Yukon
University

Yukon climate change indicators and key findings 2022

This publication may be obtained from:

YukonU Research Centre, Yukon University
500 University Drive P.O. Box 2799
Whitehorse, Yukon Y1A 5K4
867 456 6986 or 1 800 661 0504
www.YukonU.ca/research

Recommended citation:

Perrin, A. & Jolkowski, D. (2022). Yukon climate change indicators and key findings 2022. YukonU Research Centre, Yukon University, 126p.

Front cover photo: Wind River, Yukon
Photo credit: Alison Perrin

PROJECT TEAM

Authors

Alison Perrin	YukonU Research Centre, Yukon University
Daniel Jolkowski	YukonU Research Centre, Yukon University

Technical Reviewers

Alyssa Benoit	YukonU Research Centre, Yukon University
Nelly Bouevitch	Government of Yukon
Rowan Brown	Government of Yukon
Sean Carey	McMaster University
Cameron Eckert	Government of Yukon
Brian Horton	YukonU Research Centre, Yukon University
Jill Johnstone	Northern Plant Ecology Lab
Sabrina Kinsella	Government of Yukon
Panya Lipovsky	Government of Yukon
Chrystal Mantyka-Pringle	Wildlife Conservation Society Canada
Molly Pratt	Mobilize Knowledge Consulting
Rachel Pugh	YukonU Research Centre, Yukon University
Clara Reid	Government of Yukon
Don Reid	Wildlife Conservation Society Canada
Stephen Roddick	Resilient North Consulting
Julien Schroder	Government of Yukon
Emma Seward	Government of Yukon
Robin Sharples	Government of Yukon
Benoit Turcotte	YukonU Research Centre, Yukon University
Tyler Williams	Government of Yukon
Katie Woodstock	Government of Yukon
3 Anonymous reviewers	

FOREWORD

The *Yukon Climate Change Indicators and Key Findings 2022* is an update of the 2015 version of the report. This work is the product of an ongoing collaboration between the Climate Change Research group at the YukonU Research Centre (formally known as the Northern Climate ExChange), and the Government of Yukon's Climate Change Secretariat. We created these reports to fill a recognized need for easy-to-access Yukon climate change data and indicators, and an analysis of key information linking climate data to relevant impacts. We hope that this report serves as a valuable tool for decision-makers, policy advisors, researchers, and the general public in the Yukon as we prepare for future change.

This report is unique, bringing together Yukon-specific data on climate and incorporating the peer-review by Yukon-based experts from a variety of backgrounds. *Yukon Climate Change Indicators and Key Findings 2022* follows the blueprint of the original report, with the addition of new data and knowledge. Written by Alison Perrin, a Yukon University researcher focused on climate change adaptation and policy in the Yukon for the past ten years, it follows the structure originally established by John Streicker, the lead author of the original report. We maintain our commitment to providing new editions of this report on a regular basis as new data, indicators, and knowledge become available.

In this report, and future iterations, we attempt to respectfully acknowledge and reflect contributions from Indigenous and scientific knowledge systems. Ultimately this is a report employing a western scientific approach, however the wealth of Indigenous knowledge of climate change in the Yukon has informed the key findings. To ensure rigour and local relevance, local experts, scientists, organizations, and government agencies reviewed the report. The expertise and assistance of these technical advisors has been an invaluable contribution towards ensuring the report is accurate and comprehensive. We appreciate their contributions, as well as the resources and contributions of the Climate Change Secretariat.

Together, the key findings of this report are clear: the impacts of climate change are here already. Climate change is directly affecting how human and natural systems function. Within the global community, efforts to reduce emissions can help avoid some of the most severe consequences of climate change, but many impacts will continue throughout this century. Alison, the Climate Change Research group of YRC, and myself want this report to inform the conversation of how Yukon can remain resilient to the impacts of climate change and thrive in a rapidly changing world.

Brian Horton
Manager, Climate Change Research
YukonU Research Centre, Yukon University
May 30, 2022

ACRONYMS

ACIA - Arctic Climate Impact Assessment
AFN Yukon - Assembly of First Nations Yukon Region
AICBR – Arctic Institute of Community-Based Research
AMAP - Arctic Monitoring and Assessment Programme
AO - Arctic Oscillation
AR4 - Fourth Assessment Report of the IPCC
AR5 - Fifth Assessment Report of the IPCC
AR6 - Sixth Assessment Report of the IPCC
CAFF - Conservation of Arctic Flora and Fauna
CAFN - Champagne and Aishihik First Nations
CCS - Climate Change Secretariat, YG
CMIP5 - Coupled Model Intercomparison Project Phase 5
CRD - Climate Resilient Development
CRI - Climate Risk Institute
CTFN - Carcross/Tagish First Nation
CYFN - Council of Yukon First Nations
ECCC - Environment and Climate Change Canada
FAO – Food and Agriculture Organization of the United Nations
FNIGC - First Nations Information Governance Centre
FNNND - First Nation of Nacho Nyak Dun
GHG - Greenhouse gas
ICC - Inuit Circumpolar Council
ICLR - Institute for Catastrophic Loss Reduction
IK - Indigenous Knowledge
ILI - Indigenous Leadership Initiative
IPCC - Intergovernmental Panel on Climate Change
ITK - Inuit Tapiriit Kanatami
KFN - Kluane First Nation
NASA - National Aeronautics and Space Administration
NCCAH (National Collaborating Centre for Aboriginal Health
NISI - Northern Infrastructure Standards Initiative
NOAA - National Oceanic and Atmospheric Administration
NRTEE - National Round Table on the Environment and the Economy
PAME - Protection of the Arctic Marine Environment
PDO - Pacific Decadal Oscillation
RAD - Resist-Accept-Direct framework
RCP - Representative Concentration Pathways
RRDC - Ross River Dena Council
SFN - Selkirk First Nation
UFA - Umbrella Final Agreement
UNEP - United Nations Environment Programme
YESAB - Yukon Environmental and Socio-economic Assessment Board
YG - Government of Yukon
YRC - YukonU Research Centre

TABLE OF CONTENTS

1.0 INTRODUCTION

Climate change is already affecting the natural environment and many aspects of human lives. In its most recent global assessment report, the Intergovernmental Panel on Climate Change (IPCC) states: “It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred” (IPCC, 2021, p.4). Ongoing change is expected to continue unless we make significant changes to reduce greenhouse gas emissions, and “climate change impacts and risk are becoming increasingly complex and more difficult to manage” (IPCC, 2022, p.20). The North is warming faster than the global average, and this trend is expected to continue in the future (Bush & Lemmen, 2019). While global and national trends provide insight into the issues related to climate change, regional information is necessary to help inform local decisions. This report seeks to assess our state of knowledge regarding climate change in Yukon.

Yukon Climate Change Indicators and Key Findings 2022 is a cross-sector, structured, evidence-based assessment of Yukon climate change knowledge. This report provides a synthesis of our understanding of key climate change impacts in Yukon. The goal of this report is to provide a broad understanding of climate change and associated impacts in the Yukon, making it useful for researchers, decision makers, and the general public. Given the dynamic challenges and opportunities presented by climate change, the intention is that this report should be updated on a regular basis, bringing in new information as our knowledge progresses. This second iteration of the report was produced by the Climate Change Research group (formerly the Northern Climate ExChange) at Yukon University’s Research Centre (YRC). It follows a similar format and methodology to the original report, *Yukon Climate Change Indicators and Key Findings 2015,* which was authored by John Streicker through the Northern Climate ExChange. In this update we bring in new data and knowledge that has emerged since 2015.

The report focuses on indicators – objective measures of climate – and on key findings, which are simple, high-level conclusions of current climate change research and Indigenous knowledge. The indicators are updated annually and are available on request at the YRC, and some are published in the annual *State of the Environment* report produced by the Government of Yukon (YG). The ten key findings are listed here in the Executive Summary with the indicators, and then expanded upon with supporting evidence in the annotated findings section of the report. Acknowledging that this report aims to provide breadth, not depth, readers are encouraged to explore the resources cited in this report if they are seeking a more comprehensive understanding of the key findings.

For the most part, this synthesis is based on western scientific knowledge. When relevant and accessible, Indigenous knowledge (IK) of climate change was available, it has been included. However, we acknowledge that the format of this assessment report is based in a western science tradition and is not conducive to effectively and respectfully communicating Indigenous knowledge within the appropriate context. Communicating IK in a science assessment is not the ideal format (Alexander et al., 2011; Ford et al., 2016; Knopp, 2020; Mistry & Berardi, 2016), however, it is important to ensure that Indigenous perspectives are included as these types of reports provide import tools for policymakers (Ford et al., 2012; Wilson, 2021). As Wilson et al. (2021) demonstrates, IK provides valuable knowledge for regional scale assessments, yet oral knowledge is not given the same weight as scientific knowledge in assessments and evidence-based decision-making. Where IK is presented in a limited capacity in this report, it is presented with equal weight.

The review process has been an important part of developing this report. It was reviewed by a group of Yukon experts drawn from a variety of fields as well as experts outside of the Yukon. The input from expert reviewers was invaluable and helped shape the key findings. There are still gaps in our understanding of the impacts of climate change, and topics that require further work to have confidence in our depth of knowledge. Some of these gaps are identified in the report as future areas of research that could improve our understanding of climate change in the Yukon.

2.0 EXECUTIVE SUMMARY: INDICATORS

Climate indicators are a measure of a complex system, chosen to provide an objective overview of the climate system and any potential change. They need to be straightforward, repeatable, and representative. The indicators are illustrated and described below, and a more complete description of each indicator is shared in *Section 6.0: Indicators*. For more information, including the full set of data, please contact the YukonU Research Centre for a copy of the digital library.

Each graph shows an indicator over time. A trend line is plotted along with the 95% confidence interval of the trend line (shown as a black line with dashed lower and upper confidence intervals). Each graph also lists two statistics, the r-value and the p-value, measures of correlation and significance respectively. An r-value of 0 demonstrates no correlation, and the closer the r-value is to 1 or -1, the strong the correlation is. The p-value demonstrates the likelihood that you would see these results even if there is no relationship between the variables; a smaller p-value indicates that it is more likely that the relationship exists. The trend lines and the statistics signify whether the indicator is changing over time or not. Trend lines should not be used to assume that the indicator would behave in a linear fashion. For example, despite a linear trend line, sea ice melt appears to be accelerating in recent years.

Projections are based on results from climate modelling organizations participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Programme using representative concentration pathways (RCPs) from the IPCC fifth Assessment Report (AR5). The RCPs 2.6, 4.5, and 8.5, representing low-, medium-, and high-emission scenarios, respectively were used in this report.

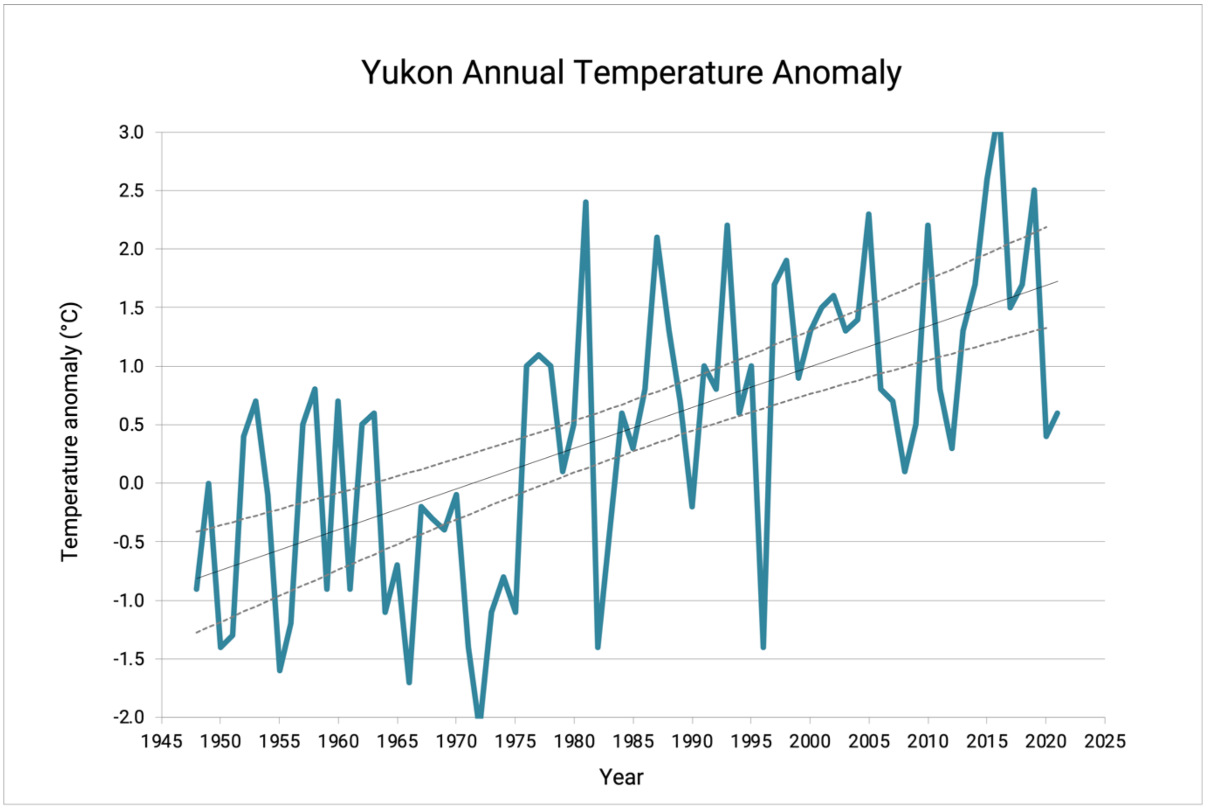

Figure 1.1. Yukon annual average temperature anomaly (r-value = 0.64 p-value < 0.01)

Implications The temperature anomaly shows us the relative change in average Yukon temperature from one year to the next. Temperature is the strongest indicator of climate change in the Yukon. The Yukon is warming significantly. Annual temperature has increased by 2°C over the past 50 years. Winters have seen the greatest increase in temperature. See *Key Finding 1.*

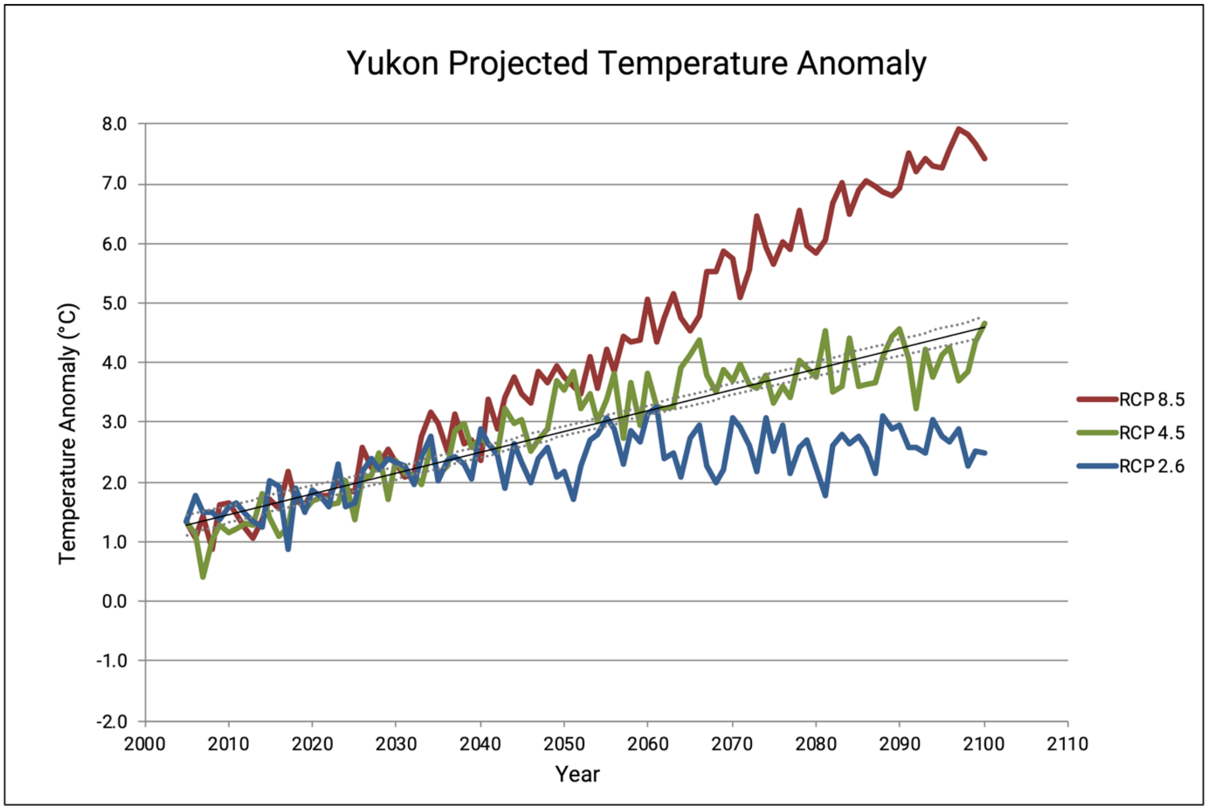

Figure 1.2. Yukon projected annual average temperature anomaly (r-value = 0.92 p-value < 0.01)

Implications The projected temperature anomaly shows us the relative change in average annual Yukon temperature projected over the next century. Temperature is projected to increase by 0.7 to 3.7°C over the next 50 years. While there is variability about the amount of warming, Yukon will continue to warm under all scenarios. Winters are projected to warm faster than any other season. See *Key Finding 1*.

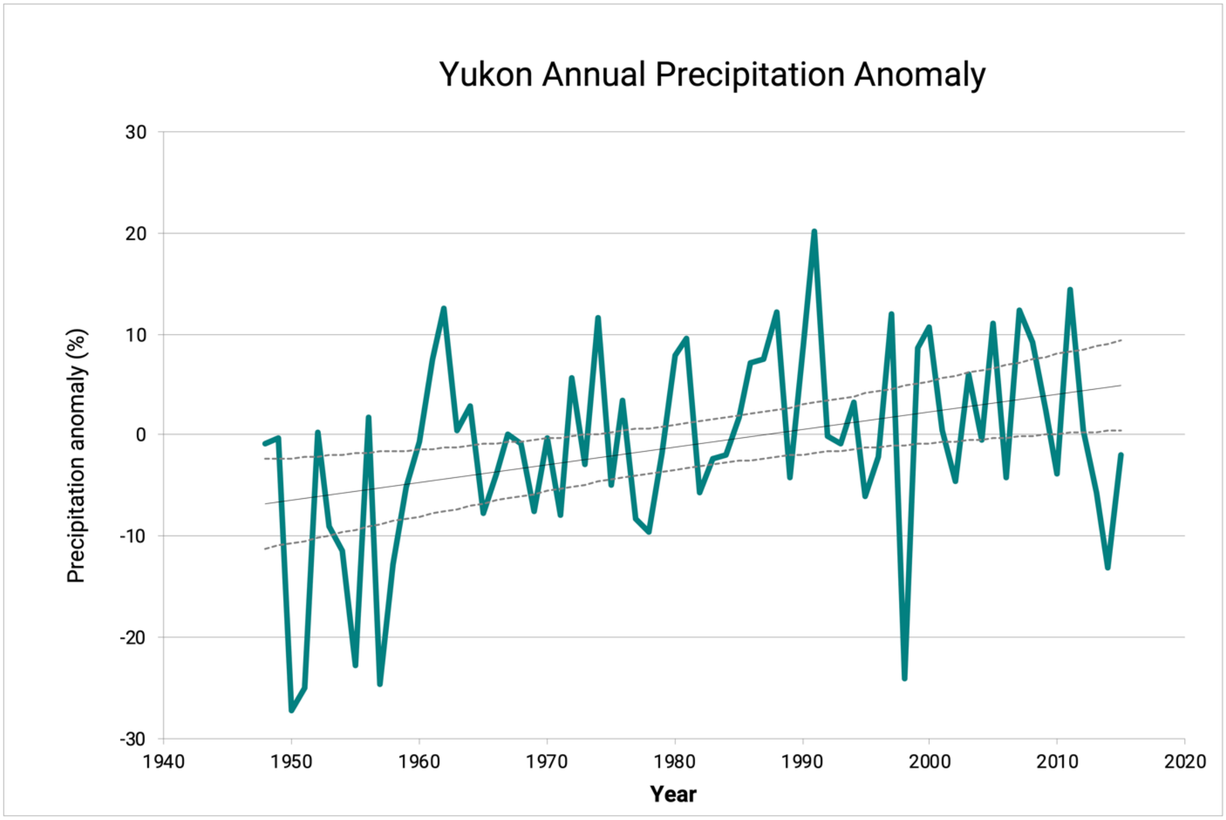

Figure 1.3. Yukon total annual precipitation anomaly (r-value = 0.35 p-value < 0.01)

Implications The precipitation anomaly shows us the relative change in percentage for total precipitation from one year to the next. The trend is significant, however, there is considerable variability in precipitation from year to year and from one location to the next within the mountainous terrain of Yukon. There are also issues with the accuracy of available precipitation data, and ECCC stopped producing annual precipitation trend data in 2016. Total annual precipitation increased by about 3% over the last fifty years of the precipitation record (1966-2015), and 12% from 1948 to 2015. Summers have seen the greatest increase in precipitation overall, although winters have also seen a big increase. See *Key Finding 1.*

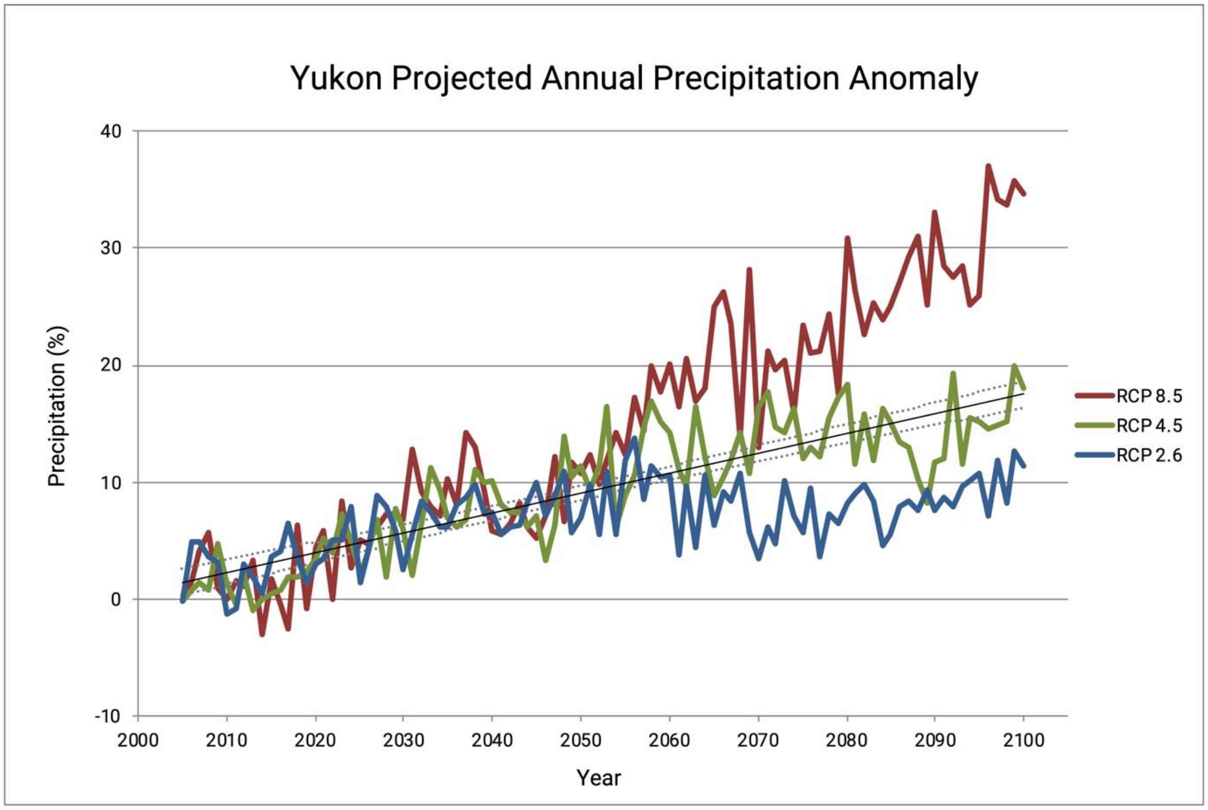

Figure 1.4. Yukon projected annual average precipitation anomaly (r-value = 0.86 p-value < 0.01)

Implications The projected precipitation anomaly shows us the relative change in total annual precipitation in Yukon projected over the next century. Precipitation is projected to increase by 4 to 17% over the next 50 years. All scenarios project a significant increase. See *Key Finding 1* and *Detailed Indicators.*

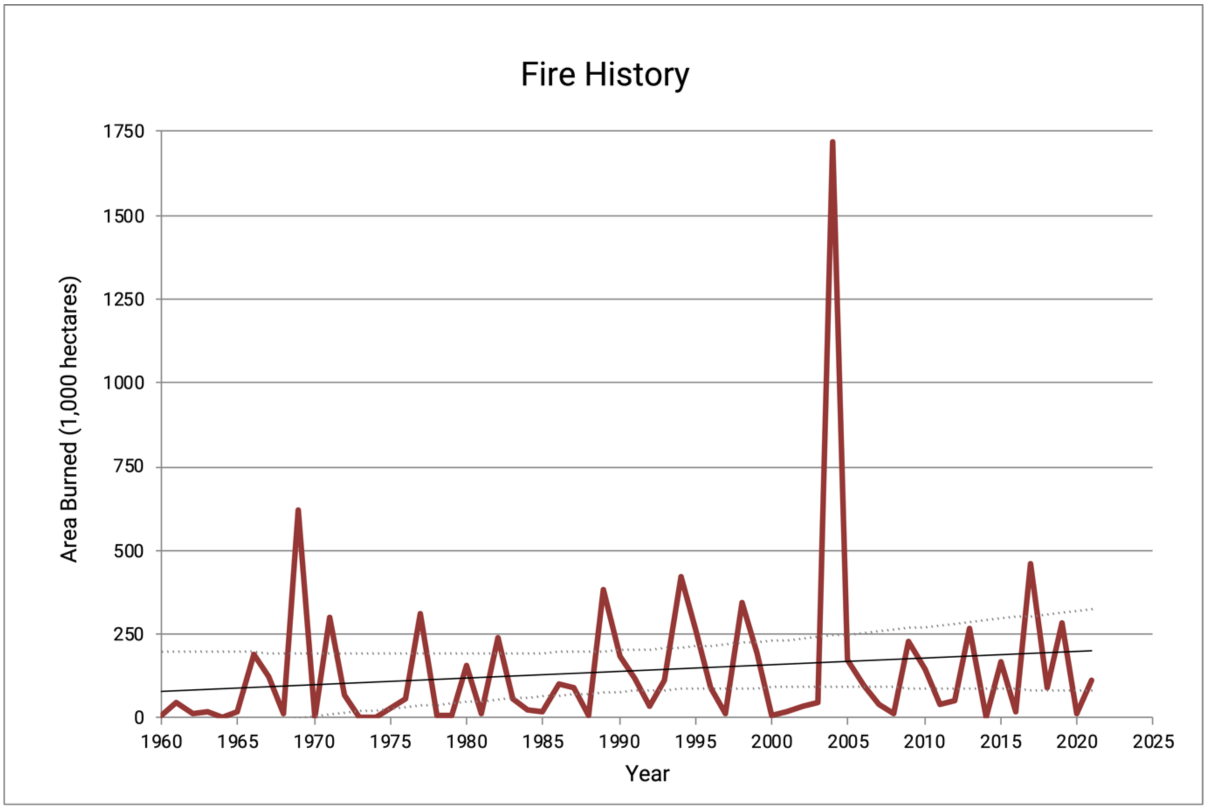

Figure 2.1. Yukon fire history (r-value = 0.15 p-value = 0.24)

Implications The number of hectares burned per year has increased over the past 50 years; however, the trend is not significant. We will need to observe fire for a longer period of time to be certain of the trend. There is potential for the conditions that increase risk of fire to become more frequent due to climate change (see *Key Finding 4*), but conditions vary considerable from year to year and between different regions. 2004 was an extreme year for wildfires in Yukon with higher-than-average summer temperatures and lower summer precipitation. Neighbouring jurisdictions including the Northwest Territories, Alaska, British Columbia, and Alberta have seen recent extreme fire seasons.

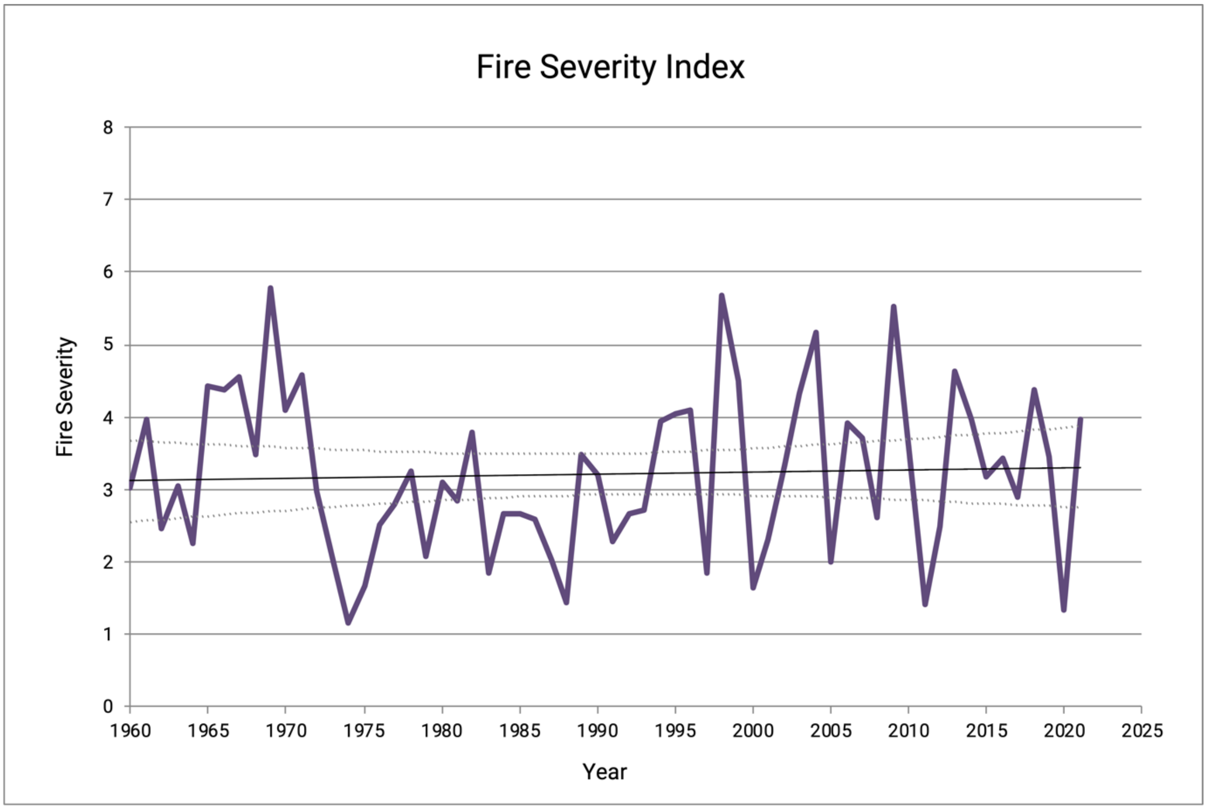

Figure 2.2. Yukon fire severity index (r-value = 0.05 p-value = 0.69)

Implications Fire severity risk has shown a small increase over the past 50 years, but the trend is not significant. As a combination of meteorological data, the severity index can have significant swings from one year to the next due to variability in temperature, precipitation, evapotranspiration, and wind. There are other variables that affect fire risk, including fuel loading, that are not captured by the fire severity index (see *Key Finding 4*). While 2004 did not show an extreme fire severity index, it was comparatively high, and it was an extreme year for wildfires in Yukon based on area burned.

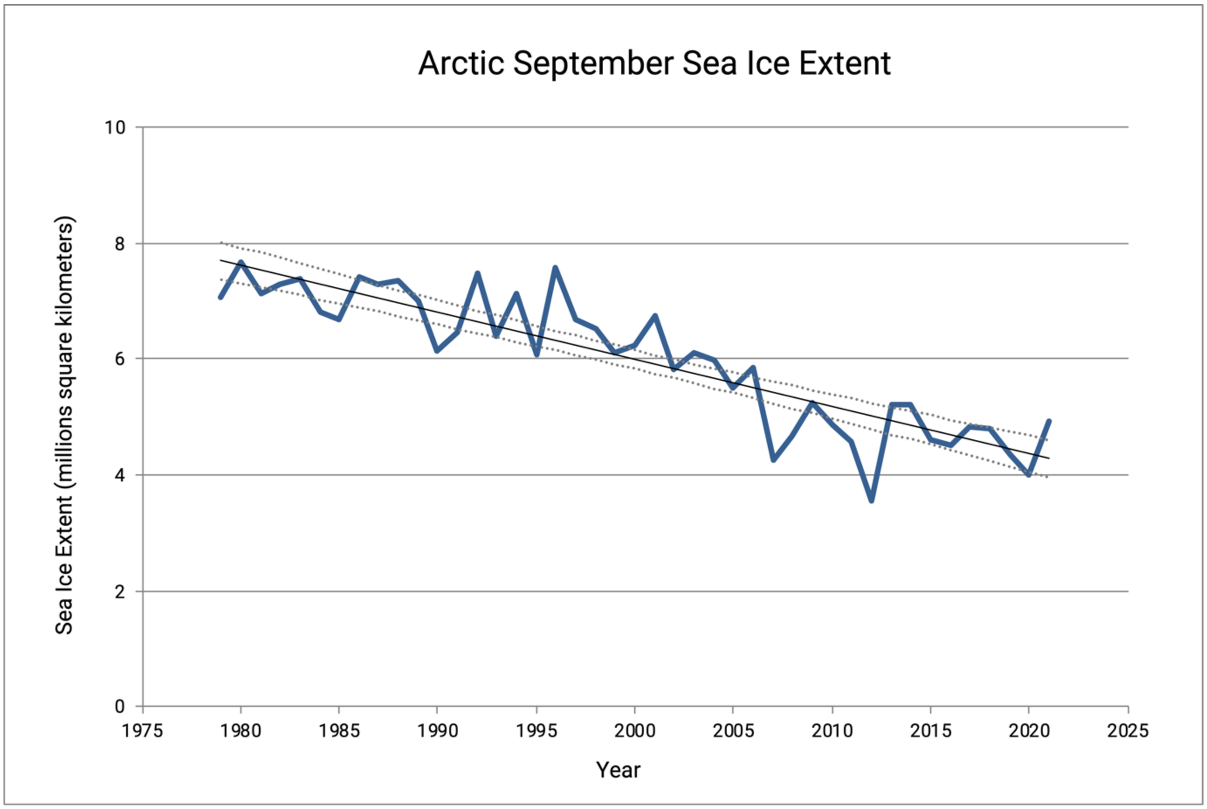

Figure 3.1. Annual Arctic September sea ice extent (r-value = -0.89 p-value < 0.01)

Implications Sea ice melt is among the most visible global indicators of climate change, and especially relevant for the circumpolar North. Since satellite observational records began in 1979, there is a clear trend: Arctic sea ice is melting. Sea ice extent reaches its minimum each year in September. September sea ice loss is averaging 80,000 km^2 per year, although there is variability from one year to the next. The net result is that summer sea ice will completely melt in the Arctic within the next decade/decades, with projections of a practically ice-free season by 2050. Sea ice melt appears to be accelerating, with most of the melt occurring in the past decade. This has wide ranging implications for the Yukon, the Arctic and the globe. See *Key Findings 2 and 10*.

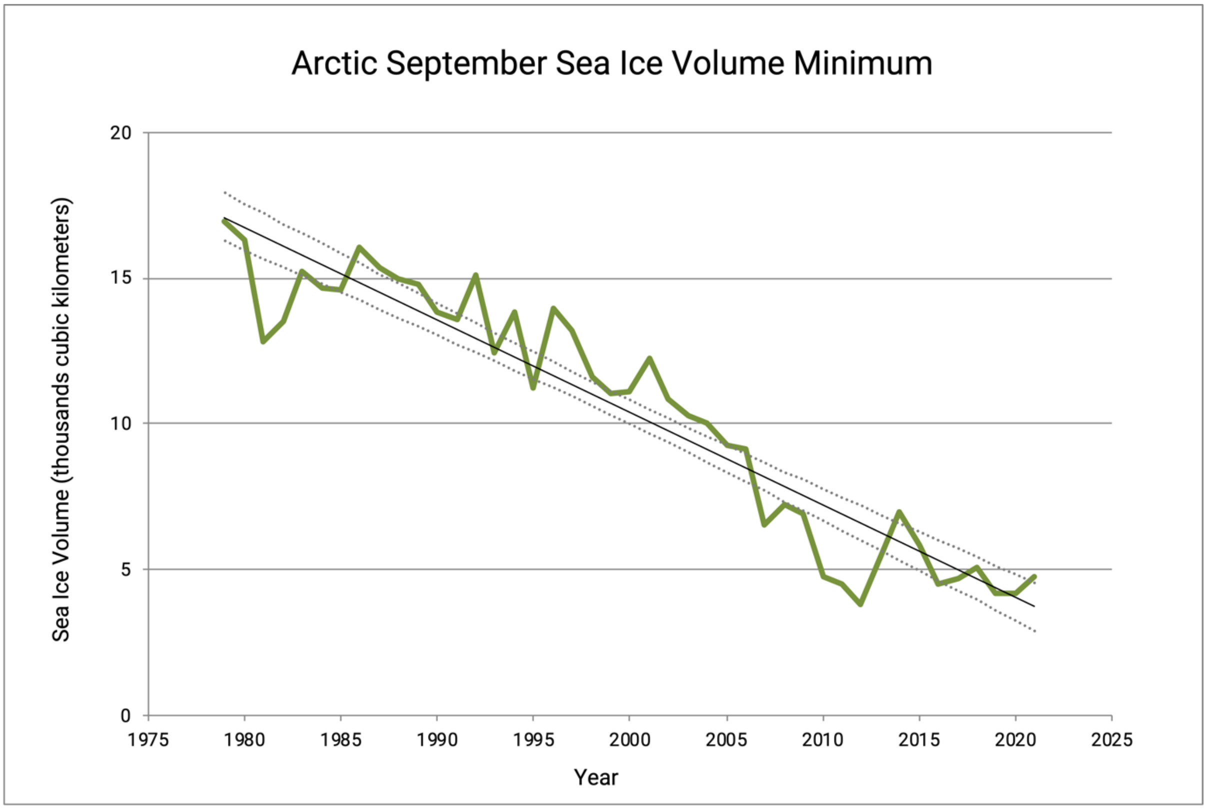

Figure 3.2. Annual Arctic September sea ice volume (r-value = -0.95 p-value < 0.01)

Implications September is the month when Arctic sea ice is at its minimum. Arctic sea ice is melting rapidly at a rate of ≈ 300 km3 sea ice loss per year, indicating loss in both the thickness and coverage of sea ice. Sea ice melt appears to be accelerating; less ice is surviving from one year to the next and the ice that is lasting for more than one season is thinning significantly. See *Key Findings 2 and 10*.

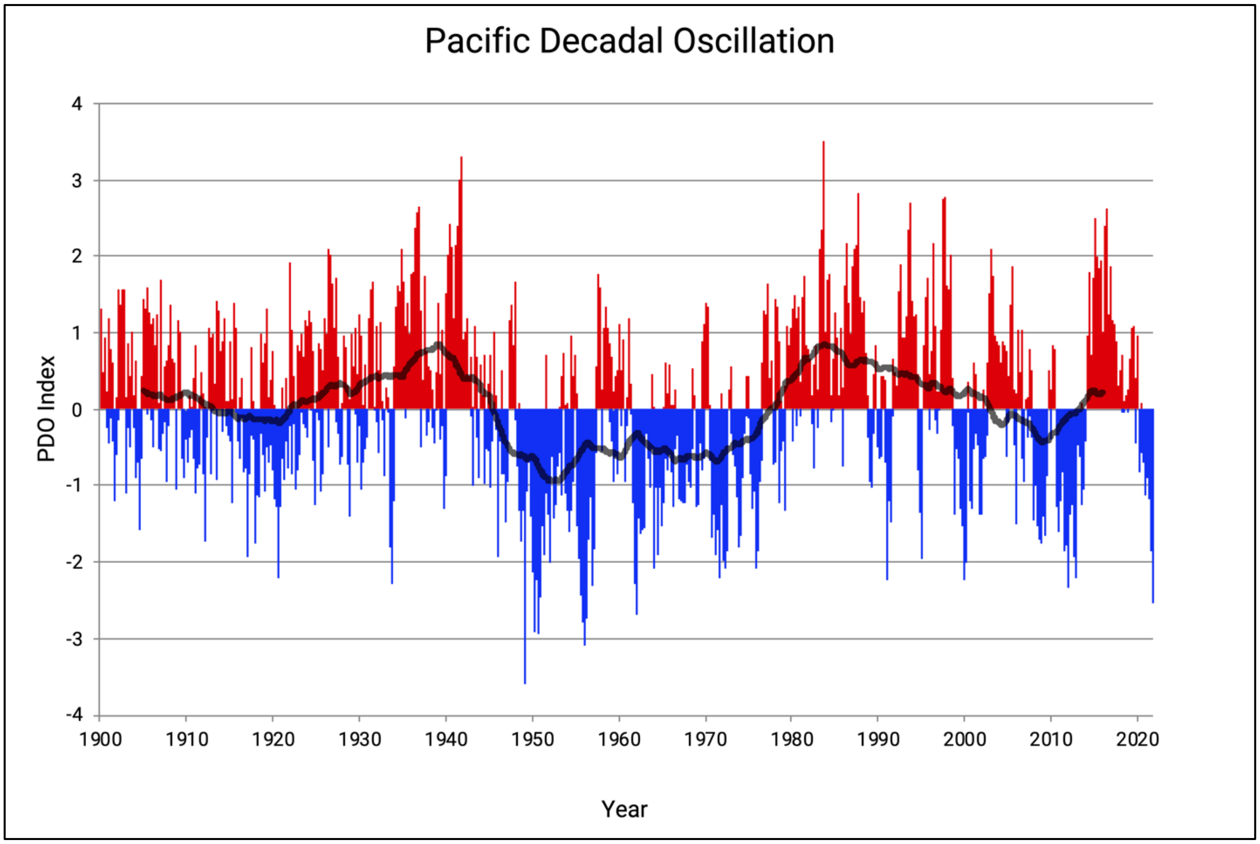

Figure 4.1. Pacific Decadal Oscillation and 5-year moving average (r-value = -0.02 p-value = 0.9)

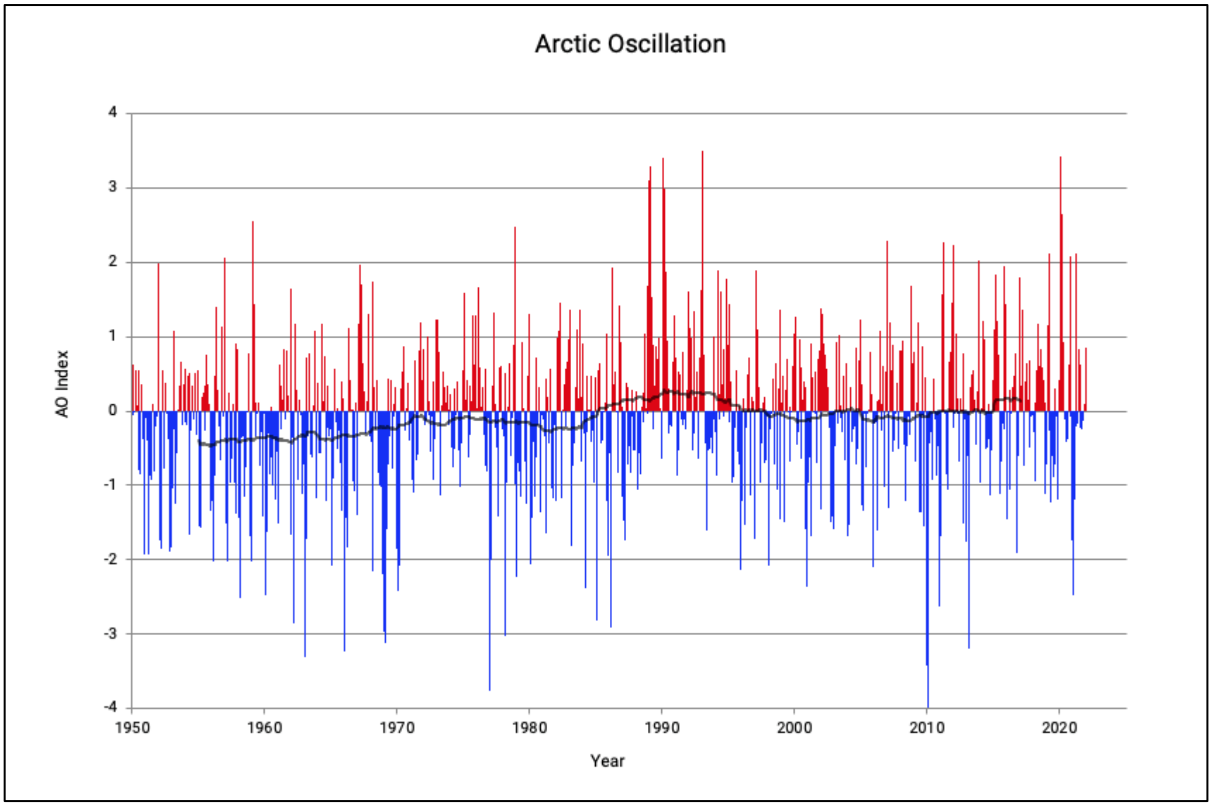

Figure 4.2. Arctic Oscillation and 5-year moving average (r-value = 0.35 p-value < 0.01)

Implications Oscillations are recurring patterns of ocean-atmosphere climate variability. They are likely the most significant natural influence on regional weather and climate. For the Yukon, two key oscillations are the Pacific Decadal Oscillation (PDO) and the Arctic Oscillation (AO). A positive phase of the PDO and a negative phase of the AO are associated with warmer temperatures in Yukon. However, these graphs show that the PDO has been dropping until very recently, while the AO has been quite flat in recent decades. Since the Yukon has been warming significantly for the past 50 years, the PDO and AO data contributes to the evidence demonstrating that anthropogenic climate change is causing increases in temperature rather than these naturally occurring cycles. See *Key Finding* 1.

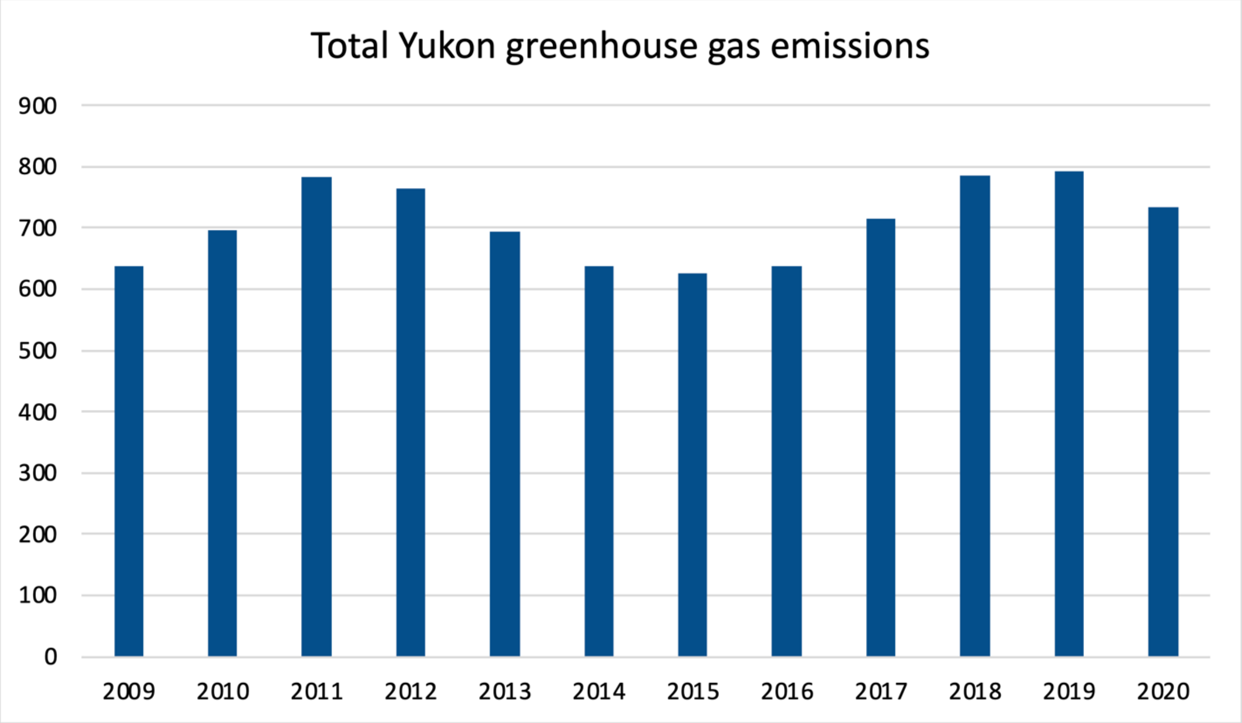

Figure 5.1. Yukon total greenhouse gas emissions

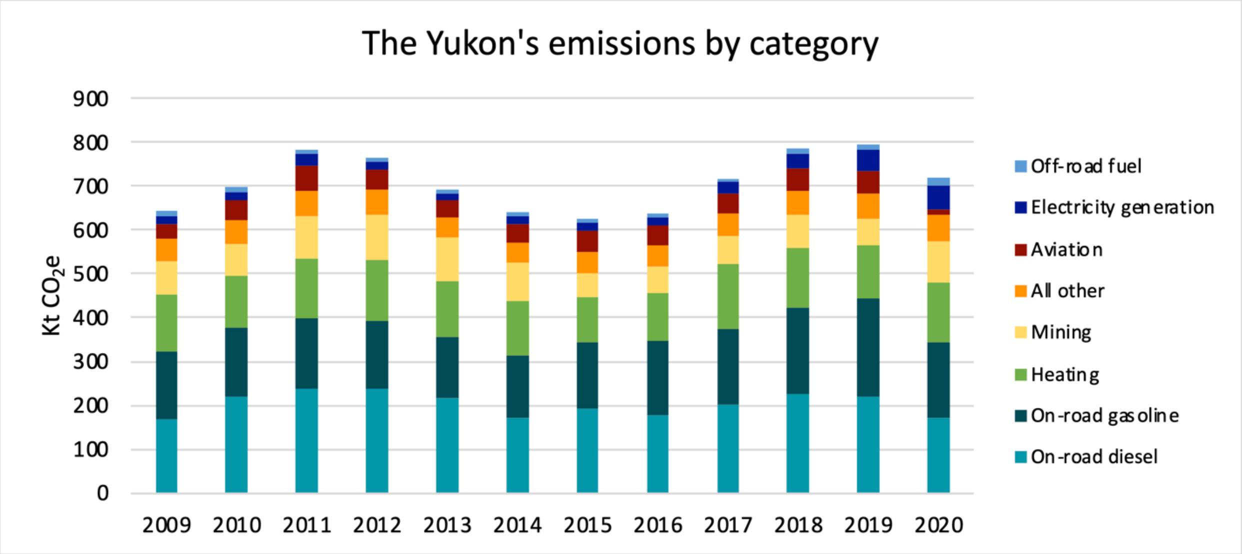

Figure 5.2 Yukon total greenhouse gas emissions by fuel type

Implications Government of Yukon has only been measuring and reporting on emissions since 2009. During this time Yukon's total emissions have grown along with Yukon's population and economy. Variations from year to year in Yukon emissions tend to come from increases in mining, aviation, and/or on-road diesel use. There has been an increase in emissions from electricity generation. A drop in emissions in 2020 appears to be due to the impact of the COVID-19 pandemic. YG's emission reduction targets are for 2030 and will have to take into account the growing population and economy. See *Key Finding 9*.

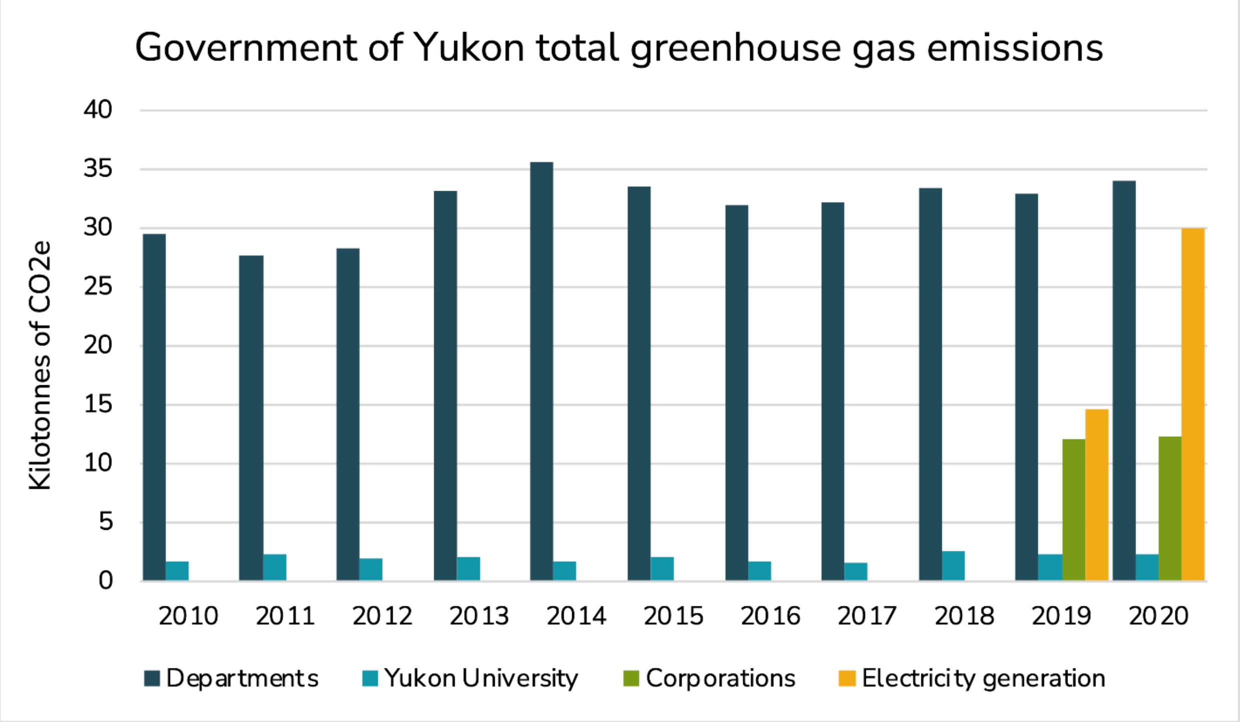

Figure 5.3. Government of Yukon greenhouse gas emissions

Implications Government of Yukon's internal emissions have also increased since 2010, along with increases in Yukon's population and economic activities. Yukon University is a separate entity, however YukonU's buildings are managed and reported on by YG's Highways and Public Works. In 2019 emissions were included for government corporations (Yukon Hospital Corporation, Yukon Housing Corporation, Yukon Liquor Corporation, Yukon Energy Corporation and Yukon Development Corporation) and for electricity generation by Yukon Energy Corporation.

3.0 EXECUTIVE SUMMARY: KEY FINDINGS

Key findings are concise statements, giving broad conclusions. Each of the ten key findings lists sub-points, including critical impacts and implications for Yukon. For more in-depth information please refer to the Annotated Findings section with references to relevant scientific evidence and Indigenous knowledge for each of the key findings.

1. Climate
   All indicators agree: The Yukon's climate is now warming rapidly, and more change is projected. (Very high confidence)

   1.1 In the Yukon, annual average temperature has increased by 2°C over the past 50 years. (Very high confidence)

1.2 Temperature in the Yukon has increased at more than double the global rate and is increasing faster than in southern Canada. (Very high confidence)
1.3 Winters are warming more than other seasons: 4°C over the past 50 years. This is primarily expressed through a decreased frequency and severity of extreme cold events (i.e., below -40°C). (High confidence)
1.4 Annual precipitation in the Yukon increased by about 3% between 1966-2015. Summers and winters have seen the largest increase in precipitation (12-19% increase). Precipitation has more variability in the data record (both spatially and temporally); therefore, we have less confidence in determining this historic trend. (Low confidence)
1.5 Increasing global concentrations of carbon dioxide and other greenhouse gases are projected to contribute to a continuing increase in annual temperature and precipitation across all scenarios. Annual warming in the Yukon is projected to be an additional 0.7 to 3.7°C over the next 50 years. Precipitation is projected to increase 4 to 17% over the next 50 years. (Medium confidence)
1.6 Increasing evapotranspiration and a lengthening of the shoulder seasons are among the projected changes that are likely to persist for the foreseeable future. (High confidence)
1.7 Additional evidence of northern warming comes from widespread melting of glaciers and sea ice, and permafrost thaw. (High confidence)
1.8 Beyond the historic and projected trends, the variability of our climate is expected to increase. This will mean an increase in extreme weather events and greater fluctuations in precipitation. (Medium confidence)
1.9 Unexpected and even larger shifts in the climate system are possible. (Medium confidence)

2. Melt and Thaw

Permafrost is thawing, glaciers are receding, and sea ice is melting. (High confidence)

2.1 Warmer temperatures have resulted in widespread melting of glaciers and sea ice, and the rate of melt is increasing. Winter ice coverage of rivers and lakes is decreasing. (High confidence)
2.2 Permafrost rates of thaw are increasing. Warmer air temperatures are increasing ground temperatures throughout Yukon. (High confidence)
2.3 Thawing ground is already disrupting transportation networks, buildings, and other infrastructure, and will continue to do so in the future. Permafrost thaw has potentially serious implications for mine dams and tailing ponds that are dependent on permafrost berms. (High confidence)
2.4 Permafrost thaw is altering the release and uptake of greenhouse gases from soils, vegetation, and coastal areas with implications for the global carbon cycle. (Medium confidence)
2.5 Arctic sea ice is melting rapidly, the majority of multi-year ice has been lost in the last ten years alone. (Very high confidence)
2.6 A reduction in sea ice, as well as changes to snow cover, reduces the albedo of the North and allows oceans and land masses to absorb more solar energy. This largely drives the increased warming rates observed in the North compared to the rest of the globe and has implications for the global climate. (High confidence)

3. Water
   Climate change is affecting and will continue to affect the hydrological regime. (High confidence)

   3.1 Changes in the hydrological regime are driven by changes in temperature and precipitation and affected by other processes including increasing glacial melt, permafrost thaw, variability in rain and snow, earlier snowmelt, and freeze-thaw cycles. (High confidence)
   3.2 Flood risk is influenced by multiple processes that are affected by climate change. Flood risk is expected to increase in some locations in the Yukon, while it may decrease in others. (High confidence)
   3.3 As the Yukon's glaciers continue to recede, glacial melt will contribute to increased river discharge and will have significant impacts on glacier dominated basins. (High confidence)
   3.4 Breakup is occurring earlier for rivers in the Yukon, which can have implications for ice jams and flooding. (Medium confidence)
   3.5 Permafrost thaw affects river and lake systems in the Yukon. Permafrost degradation contributes to an increased groundwater reservoir and changing streamflow and groundwater flow patterns. (High confidence)
   3.6 Warming temperatures, permafrost thaw, and changes in water levels negatively impact water quality through increased turbidity and in some cases through increased contaminant levels. (Medium confidence)

4. Vegetation
   Vegetation community distribution and composition are shifting. (Medium confidence)

   4.1 Treeline and shrubs are expanding rapidly in distribution and community dominance. They are moving to higher latitudes and elevations as well as infilling within current range. (High confidence)
   4.2 Changes in vegetation phenology (timing of biological phenomena) are being observed and will continue, with implications for numerous species. (High confidence)
   4.3 Increases in temperature are already causing drought stress in some species in the Yukon. (Medium confidence)
   4.4 Insect outbreaks that kill canopy trees or significantly reduce their growth have affected significant portions of the Yukon and will continue to do so. (High confidence)
   4.5 Forest and tundra fires show signs of increased frequency and severity in some areas of the Yukon, and of forcing shifts in the dominant forest type during post-fire succession. (Medium confidence)
   4.6 Permafrost thaw induces ground collapse and slumping, contributing to shifts in vegetation community type and composition. (High confidence)
   4.7 New species are arriving in the Yukon by way of various vectors with climate change facilitating range expansion to some extent. There is currently low incidence of invasive species in the Yukon. (Medium confidence)
   4.8 Higher productivity of vegetation (greening) is observed in some regions but not in other regions where water and other nutrients or landscape disturbance are limiting factors (browning). (Medium confidence)

4.9 Climate change impacts to vegetation will affect natural resource management and cultural activities on the land, requiring proactive adaptation. (High confidence)

5. Wildlife

Changes in animal species' habitat, ranges, and food sources are already being observed in the Yukon. (High confidence)

5.1 Climate change interacts with various other potentially limiting factors to drive a wide diversity of species and population-level responses in wildlife. (High confidence)
5.2 Species ranges are already, and will continue, to shift northward, bringing new species into the North while limiting some species currently present. (High confidence)
5.3 Changes in temperature and food availability will likely impact seasonal habitat selection and migratory routes. (High confidence)
5.4 The timing of critical life events (phenology) is affected by climate change for some wildlife species. (Medium confidence)
5.5 Herbivorous mammals will need to adapt to climate change impacts on the abundance, availability, and nutritional quality of food sources. (Medium confidence)
5.6 Changes in snow, including freeze-thaw cycles and increased snowpack depth, have implication for access to food for a number of Yukon species. (High confidence)
5.7 Spring and summer have seen greater levels of insect harassment for wildlife. (Low confidence)
5.8 Some fish species are experiencing habitat changes that are likely to have negative effects on population size and health. (High confidence)
5.9 Impacts of climate change in the Yukon will have implications for biodiversity in other areas of the western hemisphere because some migratory bird species depend on breeding and feeding grounds in the North. (Medium confidence)
5.10 Wildlife management and planning can be adapted or implemented to benefit wildlife species impacted by climate change. (Medium confidence)

6. Hazards and Infrastructure

The major climate change hazards in the Yukon are flood, wildfire, damage to infrastructure from thawing permafrost, and/or extreme precipitation. Infrastructure built without the future climate in mind is vulnerable. (High confidence)

6.1 Yukon communities are located along rivers and in forested areas. This makes flooding and wildfire critical hazards. Climate change is increasing the likelihood and potential severity of these hazards. (Medium confidence)
6.2 Permafrost thaw, wildfire, and more intense precipitation events will result in more landslides and subsequent sediment supply to river systems. (Medium confidence)
6.3 Existing infrastructure was designed and built based on historical climate data that may not be appropriate for future conditions. Even small increases in snow

load, storm severity and frequency, and thawing permafrost can directly affect the structural integrity of infrastructure. (High confidence)

6.4 As frozen ground thaws, some existing buildings, roads, airports, and industrial facilities are likely to be destabilized, requiring substantial rebuilding, maintenance, and investment. (High confidence)

6.5 Future development and maintenance of existing infrastructure will require new design elements to account for ongoing warming that may add to construction and maintenance costs. These costs need to be considered against the potential costs of infrastructure failure. Infrastructure damage and failure also poses major concerns for the insurance industry. (High confidence)

6.6 Industry, such as mining, is also vulnerable to climate change hazards, which can increase downstream risks. (High confidence)

6.7 As hydrological regimes change, our hydro-electric generation capacity may be affected. It is important to consider volume of flow, timing of flow, and high flows. (Medium confidence)

6.8 Guides, standards, and best practices can support efforts to identify and address hazard risk to infrastructure. (High confidence)

7. Food, health, and wellbeing

Climate change impacts health and food security in the Yukon, particularly in relation to First Nations' traditional food security. Indigenous land-based cultural revitalization and agriculture are potential opportunities to adapt to the social and health impacts of climate change. (Medium confidence)

7.1 Many Yukoners depend on hunting, fishing, and gathering. The abundance and health of these resources may be affected by climate change, and this is a key concern for Yukon First Nations and transboundary Indigenous nations. (High confidence)

7.2 Several established climate-related changes in the north affect traditional food security: hydrological impacts, increased variability of precipitation, permafrost thaw, and the freeze-thaw cycle have implications for movement of fish and wildlife, foraging, quality of traditional foods, and access to harvesting sites. (High confidence)

7.3 There is evidence that Yukoners have been consuming fewer traditional foods and more market foods due to the impacts of climate change and other societal changes, which may have negative health consequences. (Medium confidence)

7.4 Extreme weather events and subsequent disruptions to the transportation network, have the potential to disrupt the market food system. (High confidence)

7.5 Climate change exacerbates existing health inequalities including access to food. (Medium confidence)

7.6 Climate change has implications for mental health, particularly as a result of impacts on culture, traditional activities, and safety. (Medium confidence)

7.7 Where suitable soils and climate are present, agriculture has the potential to expand due to a longer and warmer growing season. Field-based agriculture may be challenged by precipitation variability. (Medium confidence)

7.8 Yukon communities and organizations are addressing climate change by engaging in community-led adaptation and food security projects, community-based monitoring, and knowledge sharing between communities. (Medium confidence)

8. Heritage, Culture, and Traditional Ways of Life
   Traditional activities, heritage sites, and intangible cultural heritage are affected by climate change. Indigenous knowledge provides important insights into the impacts of climate change and contributes to the resilience of Yukon First Nations. (High confidence)

   8.1 As the climate changes, it affects the land, the wildlife, access to food, and cultural practices of First Nations people. People who live close to the land and practice traditional ways see the detailed impacts of climate change in the North. (High confidence)
   8.2 Harvesting traditional foods and medicines does not only affect food security, but also supports the local economy and is the basis for cultural and social identity. As the climate changes, it affects the land, the wildlife, access to food, and cultural practices of First Nations people. (Medium confidence)
   8.3 Indigenous knowledge and community-based monitoring programs contribute important knowledge to our understanding of environmental change and wildlife health. Indigenous knowledge indicates that substantial changes have already occurred in the Yukon due to climate change. (High confidence)
   8.4 Cultural and heritage sites are vulnerable to flooding, wildfire, permafrost thaw, and coastal erosion. (High confidence)

9. Causes and Responses
   Climate change is human caused. (High confidence) The Yukon is responding to the impacts of climate change by adapting and addressing the causes by reducing emissions. (Medium confidence)

   9.1 There is unequivocal evidence that the climate is warming and that over the past 50+ years, human activity has been responsible for that warming. (Very high confidence)
   9.2 Adaptation is how we address the impacts of climate change. Mitigation is how we address the causes of climate change. It is important to keep in mind both of these challenges and wherever possible to look for solutions which both mitigate and adapt. (High confidence)
   9.3 Integrating climate change considerations into existing planning processes is a method of reducing risk while taking advantage of existing procedures. (Medium confidence)
   9.4 Solutions that address social inequities, cross multiple sectors, and are informed by Indigenous ways of knowing, doing, and being will improve adaptation outcomes in the Yukon. (High confidence)
   9.5 Public education, research, and in particular community-based research remain as critical needs to improve understanding of Yukon climate change and how to address it. (High confidence)
   9.6 Supporting youth engagement in research and decision-making processes strengthens the Yukon’s capacity to adapt to and mitigate climate change. (High confidence)

10. Importance of the North
    Climate change in the North is a major driver of global change. (Medium confidence)

    10.1 The boreal forest and the Arctic tundra both show indications of shifting from net greenhouse gas sinks to net sources. (Low confidence)
    10.2 Carbon and methane trapped within and below permafrost is being released into the atmosphere and ocean as permafrost thaws, leading to an acceleration of climate warming. (Medium confidence)
    10.3 The loss of Arctic sea ice, which is accelerating due to the albedo reversal from reflective ice to absorptive ocean, will have far-reaching effects. (High confidence)
    10.4 Arctic sea ice loss influences the jet stream causing new weather patterns, including extreme events, at mid-latitudes. (Low confidence)
    10.5 Glacial melt and ocean warming are leading to sea level rise. Glacial melt and diminishing sea ice also affect the global ocean currents. (High confidence)

4.0 METHODOLOGY

4.1 Introduction

The goal of this report is to summarize and communicate the current knowledge of climate change in the Yukon to a variety of audiences, from researchers to decision makers to those who are simply curious to understand how climate change is affecting Yukon. This section provides insight into how the *Yukon Climate Change Indicators and Key Findings 2022* report was developed, as well as an assessment of the scope and limitations of the report. No new research was conducted to create this report; it relies solely on publicly available data and information. Information sources include the datasets analyzed as indicators, peer-reviewed publications, reputable grey literature like government and non-governmental reports, and publicly shared Indigenous knowledge. Sources of Indigenous knowledge include videos, reports, and peer-reviewed literature prepared by Yukon First Nations and the Inuvialuit either through their own initiatives or in partnership with academics or other organizations.

Bringing Indigenous knowledge into a regional assessment report is challenging, however, IK provides important insights into climate change in the Yukon. There are also challenges with taking scientific knowledge that is often localized and trying to understand regional scale trends. We tried to overcome both of these challenges by discussing regional trends where possible but also acknowledging the variability across the Yukon and sharing local examples. Examples of local impacts and responses were sometimes sourced from news articles when relevant and where peer reviewed studies were not available.

4.2 Indicators

Climate is long-term expression of weather and is usually assessed by calculating average weather from thirty years, or more. Temperature increase is the most commonly cited indicator of climate change. However, while temperature remains a critical indicator, it is important to consider a broader range of data. The inclusion of multiple indicators provides a more complete picture of climate, the interconnection of different climate elements, and climate variability. Indicators were selected for inclusion in this report based on a set of criteria and characteristics:

Data quality:

- Has the data been collected in a systematic and standardized fashion?
- Is the source of the data reputable?

Accessibility:

- Is the data open and freely accessible?

Coverage:

- Geographic: Is there sufficient data for Yukon?
- Geographic: Is the data regionally influential for Yukon?
- Temporal: What is the length of time for the data series (given climate is a long-term average)?

Relevance:

- Is this data set representing a key component(s) of climate?
- Does it cover off one or more of the many sectors/aspects of climate change?

The best indicators are accurate, repeatable, unambiguous, and representative. One of the biggest challenges in understanding climate change is to differentiate between different signals:

- Weather (short-term variability) and climate (long-term trend and variability)
- Natural variations (e.g., ocean oscillations) and human-induced change (e.g., anthropogenic warming)
- Impacts due to climate change and impacts exacerbated by other stressors (e.g., habitat encroachment, fishing by-catch, etc.)

Each of the indicators is presented as a graph with a discussion of the indicator’s relevance. In section 6, each indicator is described through a standardized template. The source data, supporting documentation, and reference material are available in a digital library accompanying the *Yukon Climate Change Indicators and Key Findings* report and available upon request. Open data sources are useful so indicators can be updated regularly, and data can be shared and integrated into other research and analysis.

Indicators are not independent of one another. For example, temperature and precipitation can be closely related. Looking at a range of indicators will usually provide a more robust picture than just one indicator. However, data collection efforts for different indicators have not been consistent. Where relevant, details are provided below. When considering the indicators, both the trends and the variability in the data record are useful for understanding implications. It is important to look at the confidence/uncertainty and any limitations of the data as well. These are all listed in *Section 6: Detailed Indicators*.

4.3 Key Findings

Key findings are condensed, evidence-based conclusions. The key findings are derived from the indicators, scientific literature, and Indigenous knowledge. The purpose of the key findings is to allow readers to cross disciplines and to consider a range of conclusions being reached over the spectrum of knowledge. The key findings are also meant to provide coherent and concise information for decision makers. The goal is to provide findings which are relevant to diverse policies and programs.

Literature included in the 2015 version of the report was further developed with new publications, assessment reports, and other knowledge sources that have been published since then. The literature review included peer-reviewed research as well as reputable local reports. We have also included grey literature, news articles, and videos to capture Indigenous knowledge, government research, local knowledge, and policy. The *Compendium of Yukon Climate Change Science* produced annually by YukonU's Climate Change Research group was a useful source for identifying publications on climate change specific to the Yukon. Additionally, the authors of this report participated in the development of the *Yukon Climate Risk and Resilience Assessment* which arrived at findings that are consistent with those in this report.

Large-scale assessment reports, like *Canada's Changing Climate Report* (Bush & Lemmen, 2019), provide valuable information on broad changes that are being seen in Arctic and subarctic environments. Combining those national observations with locally relevant publications like Government of Yukon's *State of the Environment* report (2021b), and project-specific peer-reviewed research connects broad-scale findings to the Yukon environment. There are issues with assessment reports including the exclusion of certain types of knowledge like Indigenous knowledge and even social science perspectives (Ford et al., 2012). Another issue with assessment reports is that they provide broad, generalized overviews of climate change impacts. Often, however, changes can be localized or there can be regional variation. In this report we have tried to capture the Yukon-wide trends and a broad overview of the changes that can be expected, while also highlighting the variation that will happen across the Yukon and providing regional examples.

4.4 Limitations and Uncertainty

Uncertainty is a part of science and needs to be assessed and considered, as it is with each of the indicators (see *Section 6: Detailed Indicators*) and through the confidence ratings in the key findings. It is important to recognize that there is significant evidence, agreement, and confidence in the existing science indicating that climate change is happening and caused by anthropogenic emissions of greenhouse gasses. Some uncertainty will always remain in understanding climate systems, climate change, and projecting future climate variability.

For this report, we followed the approach of the IPCC based on their guidance to authors, "evidence is most robust when there are multiple, consistent independent lines of high-quality evidence" (Mastrandrea et al., 2010, p.2). We had subject matter experts review the key findings for completeness, accuracy, and consistency. They were asked to assess the validity of findings and assign a confidence level based on the available evidence, focusing on the type, amount, quality, and consistency of evidence. They were also asked to include their expertise and experience as a practitioner, scientist, and knowledge holder in assessing the confidence level. Not all reviewers provided confidence ratings, however, the final ratings are based on those reviews and overall support of the literature. Each key finding is assigned a level of confidence that reflects our current understanding of that finding on a scale ranging from very low, low, medium, high, to very high.

Climate change is occurring alongside other types of environmental change, including land use change, population growth, cultural shifts, harvesting pressures, pollution, and resource development. The complexity of these interrelated issues can increase uncertainty and make it challenging to separate cause and effect related to individual factors. It is important to consider climate change within the context of these interconnected factors because it will compound existing impacts and vulnerabilities (IPCC, 2022).

At the regional scale in the Yukon there is considerable variation in observed and projected climate change, influenced by topography, proximity to lakes, and differences in land cover (Bush & Lemmen, 2019). For the most part, this report communicates climate change at a regional scale, and may miss some of the variation that is seen across the territory. It is important to note that temperature and precipitation change will vary across the region, and the impacts of climate change on other systems may not be experienced to the same degree in different locations. This is particularly relevant to precipitation which varies greatly from year to year and by location. While the complexity of climate change can make it challenging to understand, understanding the risks associated with impacts (including likelihood, severity, capacity), and having a consistent treatment of uncertainties allows the reader to judge and even prioritize actions. For example, where we lack a clear understanding around a particular critical area, then a typical response might be to call for baseline monitoring or further research to refine our knowledge.

5.0 ANNOTATED FINDINGS

1. Climate
All indicators agree: The Yukon’s climate is now warming rapidly, and more change is projected. (Very high confidence)

The climate indicators listed in this report – temperature, precipitation, fire history, fire severity index, Arctic sea ice extent, and Arctic sea ice volume – all indicate a warming trend. The trends for fire history are not significant, meaning more data is required before we could be certain of using this information in a stand-alone fashion. Other indicator data that are available for specific locations in the Yukon not included here, but potentially useful for smaller-scale investigations of climate change include water (e.g., Dawson Yukon River break up, river discharge, snow water equivalent), soil moisture, greening, permafrost temperatures, among others (Box et al., 2019). All climate global circulation models (under all scenarios) project further warming for the Yukon, where temperatures are projected to continue warming at twice the global rate (ACIA, 2004; Bush & Lemmen, 2019; IPCC, 2021; UNEP, 2012).

The Pacific Decadal Oscillation (PDO) and Arctic Oscillation (AO) indicators show two of the dominant natural influences on Yukon climate. A positive phase of the PDO and a negative phase of the AO are associated with warmer temperatures in the Yukon. For the AO, a positive phase is brought about when circumpolar winds contain polar temperatures in the high north and is usually associated with colder winter temperatures in the eastern North and warmer winter temperatures in the West (Bush & Lemmen, 2019; NOAA, 2022a). These graphs show that until very recently, the PDO has been dropping – in a cooling phase since about 2007, and on a downward trend since about 1985. For the past two decades the AO has been mainly neutral, although in the past 5 years there has been a positive phase that has brought cold temperatures to some areas of the Arctic (NOAA, 2022a). Over this time period Yukon temperatures have continued to show a warming trend. The implication of the PDO and AO trends is that over the long term the anthropogenic influences of climate change are having a stronger effect than the natural influences of the PDO and/or AO. See *Detailed Indicators - 4.1 Ocean Oscillation Indicators*.

1.1 In the Yukon, annual average temperature has increased by 2°C over the past 50 years. (Very high confidence)

See the Climate Trends indicator based on Environment and Climate Change Canada's Climate Trends and Variations Bulletin (ECCC, 2021). The best fit trend line from 1972 to 2021 shows a +2°C increase in temperature, while between 1948 to 2021 shows a +2.5°C increase (ECCC, 2021). Throughout the Yukon, First Nations and the Inuvialuit have observed a warming trend (AICBR, 2016a,b; Brewster et al., 2016; Wolfe et al., 2011).

1.2 Temperature in the Yukon has increased at more than double the global rate and is increasing faster than in southern Canada. (Very high confidence)

Comparing Yukon's climate trend with the global temperature anomaly data available from the National Aeronautics and Space Administration (NASA) (https://climate.nasa.gov/vital-signs/global-temperature/) or National Oceanic and Atmospheric Association (NOAA) monthly global temperature anomaly index: (https://www.ncei.noaa.gov/monitoring-references/faq/anomalies.php#anomalies) demonstrates that the Yukon is warming at more than twice the rate of the globe (NASA, 2022; NOAA, 2022b). Over the past 50 years (1971-2020) the best fit trend line for NASA's dataset shows a +0.9°C increase in global temperature (NASA, 2022).

Taken as a whole, the Canadian North is warming at three times and Canada as a whole is warming at double the rate of the rest of the globe (Bush & Lemmen, 2019, ECCC, 2021; IPCC, 2019; IPCC, 2021). However, when we compare the Yukon to southern Canada, we find that the Yukon is warming about 1.5 times the rate of southern Canada. There is no strict definition of southern Canada, so an exact comparison is difficult; however, using ECCC's Climate Trends and Variations Bulletin, 2021, averaging the regions of Atlantic Canada, Great Lakes/St. Lawrence, Prairies, South B.C. Mountains and Pacific Coast, then, best fit trend line from 1972 to 2021 shows a +1.3°C increase in temperature, compared to +2°C increase in the Yukon.

1.3 Winters are warming more than other seasons: 4°C over the past 50 years. This is primarily expressed through a decreased frequency and severity of extreme cold events (i.e., below -40°C). (High confidence)

See the Climate Trends indicator based on ECCC's Climate Trends and Variations Bulletin (ECCC, 2021). Best fit trend line from 1972 to 2021 shows a +4.3°C increase in winter temperature in the Yukon. Higher elevations are also demonstrating more rapid warming, as evidenced in the St. Elias Mountains in western Yukon (Williamson et al., 2020). Warmer temperatures mean that at times winter precipitation is coming as rain. The Champagne & Aishihik First Nations (CAFN) have noted that due to warming winters, there is an increase in rain in winter, and this has been seen in other regions of the Yukon as well, which can have implications for foraging wildlife, trees and other vegetation, and travel on the land (CAFN, 2006; ArcticPeoples, 2013).

1.4 Annual precipitation in the Yukon increased by about 3% between 1966-2015. Summers and winters have seen the largest increase in precipitation (12-19% increase). Precipitation has more variability in the data record (both spatially and temporally); therefore, we have less confidence in determining this historic trend. (Low confidence)

See the Climate Trends indicator based on ECCC's Climate Trends and Variations Bulletin, 2015. Best fit trend line from 1966 to 2015 shows a +2.8% increase in precipitation. The standard deviation over that time period is ±8.17%. Best fit trend line from 1966 to 2015 shows a +19.3% increase in summer precipitation and a 12.1% increase in winter precipitation. However, as shown by the precipitation indicator, there is a lot of interannual variability with precipitation (Box et al., 2019). There are also considerable challenges with precipitation monitoring in the Yukon, particularly as weather stations have moved and data collection has become automatic requiring data reconciliation with past manual observations. ECCC has not reported precipitation trends and variations since 2016 because of issues with the data (ECCC, personal communication, September 14, 2018), however their existing data is the best available Yukon-wide annual precipitation data. Yukon First Nations have also observed increases in precipitation across the Yukon, although CAFN and the Inuvialuit have both noted a decrease in snow in their respective territories (Alaska Science for All UAF GI, 2022; Brewster et al., 2016; CAFN, 2006).

Precipitation in Canada increased by 20% from 1948-2012 and increased more in northern Canada (32.5% between 1948-2012) than in southern Canada (Bush & Lemmen, 2019). Using ECCC's Climate Trends and Variations Bulletin, 2015, from 1948-2015 precipitation in Yukon changed by +11.8% with a standard deviation of ±9.23%, so overall less than in Canada as a whole.

1.5 Increasing global concentrations of carbon dioxide and other greenhouse gases are projected to contribute to a continuing increase in annual temperature and precipitation across all scenarios. Annual warming in the Yukon is projected to be an additional 0.7 to 3.7°C over the next 50 years. Precipitation is projected to increase 4 to 17% over the next 50 years. (Medium confidence)

Currently global greenhouse gas emissions (GHGs) continue to rise and will continue to cause further warming in the future (Bush & Lemmen, 2019; IPCC, 2021). There is a certain amount of future climate change that will happen based on past emissions, regardless of current and future emission reductions (IPCC, 2021). Temperature, precipitation and precipitation intensity are projected to increase in the Arctic, with increased frequency of heavy precipitation events (Bush & Lemmen, 2019; IPCC, 2021). There will continue to be variability from year to year, particularly with precipitation which can also vary significantly within different regions of the Yukon.

Projections are based on results from climate models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Programme using representative concentration pathways (RCPs) from the IPPC fifth Assessment Report (AR5). Three RCPs are included; RCP2.6 is for a low greenhouse gas emission future based on a high level and effectiveness of emission reduction policies, while RCP8.5 is for a high greenhouse gas emission future without measurable progress in policies to mitigate climate change (IPCC, 2019). RCP4.5 is an intermediate greenhouse gas emission future with improved mitigation policies that falls between 2.6 and 8.5. The best fit trend line from 2005 to 2100 shows a +0.4°C/decade increase in temperature using data based on RCP4.5. For more information see the Climate Projection indicators based on data supplied by ECCC on Climatedata.ca. While there is inherent uncertainty in climate models, they provide credible estimates of future climate change, particularly at larger scales. These models represent current understanding of physical, chemical, and biological processes and have demonstrated the ability to accurately reproduce observed features of current and past climate (IPCC, 2014). Despite improvements from the AR4 model projections used in the previous version of this report, there is still a range of confidence in model estimates depending on the climate variable (e.g., higher confidence for temperature than precipitation) (IPCC, 2014). With the upcoming release of the Sixth Assessment Report, improved climate projections are expected to be released based on CMIP6 (IPCC, 2021).

1.6 Increasing evapotranspiration and a lengthening of the shoulder seasons are among the projected changes that are likely to persist for the foreseeable future. (High confidence)

In the Yukon, it is possible that evapotranspiration increases will happen faster than precipitation increases, meaning that more rain will not necessarily result in more ground moisture (Bush & Lemmen, 2019; ECCC, 2021). Some areas of the Yukon may experience drier conditions, while others may be wetter. Loss of soil moisture and drier conditions have already been observed by Yukon First Nations (Alaska Science for All UAF GI, 2022; ArcticPeoples, 2013; CAFN, 2006; KFN, 2014; Wolfe et al., 2011). Changes to seasons are already being observed in the Yukon, with winter arriving later and spring arriving earlier. This change in seasonality is a direct consequence of warming spring and autumn seasons (Bush & Lemmen, 2019; ECCC, 2021). An increase in frost-free days is expected in the future and will have implications for wildlife adapted to cold weather. It may be favourable for some vegetation and provide opportunities for agriculture, although an increase in evapotranspiration and less moisture availability would also affect growing seasons. With regional precipitation variability, these opportunities will depend greatly on local conditions. For information on climate projections see *Detailed Indicators - 1.2 Climate Projections.*

1.7 Additional evidence of northern warming comes from widespread melting of glaciers and sea ice, and permafrost thaw. (High confidence)

See full references below in *Key Finding 2 – Melt and Thaw*.

1.8 Beyond the historic and projected trends, the variability of our climate is expected to increase. This will mean an increase in extreme weather events and greater fluctuations in precipitation. (Medium confidence)

Globally, there have been observed increases in extreme weather events, including temperature extremes, heavy precipitation, and rain in winter (IPCC, 2021). Extreme heat events have increased in the Arctic over the past 20 years, while minimum temperatures have increased at three times the global rate (IPCC, 2021). While an overall increase in precipitation is expected in the North, extreme precipitation events, which could include torrential rains or rain in winter, are also likely to increase (IPCC, 2021). Of particular concern are intense rains that coincide with spring melt, leading to intensified spring freshets and potential flooding and road washouts (see *Indicator 2. Water* for more information).

1.9 Unexpected and even larger shifts in the climate system are possible. (Medium confidence)

Due to already existing greenhouse gas levels, there is a certain amount of future change that is unavoidable. Different aspects of the climate system may respond at different rates of change to temperature change (IPCC, 2021). There are also tipping points in the climate system that once they are crossed can't be uncrossed on timescales relevant to society, leading to irreversible change. Examples of irreversible changes include permafrost thaw, glacier melt, and other changes in the cryosphere (IPCC, 2021). The ocean has warmed at a rate that doubled in the past thirty years (IPCC, 2019), and that warming, will create ongoing change for a while (IPCC, 2019; IPCC, 2021). Ocean acidification and sea level rise will continue to change, although there will be regional differences in sea level rise (IPCC, 2019). Permafrost will also continue to thaw in the future based on existing warming and emissions.

2. Melt and Thaw

Permafrost is thawing, glaciers are receding, and sea ice is melting. (High confidence)

Warmer temperatures have resulted in widespread melting of glaciers and sea ice and the rate of melt is increasing (Box et al., 2019; Bush & Lemmen, 2019; IPCC, 2019; IPCC, 2021; Shugar & Clague, 2018). Warming and thawing of permafrost is projected to continue (AMAP, 2021a; Bush & Lemmen, 2019; IPCC, 2019; Smith et al., 2022). The St. Elias icefields in Southwest Yukon have shown retreat in glacier fronts and volumes contributing to global sea level rise, and potentially to slope instability (Barrand & Sharp, 2010; Derksen et al., 2012; IPCC, 2021; Larsen et al., 2015; UNEP, 2012). The Arctic Ocean is projected to be summer-ice-free this century (Box et al., 2019; Bush & Lemmen, 2019; IPCC, 2019; IPCC, 2021).

2.1 Warmer temperatures have resulted in widespread melting of glaciers and sea ice, and the rate of melt is increasing. Winter ice coverage of rivers and lakes is decreasing. (High confidence)

Yukon's glaciers lost 22% of surface area in 50 years, between 1957-58 and 2007-08, and have experienced rapid losses since then, contributing to increased river flow and global sea level rise (Barrand & Sharp, 2010; Derksen et al., 2012; IPCC, 2021; Larsen et al., 2015). In the St. Elias mountains, glaciers are predicted to lose 60-80% of their total volume by 2100 (Chesnokova et al., 2020). Since glaciers store a large volume of water, changes to glaciers can have large impacts to downstream hydrology (Chesnokova et al., 2020, Shugar et al., 2017, Ochwat et al., 2020). In 2016 the Kaskawulsh Glacier, the primary tributary of the Ä'äy Chù (Slims River), was diverted into the Kaskawulsh River which drains into the Alsek River and eventually the ocean. This greatly reduced the discharge of the Slims River causing summer peak levels in Łù'àn Män (Kluane Lake) to fall 1.5 to 2.0 m below the historical mean record, prevented glacial meltwater sediments from Ä'äy Chù from entering Łù'àn Män with potential impacts on water quality, and altered the discharge and water levels in downstream rivers (e.g., the White River watershed, a tributary of the Yukon River). These effects ultimately combine to drive large scale landscape and ecosystem changes (Shugar & Clague, 2018; Shugar et al., 2017; Southwick & Ballegooyen, 2019). For Kluane First Nation (KFN) these changes mean adapting to changing lake levels and adjusting their traditions around fishing and lake travel (Southwick & Ballegooyen, 2019).

Changes to river and lake ice regimes have also been observed, with climate change extending the open-water period and reducing the period of ice coverage in winter (Box et al., 2019; Government of Yukon, 2021b). The breakup date on the Yukon River in Dawson has advanced by 7 days on average since 1896 (Government of Yukon, 2021b). Warmer autumn temperatures have led to later freeze up on lakes, including Łù'àn Män (Kluane Lake) (Southwick & Ballegooyen, 2019). With longer open-water periods, strong winds and associated wave action cause increasing erosion along shorelines. This impact is especially noted on lakes where water levels are regulated as lakes are held at high water levels when wind speeds are at their seasonal maximum. (Bush & Lemmen, 2019; McKillop et al., 2019; McKnight, 2017).

2.2 Permafrost rates of thaw are increasing. Warmer air temperatures are increasing ground temperatures throughout Yukon. (High confidence)

Permafrost thaw typically occurs through an increase in the depth of the active layer, the layer of earth between the ground surface and permafrost that freezes and thaws seasonally. The rate of change is influenced by climate factors like increasing temperature and rain, as well as by local biophysical factors such as forest cover, active layer depth, thickness of cryosols, soil composition, and local ground disturbance. Long-term monitoring shows that permafrost temperatures are warming at almost all monitoring sites across North America (Box et al., 2019; IPCC, 2019; Smith et al., 2010; 2019; 2022) and the active layer continues to thicken (Stockton et al., 2019; Smith et al., 2022).

Evidence of permafrost thaw is being observed across the North and the Yukon, with impacts on natural environments and built infrastructure (AMAP, 2021a; Bush & Lemmen, 2019; Calmels et al., 2015; IPCC, 2019). Thermal erosion, thermokarst, retrogressive thaw slumps, and degradation of palsas and ice wedges can have dramatic impacts on the landscape (Calmels et al., 2021; Kokelj et al., 2015; Nitze et al., 2018; Ramage et al., 2017; Smith et al., 2019). Yukon First Nations have observed the impacts of permafrost thaw on local ecosystems and travel routes, and in many Yukon communities, permafrost thaw has affected local housing and infrastructure (AICBR, 2016a; AICBR, 2016b; ArcticPeoples, 2013; Calmels et al., 2016; Laxton & Coates, 2011). Thawing permafrost can mobilize mercury stored in frozen soils, which can then enter aquatic systems (Mu et al., 2019; Staniszewska et al., 2022; Zdanowicz et al., 2018) and may become a concern for traditional food security.

All of Yukon lies within the permafrost zone with approximately 50-60% of the territory predicted to be underlain by permafrost (Bonnaventure et al., 2012; Heginbottom et al., 1995), so changes to permafrost can have far reaching implications for Yukon landscapes and systems. Changes to permafrost are already impacting the microtopography of the landscape (e.g., with slumping or thawing of ground ice) which drives changes to vegetation communities and can ultimately have implications for the larger ecosystem (Wolter et al. 2016). Thawing permafrost contributes to increased winter water flow and changes to lake ecosystems in the continuous and discontinuous permafrost zones (Crites et al., 2020; Warren & Lulham, 2021). It can cause some areas to become wetter, even creating new wetlands, yet in other areas it can cause lakes and wetlands to drain (ACIA, 2004; Warren & Lulham, 2021). For more discussion on this see *Key Finding 3. Water*.

Wildfire speeds up permafrost thaw by removing the insulating vegetation layer on top of the ground. With the potential for increasing wildfire in the future, there could be accelerated impacts on permafrost and active layer thickness, contributing to destabilizing slopes and landscape change (Benkert et al., 2015; Blais-Stevens et al., 2011; Coates & Lewkowicz, 2008; IPCC, 2019; Lipovsky et al., 2006; Michaelides et al., 2019; Northern Climate ExChange, 2013; UNEP, 2012).

2.3 Thawing ground is already disrupting transportation networks, buildings, and other infrastructure, and will continue to do so in the future. Permafrost thaw has potentially serious implications for mine dams and tailing ponds that are dependent on permafrost berms. (High confidence)

Permafrost degradation will disrupt transportation, buildings and other infrastructure as it thaws. Developed areas like cleared land, roadways, buildings, mine dams and tailing ponds are particularly vulnerable to permafrost changes (Calmels et al., 2016; EBA Engineering Consultants Ltd., 2004; Laxton & Coates, 2011; Mohammadimanesh et al., 2019). While some of these changes are already happening, it is expected that the magnitude and frequency of permafrost thaw will continue to increase (Patton et al., 2019). See more information in *Key Finding 6 – Hazards and Infrastructure*.

2.4 Permafrost thaw is altering the release and uptake of greenhouse gases from soils, vegetation, and coastal areas with implications for the global carbon cycle. (Medium confidence)

Permafrost thaw has implications for the global carbon cycle. Greenhouse gases are released as thawed organic material breaks down, contributing to the acceleration of climate change (ACIA, 2004; Schaefer et al., 2014; Schuur et al., 2015). This thaw also drives increased coastal erosion. It is estimated that the Yukon's northern shoreline is retreating at the mean rate of 0.7 metres per year across the Yukon, with some locations losing as much as 9 metres per year (Couture & Pollard, 2017; Couture et al., 2018). Terrestrial carbon inputs into the ocean from eroded coastlines, compounded with changing ocean temperatures, reduce the capacity of the ocean to absorb atmospheric carbon which will also have impacts on the global carbon cycle (Couture & Pollard, 2017; Couture et al., 2018).

2.5 Arctic sea ice is melting rapidly, the majority of multi-year ice has been lost in the last ten years alone. (Very high confidence)

Arctic sea ice has seen increasing melt with a loss in both summer extent and volume (IPCC, 2019). Current Arctic sea ice is at its lowest level since 1850 with large volume losses since 2012 and it is expected that practically ice-free conditions will be experienced at least once before 2050 (Box et al., 2019; IPCC, 2019; IPCC, 2021). Mean arctic sea ice thickness continues to decrease as thick, multi-year ice is replaced with thinner seasonal ice in winter (IPCC, 2019; Lindsay & Schweiger, 2015). The overall ice extent has decreased significantly since 1979 and Arctic summer sea ice losses have been happening faster than models projected (Bush & Lemmen, 2019; IPCC, 2021). Additionally, sea ice has become more mobile and is easily disturbed by wind and waves, reducing the overall strength and increasing deformation (Liu et al., 2019). Inuit have observed changes in sea ice, affecting access to traditional travel routes and safety on the ice (Ford et al., 2019). Arctic sea ice has been observed since the late 1970s using satellite data. Using 1980-2009 as a baseline, and then comparing the last ten years (2012 to 2021), the sea ice minima (comparing each year when the sea ice is at its annual minimum extent in September) has decreased significantly. Ice extent has gone from 6.5 million km2 to 4.6 million km2, or a loss of 29% in the last decade (Fetterer et al., 2017; National Snow and Ice Data Center, 2022). Ice volume has gone from 12.4 thousand km3 to 4.9 thousand km3, or a loss of 60% in the last decade (Schweiger et al., 2011; Polar Science Center, 2022; Zhang & Rothrock, 2003). The Inuvialuit have observed changes to sea ice near the North Slope of the Yukon, noting the negative impact this has on their ability to travel by sea ice (Brewster et al., 2016; Helander & Mustonen, 2004). They have also identified increases in coastal erosion in areas that are seeing reduced ice cover and increasing wave action.

2.6 A reduction in sea ice, as well as changes to snow cover, reduces the albedo of the North and allows oceans and land masses to absorb more solar energy. This largely drives the increased warming rates observed in the North compared to the rest of the globe and has implications for the global climate. (High confidence)

Declining sea ice and reduced snow cover drive a positive feedback loop. As the area of sea ice declines, less solar energy is reflected, further warming the atmosphere which in turn reduces sea ice even more. The Beaufort Sea is projected to have long ice-free periods in summer by mid-century (Bush & Lemmen, 2019). The length of season in which the Northwest Passage and Northern Sea Route are open to navigate is projected to increase by more than 150% (DeRepentigny et al., 2016). Loss of summer sea ice will contribute to continued increases in Arctic temperature and may contribute to changes in the climate of North America, including increased frequency of extreme weather events (Cohen et al., 2014; DeRepentigny et al., 2016; Francis & Vavrus, 2015; IPCC, 2019; Liu et al., 2019). A seasonally ice-free Arctic Ocean can have far reaching consequences for Arctic ecosystems as well. Longer open water seasons, earlier winter ice breakup, increased wave height and atmospheric warming contribute to coastal erosion creating a positive feedback loop. Atmospheric warming increases permafrost temperature and deepens the active layer which lowers energy requirements for it to thaw, making permafrost laden coast lines more vulnerable to impacts of reduced sea ice and larger waves (Couture et al., 2018; Cunliffe et al., 2019).

Spring snow cover days have declined by 6-8 days since 1948 in southwest Yukon (Chesnokova et al., 2020), although this trend is being observed throughout the territory with decreasing snow cover mainly being driven by earlier spring melt (ACIA, 2004; Box et al., 2019; Bush & Lemmen, 2019). Rain on snow events, unseasonal thaws and early snow melt events are also becoming more common in the Arctic (Bokhorst et al., 2016; Box et al., 2019). While these changes drive local warming, there has been some evidence that they influence extreme weather events across the Northern Hemisphere mid-latitudes, although this is an area that requires more study (Cohen et al., 2014; Cohen et al., 2020; Romanowsky, et al., 2019).

3. Water
Climate change is affecting and will continue to affect the hydrological regime. (High confidence)

Changes in the hydrological regime in Yukon are already being observed and are projected to intensify with future climate change, including changing water quality and water-course flows, timings, and volumes (Environment Yukon, 2011; Warren & Lulham, 2021). Changes to water and the hydrological regime have implications for flooding and the integrity of infrastructure, recreation and tourism, relationships to the land, and other aspects of Yukon life (Environment Yukon, 2011; KFN, 2014; NRTEE, 2009; Wolfe et al., 2011). The hydrologic cycle is complex and demonstrates significant natural variability, however, the fluctuations in precipitation and increases in streamflow that have been observed are outside the natural range of variability (Environment Yukon, 2011). “Climate change is intrinsically linked with hydrological changes” (Environment Yukon, 2011, p.ii), but the impacts vary across different regions in the Yukon. Changes in the hydrological regime in the Yukon are affected by changes in temperature, precipitation, glacial melt, permafrost degradation, earlier snowmelt, and freeze-thaw cycles.

3.1 Changes in the hydrological regime are driven by changes in temperature and precipitation and affected by other processes including increasing glacial melt, permafrost thaw, variability in rain and snow, earlier snowmelt, and freeze-thaw cycles. (High confidence)

Trends and projections in precipitation show more interannual and spatial variability than temperature and other temperature-related indicators (Environment Yukon, 2011; ECCC, 2021; IPCC, 2021). Although the trend shows increased precipitation in the Yukon overall, changes have not been consistent in all areas of the Yukon (Janowicz, 2010). Projections for precipitation in the Yukon indicate that it will increase, particularly in winter (Environment Yukon, 2011; Warren & Lulham, 2021). See *Indicators 1.1* and *2.1* for more information on temperature and precipitation in the Yukon. While increases in precipitation have been observed and are projected in the future, the available data is the result of tools that show inconsistency in measurement accuracy (Scaff et al., 2015), making it difficult to reliably project precipitation in the future or have significant confidence in the magnitude of observed trends. In general, the Yukon is expected to be wetter in the future, however regional variability and variability from year to year will continue. Water availability could be an issue during the growing season in some areas of the Yukon if increased precipitation does not compensate for increasing temperatures and evapotranspiration, with implications for wildfire risk, vegetation growth, and agriculture (IPCC, 2022).

Changes in the hydrological response that have been observed include changing precipitation patterns, more intense and extreme precipitation, shorter snow cover and ice cover seasons, changes in runoff and soil moisture, changes in vegetation, and changes in evapotranspiration (Bates et al., 2008; Box et al., 2019; IPCC, 2019). Warming temperatures have resulted in earlier snow melt and shorter overall snow cover and ice cover seasons (Government of Yukon, 2021b). Streamflow patterns are changing; however, there is variability among watersheds, seasons, and between tributaries and major rivers (Chen & She, 2020; Environment Yukon, 2011; Janowicz & Hinzman, 2019; Warren & Lulham, 2021). It is projected that many rivers in the Yukon will continue to see increased winter flows which can be linked to both precipitation trends and shorter winters with occasional mid-winter runoff (Environment Yukon, 2011; Janowicz & Hinzman, 2019; Warren & Lulham, 2021).

3.2 Flood risk is influenced by multiple processes that are affected by climate change. Flood risk is expected to increase in some locations in the Yukon, while it may decrease in others. (High confidence)

There are multiple processes that affect flood risk in the Yukon, including rain and storm events, rain on snow, spring freshets, ice jams, and glacial melt. Rain and storm events are expected to increase with climate change, as is winter precipitation which creates a bigger snowpack (Environment Yukon, 2011; Warren & Lulham, 2021). At the same time, a shorter period of snow cover is expected and earlier spring melt (Bush & Lemmen, 2019; Environment Yukon, 2011; Warren & Lulham, 2021). With increased snowpack, rain on snow events, and earlier melt, earlier peak flows and more intense spring freshets are likely. Depending on timing and interaction with river break up (see *Key Finding 3.4*), these changes may contribute to increased frequency and magnitude of floods in some areas (Environment Yukon, 2011; Janowicz & Hinzman, 2019; Warren & Lulham, 2021). This is more of a concern for rivers that are showing increases in peak flows and annual discharge. Some major Arctic rivers are showing increases in annual discharge and peak flows, including the Yukon River, Peel River, and Alsek River (Box et al., 2019), while others are showing reduced peak flows, including the Liard River and Pelly River. Monitoring on the Ross River, Takhini River, and White River all show decreasing trends in annual maximum flow (Government of Yukon, 2021b).

3.3 As the Yukon’s glaciers continue to recede, glacial melt will contribute to increased river discharge and will have significant impacts on glacier dominated basins. (High confidence)

The cryosphere plays an important role in Yukon’s water resources and is particularly vulnerable to climate change as evidenced by the dramatic loss of glacial cover over the last 75 years (see *Key Finding 2 Melt and Thaw*) (Barrand & Sharp, 2010; Derksen et al., 2012; Environment Yukon, 2011; Shugar & Clague, 2018). Increased glacial melt will have significant impacts on glacier dominated basins, but the impact of glacial inputs will vary among watersheds (Chesnokova et al., 2020; IPCC, 2021; Larsen et al., 2015; Shugar & Clague, 2018; Shugar et al., 2017). As a dramatic example, changes in the Ä’äy Chù (Slims River) watershed, where the summer freshet has been reduced significantly, have considerably affected water levels in Łù’àn Män (Kluane Lake) (Shugar & Clague, 2018; Southwick & Ballegooyen, 2019). However, southwestern Yukon is generally seeing increasing discharge related to increased precipitation and glacial inputs (Janowicz & Hinzman, 2019; Parrott et al., 2017; Warren & Lulham, 2021).

3.4 Breakup is occurring earlier for rivers in the Yukon, which can have implications for ice jams and flooding. (Medium confidence)

Spring breakup is happening earlier in most large rivers of Yukon, including the Yukon River at Dawson City and Ch’oodeenjìk at Old Crow (Government of Yukon, 2021b; Janowicz, 2017). The impact of this change on the frequency and intensity of ice jam floods is still uncertain (Turcotte, 2021). Breakup in the Yukon is mainly driven by air temperatures, snowpack, winter intensity (i.e., coldness), and fall precipitation. The ice cover season is becoming shorter (Government of Yukon, 2021b) and mid-winter break up events, which can lead to flooding, have been observed (Janowicz, 2010). However, climate change and associated weather anomalies seem to generate impacts on river ice breakup parameters that cancel each other, therefore supporting current observations about the absence of a defined trend in the frequency of ice-jam floods for large rivers (Turcotte et al., 2019; Turcotte, 2021). Smaller rivers respond faster to variable weather conditions and are more often affected by spring ice jams. Spring break-up usually occurs before the snowmelt freshet, however changes in snowmelt timing have been observed bringing those two events closer together (Janowicz, 2017). It is expected that warmer winter temperatures and increased rain in winter could cause mid-winter breakup events in small and steep river systems like the Klondike River (Janowicz, 2010), and eventually could affect larger systems further north.

Mid-winter breakup events can cause flooding but can also increase the likelihood of spring breakup floods, and related impacts on infrastructure, public safety, and aquatic ecosystems can be expected in the future (NRTEE, 2009). Koyukon Athabascan knowledge of the Yukon River system from near Fairbanks indicates that ice is not as thick and there are places on the river that remain ice-free, impacting winter travel (Wilson et al., 2015). Winter-long, ice-free areas along rivers of Yukon may also be explained by altered river ice formation patterns that could result from a changing climate (Turcotte, 2020). Flooding, riverbank erosion, and infrastructure damage will continue to represent concerns with river flooding, especially in small river systems (NRTEE, 2009).

3.5 Permafrost thaw affects river and lake systems in the Yukon. Permafrost degradation contributes to an increased groundwater reservoir and changing streamflow and groundwater flow patterns. (High confidence)

Changes to the active layer with permafrost thaw mean that more groundwater is entering surface streamflow (Crites et al., 2020; Environment Yukon, 2011; Janowicz & Hinzman, 2019; Prowse, 2009), a process confirmed in the Yukon River Basin and Ch’oodeenjìk (Porcupine River) (Environment Yukon, 2011). Similar changes have been observed in the Northwest Territories, with permafrost thaw contributing to higher stream discharge (Crites et al., 2020; St. Jacques & Sauchyn, 2009). Changes to streamflow and groundwater flow patterns include increased winter low flows. Northern parts of the Yukon are seeing increasing winter discharge related to permafrost interactions and increased precipitation (Janowicz & Hinzman, 2019; Warren & Lulham, 2021), however this is an area that could benefit from more research (McKenzie et al., 2021).

Some Yukon lakes are also seeing significant changes due to permafrost thaw; in areas of discontinuous permafrost lakes may be shrinking or disappearing, whereas in areas of continuous permafrost they are often expanding due to water inputs (UNEP, 2012; Warren & Lulham, 2021). Across the Yukon, First Nations have observed changes in lakes, including lower water levels and the disappearance of waterbodies (AICBR, 2016a; ArcticPeoples, 2013; CAFN, 2006; KFN, 2014). In the Old Crow Flats the Vuntut Gwitchin have observed dynamic lake changes with some lakes draining and drying, while new lakes appear, or existing lakes grow larger (Alaska Science for All UAF GI, 2022; Kassi et al., 2010; Lantz, 2017). Overall, the area is getting wetter with rainfall and permafrost thaw as the main contributors (MacDonald et al., 2021). With projections for widespread permafrost thaw in the future, there will be significant implications for northern hydrology (IPCC, 2019; IPCC, 2021; UNEP, 2012).

3.6 Warming temperatures, permafrost thaw, and changes in water levels negatively impact water quality through increased turbidity and in some cases through increased contaminant levels. (Medium confidence)

Changing water levels, increasing precipitation, landslides, permafrost thaw, and erosion, which vary across the Yukon, all contribute to water quality issues (Bates et al., 2008; Environment Yukon, 2011). Where there is increased rainfall and snowfall, more runoff delivers a higher load of sediments to rivers (Platts et al, 1989). In some parts of the Yukon, increasing landslides and erosion also affect sediment concentrations in rivers and lakes. Increased sediment loads and turbidity can affect fish habitat, particularly affecting salmon (Dornblaser & Striegl, 2009) which are an important species for Yukon First Nations. With higher discharge in the summer there can be faster moving water and more debris in the water, which can reduce the ability of Chinook fry to forage (Neuswanger et al., 2015). Sediment deposition can affect habitat by changing channel morphology and spawning beds (Platts et al., 1989), decreasing growth and survival rates for juveniles (Suttle et al., 2004), and reducing survival rates of incubating embryos by affecting oxygen availability (Greig et al., 2005). Fine sediments in water affect primary productivity which has implications for the rest of the food chain (Wood & Armitage, 1997). Higher water temperatures can also affect water quality by creating conditions conducive to the growth of cyanobacteria, which has implications for ecosystem and human health (Bates et al., 2008; Environment Yukon, 2011; Warren & Lemmen, 2014).

Permafrost thaw and changes in groundwater flow can alter water chemistry, with implications for fish, wildlife, and human health. Permafrost thaw can release contaminants into both groundwater and surface water, and this is expected to increase with a changing climate (Colombo et al., 2018). This process is dependent on landscape and geomorphic factors, as well as local temperature and precipitation change (Staniszewska et al., 2022). The release of contaminants into rivers and lakes through landslides, erosion, and permafrost thaw is a concern, particularly if there is uptake by fish which are then being consumed by people. Mercury is a contaminant of concern in the Arctic and levels in rivers and lakes have been correlated with thawing permafrost (Mu et al., 2019; Schuster et al., 2011a; Zdanowicz et al., 2018). Recent research developed a baseline understanding of arsenic and uranium in the Dawson City area, noting the potential for permafrost thaw to contribute to water concentrations and advising ongoing monitoring for change (Skierszkan et al., 2020). In the Chyàh Njìk (Old Crow River), which has low mercury and lead quantities on average, concentrations show short-term increases related to erosion during periods of freshets and high rainfall indicating that potential increases in precipitation could affect contaminant levels (Staniszewska et al., 2022). While we have some confidence that these changes are happening, this is an area that is understudied in the Yukon. In particular, the movement of contaminants from permafrost to water bodies is an under researched topic (Colombo et al., 2018). More research is needed to monitor both physical and chemical changes in rivers and lakes, to understand the processes causing these changes, and to identify the implications for ecosystem services (McKenzie et al., 2021).

4. Vegetation

Vegetation community distribution and composition are shifting. (Medium confidence)

Large scale vegetation changes are being observed in the North and are expected to have wide-ranging implications across tundra and boreal ecosystems. These changes affect biodiversity, ecological interactions, and have implications for nutrient cycling (ACIA, 2004; Aitken et al., 2008; Bjorkman et al., 2020; CAFF, 2010; Gienapp et al., 2008; Myers-Smith et al., 2019; Myers-Smith et al., 2011; Reid et al., 2022; Rowland et al., 2016; Warren & Lulham, 2021). Warming temperatures, changes in precipitation, snow cover, permafrost thaw, tundra and forest fires, intensity of herbivory, and land development all contribute to vegetation change (ACIA, 2004; Box et al., 2019; Furgal & Prowse, 2008; Hinzman et al., 2005; Myers-Smith et al., 2019; Myers-Smith et al., 2011; Reid et al., 2022; Warren & Lulham, 2021).

Shifts in range of individual species are a mechanism for adapting to climactic changes, but are not well understood in plant species, particularly in the Yukon (Aitken et al., 2008). Shifting distributions and grassland advances, as well as local-scale biodiversity changes, are projected in the future (Aitken et al., 2008; Bjorkman, 2013; Bjorkman et al., 2020; Gienapp et al., 2008; Rowland et al., 2016). Changes in species distribution are already being observed including treeline advancement (Bjorkman et al., 2020). Changes to vegetation spatial distribution will depend on how existing species respond to climactic changes and can have impacts on ecosystem dynamics (Warren & Lulham, 2021).

4.1 Treeline and shrubs are expanding rapidly in distribution and community dominance. They are moving to higher latitudes and elevations as well as infilling within current range. (High confidence)

Shrubification and treeline advance have already been observed in the Yukon, and grassland advances are expected in the future (Aitken et al., 2008; Bjorkman, 2013; Gienapp et al., 2008; Rowland et al., 2016). The treeline has moved northward in latitude and upward in elevation as the forest expands into areas that were previously northern tundra or alpine environments, as well as infilling at treeline (Assmann, et al., 2020; Box et al., 2019; Danby & Hik, 2007a,b,c; Myers-Smith et al., 2019; Myers-Smith & Hik, 2018). These changes are due to the effects of climate change including longer growing seasons, warmer soil temperatures, increased active layer depth, and in some areas, increased precipitation (CAFF, 2010; CAFN, 2006; Myers-Smith et al., 2019; Myers-Smith & Hik, 2018; Parrott et al., 2018; Warren & Lemmen, 2014). Increased growth and expansion of shrub and tree communities is also happening in forests and forest grassland ecotones

(Conway & Danby, 2014; Grabowski, 2015). Satellite imagery has shown significant greening in the northern regions of the boreal forest including the Yukon (Berner & Goetz, 2022). Shrub advance is happening faster than treeline advance (Brown et al., 2019), with shrubs and other taller, denser vegetation showing doubling of average plant canopy height per decade and doubling of abundance (Myers-Smith et al., 2019). Changes in tree growth and treeline advance are limited by moisture more so than air temperature, so while warming temperature plays a role, seasonal precipitation impacts seed production and ultimately range expansion. (Brown et al., 2019; Dearborn & Danby, 2018). Shrubification will have implications for herbivores, as well as for snow distribution and, ultimately, albedo (Elmendorf et al., 2012; Myers-Smith et al., 2011).

The Inuvialuit have observed increased shrub growth in the North Slope where it has made travel on the land more difficult (Brewster et al., 2016; Merculieff et al., 2017). The Vuntut Gwitchin have also seen increased willow growth in the Old Crow Flats. Willows have the potential to alter ecosystem dynamics in areas within the Old Crow Flats with deep cultural significance (AICBR, 2016b; ArcticPeoples, 2013; Kuntz et al., 2018). Several Yukon First Nations have observed changes to vegetation, including more willows in areas that are already wet or are shifting to wetter soil moisture regimes (ArcticPeoples, 2013; Brewster et al., 2016; Furgal & Prowse, 2008; Kuntz et al., 2018; Merculieff et al., 2017).

4.2 Changes in vegetation phenology (timing of biological phenomena) are being observed and will continue, with implications for numerous species. (High confidence)

Changes in phenology have been observed in areas with rapid temperature warming and earlier spring snowmelt, with plants flowering and senescing earlier, and trees budding in winter (Bjorkman, 2013; Bjorkman et al., 2020; CAFN, 2006; Choi et al., 2010; Oberbauer et al., 2013; Potter & Alexander, 2020; Warren & Lulham, 2021). Vegetation communities are greening earlier in the spring, currently at a rate of 9 days earlier per decade (Myers-Smith et al., 2019). Champagne and Aishihik First Nations have observed trees budding earlier on their traditional territory (CAFN, 2006; Merculieff et al., 2017). Snow melt in the North is happening earlier in spring, exposing the ground to warming and earlier plant growth (Choi et al., 2010), which can subsequently affect animal activity and behaviour (Severson et al., 2021). However, there is regional variability in regard to changing snowmelt phenology (Littell et al., 2018). Phenological mismatch is a potential implication of climate change, including flowering periods not coinciding with pollinating activity (Byers, 2017; Straka, 2012), or vegetation growth not happening at the same time as animal activity or migration (Gustine et al., 2017; Post & Forchhammer, 2007). Phenological mismatch is an area that is under researched in the Yukon.

4.3 Increases in temperature are already causing drought stress in some species in the Yukon. (Medium confidence)

The direct effects of changing temperature and precipitation patterns are the dominant climactic considerations for vegetation. Boreal forests in the Yukon are experiencing changes at the community and ecosystem level, with plant productivity increasing in some areas due to increasing temperatures and longer growing seasons but declining in areas where plant productivity is limited by reduced precipitation (Boonstra et al., 2018; Reid et al., 2022). Despite a general lack of quality precipitation data in the Yukon, there is evidence of significant regional and inter-annual variability in precipitation currently. While projections for the Yukon are for increased precipitation in the future, continued variability is expected. There will be risk of drought stress in regions where precipitation increases do not compensate for increasing evapotranspiration. Increasing temperature is already inducing drought stress in some areas and is a limiting factor in regeneration of native species in disturbed areas (Hogg & Wein, 2005; Lister, 2010; Price et al., 2013; Reid et al., 2022; Strong, 2017). An increase in temperature without a corresponding increase in precipitation would likely lead to changes in vegetation such as a shift from deciduous forest to grasslands, or from spruce forest to deciduous (Price et al., 2013; Strong, 2017).

4.4 Insect outbreaks that kill canopy trees or significantly reduce their growth have affected significant portions of the Yukon and will continue to do so. (High confidence)

Two of the main climate change-related forest health threats monitored by the Forest Management Branch are spruce bark beetle and mountain pine beetle, both insect disturbances that are directly linked to climate change (Energy, Mines and Resources, 2021). Another concern for Yukon forests is the dieback of aspen which is partly due to drought. The dieback of aspen is also impacted by the expansion of pests like the serpentine leafminer which is associated with climate change (Boyd et al., 2021). Aspen dieback has been increasing in the Dawson region since 2009 (Energy, Mines and Resources, 2021), and with climate change could continue to increase.

The spruce bark beetle outbreak, intensified by warmer conditions and drought stress, has made a significant impact on the forest ecosystem in southwest Yukon (Energy, Mines and Resources, 2021; Price et al., 2013). The outbreak in southwest Yukon lasted approximately 20 years and killed half of the mature spruce within the infestation area (approximately 63 x 63 kilometres) (Energy, Mines and Resources, 2021). Drought was a key factor in initiating the outbreak, and the influence of cooler winter weather and less drought contributed to the spruce bark beetle decline. Another factor was the depletion of mature trees, as the spruce bark beetles survival rates were lower in younger and healthier spruce stands (Energy, Mines and Resources, 2021; Campbell et al., 2019). Currently, the mountain pine beetle has not been identified within the Yukon but has been confirmed within 80 kilometres of the southern border (Energy, Mines and Resources, 2021; Hodge, 2012). Climate change is creating conditions that allow the mountain pine beetle to expand into areas which were previously climactically unsuitable, like the Yukon. This is a serious concern considering the significant impact of the pine beetle on British Columbia forests (Dhar et al., 2016; Energy, Mines and Resources, 2021; Nealis & Peter, 2008). It is a novel forest pest for lodgepole pine in the Yukon (Cudmore et al., 2010) and trees here may have little natural resistance.

4.5 Forest and tundra fires show signs of increased frequency and severity in some areas of the Yukon, and of forcing shifts in the dominant forest type during post-fire succession. (Medium confidence)

The number of hectares burned per year in the Yukon and the fire severity index both show only a small increase since 1960 (see *Indicator 2.1 and 2.2*). Increasing fire risk has been projected for the northern boreal forest ecosystem with climate change (Boulanger et al., 2017). However, increases in precipitation are also projected for the Yukon, and future wildfire risk will be dependent on both precipitation and the availability of fuels. There is significant regional and interannual variability in precipitation in the Yukon (see *Indicator 1.2*) which is likely to continue in the future affecting wildfire as well.

Post fire recovery, along with precipitation and temperature, has been observed to support shifts in vegetation when forest succession does not follow typical patterns (Baltzer et al., 2021; Johnstone et al., 2010; Mack et al., 2021). Spruce regeneration after fire is inhibited by warmer temperatures, providing opportunity for a potential transition in the boreal forest to more deciduous trees, particularly aspen (Baltzer et al., 2021; Hogg & Wein, 2005; Johnstone et al., 2010; Mack et al., 2021; Price et al., 2013). This would have significant implications at the ecosystem scale. Lichens are also slow to re-grow after disturbances like forest fire and have declined in recent years (Bjorkman et al., 2020; Elmendorf et al., 2012; Macander et al., 2020; Russell & Johnson, 2019).

4.6 Permafrost thaw induces ground collapse and slumping, with subsequent shifts in vegetation community type and composition. (High confidence)

Permafrost thaw is a direct impact of warming temperatures and is also induced by flooding, erosion, and other ground disturbances. Permafrost thaw can alter soil moisture conditions, leading to a variety of vegetation shifts (Burn & Friele, 1989). Some areas are becoming wetter with permafrost thaw, while others are becoming drier due to lake drainage. Where lakes have drained in the Old Crow Flats, there has been increased willow growth, which has varying implications for wildlife populations. For example, this change is beneficial for moose but has led to a loss of lake habitat for muskrat populations (Lantz, 2017). A study focused on the Whitehorse and Kluane areas found that permafrost degradation led to a shift in species from those that thrived in wetter conditions (Vogt, 2021). This included losses in lichens, berries, and forbs, and a general loss in forest cover (Vogt, 2021). Research on Herschel Island found that vegetation communities on active thaw slumps were different than those on stabilized slumps, and post-stabilization succession from grass-dominated to willow-dominated communities takes two or three hundred years (Cray & Pollard, 2015). In the Mayo area re-establishment of original forest cover took 35-50 years after disturbance by retrogressive thaw slumps (Burn & Friele, 1989).

4.7 New species are arriving in the Yukon by way of various vectors with climate change facilitating range expansion to some extent. There is currently low incidence of invasive species in the Yukon. (Medium confidence)

New plant species are expected in the Yukon as climate change influences ongoing biome and range shifts (Wallingford et al., 2020). Similarly, some plant species within the Yukon will shift their ranges due to climate change. New plants species are also introduced to the Yukon through human activities, with highways being a key vector (Wurtz et al., 2019). Warming temperatures, changes to precipitation, and longer shoulder seasons are expected to facilitate range expansion of new species, at the same time creating conditions for new species to be competitive (Bennett & Mulder, 2008; Wurtz et al., 2019).

Range-shifting species and introduced species are not necessarily classified as invasives; invasive species are specifically new species that cause environmental, economic, or social harm (CAFF & PAME, 2017; Yukon Invasive Species Council, 2011). Currently the Yukon has fairly low incidence of invasive species, generally occurring in disturbed landscapes. Although climate change may create optimal conditions for invasive species to thrive by stressing native species, there is little evidence to date demonstrating that climate change will facilitate invasiveness, and proactive management can help reduce the impact of invasives (Wurtz et al., 2019; Yukon Invasive Species Council, 2011).

4.8 Higher productivity of vegetation (greening) is observed in some regions but not in other regions where water and other nutrients or landscape disturbance are limiting factors (browning). (Medium confidence)

Greening and browning in the Arctic are influenced by a number of ecological processes including plant recruitment, extreme weather events, disease outbreaks, herbivore population changes, wildfire, and other disturbances (Myers-Smith et al., 2020). These trends are generally observed using remote sensing techniques including Normalized Difference Vegetation Index (NDVI), however in situ observations do not always agree with satellite observations (Myers-Smith et al., 2020). Warmer temperatures are facilitating higher productivity in vegetation in some areas; however, this is limited by the availability of water and other nutrients (Chen et al., 2021; McPartland et al., 2020). The result is that some areas are greening, showing increasing productivity, while other areas are browning, showing decreasing productivity with generally high spatial variability within the Yukon in terms of greening and browning.

4.9 Climate change impacts to vegetation will affect natural resource management and cultural activities on the land, requiring proactive adaptation. (High confidence)

Climate change impacts on vegetation will affect species that are both culturally and economically important, including berries and trees (Alaska Science for All UAF, 2022; Furgal & Prowse, 2008; Merculieff et al., 2017). Changes in berry production have been noted by Yukon First Nations including reduced quantity and size (Alaska Science for All UAF GI, 2022; Merculieff et al., 2017). There are also climate change-related challenges for travel on the land, with increases in blowdown from beetle kill creating hazards and requiring trail clearing, and increased shrub and willow growth obstructing travel routes (Merculieff et al., 2017). Resource industries have found some degree of opportunities through adaptation. For example, the timber industry in southwest Yukon is finding ways to adapt to the beetle infestations that have significantly impacted local spruce stands (Ogden & Innes, 2008). CAFN and YG collaborated on a forest management plan that incorporates an adaptive management approach and includes actions to reduce fire risk hazards and manage forest renewal and habitat along with providing opportunities for the forestry industry (Furgal & Prowse, 2008, Alsek Renewable Resource Council et al., 2004).

Proactive adaptation can be achieved by conserving and protecting large areas to maintain resilient natural ecosystems (Carroll & Noss, 2020; IPCC, 2022). Current research recommends conservation of 30%-50% of land, freshwater, and ocean areas to support natural ecosystems (IPCC, 2022). Conservation strategies can take into account future ranges, particularly for plant species that have a narrow range of climactic tolerance (Wallingford et al., 2020). The Resist-Accept-Direct (RAD) framework provides three management approaches that can be used to adapt to ecological change (Lynch et al, 2022; Schuurman et al., 2022; Schuurman et al, 2020). These include: (i) resisting change by restoring conditions; (ii) accepting change by allowing the ecosystem to change as it will into a potentially unknown new state; and (iii) directing change by facilitating a shift towards a new state that can sustain expected climactic changes and provides desired ecosystem services (Lynch et al, 2022; Schuurman et al., 2022; Schuurman et al., 2020; Wallingford et al., 2020). The RAD framework is supported by monitoring programs, experiments that test interventions, pilot studies, and other adaptive approaches.

Monitoring programs are critical to observing changes in Yukon vegetation and related environmental drivers of change. These programs provide the necessary information to adapt conservation and management programs (Bjorkman et al., 2020). See *Key Finding 5.10* for discussion of Indigenous-led conservation and monitoring programs. Conceptual modeling and scenario analyses are both adaptive processes that support conservation and management by providing insight into projected changes in the future. Active interventions and pilot studies can be used to simulate climate change to test vegetation responses, including the use of greenhouses or open-top chambers (Lynch et al., 2022).

5. Wildlife
Changes in animal species’ habitat, ranges, and food sources are already being observed in the Yukon. (High confidence)

This section explores some of the changes that have been observed in animal habitat, ranges, and distribution. While there is strong confidence that climate change is a stressor for Yukon wildlife, identifying the specific cause and effect relationships linking a change in climate to vegetation and ultimately animal responses is not always possible. Both Indigenous and scientific knowledge are documenting these changes and together providing information that helps us project future change, however understanding the complexity of ecosystem change will require large-scale and long-term monitoring studies and experiments. With these shifts in biodiversity, there will be impacts in the future on the availability, quality, and accessibility of the traditional foods and resources which Yukoners rely on. This has implications for land planning, management, conservation, and ongoing monitoring programs. (Boonstra, et al., 2018; Davidson et al., 2020; Furgal & Prowse, 2008; Gagnon et al., 2020; IPCC, 2022; Meltofte, 2013; Severson et al., 2021).

5.1 Climate change interacts with various other potentially limiting factors to drive a wide diversity of species and population-level responses in wildlife. (High confidence)

The cumulative impacts of climate change and other landscape level changes make it challenging to project how individual wildlife, fish, and bird species will be affected (Davidson et al., 2020; Humphries et al., 2004; IPCC, 2022). In more developed areas of the Yukon, roads, resource development, and other human-caused stressors are major contributors to cumulative impacts. While there is evidence that some species, like the porcupine caribou herd, are thriving or adapting in certain locations due to increases in the available amount of food and favourable conditions at optimum times of the year, this cannot be applied to other areas or populations (Gagnon et al., 2020; Mallory & Boyce, 2017; Severson et al., 2021). Climate change is potentially a factor in the recent collapse of low-elevation populations of the Arctic ground squirrel population in southwest Yukon demonstrating how a warmer climate and increased plant growth can have ramifications for specific wildlife species (Werner et al., 2015). For some species, changes in temperature and precipitation will directly affect them. For example, muskoxen in northern Yukon are vulnerable to heat stress in warmer summer temperatures (Cuyler et al., 2020).

5.2 Species ranges are already, and will continue, to shift northward, bringing new species into the North while limiting some species currently present. (High confidence)

In places where there has been dramatic habitat change, some species are already shifting their distribution or range northward, higher in elevation, or to areas that will better satisfy their needs under changing climatic conditions (Chen et al., 2011; Leung & Reid, 2013). This is generally driven by vegetation change, which normally lags behind changes in the climate (see *Key Finding 4. Vegetation* for more information). In the Beaufort Coastal Plain in northern Yukon, beavers have recently appeared in the tundra environment, potentially facilitated by shrubification in the region (Jung et al., 2016). The northern part of the territory will likely see other subarctic species establishing themselves and potentially outcompeting Arctic mammals that have less capacity to adapt to warmer conditions (Berteaux et al., 2014; Humphries et al., 2004; Jung et al., 2016). Mule deer have extended their range and abundance across Southwest Yukon, however their impact on other populations is still being studied (Boonstra et al., 2018). Changes in species ranges have implications for biodiversity, ecosystem dynamics, as well as for land planning (Warren & Lulham, 2021).

Non-native species are often introduced through human activities, but climate change increases Yukon’s vulnerability to colonization of invasive species, particularly as it stresses native species and makes conditions optimal for new species to thrive (CAFF & PAME, 2017; IPCC, 2022; Yukon Invasive Species Council, 2011). Although the migration of new species northwards within their range has already been observed and will continue to have significant impacts on the ecosystem dynamics of terrestrial and aquatic communities (Furgal & Prowse, 2008; Guyot et al., 2006; Leung & Reid, 2013), to date Yukon has seen a lower incidence and fewer invasive species than neighbouring jurisdictions of British Columbia and Alaska (Wurtz et al., 2019; Yukon Invasive Species Council, 2011). However not all non-native species are invasive and species range extensions are expected with climate change. Reducing the introduction and spread of invasive species in the Yukon contributes to the resilience of the native ecosystem in dealing with climate change and other stressors (CAFF & PAME, 2017).

5.3 Changes in temperature and food availability will likely impact seasonal habitat selection and migratory routes. (High confidence)

Increases in summer and fall temperatures affect how wildlife select habitat, as do changes to food sources and predator behaviour, as has already been observed with moose in northern Yukon (Cooley et al., 2019). Yukon First Nations have identified changes in caribou migration patterns and the appearance of new species which affects traditional food harvests (ArcticPeoples, 2013; Guyot et al., 2006; Merculieff et al., 2017). In the Old Crow

Flats, permafrost thaw is driving landscape change by causing lake drainage. While muskrat lose critical lake habitat, this change also leads to the growth of willows, providing habitat for moose (Cooley et al., 2019; Lantz, 2017). Vegetation productivity affects habitat selection for herbivores, and as temperatures warm and some regions see precipitation increases, this will affect habitat selection and migration routes. As an example, it is projected that changes in spring phenology will result in the Porcupine caribou herd selecting calving and post-calving habitat further west in Alaska where plant productivity is projected to increase, putting them potentially in conflict with resource development (Severson et al., 2021).

5.4 The timing of critical life events (phenology) is affected by climate change for some wildlife species. (Medium confidence)

The timing of critical life events (or phenology) can be affected by earlier spring and later fall. This can have implications for specific species but also at the ecosystem scale (Davidson et al., 2020; Loring and Gerlach, 2009; Ta’an Kwäch’än Council, 2021; Warren & Lulham, 2021). Changes in phenology can impact key relationships in the food web when timing becomes mismatched (Davidson et al., 2020; IPCC, 2022). Changes in the timing of bird migrations and hatching have already been observed, and there is potential for this to result in birds arriving at breeding grounds after the snowmelt and the onset of nesting conditions (Warren & Lulham, 2021). A recent study in Herschel Island shows that shorebirds and passerines adjust the timing of their lay dates in response to earlier snow melt, while other species do not (Grabowski et al., 2013). There is potential for mismatch in relation to timing of hatching and food availability and ongoing monitoring is recommended to assess changes (Bolduc et al., 2013; Leung et al., 2018). Red squirrels in the Yukon provide an example of phenology change that varies seasonally and is indirectly linked to climate change through the impact of warmer temperatures on food availability (Berteaux et al., 2004; Lane et al., 2018; Price et al., 2013). The breeding dates of red squirrels are earlier in spring following years of high productivity in white spruce cones. Temperature and precipitation are important factors in cone production; however, these relationships and the influence of extreme weather events in cone production are challenging to model based on available data (Krebs et al., 2012; Leeper et al., 2020).

5.5 Herbivorous mammals will need to adapt to climate change impacts on the abundance, availability, and nutritional quality of food sources. (Medium confidence)

Herbivorous mammals like woodland and barren ground caribou, moose, mountain sheep, and small mammals, will need to adapt to changes in food abundance, availability, and nutritional quality (Mallory & Boyce, 2017). There have been observed changes in small mammal populations linked to the impacts of climate change on plant production, including shifts in dominant species, which could indicate a major shift within boreal ecosystems. The populations of several small mammal species in the Kluane region, including red-back vole and deer mice, have increased at least partially due to more productive vegetation (Boonstra et al., 2018; Krebs et al., 2019).

Reduced summer food availability has been identified as an issue for herbivorous species like boreal caribou and mountain sheep in certain areas (Davidson et al., 2020; Furgal &

Prowse, 2008; Health Canada, 2012; Van de Kerk et al., 2020). Wildfires can affect the availability of food (Health Canada, 2012; Palm et al., 2022; Warren & Lemmen, 2014), particularly lichen which is slow to regrow and has already declined in some areas (Bjorkman et al., 2020; Elmendorf et al., 2012; Macander et al., 2020; Russell & Johnson, 2019). Although the feeding grounds of caribou are impacted by climate change, there is variability across the Yukon (Mallory & Boyce, 2017). While some populations may be thriving (Gagnon et al., 2020), others are affected by wetter conditions, wildfire, or other impacts on the diversity and accessibility of vegetation (Davidson et al., 2020; Furgal & Prowse, 2008; Health Canada, 2012). In the feeding grounds of the porcupine caribou there has been a trend towards earlier snowmelt and warmer, extended summers with increased food availability (Russell & McNeil, 2005).

5.6 Changes in snow, including freeze-thaw cycles and increased snowpack depth, have implication for access to food for a number of Yukon species. (High confidence)

Winter and spring feeding have become more difficult for herbivorous mammals due to deeper snows and increased layers of ice on and in the snow. Freeze-thaw and rain-on-snow events in winter, which are increasing with climate change, create ice layers on or in the snowpack restricting the ability of animals like caribou and other ungulates to dig through the snow to access food (Davidson et al., 2020; Furgal & Prowse, 2008; Health Canada, 2012; Van de Kerk et al., 2020). Snow depth plays a role in habitat selection for a number of species including the porcupine caribou herd, who will choose winter areas with lower snow depths (McNeil et al., 2005). Changes in conditions can also affect predator-prey dynamics, by favouring one species over another (Davidson et al., 2020; Peers et al., 2020). As an example, low snow depths and harder snow surfaces benefit coyotes, giving them an advantage as a predator (Peers et al., 2020).

5.7 Spring and summer have seen greater levels of insect harassment for wildlife. (Low confidence)

Increased insect harassment has been identified as an issue for caribou in the Yukon, and a potential concern for other species, including muskox and mountain sheep (Cuyler et al., 2020; Davidson et al., 2020; Furgal & Prowse, 2008; Health Canada, 2012; Van de Kerk et al., 2020). Insect harassment affects animal activity patterns, causing individuals to spend more time standing and moving, and less time resting and eating (Downes et al., 1986). It is expected that longer, warmer summers will increase insect harassment for these species in the future (Mallory & Boyce, 2017). Insect harassment can affect habitat selection for some wildlife populations (e.g., caribou) (McNeil et al., 2005), and increasing insect harassment earlier or later in the summer season may affect future habitat choices. In years with high insect numbers, the porcupine caribou herd tends to be more widely dispersed during early summer and use microhabitat to avoid insects (McNeil et al., 2005). Woodland caribou in eastern and southwestern Yukon also use microhabitat and snow patches as insect relief during the summer (Downes et al., 1986; Ion & Kershaw, 1989). More research could be done to understand the relationships between climate change, insect harassment, and changes to available microhabitat for specific wildlife populations.

5.8 Some fish species are experiencing habitat changes that are likely to have negative effects on population size and health. (High confidence)

Lake and river fish habitat is being affected by changing water temperatures, levels, flow regimes, and turbidity, putting stress on some fish species. Some populations of lake-based fish have low dispersal rates and are limited to their current habitat (Potié & Reid, 2021). River-based fish may have more opportunities to adapt, but the cumulative impacts of climate change and other environmental changes in river basins will affect their habitat and adaptability.

For long migration species such as salmon, there are other downstream influences, like changes to ocean conditions, which are sometimes climate related. Anadromous species like salmon are impacted by changes in both freshwater and marine conditions, including air, water and sea temperatures, sea ice cover, water levels, coastal winds, sediments, etc. These can impact the timing of when they transition between river and ocean, the run size, growth, and distribution (IPCC, 2022). Landscape transformation due to permafrost thaw, wildfire, and changes in vegetation impact freshwater ecology, and this results in changes in biodiversity from the micro scale to fish species (Goedkoop et al., 2021). Increases in water temperatures influence on salmon growth, survival, and spawning success (Murdoch et al., 2022). Increased precipitation and permafrost thaw cause erosion and increased sediment in rivers, impacting spawning and juvenile salmon (Murdoch et al., 2022). There are still gaps in understanding how ongoing climate change will affect these relationships and further research and conservation action is recommended for Yukon salmon populations (Murdoch et al., 2022).

Salmon are important both culturally and as a food source for Yukon First Nations. With smaller runs, impacts of downstream harvesting, and even local extirpation in some tributaries (Ta’an Kwäch’än Council, 2021). Indigenous communities across the Arctic, including the Yukon, have shared knowledge of observed changes already happening to freshwater systems including decreasing water levels and increased draining and drying of lakes and rivers, shorter time with ice coverage (later freeze up and earlier melt), thinner ice, warmer water temperatures, increase in permafrost thaw, and eroding banks changing river flow and contributing sediment to water systems (ArcticPeoples, 2013; Kassi et al., 2010; Knopp et al, 2020; Kuntz et al., 2018; Merculieff et al., 2017, Wolfe et al., 2011).

5.9 Impacts of climate change in the Yukon will have implications for biodiversity in other areas of the western hemisphere because some migratory bird species depend on breeding and feeding grounds in the North. (Medium confidence)

Arctic ecosystems have importance for global biodiversity, with many species migrating between Arctic regions and other parts of western hemisphere (Bush & Lemmen, 2019; Meltofte, 2013; Environment Yukon; 2011; Warren & Lulham, 2021). The Yukon supports many significant bird populations that migrate North for the summer, returning to other regions to over winter (Meltofte, 2013). The breeding and feeding grounds for many of the migratory birds coming to the North are expected to experience vegetation changes and other landscape scale changes in the future that could reduce breeding areas and impact available food sources (ACIA, 2004; Environment Yukon, 2011; Warren & Lulham, 2021).

Longer summer seasons affect the range and reproductive habits of some migratory birds. New bird species are being spotted in areas previously not within their range, including the barn swallow in Herschel Island, signalling that ecosystem change is already happening (Winker & Gibson, 2018).

5.10 Wildlife management and planning can be adapted or implemented to benefit wildlife species impacted by climate change. (Medium confidence)

The IPCC (2022) recommends conservation as a key action for preserving natural ecosystems, with a suggested target of conserving 30%-50% of Earth's land, freshwater and ocean. Indigenous protected areas play a role in Canada in the conservation of natural ecosystems, with recent commitments to support Indigenous protected areas (Carroll & Ray, 2020; Zurba et al., 2019). When developing species-specific conservation strategies, incorporating future change is an important consideration, particularly for species with a narrow range of climactic tolerance like the collared pika (Kukka et al., 2020) or those restricted by physical boundaries like some lake-dependent species (Potié & Reid, 2021). Through conservation management and land planning processes, the Yukon has opportunities to contribute to the protection of key ecosystems (Carroll & Noss, 2020; Carroll & Ray, 2020). Creating conservation plans and protected areas with climate change in mind requires networks of large, intact protected areas that represent different landscape types, consider natural disturbances, and protect key wildlife corridors (Carroll & Noss, 2020; Wulder et al., 2018). An example of an adaptive strategy is to identify potential wildlife refugia and incorporate them into conservation and management plans (Stralberg et al., 2020). Wildlife refugia can include sites or regions that that link current and future habitat or are resistant to climate change, like peat wetlands in the boreal forest (Michalak et al., 2020; Stralberg et al., 2020). For more discussion on proactive adaptation see *Vegetation Key Finding 4.9.*

6. Hazards and Infrastructure

The major climate change hazards in the Yukon are flood, wildfire, and damage to infrastructure from thawing permafrost and/or extreme precipitation. Infrastructure built without the future climate in mind is vulnerable. (High confidence)

The main sectors that are vulnerable to climate-induced natural hazards in the Yukon are infrastructure, food security, energy security, and natural ecosystems (Engineers Canada, 2018; Hennesey and Streicker, 2011; Janowicz, 2010; IPCC, 2022). Climate change poses a significant threat to northern infrastructure, with the main concerns being wildfire, flooding, permafrost, and landslides (AMAP, 2021a; IPCC, 2021; IPCC, 2022; NRTEE, 2009; Warren & Lulham, 2021). Northern infrastructure threatened by climate change includes houses, buildings, roads, telecommunication systems, energy systems, waste treatment and containment sites, mine sites, and tailings ponds among others. The Yukon is heavily reliant on the global supply chain and transportation networks outside of the territory; the effects of extreme weather and other climate-related hazards in other regions of the globe impacts both the availability and costs of goods in the Yukon (IPCC, 2021; IPCC, 2022).

6.1 Yukon communities are located along rivers and in forested areas. This makes flooding and wildfire critical hazards. Climate change is increasing the likelihood and potential severity of these hazards. (Medium confidence)

All 26 of the Yukon's communities are situated on or in close proximity to a significant waterway (i.e., lake or river) and all are within the boreal forest. Furthermore, all communities are served by a limited road network, which is also vulnerable to flood and fire. Old Crow is the only fly-in community and receives supplies by plane, making it equally reliant on the transportation network. Based on this proximity to forest and waterway, forest fire and flood are critical climate-related hazards threatening most Yukon communities. Both have implications for public safety, infrastructure, food security, energy security, and natural ecosystems. (Hennesey & Streicker, 2011; Janowicz, 2010; IPCC, 2021; NRTEE, 2009). Where risk assessments have been conducted, a number of assets have been identified as at risk to flooding including 20% of Yukon's health facilities (Clark et al., 2021; Turcotte & Saal, 2022a; 2022b).

Changes to river ice break up, along with increases in winter precipitation, can cause flooding and damage infrastructure (Janowicz, 2010; NRTEE, 2009). Communities that are located on floodplains are particularly vulnerable, while highways in mountainous areas are vulnerable to washouts, and in Yukon this also impacts fibre optic cables which are located along highways (NRTEE, 2009). Washouts have already occurred in numerous locations in the Yukon highway network, including events in 2012 when all major highways bringing goods into the Yukon were blocked by washouts (Research Northwest & Morrison Hershfield, 2017). Climate change will likely slow the formation of icing in streams and small rivers, and when paired with increased fall flows can cause variation in ice coverage and thickness, potentially contributing to increased winter and spring floods (Burrell et al., 2022). See *Key Finding 3. Water* for more information on the impacts of the changing hydrologic regime on flooding in the Yukon.

Fire history in the Yukon does not show a significant trend (see *Burned Area Indicator*), and it is expected that there will continue to be annual variability in wildfire activity. However, increased wildfire activity is already being felt in neighbouring jurisdictions (Flannigan et al., 2008) and in some areas of the Yukon, as noted by First Nations who have seen increases in fire frequency (Alaska Science for All UAF GI, 2022). Wildfire is strongly linked to weather, and with climate change is projected to increase significantly in the Canadian boreal forest in the future (by 50-100% by the end of the century), although there will be variability from year to year (Flannigan et al., 2008; McCoy & Burn, 2005; Warren & Lemmen, 2014; Warren & Lulham, 2021). In the Yukon where increases in precipitation are projected, the risk for wildfire is not projected to increase significantly, but annual and regional variability will influence how wildfire impacts different areas. There is potential for an increase in lightning-caused wildfires with increases in extreme weather events and storms (Kochtubajda et al., 2011).

Natural hazards like flooding and wildfire have direct and indirect health implications that range from immediate (e.g., wildfire smoke inhalation) to long-term (e.g., exposure to mould or contaminants in housing) and can also affect mental health (Berry & Schnitter, 2022; Clayton et al., 2021; IPCC, 2021; Macfarlane, R., 2020). Flooding can damage water treatment, sanitation, and waste management facilities leading to exposure to contaminated water (Warren et al., 2005). See *Key Finding 7. Food, Health, and Well-being* for more information on the impacts of hazards and extreme events on health.

6.2 Permafrost thaw, wildfire, and more intense precipitation events will result in more landslides and subsequent sediment supply to river systems. (Medium confidence)

Landslides are common in a permafrost environment, exacerbated by warmer temperatures and extreme precipitation events, as well as intensified spring freshets (Benkert et al., 2015; Coates & Lewkowicz, 2008; Patton et al., 2019; Warren & Lemmen, 2014). Landslide patterns are changing so rapidly that land managers are finding it challenging to predict and plan for risk. (Patton et al., 2019). Forest fires contribute to permafrost thaw and increased occurrence of landslides by removing the insulating vegetation layer, exposing frozen ground to thaw and destabilizing slopes (Benkert et al., 2015; Blais-Stevens et al., 2011; Coates & Lewkowicz, 2008; Lipovsky et al., 2006; Michaelides et al., 2019; Northern Climate ExChange, 2013). These types of permafrost-induced landslides, brought on by warming temperatures, environmental change, rainfall, and/or forest fires, have already been observed around Dawson City and Old Crow, along the Dempster Highway, and across southwestern Yukon (Huscroft et al., 2003; Lipovsky et al., 2006; Turner et al., 2021). In cases where landslides occur in large numbers in a region, such as the Dawson City wildfire and subsequent landslides in 2004, their cumulative effects can impact sediment loads in streams and rivers which has implications for fish and aquatic ecosystems (Lipovsky et al., 2006; Turner et al., 2021).

6.3 Existing infrastructure was designed and built based on historical climate data that may not be appropriate for future conditions. Even small increases in snow load, storm severity and frequency, and thawing permafrost can directly affect the structural integrity of infrastructure. (High confidence)

While new codes and standards require that climate change be considered in the design of new infrastructure, existing infrastructure was in many cases designed based on historical climate data. Current infrastructure is at risk to flooding, wildfire, permafrost thaw, higher snow and ice loads, and increased moisture and humidity (IPCC, 2022; IPCC, 2021; NRTEE, 2009; Warren & Lulham, 2021). Some of the impacts already experienced in the Yukon include highway washouts and landslides, damage from permafrost thaw to roads and buildings, roof collapse from snow loads, wastewater system failure due to permafrost thaw and changing precipitation patterns, and unexpected increases in water inputs in mine water treatment systems (Janowicz, 2010; Pearce et al., 2011; Pearce et al., 2009 Research Northwest & Morrison Hershfield, 2017; Steenhof & Duteau, 2021; Warren & Lulham, 2021). Increased precipitation, and in particular the timing and rate of snowmelt, impacts roads, wastewater treatment, snow removal, avalanche size and frequency, drainage, and water supply (Instanes et al., 2015; NRTEE, 2009; Parrott et al., 2018; Steenhof & Duteau, 2021; Warren & Lemmen, 2014). Increases in winter snowfall have caused rising costs for the City of Whitehorse and have led to a review of snow and ice policy (Waddell, 2022). Avalanche hazard is increasing, impacting maintenance costs on roads through mountain passes maintained by Yukon government and serving as key transportation routes between Yukon and Alaska (Parrott et al., 2018; Warren & Lemmen, 2014). Avalanche hazard also impacts mine road maintenance and safety (Perrin et al., 2015b). In 2019 avalanche activity along the highway between Skagway, AK and Carcross, YT affected the Yukon's fuel supply causing concern for the energy system and leading to a re-evaluation of the supply chain (CBC, 2020).

6.4 As frozen ground thaws, some existing buildings, roads, airports, and industrial facilities are likely to be destabilized, requiring substantial rebuilding, maintenance, and investment. (High confidence)

Permafrost thaw poses a significant threat to northern infrastructure, planning, and development, and is already causing costly damage and even infrastructure failure (Benkert et al., 2015; Calmels et al., 2016; IPCC, 2022; Laxton & Coates, 2011; NRTEE, 2009). Permafrost thaw affects public infrastructure, industrial infrastructure, and individual homes (IPCC, 2022; Warren & Lulham, 2021). Identifying potential infrastructure vulnerabilities related to permafrost requires an understanding of ground and environmental conditions including permafrost and ground ice, surface water drainage, groundwater, surficial geology, and slope stability (Northern Climate ExChange, 2011).

The Yukon highway network is essential for accessing communities and industrial sites, providing healthcare, and moving supplies, yet there are only a few roads that link the territory to neighbouring jurisdictions (Calmels et al., 2015; de Grandpré et al., 2010). The Alaska, Klondike, and Dempster Highways are all vulnerable to permafrost thaw and in some areas significant impacts of permafrost thaw are already evident, although sections of the highways range from low to high vulnerability (Best et al., 2019; de Grandpré et al., 2010; Calmels et al., 2015; Stockton et al., 2019). Permafrost thaw can be affected by approaches to construction, maintenance, and use of highways; snow removal and changes to shrub regime affected by clearing have been shown to impact thaw (Stockton et al., 2019). A major thaw slump occurred near the Alaska Highway and was discovered in 2019. It has since been instrumented and used as a study site so researchers can monitor movement in the slope and learn about the interaction of retrogressive thaw slumps and road corridors to develop geohazard alarm systems (Calmels et al., 2021).

Housing built on permafrost often requires ongoing maintenance by homeowners and there are other considerations to mitigate the impacts of permafrost thaw including snow removal and removal of house skirting in addition to proper surface drainage (Department of Environment and Natural Resources, 2015). Cultural and recreation infrastructure like travel routes, trails, and cultural sites are also impacted by permafrost thaw, and subsequent coastal erosion (Irrgang et al., 2019; Radosavljevic et al., 2015).

6.5 Future development and maintenance of existing infrastructure will require new design elements to account for ongoing warming that may add to construction and maintenance costs. These costs need to be considered against the potential costs of infrastructure failure. Infrastructure damage and failure also poses major concerns for the insurance industry. (High confidence)

Designing resilient infrastructure requires knowledge of current and future climate conditions, as well as understanding of geomorphology including permafrost conditions (Stephani et al., 2010). Understanding permafrost is also critical for all stages of large resource development projects (EBA, 2004). The impacts of climate change on Yukon's infrastructure will have both economic and social costs (IPCC, 2022; UNEP, 2012; Warren & Lulham, 2021). Climate change threatens infrastructure, and for large, engineered infrastructure there are clear safety concerns related to those risks. Incorporating climate change into infrastructure design will have related costs, however when adaptation is focused on highly vulnerable components, this becomes cost-effective when compared to the costs of ongoing maintenance, early replacement, or catastrophic failure (EBA, 2004; Engineers Canada, n.d.; Pearce et al., 2011; Stephani et al., 2010). The social costs and indirect consequences of infrastructure failure are not always incorporated in those calculations, but closures to important buildings, bridges, and roads can have downstream impacts when people cannot access necessary services (UNEP, 2012). There are examples from across the North of reduced services due to infrastructure damage, including the school in Ross River which was affected by permafrost thaw (Calmels et al., 2016; Laxton & Coates, 2011). Insurance costs related climate change impacts on infrastructure have become a key concern for the insurance industry (Insurance Institute, 2020). In cases where impacts are not covered by insurance, for example overland flooding, government costs for covering damage have increased (Crawford, 2022).

6.6 Industry, such as mining, is also vulnerable to climate change hazards, which can increase downstream risks. (High confidence)

The Canadian mining industry, including Yukon mines, have experienced the impacts of climate change, posing significant environmental and economic risks to the industry and the downstream environment (Pearce et al., 2011; Perrin et al., 2015a; Perrin et al., 2015b; Warren & Lulham, 2021). Permafrost thaw puts mining infrastructure at risk, particularly tailings ponds built using permafrost dams, with potentially severe impacts to surrounding ecosystems (EBA, 2004; Pearce et al., 2009; Pearce et al., 2011; Perrin, 2015b). Climate change poses challenges for mining operations that could affect profitability and potentially feasibility considering their current ability to manage risks posed by permafrost thaw or increases in winter precipitation and rapid melt leading to increased spring runoff (Instanes et al., 2015). An example of this was the impact of intense rainfall at the Minto Mine causing the water treatment system to be overloaded and leading to a higher rate of discharge and a fine for the company. The water storage pond had been designed based on occasional seasonal summer drought, without taking climate change and increasing precipitation into consideration (Pearce et al., 2011; Duerden et al., 2014). Victoria Gold also ran into unexpected problems at the Eagle Gold Mine in 2020 with an unusually high snowpack and sudden melt (Gignac, 2020). They adapted reactively to manage the issue, but examples like these highlight the need for proactive adaptation.

6.7 As hydrological regimes change, our hydro-electric generation capacity may be affected. It is important to consider volume of flow, timing of flow, and high flows. (Medium confidence)

Changes to the hydrological regime in the Yukon will have implications for hydro-electric generation. While there are several facilities contributing to Yukon's electrical system, the Whitehorse Rapids hydro plant on the Yukon River is the main source of power. Past studies have projected increased annual runoff and higher flows in early spring and late fall for the Yukon River, mainly fed by high elevation snowmelt and glacial melt, and potentially extending the period of viable hydro-power production (Northern Climate ExChange, 2014; Samuel et al., 2016). Increases in annual river discharge have been noted in some northern rivers, indicating that the hydrological cycle is intensifying but there is regional and seasonal variability which will affect overall annual production capacity (Bush & Lemmen, 2019; Déry et al., 2009). Extreme conditions are challenging for managing hydropower production, with high water levels or drought both leading to emergency amendments, as happened with high levels at the Whitehorse Rapids Generating Station in 2021, while dry conditions led to an emergency license amendment in Mayo in 2019 (Yukon Water Board, 2019; 2021).

6.8 Guides, standards, and best practices can support efforts to identify and address hazard risk to infrastructure. (High confidence)

Vulnerability assessments play a role in understanding risk and identifying adaptation opportunities, particularly regarding infrastructure (Ford et al., 2014). There are diverse ways to conduct vulnerability assessments, including formalized approaches like the PIEVC (ICLR & CRI, 2020) or more informal community-based assessments. Best practices for vulnerability assessments include involving stakeholders and practitioners and using a range of climate scenarios to forecast future change (Ford et al., 2014). As an example, the Yukon Environmental and Socio-economic Assessment Board (YESAB) has created a guide for assessing geohazards and risk for linear infrastructure in the Yukon (Guthrie & Cuervo, 2015).

The Northern Infrastructure Standardization Initiative (NISI) has produced a number of guidelines for the North related to community drainage systems, snow loads, building in permafrost, fire resilient planning, and the impacts of extreme weather on buildings (Canadian Standards Association, 2022). Some of the guidelines have accompanying outreach materials and training modules targeted at less technical audiences. Government of Canada has developed a climate lens for infrastructure that incorporates both climate change mitigation and adaptation considerations (Infrastructure Canada, 2019). The Transportation Association of Canada has produced guidelines for building and maintaining transportation infrastructure built on permafrost (Transportation Association of Canada, 2010). Natural Resources Canada has developed guidance for flood mapping and is currently administering a funding program to support mapping initiatives led by provinces and territories (Natural Resources Canada, 2022; 2019; 2018).

New guidance is available for the mining industry, including guidance on climate change adaptation, a protocol for including climate change in projects, and water-related guidelines that take an adaptive management approach (Golder, 2021; Government of Yukon, 2021a; Mining Association of Canada, 2021). In recent years, an emphasis on case study research has brought examples of both the impacts of climate change on the mining industry and successful examples of adaptation.

7. Food, health, and wellbeing

Climate change impacts health and food security in the Yukon, particularly in relation to First Nations’ traditional food security. Indigenous land-based cultural revitalization and agriculture are potential opportunities to adapt to the social and health impacts of climate change. (Medium confidence)

Health indicators related to climate change are both direct and indirect and can be viewed as both collective and individual. They can include direct biophysical indicators such as injury and death from extreme weather events, unpredictable environments (like thin ice or erosion) and natural disasters, and indirect indicators from impacts on environmental and human systems (Ford et al., 2013; Guyot et al., 2006; Jacob et al., 2010; Laidler et al., 2009; Lynn et al., 2013; Tam et al., 2013). Indirect indicators include permafrost thaw, extreme weather days, ice conditions, and other environmental indicators that affect safety, access to travel routes, damage to infrastructure, and ability to practice traditional harvesting (Healey, 2015; ICC Alaska, 2020; Macfarlane, 2020; Novak et al., 2018; Parlee et al., 2014). They also include mental, emotional, social, and spiritual health, connection to culture (Allison, 2015; Durkalec et al., 2015; Wilson, 2003), food security, and ability to take action to adapt to and mitigate climate change (Cunsolo Willox et al., 2013; Cunsolo Willox et al., 2012; Healey, 2015).

Climate change has the potential to negatively impact food security in Yukon including traditional, market, and local food systems (Loring & Gerlach, 2015; Pratt et al., 2016; Sheedy, 2018; Vermeulen et al., 2012). Other contributing factors to food security include government policies, remoteness, rising food and fuel costs, lack of accessible healthy food sources, decline in traditional food harvesting, impacts of resource development, and the ongoing impacts of colonization and intersections with capitalism and globalization (Agriculture and Agri-Food Canada, 2022; AICBR, 2016a; AMAP, 2021b; Beaumier et al., 2014; Council of Canadian Academies, 2014; Cruickshank et al., 2019; FAO, 2013; Hou & Sneyd, 2020; IPCC, 2022; Macfarlane, 2020; NCCAH, 2013; Whyte, 2017, 2018; Wilson et al., 2020). Food security "exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 2009). Measuring food security usually focuses on availability (i.e., production and supply), quality/utilization (i.e., intake and nutritional status), and accessibility (ability to gain sufficient quantity and quality of food) (Barrett, 2010; Lam et al., 2019; Perez-Escamilla & Segall-Correa 2008; Webb et al., 2006). Food sovereignty is more than just sustainable access to food but is the ability to govern and make decisions about the food system (Council of Canadian Academies, 2014).

Climate change and food security can have significant impacts on the health and wellbeing of Yukon residents, particularly Yukon First Nations (AMAP, 2021b; Council of Canadian Academies, 2014; IPCC, 2022; Macfarlane, 2020, Reading & Wein, 2009). Yukon has one of the highest food insecurity rates in Canada; in 2011 it was the third highest amongst the provinces and territories, and most recent estimates are that it is 15.3% (Caron & Plunkett-Latimer, 2022), and affects 1 in 5 children in the territory (Tarasuk & Mitchell, 2020). Indigenous communities are more likely to deal with food insecurity, as evidenced by the First Nations Regional Health Survey, which found that 54.2% of First Nations households across Canada were moderately to severely food insecure (FNIGC, 2018a,b; Council of Canadian Academies, 2014). In the Yukon, the number of students reporting going to bed hungry has decreased over the past 8 years, except for rural high school students, which is also the demographic that is more likely to eat breakfast at school (Lambe et al., 2019). It is expected that ongoing food security issues will be exacerbated with future climate change (Hou & Sneyd, 2020; IPCC, 2022; Macfarlane, 2020; Sheedy, 2018). Food security is not the only impact on the health of Yukoners; some of the main climate change impacts related to health hazards in Yukon are floods, wildfires, extreme weather, intense precipitation, later freeze-up and earlier thaw of water systems, permafrost thaw impacts on infrastructure and access to the land, landslides, and the related mental health impacts of anxiety or grief (AMAP, 2021b; Macfarlane, 2020, Cunsolo & Ellis, 2018; Cunsolo & Landman, 2017; Guyot et al., 2006).

7.1 Many Yukoners depend on hunting, fishing, and gathering. The abundance and health of these resources may be affected by climate change, and this is a key concern for Yukon First Nations and transboundary Indigenous nations. (High confidence)

Many Yukoners, but particularly First Nations communities, rely on traditional foods for a portion of their sustenance, and climate change has the potential to change the landscape and alter the availability and quality of subsistence wildlife and vegetation (Hou & Sneyd, 2020; Lambden, 2007; Research Northwest & Morrison Hershfield, 2017). Common traditional food species are moose, caribou, berries, salmon, trout, and whitefish (Batal et al., 2005; Schuster et al., 2011b; Sheedy, 2018). The Indigenous approach to and practices surrounding interactions with foods are interdependent, intergenerational, and holistic (Berkes, 2017). In a 2011 survey of Yukon First Nations, respondents identified fisheries, wildlife harvest, and seasonal conditions as the areas of concern related to climate change that most impacted their lives (CYFN, 2011). Improving food security and adapting to climate change from a food sovereignty approach, which recognizes the interrelation between rights, relationships and knowledge systems impacting decision-making and participation around food systems, is key to long-term conservation and stewardship of land, water and air and the co-management of these resources between Indigenous and non-Indigenous governments and Peoples (Batal et al*., 2021). There are still a number of barriers to sustainable implementation of traditional food initiatives, notably a lack of sustainable funding as most are funded through short-lived project-specific funding.

7.2 Several established climate-related changes in the north affect traditional food security: hydrological impacts, increased variability of precipitation, permafrost thaw, and the freeze-thaw cycle have implications for movement of fish and wildlife, foraging, quality of traditional foods, and access to harvesting sites. (High confidence)

Food security in a northern context includes considerations around availability, access, and quality (Cruickshank et al., 2019; Cunsolo Willox et al., 2015; Guyot et al, 2006; Hou & Sneyd, 2020). Availability of traditional foods is affected by shifting species' ranges, increases in parasite numbers, a shift in freeze/thaw patterns of key water systems due to warming temperatures, ecosystem change through thawing permafrost, forest fires, increased tree cover, water quality in freshwater systems, and changes to seasonality that affect species distribution, timing of migration, and migration routes (Blom et al., 2022; Hou & Sneyd, 2020; Cruickshank et al., 2019; Health Canada, 2012; Hou & Sneyd, 2020; KFN, 2014; Walker et al., 2017). Changes in the availability of fish, berries, and other food sources have been observed already and documented by both Indigenous Knowledge holders and scientific monitoring (Guyot et al., 2006; KFN & AICBR, 2016; Lambden, 2007; Walker et al., 2017; Wesche & Chan, 2010, Wein & Freeman, 1995). Changes have been observed in caribou migration patterns, moose and salmon populations, and in the availability of plants (Hou & Sneyd, 2017; Wesche & Chan, 2010). As an example, significant changes in chinook salmon have been observed on the Yukon River, correlated with increases in fishing and warming water temperatures (Jones, n.d.; von Biela et al., 2020). Increasing freshwater and ocean temperatures are expected to cause declines in a number of Yukon fish species including salmon in the Yukon River and lake trout (Mackenzie-Grieve & Post, 2006; von Biela et al., 2020). Salmon, chinook salmon in particular, are highly valued by communities and play a role in sustaining the health and cultural practices interconnected with the fishery (Linklater, 2014; SFN & AICBR, 2016).

Accessing traditional foods requires the ability to travel safely over the land and water and this is impacted by changes in freeze up and break up, while permafrost thaw can impact the integrity of traditional travel routes (AICBR, 2016a; Friendship, 2010; Merculieff et al., 2017). Permafrost thaw, increasing willow growth, changing ice regimes, and changes in water levels are already affecting access to harvesting areas and subsequently impact traditional harvest and food security (Brewster et al., 2016; Merculieff, 2017; Wesche & Chan, 2010; Rosol et al., 2016). With these changes to traditional routes, the ability to predict weather and the reliability of Indigenous and local knowledge of where, how, and when to travel is affected, forcing harvesters to adapt their approach to hunting or fishing, which can sometimes add expense or new safety concerns (Furgal & Prowse, 2008; Guyot et al., 2006; Sheedy, 2018; Spring et al., 2018; Wesche & Chan, 2010).

The quality of traditional foods is affected by stress caused by changes in weather patterns, disease, parasites, and malnutrition from lack of access to food (KFN & AICBR, 2016; Furgal & Prowse, 2008). Changes have been noted in the quality or health of some traditional food species, including qualities like the firmness of fish flesh or the appearance of fish scales (Lambden, 2007). Food safety is an added challenge with changes to food storage options, like using community freezers and root cellars (Berry & Schnitter, 2022; KFN, 2014). There is no definitive region-wide assessment of changes related to availability, access, and quality of traditional foods, but there is consistency in the concerns identified by individual First Nations (KFN, 2014; SFN & AICBR, 2016). Empowering local decision-making is seen as vital to ensuring resilience.

7.3 There is evidence that Yukoners have been consuming fewer traditional foods and more market foods due to the impacts of climate change and other societal changes, which may have negative health consequences. (Medium confidence)

Many Yukoners eat a mixed diet with both wild or traditional foods and market foods (Sheedy, 2018). Traditional food is more than just nutrition. It is “regarded as natural and fresh, tasty, healthy and nutritious, inexpensive, and socially and culturally beneficial” (Lambden, 2007, p.308). However, there are a number of barriers in contemporary lifestyles to harvesting traditional food. The underlying factors identified in research across the Canadian North influencing this dietary transition are a lack of access to the land, loss of traditional harvesting skills, less time available to practice traditional pursuits, high costs of fuel and hunting equipment, low income, increased access to market foods, and climate-related changes to environment and species (Blom et al., 2022; Egeland, 2010; Hou & Sneyd, 2020; Huntington & Fox, 2005; ITK & ICC Canada, 2013; SFN & AICBR, 2016; Sheedy, 2018). Food security studies have tracked a shift in diet amongst Yukoners to a more market food-based diet, impacting the nutritional quality of the diet (AMAP, 2021b;

Friendship, 2010; Kuhnlein et al., 2004; Macfarlane, 2020; Spring, 2018; Willows, 2005), particularly among Indigenous children (Kuhnlein & Receveur, 2007; Morrison et al., 1995; Nakano et al., 2005; Receveur et al., 1997). Rural Yukon students are more likely to eat traditional foods than urban, particularly high school aged students (Lambe et al., 2019). Traditional diets are high in animal protein and micronutrients and low in saturated fat, sodium and refined carbohydrates (Egeland et al., 2010; Kuhnlein et al., 2004; Kuhnlein & Receveur, 2007; Willows, 2005l). A shift towards a market diet presents in higher rates of chronic dietary diseases like cardiovascular disease, diabetes, and obesity (Galloway et al., 2010; Kuhnlein et al, 2004; Reading, 2015).

Climate change exacerbates this declining health trend by affecting access to and availability of country foods and essential nutrients (Cunsolo Willox, 2015; Sheedy, 2018; Wein & Freeman, 1995). Traditional food sharing practices and current programs like the *Traditional Food Program* in Yukon hospitals are critical for ensuring that culturally appropriate foods are available. Harvesting support programs, such as the Harvesters Support Grant offered through Nutrition North Canada in some areas of the Canadian North, help to reduce access barriers to traditional foods.

7.4 Extreme weather events and subsequent disruptions to the transportation network, have the potential to disrupt the market food system. (High confidence)

Yukon relies heavily on market foods as the main source of food in the territory, which means that the impacts of climate change on the global food industry affect the availability, quality, and cost of food in the Yukon (Clark et al., 2021; Institute for Sustainable Food Systems, 2015). This includes the impacts of climate change on food production, storage, and transportation. For example, droughts in crop-producing regions or extreme weather events that affect food processing plants can result in higher prices or less availability.

With most market foods coming from outside of the territory, road infrastructure is a key part of food security in the Yukon. Road systems are impacted by increasing prevalence and severity of natural disasters including fire and flood, permafrost thaw, unpredictable weather, extreme events and increased avalanches (Hou & Sneyd, 2020; Parrott et al., 2018; Pratt, 2019; Warren & Lemmen, 2014). Transportation infrastructure outside of the Yukon is critical for our food supply, and the disruption of the network in British Columbia by flooding or forest fires also affects Yukon. Disruptions to highway infrastructure within the Yukon can interrupt supply chains and disrupt access to market foods, as evidenced in the 2012 washouts on Yukon highways that resulted in grocery store shelves running out of food within a few days (Hou & Sneyd, 2020; Macfarlane, 2020; Walker et al., 2017). This spurred many Yukon communities to prioritize adaptation and food security planning (CTFN & AICBR, 2019; Dorward et al., 2014; FNNND & AICBR, 2019).

7.5 Climate change exacerbates existing health inequalities including access to food. (Medium confidence)

Climate change can exacerbate existing health inequities, putting added strain on people who are struggling with food insecurity, health issues, exposure to hazards, or inadequate housing (Clark et al., 2021; Clayton et al., 2021; Cunsolo Willox, 2015; Hrenchuk, 2020;

Macfarlane, 2020; IPCC, 2022). Marginalized populations already dealing with structural inequities including colonization, racism, and low income may be affected by increased exposure and/or sensitivity to climate impacts and may also have reduced capacity to adapt through less access to resources (Agriculture and Agri-Food Canada, 2022; Clark et al., 2021; Hrenchuk, 2020; Sheedy, 2018). This includes the unique challenges related to remote communities with large distances from hospitals, limited access to health and social services, and a greater dependence on the environment (Macfarlane, 2020). For many Yukon communities, the closest grocery store is several hundred kilometres away, leaving them more vulnerable to supply chain disruptions and volatility in gas prices (Alatini et al., 2016; Cruikshank et al., 2019; Hrenchuk, 2020). Social and food safety nets are programs that support well-being by ensuring that a minimum level of food is available, however, these are emergency support systems and need to be implemented in tandem with other initiatives that support food sovereignty (FAO, n.d.)

For Yukon First Nations, the impacts of climate change and other environmental changes on traditional foods compound the effects of colonial legacies on people’s ability to harvest (Beaumier et al., 2015; Cunsolo Willox, 2015; Hou & Sneyd, 2020; Macfarlane, 2020; NCCAH, 2013; Whyte, 2017, 2018). The legacies of colonization include the disruption of traditional lifestyles and the transfer of Indigenous knowledge around hunting practices, the relocation of people to communities, and reduced access to traditional hunting areas, creating more reliance on market foods and the need to participate in the market economy (AICBR, 2016a; Sheedy, 2018). Some may have challenges accessing the equipment they need to harvest, while others experience the limitations of modern lifestyles, with limited time available to go harvesting (Blom et al., 2022; Hou & Sneyd, 2019; Lambden et al., 2006; Schuster et al., 2011b; Sheedy, 2018).

More vulnerable members of the population, particularly those with chronic illness and physical disabilities, experience the health impacts of climate change more than others (Macfarlane, 2020). Increased wildfires both in and near the Yukon make air quality a health concern, particularly for the elderly and those with chronic respiratory illnesses. (Macfarlane, 2020; Warren & Lemmen, 2014). While extreme heat is uncommon in the Yukon, summer heat warnings are increasing. These events pose challenges for the elderly or those with existing health issues, as many Yukon homes do not have air conditioning or a means of moderating heat (Macfarlane, 2020). People who are lacking secure housing may not be able to avoid the impacts of wildfire smoke or extreme heat.

Extreme events, increasing snow loads, flooding, and shifting due to permafrost thaw can affect housing integrity, requiring costly maintenance and potentially increased insurance costs (Department of Environment and Natural Resources, 2015; Macfarlane, 2020). For those in rental homes or without the resources or agency to manage repairs, the impacts on their housing can have associated physical and mental health impacts, and in cases where there is severe damage to housing, this can increase the risk of homelessness (Bezgrebelna et al., 2021; Macfarlane, 2020).

7.6 Climate change has implications for mental health, particularly as a result of impacts on culture, traditional activities, and safety. (Medium confidence)

Climate anxiety is caused by grief, fear, and guilt, and can cause increased anxiety for people already struggling with food insecurity or health issues (Berry & Schnitter, 2022; Clayton et al., 2021). Sometimes this comes from stress and overwhelm arising from feeling helpless or feeling an inability to adapt to changes, particularly for youth and Elders (Berry & Schnitter, 2022; Clayton et al., 2021; Furgal & Prowse, 2008; Macfarlane, 2020). It can manifest itself as a variety of conditions including depression, eco-anxiety, suicidal ideation, violence, addictions, post-traumatic stress disorder, among other mental health outcomes (Berry & Schnitter, 2022). Climate change disproportionately affects the mental health of people already living with existing physical or mental health conditions and those living in low socio-economic conditions, without food or housing security (Berry & Schnitter, 2022; Clark et al., 2021; Clayton et al., 2021). People who have a strong connection to the local environment may feel grief from the loss of cultural activities and disconnection from culture (Berry & Schnitter, 2022; Clark et al., 2021; Clayton et al., 2021; Cunsolo Willox et al., 2015; Healey, 2015; IPCC, 2022; Macfarlane, 2020). They may feel a sense of loss of place or identify, or loss of ability to feel safe in their local environment (Cunsolo Willox et al., 2012; Sawatzky et al., 2020). As people lose access to recreational activities or special places that are affected by environmental change, this can affect both their mental and physical health (Berry & Schnitter, 2022; Clark et al., 2021). Finding avenues for engagement in activities that support local adaptation like community-based monitoring, research and knowledge sharing can contribute to improved mental health (Sawatzky et al., 2020).

Increases in emergency events like flooding and wildfire lead to increased anxiety and affect mental health (Berry & Schnitter, 2022; Clark et al., 2021; Clayton et al., 2021; Macfarlane, 2020). Relocation during an emergency can cause both physical and mental stress (Cianconi et al., 2020). In the case of the Fort McMurray fire in Alberta, depression rose by 50% afterwards (Clark et al., 2021). While these are discrete events with immediate impacts to safety and mental health, in some cases there can be long-term impacts on mental health including post-traumatic stress disorder (Clark et al., 2021; Zhong et al., 2018). Currently there is no available data on how Yukoners are experiencing climate anxiety or other mental health impacts of climate change. However, about 50% of Yukoners rate the quality and accessibility of mental health services as poor or fair raising concerns about how prepared the Yukon is to support increasing mental health issues (Smale & Gao, 2021).

7.7 Where suitable soils and climate are present, agriculture has the potential to expand due to a longer and warmer growing season. Field-based agriculture may be challenged by precipitation variability. (Medium confidence)

There is potential that as the climate changes there may be opportunities for increased small-scale agriculture in the Yukon. Warmer temperatures, potential increases in precipitation, and longer growing seasons could make the Yukon more conducive to growing a wider range of foods (Macfarlane, 2020; Sheedy, 2018; Walker et al., 2017). Potential for agricultural will vary across the territory depending on local soil, climate, and water regimes as there is a lot of variability in precipitation from year to year and limited land currently suitable for agriculture (Energy, Mines and Resources, 2016; Macfarlane, 2020; Sheedy, 2018; Walker et al., 2017). While the Government of Yukon’s food strategy to promote agriculture and local foods does not discuss climate change, their subsequent agriculture policy acknowledges the challenges and opportunities that climate change will bring to Yukon's agriculture industry (Energy, Mines and Resources, 2020; Energy, Mines and Resources, 2016). Permafrost thaw has provided a challenge for agricultural development, infrastructure, and production that has led to adaptations for conventional agricultural methods (McKenna et al., 2015). Challenges that increase costs include the need for irrigation, managing interactions between wild and domesticated animals, and lack of food storage (Energy, Mines and Resources, 2020; Sheedy, 2018), while socio-economic challenges include the availability of long-term funding and staff retention and training. Local agriculture can contribute to land degradation and GHG emissions through land clearing and waste production, as well as having impacts on nearby ecosystems (Cooke, 2017; Energy, Mines and Resources, 2020; Yacura & Osborne, 2019). In the Yukon the proportion of GHGs arising from agriculture is small (0.03 Mt), but it has increased 5.6% from 2005 to 2020. This number includes non-energy GHG emissions (not fossil fuel use) related to the production of crops and livestock. YG promises to encourage a sustainable industry by researching ways to reduce greenhouse gas emissions and providing tools to promote adaptation (Energy, Mines and Resources, 2020).

Local production and sale of agricultural products could have an impact on food security, sustainability, and potentially reduce transportation costs in the long term (Energy, Mines and Resources, 2016; Macfarlane, 2020). However, availability of local food is dependent on production, which is limited by climate, land availability, and cost of production (Sheedy, 2018; Walker et al., 2017). Currently local food production only supports a small amount of the food consumed in the Yukon, and costs of local food are generally higher than imported market foods affecting accessibility for people living in low-income conditions (Sheedy, 2018). There is increased interest in local food production, demonstrated through the popularity of farmer's markets, community gardens, personal and industrial greenhouses, First Nation-run farms, and agricultural businesses (Research Northwest & Morrison Hershfield, 2017). Local food production can be a strategy to support food sovereignty for Yukon First Nations because it provides an opportunity to increase community food security, participate in decision-making around food production, and engage in agricultural models that reflect First Nation worldviews (Blom et al., 2022). Yukon First Nations are using food production through local farms and greenhouses as an adaptation strategy that tackles food security and food sovereignty for their citizens, as providing economic opportunities (Centre for Indigenous Environmental Resources, Inc., 2006; Chen & Natcher, 2019; Hou & Sneyd, 2020; Research Northwest & Morrison Hershfield, 2017).

7.8 Yukon communities and organizations are addressing climate change by engaging in community-led adaptation and food security projects, community-based monitoring, and knowledge sharing between communities. (Medium confidence)

Yukon communities are resilient, however, climate change puts added strain on their resources, particularly where there are small governments and organizations dealing with many challenges (AMAP, 2017). Indigenous governance plays an important role in tackling climate change, particularly as Yukon First Nations have long histories of being stewards of their lands, waters and resources (RRDC & AICBR, 2019; SFN & AICBR, 2016; Whyte, 2017). Because of this intimate interrelation with the environment and place-based knowledge, Indigenous Peoples possess unique perspectives, knowledge, and capacities to adapt to and lead solutions to climate change (Berkes, 2017; Ban et al. 2018; FAO. 2021;

Whitney et al., 2020). First Nation-led strategies that engage with the food system through land-based cultural revitalization support food sovereignty (Blom et al., 2022; Council of Canadian Academies, 2014). Small-scale local agriculture can also be part of a food sovereignty framework (Blom et al., 2022). These strategies can support adaptation to the social, environmental, and health impacts of climate change, while also in some cases reducing greenhouse gas emissions (Agriculture and Agri-Food Canada, 2022). However, there are challenges in developing and sustaining food security, knowledge sharing, and monitoring initiatives including funding and retaining staff. Economic sovereignty for First Nation governments to initiate and maintain these programs is part of developing solutions. This is exemplified by the outcomes of renewable energy projects led by Yukon First Nations, including generating revenue, supporting energy security and sovereignty, and reducing emissions.

Community-based research can support First Nations and communities in maintaining food security through strategies that are locally based and culturally appropriate (Kassi et al., 2017; KFN, 2014; SFN & AICBR, 2016; Walker et al., 2017). Many Yukon communities are involved in community-based monitoring projects focused on contaminants and other issues related to food quality and safety. These types of programs, along with land guardians and other Indigenous monitoring programs support food security and contribute to community adaptive capacity (Lake et al., 2012; Lam et al., 2019). As an example, Kluane First Nation citizens were concerned about contaminants in fish which is an important source of subsistence and nutrition (Alatini et al., 2016; KFN & AICBR, 2016; Research Northwest & Morrison Hershfield, 2017). They initiated a research project that investigated contamination and provided critical information for making good food choices, as well as exposing youth in the community to new research skills (Alatini et al., 2016; KFN & AICBR, 2016). Involving youth in these initiatives supports their education and can provide a sense of agency when faced with climate anxiety (Kassi et al., 2017; MacKay et al., 2020; Peace & Myers, 2012). Reconnecting with the land is also an important part of taking climate action particularly for First Nations youth in the Yukon (Yukon First Nations Climate Action Fellowship, 2021). Other adaptation initiatives include hunter support programs, addressing food wastage by providing community food storage, and sharing knowledge and skills around preserving and food-sharing (Berry & Schnitter, 2022; KFN, 2014; Sheedy, 2018; Wilson et al., 2019).

8. Heritage, Culture, and Traditional Ways of Life

Traditional activities, heritage sites, and intangible cultural heritage are affected by climate change. Indigenous knowledge provides important insights into the impacts of climate change and contributes to the resilience of Yukon First Nations. (High confidence)

Science alone does not provide the knowledge required to understand climate change and support adaptation to the impacts being felt in the Yukon; Indigenous knowledge provides critical insights into the changes that are already occurring as well as strategies for adaptation (CYFN, 2011; Merculieff et al., 2017; Pearce et al., 2015; Warren & Lulham, 2021). In the community-based report *Yukon Climate Change Needs Assessment* which surveyed Yukon First Nations, respondents overwhelmingly agreed that Indigenous knowledge plays a role in finding solutions to climate change (CYFN, 2011). However, only 50% felt that it was being used, indicating that Yukon First Nations believe that Indigenous knowledge is not being used to its full potential. Respondents noted that this was primarily due to a lack of resources. No follow up has been done to evaluate if more has been done to include Indigenous knowledge and perspectives in climate change adaptation in the Yukon since 2011.

8.1 People who live close to the land and practice traditional ways see the detailed impacts of climate change in the North. Many of them want to share this knowledge but tend to be marginalized in the broader conversations about impacts. (High confidence)

Food is part of culture, as is the process of hunting and gathering, and by impacting traditional food sources climate change has potential implications for cultural practices, relationship to the land, and mental health (Cunsolo Willox et al., 2015; Loring & Gerlach, 2009). People who live close to the land and practice traditional ways can be the first to feel the impacts of climate change in the North as some aspects of traditional ways of life may become more difficult. They observe the impacts of climate change and provide important information on how climate change is affecting ecosystems at a local scale (Merculieff et al., 2017). Indigenous knowledge provides early warnings of the impact of climate stressors, particularly within complex ecological systems, where it can provide critical insight for understanding and maintaining ecological integrity (Merculieff et al., 2017). This knowledge is vital for community adaptation, and Yukon First Nations are prioritizing opportunities for citizens to spend time on the land, particularly bringing youth and Elders together at events like culture camps (CAFN & Alsek Renewable Resource Council, 2009). Community-based monitoring programs like Indigenous guardians support these relationships and provide important information for conservation and management (Aronsson et al., 2021; FNNND & AICBR, 2019; Zurba et al., 2019).

8.2 Harvesting traditional foods and medicines does not only affect food security, but also supports the local economy and is the basis for cultural and social identity. As the climate changes, it affects the land, the wildlife, access to food, and cultural practices of First Nations people. (Medium confidence)

Chapter 16 of the Umbrella Final Agreement (UFA) (1993) guarantees the rights of Yukon First Nations to harvest and to manage fish and wildlife. Food and culture are inextricably linked, and traditional hunting and gathering practices are critically important to local culture and health, yet the the relationships that people have with the land are challenged by climate change (Cruikshank et al., 2019; FNIGC, 2018b; KFN, 2014; Loring & Gerlach, 2009; Furgal & Prowse, 2008; Sheedy, 2018; Rosol et al., 2016). Traditional foods and medicines are important for both local culture and well-being (Cruikshank et al., 2019; Furgal & Prowse, 2008). By connecting people to their culture, and bringing community members together, traditional foods and associated practices support physical, spiritual, mental, and cultural well-being (Schuster et al., 2011b; Wesche & Chan, 2010; Rosol et al., 2016). Cultural traditions and knowledge sharing around food include community hunts, fishing, and harvesting as well as traditions around food sharing and preserving, including community feasts (AICBR, 2016a,b; FNIGC, 2018b; Wesche & Chan, 2010; Rosol et al, 2016). These activities around food are part of sharing knowledge, stories, traditions, and the importance of cultural places (Adger et al., 2011). Time spent on the land, and culture camps have been identified as key actions to support health in Indigenous communities (CAFN & Alsek Renewable Resource Council, 2009). Changes in seasons due to warming temperatures impacts planning around hunting, fishing, and gathering, requiring flexibility on when and where to go and making it more challenging to organize community cultural events. (Walker et al., 2017; Hou & Sneyd, 2020). The integration of traditional values into decision-making around land and water supports the mental and spiritual health of community members, and while some Indigenous knowledge of environmental conditions may not be relevant to today's conditions, people are adapting their knowledge and traditions (Furgal & Prowse, 2008).

8.3 Indigenous knowledge and community-based monitoring programs contribute important knowledge to our understanding of environmental change and wildlife health. Indigenous knowledge indicates that substantial changes have already occurred in the Yukon due to climate change. (High confidence)

There are opportunities for Indigenous and scientific knowledge to be used together in evidence-based decision-making to support adaptation that is grounded in both (Government of Yukon, 2016; Mistry & Berardi, 2016; Ogden et al., 2016). Indigenous knowledge provides valuable insight into the interrelationships that are affected by climate change, long-term observations and trends in landscape changes, and the appearance of new species or disappearance of existing species (McGrath, 2018; Wheeler et al., 2020). In Canada's North, monitoring programs have poor spatial coverage, and there is considerable variability in the consistency and funding support for these programs (Aronsson et al., 2021). Indigenous knowledge and long-term community-based monitoring programs can both provide important information on key species, and when paired with climate trends can begin to show how a changing climate may impact wildlife in the future (Gagnon et al., 2020; Knopp et al., 2020). As an example, the Porcupine caribou herd has been increasing in numbers and thriving despite significant changes in the region, as demonstrated through an Indigenous-led community-based monitoring program that tracks seasonal body condition (Gagnon et al., 2020). At the same time, caribou populations in other areas may be experiencing declines. In this example, Indigenous knowledge brings insight into local conditions, showing that broad trends are not consistent across the country and local information is important.

Climate change research, particularly in the natural sciences, has much to be gained from Indigenous perspectives (Wong et al., 2020). Indigenous northerners are often the ones alerting us to impacts on wildlife, particularly key food species, and changes to harvesting and hunting areas (Clark et al., 2016; Merculieff et al., 2017; Newton et al., 2005; Wesche & Chan, 2010). Indigenous, local, and scientific knowledge all confirm that climate change is already affecting Yukon's land, wildlife, water, and people (Government of Yukon, 2020, Merculieff et al., 2017; Research Northwest & Morrison Hershfield, 2017). Yukon First Nations and transboundary Indigenous groups have documented changes to lakes and river, vegetation, fish, and wildlife, as well as evidence of permafrost thaw (AICBR, 2016a,b; Alaska Science for All UAF GI, 2022; ArcticPeoples, 2013; Brewster et al., 2016; Merculieff et al., 2017; Pearce et al., 2015). The Inuvialuit are concerned about rapid changes along the north coast of the Yukon and the associated impacts they have observed on fish (Brewster et al., 2016; Tyson & Heinemeyer, 2017). Yukon First Nations have noted changes in climatic conditions and impacts on fisheries and wildlife harvests (AICBR, 2016a,b; CAFN, 2006; CAFN, 2009; Kassi et al., 2010). Researching climate change from multiple worldviews is required to meet these growing challenges, and this requires support for practices that maintain ongoing interaction with the local environment (Ford et al, 2016).

8.4 Cultural and heritage sites are vulnerable to flooding, wildfire, permafrost thaw, and coastal erosion. (High confidence)

Cultural sites like fish camps, culture camps, historical buildings, and other gathering places are often in areas close to water, in forested areas, or built on permafrost, leaving them vulnerable to the impacts of climate change. Coastal erosion, driven by permafrost thaw, is already affecting cultural sites and travel routes in the North Slope of the Yukon (Irrgang et al., 2019; Radosavljevic et al., 2015). Sea level rise is expected to cause flooding in low-lying coastal areas and increase risk to heritage sites on Qikiqtaruk (Herschel Island), an area of cultural importance to the Inuvialuit (Bush & Lemmen, 2019; Olynyk, 2008). Permafrost thaw has an impact on trails, cemeteries, recreation sites, travel routes, and other important cultural infrastructure in other areas of the Yukon as well including Dawson City where the impacts of permafrost are visible on historical buildings (Benkert et al., 2015).

9. Causes and Responses

Climate change is human caused. (High confidence) The Yukon is responding to the impacts of climate change by adapting and addressing the causes by reducing emissions. (Medium confidence)

The effects of climate change are already apparent on human and natural systems (IPCC, 2022; Bush & Lemmen, 2019). Present and future decisions and actions will determine the level of future disruption and how resilient these systems are (IPCC, 2022). The Yukon is taking actions to reduce emissions and respond to the impacts of climate change. These actions are led by Yukon organizations and governments, but also include efforts by the general public to minimize their carbon emissions and prepare for future change. A number of governments and organizations in the Yukon have declared a climate emergency, including Assembly of First Nations Yukon Region (AFN Yukon), Council of Yukon First Nations (CYFN), the fourteen Yukon First Nation governments, City of Whitehorse, and Government of Yukon. In 2020, Government of Yukon released *Our Clean Future*, a strategy that was developed in consultation with Yukon First Nations, transboundary Indigenous nations, and Yukon municipalities. This strategy tackles climate change, energy, and the green economy and includes a greenhouse gas reduction target and a resilience target for the Yukon (Government of Yukon, 2020). YG has two external advisory groups; an expert panel that advises on approaching YG’s greenhouse gas target, and a youth panel on climate change that provides advice on how to address climate change. In 2020 Yukon First Nations, AFN Yukon, and CYFN signed a climate change emergency declaration and initiated the development of a climate change strategy (AFN Yukon & CYFN, 2020). Key concerns for Yukon First Nations include traditional food sources, wildfire, and flooding, are often the focus of First Nation-led adaptation projects (CYFN, 2011; Peace & Myers, 2012). The Yukon First Nations Climate Action Fellowship is currently developing a vision and action plan for Yukon First Nations in collaboration with AFN Yukon and CYFN (Yukon First Nations Climate Action Fellowship, 2021).

9.1 There is unequivocal evidence that the climate is warming and that over the past 50+ years, human activity has been responsible for that warming. (Very high confidence)

Overwhelmingly the physical science indicates that observed climate change is due to human influence on the climate system (see *Key Finding 1: Climate*) and is caused by human activities including burning fossil fuels, increasing industrial activities, agriculture, waste management and clearing forests for development (Bush & Lemmen, 2019; IPCC, 2021). According to the IPCC, "it is unequivocal that human influence has warmed the atmosphere, ocean and land" (2021), noting that there have been widespread changes. There is evidence that the changes that have taken place over the last fifty years are unprecedented, and that greenhouse gas levels have surpassed levels experienced (IPCC, 2021).

9.2 Adaptation is how we address the impacts of climate change. Mitigation is how we address the causes of climate change. It is important to keep in mind both of these challenges and wherever possible to look for solutions which both mitigate and adapt. (High confidence)

Climate resiliency involves decisions that combine adaptation and mitigation thereby reducing climate change, while also preparing for its impacts (IPCC, 2022; NRTEE, 2009). Climate Resilient Development (CRD) is an approach that focuses on mitigation and adaptation while incorporating social inequity considerations (IPCC, 2022). CRD highlights the interrelatedness of different actors and organizations in achieving adaptation and mitigation goals. The Yukon is part of the fastest warming region in the world and adaptation strategies will be critical in managing the impacts of climate change. While climate change in the Yukon is the result of global actions and decisions, the Yukon's efforts to reduce emissions are still an important part of mitigating climate change. Current climate change mitigation priorities include a number of strategies to reduce emissions focused on transportation, heating, and the energy system (Government of Yukon, 2020).

Yukon's energy system provides opportunities for both adaptation and mitigation to ensure that it is resilient. The electric distribution network only reaches some of the territory, with many communities relying on local energy sources. There are a variety of energy sources contributing to the Yukon's power system, including hydropower, diesel, LNG, biomass, gasoline, wind, and solar. The Yukon's energy system is currently close to its maximum power generation capacity, and future planning and development is essential to support a growing population (Chen et al., 2018). There are competing concerns regarding cost, environmental considerations, and climate change in relation to new power generation choices (Chen et al., 2018), but recent commitments are to increase renewable energy production (Government of Yukon, 2020).

Land planning also provides opportunities to address both mitigation and adaptation. Creating large networks of protected areas is a key adaptation strategy for preserving natural ecosystems, however it also can support carbon sequestration (Carroll & Ray, 2020). Indigenous-led protected areas contribute to adaptation and mitigation, while also supporting reconciliation by respecting self-determination and ensuring that cultural considerations are incorporated into land planning (Courtois, 2021; ILI, 2020; Zurba et al., 2019). See *Key Finding 5.10* for further discussion.

9.3 Integrating climate change considerations into existing planning processes is a method of reducing risk while taking advantage of existing procedures. (Medium confidence)

Mainstreaming climate change involves incorporating climate change into existing initiatives, processes, policies, or programs. It reduces the need for additional processes and increased resources, by taking advantage of those currently available. It also ensures that climate change is being considered throughout different sectors (IPCC, 2022). "Mainstreaming adaptation means to strategically integrate climate change considerations into ongoing planning, policy and other decision-making processes at the local level" (Hennesey & Streicker, 2011, p.30). This is particularly important in small organizations and governments, where capacity is already stretched and adding another climate change planning process on top of existing work adds strain to the organization's resources. Mainstreaming ensures that climate change impacts are considered in concert with interrelated issues and responses are integrated into daily operations. Building networks and partnerships and sharing knowledge encourage mainstreaming and build capacity to adapt (Warren & Lulham, 2021). Key areas where climate change considerations can be integrated into existing planning processes include energy planning, emergency preparedness, sustainability planning, resource management, infrastructure development, land-use planning, engineering design, transportation planning, etc. Risk management tools like the guides identified in *Key Finding 6: Hazards* can be used to reduce infrastructure vulnerabilities and adapt more effectively to climate change in Canada's North.

9.4 Solutions that address social inequities, cross multiple sectors, and are informed by Indigenous ways of knowing, doing, and being will improve adaptation outcomes in the Yukon. (High confidence)

Northern communities are resilient; however, climate change adds stress and strain to community capacity and resilience. Climate change inordinately affects people who live close to the land, rural communities, and populations that have less access to resources (Clayton et al., 2021; IPCC, 2022; Macfarlane, 2020; Sheedy, 2018). Ensuring that northern interests and local contexts are represented and incorporated in the development of climate change adaptation and mitigation solutions, plans and strategies is critical, particularly for solutions targeted at rural Yukon communities and Yukon First Nations. Yukon communities and First Nation governments are for the most part small and responding to and planning for climate change places added strain on their programs and planning processes (AMAP, 2017). However, northern communities have already demonstrated their resilience to climate change, including adapting to increasing extreme weather events, the impacts of permafrost thaw on housing and other infrastructure, and changes to local ecosystems (AMAP, 2017; Furgal & Prowse, 2008). Locally led initiatives that nurture relationships to the land, culture, and community provide opportunities for climate action grounded in a local context. Yukon First Nations are leading monitoring and conservation programs within their traditional territories that contribute to local resilience through skill development, employment, strengthening connections to the land, and providing a direct link to local decision-making (FNNND & AICBR, 2019; Kouril et al., 2016; Warren & Lulham, 2021).

Some First Nations or communities are engaging in community-led prioritization or planning processes to identify actions to address climate change. The Vuntut Gwitchin went through a community-based process to review available environmental knowledge of their traditional territory and identify monitoring and knowledge gaps for future projects (Kuntz et al., 2018). KFN and Selkirk First Nation (SFN) both developed food security strategies that include actions to maintain traditional food security (Cruickshank et al., 2019; KFN, 2014; SFN & AICBR, 2016; Walker et al., 2017). AICBR's community climate champions identified opportunities for climate action in several Yukon communities while also providing opportunities for rural youth to be involved in research (AICBR, 2020; CTFN & AICBR, 2019; FNNND & AICBR, 2019). They identified potential actions including research priorities, land-based activities, policy initiatives, ways to reduce emissions, and farming and food security actions. Opportunities for First Nations and communities to share information encourage the growth of adaptation (Sheedy, 2018; Pratt, 2019). As an example, the Yukon First Nations Climate Action Gathering hosted by AFN Yukon and CYFN in 2020 brought people together from across the Yukon to share stories of adaptation and mitigation in their communities. Websites like AICBR's map of climate and food systems highlight the strengths within the Yukon food system, particularly at the community scale, and provide a virtual space for sharing adaptation strategies (AICBR, 2020; Pratt, 2019).

Traditionally governance and decision-making processes have privileged scientific evidence. However, equitable decision-making around climate change, including research and monitoring, requires space for Indigenous ways of knowing and governing (Wheeler et al., 2020; Wilkens & Datchoua-Tirvaudey, 2022). Decision-making processes that incorporate both Indigenous and scientific knowledge are strengthened and provide valuable opportunities to increase both research and management capacity (IPCC, 2022; Ogden et al., 2016). Indigenous-led and community-based research and monitoring programs, as well as the co-production of knowledge, are critical approaches for informing local decision-making (Hill et al., 2020; Latulippe & Klenk, 2020; Wheeler et al., 2020; Wilkens & Datchoua-Tirvaudey, 2022; Williams & Hardison, 2013).

9.5 Public education, research, and in particular community-based research remain as critical needs to improve understanding of Yukon climate change and how to address it. (High confidence)

Strengthening the Yukon's capacity to address climate change requires increased science capacity and information use in the Yukon. As a region at the frontlines of climate change, the North is a prime location for research on the impacts of climate change (Canadian Polar Commission, 2014). There are opportunities for research from this region to inform global science and policy, but also a critical need for research to inform local science and policy (AMAP, 2021a; Canadian Polar Commission, 2014; Government of Yukon, 2020, 2016). While numerous government and academic researchers come to the Yukon to conduct climate change research, there is also considerable research happening by local researchers working for First Nations, Yukon government, Yukon University, local non-governmental organizations, industry, and the private sector. This knowledge economy has been growing and diversifying, providing opportunities for Yukon-led research relevant to environmental change in the Yukon (Petrov, 2016; Voswinkel, 2012). The meaningful engagement and inclusion of Yukon First Nations in research that impacts their culture and food systems also plays an important role in upholding the rights as described under the

UFA and is a step towards reconciliation and supporting Indigenous self-determination (Wong et al., 2020) and is crucial for advancing community-led climate solutions.

Engaging the public and building awareness of climate change are important avenues for promoting adaptation and mitigation (Feinstein & Mach, 2019; Government of Yukon, 2020; Warren & Lulham, 2021). Yukon youth have identified the need for more climate change material in the education system and increased public education (Yukon Youth Panel on Climate Change, 2021). Climate education is a key strategy to support climate action, and locally relevant education materials that include engaging or experiential activities are more effective at reaching youth (Monroe et al., 2017; Reid, 2019). Education initiatives targeted at practitioners can also build adaptive capacity by supporting the integration of climate change resources and considerations into a range of sectors (Feinstein & Mach, 2019). In developing education and training materials, there are opportunities to build on the existing strengths in the Yukon including Indigenous expertise, local climate change research, and the technical expertise of Yukon practitioners (Government of Yukon, 2020). There are opportunities for more climate change material in the Yukon education system including the development of climate change-focused courses.

9.6 Supporting youth engagement in research and decision-making processes strengthens the Yukon’s capacity to adapt to and mitigate climate change. (High confidence)

Bringing youth voices into decision-making processes contributes to adaptation and mitigation capacity (Government of Yukon, 2020; IPCC, 2022; MacKay et al., 2020). Engaging youth in climate change education, projects, and decision-making can foster a sense of purpose and help to alleviate anxiety and grief related to climate change (MacKay et al., 2020; Peace & Myers, 2012). Opportunities for First Nations youth to spend time on the land and connect with Elders are critical for fostering relationships to the land and sharing knowledge (Adger et al., 2011; Gartler et al., 2022). Youth mentorship through educational programs, harvest and culture camps, and projects that support intergenerational knowledge exchange also contribute to Indigenous leadership of co-management (KFN, 2014; KFN & AICBR, 2016). Youth play an important role as climate change champions in their communities and can be effective leaders in both sharing knowledge and inspiring action (Gartler et al., 2022; Peace & Myers, 2012). As an example, fish camps hosted by the SFN to foster connections between youth and Tutchone traditions were successful at further developing their relationships with the land and Elders, as well as identifying climate change strategies (Richards et al., 2019).

10. Importance of the North

Climate change in the North is a major driver of global change. (Medium confidence)

The North has most of the known significant feedback mechanisms for the global climate. In effect this means that what happens across the North will have consequences for the global climate system. The cryosphere, which includes snow, river and lake ice, sea ice, glaciers, ice shelves and ice sheets, and permafrost, is an important part of the North’s ecosystems, and also plays an important role in the Earth’s climate system (Bush & Lemmen, 2019; IPCC, 2021). Thaw and melt impact the water cycle, sea level rise, snow-ice albedo, and surface gas exchange. Together with Alaska, the Yukon is home to the third largest icefield in the world and is also underlain by sporadic to continuous permafrost. The boreal forest also plays an important role in sequestering carbon, impacted by landscape change through development or wildfire (Bush & Lemmen, 2019). The Yukon, with the rest of the North, plays an important role in global climate change, particularly through key feedback mechanisms. The term “positive feedback” refers to a mechanism which accelerates a change while also being a result of that change. Though less common, “negative feedback” is a mechanism that cancels itself. In climate systems, feedbacks often play an important role in future climate change, yet they can be hard to quantify (IPCC, 2021). Examples are provided in the following sections.

10.1 The boreal forest and the Arctic tundra both show indications of shifting from net greenhouse gas sinks to net sources. (Low confidence)

There are several processes related to climate change that affect the ability of the boreal forest and Arctic tundra to act as carbon sinks, including changing fire regimes, vegetation productivity and decomposition rates, and permafrost thaw (ACIA, 2004; Bjorkman et al., 2020; Bradshaw & Warkentin, 2015; Harris et al., 2021; Kurz & Apps, 1999; Warren & Lulham, 2021). While wildfire risk overall is not expected to increase in the Yukon, some areas that are drier could experience more frequent and severe forest fires. Wildfires release carbon into the atmosphere, contributing to increased climate change, while also reducing the productivity of the forest. Drought can impact productivity in the boreal forest, leading to a reduction in its role as a biomass carbon sink (Green et al., 2019; Ma et al., 2012). Overall, changes to the productivity of the boreal forest and potential increases in wildfire frequency and severity may cause a reduction in the boreal forest’s impact as a CO_2 sink (Ma et al., 2012; Yuan et al., 2012; Zhao, et al., 2021).

10.2 Carbon and methane trapped within and below permafrost is being released into the atmosphere and ocean as permafrost thaws, leading to an acceleration of climate warming. (Medium confidence)

Permafrost thaw is releasing carbon and methane into the atmosphere and will continue to do so with increased thaw in the future. Permafrost contains almost twice the carbon that is in the atmosphere, and it is estimated that widespread permafrost thaw over the next century could release between 10s and 100s of billions of CO_2 thereby accelerating climate change (IPCC, 2019; UNEP, 2012). Coastal erosion, driven by a combination of permafrost thaw and storm events, releases carbon into the ocean. Increasing carbon concentrations in the ocean have already been linked to terrestrial sources, of which a key source in the Beaufort Sea is the Yukon shoreline where rapid permafrost thaw is happening (Couture et al., 2018).

10.3 The loss of Arctic sea ice, which is accelerating due to the albedo reversal from reflective ice to absorptive ocean, will have far-reaching effects. (High confidence)

Snow-ice albedo change includes the loss of Arctic sea ice, melt back of glaciers, vegetation change, and changes to snow cover through earlier snow melt. Sea ice provides a barrier between the ocean and atmosphere limiting gas exchange between the two (IPCC, 2021). It also affects the salinity and thereby the circulation of the ocean. When sea ice melts back, more of the ocean surface is exposed, changing the reflectivity, and allowing more heat to be absorbed. Warming ocean temperatures then contribute to more melt, accelerating the process in what is called positive feedback (ACIA, 2004; IPCC, 2021). Arctic sea ice in September, when it is at its minimum, has decreased by about 40% in surface area comparing trends from 1979-1988 and 2010-2019 (IPCC, 2021). There is high confidence that this rapid loss in sea ice is caused by human influence on the climate system (IPCC, 2021). Sea ice projections indicate that we will experience at least one year without sea ice in the Arctic by 2050 (IPCC, 2021). The loss of multi-year sea ice, increased winds, and increased sea-ice mobility all contribute to increased melt and slower grow back of ice in the autumn (Overland & Wang, 2013).

Other changes to albedo include the northern tundra in the Yukon and high-altitude areas which provide a reflective surface in the winter when covered in snow (high albedo). In comparison, forested areas are darker and absorb more energy (low albedo). The expansion of the treeline and taller canopy growth in these areas contributes to the loss of reflective surfaces in the winter in the Yukon, ultimately impacting regional climate and amplifying climate change through positive feedback (Bjorkman et al., 2020; Myers-Smith et al., 2011; Warren & Lemmen, 2014).

10.4 Arctic sea ice loss influences the jet stream causing new weather patterns, including extreme events, at mid-latitudes. (Low confidence)

The loss of sea ice has possible implications for the mid-latitudes, potentially causing extreme events and other changes to weather patterns (AMAP, 2021a; Cohen et al., 2014; IPCC, 2017). A warming Arctic and sea-ice loss both affect the jet stream, “as the Arctic continues to warm faster than elsewhere in response to rising greenhouse-gas concentrations, the frequency of extreme weather events caused by persistent jet-stream patterns will increase” (Francis and Vavrus, 2015, p.1, Coumou et al., 2018). This is linked to changing wind patterns, bringing cold air to mid-latitudes, and has been linked to unusually cold weather in the mid-western United States, snowier winters in eastern North America, and prolonged heat waves and dry conditions in Europe (Cohen et al., 2014; Romanowsky, et al., 2019). However, models do not consistently recreate these observed patterns meaning that the cause-and-effect mechanisms linking rapid Arctic warming to mid-latitude weather and climate require further study to better understand their relationship (Cohen et al., 2020).

10.5 Glacial melt and ocean warming are leading to sea level rise. Glacial melt and diminishing sea ice also affect the global ocean currents. (High confidence)

Global mean sea level rise has increased by approximately 0.2 metres in the past century and the rate of sea level rise increase doubled over the last fifty years (IPCC, 2021). Glacial and ice sheet melt, and thermal expansion are the main causes of global sea level rise, being felt across most of the Arctic and around the world, although with regional differences (ACIA, 2004; IPCC, 2021). Sea level rise will continue, even with aggressive action to mitigate climate change, a certain amount of change is irreversible (IPCC, 2019; IPCC, 2021). Increased wave heights, partially due to loss of sea ice, compounded with sea level rise and permafrost thaw, contribute to coastal erosion on the North Slope (IPCC, 2019).

The mechanism which drives most of the ocean circulation is the thermohaline circulation - the sinking of dense cold and salty water - in the polar regions. Freshwater additions from glacial melt and river runoff affect ocean circulation and the movement of ocean water between the poles and the tropics (ACIA, 2004; IPCC, 2019). Warming ocean temperatures and increased freshwater runoff reaching the ocean have changed the density in the upper levels of the ocean in the Arctic have changed how the layers in the ocean mix (IPCC, 2019). Less mixing of the ocean layers also means there is less oxygen and changes in biogeochemistry, including acidification (IPCC, 2019).

6.0 DETAILED INDICATORS

1.1 Climate Trend Indicators: Temperature

Description	Temperature trends. Updated 26-Jan-2022 Historic temperature changes.
Implications	Yukon is warming significantly. Annual temperature has increased by 2°C over the past 50 years. See *Key Finding 1*.
Rationale	Temperature is one of the most common climate variables, and data has been collected in Yukon since 1948.
Data	Source: Environment and Climate Change Canada Coverage: Yukon and Northern B.C. ∆T is provided for all of Canada. In the regional breakdowns, Yukon is grouped with Northern B.C. The data spans from 1948 to present. Completeness: No missing data; however, it should be noted that not all regions of Yukon are represented all of the time. Timeliness: The data and report are kept current and updated seasonally.
Methods	The data represents the departure from the 30-year (1961-1990) climate baseline - sometimes called a climate normal. Temperature is given as a temperature anomaly or change in °C. The data is derived from meteorological stations across the country. There is little or no detail about the numbers or locations of those stations and their data quality.
Limitations	There are several limitations to this data, first is that Northern B.C. is included in the regional separation. This means that the results could be skewed towards southern Yukon. Another limitation is that we are not supplied with information about the input data, nor the model to go from discrete data points to the regional trend. Therefore, it is important to compare this data to local meteorological station data and projections to test our confidence in the results.

References	https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html Environment and Climate Change Canada Climate Trends and Variations Bulletin

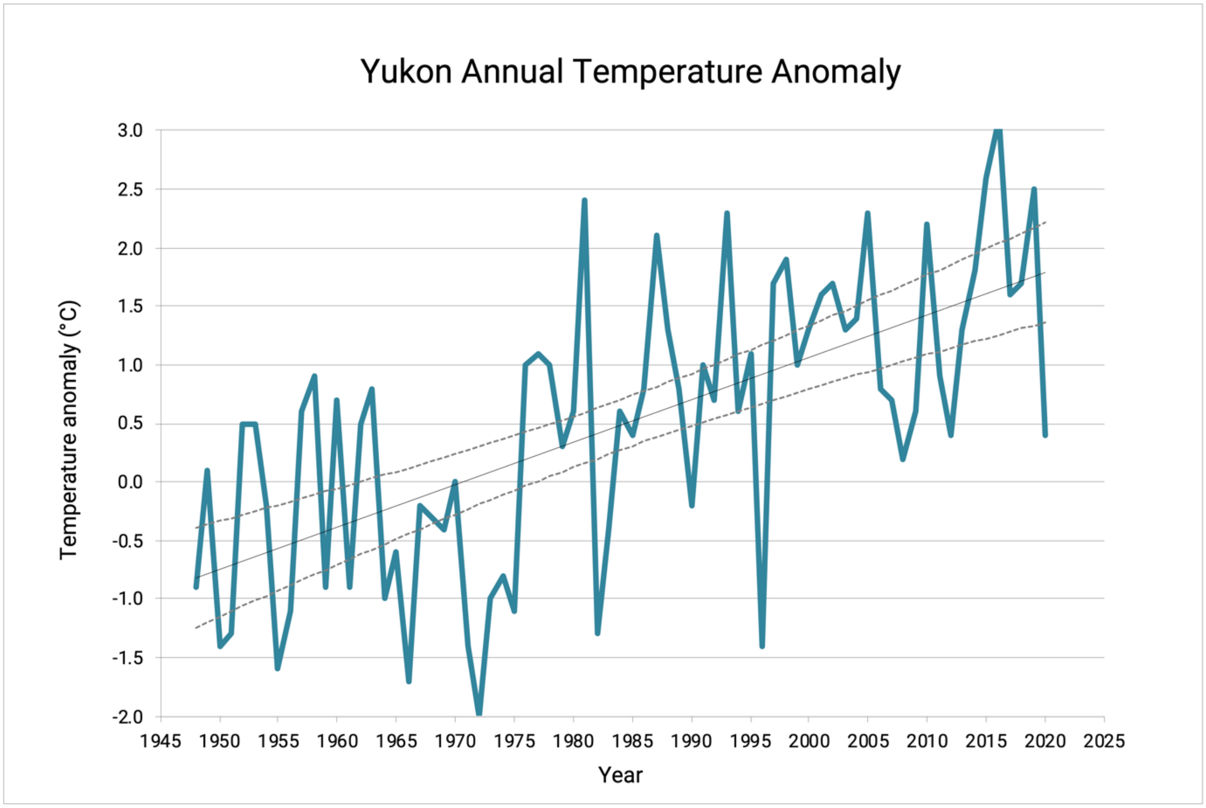

Figure 1.1. Yukon annual average temperature anomaly (r-value = 0.64 p-value < 0.01)

1.2 Climate Trend Indicators: Precipitation

Description	Climate Trends Updated 31-Sep-2016 Historic precipitation changes.
Implications	Precipitation in Yukon is increasing, but with considerable variability. This trend is significant. Precipitation varies annually and also geographically across the territory. Total precipitation has increased by 11.8% from 1948 to 2015. See *Key Finding 1.*
Rationale	Precipitation is one of the most common climate variables.
Data	Source: Environment Canada

	Coverage: Yukon and Northern B.C. ∆P is provided for all of Canada. In the regional breakdowns, Yukon is grouped with Northern B.C. The data spans from 1948 to 2015. Completeness: ECCC stopped reporting ∆P mid-way through 2016. It should be noted that not all regions of Yukon are represented all of the time. For example, in the 2013 data for precipitation, the accompanying map shows gaps in St. Elias and North Yukon. Timeliness: The data and report are no longer being updated.
Methods	The data represents the departure from the 30-year (1961-1990) climate baseline - sometimes called a climate normal. Precipitation departures are given as a % change. The data is derived from meteorological stations across the country. There is little or no detail about the numbers or locations of those stations and their data quality.
Limitations	There are several limitations to this data, first is that Northern B.C. is included in the regional separation. This means that the results could be skewed towards southern Yukon. Another limitation is that we are not supplied with information about the input data, nor the model to go from discrete data points to the regional trend. Therefore, it is important to compare this data to local meteorological station data and projections to test our confidence in the results. Changes in how precipitation is measured, and a relatively poor record of winter precipitation, also increase uncertainty in this dataset.
References	https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html Environment and Climate Change Canada Climate Trends and Variations Bulletin

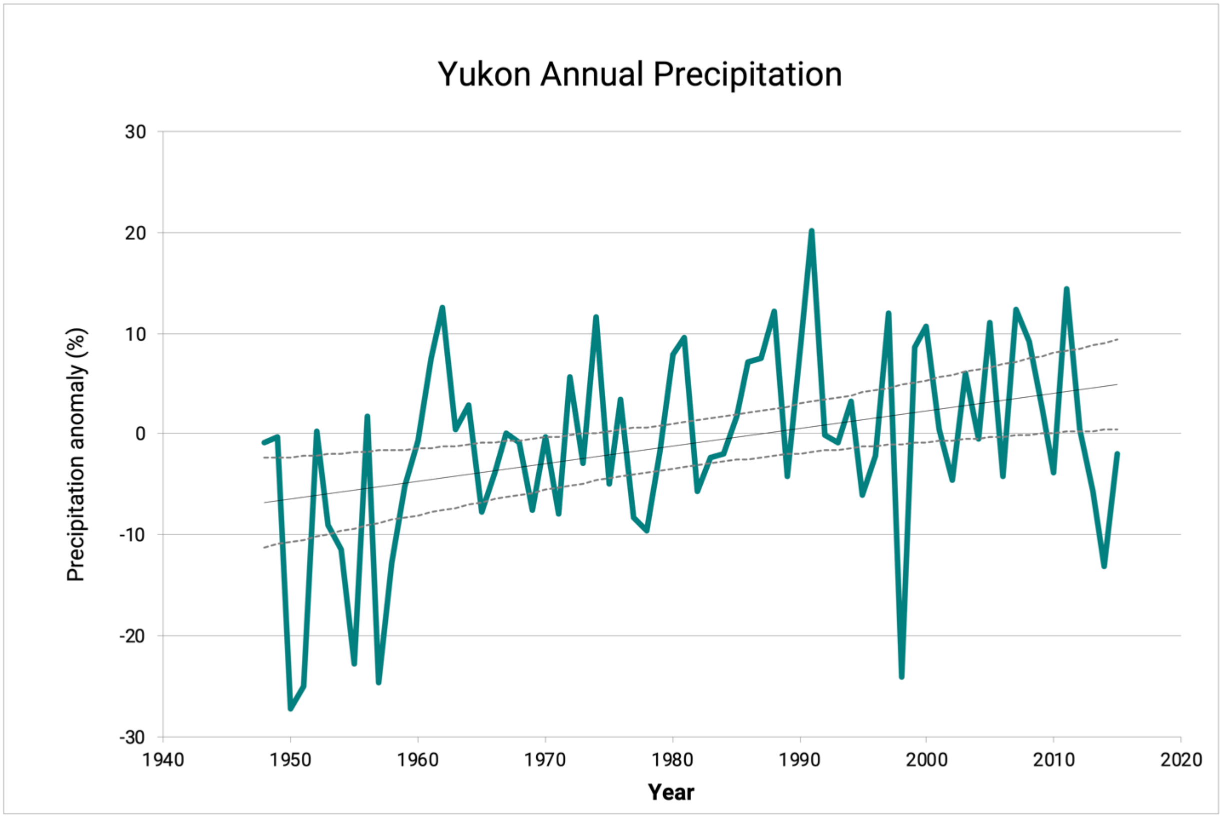

Figure 1.2. Yukon total annual precipitation anomaly (r-value = 0.35 p-value < 0.01)

1.3 Climate Projection Indicators

Description	Climate Projections Updated 2-Dec-2020 Global circulation model projections of temperature and precipitation based on the IPCC fifth Assessment Report.
Implications	Yukon is projected to warm and to have increased precipitation over the coming decades. All scenarios project significant change. Temperature is projected to increase by 0.7 to 3.7°C over the next 50 years and precipitation is projected to increase by 4 to 17%. See *Key Finding 1*.
Rationale	Global Circulation Models are the standard method of projecting future climate change.
Data	Source: Environment and Climate Change Canada Coverage: Yukon The projection spans from 2006 to 2100. Completeness: Not applicable

Methods	These projections use the CMIP5 climate model datasets from an ensemble of 24 climate models. Results are downscaled and bias-adjusted using the BCCAQv2 method. These projections are based on three of the four representative concentration pathways (RCPs) from the IPPC fifth Assessment Report. Using several emissions scenarios gives a sense of the range of model projections for the Yukon. The model data is then converted to ∆T and ∆P and adjusted to match the overlap of the time periods (2006 to present) for comparison purposes with the climate trend indicators.
Limitations	All projections have limitations; it is important to compare them alongside trends and alongside each other. Sources of uncertainty include natural climate variability, differences between climate models, and differences in future human emissions of greenhouse gases. The biggest limitation is not the model, it is rather that we cannot predict future emissions which are closely tied to economy, technology and behaviour. By choosing a range of emission scenarios (RCPs 8.5, 4.5, and 2.6) we consider a range of possible futures.
References	https://climatedata.ca/about/ [Accessed on December 2, 2020] Environment and Climate Change Canada Climate information provided by Climatedata.ca, a collaboration between the Pacific Climate Impacts Consortium (PCIC), Ouranos Inc., the Prairie Climate Centre (PCC), Environment and Climate Change Canada (ECCC), Centre de Recherche Informatique de Montréal (CRIM) and Habitat7. BCCAQv2 method: Cannon, A.J., S.R. Sobie, and T.Q. Murdock, 2015: Precipitation by Quantile Mapping: How Well Do Methods Preserve Changes in Quantiles and Extremes? Journal of Climate, 28(17), 6938-6959, doi:10.1175/JCLI-D-14- 00754.1.

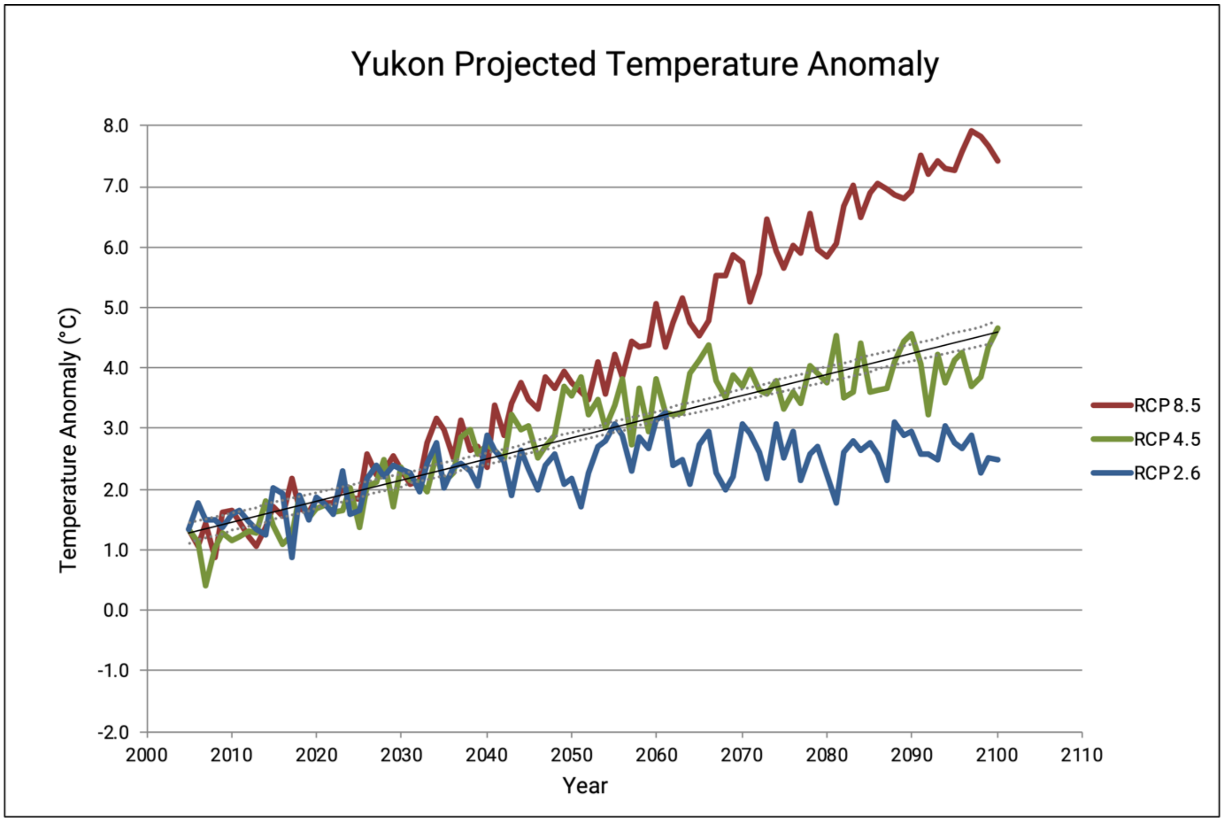

Figure 1.2. Yukon projected annual average temperature anomaly (r-value = 0.92 p-value < 0.01)

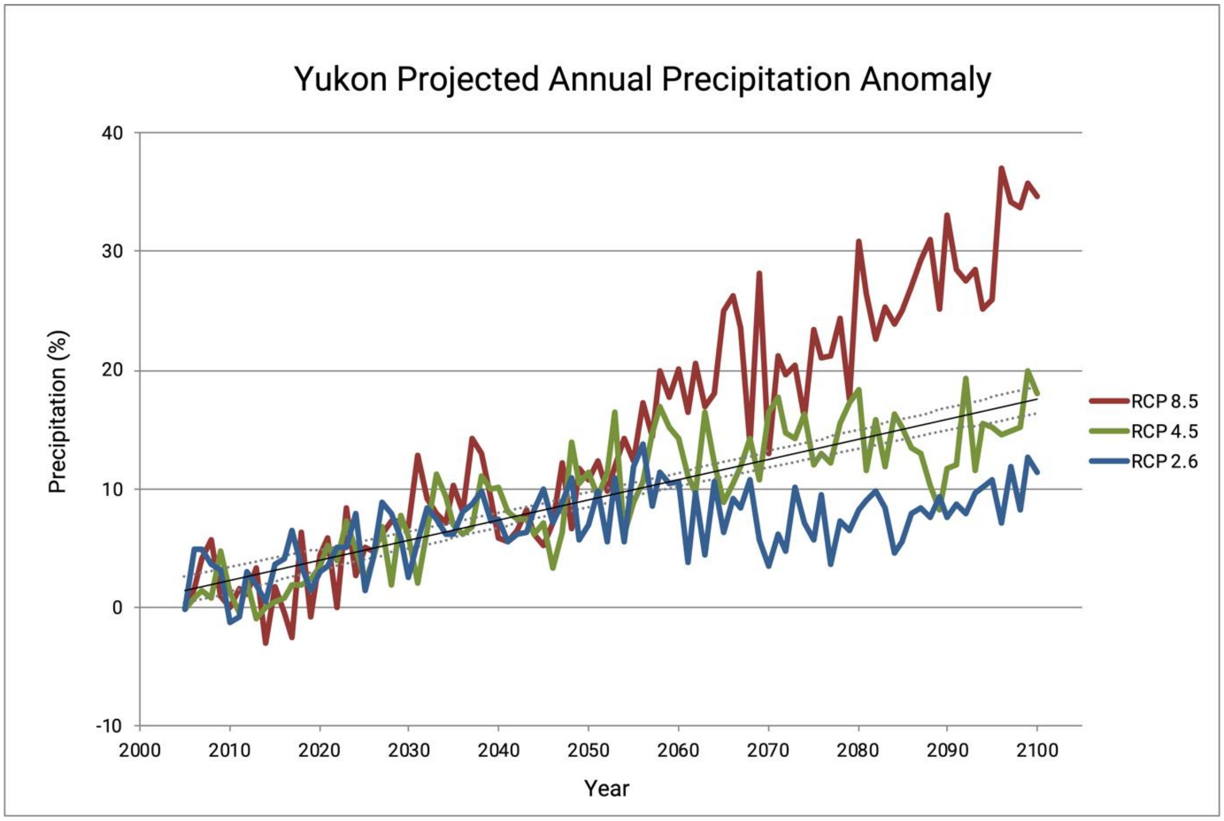

Figure 1.4. Yukon projected total annual precipitation anomaly (r-value = 0.86 p-value < 0.01)

2.1 Fire History Indicator

Description	Fire History Updated 4-Mar-2021 Yukon fire history: annual area burned.
Implications	The number of hectares burned per year has increased over the past 50 years; however, the trend is not significant. 2004 was an extreme year for wildfires in Yukon. We need to observe fire for a longer period of time to be certain of the trend. Neighbouring jurisdictions have seen recent extreme fire seasons. In 2014 the Northwest Territories had 3.4 million hectares burned (highest in recent decades), while in 2015 Alaska's fires burned 2.1 million hectares which was the second highest year on record and 1.1 million hectares in 2019. Alberta and British Columbia have also had extreme fire seasons in recent years. (www.forestry.alaska.gov and https://www.fraserinstitute.org/sites/default/files/trends-in-canadian-forest-fires-1959-2019.pdf for more information).
Rationale	Fire represents an intersection of weather (including temp, precipitation, humidity, wind, storm/lightning) and fuels (including forest growth).

Data	Source: Wildland Fire Management, Community Services, Yukon Government Coverage: Spatial coverage is Yukon. The data spans from 1955 to present, although we are plotting from 1960. Completeness: No missing data. Timeliness: The data and report are kept current and updated annually.
Methods	Wildland Fire Management Branch monitors and maps the area burned across Yukon each fire season. Some of the fires were verified using LANDSAT imagery while others are best estimates. There is another data record showing number of fires, however, total area burned is a clearer indicator.
Limitations	From correspondence with the Wildland Fire Management Branch, it was suggested that the earlier data (1950's) had questionable coverage; therefore, only the data from 1960 forward is being plotted. Another issue, which may affect the area burned is whether some of the fires (in any given year) are approaching communities. Whenever there is a threat to a community or an important assets then active fire suppression is employed, affecting the burned area. Finally, forest management practices as well as fire management practices may also have an influence on fires.
References	Data available on request. Wildland Fire Management Branch Department of Community Services Government of Yukon

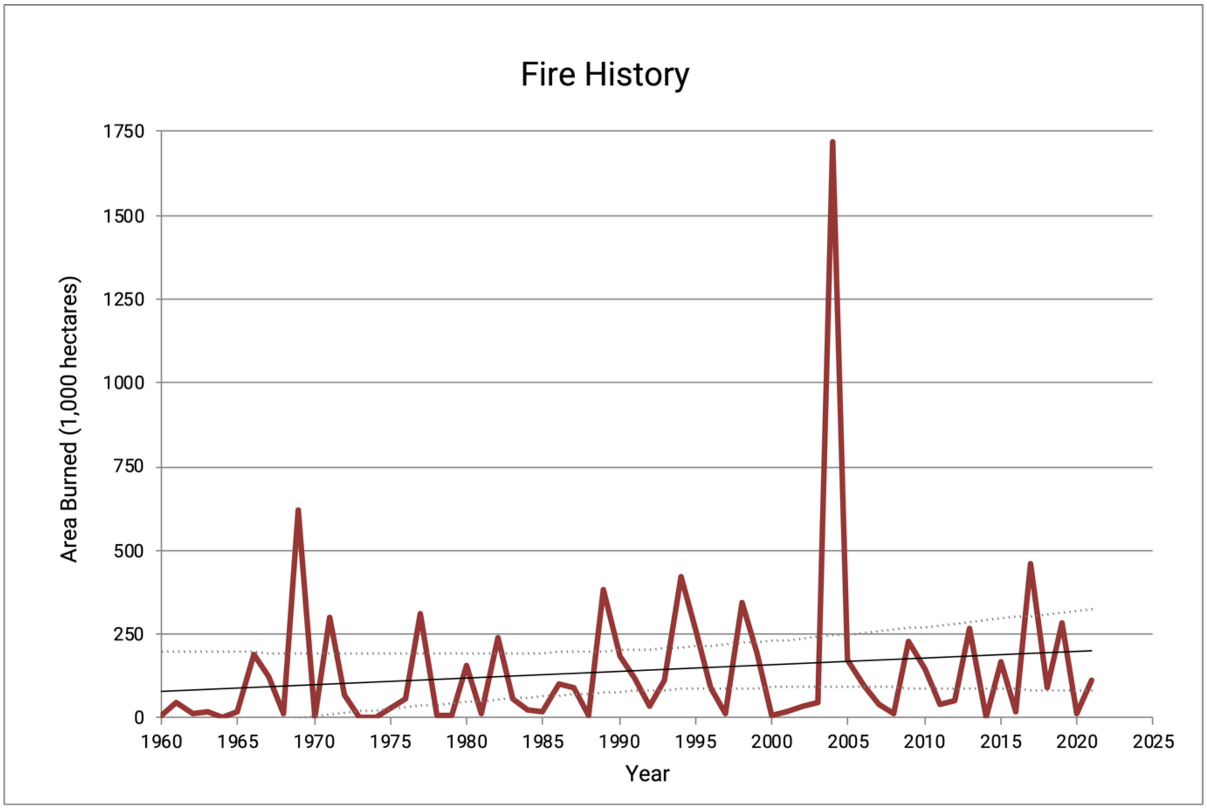

Figure 2.1. Yukon fire history (r-value = 0.15 p-value = 0.24)

2.2 Fire Severity Indicator

Description	Fire Severity Index Updated 4-Mar-2022 A relative measure of weather conditions which affect the potential severity of fires.
Implications	Even though fire severity risk has increased over the past 50 years, with the data we have, the trend is not significant. The severity index can have significant swings from one year to the next.
Rationale	The severity index is a combination of meteorological data, which gives us another insight into climate. It is a unit-less, relative number.
Data	Source: Wildland Fire Management Branch, Community Services, Government of Yukon Coverage: Spatial coverage is nominally Yukon, based on meteorological stations from the following 8 communities: Whitehorse, Carmacks, Mayo, Dawson City, Haines Junction, Ross River, Watson Lake, Teslin. The data spans from 1960 to present, calculated during the summer fire season: June, July, August. Completeness: No missing data. Timeliness: The data and report are kept current and updated each summer.

Methods	Wildland Fire Management Branch calculates the daily severity index (DSR). DSR is a unit-less numeric rating of the relative difficulty of controlling fires. It is based upon an evaluation of the fire weather and accurately reflects the expected efforts required for fire suppression. It includes such things as temperature, precipitation, relative humidity, and wind. The DSR is another means of describing fire danger, which is most often portrayed for the public through colour-coded highway signs.
Limitations	As a unit-less number, the fire severity index should only be used as an indication of relative change over time. It is more an indication of weather and climate (showing the potential risk of fire events) rather than a measure of fire or even fuel loading. It is only measured over the summer months, when there is an appreciable risk of forest fires.
References	Data available on request. Wildland Fire Management Branch Protective Services Department of Community Services Government of Yukon

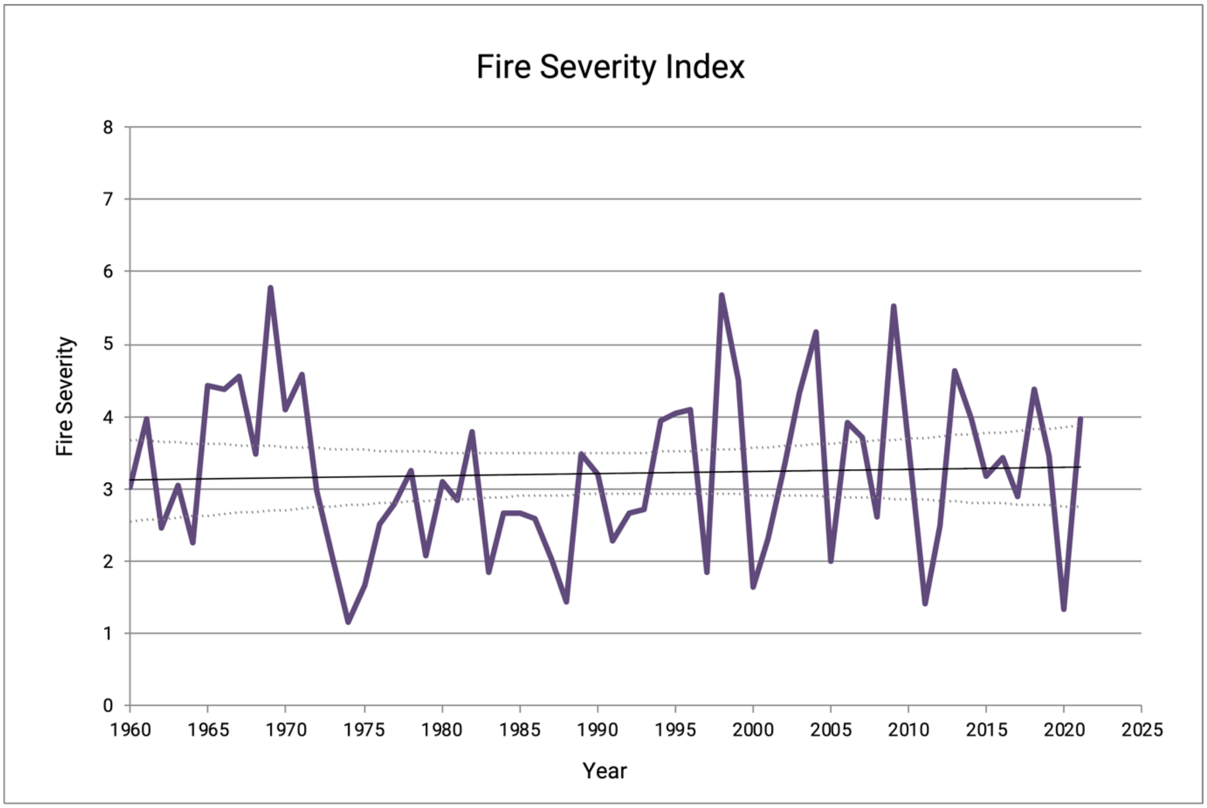

Figure 2.2. Yukon fire severity index (r-value = 0.05 p-value = 0.69)

3.1 Arctic Sea Ice Extent Indicator

Description	Arctic Sea Ice Extent Updated 18-Jan-2022 Monthly average area (in millions of square kilometers) of Arctic and other northern oceans with at least 15% ice concentration.
Implications	Arctic sea ice is melting. Sea ice loss is averaging 80,000 km^2 per year, although there is significant variability from one year to the next. The net result is that summer sea ice will melt out in the Arctic within the next decade/decades. Sea ice melt appears to be accelerating, with most of the melt occurring in the past decade. This has wide-ranging implications for the Arctic and the globe.
Rationale	Sea ice melt is the most apparent global indicator of climate change, and especially relevant for the circumpolar North. As the Earth's energy alters, most of the energy goes into the oceans and the remainder into ice, soil, and the atmosphere. The Arctic Ocean is a confluence of the ice, ocean, and atmosphere.
Data	Source: National Snow and Ice Data Centre Coverage: Arctic (Northern Hemisphere sea ice). Satellite data comes from near polar orbits; however, the pole itself (1.19 million square kilometers prior to 1987 and 0.31 million square kilometers post 1987) is not observed, and assumed to be ice covered. The data spans from Nov-78 to present. Completeness: Missing data (Dec-87, Jan-88) are flagged as missing. Timeliness: The data is kept current and updated monthly.
Methods	The data is derived from daily satellite images averaged over the month. Using the EASE Grid (nominally 25km x 25km grid), each grid cell is assessed to determine if there is at least 15% ice coverage. Because sea ice has such a wide annual variation in distribution, it is typical to compare data from a particular month over time. Most often September is used as it has the sea ice minimum extent.
Limitations	This data is a clear and straightforward measure of change when observed over time. Sometimes users will mistakenly try and use the change from one year to the next to suggest a trend. It is important to observe the long-term trend. Sea ice extent does not give a clear picture of sea ice volume, because ice thickness can vary significantly with age. There are measures of sea ice volume, however measuring volume is less accurate than measuring spatial extent.

References	http://nsidc.org/data/g02135.html National Snow and Ice Data Center CIRES, 449 UCB University of Colorado Boulder, CO USA 80309-0449 Phone: +1 303-492-6199 Fax: +1 303-492-2468 E-mail: nsidc@nsidc.org Fetterer, F., K. Knowles, W.N. Meier, M. Savoie, and A.K. Windnagel. 2017, updated daily. Sea Ice Index, Version 3. Boulder, Colorado USA. Ice Extent. NSIDC: National Snow and Ice Data Center. DOI: https://doi.org/10.7265/N5K072F8.

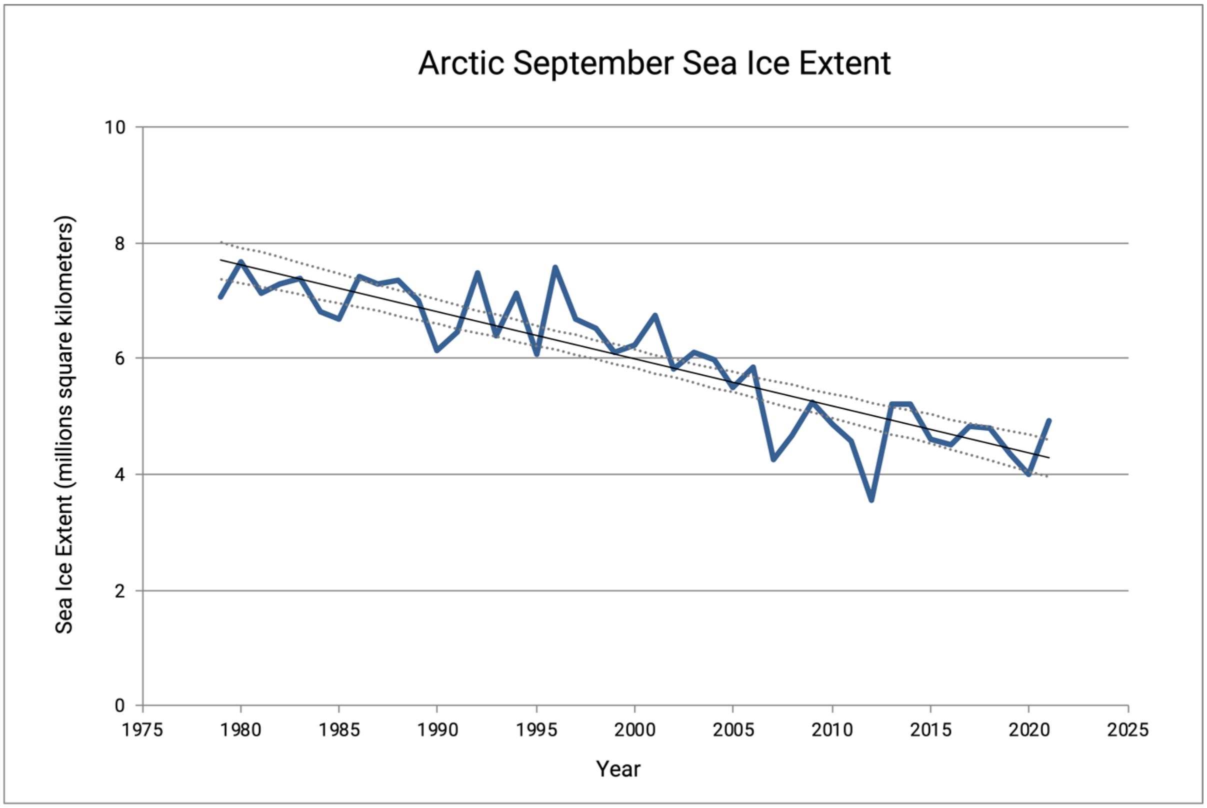

Figure 3.1. Annual Arctic September sea ice extent (r-value = -0.89 p-value < 0.01)

3.2 Arctic Sea Ice Volume Indicator

Description	Arctic Sea Ice Volume Updated 18-Jan-2022 Monthly calculated Arctic sea ice volume (in 10^3 km^3)
Implications	Arctic sea ice currently demonstrates a significant downward trend, melting rapidly at a rate of ≈ 300 km^3 sea ice loss per year, indicating loss in the thickness and coverage of sea ice. Less and less of the ice is

	surviving from one year to the next and the ice that is lasting for more than one season is thinning significantly. The net result is that summer sea ice will melt out in the Arctic within the next decade/decades. Sea ice melt appears to be accelerating, with most of the melt occurring in the past decade. This has wide ranging implications for the Arctic and the globe.
Rationale	Sea ice melt is the most apparent global indicator of climate change, and especially relevant for the circumpolar North. As the Earth's energy alters, most of the energy goes into the oceans and the remainder into ice, soil, and the atmosphere. The Arctic Ocean is a confluence of the ice, ocean, and atmosphere.
Data	Source: University of Washington Pan-Arctic Ice-Ocean Modeling and Assimilation System (PIOMAS) Coverage: Arctic (Northern Hemisphere sea ice). PIOMAS Release 2.1 The data spans from 1979 to present. Completeness: No missing data. Timeliness: The data is kept current and outputted monthly.
Methods	Based on satellite data combined with a Thickness and Total Energy Distribution (TED) Sea-Ice Model. The model is complex, and users should note that these are calculated values rather than direct observations. Because sea ice has such a wide annual variation in distribution, it is typical to compare data from a particular month over time. Most often September is used as it has the sea ice minimum extent.
Limitations	This model output gives a strong indication of climate change over time. Sometimes users will mistakenly try and use the change from one year to the next to suggest a trend. It is important to observe the longer term trend. Sea ice volume calculations are inherently less certain than ice extent observations; however volume provides a clearer indication of sea ice change. In general terms there is more certainty in recent calculations and less in older calculations. The reason for this is that there has been more ground truthing with ice transects in recent years. From a paper published by Schweiger in August 2011, uncertainty is ±24% in volume and ±36% in the trend.

References http://psc.apl.uw.edu/research/projects/arctic-sea-ice-volume-anomaly/data/
Polar Science Center, Applied Physics Laboratory, University of Washington
1013 NE 40th Street, Box 355640, Seattle, WA 98105-6698
Phone: +1 206-543-6613
Fax: +1 206-616-3142
E-mail: PSCAdmin@apl.washington.edu
Data: Zhang, J. & D. Rothrock, 2003. Modeling global sea ice with a thickness and enthalpy distribution model in generalized curvilinear coordinates. Monthly Weather Review, vol. 131(5), p.845-861.
Model: Schweiger, A., R. Lindsay, J. Zhang, M. Steele, H. Stern & R. Kwok, 2011. Uncertainty in modeled Arctic sea ice volume. Journal of Geophysical Research, vol. 116, doi:10.1029/2011JC007084.

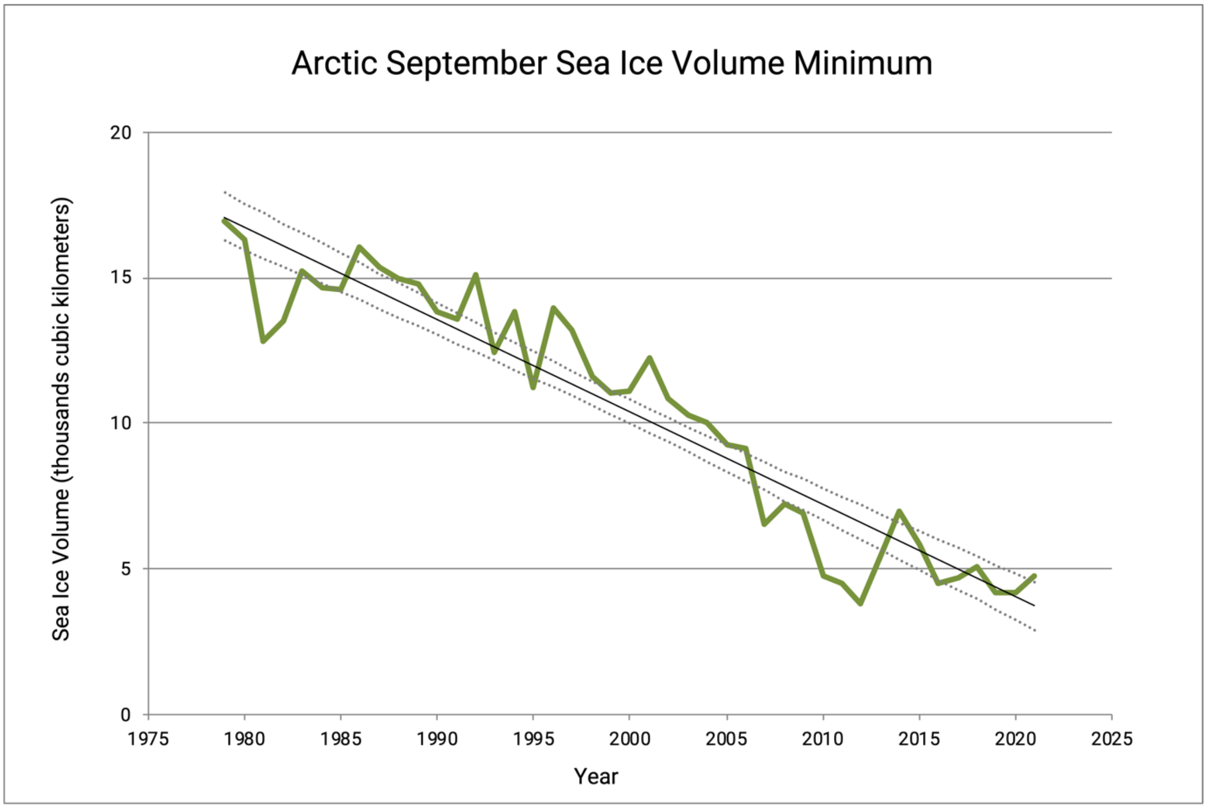

Figure 3.2. Annual Arctic September sea ice volume (r-value = -0.95 p-value < 0.01)

4.1 Ocean Oscillation Indicators

Description Pacific Decadal Oscillation and Arctic Oscillation
Updated 15-Mar-2022
Monthly mean Sea Surface Temperature (SST) anomalies

Implications Oceans act to distribute the climate and oscillations are recurring patterns of ocean-atmosphere climate variability. They are likely the most

	significant natural influence on regional weather and climate. For Yukon, two key oscillations are the Pacific Decadal Oscillation (PDO) and the Arctic Oscillation (AO). A positive phase of the PDO and a negative phase of the AO are associated with warmer temperatures in Yukon. These graphs show that the PDO has been dropping while the AO has been quite flat in recent decades. Since Yukon has been warming, this is the clearest evidence that it is anthropogenic climate change rather than a naturally occurring cycle.
Rationale	Monthly mean global average SST anomalies are removed to separate this pattern of variability from global climate change. Oceans, especially the surface temperatures of oceans, have a strong effect on the atmosphere and thus the climate. It is important to watch the PDO alongside climate change to try to discern natural variability from anthropogenic (human-caused) climate change.
Data	Source: Joint Institute for the Study of the Atmosphere and Ocean, (JISAO). JISAO is a joint program involving NOAA and the University of Washington Coverage: Pacific Ocean poleward of 20°N The index is a unit-less measure. A positive value indicates a warm sea surface temperature in the Pacific Northwest. The data spans from 1900 to present. Completeness: No missing data. Timeliness: The data is kept current and outputted monthly.
Methods	The data is derived from Sea Surface Temperature observations. United Kingdom Meteorological Office Historical SST data set for 1900-81. Reynold's Optimally Interpolated SST (V1) for January 1982-Dec 2001). Optimally Interpolated SST Version 2 (V2) beginning January 2002.
Limitations	This data is an important measure of climate variability which pre-dates the current warming trend in the global climate. Even though it is called an "oscillation" there are no good predictive methods for the PDO.

References	PDO data: https://psl.noaa.gov/gcos_wgsp/Timeseries/Data/pdo.long.data Joint Institute for the Study of the Atmosphere and Ocean, JISAO (NOAA and University of Washington) Zhang, Y., J.M. Wallace, D.S. Battisti, 1997. ENSO-like interdecadal variability: 1900-93. Journal of Climate, vol. 10, p. 1004-1020. Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis, 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society, vol. 78, p. 1069-1079. AO data: http://www.ncdc.noaa.gov/teleconnections/ao/ National Oceanic and Atmospheric Administration (NOAA)

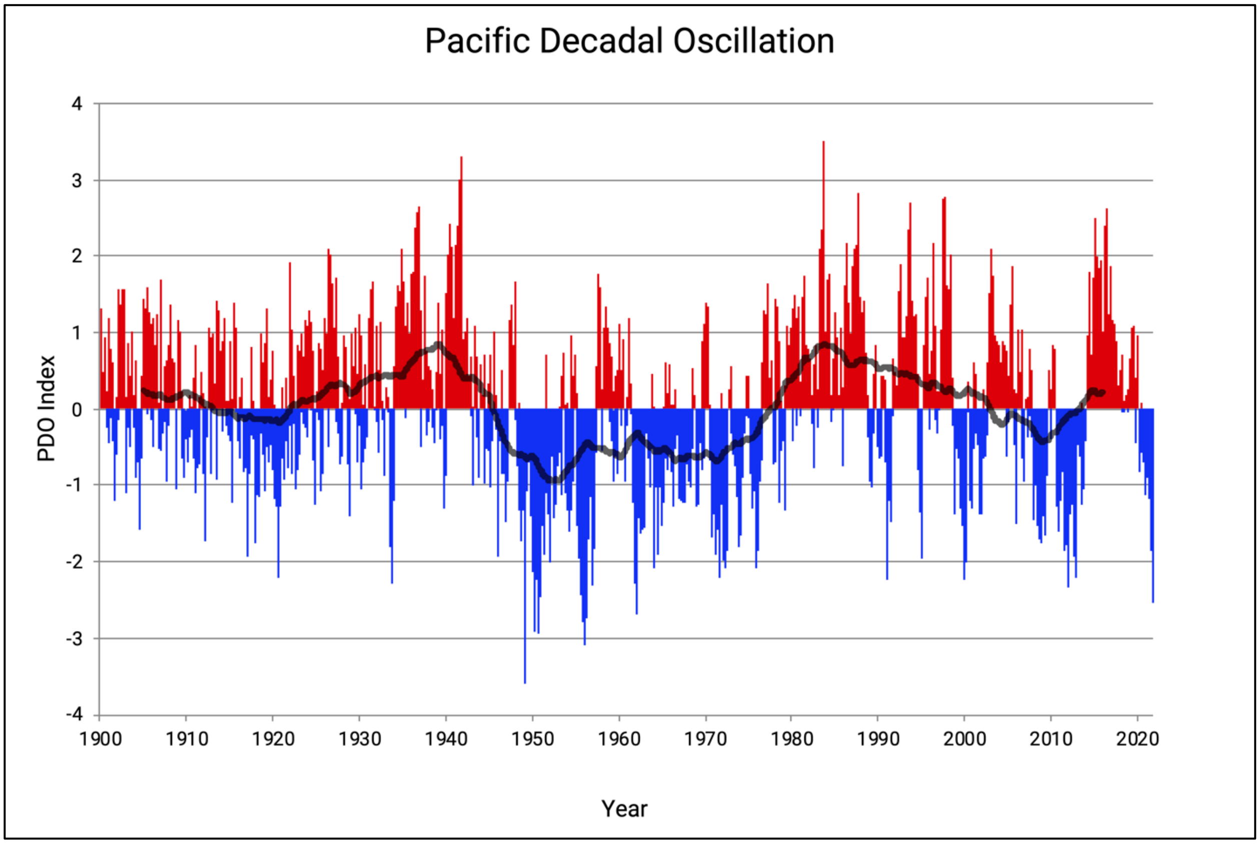

Figure 4.1. Pacific Decadal Oscillation and 5-year moving average (r-value = -0.02 p-value = 0.9)

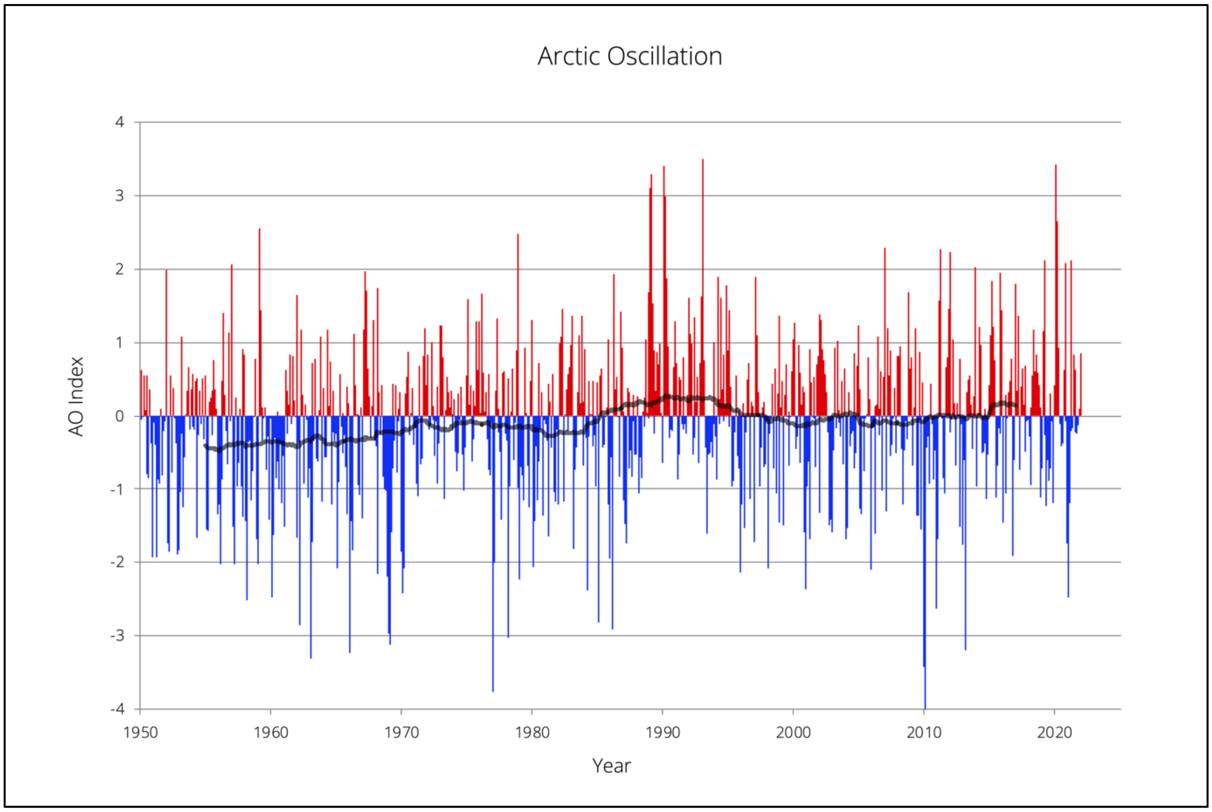

Figure 4.2. Arctic Oscillation and 5-year moving average (r-value = 0.35 p-value < 0.01)

5.1 Yukon Greenhouse Gas Emissions Indicator

Description	Yukon Greenhouse Gas Emissions Updated September 2022 Annual GHG emissions (in ktonne CO_2 equivalent)
Implications	Government of Yukon reports on Yukon's emissions using a combination of federal and territorial data. The territorial data used is only available from 2009 onwards. During this time, Yukon's total emissions have grown along with Yukon's population and economy. Variations from year to year in Yukon emissions tend to come from increases in mining, aviation, and/or on-road diesel use. There has been an increase in emissions from electricity generation. Government of Yukon's internal emissions have also increased since 2010. Achieving YG's emission reduction targets by 2030 will require more action if there continues to be growth in Yukon's economy. (Environment Yukon, 2021a,b)
Rationale	Greenhouse gas emissions from human activities are the dominant cause of the climate change we are currently experiencing (see *Key Finding 9 – Causes and Reponses*). The Yukon government has committed to tracking and reducing emissions including a target to reduce Yukon's GHGs for all areas except mining by 45% below 2010 levels by 2030. YG also has a target for its

	internal operations to reduce its GHGs from building heating and electricity by 30% below 2010 levels by 2030. YG has committed to working with industry to develop a mining-specific emissions reduction target by the end of 2022.
Data	Sources: For Yukon-wide emissions there are two main sources for emissions data including Government of Canada's National Inventory Report and Yukon's fuel tax databases which track the total volume of fuel purchased in the Yukon based on taxes paid. Government of Yukon's internal emissions are reported through the Climate Registry periodically and on Government of Yukon's Climate Change Information web page annually. These include YukonU's building emissions as those are managed by YG's Highways and Public Works. In 2019 emissions for government corporations (Yukon Hospital Corporation, Yukon Housing Corporation, Yukon Liquor Corporation, Yukon Energy Corporation and Yukon Development Corporation) and for electricity generation by Yukon Energy Corporation were added. Coverage: The National Inventory Report data goes from 1990 to present. YG reports on Yukon-wide emissions from 2009 to present, as it incorporates fuel tax data which is only available from 2009 onwards. The Government of Yukon internal emissions data goes from 2010 to present, however data on corporations and electricity generation starts in 2019. Timeliness: The data typically has a 2-year lag. Completeness: The data is complete; however, the National Inventory Report does not release a breakdown of all yearly data from 1990 to present for each province and territory. Emissions methodology changes over time and historic emissions values are updated retroactively.
Methods	The National Inventory Report uses a sector-by-sector accounting methodology and YG uses fuel sales; these two databases are combined as explained in YG's Yukon emissions report to provide Yukon's emissions totals. Yukon government emissions reporting includes only those entities for which YG controls financial policies. Data comes mainly from databases tracking building energy consumption and fleet vehicle fuel consumption.
Limitations	As the accounting methodology is improved, updates are applied to previous years so the annual findings are comparable, but this means numbers may change from year to year, which can be challenging for policymakers.

References

Environment Yukon. (2022a). Greenhouse gas emissions in the Yukon: 2020. Government of Yukon, 20p. https://yukon.ca/en/greenhouse-gas-emissions-yukon-2019

Environment Yukon. (2022b). Government of Yukon greenhouse gas emissions: 2020. Government of Yukon, 28p. https://yukon.ca/en/government-yukon-greenhouse-gas-emissions-2019

Environment and Climate Change Canada. (2022). National inventory report 1990-2020: Greenhouse gas sources and sinks in Canada, part 3. Government of Canada, 83p. https://publications.gc.ca/collections/collection_2021/eccc/En81-4-2019-3-eng.pdf

Government of Yukon. (2022, April 28). *Climate change information*. https://yukon.ca/en/science-and-natural-resources/research-and-monitoring/access-yukon-climate-change-information

Climate Registry 2015: https://www.cris4.org/frmPublicReport.aspx?reportID=2h9W3NP9LD%2b8ZI95KlCiBg%3d%3d&region=0&detail=1&boundary=0

Climate Registry 2010: https://www.cris4.org/frmPublicReport.aspx?reportID=24sK1CnmHgcgOKkrCw9Jvg%3d%3d&region=0&detail=1&boundary=0

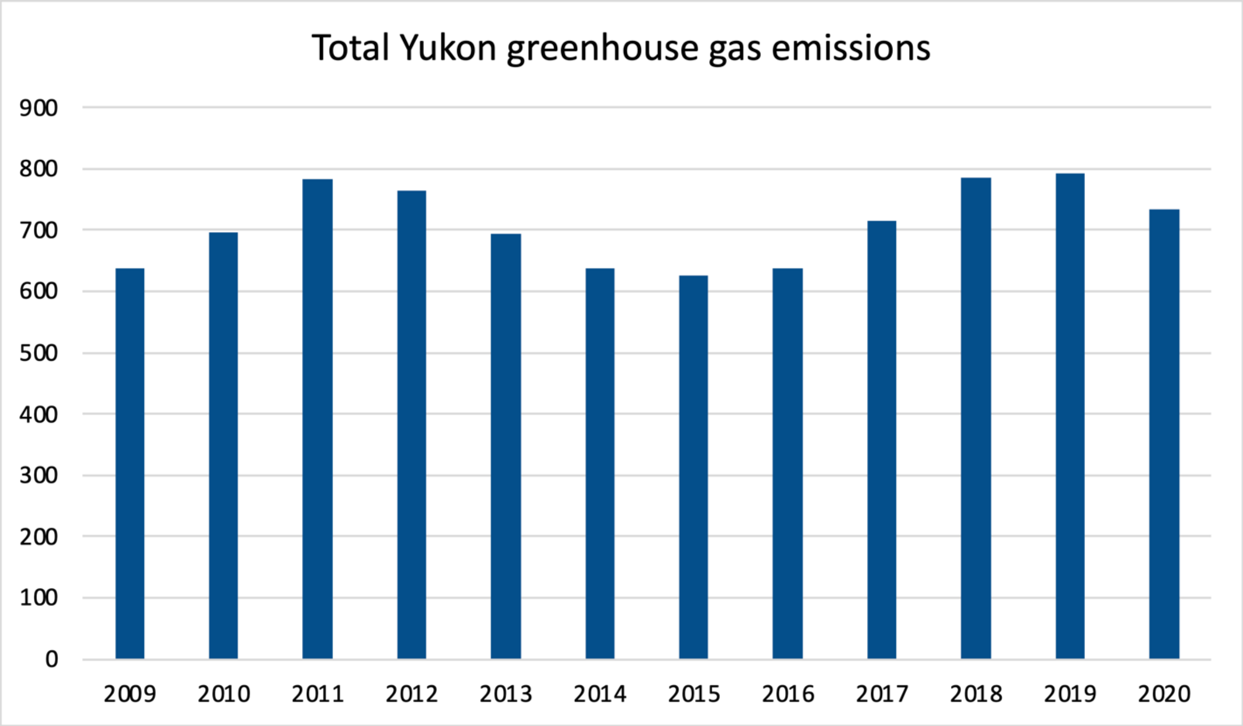

Figure 5.1. Yukon total greenhouse gas emissions

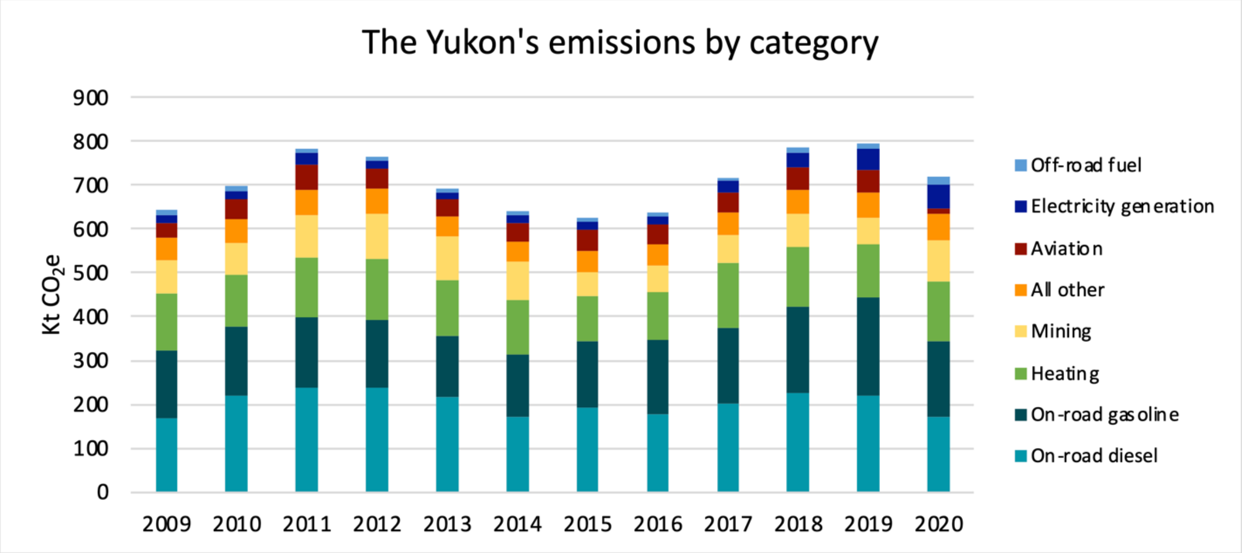

Figure 5.2 Yukon total greenhouse gas emissions by fuel type

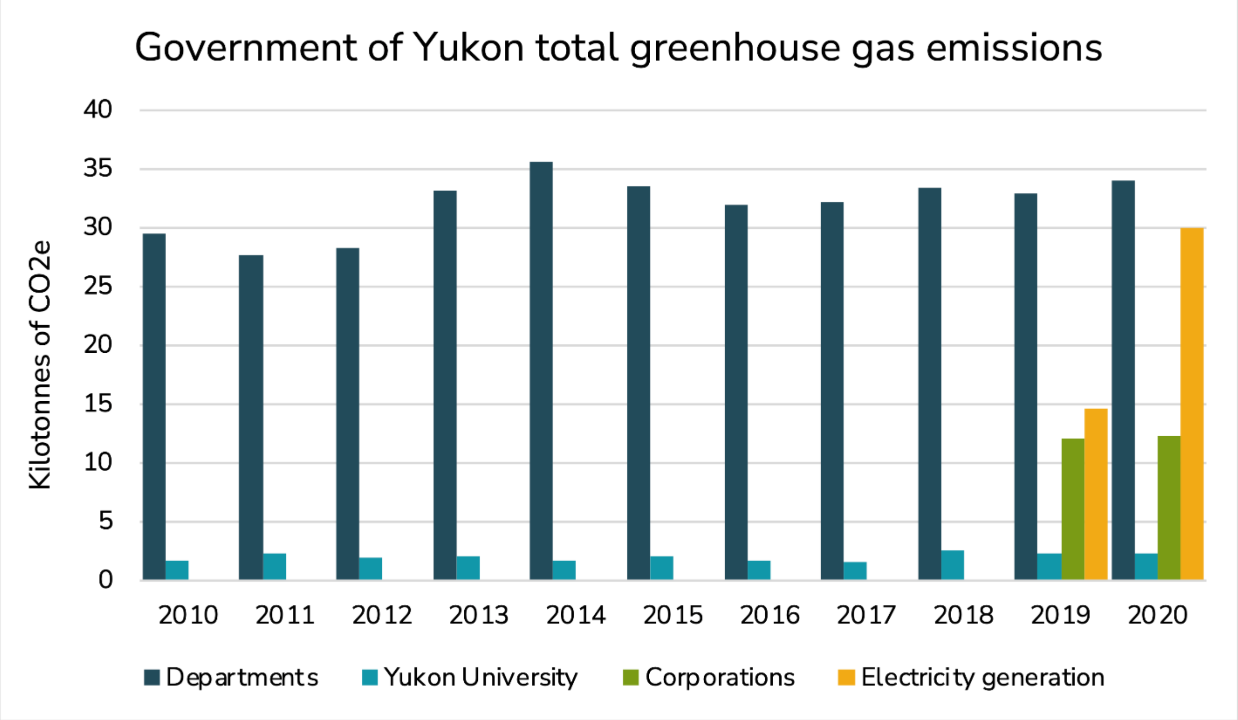

Figure 5.3. Government of Yukon greenhouse gas emissions

REFERENCES

ACIA (Arctic Climate Impact Assessment). (2004). *Impacts of a warming climate – Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, UK, 140p.

Adger, W. N., Barnett, J., Chapin III, F. S., & Ellemor, H. (2012). This must be the place: Underrepresentation of identity and meaning in climate change decision-making. *Global Environmental Politics, 11*(2), 1-25.

Agriculture and Agri-Food Canada. (2022). *Canada's national pathways document.* Government of Canada. https://agriculture.canada.ca/en/about-our-department/transparency-and-corporate-reporting/public-opinion-research-and-consultations/share-ideas-toward-healthier-more-sustainable-and-more-equitable-food-systems-consultation-canadas/canadas-national-pathways-document

AICBR (Arctic Institute of Community-Based Research). (2016a, November 9). *Remembering our past nourishing our future* [Video]. YouTube. https://www.youtube.com/watch?v=4XjV0WzIPfE

AICBR. (2016b, July 6). *Our changing homelands our changing lives* [Video]. YouTube. https://www.youtube.com/watch?v=rhdo4blsgHM

AICBR. (2020). Stories of food, culture and community resiliency: Building sustainable local and traditional food systems as an adaptation to climate change in the Yukon. Arctic Institute of Community-based Research. https://storymaps.arcgis.com/stories/3e7b3260ec8b4d0289d78861238d128c

Aitken, S. N., Yeaman, S., Holliday, J. A., Wang, T., & Curtis-McLane, S. (2008). Adaptation, migration or extirpation: Climate change outcomes for tree populations. *Evolutionary Applications, 1*(1), 95-111.

Alaska Science for All UAF GI. (2022, February 4). *Voices of the caribou people* [Video]. YouTube. https://www.youtube.com/watch?v=AoM6alBGt64

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.

Alexander, C., Bynum, N., Johnson, E., King, U., Mustonen, T., Neofotis, P., Oettlé, N., Rosenzweig, C., Sakakibara, C., Shadrin, V., Vicarelli, M., Waterhouse, J., & Weeks, B. (2011). Linking Indigenous and scientific knowledge of climate change. *BioScience, 61*(6), 477-484.

Allison, E. A. (2015). The spiritual significance of glaciers in an age of climate change. *Wiley Interdisciplinary Reviews: Climate Change, 6*, 493-508.

Alsek Renewable Resource Council, Government of Yukon, & CAFN (Champagne & Aishihik First Nations). (2004). *Strategic forest and management plan for the Champagne and Aishihik Traditional Territory*. Haines Junction & Whitehorse, Yukon, p.75.

AMAP (Arctic Monitoring and Assessment Programme). (2021a*). Arctic climate change update 2021: Key trends and impacts, Summary for policy-makers*. AMAP Secretariat, Tromsø, Norway, 15p.

AMAP. (2021b). Human health in the Arctic 2021: Summary for policy-makers. AMAP Secretariat, Tromsø, Norway, 15p.

AMAP. (2017). Adaptation actions for a changing Arctic: Perspectives from the Bering-Chukchi-Beaufort region. Arctic Monitoring and Assessment Programme, Oslo, Norway, xiv + 33p.

ArcticPeoples. (2013, January 16). *Through Arctic eyes* [Video]. YouTube. https://www.youtube.com/watch?v=e-eghbcw_GQ

Aronsson, M., Heiðmarsson, S., Jóhannesdóttir, H., Barry, T., Braa, J., Burns, C. T. Coulson, S. J., Cuyler, C., Falk, K., Helgson, H., Lárusson, K. F., Lawler, J. P., Kulmala, P., MacNearney, D., Oberndorfer, E., Ravolainen, V., Schmidt, N. M., Soloviev, M., Coon, C., & Christensen, T. (2021). *State of the Arctic terrestrial biodiversity report*. Conservation of Arctic Flora and Fauna International Secretariat, Akureyri, Iceland, 123p. ISBN 978-9935-431-94-3.

AFN Yukon (Assembly of First Nations Yukon Region) & CYFN (Council of Yukon First Nations). (2020). Yukon First Nations climate change emergency declaration. https://afnyukon.ca/yukon-first-nation-climate-change-emergency-declaration/

Assmann, J. J., Myers-Smith, I. H., Kerby, J. T., Cunliffe, A. M., & Daskalova, G. N. (2020). Drone data reveal heterogeneity in tundra greenness and phenology not captured by satellites. *Environmental Research Letters, 15.* 10.1088/1748-9326/abbf7d

Baltzer, J. L., Day, N. J., Walker, X. J. Greene, D., Mack, M. C., Alexander, H. D., Arsenault, D., Barnes, J., Bergeron, Y., Boucher, Y., Bourgeau-Chavez, L., Brown, C. D., Carrière, S., Howard, B. K., Gauthier, S., Parisien, M.-A., Reid, K. A., Rogers, B. M., Roland, C., Sirois, L., Stehn, S., Thompson, D. K., Turetsky, M. R., Veraverbeke, S., Whitmas, E., Yang, J., & Johnstone, J. F. (2021). Increasing fire and the decline of fire adapted black spruce in the boreal forest. *PNAS, 118*(45), e2024872118.

Ban, N. C., Frid, A., Reid, M., Edgar, B., Shaw, D., & Siwallace, P. (2018). Incorporate Indigenous perspectives for impactful research and effective management. *Nature Ecology & Evolution, 2*(11), 1680–1683.

Barrand, N. E. & Sharp, M. J. (2010). Sustained rapid shrinkage of Yukon glaciers since the 1957-1958 International Geophysical Year. *Geophysical Research Letters, 37*(10). https://doi.org/10.1029/2009GL042030.

Barrett, C. B. (2010). Measuring Food Insecurity. *Science. 327* (5967), 825–828. DOI: 10.1126/science.1182768

Batal, M., Chan, H. M., Fediuk, K., Ing, A., Berli, P. R., Mercille, G., Sadik, T., & Johnson-Down, L. (2021). First Nations households living on-reserve experience food insecurity: Prevalence and predictors among ninety-two First Nations communities across Canada. *Canadian Journal of Public Health, 112*, 52–63. https://doi.org/10.17269/s41997-021-00491-x

Batal, M., Gray-Donald, K., Kuhnlein, H. V., & Receveur, O. (2005). Estimation of traditional food intake inindigenous communities in Denendeh and the Yukon. *International Journal of Circumpolar Health, 64*(1), 46–54. https://doi.org/10.3402/ijch.v64i1.17953

Bates, B. C., Kundzewicz, Z. W., Wu, S., & Palutikof, J. P. (2008). *Climate change and water.* Intergovernmental Panel on Climate Change, Geneva, 210p.

Beaumier, M., Ford, J., & Tagalik, S. (2014). The food security of Inuit women in Arviat, Nunavut: The role of socio-economic factors and climate change. *Polar Record, 51*, 1-10. 10.1017/S0032247414000618.

Benkert, B. E., Kennedy, K., Fortier, D., Lewkowicz, A., Roy, L. P., Grandmont, K., de Grandpré, I., Laxton, S., McKenna, K., & Moote, K. (2015). *Dawson City Landscape Hazards: Geoscience mapping for climate change adaptation planning.* Northern Climate ExChange, Yukon Research Centre, Yukon College, 116p. and 2 maps.

Bennett, B. A. & Mulders, R. S. (2009). Natives gone wild: Climate change and a history of a Yukon invasion. In Darbyshire, S. J. & Prasad, R. (Eds.), *The view from the North: Proceedings of the Weeds Across Borders 2008 Conference, May 27-30, 2008, Banff, AB*. (pp. 235-248). Alberta Invasive Species Council, Lethbridge, AB. https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/31658.pdf

Berkes F. (2017). *Sacred ecology*. 4th edition. Routledge, New York, New York. 394 p.

Berner, L. T. & Goetz, S. J. (2021). Satellite observations document trends consistent with a boreal forest biome shift. *Global Change Biology, 2022*(28), 3275-3292. DOI: 10.1111/gcb.16121

Berry, P. & Schnitter, R. (Eds.). (2022). *Health of Canadians in a changing climate: Advancing our knowledge for action*. Government of Canada, Ottawa, ON, 768p. https://changingclimate.ca/site/assets/uploads/sites/5/2022/02/CCHA-REPORT-EN.pdf

Berteaux, D., Réale, D., McAdam, A. G., & Boutin, S. (2004). Keeping pace with fast climate change: Can Arctic life count on evolution? *Integrative and Comparitive Biology, 44*(2), 140-151. https://doi.org/10.1093/icb/44.2.140

Best, M., Fage, I., & Ryan, S. (2019). Mapping the distribution of permafrost using the Resolve Airborne EM System: Klondike Highway, Yukon, Canada. *CSEG Recorder, 44*(7), 12p.

Bezgrebelna, M., McKenzie, K., Wells, S., Ravindran, A., Kral, M., Christensen, J., Stergiopoulos, V., Gaetz, S., & Kidd, S. A. (2021). Climate change, weather, housing precarity, and homelessness: A systematic review of reviews. *International Journal of Environmental Research and Public Health, 18,* 5812. https://doi.org/10.3390/ijerph18115812

Bjorkman, A. D. (2013). Ecological and evolutionary consequences of experimental warming in a high Arctic tundra ecosystem. *Arctic, 66*(4), 512-515.

Bjorkman, A. D., Criado, M. G., Myers-Smith, I. H., Ravolainen, V., Jónsdóttir, I. S., Westergaard, K. B., Lawler, J. P., Aronsson, M., Bennett, B., Gardfjell, H., Heiðmarsson, S., Stewart, L., & Normand, S. (2020). Status and trends in Arctic vegetation: Evidence from experimental warming and long-term monitoring. *Ambio, 49*, 678-692.

Blais-Stevens, A., Kremer, M., Page, A., & Couture, R. (2011). Regional landslide susceptibility mapping along the Yukon Alaska Highway Corridor: A qualitative heuristic approach. Geological Survey of Canada, Open File 6946, 1 CD-ROM. DOI: 10.4095/288986

Blom, C. D. B., Steegeman, P., Voss, C., & Sonneveld, B. G. J. S. (2022). Food in the cold: Exploring food security and sovereignty in Whitehorse, Yukon. *International Journal of Circumpolar Health, 81*(1), 14p.

Bokhorst, S., Pedersen, S. H., Brucker, L., Anisimov, O., Bjerke, J. W., Brown, R. D., Ehrich, D., Essery, R. L. H., Heilig, A., Ingvander, S., Johansson, C., Johansson, M., Jónsdóttir, I. S., Inga, N., Loujus, K., Macelloni, G., Mariash, H., McLennan, D., Rosqvist, G. N., Sato, A., Savela, H., Schneebeli, M., Sokolov, A., Sokratov, S. A., Terzago, S., Vikhamar-Schuler, D., Williamson, S., Qiu, Y., & Callaghan, T. V. (2016). Changing Arctic snow cover: A review of recent developments and assessment of future needs for observations, modelling, and impacts. *Ambio 45*(5), 516-537. https://doi.org/10.1007/s13280-016-0770-0.

Bolduc, E., Casajus, N., Legagneux, P., McKinnon, L., Gilchrist, H. G., Leung, M., Morrison, R. I. G., Reid, D., Smith, P. A., Buddle, C. M., & Bêty, J. (2013). Terrestrial arthropod abundance and phenology in the Canadian Arctic: modelling resource availability for Arctic-nesting insectivorous birds. *The Canadian Entomologist, 145*(2), 155-170.

Bonnaventure, P. P., Lewkowicz, A. G., Kremer, M., & Sawada, M. C. (2012). A permafrost probability model for the southern Yukon and northern British Columbia, Canada. *Permafrost and Periglacial Processes, 23*(1)*,* 52-68. DOI: 10.1002/ppp.1733

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, 13*, 123-138. DOI: 10.1111/1749-4877.12288

Boulanger, Y., Taylor, A. R., Price, D. T., Cyr, D., McGarrigle, E., Rammer, W., Sainte-Marie, G., Beaudoin, A., Guindon, L., & Mansuy, N. (2017). Climate change impacts on forest landscapes along the Canadian southern boreal forest transition zone. *Landscape Ecology, 32*, 1415-1431.

Box, J. E., Colgan, W. T., Chistensen, T. R., Schmidt, N. M., Lund, M., Parmentier, F-J., Brown, R., Bhatt, U. S., Euskirchen, E. S., Romanovsky, V. E., Walsh, J. E., Overland, J. E., Wang, M., Corell, R. W., Meier, W. N., Wouters, B., Mernild, S., Mård, J., Pawlak, J., & Olsen, M. S. (2019). Key indicators of Arctic climate change: 1971 – 2017. *Environmental Research Letters, 14*(2019), 045010, 18p. DOI: 10.1088/1748-9326/aafc1b

Boyd, M. A., Berner, L. T., Foster, A. C., Goetz, S. J., Rogers, B. M., Walker, X. J., & Mack, M. C. (2021). Historic declines in growth portend trembling aspen death during a contemporary leaf miner outbreak in Alaska. *Ecosphere, 12*(6), e03569.

Bradshaw, C. J. & Warkentin, I. G. (2015). Global estimates of boreal forest carbon stocks and flux. *Global and Planetary Change, 128,* 24-30.

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). Fisheries and Oceans Canada, Winnipeg, MB.

Brown, C. D., Dufour-Tremblay, G., Jameson, R. G., Mamet, S. D., Trant, A. J., Walker, X. J., Boudreau, S., Harper, K. A., Henry, G. H. R., Hermanutz, L., Hofgaard, A., Isaeva, L., Kershaw, G. P., & Johnstone, J. F. (2019). Reproduction as a bottleneck to treeline advance across the circumarctic forest tundra ecotone. *Ecography 42*(1): 137–147. DOI:10.1111/ecog.03733.

Burn, C. R., & Friele, P. A. (1989). Geomorphology, vegetation succession, soil characteristics and permafrost in retrogressive thaw slumps near Mayo, Yukon Territory. *Arctic*, 31-40.

Burrell, B. C., Beltaos, S., & Turcotte, B. (2022). Effects of climate change on river-ice processes and ice jams. *International Journal of River Basin Management, 2022,* 1-21. DOI:10.1080/15715124.2021.2007936

Bush, E. & Lemmen, D. S. (Eds.). (2019). *Canada's changing climate report*. Government of Canada, Ottawa, ON. 444p. https://changingclimate.ca/CCCR2019/

Byers, D. L. (2017). Studying plant–pollinator interactions in a changing climate: a review of approaches. *Applications in plant sciences*, *5*(6), 1700012.

CAFF (Conservation of Arctic Flora and Fauna). (2010). *Arctic biodiversity trends 2010 – Selected indicators of change*. Conservation of Arctic Flora and Fauna, Akureyri, Iceland, 121p. Retrieved from: https://oaarchive.arctic-council.org/handle/11374/196.

CAFF & PAME (Protection of the Arctic Marine Environment). (2017). *Arctic invasive alien species: Strategy and action plan.* Conservation of Arctic Flora and Fauna and Protection of the Arctic Marine Environment, Akureyri, Iceland, 19p. ISBN: 978-9935-431-65-3

CAFN (Champagne & Aishihik First Nations). (2006). *Climate change in our backyard I: 2006 conference report.* Champagne & Aishihik First Nations, Haines Junction, YT.

CAFN. (2009). *Climate change in our backyard II: 2009 conference report.* Champagne & Aishihik First Nations, Haines Junction, YT, 28p.

CAFN & Alsek Renewable Resource Council. (2009). *Climate change in our backyard II conference report.* Haines Junction, YT, 29p.

Calmels, F., Roy, L.-P., Laurent, C., Amyot, F., Cubley, J., & Lipovsky, P. (2021). *Assessment and monitoring of a new retrogressive thaw slump at km 1456 of the Alaska Highway: A rare opportunity*. YukonU Research Centre, Yukon University, 72p. https://www.yukonu.ca/sites/default/files/inline-files/PGR_2021_01_Tak_Slump_NTAI_0.pdf

Calmels, F. B., Horton, B., Roy, L.-P., Lipovsky, P., & Benkert, B. (2016). Assessment of risk to infrastructure from permafrost degradation and a changing climate, Ross River. Northern Climate ExChange, Yukon Research Centre, Yukon College, 88p. https://www.yukonu.ca/sites/default/files/inline-files/ross%20river%20permafrost%20high-res_final.pdf

Calmels, F., Roy, L.-P., Laurent, C., Pelletier, M., Kinnear, L., Benkert, B., Horton, B., & Pumple, J. (2015). *Vulnerability of the North Alaska Highway to permafrost thaw: A field guide and data synthesis*. Northern Climate ExChange, Yukon Research Centre, Yukon College, Whitehorse, YT.

Campbell, E. M., Antos, J. A., & vanAkker, L. (2019). Resilience of southern Yukon boreal forests to spruce beetle outbreaks. *Forest ecology and management, 433*), 52–63. https://doi.org/10.1016/j.foreco.2018.10.037.

Canadian Polar Commission. (2014). *The state of Northern knowledge in Canada*. Government of Canada, 42p.

Canadian Standards Association. (2022). Northern Infrastructure Standardization Initiative (NISI). https://www.csagroup.org/store/northern-infrastructure-standardization-initiative/

CTFN (Carcross/Tagish First Nation) & AICBR. (2019). Our life is in the water | our breath is in the water: Building self-sufficiency and preserving our stories for the next seven generations - assessing climate change and adaptation in Carcross, Yukon. Arctic Institute of Community-Based Research, Whitehorse, YT, 27p.

Caron, N., & Plunkett-Latimer, J. (2022). *Canadian income survey: Food insecurity and unmet health care needs, 2018 and 2019* (Income Research Paper Series). Statistics Canada. https://www150.statcan.gc.ca/n1/en/pub/75f0002m/75f0002m2021009-eng.pdf?st=tla0FP3k

Carroll, C. & Noss, R. F. (2020). Rewilding in the face of climate change. *Conservation Biology, 35*(1), 155-167. DOI: 10.1111/cobi.13531

Carroll, C. & Ray, J. C. (2020). Maximizing the effectiveness of national commitments to protected area expansion for conserving biodiversity and ecosystem carbon under climate change. *Global Change Biology, 27*, 3395-3414. DOI: 10.1111/gcb.15645

CBC. (2020, October 15). *Yukon Energy's fuel supply reached 'critical' point last winter, says energy minister.* CBC. https://www.cbc.ca/news/canada/north/yukon-fuel-supply-scare-1.5762708

Centre for Indigenous Environmental Resources. (2006). How climate change uniquely impacts the physical, social and cultural aspects of First Nations. Assembly of First Nations, 53p.

Chen, A. & Natcher, D. (2019). Greening Canada's Arctic food system: Local food procurement strategies for combating food insecurity. *Canadian Food Studies, 6*(1), 140-154.

Chen, I.-C., Hill, J. K., Ohlemüller, R., Roy, D. B., & Thomas, C. D. (2011). Rapid range shifts of species associated with high levels of climate warming. *Science, 333*, 1024-1026. DOI: 10.1126/science.1206432

Chen, J. P., Huang, G., Baetz, B. W., Lin, Q. G., Dong, C., & Cai, Y. P. (2018). Integrated Inexact Energy Systems Planning under Climate Change: A Case Study of Yukon Territory, Canada. *Applied Energy, 229*, 493–504. https://doi.org/10.1016/j.apenergy.2018.06.140.

Chen, A., Lantz, T. C., Hermosilla, T., & Wulder, M. A. (2021). Biophysical controls of increased tundra productivity in the western Canadian Arctic. *Remote Sensing of Environment, 258,* 112358. DOI: 10.1016/j.rse.2021.112358.

Chen, Y. & She, Y. (2020). Long-term variations of river ice breakup timing across Canada and its response to climate change. *Cold Regions Science and Technology, 176.* 10.1016/j.colregions.2020.103091

Chesnokova, A., Baraër, M., Laperrière-Robillard, T., & Huh, K. (2020). Linking mountain glacier retreat and hydrological changes in Southwestern Yukon. *Water Resources Research, 56*(1), e2019WR025706. https://doi.org/10.1029/2019WR025706.

Choi, G., Robinson, D. A., & Kang, S. (2010). Changing northern hemisphere snow seasons. *Journal of Climate, 23*(19), 5305-5310.

Cianconi, P., Betrò, S., & Janiri, L. (2020). The impact of climate change on mental health: a systematic descriptive review. *Frontiers in psychiatry, 74*.

Clark, D. G., Ness, R., Coffman, D., & Beugin, D. (2021). *The health costs of climate change: How Canada can adapt, prepare, and save lives.* Canadian Institute for Climate Choices, 65p. https://climatechoices.ca/wp-content/uploads/2021/06/ClimateChoices_Health-report_Final_June2021.pdf

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.

Clayton, S., Manning, C., Speiser, M., & Hill, A. N. (2021). *Mental health and our changing climate: Impacts, implications, and guidance.* American Psychological Association & ecoAmerica, Washington, DC, 87p.

Coates, J. & Lewkowicz, A. G. (2008, June 29-July 3). *Landsliding following forest fire on permafrost slopes*, *Klondike Area, Yukon, Canada*. 9th International Conference on Permafrost, Fairbanks, AK.

Cohen, J., Screen, J. A., Furtado, J. C., Barlow, M., Whittleston, D., Coumou, D., Francis, J., Dethloff, K., Entekhabi, D., Overland, J., & Jones, J. (2014). Recent Arctic amplification and extreme mid-latitude weather. *Nature Geoscience, 7*(9), 627–637. DOI: 10.1038/ngeo2234

Cohen, J., Zhang, X., Francis, J., Jung, T., Kwok, R., Overland, J., Ballinger, T. J., Bhatt, U. S., Chen, H. W., Coumou, D., Feldstein, S., Gu, H., Handorf, D., Henderson, G., Ionita, M., Kretschmer, M., Laliberte, F., Lee, S., Linderholm, H. W., Maslowski, W., Peings, Y., Pfeiffer, K., Rigor, I., Semmler, T., Stroeve, J., Taylor, P. C., Vavrus, S., Vihma, T., Wang, S., Wendisch, M., Wu, Y., & Yoon, J. (2020). Divergent consensuses on Arctic amplification influence on midlatitude severe winter weather. *Nature Climate Change, 10,* 20-29. DOI: 10.1038/s41558-019-0662-y

Colombo, N., Salerno, F., Gruber, S., Freppaz, M., Williams, M., Fratianni, S., & Giardino, M. (2018). Impacts of permafrost degradation on inorganic chemistry of surface fresh water. *Global and Planetary change, 162*, 69-83.

Conway, A. J. & Danby, R. K. (2014). Recent advance of forest-grassland ecotones in southwestern Yukon. *Canadian Journal of Forest Research 44*(5), 509–520. DOI:10.1139/cjfr-2013-0429.

Cooke, H. (2017). Securing a Wild Future-Planning for Landscape-Scale Conservation of Yukon's Boreal Mountains. WCS Canada Conservation Report No. 9.

Cooley, D., Clarke, H., Graupe, S., Landry-Cuerrier, M., Lantz, T., Milligan, H., Pretzlaw, T., Larocque, G., & Humphries, M. M. (2019). The Seasonality of a Migratory Moose Population in Northern Yukon. *Alces,* 55, 105-130.

Coumou, D., Di Capua, G., Vavrus, S., Wang, L., & Wang, S. (2018). The influence of Arctic amplification on mid-latitude summer circulation. *Nature Communications, 9*(1), 1-12.

Council of Canadian Academies. (2014). *Aboriginal food security in Northern Canada: An assessment of the state of knowledge.* The Expert Panel on the State of Knowledge of Food Security in Northern Canada, Council of Canadian Academies, Ottawa, ON, 256p.

Courtois, V. (2021). U.S. and canada call for supporting Indigenous-led conservation. Retrieved from: https://www.ilinationhood.ca/blog/uscanadarecognition

Couture, N. J., Irrgang, A., Pollard, W., Lantuit, H., & Fritz, M. (2018). Coastal erosion of permafrost soils along the Yukon Coastal Plain and fluxes of organic carbon to the Canadian Beaufort Sea. *Journal of Geophysical Research: Biogeosciences, 123*(2), 406–422. https://doi.org/10.1002/2017JG004166.

Couture, N. J. & Pollard, W. H. (2017). A model for quantifying ground-ice volume, Yukon Coast, Western Arctic Canada. *Permafrost and Periglacial Processes, 28*(3) 534–442. https://doi.org/10.1002/ppp.1952.

Crawford, L. (2022, February 25). Over $8.5 million spent on last summer's flood in Yukon. *Yukon News*. https://www.yukon-news.com/news/over-8-5-million-spent-on-last-summers-flood-in-yukon/

Cray, H. A. & Pollard, W. H. (2015). Vegetation recovery patterns following permafrost disturbance in a Low Arctic setting: case study of Herschel Island, Yukon, Canada. *Arctic, Antarctic, and Alpine Research, 47*(1), 99-113.

Crites, H., Kokelj, S. V., & Lacelle, D. (2020). Icings and groundwater conditions in permafrost catchments of Northwestern Canada. *Scientific Reports 10*(1), 3283. https://doi.org/10.1038/s41598-020-60322-w.

Cruickshank, A., Notten, G., Wesche, S., Ballegooyen, K., & Pope, G. (2019). Co-management of traditional foods: Opportunities and limitations for food security in northern First Nation communities. *Arctic, 72*(4), 360-380.

Cudmore, T. J., Björklund, N., Carroll, A. L., & Staffan Lindgren, B. (2010). Climate change and range expansion of an aggressive bark beetle: evidence of higher beetle reproduction in naïve host tree populations. *Journal of Applied Ecology*, *47*(5), 1036-1043.

Cunliffe, A. M., Tanski, G., Radosavljevic, B., Palmer, W. F., Sachs, T., Lantuit, H., Kerby, J. T., & Myers-Smith, I. H. (2019). Rapid retreat of permafrost coastline observed with aerial drone photogrammetry. *The Cryosphere 13*, 1513-1528. https://doi.org/10.5194/tc-13-1513-2019.

Cunsolo, A., & Ellis, N. R. (2018). Ecological grief as a mental health response to climate change-related loss. *Nature Climate Change*, *8*(4), 275-281.

Cunsolo, A., & Landman, K. (Eds.). (2017). *Mourning nature: Hope at the heart of ecological loss and grief*. McGill-Queen's Press-MQUP.

Cunsolo Willox, A., Harper, S.L., Ford, J.D., Edge, V.L., Landman, K., Houle, & Wolfrey. C. (2013). Climate change and mental health: an exploratory case study from Rigolet, Nunatsiavut, Canada. *Climatic Change, 121*(2), 255-270.

Cunsolo Willox, A., Harper, S.L., Ford, J.D., Landman, K., Houle, K., Edge, V.L., Rigolet Inuit Community Government. (2012). "From this place and of this place:" climate change, sense of place, and health in Nunatsiavut, Canada. *Soc. Sci. Med., 75*, 538e547. http://dx.doi.org/10.1016/j.socscimed.2012.03.043.

Cunsolo Willox, A., Stephenson, E., Allen, J., Bourque, F., Drossos, A., Elgarøy, S., Kral, M. J., Mauro, I., Moses, J., Pearce, T., MacDonald, J. P., & Wexler, L. (2015). Examining relationships between climate change and mental health in the Circumpolar North. *Regional Environmental Change, 15,* 169-182. DOI 10.1007/s10113-014-0630-z

Cuyler, C., Rowell, J., Adamczewski, J., Anderson, M., Blake, J., Bretten, T., Brodeur, V., Campbell, M., Checkley, S. L., Cluff, H. D., Côté, S. D., Davison, T., Dumond, M., Ford, B., Gruzdev, A., Gunn, A., Jones, P., Kutz, S., Leclerc, L.-M., Mallory, C., Mavrot, F., Mosbacher, J. B., Okhlopkov, I. M., Reynolds, P., Schmidt, N. M., Sipko, T., Suitor, M., Tomaselli, M., & Ytrehus, B. (2020). Muskox status, recent variation, and uncertain future. *Ambio, 49*(3), 805-819. DOI: 10.1007/s13280-019-0105-x

CYFN (Council of Yukon First Nations). (2011). *Yukon climate change needs assessment.* Whitehorse, YT, 67p.

Danby, R. & Hik, D. (2007a). Evidence of recent treeline dynamics in southwest Yukon from aerial photographs. *Arctic, 60*(4), 411-420.

Danby, R. & Hik, D. (2007b). Responses of white spruce (*Picea glauca*) to experimental warming at a subarctic alpine treeline. *Global Change Biology, 13*, 437-451. DOI: 10.1111/j.1365-2486.2006.01302.x

Danby, R. & Hik, D. (2007c). Contingency and rapid change in recent subarctic alpine tree line dynamics. *Journal of Ecology, 95*(2), 352-363.

Davidson, S. C., Bohrer, G., Gurarie, E., LaPoint, S., Mahoney, P. J., Boelman, N. T., Eitel, J. U. H., Prugh, L. R., Vierling, L. A., Jennewein, J., Grier, E., Couriot, O., Kelly, A. P., Meddens, A. J. H., Oliver, R. Y., Kays, R., Wikelski, M., Aarvak, T., Ackerman, J. T., Alves, J. A., Bayne, E., Bedrosian, B., Belant, J. L., Berdahl, A. M., Berline, A. M., …, Hebblewhite, M. (2020). Ecological insights from three decades of animal movement tracking across a changing Arctic. *Science, 370*, 712-715.

Dearborn, K. D. & Danby, R. K. (2018). Climatic drivers of tree growth at tree line in southwest Yukon change over time and vary between landscapes. *Climatic Change, 150*(3), 211–225. https://doi.org/10.1007/s10584-018-2268-1.

de Grandpré, I., Fortier, D., & Stephani, E. (2010, September 12-16). *Impact of groundwater flow on permafrost degradation: Implications for transportation infrastructures*. 63rd Canadian Geotechnical Conference & 6th Canadian Permafrost Conference, Calgary, AB.

Department of Environment and Natural Resources. (2015). *A homeowner's guide to permafrost in the Northwest Territories*. Government of the Northwest Territories, Yellowknife, NT, 22p. ISBN 978-0-7708-198-4

DeRepentigny, P., Tremblay, L. B., Newton, R., & Pfirman, S. (2016). Patterns of sea ice retreat in the transition to a seasonally ice-free Arctic. *Journal of Climate 29*(19), 6993-7008. https://doi.org/10.1175/JCLI-D-15-0733.1.

Derksen, C., Smith, S. L., Sharp, M., Brown, L., Howell, S., Copland, L., Mueller, D. R., Gauthier, Y., Fletcher, C. G., Tivy, A., Bernier, M., Bourgeois, J., Brown, R., Burn, C. R., Duguay, C., Kushner, P., Langlois, A., Lewkowicz, A. G., Royer, A., & Walker, A. (2012). Variability and change in the Canadian cryosphere. *Climatic Change, 115*, 59–88. DOI: 10.1007/s10584-012-0470-0

Déry, S. J., Hernández-Henríquez, M. A., Burford, J. E., & Wood, E. F. (2009). Observational evidence of an intensifying hydrological cycle in northern Canada. *Geophysical Research Letters, 36,* L13402. DOI: 10.1029/2009GL038852

Dhar, A., Parrott, L., & Hawkins, C. D. B. (2016). Aftermath of mountain pine beetle outbreak in British Columbia: Stand dynamics, management response and ecosystem resilience. *Forests, 7*(171), 19p. DOI:10.3390/f7080171

Dornblaser, M. M. & Striegl, R. G. (2009). Suspended sediment and carbonate transport in the Yukon River Basin, Alaska: Fluxes and potential future responses to climate change. *Water Resources Research, 45*(6).

Dorward, C., Kassi, N., Chiu, C., Mullinix, K. (2014). *Our food security today and tomorrow in Carcross/Tagish First Nation*. Carcross/Tagish First Nation, Institute for Sustainable Food Systems & Arctic Institute of Community-Based Research, 24p. https://www.kpu.ca/sites/default/files/ISFS/CTFN%20Community%20Food%20Report_2014.12.16_FINAL%20APPROVED.pdf

Downes, C. M., Theberge, J. B., & Smith, S. M. (1986). The influence of insects on the distribution, microhabitat choice, and behaviour of the Burwash caribou herd. *Canadian Journal of Zoology*, *64*(3), 622-629.

Duerden, F., Pearce, T., Ford, J., Pittman, J., Kinnear, L., & Perrin, A. (2014). Case studies of adaptation to climate change in the Yukon mining sector: From planning and operation to remediation and restoration. Ottawa, ON: Report submitted to Climate Change Impacts and Adaptation Division, Natural Resources Canada. 22 p.

Durkalec, A., Furgal, C., Skinner, M. W., & Sheldon, T. (2015). Climate change influences on environment as a determinant of Indigenous health: Relationships to place, sea ice, and health in an Inuit community. *Social Science & Medicine, 136*, 17-26. http://dx.doi.org/10.1016/j.socscimed.2015.04.026

EBA (EBA Engineering Consultants Ltd). (2004). *Permafrost considerations for effective mine site development in the Yukon Territory.* Mining and Environment Research Group, Whitehorse, YT, 33p. https://ygsftp.gov.yk.ca/publications/MPERG/2004/2004_1.pdf

ECCC (Environment and Climate Change Canada). (2021). Climate Trends and Variations Bulletin. Government of Canada. Accessed January 27, 2022 https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html.

Egeland, G.M., Faraj, N., & Osborne, G. (2010). Cultural, socioeconomic, and health indicators among Inuit preschoolers: Nunavut Inuit Child Health Survey, 2007–2008. *Rural Remote Health, 2010*, 10:1365.

Elmendorf, S. C., Henry, G. H. R., Hollister, R. D., Björk, R. G., Bjorkman, A. D., Callaghan, T. V., Collier, L. S., Cooper, E. J., Cornelissen, J. H. C., Day, T. A., Fosaa, A. M., Gould, W. A., Grétarsdóttir, J., Harte, J., Hermanutz, L., Hik, D. S., Hofgaard, A., Jarrad, F., Jónsdóttir, I. S., Keuper, F., Klanderud, K., Klein, J. A., Koh, S., Kudo, G., Lang, S. I., Loewen, V., May, J. L., Mercado, J., Michelsen, A., Molau, U., Myers-Smith, I. H., Oberbauer, S. F., Pieper, S., Post, E., Rixen, C., Robinson, C. H., Schmidt, N. M., Shaver, G. R., Stenström, A., Tolvanen, A., Totland, Ø., Troxler, T., Wahren, C.-H., Webber, P. J., Welker, J. M., & Wookey, P. A. (2012). Global assessment of experimental climate warming on tundra vegetation: Heterogeneity over space and time. *Ecology Letters, 15,* 164-175. DOI: 10.1111/j.1461-0248.2011.01716.x

Energy, Mines and Resources. (2021). *2020 Yukon forest health report*. Government of Yukon, Whitehorse, YT, 35p.

Energy, Mines and Resources. (2020). *Cultivating our future: 2020 Yukon agriculture policy*. Government of Yukon, Whitehorse, YT, 42p.

Energy, Mines and Resources. (2016). *Local food strategy for Yukon: Encouraging the production and consumption of Yukon-grown food 2016-2021*. Government of Yukon, Whitehorse, YT, 29p.

Engineers Canada. (2018). *Principles of climate change adaptation and mitigation for professional engineers*. https://engineerscanada.ca/public-guideline-principles-of-climate-adaptation-and-mitigation-for-engineers#-climate-change-and-engineers

Engineers Canada. (n.d.). *Climate change and extreme weather events* [Policy brief]. https://engineerscanada.ca/sites/default/files/public-policy/climatechange-en.pdf

Environment Yukon. (2011). *Yukon water: An assessment of climate change vulnerabilities*. Government of Yukon, Whitehorse, YT, 81p. https://open.yukon.ca/sites/default/files/yukonwater_climatechange_report_0.pdf

FAO (Food and Agriculture Organization of the United Nations). (2009). *Declaration of the World Food Summit on Food Security*. Food and Agriculture Organization of the United Nations, Rome.

FAO. (2013). *The State of Food Insecurity in the World: The multiple dimensions of food security*. Food and Agriculture Organization of the United Nations, Rome, 52p. https://www.fao.org/3/i3434e/i3434e.pdf

FAO. (n.d.). *Safety nets and the right to food*. Food and Agriculture Organization of the United Nations, Rome, Rome. https://www.fao.org/3/J1444E/J1444E.htm

FAO. 2021. *The White/Wiphala Paper on Indigenous Peoples' food systems*. Food and Agriculture Organization of the United Nations, Rome. https://doi.org/10.4060/cb4932en

Feinstein, N. W. & Mach, K. J. (2019). Three roles for education in climate change adaptation. *Climate Policy,* 5p. DOI: 10.1080/14693062.2019.17011975

Fetterer, F., K. Knowles, W.N. Meier, M. Savoie, and A.K. Windnagel. 2017, updated daily. Sea Ice Index, Version 3. Boulder, Colorado USA. Ice Extent. NSIDC: National Snow and Ice Data Center. DOI: https://doi.org/10.7265/N5K072F8

Flannigan, M., Stocks, B., Turetsky, M., & Wotton, M. (2008). Impacts of climate change on fire activity and fire management in the circumboreal forest. *Global Change Biology, 14,* 1-12. DOI: 10.1111/j.1365-2486.2009.01660.x

FNIGC (First Nations Information Governance Centre). (2018a). National report of the First Nations Regional Health Survey, phase 3: Volume one. Ottawa, ON, 180p.

FNIGC. (2018b). National report of the First Nations Regional Health Survey, phase 3: Volume two. Ottawa, ON, 165p.

FNNND (First Nation of Na-Cho Nyak Dun) & AICBR. (2019). Protecting/preserving the animals, the land, the waters, our heritage, our language, and our culture: Assessing climate change and adaptation in Mayo, Yukon. Arctic Institute of Community-Based Research, Whitehorse, YT, 28p.

Ford, J. D., Clark, D., Pearce, T., Berrang-Ford, L., Copland, L., Dawson, J., New, M., & Harper, S. L. (2019). Changing access to ice, land and water in Arctic communities. *Nature Climate Change, 9,* 335-339. DOI: 10.1038/s41558-019-0435-7

Ford, J. D., Cameron, L., Rubis, J., Maillet, M., Nakashima, D., Willox, A. C., & Pearce, T. (2016). Including indigenous knowledge and experience in IPCC assessment reports. *Nature Climate Change*, *6*(4), 349-353.

Ford, J. D., Champalle, C., Tudge, P., Riedlsperger, R., Bell, T., & Sparling, E. (2014). Evaluating climate change vulnerability assessments: A case study of research focusing on the built environment in northern Canada. *Mitigation and Adaptation Strategies for Global Change, 20*(8), 1267-1288.

Ford, J.D., McDowell, G., Shirley, J., Pitre, M., Siewierski, R., Gough, W., Duerden, F., Pearce, T., Adams, P., & Statham, S. (2013). The dynamic multiscale nature of climate change vulnerability: an Inuit harvesting example. *Annals of the Association of American Geographers, 103*, 1193-1211.

Ford, J. D., Vanderbilt, W., & Berrang-Ford, L. (2012). Authorship in IPCC AR5 and its implications for content: Climate change and Indigenous populations in WGII. *Climatic Change, 113,* 201-213. DOI: 10.1007/s10584-011-0350-z

Francis, J. A. & Vavrus, S. J. (2015). Evidence for a wavier jet stream in response to rapid Arctic warming. *Environmental Research Letters, 10,* 014005. http://dx.doi.org/10.1088/1748-9326/10/1/014005

Friendship, K. (2010). *Climate change and food security in the North: A literature review 2010*. Arctic Health Research Network-YT, Whitehorse, YT, 16p.

Furgal, C. & Prowse, T. D. (2008). Northern Canada. In Lemmen, D. S., Warren, F. J., Lacroix, J., & Bush, E. (Eds*.), From impacts to adaptation: Canada in a changing climate 2007*. Natural Resources Canada, Government of Canada, Ottawa, ON, 57-118.

Gagnon, C. A., Hamel, S., Russell, D. E., Powell, T., Andre, J., Svoboda, M. Y., & Berteaux, D. (2020). Merging Indigenous and scientific knowledge links climate with the growth of a large migratory caribou population. *Journal of Applied Ecology, 57,* 1644-1655. 10.1111/1365-2664.13558

Galloway, T., Young, T. K., & Egeland, G. M. (2010). Emerging obesity among preschool-aged Canadian Inuit children: Results from the Nunavut Inuit Child Health Survey. *International Journal of Circumpolar Health, 69*, 151–157.

Gartler, S., Melancon, T., & Peter, Y. (2022). Indigenous youth perspectives on extractivism and living in a good way in the Yukon. In Stammler, F. & Toivanen, R. (Eds.), *Young people, wellbeing and placemaking in the Arctic* (pp. 120-143). Routledge, Oxon & New York.

Gienapp, P., Teplitsky, C., Alho, J. S., Mills, J. A., & Merilä, J. (2008). Climate change and evolution: Disentangling environmental and genetic responses. *Molecular Ecology, 17,* 167-178. DOI: 10.1111/j.1365-294X.2007.03413.x

Gignac, J. (2020, June 1). Yukon gold mine forced to release 43 million litres of wastewater amid spring runoff. *The Narwhal*. https://thenarwhal.ca/yukon-gold-mine-release-43-million-litres-wastewater/

Goedkoop, W., Culp, J. M., Christensen, T., Christofferson, K. S., Fefilova, E., Guðbergsson, G., Lárusson,K. F., Liljaniemi, P., Novichkova, A. A., Ólafsson, J. S., Sandøy, S., & Lento, J. (2021). Improving the framework for assessment of ecological change in the Arctic: A circumpolar synthesis of freshwater biodiversity. *Freshwater Biology, 67*(1), 210-223.

Golder. (2021). *Guide on climate change adaptation for the mining sector*. Mining Association of Canada, 148p. https://mining.ca/wp-content/uploads/2021/10/MAC-Climate-Change-Guide-June-2021.pdf

Government of Yukon. (2022a). *Greenhouse gas emissions in the Yukon: 2020.* Government of Yukon, 28p. https://yukon.ca/sites/yukon.ca/files/env/env-greenhouse-gas-emissions-yukon-2020.pdf

Government of Yukon. (2022b). *Government of Yukon greenhouse gas emissions: 2020.* Government of Yukon, 28p. https://yukon.ca/sites/yukon.ca/files/env/env-government-yukon-greenhouse-gas-emissions-2020.pdf

Government of Yukon. (2021a). *Guidelines for developing adaptive management plans in Yukon: Water-related components of quartz mining projects*. Whitehorse, YT, 48p. https://yukon.ca/sites/yukon.ca/files/env/env-amp-guidelines.pdf

Government of Yukon. (2021b). *Yukon state of the environment interim report 2021*. Government of Yukon, Whitehorse, YT, 96p. https://yukon.ca/sites/yukon.ca/files/env/env-yukon-state-environment-interim-report-2021.pdf

Government of Yukon. (2020) Our clean future: A Yukon strategy for climate change, energy and a green economy. Whitehorse, YT, 70p.

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

Grabowski, M. M. (2015). Interspecific boreal shrub growth response to climate, fertilization and herbivory. Master of Science, University of British Columbia.

Grabowski, M. M., Doyle, F. I., Reid, D. G., Mossop, D, & Talarico, D. (2013). Do Arctic-nesting birds respond to earlier snowmelt? A multi-species study in north Yukon, Canada. *Polar Biology, 36*(8), 1097-1105. DOI: 10.1007/s003000-013-1332-6

Green, J. K., Seneviratne, S. I., Berg, A. M., Findell, K. L., Hagemann, S., Lawrence, D. M., & Gentine, P. (2019). Large influence of soil moisture on long-term terrestrial carbon uptake. *Nature*, *565*(7740), 476-479.

Greig, S., Sear, D., & Carling, P. (2005). The impact of fine sediment accumulation on the survival of incubating salmon progeny: implications for sediment management. *Science of the Total Environment, 344*(1-3), 241-258.

Gustine, D., Barboza, P., Adams, L., Griffith, B., Cameron, R., & Whitten, K. (2017). Advancing the match-mismatch framework for large herbivores in the Arctic: Evaluating the evidence for a trophic mismatch in caribou. *PLoS ONE 12*(2), e0171807. https://doi.org/10.1371/journal.pone.0171807

Guthrie, R. & Cuervo, V. (2015). *Geohazards and risk: A proponent's guide to linear infrastructure*. Yukon Environmental and Socio-economic Board, Whitehorse, YT, 47p.

Guyot, M., Dickson, C., Paci, C., Furgal, C., & Chan, H. M. (2006). Local observations of climate change and impacts on traditional food security in two northern aboriginal communities. *International Journal of Circumpolar Health, 65*(5), 403-415. https://doi.org/10.3402/ijch.v65i5.18135

Harris, N. L., Gibbs, D. A., Baccini, A., Birdsey, R. A., de Bruin, S., Farina, M., Fatoyinbo, L., Hansen, M. C., Herold, M., Houghton, R. A., Potapov, P. V., Suarez, D. R., Roman-Cuesta, R. M., Saatchi, S. S., Slay, C. M., Turubanova, S. A., & Tyukavina, A. (2021). Global maps of twenty-first century forest carbon fluxes. *Nature Climate Change, 11*(3), 234-240. DOI: 10.1038/s41558-020-00976-6

Healey, G. K. (2015). *Exploring human health-related indicators of climate change in Nunavut*. Qaujigiartiit Health Research Centre, Iqaluit, NU, 20p.

Health Canada. (2012). Ross River First Nation Yukon: Caribou culture and climate change. http://climatetelling.ca/community/ross-river-caribou.

Heginbottom, J. A., Dubreuil, M. A., & Haker, P. T. (1995). Canada permafrost, 1:7,500,000 scale. In *The national atlas of Canada,* 5th edition. Sheet MCR 4177. National Resources Canada, Ottawa, ON.

Helander, E. & Mustonen, T, (Eds.). (2004). *Snowscapes, dreamscapes – Snowchange book on community voices of change*. Tampere Polytechnic Publications, Tampere, Finland, 568p.

Hennesey, R. & Streicker, J. (2011). *Whitehorse climate change adaptation plan.* Northern Climate ExChange, Yukon Research Centre, Yukon College, Whitehorse, YT, 84p.

Hill, R., Adem, C., Alangui, W. V., Molnár, Z., Aumeeruddy-Thomas, Y., Bridgewater, P., Tengö, M., Thaman, R., Adou Yao, C. Y., Berkes, F., Carino, J., Carneiro da Cunha, M., Diaw, M.C., Díaz, S., Figueroa, V.E., Fisher, J., Hardison, P., Ichikawa, K., Kariuki, P., Karki, M., Lyver, P. O. B., Malmer, P., Masardule, O., Oteng Yeboah, A. A., Pacheco, D., r Pataridze, T., Perez, E., Roué, M.-M., Roba, H., Rubis, J., Saito, O., & Xue, D. (2020). Working with Indigenous, local and scientific knowledge in assessments of nature and nature's linkages with people. *Current Opinion in Environmental Sustainability. 43*, 8-20, DOI: 10.1016/j.cosust.2019.12.006.

Hinzman, L., Bettez, N., Bolton, W., Chapin, F., Dyurgerov, M., Fastie, C., Griffith, B., Hollister, R., Hope, A., Huntington, H., Jensen, A. M., Jia, G. J., Jorgenson, T., Kane, D. L., Klein, D. R., Kofinas, G., Lynch, A. H., Lloyd, A. H., McGuire, A. D., Nelson, F. E., Oechel, W. C., Osterkamp, T. E., Racine, H. H., Romanovsky, V. E., Stone, R. S., Stow, D. A., Sturm, M., Tweedie, C. E., Vourlitis, G. L., Walker, M. D., Walker, D. A., Webber, P. J., Welker, J. M., Winker, K. S., & Yoshikawa, K. (2005). Evidence and implications of recent climate change in northern Alaska and other Arctic regions. *Climactic Change, 72,* 251-298.

Hodge, J. (2012). Mountain pine beetle pest risk analysis for Yukon lodgepole pine forests. JCH Forest Pest Management, Coldstream, BC, 84p.

Hogg, E. H. & Wein, R. W. (2005). Impacts of drought on forest growth and regeneration following fire in southwestern Yukon, Canada. *Canadian Journal of Forest Research, 35*, 2141-2150. DOI:10.1139/X05-120

Hou, S., & Sneyd, L. (2020). The right to food in Canada’s North: Food security and sustainability in Yukon Territory.” *SURG Journal 12*(1).

Hrenchuk, C. (2020). *Food security in Yukon: A snapshot.* The Yukon Energy Food Security Network, 22p. https://img1.wsimg.com/blobby/go/cb8c5534-9409-4118-a217-5bd492dadd19/downloads/Food%20Security%20in%20Yukon%20Novemeber%202020%20Report.pdf?ver=1623091293956

Humphries, M. M., Umbanhowar, J., & McCann, K. S. (2004). Bioenergetic prediction of climate change impacts on northern mammals. *Integrative and Comparative Biology, 44,* 152-162. DOI: 10.1093/icb/44.2.152

Huntington, H., & Fox, S. (2005). The changing Arctic: indigenous perspectives. In *Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, UK, pp. 61–98.

Huscroft, C. A., Lipovsky, P. S. & Bond, J. D. (2003). Permafrost and landslide activity: Case studies from southwestern Yukon Territory. *Yukon Exploration and Geology, 2003,* 107-120.

ICC Alaska (Inuit Circumpolar Council Alaska). (2020). Food sovereignty and self-governance: Inuit role in managing Arctic marine resources. Inuit Circumpolar Council Alaska, Anchorage, AK.

ICLR & CRI (Institute for Catastrophic Loss Reduction & Climate Risk Institute). (2020). PIEVC program. Institute for Catastrophic Loss Reduction (ICLR), Climate Risk Institute (CRI), & Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://pievc.ca

Ion, P. G., & Kershaw, G. P. (1989). The selection of snowpatches as relief habitat by woodland caribou (Rangifer tarandus caribou), Macmillan Pass, Selwyn/Mackenzie Mountains, NWT, Canada. *Arctic and Alpine Research*, *21*(2), 203-211.

ILI (Indigenous Leadership Initiative). (2020). Indigenous-led conservation: Job and economic opportunities that work for nature. Retrieved from: https://www.ilinationhood.ca/publications/job-and-economic-opportunities

Infrastructure Canada. (2019). *Climate lens – general guidance*. Government of Canada. Retrieved March 28, 2022, from https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html.

Instanes, A., Kokorev, V., Janowicz, R., Bruland, O., Sand, K., & Prowse, T. (2015). Changes to freshwater systems affecting Arctic infrastructure and natural resources. *Journal of Geophysical Research: Biogeosciences, 121*, 567-585. DOI:10.1002/2015JG003125

Institute for Sustainable Food Systems. (2015). *Yukon food system design and planning project: State of the Yukon food system 2011/2012.* Kwantlen Polytechnic University, 110p. https://www.kpu.ca/sites/default/files/ISFS/YFSDPP-State%20of%20Yukon%20Food%20System_2015.01_1.pdf

Insurance Institute. (2020). *Climate risks: Implications for the insurance industry in Canada*. Insurance Institute. https://www.insuranceinstitute.ca/en/resources/insights-research/Climate-risks-report

IPCC (International Panel on Climate Change). (2022). Climate change 2022: Impacts, adaptation, and vulnerability (Contribution of Working Group II). In Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegria, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., & Rama, B. (Eds.), *Sixth assessment report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK & New York, NY. In Press.

IPCC (International Panel on Climate Change). (2021). Climate change 2021: The physical science basis (Contribution of Working Group I). In Masson-Delmotte, V., Zhai, A., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., Maycock, T. K., Waterfield, T., Yelekçi, O., Yu, R., & Zhou, B. (Eds.), *Sixth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK & New York, NY.

IPCC (International Panel on Climate Change). (2019). *IPCC special report on the ocean and cryosphere in a changing climate* (Pörtner, H.-O., Roberts, D. C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegria, A., Nicolai, M., Okem, A., Petzold, J., Rama, B., Weyer, N. M., Eds.). Cambridge University Press, Cambridge, UK and New York, NY, 755p. DOI: 10.1017/9781009157964

IPCC (International Panel on Climate Change). (2014). *Climate change 2014: Impacts, adaptation, and vulnerability, Part A: Global and sectoral aspects*. Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., & White, L. L. (Eds.). Cambridge University Press, Cambridge, UK, 132p.

Irrgang, A. M., Lantuit, H., Gordon, R. R., Piskor, A., & Manson, G. K. (2019). Impacts of past and future coastal changes on the Yukon coast - Threats for cultural sites, infrastructure, and travel routes. *Arctic Science, 5*(2), 107–126. https://doi.org/10.1139/as-2017-0041.

ITK (Inuit Tapiriit Kanatami) & ICC Canada. (2013). Inuit and the right to food. Inuit Tapiriit Kanatami (ITK) & Inuit Circumpolar Council of Canada (ICC Canada), Ottawa, ON, 11p. https://alaskaindigenous.files.wordpress.com/2012/07/inuit-and-the-right-to-food-itk-un-submission.pdf

Jacob, C., McDaniels, T., & Hinch, S. (2010). Indigenous culture and adaptation to climate change: sockeye salmon and the St’át’imc people. *Mitigation and Adaptation Strategies for Global Change, 15*, 859-876.

Janowicz, R. J. (2010). Observed trends in the river ice regimes of northwest Canada. *Hydrology Research, 41*(6), 462-470.

Janowicz, J. R. (2017, July). Impacts of climate warming on river ice break-up and snowmelt freshet processes on the Porcupine River in Northern Yukon. In *19th CRIPE Workshop on the Hydraulics of ice covered rivers*, 9-12.

Janowicz, J. R. & Hinzman, L. D. (2019). 3.2 Hydrologic response in the Northwest Boreal region: Impacts on natural resources, ecosystems, and communities. In Sesser, A. L., Rockhill, A. P., Magness, D. R., Reid, D., DeLapp, J., Burton, P. J., Schroff, E., Barber, V., & Markon, C., (Eds.) *Drivers of landscape change in the Northwest Boreal region*. University of Alaska Press, Fairbanks, AK.

Johnstone, J. F., McIntire, E. J. B., Pedersen, E. J., King, G., & Pisaric, M. J. F. (2010). A sensitive slope: Estimating landscape patterns of forest resilience in a changing climate. *Ecosphere 1*(6), 14p. DOI:10.1890/ES10-00102.1

Jones, S. (n.d.) Chinook salmon collapse: Causes and approaches to restoration. Yukon Conservation Society, 5p. https://static1.squarespace.com/static/6009a9b2949f23737ee418af/t/627050cd2db62b2e43761b5d/1651527887691/Conservation-ChinnookSalmonCollapse%26Restoration.pdf

Jung, T. S., Frandsen, J., Gordon Sr., D. C., & Mossop, D. H. (2016). Colonization of the Beaufort Coastal Plain by beaver (*Castor canadensis*): A response to shrubification of the tundra? *The Ottawa Field-Naturalists’ Club, 130*(4), 332-335.

Kassi, N., Friendship, K., & Butler-Walker, J. (2010). Vuntut Gwitchin climate change and health research in northern Yukon: What do our changing homelands mean for our health? Phase 2: Knowledge into action. Arctic Health Research Network – Yukon, Whitehorse, YT, 24p.

Kassi, N., Pratt, M., Van Bibber, M., Friendship, K., Walker, J. B., Alatini, M., Johnson, M. J., Alfred, R. & Alfred, E. (2017). The partnerships, the productions, and the people behind the lens: Promoting youth wellness through community-based research and filmmaking. *Northern Public Affairs Magazine, 5*(2).

KFN (Kluane First Nation). (2014). Nourishing our future: An adaptive food security strategy to ensure the cultural and physical well-being of the Kluane First Nation against the impacts of climate change in the Yukon. Arctic Institute of Community-Based Research, Whitehorse,YT, 43p.

KFN & AICBR. (2016). Nourishing our future: Building on Kluane First Nations community food security strategy & youth engagement in traditions related to fisheries and fish health in Kluane Lake. Arctic Institute of Community-Based Research, 51p.

Kochtubajda, B., Burrows, W. R., Green D., Liu, A., Anderson, K. R., & McLennan, D. (2011). Exceptional cloud-to-ground lightning during an unusually warm summer in Yukon, Canada. *Journal of Geophysical Research, 116,* D21206. DOI: 10.1029/2011JD016080

Kokelj, S. V., Tunnicliffe, J., Lacelle, D., Lantz, T. C., Chin, K. S., & Fraser, R. (2015). Increased precipitation drives mega slump development and destabilization of ice-rich permafrost terrain, northwestern Canada. *Global and Planetary Change, 129*, 56-68. DOI: 10.1016/j.gloplacha.2015.02.008

Kouril, D., Furgal, C., & Whillans, T. (2016). Trends and key elements in community-based monitoring: A systematic review of the literature with an emphasis on Arctic and Subarctic regions. *Environmental Reviews, 24*(2), 151-163.

Knopp, J. A., Levenstein, B., Watson, A., Ivanova, I., Lento, J. (2020). Systematic review of documented Indigenous Knowledge of freshwater biodiversity in the circumpolar Arctic. *Freshwater Biology, 67*(1) p.194-209 https://doi.org/10.1111/fwb.13570.

Krebs, C. J., Boonstra, R., Gilbert, B. S., Kenney, A. J., & Boutin, S. (2019). Impact of Climate Change on the Small Mammal Community of the Yukon Boreal Forest. *Integrative Zoology*, 2019, 1749–4877.12397. https://doi.org/10.1111/1749-4877.12397.

Krebs, C. J., LaMontagne, J. M., Kenney, A. J., & Boutin, S. (2012). Climatic determinants of white spruce cone crops in the boreal forest of southwestern Yukon. *Botany*, *90*(2), 113-119.

Kuhnlein, H. V., & Receveur, O. (2007). Local cultural animal food contributes high levels of nutrients for Arctic Canadian Indigenous adults and Children. *The Journal of Nutrition, 137*(4), 1110–1114. https://doi.org/10.1093/jn/137.4.1110

Kuhnlein, H. V., Receveur, O., Soueida, R., & Egeland, G. M. (2004). Arctic indigenous peoples experience the nutrition transition with changing dietary patterns and obesity. *The Journal of nutrition*, *134*(6), 1447-1453.

Kukka, P. M., Thomas, J. P., Benjamin, J. E., & Jung, T. S. (2020). Rapid assessment of site occupancy by collared pika (*Ochotona collaris)* at the leading edge of their range. *European Journal of Wildlife Research,* (2020)*,* 9p.

Kuntz, J., Firelight Research Inc., & Vuntut Gwitchin First Nation. (2018). Nanh kak ejuk gweedhaa nakhwaandèe hah gwanaa'in - “watching changes on the land with our eyes”: A report on environmental monitoring activities and priorities within the lands of the Vuntut Gwitchin First Nation. Vuntut Gwitchin Government.

Kurz, W. A., & Apps, M. J. (1999). A 70-year retrospective analysis of carbon fluxes in the Canadian forest sector. *Ecological applications*, *9*(2), 526-547.

Laidler, G. J., Ford, J. D., Gough, W. A., Ikummaq, T., Gagnon, A. S., Kowal, S., Qrunnut, K., & Irngaut, C. (2009). Travelling and hunting in a changing Arctic: assessing Inuit vulnerability to sea ice change in Igloolik, Nunavut. *Climatic Change, 94*, 363-397.

Lake, I. R., Hooper, L., Abdelhamid, A., Bentham, G., Boxall, A. B. A., Draper, A., Fairweather-Tait, S., Hulme, M., Hunter, P. R., Nichols, G., & Waldron, K. W. (2012). Climate change and food security: Health impacts in developed countries. *Environmental Health Perspectives, 120*(11), 1520-1526. DOI:10.1289/ehp.1104424

Lam, S., Dodd, W., Skinner, K., Papadopoulos, A., Zivot, C., Ford, J., Garcia, P. J., & Harper, S. L. (2019). Community-based monitoring of Indigenous food security in a changing climate: Global trends and future directions. *Environmental Research Letters*, *14*(7), 073002. https://doi.org/10.1088/1748-9326/ab13e4

Lambden, J., Receveur, O., & Kuhnlein, H. V. (2007). Traditional food attributes must be included in studies of food security in the Canadian Arctic. *International Journal of Circumpolar Health, 66*(4), 308-319.

Lambe, L., McIver, T., Kim, S., Mayne, K., Craig, W., & King, M. (2019). *Health and health-related behaviours among young people in Yukon*. Government of Yukon, 153p. Accessed from https://yukon.ca/sites/yukon.ca/files/hss/hss-imgs/hbsc_yukon_report_2018_final.pdf

Lane, J. E., McAdam, A. G., McFarlane, S. E., Williams, C. T., Humphries, M. M., Coltman, D. W., Gorrell, J. C., & Boutin, S. (2018). Phenological shifts in North American red squirrels: disentangling the roles of phenotypic plasticity and microevolution. *Journal of Evolutionary Biology*, *31*(6), 810-821.

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

Larsen, C., Burgess, E., Arendt, A., O’Neel, S., Johnson, A., & Kienholz, C. (2015). Surface melt dominates Alaska glacier mass balance. *Geophysical Research Letters, 42*, 5902–5908. doi:10.1002/2015GL064349.

Latulippe, N. & Klenk, N. (2020). Making room and moving over: Knowledge co-production, Indigenous knowledge sovereignty and the politics of global environmental change decision-making. *Current Opinion in Environmental Sustainability, 42*, 7-14.

Laxton, S. & Coates, J. (2011). Geophysical and borehole investigations of permafrost conditions associated with compromised infrastructure in Dawson and Ross River, Yukon. In MacFarlane, K. E., Weston, L. H., & Relf, C. (Eds.), *Yukon exploration and geology 2010*. Yukon Geological Survey, Whitehorse, YT, 135-148. https://ygsftp.gov.yk.ca/publications/yeg/yeg10/YEG/09_Laxton_Coates.pdf

Leeper, A. C., Lawrence, B. A., & LaMontagne, J. M. (2020). Plant-available soil nutrients have a limited influence on cone production patterns of individual white spruce trees. *Oecologia*, *194*(1), 101-111.

Leung, M. C.-Y., Bolduc, E., Doyle, F. I., Reid, D. G., Gilbert, B. S., Kenney, A. J., Krebs, C. J., & Bêty, J. (2018). Phenology of hatching and food in low Arctic passerines and shorebirds: is there a mismatch? *Arctic Science, 4*(4), 538-556. DOI: 10.1139/as-2017-0054

Leung, M. C., & Reid, D. G. (2013). New species records for butterflies (Lepidoptera) on Herschel Island, Yukon, Canada, with notes on natural history. *The Canadian Entomologist*, *145*(2), 227-234.

Lindsay, R. & Schweiger, A. (2015). Arctic sea ice thickness loss determined using subsurface, aircraft, and satellite observations. *The Cryosphere, 9*, 269–283.

Linklater, E. (2014). *Yukon River Cultural Fisheries Project*. Yukon Salmon Sub-Committee & Yukon River Chinook Salmon Stock Restoration, 13p. Retrieved from: https://yssc.ca/wp-content/uploads/2019/03/YukonRiverCulturalFisheriesProject_final1.pdf

Lipovsky, P. S., Coates, J., Lewkowicz, A. G., & Trochim, E. (2006). Active-layer detachments following the summer 2004 forest fires near Dawson City, Yukon. In Emond, D. S., Bradshaw, G. D., Lewis, L. L., & Weston, L. H. (Eds.), *Yukon Exploration and Geology 2005*, 175-194.

Lister, D. (2010). An evaluation of factors influencing spontaneous vegetation succession in northern latitude disturbances: Assessment of natural recolonization of disturbances in Yukon. British Columbia Mine Reclamation Symposium, Vancouver, BC.

Littell, J. S., McAfee, S. A., & Hayward, G. D. (2018). Alaska snowpack response to climate change: Statewide snowfall equivalent and snowpack water scenarios. *Water*, *10*(5), 668.

Liu, J., Chen, Z., Hu, Y., Zhang, Y., Ding, Y., Cheng, X., Yang, Q., Nerger, L., Spreen, G., Horton, R., Inoue, J., Yang, C., Li, M., & Song, M. (2019). Towards reliable Arctic sea ice prediction using multivariate data assimilation. *Science Bulletin, 64*(1), 63–72. https://doi.org/10.1016/j.scib.2018.11.018.

Loring, P. A. S. & Gerlach, C. (2015). Searching for progress on food security in the North American North: A research synthesis and meta-analysis of the peer-reviewed literature. *Arctic, 68*(3), 380-392.

Loring, P. & Gerlach, S. C. (2009). Food, culture, and human health in Alaska: An integrative health approach to food security. *Environmental Science & Policy, 12*(4), 466-478.

Lynch, A. J., Thompson, L. M., Morton, J. M., Beever, E. A., Clifford, M. Limpinsel, D., Magill, R. T., Magness, D. R., Melvin, T. A., Newman, R. A., Porath, M. T., Rahel, F. J. Reynolds, J. H., Schuurman, G. W., Sethi, S. A., & Wilkening, J. L. (2022). RAD adaptive management for transforming ecosystems. *BioScience 72*(1), 45-56. DOI:10.1093/biosci/biab091

Lynn, K., Daigle, J., Hoffman, J., Lake, F., Michelle, N., Ranco, D., Viles, C., Voggesser, G., & Williams, P. (2013). The impacts of climate change on tribal traditional foods. In J. K.

Maldonado, B. Colombi, R. Pandya (Eds), *Climate Change and Indigenous Peoples in the United States* (pp. 37-48). Springer, Cham.

Ma, Z., Peng, C., Zhu, Q., Chen, H., Yu, G., Li, W., Zhou, X., Wang, W., & Zhang, W. (2012). Regional drought-induced reduction in the biomass carbon sink of Canada's boreal forests. *Proceedings of the National Academy of Sciences, 109*(7), 2423-2427.

Macander, M. J., Palm, E. C., Frost, G. V., Herriges, J. D., Nelson, P. R., Roland, C., Russell, K. L. M., Suitor, M. J., Bentzen, T. W., Joly, K., Goetz, S. J., & Hebblewhite, M. (2020). Lichen cover mapping for caribou ranges in interior Alaska and Yukon. *Environmental Research Letters, 15*(2020), 055001. DOI: 10.1088/1748-9326/ab6d38

MacDonald, L. A., Turner, K. W., McDonald, I., Kay, M. L., Hall, R. I., & Wolfe, B. B. (2021). Isotopic evidence of increasing water abundance and lake hydrological change in Old Crow Flats, Yukon, Canada. *Environmental Research Letters, 16,* 124024. DOI: 10.1088/1748-9326/ac3533

Macfarlane, R. (2020). *Health effects of extreme weather events and wildland fires: A Yukon perspective*. Office of the Chief Medical Officer of Health, Whitehorse, YT, 30p. https://yukon.ca/sites/yukon.ca/files/hss/climate_change_report_web_feb.2020_0.pdf

Mack, M. C., Walker, X. J., Johnstone, J. F., Alexander, H. D., Melvin, A. M., Jean, M., & Miller, S. N. (2021). Carbon loss from boreal forest wildfires offset by increased dominance of deciduous trees. *Science, 372*, 280-283.

MacKay, M., Parlee, B., & Karsgaard, C. (2020). Youth engagement in climate change action: Case study on Indigenous youth at COP24. *Sustainability, 12*, 6299. DOI: 10.3390/su12166299

Mackenzie-Grieve, J. L. & Post, J. R. (2006). Projected impacts of climate warming on production of lake trout (Salvelinus namsycush) in southern Yukon lakes. *Canadian Journal of Fisheries and Aquatic Sciences, 63,* 788-797. DOI: 10.1139/F05-257

Mallory, C. D., & Boyce, M. S. (2018). Observed and predicted effects of climate change on Arctic caribou and reindeer. *Environmental Reviews*, *26*(1), 13-25.

McCoy, V. M. & Burn, C. R. (2005). Potential alteration by climate change of the forest-fire regime in the boreal forest of central Yukon Territory. *Arctic 58*(3), 276-285.

McGrath, N. (2018). *Indigenous knowledge in environmental co-management in the Yukon* [Master's thesis, Royal Roads University]. Royal Roads University Library. https://viurrspace.ca/bitstream/handle/10613/8724/McGrath_royalroads_1313O_10583.pdf?sequence=1&isAllowed=y

McKenna, K., Davies, K., Smith, S., & Gasser, P.-Y. (2015). Agricultural adaptations to changing permafrost conditions in southern Yukon. GeoQuébec 2015, Québec City, QC.

McKenzie, J. M., Kurylyk, B. L., Walvoord, M. A., Bense, V. F., Fortier, D., Spence, C., & Grenier, C. (2021). Invited perspective: What lies beneath a changing Arctic?. *The Cryosphere*, *15*(1), 479-484.

McKillop, R., Sacco, D., & Cronmiller, D. (2019). Permafrost-related erosional effects of water level regulation and climate change along the shorelines of Aishihik and Canyon Lakes, Southwest Yukon. *Cold Regions Engineering 2019*, 289–297. https://doi.org/10.1061/9780784482599.034.

McKnight, E. (2017). Characterizing and monitoring the water properties and dynamics of Lhù’ààn Mā̀n (Kluane Lake), Yukon, in the face of climate change. *Arctic, 70*(4), 435–40.

McNeil, P., Russell, D. E., Griffith, B., Gunn, A., & Kofinas, G. P. (2005). Where the wild things are: Seasonal variation in caribou distribution in relation to climate change. *Rangifer*, 51-63.

McPartland, M. Y., Montgomery, R. A., Hanson, P. J., Phillips, J. R., Kolka, R., & Palik, B. (2020). Vascular plant species response to warming and elevated carbon dioxide in a boreal peatland. *Environmental Research Letters, 15*(12), 12p.

Meltofte, H. (Ed.). (2013). *Arctic biodiversity assessment: Status and trends in Arctic biodiversity*. Conservation of Arctic Flora and Fauna, Akureyri, Iceland, 674p.

Merculieff, I., Abel, P., Allen, Chief J., Beaumier, M., Bélanger, V., Burelle, M.-A., Dickson Jr., T., Ebert, M., Henri, D., Legat, A., Larocque, B., Netro, L., & Zoe-Chocolate, C. (2017). *Arctic Traditional Knowledge and wisdom: Changes in the North American Arctic - Perspectives from Arctic Athabaskan Council, Aleut International Association, Gwich’in Council International, and published accounts.* Conservation of Arctic Flora and Fauna, Akureyri, Iceland, 78p. ISBN978-9935-431-61-5

Michaelides, R. J., Schaefer, K., Zebker, H. A., Parsekian, A., Liu, L., Chen, J., Natali, S., Ludwig, S., & Schaefer, S. R. (2019). Inference of the impact of wildfire on permafrost and active layer thickness in a discontinuous permafrost region using the remotely sensed active layer thickness (ReSALT) algorithm. *Environmental Research Letters, 14* (2019). https://doi.org/10.1088/1748-9326/aaf932.

Michalak, J. L., Stralberg, D., Cartwright, J. M., & Lawler, J. J. (2020). Combining physical and species-based approaches improves refugia identification. *Frontiers in Ecology and the Environment*, *18*(5), 254-260.

Mining Association of Canada. (2021). *Towards sustainable mining: Climate change protocol*. 34p. https://mining.ca/wp-content/uploads/dlm_uploads/2021/08/FINAL-Climate-Change-Protocol-ENGLISH.pdf

Mistry, J. & Berardi, A. (2016). Bridging Indigenous and scientific knowledge. *Science, 352*(6291), 1274-1275

Mohammadimanesh, F., Salehi, B., Mahdianpari, M., English, J., Chamberland, J., & Alasset, P-J. (2019). Monitoring surface changes in discontinuous permafrost terrain using small baseline SAR interferometry, object-based classification, and geological features: A case study from Mayo, Yukon Territory, Canada. *GIScience & Remote Sensing, 56*(4), 485-510. https://doi.org/10.1080/15481603.2018.1513444.

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., & Chaves, W. A. (2017). Identifying effective climate change education strategies: A systematic review of the research. *Environmental Education Research,* 22p. DOI: 10.1080/13504622.2017.1360842

Morrison, N. E., Receveur, O., Kuhnlein, H. V., Appavoo, D. M., Soueida, R., & Pierrot, P. (1995). Contemporary Sahtú Dene/Métis use of traditional and market food. *Ecology of Food and Nutrition, 34*(3), 197–210. https://doi.org/10.1080/03670244.1995.9991460

Mu, C., Zhang, F., Chen, X., Ge, S., Mu, M., Jia, L., Wu, Q., & Zhang, T. (2019). Carbon and mercury export from the Arctic rivers and response to permafrost degradation. *Water Research, 161*(September), 54–60. https://doi.org/10.1016/j.watres.2019.05.082.

Murdoch, A. M., Cooke, S. J., Connors, B., Lapointe, N., Mills-Flemming, J., & Mantyka-Pringle, C. (2022, May). *How is Canadian-origin Yukon River Chinook Salmon responding to environmental change?* [Virtual presentation]. Yukon Fish Community of Practice Speaker Series.

Myers-Smith, I. H., Forbes, B. C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K. D., Macias-Fauria, M., Sass-Klaassen, U., Levesque, E., Boudreau, S., Ropars, P., Hermanutz, L., Trant, A., Siegwart-Collier, L., Wijers, S., Rozema, J., Rayback, S. A., Schmidt, N. M., Schaepman-Strub, G., Wipf, S., Rixen, C., Menard, C. B., Venn, S., Goetz, S., Andreu-Hayles, L., Elmendorf, S., Ravolainen, V., Welker, J., Grogan, P., Epstein, H. E., & Hik, D. S. (2011). Shrub expansion in tundra eco-systems: Dynamics, impacts and research priorities. *Environmental Research Letters, 6*(4), 045509, 15p.

Myers-Smith, I. H., Grabowski, M. M., Thomas, H. J. D., Angers-Blondin, S., Daskalova, G. N., Bjorkman, A. D., Cunliffe, A. M., Assmann, J. J., Boyle, J., McLeod, E., McLeod, S., Joe, R., Lennie, P., Arey, D., Gordon, R., & Eckert, C. (2019). Eighteen years of ecological monitoring reveals multiple lines of evidence for tundra vegetation change. *Ecological Monographs, 89*(2), e01351. https://doi.org/10.1002/ecm.1351.

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

Myers-Smith, I. H., Kerby, J. T., Phoenix, G. K., Bjerke, J. W., Epstein, H. E., Assmann, J. J., John, C., Andreu-Hayles, L., Angers-Blondin, S., Beck, P. S. A., Berner, L. T., Bhatt, U. S., Bjorkman, A. D., Blok, D., Bryn, A., Christiansen, C. T., Cornelissen, J. H. C., Cunliffe, A. M., Elmendorf, S. C., Forbes, B. C., Goetz, S. J., Hollister, R. D., de Jong, R., Loranty, M. M., Macias-Fauria, M., Maseyk, K., Normand, S., Olofsson, J., Parker, T. C., Parmentier, F.-J. W., Post, E., Schaepman-Strub, G., Stordal, F., Sullivan, P. F., Thomas, H. J. D., Tømmervik, H., Treharne, R., Tweedie, C. E., Walker, D. A., Wilmking, M., & Wipf, S.

(2020). Complexity revealed in the greening of the Arctic. *Nature Climate Change, 10,* 106-117. DOI: 10.1038/s41558-019-0688-1.

Nakano, T., Fediuk, K., Kassi, N., & Kuhnlein, H. V. (2005). Food use of Dene/Métis and Yukon children. *International Journal of Circumpolar Health, 64*(2), 137–146. https://doi.org/10.3402/ijch.v64i2.17966

NASA (National Aeronautics and Space Administration). (2022). Global temperature. Global Climate Change, NASA. Accessed March 27, 2022 https://climate.nasa.gov/vital-signs/global-temperature/.

National Snow and Ice Data Center. (2022). Arctic sea ice extent. Accessed March 27, 2022 http://nsidc.org/data/g02135.html.

Natural Resources Canada. (2022, May 17). *Flood hazard identification and mapping program.* https://www.nrcan.gc.ca/science-and-data/science-and-research/natural-hazards/flood-hazard-identification-and-mapping-program/24044

Natural Resources Canada. (2019). *Federal geomatics guidelines for flood mapping* (Version 1.0, General Information Product 114e). Government of Canada. https://ftp.maps.canada.ca/pub/nrcan_rncan/publications/STPublications_PublicationsST/299/299810/gip_114_en.pdf

Natural Resources Canada. (2018). *Federal flood mapping framework* (Version 2.0, General Information Product 112e). Government of Canada, 26p. https://publications.gc.ca/collections/collection_2019/rncan-nrcan/M113-3-1-2018-eng.pdf

NCCAH (National Collaborating Centre for Aboriginal Health). (2013). *Nutrition Fact Sheet*. Prince George, BC.

Nealis, V. & Peter, B. (2008). *Risk assessment of the threat of mountain pine beetle to Canada's boreal and eastern pine forests*. Canadian Forest Service, Pacific Forestry Centre, Victoria, BC, 31p.

Neuswanger, J. R., Wipfli, M. S., Evenson, M. J., Hughes, N. F., & Rosenberger, A. E. (2015). Low productivity of Chinook salmon strongly correlates with high summer stream discharge in two Alaskan rivers in the Yukon drainage. *Canadian Journal of Fisheries and Aquatic Sciences, 72*(8), 1125-1137.

Newton, J., Paci, C. D. J., & Ogden, A. (2005). Climate change and natural hazards in Northern Canada: Integrating Indigenous perspectives with government policy. In E. C. Haque, (Ed.), *Mitigation of natural hazards and disasters: International perspectives* (pp.209-239). Springer, Dordrecht, Netherlands.

Nitze, I., Grosse, G., Jones, B. M., Romanovsky, V. E., & Boike, J. (2018). Remote sensing quantifies widespread abundance of permafrost region disturbances across the Arctic and Subarctic. *Nature Communications 9*(1), 5423. https://doi.org/10.1038/s41467-018-07663-3.

NOAA (National Oceanic and Atmospheric Association). (2022a). Arctic oscillation (AO). National Centers for Environmental Information, NOAA. Accessed March 27, 2022 https://www.ncdc.noaa.gov/teleconnections/ao/.

NOAA (National Oceanic and Atmospheric Association). (2022b). Global surface temperature anomalies. National Centers for Environmental Information, NOAA. Accessed March 27, 2022 (https://www.ncei.noaa.gov/monitoring-references/faq/anomalies.php#anomalies).wind

Northern Climate ExChange. (2014). Projected future changes in glaciers and their contribution to discharge of the Yukon River at Whitehorse. Yukon Research Centre, Yukon College, Whitehorse, YT, 44p.

Northern Climate ExChange. (2013). Burwash Landing and Destruction Bay landscape hazards: Geological mapping for climate change adaptation planning. Yukon Research Centre, Yukon College, Whitehorse, YT, 44p.

Northern Climate ExChange. (2011). *Pelly Crossing landscape hazards: Geological mapping for climate change adaptation planning*. Yukon Research Centre, Yukon College, Whitehorse, YT, 56p.

Novak, R., Jantarasami, L., Singletary, L., Delgado, R., Marino, E., McNeeley, S., Narducci, C., Raymond-Yakoubian, J., & Whyte, K. (2018). Tribes and indigenous people. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. DOI: 10.7930/NCA4.2018.CH15.

NRTEE (National Round Table on the Environment and the Economy). (2009). *True North: Adapting infrastructure to climate change in northern Canada*. Ottawa, ON, 146p.

Oberbauer, S. F., Elmendorf, S. C., Troxler, T. G., Hollister, R. D., Rocha, A. V., Bret-Harte, M. S., Dawes, M. A., Fosaa, A. M., Henry, G. H. R., Høye, T. T., Jarrad, F. C., Jónsdóttir, I. S., Klanderud, K., Klein, J. A., Molau, U., Rixen, C., Schmidt, N. M., Shaver, G. R., Slider, R. T., Totland, Ø., Wahren, C.-H., & Welker, J. M. (2013). Phenological response of tundra plants to background climate variation tested using the International Tundra Experiment. *Phil Trans Royal Society B, 368*, 20120481. http://dx.doi.org/10.1098/rstb.2012.0481

Ochwat, N. E., Marshall, S. J., Moorman, B. J. Criscitiello, A. S., & Copland, L. (2020). Meltwater storage in the firn of Kaskawulsh Glacier, Yukon Territory, Canada. *The cryosphere discussions*, 2020, 1–21. https://doi.org/10.5194/tc-2020-119.

Ogden, A. E. & Innes, J. L. (2008). Climate change adaptation and regional forest planning in southern Yukon, Canada. *Mitigation and Adaptation Strategies for Global Change, 13*(8), 833-861.

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.

Olynyk, M. D. (2008). Summary of the significance of and threats to cultural resources located at the historic settlement area on Herschel Island Territorial Park of Yukon. *Heritage and Risk*, 212-214.

Overland, J. E. & Wang, M. (2013). When will the summer Arctic be nearly sea ice free? *Geophysical Research Letters, 40*(10), 2097-2101. DOI: 10.1002/grl.50316

Palm, E. C., Suitor, M. J., Joly, K., Herriges, J. D., Kelly, A. P., Hervieux, D., Russell, K. L. M., Bentzen, T. W., Larter, N. C., & Hebblewhite, M. (2022). Increasing fire frequency and severity will increase habitat loss for a boreal forest indicator species. *Ecological Applications*, e2549, 18p. https://doi.org/10.1002/eap.2549.

Parlee, B. L., Goddard, E., Łutsël K'é Dene First Nation, & Smith, M. (2014). Tracking change: traditional knowledge and monitoring of wildlife health in northern Canada. *Human Dimensions of Wildlife, 19*, 47–61.

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

Patton, A. I., Rathburn, S. L., & Capps, D. M. (2019). Landslide response to climate change in permafrost regions. *Geomorphology, 340*(September), 116–128. https://doi.org/10.1016/j.geomorph.2019.04.029.

Peace, D. M. & Myers, E. (2012). Community-based participatory process – Climate change and health adaptation program for northern First Nations and Inuit in Canada. *International Journal of Circumpolar Health, 71*(1), 18412. DOI: 10.3402/ijch.v71i0.18412

Pearce, T., Ford, J., Cunsolo Willox, A., & Smit, B. (2015). Inuit Traditional Ecological Knowledge (TEK), subsistence hunting and adaptation climate change in the Canadian Arctic. *Arctic, 68*(2), 233-245.

Pearce, T. D., Ford, J. D., Prno, J., Duerden, F., Berrang-Ford, L., Smith, T. R., Pittman, J., Reid, A., Beaumier, M., & Marshall, D. (2009). *Climate change and Canadian mining: Opportunities for adaptation.* David Suzuki Foundation, 150p.

Pearce, T. D., Ford, J. D., Prno, J., Duerden, F., Pittman, J., Beaumier, M., Berrang-Ford, L., & Smit, B. (2011). Climate change and mining in Canada. *Mitigation and Adaptation Strategies for Global Change, 16*(3), 347-368. https://doi.org/10.1007/S11027-010-9269-3

Peers, M. J. L., Majchrzak, Y. N., Menzies, A. K., Studd, E. K., Bastille-Rousseau, G., Boonstra, R., Humphries, M., Jung, T. S., Kenney, A. J., Krebs, C. J., Murray, D. L., & Boutin, S. (2020). Climate change increases predation risk for a keystone species of the boreal forest. *Nature Climate Change, 10*(12), 1149-1153.

Perez-Escamilla, R., & Segall-Correa, A. M. (2008). Food Insecurity measurement and indicators. *Revista de Nutrição, 21*(5), 15-26. DOI:10.1590/s1415-52732008000500003.

Perrin A., Dion J., Eng S., Sawyer J. R., Nodelman N., Comer N., Auld H., Sparling E., Harris M., Nodelman J. Y. H., & Kinnear L. (2015a). *Economic implications of climate change adaptations for mine access roads in northern Canada*. Northern Climate ExChange, Yukon Research Centre, Yukon College. 93 p.

Perrin A., Eng S., Sparling E., Auld H., Comer N., Bevington A., & Kinnear L. (2015b). *Enhancing knowledge transfer to decision-makers with respect to climate change impacts on the cryosphere*. Northern Climate ExChange, Yukon Research Centre, Yukon College.

Petrov, A. (2016). Exploring the Arctic's "other economies": Knowledge, creativity and the new frontier. *The Polar Journal, 6*(1), 51-68. http://dx.doi.org/10.1080/2154896X.2016.1771007

Platts, W. S., Torquemada, R. J., McHenry, M. L. & Graham, C. K. (1989). Changes in salmon spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. *Transactions of the American Fisheries Society, 118*(3), 274-283.

Polar Science Center (2022). PIOMAS Data. Applied Physics Laboratory, University of Washington. Accessed March 27, 2022 from psc.apl.uw.edu/research/projects/arctic-sea-ice-volume-anomaly/data/.

Potié, J., & Reid, D. (2021). Conservation of Lakeshore Zones in the Northern Boreal Mountains: State of Knowledge, and Principles and Guidelines for Planning and Management. WCS Canada Conservation Report No. 14.

Post, E., & Forchhammer, M. C. (2008). Climate change reduces reproductive success of an Arctic herbivore through trophic mismatch. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1501), 2367-2373.

Potter, C., & Alexander, O. (2020). Changes in vegetation phenology and productivity in Alaska over the past two decades. *Remote Sensing*, *12*(10), 1546.

Pratt, M. (2019). *Mapping Yukon climate change & northern food systems assets: Summary report*. Arctic Institute of Community-Based Research & Government of Yukon, 69p. https://emrlibrary.gov.yk.ca/ebooks/arctic-institute-of-community-based-research/mapping-yukon-climate-change-and-northern-food-systems-assets-2019.pdf

Pratt M, Friendship K, Kassi N, Butler Walker J. (2016). *Working together towards a food secure Yukon*. Arctic Institute of Community-Based Research, Whitehorse, YT, 25p.

Price, D. T., Alfaro, R. I., Brown, K. J., Flannigan, M. D., Fleming, R. A., Hogg, E. H., Girardin, M. P., Lakusta, T., Johnston, M., McKenney, D. W., Pedlar, J. H., Stratton, T., Sturrock, R. N., Thompson, I. D., Trofymow, J. A., & Venier, L. A. (2013). Anticipating the consequences of climate change for Canada's boreal forest ecosystems. *Environmental Reviews, 21*, 322-365. DOI: 10.1139/er-2013-0042

Prowse, T. D. (2009). Introduction: Hydrological effects of a shrinking cryosphere. *Hydrological Processes, 23,* 1-6.

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,* 900-915. DOI: 10.1007/s12237-015-0046-0

Ramage, J. L., Irrgang, A. M., Herzschuh, U., Morgenstern, A., Couture, N., & Lantuit, H. (2017). Terrain controls on the occurrence of coastal retrogressive thaw slumps along the Yukon Coast, Canada. *Journal of Geophysical Research: Earth Surface, 122*(9), 1619-1634. DOI: 10.1002/2017JF004231

Reading, J. (2015). Confronting the growing crisis of cardiovascular disease and heart health among aboriginal peoples in Canada. *Canadian Journal of Cardiology, 31*(9), 1077-1080.

Reading, C. L., & Wien, F. (2009). *Health Inequalities and Social Determinants of Aboriginal Peoples' Health*. National Collaborating Centre for Aboriginal Health, Prince George, BC. Retrieved from https://www.ccnsa-nccah.ca/docs/determinants/RPT-HealthInequalities-Reading-Wien-EN.pdf

Receveur, O., Boulay, M., & Kuhnlein, H. V. (1997). Decreasing traditional food use affects diet quality for adult Dene/Métis in 16 communities of the Canadian Northwest Territories. *The Journal of Nutrition, 127*(11), 2179–2186. https://doi.org/10.1093/jn/127.11.2179

Reid, A. (2019). Climate change education and research: Possibilities and potentials versus problems and perils? *Environmental Education Research, 25*(6), 767-790. DOI: 10.1080/13504622.2019.1664075

Reid, K. A., Reid, D. G., & Brown, C. (2022). Patterns of vegetation change in Yukon: Recent findings and future research in dynamic subarctic ecosystems. *Environmental Reviews, 30*, 380-401.

Research Northwest & Morrison Hershfield. (2017). *Yukon 'state of play': Analysis of climate change impacts and adaptation*. Government of Yukon, Whitehorse, YT, 68p.

Richards, G., Frehs, J., Myers, E., & Van Bibber, M. (2019). The climate change and health adaptation program: Indigenous climate leaders' championing adaptation efforts. *Health promotion and chronic disease prevention in Canada, 39*(4), 127-130. https://doi.org/10.24095/hpcdp.39.4.03

Romanowsky E., Handorf, D., Jaiser, R., Wohltmann, I., Dorn, W., Ukita, J., Cohen, J., Dethloff, K., & Rex, M. (2019). The role of stratospheric ozone for Arctic-midlatitude linkages. *Scientific Reports, 9,* 7962. https://doi.org/10.1038/s41598-019-43823-1

Rosol, R., Powell-Hellyer, S., & Chan, H. M. (2016). Impacts of decline harvest of country food on nutrient intake among Inuit in Arctic Canada: impact of climate change and possible adaptation plan. *International Journal of Circumpolar Health, 75*, 31127. https://doi.org/10.3402/ijch.v75.31127

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.

RRDC (Ross River Dena Council) and AICBR. 2019. *Our land | our people: Protecting and preserving our land, language and culture for future generations - assessing climate change and adaptation in Ross River, Yukon*. Arctic Institute for Community-based Research, Whitehorse, YT, 25p.

Russell, D. E. & McNeil, P. (2005). *Summer ecology of the porcupine caribou herd.* Porcupine Caribou Management Board, Whitehorse, YT, 14p.

Russell, K. L. M. & Johnson, C. J. (2019). Post-fire dynamics of terrestrial lichens: Implications for the recovery of woodland caribou winter range. *Forest Ecology and Management, 434*(2019), 1-17.

Samuel, J., Kavanaugh, J., Benkert, B., Samolczyck, M., Laxton, S., Evans, R., Saal, S., Gonet, J., Horton, B., Clague, J., Harmer, Z., & Kinnear, L. (2016). *Evaluating climate change impacts on the upper Yukon River basin: Projecting future conditions using glacier, climate and hydrological models.* Yukon Research Centre, Yukon College, Whitehorse, YT, 113p. https://www.yukonu.ca/sites/default/files/inline-files/YukonRiverHydrology_Samuel_Final%20%281%29_1.pdf

Sawatzky, A., Cunsolo, A., Jones-Bitton, A., Gillis, D., Wood, M., Flowers, C., Shiwak, I., The Rigolet Inuit Community Government, & Harper, S. L. (2020). “The best scientists are the people that’s out there”: Inuit-led integrated environment and health monitoring to respond to climate change in the Circumpolar North. *Climatic Change*, *160*(1), 45-66.

Scaff, L., Yang, D., Li, Y., & Mekis, E. (2015). Inconsistency in precipitation measurements across the Alaska-Yukon border. *The Cryosphere, 9,* 2417-2428. DOI: 10.5194/tc-9-2417-2015

Schaefer, K., Lantuit, H., Romanovsky, V. E., Schuur, E. A., & Witt, R. (2014). The impact of the permafrost carbon feedback on global climate. *Environmental Research Letters 9*, 085003, 9p.

Schuur, E. A. G., McGuire, A. D., Schädel, C., Grosse, G., Harden, J. W., Hayes, D. J., Hugelius, G., Koven, C. D., Kuhry, P., Lawrence, D. M., Natali, S. M., Olefeldt, D., Romanovsky, V. E., Schaefer, K., Turetsky, M. R., Treat, C. C., & Vonk, J. E. (2015). Climate change and the permafrost carbon feedback. *Nature*, *520*(7546), 171-179. DOI: 10.1038/nature14338

Schuurman, G. W., Hoffman Hawkins, C., Cole, D. N., Lawrence, D. J., Morton, J. M., Magness, D. R., Cravens, A. E., Covington, S., O’Malley, R., & Fisichelli. N. A. (2020). *Resist-accept-direct (RAD) - A framework for the 21st-century natural resource manager*.

Natural Resource Report NPS/NRSS/CCRP/NRR—2020/ 2213. National Park Service, Fort Collins, Colorado. https://doi.org/10.36967/nrr-2283597.

Schuurman, G. W., Cole, D. N., Cravens, A. E., Covington, S., Crausbay, S. D., Hoffman Hawkins, C., Lawrence, D. J., Magness, D. R., Morton, J. M., Nelson, E. A., & O'Malley, R. (2022). *BioScience, 72*(1), 16-29. DOI:10.1093/biosci/biab067

Schuster, P., Striegle, R., Aiken, D., Krabbenhoft, D., Dewild, J., Butler, K., Kamark, B., & Dornblaser, M. (2011a). Mercury export from the Yukon River Basin and potential response to a changing climate. *Journal of Environmental Science & Technology, 45*(21), 9262-9267.

Schuster, R. C., Wein, E. E., Dickson, C., & Chan, H. M. (2011b). Importance of traditional foods for the food security of two First Nations communities in the Yukon, Canada. *International Journal of Circumpolar Health, 70*(3), 286–300. https://doi.org/10.3402/ijch.v70i3.17833

Schweiger, A., R. Lindsay, J. Zhang, M. Steele, H. Stern & R. Kwok, 2011. Uncertainty in modeled Arctic sea ice volume. Journal of Geophysical Research, vol. 116, DOI:10.1029/2011JC007084

SFN (Selkirk First Nations) & AICBR. (2016). *Adapting to climate change and keeping our traditions*. Arctic Institute of Community-Based Research, 35p. https://static1.squarespace.com/static/56afc7218259b53bd8383cb8/t/57ab923e59cc68307527742f/1470861914849/Selkirk+Climate+Change+Adaptation+Plan_CommunityReport_final%5B2%5D.compressed.pdf

Severson, J. P., Johnson, H. E., Arthur, S. M., Leacock, W. B., & Suitor, M. J. (2021). Spring phenology drives range shifts in a migratory Arctic ungulate with key implications for the future. *Global Change Biology, 00,* 1-18. 10.1111/gcb.15682

Sheedy, A. (2018). The impacts of climate change on traditional and local food consumption in the Yukon. Arctic Institute of Community-Based Research, 55p

Shugar, D. H., Clague, J. J., Best, J. L., Schoof, C., Willis, M. J., Copland, L., & Roe, G. H. (2017). River piracy and drainage basin reorganization led by climate-driven glacier retreat. *Nature Geoscience 10*(5), 370-375. https://doi.org/10.1038/ngeo2932.

Shugar, D. H. & Clague, J. J. (2018). Changing glaciers, changing rivers. In L. Parrott, Z. Robinson, & D. Hik (Eds.), *The Alpine Club of Canada's state of the mountains report* (Vol. 1, pp. 4-11). The Alpine Club of Canada, Canmore, AB.

Skierszkan, E. K., Dockrey, J. W., Mayer, K. U., & Beckie, R. D. (2020). Release of geogenic uranium and arsenic results in water-quality impacts in a subarctic permafrost region of granitic and metamorphic geology. *Journal of Geochemical Exploration*, *217*, 106607.

Smale, B., & Gao, M. (2021). *A profile of wellbeing in the Yukon during the COVID-19 pandemic.* Canadian Index of Wellbeing & University of Waterloo, Waterloo, ON.

https://yukon.ca/sites/yukon.ca/files/eco/eco-profile-wellbeing-yukon-during-covid19-pandemic_.pdf

Smith, S., O'Neill, H., Isaksen, K., Noetzli, J., & Romanovsky, V. E. (2022). The changing thermal state of permafrost. *Nature Reviews Earth & Environment, 3*, 10-23. DOI: 10.1038/s43017-021-00240-1

Smith, S. L., Romanovsky, V. E., Lewkowicz, A. G., Burn, C. R., Allard, M., Clow, G. D., Yoshikawa, K., & Throop, J. (2010). Thermal state of permafrost in North America: A contribution to the International Polar Year. *Permafrost and Periglacial Processes, 21*, 117-135. DOI:10.1002/ppp.690

Smith, S. L., Duchesne, C., & Lewkowicz, A. G. (2019, August 18-22). *Tracking changes in permafrost thermal state in northern Canada*. 18th International Conference on Cold Regions Engineering and 8th Canadian Permafrost Conference, Quebec City, QC. https://doi.org/10.1061/9780784482599.077.

Southwick, T., & Ballegooyen, K. (2019). Living and breathing change: A Southern Tutchone perspective on climate and research. In L. Parrott, Z. Robinson, & D. Hik (Eds.), *The Alpine Club of Canada's state of the mountains report* (Vol. 2, pp. 14-17). The Alpine Club of Canada, Canmore, AB.

Spring, A., Carter, B., & Blay-Palmer, A. (2018). Climate change, community capitals, and food security: Building a more sustainable food system in a northern Canadian boreal community. *Canadian Food Studies, 5*(2), 111-141.

St. Jacques, J.-M. & Sauchyn, D. J. (2009). Increasing winter baseflow and mean annual streamflow from possible permafrost thawing in the Northwest Territories, Canada. *Geophysical Research Letters, 36,* 6p., L01401. DOI: 10.1029/1008GL035822

Staniszewska, K. J., Reyes, A. V., Cooke, C. A., Miller, B. S., & Woywitka, R. J. (2022). Permafrost, geomorphic, and hydroclimatic controls on mercury, methylmercury, and lead concentrations and exports in Old Crow River, arctic western Canada. *Chemical Geology, 596,* 1200810.

Steenhof, P. & Duteau, M. (2021). Investigating standards for small water and wastewater systems in northern Canada. *The Northern Review, 51*(2021), 105-131. https://doi.org/10.2258/nr51.2021.008

Stephani, E., Fortier, D., & Shur, Y. (2010). Applications of cryofacies approach to frozen ground engineering – Case study of a road test site along the Alaska Highway (Beaver Creek, Yukon, Canada). GEO2010: 63rd Canadian Geotechnical Conference and 6th Canadian Permafrost Conference, Calgary, AB.

Stockton, E. J., Burn, C. R., Idrees, M., Calmels, F., & Elmer, K. (2019, August 18-22). *Monitoring ground temperatures in permafrost along the Dempster Highway, Yukon and NWT*. 18th International Conference on Cold Regions Engineering and 8th Canadian Permafrost Conference, Quebec City, QC. https://doi.org/10.1061/9780784482599.011.

Straka, J. R. (2012). Humming along or buzzing off?: the elusive consequences of plant-pollinator mismatches and factors limiting seed set in the Coast Range of British Columbia (Doctoral dissertation).

Stralberg, D., Arseneault, D., Baltzer, J. L., Barber, Q. E., Bayne, E. M., Boulanger, Y., Brown, C. D., Cooke, H. A., Devito, K., Edwards, J., Estevo, C. A., Flynn, N., Frelich, L. E., Hogg, E. H., Johnston, M., Logan, T., Matsuoka, S. M., Moore, P., Morelli, T. L., Morisette, J. L., Nelson, E. A., Nenzén, H., Nielsen, S. E., Parisien, M.-A., Pedlar, J. H., Price, D. T., Schmiegelow, F. K. A., Slattery, S. M., Sonnentag, O., Thompson, D. K., & Whitman, E. (2020). Climate-change refugia in boreal North America: what, where, and for how long?. *Frontiers in Ecology and the Environment*, *18*(5), 261-270.

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

Suttle, K. B., Power, M. E., Levine, J. M., & McNeely, C. (2004). How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. *Ecological Applications, 14*(4), 969-974.

Ta’an Kwäch’än Council. (2021). *Fox Creek chinook salmon restoration project: Final report*. The Yukon River Panel and the Pacific Salmon Commission, 28p.

Tam, B. Y., Gough, W. A., Edwards, V., & Tsuji, L. J. (2013). The impact of climate change on the well-being and lifestyle of a First Nation community in the western James Bay region. *The Canadian Geographer, 57*, 441-456.

Tarasuk, V. & Mitchell, A. (2020). *Household food insecurity in Canada, 2017-18.* Research to identify policy options to reduce food insecurity (PROOF), Toronto, ON, 27p. Retrieved from https://proof.utoronto.ca

Transportation Association of Canada. (2010). *Primer on developing and managing transportation infrastructure in permafrost regions.* Transportation Association of Canada, Ottawa, ON, 8p.

Turcotte, B. (2021). Flooding processes and recent trends in ice-induced high water levels along rivers of northwestern Canada. In *Proceedings of the 21st Workshop on the Hydraulics of Ice Covered Rivers*. CGU HS CRIPE, Saskatoon, SK.

Turcotte, B. (2020). Will there be an ice bridge this winter? Predicting spatio-temporal freeze-up patterns along the Yukon River, Canada. In *International Association for Hydro-Environment Engineering and Research (IAHR) Symposium on Ice*. Trondheim, Norway.

Turcotte, B., Burrell, B. C., Beltaos, S., & She, Y. (2019). The impact of climate change on breakup ice jams in Canada: State of knowledge and research approaches. In *Proceedings of the 20th Workshop on the Hydraulics of Ice Covered Rivers*. CGU HS CRIPE, Ottawa, ON.

Turcotte, B., & Saal, S. (2022a). *Flooding in Dawson: Exposure analysis and risk reduction recommendations*. YukonU Research Centre, Yukon University, Whitehorse, YT, 90p.

Turcotte, B., & Saal, S. (2022b). *Flooding in Old Crow: Exposure analysis and risk reduction recommendations*. YukonU Research Centre, Yukon University, Whitehorse, YT, 87p.

Turner, K. W., Pearce, M. D., & Hughes, D. D. (2021). Detailed monitoring of a retrogressive thaw slump from remotely piloted aircraft systems and identifying associated influence on carbon and nitrogen export. *Remote Sensing, 13*(171), 26p. https://doi.org/10.3390/rs13020171

Tyson, W. & Heinemeyer, K. (2017). Inuvialuit Traditional Knowledge of wildlife habitat on the Yukon North Slope.

UNEP (United Nations Environmental Programme). (2012). *Policy implications of warming permafrost.* United Nations Environment Programme, Nairobi, Kenya, 30p. ISBN: 978-92-807-3308-2.

Van de Kerk, M., Arthur, S., Bertram, M., Borg, B., Herriges, J., Lawler, J., Mangipane, B., Koizumi, C. L., Wendling, B., & Prugh, L. (2020). Environmental Influences on Dall's Sheep Survival. *The Journal of Wildlife Management, 84*(6), 1127-1138. https://doi.org/10.1002/jwmg.21873.

Vermeulen, S. J., Campbell, B. M., Ingram, J. S. I. (2012). Climate Change and Food Systems. *Annual Review of Environment and Resources, 37*(1), 195-222

Vogt, N. S. (2021). Influence of permafrost characteristics on vegetation change in Yukon and Northwest Territories, Canada (Masters dissertation).

von Biela, V., Bowen, L., McCormick, S. D., Carey, M. P., Donnelly, D. S., Waters, S., Regish, A. M., Laske, S. M., Brown, R. J., Larson, S., Zuray, S., & Zimmerman, C. E. (2020). Evidence of prevalent heat stress in Yukon River Chinook salmon. *Canadian Journal of Fisheries and Aquatic Sciences, 77*(12), 1878-1892. DOI: 10.1139/cjfas-2020-0209.

Voswinkel, S. (2012). *Survey of Yukon's knowledge sector: Results and recommendations.* Ylynx Management Consulting, Inc. & Yukon Research Centre, Yukon College, Whitehorse, YT, 88p.

Waddell, S. (2022, February 17). *Whitehorse council boosts snow budget; will review snow policy.* Yukon News. https://www.yukon-news.com/news/whitehorse-council-boosts-snow-budget-will-review-snow-policy/

Walker, J. B., Kassi, N. Friendship, K. & Pratt, M. (2017). Stories of Yukon food security. *Northern Public Affairs, 5*(1)*,* 33-38.

Wallingford, P. D., Morelli, T. L., Allen, J. M., Beaury, E. M., Blumenthal, D. M., Bradley, B. A., Dukes, J. S., Early, R., Fusco, E. J., Goldberg, D. E., Ibáñez, I., Laginhas, B. B., Vilà, M., & Sorte, C. J. (2020). Adjusting the lens of invasion biology to focus on the impacts of climate-driven range shifts. *Nature Climate Change*, *10*(5), 398-405.

Warren, F. J. & Lemmen, D. S. (Eds.). (2014). *Canada in a changing climate: Sector perspectives on impacts and adaptation.* Government of Canada, Ottawa, ON, 286p.

Warren, F. & Lulham, N. (Eds.). (2021). *Canada in a changing climate: National issues report.* Government of Canada, Ottawa, ON, 734p.

Warren, J. A., Berner, J. E., & Curtis, T. (2005). Climate change and human health: Infrastructure impacts to small remote communities in the north. *International Journal of Circumpolar Health, 64*(5), 487-497. DOI: 10.3402/ijch.v64i5.18030

Webb, P., Coates, J., Frongillo, E. A., Rogers, B. L., Swindale, A., Bilinsky, P. (2006). Measuring household food insecurity: why it’s so important and yet so difficult to do. *The Journal of Nutrition, 136*(5), 1404-1408. DOI:10.1093/jn/136.5.1404S

Wein, E., & Freeman, M. (1995). Frequency of traditional food use by three Yukon First Nations living in four communities. *Arctic, 48*(2), 161-171.

Werner, J. R., Krebs, C. J., Donker, S. A., Boonstra, R., & Sheriff, M. J. (2015). Arctic ground squirrel population collapse in the boreal forests of the southern Yukon. *Wildlife Research, 42*(2), 176-184.

Wesche, S. D. & Chan, M. H. (2010). *Adapting to the Impacts of Climate Change on Food Security among Inuit in the Western Canadian Arctic*. Community Health Sciences, University of Northern British Columbia, Prince George, B.C.

Wheeler, H. C., Danielsen, F., Fidel, M., Hausner, V., Horstkotte, T., Johnson, N., Lee, O., Mukherjee, N., Amos, A., Ashthorn, H., Ballari, Ø., Behe, C., Breton-Honeyman, K., Retter, G-B., Buschman, V., Jakobsen, P., Johnson, F., Lyberth, B., Parrott, J. A., Pogodaev, M., Sulyandziga, R., Vronski, N. (2020). The need for transformative changes in the use of Indigenous knowledge along with science for environmental decision-making in the Arctic. *People and Nature, 2020*(2), 544-556. DOI: 10.1002/pan3.10131

Whitney, C., Frid, A., Edgar, B., Walkus, J., Siwallace, P., Siwallace, I., & Ban, N. (2020). “Like the plains people losing the buffalo”: Perceptions of climate change impacts, fisheries management, and adaptation actions by Indigenous peoples in coastal British Columbia, Canada. *Ecology and Society, 25*(4), 33p.

Whyte, K., 2017. Indigenous climate change studies: Indigenizing futures, decolonizing the Anthropocene. *English Language Notes, 55*, 153-162.

Whyte, K. 2018. What Do Indigenous Knowledges Do for Indigenous Peoples? In M.K. Nelson and D. Shilling (Eds) *Traditional Ecological Knowledge: Learning from Indigenous Practices for Environmental Sustainability*. Cambridge University Press.

Wilkens, J. & Datchoua-Tirvaudey, A. R. C. (2022). Researching climate justice: A decolonial approach to global climate governance. *International Affairs, 98*(1), 125-143. DOI: 10.1093/ia/iiab209

Williams, T., & Hardison, P. (2013). Culture, law, risk and governance: Contexts of traditional knowledge in climate change adaptation. In: J. K. Maldonado, B. Colombi, & R. Pandya, (Eds) *Climate change and Indigenous Peoples in the United States*. Springer, Cham. https://doi.org/10.1007/978-3-319-05266-3_3

Williamson, S. N., Zdanowicz, C., Anslow, F. S., Clarke, G. K. C., Copland, L., Danby, R. K., Flowers, G. E., Holdsworth, G., Jarosch, A. H., & Hik, D. S. (2020). Evidence for elevation-dependent warming in the St. Elias Mountains, Yukon, Canada. *Journal of Climate, 33*(8), 3253-3269. https://doi.org/10.1175/JCLI-D-19- 0405.1.

Willows, N. (2005). Determinants of healthy eating in Aboriginal peoples in Canada: The current state of knowledge and research gaps. *Canadian Journal of Public Health, 96*(3), 32-36.

Wilson, A., Levkoe, C. Z., Andrée, P., Blay-Palmer, A., Boulet, A., Brockington, M., Ferguson, R., Galloway, T., Martin, D., Martorell, H., Robidoux, M., Skinner, K., Spring, A., & Wesche, S. (2019). *Cultivating food sovereignty and sustainable food systems in the North: A review and recommendations*. Food Secure Canada, Montreal, QC, 16p.

Wilson, A., Levkoe, C. Z., Andrée, P., Skinner, K., Spring, A., Wesche, S., & Galloway, T. (2020). Strengthening Sustainable Northern Food Systems: Federal Policy Constraints and Potential Opportunities. *Arctic*, *73*(3), 292–311.

Wilson, K. (2003). Therapeutic landscapes and First Nations peoples: an exploration of culture, health and place. *Health and Place, 9*(2), 83-93. https://www.sciencedirect.com/science/article/abs/pii/S1353829202000163

Wilson, K., Arreak, A., Sikumiut Committee, Bell, T., & Ljubicic, G. (2021). The Mittimatalik Siku Asijjipallianinga (Sea Ice Climate Atlas): How Inuit Knowledge, earth observations, and sea ice charts can fill IPCC climate knowledge gaps. *Frontiers in Climate, 3*, 715105. DOI: 10.3389/fclim.2021.715105

Wilson, N. J., Walter, M. T., & Waterhouse, J. (2015). Indigenous knowledge of hydrologic change in the Yukon River Basin: A case study of Ruby, Alaska. *Arctic, 68*(1), 93-106. http://dx.doi.org/10.14430/arctic4459

Winker, K., & Gibson, D. D. (2018). Some broad-scale effects of recent and future climate change among migratory birds in Beringia. In W. D. Shuford, R. E. Gill Jr., & C. M. Handel (Eds.), *Trends and tradition: Avifaunal change in western North America* (Studies of Western Birds 3, pp. 432–440. Western Field Ornithologists, Camarillo, CA. DOI 10.21199/SWB3.23.

Wolfe, B. W., Humphries, M. M., Pisaric, M. F. J., Balasubramaniam, A. M., Burn, C. R., Chan, L., Cooley, D., Froese, D. G., Graupe, S., Hall, R. I., Lantz, T., Porter, T. J., Roy-

Leveillee, P., Turner, K. W., Wesche, S. D., & Williams, M. (2011). Environmental change and traditional use of the Old Crow Flats in northern Canada: An IPY opportunity to meet the challenges of the new northern research paradigm. *Arctic, 64*(1), 127-135).

Wolter, J., Lantuit, H., Fritz, M., Macias-Fauria, M., Myers-Smith, I., & Herzschuh, U. (2016). Vegetation composition and shrub extent on the Yukon Coast, Canada, are strongly linked to ice-wedge polygon degradation. *Polar Research, 35*(1), 27489. https://doi.org/10.3402/polar.v35.27489.

Wong, C., Ballegooyen, K., Ignace, L., Johnson, M. J. & Swanson, H. (2020). Towards reconciliation: 10 calls to action to natural scientists working in Canada. *FACETS, 5*, 769-783.

Wood, P. J. & P. D. Armitage. (1997). Biological effects of fine sediment in the lotic environment. *Environmental Management, 21*(2), 203-217.

Wulder, M. A., Cardille, J. A., White, J. C., & Rayfield, B. (2018). Context and opportunities for expanding protected areas in Canada. *Land, 7*(137), 21p. DOI: 10.3390/land7040137

Wurtz, T. L., Bennett, B. A., & Leung, M. C. (2019). 2.3 Invasive species in the Northwest Boreal region. In Sesser, A. L., Rockhill, A. P., Magness, D. R., Reid, D., DeLapp, J., Burton, P. J., Schroff, E., Barber, V., & Markon, C., (Eds.) *Drivers of landscape change in the Northwest Boreal region*. University of Alaska Press, Fairbanks, AK.

Yacura, D., & Osborne, J. (2019). *Waste characterization study for a northern Canadian abattoir – Naturally Northern Meats.* Hemmera Envirochem Inc. & Balance BioGas, Whitehorse, YT, 17p.

Yuan, F. M., Yi, S. H., McGuire, A. D., Johnson, K. F., Harden, J. W., Kasischke, E. S., & Kurz, W. A. (2012). Assessment of boreal forest historical C dynamics in the Yukon River Basin: Relative roles of warming and fire regime change. *Ecological Applications, 22*, 2091-2109. DOI:10.1890/11-1957.1

Yukon First Nations Climate Action Fellowship. (2021). Reconnection vision and action plan. https://www.yfnclimate.ca/yfnrvap

Yukon Invasive Species Council. (2011). *The effects of climate change on invasive species and their potential impacts in Whitehorse.* Industrial Forest Service Ltd., Prince George, BC, 83p. https://www.yukoninvasives.com/index.php/en/docman-root/resources/reports/34-the-effect-of-climate-change-on-invasive-species-and-their-potential-impact-in-whitehorse/file

Yukon Water Board. (2019). *Emergency amendment of licence* (Licence No. HY99-012). Yukon Water Board and Government of Yukon.

Yukon Water Board. (2021). *Water licence amendment* (Licence No. HY99-010). Yukon Water Board and Government of Yukon.

Yukon Youth Panel on Climate Change. (2021). Our recommendations, our future: Programs and policies to embolden the Yukon's climate action. Whitehorse, YT, 10p.

Zdanowicz, C., Karlsson, P., Beckholmen, I., Roach, P., Poulain, A., Yumvihoze, E., Martma, T., Ryjkov, A., & Dastoor, A. (2018). Snowmelt, glacial and atmospheric sources of mercury to a subarctic mountain lake catchment, Yukon, Canada. *Geochimica et Cosmochimica Acta, 238*(October), 374–393. https://doi.org/10.1016/j.gca.2018.06.003

Zhang, J. & Rothrock, D. A. (2003). Modeling global sea ice with a thickness and enthalpy distribution model in generalized curvilinear coordinates. *Monthly Weather Review, 131*(5), 845-861.

Zhao, B., Zhuang, Q., Shurpali, N., Köster, K., Berninger, F., & Pumpanen, J. (2021). North American boreal forests are a large carbon source due to wildfires from 1986 to 2016. *Nature, 11*, 7723. DOI: 10.1038/s41598-021-87343-3.

Zhong, S., Yang, L., Toloo, S., Wang, Z., Tong, S., Sun, X., Crompton, D., FitzGerald, G., & Huang, C. (2018). The long-term physical and psychological health impacts of flooding: a systematic mapping. *Science of the total environment*, *626*, 165-194.

Zurba, M., Beazley, K. F., English, E., & Buchmann-Duck, J. (2019). Indigenous protected and conserved areas (IPCAs), Aichi Target 11 and Canada's pathway to Target 1: Focusing conservation on reconciliation. *Land, 8*(10), 20p. DOI: 10.3390/land8010010