Compendium of Yukon Climate Change Science

2018 Supplement

Northern Climate ExChange
YUKON RESEARCH CENTRE • Yukon College

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Front cover photograph: *Kluane National Park, Yukon, Canada*
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 2017 and 2018. 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
- Northern Research Institute Fellowship Grants list
- Government of Canada and Government of Yukon websites
- Internet searches
- Internal knowledge
- NCE Library

The Compendium is not an exhaustive list of climate change-related work in Yukon over the 2017-2018 period. A greater emphasis was placed on information that is available online between 2017 and May 31, 2018. 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 2017-2018 edition of the Compendium expands upon the previous edition (2003-2013). I would like to thank Nina Vogt, 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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June 2018

CONTENTS

1. CLIMATE

1.1. Vegetation

Climate warming as a driver of tundra shrubline advance

Research Location: Kluane Region, Yukon

Publication Type: Journal Article

Publication Date: 2017

Abstract:
1. Climate warming is predicted to alter ecological boundaries in high-latitude ecosystems including the elevational or latitudinal extent of tall shrubs in Arctic and alpine tundra. Over 60 studies from 128 locations around the tundra biome have investigated shrub expansion in tundra ecosystems; however, only six studies test whether shrublines are actually advancing up hill-slopes or northward into tundra where tall shrubs are currently absent.
2. We test the hypothesis that willow shrublines have expanded to higher elevations in relation to climate across a 50 × 50 km area in the Kluane Region of the southwest Yukon, Canada by surveying 379 shrubs at 14 sites and sampling 297 of the surveyed shrubs at 10 sites. We compared growth and recruitment to climate variables to test the climate sensitivity of shrub increase using annual radial growth analysis, age distributions and repeat field surveys to estimate the current rate of shrubline advance.
3. We found consistent and increasing rates of recruitment of alpine willows, with estimates of faster advancing shrublines on shallower hill-slopes. Mortality was extremely low across the elevation gradient. Aspect, elevation and species identity did not explain variation in recruitment patterns, suggesting a regional factor, such as climate, as the driver of the observed shrubline advance.
4. Annual radial growth of willows was best explained by variation in summer temperatures, and recruitment pulses by winter temperatures. Measured recruitment rates are ~20 ± 5 individuals per hectare per decade (*M* ± *SE*) and measured rates of increased shrub cover of ~5 ± 1% per decade (*M* ± *SE*) measured at the Pika Camp site between field surveys in 2009 and 2013. Our results suggest that shrubline will continue to advance over the next 50 years, if growing conditions remain suitable. However, if future conditions differ between summer and winter seasons, this could lead to contrasting trajectories for recruitment vs. growth, and influence the vegetation change observed on the landscape.
5. *Synthesis.* Our findings in the context of a review of the existing literature indicate that elevational and latitudinal shrublines, like treelines, are advancing in response to climate warming; however, the trajectories of change will depend on the climate drivers controlling recruitment vs. growth.

Local Relevance: One of the impacts of climate change is the elevational or latitudinal advance of the shrubline into the Arctic and alpine tundra. This has widespread impacts on a variety of species within the ecosystem and can drastically change the ecological composition of an area. This particular study tested the willow shrubline advance over the past 50 years in the Kluane region of southwest Yukon. Tundra ecosystems are particularly at risk of climate-induced range expansion because they are

constrained by climate and are experiencing climatic change at a rate twice that of the global average. It is important to understand the dynamics of shrubline advance in order to implement adaptive measures for conservation as well as socio-economic impacts.

Keywords: age distributions; alpine; climate; high-latitude; range expansion; recruitment; shrub; tundra, willow (*Salix*); Yukon

Citation: Myers-Smith, I. H., & Hik, D. S. (2018). Climate warming as a driver of tundra shrubline advance. *Journal of Ecology, 106*(2), 547-560.

Tundra vegetation stability versus lake-basin variability on the Yukon Coastal Plain (NW Canada) during the past three centuries

Research Location: Yukon Coastal Plain, North Yukon

Publication Type: Journal Article

Publication Date: 2017

Abstract: Paleoclimate reconstructions of the northern Yukon show cooler conditions before AD 1850 followed by gradual warming, and 20th-century temperature measurements indicate decadal-scale temperature fluctuations. The impact of climate on regional vegetation and lake systems has seldom been observed on this scale, however. With this study, we provide a sub-decadal reconstruction of regional vegetation and lake-basin development for the past 300 years, covering the 'Little Ice Age' and the period of recent warming, in low Arctic tundra. We analyzed a short lake sediment core from the Yukon Coastal Plain. The age-depth relationship of the core is based on 210Pb/137Cs validated by AMS radiocarbon dating. We analyzed terrestrial pollen abundances as proxies for regional vegetation development, and we used grain size and biogeochemical analyses (TOC, TN, TOC/TN, δ13C) and the analysis of semiaquatic pollen to describe the lake development. Stable abundances of regional pollen taxa between AD 1730 and AD 2012 accompanied by climatic warming indicated that the regional vegetation was not sensitive to climate change. Based on changes in TOC/TN, δ13C and pollen of shallow water taxa, we reconstructed an increase in lake water depth after AD 1910 that likely followed climatic warming. We attributed this development to climate-driven thaw subsidence in the lake basin. The impact of widespread permafrost thaw on regional vegetation needs to be better constrained in order to predict the limits of vegetation stability and drivers of lake changes in the region.

Local Relevance: The Yukon Coastal Plain is especially vulnerable to impacts of climatic warming because of its soil composition. It is comprised of ice rich permafrost with unconsolidated sediments which are more susceptible to erosion. This has the potential to change Tundra vegetation change on a regional level. A reconstruction of the past 300 years in the Yukon coastal plain of tundra vegetation shows the recent period of warming from 1910. This was completed by analyzing lake sediment cores using an age/depth relationship based on radio-carbon dating. Regional vegetation development was assessed by grain size and biochemical analysis of pollen. Stable abundances of pollen indicated that regional vegetation was not sensitive to the changes in climate. An increase of lake water depth was constructed; using semiaquatic pollen, to correspond with a time of global warming in 1910. This is

considered to be due to an increase of climate driven regional permafrost thaw. The largest temperature increase in the study occurred after 1970 which was followed by a rise in mean annual ground temperature in the Mackenzie Delta and on Herschel Island. This provides a paleo-perspective on the relationships between climate, vegetation, and permafrost which can be used as baseline data.

Keywords: Arctic; lake sediment; late Holocene; 'Little Ice Age', permafrost thaw; pollen; Yukon Coastal Plain; Mackenzie Delta

Citation: Wolter, J., Lantuit, H., Herzschuh, U., Stettner, S., & Fritz, M. (2017). Tundra vegetation stability versus lake-basin variability on the Yukon coastal plain (NW Canada) during the past three centuries. *The Holocene, 27*(12), 1846-1858.

1.2. Permafrost and Periglacial Landscapes

Deep Yedoma permafrost: A synthesis of depositional characteristics and carbon vulnerability

Research Location: Siberia, Alaska, and Yukon, Canada

Publication Type: Literature Review

Publication Date: 2017

Abstract: Permafrost is a distinct feature of the terrestrial Arctic and is vulnerable to climate warming. Permafrost degrades in different ways, including deepening of a seasonally unfrozen surface and localized but rapid development of deep thaw features. Pleistocene ice-rich permafrost with syngenetic ice-wedges, termed Yedoma deposits, are widespread in Siberia, Alaska, and Yukon, Canada and may be especially prone to rapid-thaw processes. Freeze-locked organic matter in such deposits can be re-mobilized on short time-scales and contribute to a carbon-cycle climate feedback. Here we synthesize the characteristics and vulnerability of Yedoma deposits by synthesizing studies on the Yedoma origin and the associated organic carbon pool. We suggest that Yedoma deposits accumulated under periglacial weathering, transport, and deposition dynamics in non-glaciated regions during the late Pleistocene until the beginning of late glacial warming. The deposits formed due to a combination of aeolian, colluvial, nival, and alluvial deposition and simultaneous ground ice accumulation. We found up to 130 gigatons of organic carbon in Yedoma, parts of which are well-preserved and available for fast decomposition after thaw. Based on incubation experiments, up to 10% of the Yedoma carbon is considered especially decomposable and may be released upon thaw. The substantial amount of ground ice in Yedoma makes it highly vulnerable to disturbances such as thermokarst and thermo-erosion processes. Mobilization of permafrost carbon is expected to increase under future climate warming. Our synthesis results underline the need of accounting for Yedoma carbon stocks in next generation Earth-System-Models for a more complete representation of the permafrost-carbon feedback.

Local Relevance: Permafrost is a distinct feature of the terrestrial Arctic and is vulnerable to climate warming. Permafrost degrades in different ways, including deepening of a seasonally unfrozen surface and localized but rapid development of deep thaw features. Pleistocene ice-rich permafrost with syngenetic ice-wedges, termed Yedoma deposits, are widespread in Siberia, Alaska, and Yukon, Canada

and may be especially prone to rapid-thaw processes. Freeze-locked organic matter in such deposits can be re-mobilized on short time-scales and contribute to a carbon-cycle climate feedback. Yedoma deposits accumulated under periglacial weathering, transport, and deposition dynamics in non-glaciated regions due to a combination of aeolian, colluvial, nival, and alluvial deposition and simultaneous ground ice accumulation. The unglaciated regions of northwest Canadian lowlands were favourable for Yedoma deposition because an extreme continental climate combined with a low topographic gradient causing steady conditions for polygonal ice wedge growth with ongoing sedimentation by water and wind. Mobilization of permafrost carbon is expected to increase under future climate warming. This paper underlines the need of accounting for Yedoma carbon stocks in Earth-System-Models for a complete representation of the permafrost-carbon feedback processes.

Keywords: Perennial frozen ground, thermokarst, Arctic, late Pleistocene, greenhouse gas source, climate feedback; deep yedoma; northwest Canadian lowlands; permafrost-carbon feedback

Citation: Strauss, J., Schirrmeister, L., Grosse, G., Fortier, D., Hugelius, G., Knoblauch, C., … & Shmelev, D. (2017). Deep Yedoma permafrost: A synthesis of depositional characteristics and carbon vulnerability. *Earth-Science Reviews, 172,* 75-86.

Vegetation succession and environmental conditions following catastrophic lake drainage in Old Crow Flats, Yukon

Research Location: Old Crow Flats, Yukon

Publication Type: Journal Article

Publication Date: 2017

Abstract: Increases in the frequency and magnitude of disturbances associated with the thawing of ice-rich permafrost highlight the need to understand long-term vegetation succession in permafrost environments. This study uses field sampling and remote sensing to explore vegetation development and soil conditions following catastrophic lake drainage in Old Crow Flats (OCF). The data presented show that vegetation on drained lake basins in OCF is characterized by two distinct assemblages: tall willow stands and sedge swards. Field sampling indicates that these alternative successional trajectories result from variation in soil moisture following drainage. Increased willow mortality on older drained basins suggests that intraspecific competition drives self-thinning in shrub thickets. This finding, combined with data from paleoecological studies and contemporary vegetation in OCF, suggests that willow stands on drained lake basins are seral communities. These results also indicate that the increase in number of catastrophic drainages that occurred between 1972 and 2010 will alter regional vegetation in ways that affect wildlife habitat, permafrost conditions, and local hydrology.

Local Relevance: In continuous permafrost zones, such as Old Crow Flats, Yukon, increasing temperatures can cause permafrost thaw. The combination of unconsolidated sediments with increasing water content as a result of ice chunk thaw in permafrost creates unstable soil which makes it more susceptible to mechanical erosion. This can lead to catastrophic lake drainages which occur within 1-2 days, altering the landscape from aquatic to terrestrial.

Vuntut Gwich'in traditional knowledge indicates that an increased number of lakes have been draining and drying in the Old Crow Flats. There has been an increased abundance of catastrophic lake drainages between 1952 and 2010. The increase of wildfires in the area is also having a positive feedback on this process, which has significantly increased the terrestrial surface area of the Old Crow Flats. This has been shown to have a positive impact on moose populations and a negative impact on muskrat populations.

Keywords: Subarctic; thermokarst; climate change; shrubs; disturbance; succession; Old Crow flats; Vuntut Gwich'in; permafrost thaw; catastrophic lake drainage

Citation: Lantz, T. C. (2017). Vegetation succession and environmental conditions following catastrophic lake drainage in Old Crow Flats, Yukon. *Arctic, 70*(2).

1.3. Mountain Landscapes

The Alpine Club of Canada's state of the mountains report

Research Location: Canadian Alpine

Publication Type: Technical Report

Publication Date: 2018

Excerpt: In 2011, The Alpine Club of Canada (ACC) published the first State of the Mountains Report, which highlighted the startling impacts of climate change on the alpine environment of Alberta and British Columbia. As Canada's national mountaineering organization, the ACC has a responsibility to act as a steward of our mountains, and the 2011 report was motivated by a commitment to summarize and better communicate an understanding of the environmental forces affecting these high places.

The 2018 report continues this tradition and is the beginning of an annual State of the Mountains Report, produced by the ACC in collaboration with mountain researchers, community members, and partner organizations. We are particularly grateful to the experts who have provided their insights and perspectives this year, and to the Royal Canadian Geographical Society and *Canadian Geographic* magazine for their contributions. The "On the Map" pages in the May-June 2018 issue of *Canadian Geographic* complement the material in this report, and we hope that these will together provide a valuable resource for learning about Canada's mountains. Globally, mountains matter more than ever.

This 2018 report begins with a feature essay, by Dan Shugar and John Clague, describing the dramatic changes that occur when retreating glaciers abruptly alter the flow of mountain rivers and entire watersheds. In many ways, these observations can be considered a form of time travel into the future, providing a glimpse of some of the consequences associated with the rapid loss of mountain glaciers to come.

This essay is followed by 11 shorter "knowledge highlights", providing expert summaries related to ways that people live in changing mountains, and some of the striking transformations occurring in the physical environment and for plants and animals. A consistent theme throughout is a call for better information about the magnitude, rates, and projected impact of changes that are taking place.

Local Relevance: The Alpine Club of Canada's 2018 state of mountains report gives a snapshot of ongoing research regarding climate change in the mountain landscapes in Canada and its potential impacts in a variety of disciplines. The Changing Glaciers, Changing Rivers section highlights the impacts that the reduction in the cryosphere, due to climate change, will have on local hydrology. It discusses the concept of "river piracy" in which part of a watershed is captured by another river. The most predominate changes to the watersheds, from alterations to the cryosphere in Yukon systems, occurred during the Pleistocene Epoch; which was 2.6 million years ago to 11,800 years ago. In 2016, river piracy occurred on the Slims River in Yukon in a period of a few days when most of the water feeding it was diverted to the Kaskawulsh River.

The Snow Avalanches section discusses the increasing hazard and how to mitigate risk to users. Fatalities in Yukon due to avalanches from 1980 to 2018 include only 2% of the total national amount. However, there is increasing usage of the alpine area by individual users and increasing risks of avalanches due to climate change. An interdisciplinary approach is being taken in avalanche safety research in order to incorporate the socio attributes which contribute to avalanche fatalities.

The Mountain Legacy Project focuses on recreating pictures of the same natural areas years after the initial photograph was taken, including extensive coverage of mountain ranges in Yukon. The goal of this project is to document changes in mountain landscapes. Two common themes have emerged through this project which include loss of glaciation and alpine treeline ecotone advance. Photos can be accessed publicly through www.mountainlegacy.ca.

Keywords: mountains; permafrost; river piracy; avalanche safety research; Mountain Legacy Project; Yukon River

Citation: Parrott, L., Robinson, Z., & Hik, D. (Eds.) (2018). *The Alpine Club of Canada's state of the mountains report.* Canmore, AB: The Alpine Club of Canada.

2. FORESTRY

Episodic and systematic tree ring-width variation (AD 1763-2013) in the Takhini valley, southwest Yukon, Canada

Research Location: Takhini Valley, Yukon

Publication Type: Journal Article

Publication Date: 2017

Abstract: A tree-ring analysis of 764 white spruce (*Picea albertiana*) in the Takhini Valley of southwest Yukon was conducted to assess short- and long-term variation in growth and local climate. The resulting chronology spanned the period from AD 1763 to 2013. A polynomial regression ($R= 0.720$, $p<0.001$) indicated that the pre-1840 segment of the chronology had below-normal tree ring-width index (RWI) values (average 0.64, with modest variation), but the subsequent segment had greater variation and a steady increase in ring width index (RWI) values (average 0.89) until- 1920. After 1930, RWI values

began to increase again (average 1.06) with 51% more variation than had previously occurred. Peak RWI values after 1930 were double those of the early 1800s. RWI values were uncorrelated with air temperature variables (except September minima), but weakly and positively correlated ($r<0.35$) with precipitation variables. RWI values were moderately correlated with annual heat-moisture index values ($r+ -0.415$, $p<0.001$) although more strongly with RWI values less than 1.1 ($R= -0.631$, $p<0.001$). Therefore, the RWI chronology was interpreted from an ecological moisture-balance perspective, with possible long-term temperature changes estimated from archival sources. The latter suggested a 2.1-3.1°C rise since the early 1800s. Extreme RWI values and portions of the chronology were associated with known environmental events.

Local Relevance: Between 1956 and 2005 temperatures increased by 1.8°C in the Yukon. In the capital, Whitehorse, temperatures increased by 2.7°C in contrast to the global increase of 0.7°C. It is predicted that there will be only a minimal increase in precipitation in Yukon. The increase in temperature without a corresponding increase in precipitation would likely lead to changes in wildlife distribution, abundance, and vegetation dynamics. An analysis was conducted of White Spruce (*Picea glauca var. albertiana*) to determine variation in growth in relation to regional climate fluctuations between 1763 and 2013. No single variable explained variation in the Takhini valley chronology, but a moisture value perspective was helpful in identifying tree growth variation in relation to climate.

Keywords: dendrochronology; climate; forest history; moisture; paleoclimate; ring-width; white spruce; Yukon; Takhini valley

Citation: Strong, W. L. (2017). Episodic and systematic tree ring-width variation (AD 1763-2013) in the Takhini valley, southwest, Yukon, Canada. *Arctic*, *70*(4), 389–402.

3. HYDROLOGY

3.2. Rivers

Hydrology of the North Klondike River: Carbon export, water balance and inter-annual climate influences within a sub-alpine permafrost catchment

Research Location: Klondike River Basin, West Central Yukon

Publication Type: Journal Article

Publication Date: 2017

Abstract: Arctic and Subarctic watersheds are undergoing significant changes due to recent climate warming and degrading permafrost, engendering enhanced monitoring of Arctic rivers. Smaller catchments provide understanding of discharge, solute flux and groundwater recharge at the process level that contributes to an understanding of how larger Arctic watersheds are responding to climate change. The North Klondike River, located in west central Yukon, is a sub-alpine permafrost catchment, which maintains an active hydrological monitoring station with a record of >40 years. In addition to

being able to monitor intra-annual variability, this data set allows for more complex analysis of streamflow records. Streamflow data, geochemistry and stable isotope data for 2014 show a groundwater-dominated system, predominantly recharged during periods of snowmelt. Radiocarbon is shown to be a valuable tracer of soil zone recharge processes and carbon sources. Winter groundwater baseflow contributes 20 % of total annual discharge, and accounts for up to 50 % of total river discharge during the spring and summer months. Although total stream discharge remains unchanged, mean annual groundwater baseflow has increased over the 40-year monitoring period. Wavelet analysis reveals a catchment that responds to El Niño and longer solar cycles, as well as climatic shifts such as the Pacific Decadal Oscillation.

Local Relevance Thawing permafrost, in northern systems, has been hypothesized to allow deeper groundwater contribution to the drainage network and an increased active layer thickness resulting in deeper supra-permafrost pathways and a change in the seasonality of discharge. It is suggested, that an effective strategy to assess climate-based influences in Arctic river basins would identify and monitor smaller tributaries sensitive to glacial melting, permafrost thaw and changes in watershed hydrology. The North Klondike River is ideal for such a groundwater hydrology study as it lies between discontinuous and continuous permafrost zones. Also, there is a wealth of baseline hydrologic data from the North Klondike River as the Yukon Government has been monitoring it since 1974. The dominance of deep groundwater may play a role in permafrost degradation in combination with climatic warming through the transfer of thermodynamic potential into the subsurface.

Keywords: carbon-13; carbon-14; catchment; groundwater; hydrogen-2; hydrogen-3; isotope hydrology; North Klondike River; oxygen-18; sub-alpine permafrost; water balance

Citation: Lapp, A., Clark, I., Macumber, A., & Patterson, T. (2017). Hydrology of the North Klondike River: carbon export, water balance and inter-annual climate influences within a sub-alpine permafrost catchment. *Isotopes in Environmental and Health Studies, 53*(5), 500-517.

3.3. Lakes

Characterizing and monitoring the water properties and dynamics of Lhù'àän Män (Kluane Lake), Yukon, in the face of climate change

Research Location: Yukon

Publication Type: Journal Article

Publication Date: 2018

Excerpt: Climate change amplification in the Arctic is increasing the impacts on both terrestrial and aquatic systems in northern regions (Serreze and Barry, 2011; Vincent et al., 2011). The impacts on large lakes are of particular interest: these waterbodies hold a significant portion of the North's freshwater, provide habitat and travel corridors for many species, regulate hydrological processes and local climate, and have significant cultural value (Evans, 2000; Rouse et al., 2005; Vincent et al., 2011; Cott et al., 2016; Reist et al., 2016). Studies have shown that these large lakes are sensitive to incremental and cumulative climatic changes and that small shifts in physical, chemical, and biological water properties may have

significant consequences for surrounding ecosystems and communities (Magnuson et al., 2000; Smol et al., 2005; Rosenzweig et al., 2007; Adrian et al., 2009; Heino et al., 2009; Mueller et al., 2009; Schindler, 2009). For example, increasing air temperatures may cause longer open-water seasons and increased water temperatures, which affect oxygen availability, productivity, and habitat for aquatic species (Vincent, 2009; Prowse et al., 2011). Glacier-influenced systems are also susceptible following changes in the contribution of glacial meltwater to headwater lakes (Shugar et al., 2017).

Local Relevance: Baseline studies were done on Lhù'àän Män in 2015 to identify monitoring sites, which was prior to the disappearance of Ä'äy Chù (Slims River). The Kaskawulsh Glacier no longer feeds Ä'äy Chù, which has resulted in a decreased lake level in Lhù'àän Män, which was at its lowest recorded level since 1952. Ongoing monitoring of the lake can be compared to 2015 data, providing a unique opportunity to directly assess the impacts of climate change on Yukon hydrology.

Keywords: Ä'äy Chù; Lhù'àän Män; Kluane, Kaskawulsh Glacier; thermal dynamics; freshwater

Citation: McKnight, E. (2017). Characterizing and monitoring the water properties and dynamics of Lhù'àän Män (Kluane Lake), Yukon, in the face of climate change. *Arctic, 70*(4), 435-440.

3.4. Evapotranspiration

Hydrological variability and changes in the Arctic circumpolar tundra and the three largest pan-Arctic river basins from 2002 to 2016

Research Location: Lena River basin in eastern Siberia in the Russian Federation, Yukon River basin in Alaska, Mackenzie River basin in northern Canada

Publication Type: Journal Article

Publication Date: 2018

Abstract: The Arctic freshwater budget is critical for understanding the climate in the northern regions. However, the hydrology of the Arctic circumpolar tundra region (ACTR) and the largest pan-Arctic rivers are still not well understood. In this paper, we analyze the spatiotemporal variations in the terrestrial water storage (TWS) of the ACTR and three of the largest pan-Arctic river basins (Lena, Mackenzie, Yukon). To do this, we utilize monthly Gravity Recovery and Climate Experiment (GRACE) data from 2002 to 2016. Together with global land reanalysis, and river runoff data, we identify declining TWS trends throughout the ACTR that we attribute largely to increasing evapotranspiration driven by increasing summer air temperatures. In terms of regional changes, large and significant negative trends in TWS are observed mainly over the North American continent. At basin scale, we show that, in the Lena River basin, the autumnal TWS signal persists until the spring of the following year, while in the Mackenzie River basin, the TWS level in the autumn and winter has no significant impact on the following year. As expected global warming is expected to be particularly significant in the northern regions, our results are important for understanding future TWS trends, with possible further decline.

Local Relevance: Spatiotemporal variations in the terrestrial water storage of the Arctic circumpolar tundra region have experienced a declining trend due to increasing evapotranspiration caused by increasing summer air temperatures. Three pan-Arctic river basins were analyzed, which includes two in Yukon; Yukon River basin and Mackenzie River basin. In the Mackenzie River basin, a significant upward trend in winter baseflow and mean annual flow due to permafrost thawing was found. The inflow of terrestrial water into the Arctic Ocean influences the circulation, winter sea ice cover and boreal climates. It is important to understand any changes in hydrological trends in this region as the have potential to create feedback loops which amplify the impacts of climate change.

Keywords: Arctic hydrological cycle; terrestrial water storage; satellite gravimetry observation; permafrost distribution; global land data assimilation system

Citation: Suzuki, K., Matsuo, K., Yamazaki, D., Ichii, K., Iijima, Y., Papa, F., … & Hiyama, T. (2018). Hydrological variability and changes in the Arctic circumpolar tundra and the three largest pan-Arctic river basins from 2002 to 2016. *Remote Sensing, 10*(3), 402.

4. METHODOLOGIES

4.1. Government Reports

Yukon state of the environment reporting on indicators 2018

Research Location: Yukon

Publication Type: Report

Publication Date: 2018

Excerpt: State of the environment reports show the public how Yukon is progressing towards the goal of maintaining and improving the quality of Yukon's natural environment for this and future generations. They reflect on the status of the environment and help guide future decision-making. The reports also:

- provide early warning and analysis of potential environmental problems;
- chart the achievement of the objectives set out in the *Environment Act*; and
- provide baseline information for environmental planning, assessment and regulation.

Under Yukon's *Environment Act* the Minister of Environment must table a full state of the environment report in the legislature every three years, as well as interim reports in the intervening years. This year, the report transitioned to an accessible and interactive online version that will be periodically updated. The report provides information on climate change, air, water, landscape, and fish and wildlife. Analysis is provided through key indicators used to monitor, describe, and interpret changes in the environment. The report uses the most recent and best information available.

Keywords: community-based; climate change; temperature variation; Yukon; Arctic; greenhouse gases; precipitation

Citation: Government of Yukon. (2018). *Yukon State of the Environment: Reporting on environmental indicators - 2018*. Whitehorse: Environment Yukon.

Yukon 'state of play': Analysis of climate change impacts and adaptation

Location: Yukon

Publication Type: Report

Publication Date: 2017

Summary: This report was commissioned by Environment Yukon's Climate Change Secretariat to provide the public and other stakeholders with an understanding of how climate change is affecting

Yukon, what actions have been taken to date to help us adapt, and the key challenges that we'll need to address to adapt in the future. This work will also explore the economic challenges and opportunities related to adaptation. This is not a comprehensive analysis of all the issues around climate change and adaptation efforts. It is a synthesis of existing knowledge and provides a focused snapshot of selected key adaptation challenges in the Yukon.

Adaptation to climate change starts when governments, communities, and individuals adjust their expectations about the future and make decisions to better prepare for changing conditions. Yukon has already started to adapt to the effects of climate change and decision makers have an interest in addressing present and future climate change impacts through adaptation. Growing concern for Yukon's changing climate has led to increased research and adaptation initiatives that contribute to the development of new knowledge and local capacity and expertise. Ensuring that the climate change funding and programming opportunities substantively enhance the adaptive capacity of communities is critical to Yukon's long-term adaptation efforts.

Local Relevance: This report analyses the effects of climate change on the Yukon and methods of adaptation. It utilizes community level observations of climate change, such as ice break up on the Yukon River in Dawson City; new bird species on Qikiqtaruk-Hershel Island; and Yukon First Nation Elder's Traditional Knowledge of climate change impacts to water, wildlife, and traditional foods. It outlines the increase in extreme weather events and highlights opportunities for adaptation to wildfire and increasing floods in the Yukon. It discusses the changing landscape and suggests an adaptation opportunity in agriculture. The report also discusses the social impacts of climate change while highlighting adaptation strategies such as community-based climate monitoring.

Keywords: adaptation; community-level; extreme weather events; community-based; climate monitoring; ice breakup

Citation: Research Northwest & Morrison Hershfield. (2017). *Yukon 'state of play': Analysis of climate change impacts and adaptation*.

Carbon pricing in the Yukon- Potential impact analysis

Location: Yukon

Publication Type: Report

Publication Date: 2018

Excerpt: This document provides data on potential estimated impacts of carbon pricing in the Yukon. It is important to note that the results provide an estimated order of magnitude based on modeling and available data rather than a precise assessment of specific impacts. The economic costs and benefits of carbon pricing depend on the design of the system and how jurisdictions use the resulting revenue. Costs will also vary across the country, according to the degree of fossil fuel use for electricity generation, the types of fuels used for heating, and the mix of economic activity, and costs will vary across households and businesses reflecting these and consumption differences.

Local Relevance: In 2016 the Government of Canada announced its pan-Canadian benchmark for Carbon pricing. This benchmark requires that all Canadian jurisdictions have carbon pricing in place by 2018. This is part of the federal government's broader commitment to reduce greenhouse gas emissions by 30% of its 2005 levels by 2030. The Department of Environment and Climate Change Canada and Finance Canada, in collaboration with the Government of Yukon, undertook this analysis to determine what the economic impact of the implementation of a carbon tax would be on industry and households in Yukon. The EC-PRO model was utilized to capture characteristics of production and consumption patterns. This model includes information on energy use and greenhouse gas emissions related to fossil fuels.

A cost increase per household is projected in Yukon, and for Whitehorse the average annual projected increase is $250. There is a positive correlation between the amount of increase of cost per household and the extent of isolation of a community. For example, Old Crow, Yukon's most remote community, is projected to see an average cost increase of $425 per household.

Keywords: greenhouse gases; GDP; carbon pricing; household impacts; EC-PRO; Old Crow; Whitehorse

Citation: Government of Yukon. (2018). *Carbon pricing in the Yukon - Potential impact analysis*.

4.2. Cumulative Effects Assessment

Wildlife in Cumulative Effects Assessment: Assessing Needs and Processes in Southwest Yukon

Location: Kluane Region, Yukon

Publication Type: Thesis

Publication Date: 2017

Abstract: The Southwest Yukon is a large mountainous area, famed for its wilderness and wildlife resources. Wildlife is of particular significance in this region because of its ecological and cultural values, for consumptive and subsistence harvesting, and as a base for considerable tourism. While Kluane National Park and Reserve encompasses 22,000 km^2 at the heart of this region, there are still current and pending threats to the region's wildlife. Small and large-scale developments and human activities

have the potential to contribute to adverse effects on wildlife. Land and resource management, including environmental impact assessment, takes place through a complex set of mainly co-management institutions resulting from comprehensive land claims and Federal devolution of powers to the Government of Yukon. Drawing on a literature review, document analysis, and semi-structured key informant interviews, I assessed why, despite its mandated requirement, assessment of cumulative effects on wildlife is rarely occurring in this region. I identify a range of challenges and potential responses with broad applicability for improving consideration of wildlife in Yukon CEA. Six key areas of gaps and obstacles are: data, research, monitoring, capacity and time limitations, political challenges, and the region's land use planning context. Major options for improvement include institutional guidance for researchers on needed and useful research projects; improved financial and human capacity support to fill data gaps, standardized monitoring programs; a comprehensive, inter-jurisdictional data management system, improved collaboration between departments, boards and stakeholders; fuller development of a common, accessible CEA guide and tools; and development of the land use planning context for environmental and development assessment.

Local Relevance: Cumulative effects assessments can be executed at any extent (individual to ecosystem), based on valued ecosystem components (VEC). They evaluate how multiple disturbances impact the VECs and whether or not there are synergistic effects. Disturbances can be anthropogenic or natural and include insect infestation, wildfires, habitat alteration, and climate change. Through the Yukon Environment and Socio-economic Assessment Act, it is mandated that cumulative effects assessments are executed for every project which goes through the Yukon Environment and Socio-economic Assessment Board (YESAB) process. Climate change is occurring at a faster rate in the North and needs to be included in any YESAB process. This paper assesses the extent to which this requirement is being met with regards to wildlife in the Kluane region of Yukon.

Keywords: Participatory scenario planning; Arctic; climate change; adaptation; vulnerability; cumulative effects assessment; valued ecosystem components (VEC); disturbance; YESAB

Citation: Drukis, S. (2017). *Wildlife in Cumulative Effects Assessment: Assessing Needs and Processes in Southwest Yukon*. Wilfrid Laurier University.

4.3. Participatory Planning

Participatory scenario planning and climate change impacts, adaptation and vulnerability research in the Arctic

Location: Circumpolar

Publication Type: Journal Article

Publication Date: 2018

Abstract: Participatory scenario planning (PSP) approaches are increasingly being used in research on climate change impacts, adaptation, and vulnerability (IAV). We identify and evaluate how PSP has been

used in IAV studies in the Arctic, reviewing work published in the peer-reviewed and grey literature (n =43). Studies utilizing PSP commonly follow the stages recognized as 'best practice' in the general literature in scenario planning, engaging with multiple ways of knowing including western science and traditional knowledge, and are employed in a diversity of sectors. Community participation, however, varies between studies, and climate projections are only utilized in just over half of the studies reviewed, raising concern that important future drivers of change are not fully captured. The time required to conduct PSP, involving extensive community engagement, was consistently reported as a challenge, and for application in Indigenous communities requires careful consideration of local culture, values, and belief systems on what it means to prepare for future climate impacts.

Local Relevance: This paper provides a systematic review of work that includes participatory scenario planning in response to potential climate change impacts in the Arctic. It reviews a number of articles from northern Canada, including the Yukon. As a remote region where many people still rely partially on the land to provide resources, the impacts of climate change have the potential to drastically alter ways of life in the Yukon. Participatory scenario planning is a helpful tool for communities to assess how to mitigate these impacts.

Keywords: Participatory scenario planning; Arctic; climate change; adaptation; vulnerability

Citation: Flynn, M., Ford, J. D., Pearce, T., & Harper, S. L. (2018). Participatory scenario planning and climate change impacts, adaptation and vulnerability research in the Arctic. *Environmental Science and Policy*.

4.4. Co-management

Managing traditional foods through co-management: Opportunities and limitations for food security in Kluane First Nation

Location: Kluane First Nation Traditional Territory

Publication Type: Summary Report

Publication Date: 2018

Excerpt: This research was undertaken to examine how Kluane First Nation (KFN) could enhance its traditional food security through the co-management of its traditional territory. KFN recognizes the importance of maintaining traditional food security and has taken concrete policy steps in this direction, including the development of its own food security strategy that identifies key actions to help move the community toward this goal. KFN participated in the current research project to complement the implementation of their food security strategy. People are considered food secure when they "at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO, 2015, p. 53). Northern food security is predicated on four "pillars" and their stability over time. Namely, food must be available (supplied in the store or on the land), accessible (obtainable through physical, economic, social or other

means), of good quality (safe for consumption and of sufficient nutritional value), and usable (based on available food knowledge/skills and equipment, and food preferences).

Local Relevance: Climate change has the potential to impact food security in Yukon, as many First Nations communities rely on wild foods for a portion of their sustenance. Climate change has the potential to change the landscape and alter the availability of subsistence wildlife and vegetation. In the past, government policies have been major factors in food insecurity. With the main KFN community several hours from the nearest grocery store, Kluane First Nation's citizens rely heavily on the land as a "provider". The Kluane First Nation chooses to use bottom-down policy to help enhance traditional food security and seeks to improve co-management regimes within its traditional territory.

Keywords: co-management; traditional foods; Kluane First Nation; food security

Citation: Cruickshank, Ainslie; Notten, Geranda; Wesche, S. (2018). *Managing traditional foods through co-management: Opportunities and limitations for food security in Kluane First Nation*.

5. WILDLIFE

5.1. Genetics

Diversification of deermice (Rodentia: genus Peromyscus) at their north-western range limit: Genetic consequences of refugial and island isolation
Location: Yukon and Southeast Alaska

Publication Type: Journal Article

Publication Date: 2017

Abstract: We surveyed the genetic variability of deermice (genus Peromyscus) at the north-western edge of their range to test for occupancy in multiple, hypothesized ice-free regions during the late Pleistocene and explore post-glacial dynamics. We used sequences from four independent nuclear and mitochondrial loci from 341 specimens of Peromyscus maniculatus, Peromyscus keeni and Peromyscus sp. (Yukon) to assess species limits, population structure, and demographical change as a result of historical climate change, using a Bayesian approach. Species distribution models were built in MaxEnt to explore the niche overlap amongst genetically distinct species. Divergence amongst three lineages began before the last interglacial, and each shows signs of post-glacial expansion. Multilocus species trees strongly support P. keeni and Peromyscus sp. (Yukon) as independent from P. maniculatus. Substantial substructure was observed for P. keeni across the fragmented Alexander Archipelago. Northern lineages or clades (Peromyscus sp. and P. keeni) differed in potential ecological distributions. At the extreme north-western range of deermice in North America, three distinct lineages persist reflecting divergence in at least three ice-free regions [Beringia, Coastal (near Southeast Alaska) and Southern Continental] throughout the latest Pleistocene glacial cycles. Although spatially proximate in Yukon, no locations were identified where these lineages are in contact. Further, west along the Pacific Coast, P. keeni is widespread across the complex landscape of Southeast Alaska, yet there is limited

contemporary gene flow amongst island populations, a finding consistent with the barriers produced by rising sea levels at the end of the Last Glacial Maximum.

Local Relevance: Species persist within an area which biotic and abiotic attributes are optimal for fitness and in essence; survival. As climate warms, the current habitat of many species is changing at a fast rate. Ultimately, a species with expand, contract, move, or cease to exist. Refugia is an area that is only likely to experience moderate climate change so that its attributes stay within the parameters of a particular species survival needs. As the north is experiencing climate change at a rate twice that of the global average, it is important to know how such population movements towards Refugia, or contractions, affect the overall fitness of a species.
In the Yukon, interglacial cycles caused landscape fragmentation, isolation and population expansion. Beringia is an example of Refugia which existed ice-free during the Wisconsin glacial stage 20,000 years ago. Identifying species and characterizing communities which survived in glacial Refugia gives us an understanding of temporal and spatial dynamic of special response to climatic shifts. This understanding of past shifts in population dynamics as a result of climate change can help to forecast future special responses to climate change. It will give management the tools to form conservation strategies for many species which reside in the Yukon.

Keywords: endemism; glacial refugia; *Peromyscus*; phylogeography; Southeast Alaska; Yukon; Beringia; refugia

Citation: Sawyer, Y. E., Flamme, M. J., Jung, T. S., MacDonald, S. O., & Cook, J. A. (2017). Diversification of deermice (Rodentia: genus Peromyscus) at their north-western range limit: genetic consequences of refugial and island isolation. *Journal of Biogeography*.

Long-Distance Movement of a Female Polar Bear from Canada to Russia

Location: Yukon & Russia

Publication Type: Journal Article

Publication Date: 2017

Abstract: Polar bears (Ursus maritimus) display fidelity to large geographic regions, and their movements are influenced by sea ice distribution. Polar bear subpopulations are moderately distinct from one another, and long-distance movements between subpopulations are rare. We describe and analyze the movements of a female polar bear tracked by satellite telemetry from spring 2009 for 798 days. This female traveled an exceptionally long distance (totaling 11 686 km) from the sea ice off the Yukon, Canada (Southern Beaufort Sea subpopulation) to Wrangel Island, Russia (Chukchi Sea subpopulation). In comparison to other polar bears in this study, this bear traveled farther, moved faster, and had a much larger home range in the first year. Furthermore, the calculation of home range size by two different methods demonstrated that the commonly used minimum convex polygon method overestimated the home range compared to the less biased Brownian bridge movement model. This female's long-distance movement was unusual and provides additional evidence for gene flow between subpopulations. Monitoring polar bear movements is useful to track such events, which is especially

important at present because sea ice loss due to climate change can affect subpopulation boundaries and influence management.

Local Relevance: The Southern Beaufort Sea sub-population of polar bears is distributed throughout the northern coastline of Yukon and Alaska and on sea ice in the southern Beaufort Sea. This population has been in decline due to the loss of sea ice in response to climate change, and climate projections estimate that sea ice loss will continue. Sea ice is crucial for polar bear populations to travel and access food, as they rely on the sea ice to hunt their main prey, the ringed seal. It is important to understand the movements of polar bears and how those change with the disappearance of sea ice in order to create a conservation strategy. For example, the movements of this one female polar bear indicate that she travelled to Wrangel Island, Russia, which is in the Chukchi Sea subpopulation home range. This indicates the possibility of gene flow between populations.

Keywords: polar bear *(Ursus maritimus)*; gene flow; home range; long-distance movement; Brownian bridge movement model; minimum convex polygon; climate change; Beaufort Sea; Chukchi Sea

Citation: Johnson, A. C., Pongracz, J. D., & Derocher, A. E. (2017). Long-distance movement of a female polar bear from Canada to Russia. *Arctic*.

5.2. Rewilding

Impact of rewilding, species introductions and climate change on the structure and function of the Yukon boreal forest ecosystem

Research Location: Kluane Region, Yukon

Publication Type: Journal Article

Publication Date: 2018

Abstract: Community and ecosystem changes are happening in the pristine boreal forest ecosystem of the Yukon for 2 reasons. First, climate change is affecting the abiotic environment (temperature, rainfall and growing season) and driving changes in plant productivity and predator-prey interactions. Second, simultaneously, change is occurring because of mammal species reintroductions and rewilding. The key ecological question is the impact these faunal changes will have on trophic dynamics. Primary productivity in the boreal forest is increasing because of climatic warming, but plant species composition is unlikely to change significantly during the next 50 - 100 years. The 9 - 10-year population cycle of snowshoe hares will persist but could be reduced in amplitude if winter weather increases predator hunting efficiency. Small rodents have increased in abundance because of increased vegetation growth. Arctic ground squirrels have disappeared from the forest because of increased predator hunting efficiency associated with shrub growth. Reintroductions have occurred for 2 reasons: human reintroductions of large ungulates and natural recolonization of mammals and birds extending their geographic ranges. The deliberate rewilding of wood bison (Bison bison) and elk (*Cervus canadensis*) has changed the trophic structure of this boreal ecosystem very little. The natural range expansion of mountain lions (Puma concolor), mule deer (*Odocoileus hemionus*) and American marten (*Martes americana*) should have few ecosystem effects. Understanding potential changes will require long-term monitoring studies and experiments on a scale we rarely deem possible. Ecosystems affected by climate

change, species reintroductions and human alteration of habitats cannot remain stable and changes will be critically dependent on food web interactions.

Local Relevance: Ecosystem dynamics are fluctuating in boreal forest ecosystems in Yukon in response to climate change, and simultaneously in response to mammal species reintroductions and rewilding. Species reintroductions include both human-mediated processes, and range expansion due to climate change or land-use impacts. This paper looks at the Kluane region of southwest Yukon and the dynamics of the system in entirety as related to impacts from intentional rewilding as a management practice and range expansion in response to climate and land-use change. The most prominent change seen in the structure of the boreal forest ecosystem in the Kluane region is an increase of primary productivity and advance of the shrubline.

Keywords: community stability; introduced species; population cycles; trophic dynamics; boreal forest ecosystem; recolonization

Citation: Boonstra, R., Boutin, S., Jung, T. S., Krebs, C. J., & Taylor, S. (2018). Impact of rewilding, species introductions and climate change on the structure and function of the Yukon boreal forest ecosystem. Integrative Zoology.

5.3. Bio-indicators

Cortisol levels in beluga whales (Delphinapterus leucas): Setting a benchmark for Marine Protected Area monitoring

Research Location: Tarium Niryutait Marine Protected Area, Mackenzie Delta Region, Northwest Territories, and Yukon

Publication Type: Journal Article

Publication Date: 2017

Abstract: Beluga whales *(Delphinapterus leucas)* are facing profound changes in their habitat, with impacts expected at the individual and population level. Detecting and monitoring exposure and response to environmental stressors is necessary for beluga conservation and management of human activities. Cortisol has been proven as a useful tool to assess stress on wildlife. Cortisol was measured in three blubber layers and plasma in subsistence hunted beluga whales from the summers of 2007 to 2010 using an HPLC/MS/MS. We assessed the effect of biological and biochemical factors. Cortisol ranged from undetectable to 17.8 ng/g in blubber and 2.5 to 61.2 ng/mL in plasma. Concentrations were highest in the inner blubber layer likely reflecting circulating levels. All tissues were significantly higher in 2008 for reasons that remain unclear. Cortisol levels were on par with resting levels in captive belugas. Best fit models for cortisol revealed age to be an important determinant along with length and blubber thickness. Lack of relationships with biochemical factors such as organic contaminants suggests current cortisol levels are not significantly influenced by present contaminant concentrations. Our findings support the use of middle and outer blubber tissues for an integrated measure of chronic stress that are less subject to the influence of acute stress.

Local Relevance: The Tarium Niryutait Marine Protected Area was established in 2010 and consists of the three areas Niaqunnaq, Okeevik, and Kittigaryuit. Niaqunnaq is located in Mackenzie Bay, in the Arctic; which borders the north slope of Yukon. The north slope of Yukon is included in the Inuvialuit Final agreement and its terrestrial and bordering marine areas have been used for a long time for subsistence harvest. Niaqunnaq is an integral habitat for Beluga Whales *(Delphinapterus leucas)*, which are an integral part of Inuvialuit subsistence harvest. The Arctic is particularly susceptible to the effects of climate change and the Arctic ecosystem is experiencing increased anthropogenic pressure due to ice melt and increasing accessibility by ships. This has increased shipping, commercial fishing, contaminants, and resource exploration and extraction. A useful tool in monitoring effects of climate change on the ecosystem is to find indicators. Beluga whales can serve as an indicator species because they are well studied with a plethora of baseline data; have a circumpolar distribution; and are an apex predator in their tropic system.

Keywords: hormones; marine mammals; physiology; Beaufort Sea; cortisol; environmental stressors; Tarium Niryutait Marine Protected Area; Mackenzie Delta; Inuvialuit; beluga whale (*Delphinapterus leucas)*

Citation: Loseto, L. L., Pleskach, K., Hoover, C., Tomy, G. T., Desforges, J.-P., Halldorson, T., & Ross, P. S. (2017). Cortisol levels in beluga whales (Delphinapterus leucas): Setting a benchmark for Marine Protected Area monitoring. Arctic Science, 0(2017), 1–15.

Spatial variation of mercury bioaccumulation in bats of Canada linked to atmospheric mercury deposition

Research Location: Quebec, Ontario, Alberta, Newfoundland and Labrador, New Brunswick, Manitoba, British Columbia, the Northwest Territories, Yukon

Publication Type: Journal Article

Publication Date: 2018

Abstract: Wildlife are exposed to neurotoxic mercury at locations distant from anthropogenic emission sources because of long-range atmospheric transport of this metal. In this study, mercury bioaccumulation in insectivorous bat species (Mammalia: Chiroptera) was investigated on a broad geographic scale in Canada. Fur was analyzed (n = 1178) for total mercury from 43 locations spanning 20° latitude and 77° longitude. Total mercury and methylmercury concentrations in fur were positively correlated with concentrations in internal tissues (brain, liver, kidney) for a small subset (n = 21) of little brown bats (Myotis lucifugus) and big brown bats (Eptesicus fuscus), validating the use of fur to indicate internal mercury exposure. Brain methylmercury concentrations were approximately 10% of total mercury concentrations in fur. Three bat species were mainly collected (little brown bats, big brown bats, and northern long-eared bats [M. septentrionalis]), with little brown bats having lower total mercury concentrations in their fur than the other two species at sites where both species were sampled. On average, juvenile bats had lower total mercury concentrations than adults but no differences were found between males and females of a species. Combining our data set with previously published data for eastern Canada, median total mercury concentrations in fur of little brown bats

ranged from 0.88–12.78 µg/g among 11 provinces and territories. Highest concentrations were found in eastern Canada where bats are most endangered from introduced disease. Model estimates of atmospheric mercury deposition indicated that eastern Canada was exposed to greater mercury deposition than central and western sites. Further, mean total mercury concentrations in fur of adult little brown bats were positively correlated with site-specific estimates of atmospheric mercury deposition. This study provides the largest geographic coverage of mercury measurements in bats to date and indicates that atmospheric mercury deposition is important in determining spatial patterns of mercury accumulation in a mammalian species.

Local Relevance: The little brown bat (Myotis lucifugus) and northern long-eared bat (M. septentrionalis) have experienced large decreases in population due to white nose syndrome. Both species were listed as endangered under the Canadian *Species at Risk Act* in 2013. Out of 1178 samples of fur collected during the study, 167 samples were collected from bat biologists in the Yukon. The extent of the little brown bat's (Myotis lucifugus) home range terminates at the tree line in the Yukon whilst the extent of the of long-eared bat's (M. septentrionalis) home range comprises the south-eastern tip of Yukon. The lowest concentrations of mercury were found in bats sampled in the Yukon. This geographic variation of mercury content in bats is explained by atmospheric distribution. Mercury concentrations in fur were a good indicator of mercury accumulation in internal tissues. Both total mercury and methylmercury concentrations in fur were positively correlated which makes it a useful, non-lethal method of collection of samples to study bioaccumulation in the local bat population.

Keywords: Chiroptera; bioaccumulation; little brown bat; fur; brain; mercury

Citation: Chételat, J., Hickey, M. B. C., Poulain, A. J., Dastoor, A., Ryjkov, A., McAlpine, D., & Hobson, D. (2018). Spatial variation of mercury bioaccumulation in bats of Canada linked to atmospheric mercury deposition. *Science of the Total Environment, 626,* 668-677.

5.4 Fitness

Predicting the fitness effects of climate change on snowshoe hares

Research Location: Kluane Region, Yukon

Publication Type: Journal Article

Publication Date: 2017

Excerpt: Climate change is considered one of the greatest potential threats to global biodiversity (Thomas et al., 2004). Currently, it is altering the distribution and abundance of numerous species (Parmesan, 2006), causing numerical declines in populations that are unable to adapt (Kausrud et al., 2008) and potentially leading to species extinction (McLaughlin et al., 2002). Predicting the impacts of climate change on species demography, however, remains challenging because of the complexities associated with species' responses to shifting environments. One such complexity is how climate disruption affects biotic interactions (Heller and Zavaleta, 2009) and in particular, predator-prey

dynamics (Post et al., 1999). Predator-prey interactions are characterized by five stages (see Fig 1; adapted from Sih, 2011), and the likelihood of a prey being consumed is determined by the frequency of encounters and the conditional probability of each subsequent stage in the interaction. Therefore, climate change may reduce prey survival either by increasing encounter rates or by increasing the probability of any stage in the interaction. For example, increased snow depth caused wolves (Canis lupus) to hunt in larger packs, improving hunting success, which subsequently tripled kill rates of moose (Alces alces; Post et al. 1999).

Local Relevance: Snowshoe Hares (Lepus americanus) are a well-studied keystone species in the Kluane region of Yukon with a wealth of baseline data. This makes them an excellent candidate to assess the effects of climate change. They exist within a 10-year cyclic pattern which is highly influenced by predator-prey interactions. Snowshoe hares change fur colour to camouflage with their habitat; white in winter and brown in summer. The temporal seasonal shifts have caused a mis-match between habitat and camouflage, potentially decreasing the cryptic abilities of the hares and ultimately, their fitness.

Keywords: snowshoe hares; Kluane; fitness; predator-prey; plasticity

Citation: Peers, M. J. L. (2017). Predicting the fitness effects of climate change on snowshoe hares. *Arctic*, *70*(4), 430-434.

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