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Assessing the impact of small, Canadian Arctic River flows to the freshwater budget of the Canadian Archipelago
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Summary

Assessing the impact of small, Canadian Arctic river flows to the freshwater budget of the Canadian Archipelago (or SCARFs) is a scientific research project funded by the National Science Foundation (USA). The purpose of this project is to collect water samples from seven different rivers and their adjoining estuaries throughout the Canadian Arctic Archipelago in order to determine how their chemical signatures differ from larger North American rivers such as the Mackenzie and Yukon Rivers and whether these signatures can be used within the ocean to discriminate sources.

During the second year of this three-year program, river sites initially sampled during the summer of 2014 were revisited. These included the Coppermine, Ellice, Back, Hayes, Kuujuua, Thomsen, Cunningham, and Kangiqtugaapk Rivers. Two additional rivers were also sampled: the Karasok River (on the northwestern edge of Banks Island; details provided in section 3.5) and the Koogaaluk River (north of Clyde River; details provided in section 3.7). Identical to the methods used in 2014, river water was collected using a 1 L bottle attached to the end of an extendable pole. After wading into the river and using the pole to collect 2-3 L of water from near the central channel of the flow, these bulk samples were filtered on the bank of the river and sub-sampled into smaller bottles for chemical analyses. These analyses will include total alkalinity, stable oxygen isotope composition ($\delta^{18}O$), nutrients (nitrate, nitrite, ammonium, phosphate, and silicic acid), major cations (sodium, potassium, calcium, and magnesium), major anions (chloride, sulfate, and bicarbonate), strontium, strontium isotope composition ($^{87}Sr/^{86}Sr$), and dissolved organic carbon. Using a portable probe and meter, the temperature, conductivity, and pH of the rivers were also measured.

In addition to river sampling from the bank, small, inflatable boats equipped with portable, outboard motors (6 horsepower) were used to collect water samples from the regions extending both offshore and alongshore of the river mouths. Samples were collected from 26 different locations (or "stations") at depths of 0.5, 1, 2, 4, 6, 8, 10, and 15 meters below the surface. Water was collected from these various depths using weighted tubes of different lengths that were hung over the side. A peristaltic pump head was attached to the end of a battery powered drill and the water pumped up through the tubes to the surface. After flushing the tubes, water was filtered and collected into small bottles for chemical analyses (identical to those conducted on the river water samples). A small instrument that measures conductivity, temperature, and depth (CTD) was also lowered over the side of the boat and through the water column to measure vertical profiles of water temperature, salinity, and pressure (this gives us the depth). This work was completed so that the movement of the river plumes and the contribution of this freshwater to the channels and straits of the Canadian Arctic Archipelago could be assessed.

A brief article has also bee published in the popular science newsletter EOS (Alkire, M.B., A. D. Jacobson, G.O Lehn, and R.W. Macdonald. 2015. Small rivers could have big impact on Arctic Ocean, *Eos* 96, doi:10.1029/2015EO034005). In this article, the

purpose of the project is described and preliminary results from the river sampling conducted during the 2014 field season are briefly discussed. A pdf copy of this article is attached for convenience.

1. Permits

All necessary permits, licenses, and approvals required to conduct the field work were acquired or renewed prior to our work commencing in July 2015. A comprehensive list is presented in Table 1.

Table 1. Summary of permits, licenses, and approvals acquired to conduct field work in Nunavut and the Northwest Territories.

Institution or Agency	Permit	Status
Nunavut Research Institute	Scientific Research License (02 002 15R-M)	Granted
Nunavut Water Board	Approval to proceed without a license (8WLC-CAR1415)	Granted
Ahiak Area Co-management Committee	License to work within Queen Maud Gulf Bird Sanctuary (NUN-MBS-14-03)	Valid between June & October in 2014, 2015, & 2016
Nunavut Impact Review Board	Conformity to North Baffin Regional Land Use Plan	Confirmed
Nunavut Impact Review Board	Screening (File 13YN042)	Project allowed to proceed without review, after conforming to recommendations outlined by Environment Canada
Aurora Research Institute	Scientific Research License (15602)	Granted
Northwest Territories Water Board	Permission to collect water samples without a license	Granted
Inuvialuit Land Administration	Right to access private lands (ILA14HN025)	Granted
Parks Canada	Research and Collection Permit (AUL-2015-16137)	Granted
Parks Canada	Aircraft Landing Permit (Registration #2015042)	Granted
Parks Canada	Northern Park Backcountry Excursion/Camping Permit (Registration #2015042)	Granted
Parks Canada	Bear monitor business license and firearm permit	Granted to Jeff Kuptana (wildlife monitor)
Environmental Impact Screening Committee	Review (Registry file #02-15-01)	Project does not meet definition of development

2. Community support

Similar to 2014, the Hunters and Trappers Organizations in Kugluktuk, Cambridge Bay, Gjoa Haven, and Ulukhaktok as well as the Illisaqsivik Society (Clyde River) were contacted for guidance, consultation, and support both before and during field work. Representatives from these organizations aided in the hiring of local residents to act as wildlife monitors. In addition, the field technicians initially hired in 2014 to collect water samples from the Coppermine (Jorgen Anablak) and Kangiqtugaapk (Esa Qillaq and Niore Iqaluqjuak) Rivers agreed to resume these duties during the summer of 2015.

3. Field activities

The research team consisted of four members: Matthew Alkire (principle investigator) from the University of Washington, Gregory Lehn (doctoral student) from Northwestern University, John Kelly (field assistant and middle school science teacher) from St. Louis, Missouri, and Robie Macdonald (consultant and co-investigator) from Fisheries & Oceans, Canada. Co-principle investigator Andrew Jacobson (Northwestern) was unable to participate in field work. The Twin Otter flight crew from Kenn Borek Air, Ltd. consisted of pilot James Haffey, co-pilot Douglas Westersund, and engineer Stephen Martyniuk.

3.1. Coppermine River

Using a small boat rented from the local Hunters & Trappers Organization (HTO), the Coppermine River was sampled on July 21 at the same location that was visited the previous summer. Over the course of two days (July 24-25), two inflatable boats were utilized in the collection water samples from five stations located both northward (offshore) and eastward (alongshore) of the Coppermine River mouth. The CTD was deployed at many more locations to facilitate general tracking of the river plume and inform on potential water sampling locations. Lower salinities (< 15) were interpreted as evidence of the presence of river water although there may have been significant influences from sea ice melt. Analyses of the water samples will determine the actual contributions of river water versus sea ice melt at each location. Salinities were quite low ($\leq$ 5) at most locations where the CTD was deployed, indicating widespread influence from the Coppermine River and sea ice meltwater. The main river plume extended primarily westward along the main (and deepest) channel, likely a consequence of the predominant winds. A total of 46 vertical profiles of temperature and salinity were collected with the CTD and water samples for chemical analysis were collected at 5 of these locations. After sampling was completed, Alkire gave a short (~20 minute) presentation to the public describing the purpose of the project and the methods utilized over the last few days to collect water samples from the river and the estuary.

Wildlife sightings: Multiple seals (~20) were observed at a distance during the course of our estuary sampling.

3.2. Ellice River

The Ellice River and the adjoining estuary were sampled on July 31. Upon arrival at the intended landing site, two grizzly bears (or brown bears) were spotted on the ground. However, during the search for an alternate landing site, the bears ran off and the plane landed at the intended site (Table 2). After the river sampling was completed, another landing site was sought closer to the river mouth. After searching for a suitable strip, the Twin Otter landed at a site located ~10.4 km northeast from the site of the river sampling. Similar to the situation in the Coppermine River estuary, a large area near the river mouth was quite shallow (< 5 m deep) and fresh (salinity $\leq$ 5). The river plume was tracked approximately 6.5 km offshore (northward) until the edge of the ice pack was encountered and no further progress could be safely made with the inflatable boats. A

total of 24 vertical profiles of temperature and salinity were collected with the CTD and water samples for chemical analysis were collected at 4 of these locations.

Wildlife sightings: Two grizzly bears

3.3. Back and Hayes Rivers

The research team departed Cambridge Bay on August 1 to sample the Back and Hayes Rivers. During the previous year, the team had traveled to Gjoa Haven prior to sampling the Back and Hayes Rivers. This year, the sampling schedule coincided with the Canadian Civic Holiday weekend (July 31- August 3) and it was uncertain whether bear monitors in Gjoa Haven would be available to accompany the team into the field. The team therefore remained in Cambridge Bay and hired Anablak for additional work. The river sites occupied in 2015 were identical to those visited the previous year. The stages (or levels) of both rivers appeared somewhat lower compared to those in 2014. Presumably, the lower water level was a consequence of sampling the river later during the summer (August) compared to the 2014 visit (June and July). After the river sampling was completed, the team returned to Cambridge Bay. On August 2, the team again departed Cambridge Bay and searched for a landing site near the confluence of the two rivers. The Back and Hayes Rivers converge just upstream of the outflow into the estuary. Therefore, the plane was landed at one site to access the estuary that receives water from both rivers. The samples collected from the estuary may help to separate and quantify the contributions from both of the rivers to the estuary. The winds were fairly strong (10-12 knots) which, together with shallow water, resulted in large and steep waves that made sampling conditions in the small boats hazardous. As a result of these unfavorable conditions, work was limited to the collection of 20 CTD casts and only two sites where water samples were taken. Very similar to the situations encountered in the Coppermine and Ellice estuaries, bottom depths were mostly shallow (< 6 m) and waters mostly fresh (salinities < 2) throughout the area that was sampled; however, deeper and more saline waters were encountered at a couple of locations where the bottom depth was ~14 m and maximum salinities (near the bottom) were ~19. Water samples were collected at one of these locations.

Table 2. Coordinates denoting river sampling locations and Twin Otter landing sites.

River or estuary	N Latitude (decimal degrees)	W Longitude (decimal degrees)
Coppermine River	67.769	115.246
Ellice River	67.976	104.005
Ellice estuary	68.068	103.954
Back River	67.070	95.307
Hayes River	67.167	95.153
Back & Hayes estuary	67.308	95.167
Kuujuua River & estuary	71.268	116.765
Thomsen River	73.859	119.816
Karasok River & estuary	74.459	122.911
Cunningham River	74.061	93.790
Cunningham Inlet/estuary	74.121	93.874
Kangiqtugaapk River	70.475	68.532
Koogaaluk River	70.702	68.996

3.4. Kuujuua River

The research team departed Ulukhaktok on August 6 to collect water samples from the Kuujuua River and estuary. The Twin Otter landed in the same location that was occupied in 2014, near the mouth of the river. Weather conditions were unfavorable for sampling as strong winds (12-15 knots), rain, and larger waves made operations difficult. The research team split up to sample the river and the estuary simultaneously. However, due to the poor weather conditions, work in the estuary was limited to only two CTD profiles and one station where water samples were collected. The following day (August 7), the research team returned to the site. The weather had improved and conditions were much more favorable for sampling. A total of 31 CTD profiles were collected throughout the nearshore region and water samples were collected from 4 stations. In contrast to the estuaries previously sampled, higher salinities ($S > 28$) were frequently found throughout the region. Lower salinities (and presumably most of the river water) were concentrated along the edge of a peninsula south of the river mouth. The predominate wind conditions (blowing toward the south) over the preceding few days was likely responsible for this distribution of the river water. Alternatively, much of the river water that was discharged into the estuary during the spring flood/peak flow period might have moved offshore prior to the sampling period. This scenario would imply a very short residence time of river water inside the estuary.

Wildlife sightings: One bearded seal that circled one of the boats several times before losing interest and moving on.

3.5. Thomsen and Karasok Rivers

The research team departed Sachs Harbour on August 9 to enter Aulavik National Park and sample the Thomsen River and adjoining estuary. However, after arriving at the intended landing site near the mouth of the Thomsen River where it empties into Castel Bay, it was discovered that sea ice conditions in the bay were quite heavy up to the coastline. A high concentration of landfast and pack ice in the estuary would complicate and limit sampling operations using the inflatable boats; however, the team was prepared to restrict sampling to locations near the mouth and very close to shore (areas that remained relatively ice free). Unfortunately, after attempting to land at a few sites, the pilot concluded that the soils were too soft and the danger of getting the aircraft stuck was high. Unfavorable wind conditions prevented landing at alternative Castel Bay sites. The team therefore retreated upstream to find a suitable landing site to sample the Thomsen River. However, the intended landing site (where the aircraft was landed the previous year) had been eroded and engulfed by a recent meandering of the river. Instead, the plane was diverted farther upstream to a new landing site (Table 2) where the team successfully collected samples from the river. The team then returned to Sachs Harbour to refuel and consider alternate plans as access to the Thomsen River mouth and Castel Bay was blocked by sea ice and landing conditions were unfavorable.

Since permits were not acquired to sample elsewhere in the park, rivers outside of the park boundaries were sought as alternate sampling locations. Two rivers on the northern reaches of Banks Island were deemed suitable: the Ballast River, located on the northwestern shore of Banks Island, and the Parker River, on the northeastern side of the

island. On August 10, the team departed Sachs Harbour and flew to Ulukhaktok to drop off two members (Alkire and Kelly) that were departing early to join other projects. After dropping them off, the rest of the team (Lehn and Macdonald) traveled to the Parker River site to assess conditions. Sea ice conditions were found to be heavy in this location, so the team moved on toward the Thomsen River mouth to determine whether or not conditions had improved. Conditions had not improved, so the team continued further west to investigate the Ballast River site. The team actually landed at the Karasok River (Table 2), originally mistaking it for the Ballast River. Despite the confusion, conditions were suitable for sampling and a total of 16 vertical profiles of temperature and salinity were measured using the CTD and water samples were collected at 3 stations.

3.6. Cunningham River

On August 12, the team traveled from Resolute to the mouth of the Cunningham River. The aircraft was landed on the west side of bay, just south of the river mouth (Table 2). Upon landing, tourists staying at the Arctic Watch camp approached and asked questions about the airplane and the research being conducted. After a short discussion, the guides from the Arctic Watch camp (http://www.arcticwatch.ca) helped the team bring equipment from the aircraft to the shoreline (~0.5 km). A total of 21 vertical profiles of temperature and salinity were collected using the CTD. The area near the river mouth was shallow and salinities were relatively high (> 19), indicating less freshwater in this estuary than encountered for preceding rivers. The team traveled further offshore until depths of ~15 m were encountered and collected water from 3 stations. As the winds rose, wave heights increased (1.5 m swell) offshore and the team finished early as conditions progressively worsened.

The following day (August 13), the team returned to the area and landed at a site farther upstream to sample the river (identical to the location visited in 2014; Table 2). After delivering four barrels of fuel to the Arctic Watch camp, the team sampled the Cunningham River and was again helped by guides from Arctic Watch to transport gear from the airplane down to the river mouth. Although the team collected an additional 15 vertical profiles using the CTD, a surface sample at the river mouth, and water samples from 1 station, they were unable to locate a significant freshwater plume. The general lack of freshwater on the west side of the inlet (where the sampling stations were located) and across the southern edge of the inlet where the river enters the inlet (where CTD casts were collected) indicates either a short residence time of river water entering from the Cunningham River following the short peak discharge period or a concentration of the river plume on the northeastern side of the inlet.

3.7. Clyde River (Kangiqtugaapk and Koogaaluk Rivers)

The team traveled to Clyde River on August 17. They first met with the Ilisaqsivik Society to review equipment and logistics needs of the two field technicians (Qillaq and Iqaluqjuak) who have been sampling the river on a weekly basis since the river broke in July. On August 19, the team and the technicians sampled the Kangiqtugaapk River. The Kangiqtugaapk River flows into a small embayment that connects to Baffin Bay. However, the river itself is quite small and the distance between the river mouth and the connection to Baffin Bay is > 10 km. Therefore, additional rivers were sought such that a

direct connection to Baffin Bay could be sampled. With the help and guidance of the Ilisaqsivik Society, the team was transported by freighter canoe (captained by Qillaq) to the Koogaaluk River on August 21(Table 2). Sea ice was heavy along portions of the coast between Clyde River and the Kooglaaluk River, requiring a fair number of course deviations to arrive on site. The estuary itself, however, was relatively clear of sea ice. Using the boat as a sampling platform, the team collected a sample at the river mouth, water from 3 stations offshore of the river mouth (i.e., within Baffin Bay), and 16 vertical profiles of temperature and salinity with the CTD.

Wildlife sightings: During the trip, Qillaq caught 8 Arctic char in a net set near the river mouth and shot 1 seal. They also spotted a bowhead whale and a polar bear in Baffin Bay on the transit south between the Koogaaluk River site and Clyde River. The team did not participate in any fishing or hunting during the trip; they acted solely as passengers during these activities.

4. Preliminary Results

Samples have only recently arrived at laboratory facilities in Seattle and Chicago and chemical analyses have not yet been completed. Processing of the data collected using the CTDs is ongoing and the quality (accuracy) of the data will be determined after salinity measurements have been completed on bottle samples. Preliminary analyses of the CTD data did indicate that the estuaries of the Coppermine, Ellice, and Back and Hayes Rivers were quite fresh during the sampling period (late July and early August) whereas those of the Kujjuua, Cunningham, and Karasok were more saline. Stations sampled in Baffin Bay, extending from the mouth of the Koogaaluk River indicated a significant river plume overlying the more saline waters of the bay. These differences may be related to wind conditions, sea ice, the magnitude of the river discharge, local currents, and/or topographic influences (both above and below the surface of the water). Additional work is necessary to evaluate these differences as they are important to the distribution of freshwater (both river water and sea ice meltwater) within the estuary and its eventual export out of the estuary and into the coastal ocean. Images taken during landing and after takeoff of the aircraft may also help to determine plume and ice distributions during the sampling period.

The chemical analysis of the newly collected river samples as well as subsequent analyses of samples collected by local field technicians in Kugluktuk (Coppermine River) and Clyde River (Kangiqtugaapk River) will inform on both the seasonal and interannual variability of river chemistry across the Canadian Archipelago. The natural chemistry of the rivers generally changes with the volume of the flow (e.g., seasonal variability). The weekly collection of samples between the spring flood and freeze-up will allow an assessment of the magnitude of these changes between the high and low flow periods. Continuation of the times series through this summer (2015) and its extension next summer (2016) will provide information on chemical changes in different years. Together, knowledge of the seasonal and interannual variability in the chemical signatures of the rivers studied will help to better constrain the chemical fingerprints of the rivers; this will help researchers studying freshwater in the Arctic Ocean and Baffin Bay to understand the origins and distributions of different freshwater sources, including small and large North American rivers, Siberian rivers, sea ice melt, and glacial melt.

5. Website

This report as well as all data collected as part of this project are freely available on the project website: www.canadianriversproject.org.

The data sets will be regularly updated as more results are obtained. In addition to the data, tutorials explaining the use of the chemical parameters to learn about the Arctic and subarctic seas have also been made available. More tutorials are planned and will be uploaded to the website as the project progresses.

6. Acknowledgments

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7. Questions/comments

If there are any questions, concerns, or comments regarding this report or work related to the research project, please feel free to contact the principle investigator:

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