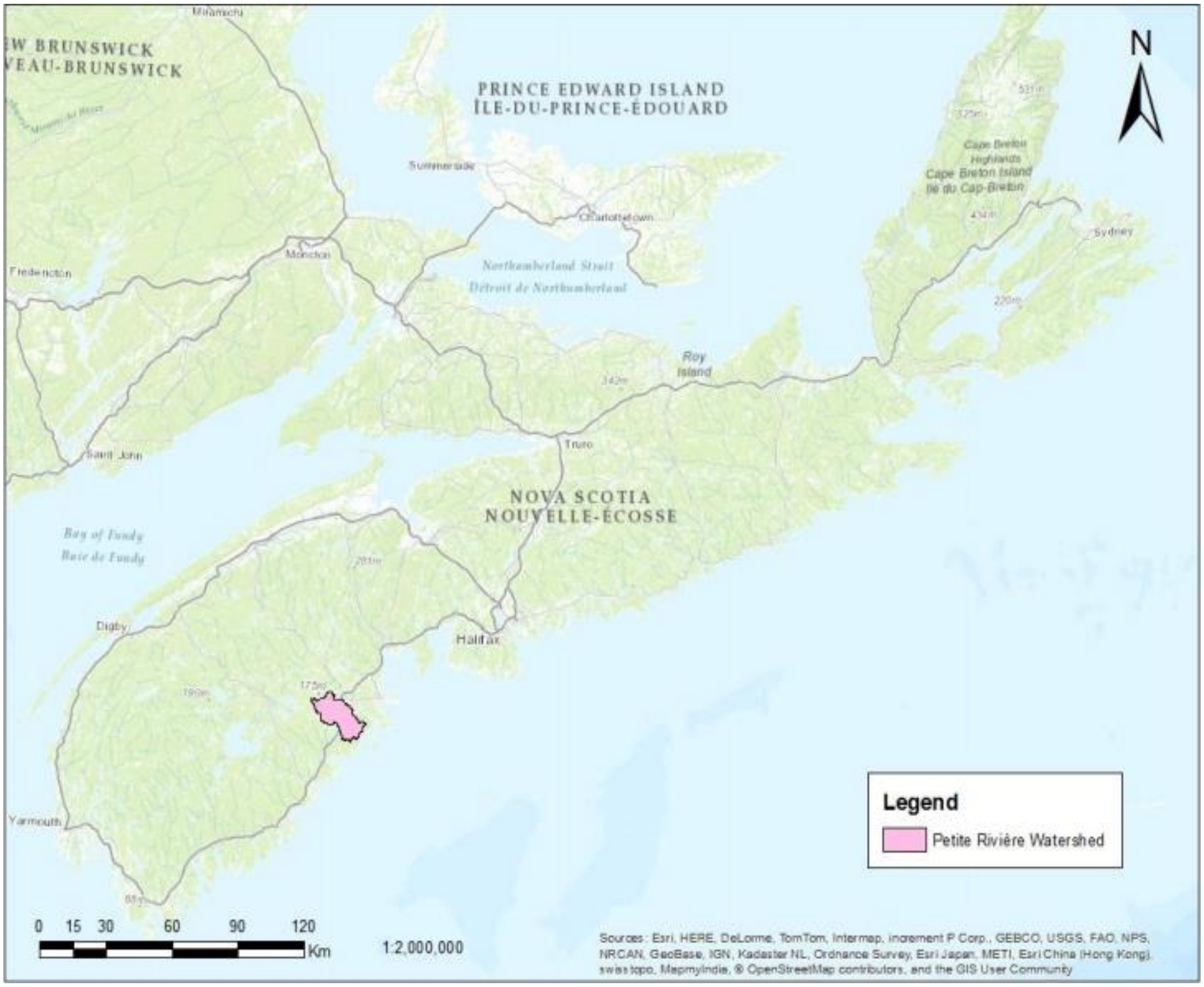

Figure 1: Map of Nova Scotia, with the Petite Rivière watershed highlighted in pink.

Coastal Action created the Petite Rivière Watershed Program (PRWP) to monitor the health of the watershed and its inhabitants. The program has been running continuously since 2010, with support from the Government of Canada's Species at Risk Habitat Stewardship Program.

1.2. Program Objectives

In an effort to monitor and protect the health of the Petite Rivière watershed, the PRWP's goals are to:

- Create a long-term water quality database for the watershed to help evaluate ecosystem health.
- Provide a water quality baseline for any disturbances that occur in the region.
- Monitor and assess water quality changes within the Petite Rivière watershed to help understand the effects on biotic – and human – health.
- Promote collaboration by uploading data to the Atlantic Datastream database.

More information on the PRWP and water quality trends for the Petite Rivière watershed are available in the *Petite Rivière 5-Year Water-Quality Report.*

1.3. Report Objectives

The objective of this report is to provide a general review of the 2018 water and sediment data within the Petite Rivière, with a focus on assessing any possible impacts to Atlantic whitefish. This report reviews the field work results from water and sediment samples collected in 2018 at:

- 18 sites throughout Petite Rivière
- 10 sites located within the headwaters of Milipsigate Lake
- 1 site within Milipsigate Lake

This report is one of three (2018, 2019, and 2020), as part of a multi-year project to investigate water and sediment quality within the Petite Rivière watershed.

2. Methods

2.1. Water Quality Sampling Throughout the Petite Rivière Watershed

Coastal Action staff sampled the physical water characteristics at 18 sites throughout the Petite Rivière monthly in 2018 (Table 1). The physical water characteristics were measured using a multi-parameter YSI sonde, which was calibrated monthly to ensure accuracy. The dissolved oxygen (DO) probe of the YSI was calibrated three times in the field to avoid instrument drift. The YSI recorded water temperature, pressure, specific conductivity (SPC), salinity, total dissolved solids (TDS), DO, and pH of the water in the field.

Table 1: Start of sampling, site type, and GPS coordinates of the 18 water quality sampling sites throughout the Petite Rivière.

Start of Sampling	Current Site Name	Current Site Nickname	Site Type	Latitude	Longitude
May 2010	Milipsigate Dam	Milipsigate	Lake	N 44.34448	W 064.59073
	Birch Brook	Birch	River/Stream	N 44.33183	W 064.63570
	Minamkeak Brook	Minamkeak	Lake	N 44.31993	W 064.59843
	Hebb Lake to Fancy Lake Outlet	Fancy	River/Stream	N 44.35044	W 064.53985
	Conquerall Mills Dam	Conquerall	River/Stream	N 44.30833	W 064.52599
	Hebb Mill Brook (Publicover Lake)	HebbMill	River/Stream	N 44.29110	W 064.51426
	Italy Cross Intersection (Wallace Brook)	Italy	Culvert	N 44.26202	W 064.48882
	Crousetown Dam	Crousetown	Dam	N 44.26188	W 064.48510
	Brown Branch Brook	BrownBranch	Culvert	N 44.24802	W 064.47700
	Wamback Mill Brook	WambackMill	River/Stream	N 44.23883	W 064.45638
	Petite Riviere Head of Tide	HeadofTide	River Estuary	N 44.23420	W 064.44730
May 2011	Hebbville Dam	Hebbville	Dam	N 44.35199	W 064.54532
Nov 2011	Wallace Brook (Wallace Lake)	Wallace	Culvert	N 44.27216	W 064.52512
	Weagle's Dam Outlet	Weagle	River/Stream	N 44.34456	W 064.54189
	Wildcat Brook	Wildcat	River/Stream	N 44.36694	W 064.58411
May 2012	Frederick's Brook	Frederick	Culvert	N 44.31488	W 064.65692
	Kaulback Brook	Kaulback	Culvert	N 44.27448	W 064.45704
	Fire Pond	FirePond	Lake	N 44.23794	W 064.45856

2.2. Water Quality Survey of Milipsigate Lake Headwaters

Coastal Action employees sampled the physical water characteristics at 10 sites throughout the headwaters of Milipsigate Lake once in November 2018 (Table 2). The physical water characteristics were measured using a multi-parameter YSI sonde, which was calibrated monthly to ensure accuracy. The dissolved oxygen (DO) probe of the YSI was calibrated three times in the field to avoid instrument drift. The YSI recorded water temperature, pressure, SPC, salinity, TDS, DO, and pH of the water in the field (known as *in-situ*).

Table 2: Sampling date, site type, and GPS coordinates of the 10 water quality sampling sites in the headwaters of Milipsigate Lake within the Petite Rivière watershed.

Sampling Date	Site Name	Site Type	Sampling Method	Latitude	Longitude
Nov 7, 2018	MILI1	River/Stream	Car	44.33174	-64.6356
	MILI2	River/Stream	Car	44.33069	-64.639
	MILI3	River/Stream	Car	44.33078	-64.6391
	MILI4	River/Stream	Car	44.33964	-64.6493
	MILI5	River/Stream	Car	44.35093	-64.6658
	MILI6	River/Stream	Car	44.34864	-64.6795
	MILI7	River/Stream	Car	44.32686	-64.591
Nov 9, 2018	MILI8	River/Stream Mouth to Lake	Boat	44.34632	-64.6004
	MILI9	River/Stream Mouth to Lake	Boat	44.32861	-64.6156
	MILI10	River/Stream Mouth to Lake	Boat	44.32052	-64.6212

Water samples were also collected at all 10 headwater sites and sent to the accredited Maxxam Analytics Laboratory (Maxxam) in Bedford, NS to be tested for various chemicals. Each sample was tested for chloride, total nitrogen, nitrate plus nitrite, total organic carbon (TOC), total phosphorus, total suspended solids (TSS), and total metals.

2.3. Water and Sediment Sampling within Milipsigate Lake

Coastal Action staff sampled the physical water characteristics at one site within Milipsigate Lake once in November 2018 (Table 3). The physical water characteristics were measured using a multi-parameter YSI sonde, which was calibrated monthly to ensure accuracy. The dissolved oxygen (DO) probe of the YSI was calibrated three times in the field to avoid instrument drift. The YSI recorded water temperature, pressure, SPC, salinity, TDS, DO, and pH of the water in the field.

Table 3: Sampling date, site type, and GPS coordinates of the lake water and sediment samples collected from Milipsigate Lake within the Petite Rivière watershed.

Sampling Date	Site Name	Site Type	Sampling Method	Latitude	Longitude
Nov 9, 2018	MILI LAKE	Lake	Boat	44.32707	-64.5941
	MILI SEDIMENT	Lake	Boat, Ekman Dredge	44.32954	-64.599

One water sample was collected from within the lake and sent to Maxxam to be tested for various chemicals. The sample was tested for chloride, total nitrogen, nitrate plus nitrite, total organic carbon (TOC), total phosphorus, total suspended solids (TSS), and total metals.

One sediment sample was collected from within the top 30-cm of the substrate of the lake, using an Ekman Dredge, and sent to Maxxam to be tested for various chemicals. The sediment sample was tested for total nitrogen, TOC, nitrate plus nitrite, total solids, total phosphorus, and total metals.

3. Results and Discussion

3.1. Water Quality Throughout the Petite Rivière Watershed

Water temperatures in the 18 Petite Rivière sites ranged from 0.2 to 27.4°C throughout 2018 (Figure 2). All except one site – Kaulback Brook – exceeded 20°C, the temperature threshold for fish (NSSA, 2014). All threshold exceedances occurred in July, August, and September. Due to temperatures exceeding the threshold by more than 5°C at seven of the 18 sites, groundwater infiltration and shaded sections of the river are important for providing thermal refuge for fish during the summer months.

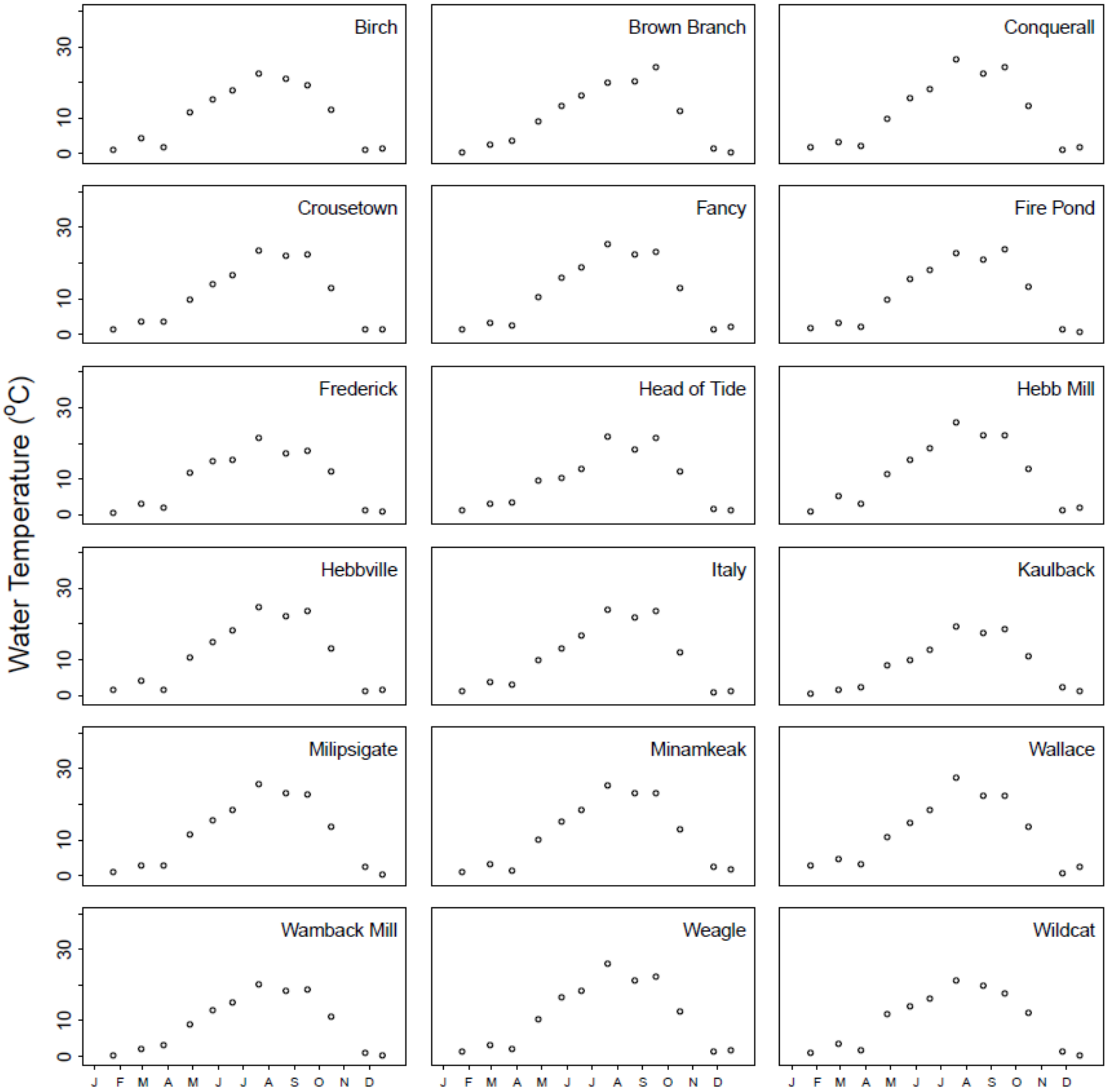

Figure 2: Water temperatures for the 18 sites within the Petite Rivière watershed, measured monthly in 2018.

The DO throughout the Petite Rivière watershed ranged from 4.4 to 15.0 mg/L (Figure 3). Although 10 of the 18 sites fell below the 6.5 mg/L threshold for cold-water aquatic life, as set by Canadian Council of Ministers of the Environment (CCME, 1999), the minimum recorded DO was only 4.4 mg/L, well above the <2.1 mg/L DO concentrations known to cause detrimental effects to aquatic organisms (Moss and Scott, 2011; Nebeker et al., 1992). As the program's sampling frequency is monthly, the full range of DO concentrations at higher frequencies is unknown, and therefore it is unclear how low DO falls at each site and how long each DO period lasts.

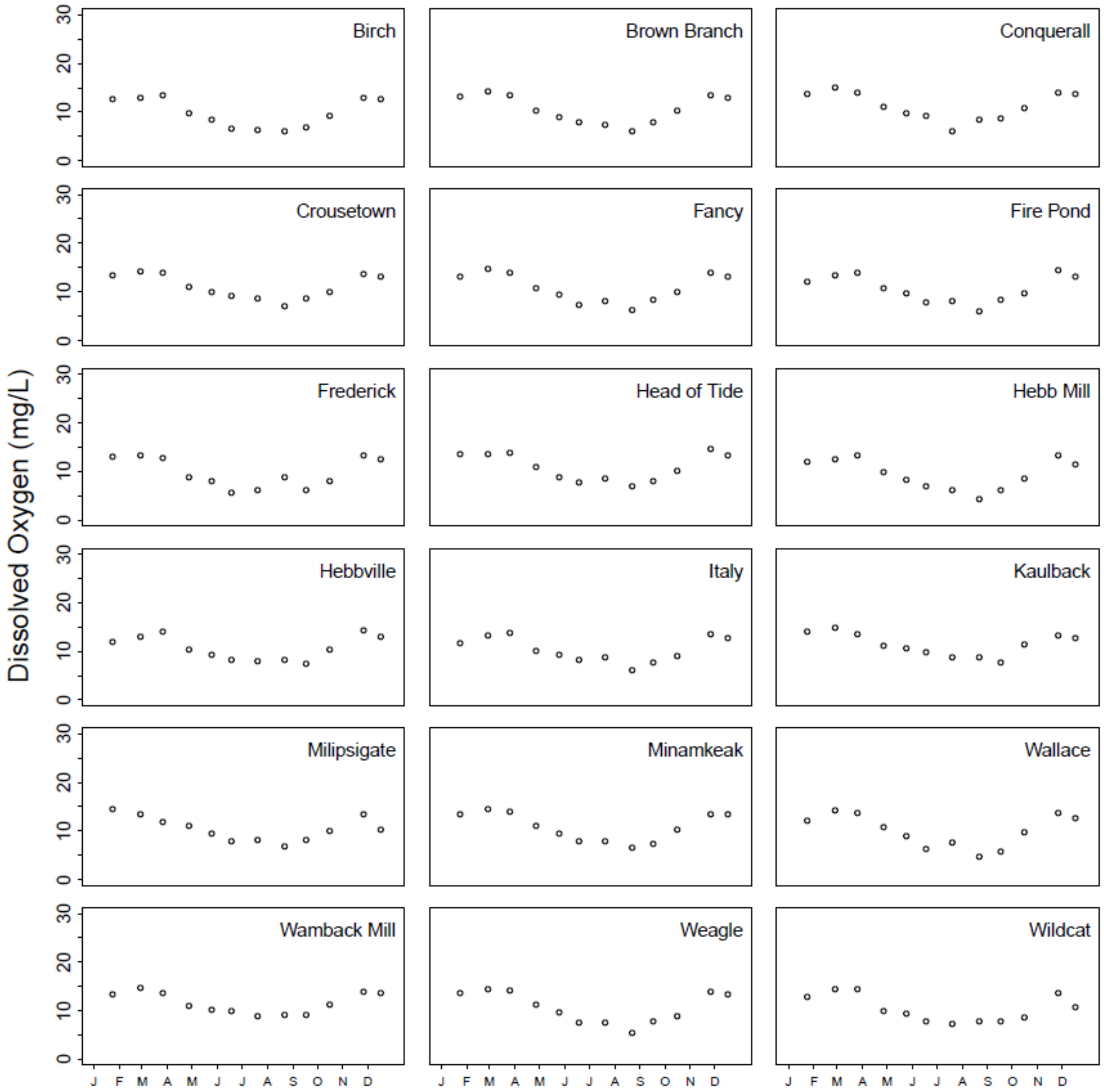

Figure 3: Water DO for the 18 sites within the Petite Rivière watershed, measured monthly in 2018.

TDS ranged from 16.9 to 29,698.5 mg/L throughout the Petite Rivière 18 sites in 2018 (Figure 4); however, most sites fell below 116.35 mg/L, as the 29,698.5 mg/L measurement was recorded at the Head of Tide site and influenced by the ocean at high tide. Although the effects of TDS on fish are dependent on life stage (Weber-Scannell and Duffy, 2007), juvenile and mature Salmonidae can survive in waters with TDS greater than 2,000 mg/L. As 17 of the 18 sites had TDS concentrations below 2,000 mg/L, it appears TDS concentrations within the Petite Rivière watershed, aside from the Head of Tide site, do not pose a threat to aquatic organisms.

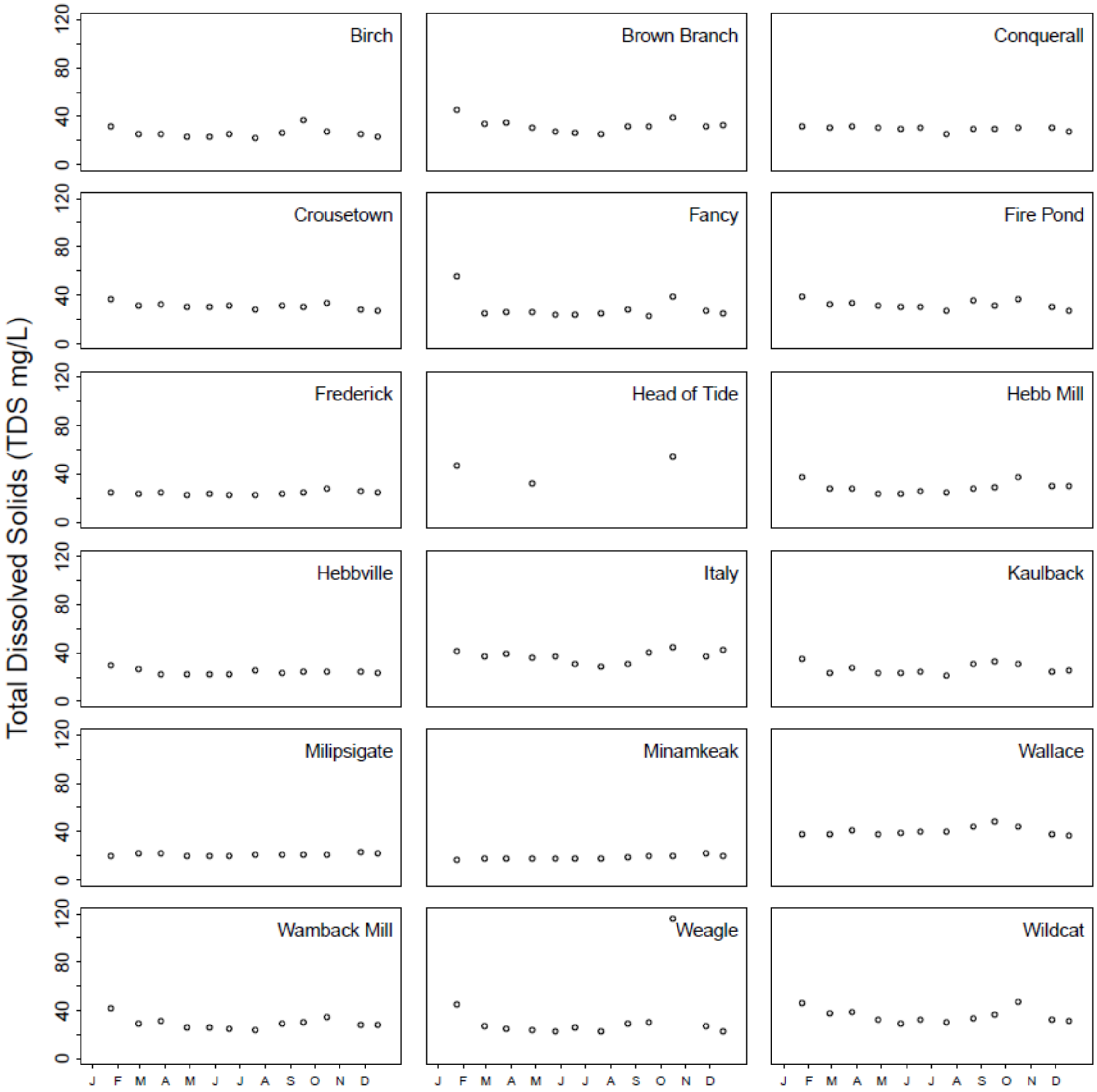

Figure 4: Water TDS for the 18 sites within the Petite Rivière watershed, measured monthly in 2018.

The pH of the 18 Petite Rivière sites ranged from 3.23 to 7.85 in 2018 (Figure 5). Compared to the 6.5-pH threshold set by the CCME for the protection of aquatic life (CCME, 2007), all 18 sites fell below the threshold. All sites also fell below the 5.5-pH south shore-specific threshold set by Environment Canada. The acidity of the Petite Rivière poses a threat to aquatic organisms. All sites had minimum pH values below 5.0-pH, a pH known to decrease the survival of Atlantic whitefish eggs (Cook et al., 2010). As the sampling frequency limits data to a monthly-basis, the true range of pH within the watershed is unknown. Although the sampling frequency limits our knowledge on the length of low-pH periods, the acidity of each site is increasing (MacLeod, 2018), therefore the total length of time in which pH threatens aquatic life is increasing.

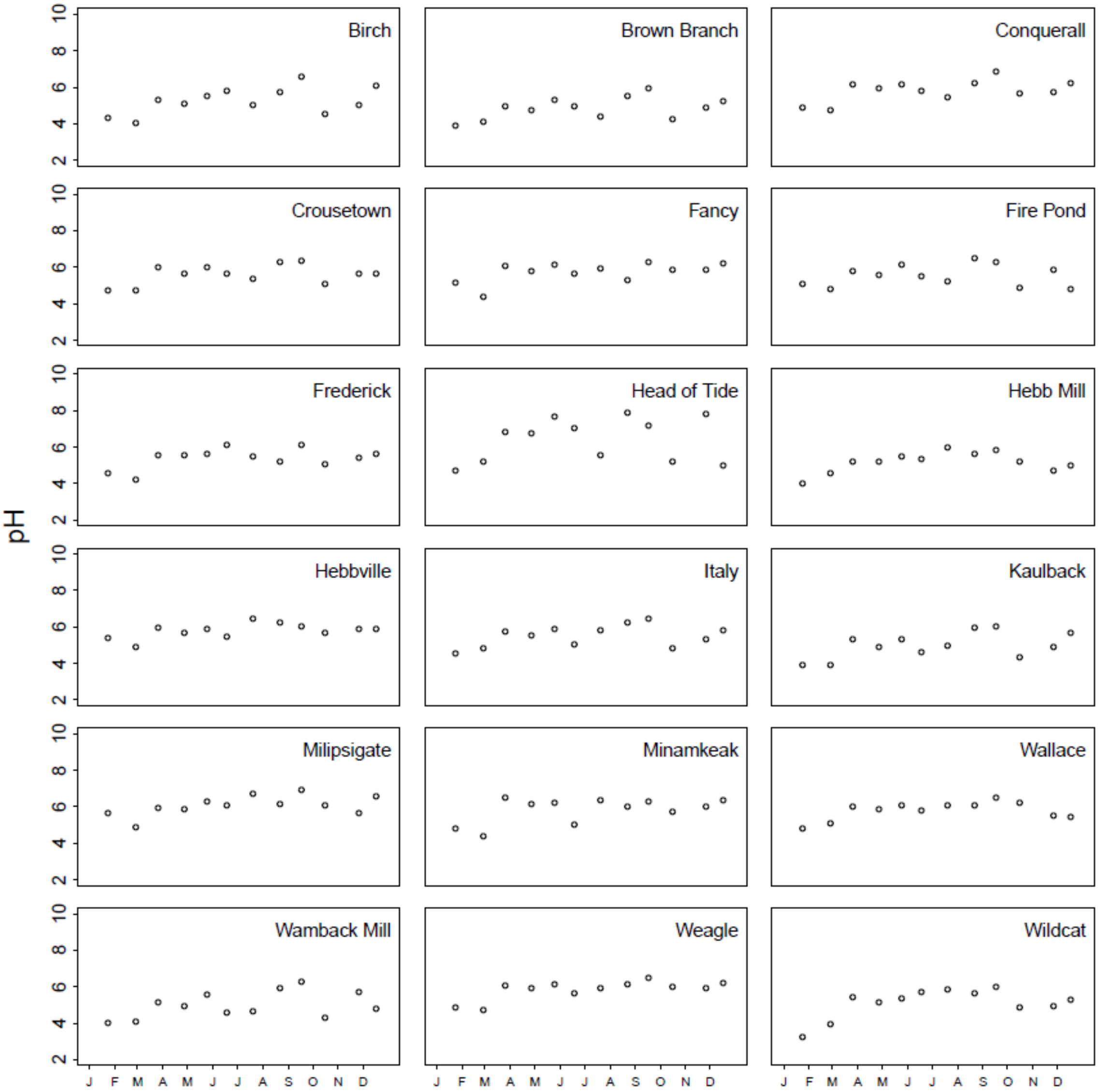

Figure 5: Water pH for the 18 sites within the Petite Rivière watershed, measured monthly in 2018.

3.2. Water Quality Within the Milipsigate Lake Headwaters

Physical water characteristics within the ten Milipsigate Lake headwaters may be posing a threat to aquatic life survival (Table 4). As samples were collected in November 2018, water temperatures were well below the 20°C threshold for cold-water fish. As no thresholds exist for conductivity and TDS, the measurements from the ten headwaters should not affect fish. The elevated TDS concentration at the MILI 7 site (108 mg/L) compared to the other nine sites (<30 mg/L) may pose a threat to organisms within the water due to less light penetration; however, as this site was within an abandoned-gold-mine-turned-wetland, elevated TDS concentrations are normal in wetlands and therefore should not affect wetland-specific organisms. DO was above the CCME's 6.5 mg/L minimum requirement for eight of the ten sites, with DO dropping to 5.78 and 0.68 mg/L at the remaining two sites. As measurements were only done once, it is unclear how long these low-DO periods lasted; however, fish can survive in low-DO conditions for short periods, and for the 0.68 mg/L (MILI 7) site, few fish would be exposed to the low-DO concentrations due to its low-productivity wetland environment. Finally, the pH measurements of seven of the ten headwater sites were more acidic than CCME guidelines and Environment Canada recommend. The CCME's natural pH range for streams is 6.5-9.0; in the South Shore of Nova Scotia, Environment Canada uses a 5.5-miniumum pH threshold to account for the more acidic bedrock and soils that exist in the region. Seven of the ten sites had values below 5.5, and five sites were below 4.5-pH. Unfortunately, because 70% of sites were below the 5.0-pH threshold known to negatively affect Atlantic whitefish eggs, the acidity of the Milipsigate Lake headwaters may be impacting the survival of the Atlantic whitefish population and other aquatic organisms within the headwater streams and the lake itself.

Nutrients within the ten sites do not appear to indicate any point source pollution issues within the headwaters (Table 4). Phosphorus concentrations never exceeded 0.019 mg/L, 0.011 mg/L below the 0.03 mg/L phosphorus guidelines for streams and rivers set by the Ontario Ministry of Environment (MOE, 1979). In addition, nitrate plus nitrite concentrations were not detectable at any site, and total nitrogen concentrations were below the 0.9 mg/L used by Dodds and Welch (2000) for freshwater environments to avoid nutrient loading and eutrophication.

Metal concentrations within the headwaters of Milipsigate Lake indicate both point source and non-point source contamination of the waters, with metal concentrations exceeding CCME guidelines (Table 4). Aluminum and iron were regularly exceeded at the headwater sites, with 100% and 80% of sites exceeding guidelines, respectively. Aluminum concentrations within the headwaters pose a significant hazard to aquatic organisms, as concentrations were up to 60 times the CCME threshold. Elevated levels of aluminum and iron have led to fish mortality, and reduced reproduction of invertebrates, amphibians, and plants (Baker and Schofield, 1982; Sparling and Lowe, 1996; Rosseland et al., 1990). As the bedrock in the region is the Halifax Formation – a formation with high amounts of iron and aluminum – the presence of these two metals in the headwaters appears natural and not from a point source.

Arsenic and copper were also found to exceed CCME guidelines, but not at all sites, suggesting the influence of a point source. MILI 2 exceeded the 2.00 µg/L copper threshold by 0.3 µg/L. The MILI 2 site was chosen due to its proximity downstream of a quarry. Though TDS and nutrients within the site indicate minimal pollution influence, the elevated copper concentrations may be due to continued disturbance and flushing of tailings and debris piles from the site. Monitoring for changes in water quality at MILI 2 is recommended to confirm whether copper (and other metal) concentrations are increasing, and to mitigate any degradation to the environment from possible point sources. At MILI 7, arsenic and copper exceeded CCME guidelines. This site was once an operational gold mine, but now acts as a wetland. High concentrations of arsenic and copper at this site show the continued effects of the previous land-use. Arsenic was a key component for the extraction of gold in gold mines and may be the source of the elevated arsenic at MILI 7. As arsenic was only an issue at MILI 7, it appears to be site specific and therefore a point source issue – supporting the hypothesis that the source is related to gold mine activities. Although the arsenic appears to only be an issue at MILI 7, this site is within the headwaters of Milipsigate Lake and the flushing of the water at this site during storms may cause high metal concentrations to affect downstream habitat.

Both point source issues (land disturbance) and non-point source issues (geology) are impacting the water quality of the Milipsigate Lake headwaters. Due to their position in the watershed, the elevated metals should not pose a risk to aquatic organisms in the lower parts of the watershed, as Milipsigate Lake would act as a buffer and catchment for metals. Unfortunately, Milipsigate Lake is one of the three lakes in the world hosting the Atlantic whitefish population, and therefore the protection this lake provides to the downstream section of the Petite Rivière watershed also increases the accumulation and exposure of metals from these streams to the lake’s endangered whitefish.

Table 4: Physical and chemical water quality from ten headwater streams above Milipsigate Lake sampled in 2018. Parameter thresholds are set based on the CCME guidelines for the protection of aquatic life, with the temperature threshold based off the NSSA guidelines and pH threshold set by Environment Canada for the Nova Scotia South Shore region. Red indicates a measurement exceeds its CCME threshold. ND = Not Detectable (below the detection limit).

Site Date Time	Units	Detection Limit	Thresholds	MILI1 Nov 7 /18 9:50	MILI2 Nov 7 /18 10:13	MILI3 Nov 7 /18 10:28	MILI4 Nov 7 /18 10:42	MILI5 Nov 7 /18 11:04	MILI6 Nov 7 /18 11:20	MILI7 Nov 7 /18 13:55	MILI8 Nov 9 /18 10:03	MILI9 Nov 9 /18 10:59	MILI10 Nov 9 /18 11:24
Temperature	oC	N/A	20	10.4	10.6	10.9	10.6	10.7	10.9	10.1	7.8	8.3	9.3
Pressure	mmHg	N/A		748	748	747.9	747.3	747.1	747	747.9	764.3	764.6	764.6
DO	%	N/A		82.4	87.1	70.1	89.8	52.1	91.1	6.1	84.9	96	68.8
DO	mg/L	N/A	6.5	9.2	9.7	7.74	10.01	5.78	10.06	0.68	10.11	11.3	7.98
SPC	mS/cm	N/A		0.035	0.044	0.029	0.039	0.042	0.041	0.167	0.044	0.035	0.03
TDS	mg/L	N/A		23	29	19	26	27	27	108	29	23	20
Salinity	ppt	N/A		0.02	0.02	0.01	0.02	0.02	0.02	0.08	0.02	0.02	0.01
pH	pH	N/A	5.50	4.34	5.98	4.75	4.37	4.2	3.88	6.26	5.74	4	4.88
Total Phosphorus	mg/L	0.004		0.012	0.007	0.013	0.008	0.010	0.005	0.019	0.011	0.008	0.009
Nitrate + Nitrite (N)	mg/L	0.050		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Organic Carbon (C)	mg/L	0.50		14	13	11	13	16	12	9.2	6.7	13	16
Dissolved Chloride (Cl-)	mg/L	1.0	120000	5.8	5.3	4.9	6.8	7.2	6.1	4.5	6.0	6.2	5.1
Total Suspended Solids	mg/L	1.0		1.2	3.4	1.0	1.4	ND	ND	ND	1.0	1.4	ND
Total Nitrogen (N)	mg/L	0.020		0.407	0.389	0.473	0.326	0.400	0.312	0.313	0.316	0.311	0.414
Total Aluminum (Al)	ug/L	5.0	5.0	250	230	130	300	250	210	110	78	220	290
Total Antimony (Sb)	ug/L	1.0		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Arsenic (As)	ug/L	1.0	5.0	ND	1.8	ND	ND	ND	ND	7.6	2.9	ND	2.7
Total Barium (Ba)	ug/L	1.0		2.7	2.9	1.9	2.9	2.5	2.1	4.4	1.7	2.7	3.1
Total Beryllium (Be)	ug/L	1.0		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Bismuth (Bi)	ug/L	2.0		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Boron (B)	ug/L	50	1500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Cadmium (Cd)	ug/L	0.010	0.090	0.015	0.012	0.019	0.026	0.024	0.014	0.015	ND	0.027	0.022
Total Calcium (Ca)	ug/L	100		1000	4500	940	700	660	380	18000	1300	890	1600
Total Chromium (Cr)	ug/L	1.0	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Cobalt (Co)	ug/L	0.40		0.53	0.74	ND	0.46	ND	0.46	0.54	ND	0.52	0.48
Total Copper (Cu)	ug/L	2.0	2.0	ND	2.3	ND	ND	ND	ND	2.3	ND	ND	ND
Total Iron (Fe)	ug/L	50	300	960	660	280	1100	820	660	150	310	830	470
Total Lead (Pb)	ug/L	0.50	1.0	ND	0.51	ND	ND	ND	ND	ND	ND	ND	ND
Total Magnesium (Mg)	ug/L	100		550	660	570	540	460	370	600	520	510	410
Total Manganese (Mn)	ug/L	2.0		56	65	46	50	34	31	87	29	53	80
Total Molybdenum (Mo)	ug/L	2.0	73	ND	ND	ND	ND	ND	ND	13	ND	ND	ND
Total Nickel (Ni)	ug/L	2.0	25	ND	2.0	ND	ND	ND	ND	ND	ND	ND	ND
Total Phosphorus (P)	ug/L	100		ND	ND	ND	ND	ND	ND	ND	ND	ND	190
Total Potassium (K)	ug/L	100		350	410	610	300	560	160	600	290	280	360
Total Selenium (Se)	ug/L	1.0	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Silver (Ag)	ug/L	0.10	0.25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Sodium (Na)	ug/L	100		3800	3200	2500	4100	4400	3400	2500	3500	3700	2600
Total Strontium (Sr)	ug/L	2.0		6.9	25	7.1	5.0	4.3	2.9	84	9.0	6.5	11
Total Thallium (Tl)	ug/L	0.10	0.80	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Tin (Sn)	ug/L	2.0		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Titanium (Ti)	ug/L	2.0		2.1	3.3	2.0	2.5	2.3	ND	ND	ND	2.3	2.3
Total Uranium (U)	ug/L	0.10	15	ND	0.14	ND	ND	ND	ND	ND	ND	ND	ND
Total Vanadium (V)	ug/L	2.0		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Zinc (Zn)	ug/L	5.0	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

3.3. Water and Sediment Quality within Milipsigate Lake

3.3.1. Water Quality

The physical water quality of Milipsigate Lake was within guidelines for the protection of aquatic life (Table 5). As sampling occurred in November, the water temperature was well below the 20ºC cold-water fish threshold. Dissolved oxygen was at 10.8 mg/L, well above the 6.5 mg/L minimum. Conductivity, TDS, and salinity were all within expected freshwater ranges, suggesting minimal influence from pollution sources. Although the 5.55-pH was above the 5.50 pH threshold set for the south shore of Nova Scotia, it is a lower pH than that expected of lake bodies. As samples were collected following a large rainstorm, it is possible that the increase in volume of water entering the lake from its acidic headwaters (see Section 3.2) influenced the lake's pH and increased its acidity.

Nutrient concentrations within the lake are within known acceptable concentrations for aquatic life (Table 5). The phosphorus concentration was 0.004 mg/L – this meets the ≤0.02 mg/L guidelines for lakes set by Ontario's Ministry of Environment and Climate Change (MOE, 1979). Total nitrogen (0.239 mg/L) was within the ≤0.3 mg/L guideline set by Underwood and Josselyn (1979) for oligotrophic lakes. In addition, nitrate and nitrite – key indicators of pollution – were not detectable within the lake. The apparent oligotrophic status of Milipsigate Lake indicates low productivity and a suitable habitat for fish.

Metal concentrations in Milipsigate Lake indicate that one metal poses a risk to Milipsigate Lake's aquatic life (Table 5). Only aluminum exceeded its CCME guideline, with the total aluminum concentration from Milipsigate Lake nine times the CCME guideline. The presence of aluminum in the lake's water may be a combination of natural and anthropogenic sources. Although the bedrock within the region has a high concentration of aluminum, the continued input of aluminum-rich water from Milipsigate Lake's headwaters (see Section 3.2) may be further influencing the lake's aluminum concentrations. In addition, land-use practices that expose the aluminum-rich bedrock to erosion may augment the amount of aluminum entering the headwaters and eventually the lake. Continuous exposure to high aluminum concentrations by aquatic organisms – especially Atlantic whitefish – may cause long-term negative effects on the organisms and their populations (Baker and Schofield, 1982; Sparling and Lowe, 1996; Rosseland et al., 1990). Although biological samples from the lake were not collected and analyzed for metals to confirm the effects on organisms within the lake, aluminum should be considered a threat to the Atlantic whitefish population within Milipsigate Lake.

Table 5: Physical and chemical water quality from Milipsigate Lake, sampled in 2018. Parameter thresholds are set based on the CCME guidelines for the protection of aquatic life, with the temperature threshold based off the NSSA guidelines and pH threshold set by Environment Canada for the Nova Scotia South Shore region. Red indicates a measurement exceeds its CCME threshold. ND = Not Detectable (below the detection limit).

Site **Date** **Time**	**Units**	**Detection Limit**	**Thresholds**	**Mili Lake** **Nov 9 /2018** **12:02**
Temperature	oC	N/A	20	9.4
Pressure	mmHg	N/A		764
DO	%	N/A		94.3
DO	mg/L	N/A	6.5	10.8
SPC	mS/cm	N/A		0.028
TDS	mg/L	N/A		18
Salinity	ppt	N/A		0.01
pH	pH	N/A	5.50	5.55
Total Phosphorus	mg/L	0.004		0.004
Nitrate + Nitrite (N)	mg/L	0.050		ND
Total Organic Carbon (C)	mg/L	0.50		4.2
Dissolved Chloride (Cl-)	mg/L	1.0	120000	5.0
Total Suspended Solids	mg/L	1.0		1.2
Total Nitrogen (N)	mg/L	0.020		0.239
Total Aluminum (Al)	ug/L	5.0	5.0	47
Total Antimony (Sb)	ug/L	1.0		ND
Total Arsenic (As)	ug/L	1.0	5.0	ND
Total Barium (Ba)	ug/L	1.0		2.0
Total Beryllium (Be)	ug/L	1.0		ND
Total Bismuth (Bi)	ug/L	2.0		ND
Total Boron (B)	ug/L	50	1500	ND
Total Cadmium (Cd)	ug/L	0.010	0.09	ND
Total Calcium (Ca)	ug/L	100		1000
Total Chromium (Cr)	ug/L	1.0	1.0	ND
Total Cobalt (Co)	ug/L	0.40		ND
Total Copper (Cu)	ug/L	2.0	2.0	ND
Total Iron (Fe)	ug/L	50	300	73
Total Lead (Pb)	ug/L	0.50	1.0	ND
Total Magnesium (Mg)	ug/L	100		500
Total Manganese (Mn)	ug/L	2.0		16
Total Molybdenum (Mo)	ug/L	2.0	73	ND
Total Nickel (Ni)	ug/L	2.0	25	ND
Total Phosphorus (P)	ug/L	100		ND
Total Potassium (K)	ug/L	100		330
Total Selenium (Se)	ug/L	1.0	1.0	ND
Total Silver (Ag)	ug/L	0.10	0.25	ND
Total Sodium (Na)	ug/L	100		3300
Total Strontium (Sr)	ug/L	2.0		7.0
Total Thallium (Tl)	ug/L	0.10	0.80	ND
Total Tin (Sn)	ug/L	2.0		ND
Total Titanium (Ti)	ug/L	2.0		ND
Total Uranium (U)	ug/L	0.10	15	ND
Total Vanadium (V)	ug/L	2.0		ND
Total Zinc (Zn)	ug/L	5.0	30	ND

3.3.2. Sediment Quality

The sediment sample collected from Milipsigate Lake in November 2018 indicates a high degree of metal contamination within the lake's substrate (Table 6). To fully understand the levels of contamination, sediment data were compared to two guidelines – the Interim Sediment Quality Guideline (ISQG) and the Nova Scotia Environmental Quality Standards (NSEQS). The ISQG is set by the CCME as the total concentration of chemicals recommended in surficial sediment (CCME, 2001), while the NSEQS uses many of the same guidelines as the CCME's Probable Effect Level (PEL), which is the upper value in which adverse effects are expected for organisms (NSE, 2014; CCME, 2001). Within the Milipsigate Lake substrate, cadmium, lead, and zinc exceeded the ISQG thresholds, while arsenic, mercury, and selenium exceeded both thresholds. The NSE (2014) has stated that PEL guidelines provide a better indicator of the potential for adverse effects to populations compared to ISQG, therefore, the exceedance of three metals beyond PEL guidelines suggests a substantial current threat to organisms within Milipsigate Lake. The metals can adversely affect organisms by bioaccumulation of metal concentrations through the food-chain, competing and limiting the uptake of other essential elements, inactivating enzymes, and disrupting metabolic pathways (Eggleton and Thomas, 2004). In the Coeur d'Alene River of Idaho, USA – impacted from mining activities similar to Milipsigate Lake – elevated arsenic, cadmium, copper, lead, mercury, and zinc concentrations were recorded, and found to be present in elevated levels in invertebrates and fish (Farag et al., 1998). Farag and others also found that early life-stage fish were exposed to greater doses of metals, as their diets relied on invertebrates – invertebrates which were heavily exposed and contaminated with metals from within the sediment. Although it is unclear how long metal concentrations have been elevated to these adverse-effect-causing levels in Milipsigate, it is clear that current exposure to these levels will be negatively impacting Atlantic whitefish populations, especially those in early lifestages, and will continue to have adverse effects with continued exposure.

Metal concentrations within Milipsigate Lake are higher than those reported in other lakes in Nova Scotia. A study by Kirk (2018) investigated metals in the substrate of four Kejimkujik Lakes: Hilchemakaar, Big Dam East, Cobrielle, and Peskowesk (Table 6). Although the metal levels within the four lakes exceeded ISQG and NSEQS thresholds, the highest concentrations found were lower than those of Milipsigate Lake. Both Milipsigate Lake and the Kejimkujik region had previous gold mine activities, which may be influencing the higher metal concentrations recorded at both; however, the increased metals within Milipsigate Lake indicates that there is a greater negative influence of both natural and anthropogenic affecting Milipsigate Lake's sediment quality. As Atlantic whitefish continue to be observed within Milipsigate Lake, the effect-level of the sediment's contamination on the fish survival rates; however, as Kejimkujik lakes have lower metal concentrations, they may pose a safe alternative – pending water quality – for the translocation of the Atlantic whitefish population.

Table 6: Chemical sediment quality from Milipsigate Lake, sampled in 2018 and the range of metal concentrations reported in the four Kejimkujik Lakes monitored from 2000-2009 by Kirk (2018). Parameter thresholds are set based off of the ISQG and NSEQS guidelines. Red indicates a measurement exceeds both the ISQG and NSEQS thresholds, while yellow indicates that the ISQG threshold has been exceeded. ND = Not Detectable (below the detection limit).

Site Date Time	Units	ISQG Threshold	NSEQS Threshold	Detection Limit	MILI SEDIMENT Nov 9 /2018 13:00	Kejimkujik Lakes' Range
Nitrate + Nitrite (N)	mg/kg			0.25	0.38	
Total Organic Carbon	mg/kg			500	170000	
Acid Extractable Aluminum (Al)	mg/kg			10	22000	
Acid Extractable Antimony (Sb)	mg/kg		25	2.0	ND	
Acid Extractable Arsenic (As)	mg/kg	5.9	17	2.0	140	3.55-27.1
Acid Extractable Barium (Ba)	mg/kg			5.0	55	
Acid Extractable Beryllium (Be)	mg/kg			2.0	ND	
Acid Extractable Bismuth (Bi)	mg/kg			2.0	ND	
Acid Extractable Boron (B)	mg/kg			50	ND	
Acid Extractable Cadmium (Cd)	mg/kg	0.6	3.5	0.30	1.2	0.1-0.4
Acid Extractable Chromium (Cr)	mg/kg	37.3	90	2.0	24	
Acid Extractable Cobalt (Co)	mg/kg			1.0	25	
Acid Extractable Copper (Cu)	mg/kg	35.7	197	2.0	24	
Acid Extractable Iron (Fe)	mg/kg		47,766	50	37000	
Acid Extractable Lead (Pb)	mg/kg	35	91.3	0.50	73	43-62.5
Acid Extractable Lithium (Li)	mg/kg			2.0	15	
Acid Extractable Manganese (Mn)	mg/kg		1,100	2.0	890	28.7-666
Acid Extractable Mercury (Hg)	mg/kg	0.17	0.486	0.10	0.68	0.14-0.345
Acid Extractable Molybdenum (Mo)	mg/kg			2.0	3.5	
Acid Extractable Nickel (Ni)	mg/kg		75	2.0	27	
Acid Extractable Phosphorus (P)	mg/kg			100	1700	
Acid Extractable Rubidium (Rb)	mg/kg			2.0	7.5	
Acid Extractable Selenium (Se)	mg/kg		2	1.0	3.6	1.39-3.17
Acid Extractable Silver (Ag)	mg/kg		1	0.50	ND	
Acid Extractable Strontium (Sr)	mg/kg			5.0	18	
Acid Extractable Thallium (Tl)	mg/kg			0.10	0.17	
Acid Extractable Tin (Sn)	mg/kg			2.0	3.4	
Acid Extractable Uranium (U)	mg/kg			0.10	1.5	
Acid Extractable Vanadium (V)	mg/kg			2.0	23	
Acid Extractable Zinc (Zn)	mg/kg	123	315	5.0	130	

4. Conclusion

- The headwaters of Milipsigate Lake can supply sufficient dissolved oxygen and temperature refuge to organisms within the streams; however, the high acidity of the headwaters poses a risk to aquatic life. As samples were only collected in November, it is unclear how temperature, DO, and pH change throughout the remainder of the seasons.
- The Milipsigate Lake headwaters indicate natural and anthropogenic sources affecting water quality. Elevated levels of aluminum and iron throughout the headwaters may be attributed to the metal-rich Halifax Formation which underlies the area, while previous gold mining activities and ongoing quarries may be further disturbing the water and increasing the leaching of other metals – including copper and arsenic.
- Low pH and high acidity within the Milipsigate Lake may be a risk to aquatic organisms and may be further influenced by inputs from the acidic, aluminum-rich headwater streams.

- The sediment of Milipsigate Lake is heavily contaminated with metals and poses a risk to Atlantic whitefish via direct exposure and through bioaccumulation, with early life stages at the greatest risk of high-metal dosage exposure.

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