Wildlife Management Advisory Council
North Slope

Yukon North Slope
Wildlife Conservation and Management Plan
2021

Companion Report 2: Climate Change Effects / Hila aallanguqtuq

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Companion Report to the Yukon North Slope Wildlife Conservation and Management Plan Number 2: Climate Change Effects / Hila aallanguqtuq

Table of Contents

Figures

Tables

About the Companion Report

This report is a companion document to the *Yukon North Slope Wildlife Conservation and Management Plan* (WMAC (NS), 2022). The *Yukon North Slope Wildlife Conservation and Management Plan* (the Plan) is grounded in traditional knowledge and Western science. It addresses traditional use and wildlife conservation and management issues affecting the Yukon North Slope. Strategies in the Plan align with actions underway or planned by a range of agencies and organizations with jurisdiction on the Yukon North Slope.

This companion report summarizes the information that was used to support the objectives and strategies in the Plan, and provides references for the studies used in its development. The companion report draws from authoritative works, reports that synthesize knowledge and issues, and presentations of recent research findings. Sources include traditional knowledge and traditional use, scientific reports and journal articles, and management and conservation reports.

Companion Report Table of Contents

Each chapter is available for download at https://wmacns.ca/what-we-do/conservation-plan/companion.

There are fourteen companion reports, addressing four selected topics of key interest as well as ten wildlife species featured in the Plan. This companion report summarizes the information that guides the objectives, strategies and conservation requirements in the *Yukon North Slope Wildlife Conservation and Management Plan*.

Companion Report: Climate Change Effects / Hila aallanguqtuq

This companion report is one of four reports on selected topics that cut across species divisions for the Plan. The phrase Hila aallanguqtuq is from the Inuvialuktun Uummarmiutun dialect, and can be translated as 'weather is changing' (IRC, 2020). Information presented in this chapter is drawn from research, monitoring, policy and planning initiatives at regional, national, and circumpolar scales. The climate change effects-related objectives and actions in Yukon North

Slope plans and programs are listed. The report also summarizes observations of climate change and projected effects related to wildlife and Inuvialuit traditional use on the Yukon North Slope.

Introduction to Climate Change Effects

Climate change is a central theme of the *Yukon North Slope Wildlife Conservation and Management Plan*. The plan is grounded in five principles, one of which states: "Climate change effects on the Yukon North Slope should be considered in all aspects of wildlife conservation, Inuvialuit traditional use, and management planning." Climate change is also directly addressed in two of the Plan's strategies.

Climate Change Strategies in the *Yukon North Slope Wildlife Conservation and Management Plan*

Strategy B3. Climate Change Effects: Monitor effects of climate change on Yukon North Slope ecosystems. Promote and engage in studies that contribute to understanding and forecasting the effects of climate change on wildlife and habitat. On an ongoing basis, assess options and implement measures for mitigation and adaptation to address climate change effects in the management of wildlife and wildlife habitats.

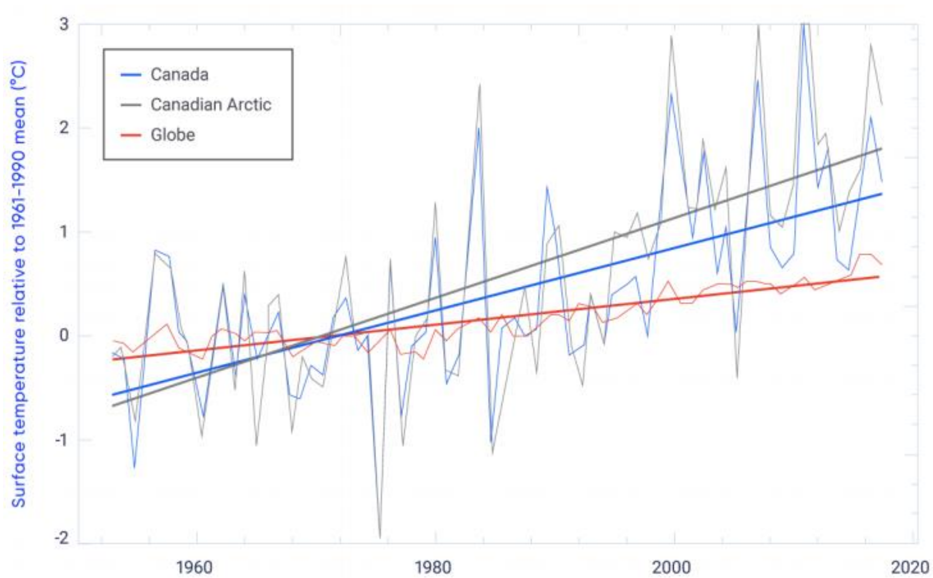
Strategy C2. Climate Change and Traditional Use: Employ monitoring and directed research to track and understand current and future effects of climate change on Inuvialuit traditional use of the Yukon North Slope. On an ongoing basis, assess options and implement measures for mitigation and adaptation, to enhance the resilience of traditional use to climate change.

Climate change is occurring most rapidly in northern latitudes. Temperatures north of 60° were the second highest on record (since 1900) during October 2019 to September 2020. This continues a trend of record-breaking climate-induced changes in the Arctic, including increasing temperatures, loss of sea ice, and greening of lower Arctic tundra ecosystems. Inuvialuit have observed climate change effects on the Yukon North Slope including changes in temperature, weather, precipitation, permafrost and ice conditions, especially since the 1980s (IRC, 2016; Joint Secretariat, 2015). Specifically, these changes include increases in surface air temperatures, which is more pronounced in Northern Canada (Figure 2-1, X. Zhang et al., 2019). Extreme weather events, such as thunderstorms, windstorms and forest fires, as well as precipitation have increased. The delayed winter season, due to warmer temperatures, has led to more precipitation falling as rain, rather than snow, during winter months (IRC, 2016; X. Zhang et al., 2019). Permafrost thawing has resulted in landscape slumping and the development of thermokarst landforms, irregular surfaces of marshy hollows and hummocks (Derksen et al., 2019). During the winter, ice on lakes is thinner and breaks up earlier than it did historically; a similar trend for sea ice occurs during summer months (Derksen et al., 2019).

Changes in climate influence wildlife, causing range shifts, increased or altered predation and competition, phenological mismatches, and altered biodiversity (Tape, Gustine, Ruess, Adams, & Clark, 2016; Tape, Jones, Arp, Nitze, & Grosse, 2018; Zhou et al., 2020). Changes in climate directly affect Inuvialuit traditional use by making reliable weather cues that have been passed down across generations no longer valid, resulting in altered or unsafe travel routes due to changes such as decreased ice thickness (IRC, 2016; Nickels, Furgal, Buell, & Moquin, 2005). As wildlife locations and behaviors shift, harvested animals may not occur in the same locations they have historically, thus hunting routes and camp locations may need to adapt (IRC, 2016; Nickels et al., 2005). The interconnectedness of people, landscape and wildlife illustrates how drastically the Inuvialuit way of life may be impacted by changes in climate, but also how their traditional knowledge will continue to be key to their survival (IRC, 2016; Nickels et al., 2005). The value of local knowledge as a way to understand environmental change is increasingly recognized, and confirms the need to involve local people in future research and monitoring processes (IRC, 2016; Nickels et al., 2005).

This chapter presents observed changes in climate (e.g., warming temperatures, decreased snowfall, diminishing sea ice) and future climate change projections for Canada produced under different emissions scenarios. Where possible, we ground climate model projections in examples of trends on the Yukon North Slope observed by Inuvialuit and through local research studies. The climate change projections considered in this report include Representative Concentration Pathways (RCP) 2.6 (lower projected emissions) and RCP 8.5 (high projected emissions, sometimes called "business as usual") (Bush & Lemmen, 2019).

Figure 2- 1. Rates of warming for Canada, the Canadian Arctic and globally



Historical observations of annual mean surface temperature for Canada (blue), the Canadian Arctic (grey) and the global average (red). The rate of surface warming in Canada is greater than twice the rate of surface warming for the globe, and the rate of surface warming in the Canadian Arctic is approximately three times the global rate. Source: Figure 3.3 (Flato, Gillett, Arora, Cannon, & Anstey, 2019), Canadian results use Adjusted and

Homogenized Canadian climate data (Vincent et al., 2015) and the global result use HadCRUT data set (Morice, Kennedy, Rayner, & Jones, 2012).

Climate Change Effects on the Yukon North Slope: Selected Studies and Syntheses of Research Results

This section summarizes information about key changes occurring in the north due to climate change, with an annotated listing of selected reports, community observations, scientific papers, and other resources that provide support to the *Yukon North Slope Wildlife Conservation and Management Plan* and highlight issues and research directions that will be important to consider during its implementation.

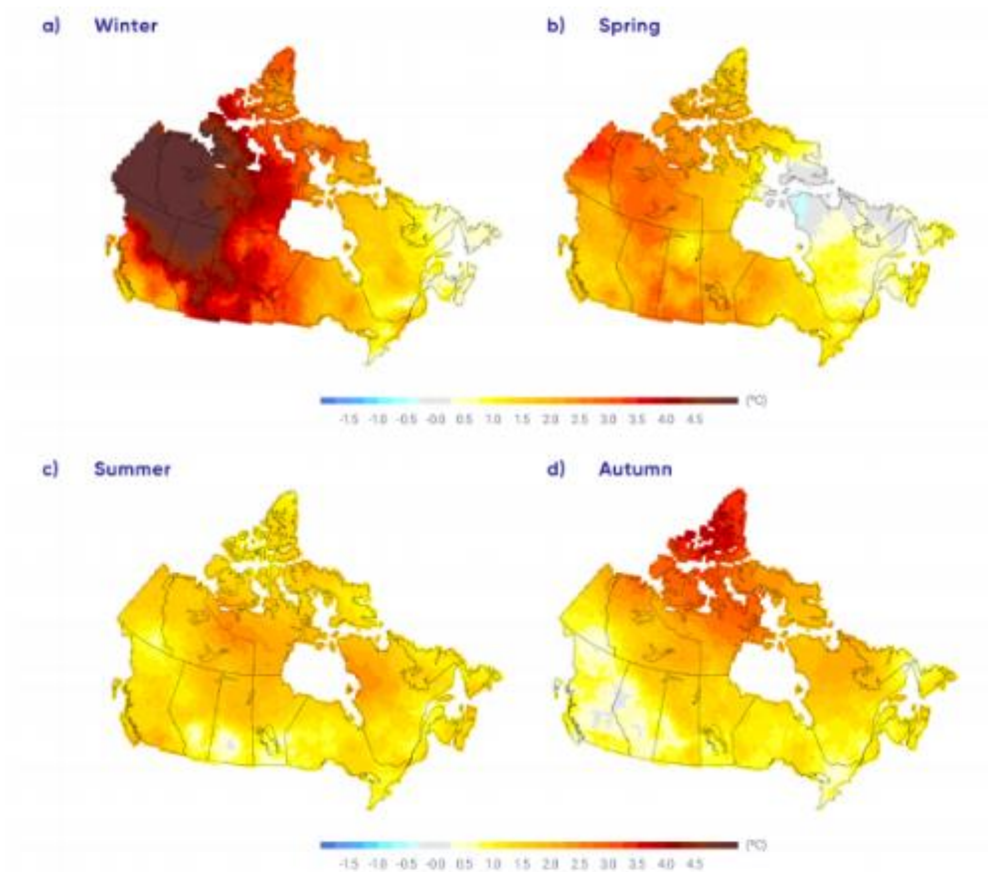
Temperature and Arctic Amplification

Over the last 50 years, annual air temperatures have increased globally, and these increases are most pronounced at northern latitudes (Figure 2- 2). The Arctic has warmed at more than twice the rate of global temperature increases, a phenomenon which is referred to as Arctic amplification. The annual mean Arctic temperatures over the period of 2014 to 2019 have exceeded all previous records.

Temperatures are projected to continue increasing during all seasons across Canada under both the low (RCP 2.6) and high (RCP 8.5) emissions scenarios (Zhang et al., 2019) and temperatures in Yukon have increased by 2°C over the last 50 years (Streicker, 2016).

- Historic and projected trends in temperature across Canada (X. Zhang et al., 2019)
  Historic and projected temperature increases are not uniform across Canada throughout the year. The largest observed temperature increases from 1948-2016 occurred in northern Canada, and they were greatest in the winter (4.3° C) followed by autumn (2.3° C), spring (2.0° C), and summer (1.6° C) (Map 2-1). Temperatures are projected to continue increasing during all seasons across Canada under both the low and high emissions scenarios. This has led to a decrease in the length of the winter season and increase in the length of the growing season.

Figure 2- 2. Observed changes (°C) in temperature across all seasons in Canada (1948-2016)



The observed changes (°C) in mean temperatures between 1948 and 2016 for the four seasons: winter (a), spring (b), summer (c) and autumn (d). Source: Figure 4.4 (X. Zhang et al., 2019) updated from Vincent et al. (2015)

- Observed temperature trends in the ISR (IRC, 2016; Nickels et al., 2005)
  General trends related to temperature observed in the ISR include increased average air temperature, particularly in the winter, increased ground and marine temperatures, warmer winter seasons, and increased seasonal variability in relation to temperature (day to day, hour to hour). The summer heat is more intense, and there are fewer extreme cold days in the winter.

- Processes and impacts of Arctic amplification: A research synthesis (Serreze & Barry, 2011)
  Trends and variability in surface air temperature tend to be larger in the Arctic region than for the Northern Hemisphere or globally. Arctic amplification is expected to become stronger in coming decades, invoking changes in atmospheric circulation, vegetation, and the carbon cycle, with impacts both within and beyond the Arctic.

Sea Ice

Climate change is impacting sea ice extent, thickness, and age. In the Beaufort Sea, summer sea ice extent has significantly declined. In 2018, a 68% decline in sea ice extent was observed, compared to baseline estimates (1979-1989) (J. Stroeve & Notz, 2018). The extent of Arctic sea ice is expected to continue to decline under all emissions scenarios with the likelihood of Arctic ice-free periods in summer and fall increasing under higher emissions scenarios (Figure 2-4; Stroeve and Notz, 2018).

Increased summer melt results in younger sea ice (Figure 2- 3), which is saltier, thinner, weaker, and therefore more likely to melt during summer. Between 1985 and 2019, the amount of very old (over 4 years) ice in the Arctic Ocean's ice pack declined from 33% to 1.2% (Lindsay & Schweiger, 2015).

The loss of summer sea ice has significant implications for marine fish and wildlife species, as well as for the traditional use and travel for Inuvialuit. These implications are discussed later in this report.

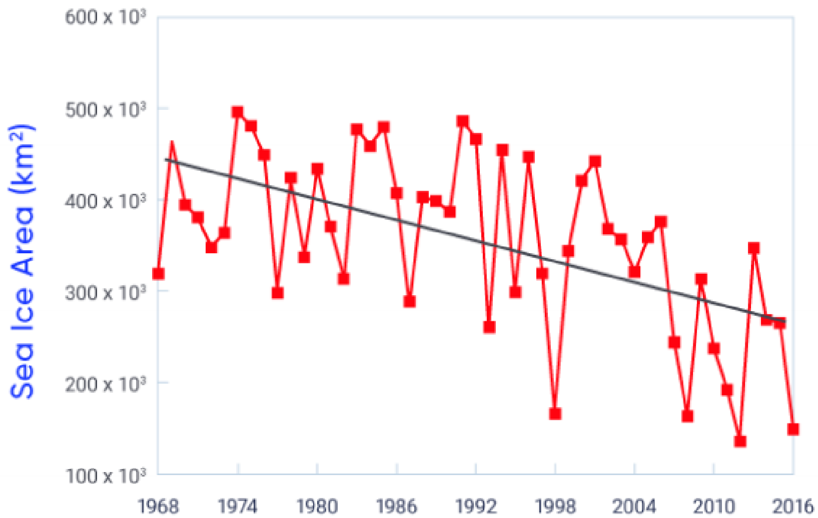
- Observed changes in ice conditions across the ISR (IRC, 2016; Nickels et al., 2005)
  Changes in ice conditions decrease safety and increase difficulties of winter travel. Specifically, the ice is thinner, ice near the shorelines is rougher, and ice freezes later in the fall and breaks up earlier in the spring than it did historically. In some years up to a month difference was reported.

- Reduced sea ice thickness (Hynes, Wesche, & Aklavik HTC, 2017).
  Community-based monitoring at Tapqaq (Shingle Point) indicates that reduced ice thickness has made travel less safe over the past 5 to 10 years. This is a concern for Inuvialuit who use boats to access the Yukon North Slope: for example, summer sea ice is further off the coast, which allows large waves to form between the ice and shore, creating dangerous boating conditions.

- The Arctic's rapidly shrinking sea ice cover: a research synthesis (J. C. Stroeve et al., 2012)
  The sequence of extreme September sea ice extent minima over the past decade suggests acceleration in the response of the Arctic sea ice cover to external forcing, hastening the ongoing transition towards a seasonally open Arctic Ocean.

- Observed and projected trends in glaciers, and sea, river and lake ice across Canada (Derksen et al., 2019)
  The Beaufort Sea has lost summer sea ice at a rate of 8.3% per decade (Figure 2-5). Increased temperatures, under all emissions scenarios, will likely result in continued reduction of sea ice in the summer and potentially the winter.

Figure 2- 3. Beaufort Sea ice loss from 1968-2016



Time series of summer sea ice for the Beaufort Sea (-8.3% per decade). Source: Figure 5.8 (Derksen et al., 2019) adapted from Mudryk et al. (2018)

Precipitation

The average total precipitation across the Arctic has increased and is projected to continue to increase, including on the Yukon North Slope. This is a result of warmer and moister air, linked to jet stream patterns and sea ice retreat (Bintanja, 2018). Although precipitation has increased during all seasons, the most notable increases have been observed during the winter months (Map 2-2, Zhang et al., 2019).

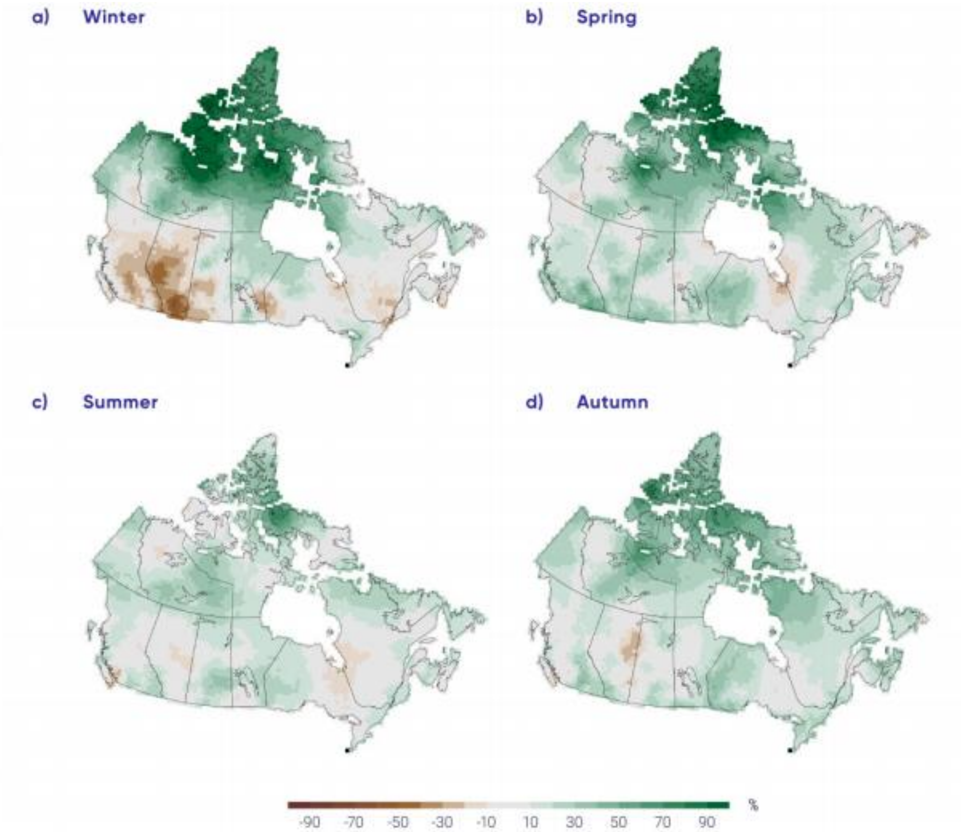
Arctic precipitation is expected to increasingly fall as rain, although changes in the expected proportion of snow versus rain vary dramatically based on season and region, and are difficult to predict at the regional scale (Bintanja & Andry, 2017). This has profound hydrological and ecological consequences in the Arctic, such as increased permafrost thaw (Douglas, Turetsky, & Koven, 2020), run-off and flooding (Bintanja & Andry, 2017; Il Jeong & Sushama, 2018) and impacts on wildlife species (Boelman et al., 2019; Rennert, Roe, Putkonen, & Bitz, 2009).

- Observed precipitation and weather trends in the ISR (IRC, 2016; Nickels et al., 2005)
  Overall observed weather conditions identify weather as being more variable and less predictable. For the ISR as a whole, conditions are drier; however, wetter and colder summers have been observed in certain areas of the ISR. Reports of more variable weather included an increase in thunderstorms (including more forceful rain), windstorms, funnel winds, and freezing rain events.

- Historic and projected trends in precipitation across Canada (X. Zhang et al., 2019)
  General trends indicate that precipitation has increased during all seasons on the Yukon North Slope with the greatest increases predicted in winter (Figure 2- 4). Data for extreme precipitation events (i.e., those occurring over a day or less) are lacking; however, in the high

emissions scenario these extreme events are expected to increase. Additionally, both emissions scenarios have high confidence in the likelihood of precipitation falling as rain versus snow during winter months.

Figure 2- 4. Observed changes (%) in precipitation across all seasons in Canada (1948-2012)



Observed changes in normalized seasonal precipitation (%) between 1948 and 2012 for the four seasons. Source: Figure 4.16 (X. Zhang et al., 2019) updated from Vincent et al. (2015)

- Rain-on-snow events in North America (Il Jeong & Sushama, 2018)
  Warmer air temperatures are predicted to increase the occurrence of rain-on-snow events from November through March in the high latitude and mountainous regions of North America, including the Yukon North Slope. Rain-on-snow events result in increased runoff and subsequent flooding. They may also increase 'icing' events, where a crust of ice forms after rain in freezing temperatures.

Snow Cover

Snow cover is an essential part of the Arctic, where snow typically covers the landscape for 8-10 months of the year. Therefore, observed reductions in snow cover and the predicted continuation of snow cover loss (Derksen et al., 2019) are of high concern. Snow cover reduction has been found to explain ~70% of the reduced surface albedo (the fraction of sunlight reflected by the Earth's surface) in the Arctic (R. Zhang, Wang, Fu, Rasch, & Wang, 2019).

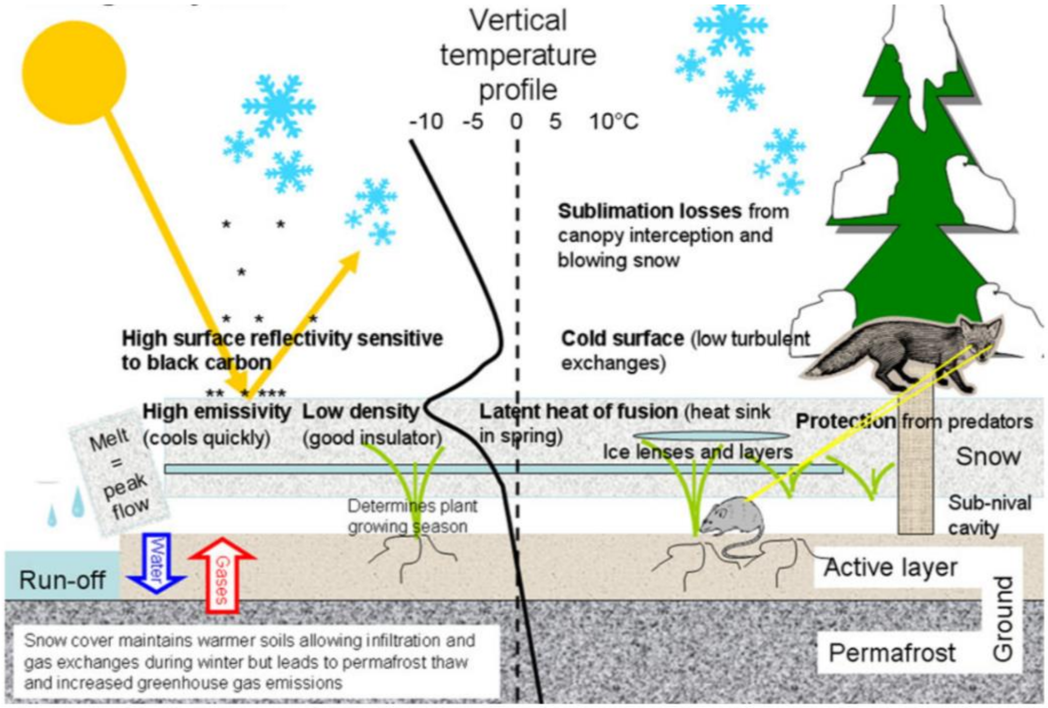
Reductions in snow cover and variations in seasonal timing and duration as well as altered physical properties of the snow pack are linked to warmer temperatures and precipitation falling as rain (Kim, Kimball, Du, Schaaf, & Kirchner, 2018; R. Zhang et al., 2019).

Snow cover provides thermal insulation, which influences ice thickness as well as permafrost (Callaghan et al., 2011). For example, the air temperature above snow cover may be -20°C, but the soil temperature will remain around 0°C if covered by 50cm of snow (Pomeroy & Brun, 2001). As the near-ground surface is typically protected from freezing, the soil layer and wildlife in the subnivean zone (area between the ground surface and the bottom of the snow cover) are shielded from extreme weather conditions (Figure 2– 5) (Callaghan et al., 2011). Snow cover loss also results in a longer growing season, reduced spring floods, and decreased permafrost, which accelerates freshwater release (Kim et al., 2018).

Wet snow typically falls in the spring, when temperatures are warmer, but it is now falling in autumn and winter, when the dry snow associated with colder temperatures historically fell (Kim et al., 2018). Thawing and refreezing associated with spring wet snow conditions in Alaska and western Canada during 2015 and 2016 were determined to contribute to an ~25% decrease in snow cover albedo compared to dry snow conditions (Kim et al., 2018).

People and wildlife that live in the Arctic are well-adapted to snow. A decrease in snow alters not only climate, hydrological and ecological systems, but also impacts social and traditional use, including travel routes, animal harvest, and traditional food webs (Callaghan et al., 2011). Unfortunately, due to challenges in monitoring and collecting data on snow cover, snow melt, and energy dynamics at higher latitudes and elevations within the Arctic, including the Yukon North Slope, there is a lack of information on rates of loss or change (Kim et al., 2018).

Figure 2- 5. Snow cover is an important component of climate, hydrological and ecological systems in the Arctic



Overview of the interactions of snow cover with multiple features – the black line indicates an idealized ground-snow-atmosphere temperature profile. This aims to highlight the strong temperature gradients occurring near the snow surface (snow is represented by the off white/gray rectangle). Source: (Callaghan et al., 2011)

- Observed and projected trends in snow cover and sea ice across Canada (Derksen et al., 2019)

  Across most of Canada, seasonal snow cover has decreased since the 1980s, and to a lesser degree snow accumulation has also decreased. Warmer temperatures result in more precipitation falling as rain, and snow arriving later and melting earlier. Low and high emissions scenarios project that snow cover duration will continue to decline as the surface air temperature increases.

- Observed snow trends in the ISR (IRC, 2016; Nickels et al., 2005)

  A decrease in snowfall has been observed in the ISR.

Permafrost

Permafrost is highly sensitive to increasing air temperatures and changes in snow cover (Chadburn et al., 2017; Crites, Kokelj, & Lacelle, 2020; Derksen et al., 2019). The temperature of permafrost in the North Slope of Alaska has increased by ~3°C over the last 40 years (Zhang et al., 2003). This has led to rapid thawing of permafrost, resulting in freshwater release and ground instability as well as additional GHG release and landscape changes including slumping, formation of thermokarsts, and the expansion (or occasional draining) of lakes (Derksen et al., 2019; Nickels et al., 2005). Permafrost melt also increases erosion, mudslides, and landslides (IRC, 2016; Nickels et al., 2005). Coastal erosion, which has been observed at Qikiqtaruk (Herschel Island) and Tapqaq (Shingle Point), on the Yukon North Slope, is of particular concern due to the potential loss of cultural features near the coast (Cunliffe et al., 2019; Irrgang, Lantuit, Gordon, Piskor, & Manson, 2019; Radosavljevic et al., 2016).

- Observed and projected trends in permafrost across Canada (Derksen et al., 2019)
  Permafrost temperature has increased at an estimated rate of ≤0.5°C per decade across Canada. As mean air temperature is projected to increase under all emissions scenarios, large areas of permafrost warming and thawing are expected by mid-century. In the MacKenzie Valley, the thickness of the permafrost active layer (i.e., the soil layer above the permafrost that thaws and freezes annually) has increased by ~10% since 2000. The thawing of ice-rich permafrost results in ground instability and additional GHG release, likely accelerating climate change impacts. Also, northern soils in Canada efficiently store mercury which becomes vulnerable to release as permafrost thaws.

- Observed changes in permafrost across the ISR (IRC, 2016; Nickels et al., 2005)
  The permafrost melting has caused slumping to occur, as well as rising in areas where it is forced up from underneath, creating larger and new islands. Specifically, Tapqaq (Shingle Point) is said to be dropping, decreasing in terms of relief, but also growing at a rate of ~4 feet per year (since 1990) due to siltation and deposition. This sediment flush from permafrost melt is filling in small bays and safe harbors along the Yukon North Slope, which affects safety and access for Inuvialuit boaters.

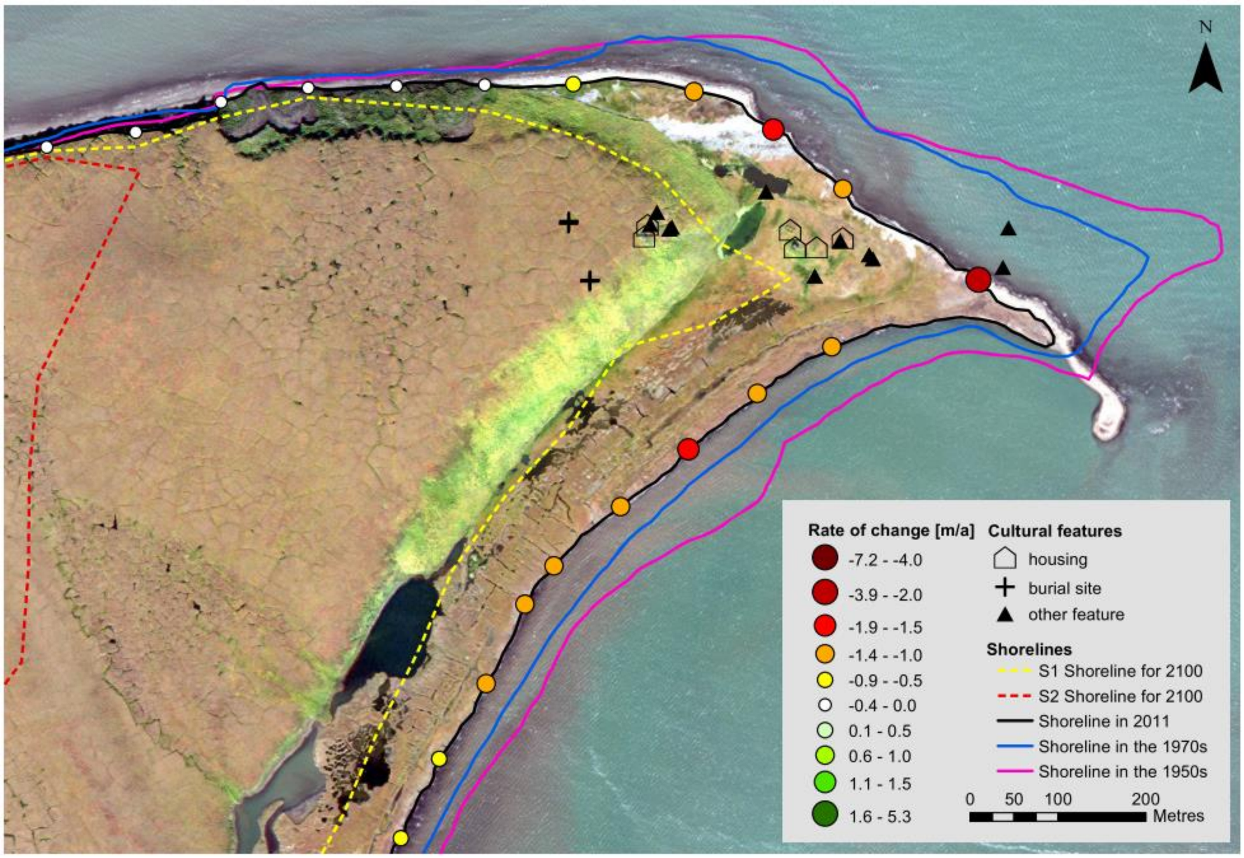
- Landscape slumping and downslope influences (Kokelj, Tunnicliffe, Lacelle, Lantz, & Fraser, 2015)
  Large slumps (>20 ha) were observed in the Peel Plateau. These slumps displace previously frozen materials (including cultural features), impact drainage networks and increase stream sediment loads downslope. Increases in rainfall have likely accelerated their presence and impact.

- Erosion and slumping (Friendship & Community of Aklavik, 2011; IRC, 2016)
  Changes result in modifications to the water course of rivers; this affects fish health and increases safety risks for Inuvialuit travel.

- Erosion and flooding (Radosavljevic et al., 2016)
  Coastal erosion has increased, particularly in areas where temperature increases exceed the global mean (such as on the Yukon North Slope). This has been observed in Alaska and along Qikiqtaruk (Herschel Island) at Simpson Point. Increases in erosion and flooding due to warming temperatures, sea level rise, longer open water periods and increased extreme weather events make infrastructure and cultural and ecological sites along coastlines increasingly vulnerable.

- **Reduction in shorelines (Cunliffe et al., 2019; Irrgang et al., 2019)**
  Shoreline loss was observed on Qikiqtaruk (Herschel Island) (Cunliffe et al., 2019) and predicted over ~210 km of Yukon shoreline from the Alaska border to Tapqaq (Shingle Point), including the 10-40 km wide coastal plain in the eastern Yukon North Slope (Irrgang et al., 2019). Predicted shoreline loss on the Yukon North Slope (not including Herschel Island/ Qikiqtaruk) is expected to result in the loss of 45-60% of cultural features, including burial sites, cabins, camps, and travel routes) by 2100 (Figure 2- 6). Erosion and sedimentation are predicted to continue to threaten cultural features, travel routes and coastal life along the Yukon coast.

Figure 2- 6. Observed and predicted changes in shoreline and the location of cultural features at Qargialuck, Catton Point, Yukon North Slope



Historic shoreline data from the 1950s (pink line) and 1970s (blue line) show that significant land loss has already occurred at Qargialuck, and may be representative of shoreline losses in other areas of the Yukon North Slope. Two scenarios of potential future shoreline loss display the vulnerability of cultural features and infrastructure along the coastline. S1 is conservative (yellow dashed line) and S2 represents dynamic, increased change (red dashed line). The rate of change [m/a] was estimated from historic shoreline levels. Source: (Irrgang et al., 2019, Figure 2)

Inland Water and Ice

Permafrost and hydrology are linked in Arctic systems, and increased temperatures not only reduce permafrost but influence basewater (streamflow sustained between precipitation events) and groundwater flows. To date, small changes in total annual discharge in northwestern Canada have been observed, but as temperatures continue to rise, so will increases in winter groundwater and baseflow (Crites et al., 2020). Permafrost type (discontinuous or continuous) as well as reductions in permafrost thickness will influence inland water and ice formation on lakes, rivers and streams (Crites et al., 2020; Nitze et al., 2017).

As permafrost continues to melt on the Yukon North Slope, the increasing thickness of the active layer may result in increased connectivity of ground water, as well as evapotranspiration (evaporation and transpiration of water from the surface to the atmosphere). These may result in hydrological changes such as dynamic lake responses and increased thermokarst formations (Nitze et al., 2017; Stern & Gaden, 2015). Wetlands may be affected, though changes to wetlands are difficult to predict (Callaghan et al., 2011).

Overall, inland ice on lakes and rivers is expected to decrease in thickness, form later in the fall and break up earlier in the spring (Derksen et al., 2019). Inland ice is important not only during the winter, but also in the summer, as it melts slower than snowpack and thus helps to recharge rivers and streams later in the season (Crites et al., 2020).

Glaciers are expected to decrease across the Canadian Arctic, resulting in increased groundwater (Derksen et al., 2019). Although glaciers are absent on the Yukon North Slope, their loss in the surrounding landscape may influence the local hydrology due to increases in groundwater.

- Observed and projected trends in glaciers, and sea, river and lake ice across Canada (Derksen et al., 2019)
  Spring lake and river ice breakup is expected to occur earlier (10-25 days) and fall freeze up later (5-15 days), by mid-century. Seasonal ice thickness is expected to decrease (10-50 cm) and mid-winter breakup and ice jam events are expected to increase.

- Observed changes in water across the ISR (IRC, 2016)
  Increased flooding, erosion or disappearance of islands and sandbars, rising waterline and higher/more frequent waves.

- Freshwater climate related effects identified (Nickels et al., 2005)
  Freshwater levels are lower and sedimentation in water bodies has increased. In some areas, sandbars are larger and/or higher.

- Climate change issues identified by the community of Aklavik, Northwest Territories (Friendship & Community of Aklavik, 2011; IRC, 2016)
  More open water, overflow, and shallow waters make travel more difficult; shallow waters also affect the ability of barges to deliver supplies to Aklavik.

Shifting Ecosystems and Vegetation

Arctic ecosystems are experiencing landscape and vegetation shifts due to warming temperatures. These climate change effects include permafrost thaw, a longer growing season, shrub expansion and enhanced vegetation productivity, or 'Arctic greening' (Myers-Smith et al., 2011, 2019; Nickels et al., 2005; Prowse, Terry, Fred, & James, 2009; Rowland, Fresco, Reid, & Cooke, 2016). These changes influence rates of carbon cycling. Ecosystems shifts have caused the expansion of vegetation and animal species into the region that were historically uncommon or absent in the Arctic (IRC, 2016; Nickels et al., 2005). Changes due to shifting ecosystems such as expanding shrubs indirectly impact the subnivean zone (area between the ground surface and the bottom of the snowpack). Shrubs limit snow compaction, creating a thick, low-density snow layer, which can more than double the insulating property of the snowpack (Berteaux et al., 2017).

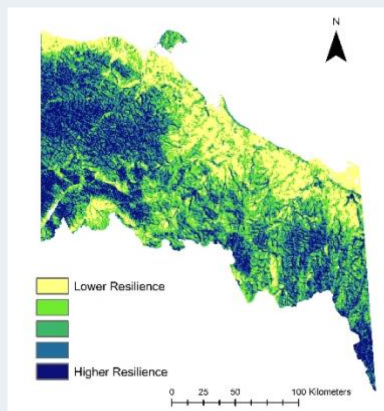
Climate change emissions scenarios predict that 'cliome' shifts (climatic patterns, vegetation communities, and soil characteristics) will occur across the Yukon North Slope; however, the number of cliome shifts increases over time and in higher emissions scenarios (Rowland et al., 2016; SNAP, 2012). In general, it is expected that more cliome shifts indicates greater ecological stress and change across the Yukon North Slope (Rowland et al., 2016; SNAP, 2012).

- Observed changes in vegetation across the ISR (IRC, 2016; Nickels et al., 2005)
  The land is greening, plants are increasing in size and abundance. New species of vegetation have been observed moving into local areas (e.g., willow, spruce, and grasses). Changes in rainfall, intense heat, colder summer conditions and increased erosion have negatively impacted berry production.

- Increased shrubification in the arctic, high-latitude, tundra ecosystems (Myers-Smith et al., 2011, 2019)
  Shrubification, meaning an increase in shrub abundance, cover and biomass, is expanding over tundra environments in the circumpolar Arctic, including the Yukon. This change is driven by warmer temperatures, shifts in snow cover and herbivory intensity, increased permafrost thaw and tundra fires. Shrubification has the potential to further alter regional climate, soil temperatures, nutrient cycling, biodiversity, and ecosystem services.

Terrestrial Resilience

Certain Landscapes may be resilient to ecosystem and vegetation shifts – that is, they may have the ability to maintain biological diversity and ecological function, despite the effects of climate change (Buttrick et al., 2015; Gunderson, 2000). In general, it is expected that mountainous areas of the Yukon North Slope will have higher resiliency due to their topographic complexity, whereas the coastal plains will have lower resilience primarily because they lack topographic diversity. However, this result is influenced by local variations in the landscape and the species that are adapted to them.



The map above estimates potential terrestrial resilience across the Yukon North Slope. Source: analysis completed by RRCS based on procedures described by Buttrick et al. (2015); map produced by

- Vegetation shifts and terrestrial resiliency (Prowse et al., 2009)
  Grasses, sedges, flowering species, and moss (*Tomentypnum nitens*) have increased in productivity and abundance. Other species occurring in high northern latitudes are expected to decrease. Cumulative impacts of climate change will result in altered plant community structure and composition.

- Cliome shifts (Rowland et al., 2016; SNAP, 2012)
  One predicted response of ecosystem change for the Yukon was produced by the Scenarios Network for Arctic Planning (SNAP). This analysis predicts potential climate-biomes 'cliomes' likely to exist within the Yukon under various emissions scenarios and time spans. These

cliomes characterize climatic patterns and vegetation communities to best predict changes. They account for time lags associated with vegetation change as well as soil influences. They are intended to identify dynamic areas within the landscape, as well as potential refugia and resilient areas, to guide management.

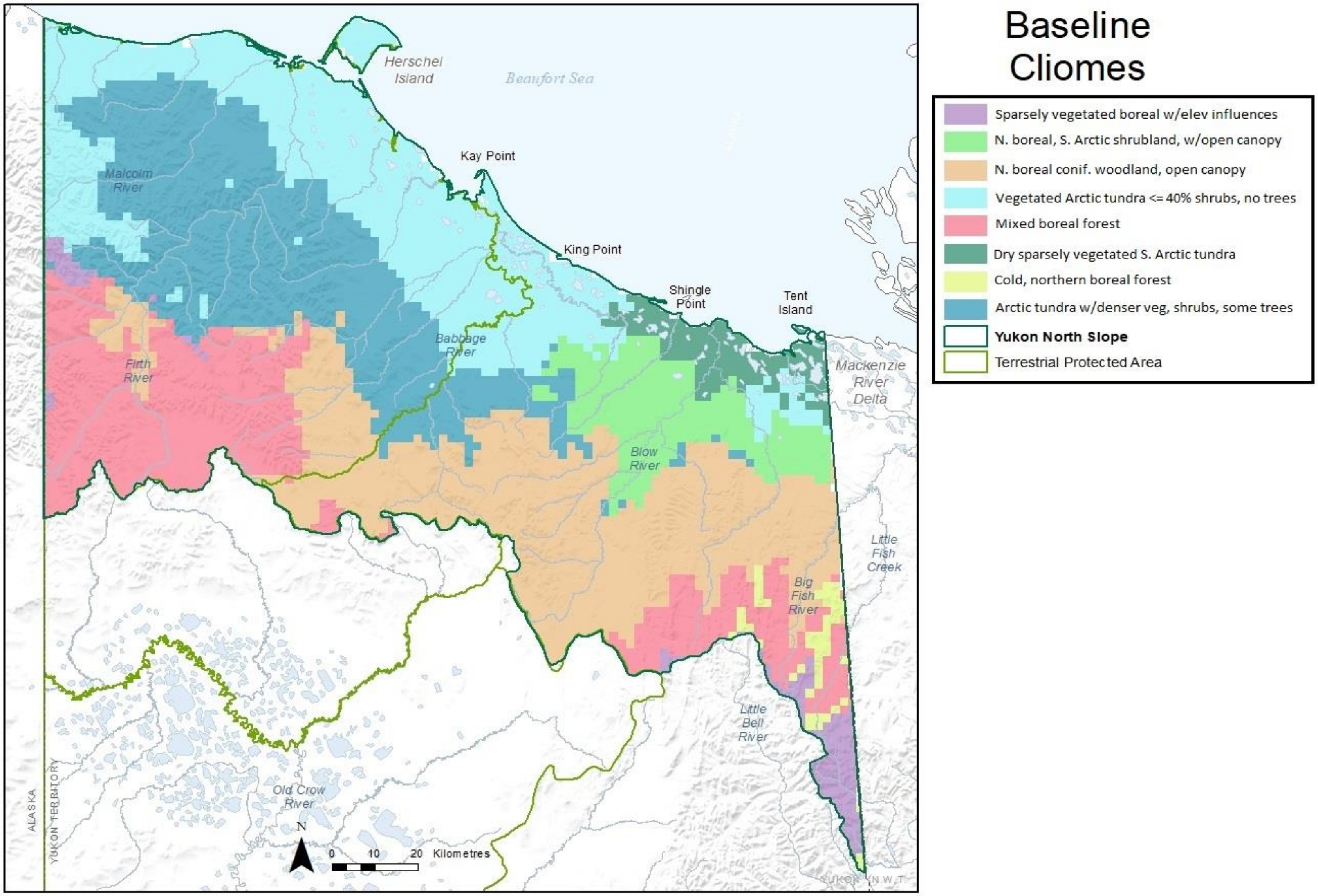
Multiple transitions between cliomes may occur. But not all shifts are equal, although all shifts likely indicate ecological stress on the environment. For example, throughout much of the Arctic, cliomes that are dominated by shrubby grass/moss/lichen/tundra are predicted to shift to forest cliomes, which is a profound change. However, shifts between shrubby grass, moss, lichen, and tundra environments are likely to be more minor in their overall influence on wildlife. By the 2070s and 2090s the cliomes that are expected to dominate the Yukon North Slope include new types such as boreal forest with coastal influence and intermixed grass and tundra, dry boreal wooded grasslands, and densely forested southern boreal forests.

Table 2- 1. Predicted cliome shift trends (compared to the baseline in 1961-1990) in the Yukon at the end of the century (2060s-2090s)

Cliome – Land cover description	Predicted trend
(1) Northern Arctic sparsely vegetated tundra with up to 25% bare ground and ice, with an extremely short growing season	Decline
(3) Densely vegetated arctic tundra with up to 40% shrubs	Absent
(4) Arctic tundra with denser vegetation and more shrub cover including some small trees	Absent
(5) Dry sparsely vegetated southern arctic tundra	Absent
(6) Northern boreal/southern artic shrubland, with an open canopy	Absent
(7) Northern boreal coniferous woodland, open canopy	Absent
(8) Dry boreal wooded grasslands – mixed coniferous forests and grasses	Decline
(9) Mixed boreal forest	Absent
(10) Boreal forest with coastal influence and intermixed grass and tundra	Increase
(11) Cold northern boreal forest	Absent
(12) More densely forested closed-canopy boreal forest	Decline
(13) Sparsely vegetated boreal forest with elevation influences	Decline
(14) Densely forested southern boreal	Increase
(15) Southern boreal/aspen parkland	Increase
(16) Southern boreal, mixed forest	Increase
(17) Coastal rainforest, wet, more temperate	Increase
(18) Prairie and grasslands	Emerge (currently not present)

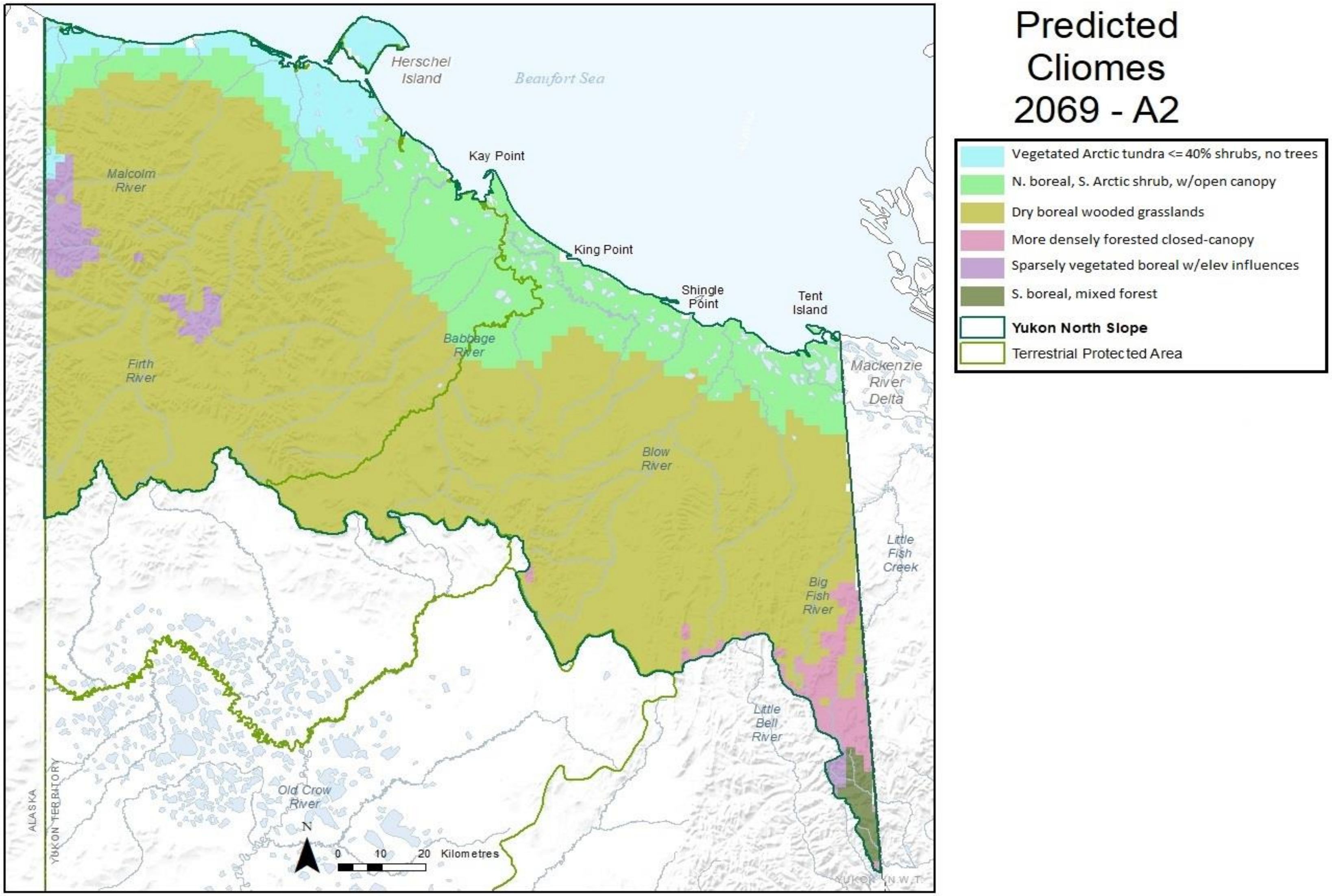
Note cliome (2) is not found in the Yukon under present or future climate conditions. Source: (Rowland et al., 2016).

Map 2- 1. Yukon North Slope baseline cliomes



Baseline cliomes predicted across the Yukon North Slope. Source data (SNAP, 2012), map produced by RRCS 2019

Map 2- 2. Yukon North Slope predicted cliomes



Predicted cliomes under a high emissions scenario (A2) across the Yukon North Slope. Note that most areas are expected to undergo cliome changes in the next 50 years. Source data (SNAP, 2012), map produced by RRCS 2019

- Changes in disturbance regimes (X. Zhang et al., 2019)
  Weather extremes, caused by changes in the frequency of precipitation and temperature, have increased the likelihood of drought, wildfire, and flood events in Western Canada.

- Observed changes in wildlife across the ISR (IRC, 2016; Nickels et al., 2005)
  People have observed changes in the health, behaviour, and distribution of arctic wildlife species, including marine and terrestrial species, birds, fish, and insects. General observations include: decreased health of marine and terrestrial wildlife and fish; changes in migration and distribution patterns; and the appearance of new species of marine and terrestrial mammals, birds, fish, and insects. Additionally, unfamiliar animals have appeared on the Yukon North Slope (e.g., grasshoppers at Tapqaq).

Potential Impacts on Wildlife and Habitat

The cascading effects of a changing climate have year-round implications for wildlife and habitat within the Yukon North Slope. Potential wildlife implications include: increases or decreases in competition for habitat and resources; shifting plant and animal ranges; alteration in prey sources and diets; changes in reproduction and survival rate; and expanding boreal species, parasites, diseases, and invasive species. Many of these potential responses have been observed and reported by Inuvialuit (Nickels et al., 2005; WMAC (NS) & Aklavik HTC, 2018b). These responses may be positive or negative. Whether the potential benefits, such as increased habitat availability, will outweigh potential negatives such as emerging diseases is yet to be seen. Observed responses to climate change effects are summarized below. See the dedicated companion reports for focal species, which describe climate change effects on wildlife in more detail.

> **Climate Change effects on Wildlife and Habitat in the Yukon North Slope Wildlife and Conservation Management Plan**
>
> Strategy B3. Monitor effects of climate change on Yukon North Slope ecosystems. Promote and engage in studies that contribute to understanding and forecasting the effects of climate change on wildlife and habitat. On an ongoing basis, assess options and implement measures for mitigation and adaptation to address climate change effects in the management of wildlife and wildlife habitats.
>
> Priorities:
>
> – Monitor climate change and its effects and improve understanding of linkages between changes in climate and effects on ecosystems and wildlife, and on the interactions between climate change and other stressors, such as contaminants, through collection of scientific data and Inuvialuit traditional knowledge.
> – Adjust actions, where possible, to adapt to effects of climate change on wildlife and wildlife habitat.
> – Take steps to reduce greenhouse gas emissions.

Throughout the northern landscape, changes in climate and precipitation patterns have led to phenological (seasonal timing) shifts. For example, on Qikiqtaruk, spring occurs ~9 days earlier each decade (Myers-Smith et al., 2019). This can result in phenological mismatches for species that migrate to forage for resources that are now peaking in quality or abundance earlier due to earlier spring conditions (Choi et al., 2019). Climate-driven species expansions, particularly to northern regions, may add the challenge of differentiating between what is an invasive species and what is natural range expansion (SNAP, 2012).

> "Well, when I was a little girl I never used to… see hardly any moose. And today, it's totally different. It's because… we're having earlier [growing] seasons."
>
> Source: PIN 1, Inuvialuit Traditional Knowledge of Wildlife Habitat, Yukon North Slope (WMAC (NS) & Aklavik HTC, 2018a) p. 30

Wildlife Range/Distribution Shifts

Terrestrial

Moose (*Alces alces*) have been observed to be locallly more abundant than they were historically on the Yukon North Slope, and this may be due to changes in vegetation associated with climate change (WMAC (NS) & Aklavik HTC, 2018a). Beaver (*Castor canadensis*) is another species with a northern expansion (potentially) promoted by increased temperatures (IRC, 2016; Tape et al., 2018). Beaver distribution was previously thought to be limited to the treeline end; however, beavers and their dams have been observed on and near the Babbage River since 2008 (Jung, Frandsen, Gordon, & Mossop, 2017; Tape et al., 2018). Beaver dams create ponds that subsequently raise water temperatures downstream. This can influence permafrost stream ice regimes, freshwater, and riparian habitat (Tape et al., 2018).

Increased Temperature – A Potential Catch 22

Increased temperatures may promote the expansion of plant species that moose like to forage; however, moose are highly sensitive to thermoregulatory (heat) stress, and hence increased temperatures may cause population declines in moose.

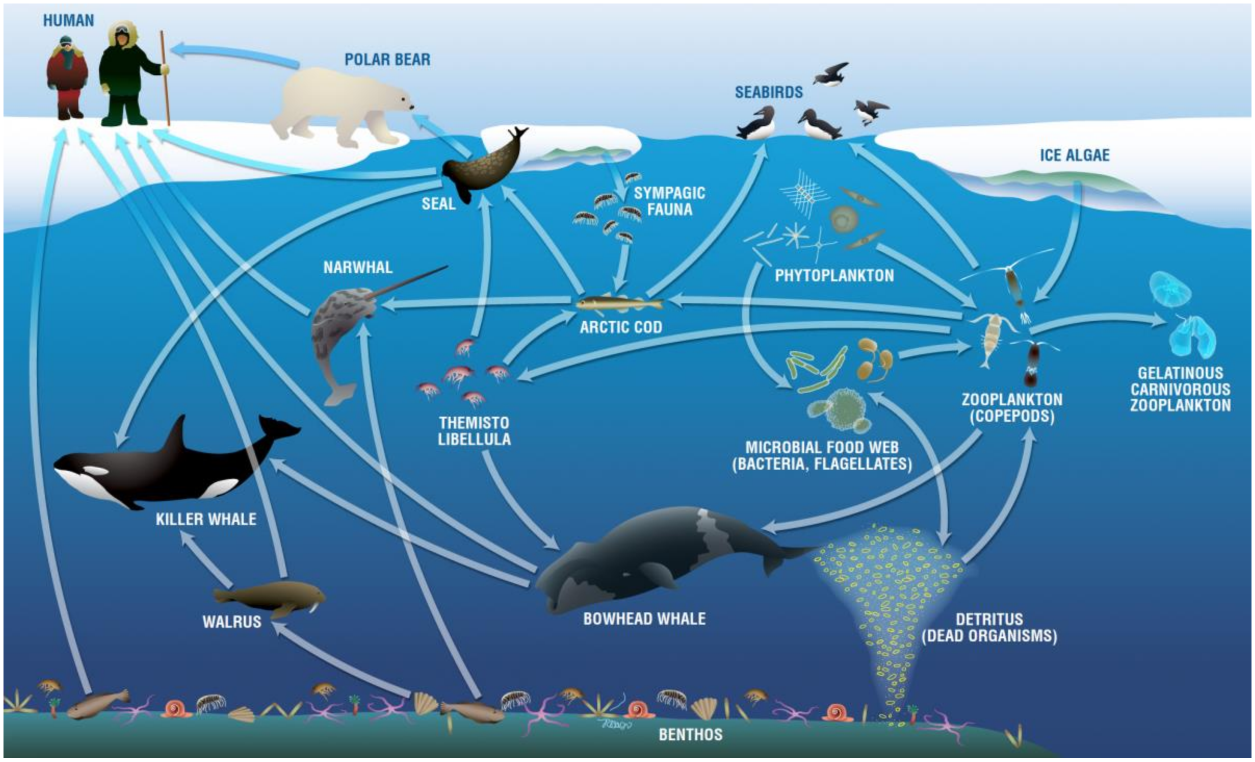
These warm ponds and downstream waters may provide new spawning habitat for fish species such as Dolly Varden (locally known as 'char') (*Salvelinus malma*) and salmon species. The warmer waters may also promote the spread of fish species currently limited in arctic lakes (such as walleye), further altering competition and predation pressure (Dunmall, Mochnacz, Zimmerman, Lean, & Reist, 2016; Poesch, Chavarie, Chu, Pandit, & Tonn, 2016). However, beaver dams could also block passage or generate siltation of spawning beds and restrict fish spawning and species expansions (Tape et al., 2018). Dolly Varden habitat is being affected by the erosion of riverbanks, limiting their ability to access parts of their range. Broad Whitefish range is changing, in part due to salinity changes in coastal waters.

> …you know, we've never had salmon in the area before, and now they're starting to… pop up in places where we're getting the Arctic char. - PIN 101, p. 42
>
> …the erosion on the hills…make the creek shallow… Probably harder [for Dolly Varden char] to get up to where they're supposed to spawn. - PIN 111, p. 42
>
> Well, whitefish never used to be at Shingle Point long ago, when I was a little girl… Now the fish from the Delta are starting to come into that area… Because our water is not as salty as before. - PIN 1, p. 43
>
> *Source: Inuvialuit Traditional Knowledge of Wildlife Habitat, Yukon North Slope (WMAC (NS) & Aklavik HTC, 2018a)*

Marine

The marine food web is complex. Climate change has an impact on the entire food web, through a number of different pathways (Figure 2-7). Climate change effects, including warming and sea ice reduction, are of high concern for marine mammals such as polar bears (*Ursus maritimus*) and ringed seals (*Pusa hispida*), occurring in the Southern Beaufort Sea (Joint Secretariat, 2017; WMAC (NS), 2012). Loss of sea ice may result in polar bears seasonally shifting their distribution inland. This would alter prey sources and den locations, and increase competition for habitat and resources, potentially having negative consequences on population stability and productivity (Fischbach, Amstrup, & Douglas, 2007; Mckinney, Atwood, Iverson, & Peacock, 2017). Ringed seals are the primary prey of polar bears; stable sea ice in areas with high quantity prey is critical to ringed seal survival (WMAC (NS), 2012). Over the past few decades, ringed seal populations in the Beaufort Sea have exhibited declines in body condition (Harwood et al., 2015). These declines, which include lower reproductive and survival rates, are linked to decreases in their preferred winter food source, Arctic cod (*Boreogadus saida*), and declines in summer sea ice (Harwood et al., 2015; Spear et al., 2019).

Figure 2- 7. Simplified marine food-web of feeding relationships among species in the Canadian Arctic



This marine food-web shows how disruptions to one species or component (such as sea ice) will influence the other organisms in the marine environment. Note that some species have multiple prey options that may shift as the food web is disrupted. Source: (Darnis et al., 2012)

During summer months, ringed seals and bowhead whales (*Balaena mysticetus*) feed on zooplankton, which are present in the nutrient rich waters of the Beaufort Sea (Harwood et al., 2015; WMAC (NS), 2012). Zooplankton diversity and production are linked to upwellings in nutrient rich waters and sea ice algae production. Losses in sea ice, and its associate algae, have led to smaller, less nutritious zooplankton off the western coast of Alaska (Spear et al., 2019). However, some zooplankton species (euphausiids; krill) have been linked to warmer conditions and increased upwellings and may provide supplementary prey sources for marine mammals (Spear et al., 2019). The body condition of bowhead whales in the Beaufort Sea has increased over the past 40 years (Harwood et al., 2015). This has been linked to upwelling, longer periods of open water, potentially increased zooplankton productivity, and less competition from fish for the zooplankton (Harwood et al., 2015). The marine mammal food-web is intricately linked, however, and the same decreases in summer sea ice that promote improved body condition in bowhead whales may also lead to an increase in killer whales (*Orcinus orca)*, which would negatively impact marine mammals, including the bowhead (Darnis et al., 2012).

Changing weather and disturbance regimes

Increases in extreme weather events, rain, and changes in snow density on the Yukon North Slope (IRC, 2016; Kim et al., 2018; Nickels et al., 2005) are likely to put wildlife populations such as caribou (*Rangifer tarandus*), muskox (*Ovibos moschatus*), and Dall's sheep (*Ovis dalli dalli*) at increased risk of population decline. These species are vulnerable to icing events during winter months, as the ice crust restricts their access to food and negatively impacts their reproductive success and survival (Berteaux et al., 2017; WMAC (NS), 2012). For example, increased freeze-thaw frequency is linked to reduced adult survival in sheep (Van de Kerk et al., 2020; Van De Kerk, Verbyla, Nolin, Sivy, & Prugh, 2018). Adult caribou, which are also vulnerable to freeze-thaw frequency, showed health declines following increased spring temperatures. This may have been caused by decreased access to ground lichens due to ice cover (Gagnon et al., 2020).

Snow cover and condition also impact wildlife movement, predator-prey dynamics, and thermal insulation. Deep, soft, and wet snow may impede animal movement, particularly of ungulates, and increase predation risks (Duquette, 1988; Nicholson, Arthur, Horne, Garton, & Del Vecchio, 2016). The subnivean zone allows small mammal species such as lemmings (Lemmus spp.), shrews (Sorex spp.) and mustelids (Mustela spp.) to move and forage under the snow, while being protected from predators (Berteaux et al., 2017). Therefore, variability in snow cover and duration may negatively influence small mammal survival. In some cases it may expose them to phenology mismatches, where their white winter coats remain in snow-free landscapes (Berteaux et al., 2017; Boelman et al., 2019).

> I remember a few years back… we had a really warm spell and we had some rain [in January], and you notice a lot of dead caribou… it got cold and the caribou couldn't break through the crust on the snow.
>
> *Source: PIN 302, Inuvialuit Traditional Knowledge of Wildlife Habitat, Yukon North Slope (WMAC (NS) & Aklavik HTC, 2018a), p. 25*

Wildfires, which are increasing in a warming Arctic (X. Zhang et al., 2019), decrease the quality of caribou winter habitat by destroying lichens, which take over 50 years to recover. However, moose habitat is likely to increase post wildfire, and therefore caribou may experience both habitat loss and increased competition (Joly, Duffy, & Rupp, 2012).

Vegetation Shifts

Plant canopy height, as well as shrub and graminoid (grass and grass-like plants) abundance has been increasing by two-fold per decade, while bare ground cover is being reduced by half per decade (Myers-Smith et al., 2019). Shrubification benefits some species, including moose (*Alces alces*), snowshoe hares (*Lepus americanus*) and shrub-nesting birds (Stern & Gaden, 2015; Tape et al., 2016). However, shrubification may negatively impact upland bird species. Increased competition from species that forage on willows may negatively influence some species, such as the ptarmigan (*Lagopus* spp.) (Stern & Gaden, 2015; Tape et al., 2016). Expanding shrubs may negatively impact caribou populations, as the expanding shrubs are unlikely to contain high-quality forage and more likely to contain species with anti-browsing toxins (Fauchald, Park, Tømmervik, Myneni, & Hausner, 2017). Shrubification also reduces lichen cover, which caribou depend on in the winter (Fraser, Lantz, Olthof, Kokelj, & Sims, 2014).

Vegetation shifts can also have secondary effects, shaping trophic levels. For example, with shrubification creating a more abundant food source for moose, the moose population may then be able to support a larger predator population. While the Porcupine Caribou Herd is not a predator-limited population, increased predation in addition to other stressors (climate-induced or otherwise) could be a notable concern in the future.

Parasites and Disease

Parasites are essential to ecosystem function. However, high levels of parasites or expanding diversity of parasites may have a negative influence on wildlife populations by lowering reproduction rates or increasing mortality rates (Kutz et al., 2012). There have been cases of parasite range expansion and transmission between species observed on or expanding towards the Yukon North Slope. These include lungworm (*Protostrongylus stilesi and Parelaphostrongylus odecoilei*) incursions in Dall's sheep in regions of the NWT, including the Mackenzie and Northern Richardson mountains (Hoberg et al., 2002). *P. stilesi* was also detected in muskox on the Arctic Coastal Plain in the Yukon North Slope; this specific lungworm can pass between muskox and Dall's sheep (Hoberg et al., 2002). However, Dall's sheep are believed to be the original carrier of the lungworm, *P. stilesi* (Hoberg et al., 2002). *M. ovi* was documented in Alaska within caribou in the Forty mile and Nelchina herds and Dall's sheep in the eastern Alaska Range, Talkeetna Mountains, and Wrangell Mountains (ADF&G, n.d.). It is unknown how Dall's sheep will respond to *M. ovi,* and this bacteria along with those in the family Pasteurellaceae (which are likely to spread north) cause respiratory diseases like pneumonia that have devastated bighorn sheep populations elsewhere (Jex et al., 2016).

Other parasites expected to expand their ranges north as the climate warms include winter ticks (*Dermacentor albipictus*) and legworm (*Onchocerca cervipedis*). Winter ticks have been documented in Carmacks, YT, and Normal Wells, NWT, and they are of high concern for moose (Yukon Environment, 2016). The nematode, legworm, is of highest concern to moose and caribou (Verocai et al., 2012).

Biting Insects

An observed increase in mosquitoes has been attributed to rising temperatures, melting permafrost, increased groundwater, and extreme rain and flood events that produce ideal breeding conditions for these insects (WMAC (NS) & Aklavik HTC, 2009). Insect harassment is greatest during summer months and may influence fall health for wildlife such as caribou (Gagnon et al., 2020).

…it gets pretty hot some summers…and we'll have a lot of bugs… we know we're not going to have good shape [healthy] caribou because… they're mostly running all the time.

Source: PIN 6, Inuvialuit Traditional Knowledge of Wildlife Habitat, Yukon North Slope (WMAC (NS) & Aklavik HTC, 2018a), p. 25

Potential Impacts on Traditional Knowledge and Use

The environment influences every aspect of Inuvialuit life. The impacts of climate change affect traditional use as a foundation of Inuvialuit culture and knowledge (Figure 2- 8). The effects of climate change on wildlife, habitat, and geophysical and weather conditions as described in this report have carry-through effects on traditional use. These impacts are interrelated and complex. Inuvialuit have experienced and adapted to climatic and ecological change in the past, over many hundreds of years. However, the change that is now occurring is at a pace and scale that will test the limits of adaptability.

Climate change may impact traditional knowledge and use both directly and indirectly. Cultural and ecological sites along coastlines are highly vulnerable as erosion increases and sea levels rise (Radosavljevic et al., 2016). Additionally, reduced ice thickness has made travel less safe over the past 5 to 10 years, and access to traditional fishing areas has changed (Hynes et al., 2017). Inuvialuit have expressed concerns about decreasing water levels and the effect of increased water temperatures on fish and harvest (Hynes et al., 2017).

Climate Change and Traditional Use in the Yukon North Slope Wildlife and Conservation Management Plan

Strategy C2. Employ monitoring and directed research to track and understand current and future effects of climate change on Inuvialuit traditional use of the Yukon North Slope. On an ongoing basis, assess options and implement measures for mitigation and adaptation, to enhance the resilience of traditional use to climate change

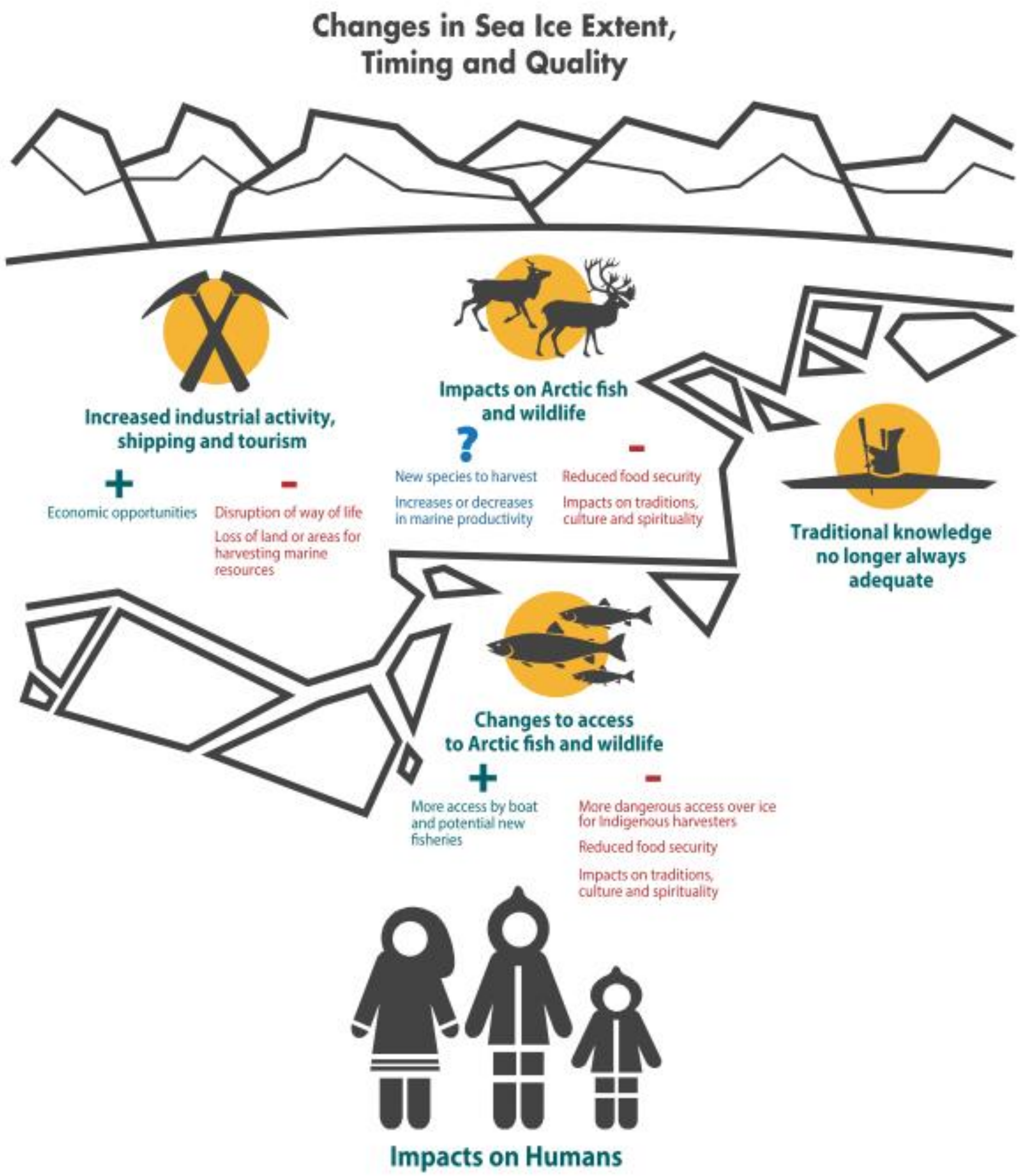
Priorities:

- Monitor climate change impacts on traditional use using Inuvialuit knowledge, community-based monitoring and Western science
- Mobilize Inuvialuit and scientific knowledge of the climate change impacts on Yukon North Slope, along with culturally-informed adaptations, to ensure ongoing and adequate Inuvialuit traditional use
- Work to develop infrastructure support associated with investments in Inuvialuit traditional use

The increased risks caused by changing and unpredictable weather and landscape conditions may keep some Inuvialuit from participating in traditional activities (Friendship & Community of Aklavik, 2011). This may negatively influence other aspects of traditional life including language, oral history, and cultural values (Friendship & Community of Aklavik, 2011). It also highlights a potential need to diversify hunting/fishing approaches as historic areas or methods may not be as successful or viable (Friendship & Community of Aklavik, 2011).

"Inuvialuit notice the effects of climate change on a daily basis. In the past, they relied on their TK when they went out on the ice, but changing ice conditions have thrown some uncertainty into the reliability of this knowledge and made harvesting increasingly dangerous and difficult." Source: Inuvialuit and Nanuq (Joint Secretariat, 2015, p. 196)

Figure 2- 8. Impacts to Sea Ice and cascading effects on humans



(Adapted from: Eamer et al. 2013. Life Linked to Ice: A guide to sea-ice-associated biodiversity in this time of rapid change. CAFF Assessment Series No. 10, p.64)

This diagram shows the pathways in which changes to sea ice extent, timing, and quality can impact traditional use, traditional knowledge, and cause other human impacts (ITK, 2019 adapted from Eamer *et al.* 2013).

Travel

> All the land where we travel long ago, easy to travel, it's not like that anymore. It's too much changes now, the creeks are drying out, the lakes is getting shallow. You'd be lucky to get into some places where we used to just go with boats. It's not like that anymore.
>
> *Source: Annie B. Gordon, (WMAC (NS) & Aklavik HTC, 2009) p. 63*

Climate change has been affecting travel routes on the Yukon North Slope and routes used to access the Yukon North Slope. Creeks that were used in past are dried out now (WMAC (NS) & Aklavik HTC, 2018b). In the past, sea ice conditions created favourable corridors for safe travel along the coast but that does not happen anymore. In particular, the Mackenzie Delta is "… a huge interconnected network of travel routes. It is easy to get lost in this labyrinth, and even the most experienced land users have been temporarily disoriented on occasion, particularly since Delta topography is in constant flux as a result of geological and climate change processes" (WMAC (NS) & Aklavik HTC, 2018b). Furthermore, unpredictable ice and weather patterns make travel riskier (WMAC (NS) & Aklavik HTC, 2018b). Safe havens become even more important when the weather is unpredictable, but safe havens are changing too.

> When we were kids, waiting for this wind to calm down…because we can't take chances. Even our relatives from Alaska was with us. They told us, we can't ever take chances because sometimes the wind blows this way [gestures] and it's rough. We can't go until the wind change. Like, it blows that way [gestures]; then it's calm, you can go. Same thing with over here at Shingle. Say you want to go to Herschel Island and the wind is blowing from the ocean in [toward land], it's rough. You can't go. But when the wind blows from the mountains, this way [gestures], we can go. It's calm. It's rough out here, but it's calm in here. That's what we learned from our elders. They always say wait until the wind blows from this side [gestures] or wait until it's calm. Growing up, there used to be ice out here; used to be so good. We used to travel through icebergs all the way nonstop to Barter Island, Alaska. It used to take us 16 hours with speedboats, right through the ice- bergs and everything. But nowadays, it's so dangerous. There's no ice, nothing, it's always rough.
>
> *Source: PIN 109, Yukon North Slope Inuvialuit Traditional Use Study, (WMAC (NS) & Aklavik HTC, 2018), p. 31-32.*

Food security

Climate change may negatively impact Inuvialuit food security, as access to wildlife may decrease and below-ground freezer capability may be lost (ITK, 2019). This may result in an increased reliance on expensive outside food sources (Friendship & Community of Aklavik, 2011). Additionally, as climate change alters animal behaviour, and as some species decline and others increase, the animals that make up the traditional food basket may shift (Friendship & Community of Aklavik, 2011).

Disease

Increased exposure to vector-borne and zoonotic diseases and contaminants may increase health concerns not previously observed in the region (ITK, 2019).

Harvest

Increased travel risks and the safety of hunters may be directly affected by climate change impacts such as changing and unpredictable ice conditions. Travel routes may be adapted to align with changing wildlife movements and distributions (ITK, 2019), as new areas for harvesting may need to be considered for species that are no longer as plentiful or accessible (e.g., caribou) (IRC, 2016). Proactive measures have been taken to potentially circumvent climate change effects on specific species. For example, Aklavik Inuvialuit have adjusted Dolly Varden char harvest by holding an Aboriginal communal fishing license allocation for the Big Fish River (Danny C. Gordon, personal communication, April, 2019; Aklavik HTC, Aklavik Community Corporation, WMAC (NWT), FJMC, & Joint Secretariat, 2016; DFO, 2018).

Cultural Sites

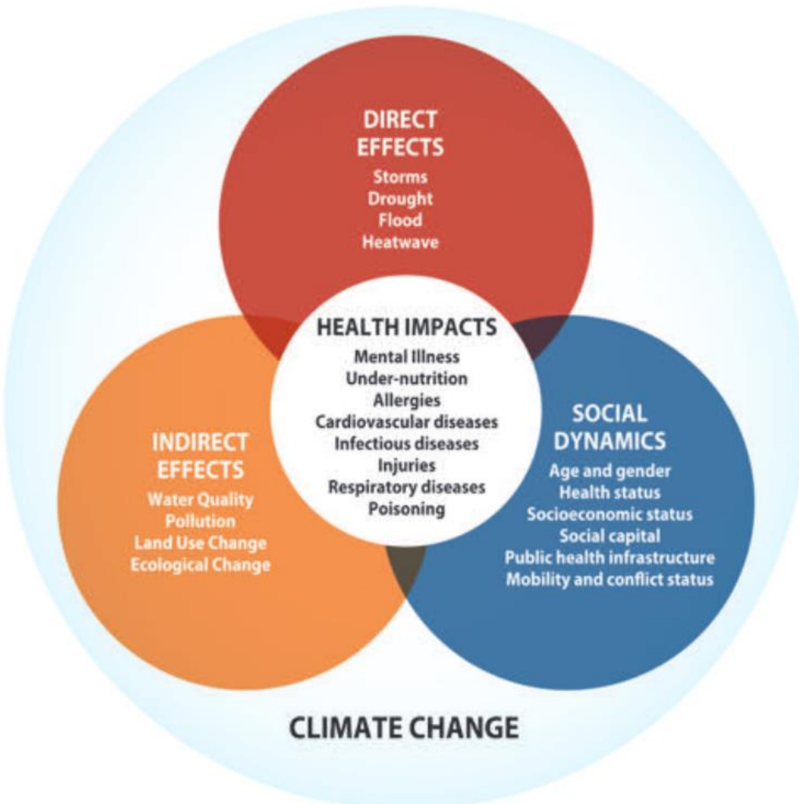
Cultural sites, such as cabins and camps, are being affected by climate change impacts to the landscape. Some cabins and camps are being lost to erosion and some are no longer accessible due to landscape changes. Some cabins have been moved multiple times in response to cultural erosion (WMAC (NS) & Aklavik HTC, 2018b) Cabins and camps provide a place to shelter from the elements and are typically located near a water source. A real or functional loss of these important sites can negatively impact the ability to harvest and conduct other traditional use activities on the Yukon North Slope. The loss of other cultural and spiritual sites to erosion or a changing landscape may contribute to an overall loss of culture as well as mental health impacts.

Socioeconomic Impacts

Climate change may cause socioeconomic impacts to Inuvialuit who use the Yukon North Slope. This may further affect their ability to access the Yukon North Slope. Changes to sea ice may result in an increase in Arctic-based resource extraction, which could increase participation in the wage economy. Access to wages could increase the ability to purchase and maintain equipment to access the Yukon North Slope, and yet could also restrict the ability of Inuvialuit to partake in traditional use activities. Working a set schedule and having limited opportunities to leave town could lead to land users traveling in inclement weather, because they feel they have no other choice.

Climate change will impact also impact human health, which is directly related to environmental change and will affect the future ability of Inuvialuit to use the Yukon North Slope and pass on traditional knowledge about the land (ITK, 2019).

Figure 2- 9. Climate change and the link to health impacts.



(Adapted fromWatts et al. 2015. Health and climate change: policy responses to protect public health. The Lancet 386(10006): 1861-1914, https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)60854-6/fulltext)

Source: National Inuit Climate Change Strategy (ITK, 2019).

Cumulative Effects

Climate change will result in cumulative impacts to traditional use; that is, impacts that occur as a result of multiple climate change effects. Already, climate change is causing interrelated and complex impacts to the Yukon North Slope. The following story reveals how climate change impacts interact to create cumulative effects to Inuvialuit traditional use:

> I travelled with my father-in-law first time in '92 or '93. He's passed now. He was the one that was telling me stories all the way from Shingle Point…to Kaktovik; where people had camps, like at King Point, or Kay Point…and people that travelled along the coastline, where his father had a store, and where my grandfather's buried. It was really interesting. We travel there when we can, but now it's too dangerous because there's no safe havens any more. All those creeks that were actually there when we were travelling are all dried out, and you can't go out to the creeks anymore….On our way, where [someone's] dad showed us [where] his brother had a cabin, they went up a hill and they built a cabin. Then, when we were going down…when we went to check the cabin where it was, all the ground is flat; no more hills. They're all

flat. When you look on the ground, there's openings, and you look under, and there's ice and water running. You can see that the land is collapsing. So it's really dangerous to travel now....That's along the coastline going to Kaktovik....on the Alaskan side....When we used to travel [to] Herschel, we used to go all along the waterline, where it's open now. [But] now, this part around here [pointing towards the area between Herschel Island and Ptarmigan Bay]...is all drying out. We used to go here. Now we have to really watch where we go because there's so much sand bar [pointing to the eastern entrance to Workboat Passage]."

Source: PIN 108 in Yukon North Slope Inuvialuit Traditional Use Study, (WMAC (NS) & Aklavik HTC, 2018), p. 32

Cumulative effects of climate change will also impact Inuvialuit traditional knowledge. The relevance of existing knowledge during a time of rapid environmental change, the ability to gain new knowledge out on the land, and the opportunity to transmit knowledge to future generations will all be impacted by the interacting, cumulative effects of climate change.

Selected Studies and Traditional Use Research Relevant to the Yukon North Slope

This section is an annotated listing of selected traditional use reports, papers, and other resources that provide support to the *Yukon North Slope Wildlife Conservation and Management Plan* and highlight issues and research directions that will be important to consider during its implementation.

There has been extensive documentation of traditional use of the Yukon North Slope including traditional use studies as well as traditional use information incorporated into research on specific species, climate change impacts, or oral history. The studies described below are the foundational publications that inform the understanding of traditional use in the Plan.

- Yukon North Slope Inuvialuit Traditional Use Study (WMAC (NS) & Aklavik HTC, 2018b)
  In 2015, 40 Inuvialuit community members were interviewed in the community of Aklavik to describe their traditional use of the Yukon North Slope. Interviewees were asked to map traditional use within their "living memory," including kill sites and harvesting areas for fish, wildlife, berries, and medicinal plants, as well as cultural sites, such as cabin and tent sites, birth sites, burial locations, and places of cultural, historical, or personal importance. Interviewees also documented travel routes and safe havens. In total, 2,091 features were mapped on 1:125,000-scale maps. Interviewees also described the shifts that have occurred in traditional use over their lifetimes, including adoption of new technologies, response to landscape and climate change, and the impacts of societal change. This mapping effort

documents a change in the geographical extent of traditional use by the Aklavik Inuvialuit over time. A contraction in the spatial footprint of traditional use is attributed to numerous factors, including the collapse of the fur trade, a shift to permanent year-round residency in Aklavik, the impacts of mandatory schooling and reliance on wage labor, increasing costs of purchasing and maintaining harvesting equipment, and less predictable weather patterns due to climate change. However, the Yukon North Slope continues to make a significant contribution to Inuvialuit livelihoods, and the importance of the landscape cannot be quantified simply in economic or subsistence terms. Interviewees were clear to emphasize their personal connections to the Yukon North Slope and the role that the landscape plays in their culture.

- Unikkaaqatigiit Inuit Perspectives on Climate Change (Nickels et al. 2005)
  In response to rapid environmental change in the Arctic, the Inuit Tapiriit Kanatami, the Nasivvik Centre for Inuit Health and Changing Environments at Laval University, and the Ajunnginiq Centre at the National Aboriginal Health Organization cooperated with regional Inuit communities to conduct a series of workshops discussing environmental change and its impacts on Inuit land-users. These workshops were held between 2002 and 2005, and included the ISR communities of Aklavik, Inuvik, Tuktoyaktuk, Paulatuk, and Ulukhaktok (known then as Holman). The workshops were community-focused, not landscape-specific, so it is not possible to identify which Akalvik responses were directed towards changes on the North Slope and which responses were made in relation to other parts of the ISR. However, Aklavik residents identified a range of environmental changes that impact traditional use. These include changes in ice conditions and resulting impacts to travel, changes in sea level, decreased health in fish and wildlife, and changing precipitation patterns, all of which impact traditional use of the land.

Links to Plans and Programs

This section lists plans and programs that link to the objectives and strategies of the *Yukon North Slope Wildlife Conservation and Management Plan*. These plans and programs informed the development of the Yukon North Slope Plan and are an integral part of its implementation.

- *Integrated Ocean Management Plan for the Beaufort Sea: 2009 and Beyond* (BSP, 2009)
  Recognizes the impact of climate change on the region, including impacts to wildlife and traditional use, and speaks to assessing and developing an adaptive management response to climate change. Specific concerns are activities made possible by reduced of sea ice, including increased shipping, tourism, commercial fishing, and mining.

- *Tarium Niryutait Marine Protected Areas Monitoring Plan* (DFO & FJMC, 2013)
  Establishes ecological indicators for monitoring within the marine protected area that include stressors related to climate-change.

- *Inuvialuit on the Frontline of Climate Change: Development of a Regional Climate Change Adaptation Strategy* (IRC, 2016)
  Workshops and interviews were held from 2015-2016 in all six Inuvialuit communities to discuss climate change impacts and adaptation strategies. This document highlights observed climate changes and an adaptation plan for the ISR. Subsistence hunting and fishing is one of five categories where adaptation efforts are described. The plan is not Yukon North Slope-specific but lists strategies to support continued traditional harvesting for the community of Aklavik.

- *Inuvialuit Settlement Region Polar Bear Joint Management Plan* (Joint Secretariat, 2017)
  Effects of climate change are incorporated throughout, including monitoring of polar bear populations and their habitat and prey to inform management. The plan states that "actions will be taken to ensure that the impact of climate change on polar bears is highlighted through the appropriate regional, national and international fora, and that effects of climate change on polar bears are monitored and mitigation actions taken where possible." (p. 1)

- *Herschel Island-Qikiqtaruk Territorial Park Management Plan* (Herschel Island-Qikiqtaruk Management Plan Review Committee, 2018)
  Recognizes significant climate-change-induced stressors and changes to natural systems, including wildlife population shifts occurring in and around the Park. Maintains long-term monitoring datasets that track change across decades and systems (species and ecological integrity), particularly through the Herschel Island–Qikiqtaruk Inventory, Monitoring, and Research Program.

- Ivvavik National Park of Canada Management Plan (Parks Canada, 2018)
  Recognizes the significant changes to the natural systems within the Park. Acknowledges the Park's role in establishing benchmarks for measuring changes in ecosystem integrity and communicating those changes local and nationally.

- Canada's Changing Climate Report (Bush & Lemmen, 2019)
  Contains multiple chapters (individually cited throughout) that describe observed climate trends as well as emission scenarios projected trends. Temperature, precipitation, permafrost, sea ice, etc. are all evaluated.

- Our Clean Future: A Yukon strategy for climate change, energy and a green economy (Yukon Government, 2020)
  Provides territory-wide policy guidance on reducing emissions, renewable energy, climate change adaptations, and a green economy.

- Yukon Government, Government of Canada, and universities, and non-government-led climate, ecological, and wildlife research and monitoring programs
  In addition to the two park plans listed above, ongoing monitoring and research projects track changes and examine underlying ecological relationships on the Yukon North Slope. Ongoing work includes climate and hydrology monitoring and studies on ocean and sea-ice

conditions, snowpack, permafrost, erosion and slumping, vegetation, and habitats and population characteristics of wildlife species. All these current programs aid in tracking change.

- Arctic Report Cards (Arctic Program, n.d.)
  Issued annually since 2006, the Arctic Report Card is a timely and peer-reviewed source for clear, reliable, and concise environmental information on the current state of different components of the Arctic environmental system relative to historical records. The Report Card is intended for a wide audience, including scientists, teachers, students, decision-makers, and the general public interested in the Arctic environment and science. It is produced through the Arctic Program of the US National Oceanic and Atmospheric Administration (NOAA).

Knowledge Strengths and Gaps

Recent reports identify projected climate trends and also set out guidelines for adaptation (Bush & Lemmen, 2019; Yukon Government, 2020). However, knowledge gaps persist in most areas about climate change effects in the Arctic and specifically on the Yukon North Slope, including environmental information such as snow cover, wildlife responses, and the potential emergence/expansion of diseases, parasites, or invasive species. Changes in the ecosystem due to climate change may also increase exposure to contaminants; however, the potential interactions of climate change and contaminants are mostly unknown (Braune, 2011, also see companion report on contaminants; McKinney et al., 2015). The WCMP (Objective E) provides guidance for new research on the Yukon North Slope.

Ultimately, all climate change and response predictions contained in this chapter provide guidance at the landscape scale, but they cannot provide the exact fate of any specific species (SNAP, 2012). However, the predictions can help to inform community and regional planning (SNAP, 2012).

Inuvialuit, particularly Aklavik residents and those that regularly spend time on the Yukon North Slope, are well-positioned to lead the monitoring of climate change effects. The combination of local and traditional knowledge with regular visits to the Yukon North Slope form a foundation for understanding change. Most importantly, Inuvialuit are and will continue to be most affected by climate change in this place. As such, it is imperative that Inuvialuit are leaders in both monitoring and adaption, with meaningful support from partners like governments and co-management organizations.

Adaptation to Climate Change

The capability of species to disperse increases their ability to adapt to climate change through movement (SNAP, 2012). However, less mobile species may be greatly influenced by landscape connectivity and permeability. On the Yukon North Slope, the northern limit of the landscape abutting the ocean also creates unique restrictions to potential movement. Therefore, different wildlife management strategies may be required to promote species adaptation, maximize resiliency, protect movement corridors, stepping stones, or refugia, and increase landscape permeability to conserve biodiversity (Mawdsley, Malley, & Ojima, 2009).

Potential Changes in Commercial Access

Reductions in sea ice and longer periods of open water may lead to increased shipping and tourism (via cruise ships) in the Beaufort Sea (BSP, 2009) (See also: Herschel Island-Qikiqtaruk Management Plan Review Committee, 2018). Additionally, there may be increased pressure to expand commercial fishing and mining in the Arctic region as seasonal access increases (BSP, 2009).

Climate Change Effects Monitoring and Research of Yukon North Slope Wildlife

Plans and research papers relevant to the Yukon North Slope (summarized above) recommend continued monitoring of climate change and its potential effects on species, particularly for species at high risk from the predicted changes. Periodic repeated sampling of wildlife populations is important as it establishes a record for evaluating population status and trends and potential links to the effects of climate change. Specific monitoring and/or research may be required to gather information on how climate change may be influencing these species.

Traditional Use and Traditional Knowledge

Inuvialuit traditional use and traditional knowledge of wildlife and habitats on the Yukon North Slope was documented in 2018 and highlight Inuvialuit observations of climate change. In 2019, Inuit Tapiriit Kanatami released the National Inuit Climate Change Strategy (ITK, 2019). The Inuvialuit Regional Corporation released *Inuvialuit on the Frontline of Climate Change* in 2016, which presents regional climate change adaptation plans for each Inuvialuit Community (IRC, 2016). The Inuvialuit Regional Corporation is currently producing an Inuvialuit climate change strategy. Inuvialuit-informed climate change adaptation strategies are therefore a knowledge strength. However, there is a knowledge gap in documenting ongoing traditional knowledge of how Inuvialuit and wildlife are adapting to climate change, and documenting ongoing changes to traditional use as a result of climate change.

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