IMALIRIJIIT: A community-based environmental monitoring program in the George River watershed, Nunavik, Canada

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Abstract

Canada's North is experiencing a growing interest in community-based environmental monitoring (CBEM) as resource exploitation and climate change increasingly impact these remote territories, and as recognition of the value and relevance of indigenous knowledge increases. IMALIRIJIIT, a CBEM program involving Science Land Camps, capacity-building workshops and scientific data collection with the participation of youth, Elders, local experts and researchers was co-initiated by the Inuit community of Kangiqsualujjuaq in Nunavik (Quebec) and university-affiliated researchers. This hands-on and land-based program aims to establish a sustainable environmental monitoring program of the George River, before the start of operations of a rare earth elements (REEs) mining project in its upper watershed. The community wanted its own independent and long-term environmental monitoring program to collect baseline data and promote local capacity-building. IMALIRIJIIT program includes water quality measurements, biomonitoring for contaminant and REEs analysis in traditional foods, remote sensing analysis of water quality parameters and vegetation change at the watershed scale as well as interactive mapping of traditional ecological knowledge related to the George River. The outcomes and challenges of the IMALIRIJIIT Program are discussed in order to identify the conditions for the successful implementation of CBEM and environmental stewardship in the George River watershed, Nunavik.

Keywords: community-based water monitoring; participatory action research; Inuit knowledge; local and traditional ecological knowledge; George River watershed; environmental education and stewardship

Résumé

Le Nord canadien suscite un intérêt grandissant quant aux pratiques de suivi environnemental communautaire. Ce phénomène peut s'expliquer par les impacts de l'exploitation des ressources et des changements climatiques sur ces territoires éloignés qui augmentent en même temps que la valorisation des savoirs autochtones locaux. IMALIRIJIIT, un programme de suivi environnemental communautaire intégrant des camps scientifiques sur le terrain, des ateliers de développement de compétences ainsi que de la collecte de données scientifiques avec la participation de jeunes, d'aînés, d'experts locaux et de chercheurs, a été co-initié en 2016 par la communauté de Kangiqsualujjuaq au Nunavik (Québec) et des chercheurs universitaires. Ce programme privilégie une approche « mains-à-la-pâte » basée sur le territoire pour un suivi environnemental communautaire et durable de la rivière George en réaction à un projet minier d'extraction de terres rares dans le haut de son bassin versant. La communauté s'inquiète des impacts potentiels de ce projet minier sur la rivière George, qui est un lieu privilégié pour la pratique d'activités traditionnelles de chasse, de pêche et de cueillette. La communauté souhaitait donc mettre en place son propre programme de suivi environnemental indépendant et à long terme afin de documenter l'état de référence et d'encourager le développement de compétences à l'échelle locale. Le programme IMALIRIJIIT comprend des mesures de la qualité de l'eau, la biosurveillance des contaminants et des terres rares dans les aliments traditionnels, l'analyse par imagerie satellitaire de certains paramètres de la qualité de l'eau et de l'évolution de la végétation à l'échelle du bassin versant ainsi que la cartographie interactive du savoir autochtone lié à la rivière George. Les résultats du programme IMALIRIJIIT ainsi que les défis rencontrés sont discutés afin d'identifier les facteurs de succès d'un programme de suivi environnemental communautaire et d'une intendance environnementale dans le bassin versant de la rivière George au Nunavik.

Mots-clés: suivi environnemental communautaire, recherche-action participative, recherche collaborative, savoir écologique traditionnel, savoir inuit, éducation à l'environnement, bassin versant de la rivière George, Nunavik

Introduction

The Arctic is one of the most rapidly changing regions on the planet. Inuit communities are thus facing many challenges with accelerated warming in this region (AHDR 2015; Pearce et al. 2009). There is also significant pressure to exploit northern natural resources (e.g., mining; Asselin 2011; Brun et al. 2017) thereby increasing human impacts on terrestrial, freshwater and marine ecosystems with implications for long-term sustainable land and sea use by Arctic residents (Prowse and Furgal 2009). Adjusting to global climate and socio-environmental change has become a major issue for northern communities, as well as for researchers. Simultaneously, there are calls for sustainable development by local governments and populations. Parnasimautik, for example, is an initiative where the Inuit of Nunavik, the northern part of Québec in eastern Canada, outline their own vision of the development priorities for the Arctic (ARK 2014). Many arctic communities are concerned about their future and wish to better understand the social, environmental and economic changes related to ongoing industrial development and climate change (Rodon et al. 2014). They are concerned about the effects of climate change, mining and non-traditional lifestyles on their health, well-being and quality of life (Pearce et al. 2015). They also worry about the future and the education of youth, the widening generation gap, the preservation of traditional hunting, fishing and gathering techniques, as well as threats to Inuit culture and language (Laugrand and Oosten 2009; Garakani 2016).

It is widely acknowledged that there is a need for long-term and more effective environmental monitoring in the Arctic to better understand the diverse impacts of socio-environmental changes on socio-ecological systems, as well as to support local management in the face of rapid global change (Lindenmayer and Likens 2009; Dallman et al. 2011; Meltofte 2013). However, many have argued that top-down monitoring conducted exclusively by academic scientists, which ignores community stewards and excludes other ways of understanding the environment, is insufficient to address these changes (Danielsen et al. 2005; Dickinson et al. 2010). Brunet et al. (2017) rightly point out that: "scientists, in this context, are being increasingly asked to reconcile the outcomes of research with the socio-economic reality of the Arctic" (p. 483). Building local capacity through Arctic research is essential to ensure the sustainable development of this region (Parlee and Furgal

2012; Brunet et al. 2017). Regarding local capacity building, Ferrazzi et al. (2018) state that: "among the most effective means for Indigenous engagement and knowledge transfer is the training and remuneration of community members as co- researchers" (p.6). Approaches to long-term monitoring that focus on public participation in scientific research, also known as "community-based monitoring" [1] (Whitelaw et al. 2003) and "citizen science" (Shirk et al. 2012; Chandler et al. 2016) have become increasingly widespread across the circumpolar region (Conrad and Hilchey 2011; Herrmann et al. 2014; Johnson et al. 2016). Indigenous communities across the Arctic regions in North America are establishing community-based monitoring projects, such as: the Gwich'in and Inuvialuit of the Arctic Borderlands region of Alaska, Yukon and the Northwest Territories (NWT) (Gordon et al. 2008); the Chipewyan Dene of Lutsel K'e, NWT (Parlee et al. 2005); the Inuit of Clyde River and Old Crow, Nunavut (Gearheard et al. 2011; Brammer et al. 2016).

In this paper, we will refer to community-based environmental monitoring (CBEM) which has numerous advantages: it can build bridges between indigenous and scientific knowledge, build trust between communities and institutionalized science, engage community members in the scientific process, and generate community-oriented data for management decisions (Danielsen et al. 2013). CBEM can also allow scientists and local communities more easily obtain samples year-round, thereby providing higher resolution time series. CBEM can help awaken an interest in science for both junior and high school students, increase retention in the school system, and help students gain exposure to a research and university environment (Conrad and Hilchey 2011). It can also encourage more students to enrol in post-secondary education – which is significant in the North where post-secondary enrolment is low compared to the rest of Canada (Statistics Canada 2009).

Indigenous knowledge and understanding of environmental dynamics over time can provide useful information to assess ecosystem change (Pearce et al. 2009). Indigenous knowledge (IK) or traditional ecological knowledge[2] (TEK; Berkes 2008) can contribute greatly to the design and process of CBEM. In this paper, we will also refer to Inuit knowledge, which is more specific than Indigenous knowledge, and inclusive of local and traditional ecological knowledge. As long-term inhabitants, Arctic residents are regularly making environmental observations using key visual indicators, such as the timing of lake and river freeze and break-up, ice thickness, wind speed and storm severity, the distribution and abundance of specific plant and animal species, and the dates at which certain animal migrations occur (Royer et al. 2013; Cuerrier et al. 2015). For residents, observing and understanding changes in environmental conditions often incorporates local knowledge and is vital to successful hunting, fishing, gathering, safe travel and cultural activities, as well as to the ability to adapt to change (Peloquin and Berkes 2010; Eira et al 2013). As scientific assessment of change in the Arctic moves increasingly from documentation to development of

[1] Community-based monitoring is: "a process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track, and respond to issues of common community concern." (Whitelaw et al. 2003:8).

[2] Here we use Berkes' definition of traditional ecological knowledge as: "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and their environment" (Berkes 2008:8).

strategies for adaptation, interest is rising in using multiple knowledge systems, and in community-based participatory approaches to science, particularly in environmental monitoring (Raymond et al. 2010; Riseth et al. 2011; Tengö et al. 2014).

CBEM projects have the potential to increase the integration of participatory research methods, to improve the observation and monitoring of changes in the Arctic, and to facilitate community control over resource management decisions. However, there are also difficulties associated with CBEM, such as non-systematic data collection, logistic hurdles, unfamiliarity of citizens with scientific protocols, skepticism regarding science, volunteers losing interest, and defining data ownership (Cohn 2011; Hobbs and White 2012; Shirk et al. 2012). One key problem is that many CBEM projects remain under-documented and are often unconnected to wider Arctic monitoring networks (Huntington et al. 2011; Johnson et al. 2015). Huntington et al. (2013) notes that there has not been a significant study of the “accuracy of community-based monitoring of natural resources in the Arctic”. A recent review of the current state of CBEM in the Arctic highlighted the need to connect citizen science/CBEM and scientist-executed monitoring to capture more dimensions of environmental change in this remote region (Johnson et al. 2016).

Furthermore, although it is important to consider the views of youth alongside adult perspectives in community-based research, youth continue to be under-represented in CBEM as primary informants and active research participants (MacDonald et al. 2013). Youth under 24 years old now represent over 50% of Northern Canada indigenous populations (Statistics Canada 2011). It is important to engage local indigenous youth in CBEM as youth can be a source of land-based knowledge concerning environmental change that differs from older generations (MacDonald et al. 2013). Youth participation in CBEM can also create a motivation for pursuit of formal schooling (Brunet et al. 2016), or be an opportunity for new or renewed connection to the land and between generations (Cuerrier et al. 2012).

In this paper, we focus our analysis on the project IMALIRIJIIT, a CBEM program involving Science Land Camps, capacity-building workshops and scientific data collection with the participation of youth, Elders, local experts and researchers that was co-initiated by the Inuit community of Kangiqsualujjuaq (Nunavik) (Figure 1) and university researchers. IMALIRIJIIT was the team name chosen by youth participants in 2016 and means “those who study water” in Inuktitut. IMALIRIJIIT aims to establish a long-term environmental monitoring program in the George River watershed, before the start of a rare earth elements (REEs) mining project in the upper watershed. In this CBEM program, we try to find a balance between Western Science and Inuit knowledge as complementary knowledge systems, following the current movement for decolonizing research and science education (Aikenhead 2010; Evering 2012; Smith 2013; Hébert-Houle 2018). Building on the participating researchers’, Kangiqsualujjuamiut’s and youth’s expectations and perceptions of this CBEM/Science Land Camp project, we identified multiple perspectives regarding opportunities, advantages and limitations associated with CBEM. Here, we present and discuss the objectives, the methodology employed, and the outcomes and challenges of the IMALIRIJIIT Program. This analysis aims to identify the conditions necessary for the sustainable implementation of CBEM and environmental stewardship in the George River watershed, Nunavik.

Methods

Project development with the Kangiqsualujjuaq community

A group of researchers affiliated with the Université du Québec à Trois-Rivières (UQTR) and the Centre d'Études Nordiques (CEN), launched a project call to the Inuit communities of Nunavik in the summer of 2015 to evaluate their interest in undertaking a Science Land Camp. This initiative sought to build a CBEM project involving the local youth while addressing a local environmental issue to be chosen by the community.

The community of Kangiqsualujjuaq, located at the mouth of the George River (Figure 1), answered the project call and submitted a resolution to the Municipal Council to confirm their interest in participating. Researchers then traveled to Kangiqsualujjuaq from October 26th to 30th 2015 to consult with representatives from four groups in the community: the Municipal Council, the Landholding Committee, the Culture Committee and the Youth Committee. After brainstorming with each group about environmental issues for the context of a Science Land Camp, the researchers proposed three different scenarios: 1) Monitoring the George River water quality; 2) Studying vegetation and landscape changes in the Koroc River area; and 3) Inventorying the edible marine resources in a local area. The first scenario was unanimously chosen by the community in consideration of a REEs mining project that was planning to begin operations in the upper portion of the George River watershed. The George River flows northerly for 505 km towards Ungava Bay and its watershed spreads over 41 700 km². The river and its banks (1 320 km²) are protected under Quebec's Law since 2008 and part of the river is included in the Ulittaniujalik Park, created in 2016. Strange Lake, a simple open pit mining project that was proposed by Quest Rare Minerals Ltd., was planning to mine materials to be physically upgraded by a floatation concentrator located on site, then transported to a hydrometallurgical plant at Bécancour, Quebec (Quest Rare Minerals Ltd., 2015). Kangiqsualujjuamiut were concerned about this mining project as the river is crucial to traditional activities of fishing, hunting and gathering. The community therefore wanted their own independent and long-term environmental monitoring program to collect baseline data and promote local capacity-building.

Multidisciplinary scientific team

Partnerships were developed with researchers from different departments, universities (Quebec, France), federal and provincial government agencies, local research centres, and NGOs to form a multidisciplinary scientific team with expertise in human and physical geography, remote sensing, plant ecology, hydrology and ecotoxicology, as well as science education with indigenous communities,.

IMALIRIJIIT Program

Objective 1: To implement a sustainable and collaborative environmental monitoring program of the George River watershed managed from Kangiqsualujjuaq, Nunavik.

To implement a sustainable and collaborative CBEM program of the George River watershed as requested by the community, we organized two Science Land Camps in 2016 and 2017. The Science Land Camps have both a scientific and educative mission, allowing for data collection, the creation of interest in natural science and the building of local capacities in water quality monitoring, as well as biosampling (sediments, plant and animal tissues) and data management. This program also includes the study of contaminants in country food (aquatic and terrestrial) collected in the George River area in collaboration with the local Hunter's Support Program.

Objective 2: To study water quality and environmental change at the watershed scale.

For this second objective, remote sensing served as a complementary tool for *in situ* measurements to estimate three water quality parameters at the watershed scale: turbidity (water cloudiness), chlorophyll-*a* and temperature. Traditional ecological knowledge (TEK) is used as another tool to document changing land use in the George River watershed.

***Objective 3: To develop an interactive multimedia map of the George River watershed*.**

An interactive multimedia map is being produced, using uMap platform, as a novel way to present quantitative and qualitative data and to leave a tangible and interactive legacy for the community. The map will be based on interviews focusing on land use and Inuit knowledge and observations during the land camps and data collection (e.g. fieldwork photos, GPS data, environmental data, audios, videos). Some community members will be trained to update the map with new information as the work continues in the future.

[Figure 1 near here]

2016 Science Land Camp

Prior to the camp, a reconnaissance trip was organized on the river, in collaboration with Parks Nunavik. Two meetings with the youth participants also took place in the community to introduce everyone, explain the project goals, discuss logistics and familiarize with the sampling materials and tools prior to departure.

The first Science Land Camp took place on the George River (Figure 1) from July 22nd to July 29th 2016. The participants included eight students from 12 to 17 years old (three boys and five girls), two elders, three guides and one assistant, three cooks, one child, and five researchers, including an Inuk water quality researcher from Pond Inlet, Nunavut. There was a total of 23 people. The two Elders were born in this area and shared some life stories of their childhood during the evening activities. They cooked bannock everyday and acted as counsellors for the youth. Guides, assistants, cooks and elders also hosted youth in their tents.

Several hands-on pre-sampling workshops were organized on site for the first two days including mapping, satellite imagery, GPS, and water chemistry. The students learned to handle the equipment with care and understood the importance of wearing gloves while sampling water and manipulating chemicals. They also learned to record and compile the data correctly, an essential skill for a scientist, as the noted values need to be easily associated with the sampling station when compiling the results.

2017 Science Land Camp

In 2017, the Science Land Camp took place from July 21st to 30th. The team included 28 people: six researchers, 11 youth from 13 to 17 years old (seven boys and four girls), four guides, two cooks, two elders, one local coordinator and two children. All youth participants were new recruits.

In 2017, researchers decided to do a substantial part of the water quality data collection before the arrival of the youth, so that they could be more dedicated to the educational goals for the youth. In the second year, the educational program was more diverse and formally-structured. It was oriented towards introducing several fields of natural and physical sciences (hydrology, geology and sedimentary processes, geomorphology, plant ecology, botany, entomology, invertebrate zoology, physical chemistry, maps and GPS, biomonitoring), as well as Inuit knowledge.

A local youth coordinator was chosen by the community and a coordinator of the educational program was designated from within the group of researchers. Icebreaker activities were organized by the whole group of researchers such as games and a discussion comparing “what researchers do” to “what hunters do”. The two youth coordinators organized activities for three days before the youth’s departure, including a visit to a geologist camp based in the community where the geologists talked about basic geology, exploration techniques, and the realities of their work.

Data collection

Water sampling stations

According to local knowledge, tidal influence ends around the Qikirtaaluit Islands (Figure 1). In 2016, five sampling stations were established along a 35 km stretch of the river, between Helen Falls (a 3 km long rapid requiring a portage) and Qikirtaaluit Islands. In this segment, the river’s width ranges from 0.7 km to 1.7 km. Remote sensing was used to quantify the level of chlorophyll-*a* and turbidity, thus influencing the location of some sample stations. In 2017, the same five stations were sampled, with the addition of five new stations: three in the same stretch of the river, including two tributary brooks, one between the two rapids in the tidal mixing zone, and one in the estuary.

Water physical-chemistry

Water physico-chemistry variables (temperature, pH, specific conductivity, dissolved oxygen, turbidity, hardness, temperature, color) were measured *in situ* with manual kits and an electronic probe (YSI Pro Plus). Water samples were collected (unfiltered and filtered) for laboratory analyzes of nutrients, dissolved organic carbon, major ions, chlorophyll-*a*, trace metals and REEs (Environment and Climate Change Canada and University of Montreal). Nutrient, ions and chlorophyll-*a* samples were filtered using a filtration unit and a manual pump (Figure 2). Trace metal and rare earth element samples were filtered using acid-washed polypropylene/polyethylene syringes (without rubber gaskets) and filters with a polyethersulfone membrane (Whatman GD/XP, pore size 0.45 µm). Samples were collected using the "clean hands, dirty hands" sampling protocol for trace metals (St-Louis et al. 1994). In 2017, additional probes (YSI EXO1 and YSI 6600V2) were used for continuous measurement of water quality parameters (i.e. temperature, specific conductivity, total algae, dissolved oxygen, turbidity, pH) at several stations. Guides, cooks and youth all participated in the water collection and filtration in both 2016 and 2017.

Trace metal sampling protocols involve strict precautions to avoid sample contamination and can be difficult to execute properly in remote areas with untrained participants. Participatory sampling techniques were improved in 2017 by better training and communication with the adult guides.

[Figure 2 near here]

Contaminants and biological sampling

A monitoring survey examining contaminants in country food was initiated in 2017 in collaboration with the local coordinator from the Hunter's Support Program. Inuktitut and English sampling kits were prepared for whitefish, seals, caribou and lichens. Hunters had to follow sampling protocols and fill out sampling forms with identification, measurements and tissue collection details for a financial compensation. The samples were frozen and later sent to University of Montreal for laboratory analysis of contaminants. One young bearded seal was harvested during the 2017 land camp near a sampling station and tissue samples were collected to complement the contaminant survey.

As REEs accumulate to greater levels in sediments and benthic organisms (Amyot et al. 2017; MacMillan et al. 2017), the analysis of REEs in sediments, macro-invertebrates, plants (lichen) and fish was included in the 2017 sampling campaign. Sediments and biofilm were collected at several sampling stations.

Macroinvertebrates

Macro-invertebrates live in freshwater ecosystems and their species abundance and diversity can be used to provide insights into the health of these ecosystems (Moisan 2017). Macro-invertebrates are good indicators of the water quality as these organisms spend at least part of their lifecycles on the riverbed. In 2016 and 2017, a macro-invertebrate inventory was completed at the mouth of a tributary brook, between stations 4 and 5, following the MDDEFP (2013) sampling protocol for rocky riverbeds (Figure 3).

[Figure 3 near here]

Hydrology and Remote sensing

The study of environmental change at the landscape scale is ongoing and will rely on remote sensing. Two databases for optical remote sensing will be used from available and free satellite archives: Landsat-5, 7, 8 (NASA) since 1984 (resolution 15 m), Sentinel-2 (ESA) since 2015 (resolution 10 m). Ice onset and breakup, as well as snow melt, will be documented from these historical time series dataset, for the reason that these two parameters influence runoff, discharge and water quality. This work will focus on three water quality parameters: chlorophyll-*a*, salinity and turbidity. Data retrieved during July 2016 and 2017 from Landsat-8 and Sentinel-2 images will be compared with (i) *in situ* measurements and laboratory analyses, and (ii) the referenced methodologies of image classification available from the literature (Ritchie et al. 2003; El-Alem et al. 2012). River surveys were completed in 2016 and 2017 at strategic locations to map water depths, and these results will be used to test approaches for remote sensing of river bathymetry. Finally, at the watershed scale, NDVI analyses of Landsat time series will be used to assess environmental change including vegetation (greening or browning), landslides, and channel erosion and sedimentation.

Inuit knowledge

Inuit knowledge was also used as a tool to document the land use by Inuit, the ecology of animal and plant species, the river's biophysical processes and the observed changes in the George River watershed. Pre-existing data is being reviewed and enriched by new interviews conducted with local knowledge holders in Kangiqsualujjuaq. Semi-structured interviews used a questionnaire about life stories, land uses, animal and plant species, local toponymy, changes in the river watershed, as well as stories and songs linked to the river. These interviews were made with paper and digital map supports (Google Earth, uMap) when an Internet connection is available. All elders who participated in the Science Land Camps were interviewed and five additional semi-structured interviews were conducted in the community with local guides/hunters. We obtained an Ethics Certificate for research with humans from Université du Québec à Trois-Rivières (CER-16-225-07.14).

Recreational activities

Various recreational activities were conducted between scientific workshops and sampling periods to foster intergenerational and intercultural exchanges (fishing, games, swimming, hiking, boating, etc.) and positive relationship between scientists and community members. In addition, recognition and initiation events such as Scientist of the Day and certificates were used as motivation and self-esteem boosters for the youth during the camp.

Observations throughout the camp

A qualitative documentation method was used during the 2016 and 2017 land camps. The two main methodologies used were observation of participants and researcher's journals (Laperrière 2009; Noiseux 2010). An evaluation questionnaire was also filled by the students at the end of the 2017 camp, with the help of the two youth coordinators. To date, this qualitative data has not been analyzed. It was mostly used to get a better sense of researchers' experience and to improve the future science land camps.

Hands-on, land-based approach

The IMALIRIJIIT program is based on a hands-on and land-based approach (Cleary and Peacock 1998; Klug and Whitfield 2003; Castagno and Brayboy 2008). For example, in 2016 students completed a site characterization at each station by observing their environment and taking notes about the physical characteristics of the water, shoreline, vegetation and, more generally, the landscape. The students also had to note the GPS coordinates. The students then completed water sampling and physical chemistry measurements with supervision from a researcher (Figure 4) using the manual kits. At each sampling station, the students also assisted with the YSI probe measurements. Guides and cooks also actively participated in the sampling activities.

Students were provided with personal notebook and several iPads were provided in 2017 to take GPS coordinates, pictures and videos.

[Figure 4 near here]

Results

Science Land Camps

These were significant improvements in the 2017 Science Land Camp. First the presence of a local coordinator before and during the camp helped our youth coordinator to gain trust from the youth at the beginning and to deal with some situations during the camp. The guides were also more involved with the youth. Some guides participated in 2016 and 2017 camps so they knew us better and also what to expect. The activities in the community with the youth for the first three days allowed a better bonding between the youth and the scientific youth coordinator and permitted the rest of the team to concentrate their efforts on the scientific sampling before youth's arrival. The scientific activities were also more structured and diversified, which helped to keep youth's interest. Organized recreational activities in the evenings contributed to reinforce relationships between the youth and researchers. The ceremonies and initiations were as successful as in 2016 but in 2017 the youth received apprentice and full scientist certificates, respectively at mid-camp and at the end of the camp, which were very much appreciated. These ceremonies were held at strategic moments and helped to bring everybody together and to cheer up the participants when some were discouraged or getting homesick.

Data collection

Water quality

In general, the 10 different sampling sites showed relatively similar physico-chemical signatures, indicating that the river water is very well-mixed. The George River water quality data was similar to the data collected in 2015 for the neighbouring river, the Koroc also flowing from south to north and discharging into Ungava Bay (see Table 1). During the sampling period in July, the river water had a temperature of 16°C, neutral pH (therefore not acidic or alkaline), well oxygenated waters, and with low electrical conductivity. The water was also very soft (low levels of $CaCO_3$). The George River is oligotrophic (low in nutrients like nitrogen and phosphorus) with low chlorophyll concentrations, meaning not much algal (or plant) growth in the waters.

The concentrations of trace metals and rare earth elements in the George River are very low and all measurements were under the existing Canadian water quality guidelines. Note: guidelines do not currently exist for rare earth elements.

[Table 1 near here]

We compared measurements made by youth using manual kit test methods with the measurements obtained using a YSI Pro probe for temperature, dissolved oxygen and pH (Table 2). The results differ slightly, however the samples were not collected at precisely the same locations (i.e., up to 10 meters apart).

[Table 2 near here]

Our findings show that these two approaches are complementary. The YSI probe is expensive yet easy to deploy and provides accurate scientific data, whereas the manual tests are less expensive, more hands-on, and a more enjoyable method for teaching the youth participants. Both methods can be used in a CBEM to validate each other and to engage youth in scientific data collection.

Contaminants and biological sampling

Metals and rare earth elements were also sampled in lichens to monitor the quality of the atmosphere, as lichens take up all their nutrients from the air (they have no root system). Lichen samples collected from around the community and from the George River watershed showed higher levels of metals than surface waters, indicating that they could be used as a good bio-indicator of air quality. As some metals can potentially accumulate in plants and animals, we are currently studying the levels of these metals (and mercury) in fish, seals, caribou, hare and ptarmigan. These data are currently being analyzed in the laboratory and will provide us with a general portrait of the metals and rare earth elements present in the George River watershed, allowing us to monitor the water, plants and animals not yet affected by mining activities.

Macro invertebrates

The dominant macro-invertebrate groups in the samples collected in a tributary brook near station seven (7) were *Ephemeroptera* (e.g. mayflies), *Plecoptera* (e.g. stoneflies) and *Trichoptera* (e.g. caddisflies), along with *Diptera* (e.g. blackflies, mosquitoes) and *Hydracarina* (water mites). The first three groups are indicators of good water quality (Moisan 2017), while the abundance of black flies and mosquitoes during the sampling period may explain the abundance of *Diptera*.

Hydrology

In both years, data were collected at a period when the river was returning to summer base flow. Mean water depth within the surveyed reaches is approximately 5 meters (m) but pools with depths exceeding 60 m were measured downstream of Sarvakallak rapids. Both in 2016 and 2017, the water level in the river was lower near the end of the camp (one week later) making navigation more hazardous. Tide amplitude in George River's estuary is approximately 12 m (Fisheries and Oceans Canada 2017). Consequently, tides dictate navigation's timing through rapids and shallow riverbed sections, particularly downstream from Qikirtaaluit Islands.

From visual observations, it was determined that the riverbed, in the segment from Helen's fall to the estuary, is composed of sediments ranging in size from sand to large boulders; aquatic vegetation is very rare and sparse. Boulders as large as 1 m in diameter are distributed non-uniformly across the riverbed making navigation out of known routes especially dangerous. From the estuary, waters are not clear enough to distinguish the riverbed at comparable depth. However, massive boulders (i.e. 10 m in diameter) and bedrock outcrops can cause navigation problems at low tide.

We estimate that the flow rate of the George River at the Lac de la Hutte sauvage station was approximately 560 m^3/s in late July 2016 and 645 m^3/s in late July 2017. Based on the historical records, the late July flow rates for both 2016 and 2017 were below average. Analysis of historical flow records for the George River indicates that there has been a slight but significant decrease (nearly 1%) in mean annual discharge since the mid-1970s. This decreasing trend is associated with reduced flow during the summer period. Winter flow rates appear to be stable. We do not yet know the factors responsible for this downward trend in summer flows; further analysis of hydrologic and climate factors will be required to determine causes.

Remote sensing

We have explored the potential of two different satellite platforms to assess the current and historical water quality of the George River. The two platforms are: (i) the Landsat TM series of satellites operated since 1984 by the United States government (NASA); and (ii) the A & B Sentinel-2 platforms in operation since 2015 by the European Space Agency. These satellites capture routine images of the George River watershed at intervals of 7 to 9 days (Landsat 8) and between 5 to 13 days (Sentinel-2) and thus provide an ongoing image record of the watershed. These datasets are atmospherically corrected and georeferenced by using previous studies (Table 3). Field-sampling campaigns are undertaken to validate these corrections, and to set the relationship between optical properties versus ground-based measurements. As there are no historical records of water quality for the George River, the data available from these satellite platforms provide the only current means of determining long-term trends in water quality. There are several important challenges in using satellite imagery to develop an historical record of the water quality for the George River: (i) the obstruction of the earth's surface by cloud cover which reduces the frequency of images valuable for analysis; and (ii) the development of robust relationships between the satellite images and specific water quality parameters. To date, our results are encouraging for the following parameters: river depth, turbidity (water cloudiness), and salinity (salt concentration in water).

[Table 3 near here]

We see in Figure 5 that inserts *b* versus *a* (Chlorophyll-*a* level), and *e* versus *c* or *d* (Turbidity level) indicate a more obvious separation in the middle of the image between both segments of the river, at the border of Ford Island (Figure 1). In this context, the high temporal resolution of Sentinel-2 A&B platforms (5-day revisit) is essential for a continuous monitoring of Arctic hydrological systems.

[Figure 5 near here]

Inuit knowledge and interactive mapping

Interviews and discussions gathering youth and elders took place several times on the land to encourage intergenerational knowledge transfer. They were used to link local knowledge and environmental science by documenting Inuit knowledge related to the George River, observations of hydrological changes, and navigation skills. Individual interviews with some of the guides were also held in the community with the help of printed maps. An interactive map (uMap) of the George River watershed was designed to integrate the interviewees' observations.

A 3-day interactive mapping workshop was organized in Montréal, in March 2018, with three northern trainees: one from Kangiqsualujjuaq, one from Kuujjuaq (Nunavik Parks) and one from Kawawachikamach. The trainees learned how to create new maps with audiovisual content, map features and layers, and also how to organize and share geographical and qualitative data. This training fostered the first steps of a potential collaboration between Kangiqsualujjuaq Inuit community and the Naskapi Nation of Kawawachikamach to share their knowledge and land use related to the George River watershed.

An activity of mental mapping was organized at the beginning of the camp where the youth had to draw in teams, their representation of the river and its various components.

Community participation

Regarding local participation, the community has been heavily involved for the past two years for all logistical and financial aspects. It is significant that the community has been able to secure funds in advance for a 2018 Science Land Camp from local and regional Nunavik organisations. The local Youth Committee has been very active from the start of the project and has now transferred the logistical oversight to the municipal government. Communication with local authorities has always been effective.

Outcomes

Building local capacity in environmental monitoring and stewardship

One of the main objectives of the IMALIRIJIIT program, was to train Inuit youth and community members from Kangiqsualujjuaq in environmental monitoring and field-based monitoring studies.

The 2016 Science Land Camp focused on water quality measurements and the participants learned more about physical chemistry and the importance of replication in scientific protocols. The 2017 camp adopted a global approach to study the George River watershed and introduced the participants to the scientific process and a variety of scientific disciplines. This second edition was designed to spark youth's interest towards natural sciences through land-based and hands-on activities. For both years, the youth participants learned the importance of taking notes in the field, by recording environmental data and observations. They gained confidence in their capacity to participate in scientific activities even though this initially seemed foreign to them. They grew more committed to the project over the land camp and displayed a sense of pride in their work.

Participating in scientific measurements with committed local adults and elders, as well as researchers, had a positive impact on the youth. By the end of the week, the youth felt that the important aspects were the structured and safe camp setting, as well as conducting meaningful work for the community and being out on the land every day. Their attitude towards the researchers had changed, becoming more trustful. They were more committed to the project and displayed a sense of pride in their work. Here are some extracts from one participant researcher's journal:

'One of the more remarkable things to me was that at first, the youth weren't interested at all in spending any time in the "Science tent" and wanted to be left alone in their own tents. But after trust was gained and better relationships established, the youth were constantly saying "Let's go to the Science Tent" and willing (even excited) to come do activities in the Science tent (during free time in afternoons, evenings etc.). They even spent hours sorting benthic invertebrates'.

'Another observation would be that youth were initially unwilling to participate in science activities and at the end they were constantly pestering me to help with my own sampling (that didn't plan to involve them) i.e. filtering and taking inverts for contaminants'.

During both years, we observed a strong interest from some guides in the scientific activities, data collection and scientific protocols. Upon return to the community, the two elder participants (who had grown up in the George River area) went on the local radio to say that they had appreciated their experience. One guide also gave a 10-minute speech informing people about the camp's activities, including the importance of the involvement and training of the youth, the relevance of the environmental protection of the river and also his pride at seeing Inuit doing science, referring to Anaviapik Soucie's work (Anaviapik Soucie et al. 2015). After the camp, researchers were invited to give a local public presentation during the Youth Conference. In October 2016, the mayor and one student were invited to do a joint oral presentation about this whole experience at the 20th Biennial Inuit Studies Conference in St. John's, Newfoundland. In December 2017, the mayor gave a joint oral presentation at the Arctic Change Conference in Quebec City.

Building trust between researchers and participants, community authorities and representatives

There is no magic recipe to building trust and reciprocity between researchers and community authorities and representatives. For this project, researchers spent as much time in the community as possible, participated in local events, and had an open, friendly and respectful attitude towards the community members (Castleden et al. 2012). They made efforts to have frequent and open communication with community authorities and key people in the community. The researchers shared information and results in relevant and comprehensive ways (Brunet et al. 2014; Dyer et al. 2014) at the local Parnasimautik meetings with simultaneous translation and radio diffusion. The mayor was a co-principal investigator for a grant proposal submitted in 2017 and the leader for two others submitted in 2018. Personal affinities with community representatives and members were also non-negligible factors for the success of this project.

During the 2017 Science Land Camp, having a designated youth coordinator among the researchers also greatly facilitated the bonding and the confidence between the youth and researchers. Youth trusted in her leadership as she was designated to interact with them on logistical and educational aspects.

Overall the IMALIRIJIIT CBEM program using a hands-on and land-based approach allowed the community and researchers to better merge Inuit ways and scientific procedures. It also highlighted the similarities between the scientific method and the Inuit hunting and gathering culture such as observation, inquiry, analysis and problem solving. People, especially youth, can relate to things they are familiar with and then get more engaged in the learning process (Hébert-Houle 2018). For the older participants (guides, elders), they contributed to the collective body of knowledge around the George River watershed by sharing their land use personal records and by providing samples for the analysis of country food's quality.

The production of an interactive map will also be a useful outreach tool allowing the democratization of this knowledge and generating interest for adding new content to the existing work in a continuous process. In addition, the sample collection represents an economic opportunity for hunters, though encouraging these traditional activities and the gathering of country food. The Science Land Camp also generates important economic benefits for participants and valorizes their outdoor and survival skills. This collaborative and multidisciplinary initiative benefits the researchers, the local community and regional organizations such as Nunavik Parks.

It is also very beneficial to share activities with community members such as drinking tea and eating together, doing hunting/fishing/gathering activities, and playing games. This time investment helps to foster a positive relationship between scientists and aboriginal communities. They tend to make scientists more "humans", and science more accessible.

Challenges

Simplify data collection & management, collect more data types and increase data quality

It is not always easy to combine scientific and community priorities concerning data collection. There may be concern about data quality because of lack of direct supervision over time.

The two sampling campaigns are currently being analysed to compile a baseline dataset. This step will allow the researchers to select indicators and appropriate protocols for simple data collection and management by community members over the long-term. Researchers have to select good local candidates who could be trained for future sampling campaigns. Special efforts were made in 2017 with Parks Nunavik to standardize the water quality sampling protocols so that data is comparable and to enable collaborative sampling efforts in future years. To help establish this collaboration, a conservation officer and education specialist with Nunavik Parks accompanied the researchers during the sampling campaign and science land camp in 2017.

Different priorities

Academics usually focus on data quality and management for analyses and scientific publications. They also face time and budget constraints from their professional and personal agendas and from funding agencies. Communities can have other priorities, focusing more on economic development, land planning, social issues and education over data collection. Community priorities do not always line up with academic agendas, but common ground can be found based on discussions and mutual trust (Table 4).

[Table 4 near here]

The privacy and the use of the information gathered may be seen from different perspectives by academics and communities. For example, the data from samples analysed in southern laboratories is very valuable for both users, however the intellectual property is usually owned by the academics. This ownership can be more clearly defined beforehand in an agreement with the community. On the other hand, local knowledge is usually owned by the community and its publication has to be approved by the knowledge holders. The privacy of the data will depend on individual, collective and mutual agreements and may vary according to the funding context and the contract terms.

The utility of information may vary for academics who may use it for research, communication and teaching, and for communities who may use it for decision-making, influencing policies and protection of their living environment and lifestyle (Table 4).

To meet local training needs and capacities, academics may also need to adapt their protocols, methodology and sampling tools. Keep it simple is the most common community concern (see Appendix 1 and 2).

Other challenges

Repetitive measurements can diminish youth interest in data collection, so it is important to develop diverse strategies as well as novel and dynamic educational tools and approaches. To address this challenge, illustrated and simple field protocols were developed for water physical chemistry sampling procedures.

To involve hunters in sample collection, special efforts need to be undertaken to provide clear and illustrated instructions. Bilingual sampling kits were prepared for this study and distributed to hunters for collecting animal tissues and lichens.

Data privacy and intellectual property should be continuously discussed between parties and the rights of individuals to stay anonymous must be respected through using consent forms. It is especially true with the increasing use of open source tools and social media.

High costs and complex logistics are significant challenges for northern CBEM projects. Long term funding is an essential condition for making initiatives such as the IMALIRIJIIT program sustainable. It needs commitment from local and regional institutions as well as from government agencies, with academic institutions in support. Long-distance collaboration with northern partners is another challenge and the budget should allow for sufficient travel and accommodation costs as face-to-face meetings are often crucial to a project's success. Alternative modes of communication should also be explored, such as social media. Lastly, coordination of academic participants and budget in multidisciplinary teams represents an additional challenge due to economic and time constraints.

Discussion

Combining scientific goals and TEK

CBEM draws on both TEK and conventional scientific and technical approaches. TEK can contribute in a variety of ways to a better data collection by helping to identify monitoring priorities, to locate monitoring stations, and by providing insights for analyzing observations (Johnson et al. 2016). In the IMALIRIJIIT CBEM Program, local Inuit knowledge was determinant for the pre-selection of the study area and the sampling sites, and for the navigation and camping logistics.

Hydrology data for the Arctic are scarce and disparate due to a limited number of stations and limited time records (Muster 2018). CBEM can help to fill lack of data as it co-produces observations (Johnson et al. 2016). In the IMALIRIJIIT CBEM Program, the use of local knowledge in the George River regarding sedimentation and hydrological processes was very helpful for interpretation and validation of remote sensing data at the watershed scale. Similarly, Kainer et al. (2009) noted that knowledge exchange and interpretations of findings by different knowledge systems can foster a better understanding of the phenomena under study. Thus, TEK, including Inuit, Naskapi and Innu knowledge, can help to fill gaps in the scientific knowledge in subarctic freshwater ecosystems, such as the George River watershed.

Co-production approaches that draw on indigenous and scientific methods can help to develop novel questions (Johnson et al. 2016). This occurred in the IMALIRIJIIT CBEM program, when the community expressed its interest in monitoring the country food quality as a complement to the water quality monitoring. This allowed the extension of the scientific team and the monitoring program by recruiting an ecotoxicologist and starting a contaminant study with local hunters collecting samples of fish, caribou, seals and lichens. Thus, CBEM supported the development of new partnerships (Brummer et al. 2016). It also led to grant co-applications with Kangiqsualujjuaq northern village which were successful. Considering both researchers and community interests and priorities is proving to be beneficial for all parties (Brunet et al. 2017). Hiring a local coordinator both in the community for the sample collection by hunters and during the science land camp has been very effective. This contamination study initiated through the IMALIRIJIIT CBEM program can produce data that decision-makers, such as Kativik Regional Government, need to make informed decisions about the food security of the Arctic in the context of change (Danielsen et al. 2013; 2014).

The choice of the bio-indicators for a simple and sustainable long term monitoring will be discussed between our research team and local representatives (e.g., liver of fish, lichens, sediments, macro-invertebrates, biofilm etc.). Collectively, we will create the protocols and verify the feasibility, the costs, and the persons to be trained and hired. Thus, CBEM can rise the capacity of Kangiqsualujjuaq village to document and respond to change, and of scientific researchers to collect year- round data (Johnson et al. 2015).

Inuit culture is based on traditions of orally transmitting knowledge between generations and learning by watching. Compared to conventional scientific monitoring CBEM has a higher potential to foster intergenerational knowledge transmission as it engages and involves community's local experts (Johnson et al. 2016; Kanu et al. 2016). The science land camp was an excellent occasion for local knowledge holders to transmit land skills to youth while traveling between sampling sites and for activities. For example, during travel, one guide was teaching his cousin's son navigation skills and how to "read the river".

Over the years, researchers should continually evaluate the success of the data collection in collaboration with community members and trained participants. Data collected by researchers and community members are complementary and the contaminant sampling campaign is a good example of researchers benefiting from hunters' skills to collect fish, seal and caribou tissues. Collection of TEK across the George River watershed can also be done by community members from Kangiqsualujjuaq and upstream communities, such as the Naskapi Nation of Kawawachikamach and the Innu community of Matimekosh-Lac John.

Incentivizing participation in CBEM in northern communities

A real partnership can be developed between researchers and indigenous communities through working on environmental issues identified by the community, training local resources, dealing with logistical and financial problems, and traveling and camping together on the land. Co-designed CBEM projects meet all these criteria. Community representatives, guides and youth all appreciated having hands-on and land-based training, and were eager to learn more about their environment in a different and complementary way. Youth and adults discovered a passion for different scientific fields. For example, one youth was passionate about insects, another about rocks and minerals, a third one about medicinal plants and botany while one of the guides was eager to learn about geomorphology, landscape formation and hydrological processes. Learning about science and collecting scientific data in an outdoor environment while contributing to a local problematic made a big difference in the way people perceived science and committed themselves in the learning process.

Building a long-term project is crucial to earn trust from local authorities and to work in an effective and collaborative way (Christopher 2008). As stakeholders get more confident with the researchers, they will be more at ease to discuss any adjustment to respect community needs and realities. In the IMALIRIJIIT CBEM, the Youth Committee was extremely involved in 2016 and 2017 but they have signified to the municipal authorities that the northern village should take over responsibility for the project as it was becoming too big to support for a small group of volunteers. In this instance, instead of abandoning the project, the community found a way to ensure the project's continuation while respecting everyone's interests and personal constraints

In the future, better coordination with other activities going on in the community is recommended to facilitate logistical issues such as recruiting guides and youth participants. For example, we consider the possibility of merging with another camp more oriented towards traditional activities. It is important to respect the objectives of both the community and scientists, in order to better merge TEK and scientific knowledge and to get a stronger ownership of the CBEM by the local community (Brunet et al. 2017). The timing of the science land camp could also be more in line with local constraints such as the water level in the river and the abundance of biting insects. Combining our two types of expertise and knowledge in a multidisciplinary and multicultural approach is a good way to create a simple, sustainable and low-cost sampling plan (Carr 2004).

Such initiatives can become a learning and empowering tool for both academics and indigenous communities in environmental monitoring and resource management (Brunet et al. 2017; Johnson et al. 2015, 2016).

Fulfilling both educational and scientific objectives is demanding and needs more funding, energy and time (Cuerrier et al. 2012), but our scientific field campaign was greatly facilitated through the successful partnership that was developed while organizing the science land camps with community members. The commitment we showed towards youth training and empowerment also gained us respect from the community. Collectively, we put the focus not just on *what* is measured but on *how* it is measured and *who* decides which data is important. Working with the community in a participatory way on equal footing from the outset and throughout the IMALIRIJIIT program was essential for building trust and for community's involvement. These factors will help the choice of meaningful and achievable water quality indicators for this river, more relevant than those set by top-down methods (Gearheard and Shirley 2007; Pearce et al. 2009; Phillipson et al. 2012; Grimwood et al. 2012).

Conclusion

The baseline dataset for the environmental monitoring of the George River will be compiled during the two completed years and the upcoming 2018 camp. In the long-term, essential water quality indicators should be defined, as well as the sampling effort and frequency that is needed for such a program to be sustainable. It is now clear that youth training is not sufficient as there is a high turnover between years, as youth move away for further education or enter the work force. Efforts will need to be put into training adults from the community, identified through participation in the Science Land Camps. This would also contribute to create much needed jobs such as field or research assistants in northern communities and create local interest for involvement in science projects. Another way of combining research interests with local interests and needs is the compensation paid to the hunters to provide plant and animal samples for the country food contaminant study (Bordeleau et al. 2016). This program benefits both the researchers to get samples throughout the year and over a large area, while helping the hunters pay for the substantial traveling costs of traditional subsistence activities.

Co-learning and engaging in common activities also improved the cultural capacities of members of our research team who were unfamiliar with Inuit culture (Brunet et al. 2016). Together we have developed a shared understanding of research ethics in an Inuit context that fostered the success of our research (Asselin and Basile 2012).

This project is a good example of a successful collaboration between an indigenous community and researchers to address local environmental issues identified by the local stakeholders. However, academic institutions need to stay in a supportive role and accompany arctic communities in this long-term process of building local capacity for environmental monitoring. Northern institutions and both provincial and federal government agencies will need to commit funds and display political will in order to support Inuit communities' involvement in science by starting CBEM programs that stay "their own project".

A land-based approach allows indigenous people to realize that science is all around them in the environment and that researchers and hunters share many skills. Field work presents many opportunities to learn about science and scientific protocols in a way that resonates with indigenous communities. It is time that researchers become allies instead of aliens in indigenous communities.

Recommendations for local success

1. Define clear objectives: define clear CBEM objectives that are based on local context, priorities, capacities, and environment;
2. Mutual benefits: Find significant ways of compensating participants in data collection so both parties benefit from the collaboration for a sustainable partnership; ensure data collectors can serve additional practical functions in the field beyond data collection (e.g. easy to use data collection protocols, usefulness of collected data for the community, economical benefits allowing them to pursue their traditional hunting and gathering activities, return of data to community);
3. Keep it simple: place priority on simplifying the process of data collection and recording, sample shipping, etc.;
4. Intergenerational bridge-building: Engage as many youth as possible, with a particular focus on bringing elders and youth together on the land (i.e. interviews, story-telling, traditional activities);
5. Build linkages: create collaborations with other local organisations who are doing monitoring (i.e. link with Nunavik Parks) to standardise the sampling protocols;
6. Outreach and education: develop attractive outreach tools (i.e. interactive cartography to integrate local knowledge, language tool, teaching tool for school, comic strips); the most motivated youth will be invited and funded to travel to the South and visit universities to build interest and to receive specific training (i.e. interactive mapping);
7. Local coordination: the involvement and/or hiring of local coordinators makes a big difference, both for sample collection throughout the year and for helping in managing Inuit staff and youth participants in culturally relevant ways during the science land camps;
8. Good timing: participation, recruitment and attendance to activities may face competition with other local and regional events. We have to adapt our agendas as much as possible.
9. Local presence: spend time in the community and have face to face meetings as much as possible to facilitate organisation and to maintain a trustful relationship with local partners.

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Supplemental online material

Simplified field protocols designed for water sampling by community members (Appendix 1) and data collection sheets for community members (Appendix 2) are available online. The authors are solely responsible for the content and functionality of these materials. Queries should be directed to the corresponding author.

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Table 1: Water quality analysis of water samples collected in the George River (2016-2017) and in the Koroc River (2015), Nunavik

Parameter (average)	George River July 2016 n=5	George River July 2017 n=10	Koroc River August 2015 n=4
Temperature (°C)	16	12.5	N/A
pH	7.05	7.07	6.60
Dissolved oxygen (mg O_2/L)	10.57	10.88	8.62
Conductivity (μS/cm)	13.5	12.53	28.88

Table 2: Comparison of results from measurements using YSI Pro Probe with manual test methods done by youth

Parameter	Manual test	YSI Pro Probe
2016 (average from stations 1 to 5)		
Temperature (°C)	17	16.12
Dissolved oxygen (mg/L)	9.1	10.57
pH	6.3	7.05
2017 (station 8)		
Temperature (°C)	10	9.6
Dissolved oxygen (mg/L)	9	10.84
pH	$6.5 \leq pH \leq 7$	6.8

Table 3: Interpolation formulas from the literature applied for two water quality metrics

Parameter	Source	L8 Bands (µm)	S2 Bands (µm)
Chl-*a*	Giardino et al. 2001	0.480-0.655	0.490-0.665
	Torbik et al. 2008	eΛ [0.655/0.480]	eΛ [0.600/0.485]
	Shafique et al. 2003	0.865/0.655	0.705/0.665
Turbidity (SSC)	Yamagata et al. 1988	0.655+0.865	0.665+0.842
	Shafique et al. 2003	none	0.710-0.740

Table 4: Conciliation of scientific, educational and community objectives for the Imalirijiit community-based environmental monitoring project of the George River, Nunavik

Scientific objectives	Educational objectives	Community objectives
Baseline data for water quality of George River	Mentoring with an Inuk researcher in water quality	Monitoring the water quality of George River
Remote sensing analysis to study depth, turbidity, Chl-*a*, and vegetation change	Sparking Inuit Youth's interest in natural sciences	Long-term environmental monitoring, at a larger scale
Analysis of contaminants in key species in the George River watershed	Training local people in biomonitoring	Protection of natural resources and traditional food (country food)
Monitoring REEs in northern environments	Introduction to geology, chemistry, ecotoxicology, natural sciences	Independence from the mine
Hydrological characterization of the river	Hands-on learning, land-based approach	Training the youth in water quality monitoring
Development of an interactive map as outreach	Intercultural and intergenerational sharing	Archiving of local knowledge, accessibility of the results
Multidisciplinary approach	Adapted protocols and diversified tools	Multi-stakeholder approach for collaborative work

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Figure 1: Location of the George River watershed, Kangisuallujjuaq, the mining site and the water sampling stations during Land Science Camps 2016 and 2017.

Figure 2: George River water quality sampling (Science Land Camp 2017)

Photo credit: Justine A. Rowell

Figure 3: Young Kangiqsualujjuamiut carrying out a macro-invertebrate inventory in a little tributary creek draining into George River (Science Land Camp 2017).

Photo credit: Mary Emudluk

Figure 4: Students carrying out water sampling and physical chemistry measurements (Science Land Camp, 2016)

Photo credit: Émilie Hébert-Houle

Figure 5: Spatiotemporal patterns observed in satellite multispectral data (i.e. Landsat-8, acquired on 07-27-2016 and Sentinel-2A, 07-07-2016). Figure a shows chlorophyll-*a* index (Giardino+Torbik+Shafique) for L8 and Figure b for S2A; Turbidity (Yamagata) for L8 (Figure c) and S2A (Figure d); and Turbidity S2A (Shafique) (Figure e). Laboratory analysis of water samples at fieldwork stations (yellow dots) indicate low chlorophyll-*a* concentration (0.1 to 0.9μg/L) and alkalinity ($CaCO_3$) values ranging from 2.8 to 5.1 mg/L.