Progress Report: River Studies in the Fort Severn Area, 2011-2013

The Severn River at Fort Severn

Cooperative Freshwater Ecology Unit

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2014

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Background

Northern Ontario is a vast, often very remote area. The far north of Ontario, especially the Hudson Bay Lowlands physiographic region, is very unique, containing the southernmost non-alpine tundra and southernmost population of polar bears in North America. The immense peatlands and extensive permafrost areas are a globally significant store of carbon. Despite the uniqueness and importance of the Hudson Bay Lowlands, its ecosystems have been greatly understudied (Far North Science Advisory Panel, 2010; Abraham et al., 2011).

As part of efforts to expand the scientific knowledge of aquatic systems in the Hudson Bay Lowlands, during 2010 discussions about possible scientific collaborations were held with the chief and council of the Washaho First Nation at Fort Severn. Area rivers and the fisheries they contain were identified as particularly important resources for the community of Fort Severn. Study plans were then developed to begin to better understand the chemistry and biology of a number of rivers in the Fort Severn area. Two projects were subsequently initiated:

1) Sampling of fish from the Severn River for contaminant analyses. Discussions with the community identified whitefish, pike and white sucker as the local fish most harvested by the community, thus the sampling program targeted these species.

2) Sampling of chemistry, invertebrates, and fish from selected rivers between Fort Severn and the Manitoba border. These rivers were identified as important sites for harvesting sea run brook trout.

Progress

Severn River

During summer 2011, samples of whitefish, pike and sucker were collected and field processed by Mr. Timothy Miles of Fort Severn. Twenty individuals of each species were collected. Each fish was weighed and measured and a flesh sample was collected for subsequent analysis for mercury and other contaminants at the Ministry of the Environment laboratory in Toronto.

The results of these analyses were recently published in the 2013-2014 edition of Guide to Eating Ontario Sport Fish. A copy of this publication was provided to the Fort Severn Band office. The guide is also available at www.ontario.ca/fishguide

Other Area Rivers

2011 Study

During July 2011, sampling was conducted on five rivers draining to Hudson Bay between Fort Severn and the Manitoba border: the Pipowatin, Black Currant, Majikan, Tamuna and Mintiagan rivers. The survey crew consisted of Timothy Miles and Owen Miles of Fort Severn, Bill Keller from Laurentian University, Chris Jones from the Ontario Ministry of the Environment, and Lee Haslam from the Ontario Ministry of Natural Resources. Tommy Miles of Fort Severn assisted greatly with study planning and logistics.

At each river, water samples were collected and the communities of bottom-living invertebrates (insects, crustaceans, worms, etc.) were sampled as a first step toward developing the scientific understanding of the chemical and biological nature of these northern rivers. In four of the rivers (excluding the Black Currant) fish were collected and processed for contaminant analyses. Brook trout were sampled in all four of these rivers (10 from each). Additionally, ten whitefish were collected from the Pipowatin River. These fish samples have not yet been analysed. Results will be provided to the community when they are available.

The results of the chemistry and invertebrate surveys were recently published in the scientific journal Polar Biology (Jones et al., 2013). A copy of that paper is provided in the Appendix to this progress report. Data tables from that study are also provided in the Appendix. This work has provided important baseline information which will allow assessment of future changes, and could be a first step in the development of a long-term monitoring program.

Fish sampling

2012 Study

Previous work elsewhere on the Hudson Bay coast has demonstrated that climate-related warming events can periodically cause fish death in at least some coastal rivers, like the Sutton River, east of the community of Peawanuck (Gunn and Snucins, 2010). Because future climate warming is expected to be particularly pronounced in the far north of Ontario, it is important to begin to document the current water temperatures in northern rivers such as those in the area of Fort Severn.

Therefore, during 2012, recording thermometers were installed in three rivers (Pipowatin, Black Currant, Majikan) during July 8-14. In each river, recording thermometers were placed at three locations; near the mouth, at the treeline, and about halfway between the mouth and treeline. Temperature recorders were retrieved in October. Installation and retrieval were done by Timothy Miles and Owen Miles of Fort Severn.

Plots of the temperature records collected at each river and maps of the sampling locations are provided in the Appendix.

2013 Study

Temperature monitoring was only continued on the Pipowatin River during 2013. Recording thermometers were installed by Timothy Miles on July 6 at the same three locations used in 2012. They were retrieved on September 24 by Timothy Miles, and Bill Keller, Laurentian University. During the September trip, water samples for chemistry analyses were also collected from each site. The results of the chemistry analyses are given in the Appendix.

Summary

From initial discussions in August 2010, two aquatic science projects were developed and implemented in and around the community of Fort Severn. This work is helping to develop the current scientific understanding of what the rivers of the Hudson Bay Lowlands, and the biological communities in them, are like. This progress report summarizes the aquatic science work that has been conducted so far around Fort Severn and provides summaries of the data collected. This information is valuable as a record of baseline conditions from which future changes can be determined. It is also hoped that this current information on aquatic ecosystems may be useful for land use planning purposes. We will be examining the data in more detail and will keep the community informed of any important results that may emerge. We greatly hope to continue such collaborative studies with the community of Fort Severn.

References

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Jones, F.C., Sinclair, S., and Keller, W., 2014: Benthic macroinvertebrate communities in five rivers of the Coastal Hudson Bay Lowland. *Polar Biology* 37: 141-147.

Acknowledgements

This work was supported by the Ontario Ministry of the Environment through the Climate Change and Multiple Stressor Research Program at Laurentian University.

Sampling bottom-living invertebrates

Appendices

A1: The Polar Biology paper based on the 2011 survey of five coastal rivers.

A2: Summary of river chemistry for the Mintiagan, Tamuna, Majikan, and Black Currant rivers, July 2011 and the Pipowatin River, July 2011 and September 2013. "ND" denotes Not Detected

A3: Summary of bottom-living invertebrates found in the Mintiagan, Tamuna, Majikan, Black Currant, and Pipowatin rivers, July 2011. Data for 3 samples are presented, S1, S2 and S3 as well as taxa found "+" during a Large/Rare taxa (L/R) targeted search.

A4. Summary of habitat characteristics for 3 samples at each sampling site in the Mintiagan, Tamuna, Majikan, Black Currant, and Pipowatin rivers, July 2011.

A5. Summary of water temperature records for 3 locations on the Pipowatin River, 2012 and 2013.

A6. Summary of water temperature records for 2 locations on the Black Currant River, 2012.

A7. Summary of water temperature records for 3 locations on the Majikan River, 2012.

The study team, 2011 (L to R- Timothy Miles, Bill Keller, Chris Jones, Owen Miles, Lee Haslam).


Mayfly (Heptageniidae)


Stonefly (Perlodidae)


Caddisfly (Hydropsychidae)

A1: Copy of the Polar Biology paper based on the 2011 survey of five coastal rivers. The photos show some of the families of invertebrates collected during the survey.


Scud (Hyalellidae)


Beetle larva (Elmidae)


Snail (Lymnaeidae)


Midge (Chironomidae)

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SHORT NOTE

Benthic macroinvertebrate communities in five rivers of the Coastal Hudson Bay Lowland

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Abstract As a precursor to developing a biomonitoring program for rivers of the Coastal Hudson Bay Lowland, this study characterized and compared the benthic macroinvertebrate communities and water chemistry in 5 remote, previously undescribed, rivers near Fort Severn, Ontario, Canada. The pH of river water ranged from 8.1 to 8.7, total phosphorus from 11 to 26 $\mu g\ L^{-1}$, dissolved organic carbon from 8 to 12 $mg\ L^{-1}$, and chloride from 56 to 153 $mg\ L^{-1}$. A total of 57 benthic macroinvertebrate taxa were represented, and the 10 most numerically dominant were the Chironominae (26 % of collected individuals), Orthocladiinae (16 %), oligochaetous clitellata (9 %), Hyalellidae (7 %), Hydropsychidae (6 %), Gammaridae (5 %), Elmidae (5 %), Sphaeriidae/Pisidiidae (4 %), Nemata (3 %), and Tanypodinae (3 %). Rivers' positions in ordinations of chemical and biological datasets were similar, suggesting that water chemistry has a role in structuring riverine benthic communities in the study region. Correlations between water-chemistry or habitat predictors and site-scores in the ordination of benthic macroinvertebrate taxa counts suggested that biological community structure was most associated with river-water pH, nutrient concentrations (e.g., total phosphorus, nitrogenous compounds, dissolved organic carbon, calcium, and silicate), the relative abundance of submerged macrophytes, conductivity (i.e., the concentrations of chloride and various other dissolved ions), and several geomorphological variables (e.g., bank-full river width, current speed, and the size of the dominant inorganic particles in the pavement layer of the streambed). Interest in mineral extraction and other resource-based exploration in Ontario's Far North is increasing. This study represents a start on baseline characterization for ecological monitoring and cumulative effects assessment that should proceed along with northern development.

Keywords Benthic macroinvertebrates · Rivers · Water chemistry · Hudson Bay Lowland

Introduction

Recognizing that benthic macroinvertebrates are useful and widely employed indicators for monitoring the cumulative effects of human activities (e.g., Rosenberg and Resh 1993a, b; Wright et al. 2000), a multi-sector collaborative benthic macroinvertebrate biomonitoring program (e.g., Jones et al. 2006, 2007) has been established in Ontario. Almost all of the sampling under that program (The Ontario Benthos Biomonitoring Network) takes place in

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southern Ontario, where most of the province's population is located. For this reason, northern rivers—for example, those of the Coastal Hudson Bay Lowland Ecoregion—are poorly understood.

Improving our knowledge of northern aquatic ecosystems is essential if we are to assess cumulative effects of ecological stressors that will likely coincide with northern development, resource extraction (e.g. mining, forestry), hydro-power generation, and changing climate. In Ontario, future changes in climate are expected to be most pronounced in the north, where background data are also the most limited (Far North Science Advisory Panel 2010). Major mining interests are also likely to have far reaching impacts, especially on river water. According to Baker (2010), for example, "an unchecked explosion in staking and exploration activity" concerns approximately 1.5 million hectares in what is known as the Ring of Fire area, which lies about 240 km west of James Bay, and straddles the Boreal Shield and Hudson Bay Lowland regions of north-central Ontario. Ontario Power Generation (a Government of Ontario electricity-generating crown corporation) presently operates 24 hydro-electric plants on 9 northern Ontario rivers, providing over 1600 MW of capacity (Ontario Power Generation 2013a), and new projects are underway, for example on the Mattagami and Abitibi rivers (Ontario Power Generation 2013b). Changing climate, combined with development and resource extraction has potential to influence the hydrology and geomorphology of rivers, with likely impacts on flow regime (e.g., discharge regimes, current speed) and channel form (e.g., channel width, bottom materials). In concert with these potential future changes, mining poses a threat to water quality—pH and metal concentrations being of chief concern.

The relatively small number of studies of sub-arctic riverine benthic macroinvertebrate communities—i.e., the approximately 50 results yielded by a Google Scholar search on the terms *benthic invertebrate*, *sub-arctic*, and *river*—focus on the importance of benthic macroinvertebrates as food for fish, as mediators of competition between fish species (e.g., Gabler and Amundsen 1999; Elliot 2006), and as sentinels of climate-change effects on biota (e.g., Durand et al. 2009). Questions about reference conditions and biocriteria (numerical thresholds for judging ecological condition) remain for northern rivers, as do questions about the relative importance of chemical, habitat, and ecoregional predictors of community structure. Herein we compare and contrast chemical, biological, and habitat conditions in 5 Hudson Bay tributaries. The study rivers are cherished by the community of Fort Severn, particularly for their stocks of sea-run brook charr (*Salvelinus fontinalis*), which represent an important food source. Other than Campbell et al. (1986), who characterized benthic communities of depositional areas near the mouths of the very large Moose, Albany, Attawapiskat, Winisk, and Severn rivers, we know of no published studies that have described benthic communities in the Coastal Hudson Bay Lowland.

Fig. 1 Study area, **a** regional context; and **b** showing sampled rivers and local land features in the coastal Hudson Bay Lowland

Our purpose was to begin characterizing biological and chemical river condition via a sampling expedition in 2011, thereby providing baseline information to support a future biomonitoring program for the Coastal Hudson Bay Lowland.

Methods

Between 27 and 30 July 2011, we sampled 5 medium-sized rivers that drain the Coastal Hudson Bay Lowland between Fort Severn (Ontario, Canada) and a point approximately 120 km west of Fort Severn, along the Hudson Bay coast (i.e., all rivers that could be visited during a 5-day expedition by all-terrain vehicle): the Mintiagan (56.675°N, 88.629°W), Tamuna (56.525°N, 88.291°W), Majikan (56.482°N, 88.168°N), Black Currant (56.250°N, 87.781°W) and Pipowatin (56.117°N, 87.670°W) rivers (Fig. 1). These rivers' catchments drain areas of flat wetland-dominated topography, underlain by Paleozoic limestone bedrock, and they have a high sub-arctic climate, which maintains a patchy distribution of permafrost, and has established the area as the northern latitudinal limit of tree growth.

Benthic macroinvertebrates were collected using the transect-kick-and-sweep method described for Ontario's provincial biomonitoring program (i.e., Jones et al. 2007): they were collected along transects extending bank-to-bank across the entire wetted width, perpendicular to flow direction; substrate was disturbed by the collector's feet, and dislodged animals were collected in a D-frame dip net (500-μm mesh). Three such transects were sampled (typically within a single meander sequence) in each river. Where available habitat permitted, 2 transects were located in "riffles" (i.e., areas with relatively fast current speed and shallow depth), and one was located in a "pool" (i.e., an area with relatively slow current speed and greater depth).

Macroinvertebrates and sediments were preserved immediately following their collection, using 10 % buffered formalin. After several days, formalin was rinsed from samples and replaced with 70 % ethanol. A Marchant-style (e.g., Marchant 1989) sub-sampling box was used to randomly select portions of the sample to be searched for benthic macroinvertebrates. Such searches were aided by the use of a stereo microscope, and cells from the Marchant Box were sequentially processed to obtain ∼100-counts of benthic macroinvertebrates (the entire sub-sample containing the 100th animal was entirely searched). As a cost-effective way of improving estimates of taxa richness, each 100-count sample was augmented with a 15 person*minute timed search through the remaining unprocessed sediments for large or rare taxa. Sample-processing activities therefore resulted in three 100-count samples for each river, which were supplemented by a 45 person*minute timed search for taxa not represented in the randomly processed 100-count samples.

Regarding taxonomic precision, insects, crustaceans, molluscs, and leeches were diagnosed as families, with the exception of the Chironomidae, which were assigned to their sub-families. The Coelenterata, Platyhelminthes, Nemata, Hydrachnidia, and oligochaetous clitellata were identified with no further detail (Online Resource 1). We justify our relatively coarse taxonomic resolution by reference to Ontario's provincial benthic macroinvertebrate biomonitoring program, for which bioassessments are rarely carried out with taxonomy more precise than family level.

Water samples for chemical analyses were collected as "grab samples": using a gloved hand, collection bottles were triple-rinsed in river water, and then filled just below the river's surface in an area immediately upstream of the benthic invertebrate collection locations where linear downstream flow was observed (i.e., eddies and backwaters were avoided). Chemical analyses were based on a single sample from each river, with the exception of the total phosphorus assay, for which duplicate samples were collected. Water samples were kept on ice during transportation to the analytical laboratory at the Dorset Environmental Science Centre. Samples for dissolved metal assays were acidified with nitric acid upon arrival at the laboratory, where chemical assays (for all analytes listed in Online Resource 2) were completed as per standard laboratory protocols (i.e., Ontario Ministry of the environment 1983) within 7 days of sample collection.

A variety of habitat-related measurements associated with the sampling reach or individual sampling transects were made for each river. Sampling-reach measures included geographic coordinates, elevation (both recorded in the field with a GPS, and later verified, or corrected, using maps in Google Earth), and bank-full width (a representative width was estimated as the mean of 5 measurements made using the Ruler tool in Google Earth). Transect-specific measures included water depth, hydraulic head (a surrogate for current speed; Stanfield 2010), abundances of macrophytes and algae, and dominant and second-dominant substrate pavement-layer particle sizes. Maximum depth and hydraulic head were each recorded as per Jones et al. (2007) and Stanfield (2010). Relative abundances (e.g., "absent", "present", or "abundant") of submergent macrophytes and filamentous algae were estimated visually (e.g., Jones et al. 2007). Dominant pavement-layer substrate particle types (e.g., cobble, gravel, or sand) were also described visually, as specified by Jones et al. (2007). To supplement visual descriptions, particle size was also characterized (per Stanfield 2010) by recording median-axis lengths (or, in the case of sand, silt, or bedrock, a book value corresponding with a representative length for the given substrate class) observed at 10 randomly selected locations along each benthic-invertebrate-collection transect. The methods of Jones et al. (2007) and Stanfield (2010) were used because they are standardized, widely used methods in southern Ontario, and are likely to form the basis of any future monitoring programs developed for more northerly rivers.

The structure of each river's benthic macroinvertebrate community was summarized using a series of indices, including taxonomic richness, % EPT [the proportion of a sample comprising Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies)], % Chironomidae, and % oligochaetous clitellata (percent of the sample comprising aquatic earthworms). Each river's taxonomic richness was calculated as the maximum from its 3 transect samples [each standardized to a 100-animal count using Brzusto (2013)], to which any additional taxa encountered during the large/rare search were added. Other indices were calculated as means of the three transect-specific samples. A pie chart was used to summarize how the regions' 10 most numerically dominant taxa were represented in the 100-count data compiled for each river.

A multivariate summary of community composition was obtained by ordinating the 100-count data using principal coordinates analysis (PCO). Raw taxa counts were used as the ordination input matrix (i.e., the data were not standardized or transformed in any way because taxa counts were scaled equivalently, and were estimated by identical methods), and calculations were made using the PCO computer program (Anderson 2003), based on Hellinger distance.

Chemical composition of the 5 rivers was summarized using principal components analysis (PCA), which was calculated using the Biplot add-in for Microsoft Excel (Lipkovich and Smith 2002). As the input dataset for PCA calculation, we began with the full suite of 42 chemical variables listed in Online Resource 2. From this data matrix, we then eliminated analytes that were universally below laboratory detection limits (Zn, which was below detection in 4 of the 5 rivers, was also omitted). Being invariant, and therefore providing no information useful for discriminating the rivers, the combined nitrite/nitrate variable was also removed from the dataset. Further omissions included variables that were highly redundant with one or more others (i.e., by inspection of the correlation matrix; variables were considered redundant if the absolute value of their correlation coefficient was >0.9; variable deletions were made so as to preserve as many variables as possible in the data matrix, thus variables were removed in order, according to the number of other variables they were redundant with). The 12 remaining variables (Al, Ba, Ca, Cl, Colour, Fe, Mn, ammonia and ammonium ($NH_3 + NH_4$), pH, total P, SiO_3, and Sr) were standardized to Z-scores and used as the PCA input dataset (standardization re-scaled each chemical variable equivalently, in units of standard deviations). Correlations of input predictor variables with PCO and PCA axes were calculated as Pearson's correlations. Unless otherwise noted, all data were compiled and analyzed in Microsoft Excel.

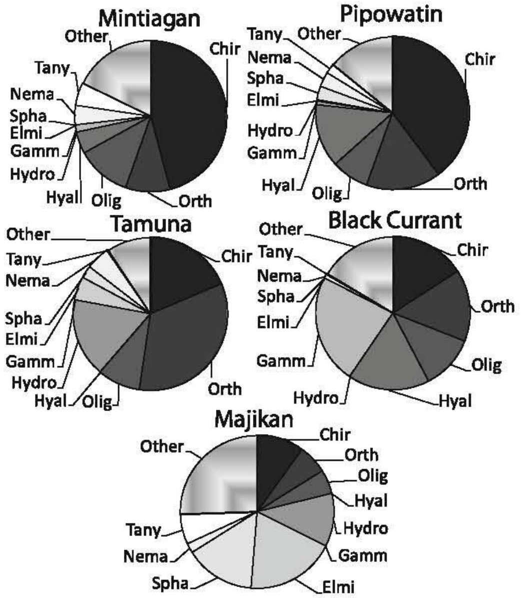

Fig. 2 River specific relative abundances of the dataset's ten most abundant taxa. Chir = Chironominae; Orth = Orthocladiinae; Olig = oligochaetous Clitellata; Hyal = Hyalellidae; Hydro = Hydropsychidae; Gamm = Gammaridae; Elmi = Elmidae; Spha = Sphaeriidae/Pisidiidae; Nema = Nemata; Tany = Tanypodinae; Other = combined abundance of all other taxa

Results and discussion

Benthic macroinvertebrate, chemistry, and habitat datasets are provided as Online Resources 1 through 3, respectively. The pH of river waters ranged from 8.1 to 8.7, the means of duplicate total phosphorus samples ranged from 11 to 26 $\mu g\ L^{-1}$, total Kjeldahl nitrogen from 392 to 695 $\mu g\ L^{-1}$, dissolved organic carbon from 8 to 12 $mg\ L^{-1}$, and chloride from 56 to 153 $mg\ L^{-1}$ (Online Resource 2).

A total of 1884 benthic macroinvertebrates, representing 42 taxa, were identified and enumerated. An additional 15 taxa were found during searches for large or rare taxa, thus 57 taxa were encountered in total. Among the 5 rivers, richness ranged narrowly between 19 and 21, EPT taxa accounted for between 4 and 27 % of collected individuals, Chironomidae between 21 and 60 %, and oligochaetous clitellata between 5 and 11 %. Based on their relative abundances, the 10 most numerically dominant benthic-macroinvertebrate taxa in the region (i.e., in the entire 5-river dataset), were the Chironominae (26 % of collected individuals), Orthocladiinae (16 %), oligochaetous clitellata (9 %), Hyalellidae (7 %), Hydropsychidae (6 %), Gammaridae (5 %), Elmidae (5 %), Sphaeriidae/Pisidiidae

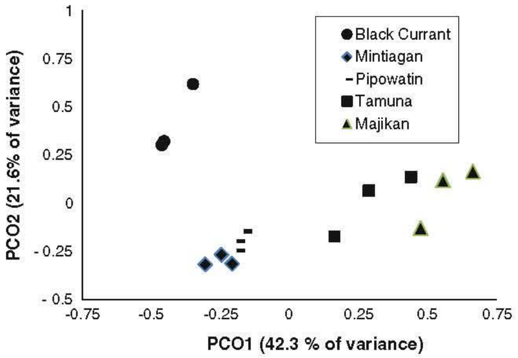

Fig. 3 Principal coordinates analysis ordination of taxa counts

Table 1 Pearson correlations of taxa counts with principal coordinates analysis axes; taxa having absolute values of $r < 0.5$ were omitted

PCO1	*r*	PCO2	*r*
Hyalellidae	−0.70	Chironominae	−0.79
Gammaridae	−0.58	Nemata	−0.64
Chironominae	−0.54	Lymnaeidae	−0.63
Erpobdellidae	−0.50	Dytiscidae	−0.52
Heptageniidae	0.54	Gammaridae	0.78
Tipulidae	0.54	Erpobdellidae	0.81
Hydrachnidia	0.57		
Glossosomatidae	0.58		
Ephemerellidae	0.59		
Philipotamidae	0.64		
Hydroptilidae	0.69		
Sphaeriidae-Pisidiidae	0.70		
Brachycentridae	0.78		
Hydropsychidae	0.82		
Elmidae	0.88		

Table 2 Pearson correlations of chemistry and habitat variables with principal coordinates analysis axes; variables having absolute values of $r < 0.5$ were omitted

PCO1	*r*	PCO2	*r*
pH	−0.98	BFW	−0.72
SM	−0.84	Elevation	−0.52
DOC	−0.72	MPS	0.56
TKN	−0.72	SO4	0.57
NH3 + NH4	−0.69	DOC	0.60
TP	−0.63	TKN	0.64
BFW	−0.54	Colour	0.66
K	−0.54	TP	0.68
Na	−0.53	K	0.74
SiO3	0.52	Na	0.75
Ca	0.53	Mg	0.75
HH	0.87	Cl	0.77
		DS	0.82
		Cations	0.82
		Anions	0.82
		Cond	0.82

TKN total Kjeldahl Nitrogen, *SM* submerged macrophytes, *DOC* dissolved organic carbon, *TP* total phosphorus, *HH* hydraulic head, *BFW* bank-full channel width, *DS* dissolved solids, *MPS* median particle size, *Cond* conductivity

(4 %), Nemata (3 %), and Tanypodinae (3 %; Fig. 2 and Online Resource 1).

The first two axes of the PCO ordination explained 63.9 % of the variance in the benthic macroinvertebrate relative abundances. The close association of the Mintiagan and Pipowatin samples in the PCO (Fig. 3) reflects the relative similarity of the benthic communities in those two rivers. Benthic communities characterizing the other rivers were more clearly distinguished. Correlations of input taxa counts with the PCO axes (Table 1), permit interpretation of the biological gradients underlying the spatial arrangement of samples in the ordination. For example, samples dominated by Hyalellidae or Gammaridae were associated with low Axis-1 scores, and tended to plot toward the left side of Fig. 3; samples with a relatively high count of Erpobdellidae were associated with high Axis-2 scores, and tended to plot in the upper region of Fig. 3. Correlations of habitat variables and chemical analytes with PCO axes (Table 2) suggest that PCO_1 primarily reflected gradients of pH, productivity or nutrient concentrations (i.e., total Kjeldahl nitrogen, dissolved organic carbon, ammonia and ammonium [$NH_3 + NH_4$], total phosphorus, the relative abundance of submerged macrophytes, Ca, and SiO_3), river size, current speed, and the concentrations of Na and K cations; whereas PCO_2 reflected gradients of river size, current speed, substrate particle size, and the ionic strength of the water.

The first two axes of the chemistry PCA (Fig. 4) accounted for a cumulative 66 % of the dataset's variance. The first principal component (PC1) reflected gradients of a variety of analytes, as indicated by axis correlations with the input variables: lying to the left Fig. 4 were sites having high TP ($r = -0.96$), Cl ($r = -0.89$), conductivity ($r = -0.87$), pH ($r = -0.85$), total Kjeldahl nitrogen ($r = -0.84$), dissolved organic carbon ($r = -0.82$), sulphate ($r = -0.78$), $NH_3 + NH_4$ ($r = -0.60$), and colour ($r = -0.57$); lying to the right in the plot were sites having relatively high SiO_3 ($r = 0.80$). The second principal component (PC2), separated rivers with relatively high concentrations of Ba (−0.94), Fe ($r = -0.87$), As ($r = -0.62$), and Sr (−0.62), which plotted low on PC2, from rivers with relatively high Cu ($r = 0.88$) and pH ($r = 0.52$). This study considered only 5 rivers, thus axis correlations should be interpreted with caution.

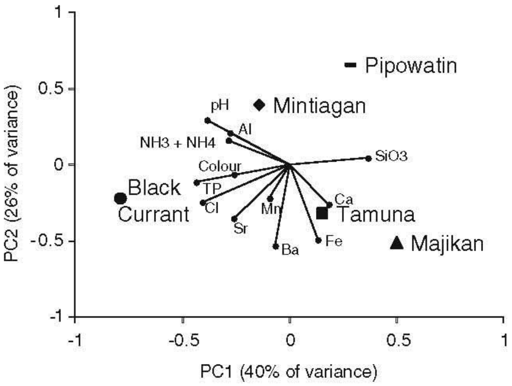

Fig. 4 Principal components analysis of water chemistry dataset

The composition of benthic macroinvertebate communities is affected by water chemistry, habitat, and biotic factors (Rosenberg and Resh 1993a, b), the relative importance of these factors being context dependent (Clements et al. 2012). Indeed the Ecological Filters model of community assembly (Poff 1997; Patrick and Swan 2011) views the relative abundances of taxa at a given location as representing that subset of the regional species pool that is able to persist at a location, given that location's dispersal constraints and habitat quality, and given biotic interactions that arise among successful colonizers. Modeling the factors that distinguish biological communities that exist among reference communities is thus a critical precursor to biomonitoring programs. Although there is presently insufficient data to begin such modeling, some clues about important factors that structure reference communities in the Coastal Hudson Bay Lowland are provided by this study. First, the rivers occupy similar positions in chemical and biological ordinations (Figs. 3, 4), which suggests that water chemistry is an important determinant of benthic community composition. Second, correlations of chemical and habitat predictors with axes in the PCO ordination of taxa counts (Table 2), suggested that the major gradients in biological composition were most associated with river-water pH, nutrient concentrations (e.g., total phosphorus, nitrogenous compounds, dissolved organic carbon, calcium, and silicate), conductivity (i.e., the concentrations of chloride and various other dissolved ions), and several geomorphological variables (e.g., bank-full river width, current speed, and the size of the dominant inorganic particles in the pavement layer of the streambed).

Monitoring northern Ontario rivers is essential, given their importance to First Nations people and the threat of ecological changes that may accompany northern development, resource extraction, and changing climate. Strong associations between benthic macroinvertebrate community composition and pH, channel width, current speed and substrate-particle size, and nutrient concentrations and conductivity suggest that benthic macroinvertebrates may be sensitive indicators of the cumulative effects of mining, hydro-power generation, and associated northern development.

To our knowledge, this study is the first to describe benthic community composition, water chemistry, and habitat in sub-arctic rivers of Ontario's extreme north-west. It represents a first step at characterizing baseline conditions and describing natural ranges of biotic, physical, and chemical condition in the region; however, additional studies are required to characterize and model reference conditions precisely enough that future bioassessments will have acceptable sensitivity.

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A2: Summary of river chemistry for the Mintiagan, Tamuna, Majikan, and Black Currant rivers, July 2011 and the Pipowatin River, July 2011 and September 2013. “ND” denotes Not Detected

			2011					2013		
			Mintiagan	Tamuna	Majikan	Black Currant	Pipowatin (1)	Pipowatin (1)	Pipowatin (2)	Pipowatin (3)
		Latitude	56.675	56.525	56.482	56.250	56.117	56.116	56.120	56.122
Chemical Variable	Units	**Longitude**	88.629	88.291	88.168	87.781	87.670	87.669	87.690	87.730
Alkalinity; Gran	mg/L CaCO3		104	126	122	117	131	101	97	99
Alkalinity; total fixed endpt	mg/L CaCO3		-	-	-	-	-	102	98	100
Aluminum	ug/L		10.0	3.5	5.1	8.0	5.3	2.8	23.6	20.5
Antimony	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ug/L		0.8	0.8	0.8	1.0	0.6	ND	ND	ND
Barium	ug/L		11.6	14.3	13.6	13.3	9.2	9.7	8.2	8.5
Beryllium	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Boron	ug/L		33	30	19	67	16	13	13	12
Cadmium	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Calcium	mg/L		36.1	46.8	48.5	44.9	47.0	41.8	35.4	33.4
Carbon; dissolved inorganic	mg/L		-	-	-	-	-	24.1	23.0	23.4
Carbon; dissolved organic	mg/L		9.0	8.2	8.7	11.9	9.7	6.3	9.0	8.9
Chloride	mg/L		86	92	76	153	56	86	48	47
Chromium	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Cobalt	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Colour; true	TCU		33	31	36	42	36	27	45	45
Conductivity	uS/cm		482	563	491	863	426	482	346	344
Copper	ug/L		0.4	0.3	0.2	0.4	0.5	0.2	0.3	0.3
Iron	ug/L		150	180	270	180	120	60	260	270
Lead	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Magnesium	mg/L		8.8	10.3	7.9	13.3	7.0	7.6	5.7	5.4
Manganese	ug/L		35.1	49.6	34.3	28.9	14	6.9	16.2	17.4
Molybdenum	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Nickel	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Nitrogen; ammonia+ammonium	ug/L		16	24	10	40	34	10	16	12
Nitrogen; nitrate+nitrite	ug/L		ND	ND	ND	ND	ND	4	4	4
Nitrogen; total Kjeldahl	ug/L		424	407	392	695	500	269	342	314
pH	none		8.57	8.28	8.09	8.72	8.50	7.93	7.96	7.95
Phosphorus; total	ug/L		15.2	12.5	11.7	25.5	11.0	8.0	8.0	10.4
Potassium	mg/L		1.220	1.370	0.735	3.160	0.590	1.120	0.775	0.745
Selenium	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Silicon; reactive silicate	mg/L		0.34	0.40	1.44	0.20	1.32	1.98	1.84	1.76
Silver	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Sodium	mg/L		49.1	51.2	37.6	104.0	30.2	29.8	24.3	24.0
Strontium	ug/L		100.0	153.0	109.0	158.0	95.6	90.5	64.6	63.1
Sulphate	mg/L		6.05	7.75	3.30	9.70	0.90	1.95	1.15	1.25
Thallium	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Titanium	ug/L		0.6	ND	ND	0.7	ND	ND	1.1	1.0
Uranium	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	ug/L		ND	ND	ND	ND	ND	ND	ND	ND
Zinc	ug/L		0.6	0.7	0.5	1.1	10.2	ND	0.6	0.7

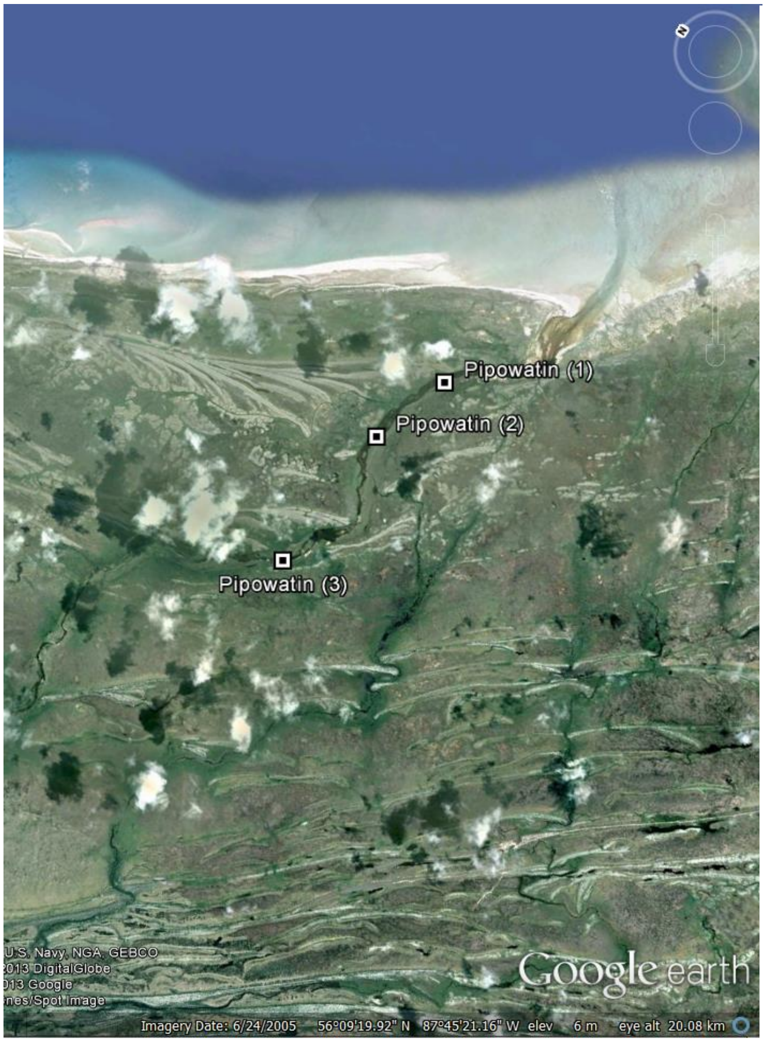
A3: Summary of bottom-living invertebrates found in the Mintiagan, Tamuna, Majikan, Black Currant, and Pipowatin rivers, July 2011. Data for 3 samples are presented, S1, S2 and S3 as well as taxa found "+" during a Large/Rare taxa (L/R) targeted search.

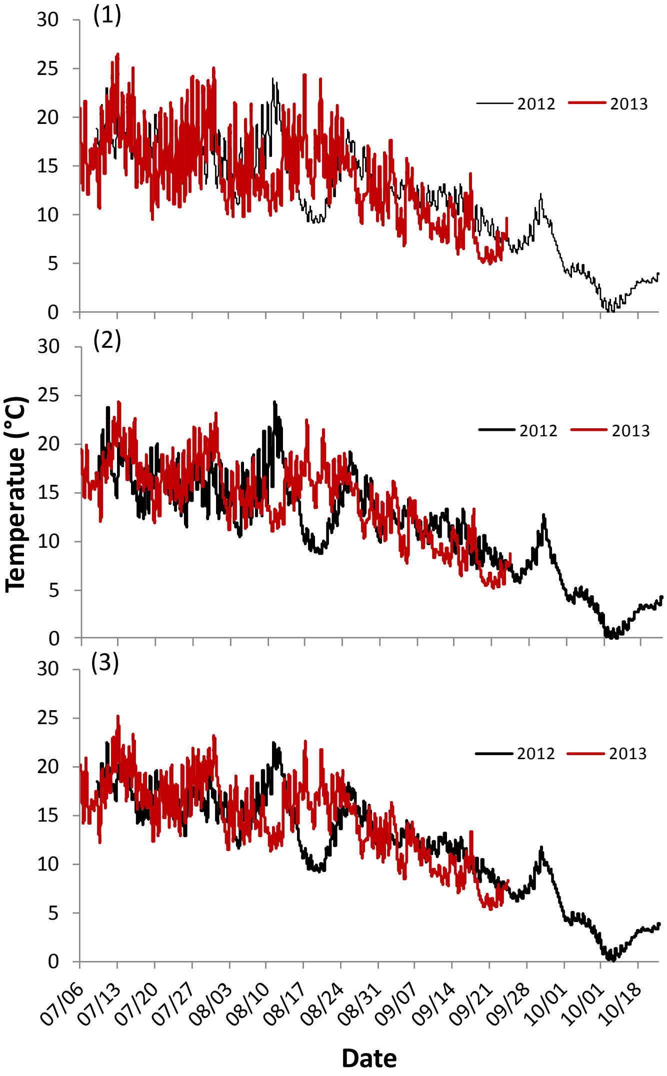
	Mintiagan				Tamuna				Majikan				Black Currant				Pipowatin			
Taxa	S1	S2	S3	L/R	S1	S2	S3	L/R	S1	S2	S3	L/R	S1	S2	S3	L/R	S1	S2	S3	L/R
Aeshnidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Baetidae	0	1	5		3	0	1		5	1	6		0	0	2		3	0	1	
Brachycentridae	0	0	0	+	0	0	2		8	4	5		0	0	1		0	0	0	
Caenidae	1	1	1		0	0	0		0	0	0		0	0	1		0	0	2	
Calopterygidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Ceratopogonidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Chironominae	72	47	59		43	15	6		4	11	24		26	34	0		52	63	37	
Chloroperlidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Coenagrionidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Cordulegastridae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Corixidae	0	1	0		0	0	0		0	0	0		0	0	0		1	0	0	
Corydalidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Dytiscidae	2	2	4		0	0	0		0	0	0		0	0	0		0	0	0	
Elmidae	0	0	0		4	5	8		31	23	20		0	0	0		0	1	0	
Empididae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Ephemerellidae	0	0	0		0	0	0		1	1	3		0	0	0		0	0	0	
Ephemeridae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	1	
Erpobdellidae	0	0	0	+	0	0	0		0	0	0		2	2	4		0	0	0	+
Gammaridae	3	3	0		0	0	0		0	0	0		23	29	35		0	0	0	
Glossiphoniidae	0	0	0		0	0	0		0	0	3		0	0	0		0	0	0	+
Glossosomatidae	0	0	0		0	0	1		2	0	0		0	0	0		0	0	0	
Gomphidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Heptageniidae	1	2	0		0	0	2		1	2	3		0	0	0	+	1	0	1	
Hyalellidae	5	5	8		0	0	0	+	0	0	0		17	13	35		16	13	22	
Hydrachnidia	0	2	1		0	1	4		7	9	7		0	2	7		5	0	1	
Hydrobiidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Hydroida	0	1	0		0	0	0		0	0	0		0	0	0		0	0	0	
Hydropsychidae	0	0	0		5	30	22		20	15	9		0	0	0		1	1	1	
Hydroptilidae	0	1	0		1	0	0		2	4	2		0	0	0	+	0	0	0	
Libelullidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Leuctridae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Leptoceridae	0	0	0	+	1	1	2		0	1	0		0	1	2		2	5	1	
Leptophlebiidae	0	0	0		0	0	0		0	0	0		0	0	0		4	5	5	
Leptohyphidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Limnephilidae	0	0	0		0	0	0	+	0	0	0		0	0	0	+	1	0	0	
Lymnaeidae	10	2	6		0	0	0	+	0	1	2		0	0	0		5	0	3	
Nemata	4	6	6		8	5	4		2	1	5		0	0	3		6	4	2	
Nemouridae	0	0	0		0	0	0		0	1	0		0	0	0		0	0	0	
Oligochaetous Clitellata	20	10	15		7	10	14		4	9	7		18	6	19		6	10	14	
Orthocladiinae	7	8	22		38	41	37		11	9	4		20	20	17		10	21	29	
Perlidae	0	0	0		0	0	0	+	0	0	0		0	0	0		0	0	0	
Perlodidae	0	0	0		0	0	0		0	0	0	+	0	0	0		0	0	0	
Philipotamidae	0	0	0		0	0	0	+	1	1	0		0	0	0	+	0	0	0	
Phryganeidae	0	0	0		2	0	0		0	0	0		0	0	0		0	0	0	+
Physidae	0	0	0		2	0	0		0	0	0		0	0	0	+	0	1	1	
Piscicolidae	1	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Planorbidae	5	3	3		1	0	0		0	0	0		0	1	1		0	0	0	+
Polycentropodidae	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Polychaete	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Psychomyiidae	0	0	0		0	0	0		0	0	2		0	0	0		0	0	0	
Rhyacophilidae	0	0	0		0	0	0		0	0	0	+	0	0	0		0	0	0	
Simuliidae	0	0	0		0	0	0		0	1	0		14	20	1		1	0	0	
Siphloneuridae	1	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Sphaeriidae-Pisidiidae	0	0	0		5	0	4		10	21	27		0	0	0		2	1	8	
Tanypodinae	5	9	5		0	0	1		2	0	23		1	0	0		5	0	3	
Tipulidae	2	2	7		4	1	3		5	2	7		0	0	0		0	0	0	
Valvatidae	0	0	1		0	0	0	+	0	0	0		0	0	1	+	1	1	2	

A4. Summary of habitat characteristics for 3 samples at each sampling site in the Mintiagan, Tamuna, Majikan, Black Currant, and Pipowatin rivers, July 2011.

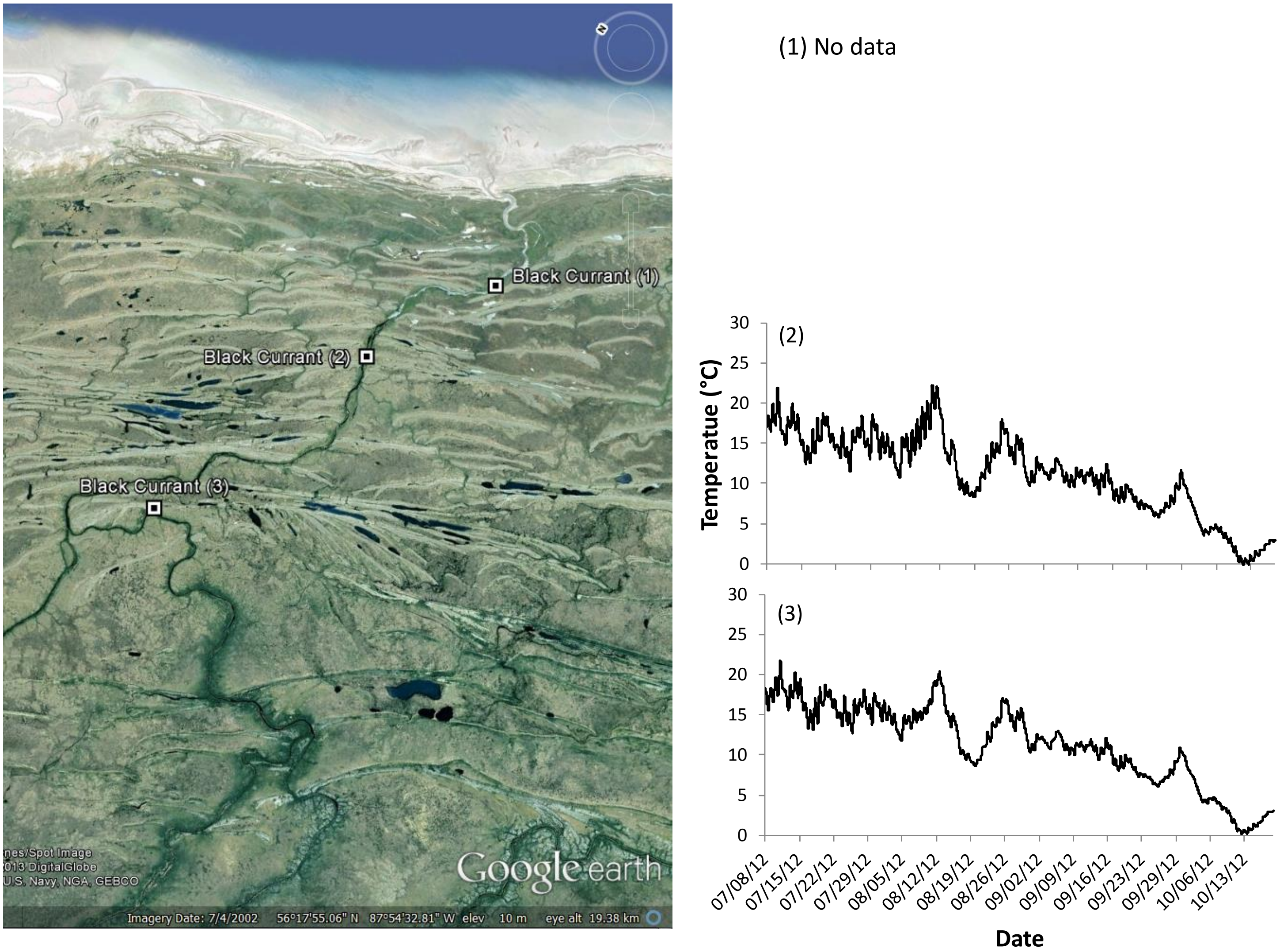
	Temperature (^{o}C)	Elevation (m asl)	Depth (m)	Hydraulic Head (mm)	Bank-full Width (m)	Median Particle Size (mm)	Submergent Macrophytes	Filamentous Algae
Mintiagan1	20	3	0.32	5	102 (20.5)	8.5	1	1
Mintiagan2			0.25	3		14	1	1
Mintiagan3			0.36	3		11	1	1
Tamuna1	20	2	0.22	20	34 (6.33)	32.5	1	2
Tamuna2			0.25	50		45	0	2
Tamuna3			0.25	60		21	1	1
Majikan1	16	2	0.34	160	29 (1.18)	42.5	0	0
Majikan2			0.42	140		28	0	0
Majikan3			0.47	90		58	0	0
Black Currant1	19	1	0.33	25	38 (9.17)	63.5	2	0
Black Currant2			0.15	10		70.5	2	0
Black Currant3			0.31	10		88.5	2	0
Pipowatin1	17	1	0.32	0	93 (5.03)	53	2	0
Pipowatin2			0.27	0		66.5	1	0
Pipowatin3			0.22	0		76.5	1	0

A5. Summary of water temperature records for 3 locations on the Pipowatin River, 2012 and 2013.





A6. Summary of water temperature records for 2 locations on the Black Currant River, 2012. The temperature recorder at site 1 was lost.



A7. Summary of water temperature records for 3 locations on the Majikan River, 2012.