



# Compendium of Yukon Climate Change Science 2017 Supplement



**Northern Climate Exchange**  
YUKON RESEARCH CENTRE • Yukon College

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**Photo Credit:** *Government of Yukon*

## Foreword

The Compendium is intended to provide an overview of recent climate change work involving Yukon. This document is intended to supplement the 2003-2013 version of the Compendium with climate change work that has taken place during 2016 and 2017. It is comprised of various types of documents, including scientific journal articles, government publications, and synopsis summaries.

Information for the Compendium was gathered through:

- ASTIS Database
- Academic Search Complete
- Polar Data Catalogue
- Yukon Biodiversity Database
- Hydrocarbon Impacts (HI) database
- Wolf Creek Research Basin database
- Kluane Lake Research Station Bibliography
- NCE Library
- Northern Research Institute Fellowship Grants list
- Forest Management in a Changing Climate: Compendium of Information Sources
- Government of Canada and Government of Yukon websites
- AANDC Present and Past Climate Change Adaptation Projects list
- Internet searches
- Internal knowledge

The Compendium is not an exhaustive list of climate change-related work in Yukon over the 2016-2017 period. A greater emphasis was placed on information that is available online between 2016 and May 31, 2017. The Northern Climate ExChange would like to recognize the focus on western scientific knowledge in this compendium and acknowledge that this information is only one type of knowledge on climate change present in the territory; there is limited traditional knowledge included. Furthermore, the Northern Climate ExChange would appreciate being informed of any relevant information that should be included, or if there are any errors in the Compendium.

The Compendium is organized broadly by topic and subsequently separated into more detailed sections. The 'Local Relevance' section of each entry highlights information directly related to climate change in Yukon.

Entries can be searched by various keywords listed in the index, and all entries have been classified based on a specific place or region within the Yukon. The keyword 'traditional knowledge' was used when the research integrated knowledge from First Nations communities, and the keyword 'local knowledge' was used when information was integrated from a multicultural community or broad area.

This supplementary 2016-2017 edition of the Compendium expands upon the previous edition (2003-2013). I would like to thank John Streicker, Bob Van Dijken, Rebecca World, Lacia Kinnear, Aynslie Ogden, and Alison Perrin for their assistance. I am also grateful to all of the Yukon First Nations that responded to our requests for information involving studies conducted in their respective traditional territories.

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# 1. Climate

## 1.1. Climate Change Modelling

### ***Examining the climate-biome ("cliome") shifts for Yukon and its protected areas***

**Research Location:** Yukon

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Protected area networks are the foundation of conservation, even in northern Canada where anthropogenic impact on the landscape is currently limited. However, the value of protected areas may be undermined by climate change in this region where the rate and magnitude is high, and shifts in vegetation communities and associated wildlife species are already underway. Key to developing responses to these changing conditions is anticipating potential impacts and the risks they pose. Capitalizing on an existing modeled dataset for Yukon from Scenarios Network for Alaska and Arctic Planning (SNAP), we examine projected shifts in the distribution of 18 clusters of climate parameters, and the vegetation communities currently associated with them (collectively termed "cliomes") across three 30-year time steps, from the present through the 2090s. By the 2090s, Yukon may lose seven cliomes and gain one. Three regional changes, if accompanied by vegetation redistribution, represent biome shifts: complete loss of climate conditions for arctic tundra in northern Yukon; emergence of climate conditions supporting grasslands in southern Yukon valleys; reduction in climates supporting alpine tundra in favor of boreal forest types across the mountains of central and northern Yukon. Projections suggest that, by the end of the 21st century, higher elevations in southern Yukon change least when compared to the turnover in cliomes exhibited by the high latitude, arctic parks to the north. This analysis can assist with: planning connectivity between protected areas; identifying novel conservation zones to maximize representation of habitats during the emerging changes; designing plans, management and monitoring for individual protected areas.

**Local Relevance:** Conservation efforts in the Yukon are founded upon networks of protected areas. These include National and Territorial parks, wilderness preserves, ecological reserves, habitat protection areas, etc. However, climate change factors have contributed to significant ecological and geophysical changes in the territory, such as permafrost and glacier melt, alpine tree line advance, and more growth of shrubs in tundra regions. Therefore, reliance on protected areas and reduced anthropogenic interaction alone is not sufficient for achieving effective conservation. This research provides a model, using data on climate parameter changes as a predictor for climate change influences on biodiversity. Given the lack of ecosystem data on Yukon-specific regions, this projection model provides insight on tentative changes to both climate and biodiversity over the next 90 years. Furthermore, this study projects an overall reduction in diversity of both biomes and climate through the shifting of dominant climates in BC, Alberta and Manitoba shifting northwards. Although these results do not predict specific ecosystem redistribution dynamics, they provide a basis for understanding conservation challenges, and informing management decisions in the future.

**Keywords:** climate change, protected areas, conservation, cliome, adaptation

**Citation:** Rowland, E., Fresco, N., Reid, D., & Cooke, H. (2016). Examining the climate-biome ("cliome") shifts for Yukon and its protected areas. *Global Ecology and Conservation*, 8, 1-17.

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## 1.2. Paleoclimate

### ***Implementation framework for climate change adaptation planning at a watershed scale***

**Research Location:** Eastern Beringia (Alaska, Yukon)

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Reconstructing climates of the past relies on a variety of evidence from a large number of sites to capture the varied features of climate and the spatial heterogeneity of climate change. This review summarizes available information from diverse Holocene paleoenvironmental records across eastern Beringia (Alaska, westernmost Canada and adjacent seas), and it quantifies the primary trends of temperature- and moisture-sensitive records based in part on midges, pollen, and biogeochemical indicators (compiled in the recently published Arctic Holocene database, and updated here to v2.1). The composite time series from these proxy records are compared with new summaries of mountain-glacier and lake-level fluctuations, terrestrial water-isotope records, sea-ice and sea-surface-temperature analyses, and peatland and thaw-lake initiation frequencies to clarify multi-centennial- to millennial-scale trends in Holocene climate change. To focus the synthesis, the paleo data are used to frame specific questions that can be addressed with simulations by Earth system models to investigate the causes and dynamics of past and future climate change. This systematic review shows that, during the early Holocene (11.7-8.2 ka; 1 ka = 1000 cal yr BP), rather than a prominent thermal maximum as suggested previously, temperatures were highly variable, at times both higher and lower than present (approximate mid-20th-century average), with no clear spatial pattern. Composited pollen, midge and other proxy records average out the variability and show the overall lowest summer and mean-annual temperatures across the study region during the earliest Holocene, followed by warming over the early Holocene. The sparse data available on early Holocene glaciation show that glaciers in southern Alaska were as extensive then as they were during the late Holocene. Early Holocene lake levels were low in interior Alaska, but moisture indicators show pronounced differences across the region. The highest frequency of both peatland and thaw-lake initiation ages also occurred during the early Holocene. During the middle Holocene (8.2-4.2 ka), glaciers retreated as the regional average temperature increased to a maximum between 7 and 5 ka, as reflected in most proxy types. Following the middle Holocene thermal maximum, temperatures decreased starting between 4 and 3 ka, signaling the onset of Neoglacial cooling. Glaciers in the Brooks and Alaska Ranges advanced to their maximum Holocene extent as lakes generally rose to modern levels. Temperature differences for averaged 500-year time steps typically ranged by 1-2 °C for individual records in the Arctic Holocene database, with a transition to a cooler late Holocene that was neither abrupt nor spatially coherent. The longest and highest-resolution terrestrial water isotope records previously interpreted to represent changes in the Aleutian low-pressure system around this time are here shown to be largely contradictory. Furthermore, there are too few records with sufficient resolution to identify sub-centennial-scale climate anomalies, such as

the 8.2 ka event. The review concludes by suggesting some priorities for future paleoclimate research in the region.

**Local Relevance:** The study of paleoclimates can offer insight on how contemporary ecosystems developed, and predict future climate scenarios and how changes in climate may determine changes in vegetation or animal populations. This systematic review compared research from a broad range of paleoclimate proxies in Holocene Eastern Beringia (i.e. Alaska, Yukon) to identify general trends in climate, as well as assess quality of various indicators. Although the researchers called for more research on spatial trends, the review highlighted major trends on the temporal scale. Early in the Holocene period (11.7-8.2 thousand years ago) temperatures and moisture levels had large fluctuations, with highs and lows larger in magnitude than present. During the middle Holocene (8.2 – 4.2 thousand years ago) the average temperature increased markedly, causing glacier retreat, which was followed by a temperature drop and neoglacial cooling in the later Holocene (4-3 thousand years ago). The authors suggested further research be done on the accuracy of various proxies in assessing paleoclimate, the spatial pattern of climate changes, and paleoclimate change dynamics in the area.

**Keywords:** Holocene, paleoclimate, Beringia, synthesis, multi-proxy, climate change

**Citation:** Kaufman, D., Axford, Y., Henderson, A., McKay, N., Oswald, W., Saenger, C., Anderson, R., Bailey, H., Clegg, B., Gajewski, K., Hu, F., Jones, M., Massa, C., Routson, C., Werner, A., Wooller, M & Yu, Z. (2016). Holocene climate changes in eastern Beringia (NW North America): A systematic review of multi-proxy evidence. *Quaternary Science Reviews*, 147, 312-339.

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## 2. Cryosphere Science

### 2.1. Permafrost and Periglacial Landscapes

#### ***Do periglacial landscapes exist? A discussion of the upland landscapes of northern interior Yukon, Canada***

**Research Location:** Eagle Plain and Barn Mountain

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Much of the northern interior Yukon was never-glaciated during the Quaternary. It has experienced cold and arid conditions for several millions of years. It represents one of the closest approximations that exist today of a periglacial landscape and provides an opportunity to assess conceptual models of periglacial landscape evolution. The terrain of two upland areas, Eagle Plain and the Barn Mountains foothills, casts doubt upon the widely-assumed rapidity of periglacial landscape modification and suggests that the complete footprint of periglaciation is rarely achieved in upland terrain.

**Local Relevance:** Eagle Plain and the Barn Mountain regions in northern interior Yukon are considered to have been part of eastern Beringia, the unglaciated land bridge that joined North America and Eurasia during the last ice age. Therefore, they are some of the only areas in North America to be unglaciated in



the last 1-3 million years. Periglacial environments contain cold, unglaciated terrain, with frost action and seasonally or perennially-frozen ground. Although around 20% of terrestrial regions on Earth experience periglacial processes, solely periglacial landscapes are rare; most areas with periglacial activity were recently covered by glaciers. Since the Eagle Plain and Barn Mountain areas were unglaciated in the last ice age, they offer a template for testing periglacial models and hypotheses. Therefore, this study analyzes pre-existing models in relation to the landscape in northern interior Yukon. The authors bring in to question the rapidity and extent of periglacial processes on never-glaciated landscapes, and call for more research in defining periglacial process mechanisms.

**Keywords:** periglacial, frost action, cryoplanation, Pleistocene landscape modification

**Citation:** French, H. (2016). Do periglacial landscapes exist? A discussion of the upland landscapes of northern interior Yukon, Canada. *Permafrost and Periglacial Processes*, 17, 219-228.

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### ***Holocene ice-wedge polygon development in northern Yukon permafrost peatlands (Canada)***

**Research Location:** Herschel Island

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Ice-wedge polygon (IWP) mires in the Arctic and Subarctic are extremely vulnerable to climatic and environmental change. We present the results of a multidisciplinary paleoenvironmental study on IWPs in the northern Yukon, Canada. High-resolution laboratory analyses were carried out on a permafrost core and the overlying seasonally thawed (active) layer, from a low-centered IWP located in a drained lake basin on Herschel Island. In relation to 14 Accelerator Mass Spectrometry (AMS) radiocarbon dates spanning the last 5000 years, we report sedimentary data including grain size distribution and biogeochemical parameters (organic carbon, nitrogen, C/N ratio,  $\delta^{13}C$ ), stable water isotopes ( $\delta^{18}O$ ,  $dD$ ), as well as fossil pollen, plant macrofossil and diatom assemblages. Three sediment units (SUs) correspond to the main stages of deposition (1) in a thermokarst lake (SU1: 4950 to 3950 cal yrs BP), (2) during transition from lacustrine to palustrine conditions after lake drainage (SU2: 3950 to 3120 cal yrs BP), and (3) in palustrine conditions in the IWP field that developed after drainage (SU3: 3120 cal yrs BP to AD 2012). The lacustrine phase (pre 3950 cal yrs BP) is characterized by planktonic-benthic and pioneer diatoms species indicating circumneutral waters, and very few plant macrofossils. The pollen record has captured a regional signal of relatively stable vegetation composition and climate for the lacustrine stage of the record until 3950 cal yrs BP. Palustrine conditions with benthic and acidophilic species characterize the peaty shallow-water environments of the low-centered IWP. The transition from lacustrine to palustrine conditions was accompanied by acidification and rapid revegetation of the lake bottom within about 100 years. Since the palustrine phase we consider the pollen record as a local vegetation proxy dominated by the plant communities growing in the IWP. Ice-wedge cracking in water-saturated sediments started immediately after lake drainage at about 3950 cal yrs BP and led to the formation of an IWP mire. Permafrost aggradation through downward closed-system freezing of the lake talik is indicated by the stable water isotope record. The originally submerged IWP center underwent gradual drying during the past 2000 years. This study highlights the sensitivity of permafrost landscapes to climate and environmental change throughout the Holocene.

**Local Relevance:** Ice-wedge polygon mires are the most prominent geographical features in lowland permafrost regions. They account for 31% of the Arctic's total landmass. However, little is known about IWP formation and dynamics in non-Yedoma regions. Yedoma is an organic-rich permafrost type found primarily in north eastern Canada and develop unique IWP morphologies. Therefore, this research takes an interdisciplinary approach to furthering our understanding of IWP landscape dynamics, including doing field work on a thermokarst basin with IWP's on Herschel Island, radiocarbon dating and geochronology, sedimentology, and diatom analysis. Resultantly, the authors classified the formation history and contributing factors for current dynamics of the IWP landscape on Herschel Island. IWP mires in thermokarst basins often conceal high concentrations of organic matter, thus making them a carbon sink. Therefore, understanding the dynamics of such regions is imperative for assessing the relationship between permafrost landscapes and climate change.

**Keywords:** permafrost peatlands, thermokarst, talik, ice-wedge polygon, pollen, diatoms, plant macrofossils, stable water isotopes, deuterium excess

**Citation:** Fritz, M., Wolter, J., Rudaya, N., Palagushkina, O., Nazarova, L., Obu, J., Rethemeyer, J., Lantuit, H., & Wetterich, S. (2016). Holocene ice-wedge polygon development in northern Yukon permafrost peatlands (Canada). *Quaternary Science Reviews*, 147, 279-297.

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***A modified landform development model for the topography of drained thermokarst lake basins in fine-grained sediments.***

**Research Location:** Old Crow Flats

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Permafrost degradation associated with the expansion of thermokarst lakes is commonly interrupted by catastrophic drainage. Subsequently, in tundra areas, permafrost aggradation in drained basins leads to uneven topography characterized by raised centres and wet, depressed margins. The genesis of such topography has been investigated in Old Crow Flats (OCF), a glaciolacustrine plain in the continuous permafrost of northern Yukon. The thermokarst lakes of OCF have a mean depth of only 1.5 m because excess ice is dominantly found only in the uppermost 10 m of the ground. Surface conditions were measured in three drained thermokarst lake basins, including relief, snow conditions, ground temperatures, near-surface ground ice, and sediment stratigraphy. Four nearby lakes provided information on wave base, shore recession patterns, and bathymetry before drainage: the bottoms of these lakes were not raised in the centre. An elevation difference of up to 2 m was recorded between drained basin margins and centres but was not associated with variations in ice-wedge density or segregated ice content. Hence basin topography was not controlled by differences in volumetric ground-ice content between margins and centres. We propose that transport of fine sediment away from eroding lake margins during lake development is the primary mechanism for the genesis of depressed margins and raised centres in drained basins of OCF. Over time, the transport results in the deposition of more and finer sediment in the central parts of lakes, where the lake bottom has subsided below wave base, than at the shallow margins, where resuspension by wave action occurs frequently. This difference

in sediment volume is revealed in the topography after drainage, when permafrost aggrades in the lake-bottom sediment and underlying talik.

**Local Relevance:** Thermokarst lakes are formed from the melting of excess ice in permafrost layers, which in turn cause further permafrost thaw. They are typically shallow and experience catastrophic drainage due to the changing permafrost landscape around them. This drainage leaves behind a basin and halts further permafrost degradation. These basins eventually develop raised centres, and lower shorelines. In coastal Alaska this centre-raised topography can have up to a 4 m difference and occurs because of:

1. Lake waves picking up finer sediments and depositing them in the lake centre, leaving the coarser material on the outside of the lake, which provide less potential for frost upheaval; and
2. A maintained permafrost shelf on the outside of the lake (i.e. littoral terraces) provide less thawed material for frost upheaval, compared to the thawed sediment in centre of the lake (i.e. taliks).

The increase freeze action potential of the finer sediment leads to the raising of the middle basin upon freezing. In the Old Crow Flats, Yukon, there is only fine sediment produced by glacial activity in the past, and no littoral terraces in the thermokarst lakes. However, the same raised centre topography occurs in the drained thermokarst lake basins. Therefore, this study proposes a mechanism by which the basin topography forms. The authors suggest that the wave action in the lakes erode the shorelines and transport fine sediment to the centre/lowest part of the lake. Therefore, after drainage occurs, there is far more sediment available for frost upheaval in the centre of the lake, leading to a raised centre of the basin upon freezing. Understanding permafrost dynamics is essential for being able to properly assess changes in the region in the future.

**Keywords:** thermokarst, permafrost, lake basins, lacustrine sediment

**Citation:** Roy-Leveillee, P., & Burn, C. (2016). A modified landform development model for the topography of drained thermokarst lake basins in fine-grained sediments. *Earth Surface Processes and Landforms*, 41, 1504-1520.

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### ***Ground thermal data collection along the Alaska Highway corridor (KP1559-1895), Yukon, summer 2015***

**Research Location:** Southwest Yukon

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Ground temperature data were acquired in July 2015 from 13 boreholes along the northwestern section of the Alaska Highway corridor between kilometre post (KP) 1559 and KP 1895 near the Alaska border. Mean annual ground temperatures, determined at or near the zero annual amplitude depth, indicate that permafrost temperature in this section of the corridor is generally above -1°C with colder conditions near the Alaska border where permafrost can be as cold as -3°C. Temperatures measured in the upper 1-2 m indicate that permafrost exists at some sites where surface temperatures are above 0°C and where a sufficient thermal offset exists. Although mean annual air

temperature in 2014-15 was higher than in 2013-14, there was no significant difference in the ground temperatures between the two years. The information obtained helps characterize regional permafrost conditions in the southern Yukon and informs climate change impact assessments and adaptation planning.

**Local Relevance:** There has been limited data collected on ground temperatures in the Alaska Highway Southern Yukon corridor since the 1970's. This corridor runs from northern British Columbia, across the discontinuous permafrost zone in the Yukon to Alaska (via Haines Junction). Ground temperatures are crucial in assessing the impact of climate change on landscape and permafrost regions. Therefore, this report provides ground temperature data from various researchers' work along the Alaska Highway, from the Haines Junction area to the border. Results showed that permafrost temperatures in this area ranged from -1°C to -3°C, and there was no significant increase in temperatures between the two years studied (i.e. 2013-14 and 2014-15).

**Keywords:** ground temperature, permafrost, Alaska Highway, air temperature, Haines Junction

**Citation:** Smith, S., Ednie, M., & Chartrand, J. (2016). Ground thermal data collection along the Alaska Highway corridor (KP1559-1895), Yukon, summer 2015. Geological Survey of Canada, open file 8000, 31.

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## 2.2. Glaciology

***Brief communication: Twelve-year cycling surging episodes at Donjek Glacier in Yukon, Canada.***

**Research Location:** Donjek Glacier, Kluane

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Surge-type glaciers repeat their short active phase and their much longer quiescent phase usually every several decades or longer, but detailed observations of the evolution cycles have been limited to only a few glaciers. Here we report three surging episodes in 1989, 2001, and 2013 at Donjek Glacier in the Yukon, Canada, indicating remarkably regular and short repeat cycles of 12 years. The surging area is limited within the ~ 20 km section from the terminus, originating in an area where the flow width significantly narrows downstream, suggesting a strong control of the valley constriction on the surge dynamics.

**Local Relevance:** There has been limited research on Yukon glacier surge dynamics, and most of what is known about movement characteristics in glaciers has been derived from work on only a few glaciers. This study offers a classification and mechanism of action for the Donjek Glacier in Kluane National Park, Yukon. With the use of Landsat optical images, flow speed of the glacier was analyzed between the years of 1986 and 2014, and terminus changes between 1973 and 2014. The spatial resolution of the imaging was not sufficient before 1986 to provide flow speed data. Furthermore, it was noted that the surge cycle of the Donjek Glacier was around 12 years, with the surge phase lasting approximately 1 year. The three surges noted were in 1989, 2001, and 2013, with speeds reaching 2, 4.5, and 3 metres per day (i.e. compared to .5 m/day during the quiescent phases). Therefore, the glacier was classified as

having an Alaskan-type surge, with the next surge expected to occur in 2025. Furthermore, the mechanism of the surge was postulated to be driven by the buildup of ice from the glacier's tributary in the valley, which is significantly narrower than upstream. As the ice builds up, water pools within the glacier, leading to a greater volume of water at the base of the glacier, and therefore increased pressure. This increase in basal water and pressure causes the glacier to surge, redistributing the built-up ice and eventually returning the glacier back to its quiescent phase.

**Keywords:** glaciology, surge dynamics, surge type glaciers

**Citation:** Lindau, K. (2016). Brief communication: Twelve-year cycling surging episodes at Donjek Glacier in Yukon, Canada. *The Cryosphere*, 10(4), 1427-1432.

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### ***Stratigraphy of Pleistocene glaciations in the St Elias Mountains, southwest Yukon, Canada***

**Research Location:** Silver Creek, Kluane

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** At least five Middle to Late Pleistocene advances of the northern Cordilleran Ice Sheet are preserved at Silver Creek, on the northeastern edge of the St Elias Mountains in southwest Yukon, Canada. Silver Creek is located 100 km up-ice of the Marine Isotope Stage (MIS) 2 McConnell glacial limit of the St Elias lobe. This site contains ~3 km of nearly continuous lateral exposure of glacial and non-glacial sediments, including multiple tills separated by thick gravel, loess and tilted lake beds. Infrared-stimulated luminescence (IRSL) and AMS radiocarbon dating constrain the glacial deposits to MIS 2, 4, either MIS 6 or mid-MIS 7, and two older Middle Pleistocene advances. This chronology and the tilt of the lake beds suggest Pleistocene uplift rates of up to 1.9 mm a<sup>-1</sup> along the Denali Fault since MIS 7. The non-glacial sediment consists of sand, gravel, loess and organic beds from MIS 7, MIS 3 and the early Holocene. The MIS 3 deposits date to between 30–36 14C ka BP, making Silver Creek one of the few well-constrained MIS 3-aged sites in Yukon. This confirms that ice receded close to modern limits in MIS 3. Pollen and macrofossil analyses show that a meadow-tundra to steppe-tundra mosaic with abundant herbs and forbs and few shrubs or trees, dominated the environment at this time. The stratigraphy at Silver Creek provides a palaeoclimatic record since at least MIS 8 and comprises the oldest direct record of Pleistocene glaciation in southwest Yukon.

**Local Relevance:** Silver Creek, Kluane, Yukon offers evidence of the area's glaciation history within the layers of rocks and fossils found in the area. However, due to restrictions in radiocarbon dating, little has been reconstructed in years prior to the last glaciation. Therefore, this research employs infrared stimulated luminescence dating, which has been used more frequently to date rock layers past the last glaciation. Samples were taken from 3 km along Silver Creek. They also examined plant, pollen and insect macrofossils to reconstruct the environmental conditions within the non-glacial periods. Results confirm hypotheses from previous researchers – there were three previous glaciation events, separated by periods of non-glacial conditions – and adds two more glaciations to the area's history. This work provides the oldest record of Pleistocene glaciation and vegetation in Southwest Yukon.

**Keywords:** Pleistocene, northern Cordilleran Ice Sheet, St Elias Mountains, Denali Fault, pollen, macrofossil analysis, infrared stimulated luminescence

**Citation:** Turner, D. G., Ward, B. C., Froese, D. G., Lamothe, M., Bond, J. D. & Bigelow, N. H. (2016). Stratigraphy of pleistocene glaciations in the St Elias Mountains, southwest Yukon, Canada. *Boreas*, 45, 521–536.

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### 3. Forestry

#### ***Predicting white spruce cone crops in the boreal forests of southern and central Yukon***

**Research Location:** Southern and Central Yukon

**Publication Type:** Journal Article

**Publication Date:** 2017

**Abstract:** White spruce (*Picea glauca* (Moench) Voss) cone crops were measured at five regional centers in southern and central Yukon for 30 years at one site from 1986 to 2015 and at four other sites during 9 to 11 years to select the best climatic model that uses cues from growing season temperature and rainfall to predict the size of cone crops. We evaluated six climatic models that use summer temperature and rainfall of years  $t - 1$  and  $t - 2$  to predict cone crops in year  $t$ . July temperatures provided the best predictors of white spruce cone crops, and no rainfall variable was related to the size of cone crops. We explored three variants of July temperatures: mean temperature, degree-days  $> 5\text{ }^{\circ}\text{C}$ , and maximum temperatures. For each of these, we used the  $\Delta T$  model that uses the difference in the July temperature measures of years  $t - 1$  and  $t - 2$ . We compared the resulting six models with corrected Akaike's information criterion (AICc) to determine their relative predictive performance. The best model combined  $\Delta T$  measures of degree-days  $> 5\text{ }^{\circ}\text{C}$  and the four highest daily maximum July temperatures with  $R^2 = 0.65$ . By comparison, the  $\Delta T$  model involving only mean July temperatures was less successful ( $R^2 = 0.49$ ). There was good regional synchrony ( $r_p = 0.7$  to  $0.8$ ) in high cone crops over southern and central Yukon during 1986 to 2015.

**Local Relevance:** The Yukon is home to many white spruce forests and seed-eating birds and mammals. Masting is the process in which an entire population of trees reproduce simultaneously. However, the determining factors of masting are poorly understood. This article sought to refine a seed crop prediction model, using temperature and rainfall data from various locations throughout the Yukon. As irregularly seeding trees, such as white spruce, often conserve energy for one to two years prior to flowering. Therefore, the researchers used data from one and two years before the year of interest to test various models. The most successful model used a combination of days measuring over  $5\text{ }^{\circ}\text{C}$ , as well as the maximum temperatures, from July to predict the cone crops. An accurate model, with broad spatial coverage, can be extremely useful for natural resource management plans, seed collection agencies, and the conservation of forests and seed-eating birds and mammals.

**Keywords:** White spruce cone production, climate, *Picea glauca*, delta-T model, mast seeding

**Citation:** Krebs, C., O'Donoghue, M., Taylor, S., Kenney, A., Hofer, E., & Boutin, S. (2017). Predicting white spruce cone crops in the boreal forests of southern and central Yukon. *Canadian Journal of Forestry Research*, 47, 47-52.

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## 4. Hydrology

### 4.1. Rivers

#### ***River piracy and drainage basin reorganization led by climate-driven glacier retreat***

**Research Location:** Kaskawulsh Glacier, Kluane Lake, Alsek River

**Publication Type:** Journal Article

**Publication Date:** 2017

**Abstract:** River piracy—the diversion of the headwaters of one stream into another one—can dramatically change the routing of water and sediment, with a profound effect on landscape evolution. Stream piracy has been investigated in glacial environments, but so far it has mainly been studied over Quaternary or longer timescales. Here we document how retreat of Kaskawulsh Glacier—one of Canada's largest glaciers—abruptly and radically altered the regional drainage pattern in spring 2016. We use a combination of hydrological measurements and drone-generated digital elevation models to show that in late May 2016, meltwater from the glacier was re-routed from discharge in a northward direction into the Bering Sea, to southward into the Pacific Ocean. Based on satellite image analysis and a signal-to-noise ratio as a metric of glacier retreat, we conclude that this instance of river piracy was due to post-industrial climate change. Rapid regional drainage reorganizations of this type can have profound downstream impacts on ecosystems, sediment and carbon budgets, and downstream communities that rely on a stable and sustained discharge. We suggest that the planforms of Slims and Kaskawulsh rivers will adjust in response to altered flows, and the future Kaskawulsh watershed will extend into the now-abandoned headwaters of Slims River and eventually capture the Kluane Lake drainage.

**Local Relevance:** The Kaskawulsh Glacier is one of Canada's largest glaciers and is a major contributor to both the Yukon River drainage (via Slims River feeding to Kluane Lake) and the Alsek River drainage (via Kaskawulsh River). However, glacial retreat in recent years has resulted in the rapid redirection of the headwaters away from Slims River to Kaskawulsh River. This resulted in large increases in water levels in the Alsek River during the melt season and may have major implications for both the chemical and biological qualities of both drainage systems. It was projected that the Kaskawulsh River could erode the dry Slims River basin, which could eventually lead to an outflow from Kluane Lake through the Kaskawulsh River. In addition, the researchers hypothesized that Kluane Lake's water levels were likely going to drop further than currently noted, forming a closed basin. This case of river piracy is unique in how rapidly it occurred, and its classification as a proglacial drainage change. Most research surrounding stream piracy captures longer term changes in previous eras, and not in concern to proglacial dynamics. Importantly, the researchers also determined that there was a .5% chance that the retreat of the glacier could have occurred under constant climatic conditions. Therefore, this rapid change in river systems

was most likely due to climate change, and more research is needed on the ecological consequences of such rapid changes.

**Keywords:** cryosphere science, geomorphology, hydrology, river piracy

**Citation:** Shugar, D., Clague, J., Best, J., Schoof, C., Willis, M., Copland, L., & Roe, G. (2017). River piracy and drainage basin reorganization led by climate-driven glacier retreat. *Nature Geoscience*, 10, 370-375.

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### ***River water temperature in relation to local air temperature in the Mackenzie and Yukon basins***

**Research Location:** Mackenzie River, Northwest Territories; Yukon River, Yukon and Alaska

**Publication Type:** Journal Article

**Publication Date:** 2017

**Abstract:** Water temperature has an important impact on many aspects of basin hydrology and ecology. In the northern regions, investigation of river thermal regimes and their changes over space and time is a challenge because of data limitations. This study determines the water temperature regimes at several locations within the Yukon and Mackenzie River basins and examines their relationship with air temperature. The Yukon and Mackenzie Rivers have distinct water temperature dynamics. They remain near zero from freeze-up in the fall to ice breakup in the spring and reach their peak temperature during mid-summer. For the locations examined, peak mean monthly water temperatures ranged from 9° to 15°C, and mean July air temperatures ranged from 13° to 16°C. The lags between water and air temperatures ranged from 1 to 40 days. The largest lag was found at the Great Bear River monitoring location, since water temperature at this site is strongly influenced by the heat storage of Great Bear Lake. Tests of three models, linear regression, logical regression (s-shape), and the physically based air2stream model, show that the air2stream model provided the best results, followed by logical regression. Linear regression gave the poorest result. Model estimates of water temperature from air temperature were slightly improved by the inclusion of discharge data. The water temperature sampling regimes had a considerable effect on model performance; long-term data provide a more robust test of a model. Comparisons of mean monthly water temperatures suggest significant spatial variability and some inconsistency between upstream and downstream sites that is due mainly to differences in data collection schemes. This study strongly demonstrates the need to improve water temperature monitoring in the northern regions.

**Local Relevance:** The Yukon and Mackenzie rivers in Alaska and Yukon, and Northwest Territories, respectively, play an extremely important ecological and hydrological role. However, there has been limited research and data collection done in these northern rivers. Therefore, this study aims to assess the water temperature dynamics in relation to air temperatures at various sites along both rivers. Results documented the maximum temperatures of both river water and air, and the lag times between the two peak temperatures in various locations. The researchers called for more studies on river water temperature dynamics in order to accurately assess the impact of climate changes on river ecosystems.

**Keywords:** rivers, water temperature, air temperature, relationship, northern basins,



**Citation:** Yang, D., & Peterson, A. (2017). River water temperature in relation to local air temperature in the Mackenzie and Yukon basins. *Arctic*, 70(1), 47-58.

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## 4.2. Lakes

### ***Biotic responses to multiple aquatic and terrestrial gradients in shallow subarctic lakes (Old Crow Flats, Yukon, Canada).***

**Research Location:** Old Crow Flats

**Publication Type:** Journal Article

**Publication Date:** 2017

**Abstract:** Biotic communities in shallow northern lakes are frequently used to assess environmental change; however, complex interactions among multiple factors remain understudied. Here, we present analyses of a comprehensive data set that evaluates the influence input waters, catchment characteristics, limnology, and sediment properties on diatom and chironomid assemblages in surface sediments of ~49 shallow mainly thermokarst lakes in Old Crow Flats, Yukon. Multivariate analyses and ANOSIM tests identified that composition of diatom (119 taxa) and chironomid (68 taxa) assemblages differs significantly ( $p < 0.05$ ) between lakes with snowmelt- versus rainfall-dominated input water. Redundancy analyses revealed strong correlation of limnological, sediment, and catchment variables with input waters. Variation partitioning analyses showed that unique effects of limnological variables account for the largest proportion of variation in diatom and chironomid assemblages (17.2% and 12.6%, respectively). Important independent roles of sediment properties (8.5% and 9.5%) and catchment characteristics (4.9% and 5.1%) were also identified. We suggest that the substantial variation shared among these classes (6.1% and 7.9%) is largely attributable to hydrological processes. Our study demonstrates the utility of multi-factor analysis in northern aquatic research and draws attention to the limitations of one-dimensional comparisons and their interpretations when modelling biotic responses to environmental change.

**Local Relevance:** The Old Crow Flats, Yukon, are covered with shallow lakes, many of which are caused by permafrost thaw (i.e. thermokarst). These lakes are home to numerous biota, including diatoms and chironomids. Although these life forms are very sensitive to environmental changes, and shallow lakes are strongly influenced by climate warming, little research has been done to provide scientists with long term data on shallow lake systems in the North. Therefore, little is understood about the impact of climate change on freshwater biota in the arctic. This research did multivariable and ANOSIM (analysis of similarity) statistical tests on several collected data variables of 49 shallow lakes in the Old Crow Flats. Results showed that the composition of biota in the shallow lakes was largely related to hydrological processes, such as the source of water (i.e. snow melt or rainfall) feeding the lake. The variation found amongst lakes suggests the importance of multidimensional analysis in assessing climate change impacts within northern lakes.

**Keywords:** thermokarst, permafrost, lake basins, lacustrine sediment

**Citation:** Balasubramaniam, A., Medeiros, A., Turner, K., Hall, R., & Wolfe, B. (2017). Biotic responses to multiple aquatic and terrestrial gradients in shallow subarctic lakes (Old Crow Flats, Yukon, Canada). *Arctic Science*, 3, 277-300.

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#### 4.3. Coastline

##### ***Erosion and flooding - threats to coastal infrastructure in the arctic: A case study from Herschel Island, Yukon Territory, Canada***

**Research Location:** Herschel Island

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Arctic coastal infrastructure and cultural and archeological sites are increasingly vulnerable to erosion and flooding due to amplified warming of the Arctic, sea level rise, lengthening of open water periods, and a predicted increase in frequency of major storms. Mitigating these hazards necessitates decision-making tools at an appropriate scale. The objectives of this paper are to provide such a tool by assessing potential erosion and flood hazards at Herschel Island, a UNESCO World Heritage candidate site. This study focused on Simpson Point and the adjacent coastal sections because of their archeological, historical, and cultural significance. Shoreline movement was analyzed using the Digital Shoreline Analysis System (DSAS) after digitizing shorelines from 1952, 1970, 2000, and 2011. For purposes of this analysis, the coast was divided in seven coastal reaches (CRs) reflecting different morphologies and/or exposures. Using linear regression rates obtained from these data, projections of shoreline position were made for 20 and 50 years into the future. Flood hazard was assessed using a least cost path analysis based on a high-resolution light detection and ranging (LiDAR) dataset and current Intergovernmental Panel on Climate Change sea level estimates. Widespread erosion characterizes the study area. The rate of shoreline movement in different periods of the study ranges from  $-5.5$  to  $2.7$   $\text{m}\cdot\text{a}^{-1}$  (mean  $-0.6$   $\text{m}\cdot\text{a}^{-1}$ ). Mean coastal retreat decreased from  $-0.6$   $\text{m}\cdot\text{a}^{-1}$  to  $-0.5$   $\text{m}\cdot\text{a}^{-1}$ , for 1952–1970 and 1970–2000, respectively, and increased to  $-1.3$   $\text{m}\cdot\text{a}^{-1}$  in the period 2000–2011. Ice-rich coastal sections most exposed to wave attack exhibited the highest rates of coastal retreat. The geohazard map combines shoreline projections and flood hazard analyses to show that most of the spit area has extreme or very high flood hazard potential, and some buildings are vulnerable to coastal erosion. This study demonstrates that transgressive forcing may provide ample sediment for the expansion of depositional landforms, while growing more susceptible to overwash and flooding.

**Local Relevance:** Yukon's historic site on Simpson Point, Herschel Island, is becoming increasingly susceptible to coastline erosion and flooding. However, in order to develop the proper risk mitigation strategies, vulnerable areas must be identified and managed. Furthermore, previous research has not taken into account permafrost degradation in coastline hazards near Simpson Point. High resolution maps of sea level rise sensitivity have proven to be a useful tool for informing coastline vulnerability in other regions of the world. However, only a circumpolar Arctic map exists with such data, which has not proven useful for the assessment of local areas. Therefore, this research offers a geohazard map and a

tool for coastal decision making, providing projections of coastline degradation 20 and 50 years into the future, and assessing the risk of erosion and flooding for the region.

**Keywords:** arctic, coastal erosion, UNESCO, vulnerability mapping, coasts

**Citation:** Radosavljevic, B., Lantuit, H., Pollard, W., Overduin, P., Couture, N., Sachs, N., Torsten, S., Helm, V., & Fritz, M. (2015). Erosion and flooding - threats to coastal infrastructure in the Arctic: A case study from Herschel Island, Yukon Territory, Canada. *Estuaries and Coasts*, 39(4). 900-915.

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## 5. Methodologies

### 5.1. Building Capacity

#### ***Government of Yukon science strategy***

**Research Location:** Yukon

**Publication Type:** Report

**Publication Date:** 2016

**Summary:** Government of Yukon Science Strategy includes an overview of the Yukon Government's plan to increase research capacity and align research and policy decisions. The Government of Yukon's vision is to support scientific research so that it can be disseminated and applied in decision making. The guiding principles for this strategy include the recognition of science and innovation, the incorporation of traditional and local knowledge, a focus on needs and coordination, the provision of resources for research, keeping pace with development and scientific advances, and the promotion of collaboration, health and social sciences, and a research community. The strategy includes a number of initiatives to support the following goals for the government: support decision making, build science capacity, improve data collection and management, stimulate private and civil sector science, promote information sharing, and manage and enhance science conduct.

**Local Relevance:** This report provides a strategy for building research capacity and giving direction to, and stabilizing, the overall research initiative in the Yukon. The strategy outlines its goals and provides a list of strategic initiatives and pre-existing example activities that support those initiatives. The government states that they will be initiating new activities to support the outlined initiatives.

**Keywords:** science strategy, Government of Yukon, capacity building, policy, research

**Citation:** Government of Yukon. (2016). Government of Yukon science strategy. Whitehorse: Government of Yukon.

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#### ***Science in the Yukon: Advancing a vision for evidence-based decision making***

**Research Location:** Yukon

**Publication Type:** Essay

**Publication Date:** 2016

**Excerpt:** In order for scientific knowledge to inform decision making (science for policy), policy that supports and cultivates scientific activity (policy for science) is required. Recent public policy announcements—including the appointment of Canada’s first Federal Minister of Science (November 2015), the release of the Government of Yukon Science Strategy (January 2016), the release of the Pan-Northern Approach to Science (April 2016), and the pending appointment of a National Chief Science Officer—indicate that both federal and territorial governments recognize the value of timely and robust knowledge in informing decision making.

The vision of the 2016 Government of Yukon Science Strategy is to support the active pursuit, gathering, and storage of scientific knowledge so it can be easily retrieved, transferred, shared, and used to support evidence-based decision making (GY, 2016a). This article discusses the context of this solution-driven vision and how it can be advanced in Yukon.

**Local Relevance:** In 2016, the Yukon Government released a strategic plan for science research in the territory. The plan was produced with the goal to build and stabilize research capacity, while generating research that addresses pressing issues in the North and informs policies. This article discusses the needs and interests of stakeholders in Yukon research (i.e. federal and Yukon Government, Yukon First Nations, Yukon College, and universities), while elaborating on goals outlined by the territorial government’s science strategy.

**Keywords:** : science strategy, Government of Yukon, capacity building, policy, research

**Citation:** Ogden, A., Schmidt, M., Dijken, B., & Kinnear, L. (2016). Science in the Yukon: Advancing a vision for evidence-based decision making. *Arctic*, 69(2), 210-221.

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## 5.2. Education

### ***The dynamic North: Northern climate change from an anthropological perspective***

**Research Location:** Southern Yukon

**Publication Type:** Essay

**Publication Date:** 2016

**Excerpt:** In recent years, the University of Calgary’s Department of Anthropology and Archaeology has fostered faculty expertise in circumpolar history, cultures, and environments. With five faculty members currently dedicated to research in the circumpolar North, we have been in a unique position not only to offer new courses on northern and Indigenous issues, but also to deepen the university’s existing research and teaching connections with northern communities. In 2016, I had the opportunity to offer a new, Yukon-based field school for undergraduates entitled “The Dynamic North: Climate, Economy and Culture in Anthropological Perspective.” This field school, coordinated by the University of Calgary’s Group Study Program, ran its pilot program for five weeks in May and June 2016 and will continue to be offered every two years. While field schools in Yukon are not new, so far most of them have been situated within natural science or archaeology degree programs. The Dynamic North, however, aims to

provide students with an unrivalled opportunity to learn firsthand about the resilience of northern Canadian societies and the challenges they face in an era of climate change, with an emphasis on contemporary environmental politics. Furthermore, students can learn experientially about the research methods, cross-cultural ethics, and politics central to social science and qualitative research in the North. I have especially emphasized the importance of meeting with and learning from northern residents themselves. With this goal in mind, I tried throughout the program to connect student research interests with deeper forms of community engagement, especially with northern Indigenous and non-Indigenous residents, local grassroots and non-profit organizations, the Yukon Government and Yukon First Nations self-government institutions. A primary goal of this program was encouraging students to critique the idea, traditionally taught in southern universities, that a researcher alone should formulate the main research questions, driven largely by her or his own interests. Students were pushed to think about what community-based research looks like and how researchers might respond to research questions formulated by Northerners, research designed by northern communities, and research carried out by Northerners in partnership with universities and other research institutions. ...

**Local Relevance:** This article outlines a Yukon-based field course offered by the University of Calgary. Although the University of Calgary offers many environment focused courses in the territory, this is the first anthropogenic, and community-centred field course. The course included 11 students, two of which were Yukon students whose tuition and expenses were provided by the university. Course content and objectives included teaching students about the cross-cultural politics, ethics, and qualitative research methods surrounding Yukon climate change (including Whitehorse, Kluane, and Carcross regions). Engagement with Indigenous and non-indigenous local individuals, organizations and governments was a large component of the course. Community-centred approaches to climate change research, collaborative methods, and the concept of different knowledge systems (i.e. local and traditional knowledge) were prioritized in the curriculum. This essay provides an example of collaborative and experiential education in the Yukon.

**Keywords:** higher education, agriculture, anthropology, capacity building

**Citation:** Peric, A. (2016). The dynamic North: Northern climate change from an anthropological perspective. *Arctic*, 69(3), 325-329.

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### 5.3. Governance

#### ***Mitigating mistrust? Participation and expertise in hydraulic fracturing governance***

**Research Location:** Yukon

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** In Canada's Yukon territory, a legislative committee was tasked with assessing the risks and benefits of hydraulic fracturing. The committee designed an extensive participatory process involving citizens and experts; however, instead of information access and public hearings fostering an open dialogue and trust, these two channels failed to de-polarize debates over hydraulic fracturing. We argue

that mistrust was reinforced because (1) weak participatory processes undermined the goals of public involvement, (2) scientific evidence and scientists themselves were not accepted as neutral or apolitical, and (3) strategic fostering of mistrust by actors on both sides of a polarized issue intensified existing doubt about the integrity and credibility of the process. The implications of a failure to restore trust in government are significant, not only for the issue of hydraulic fracturing, but for governance more broadly, as mistrust has spillover effects for subsequent public negotiations.

**Local Relevance:** As the Yukon is faced with increasing decisions about land use and resource extraction, effective decision-making processes are of high concern. This article offers a critique on a recent public consultation process surrounding hydraulic fracturing development in the Yukon. The authors posed that the communication with the public heightened the sense of mistrust due to numerous factors. These include the pre-existing mistrust in public-government relations from the Peel Watershed decision process, the lack of dialogue created in the hearings, the absence of genuine consideration of public concerns, and conflicting body of evidence surrounding the topic (i.e. uncertainty in what is considered expert opinion). Furthermore, it was postulated that the resulting mistrust hinders future decision making in the Yukon, worsens the relationship between the government and public, increases the likelihood for lawsuits, and deters outside investment in the territory. This research is highly relevant and transferable to most other policy processes in the Yukon, including those surrounding other resource development and climate change action plans.

**Keywords:** participation, expertise, hydraulic fracturing, governance, mistrust, trust

**Citation:** Neville, K., & Weinthal, E. (2016). Mitigating mistrust? Participation and expertise in hydraulic fracturing governance. *Review of Policy Research*, 33(6), 578-602.

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## 5.4. Research Techniques

### ***GPS performance in Yukon's arctic coast***

**Research Location:** Arctic Coast

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** This study analyses GPS performance in Yukon's Arctic coast to inform future research that uses this technology in the region. To test this, Telonics GPS collars were placed on stakes during the summers of 2009 and 2010 throughout the region for varying lengths of time. The fix records produced by these collars were then collected and cleaned, leaving 30 samples. Using these records combined with a digital elevation model, eight variables were extracted and analysed in an attempt to find relationships, such that a fix rate could be predicted throughout the landscape. The results indicated that very few strong relationships existed. Densimeter values proved to be the only relationship between an environmental variable and fix rate. Available sky and aspect data produced results that were contrary to those expected. Overall, Telonics Generation 3 collars had extremely high fix rates, high accuracy, and low positional dilution of precision. Moreover, there was little variation in these results. This means that future GPS studies in the region would likely require minimal correction for fix

rate bias. However, if corrections were to be made, more data would have to be gathered to ensure the results were statistically sound. The analysis suffered from the limitations of small sample size and low sample variance, among several others. Therefore, future studies should increase the number and diversity of sites tested.

**Local Relevance:** Technological advances in GPS tracking has allowed for more effective research on wildlife behavior and distribution. However, drawbacks in the accuracy of the technology can differ between regions and habitats. Determining variables of GPS signal quality are 1) the ratio of signals successfully connected versus the total number of attempted connections; and 2) the location of satellites in relation to the tracking device. This research assessed the accuracy of GPS tracking devices on the Yukon's northern coast through assessing these two variables. The researchers concluded that the accuracy of tracking was relatively high in the area, and corrections to data are likely unnecessary for wildlife tracking in the future. This work provides evidence of the suitability of GPS technology in northern wildlife research in the Yukon.

**Keywords:** Fix rate, PDOP, biotelemetry, GPS

**Citation:** Swanlund, D., Maraj, R., Schuurman, N., Hope, R., Donkers, K., Aquin, M., & Rickerby, G. (2016). GPS performance in Yukon's arctic coast. *Geografiska Annaler, Series A: Physical Geography*, 98(4), 361-368.

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## 6. Wildlife

### 6.1. Biodiversity

#### ***First record of the holarctic least shrew (*Sorex minutissimus*) and associated helminths from Canada: New light on northern pleistocene refugia***

**Research Location:** Dempster Highway

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** We report the first Canadian record of the Holarctic least shrew (*Sorex minutissimus* Zimmermann, 1780) and associated helminth worms, collected along the Dempster Highway in central Yukon in 2014. We identify the specimen based on morphological characters, characterize the habitat, report other mammals and helminth species associated with this specimen, and use mitochondrial DNA sequences to place the specimen within a phylogenetic context and address Pleistocene refugial hypotheses. Although long considered an Eurasian endemic, the diminutive least shrew was first reported from Alaska in 1994. Our new record for Canada indicates that the species may occur at least as far east as the Mackenzie River and DNA variation suggests this species persisted only in the Beringian refugium in North America during the Last Glacial Maximum. The discovery of a new mammal and associated parasites for Canada points to the urgent need for more detailed information on high-latitude biotas in North America, data that are best obtained through museum-based field surveys, particularly for small, cryptic species.

**Local Relevance:** Small mammals and their associated parasites are poorly documented and understudied in the Yukon. This research was part of a global initiative to document the distribution of small mammal hosts and their parasites in the northern Beringia region. The researchers took samples from a broad transect running north to south in the Yukon. Results yielded the first documentation of the Holarctic least shrew in Canada, and two new parasites, near the Dempster Highway in northeastern Yukon. Given the homogenous genetic composition to the Holarctic least shrew in Alaska, and the relative similarity of this species to those found in Asia, the researchers hypothesized that the small mammals were likely isolated in North America via Beringia. Documenting the diversity, distribution, and phylogenetic history of small mammals, such as the Holarctic least shrew, in northern regions is considered critical for assessing the impact of climate change on ecosystems.

**Keywords:** distribution, helminth, museum collections, *Sorex minutissimus*, holarctic least shrew

**Citation:** Cook, J., McLean, B., Jackson, D., Colella, J., Greiman, S., Tkach, V., Jung, T., & Dunnum, J. (2016). First record of the holarctic least shrew (*Sorex minutissimus*) and associated helminths from Canada: New light on northern pleistocene refugia. *Canadian Journal of Zoology*, 94, 367-372.

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***Development of a framework for management of aquatic invasive species of concern for Yukon: Literature review, risk assessment and recommendations***

**Research Location:** Yukon

**Publication Type:** Report

**Publication Date:** 2016

**Excerpt:** The increasing presence of Aquatic Invasive Species (AIS) in Canada is causing the displacement of native flora and fauna, damaging infrastructure, and costing Canadians millions of dollars annually to control. Policies to control AIS (which can be diverse species of algae, plants, and fish) have largely been reactive rather than proactive, and focused on species rather than vectors (Strayer 2009). Strategies aimed at preventing the spread of AIS are preferable to diverting financial resources to programs aimed at managing AIS after they have established.

In Yukon, the number of known or suspected AIS is small compared to the rest of Canada. That means the opportunity to prevent the spread of additional AIS in Yukon still exists. Up to now, there has been no plan in place to prevent, detect, monitor, or manage AIS in Yukon, and there has been no coordinated effort to increase public awareness of the implications of AIS introduction.

Knowledge about AIS in northern regions is generally quite minimal. This report begins to address some of the unknowns by first reviewing literature on 16 species that have already established, or could establish, in Yukon (see Appendix 1); then ranking the relative risks of those select AIS; and finally, offering recommendations on the prevention and management of 6 AIS that are of comparatively highest risk—both ecologically and economically—to Yukon.

**Local Relevance:** Aquatic invasive species have shown to have an extremely detrimental impact on ecosystems and economic burden, through displacing native species, damaging infrastructure, and costing governments millions of dollars in management resources. Although the prevalence of aquatic



invasive species is lower in the Yukon than the rest of Canada, there are few preventative strategies being employed. Therefore, this research provides an assessment of the potential risk for introduction, persistence, ecological consequence, and social and economic consequence, that various aquatic invasive species likely pose in the Yukon. The authors outline the likely pathways for introduction and associated consequences for each invasive species and give respective recommendations.

**Keywords:** aquatic invasive species, risk assessment, prevention

**Citation:** Leung, M., & Finster, A. (2016). Development of a framework for management of aquatic invasive species of concern for Yukon: Literature review, risk assessment and recommendations. Whitehorse: Yukon Department of Environment.

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## 6.2. Contaminants

### *Understanding contaminant levels in commonly consumed fish of Kluane Lake, Yukon*

**Research Location:** Kluane Lake, Burwash Landing

**Publication Type:** Summary from Synopsis Report

**Publication Date:** 2016

**Abstract:** The Kluane Lake area in the southwestern region of Yukon is the traditional territory of the Lù'àn Mǎn Ku Dǎn, the Kluane Lake People. Situated primarily in the small community of Burwash Landing, the closest grocery store for community members is 300km away. Residents depend on fish from Kluane Lake as important sources of subsistence and nutrition in their daily diets. Climate change and other factors may be affecting contaminant levels in the lake. In partnership with the University of Waterloo, Kluane Research Station, and the Arctic Institute of Community-Based Research, a small-scale study assessing current mercury levels in Lake Trout (*Salvelinus namaycush*) and Lake Whitefish (*Coregonus clupeaformis*) was undertaken in Kluane Lake. In total, 65 individual fish were analyzed for mercury levels, and for stable carbon and nitrogen isotope ratios. As expected, we found that Lake Trout occupy a significantly higher trophic position than Lake Whitefish. Lake Trout also had higher mean mercury concentrations than Lake Whitefish ( $0.086 \pm 0.091$  ppm and  $0.022 \pm 0.008$  ppm, respectively), however, only Lake Trout greater than 800 cm fork length exceeded the Subsistence Consumption Guideline for mercury (0.2 ppm). None of the Lake Whitefish sampled exceeded the Subsistence Consumption Guideline. Preliminary statistical analysis shows that fork length and stable nitrogen ratio together are the best predictors of mercury concentration in Lake Trout and Lake Whitefish. Analysis for other trace metals, including nutrients Zn, Se, and omega-3 fatty acids) and persistent organic pollutants (POPs) is on-going. Community capacity building, engagement, and outreach have been important components of this collaborative and well-leveraged project.

**Local Relevance:** Food insecurity is an increasingly prominent issue in Yukon communities. Many First Nations communities continue to rely on traditional sources of food, which are becoming less available (i.e. diminishing populations and/or lowering quality of food) due to various changes in environment. Heavy metal contaminants in wildlife are one risk to food sources that communities are facing. This research assessed the mercury levels in the fish found in Kluane Lake. The Kluane First Nation rely on

fish from Kluane Lake for its cultural and nutritional benefits. Results showed that only the larger sized Lake Trout exceeded the Subsistence Consumption Guidelines. White Fish and smaller Lake Trout were considered still safe for consumption.

**Keywords:** food security, fish, contaminants, .

**Citation:** Alatini, M., Swanson, H., Laird, B., Williams, S., Kassi, N., Walker, J.B., Friendship, K., Southwick, G., Hanley, B., Roach, P., Hik, D., & Branfireun, B. (2016). Understanding contaminant levels in commonly consumed fish of Kluane Lake, Yukon. Synopsis of research conducted under the 2015-2016 Northern Contaminants Program. Gatineau: Aboriginal Affairs and Northern Development Canada.

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### ***Measurements of cesium in arctic beluga and caribou before and after the Fukushima accident of 2011***

**Research Location:** Old Crow, Northern Yukon, Nunavut

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Concern from northern communities following the Fukushima Daiichi nuclear accident of March 2011 has prompted a reassessment of the safety of their traditional foods with respect to radioactivity levels. To this end, a study was conducted to measure the levels of radionuclides in Arctic caribou (*Rangifer tarandus*) and beluga (*Delphinapterus leucas*). The main radionuclide of concern is cesium-137, which is easily transferred through the lichen-caribou food chain. Previous studies have been conducted on the cesium-137 levels in Canadian caribou herds from 1958 to 2000, allowing researchers to determine the amount of cesium-137 in caribou specifically attributable to atmospheric weapons testing and the Chernobyl nuclear accident in 1986. In this study, samples of lichens, mushrooms, caribou, beluga and beluga prey collected before and after the Fukushima accident were analyzed for radioactivity levels. Samples were processed and measured using gamma ray spectroscopy to identify the radionuclides present and determine the radioactivity concentration. Both calibration standards and Monte Carlo simulations were used to determine the efficiency of the detectors for the samples, taking into account differences in individual sample sizes as well as matrices. In particular, a careful analysis of the atomic composition of lichens and mushrooms was performed to ensure the efficiencies for these sample types were correct. A comparison of the concentrations from before and after the accident indicated that there was no increase in radioactivity as a result of the atmospheric plume from the Fukushima accident. Some cesium-137, likely attributable to fallout from atmospheric weapons testing of the 1950s and 1960s (since there was no cesium-134 measured in the samples), was measured in the post Fukushima caribou and beluga whale samples; however, this amount was determined to be insignificant for any radiological concern ( $9.1 \pm 1.8$  and  $0.63 \pm 0.23$  Bq kg<sup>-1</sup> ww respectively). The activity concentrations of cesium-137 was about 200 times smaller than that of natural radioactive potassium in the beluga samples. Both the caribou and beluga results showed that these foods continue to be a healthy food choice for northern Canadians with respect to radioactivity, and this result has been communicated to the nearby northern communities and stakeholders.

**Relevance:** The Fukushima nuclear accident of 2011 occurred as a result of the largest recorded earthquake in Japan, with an epicenter only 180 km from the Fukushima Daiichi nuclear power plant. Accordingly, there has been a widespread effort to assess the health risks associated with the event.

This research was done in response to concern from northern Canadians about the potential for radioactive contaminants in traditional foods. Therefore, levels of Cesium-137 were measured in caribou, belugas, and both animals' food sources, and compared to measurements made before the nuclear accident. In the Yukon, caribou muscle samples were taken from an ongoing contaminant monitoring program in Old Crow, and lichen and mushrooms were collected from Chapman Lake, central Yukon. Cesium-137 is a radionuclide easily transferred through the caribou food chain, and therefore accumulation can pose a serious health risk to northern communities. This research found that there were negligible concentrations of Cesium-137 present in samples, and therefore, traditional foods were largely unaffected by the Fukushima accident and still safe to consume.

**Keywords:** beluga, caribou, cesium, lichens, Fukushima, radiation

**Citation:** Stocki, T., Gamberg, M., Loseto, L., Pellerin, E., Bergman, L., Mercier, J., Genovesi, L., Cooke, M., Todd, B., Sandles, D., Whyte, J., & Wang, X. (2016). Measurements of cesium in arctic beluga and caribou before and after the Fukushima accident of 2011. *Journal of Environmental Radioactivity*, (2016), 379-387.

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### ***Northern Dolly Varden charr total mercury concentrations: Variation by life history type***

**Research Location:** Babbage River

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** Total mercury (THg) concentrations were measured for different life-history types of Northern Dolly Varden (*Salvelinus malma malma*) from the Babbage River, Yukon, Canada to test hypotheses regarding the influence of life-history type, trophic position, and growth rate on THg tissue concentrations. In contrast to other northern anadromous fish species, higher measured THg concentrations were found in the anadromous life-history types. Standardization for common age, however, indicated that anadromous fish had lower THg concentrations than freshwater resident life-history types.  $\delta^{15}\text{N}$  was the most important factor in explaining observed differences among the individuals regardless of life-history types, with growth rate also contributing to explain among-individual variation. The contrast of higher absolute, but lower age- and size-adjusted THg levels in anadromous fish was explained by a combination of two counteracting mechanisms, including: (1) a switch to feeding at higher trophic levels and the use of more THg contaminated marine prey, and (2) somatic growth dilution that, with increasing growth efficiency, decreases THg as fish grow and age. Results underscore the importance of considering life-history variation in addition to trophic patterns, and fish sizes and age when interpreting mercury concentrations in fish with varying life histories.

**Relevance:** Northwestern First Nations peoples in Canada, such as the Gwich'in (e.g. Vuntut Gwitchin in the Yukon), rely on top predatory fish for sustenance. Many communities have growing concerns for contaminants in traditional food sources, such as Northern Dolly Varden. Therefore, this research explored the influence of life-history types on mercury (Hg) concentrations in Northern Dolly Varden in Babbage River, which flows down the north coast of the Yukon. Researchers have found evidence of three different life-history subtypes, including isolate (i.e. physically separated from other types and genetically unique, live entirely in natal streams), resident (i.e. mostly male, have access to the sea but

migrate only within their natal streams and rivers), and anadromous (i.e. seasonally migrate to the sea to feed). All types have been found in the Babbage River. This study found that Hg concentrations varied significantly among life-history types, with anadromous fish having greater absolute Hg concentrations than the other types. However, once results were adjusted for age and size, anadromous fish had lower Hg levels. Although more research is needed to further explain these results, this study provides a basis for understanding the mechanisms behind heavy metal contamination in Indigenous traditional food sources.

**Keywords:** stable isotopes, age and size adjustment, mercury, Babbage River, *Salvelinus malma*

**Citation:** Tran, L., Reist, J., & Power, M. (2016). Northern Dolly Varden charr total mercury concentrations: Variation by life history type. *Hydrobiologia*, 783, 159-175.

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### 6.3. Traditional Ecological Knowledge

#### ***Traditional ecological knowledge (TEK) at Shingle Point, YT: Observations on changes in the environment and fish populations***

**Research Location:** Shingle Point

**Publication Type:** Report

**Publication Date:** 2016

**Abstract:** Understanding the environmental changes and determining baseline information for Beaufort Sea fishes is a crucial step in sustaining the fish populations and habitats within a changing Arctic climate. Shingle Point, YT is a traditional and modern day fishing and hunting community for Western Arctic Indigenous people and is part of a marine protected area and the Inuvialuit Settlement Region (ISR). The incorporation of Traditional Ecological Knowledge (TEK) is important in understanding the changes in this coastal habitat. During the summer of 2015, Shingle Point harvesters and their families participated in TEK interviews. The interviews provided observational information on: 1) fish population changes, 2) environmental changes, 3) concerns, and 4) reasons to return to Shingle Point. Results from the TEK interviews indicate changes have been observed in the environment and coastal fish populations for decades. The utilization of TEK in the form of specific and open-ended interviews/questionnaires can be used to document and understand long-term changes in the environment and marine biota, as well as bolster quantitative research in the future, to better understand the environmental impacts of climate change on the Beaufort marine ecosystems.

**Relevance:** Qualitative research with traditional ecological knowledge is an invaluable source of information for Yukon scientists and policy makers. In remote areas with limited data on wildlife, TEK can be especially helpful in assessing long term changes in the area, while providing the social and environmental contexts and implications associated with these changes. Shingle Point, Yukon, is located on the northern coast of the territory. It has served as a fishing camp for northwestern First Nations communities, such as Aklavik and Inuvik, for thousands of years. This study did qualitative interviews and surveys with individuals and families that rely on the fishing camps. Results showed resounding concern for the health, quality, and quantity of fish populations on the coast, as well as new health risks

for consuming the fish. This work provides a basis for more research on fisheries, conservation, climate change adaptation, and food security in northern communities.

**Keywords:** traditional ecological knowledge, fish, marine conservation, qualitative research

**Citation:** Brewster, J., Neumann, D., Ostertag, S., & Loseto, L. (2016). Traditional ecological knowledge (TEK) at Shingle Point, YT: Observations on changes in the environment and fish populations. Canadian technical report of fisheries and aquatic sciences. Winnipeg: Fisheries and Oceans Canada.

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***Impacts of reintroduced bison on First Nations people in Yukon, Canada: Finding common ground through participatory research and social learning***

**Research Location:** Southwest Yukon

**Publication Type:** Journal Article

**Publication Date:** 2016

**Abstract:** From 1988-1992 wood bison (*Bison bison athabasca*) were transplanted to the southwest Yukon, inadvertently creating concerns among local First Nations about their impacts on other wildlife, habitat, and their members' traditional livelihoods. To understand these concerns we conducted a participatory impact assessment based on a multistage analysis of existing and new qualitative data. We found wood bison had since become a valued food resource, though there was a socially-determined carrying capacity for this population. Study participants desire a population large enough to sustainably harvest but avoid crossing a threshold beyond which bison may alter the regional ecosystem. An alternative problem definition emerged that focuses on how wildlife and people alike are adapting to the observed long-term changes in climate and landscape; suggesting that a wider range of acceptable policy alternatives likely exists than may have previously been thought. Collective identification of this new problem definition indicates that this specific assessment acted as a social learning process in which the participants jointly discovered new perspectives on a problem at both individual and organisational levels. Subsequent regulatory changes, based on this research, demonstrate the efficacy of participatory impact assessment for ameliorating human-wildlife conflicts.

**Relevance:** Between 1988 and 1992, 170 wood bison were reintroduced to previously occupied habitat in the southern Yukon. Prior to the twentieth century the subspecies was native to the region, and the reintroduction initiative was in concordance with a national recovery effort. However, given the success of the intervention, many First Nations were concerned with its social and ecological implications. This research was a qualitative assessment of the direct and indirect socio-economic impacts of the recently reintroduced bison herd on the Champagne Aishihik First Nation (CAFN). This research provides a greater understanding of how conservation measures, such as the woodland bison reintroduction, can influence local communities in the Yukon. Results showed that members of CAFN have gradually grown to appreciate the bison herd as a source of sustenance, especially younger generations. However, there are also concerns for limiting the size of the herd in order to minimize any detrimental effects or alterations in the ecosystem. The researchers suggested that this project provided the dialogue necessary to unite, and promote collaboration between various conservation governing bodies, and recommended that these methodologies be used for future human-wildlife conflicts and decisions.

**Keywords:** Aishihik, wood bison, common interest, community-based participatory research, First Nations, qualitative analysis, socioeconomic impact assessment

**Citation:** Clark, D., Workman, L., & Jung, T. (2016). Impacts of reintroduced bison on First Nations people in Yukon, Canada: finding common ground through participatory research and social learning. *Conservation and Society, 14*(1), 1-12.

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