



State of Climate Change and Adaptation Knowledge for the Eeyou Istchee James Bay Territory

Final Report

November 2017



Comité consultatif pour l'environnement de la Baie James
James Bay Advisory Committee on the Environment
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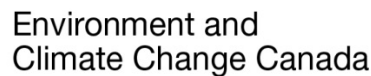
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SUMMARY

This report reviews the current state of climate change and adaptation research for the Cree Nation territory (2007 – 2017). Based on a substantial array of evidence, climate change worldwide is occurring faster in subarctic and arctic bioclimatic regions, and is already affecting a broad range of human and natural systems. Largely caused by human activities, it poses significant risks for indigenous populations living in higher latitudes.

With anthropogenic greenhouse gas (GHG) emissions at a record high, global average temperature has warmed by 0.85°C since the end of the 19th century. These changes are modifying other key parameters, such as sea ice extent and duration, precipitation patterns, river discharge, and the frequency and intensity of extreme weather events. Due to their close ties with the land, indigenous peoples are particularly vulnerable to climate change because it modifies land access, occupation and use, thereby exacerbating the effects of other stressors such as industrial development and socio-economic constraints. Although much progress has been made in terms of climate change research in Quebec, past studies have either focussed on southern Quebec or Nunavik leaving subarctic Quebec seriously data-deficient in terms of instrumental records or long-term scientific observations. However, available studies and an abundance of local observations by the Cree show rapid changes of the environment and climate conditions.

Ouranos was mandated by the James Bay Advisory Committee on the Environment (JBACE) to review the scientific and gray literature, and interview several key stakeholders in order to better identify climate impacts and adaptation initiatives in Eeyou Istchee James Bay, situated in subarctic¹ Quebec. The report has three main objectives:

- 1) Summing up climate change information for Eeyou Istchee James Bay and identifying knowledge gaps;
- 2) Indicating potential research needs and recommendations; and
- 3) Supporting multi-level governance in decision-making processes on climate change adaptation.

Annual mean air temperature in the region has warmed by 1.5°C in the last 35 years with a sharp winter warming of 2-3°C. Different models project an increase in rainfall while snow cover will decrease thawing earlier. The Cree have noticed an increase in the frequency of lightning storms and flooding, weather has become less predictable and seasons are shifting. In James Bay, sea surface temperature is rising, sea ice is retreating rapidly, and climate models project a higher river discharge in James Bay potentially modifying water properties and dynamics in the Bay. These physical changes lead to impacts on the natural and built environment, and entail a plethora of socio-economic and cultural repercussions. At the ecosystem level, local observers and scientific research report more southern species on the territory, the modification of phenological cycles, an increase in natural disturbances such as pests and invasive species and more frequent forest fires, as well as changes in the quality and availability of wildlife and plants used in traditional food systems. From a health perspective, changes in land access, accidents on the ice due to hazardous ice conditions, alteration of subsistence activities, traditional knowledge transfer, as well as the increase in diseases like diabetes and obesity, linked to changes in diet and food security, represent significant health risks and threaten Cree culture, identity and well-being. In terms of infrastructure and industry, more frequently observed climate hazards can challenge current asset design, construction, operation and maintenance leading to additional risks and costs for communities. The tourism sector, especially the cultural economy and outdoor tourism, is also vulnerable to climate change. While the majority of climate change-induced effects in Eeyou Istchee James Bay appear to be negative, climate change may also be beneficial for some sectors if activities are adapted proactively.

So far, adaptation to climate change in Eeyou Istchee James Bay has been mainly characterized by reactive, individual strategies, such as for adapting subsistence practices, or integrating climate change on a voluntary

¹ The subarctic climate is located between 50° to 70°N and characterized by a long, very cold period, and a short warm period. Eeyou Istchee James Bay is mainly located in this climate zone (Dfc, Köppen climate classification), except for the coastal area from the southern tip of James Bay up to Chisasibi which is dominated by a humid continental climate (Dfb).

basis in economic development projects. Efforts are necessary to mainstream adaptation, integrate climate change into other strategic documents, raise awareness and recognition, and then start implementing adaptation measures for the benefit of Cree society in a flexible approach that can be adjusted over time.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACI	Aanischaaukamikw Cultural Institute
CBHSSJB	Cree Board of Health and Social Services of James Bay
CNG	Cree Nation Government
CMEB	Cree Mineral Exploration Board
COTA	Cree Outfitting and Tourism Association
CREECO	Cree Regional Economic Enterprises Company
CTA	Cree Trappers' Association
CWS	Department of Capital Works and Services of the Cree Nation Government
DCI	Department of Commerce & Industry of the Cree Nation Government
EAP	Environmental authorization process
ECCC	Environment and Climate Change Canada
EIJBRG	Eeyou Istchee James Bay Regional Government
EMRWB	Eeyou Marine Region Wildlife Board
EMRPC	Eeyou Marine Region Planning Commission
ERW	Department of the Environment and Remedial Works of the Cree Nation Government
FNQLSDI	First Nations of Quebec and Labrador Sustainable Development Institute
GHG	Greenhouse gas emissions
HB	Hudson Bay
JB	James Bay
JBACE	James Bay Advisory Committee on the Environment
JBNQA	James Bay and Northern Québec Agreement
MDDELCC	Ministère du développement durable, de l'Environnement et de la Lutte contre les changements climatiques
MERN	Ministère de l'Énergie et des ressources naturelles du Québec
MTMDCT	Ministère des Transports, de la Mobilité durable et de l'Électrification des transports
NRCan	Natural Resources Canada
PRDIRT	Regional Plan for Integrated Land and Resource Development
RCP	Representative Concentration Pathway
SAT	Surface air temperature

SPN	Société du Plan Nord
SST	Sea surface temperature
UdeM	Université de Montréal
UQAT	Université de Québec en Abitibi-Témiscamingue

INTRODUCTION

Eeyou Istchee James Bay² has been occupied by the Cree for almost 5000 years (Feit 1995) and encompasses a huge territory (450,000 km²), two-thirds the size of France or almost the size of Sweden making it the one of the biggest municipality in the world. Far from being an unoccupied swath of land (see [Appendix 1](#)), the Cree use the whole of this territory for hunting, fishing, trapping and other cultural activities. The special relationship with the land, which goes beyond subsistence activities, is central to the Cree identity (Adelson 1998; JBNQA 1975), and knowledge and practices, transferred from one generation to the next, have adapted to environmental changes over time (Ohmagari & Berkes 1997; Sayles & Mulrennan 2010; Lemelin et al. 2010).

Over the last 50 years, the Cree have witnessed many rapid and complex changes to the environment due to large-scale natural resource exploitation, such as forestry, mining and hydroelectric development affecting Cree traditional lands. Rapid climate change has the potential to exacerbate the effects of major development projects and socio-economic constraints, and now stands as an additional challenge to the Cree way of life and to the maintenance of Cree identity (Ouranos 2015). For example, more frequent or intense extreme weather events or unpredictable seasonal changes modify subsistence harvesting, erode cultural continuity, endanger infrastructure assets and represent health and security risks. Yet, changes associated with the climate are difficult to predict both in terms of scope and trend. Adaptation to a changing environment was, and will remain, a key to Cree survival. Scientific data is an important source, but observations from the Cree hunters and trappers, their families and Cree authorities are also crucial when seeking to make decisions on how to adapt to such changes. Climate impacts, vulnerabilities and adaptation also need to be considered in the context of existing socio-economic changes and trends in Cree society, such as an increasingly sedentary lifestyle and shift towards a wage-based economy.

The James Bay Advisory Committee on the Environment (JBACE), as per its policy role under the James Bay and Northern Quebec Agreement (JBNQA), commissioned a first report in 2007 on the state of knowledge of climate change in Eeyou Istchee James Bay. Afterwards the committee collaborated on a project, spearheaded by the Cree Trappers' Association (CTA), designed to document and localise patterns of land use that may have been impacted by climate change. Ten years after the release of the first report, the JBACE mandated Ouranos to draw an updated picture of the situation, and develop a better grasp of the role that environmental assessment plays in that regard. This report explores socio-economic and cultural implications of climate-driven change in addition to the environmental dimension, thereby largely exceeding the scope of the first report and allowing for a better understanding of the socio-cultural context of the region. It presents the current state of climate change and adaptation knowledge in Eeyou Istchee James Bay (2007-2017) in order to:

- 1) Sum up climate change information for Eeyou Istchee James Bay and identify knowledge gaps;
- 2) Indicate potential research needs and recommendations;
- 3) Support multi-level governance in decision-making processes on climate change adaptation.

[Chapter 1](#) starts with Cree society by presenting socio-cultural repercussions of climate change on Cree culture and identity, physical and mental health, as well as livelihoods and food security, while also highlighting some adaptation strategies for subsistence harvesting and traditional food systems.

[Chapter 2](#) provides an overview of changes in the climate system in Eeyou Istchee James Bay discussing temperature, precipitation, seasons and weather patterns, ice regimes, as well as changing water levels and properties. It considers past conditions (stemming from scientific measurements and traditional knowledge) and future climate projections for the mid-21st century.

² The Cree refer to themselves as “Eeyou/Eeyouch”. Eeyou Istchee James Bay, their sacred homeland, means “the land of the Eeyou”.

Chapter 3 outlines climate change impacts on the region's ecosystems, both aquatic (marine, coastal and estuaries, freshwater, wetlands) and terrestrial (forests), highlighting implications for wildlife and vegetation dynamics, such as phenological changes, northward migration and variation in productivity and disturbance regimes, which require a rethinking of current conservation practices.

Chapter 4 describes climate change impacts on built infrastructure and industrial / economic development (mining, forestry, renewable energy, and tourism), and presents some adaptation initiatives for each sector.

Chapter 5 discusses adaptation readiness and capacity in Eeyou Istchee James Bay summing up existing adaptation strategies and challenges, and highlighting examples from other Northern Indigenous communities that could be applied in Eeyou Istchee James Bay.

Bullet points are used to indicate changes specific to Eeyou Istchee James Bay enabling the reader to quickly find information pertaining to the region. The text in bold highlights the most important elements including local, interregional and global information. The following coding can help readers searching for specific information.

-  Red boxes contain recommendations for each chapter or subsections
-  Orange boxes present sectoral adaptation strategies at the end of some subsections
-  Green boxes present additional information or case studies

Knowledge systems for understanding and engaging in climate change and adaptation science

The contents of this report are based on both scientific studies and traditional (Indigenous) knowledge as complimentary sources of information. Indigenous knowledge can provide a long-term perspective and make up for the absence of written archives or historical instrumental records (Peloquin & Berkes 2009; Alexander et al. 2011; Asselin 2015). Moreover, it is often much more detailed, and less reductionist than scientific research which tends to focus on a few selected parameters (Peloquin & Berkes 2009). The use of indigenous knowledge often proves less costly and less time-consuming (Asselin 2015). Local observations consider the cultural context of the land, and make it possible to incorporate a more moral and spiritual rather than only rational perspective (Asselin 2014). In combination with scientific studies, which are crucial to establish baseline information and allow to compare the current situation to the past and to forecast future changes, indigenous knowledge and local observations of environmental changes are valuable sources to obtain a more multi-dimensional and holistic picture of ongoing changes, expand knowledge at a local scale, and fill knowledge gaps (Alexander et al. 2011; Peloquin & Berkes 2009). Downing & Cuerrier (2011) suggest combining science and traditional knowledge for inclusive, positive actions.

Research limitations

The issue of climate change is very complex and dynamic. Its potential environmental, social, cultural and economic impacts – as well as any potential measures to adapt thereto – can be equally complex to be predicted and to be characterized. The sparse network of weather stations in Eeyou Istchee James Bay, important localized factors such as major hydroelectric development, and multi-decadal climate variability related to large-scale oscillations contribute to the difficulty of accurately describing the past evolution of the climate and to project future climate conditions. Long-term observations and contemporary modelling³ permit the establishment of causal links and trends of change with appreciable degrees of confidence. However, given that available research on these matters in Eeyou Istchee James Bay is a relatively recent and burgeoning field, it is crucial that readers exercise prudence when attempting to extrapolate local or regional point-source or site-specific observations from generalized climate change trends and vice versa.

³ Three factors of uncertainty are associated with climate models: the natural variability of the climate, the rate of future GHG emissions, and the imprecision of climate models. The relative influence of these uncertainty factors on the model depends on the time period considered, e.g. natural variability is the most important factor in projections over a few decades whereas the choice of GHG emission scenarios is more important in long-term projections (Ouranos 2015).

CONTEXT

Anthropogenic greenhouse gas emissions (GHG) have reached a record high in the last decades, and are driving changes in the global climate system unprecedented over decades to millennia (IPCC 2014). As a consequence, the last 30 years were the hottest period over the past 1400 years in the Northern Hemisphere, and globally averaged temperature (land and ocean surface) has increased by 0.85°C from 1880 to 2012 (*ibid.*). Arctic and Subarctic regions in Canada are experiencing even faster changes (*ibid.*; Ouranos 2015; Macdonald & Kuzyk 2011). In Eeyou Istchee James Bay, annual mean air temperature has increased by 1.5°C over the last 30 years (in winter by 2-3°C), and the region will likely experience some of the highest winter warming in Canada by 2050 due to the projected loss of sea ice (R. Brown, pers. comm.; Way et al. 2017; Ouranos 2015; Steiner et al. 2013; Vincent et al. 2015).

Northern indigenous peoples have stated that environmental change clearly affects their relationship with the land, their culture, livelihoods, mental health, well-being and spirituality (e.g. Berry et al. 2014; Foro et al. 2013; Brisson & Bouchard-Bastien 2014; Clayton et al. 2017; CTA 2011). This is why the direct and indirect effects of climate change on the Cree way of life are at the heart of this report; [Chapter 1](#) will portray climate change impacts on Cree culture, identity and traditional activities ([Chapter 1.1](#)), Cree physical, mental and spiritual health ([Chapter 1.2](#)), land access ([Chapter 1.3](#)) and subsistence harvesting ([Chapter 1.4](#)).

Indeed, global warming affects precipitation patterns and snow cover, modifies weather patterns such as by increasing the frequency and intensity of extreme weather events, leads to a rapid decrease in sea ice extent, heats up sea surface temperature, and adds to modifying river discharge and water properties. *Table 1* outlines past and future trends and local observations of these climate parameters in Eeyou Istchee James Bay, as obtained from the literature review presented in [Chapter 2](#). These climate parameters are interconnected and affect aquatic and terrestrial ecosystems ([Chapter 3](#)), infrastructure ([Chapter 4.1](#)), and natural resources and economic development ([Chapter 4.2](#)) at varying degrees.

Table 1: Past and projected changes of key climate parameters in Eeyou Istchee James Bay

	Past trend	Cree observations	Projected trend (2050)	
Air temperature	↑	↑	↑	+3.6°C warming of mean temperature, 5.5°C in the winter. High regional and seasonal variability.
Rainfall	↑	↑	↑	+13-20% and more extreme precipitation. High uncertainty about the amplitude of the increase and regional variability.
Snow	↓	↓	↓	Decrease in snow cover and duration in the North, and change of its characteristics. Large year-to-year variability and likelihood of differing snow trends across the region (potential increase in the South).
Extreme weather events	↑	↑	↑	Weather has become more unpredictable. The intensity and frequency of extreme weather events (e.g. flooding or storms) will increase.
Sea ice extent	↓	↓	↓	For every 1°C increase sea ice extent decreases by 14%. 50% loss of ice thickness. Freeze-up and breakup will occur 3-4 weeks later and earlier, respectively.
Sea surface temperature	↑	Unobserved or undocumented	↑	+ 1-1.5° or 0.22±0.08°C/decade
River discharge	↑	↑	↑	+2-15%, but significant variability due to hydro-electric flow modifications. Earlier onset of maximum river discharge.
Lake/river ice	↓	↓	↓	Ice forms later in autumn and melts earlier in spring.

METHODOLOGY

Most information was obtained from an **exhaustive review of the scientific and grey literature**. The following three databases were selected with input from a librarian: Web of Science, Scopus and Google Scholar. Google Scholar and additional research with google were employed to track publications in the grey literature, in addition to scientific articles, theses and reports. In order to close remaining knowledge gaps and to validate contents, several researchers from various Canadian universities, local stakeholders at the Cree Nation Government and other Cree organizations (e.g. COTA, CTA, CBHSSJB, CMEB, EMRWB, EMRPC, EIJBGR, etc.) in Eeyou Istchee James Bay, as well as Hydro Québec and some provincial ministries were contacted. This allowed obtaining additional information, often unpublished or unwritten, with respect to climate change and adaptation in their fields of expertise. However, due to time constraints and considering the limited scope of this report and its main objective to provide an updated state of knowledge on climate change and adaptation, not all the communities, researchers or organizations that may have produced reports or possess additional information could be contacted.

For the literature review, keywords were selected in English and French. To build search strings, keywords related to climate change, geographical location and different qualifiers for each chapter were combined ([Appendix 2](#)). The results were **limited to up-to-date articles with publication dates ranging from 2007 to 2017**. The documents were primarily selected based on the contents of their abstract and conclusion, and to a lesser extent based on the results and discussion sections. Additional articles were gathered via the “related contents” function on Scopus and Web of Science for shared references and cross references. For some authors, all publications were scanned based on personal recommendations by researchers or a high volume of citations. All in all, about 250 documents were selected, and then classified and stored in EndNote. This helped to determine which topics were covered well while at the same time identifying information gaps. After an in-depth study of these articles, additional information was acquired from the key stakeholders mentioned above.

CAUTIONARY NOTE: *It is very important to note that the results are based on a review of the available literature or interviews with key informants. Changes not observed by the Cree or unmeasured in scientific studies could still be present without having been described (e.g. confidential data; no written records) or may still occur in the future.*

CHAPTER I – SOCIOCULTURAL IMPACTS OF CLIMATE CHANGE ON CREE SOCIETY

1.1 CULTURE, IDENTITY AND TRADITIONAL ACTIVITIES

“Our connection with the land, and the ability of the land to provide for the current generations and for the generations to come, will be central to our collective identity as Eeyouch/Eenouch. The land has been the foundation of who we are as a people, and that connection has guided us well in the course of our struggles and our achievements throughout our history” (Dr. Matthew Coon Come, Grand Chief 1987-2017, Annual Report 2015-2016)

Socio-cultural function of place:

This special relationship with the land goes beyond mere subsistence since traditional activities on the land have a high cultural importance, and are intrinsically linked to indigenous and Cree identity, way of life and emotional well-being. Indigenous people perceive the land as a source of freedom and identity, which has therapeutic effects and is crucial for their well-being (Cunsolo et al. 2011; Cunsolo et al. 2012): *“We have this*

connection to the land that makes you feel good. It makes you, you". For the Cree, the connection with the land is a means to ensure cultural continuity and knowledge transfer to younger generations, thereby preserving Cree identity and way of life (Cree Vision of Plan Nord 2011). However, the sedentarization and relocation of the Cree in the wake of major hydro-electric development have weakened their nomadic, self-sufficient culture of subsistence, shifting Cree society further towards a wage economy and increasing dependency on formal institutions (Royer and Herrmann 2011).

- **Climate change could affect the complex relationship with the land** by exacerbating the effects of major development projects and further putting pressure on Cree culture and lifestyle ([Chapter 2](#)).
- Indeed, **health professionals and local decision-makers in Eeyou Istchee James Bay are worried about the potential loss of Cree identity and lifestyle** as a consequence of climate-related impacts (Foro et al. 2013).

The concept of **solastalgia** was created to describe "the pain or distress caused by the loss of, or inability to derive, solace connected to the negatively perceived state of one's home environment" (Albrecht et al. 2007). An elder from Chisasibi asked: "*If the land is not healthy, how can we be?*"⁴ Indeed, a sense of place is crucial for good health (Cunsolo-Wilcox et al. 2012; Albrecht et al. 2007; Hess et al. 2008). Place attachment is multidimensional, and Scannell & Gifford (2010) developed the person-process-place framework to highlight the different facets of place attachment (see [Appendix 3](#)). **Climate change negatively affects place attachment** by disrupting place-specific socio-cultural activities and connections with a specific place leading to negative impacts on emotional health and well-being (Cunsolo-Wilcox et al. 2012; Albrecht et al. 2007; Cuerrier et al. 2015). Firstly, modifications of land access and subsistence activities **endanger the function of the land as a provider of personal and cultural fulfillment, a source of renewal, healing, harmony, relaxation** (Cunsolo-Wilcox 2012; Lemelin et al. 2010). Secondly, the land's function of **enriching the soul and thereby providing emotional wellness and wholeness** to indigenous peoples is endangered because environmental changes and fewer opportunities to spend time on the land create feelings of anger, sadness, depression and uncertainty about the future (Cunsolo-Wilcox et al. 2011).

Traditional knowledge/activities and cultural continuity:

Traditional knowledge is not just a knowledge base but also a way of life and integral factor shaping the Cree mindset (Royer 2012). Elders from many indigenous groups are of the opinion that climate change has made the use of traditional knowledge less reliable (Mc Lean 2009). Fewer activities on the land can lead to a sense of **acculturation** and cultural erosion (Pétrin-Desrosiers 2014; Cree Vision of Plan Nord 2011) since identity and cultural values are closely linked to subsistence activities (Royer et al. 2013). Climate-related modifications of the land (e.g. inability to predict weather, shifting of seasons or animal migration, etc.) can lead to a **loss of confidence in traditional knowledge and expertise of the territory**, which can affect cultural and emotional well-being and spiritual health (Foro et al. 2013; Downing & Cuerrier 2011; Pétrin-Desrosiers 2014). For example, **the Cree have mentioned that they lost trust in their bush skills** (Syvänen, 2011). **Reduced access to the land may decrease traditional activities and induce a loss of traditional knowledge** negatively affecting well-being (depression, stress) and cultural integrity (Pétrin-Desrosiers 2014). Spending less time on the land also affects the transmission of native languages, which is crucial for cultural identity (Downing & Cuerrier 2011). Finally, reduced knowledge and land skills transfer contribute to **raising the rate of accidental injuries** associated with activities on the land (Ford et al. 2016).

1.2 HEALTH: PHYSICAL, MENTAL AND SPIRITUAL DIMENSIONS

For the Cree, health is based on the relationship with nature and interpersonal relationships. The Cree concept for health *miyupimaatisiun* translates into "being alive well" and recognizes the interconnectivity of all elements of the universe (Adelson 2000). This is why health of the communities, health of the environment

⁴ Statement by Joseph Marty, a Whapmagoostui elder (Adelson 2000).

and individual health are closely intertwined (*Figure 1*), and, preserving the environment and maintaining a good social cohesion go hand in hand with individual health (Brisson & Bouchard-Bastien 2014). The Cree view of health incorporates physical, emotional and spiritual dimensions and goes beyond health signifying the absence of illness (Foro et al. 2013; Lemelin et al. 2010).

- **“Being alive and well” is part of the Cree identity and it is closely linked to the health of the land, the food it provides and the rights of access to the land** (Council of Canadian Academies 2014).

Northern indigenous peoples have stated that environmental change clearly affects their relationship with the land, their culture, livelihoods, mental health and well-being (Berry et al. 2014; Foro et al. 2013; Clayton et al. 2017; Council of Canadian Academies 2014). *Figure 1* sums up how geophysical/climate impacts, such as changes in temperature, precipitation or extreme events, can lead to vulnerabilities on the individual, social and physical levels, and affect physical, mental and community health.

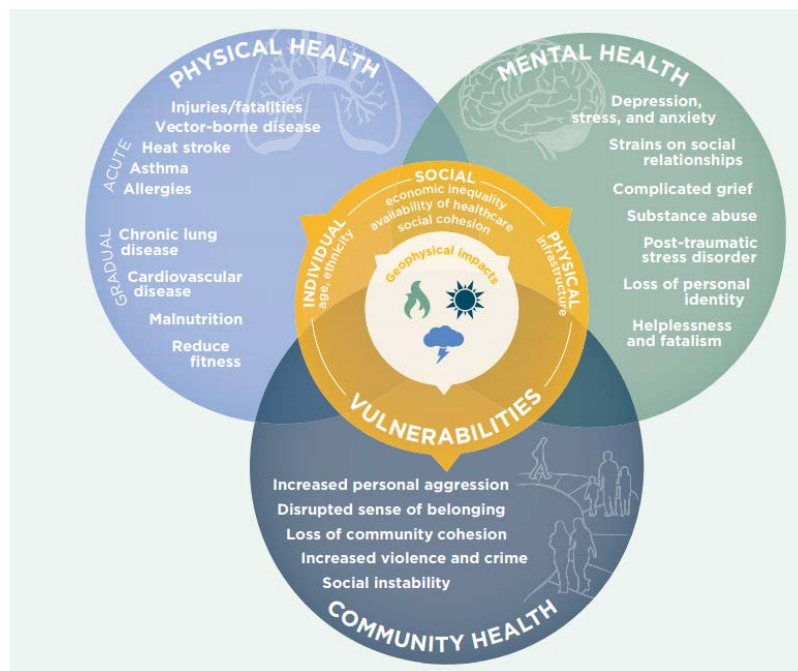


Figure 1: Climate change impacts on health. © Clayton et al. 2017

Physical health:

Climate-related effects on health are multifactorial and highly complex. Research on climate-related implications on health is quite recent (Ford 2012). According to Ford (2012), high poverty, a high sensitivity to climate-driven health risks, limited technological capacity and a high burden of ill health make populations more vulnerable to climate-related health impacts. However, it is sometimes difficult to differentiate between impacts from climate change and those from hydroelectricity, mining and forestry development projects (Pétrin-Desrosiers 2014). **Indigenous peoples are particularly vulnerable to climate change given that many live in regions affected by rapid environmental change, and their close connection with and dependence on the land for traditional activities** (Ford 2012; [Chapters 1.1 & 1.4](#)).

- **Research has demonstrated that climate change is an additional stressor that can influence health in Eeyou Istchee James Bay** (Pétrin-Desrosiers 2014).
- In a consultation with health professionals in Eeyou Istchee James Bay, the transportation risks associated with off-road vehicles and seasonal ice conditions, the inconvenience of sudden weather changes, and the changing availability and distribution of some species were the most widely mentioned effects of climate change (Foro et al. 2013). Therefore, **health professionals consider accidents on the ice** ([Chapter 1.3](#)) **and diseases like diabetes and obesity**, linked to changes in diet

and food security ([Chapter 1.4](#)), the most worrisome risks for the health sector (*ibid.*; Anctil 2008).

Table 2 summarizes potential direct climate-related health impacts in Eeyou Istchee James Bay⁵.

Table 2: Climate hazards and their potential impacts on health in Eeyou Istchee James Bay

Climate hazards	Potential health impacts	
	Mechanism	Health impact
Increase in precipitation and flooding	Changes in the distribution of insects	New diseases
	Accidents at work	Injuries, traumas
	Modified distribution of vegetation	Modification of lifestyle (diet and medicine)
Increase in the frequency and magnitude of temperature extremes and higher solar radiation	Direct exposure	Heat stroke, respiratory problems, skin cancer, cataracts, dehydration
	Variability of drinking water reserves	Diseases related to shortage and poor quality of drinking water
	Arrival of new insects and pathogens	New or more water- and vector-borne diseases
	Decrease in abundance of some varieties of wild berries and in quality of some medicinal plants	Modification of lifestyle (diet and medicine)
Decrease in distribution, thickness, stability and duration of ice cover on water bodies, and modification of snow quality and quantity	More difficulties in accessing the land, hunting grounds, traditional food	Nutritional deficiency, chronic diseases, impact on food-sharing between community members and erosion of socio-cultural values
	Decrease/modification of travel	
	More accidents and drowning	Injuries, neurological sequelae, psychological impacts, death
	Difficulty building snow shelters with soft snow	Safety risks and lower protection from storms and the cold
	Higher biomagnification of pollutants through the food web and higher transportation rates of contaminants from lower into higher latitudes due to a decrease of sea ice extent	Intoxication risks
Increase in wildfires	Evacuations	Psychological effects
	Burns	Psychological effects, death
	Intoxication with carbon monoxide	Neurological sequelae, death
	More exposure to fine particles	Respiratory and cardiovascular problems

Mental and spiritual health and well-being:

In addition to these more direct effects, climate change leads to less tangible and indirect impacts on mental health and socio-cultural well-being (see *Figure 1*). Common effects on Aboriginal peoples include **depression, sadness, fear, anxiety, frustration, anger, helplessness, distress, despair, loss, grief, hopelessness, aggression, apathy, denial and trauma** (Cunsolo-Wilcox et al. 2013). In the future, climate change will probably produce more acute, slow or chronic mental health impacts (*ibid.*; Berry et al. 2010a). For example, impacts from a climate hazard (personal injury, injury or death of a loved one, damage to or loss of property, loss of a livelihood) can cause severe psychological trauma and anxiety-related responses (Clayton et al. 2017; Berry et al. 2010a). Furthermore, **losing access to traditional food sources or culturally meaningful places and practices can provoke emotional distress, anxiety, sadness, insecurity, loss of self-efficacy and amplification of existing stressors** (Clayton et al. 2017; Dudley et al. 2015; Berry et al. 2010a; Ford 2012). Studies have even shown that higher temperatures increase the use of emergency health services in Canada as well as the levels of suicide for psychologically fragile people (Clayton et al. 2017). However, it has been argued by some researchers that climate change could also produce **positive side effects such as the strengthening of social support networks and the creation of community-led projects to tackle climate change together** (Cunsolo-Wilcox et al. 2013; Berry et al. 2010b; Hart et al. 2011). Studies in Eeyou Istchee

⁵ Table 2 is based on information from the exhaustive health report for Eeyou Istchee James Bay by Brisson & Bouchard-Bastien 2014, as well as Ford 2012 and Ford et al. 2016. Additional information for individual impacts was obtained from Barber et al. 2012, Rapinski et al. 2014 and Dudley et al. 2015.

have not yet directly investigated the complex relationship between climate change and mental health and well-being, but it seems likely that the effects described above apply to the Cree as well.

1.3 LAND ACCESS

Access to the land is necessary for harvesting bush food and practising other traditional activities ([Chapter 1.1](#)), which contribute to physical, mental, spiritual and community well-being ([Chapter 1.2](#)). Moreover, engaging in activities on the land is also a means to keep physically active (Brisson & Bouchard-Bastien 2014; Turner and Turner 2008). Climate change compromises land access and endangers civil security in Eeyou Istchee James Bay. For example, **modified and hazardous ice conditions have already led to fatalities** when people fell through the ice, including experienced hunters (CTA 2011; Pétrin-Desrosiers 2014). Some Cree communities have already **modified their public safety programs** accordingly (Waskaganish, pers. comm.).

- **Unsafe ice conditions require adjustments as to how the land can be accessed, and have forced the Cree to use alternative means of transportation, travel routes and technology.**

Trying to go around unsafe spots by snowmobile can lead to a higher consumption of gasoline (higher costs) and people can get stranded (Downing & Cuerrier 2011). The use of helicopters and planes to escape unsafe ice conditions has created **important economic expenditures** for some Cree communities (CTA 2011; FNQLSDI 2017), and prevents people who do not have the financial means from going out on the land. Cree hunters have also noticed that **softer snow makes travelling difficult and more time-consuming**, e.g. snowmobiles sink in the snow, and people cannot walk with snowshoes on the hard snow in early spring (CTA 2011). Finally, modified snow and ice conditions **change the calendar of activities and traditional harvesting cycle** ([Appendix 4](#) & [Chapter 2.2](#)), i.e. the time and place where hunting activities can take place and some areas will be exposed to a higher density of hunters and higher pressure on wildlife. To a lesser degree, other climate hazards can also affect land access such as **forest fires or flooding cutting off road access thereby** trapping people in the community or on their family grounds (Mistissini, pers. comm.).

1.4 SUBSISTENCE HARVESTING AND FOOD SECURITY

The Council of Canadian Academies (CCA) released its findings in the 2014 report *Aboriginal Food Security in Northern Canada: An Assessment of the State of Knowledge*, concluding that “**there is a food security crisis in northern Canada,**” and that the crisis is particularly acute in some Aboriginal communities. The societal shift from a nomadic, hunting culture to a more sedentary way of life has led to nutritional changes with a sharp decrease in bush food and an increase in processed foods in Eeyou Istchee James Bay (Royer and Herrmann 2011). People change their diet over time, but rapid changes over a very short timeframe can lead to serious consequences for people’s health⁶ (Turner & Turner 2008). The impacts of losing the food itself is overshadowed by the even greater effects of the loss of the knowledge related to its harvest, preparation and use, as this impairs cultural identity and pride (*ibid.*). **The less indigenous peoples make use of traditional foods and the more they rely on wage-paying jobs, the higher the loss of traditional knowledge/erosion of skills and the greater the dependency on store bought foods for food security** (CCA 2014)⁷. These store-bought foods can be nutritionally limited, increase obesity and are often expensive, especially for the more isolated communities (Downing & Cuerrier 2011). The lack of traditional food also affects mental and spiritual health (Tam et al. 2013; [Chapter 1.2](#)).

- **Traditional foods contain many important nutrients, but an extensive health study in Eeyou Istchee**

⁶ This has happened to many Aboriginal peoples all across Canada (Turner & Turner 2008).

⁷ The significantly dropping numbers of people partaking in the Hunters Income Security Program in Eeyou Istchee James Bay illustrate the trend away from traditional food sources. While the population of Eeyou Istchee James Bay has doubled from 1976-1981 to 2004-2008, the percentage of people living off the land only represents 15.3% in comparison to almost 50% in 1976-1981 (Council of Canadian Academies 2014).

James Bay has shown that they are consumed less and less and being replaced with unhealthy high-fat and high-sugar foods (Nieboer et al. 2009).

- For the Cree, **climate-driven impacts on traditional food sources have far-reaching effects on the socio-economic and health levels since they represent a substantial part of their diet.**

Changes in animal distribution, health and behaviour ([Chapters 3.1.2 & 3.2.2](#)) due to climate change and other stressors such as habitat degradation and fragmentation modify access to and quality of traditional foodstuffs for hunters and affect this source of income for beneficiaries of the Cree Hunters and Trappers Income Security Program.

- **The quality and availability of traditional food sources in Eeyou Istchee James Bay has decreased** over the last years, which can be partially attributed to climate change. The reduced quantity of game affects whole communities since meat is often shared (Tam et al. 2013; [Chapter 3.2.2](#)).
- Instead of going out on the land in October, hunters and trappers now leave more often in November due to unstable ice and bad weather conditions, which may explain the lower harvest of certain species, e.g. beaver or muskrat (CTA, pers. comm.).
- A recent **deterioration of the health and body conditions of wildlife** observed by Cree hunters includes less fat, more parasites and diseases, thinner fur and a different taste of the meat (CTA 2011; Pétrin-Desrosiers 2014; Tam et al. 2013; [Chapter 3.2.2](#)). Besides, hunting can take up more time to harvest the same amount of food and more animals need to be killed (Downing & Cuerrier 2011). On a positive note, thinner moose hides are appreciated by Cree hunters as they need to be treated less (CTA 2011).
- There seems to be a **decline in the amount of berries**, and some varieties dry out more due to warmer temperatures (CTA 2011; Tam et al. 2013; Downing & Cuerrier 2011).
- Some **medicinal plants** (e.g. Labrador tea) **seem to be negatively affected** by more extreme weather events or higher temperatures (Cavaliere 2009; Rapinski et al. 2014).⁸ This could lead to a **loss of certain healing practices** (CTA 2011; [Chapter 1.1](#)).
- Coastal communities have observed a **decline in geese** as they seem to **change their flight paths and stay in the region for a shorter period of time**, which could be due to changing climatic conditions, hydroelectric development (e.g. land-clearing for transmission lines), intensified hunting and other factors (Royer and Herrmann 2011; Pélouquin and Berkes 2010; [Chapter 3.1.3](#)).

Zoonoses can be passed on directly from animals to humans (Nieboer et al. 2013; Downing & Cuerrier 2011; Dudley et al. 2015) and are a public health concern (Sampasa-Kanyinga et al. 2013).

- **Large parts of the Cree population in Eeyou Istchee James Bay have been exposed to at least one zoonotic agent** (Nieboer et al. 2009; Sampasa-Kanyinga et al. 2013; Campagna et al. 2011). However, **there has been no declared human case** since at least 2012 indicating that the infected had not reported nor seen a physician, nor had been accurately diagnosed (CBHSSJB, pers. comm.; Lévesque et al. 2007), Sampasa-Kanyinga et al. 2013; Campagna et al. 2011).⁹
- **It is recommended to create more awareness about the symptoms of some zoonotic diseases among people handling wildlife** (as seropositivity is linked to hunting and trapping activities) **to lower exposure to zoonotic diseases**, while **medical staff should consider zoonotic agents, especially for**

⁸ Labrador tea, used for the treatment of various symptoms of diabetes, was collected in five communities of Eeyou Istchee James Bay and showed a reduction of its active phenolic compounds, likely due to temperature changes and solar radiation (Rapinski et al. 2014).

⁹ **Tularemia** (*F tularensis*) infecting hares, rabbits, muskrats, voles, beaver and squirrels **seems to become more common** among animals in Northern Canada in a warmer, wetter climate, and can be transmitted to humans, not only by ingestion but also when skinning animals (Downing & Cuerrier 2011); 14% to 27% (depending on the community) of the Cree showed serological evidence of exposure to *F tularensis*, which is especially linked to handling rabbits and muskrats (Sampasa-Kanyinga et al. 2013). **Leptospira** (transferred from rodents and dogs) had also a quite high seroprevalence in 10 to 27% of the studied population (*ibid.*; Campagna et al. 2011). Exposure to **snowshoe hare virus (SSH) virus** in Waswanipi, Whapmagoostui and Waskaganish was particularly high, which could be due to a “more conducive environment for mosquitoes and/or deer” (Sampasa-Kanyinga et al. 2013).

unusual cases (Lévesque et al. 2007; Campagna et al. 2011).

Figure 2 presents some actions that could be used to adapt subsistence harvesting and traditional food consumption in Eeyou Istchee James Bay; some of these actions (1-4) are being used already.

ADAPTATION OF SUBSISTENCE HARVESTING AND TRADITIONAL FOOD SYSTEMS

1. **Changing the mode or time of travel**
E.g. coastal to inland, return earlier, use another means of transportation, etc.
2. **Changing the composition of species harvested**
E.g. switching to another type of goose or harvesting new species.
3. **Modifying the timing or location of hunting activities**
E.g. CTA airlift service, avoid travel altogether or exchange on ice conditions by text message.
4. **Adopting new forms of technology**
E.g. cellular and satellite phones, radio announcements and official ice monitoring program to disseminate information (species movement, ice, etc.) or reactivation of the GeoPortal
5. **Incorporating climate change into community planning and policies**
E.g., in Wemindji, people proposed to create a coastal snowmobile road, and to adopt protected areas (Sylvänen 2011).
6. **Promoting how to incorporate traditional food into modern dishes or how to serve traditional food** in a contemporary manner to increase its consumption (Turner & Turner 2008)
E.g., in Mistissini, traditional food consumption is high which may be due to the fact that this is highly encouraged by promotional programs of the Band Council, such as free traditional meals four times a week (Laberge Gaudin et al. 2014).
7. **Incorporating traditional food resources into school curriculums** to engage youth (Turner & Turner 2008)
E.g., in biology or language classes

Figure 2: Climate change adaptation of subsistence harvesting in Eeyou Istchee James Bay

T2 diabetes and traditional food:

There are disproportionately high levels of abdominal obesity and diabetes in Eeyou Istchee James Bay leading to increased morbidity (Nieboer et al. 2013; Haddad et al. 2012). Ninety-one percent of all Eeyouch were considered obese based on waist circumference (Nieboer et al. 2013). Rapid lifestyle changes away from traditional food and transportation and abdominal obesity are considered potential factors for the high incidence of T2 diabetes in Eeyou Istchee James Bay (Haddad et al. 2012).¹⁰ Several exhaustive **studies in Eeyou Istchee James Bay found that promoting and maintaining traditional food consumption (and medicinal plant use) improves the physical health and social and spiritual well-being** of the Cree), and can thus help decrease obesity and diabetes rates (Laberge Gaudin et al. 2014; Proust et al. 2016; Dewailly et al. 2002; Uprety et al. 2012).¹¹ Certain traditional medicinal plants of the Cree have been shown to carry very **strong antidiabetic characteristics** (e.g. certain parts of balsam fir) (Nachar et al. 2015; Haddad et al. 2012).

For future research on climate-related health impacts, it will be important to use a multidisciplinary and more holistic approach as suggested by other researchers (e.g. Council of Canadian Academies 2014), and further analyze the complex relationship between climate change and the aforementioned sociocultural aspects such as food security, land access, mental and physical health. As Cunsolo et al. (2011; 2013) propose, it is important to create short- and long-term health and resilience programs and mobilize resources to encourage emotional / mental health and well-being in a context of climate change. It is also necessary to conduct more research to better understand the complex issues of mental health and well-being associated with environmental change in Eeyou Istchee James Bay on different groups of the population (e.g. elders, women, and youth).

¹⁰ Young Eeyouch consume less traditional foodstuffs than adults 40 years of age and older, and replace them with high-sugar and high-fat foods (Nieboer et al. 2013; Khalil et al. 2010). Young Eeyouch are diagnosed 3-5 times more often than non-Indigenous youth in Quebec with T2 diabetes (Haddad et al. 2012).

¹¹ In fact, people who eat traditional food 3 days or more weekly were also more likely to walk at least 30 minutes a day (Laberge Gaudin et al. 2014).

CHAPTER II – IMPACTS OF GLOBAL WARMING ON THE REGIONAL CLIMATE OF EYYOU ISTCHEE JAMES BAY

Eeyou Istchee James Bay is highly influenced by its continental location in proximity to a large body of water (James / Hudson Bay) with seasonal ice and a high discharge of relatively warm fresh water. Furthermore, Arctic air masses can easily enter James Bay in winter due to the sea ice cover. This presence of ice and water leads to a cooling effect in spring and a warming effect in fall and early winter. The thermal contrasts between land, ice and water bodies influence atmospheric stability, and consequently, air temperature, precipitation, winds and fog. (Brown et al. 2014)

The sparse observing network, a significant influence of local factors on the regional climate and the harsh Northern climate conditions make it difficult to describe the historic evolution of the climate and project potential climate change in Northern environments such as Eeyou Istchee James Bay (Rapaic et al. 2015; Steiner et al. 2013; Charron 2015). In Canada, there are also some data-related problems with respect to climate trends due to changes in terms of observation, instrumentation and relocation of weather stations (Vincent et al. 2015).

- **Historic regional climate data in Eeyou Istchee James Bay is particularly limited** due to the sparsity of weather stations of which only three have data spanning more than 20 years (Niemi et al. 2016; Royer 2013). These three stations are situated in proximity to Chapais, Whapmagoostui and la Grande Rivière.

Apart from these data-related problems, **multi-decadal climate variability related to large-scale oscillations such as the North Atlantic Oscillation (NAO) may also mask or strengthen climate trends** (Vincent et al. 2015), such as observed in Labrador (Wang and Viau 2014). Finally, **hydroelectric development or other industrial activities may add to the modification of local climate conditions** (Déry et al. 2016; Macdonald & Kuzyk 2011). For example, some models showed that the impoundment of the La Grande reservoir led to a localized cooling effect of air temperature in summer and a warming effect in the winter, comparable to the effects of lakes on local temperature (Irambona et al. 2016; Huziy & Sushama 2016).

The following section describes in more detail the climate conditions that prevail in the Eeyou Istchee James Bay region discussing changes of several climate parameters. It highlights i) instrumentally measured past changes, especially since the mid-20th century, ii) projected changes for the mid-21st century (climate models), and iii) local observations by the Cree, mainly from hunters and trappers, tallymen, and officials of the CNG department of the Environment and Remedial Works. In the absence of specific local information, available information for Hudson Bay (HB) will be used.

2.1 TEMPERATURE

According to the IPCC (2014), the “warming of the climate system is unequivocal” with much warmer air and water temperatures, especially since the 1950s, which have not been observed for decades to millennia. In Eeyou Istchee James Bay, air temperature has constantly warmed since 1918 with a “significant warming trend” since 1992 (Steiner et al. 2013). *Table 4* describes past and future changes of air temperature in Eeyou Istchee James Bay.

The temperature series are characterized by important year-to-year variability linked to large scale oscillations in atmospheric circulation, such as the North Atlantic Oscillation and the Eastern Pacific-North Pacific pattern, which play a crucial role for the climate in Eastern Canada (Way et al. 2017; R. Brown, pers.

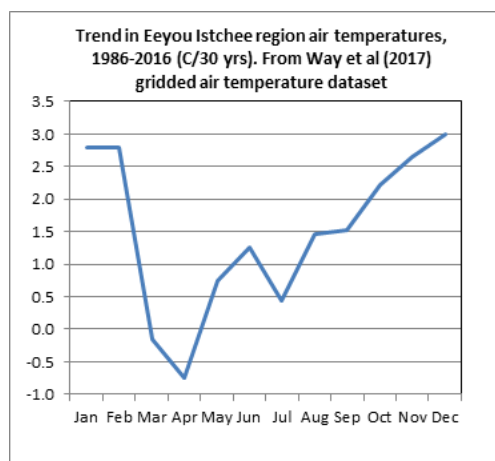
comm.). Studies in Labrador underline that current climate models cannot reproduce variability of air temperature, and observations can differ from models (Way & Viau 2014). In this context, local observations become even more important to understand temperature changes.

Table 3: Trends and observations of air temperature in Eeyou Istchee James Bay

AIR TEMPERATURE IN EYYOU ISTCHEE JAMES BAY		
Past	Cree observations	Future (2050)
✚ Temperature increase between 1,5-3°C with an accelerated warming in the last 30 years, especially in fall and winter(see Appendix 6); ✚ 12 of the 17 warmest summers in HB occurred between 1991 and 2009 with a warming trend of +0.1 to +0.3°C/decade since the 1930s; ✚ Rising surface air temperature (SAT) over HB: 0.6-0.8°C/decade (autumn) and 0.32°C/decade (spring).	✚ Warmer temperatures, more heat waves, and the sun seems stronger in the winter months; ✚ Summers are longer and hotter.	✚ Higher rate of temperature increase than globally, especially during the colder months; ✚ Rise of 3.6 °C (RCP 4.5¹²) / 3.7°C (RCP 8.5) of annual mean T; increase by 5.5 -5.7°C in Dec-Jan-Feb, and 2.2-2.4°C in June-July-Aug; ✚ More extremely warm periods and significant warming of minimum temperature of the coldest day.

Information retrieved from Brown et al. 2014; Hochheim et al. 2010; Ouranos 2015; Way et al. 2017; Estilow et al. 2015; Steiner et al. 2013; Steiner et al. 2015; Loder et al. 2015; CTA 2011; Royer 2016; Voyageur and McLean 2017, Larivière 2011; Royer et al. 2013; Diaconescu 2017; and Price et al. 2013.

The confidence level for temperature data is generally high, but there is uncertainty with respect to regional variability



[Appendix 5](#) shows the most recent 30 year period (1987-2016) of monthly air temperature trends in Eeyou Istchee James Bay. **The observed warming of mean annual air temperatures averaged over the region is ~1.5 C, but there is a strong north-south gradient as well as very different seasonal results.**

- The North has warmed more than the South;
- Winter temperatures have warmed about 2-3°C;
- Summer has warmed much less (1- 1.5°C);
- Spring (March-April) did not warm at all.

Figure 3: Monthly air temperature trends in Eeyou Istchee James

2.2 SEASONS, WEATHER PATTERNS AND EXTREME EVENTS

Seasonal changes driven by climate change, such as **later freeze-up and earlier breakup, longer/hotter summers and shorter / milder winters have been observed frequently in Eeyou Istchee James Bay** (FNQLSDI 2017; CTA 2011, Voyageur and McLean 2017; Syvänen 2011; Larivière 2011). These modifications impair the ability to foresee when and where to harvest (Voyageur and McLean 2017; [Chapters 1.1 & 1.4](#)). They thereby **affect the traditional harvesting cycle of the Cree** which is based on six seasons and the traditional activities associated with each season (see [Appendix 4](#)). In addition to modifying the seasons, climate change will affect weather patterns and increase the frequency and magnitude of extreme weather events (e.g. heavy precipitation, heat waves, flooding; storms) (IPCC 2014; compare [Appendix 6](#)). *Table 3* describes past and

¹² RCPs are climate classifications established by the IPCC. RCP 8.5 represents a global average warming of 4.9°C while RCP 4.5 represents a global average warming of 2.4°C.

future changes in weather patterns and phenomena as well as extreme meteorological events in Eeyou Istchee James Bay.

Table 4: Trends and observations of weather patterns in Eeyou Istchee James Bay

WEATHER PATTERNS AND EXTREME WEATHER EVENTS IN EYYOU ISTCHEE JAMES BAY		
Past	Cree observations	Future (2050)
- Period with above-freezing air temperature is 23 days longer than in 1925 (Kuujjuarapik); Longer growing season; More freeze-thaw events in autumn and less in spring. Wind gusts increased with rising air temperature and lower pressure across Canada (1953-2009);	Increase in the number of extreme weather events such as more lightning storms, and more frequent inland flooding¹³; Stronger thunderstorms in some regions while weaker in others; More unpredictable weather and sudden weather changes¹⁴; Unpredictable navigation, such as on Mistissini Lake; High inter- and intra-annual seasonal variability impeding weather forecasting; Change of the dominant wind direction and wind throws; The cold is more humid and goes under the skin; Winters are 2 months longer.	Higher frequency and intensity of extreme weather events; More torrential rains; Slight change of mean wind speed $\pm 5\%$ (high uncertainty), no information on wind direction; - Potentially high increase in daily wind gusts, especially in the summer (+50% at Grande Rivière station) for the end of the 21st century; Higher wave and storm surge potential in HB due to the diminished sea ice in fall/early winter (risks of coastal erosion/flooding); 15-20% increase in storm frequency and duration in HB (high uncertainty)¹⁵; Impossible to project lightning, fog and freezing rain for Quebec (insufficient information and limited research and capacity of climate models).

Information retrieved from Ouranos 2015; Charron 2015; Steiner et al. 2013; Brown et al. 2014; Savard 2016; Voyageur and McLean 2017; Syvänen 2011; FNQLSDI 2017; Royer 2016; Larivière 2011; Downing & Cuerrier 2011; CTA 2011; Cheng 2014; Cheng et al. 2014; and P. Grenier (pers. comm.).

The confidence level for weather patterns is low or undetermined for several weather phenomena

2.3 PRECIPITATION (RAIN AND SNOW)

According to the last IPCC report (2014), high latitudes are likely to experience an increase in mean annual precipitation. *Table 5* outlines past and future changes in precipitation Eeyou Istchee James Bay. Analysis of precipitation data from Kuujjuarapik Airport over 1957-2012 show **no evidence of any trends in annual or seasonal total precipitation, but a significant decrease in the fraction of precipitation falling as snow in response to warming (i.e. more rain)** (R. Brown, pers. comm.; Brown et al. 2014).

The timing (snow-on and snow-off dates), amount and physical properties of snow cover have important impacts on a wide range of ecosystem services (Callaghan et al. 2011). The longest record of daily snow depth observations in the region are from Kuujjuarapik Airport which has more or less continuous observations since 1950. *Table 6* outlines past and future changes in snow cover in Eeyou Istchee James Bay. While the data at Kuujjuarapik indicate that the **duration of snow on the ground at this location has declined at a rate of 3 days/decade** since 1950, and that **current maximum depths are decreasing**, analysis of snow survey data within the larger Eeyou Istchee James Bay territory (50-56N, 70-79W) shows **large year-to-year variability**. Similarly, analysis of spring snow cover duration showed only slight evidence (-1 day per decade over 1972-2016) of earlier snowmelt over the larger Eeyou Istchee James Bay region (Estilow et al. 2015). The different results at Kuujjuarapik may reflect the observing site where snow accumulates on an open surface that is not representative of the prevailing land cover of the region. Results from other climate simulations suggest the

¹³ Inland flooding has been mainly associated with rapid ice melt in spring, high water levels in rivers and torrential rains in five Cree communities, and floods are sometimes perceived as being more intense (FNQLSDI 2017). The 100 year flood of Temiscamie river (spring 2014) occurred only 5 years after another 100 year flood in the same watershed (Voyageur and McLean 2017).

¹⁴ For example, the Cree find it difficult to forecast incoming storms, fog occurs at unusual moments and people have noticed an unpredictable tide-wind relationship (Wemindji); hunters also take spare gas and food in case the weather changes (Whapmagoostui).

¹⁵ This is due to the fact that higher thermal contrasts increase the potential for cyclone redevelopment in fall and early winter. Impacts could be compensated by the drop of sea level (see Savard 2016).

likelihood of differing snow cover trends across the region: decreasing in the North and increasing in the South (R. Brown, pers. comm.).

Table 5: Trends and observations of precipitation in Eeyou Istchee James Bay

PRECIPITATION IN EYYOU ISTCHEE JAMES BAY		
Past	Cree observations	Future (2050)
✚ Increase in mean annual total rain and seasonal rainfall (winter / autumn) at Chapais & Kuujjuarapik. ✚ Decrease of summer rainfall in the coastal regions of James Bay. ✚ Significant decline of total precipitation falling as snow at Kuujjuarapik. ✚ Increase by 0.03 mm/day per decade (1961-2005) in HB.	✚ More rainfall, more drizzle; ✚ Local variability with some communities even reporting drier conditions; ✚ More heavy rainfall (shorter duration) leading to peak levels in waterbodies and flooding.	✚ Increase in total precipitation in Central Quebec¹⁶ for all seasons: 6-17% depending on the scenario; ✚ More frequent extreme precipitation;

Information retrieved from Steiner et al. 2013; Chassé et al. 2013; Ouranos 2015; IPCC 2014; Royer et al. 2013; Price et al. 2013; Voyageur and McLean 2017; Vincent et al. 2015; Brown et al. 2014; and CTA 2011.

The confidence level for precipitation data is low due to data limitation

Table 6: Trends and observations of snow cover and depth in Eeyou Istchee James Bay

SNOW COVER IN EYYOU ISTCHEE JAMES BAY		
Past	Cree observations	Future (2050) ¹⁷
✚ Significant decrease of snow fall in Kuujjuarapik where snow season is about 50 days shorter (compared to 1960-1970); ✚ Maximum snow depths occurs one month earlier in Kuujjuarapik in response to earlier melt (but higher variability after 1990s); ✚ Annual maximum snow depth decreased by approx. 40 cm (1960-1990) but increased recently. ✚ Decrease of snow cover duration in Southern James Bay and earlier snow melt.	✚ Later snowfall; ✚ Less snow (layers) has prevented hunters from making their blinds; ✚ Snow quality has changed and the snow is now softer: difficult travelling conditions; slushy in spring; ✚ Less but stronger snowstorms; ✚ Snow melts faster in spring.	✚ Reduction of snow cover by 25-45 days in Central Quebec; ✚ Later snow fall; ✚ Earlier thawing; ✚ About 20 cm less snow in the lowlands of Central Quebec¹⁸ and snow depth maximum in March.

Information retrieved from Brown et al. 2014; Ouranos 2015; Gough and Leung 2002; Royer 2016; Syvänen 2011; Vincent et al. 2015; CTA 2011; and R. Brown, pers. comm.

The confidence level for snow data is low due to a regional variability of vegetation cover, a lack of regional snow cover observations and the difficulty of mapping snow cover with visible satellites

2.4 ICE REGIMES (SEA AND LAKE ICE)

Sea ice decrease in extent and thickness ([Appendix 7](#)) and the positive feedback between temperature and ice reduction is considered one of the main reasons contributing to the Arctic warming much faster than other regions (Parkinson 2014). The minimum Arctic sea ice extent at the end of the summer 2016 was the second lowest in the satellite record since 1979, and Hudson Bay sea ice cover reduction is one of the highest in the circumpolar Arctic (Richter-Menge et al. 2016; Tivy et al. 2011). **Studies in the Hudson Bay system have shown that for every 1°C increase in surface air temperature (SAT) sea ice extent decreases by 14% of basin area, and an increase in 1°C in SAT delays freeze-up by 0.7 weeks** since it is closely linked to fall SATs (Hochheim & Barber 2014). In James Bay, freeze-up usually occurs after mid-November (between early November and early December) and ice melt starts in late April with most of the Bay being open water by

¹⁶ Climate models used to calculate precipitation data were based on the climate scenario RCP 8.5 ("business as usual")

¹⁷ Climate models to calculate snow data are based on RCP8.5 ("business as usual") scenario for 2041-2070. Central Quebec covers most of Eeyou Istchee James Bay. For more information see Ouranos 2015 (Chapter 1.4).

¹⁸ Calculation based on snow water content (SWE), the water level that can be measured when snow has melted completely. The ratio used is 10:1 where 10 cm of snow equal 10mm of water.

mid-July (ECCC 2017). *Table 7* describes past and future changes of sea ice and inland ice.

Table 7: Trends and observations of ice regimes in Eeyou Istchee James Bay

SEA ICE EXTENT AND SEASON AND LAKE/RIVER ICE IN EYYOU ISTCHEE JAMES BAY		
Past	Cree observations	Future (2050)
✚ Shortening of sea ice season in Eastern James Bay by approx. 10 days/decade (1979 -2013), locally even 30 days (close to Chisasibi and Waskaganish) (<i>Appendix 8</i>); ✚ Decrease of sea ice extent in Eastern HB by -11.5 $\pm$6.8%/ decade (1968-2008) and acceleration of sea ice extent decline in HB (1979-2010)¹⁹; ✚ Freeze-up is 1.6 weeks later and breakup is 1.5 weeks earlier in HB (1980-1995 vs. 1996-2010, trend acceleration); ✚ Accelerated warming of SAT and decrease of sea ice extent in autumn versus spring in HB (since 1989).	✚ Less and thinner ice on the Bay; ✚ Less or thinner ice on rivers and lakes; more water pockets and absence of ice shards; ✚ No more blue ice / more white ice and very thin layers of ice on lakes and rivers as too much snow covers the ice preventing it from freezing; ✚ Earlier melting and later freeze-up of inland ice shortens safe hunting period as lakes are still slushy and covered with holes.	✚ 50% loss of ice thickness in JB and great changes in heat content (<i>Appendix 7</i>); ✚ Ice-free period in HB will be 2 months longer; ✚ Freeze-up will occur 25-30 days later while breakup will arrive 22-25 days earlier for HB in comparison to 1961-1990.

Information retrieved from Steiner et al. 2013; Tivy et al. 2011; Cavalieri & Parkinson 2012; Kowal et al. 2017; Hochheim & Barber 2014; Hochheim & Barber 2010; Joly et al. 2011; Brown et al. 2014; Parkinson 2014; Ouranos 2015; FNQLSDI 2017; Syv nen 2011; Voyageur and McLean 2017; Macdonald & Kuzyk 2011; Royer et al. 2013; and Latifovic & Pouliot 2007.

The confidence level for sea ice is generally high

The subarctic region also accounts for a high density of lakes making them an important component of the cryosphere (Brown & Duguay 2010). These lakes have hardly been studied (Keller et al. 2014; CNG, pers. comm.) as studies focused more on sea ice. The formation of lake ice is affected by snow accumulation, wind velocity and air temperature, all of which can be altered by climate change (Brown & Duguay 2010; Latifovic & Pouliot 2007; B langer et al. 2013). RADARSAT images are a potential source of information to study ice phenology (Duguay et al. 2002). **So far, only one study has been conducted in central Eeyou Istchee James Bay (Lake Nitchequon), which showed later freeze-up and earlier breakup dates** (Brown & Duguay 2010). A study by B langer et al. (2013) projected significant changes in terms of stratification and shifts in mixing due to warmer summer temperature and later freeze-up until the end of the century. Hydrological research would provide further understanding of climate change on seasonal ice mechanism and dynamics.

2.5 WATER LEVELS AND PROPERTIES

James Bay receives 47% of the total freshwater input in Hudson Bay (Kuzyk 2014). Freshwater input, ice cover and surface heat flux all influence the distribution of water temperature and salinity levels in James Bay/Hudson Bay (Steiner et al. 2013; Kuzyk et al. 2008). **Sea surface temperature (SST) in Hudson Bay has warmed at 6 times the global trend and at almost twice the rate of polar warming** (Brand et al. 2014; Galbraith & Larouche 2011). This accelerated warming of SST correlates with the decrease of sea ice, in particular earlier breakup, and associated with this polar amplification.

No quantitative salinity trend analysis has been carried out in Hudson Bay, but **altered freshwater dynamics such as higher water levels or different pathways**, e.g. due to climate change, **could change deep water formation and freshwater dynamics** (Steiner et al. 2013; Granskog et al. 2011). Higher river discharge can also increase the ablation of sea ice in estuaries, is an important source of contaminants, and affects primary production positively by adding nutrients (Kuzyk et al. 2008; Hare et al. 2008; Kuzyk et al. 2010). A 20-year upward trend in river discharge has been projected by climate models, but it needs to be verified through monitoring if it is due to the variability of large-scale oscillation patterns such as changes in the Arctic

¹⁹ The largest negative values were observed for summer (-19.1 $\pm$ 3.9%/decade) followed by autumn (-12.9 $\pm$ 2.4% / decade) (Cavalieri and Parkinson 2012; Kowal et al. 2017).

Oscillation or global warming (Déry et al. 2011). Moreover, **major flow modifications and diversion of nine rivers in James Bay for hydropower generation**, such as the construction of the La Grande complex and diversion of the Caniapiscaw und Rupert rivers that have flooded more than 10,000 km², **have likely been modifying near shore oceanography significantly and impacting annual river discharge such as by diverging inflows from summer to winter** (Macdonald & Kuzyk 2011). All of these challenges need to be taken into consideration when assessing changes in water levels and flows (Déry et al. 2016; Macdonald & Kuzyk 2011).

Table 8 describes past and future water levels and properties in Hudson and James Bay in the context of climate change. No local observations have been recorded concerning sea surface temperature and changes of river discharge in relation to climate change.

Table 8: Trends and observations of water levels and properties in Eeyou Istchee James Bay

SEA SURFACE TEMPERATURE (SST), SALINITY AND RIVER DISCHARGE IN HUDSON/JAMES BAY	
Past	Future (2050)
✚ SST warming trend in JB: +0.25-0.5°C/decade from 1985-2013 (high in comparison with global trends 0.11°C/decade); ✚ Accelerated SST warming trend since 1965 and increase by 3.7°C in HB (1920-2011); ✚ Increase in maximum summer SST by 0,7 to 1,3°C in HB (1985-2011); ✚ Increase in river discharge since early 1990s with record annual discharge in 2005 (may be sign of intensification of hydrological cycle).	✚ SST increase in HB by 1-1.5°C, depending on the model: 0.22±0.08°C/decade; ✚ Decrease of pH in HB by 0.06 to 0.22 units; ✚ 2-15% increase in river discharge, possibly due to more precipitations, quick winter thaw, earlier spring snowmelt; ✚ Earlier onset of maximum river discharge between -10.3 and -12.6 days/century; ✚ Greatest increase in discharge in the Eastern and Northern portion of HB; ✚ Faster increase in river discharge in the future.

Information retrieved from Larouche & Galbraith 2016; Brand et al. 2014; Niemi et al. 2016; Steiner et al. 2013; Déry et al. 2016; Macdonald & Kuzyk 2011; Stadnyk et al. 2017-unpublished data; Orlova et al. 2014; IPCC 2014; Déry et al. 2011; Déry et al. 2009; Ouranos 2015 and Chassé et al. 2013.

The confidence level depends on the parameter, high for SST, medium for discharge

Sea level rise in response to climate change has been observed around the globe. However, **James Bay and most parts of the Canadian Arctic are experiencing isostatic rebound** which implies an emergence of land masses suppressed from heavy ice sheets during the last glacial period ([Appendix 9](#)). Isostatic rebound in some parts of the Hudson Bay coast is among the highest in the world (Keller et al. 2014), and results in an uplift of 10mm/year in Hudson Bay, exceeding global sea level rise (Tarasov & Peltier 2004). This process will likely continue for at least the next 1000 years (Tsuji et al. 2009). For example, **relative sea level has dropped by almost 0.5m since 1979** in the region around Grande Rivière (Savard 2016).

Considering the amplitude of past and projected changes as well as the regional diversity of Eeyou Istchee James Bay, a detailed, local study of several climatic parameters is recommended. Research should equally rely on local observations/traditional knowledge of the Cree and scientific methods (e.g. re-analysis) to identify high risk events. This kind of research will be crucial to establish more reliable baseline data and a reference climate. More reliable baseline data could be used for vulnerability assessments and community planning, thereby increasing the adaptation capacity of individuals, communities and project proponents. Research on lake ice mechanisms and dynamics as well as spatial variability should be improved, snow cover trends and precipitation are recommended given their importance for land access and subsistence harvesting. Further research on the interactions between the marine and freshwater systems is also necessary. Conducting studies on ocean dynamics and bathymetric mapping would be useful to better understand storm systems, water properties and wave action, track biological and ecological changes, capture isostatic rebound in the area and ensure marine and coastal safety.

CHAPTER III – IMPACTS ON ECOSYSTEMS

Over the course of the past 50 years, ecosystems have been degraded by human influence “more rapidly and extensively than in any comparable period of time in human history” (Millenium Ecosystem Assessment 2005: 1; Costanza et al. 2017). When ecosystem services²⁰ are degraded, the whole ecosystem may become less resilient. The changes in the physical components of the regional climate system ([Chapter 2](#)) impact aquatic and terrestrial ecosystems at different geographical and time scales. **Climate change will affect all levels of biodiversity from organisms to biomes** (Rinawati et al. 2013; Bellard et al. 2012). For example, it can alter genetic diversity, affect species distribution and life cycles, change trophic interactions at the community level, and disrupt the ecological integrity of whole biomes (*ibid.*). **Climate change is a cumulative stressor; it affects ecosystems in multiple ways, and can interact with or modulate other stressors such as industry, harvest, human population growth and contaminants** (Wrona et al. 2006; Niemi et al. 2016; Woodward and Perkins 2015). Rapid climate change could overwhelm the resilience of ecosystems and consequently, lead to degradation, temporary or permanent loss of various ecosystem services.

According to experts, climate change could surpass habitat destruction becoming the most important factor of biodiversity loss in the upcoming decades (Bellard et al. 2012). However, **some regions may actually become richer in terms of species numbers in a warmer climate, such as subarctic Quebec** (Berteaux et al. 2014). However, it remains very difficult to predict future biodiversity as it cannot only be measured in terms of species richness. Other biodiversity indices such as genetic diversity, ecosystem diversity, habitat quality or trophic interactions also need to be considered, as well as alien species that could negatively affect overall biodiversity in Quebec even if species richness increases (R. Siron, pers. comm.). As studies suggest, **it remains rather uncertain which species will be able to adapt quickly** enough to rapid anthropogenic climate change²¹, but the CC-Bio project in Quebec showed that species with a high genetic variability and short generation time are more likely to adapt (Berteaux et al. 2004; Gilg et al. 2012; Berteaux et al. 2010).

3.1 AQUATIC ECOSYSTEMS

3.1.1 JAMES /HUDSON BAY MARINE ECOSYSTEMS

Poloczanska et al. (2013) analyzed more than 200 studies on climate change impacts on marine ecosystems and found widespread evidence from around the world. **Global warming has been affecting marine ecosystems and has already led and will further lead to poleward shifts of phytoplankton and marine ectothermal animals, decoupling of resource requirements and availability, raising the extinction risks and increasing/decreasing suitable habitat for certain species in Canada’s oceans** (Drinkwater et al. 2009; Hutchings et al. 2012). For example, range shifts of marine species due to warmer temperatures and the intrusion of invasive species have been documented in Canadian Arctic waters (Niemi et al. 2016; ESSA 2017; Stewart & Lockhart 2004). Ocean acidification and an under-saturation of calcium carbonate, which negatively

²⁰ According to the Millenium Ecosystem Assessment (2005), ecosystem services include: a) provisioning services such as food, fresh water, energy and transportation; b) supporting services such as photosynthesis, carbon storage, water and habitat; c) regulating services such as climate regulation, water purification or protection from physical hazards; and d) cultural services such as recreation, education or spiritual support. Many of these functions have both a high social and economic value. The economic value has not been studied much due to its complex nature, e.g. determining the value of an ecosystem service such as protection and absorption of extreme weather events. However, the value of the nonmarket ecosystem services delivered by Canadas’s boreal forest were estimated at \$703 billion, which represents a tenfold of the market value related to commercial wood extraction (Hutchings et al. 2012). It is therefore very important, on both the socio-environmental and economic level, to preserve these precious ecosystem services.

²¹ Species can adapt to change along three axes: time (e.g. by adapting their phenology), space (e.g. by adjusting their range), and self (e.g. by modifying their physiology) (*ibid.*). Thus, species can react to climate change either by a) staying in the same region and adapting to the new conditions, b) by migrating c) by disappearing completely because they can neither adapt nor migrate (Berteaux et al. 2014; Rinawati et al. 2013; Berteaux et al. 2010).

affects invertebrates and fish using calcium to build their shells and skeletons, have been documented in the North Atlantic ocean and close to Alaska (Niemi et al. 2010; Hutchings et al. 2012; Lovejoy 2010).

Ice extent and season, freshwater discharge and input of terrestrial organic matter play a crucial role in the transformations of the ocean (Macdonald et al. 2015). Sea ice loss and higher sea surface temperature (SST) ([Chapters 2.4 & 2.5](#)) are good indicators of change in marine ecosystems because of their crucial functional and structural roles, especially in Northern latitudes (Hoegh-Guldberg & Bruno 2010; Larouche & Galbraith 2016; Niemi et al. 2010).²² According to an exhaustive expert report produced for the Royal Society of Canada the **impacts of climate change on biodiversity in Canada's oceans are and will be significant** (Hutchings et al. 2012). Climate change will most likely cause more permanent changes on biodiversity than fisheries or aquaculture (*ibid.*), or exacerbate their impacts (R. Siron, pers. comm.). **It is likely that many changes are already happening, but have not been described yet or can hardly be documented due to missing baseline information** (Wassmann et al. 2011)²³.

3.1.2 MARINE FLORA AND FAUNA

Marine organisms tend to show faster spread rates than terrestrial species, mainly due to dispersal by ocean currents. According to an extensive synthesis of the peer-reviewed literature, which found 1735 biological responses of marine species to climate change, marine species respond differently to changes with the fastest range expansions occurring in phytoplankton, bony fish, and invertebrate zooplankton. Globally, **spring phenology in the ocean has shifted from 4.4±0.7 days/decade and summer phenology by 4.4±1.1 days/decade at latitudes above 45°**. (Poloczanska et al. 2013)

Primary production:

The warming climate could have major implications for fisheries in Canada due to more pronounced vertical stratification, and thus impacts on primary production²⁴ and marine food webs (Larouche & Galbraith 2016). The marine ecosystem in Hudson Bay is characterized by a small number of trophic linkages. This implies a higher vulnerability of trophic dynamics to changes such as increased primary production (Grebmeier et al. 2006; Niemi et al. 2010). **Phytoplankton distribution, abundance, phenology and productivity will probably change with increasing water temperatures** since plankton are sensitive to temperature changes and react more quickly than species on land (Hoegh-Guldberg & Bruno 2010; Hutchings et al. 2012; Poloczanska et al. 2013). An earlier phytoplankton bloom has been observed in several international studies (*ibid.*). In the Arctic Ocean, a reorganization of the seasonality of the plankton food web has been documented with a longer phytoplankton growing season due to the longer open water season and more upwelling events (Arrigo & van Dijken 2015; Barber et al. 2012). **There is no information on primary production specifically referring to James Bay**. Therefore the following information applying to the whole of Hudson Bay is presented.

- **In Hudson Bay, primary production could be modified** due to changes in the physical environment but it is difficult to declare a general trend since data is too scarce (Steiner et al. 2013).
- **Phytoplankton biomass has increased by 20-25% while primary production has increased by 15-20%**

²² For instance, sea ice regulates the transfer of moisture, heat and gas through the ocean-sea-ice-atmosphere interface due to its high surface albedo and low thermal conductivity, thereby playing an important role in the reaction of ecosystems to climate change (Barber et al. 2012). Sea ice extent further influences surface water stratification, heat exchange, nutrient dispersal due to mixing or upwelling, as well as light penetration depth and timing (Brand et al. 2014; Barber et al. 2012; Drinkwater et al. 2009). Temperature, turbulence and advection also influence marine ecosystems (Drinkwater et al. 2009).

²³ Currently, researchers at the BAYSIS project (<http://www.asp-net.org/content/baysys-hudson-bay-system-study#overlay-context=node/7>) are examining the influence of freshwater on Hudson Bay marine and coastal systems, and will provide a scientific basis separating climate-related impacts from impacts caused by freshwater flow modifications on physical, biological and biogeochemical conditions.

²⁴ Primary production in the oceans refers to the activity of phytoplankton (microscopic organisms living in the sunlit layer of almost all water bodies) absorbing energy through photosynthesis and using carbon dioxide to produce biomass, which then serves as nutrition for zooplankton and other species.

(Frey et al. 2017; Steiner et al. 2013; Drinkwater et al. 2009)²⁵, especially between 2003 and 2016 (Frey et al. 2017).

Phytoplankton biomass may have increased in response to higher light availability (Richter-Menge et al. 2016; Tremblay et al. 2011). **Loss of sea ice decreases under-ice phytoplankton blooms** in Hudson Bay (Niemi et al. 2016; Hoover et al. 2013). Model results show that less ice algae and ice detritus lead to a **decrease of benthos and benthic fish** while at the same time increasing pelagic production, fish with a more pelagic diet will increase in contrast to species relying on benthic groups for food (Hoover et al. 2013; Drinkwater et al. 2009; Barber et al. 2012; Sibert et al. 2010).

To date, there is no information on primary production specifically referring to James Bay. Additional research needs to be conducted to confirm or dismiss the above mentioned trends for Hudson Bay and more locally for James Bay. Once published, the ArcticNet Integrated Regional Impact Study (IRIS) 3 report on the Hudson Bay complex will also provide additional information.

Zooplankton and higher trophic levels:

Impacts on lower trophic levels lead to impacts on higher trophic levels such as crustaceans, fish, seabirds and mammals (Gaston et al. 2012). These species react to climate-induced changes in different ways over varying spatial and temporal scales (Drinkwater et al. 2009). Climate change could provoke a change of the dominant zooplankton species in the world's oceans and potentially a northward migration of some species (Kjellerup et al. 2012; Villarino et al. 2015). Globally, spring **zooplankton phenology has advanced significantly by 11.6±2.9 days/decade** (Poloczanska et al. 2013). **For Hudson and James Bay, no clear trend can be established yet** (Steiner et al. 2013).

Model projections show that species will change their latitudinal and depth ranges in Canada's oceans (Hutchings et al. 2012). Shifts in habitat use such as for spawning or migration may have already occurred in Hudson Bay but no trend can be established due to a lack of data (Niemi et al. 2010). **Diseases** (pathogenic viruses/bacteria) **may spread increasingly in the future and affect marine mammals in Hudson Bay** (*ibid.*). The current climate is the main factor preventing invasion from non-indigenous aquatic species into the region and in a warmer climate this barrier could be removed (Niemi et al. 2016; Stewart & Lockhart 2004). Besides, the seaport at Churchill is vulnerable to the introduction, establishment or spread of invasive species, which could migrate to James Bay (Niemi et al. 2016).

At a global scale, fish species will react differently depending on their habitat requirements, life-history characteristics (short- or long-lived; specialist or generalist) and trophic position (predator or forage fish) – all of which determine their vulnerability (Rijnsdorp et al. 2009). Physiological processes such as growth, development and spawning are significantly influenced by temperature, which is considered the most important abiotic variable in terms of survival and growth (Sharma et al. 2007). **Fish growth, swimming speed and activity rates, reproduction, phenology, distribution, recruitment success and mortality are very sensitive to changing water temperatures, vertical stratification, mixed layer depth, sea ice, turbulence effects and advection** (Drinkwater et al. 2009). For instance, spawning time is earlier in warmer water; oxygen supply at different temperatures affects behaviour and reproduction; distributional changes can change ecosystem composition due to different migration rates, etc. (Drinkwater et al. 2009). Some of these changes have already been observed in different fish species, for example in the North Atlantic Ocean (Rijnsdorp et al. 2009).

Modifications due to climate change have been observed in Arctic marine birds; e.g. thick-billed murre in Nunavut switched their diet from Arctic cod to a more subarctic fish species (capelin) which seemed to affect chick growth and implies a higher availability and northward migration of capelin (Gaston et al. 2012). These

²⁵ As observed from satellite-derive data which doesn't show changes in deep waters (Steiner et al. 2013).

changes in phenology and migration patterns of species can have impacts on accessibility and availability to hunters (Hauser et al. 2017) ([Chapter 1.4](#)).

Global studies have investigated the potential and observed effects of climate change on fish, marine birds and marine mammals, but no such study has been conducted exclusively for James Bay. It is important to identify key species for the marine ecosystems and for local subsistence activities and economies (e.g. tourism), and conduct research on their response to climatic changes such as water temperature ([Chapter 2.5](#)), decrease of sea ice ([Chapter 2.4](#)) or increase in storm surges ([Chapter 2.2](#)).

3.1.3 COASTAL ZONES AND ESTUARIES

Permafrost has decreased by 80% since the mid-20th century due to increasing air temperatures ([Chapter 2.1](#)) and snow cover ([Chapter 2.3](#)) along the eastern coast of Hudson Bay, which has also led to a threefold increase in vegetation cover (Bouchard et al. 2014). Analysis showed a recent 130 km northward regression of permafrost while it is already very limited/marginal in James Bay (Thibault and Payette 2009).

- **Plants seem to grow higher along the coast** in some areas (Waskaganish) **while they have taken on a rusty colour and look sick** in other areas (Whapmagoostui) (CTA 2011);
- The Cree have observed the **drying up of wetlands and an overgrowth of vegetation along the coast preventing geese from stopping over and affecting rabbit and ptarmigan food sources** (CTA 2011; Rover and Herrmann 2011);
- Eeyouch have reported that **geese offspring do not grow sufficiently because vegetation is not at its maximum anymore when eggs hatch** (CTA 2011).

Coastal zones and estuaries are very productive zones that provide habitat for a multitude of species. Ice cover has an important impact on wave amplitude, current, salinity intrusion, sediment transportation processes and residual circulation in the estuary (Wang et al. 2012). These processes will most likely change in the future with less ice cover ([Chapter 2.4](#)), which could have positive or negative effects on coastal and marine ecosystems. According to Niemi et al. (2016), **increased stratification in estuaries due to higher freshwater inputs such as in Hudson Bay ([Chapter 2.5](#)) will likely shift fish community compositions in favour of euryhaline and anadromous species over marine species** (see also [Chapter 3.1.2](#)).

- **The composition of fish species has changed** (e.g. more sucker and less white fish) and **fish numbers seem to be decreasing** in Waskaganish and Whapmagoostui (CTA 2011).
- **Eelgrass along James Bay is decreasing** which may be due to multiple effects including climate change and modifications induced by hydroelectric development (*ibid.*). Considering that eelgrass survival and production is mainly driven by light, temperature and nutrients, climate change will likely induce changes in this plant by modifying these key parameters (Kaldy et al. 2014)²⁶. The reduction of eelgrass is often associated with the decline in geese on the coast.

Gaps in research need to be addressed in James Bay because “research on key species and an overall understanding of the coastal system is lacking” (ArcticNet website). For example, it needs to be researched which factors really influence eelgrass production in James Bay, or which fish species, especially those harvested by the Cree, will be affected (positively and negatively) by changes in water characteristics and coastal dynamics.

²⁶ Northward eel grass migration has already been documented for America’s East coast (Lovejoy 2008). Eelgrass reduction may be responsible for the lower numbers of geese stopping on Eastern James Bay on their migration routes, according to many Cree hunters, but more research is needed to determine which factors really influence eelgrass production in James Bay.

3.1.4 FRESHWATER ECOSYSTEMS (LAKES AND RIVERS)

The global understanding of how freshwater ecosystem processes and individual species will react to climate change is good, but there is little information on species community responses and synergies between climate change and other stressors (Woodward and Perkins 2015; Woodward et al. 2010). **Freshwater ecosystems are sensitive to global warming because species have limited options to move, both water temperature and availability are dependent on the climate, and other human-induced stressors (e.g. flow modification, water pollution, overexploitation, etc.) already affect freshwater ecosystems** (*ibid.*; Dudgeon et al. 2006; McDermid et al. 2015). *Table 9* displays the climate sensitivity of watersheds in Eeyou Istchee James Bay and other stressors for these ecosystems, based on information from an exhaustive assessment of watershed health in Canada that the WWF Canada (2017) conducted in collaboration with leading freshwater scientists. Overall, **watershed sensitivity to climate change in Eeyou Istchee James Bay is moderate**. In terms of overall health of the watersheds (including water flow/quality, fish, and benthic invertebrates), almost all watersheds in Eeyou Istchee James Bay were considered ‘data deficient’, indicating that it was not possible to establish a baseline picture due to missing information for at least two out of four health factors.

Table 9: Sensitivity of watersheds to climate change in Eeyou Istchee James Bay

Watershed	Overall threats	Threat from CC	Other important threats
<i>Grande rivière de la Baleine - Coast</i>	Low	Moderate	✚ Alteration of flows: moderate
<i>La Grande - Coast</i>	Moderate	Moderate	✚ Alteration of flows: very high ✚ Habitat loss: high
<i>Eastmain</i>	Moderate	Moderate	✚ Alteration of flows: high ✚ Habitat loss: very high
<i>Broadback and Rupert</i>	Low	Moderate	✚ Habitat loss: very high
<i>Nottaway - Coast</i>	Low	Low	✚ Habitat loss: moderate ✚ Habitat fragmentation: moderate ✚ Pollution: moderate

Information assembled from the interactive maps of the Watershed Reports available at <http://watershedreports.wwf.ca>. For the CC threat, shifting temperature patterns and changes in the amount of precipitation were considered as they can have a significant effect on watersheds. Data for water flow was obtained from the Canadian Dam Association, the HYDAT database of ECCC, and the Centre d’expertise hydrique du Québec of the MDDELCC, while climate change data comes from ECCC’s CANGRD.

Higher evaporation and evapotranspiration in response to higher temperatures could provoke a decline in water levels reducing access to spawning areas, and increase turbidity and wave action (Sharma et al. 2007). **Warmer water temperature and longer open-water periods will likely cause phenological changes, mismatches and modify food webs in lakes and rivers** (Wrona et al. 2016). Dissolved oxygen declines resulting from warmer temperatures can negatively affect embryonic development of aquatic organisms (Sharma et al. 2007).²⁷ In their extensive literature review and meta-analysis on climate-induced distributional changes of freshwater fish, Comte et al. (2012) conclude that **climate change will severely impact certain freshwater fish species in the future** (in addition to other stressors) (see also [Chapter 3.1.2](#)). Some rivers of the Western Hudson Bay Lowlands (around 55N) experienced very high water temperatures in 2001 (over 20°C) that led to unusual stratification, thermal stress and consequently, significant die-off of anadromous brook trout and white suckers (Rühland et al. 2014; Gunn & Snucins 2010; Cooperative Freshwater Ecology Unit 2013).

- No assessment on climate-related sensitivity of fish has been conducted in Eeyou Istchee James Bay.

²⁷ However, warming of air temperature is not only the factor determining water temperature. Locally, as shown in a study on Clearwater Lake, Southern Ontario by Tanentzap et al. (2008), lake water temperature can cool due to a reduction of winds (caused by forest regrowth) and an increase in underwater light attenuation (due to more organic matter).

Nevertheless, Tam et al. (2011) found that **furunculosis in fish had increased around Oujé-Bougoumou which could be due to climate change, most likely warmer air temperatures that warm up lake water**. Since Northern fish can only tolerate a limited temperature increase, higher temperatures can weaken them and make them more vulnerable to diseases. In the context of global warming and other stressors (e.g. mining), furunculosis is expected to spread further, which also affects food security (see [Chapter 1.4](#)) since people do not want to eat fish they describe as ‘disfigured’ (*ibid.*).

The duration and frequency of thermal stratification events in lakes of the Hudson Bay Lowlands may increase due to warmer temperatures (Rühland et al. 2014). Higher water temperatures could have dramatic consequences on water quality and fish habitat affecting ecosystem productivity and fish biology (Sharma et al. 2007). **The most affected fishes will likely be cold-adapted specialists** (Sharma et al. 2007; Wrona et al. 2016; Vincent et al. 2013; Comte et al. 2012; Gunn & Snucins 2010).

- **For most fish species harvested by the Cree** (Berkes & Mackenzie 1978), **habitat suitability is predicted to decrease**, such as for Salmonidae²⁸ (e.g. whitefish, trout, cisco), Acipenseridae (e.g. sturgeon), Catostomidae (e.g. white sucker), Esocidae (e.g. pike) and especially Lotidae (e.g. burbot), while Percidae (e.g. walleye, perch) may find more suitable habitat in the future (Comte et al. 2012; Lyons & Stewart 2014).
- **The Cree have observed whitefish arriving two weeks later in the last years and having less fat reserves. Fish generally seem to be smaller and less healthy** (CTA 2011).²⁹

Almost all watersheds in Eeyou Istchee James Bay are considered ‘data deficient’. Research on climate change-related impacts on freshwater systems in Eeyou Istchee James Bay has been fragmentary. It is necessary to continue research on lakes and rivers in James Bay to better understand the implications of climate change, especially with regards to fish species harvested by the Cree that could be affected by warmer water temperatures. Yves Gratton’s project aims to quantify future changes in water temperature and dissolved oxygen concentration in northern lakes located above 50°N, which will be helpful to assess habitat suitability.

3.1.5 WETLANDS

Wetlands figure among the most productive ecosystems on earth (US EPA 2017). The direct impacts of climate change on precipitation patterns ([Chapter 2.3](#)) and its indirect effects on evapotranspiration control the hydrology of wetlands (Hershkovitz et al. 2013). Changes in temperature, water input or nutrient levels can decrease the quality of their ecological functions, such as purifying and storing water or providing flood protection (Hershkovitz et al. 2013; Orlova et al. 2014). Peatlands represent 50-70% of all global wetlands, and are mostly found in the boreal forest and subarctic regions of Canada and Russia (Garneau 2017; McLaughlin & Webster 2014; [Appendix 10](#)). Peatlands such as the **James and Hudson Bay Lowlands are one of the greatest global carbon sinks, but their role in a changing climate is uncertain** (Garneau et al. 2014; Pelletier et al. 2011; Charman et al. 2013; McLaughlin & Webster 2014).

Regional climate and topography appear to play a crucial role in long-term peatland accumulation (Charman et al. 2013; Garneau et al. 2014). Warmer and wetter climate conditions, especially warmer temperatures,

²⁸ The study by Yves Gratton on climate change impacts on habitat suitability for Salmonidae (results to be published soon) will provide more localized information on future dissolved oxygen contents and water temperature in northern lakes.

²⁹ Abigail Lynch is conducting research on climate change impacts on whitefish in the Great Lakes region to help fishermen adapt by developing a decision support tool. This work could be useful for Eeyou Istchee James Bay. Results show that fall and spring temperature are important factors that influence population dynamics, besides wind and lake ice cover (for more information, visit: <http://www.miseagrant.umich.edu/explore/fisheries/climate-change-whitefish/>; Lynch et al. 2015).

favour peat accumulation whereas a warmer and drier climate would increase the decomposition rate of organic matter and CO₂ release to the atmosphere (M. Garneau, pers. comm.; Garneau et al. 2014; Charman et al. 2013). James Bay peatlands are potentially vulnerable to climate change, but may also benefit from it and become even greater carbon sinks (M. Garneau, pers. comm.).

- A higher peat accumulation rate under warmer temperatures has been observed at wetlands around Eastmain and at the La Grande complex (M. Garneau, pers. comm.; Garneau et al. 2014).
- **Carbon fixation in peatlands situated north of the 51st parallel could be favoured by climate change** due to the projected longer growth season, a rise in surface moisture and an increased hydrological cycle (Garneau 2017; McLaughlin et al. 2014; Garneau et al. 2014). However, peatlands on permafrost will probably disappear (Garneau & van Bellen 2016).
- **Peatlands in James Bay are probably less vulnerable to wildfires** as they are more humid, open and have a lower forest density than in Western Canada, and the peatland's moisture content provides a good fire protection (Garneau & van Bellen 2016; M. Garneau, pers. comm.).

More studies are needed to adequately quantify future peatland behaviour around James Bay in the face of climate change, and better characterize the biodiversity of this unique ecosystem. It should be assessed whether they will become a carbon sink (more peat accumulation) or source (more decomposition) in a changing climate, as the scientific community seems undecided on this topic (McLaughlin and Webster 2014; M. Garneau, pers. comm.). Research on precipitation amounts and soil moisture levels could be a promising avenue (M. Garneau, pers. comm.). It is also recommended to look into the human and social dimensions (e.g. livelihood issues and traditional knowledge) during baseline data collection and cumulative impacts.

3.2 TERRESTRIAL ECOSYSTEMS

3.2.1 FOREST ECOSYSTEMS

Species distribution models (SDM) generally predict suitable habitat for tree species with appreciable degrees of accuracy, but they fail to determine abundance and how species will be assembled (McKenney et al. 2007; Chambers et al. 2013). This also remains a challenge for species abundance models (SAM) which can predict the abundance of the most dominant species, but model performance is poor in terms of forecasting species assemblages, and thus predicting biodiversity (McGill et al. 2007, Chambers et al. 2013). Warmer temperatures will affect the boreal forest in various ways such as by altering forest productivity, distribution or disturbance regimes. Effects can arrive simultaneously, interact, or cumulate, but it is very hard to determine which ecosystem processes will be affected the most. Over the next 50-100 years, the **majority of climate change impacts seem to be negative for the boreal forest in Canada** (Price et al. 2013).

Forest distribution and productivity:

Graminoids and shrub-tundra experienced a 20-60% increase in green leaf area at the taiga-tundra ecotone³⁰ in Northern Canada from 1986 to 2010, which is a clear sign of the northward migration of species (McManus et al. 2012). **The boreal climate zone will probably shift 5 to 10 times quicker than the natural speed of expansion by trees** with the most important changes occurring in the ecotones (Price et al. 2013; Côté 2014). Species producing light seeds that can be distributed by winds will be favoured by these shifts in contrast to conifers producing large and heavy seeds (Price et al. 2013).

- Model projections for Eeyou Istchee James Bay by Tremblay et al. (2013) show an **increase in trees, shrubs and ferns in the North and some Eastern mountains and a decrease in the South and some**

³⁰ An ecotone describes the transition zone between two biomes, such as between the boreal forest and the treeless tundra.

central regions. They predict a general increase in grasses except for the South. The biodiversity of vascular plants would increase under a warmer and wetter climate while the richness of lichens would be reduced.

- **Black spruce in Hudson Bay has moved to higher elevations by a dozen meters** (Berteaux et al. 2014). Périe et al. (2014) indicate that black spruce may not find other suitable habitat and list it among the most vulnerable tree species to climate change in Quebec.

A higher rate of photosynthesis and respiration under warmer temperatures will likely provoke an **earlier start of the growing season** in the boreal forest, and **higher water use efficiency** (Auzel et al. 2012; Price et al. 2013). This favours an **increase in the carbon reservoir and plant productivity**, especially in Eastern Canada. At the same time, it accelerates the nutrient cycle leading to a higher decomposition rate and less carbon stored in the soil (*ibid.*; Auzel et al. 2012; Bowman & Murphy 2010).

Disturbance regimes:

Extreme weather events such as wildfires and strong winds can alter forest ecosystem dynamics. Wind affects the growth of trees (especially in the zone between taiga and tundra) and the dispersal of seeds; it can also provoke accelerated soil erosion and the delocalization of snow which in turn diminishes seedling insulation (Holtmeier & Broll 2010).

- **Considering that extreme winds may increase in Eeyou Istchee James Bay (Chapter 2.2), they could cause great damage on forest ecosystems** such as already documented in other parts of Canada, e.g. in Nova Scotia or British Columbia (Lemmen et al. 2014; Price et al. 2013).

Wildfire severity, occurrence and frequency are predicted to increase across Canada in the upcoming decades (Flannigan et al. 2016; Flannigan et al. 2009; Wotton et al. 2009; Terrier et al. 2013; Price et al. 2013; Oris et al. 2014; Lemmen et al. 2014; Flannigan et al. 2013). Holdover fires smouldering under the snow may also become more common (Price et al. 2013). In fact, for every 1°C increase in temperature, precipitations need to increase by more than 15% to prevent drying (Flannigan et al. 2016; Hély et al. 2010). In Canada, **temperature increase will outplay the increase in precipitations, thereby raising fire risk** (Flannigan et al. 2016). In Quebec, 9% of closed-canopy forests have been replaced by open lichen woodlands mainly due to wildfires over the last 50 years (Girard et al. 2008). Since the 1980s, **large fire occurrence has dramatically increased** in northeastern and northwestern Canada (Le Goff et al. 2007)³¹. The number of days of **head fire intensity** (unmanageable crown fires) **substantially exceeding the capabilities of suppression resources will rise** in the 21st century (Wotton et al. 2017; Flannigan 2017). Extreme fire weather including high temperatures and strong winds can highly influence the extent of the burned area, such as in the case of the huge Eastmain wildfire in 2013 (Erni et al. 2017). **The frequency of extreme fire weather is predicted to increase in Canada**, e.g. lightning events which will be likely to raise the frequency and intensity of wildfire (Wang et al. 2015; Flannigan 2017; Bowman & Murphy 2010; Wotton et al. 2010).

Northern Quebec has one of the highest fire frequencies and proportions of burnt land due to wildfires in North America (Erni 2016). Istchee James Bay has a burn rate of 2.1% of the land area per year, with the Northern section experiencing larger fires than the southern region (*ibid.*)³².

- **64% of south-eastern Eeyou Istchee James Bay (representing 22% of Eeyou Istchee James Bay) has a very high fire risk** (Mansuy et al. 2012).
- Although some researchers believe that the frequency and size of recent wildfires have not exceeded the variability observed during the last 175 years, **all Cree communities have already been exposed**

³¹ In Eeyou Istchee James Bay, fire size has been more important than fire frequency for long-term vegetation patterns as the relatively flat topography in the region has favoured larger wildfires in the past (Remy et al. 2017).

³² Climate change, the Pacific Decadal Oscillation and El Nino all seem to influence regional fire activity and severity in northern and central Quebec (Le Goff et al. 2007; Shabbar et al. 2011). Under El Nino conditions, wildfire severity in central Quebec seems to be higher (Shabbar et al. 2011). Mean monthly temperature maxima as well as drought have been identified as the main factors for fire occurrence and frequency (Drever et al. 2009).

to forest fires, and survey participants from six out of eight communities indicated that fire frequency had increased while participants from four communities also observed an increase in fire intensity (Erni 2016; FNQLSDI 2017).

- **The current fire season in Eeyou Istchee James Bay could lengthen from 1 month (June) to 3 months (June – August),** which would require more fire prevention measures (Le Goff et al. 2009; Price et al. 2013; Boulanger et al. 2013).
- According to Le Goff et al. (2009), **spring fires may become less frequent with a delayed seasonal peak in fire season.** August fire risk for Waswanipi could double by 2100 while the May wildfire risk would slightly decrease.

In conclusion, these disturbances can alter the composition of the forest, e.g. black spruce may recede giving way to drought and fire-adapted pine species (Price et al 2013). Other disturbance factors include **spruce budworm** or other pests and diseases. The projected increase in Northern plant richness may be reduced due to the arrival of more invasive species or parasites (Tremblay 2013; de Blois et al. 2013).

- Under current climate model predictions, spruce budworm, whose physiology is directly influenced by temperature, will be able to invade northward in Quebec, and other **pest outbreaks will likely increase due to milder winter temperatures** (Samson 2012; Lemmen et al. 2014, Price et al. 2013; see [Appendix 11](#) for future budworm migration).

More research should be undertaken to better understand insect and parasite outbreaks and invasions in Eeyou Istchee James Bay considering that pests have already been observed more commonly in the southern parts of the territory. It should be further investigated if the frequency and intensity of wildfires in Eeyou Istchee has changed, and if so, how forest management and biodiversity conservation need to be adapted accordingly.

3.2.2 FLORA AND FAUNA

Limited research has been conducted on climatic impacts on wildlife and vegetation of the North American boreal forest (Price et al. 2013). In Quebec, assessing climate-driven effect on biodiversity is challenging due to the rarity of long term studies and the high natural variability of populations that can overshadow climate impacts (D. Berteaux, conference at EDS institute 2016). Extensive **observations from naturalists** like ornithologists or local knowledge can provide much insight of past changes, and **bioclimatic niche models** are frequently used to assess if wildlife and plants will expand, displace or contract their distribution area in the light of climate change, and if new species will migrate (Berteaux et al. 2014).

Changes in phenology³³ and mismatches:

Global studies and the ones in Quebec have shown that climate change strongly influences the phenology of plants. This is why altered spring phenology has become a clear signature for climate-induced impacts. **In Quebec, an earlier onset of flowering by an average of 2 to 5 days per decade has been documented** (Berteaux et al. 2014). Changes in the phenology of plants are very important due to their influence on higher trophic levels, such as pollinators. Considering the very short growing season in Northern Quebec, the impact of a warming climate will have a much higher influence on the seasonality in this region than further south.

- The **growing season** in Northern Quebec **has lengthened** by several days from the 1980s to 2006 with an earlier start in spring, but it is unknown whether this has more positive or negative consequences for species (Samson 2012; Berteaux et al. 2014).

Climate change can decouple species' phenology from available nutritional resources (Parmesan & Hanley

³³ This refers to periodical changes in the life cycles of species, such as changes in the flowering or fructification season, arrival and departure of migratory birds, altered reproduction and migration cycles for wildlife, etc.

2015) such as an earlier onset of the growing period. This phenomenon can disrupt trophic interactions between plants and animals thereby causing mismatches (Rinawati et al. 2013; Le Corre et al. 2016). According to Nantel et al. (2014), **phenological mismatches will become more frequent** in Canada. **Birds of the boreal forest**, which are mainly insectivorous, could be affected because of the possible mismatch with the life cycles of the insects they feed on (Price et al. 2013). A mismatch could also occur between the date of arrival on calving grounds of **migratory caribou** and vegetation green-up (Le Corre et al. 2016).

Migration and distribution:

Climate change will be likely to cause a migration of species to higher elevations and northward. In contrast to phenological changes, climate-driven migration of species is very hard to measure because a species' range is never homogenous and range limits are vague. **An exhaustive global study**, including more than 2000 species, **concluded that species ranges have recently shifted on average by 16.9 km to higher latitudes and by 11m in elevation per decade** (Chen et al. 2011). A study on migratory birds in Quebec south of the 47th parallel found that 80% of the 113 species studied arrived earlier; on average by 0.9 days/decade (Berteaux et al. 2014). Butterflies in Eastern Canada (80 species) have on average moved their ranges northward by 140 km between 1970 and 2012 (*ibid.*). In this context, it is important to mention that the inertia of plants is generally much greater than for wildlife limiting their dispersion potential to find new suitable habitat (D. Berteaux, conference at EDS institute 2016). The potential **shift of bioclimatic niches is expected to be 44km/decade in Quebec which is 5 to 10 times higher than the migration speed at the end of the last glacial period** (Berteaux et al. 2014; Côté 2014).³⁴

- Several Cree communities have noticed a **higher presence of white-tailed deer, moose, coyotes and wolves** (CTA 2011; Herrmann et al. 2012; Taillon et al. 2016).
- The **increasing arrival of more pests and diseases** ([Chapter 3.2.1](#)) can affect the health of wildlife, and consequently, the food quality of the hunted game ([Chapter 1.4](#)). The Cree have noticed the **arrival of white-tailed deer carrying the *P. tenuis* parasite** which is deadly for moose and caribou, and could have a major impact on these animals (Herrmann et al. 2012).
- Cree hunters have observed a **change in the distribution of amphibians** (frogs) which now seem to be rarer inland and more abundant on the coast (Herrmann et al. 2012).
- A comparison of the CTA big and small game reports from 1992-1997 and 2012-2017 reveals a **major decline in harvest of muskrat (-76,7%), otter (-64,3%), beaver (-57,2%), caribou (-47,9%), red fox (-34%) and marten (-16,2%), while an increase in harvest can be observed for moose (+33%), lynx (+30,5%) and black bear (+9,4%)** ([Appendix 12](#)). It would be useful to determine the reasons behind these shifting harvesting trends, e.g. whether it is due to a changing availability and distribution of the species or rather hunters' preferences or activity.
- Beaver populations are predicted to substantially expand their interior range and modestly expand their northern range in Quebec, which would imply **higher beaver populations in Eeyou Istchee James Bay** (Jarema et al. 2009)³⁵. However, beaver harvest in Eeyou Istchee James Bay has decreased by almost 60% from 2012-2017 versus 1992-1997 ([Appendix 12](#)).
- **Polar bears** in Hudson Bay have been greatly impacted by the loss of sea ice as their hunting and resting platform. This affects their distribution, physical health and cub mortality, and has also led to much more frequent bear sightings in proximity to Cree camps searching for food (Moore & Huntington 2008; Obbard & Middel 2012; Herrmann et al. 2012; CTA 2010; Hossein 2017; EMRWB, pers. comm.).

³⁴ In this context it is important to note that these values do not represent the actual migration of species on the ground but rather the potential shift of bioclimatic niches in response to climate change (R. Siron, pers. comm.). Only some species, in particular weeds, will follow this quick migration while others, such as trees, will not be able to disperse fast enough northward (Berteaux et al. 2014).

³⁵ Currently, beaver populations are highest in southwestern Quebec declining from west to east and decreasing at 49°N. From 49°N to about 58°N there is a low beaver density. It would be necessary to monitor changes of the interior populations, not only at the northern range limit, in order to adequately apprehend potential climate-driven changes (Sharma et al. 2009).

The current range of **woodland caribou**³⁶ may decrease significantly due to increased predation (e.g. more wolves due to higher moose population), habitat change, mismatches between changing plant phenology and grazing, physiological constraints due to higher temperatures (e.g. impacts on health) and more diseases (e.g. *P. tenuis*) (Price et al. 2013; Sharma et al. 2009; Racey 2005; Taillon et al. 2016). The complex interactions between different stressors makes the future of Northern Quebec's caribou herds very uncertain (Nantel et al. 2014).³⁷ **Migratory woodland caribou** appear to be affected by decreasing ice on lakes and rivers hampering their migratory movements in spring and fall and increasing their energy needs (Leblond et al. 2016; Sharma et al. 2009; Hénault-Richard et al. 2014). Le Corre et al (2016) found that migratory caribou adjusted their migration patterns according to weather conditions, e.g. they advanced spring migration in mild winters (possibly to avoid travelling in soft snow and increasing their energy needs) and delayed it when there was abundant snowfall in April; they also seemed to start fall migration earlier, although other studies found a delay of fall migration (Taillon 2013).³⁸

- In a survey, **a third of the Cree respondents mentioned a change in the distribution of woodland caribou, but the direction of change is not clear** (Herrmann et al. 2012). Another study with Cree hunters found that woodland caribou harvest has decreased, especially on the coast which may be linked to a changing distribution of caribou (Royer and Herrmann 2011, see also [Appendix 12](#)).

In conclusion, Eeyou Istchee James Bay has undergone major transformations due to industrial development, e.g. hydro-electric installations and road and railroad networks in the southern part of the territory for the mining and forestry sector. The Government of Quebec's goals for the Plan Nord include that 20% of the territory shall become protected areas in 2020, and 30% shall be exempt from industrial activities by 2035 (SPN 2017). The Cree are of the firm opinion that these 50% protected area, must apply to each region independently, not the territory covered by the Plan Nord as a whole, and that all past industrial development needs to be taken into account when designing protected areas. To date, very little information has been compiled on the ecosystems in Eeyou Istchee. Considering major impacts from industrial development that can be exacerbated by climate change, it becomes a "pressing need to strengthen our knowledge of these ecosystems, using both Cree knowledge and scientific data and analysis" (Cree Vision of Plan Nord 2011).

In cooperation with local stakeholders, it is necessary to conduct more research on climate impacts on vegetation and wildlife dynamics such as migration, phenological changes and resilience of species under higher temperature and altered precipitation patterns, especially for those of cultural and economic importance. Monitoring of species, establishing movement corridors (Gonzalez 2013) and protected areas (Bélanger 2013), or practising assisted migration should be considered in this context of evolving biodiversity, and it needs to be decided which species should be protected and where. Lastly, it seems essential to develop effective climate change adaptation strategies for biodiversity conservation in the light of climate change and economic development.

³⁶ As far as the boreal woodland caribou (three herds in southern Eeyou Istchee James Bay) is concerned, it is already listed as "threatened" on the federal level and "vulnerable" in Quebec, as its numbers are declining and its habitat is severely degraded (Rudolph et al. 2012); climate change could certainly accelerate its decline. The detailed report by Rudolph et al. (2012) highly recommends that no subsistence hunting should be practiced, and that further habitat degradation for resource development in caribou habitat should be prevented.

³⁷ Woodland caribou in Quebec seem to be affected negatively by climate-associated factors on top of other not climate-related stressors and cannot recover from their current low numbers (Nantel et al. 2014). However, some studies showed that direct human alteration of caribou habitat, such as logging activities, influenced woodland caribou twice as much as climate-driven changes (Beguín et al. 2013; Faille et al. 2010).

³⁸ Migratory caribou are one of two ecotypes of woodland caribou found in Quebec. The migratory caribou from the Rivière-aux-Feuilles (RFH) herd migrate from the tundra of northern Nunavik between October and December to northern Eeyou Istchee James Bay. In April, they return to their calving grounds up north where they arrive in late May. See Taillon et al. (2016), p. 40 for a detailed depiction of spring and fall migration.

CHAPTER IV – IMPACTS ON BUILT INFRASTRUCTURE AND ECONOMIC DEVELOPMENT

4.1 BUILT INFRASTRUCTURE

Built infrastructure includes a variety of assets such as transportation networks, private/public buildings, energy/telecommunication infrastructure, as well as water/wastewater infrastructure. Climate hazards can lead to failures of different infrastructure assets interrupting essential community services and disrupting economic activities while also provoking health and security risks (FNQLSDI 2017). Expensive municipal infrastructures in Eeyou Istchee James Bay such as wastewater treatment plants or waste-/rainwater drainages and culverts are constructed relying on old data without considering climate-related risks such as evolving snow cover and melt and more heavy rainfalls (JBACE, pers. comm.). According to the Department of Capital Works and Services (CWS) of the CNG (pers. comm.), climate change may modify the length of the construction season, impact soil conditions, cause drainage issues following heavier than usual rainfall, and affect transportation by boat of materials and equipment to Whapmagoostui due to hazardous ice conditions or extreme weather. **These and other climate hazards challenge current infrastructure design, construction, operation and maintenance, and create additional risks and costs**, and need to be taken into consideration to improve infrastructure and maintain assets properly (Félio 2012).

Figure 4 illustrates challenges to infrastructure management with respect to climate change as outlined by a survey of key stakeholders in the Public Works and Public Safety departments of eight Cree communities in Eeyou Istchee James Bay (FNQLSDI 2017).

CLIMATE CHANGE IMPACTS ON INFRASTRUCTURE AS OBSERVED BY PROFESSIONALS OF PUBLIC WORKS AND PUBLIC SAFETY DEPARTMENTS IN EIGHT CREE COMMUNITIES (FNQLSDI 2017)

- **Inland flooding** due to high water levels in rivers, heavy and sudden rainfalls and rapid snow ice melt has already impacted infrastructure in seven communities, such as by flooding camps or washing out bridges;
- **Forest fires** have impacted infrastructure in all participating communities, such as by causing power outages;
- **Impacts have been primarily observed on ancestral lands (7/8)**, but also in the community itself (5/8).
- **Assets considered a priority were buildings, transportation, and water management.**
 - **Transportation** (8/8). E.g., the 2013 forest fire in Eastmain cut off the only access road to Eastmain thereby isolating the community (the James Bay Highway was closed for over 300 km, Breton et al. 2017). In Nemaska, the access road was flooded due to high water levels from sudden snow melt.
 - **Buildings** (8/8). E.g., less ice cover has increased erosion and some Cree camps have been exposed to this. Cree camps have been flooded due to high water levels, and property on ancestral land has been lost to forest fires.
 - **Water management** (4/8). E.g., a power outage (caused by a forest fire) at the wastewater plant in Oujé-Bougoumou disrupted its services and led to raw sewage being dumped directly into the river. More frequent freeze-thaw cycles seem to have caused ice layers to block the drainage system in Mistissini.
- Climate-induced impacts on assets have already led to **budget overruns** in a third of the communities, mostly as far as transportation and buildings are concerned, followed by energy infrastructure.

Figure 4: Climate change impacts on infrastructure in Eeyou Istchee James Bay

According to the CWS (pers. comm.), **few impacts on infrastructure have been observed**, which explains why **no climate-related measures** have been taken with regards to infrastructure, **and climate change is not yet included in decision-making processes or infrastructure design**. However, the community master development plan includes some erosion mitigation measures and “no build” zones (*ibid.*). No information on vulnerabilities, impacts or adaptation to climate change could be obtained from Cree economic development entities such as CREECO, AirCreebec, mining companies or the Cree Construction and Development Company.

The following information describes general climate-related infrastructure challenges that can be useful for local decision-makers. Climate change can affect built infrastructure in various ways. According to FNQLSDI

(2017), climate hazards can **deteriorate access or connectivity and provoke evacuation**, thereby creating risks to civil security and reducing services. They can further **decrease material durability, cause premature aging as well as more breakages, repairs and reconstructions**. Hazards can lead to **increased costs or higher frequency in terms of repairs, insurance and maintenance**. They can impose the **modification of construction planning and construction codes**. Some climate impacts may turn out to be positive, i.e. reduced road maintenance due to milder temperatures, or the creation of jobs and development of climate-specific expertise.

Missing information about the state of infrastructure as well as inadequate management and maintenance practices make infrastructure vulnerable to climate change **all across the province of Quebec whereas well-maintained infrastructure is more resilient in a changing climate** (Ouranos 2015 Andrey et al. 2014). *Figure 5* presents some reflections on future adaptation of infrastructure in Eeyou Istchee James Bay.

CLIMATE CHANGE ADAPTATION OF INFRASTRUCTURE

Adaptation measures can be applied at different moments of the life cycle of an asset, such as at the planning (e.g. better adapted building materials), construction (e.g. revision of building codes and design), and maintenance (e.g. retrofit) stages. **Several available climate scenarios should be included in infrastructure planning** since infrastructure assets are often little adaptable and have a long life cycle. **Climate uncertainty has to be integrated into risk analysis** as well (Bourque & Simonet 2008).

According to infrastructure management professionals in Eeyou Istchee James Bay, the **best general strategies to avoid future negative impacts of climate change included i) adapting the different types of infrastructure, ii) raising awareness among community residents and providing training**, as well as **iii) collaborating with external experts** (FNQLSDI 2017). The best actions to reduce future negative impacts on assets included the following options:

- Having access to maps of at-risk areas such as zones that are vulnerable to flooding or forest fires;
- Providing access to accurate forecasts regarding floods and forest fires;
- Raising awareness about the risks of climate-related disasters and the associated costs;
- Adapting construction planning and code to climate risks in order to reduce the negative impacts on infrastructure in the event of a disaster.

The risk-based assessment protocol developed by the **PIEVC** (Public Infrastructure Engineering Vulnerability Committee) is a great tool for engineers and planners enabling them to assess the vulnerabilities of infrastructure to extreme weather events and future climate change, to plan accordingly and design climate-resilient assets: <https://pievc.ca/>.

Figure 5: Climate change adaptation of infrastructure in Eeyou Istchee James Bay

It is important to act proactively by analyzing and reducing potential vulnerabilities, risks and costs associated with infrastructure maintenance, investment and replacement, such as by incorporating climate resilience into building design codes or in investments for retrofits. Climate-resilient norms, designs and building codes as well as climate-considerate asset planning could be promoted in awareness campaigns and professional trainings so that they can be included by local stakeholders in anticipation of future climatic conditions. Considering the future demographic development of the region and its increased need for housing (CNG 2015b) and other public and private infrastructure-related services, it appears pertinent to start considering projected climate trends that can raise risks and costs. The Ministry of transportation (MTMDET) will analyze the impacts of extreme weather events and climate change on mobility and connectivity along the James Bay Highway, which will help to identify vulnerabilities in terms of terrestrial transportation.

4.2 NATURAL RESOURCES AND ECONOMIC DEVELOPMENT

For the whole of Canada, little information on climate change impacts on natural resource development and industry is available as companies seem reluctant to disclose information in order to prevent damaging their competitiveness (Kovacs & Thisthethwaite 2014). According to the Department of Commerce and Industry (DCI) (pers. comm.), companies operating in Eeyou Istchee James Bay are starting to adjust project conceptions and to consider climate change following a common sense approach. However, the recent **modernization of Quebec’s environmental authorization process (EAP) promotes adaptation to climate change and reduction of GHG emissions** in the legal framework. A project proponent may be required to implement climate risk-considerate adaptation measures (“test climat”). According to the Department of the Environment and Remedial Works (ERW), this will favour project resilience and better protect the natural and social environment (Voyageur and McLean 2017). In this context, it will be crucial to consider regional climate projections ([Chapter 2](#)) and the socio-economic context of the North ([Chapter 1](#)) that differ from those of the South.

4.2.1 MINING

Eeyou Istchee James Bay is very rich in precious and base metals. Recently, a large gold discovery has been made in the Opinaca Reservoir area, and other areas promise substantial reserves of diamonds and gold (Otish Mountains) or lithium (Nemaska area). Quebec’s first diamond mine *Renard* was opened on Mistissini trapline M-11 in 2016. (Larbi & MacKinnon 2016) The ore found in Eeyou Istchee James Bay is of very high quality (Larbi 2017). All of these factors explain the recent boom in mining exploration, which is expected to further increase the need for workers (*ibid.*). Since climate is a crucial factor influencing a mine’s yearly operation conditions (Pearce et al. 2009a; Bussière et al. 2017), potential impacts and risks of a changing climate on the mining cycle need to be taken into account.³⁹ **Climate change has been acknowledged as an emerging concern by 75% of practitioners in the mining sector in Canada** (Ford et al. 2011; Pearce et al. 2011). In a survey conducted by Ford et al. (2011), respondents employed in the Canadian mining sector indicated that the most common climate hazards were: heavy rainfall (71%), heavy snowfall (56%), storm events (33%), flooding (25%), and cold temperatures (19%).

Climate impacts on mining infrastructure and transportation networks as well as hydrology and operations are key areas of concern for the mining industry (Duerden et al. 2014). Climate-related risks (e.g. extreme events) are being considered more and more by investors and financial institutions because climate change could lead to operation costs beyond forecasts, or the need for unplanned capital investment (Acclimatise 2010). **No case studies on climate-related impacts on mining have been carried out in Eeyou Istchee James Bay**, and the following general information applies to all mining sites.

Climate change impacts the whole mining cycle from planning and site selection to operations and also the post-operation phase (Lemmen et al. 2014). The **exploration phase has a low vulnerability to climate change because it is carried out over a short period of time and people can adapt along the way** (Bussière et al. 2017). In the exploitation phase, operations can be disrupted or delayed and built assets and transportation infrastructure (on-site and access roads) may be disrupted or weakened, e.g. from flooding, cyclones or forest fires (Duerden et al. 2014; Pearce et al. 2011). This can lead to high economic losses, for example due to higher maintenance costs or delayed exportation of products (Acclimatise 2010). The variability of climate extremes can become problematic in terms of water and residue management (e.g. capacity of retention basins, spillways, etc.) (Bussière et al. 2017). Moreover, operation costs and risks may rise (Duerden et al. 2014). This has been observed at some sites across Canada. For example, more frequent power outages and

³⁹ Some concrete impacts include structural weakening of assets; drainage issues and release of pollutants; washouts or slope failure due to heavy rains; dust pollution or breakage of assets due to high winds; power outage and service disruption due to storms or forest fires, diverse socio-environmental post-operational problems due to changing climatic conditions, and on a positive note longer operating season due to milder climatic conditions (Pearce et al. 2011, Ford et al. 2010; Duerden et al. 2014).

associated loss of productivity can threaten the economic viability of mining operations, which may also prevent foreign capital investments (Acclimatise 2010). All in all, **the vulnerability of the exploitation phase is considered less critical for Quebec’s mining sector due to its restricted life cycle**, but companies need tools to integrate climate change into asset construction and planning (Bussière et al. 2017). An exhaustive vulnerability assessment of the mining sector in Quebec found that the **restoration phase was the most vulnerable to climate change as it usually only considers historic climate conditions and not future projections** (*ibid.*). For example, abandoned mining sites can become problematic when a site gets flooded overtopping the capacity of the tailings dyke and contaminating the surroundings.

Figure 6 presents some reflections on future adaptation of the mining sector in Eeyou Istchee James Bay.

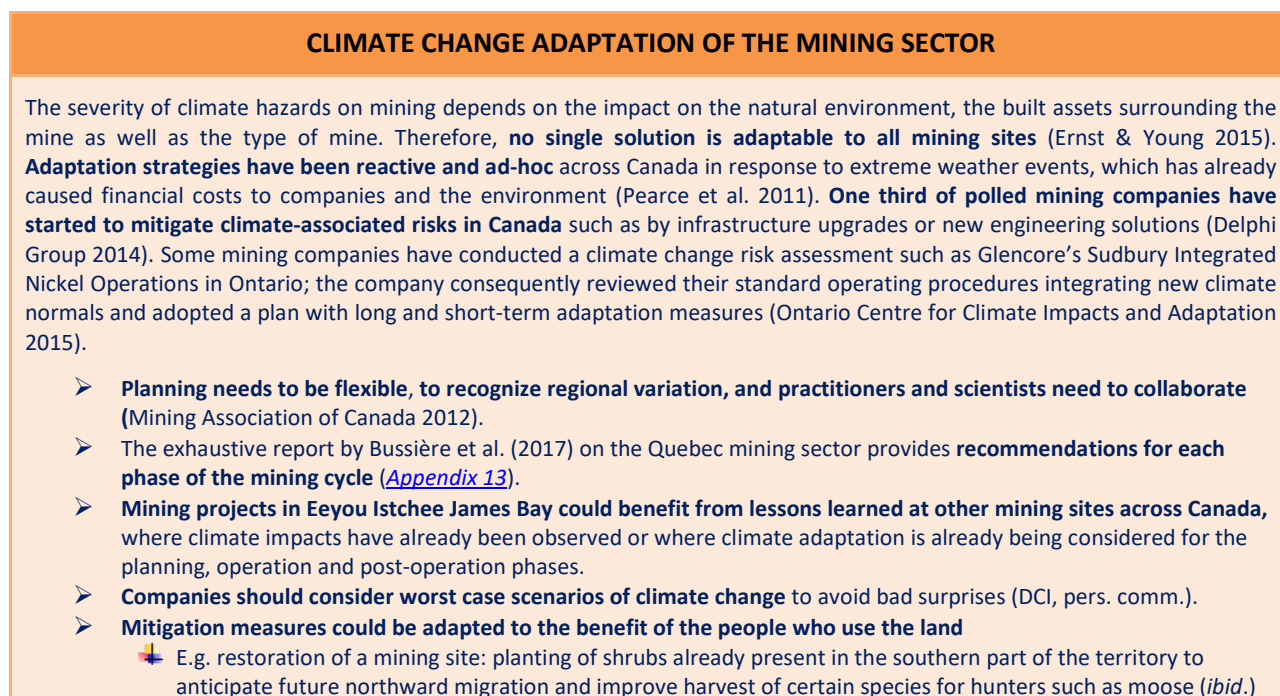


Figure 6: Climate change adaptation of the mining sector in Eeyou Istchee James Bay

4.2.2 HYDROELECTRIC ENERGY

Energy supply, transmission and demand are all vulnerable to climatic variability (Lemmen et al. 2014; Delphi Group 2017). The subsector of energy transmission and distribution is one of the most vulnerable to climate change (Wilson 2017). For example, **transmission lines and other energy distribution infrastructure are vulnerable to extreme weather events**, and **production facilities could be exposed to more flooding, forest fires, severe storms or ice hazards** disrupting energy supply (Lemmen et al. 2014; Ouranos 2015). The hazards are projected to become more frequent in Eeyou Istchee James Bay (see [Chapters 2.2](#) & [3.2.1](#)). Many industries rely on electricity, and consequently, impacts on the energy sector may indirectly influence other sectors as well (Delphi Group 2017).

- **Power outages in several communities in Eeyou Istchee James Bay have occurred frequently due to forest fires** (FNQLSDI 2017). Since forest fires are predicted to increase in the future ([Chapter 3.2.1](#)) these kinds of power outages could occur more frequently.

Considering the **geographical location and the lifespan of energy infrastructure** is very important in the context of a changing climate (Delphi Group 2017) since the life span of assets such as a hydropower dams is about 100 years. This makes them highly vulnerable to environmental changes (e.g. changes in maximum precipitation could increase flooding risks) (Clavet-Gaumont et al. 2017). Climate change affects the timing and magnitude of river flows (Chapter 1.5), and requires action on adaptive reservoir management (Lemmen

et al. 2014; Lemmen et al. 2016).

- **An increased river flow in response to higher precipitation (Chapters 2.3 & 2.5) could be beneficial for hydroelectric power generation in Eeyou Istchee James Bay, but higher hydrologic variability could provoke overflows** (Lemmen et al. 2014).

For the whole Canadian energy sector, no risk-based economic analyses have been conducted, and stakeholders relate this to missing (political) guidance (Delphi Group 2017). **No lessons learned are made public**, even though large companies in the energy sector seem to assess physical climate risks annually (*ibid.*). Nevertheless, in Ontario, the Infrastructure Engineering Vulnerability Committee (OIEVC) Protocol was applied to assess the vulnerability of the electrical transmission sector and Toronto's Hydro-Electric System (Wilson 2017). In Quebec, the big ice storm in 1998 led to the implementation of new construction criteria for electrical transmission facilities (Eyzaguirre & Warren 2014). *Figure 7* presents the main barriers to adaptation, and current adaptation projects from Hydro Québec.

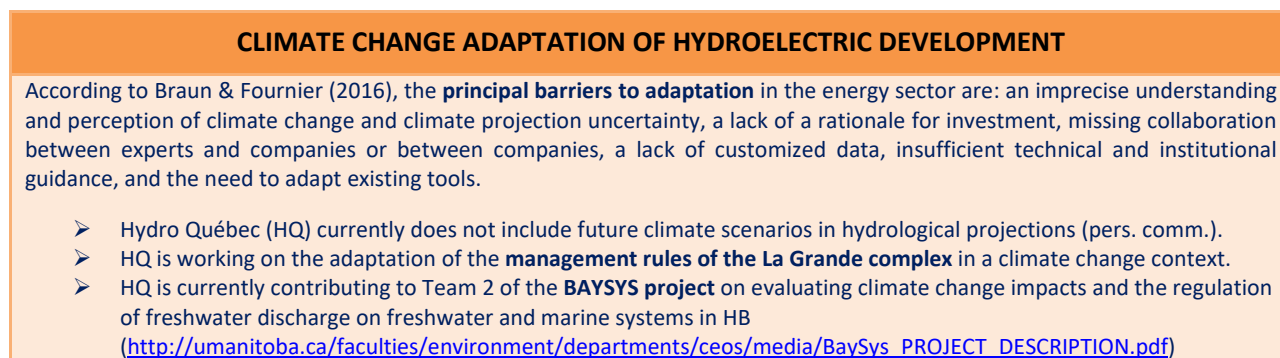


Figure 7: Climate change adaptation of hydroelectric development

4.2.3 FORESTRY

Climate change affects the distribution, productivity, composition and disturbance regimes of forests ([Chapter 3.2.1](#)), and will therefore also influence forestry activities (Lemmen et al. 2014; CEAFFCC⁴⁰ 2017; Boccanfuso et al. 2014). Considering the rapidity and amplitude of changes, it will be necessary to integrate projected changes into sustainable forestry management such as by adjusting composition planning (CEAFFCC 2017).⁴¹ The following information applies to the boreal forest in general.

- A longer growing season and higher forest productivity could **raise revenues**.
 - Climate change can positively and negatively (e.g. more pest outbreaks) influence **wood harvest and the quality of forest products** (berries, mushrooms, medicinal plants), and its cultural and recreational value ([Chapter 3.2](#); Lemmen et al. 2014; CTA 2011).
 - The predicted higher wildfire occurrence and intensity ([Chapter 3.2.1](#)) may lead to **a loss of timber production, endanger forestry operations and the safety of workers** (Le Goff et al. 2009). Forest fire risk also needs to be considered to determine where sustainable forestry practices will be possible (see [Appendix 14](#)).
- 🔥 Climate change adds a **new layer of complexity to fire management**⁴², and more resources

⁴⁰ Comité d'experts sur l'aménagement écosystémique des forêts et les changements climatiques (CEAFFCC)

⁴¹ For more information see the complete volume of the Canadian Journal of Forest Research dedicated to the boreal forest of Quebec: *Assessing the biophysical potential for sustainable forest management: a case study from Quebec's boreal forest* (Vol. 45, issue 5) (Jobidon & Bergeron 2015).

⁴² For successful sustainable management, people need fire mapping programs to track fire activity, monitoring of biodiversity indicator species and cost-benefit analysis of management interventions (*ibid.*). It is recommended that land management strategies for fire-sensitive forest areas include these risks (MERN 2013). It is important to anticipate where the fire load will be high in the future in order to adapt fire management practices. Resources (e.g. staff, material, etc.) need to be redistributed to keep escape fire rates low (projected to increase in Canada) (Wotton et al. 2010). Using deciduous species as a fire mitigation strategy could prove to

(time, effort) will be needed to extinguish and manage wildfires (Bowland & Murphy 2010; Price et al. 2013).

- Climate hazards can create **additional risks and costs for forestry operations**, e.g. in terms of forest access. In Eeyou Istchee James Bay, a costly bridge built by a forestry company was washed out due to an extremely high spring melt and forest fires can cut off access roads (DCI, pers. comm.).

Across Canada, climate awareness has increased among forestry practitioners and governments, and current practices rely more and more on an adaptive approach instead of crisis management (Lemmen et al. 2014). The Canadian Council of Forest Ministers has labelled climate change one of two national priorities for sustainable forest management (Lemmen et al. 2014). *Figure 8* outlines recent research on adaptation of the forestry sector.

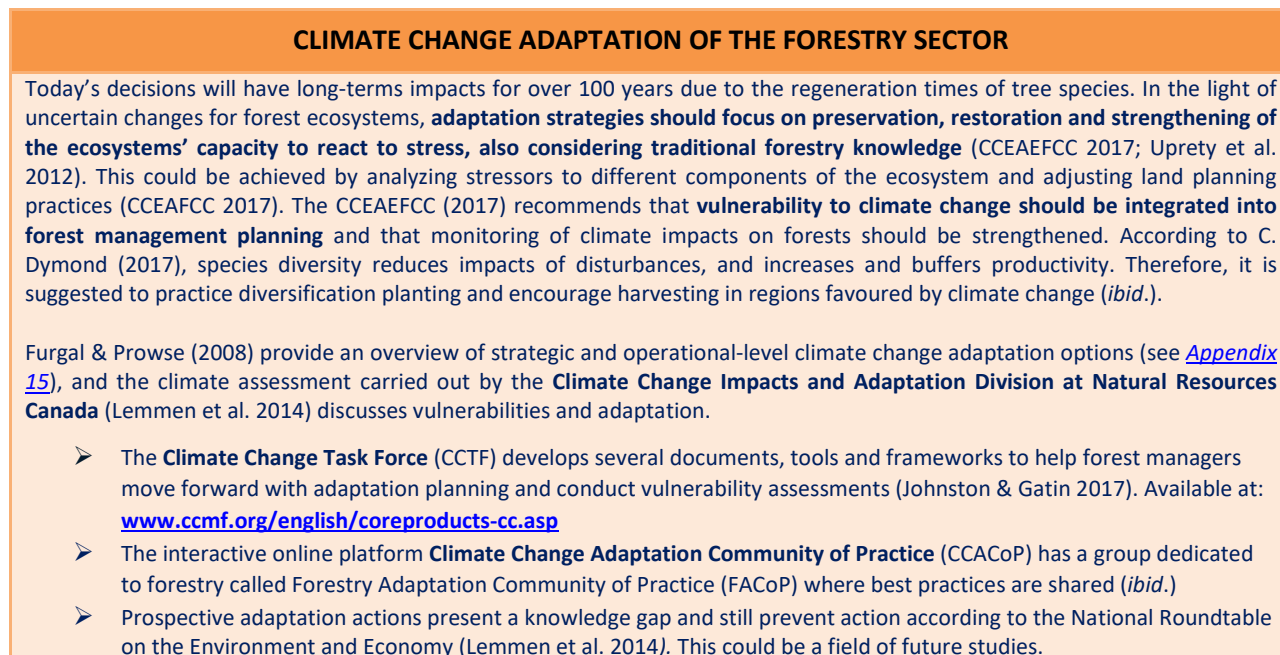


Figure 8: Climate change adaptation of the forestry sector in Eeyou Istchee James Bay

4.2.4 TOURISM

Outdoor, adventure and cultural tourism in Eeyou Istchee James Bay rely on weather conditions and the presence of iconic species and certain plants. Tourism can be positively or negatively affected by climate change. **To our knowledge, no publicly available study or report focuses specifically on tourism and climate change in Eeyou Istchee James Bay.** Therefore, the following information was extracted from other case studies, general reports, and information provided by local stakeholders in order to draw a picture of the potential impacts of climate change.

- **Warmer temperatures could be beneficial for longer touristic seasons and more summer recreational activities** and potentially higher revenues (Lemmen et al. 2016), whereas **revenues from winter activities** (ski, snowmobile, and snowshoe) **may be affected** from unpredictable weather patterns, softer snow, later freeze-up of lakes, and unstable ice conditions (see [Chapter 2](#)).
- **The quality of sports fishing** (pike, walleye, lake, and speckled trout), **hunting** (e.g. caribou) and **wildlife watching could be negatively or positively impacted** by climate-induced changes in wildlife distribution, abundance and health (COTA, pers. comm.; Kovacs & Thistlethwaite 2014; [Chapters 3.1.4](#)

be efficient to reduce fire propagation and improve public safety (*ibid.*; Flannigan 2017). Younger stands of trees also significantly lower the burn rate by about 50% (Erni et al. 2017).

and 3.2.2). Lower abundance and quality of game may put higher pressures on subsistence harvesters (Chapter 1.4) and increase competition with sport hunters. In fact, due to the decline in migratory caribou, a moratorium will be effective on February 1, 2018 for sports hunting of caribou.

- **Tourism infrastructure** (e.g., wharves, coastal properties, hunting and fishing outfitters and camps) distributed all across the region (Appendix 1) **and cultural sites could be damaged by more extreme weather events** (Chapter 2.2) and also **pose safety problems** (e.g. evacuation, energy supply) (Lemmen et al. 2016; Savard 2016).
- The **cultural economy**, i.e. Cree arts and crafts and the Cree way of life, may be affected if certain materials found in the natural environment are not available anymore, skills are not transferred to produce crafts, and intergenerational knowledge of Cree life is transferred less from the elders to the youth (Cree Vision of Plan Nord 2011; COTA pers. comm.).
- COTA is currently evaluating the **touristic potential of a polar bear viewing boat tour** on North and South Twin Islands 60km offshore from Wemindji (Hossein 2017). Besides understanding bear behaviour in response to a higher human presence or the capacity of Wemindji to accommodate a substantial flux of tourists, knowing weather conditions (e.g. extreme weather events, strong waves, sea currents, unpredictable weather etc.) (Chapter 2) and how they will be impacted by climate change will be important to guarantee safe rides for tourists by boat and the feasibility and economic viability of such a project (Hossein 2017; Tyrrell 2006; COTA pers. comm.).

Figure 9 presents some aspects of adaptation of the tourism sector in Canada and Eeyou Istchee James Bay.

CLIMATE CHANGE ADAPTATION OF THE TOURISM SECTOR

In response to climate change, the tourism sector in Canada has implemented various ad-hoc adaptation strategies such as snowmaking, air-conditioning, fire-smart landscaping, communication via web cams and seasonal business diversification. However, stakeholders in the sector have not assessed long-term environmental and financial sustainability of their practices, or investigated in how far current adaptation practices will be sufficient in the future. Generally, climate change has not been perceived as a great risk, and even if adaptation measures are being used they are often kept behind closed doors for strategic reasons. Nevertheless, Parks Canada, the Tourism Industry Association of British Columbia and some provincial parks agencies have been very proactive in climate-considerate planning, and could help the outdoor tourism sector in Eeyou Istchee James Bay adapt. (Kovacs & Thistlethwaite 2014)

- **Since Eeyou Istchee James Bay may both suffer and benefit from climate change, it would be important to seize future opportunities while also preparing for potential losses.**
- **COTA suggests that planned activities of coastal tourism** (e.g. boat cruises) **and outfitters should consider climate risks to revenues and civil security**, such as unpredictable weather patterns, extreme events and changes in the availability and quantity of certain species that are important for sports fishing and hunting (pers. comm.).
- More information on climate impacts and cost-effectiveness of adaptation strategies for tourist operators may present promising research avenues for the future.

Figure 9: Climate change adaptation of the tourism sector in Eeyou Istchee James Bay

In terms of industrial and economic development, it is essential to understand the vulnerabilities of the mining, forestry, hydroelectricity, and tourism sectors as there is a lack of local case studies and hazard mapping for land-use planning and development (cumulative impacts). Climate hazards should be considered in medium and long term planning, as they may have significant impacts on the environment, operations, infrastructure and civil security. It will be necessary to use up-to date climate information and anticipate risks on the life cycle of installations and operations. New climate information should be communicated in a user-friendly, collaborative and practical manner so that stakeholders can better appreciate the risks for their sector and adapt activities accordingly.

CHAPTER V – ADAPTATION TO CLIMATE CHANGE

International climate policies have significantly focused on curbing GHG emissions in order to prevent dramatic climate change and the crossing of key climate tipping points (Ford 2012). Yet, proactive adaptation measures are necessary because global warming is unavoidable. It will have significant socio-economic and environmental effects. According to Ford (2012), adaptation is considered a crucial aspect of climate policy from the local to the international level. It provides populations with the means to preserve their culture, to assert livelihoods and to strengthen health and economic development.

5.1 ADAPTATION READINESS AND CAPACITY

At the international level, the Paris Agreement (2016) aims at keeping global temperature rise below 2°C and strengthens the ability of 160 countries to adapt to the impacts of climate change (IPCC 2014). At the national level, many governments have developed climate change adaptation plans in recent years, and sectoral adaptation initiatives have been put into place (Ford 2012; IPCC 2014; Ouranos 2015). Recently, Canada has released the pan-Canadian framework on clean growth and climate change (2016). This strategy recognizes the particular vulnerabilities and rights of indigenous peoples, and also draws on traditional knowledge for decision-making. There are also several other mechanisms such as the Climate Change Adaptation Platform (NRCan) and different federal programs that support climate change adaptation research and exchanges (e.g. ECCC, Health Canada, AANDC). At the provincial level, Quebec has its own strategy on climate change adaptation for 2013-2020 to reduce emissions and improve resilience for the benefit of Quebec society.

5.1.1 VULNERABILITIES AND TRADITIONAL KNOWLEDGE

Indigenous peoples are often described as “powerless victims of climate change” (Ford 2012). Yet, this underestimates their capacity to adjust and use traditional knowledge systems for adaptation purposes. As stated by an elder of Weenusk in Western James Bay: *“The Cree have always adapted and they always will. Just like every other species out there. Some migrate. Some stay and adapt”* (Lemelin et al. 2010:8). Indigenous peoples have adapted to natural and cyclical changes of the environment for generations, but unexpected and abrupt changes can become problematic (Larivière 2011).

Almost everyone speaks Cree in Eeyou Istchee James Bay, and cultural continuity and the preservation of traditional activities is encouraged in many ways, for example through specific cultural programs organized on the community level, or widely celebrated festivities and holidays such as Goose Break and the Walking out Ceremony. Nevertheless, the Cree, as well as other indigenous communities, face common challenges with respect to cultural continuity and knowledge transfer trying to preserve cultural activities and language in a rapidly changing and increasingly modernized world (Cree Vision of Plan Nord 2011). Preserving and transmitting traditional knowledge to the next generation is seen by the research community as a major key to adaptation success in the long run because it can reduce vulnerability to climate change (Ford 2012). Several case studies have also shown that linking local knowledge to scientific observations increases the pertinence of adaptation measures (Ouranos 2015).

When engaging in climate change adaptation, it is important to **determine the nature and extent of vulnerability⁴³ of a population exposed to climate change** in order to find the best and most effective adaptation actions that are also culturally appropriate (Syvänen 2011; Downing & Cuerrier 2011). For example, an appropriate adaptation measure for the inland communities of Eeyou Istchee James Bay may be useless on the coast or vice versa. An action sufficient for one community or group of people (e.g. elders,

⁴³ Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of the capacity to cope and adapt.

children, hunters, etc.) might be insufficient for another since vulnerabilities are not the same, and thus cannot be treated the same way.

5.1.2 A FLEXIBLE AND PARTICIPATIVE ADAPTATION PROCESS

According to Pearce et al. (2012), it is essential to ensure community participation during adaptation research, planning and application to grasp the full extent of what we are adjusting to. Experiences in the Canadian Arctic have revealed that community-driven research, community based-monitoring or co-management practices can be challenging at times, but appear to be means that encourage exchange between communities of different knowledge systems and foster recognition and value of traditional knowledge (AACA 2015; IAIA 2017; Ouranos Symposium 2017 – Session on northern environments).

Adaptation initiatives, strategies or plans should be considered as dynamic and ‘living documents’ that need to be updated and require continual reassessment (Pearce et al. 2009b; Pearce et al. 2012). Adaptation planning should be regarded as **“the initiation of a practical and ongoing conversation that will shape actions through time”** trying to **“develop a framework for integrating and responding to new and changing information”**, not creating a static knowledge base (*ibid.*). Adaptation should be a **flexible, adjustable and continuous learning process which requires evaluation and monitoring of implemented adaptation actions and evolving climate risks** (Ouranos 2015; Ouranos 2010). Adaptation requires both **short-term** (i.e. switching species or modifying the time and location of the hunt) and **long-term adaptation** strategies (i.e. modifying cultural practices) (Berkes & Jolly 2002).

According to Ouranos (2015), **adaptation can take various forms**, such as physical and structural adaptation relying on engineering and technological innovations. It can also occur through institutional leverage such as guides, regulations, economic and financial tools and governmental adaptation plans. The third type of adaptation implies communication tools and knowledge sharing.

5.1.3 EXISTING ADAPTATION INITIATIVES IN EEYOU ISTCHEE JAMES BAY

This state of climate change and adaptation knowledge indicates that Eeyou Istchee James Bay is in the initial phases of the adaptation process (Figure 10- 1,2,3).

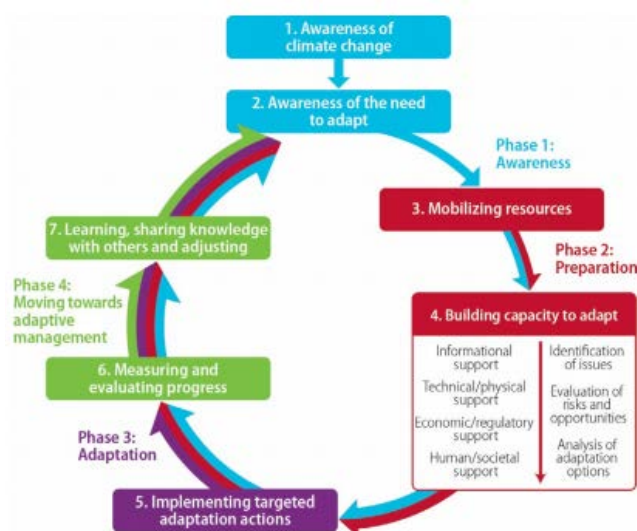


Figure 10: Stages and steps of the adaptation process. ©Eyzaguirre and Warren 2014

At this stage, awareness of climate impacts and needs for adaptation are becoming apparent, but regional organizations may need more information and support (e.g. strategic, technical, financial, human resources, etc.) to implement strategic targeted actions. So far, there are very few initiatives regarding infrastructure,

industry, ecosystem management and subsistence harvesting besides those already outlined in the previous chapters (*Figures 1, 5-9*). This may be due to a lack of accessible information, or because climate change has not yet been defined as a priority issue. **Several monitoring and adaptation measures have been put into place in Mistissini, Whapmagoostui and Waskaganish** ([Appendix 16](#)), mainly related to ice conditions and safety measures, but also water temperature and land access. These actions are mostly spontaneous and restricted locally and do not include any systematic data collection (CTA 2011).

Generally speaking, **proactive adaptation initiatives are rare or actions are not documented in written form**. Community adaptation actions such as announcements on the radio to warn people about unsafe ice conditions (Whapmagoostui), ice monitoring after freeze-up by the Fire Department (Mistissini), and marking a safe ice path by the Police and Safety department (Whapmagoostui) are used on an ad-hoc basis (CTA 2011). Besides, young hunters usually carry cell phones to communicate and check the weather in advance (Larivière 2011). The CTA made a call for action in 2011 stating that new security and safety awareness programs were needed to prevent accidents on the ice, in particular in spring (Royer et al. 2013). In the context of the *Wemindji Protected Areas Partnership*, the Cree Nation of Wemindji is developing a conservation strategy to establish an interconnected network of protected areas, safeguard wildlife, ensure food security and make sure that Cree values are considered in conservation planning. One key goal of this strategy is to build in resilience to climate change such as by creating areas that can buffer disturbances and accommodate wildlife shifts (CNG 2015a).

The Cree Nation Government also participates in the interregional monitoring of caribou, **the Ungava Peninsula Caribou Aboriginal Roundtable**, together with the Inuit of Nunavik and Nunatsiavut, the NunatuKavut Community Council, the Naskapi Nation of Kawawachikamach, and the Innu communities in Quebec and Labrador.

Figure 11 presents future climate change adaptation strategies that were collected during climate change workshops carried out by the CTA.

PROPOSALS FOR CLIMATE CHANGE ACTION IN EYYOU ISTCHEE JAMES BAY (CTA 2011)

Climate change adaptation proposals elaborated by participants from Mistissini, Whapmagoostui and Waskaganish in workshops organized by the CTA included three main actions.

-  **Creating local climate change committees** based on already existing structures whenever possible. Main functions: maintaining general awareness of climate change, networking with other Aboriginal communities, holding an annual community consultation on the state of the environment and informing the people of ongoing scientific research, as well as identifying funding sources and partnerships to implement the needed activities.
-  **Monitoring climate change** to gain a better understanding of changes in collaboration with research centres. This should also create training opportunities for young Cree researchers and actively engage youth as community researchers. Suggested monitoring activities: collect data on ice and weather conditions; monitor the main ice roads and implement a warning system; monitor polar bear activity around the communities; monitor habitat and wildlife; conduct a vulnerability assessment of species of concern. Some changes could be monitored without technical equipment such as seasonal signals.
-  **Establishing security and awareness programs** which may even be included into the school curriculum, e.g. winter survival camps. It was suggested to review existing emergency response plans and add safety equipment, install preventive early warning systems for extreme events, and increase community trade for sharing traditional foods and maintaining food security.

Figure 11: Proposals for climate change action in Eeyou Istchee James Bay

Three draft action plans to tackle climate change were also elaborated for Mistissini, Waskaganish and Whapmagoostui (see [Appendix 17, 18, 19](#)). However, climate actions could not be put into place following the workshops due to a lack of funding and staff (CTA, pers. comm.). Nevertheless, these action plans and the solutions already identified to tackle climate change issues could be used in the future if funding and

resources are secured. It is to our understanding that these actions still reflect the priorities of the communities. The collaborative climate change monitoring tool **GeoPortal**, developed by the CTA, has not been used by Cree hunters and trappers since 2011, likely due to a lack of promotion and other limitations (CTA, pers. comm.). These examples indicate that **monitoring and performance control as well as financial stability and continuous funding are crucial to guarantee the effectiveness of climate change adaptation**. Experience from other community-based adaptation programs in Nunavik shows similar results.

Firstly, raising awareness among stakeholders in the fields of infrastructure, economic development, natural resource management, biodiversity conservation, health and culture can strengthen general mobilization around climate-related risks, conservation and environmental protection. Consultations with regional organisations, stakeholders, government bodies, industry, researchers and end-users could be used to point out urgent and emerging issues relating to climate change, specific to the region. Secondly, building bridges between knowledge systems, local needs and operationalization of adaptation is a major challenge but it can be achieved with robust scientific knowledge, valorization of traditional knowledge and fruitful collaborations and partnerships with the region and communities. Integrating adaptation in policy and decision-making, for example in strategic documents such as land-use plans, can provide a useful framework for action. Thirdly, given the significant challenges posed by climate change, active research bodies and governments must better coordinate research efforts to support authorities that oversee the development and protection of the territory.

5.1.4 LEARNING FROM OTHER INDIGENOUS COMMUNITIES

Some indigenous communities in Canada have implemented very promising adaptation strategies. There are projects in various fields. The following examples could provide inspiration, and their progress and results will shed a light on facilitating factors and barriers which could help advance adaptation action in Eeyou Istchee James Bay.

- Ice monitoring: *SmartICE* is a real time ice monitoring project in Labrador. <https://smartice.org/>
- Food security: Community greenhouse: <https://inuivikgreenhouse.com/>; *Avativut* project on berry productivity: http://www.cen.ulaval.ca/avativut/en_accueil.aspx; *Kuglutuk Berry Monitoring Project*: <http://www.arcticcbm.org/index.html#eyJ0IjoieCIsImkiOiIxZGY4Mjg0MWQzZW5MmYwY2Y2OTQzZTE1NTY1MjRjZiJ9>. The [Arctic Institute of Community-Based Research](#) has multiple projects on food security.
- Infrastructure: The Nain Research Centre has a multidisciplinary initiative called *Sustainable Communities* <http://nainresearchcentre.com/the-sustainable-communities-initiative/> which focuses on housing, infrastructure and community development; energy security and also food security in the context of climate change and rapid population growth. Kativik Regional Government produced a guide on climate change adaptation for municipal practices. The community of Akwesasne is currently working on adapting the PIEVC (Public Infrastructure Engineering Vulnerability Committee) protocol to a First Nations reality in terms of water management.
- Species: *Community Youth Researcher Survey on Polar Bear and Caribou* in Fort Severn, Ontario. <http://www.climate-telling.info/fort-severn.html> or the [Arctic Borderlands Ecological Knowledge Coop](#) working on caribou monitoring in the North-West-Territories, Yukon and Alaska.
- Traditional knowledge: award-winning *SIKU* project to create a living wiki-archive of Inuit knowledge. <https://arcticeider.com/siku-help>

CONCLUSION & RECOMMENDATIONS

Climate change affects social and natural environments, built infrastructure, industrial and economic development (Figure 12). Therefore, it represents a major challenge to Cree culture, identity, health and subsistence activities, which are intimately linked to the land, its occupation and use (Figure 12). Various studies have demonstrated that climate change also exacerbates existing stressors such as industrial development or socio-economic challenges (Ouranos 2015). This report demonstrates, by relying on scientific studies and local observations by the Cree, that significant changes are already occurring, e.g. warmer air temperature, more extreme events, northward migration and phenological changes in species, modifications of land access, etc.

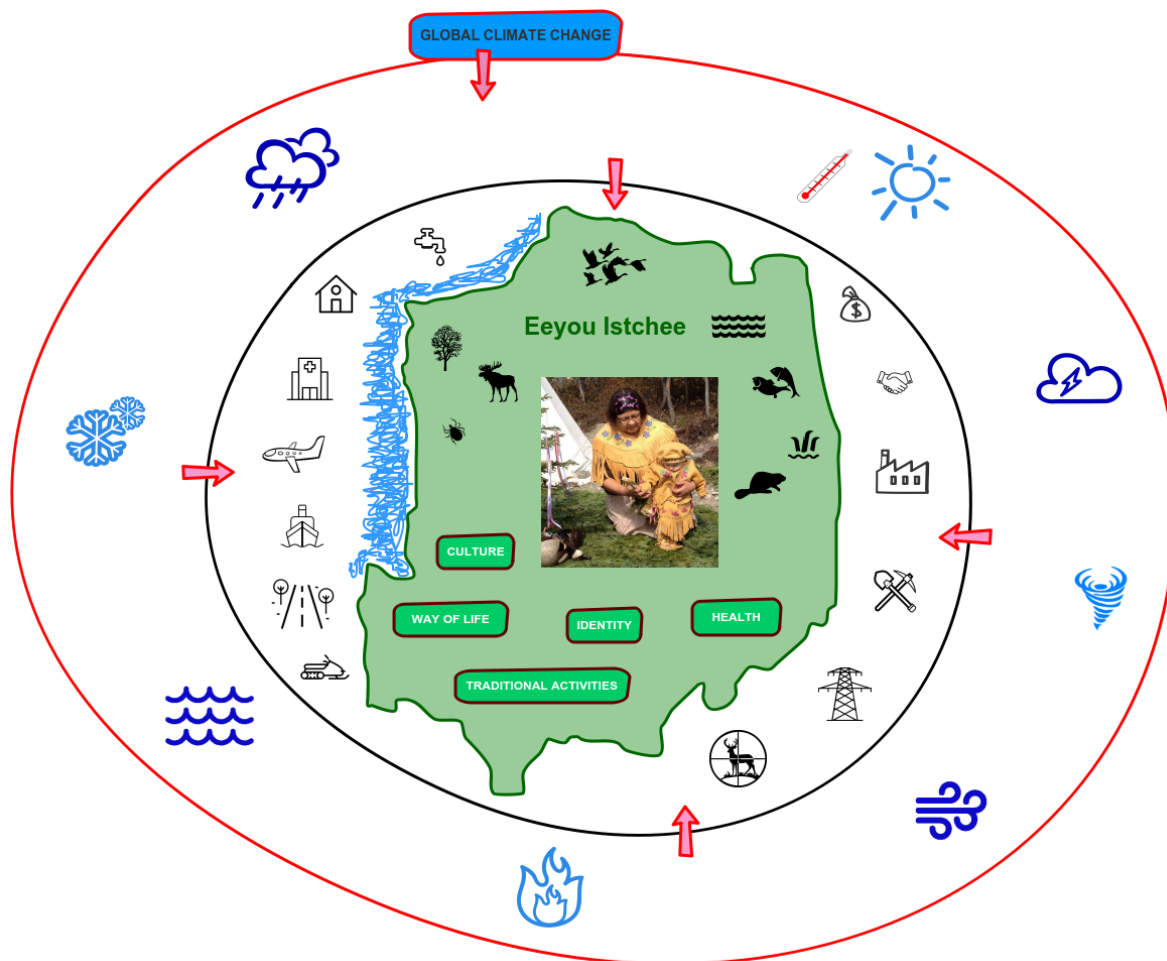


Figure 12: Impacts of climate change on the environment, economy, infrastructure, industrial development and the maintenance of Cree identity and way of life

Although some adaptation initiatives are progressing, they are still very limited and mostly voluntary or reactive, such as ways to adapt subsistence harvesting, infrastructure management or industrial development. Considering the observed and projected changes presented in this report, it appears necessary to think proactively about adaptation strategies and continue research in a region that has been largely overlooked in the past. Examples in Canada have shown that it is possible to adapt by relying on the use of general assumptions (e.g. climate events will recur, continue or increase in severity and frequency) and climate predictions with a certain degree of uncertainty (Eyzaguirre & Warren 2014).

In order to apprehend changes, mitigate effects and adapt adequately, future studies may focus on the research gaps and recommendations identified in this report and summarized in *Table 10*. However, local and regional consultations should be carried out to verify which topics are really relevant and could help the communities move forward and better prepare for the future. Research needs to take a holistic, multidisciplinary approach and should be carried out by or in cooperation with local stakeholders, while also aiming to engage and train Cree youth. Past studies in Nunavik and Nunatsiavut (Allard & Lemay 2013) as well as several ongoing studies (e.g. ArcticNet's IRIS 3 report; public consultations in the Eeyou Marine Region) can provide valuable information and research directions. Existing tools such as the GeoPortal or strategies applied at the community level (e.g. awareness and security programs) may just need to be promoted, supported more or adapted to encourage a widespread use all across Eeyou Istchee James Bay.

Table 10: State of climate change knowledge in Eeyou Istchee James Bay, research gaps and recommendations

Topic	State of knowledge		Recommendations
	2017 report	2007 report	
Culture and identity Mental & physical health Food security & subsistence	✓ ✓ ✓	✗ ✗ ✗	Study the social links to climate change. Research and analyze the complex relationship between climate change and food security, land access and health adopting a multidisciplinary and holistic approach. E.g. create short- and long-term health and resilience programs and encourage emotional health and well-being.
Air temperature Precipitation Snow Winds Lake and sea ice Sea surface temperature Sea surface salinity River discharge	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✗ ✗ ✗ ✗ ✓	Acquire data and monitor changes in the climate system. Conduct detailed, local studies of several climate parameters relying on traditional knowledge and scientific methods to establish a better reference climate and more reliable baseline data. E.g. research on lake mechanisms and dynamics, snow cover trends, frequency and intensity of extreme weather events, river flow, interaction between marine and freshwater systems, ocean dynamics and bathymetric mapping.
Aquatic ecosystems Terrestrial ecosystems Flora and fauna	✓ ✓ ✓	✗ ✓ ✓	Acquire data and monitor prioritized species. Carry out vulnerability assessments. Study the interactions between different ecosystems and also wildlife dynamics. Examine the response of iconic species to climate change, especially those harvested by the Cree and important for local economies (e.g. medicinal plants, whitefish, marine birds etc.). Study the response of wetlands (e.g. precipitation, soil moisture levels), marine (e.g. primary production), coastal and freshwater systems to climate change, monitor insect outbreaks and invasions, better understand fire frequency and intensity and repercussions on forest management. Develop an effective climate change adaptation strategy for biodiversity conservation.
Built infrastructure	✓	✗	Assess vulnerabilities, risks and costs associated with the maintenance, investment and replacement of assets. Promote climate-resilient norms, designs and building codes as well as climate-considerate asset planning in awareness campaigns and professional trainings so that they can be included by local stakeholders in anticipation of future climatic conditions.
Industry & economic development	✓	✗	Evaluate vulnerabilities and integrate climate risks into medium and long-term planning. Use up-to-date regional climate projections and anticipate risks on the life cycle of installations and operations. Communicate new climate information in a user-friendly, collaborative and practical manner.
Adaptation	✓	✗	Raise awareness and collaborate. Carry out consultations with key stakeholders. Build bridges between knowledge systems, local needs and operationalization of adaptation. Integrate adaptation into policy and decision-making. Better coordinate multi-level research efforts. Combine results from scientific research and Cree knowledge and ensure knowledge transfer. Build from existing adaptation knowledge.

The table shows the state of knowledge and scope of assembled information (scientific and local observations) for this report in comparison to the JBACE report from 2007. It also outlines recommendations identified for each chapter in the latest report.

Red cross: no information. Tick marks indicate the available level of information or research for Eeyou Istchee-James Bay.

Black: very limited. **Orange:** medium. **Green:** good

Climate change research and adaptation actions can be mainstreamed into practices, but it is important for decision and policy makers at all levels to recognize the issue and its many challenges for the Cree way of life and sustainability. Integrating climate change into frameworks such as land-use planning, resource management plans or research agendas will help to better coordinate adaptation efforts. Close collaborations among multi-level stakeholders (e.g. regional authorities, researchers, local organizations) encourage participation in the adaptation process, and can also facilitate the implementation of actions. Examples presented in this document indicate that monitoring and performance control as well as financial stability and continuous funding are crucial to guarantee the effectiveness of climate change adaptation. Finally, new information derived from climate and adaptation sciences should be communicated in a user-friendly way to the target audiences.

REFERENCES

- Acclimatise. (2010). *Building Business Resilience to Inevitable Climate Change*. Carbon Disclosure Project Report. Global Mining. Oxford.
- Adelson, N. (1998). Health beliefs and the politics of Cree well-being. *Health*, 2(1), 5-22. doi:10.1177/136345939800200101
- Albrecht, G., Sartore, G. M., Connor, L., Higginbotham, N., Freeman, S., Kelly, B., . . . Pollard, G. (2007). Solastalgia: the distress caused by environmental change. *Australas Psychiatry*, 15 Suppl 1, S95-98. doi:10.1080/10398560701701288
- Alexander, C., Bynum, N., Johnson, E., King, U., Mustonen, T., Neofotis, P., . . . Weeks, B. (2011). Linking Indigenous and Scientific Knowledge of Climate Change. *BioScience*, 61(6), 477-484. doi:10.1525/bio.2011.61.6.10
- Allard, M., & Lemay, M. (2013). *Le Nunavik et le Nunatsiavut: de la science aux politiques publiques: une étude intégrée d'impact régional des changements climatiques et de la modernisation*. ArcticNet.
- Anctil, M. (2008). Survey Highlights. *Nunavik Health Survey 2004, Qanuippitaa? How are we?* Quebec: Institut national de la santé publique du Québec & Nunavik Regional Board of Health and Social Services.
- Andrey, J., Kertland, P., & Warren, F. J. (2014). Water and Transportation Infrastructure. In F. J. Warren & D. S. Lemmen (Eds.), *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation* (pp. 233-252). Ottawa, ON: Government of Canada.
- Arrigo, K. R., & van Dijken, G. L. (2015). Continued increases in Arctic Ocean primary production. *Progress in Oceanography*, 136, 60-70. doi:<http://dx.doi.org/10.1016/j.pocean.2015.05.002>
- Asselin, H. 2015. Indigenous forest knowledge. Pages 586-596 in K. Peh, R. Corlett & Y. Bergeron (Eds.), *Routledge Handbook of Forest Ecology*. New York: Earthscan, Routledge.
- Auzel, P., Gaonac'h, H., Poisson, F., Siron, R., Calmé, S., Belanger, M., . . . Larocque, A. (2012). *Impacts des changements climatiques sur la biodiversité du Québec : Résumé de la revue de littérature*. CSBQ, MDDEP, Ouranos.
- Barber, D. G., Asplin, M. G., Papakyriakou, T. N., Miller, L., Else, B. G. T., Iacozza, J., . . . Wang, F. (2012). Consequences of change and variability in sea ice on marine ecosystem and biogeochemical processes during the 2007–2008 Canadian International Polar Year program. *Climatic Change*, 115(1), 135-159. doi:10.1007/s10584-012-0482-9
- Basso, K. (1996). *Wisdom sits in places: Landscape and Language among the Western Apache*. Albuquerque: University of New Mexico Press.
- Beguín, J., McIntire, E. J. B., Fortin, D., Cumming, S. G., Raulier, F., Racine, P., & Dussault, C. (2013). Explaining Geographic Gradients in Winter Selection of Landscapes by Boreal Caribou with Implications under Global Changes in Eastern Canada. *PLOS ONE*, 8(10), e78510. doi:10.1371/journal.pone.0078510
- Bélanger, C., Huard, D., Gratton, Y., Jeong, D. I., St-Hilaire, A., Auclair, J.-C. and Laurion, I. (2013). Impacts des changements climatiques sur l'habitat des salmonidés dans les lacs nordiques du Québec. Montréal: Ouranos, 168p.
- Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W., & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity. *Ecology letters*, 15(4), 365-377. doi:10.1111/j.1461-0248.2011.01736.x
- Berkes, F., & Jolly, D. (2002). Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. *Conservation ecology*, 5(2), 18.
- Berkes, F., & Mackenzie, M. (1978). Cree Fish Names from Eastern James Bay, Quebec. 1978, 31(4), 7. doi:10.14430/arctic2675
- Bernier, P., and Schoene, D. (2009): ; , v. 60, no., p. 5-11. (2009). Adapting forests and their management to climate change: An overview. *Unasylva*, 60(231/232).
- Berry, H. L., Butler, J. R. A., Burgess, C. P., King, U. G., Tsey, K., Cadet-James, Y. L., . . . Raphael, B. (2010a). Mind, body, spirit: co-benefits for mental health from climate change adaptation and caring for country in remote Aboriginal Australian communities. *New South Wales Public Health Bulletin*, 21(6), 139-145. doi:<https://doi.org/10.1071/NB10030>
- Berry, H. L., Bowen, K., & Kjellstrom, T. (2010b). Climate change and mental health: a causal pathways framework. *International Journal of Public Health*, 55(2), 123-132. doi:10.1007/s00038-009-0112-0
- Berry, P., Clarke, K., Fleury, M. D., & Parker, S. (2014). Human Health. In F. J. Warren & D. S. Lemmen (Eds.), *Canada in a changing climate: Sector perspectives on impacts and adaptation* (pp. 191-232). Ottawa, ON: Government of Canada.
- Berteaux, D., Blois, S. d., Angers, J.-F., Bonin, J., Casajus, N., Darveau, M., . . . Vescovi, L. (2010). The CC-Bio Project: Studying the Effects of Climate Change on Quebec Biodiversity. *Diversity*, 2(11), 1181.
- Berteaux, D., Casajus, N., & de Blois, S. (2014). *Changements climatiques et biodiversité du Québec: vers un nouveau patrimoine naturel*. Québec: PUQ.
- Berteaux, D., Réale, D., McAdam, A. G., & Boutin, S. (2004). Keeping Pace with Fast Climate Change: Can Arctic Life Count on Evolution? *Integrative and Comparative Biology*, 44(2), 140-151. doi:10.1093/icb/44.2.140
- Boccanfuso, D., Savard, L., Goyette, J., Gosselin, V., & Tanekou Mangoua, C. (2014). *An impact analysis of climate change on the forestry industry in Quebec. A dynamic CGE model*. Groupe de recherche en économie et développement international, Université de Sherbrooke.

- Bouchard, F., Francus, P., Pienitz, R., Laurion, I., & Feyte, S. (2014). Subarctic Thermokarst Ponds: Investigating Recent Landscape Evolution and Sediment Dynamics in Thawed Permafrost of Northern Québec (Canada). *Arctic, Antarctic, and Alpine Research*, 46(1), 251-271. doi:10.1657/1938-4246-46.1.251
- Boulanger, Y., Gauthier, S., Gray, D. R., Le Goff, H., Lefort, P., & Morissette, J. (2013). Fire regime zonation under current and future climate over eastern Canada. *Ecological Applications*, 23(4), 904-923.
- Bourque, A., & Simonet, G. (2008). Quebec. In D. S. Lemmen, F. J. Warren, J. Lacroix, & E. Bush (Eds.), *From impacts to adaptation: Canada in a changing climate 2007* (pp. 448). Ottawa, ON: Government of Canada, Ottawa.
- Bowman, D. M. J. S., & Murphy, B. P. (2010). Fire and biodiversity. In N. S. Sodhi & P. R. Ehrlich (Eds.), *Conservation biology for all*. New York: Oxford University Press.
- Brand, U., Came, R. E., Affek, H., Azmy, K., Mooi, R., & Layton, K. (2014). Climate-forced change in Hudson Bay seawater composition and temperature, Arctic Canada. *Chemical Geology*, 388, 78-86. doi:<https://doi.org/10.1016/j.chemgeo.2014.08.028>
- Braun, M., & Fournier, E. (2016). *Adaptation Case Studies in the Energy Sector – Overcoming Barriers to Adaptation*. Report presented to Climate Change Impacts and Adaptation Division, Natural Resources Canada, 114p.
- Breton, M.-P. (2017). Québec. In K. Palko & D. S. Lemmen (Eds.), *Climate risks and adaptation practices for the Canadian transportation sector 2016* (pp. 181-216). Ottawa, ON: Government of Canada.
- Brisson, G., & Bouchard-Bastien, E. (2014). *Changements climatiques et santé en Eeyou Istchee dans le contexte des évaluations environnementales*: Institut national de santé publique du Québec.
- Brown, L. C., & Duguay, C. R. (2010). The response and role of ice cover in lake-climate interactions. *Progress in Physical Geography*, 34(5), 671-704. doi:10.1177/0309133310375653
- Brown, R., Barrette, C., Chaumont, D., Grenier, P., Frigon, A., Roy, R., & Savard, J.-P. (2014). *Climate observations and projections for the Eeyou marine region*. Paper presented at the Symposium on Science and Traditional Knowledge in the Eeyou Marine Region Montréal.
- Bussière, B., Demers, I., Charron, P., & Bossé, B. (2017). *Analyse de risques et de vulnérabilités liés aux changements climatiques pour le secteur minier québécois*. Unité de recherche et de service en technologie minière, UQAT. Rapport préparé pour le Ministère de l'Énergie et des Ressources naturelles, 106 p. + app.
- Callaghan, T. V., Johansson, M., Brown, R. D., Groisman, P. Y., Labba, N., Radionov, V., . . . Yang, D. (2011). The Changing Face of Arctic Snow Cover: A Synthesis of Observed and Projected Changes. *AMBIO: A Journal of the Human Environment*, 40(sp1), 17-31. doi:10.1007/s13280-011-0212-y
- Campagna, S., Lévesque, B., Anassour-Laouan-Sidi, E., Côté, S., Serhir, B., Ward, B. J., . . . Dewailly, É. (2011). Seroprevalence of 10 zoonotic infections in 2 Canadian Cree communities. *Diagnostic Microbiology and Infectious Disease*, 70(2), 191-199. doi:<https://doi.org/10.1016/j.diagmicrobio.2011.01.009>
- Cavaliere, C. (2009). The Effects of Climate Change on Medicinal and Aromatic Plants. *HerbalGram*(81), 44-57.
- Cavaliere, D. J., & Parkinson, C. L. (2012). Arctic sea ice variability and trends, 1979-2010. *The Cryosphere*, 6(4), 881-889. doi:10.5194/tc-6-881-2012
- Charman, D. J., Beilman, D. W., Blaauw, M., Booth, R. K., Brewer, S., Chambers, F. M., . . . Zhao, Y. (2013). Climate-related changes in peatland carbon accumulation during the last millennium. *Biogeosciences*, 10(2), 929-944. doi:10.5194/bg-10-929-2013
- Charron, I. (2015). *Élaboration du portrait climatique régional du Nunavik*. Ouranos, Montréal.
- 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(6045), 1024-1026. doi:10.1126/science.1206432
- Cheng, C. S. (2014). Evidence from the Historical Record to Support Projection of Future Wind Regimes: An Application to Canada. *Atmosphere-Ocean*, 52(3), 232-241. doi:10.1080/07055900.2014.902803
- Cheng, C. S., Lopes, E., Fu, C., & Huang, Z. (2014). Possible Impacts of Climate Change on Wind Gusts under Downscaled Future Climate Conditions: Updated for Canada. *Journal of Climate*, 27(3), 1255-1270. doi:10.1175/jcli-d-13-00020.1
- Clavet-Gaumont, J., Huard, D., Frigon, A., Koenig, K., Slota, P., Rousseau, A., . . . Larouche, B. (2017). Probable maximum flood in a changing climate: An overview for Canadian basins. *Journal of Hydrology: Regional Studies*, 13, 11-25. doi:<http://dx.doi.org/10.1016/j.ejrh.2017.07.003>
- Clayton, S., Manning, C. M., Krygsmann, K., & Speiser, M. (2017). *Mental Health and Our Changing Climate: Impacts, Implications, and Guidance*. Washington, D.C.: American Psychological Association, and ecoAmerica.
- Comité d'experts sur l'aménagement écosystémique des forêts et les changements. (2017). *L'aménagement écosystémique des forêts dans le contexte des changements climatiques – Rapport du comité d'experts*. Québec: Gouvernement du Québec.
- Comte, L., Buisson, L., Daufresne, M., and Grenouillet, G. (2012). Climate-induced changes in the distribution of freshwater fish: observed and predicted trends. *Freshwater Biology*, 58: 625-639. doi:10.1111/fwb.12081
- Cooperative Freshwater Ecology Unit (2013). Second Progress Report – Aquatic Ecosystem Studies in the Hawley Lake / Sutton River area of the Hudson Bay Lowlands, 2009 – 2012. Available at: <http://www3.laurentian.ca/livingwithlakes/wp-content/uploads/2013/08/Hawley-L-Sutton-R-Progress-Rept-2013-final.pdf>.

- Costanza, R., de Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Grasso, M. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services*, 28, 1-16. doi:10.1016/j.ecoser.2017.09.008
- Côté, C. (2014). Vers un Québec au climat transformé. *La Presse*.
- Council of Canadian Academies. (2014). *Aboriginal food security in Northern Canada: an assessment of the state of knowledge*. Council of Canadian Academies: Expert Panel on the State of Knowledge of Food Security in Northern Canada.
- Cree Nation Government. (2015a). *Cree regional conservation strategy*. 19pp.
- Cree Nation Government. (2015b). *Reflecting on the kind of development we need, and how we can achieve it*. Stronger Together Eeyou-Eenou Economic Development Conference. Mistissini.
- Cree Trappers Association. (2010). *Impacts and Adaptation Measures for the Hunters, Trappers and Communities of Eeyou Istchee: Mistissini Community Report*.
- Cree Trappers Association. (2010). *Impacts and Adaptation Measures for the Hunters, Trappers and Communities of Eeyou Istchee: Waskaganish Community Report*.
- Cree Trappers Association. (2010). *Impacts and Adaptation Measures for the Hunters, Trappers and Communities of Eeyou Istchee: Whapmagoostui Community Report*.
- Cree Trappers Association. (2011). *Climate change in Eeyou Istchee - Identification of impacts and adaptation measures for the Cree hunters, trappers and communities*. Canada.
- Cree Working Group on the Plan Nord. (2011). *Cree vision of Plan Nord*.
- Cuerrier, A., Turner, N., C Gomes, T., Garibaldi, A., & Downing, A. (2015). *Cultural Keystone Places: Conservation and Restoration in Cultural Landscapes* (Vol. 35).
- Cunsolo Willox, A., Harper, S. L., Edge, V. L., Landman, K., Houle, K., & Ford, J. D. (2011). The land enriches the soul: On climatic and environmental change, affect, and emotional health and well-being in Rigolet, Nunatsiavut, Canada. *Emotion, Space and Society*, 6, 14-24. doi:<http://dx.doi.org/10.1016/j.emospa.2011.08.005>
- Cunsolo Willox, A., Harper, S. L., Ford, J. D., Landman, K., Houle, K., & Edge, V. L. (2012). "From this place and of this place:" climate change, sense of place, and health in Nunatsiavut, Canada. *Soc Sci Med*, 75(3), 538-547. doi:10.1016/j.socscimed.2012.03.043
- Cunsolo Willox, A., Harper, S. L., Ford, J. D., Edge, V. L., Landman, K., Houle, K., . . . Wolfrey, C. (2013). Climate change and mental health: an exploratory case study from Rigolet, Nunatsiavut, Canada. *Climatic Change*, 121(2), 255-270. doi:10.1007/s10584-013-0875-4
- de Blois, S., Boisvert-Marsh, L., Schmucki, R., Lovat, CA, Byun, C., Gomez-Garcia, P., Otfinowski, R., Groeneveld, E., & Lavoie, C. (2013). Outils pour évaluer les risques d'invasion biologique dans un contexte de changements climatiques. McGill University. Montréal, Québec. 80 p. + app.
- Delphi Group. (2014). *Climate Adaptation in the Canadian Mining Sector*. Report prepared for the Mining Association of Canada.
- Delphi Group. (2017). *Energy Sector Adaptation State of Play 2016 Report*. Ottawa. Report prepared for Natural Resources Canada, Climate Change Impacts and Adaptation Division.
- 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(13). doi:10.1029/2009GL038852
- Déry, S. J., Mlynowski, T. J., Hernández-Henríquez, M. A., & Straneo, F. (2011). Interannual variability and interdecadal trends in Hudson Bay streamflow. *Journal of Marine Systems*, 88(3), 341-351. doi:<http://dx.doi.org/10.1016/j.jmarsys.2010.12.002>
- Déry, S. J., Stadnyk, T. A., MacDonald, M. K., & Gauli-Sharma, B. (2016). Recent trends and variability in river discharge across northern Canada. *Hydrology and Earth System Sciences*, 20(12), 4801.
- Dewailly, E., Blanchet, C., Gingras, S., Lemieux, S., & Holub, B. J. (2002). Cardiovascular disease risk factors and n-3 fatty acid status in the adult population of James Bay Cree. *The American Journal of Clinical Nutrition*, 76(1), 85-92.
- Diaconescu, E. (2017). *Développement de scénarios climatiques pour le Canada basés sur les simulations régionales CORDEX*. Presentation at the 7th Ouranos Symposium, Montréal, Canada.
- Downing, A., & Cuerrier, A. (2011). A synthesis of the impacts of climate change on the First Nations and Inuit of Canada. *Indian Journal of Traditional Knowledge*, 10(1), 57-70.
- Drever, C. R., Bergeron, Y., Drever, M. C., Flannigan, M., Logan, T., & Messier, C. (2009). Effects of climate on occurrence and size of large fires in a northern hardwood landscape: historical trends, forecasts, and implications for climate change in Témiscamingue, Québec. *Applied Vegetation Science*, 12(3), 261-272. doi:10.1111/j.1654-109X.2009.01035.x
- Drinkwater, K. F., Beaugrand, G., Kaeriyama, M., Kim, S., Ottersen, G., Perry, R. I., . . . Takasuka, A. (2010). On the processes linking climate to ecosystem changes. *Journal of Marine Systems*, 79(3), 374-388. doi:<http://dx.doi.org/10.1016/j.jmarsys.2008.12.014>
- Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z.-I., Knowler, D. J., Lévêque, C., . . . Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81(2), 163-182. doi:10.1017/S1464793105006950

- Dudley, J. P., Hoberg, E. P., Jenkins, E. J., & Parkinson, A. J. (2015). Climate Change in the North American Arctic: A One Health Perspective. *EcoHealth*, 12(4), 713-725. doi:10.1007/s10393-015-1036-1
- Duerden, F., Pearce, T., Ford, J., & Pittman, J. (2014). *Case Studies Of Adaptation To Climate Change In The Yukon Mining Sector: From Planning And Operation To Remediation And Restoration*. Ottawa, Ontario: Report submitted to Climate Change Impacts and Adaptation Division, Natural Resources Canada.
- Duguay, C. R., Pultz, T. J., Lafleur, P. M., & Dray, D. (2002). RADARSAT backscatter characteristics of ice growing on shallow sub-Arctic lakes, Churchill, Manitoba, Canada. *Hydrological Processes*, 16(8), 1631-1644. doi:10.1002/hyp.1026
- Environment and Climate Change Canada (ECCC) (2013). Sea Ice Climatic Atlas for the Northern Canadian Waters 1981-2010. Retrieved from: <https://www.ec.gc.ca/glaces-ice/default.asp?lang=En&n=4B35305B-1&offset=2&toc=show> (28/09/2017).
- Dymond, C. (2017). How might climate change affect forest growth and what can we do about it. Forestry Adaptation Community of Practice (FACoP) Webinar November 7, 2017.
- Erni, S. (2016). *Régulation des régimes de feux dans la forêt boréale de la Baie James, Québec*. (Ph.D.), Institut national de la recherche scientifique, Québec.
- Erni, S., Arseneault, D., Parisien, M.-A., & Bégin, Y. (2017). Spatial and temporal dimensions of fire activity in the fire-prone eastern Canadian taiga. *Global Change Biology*, 23(3), 1152-1166. doi:10.1111/gcb.13461
- Ernst & Young. (2015). *Economic impacts of a changing climate on mine sites in Canada: Assessing proactive adaptation investments against estimated relative costs*: Report prepared for Natural Resources Canada and the Adaptation Platform Mining Working Group.
- Estilow, T. W., Young, A. H., & Robinson, D. A. (2015). A long-term Northern Hemisphere snow cover extent data record for climate studies and monitoring. *Earth Syst. Sci. Data*, 7(1), 137-142. doi:10.5194/essd-7-137-2015
- Ettenger, K. (2012). "Aapupayuu (the Weather Warms Up): Climate Change and the Eeyouch (Cree) of Northern Quebec. In D. Taylor, D. Brokensha, & P. Castro (Eds.), *Climate Change and Threatened Communities: Vulnerability, Capacity, and Action*. UK: Practical Action.
- Eyzaguirre, J., & Warren, F. J. (2014). Adaptation: Linking Research and Practice. In F. J. Warren & D. S. Lemmen (Eds.), *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation* (pp. 253-286). Ottawa, ON: Government of Canada.
- Faille, G., Dussault, C., Ouellet, J.-P., Fortin, D., Courtois, R., St-Laurent, M.-H., & Dussault, C. (2010). Range fidelity: The missing link between caribou decline and habitat alteration? *Biological Conservation*, 143(11), 2840-2850. doi:<http://dx.doi.org/10.1016/j.biocon.2010.08.001>
- Feit, H. A. (1995). Hunting and the quest for power: The James Bay Cree and Whitemen in the twentieth century. . In R. B. Morrison & C. R. Wilson (Eds.), *Native peoples: the Canadian experience* (2 ed., pp. 181-223). Toronto: McClelland and Stewart.
- Félio, G. (2012). Canadian infrastructure report card: 2012, municipal roads and water systems. Canadian Construction Association, Canadian Public Works Association, Canadian Society for Civil Engineering and Federation of Canadian Municipalities.
- First Nations of Quebec and Labrador Sustainable Development Institute (FNQLSDI). (2017). *Portrait of First Nations challenges in terms of infrastructure and emergency management in the face of climate change*. Wendake, QC.
- Flannigan, M. (2017). *The future of wildfire in Canada - hot and smoky ?*. Forestry Adaptation Community of Practice (FACoP) Webinar October 3, 2017.
- Flannigan, M. D., Wotton, B. M., Marshall, G. A., de Groot, W. J., Johnston, J., Jurko, N., & Cantin, A. S. (2016). Fuel moisture sensitivity to temperature and precipitation: climate change implications. *Climatic Change*, 134(1), 59-71. doi:10.1007/s10584-015-1521-0
- Flannigan, M., Cantin, A. S., de Groot, W. J., Wotton, M., Newbery, A., & Gowman, L. M. (2013). Global wildland fire season severity in the 21st century. *Forest Ecology and Management*, 294, 54-61. doi:10.1016/j.foreco.2012.10.022
- Ford, J. D. (2012). Indigenous Health and Climate Change. *American Journal of Public Health*, 102(7), 1260-1266. doi:10.2105/AJPH.2012.300752
- Ford, J. D., Bell, T., & Couture, N. J. (2016). Perspectives on Canada's North Coast region In D. S. Lemmen, F. J. Warren, T. S. James, & C. S. L. Mercer Clarke (Eds.), *Canada's Marine Coasts in a Changing Climate* (pp. 153-206). Ottawa, ON: Government of Canada.
- Ford, J. D., Pearce, T., Gilligan, J., Smit, B., & Oakes, J. (2008). Climate Change and Hazards Associated with Ice Use in Northern Canada. *Arctic, Antarctic, and Alpine Research*, 40(4), 647-659. doi:10.1657/1523-0430(07-040)[FORD]2.0.CO;2
- Ford, J. D., Pearce, T., Prno, J., Duerden, F., Berrang Ford, L., Beaumier, M., & Smith, T. (2010). Perceptions of climate change risks in primary resource use industries: a survey of the Canadian mining sector. *Regional Environmental Change*, 10(1), 65-81. doi:10.1007/s10113-009-0094-8
- Ford, J. D., Pearce, T., Prno, J., Duerden, F., Berrang Ford, L., Smith, T. R., & Beaumier, M. (2011). Canary in a coal mine: perceptions of climate change risks and response options among Canadian mine operations. *Climatic Change*, 109(3), 399-415. doi:10.1007/s10584-011-0029-5

- Foro, A., Béziers, L., Robinson, E., & Torrie, J. E. (2013). *Perceptions of the leaders and professionals of Eeyou Istchee in regard to climate change and its effects on human health: Report on the consultations* Cree Board of Health and Social Services of James Bay.
- Frey, K. E., Comisco, J. C., Cooper, L. W., Gradinger, R. R., Grebmeier, J. M., & Tremblay, J. É. (2017). *Arctic Ocean Primary Productivity*. Arctic Report Card 2016. <https://www.arctic.noaa.gov/Report-Card>.
- Furgal, C., & Prowse, T. D. (2008). Northern Canada. In D. S. Lemmen, F. J. Warren, J. Lacroix, & E. Bush (Eds.), *From impacts to adaptation: Canada in a changing climate 2007* (pp. 448): Government of Canada, Ottawa.
- Galbraith, P. S., & Larouche, P. (2011). Sea-surface temperature in Hudson Bay and Hudson Strait in relation to air temperature and ice cover breakup, 1985–2009. *Journal of Marine Systems*, 87(1), 66-78. doi:<http://dx.doi.org/10.1016/j.jmarsys.2011.03.002>
- Garneau, M. (2017). *Dynamique du carbone dans les tourbières boréales et subarctiques du Québec nordique*. Presentation at the Institut National Polytechnique, Toulouse.
- Garneau, M., & van Bellen, S. (2016). *Synthèse de la valeur et la répartition du stock de carbone terrestre au Québec*: Rapport présenté au Ministère du Développement durable, Environnement et Lutte contre les changements climatiques du Québec.
- Garneau, M., van Bellen, S., Magnan, G., Beaulieu-Audy, V., Lamarre, A., & Asnong, H. (2014). Holocene carbon dynamics of boreal and subarctic peatlands from Québec, Canada. *The Holocene*, 24(9), 1043-1053. doi:10.1177/0959683614538076
- Gaston, A. J., Smith, P. A., & Provencher, J. F. (2012). Discontinuous change in ice cover in Hudson Bay in the 1990s and some consequences for marine birds and their prey. *ICES Journal of Marine Science*, 69(7), 1218-1225. doi:10.1093/icesjms/fss040
- Gilg, O., Kovacs, K. M., Aars, J., Fort, J., Gauthier, G., Grémillet, D., . . . Bollache, L. (2012). Climate change and the ecology and evolution of Arctic vertebrates. *Annals of the New York Academy of Sciences*, 1249(1), 166-190. doi:10.1111/j.1749-6632.2011.06412.x
- Girard, F., Payette, S., & Gagnon, R. (2008). Rapid expansion of lichen woodlands within the closed-crown boreal forest zone over the last 50 years caused by stand disturbances in eastern Canada. *Journal of Biogeography*, 35(3), 529-537. doi:10.1111/j.1365-2699.2007.01816.x
- Gough, W. A., & Leung, A. (2012). Nature and fate of Hudson Bay permafrost. *Regional Environmental Change*, 2(4), 177-184. doi:10.1007/s10113-002-0048-x
- Granskog, M. A., Kuzyk, Z. Z. A., Azetsu-Scott, K., & Macdonald, R. W. (2011). Distributions of runoff, sea-ice melt and brine using $\delta^{18}\text{O}$ and salinity data — A new view on freshwater cycling in Hudson Bay. *Journal of Marine Systems*, 88(3), 362-374. doi:<http://dx.doi.org/10.1016/j.jmarsys.2011.03.011>
- Grebmeier, J. M., Overland, J. E., Moore, S. E., Farley, E. V., Carmack, E. C., Cooper, L. W., . . . McNutt, S. L. (2006). A major ecosystem shift in the northern Bering Sea. *Science*, 311(5766), 1461-1464.
- Gunn, J., & Snucins, E. (2010). Brook charr mortalities during extreme temperature events in Sutton River, Hudson Bay Lowlands, Canada. *Hydrobiologia*, 650(1), 79-84. doi:10.1007/s10750-010-0201-3
- Haddad, P. S., Musallam, L., Martineau, L. C., Harris, C., Lavoie, L., Arnason, J. T., . . . Badawi, A. (2012). Comprehensive evidence-based assessment and prioritization of potential antidiabetic medicinal plants: A case study from Canadian Eastern James Bay Cree traditional medicine. *Evidence-based Complementary and Alternative Medicine : eCAM*, 2012, 893426. doi:10.1155/2012/893426
- Hare, A., Stern, G. A., Macdonald, R. W., Kuzyk, Z. Z., & Wang, F. (2008). Contemporary and preindustrial mass budgets of mercury in the Hudson Bay Marine System: The role of sediment recycling. *Science of The Total Environment*, 406(1), 190-204. doi:<https://doi.org/10.1016/j.scitotenv.2008.07.033>
- Harsch, M. A., Hulme, P. E., McGlone, M. S., & Duncan, R. P. (2009). Are treelines advancing? A global meta-analysis of treeline response to climate warming. *Ecology letters*, 12(10), 1040-1049. doi:10.1111/j.1461-0248.2009.01355.x
- Hauser, D. D. W., Laidre, K. L., Stafford, K. M., Stern, H. L., Suydam, R. S., & Richard, P. R. (2017). Decadal shifts in autumn migration timing by Pacific Arctic beluga whales are related to delayed annual sea ice formation. *Global Change Biology*, 23(6), 2206-2217. doi:10.1111/gcb.13564
- Hart, C. R., Berry, H. L., & Tonna, A. M. (2011). Improving the mental health of rural New South Wales communities facing drought and other adversities. *Australian Journal of Rural Health*, 19(5), 231-238. doi:10.1111/j.1440-1584.2011.01225.x
- Hély, C., Girardin, M. P., Ali, A. A., Carcaillet, C., Brewer, S., & Bergeron, Y. (2010). Eastern boreal North American wildfire risk of the past 7000 years: A model-data comparison. *Geophysical Research Letters*, 37(14), n/a-n/a. doi:10.1029/2010GL043706
- Hennigs, R. (2015). *The future of Nova Scotia's network of protected areas - How does climate change need to be incorporated into biodiversity planning and management?* (M. Sc.), Université Laval, Québec, QC.

- Herrmann, T. M., Royer, M.-J. S., & Cuciurean, R. (2012). Understanding subarctic wildlife in Eastern James Bay under changing climatic and socio-environmental conditions: bringing together Cree hunters' ecological knowledge and scientific observations. *Polar Geography*, 35(3-4), 245-270. doi:10.1080/1088937x.2011.654356
- Hershkovitz, Y., Strackbein, J., & Hering, D. (2013). Climate-and-freshwater.info. Version: January 2014. Retrieved from www.climate-and-freshwater.info (15-08-2017).
- Hess, J. J., Malilay, J. N., & Parkinson, A. J. (2008). Climate Change: The Importance of Place. *American Journal of Preventive Medicine*, 35(5), 468-478. doi:https://doi.org/10.1016/j.amepre.2008.08.024
- Hochheim, K., Barber, D. G., & Lukovich, J. V. (2010). Changing Sea Ice Conditions in Hudson Bay, 1980–2005. 39-52. doi:10.1007/978-90-481-9121-5_2
- Hochheim, K. P., & Barber, D. G. (2014). An Update on the Ice Climatology of the Hudson Bay System. *Arctic, Antarctic, and Alpine Research*, 46(1), 66-83. doi:10.1657/1938-4246-46.1.66
- Hoegh-Guldberg, O., & Bruno, J. F. (2010). The impact of climate change on the world's marine ecosystems. *Science*, 328(5985), 1523-1528.
- Holtmeier, F.-K., & Broll, G. (2010). Wind as an Ecological Agent at Treelines in North America, the Alps, and the European Subarctic. *Physical Geography*, 31(3), 203-233. doi:10.2747/0272-3646.31.3.203
- Hoover, C., Pitcher, T., & Christensen, V. (2013). Effects of hunting, fishing and climate change on the Hudson Bay marine ecosystem: I. Re-creating past changes 1970–2009. *Ecological Modelling*, 264, 130-142. doi:https://doi.org/10.1016/j.ecolmodel.2013.02.005
- Hossein, T. (2017). *Polar bear wildlife viewing in Eeyou Istchee: An assessment of different perspectives and considerations*. Concordia University,
- Hutchings, J. A., Côté, I. M., Dodson, J. J., Fleming, I. A., Jennings, S., Mantua, N. J., . . . Weaver, A. J. (2012). Climate change, fisheries, and aquaculture: trends and consequences for Canadian marine biodiversity *Environmental Reviews*, 20(4), 220-311. doi:10.1139/a2012-011
- Huziy, O., & Sushama, L. (2017). Impact of lake–river connectivity and interflow on the Canadian RCM simulated regional climate and hydrology for Northeast Canada. *Climate Dynamics*, 48(3), 709-725. doi:10.1007/s00382-016-3104-9
- International Association of Impact Assessment (IAIA) (2017). Topical session : *Northern ecosystems and biodiversity under pressure: climate change and other anthropic stressors*.
- IPCC. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*. In Core Writing Team, R. K. Pachauri, & L. A. Meyer (Eds.), (pp. 151).
- Irambona, C., Music, B., Nadeau, D. F., Mahdi, T. F., & Strachan, I. B. (2016). Impacts of boreal hydroelectric reservoirs on seasonal climate and precipitation recycling as simulated by the CRCM5: a case study of the La Grande River watershed, Canada. *Theoretical and Applied Climatology*. doi:10.1007/s00704-016-2010-8
- James Bay and Northern Quebec Agreement (JBNQA). (1975). Retrieved from: <http://www.gcc.ca/pdf/LEG000000006.pdf> (02/10/2017).
- Jarema, S. I., Samson, J., McGill, B. J., & Humphries, M. M. (2009). Variation in abundance across a species' range predicts climate change responses in the range interior will exceed those at the edge: a case study with North American beaver. *Global Change Biology*, 15(2), 508-522. doi:10.1111/j.1365-2486.2008.01732.x
- Jobidon, R., & Bergeron, Y. (2015). Assessing the biophysical potential for sustainable forest management: a case study from Quebec's boreal forest - Introduction. *Canadian Journal of Forest Research*, 45(5), v-vi. doi:10.1139/cjfr-2015-0091
- Joly, S., Senneville, S., Caya, D., & Saucier, F. J. (2011). Sensitivity of Hudson Bay Sea ice and ocean climate to atmospheric temperature forcing. *Climate Dynamics*, 36(9), 1835-1849. doi:10.1007/s00382-009-0731-4
- Johnston, M., & Gatin, J. (2017). *Forestry Adaptation Initiatives across Canada. State of Play Report*. Saskatchewan Research Council.
- Kaldy, J. E. (2014). Effect of temperature and nutrient manipulations on eelgrass *Zostera marina* L. from the Pacific Northwest, USA. *Journal of Experimental Marine Biology and Ecology*, 453, 108-115. doi:https://doi.org/10.1016/j.jembe.2013.12.020
- Keller, W., Paterson, A. M., Rühland, K. M., & Blais, J. M. (2014). Introduction — Environmental Change in the Hudson and James Bay Region. *Arctic, Antarctic, and Alpine Research*, 46(1), 2-5. doi:10.1657/1938-4246-46.1.2
- Khalil, C. B., Johnson-Down, L., & Egeland, G. M. (2010). Emerging obesity and dietary habits among James Bay Cree youth. *Public Health Nutrition*, 13(11), 1829-1837. doi:10.1017/S1368980010000406
- Kjellerup, S., Dünweber, M., Swaethorp, R., Nielsen, T. G., Møller, E. F., Markager, S., & Hansen, B. W. (2012). Effects of a future warmer ocean on the coexisting copepods *Calanus finmarchicus* and *C. glacialis* in Disko Bay, western Greenland. *Marine Ecology Progress Series*, 447, 87-108. doi:10.3354/meps09551
- Kovacs, P., & Thistlethwaite, J. (2014). Industry. In F. J. Warren & D. S. Lemmen (Eds.), *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation* (pp. 135-158). Ottawa, ON: Government of Canada.
- Kowal, S., Gough, W. A., & Butler, K. (2017). Temporal evolution of Hudson Bay Sea Ice (1971–2011). *Theoretical and Applied Climatology*, 127(3), 753-760. doi:10.1007/s00704-015-1666-9

- Kuzyk, Z. A., Macdonald, R. W., Granskog, M. A., Scharien, R. K., Galley, R. J., Michel, C., . . . Stern, G. (2008). Sea ice, hydrological, and biological processes in the Churchill River estuary region, Hudson Bay. *Estuarine, Coastal and Shelf Science*, 77(3), 369-384. doi:<https://doi.org/10.1016/j.ecss.2007.09.030>
- Kuzyk, Z. Z. A., Macdonald, R. W., Johannessen, S. C., & Stern, G. A. (2010). Biogeochemical Controls on PCB Deposition in Hudson Bay. *Environmental Science & Technology*, 44(9), 3280-3285. doi:10.1021/es903832t
- Kuzyk, Z. Z. (2014). *Freshwater sources and distribution in the Hudson and James Bay systems*. Paper presented at the Symposium on Science and Traditional Knowledge in the Eeyou Marine Region Montreal.
- Laberge Gaudin, V., Receveur, O., Walz, L., Girard, F., & Potvin, L. (2014). A mixed methods inquiry into the determinants of traditional food consumption among three Cree communities of Eeyou Istchee from an ecological perspective. *International Journal of Circumpolar Health*, 73, 10.3402/ijch.v3473.24918. doi:10.3402/ijch.v73.24918
- Ladouceur, S. (2008). *Évaluation des changements environnementaux de la Baie d'Hudson et du Bassin de Foxe au cours des derniers siècles à partir de traceurs palynologiques et micropaléontologiques*. (M.Sc.), Université du Québec à Montréal, Montreal, QC.
- Laidler, G. J., Ford, J. D., Gough, W. A., Ikummaq, T., Gagnon, A. S., Kowal, S., . . . Irngaut, C. (2009). Travelling and hunting in a changing Arctic: assessing Inuit vulnerability to sea ice change in Igloodik, Nunavut. *Climatic Change*, 94(3), 363-397. doi:10.1007/s10584-008-9512-z
- Laidre, K. L., Stirling, I., Lowry, L. F., Wiig, Ø., Heide-Jørgensen, M. P., & Ferguson, S. H. (2008). Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. *Ecological Applications*, 18(sp2), S97-S125. doi:10.1890/06-0546.1
- Larbi, Y. (2017). Cree awareness and the mining boom in Eeyou Istchee [Press release]. Retrieved from <https://www.mern.gouv.qc.ca/english/mines/quebec-mines/2017-05/mineral-exploration.asp>
- Larbi, Y., Mark, R., & MacKinnon, M. (2016). *Eeyou Istchee mineral exploration activities for the year 2016*: Cree Mineral Exploration Board
- Larivière, V. (2011). *La vulnérabilité et l'adaptation aux changements climatiques: Une étude de cas à Kuujuaarapik et Whapmagoostui*. (Maîtrise en sciences de l'environnement), Université du Québec à Montréal, Montréal.
- Larouche, P., & Galbraith, P. S. (2016). Canadian Coastal Seas and Great Lakes Sea Surface Temperature Climatology and Recent Trends. *Canadian Journal of Remote Sensing*, 42(3), 243-258. doi:10.1080/07038992.2016.1166041
- Latifovic, R., & Pouliot, D. (2007). Analysis of climate change impacts on lake ice phenology in Canada using the historical satellite data record. *Remote Sensing of Environment*, 106(4), 492-507.
- Le Corre, M., Dussault, C., & Côté, S. D. (2016). Weather conditions and variation in timing of spring and fall migrations of migratory caribou. *Journal of Mammalogy*, gyw177. doi:10.1093/jmammal/gyw177
- Le Goff, H., Flannigan, M. D., & Bergeron, Y. (2009). Potential changes in monthly fire risk in the eastern Canadian boreal forest under future climate change. *Canadian Journal of Forest Research*, 39(12), 2369-2380. doi:10.1139/x09-153
- Le Goff, H., Flannigan, M. D., Bergeron, Y., & Girardin, M.-P. (2007). Historical fire regime shifts related to climate teleconnections in the Waswanipi area, central Quebec, Canada. *International Journal of Wildland Fire*, 16(5), 607-618.
- Leblond, M., St-Laurent, M.-H., & Côté, S. D. (2016). Caribou, water, and ice – fine-scale movements of a migratory arctic ungulate in the context of climate change. *Movement Ecology*, 4(1), 14. doi:10.1186/s40462-016-0079-4
- Lemelin, H., Matthews, D., Mattina, C., McIntyre, N., Johnston, M., Koster, R., & Peawanuck, W. F. N. a. (2010). Climate change, wellbeing and resilience in the Weenusk First Nation at Peawanuck: The Moccasin Telegraph goes global *Rural and Remote Health*, 10(1333).
- Lemmen, D. S., Johnston, M., Ste-Marie, C., & Pearce, T. (2014). Natural Resources. In F. J. Warren & D. S. Lemmen (Eds.), *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*. Ottawa, ON: Government of Canada.
- Levesque, B., Messier, V., Bonnier-Viger, Y., Couillard, M., Cote, S., Ward, B. J., . . . Dewailly, E. (2007). Seroprevalence of zoonoses in a Cree community (Canada). *Diagn Microbiol Infect Dis*, 59(3), 283-286. doi:10.1016/j.diagmicrobio.2007.06.002
- Loder, J. W., van der Baaren, A., & Yashayaev, I. (2015). Climate Comparisons and Change Projections for the Northwest Atlantic from Six CMIP5 Models. *Atmosphere-Ocean*, 53(5), 529-555. doi:10.1080/07055900.2015.1087836
- Lovejoy, T. E. (2008). Climate change and biodiversity. *Revue Scientifique Et Technique*, 27(2), 331-338.
- Lovejoy, T. E. (2010). Climate change. In N. S. Sodhi & P. R. Ehrlich (Eds.), *Conservation biology for all*. New York: Oxford University Press.
- Lynch, A. J., Taylor, W. W., Beard, T. D., & Lofgren, B. M. (2015). Climate change projections for lake whitefish (*Coregonus clupeaformis*) recruitment in the 1836 Treaty Waters of the Upper Great Lakes. *Journal of Great Lakes Research*, 41(2), 415-422. doi:<https://doi.org/10.1016/j.jglr.2015.03.015>
- Lyons, J., & Stewart, J. S. (2014). Predicted effects of future climate warming on thermal habitat suitability for Lake Sturgeon (*Acipenser fulvescens*, Rafinesque, 1817) in rivers in Wisconsin, USA. *Journal of Applied Ichthyology*, 30(6), 1508-1513. doi:10.1111/jai.12543

- Macdonald, R. W., Kuzyk, Z. A., & Johannessen, S. C. (2015). It is not just about the ice: a geochemical perspective on the changing Arctic Ocean. *Journal of Environmental Studies and Sciences*, 5(3), 288-301. doi:10.1007/s13412-015-0302-4
- Macdonald, R. W., & Kuzyk, Z. Z. A. (2011). The Hudson Bay system: A northern inland sea in transition. *Journal of Marine Systems*, 88(3), 337-340. doi:<https://doi.org/10.1016/j.jmarsys.2011.06.003>
- Mansuy, N., Gauthier, S., Bergeron, Y., & Robitaille, A. (2012). *Rapport final et stratégies de réflexion. Cartographie de la vulnérabilité au feu et résilience forestière pour lecteur sud-est du territoire de la Baie James*.
- McGill, B. J., Etienne, R. S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., . . . White, E. P. (2007). Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. *Ecology letters*, 10(10), 995-1015. doi:10.1111/j.1461-0248.2007.01094.x
- McDermid, J., Browne, D., Chetkiewicz, C.-L., & Chu, C. (2015). Identifying a suite of surrogate freshwater fish species: a case study of conservation prioritization in Ontario's Far North, Canada. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 25(6), 855-873. doi:10.1002/aqc.2557
- McKenney, D. W., Pedlar, J. H., Lawrence, K., Campbell, K., & Hutchinson, M. F. (2007). Potential Impacts of Climate Change on the Distribution of North American Trees. *BioScience*, 57(11), 939-948. doi:10.1641/B571106
- McLaughlin, J., & Webster, K. (2014). Effects of Climate Change on Peatlands in the Far North of Ontario, Canada: A Synthesis. *Arctic, Antarctic, and Alpine Research*, 46(1), 84-102. doi:10.1657/1938-4246-46.1.84
- Mc Lean, G. (2009). *Report of the Indigenous Peoples Global Summit on Climate Change: 20-24 April 2009, Anchorage, Alaska* (United Nations University – Traditional Initiative: Darwin, Australia).
- McManus, K. M., Morton, D. C., Masek, J. G., Wang, D., Sexton, J. O., Nagol, J. R., . . . Boudreau, S. (2012). Satellite-based evidence for shrub and graminoid tundra expansion in northern Quebec from 1986 to 2010. *Global Change Biology*, 18(7), 2313-2323. doi:10.1111/j.1365-2486.2012.02708.x
- Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.
- Mining Association of Canada. (2012). *Managing climate change risks in BC's mining sector*. Presentation by Ben Chalmers to the Fraser Basin Council on March 14, 2012.
- Meunier, C. (2007). *Portrait et impacts environnementaux connus du changement climatique sur le territoire de la Baie James*. Rapport préparé pour le Comité consultatif pour l'environnement de la Baie James, 57 p.
- Ministère de l'Énergie et des Ressources naturelles du Québec (MERN) (2013). *Rapport du Comité scientifique chargé d'examiner la limite nordique des forêts attribuables. Secteur des forêts*. Gouvernement du Québec.
- Moore, S. E., & Huntington, H. P. (2008). Arctic marine mammals and climate change: Impacts and resilience. *Ecological Applications*, 18(sp2), S157-S165. doi:10.1890/06-0571.1
- Nachar, A., Saleem, A., Arnason, J. T., & Haddad, P. S. (2015). Regulation of liver cell glucose homeostasis by dehydroabietic acid, abietic acid and squalene isolated from balsam fir (*Abies balsamea* (L.) Mill.) a plant of the Eastern James Bay Cree traditional pharmacopeia. *Phytochemistry*, 117(Supplement C), 373-379. doi:<https://doi.org/10.1016/j.phytochem.2015.07.001>
- Nantel, P., Pellatt, M. G., Keenleyside, K., & Gray, P. A. (2014). Biodiversity and protected areas. In F. J. Warren & D. S. Lemmen (Eds.), *Canada in a changing climate: Sector perspectives on impacts and adaptation* (pp. 159-190). Ottawa, ON: Government of Canada.
- Nelson, T., Coops, N., Wulder, M., Perez, L., Fitterer, J., Powers, R., & Fontana, F. (2014). Predicting Climate Change Impacts to the Canadian Boreal Forest. *Diversity*, 6(1), 133.
- Nieboer, E., Dewailly, E., Johnson-Down, L., Sampasa-Kanyinga, H., Château-Degat, M.-L., Egeland, G. M., . . . Torrie, J. (2013). Nituuchischaayihititau Aschii Multi-community Environment-and-Health Study in Eeyou Istchee 2005- 2009: Final Technical Report. In E. Nieboer, E. Robinson, & K. Petrov (Eds.), *Public Health Report Series 4 on the Health of the Population*. Chisasibi, QC: Cree Board of Health and Social Services of James Bay.
- Niemi, A., Paulic, J., & Cobb, D. (2010). *Ecosystem status and trends report: Arctic marine ecozones*. (Doc. 2010/066.).
- Niemi, A., Schimnowski, O., & Reist, J. D. (2016). *Arctic large aquatic basin climate change assessment part 2: Impacts, vulnerabilities and opportunities (IVO) - A contribution to the Aquatic Climate Change Adaptation Services Program*. (3091).
- Obbard, M. E., & Middel, K. R. (2012). Bounding the Southern Hudson Bay polar bear subpopulation. *Ursus*, 23(2), 134-144. doi:10.2192/URSUS-D-11-00030.1
- Ohmagari, K., & Berkes, F. (1997). Transmission of Indigenous Knowledge and Bush Skills Among the Western James Bay Cree Women of Subarctic Canada. *Human Ecology*, 25(2), 197-222. doi:10.1023/a:1021922105740
- Ontario Centre for Climate Impacts and Adaptation Resources. (2015). Climate change impacts & adaptation in Ontario: The mining sector. In *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*.
- Oris, F., Asselin, H., Finsinger, W., Hély, C., Blarquez, O., Ferland, M.-E., . . . Ali, A. A. (2014). Long-term fire history in northern Quebec: implications for the northern limit of commercial forests. *Journal of Applied Ecology*, 51(3), 675-683. doi:10.1111/1365-2664.12240
- Orlova, J., & Branfireun, B. A. (2014). Surface Water and Groundwater Contributions to Streamflow in the James Bay Lowland, Canada. *Arctic, Antarctic, and Alpine Research*, 46(1), 236-250. doi:10.1657/1938-4246-46.1.236

- Ouranos. (2015). *Vers l'adaptation. Synthèse des connaissances sur les changements climatiques au Québec. Édition 2015.* Montréal, Québec.
- Ouranos (2010). *Élaborer un plan d'adaptation aux changements climatiques. Guide destiné au milieu municipal québécois.* Montréal (Québec), 48 p.
- Parkinson, C. L. (2014). Spatially mapped reductions in the length of the Arctic sea ice season. *Geophysical Research Letters*, 41(12), 4316-4322. doi:10.1002/2014GL060434
- Parmesan, C., & Hanley, M. E. (2015). Plants and climate change: complexities and surprises. *Annals of Botany*, 116(6), 849-864. doi:10.1093/aob/mcv169
- Pearce, T., Ford, J. D., Caron, A., & Kudlak, B. P. (2012). Climate change adaptation planning in remote, resource-dependent communities: an Arctic example. *Regional Environmental Change*, 12(4), 825-837. doi:10.1007/s10113-012-0297-2
- Pearce, T., Ford, J. D., Prno, J., & Duerden, F. (2009a). *Climate change and Canadian mining: Opportunities for adaptation: Report prepared for The David Suzuki Foundation.*
- Pearce, T. D., Ford, J. D., Laidler, G. J., Smit, B., Duerden, F., Allarut, M., . . . Wandel, J. (2009b). Community collaboration and climate change research in the Canadian Arctic. *Polar Research*, 28(1), 10-27. doi:10.1111/j.1751-8369.2008.00094.x
- Pearce, T. D., Ford, J. D., Prno, J., Duerden, F., Pittman, J., Beaumier, M., . . . Smit, B. (2011). Climate change and mining in Canada. *Mitigation and Adaptation Strategies for Global Change*, 16(3), 347-368. doi:10.1007/s11027-010-9269-3
- Pellerin, S. & Poulin, M. (2013). *Analyse de la situation des milieux humides au Québec et recommandations à des fins de conservation et de gestion durable.* Rapport présenté au Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs, 104 p.
- Pelletier, L., Garneau, M., & Moore, T. R. (2011). Variation in CO₂ exchange over three summers at microform scale in a boreal bog, Eastmain region, Québec, Canada. *Journal of Geophysical Research*, 116(G3). doi:10.1029/2011jg001657
- Peloquin, C., & Berkes, F. (2009). Local Knowledge, Subsistence Harvests, and Social–Ecological Complexity in James Bay. *Human Ecology*, 37(5), 533-545. doi:10.1007/s10745-009-9255-0
- Peloquin, C., & Berkes, F. (2010). Local Knowledge and Changing Subsistence Strategies in James Bay, Canada. In D. G. Bates & J. Tucker (Eds.), *Human Ecology: Contemporary Research and Practice* (pp. 281-295). Boston, MA: Springer US.
- Périé, C., de Blois, S., Lambert, M.-C., & Casajus, N. (2014). *Effets anticipés des changements climatiques sur l'habitat des espèces arborescentes au Québec*: Gouvernement du Québec. Ministère des ressources naturelles, Direction de la recherche forestière.
- Pétrin-Desrosiers, C. (2017). *Climate change and health impacts in Eeyou Istchee.* An internal report presented to the Public Health Department of the Cree Board of Health and Social Services of James Bay, 66 p.
- Poloczanska, E. S., Brown, C. J., Sydeman, W. J., Kiessling, W., Schoeman, D. S., Moore, P. J., . . . Richardson, A. J. (2013). Global imprint of climate change on marine life. *Nature Clim. Change*, 3(10), 919-925. doi:10.1038/nclimate1958
<http://www.nature.com/nclimate/journal/v3/n10/abs/nclimate1958.html#supplementary-information>
- Price, D. T., Alfaro, R. I., Brown, K. J., Flannigan, M. D., Fleming, R. A., Hogg, E. H., . . . Venier, L. A. (2013). Anticipating the consequences of climate change for Canada's boreal forest ecosystems. *Environmental Reviews*, 21(4), 322-365. doi:10.1139/er-2013-0042
- Proust, F., Johnson-Down, L., Berthiaume, L., Greffard, K., Julien, P., Robinson, E., . . . Dewailly, É. (2016). Fatty acid composition of birds and game hunted by the Eastern James Bay Cree people of Québec. *International Journal of Circumpolar Health*, 75, 10.3402/ijch.v3475.30583. doi:10.3402/ijch.v75.30583
- Racey, G. D. (2005). Climate change and woodland caribou in Northwestern Ontario: a risk analysis. *Rangifer*, 25(4), 123-136.
- Rapaic, M., Brown, R., Markovic, M., & Chaumont, D. (2015). An Evaluation of Temperature and Precipitation Surface-Based and Reanalysis Datasets for the Canadian Arctic, 1950–2010. *Atmosphere-Ocean*, 53(3), 283-303. doi:10.1080/07055900.2015.1045825
- Rapinski, M., Liu, R., Saleem, A., Arnason, J. T., & Cuerrier, A. (2014). Environmental trends in the variation of biologically active phenolic compounds in Labrador tea, *Rhododendron groenlandicum*, from northern Quebec, Canada. *Botany*, 92(11), 783-794. doi:10.1139/cjb-2013-0308
- Remy, C. C., Lavoie, M., Girardin, M. P., Hély, C., Bergeron, Y., Grondin, P., . . . Ali, A. A. (2017). Wildfire size alters long-term vegetation trajectories in boreal forests of eastern North America. *Journal of Biogeography*, 44(6), 1268-1279. doi:10.1111/jbi.12921
- Richard, J. H., Wilmschurst, J., & Côté, S. D. (2014). The effect of snow on space use of an alpine ungulate: recently fallen snow tells more than cumulative snow depth. *Canadian Journal of Zoology*, 92(12), 1067-1074. doi:10.1139/cjz-2014-0118
- Richter-Menge, J., Overland, J. E., & Mathis, J. T. (2016). Arctic Report Card 2016. Retrieved from <http://www.arctic.noaa.gov/Report-Card>
- Rijnsdorp, A. D., Peck, M. A., Engelhard, G. H., Möllmann, C., & Pinnegar, J. K. (2009). Resolving the effect of climate change on fish populations. *ICES Journal of Marine Science*, 66(7), 1570-1583. doi:10.1093/icesjms/fsp056
- Rinawati, F., Stein, K., & Lindner, A. (2013). Climate Change Impacts on Biodiversity—The Setting of a Lingering Global Crisis. *Diversity*, 5(1), 114.

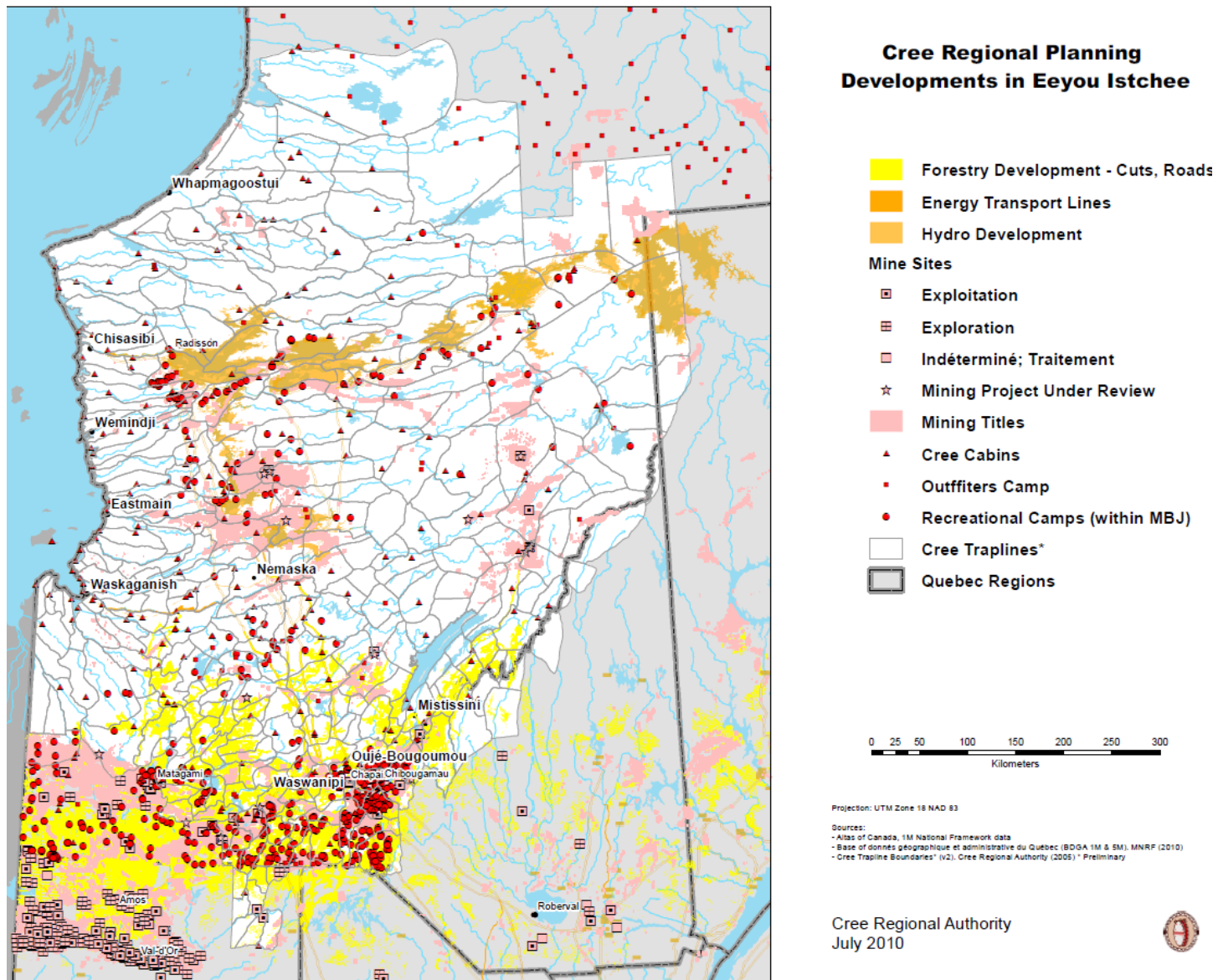
- Royer, M.-J. S. (2012). *L'interaction entre les savoirs écologiques traditionnels et les changements climatiques: les Cris de la Baie-James, la bernache du Canada et le caribou des bois*. (Ph.D.), Université de Montréal.
- Royer, M.-J. S. (2016). *Climate, environment and Cree observations*: Springer.
- Royer, M.-J. S., & Herrmann, T. M. (2011). Socioenvironmental changes in two traditional food species of the Cree First Nation of subarctic James Bay. *Cahiers de géographie du Québec*, 55(156), 575-601.
- Royer, M.-J. S., Herrmann, T. M., Sonnentag, O., Fortier, D., Delusca, K., & Cuciurean, R. (2013). Linking Cree hunters' and scientific observations of changing inland ice and meteorological conditions in the subarctic eastern James Bay region, Canada. *Climatic Change*, 119(3), 719-732. doi:10.1007/s10584-013-0773-9
- Rudolph, T. D., Drapeau, P., St-Laurent, M.-H. & Imbeau, L. (2012). Situation du caribou forestier (*Rangifer tarandus caribou*) sur le territoire de la Baie James dans la région Nord-du-Québec, Montréal, 77 p.
- Rühland, K. M., Hargan, K. E., Jeziorski, A., Paterson, A. M., Keller, W., & Smol, J. P. (2014). A Multi-Trophic Exploratory Survey of Recent Environmental Changes using Lake Sediments in the Hudson Bay Lowlands, Ontario, Canada. *Arctic, Antarctic, and Alpine Research*, 46(1), 139-158. doi:10.1657/1938-4246-46.1.139
- Sampasa-Kanyinga, H., Lévesque, B., Anassour-Laouan-Sidi, E., Côté, S., Serhir, B., Ward, B. J., Dimitrova, K. (2013). Zoonotic infections in communities of the James Bay Cree territory: An overview of seroprevalence. *Canadian Journal of Infectious Diseases and Medical Microbiology*, 24(2), 79-84.
- Samson, J. (2012). *Atlas de la biodiversité du Québec nordique: Effets des changements climatiques sur la biodiversité*.
- Savard, J.-P. (2016). *Impacts des changements climatiques sur le régime des tempêtes et les niveaux d'eau extrêmes dans la baie d'Hudson, la baie James et le détroit d'Hudson*. Montréal: Ouranos.
- Sayles, J. (2008). *Tapaiitam : human modifications of the coast as adaptations to environmental change, Wemindji, eastern James Bay*. (M. Sc.), Concordia University, Montréal.
- Sayles, J. S., & Mulrennan, M. E. (2010). Securing a future: Cree hunters' resistance and flexibility to environmental changes, Wemindji, James Bay. *Ecology and Society*, 15(4).
- Scannell, L., & Gifford, R. (2010). Defining place attachment: A tripartite organizing framework. *Journal of Environmental Psychology*, 30(1), 1-10. doi:https://doi.org/10.1016/j.jenvp.2009.09.006
- Shabbar, A., Skinner, W., & Flannigan, M. D. (2011). Prediction of Seasonal Forest Fire Severity in Canada from Large-Scale Climate Patterns. *Journal of Applied Meteorology and Climatology*, 50(4), 785-799. doi:10.1175/2010JAMC2547.1
- Sharma, S., Couturier, S., & Côté, S. D. (2009). Impacts of climate change on the seasonal distribution of migratory caribou. *Global Change Biology*, 15(10), 2549-2562. doi:10.1111/j.1365-2486.2009.01945.x
- Sharma, S., Jackson, D. A., Minns, C. K., & Shuter, B. J. (2007). Will northern fish populations be in hot water because of climate change? *Global Change Biology*, 13(10), 2052-2064. doi:10.1111/j.1365-2486.2007.01426.x
- Société du Plan Nord. (2017). Priorités. Retrieved from: <https://plannord.gouv.qc.ca/fr/priorites-daction/> (23-08-2017).
- Stadnyk, T., Déry, S., MacDonald, M., & Koenig, K. (2017). Freshwater System. In *Hudson Bay IRIS*.
- Steiner, N., Azetsu-Scott, K., Galbraith, P., Hamilton, J., Hedges, K., Hu, X., . . . van der Baaren, A. (2013). *Climate change assessment in the Arctic Basin Part 1: Trends and projections - A contribution to the Aquatic Climate Change Adaptation Services Program*.
- Steiner, N., Azetsu-Scott, K., Hamilton, J., Hedges, K., Hu, X., Janjua, M. Y., . . . Tallmann, R. (2015). Observed trends and climate projections affecting marine ecosystems in the Canadian Arctic. *Environmental Reviews*, 23(2), 191-239. doi:10.1139/er-2014-0066
- Stewart, D., & Lockhart, W. (2004). *Summary of the Hudson Bay Marine Ecosystem Overview*. Prepared by Arctic Biological Consultants, Winnipeg, for Canada Department of Fisheries and Oceans, Winnipeg, MB. Draft vi + 66p.
- Syvänen, A. L. (2011). *Wemindji Cree observations and interpretations of climate change: Documenting vulnerability and adaptability in the subarctic*. (Master of Science), Concordia, Montréal.
- Taillon, J. (2013). *Condition physique, allocation maternelle et utilisation spatio-temporelle des aires de mise bas du caribou migrateur, Rangifer tarandus*. (Master thesis), Université Laval.
- Tam, B., Gough, W. A., & Tsuji, L. (2011). The impact of warming on the appearance of furunculosis in fish of the James Bay region, Quebec, Canada. *Regional Environmental Change*, 11(1), 123-132. doi:10.1007/s10113-010-0122-8
- Tam, B. Y., Gough, W. A., Edwards, V., & Tsuji, L. J. S. (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 / Le Géographe canadien*, 57(4), 441-456. doi:10.1111/j.1541-0064.2013.12033.x
- Tanentzap, A. J., Yan, N. D., Keller, B., Girard, R., Heneberry, J., Gunn, J. M., . . . Taylor, P. A. (2008). Cooling lakes while the world warms: Effects of forest regrowth and increased dissolved organic matter on the thermal regime of a temperate, urban lake. *Limnology and Oceanography*, 53(1), 404-410. doi:10.4319/lo.2008.53.1.0404
- Tarasov, L., & Peltier, W. R. (2004). A geophysically constrained large ensemble analysis of the deglacial history of the North American ice-sheet complex. *Quaternary Science Reviews*, 23(3), 359-388. doi:<http://dx.doi.org/10.1016/j.quascirev.2003.08.004>
- Terrier, A., Girardin, M. P., Périé, C., Legendre, P., & Bergeron, Y. (2013). Potential changes in forest composition could reduce impacts of climate change on boreal wildfires. *Ecological Applications*, 23(1), 21-35. doi:10.1890/12-0425.1

- Thibault, S., & Payette, S. (2009). Recent permafrost degradation in bogs of the James Bay area, northern Quebec, Canada. *Permafrost and Periglacial Processes*, 20(4), 383-389. doi:10.1002/ppp.660
- Tivy, A., Howell, S. E. L., Alt, B., McCourt, S., Chagnon, R., Crocker, G., . . . Yackel, J. J. (2011). Trends and variability in summer sea ice cover in the Canadian Arctic based on the Canadian Ice Service Digital Archive, 1960–2008 and 1968–2008. *Journal of Geophysical Research: Oceans*, 116(C3), n/a-n/a. doi:10.1029/2009JC005855
- Tremblay, F., Marchand, M., Fenton, N., & Bergeron, Y. (2013). *Biodiversité de la flore vasculaire et invasculaire de la Baie James et évaluation de leurs vulnérabilités face aux changements climatiques*: Institut de recherche sur les forêts Université du Québec en Abitibi-Témiscamingue.
- Tremblay, J. É., Bélanger, S., Barber, D. G., Asplin, M., Martin, J., Darnis, G., . . . Gosselin, M. (2011). Climate forcing multiplies biological productivity in the coastal Arctic Ocean. *Geophysical Research Letters*, 38(18), n/a-n/a. doi:10.1029/2011gl048825
- Tsuji, L. J., Gomez, N., Mitrovica, J. X., & Kendall, R. (2009). Post-glacial isostatic adjustment and global warming in subarctic Canada: implications for islands of the James Bay region. *Arctic*, 458-467.
- Turner, N. J., & Turner, K. L. (2008). "Where our women used to get the food": cumulative effects and loss of ethnobotanical knowledge and practice; case study from coastal British Columbia. *Botany*, 86(2), 103-115. doi:10.1139/b07-020
- Uprety, Y., Asselin, H., Dhakal, A., & Julien, N. (2012). Traditional use of medicinal plants in the boreal forest of Canada: review and perspectives. *Journal of Ethnobiology and Ethnomedicine*, 8(1), 7.
- US EPA. (2017). Why are wetlands important. Retrieved from <https://www.epa.gov/wetlands/why-are-wetlands-important>
- Villarino, E., Chust, G., Licandro, P., Butenschön, M., Ibaibarriaga, L., Larrañaga, A., & Irigoien, X. (2015). Modelling the future biogeography of North Atlantic zooplankton communities in response to climate change. *Marine Ecology Progress Series*, 531, 121-142.
- Vincent, L. A., Zhang, X., Brown, R. D., Feng, Y., Mekis, E., Milewska, E. J., . . . Wang, X. L. (2015). Observed Trends in Canada's Climate and Influence of Low-Frequency Variability Modes. *Journal of Climate*, 28(11), 4545-4560. doi:10.1175/jcli-d-14-00697.1
- Vincent, W. F., Laurion, I., Pienitz, R., & Walter Anthony, K. (2013). Climate impacts on Arctic lake ecosystems. In C. R. Goldman, M. Kumagai, & R. D. Robarts (Eds.), *Climatic Change and Global Warming of Inland Waters: Impacts and Mitigation for Ecosystems and Societies* (pp. 27-42).
- Voyageur, I., & McLean, C. (2017). *Adapting project descriptions for climate change*. Paper presented at the International Association for Impact Assessment, Montréal, Canada.
- Wang, R., McCullough, G. K., Gunn, G. G., Hochheim, K. P., Dorostkar, A., Sydor, K., & Barber, D. G. (2012). An observational study of ice effects on Nelson River estuarine variability, Hudson Bay, Canada. *Continental Shelf Research*, 47, 68-77. doi:10.1016/j.csr.2012.06.014
- Wang, X., Thompson, D. K., Marshall, G. A., Tymstra, C., Carr, R., & Flannigan, M. D. (2015). Increasing frequency of extreme fire weather in Canada with climate change. *Climatic Change*, 130(4), 573-586. doi:10.1007/s10584-015-1375-5
- Warren, F. J., & Lemmen, D. S. (2014). *Canada in a changing climate: Sector perspectives on impacts and adaptation*. Ottawa, ON: Government of Canada.
- Wassmann, P., Duarte, C. M., Agustí, S., & Sejr, M. K. (2011). Footprints of climate change in the Arctic marine ecosystem. *Global Change Biology*, 17(2), 1235-1249. doi:10.1111/j.1365-2486.2010.02311.x
- Way, R. G., Lewkowicz, A. G., & Bonnaventure, P. P. (2017). Development of moderate-resolution gridded monthly air temperature and degree-day maps for the Labrador-Ungava region of northern Canada. *International Journal of Climatology*, 37(1), 493-508. doi:10.1002/joc.4721
- Way, R. G., & Viau, A. E. (2014). Natural and forced air temperature variability in the Labrador region of Canada during the past century. *Theoretical and Applied Climatology*, 121(3-4), 413-424. doi:10.1007/s00704-014-1248-2
- Wilson, M.-A. (2017). *Increasing Climate Resilience within the Energy Sector: Work of the Energy Working Group*. Paper presented at the Adaptation Platform Plenary, Ottawa.
- Woodward, G., & Perkins, D. M. (2015). Biodiversity, ecosystem functioning, and services in fresh waters: Ecological and evolutionary implications of climate change. In A. Belgrano, G. Woodward, & U. Jacob (Eds.), *Aquatic functional biodiversity: An ecological and evolutionary perspective* (pp. 127-155). London: Elsevier Inc.
- Woodward, G., Perkins, D. M., & Brown, L. E. (2010). Climate change and freshwater ecosystems: impacts across multiple levels of organization. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1549), 2093-2106. doi:10.1098/rstb.2010.0055
- Wotton, B. M., Flannigan, M. D., & Marshall, G. A. (2017). Potential climate change impacts on fire intensity and key wildfire suppression thresholds in Canada. *Environmental Research Letters*, 12(9).
- Wotton, B. M., Nock, C. A., & Flannigan, M. D. (2010). Forest fire occurrence and climate change in Canada. *International Journal of Wildland Fire*, 19(3), 253-271.
- Wrona, F. J., Johansson, M., Culp, J. M., Jenkins, A., Mård, J., Myers-Smith, I. H., . . . Wookey, P. A. (2016). Transitions in Arctic ecosystems: Ecological implications of a changing hydrological regime. *Journal of Geophysical Research: Biogeosciences*, 121(3), 650-674. doi:10.1002/2015JG003133

WWF Canada (2017). A national assessment of Canada's freshwater - Watershed reports. Available at:
[http://assets.wwf.ca/downloads/WWF Watershed Reports Summit FINAL web.pdf?_ga=2.253177481.104824520.1507753630-1578493707.1507753630](http://assets.wwf.ca/downloads/WWF_Watershed_Reports_Summit_FINAL_web.pdf?_ga=2.253177481.104824520.1507753630-1578493707.1507753630) (summary report) /
http://watershedreports.wwf.ca/?_ga=2.194923309.104824520.1507753630-1578493707.1507753630#canada/by/threat-overall/profile (interactive map and individual watershed reports)
(10/11/2017).

APPENDICES

APPENDIX 1



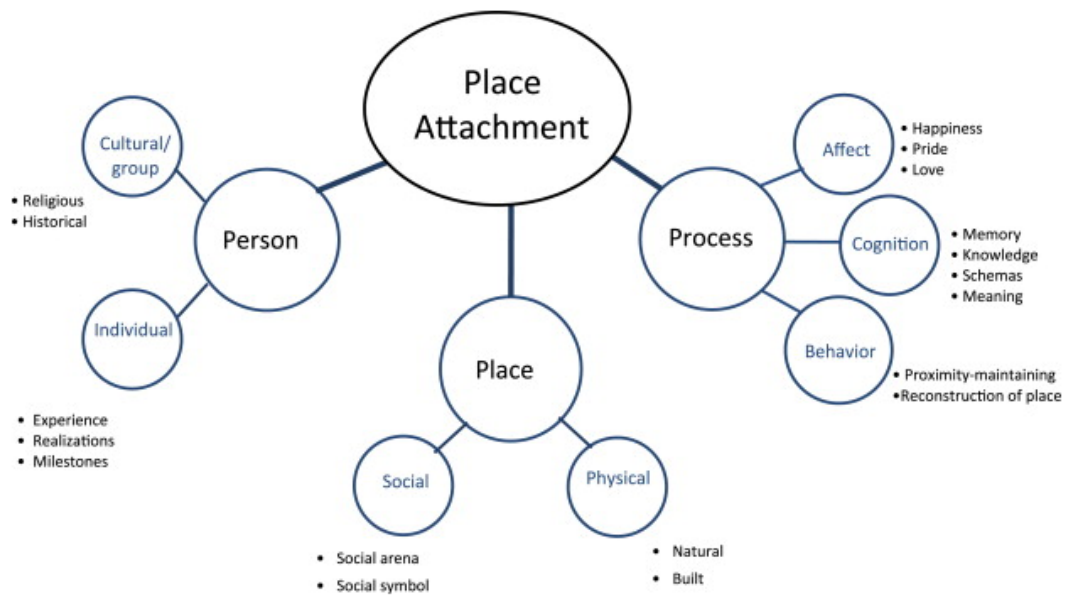
Forestry, energy transport lines and hydroelectric and mining development with Cree cabins, outfitters camps and recreational camps (Cree Regional Authority 2010)

APPENDIX 2

Category	Keywords
Climate change synonyms	Climate change, environmental change, global change, climatic change, global warming
Geographic terms	James Bay, Eeyou Istchee, Cree, James Bay Cree, Hudson Bay, subarctic Quebec
Thematic qualifiers	<u>Climate system:</u> Sea ice, weather, river, storm, wetland*, peatland*, marine ecosystem*, ecosystem <u>Ecosystems:</u> Flora, fauna, wildlife, plant*, vegetation, mammal*, fish, vertebrate*, bird*, plankton, ecosystem, freshwater ecosystem* <u>Health and culture:</u> Health, mental health, well-being, culture, identity, traditional activit*, medicinal plant, traditional knowledge <u>Infrastructure:</u> Infrastructure, built environment, industry, housing, transport*, mining, tourism <u>Adaptation:</u> Adaptation, adapt*, vulnerability
Timeframe	2007 – 2017

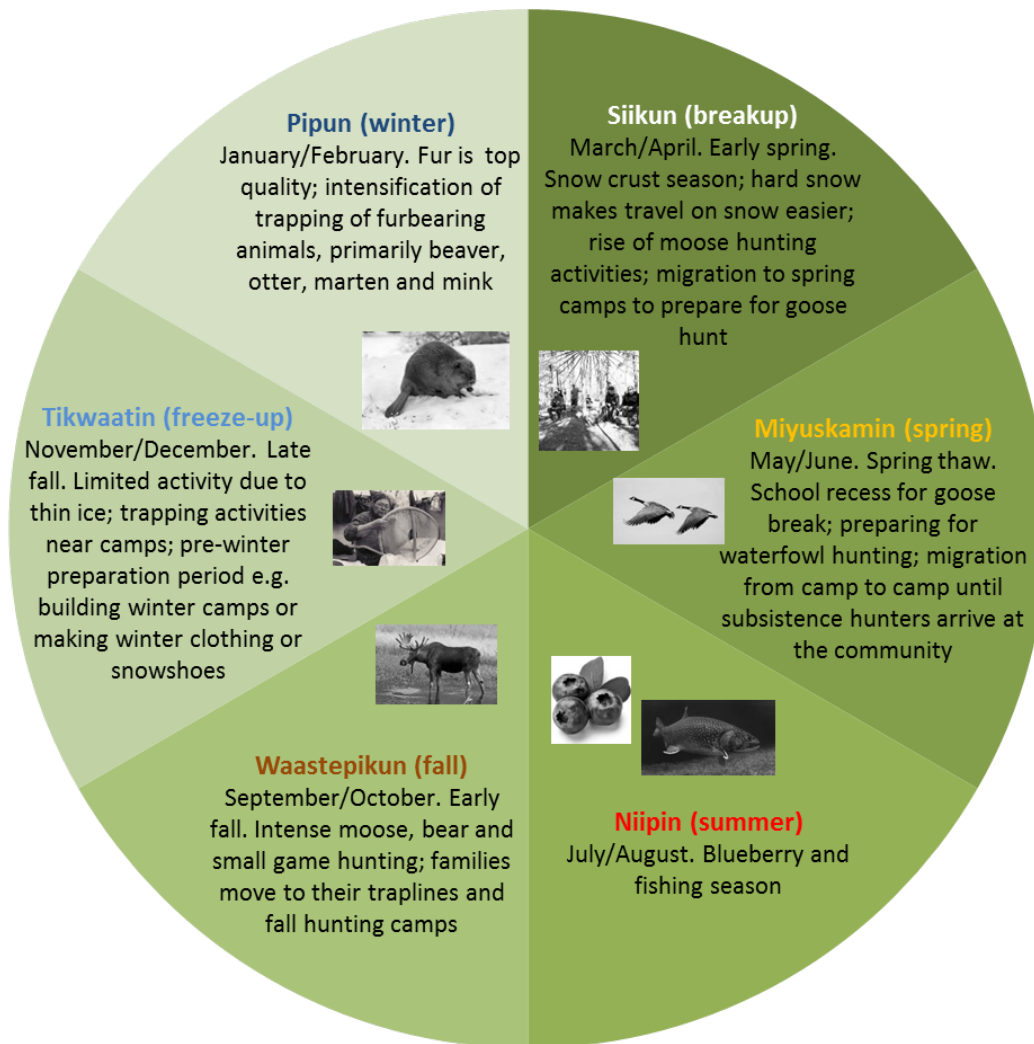
Categories and keywords used to build search strings

APPENDIX 3



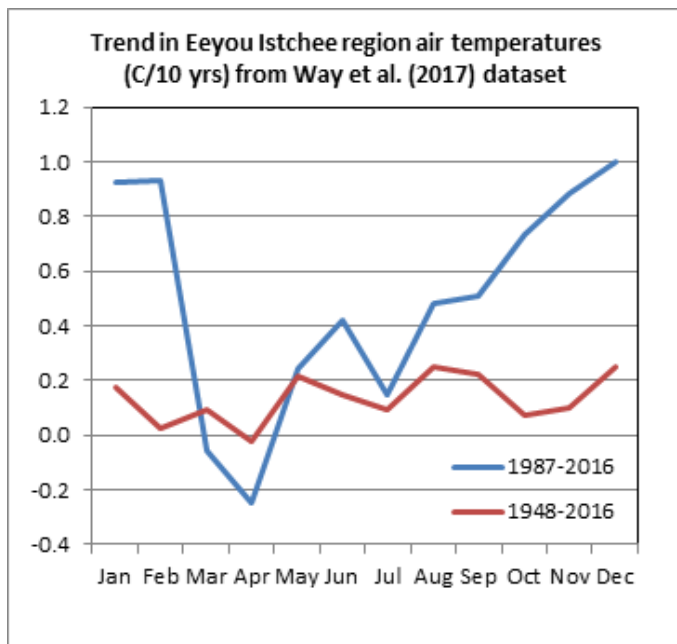
The tripartite model of place attachment (Scannell & Gifford 2010): “The person dimension of place attachment refers to its individually or collectively determined meanings. The psychological dimension includes the affective, cognitive, and behavioral components of attachment. The place dimension emphasizes the place characteristics of attachment, including spatial level, specificity, and the prominence of social or physical elements.”

APPENDIX 4



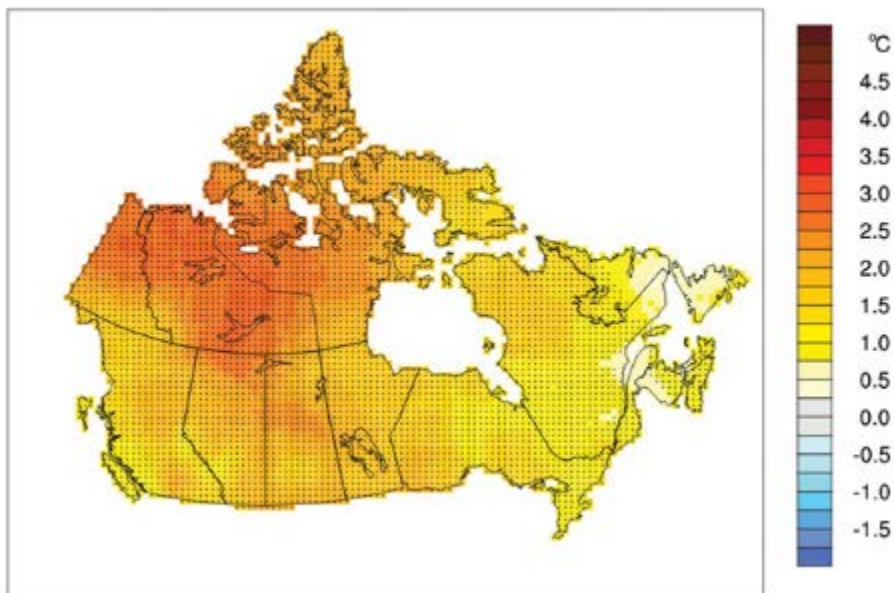
The 6 seasons of the Cree in Waswanipi and traditional activities associated with each season. Information obtained from the website of the community.

APPENDIX 5



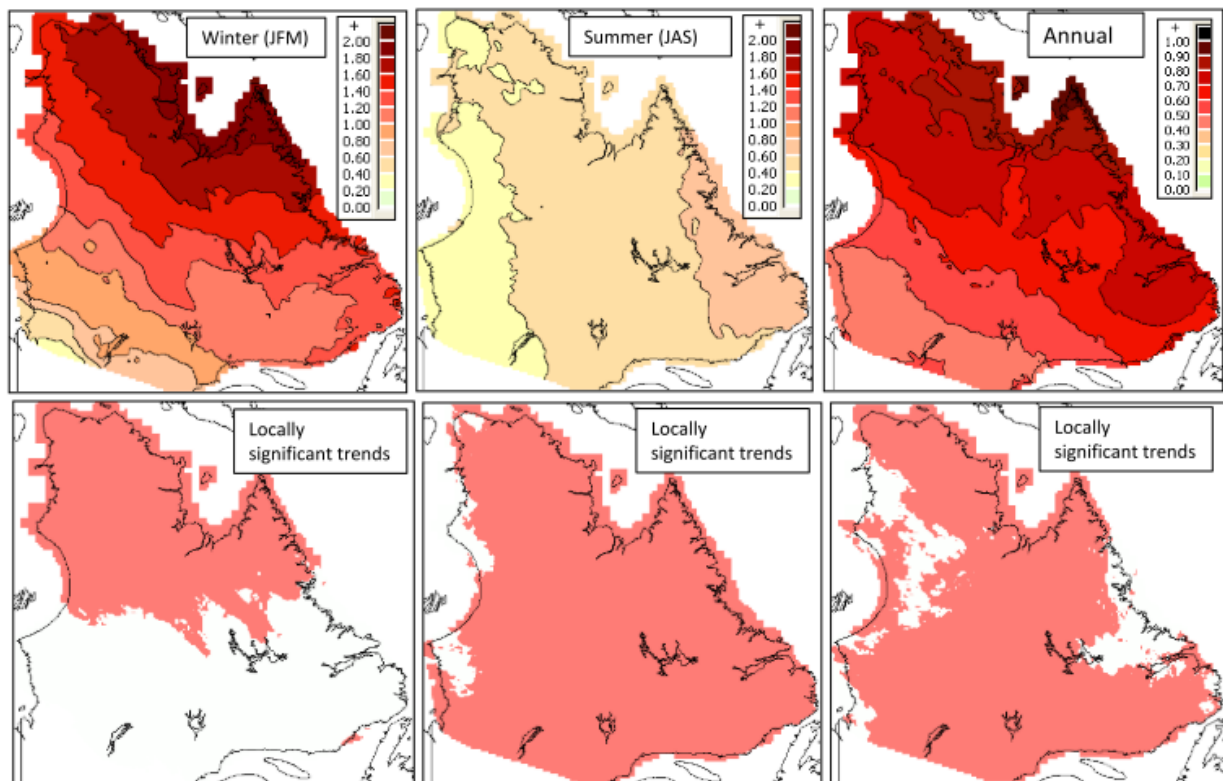
The plot compares the warming rates over the last 30 years (1987-2016) with the long term trend (1948-2016). This shows that the recent warming is stronger than the long term warming in most months, especially in the fall and winter (Oct-Feb). (R. Brown, 2017, unpublished data)

a) 1948-2012



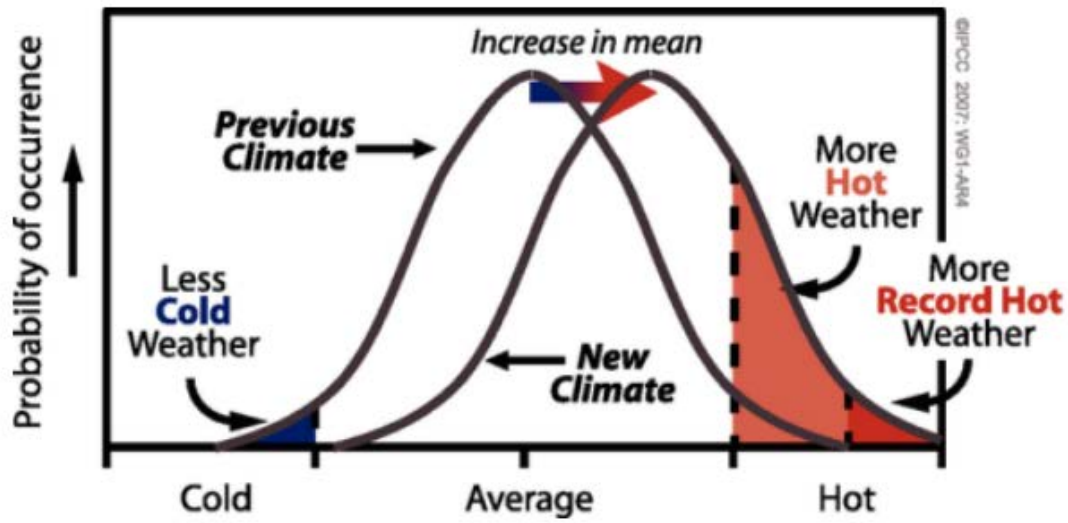
Trends in annual mean temperature from 1948-2012. Statistically significant trends at the 5% level are marked with a dot (Vincent et al. 2015)

Trend analysis over 1987-2016 of monthly surface air temperatures from the 1-km gridded dataset developed over eastern Canada by Way et al. (2017). Units are °C/decade.



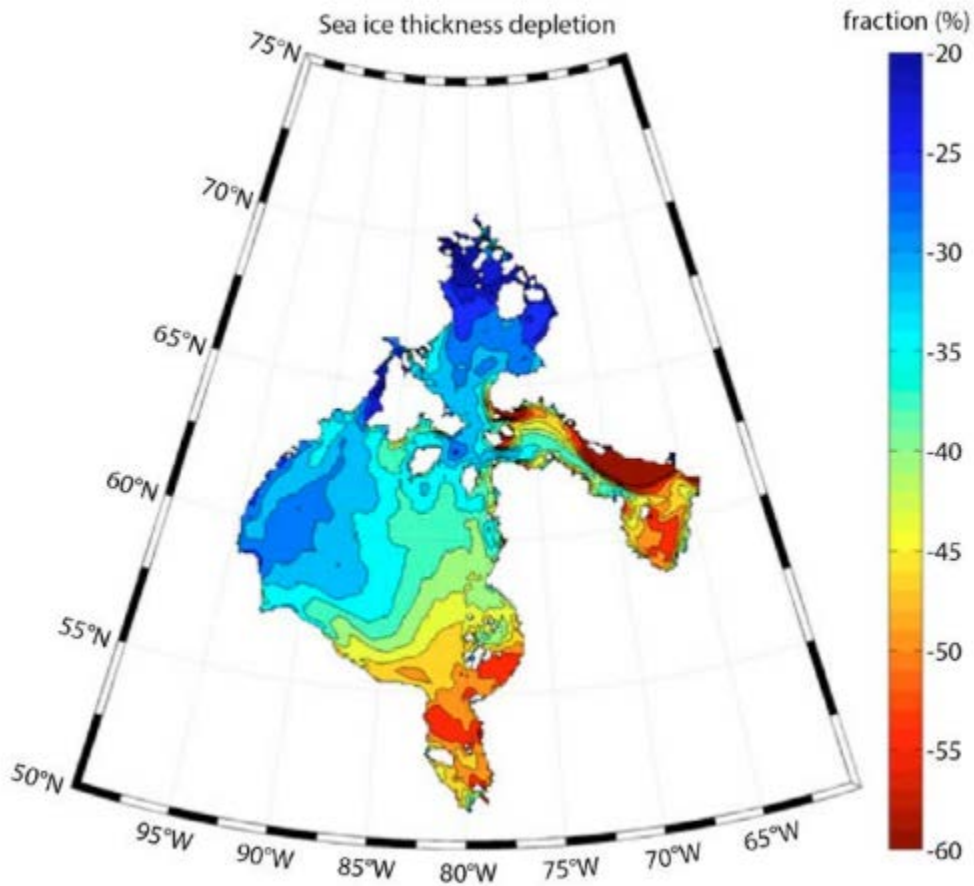
Trend analysis of surface air temperature in Eastern Canada (Way et al. 2017)

APPENDIX 6



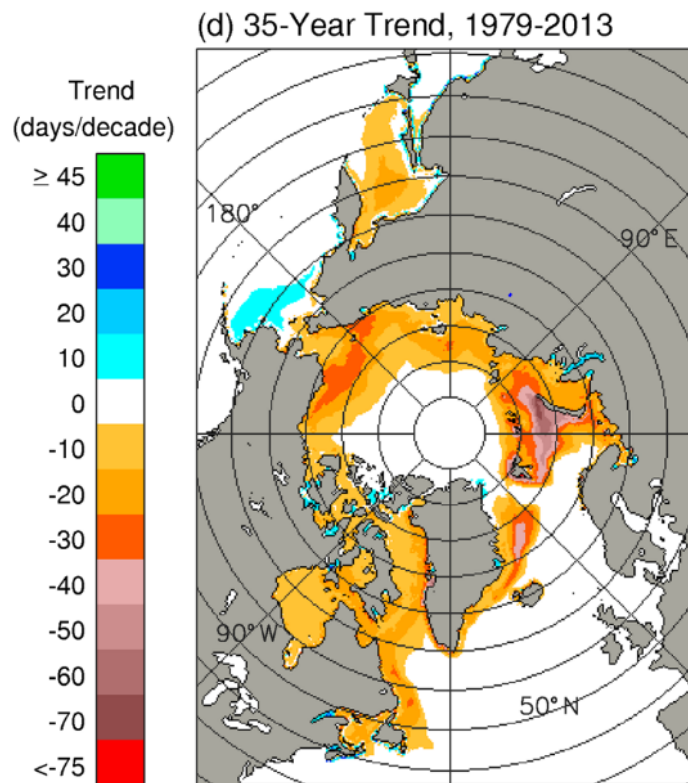
Schematic showing the increased probability of temperature driven extreme events under a warmer global climate (IPCC 2014)

APPENDIX 7



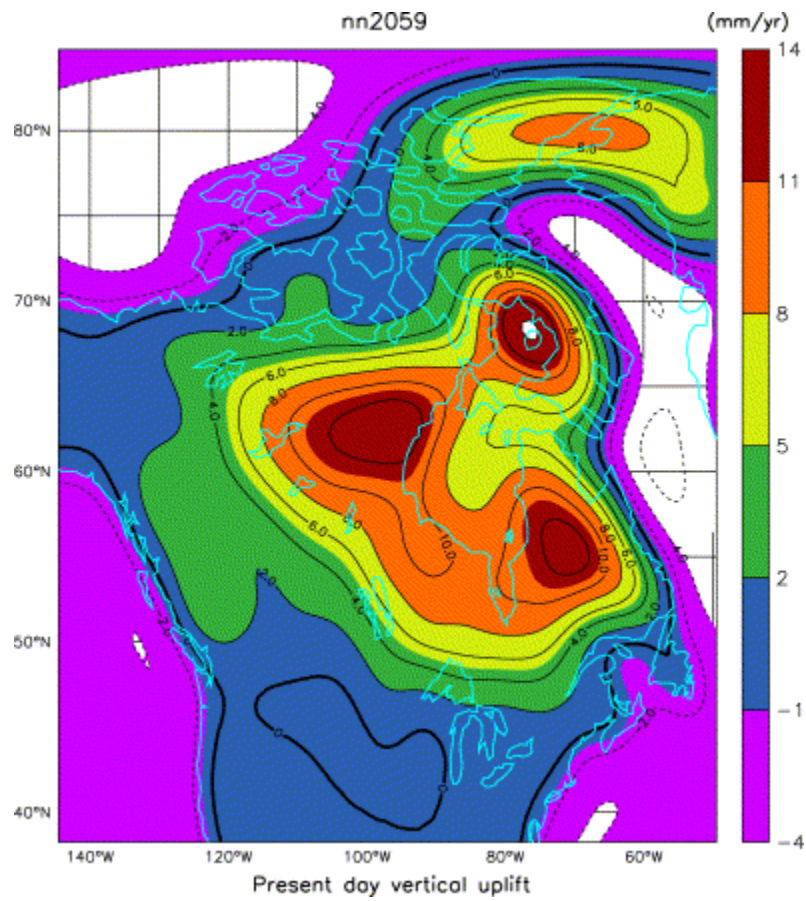
Change of relative sea ice thickness (January to April) projected for 2041-2070 in comparison to reference 1961-1990 (Joly et al. 2011)

APPENDIX 8



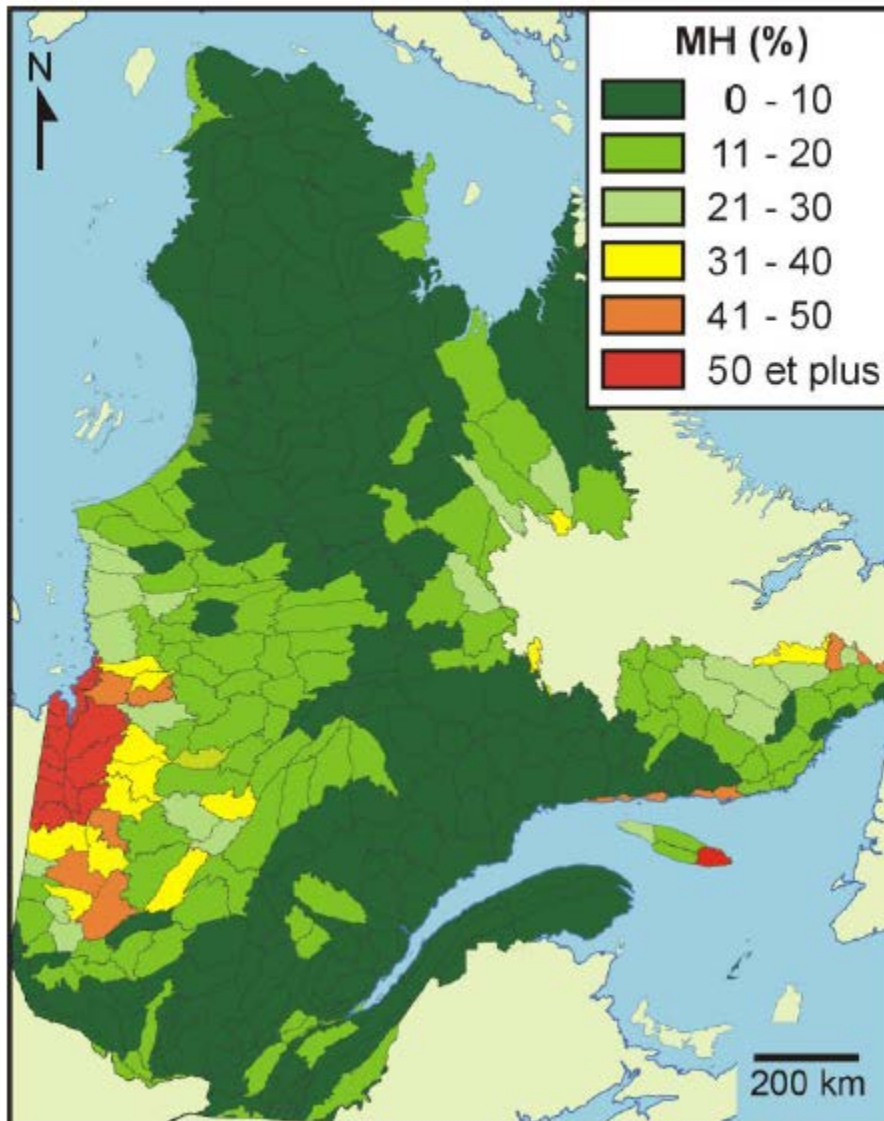
Trends in the length of the sea ice season from 1979 to 2013 (Parkinson 2014)

APPENDIX 9



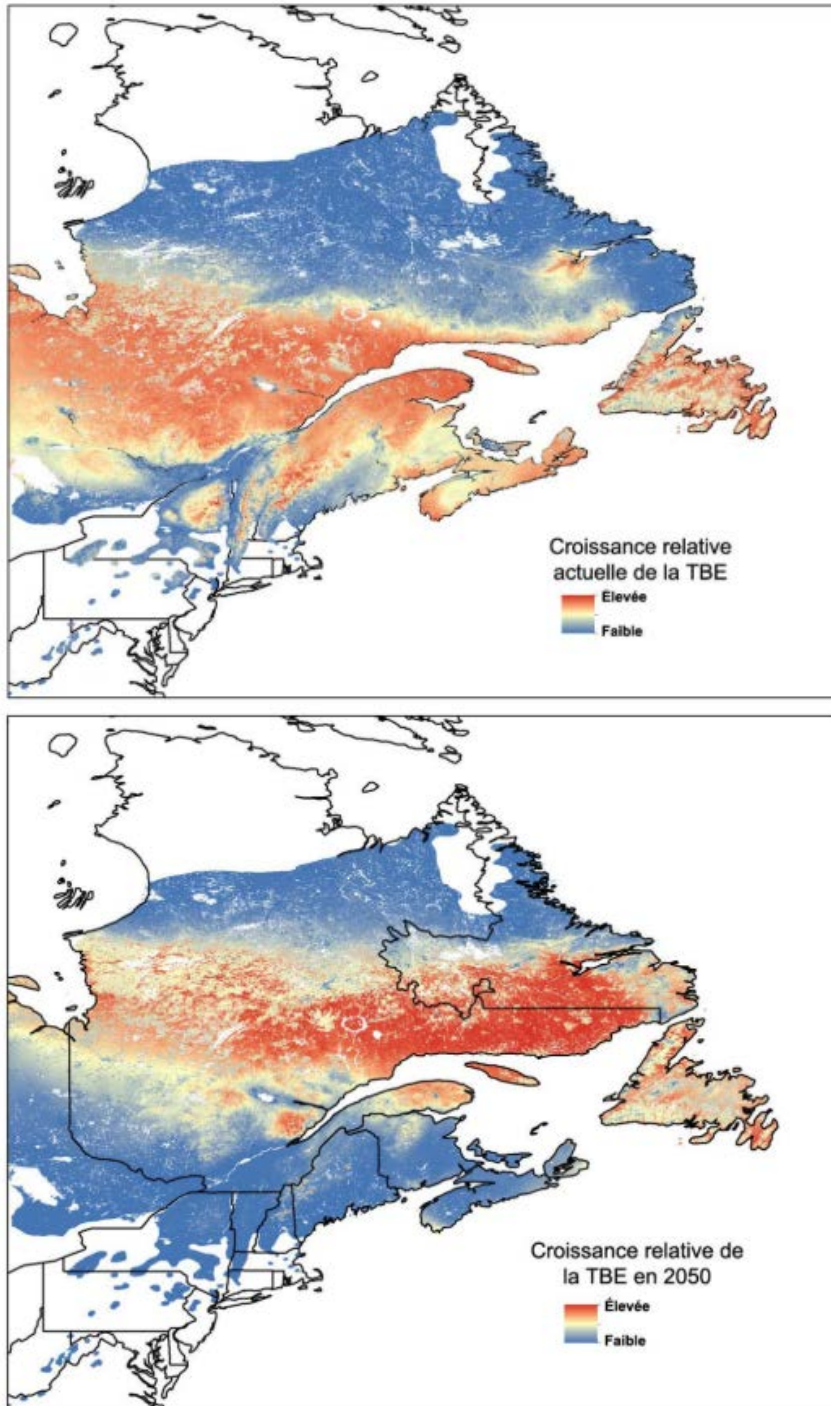
Isostatic rebound in Hudson Bay, present-day rate of uplift for model nn2059 (Tarasov 2004)

APPENDIX 10



Percentage of wetlands (MH) in Quebec. The concentration of wetlands in Eeyou Istchee James Bay is much higher than in other regions of the province (Pellerin & Poulin 2013).

APPENDIX 11



Projection of spruce budworm migrations (Régnière et al. 2012, found in Samson 2012).

APPENDIX 12

	Black bear	Caribou	Moose	Beaver	Lynx	Marten	Otter	Muskrat	Red fox
2016-2017	149	225	484	529	69	1716	52	68	66
2015-2016	160	440	483	1026	106	1547	109	217	123
2014-2015	223	204	606	798	103	1172	79	132	226
2013-2014	132	333	647	1451	129	1754	150	289	107
2012-2013	106	84	548	1342	95	2275	147	255	149
TREND 2012-2017	154	257,2	553,6	1029,2	100,4	1692,8	107,4	192,2	134,2
2006-2007	139	224	463	3141	94	2375	283	473	225
2005-2006	105	102	394	2399	96	4848	233	509	233
2004-2005	142	343	672	2291	77	4603	255	392	294
2003-2004	238	870	612	3277	117	3839	337	513	439
2002-2003	103	452	438	2980	87	2731	297	705	466
TREND 2002-2007	145,4	398,2	515,8	2817,6	88,8	3679,2	281	518,4	330,8
1996-1997	99	277	415	2460	43	2650	308	670	294
1995-1996	101	332	522	1486	31	2381	180	499	179
1994-1995	202	612	336	3318	72	2374	476	1728	222
1993-1994	98	466	316	3200	106	1382	321	913	186
1992-1993	198	733	545	1548	97	1305	218	304	135
TREND 1992-1997	139,6	484	426,8	2402,4	69,8	2018,4	300,6	822,8	203,2
TREND 1992-2017	9,40%	-47,90%	33%	-57,20%	30,50%	-16,20%	-64,30%	-76,70%	-34%
Priority	3	4	1	3	2	6	2	1	5
Decline	Muskrat	Otter	Beaver	Caribou	Red fox	Marten			
	-76,70%	-64,30%	-57,20%	-47,90%	-34%	-16,20%			
Increase	Moose	Lynx	Black bear						
	33%	30,50%	9,40%						

Data assembled and trends calculated based on the information from the big game and small game harvest reports dating from 1992 to 2017 (Hennigs, 2017). The individual reports can be found on the website of the Cree Trappers Association: <http://www.creegeoportal.ca/cta/>

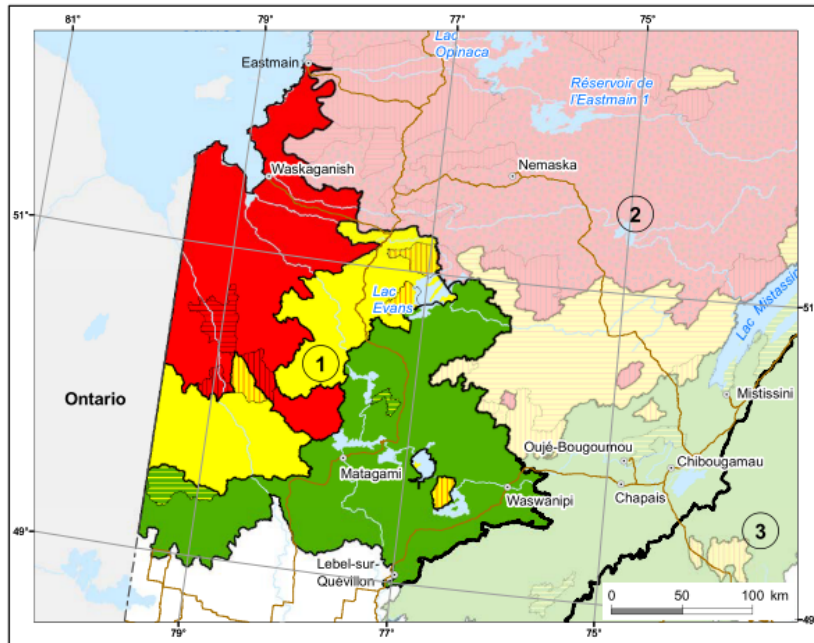
APPENDIX 13

Sommaire des recommandations par ordre d'importance

	Recommandations	Phase du processus de développement minéral
1	Développer une approche méthodologique et des critères de conception visant à intégrer les changements climatiques dans la conception des ouvrages de rétention des résidus miniers et des méthodes de restauration.	Exploitation Restauration
2	Considérer, voire même encourager, l'utilisation des modes de gestion des rejets qui rendent moins vulnérables à long terme les aires d'entreposage des rejets face aux risques géotechniques associés aux digues.	Restauration
3	Favoriser les concepts de restauration les moins vulnérables aux changements climatiques ainsi que ceux qui offrent la possibilité d'être ajustés au fur et à mesure de l'évolution du climat.	Restauration
4	Considérer que, dans les cas où la technique de recouvrements isolants sera envisagée comme méthode de restauration, elle devra faire l'objet d'une démonstration scientifique solide, qui inclut l'impact des changements climatiques sur sa performance à long terme.	Restauration
5	Supporter la recherche en lien avec la réduction de la vulnérabilité du secteur minier par rapport aux changements climatiques, notamment sur : • la performance des méthodes de restauration à long terme; • les méthodes visant à réduire les risques d'instabilités géotechniques (p. ex : résidus épaissis ou filtrés; inclusions de stérile); • l'amélioration des modèles visant l'estimation des conditions climatiques futures ; • l'adaptation des technologies de l'exploration minérale dans le contexte des changements climatiques.	Exploration Exploitation Restauration
6	Ajuster la fréquence de suivi des sites restaurés afin d'éviter la dégradation de la performance des modes de restauration dans le temps attribuable aux changements climatiques et/ou à d'autres phénomènes.	Restauration
7	S'assurer que les garanties financières soient modulées pour tenir compte des effets des changements climatiques sur la performance à long terme des méthodes de restauration.	Restauration
8	S'assurer que, dans le contexte des changements climatiques la protection du territoire n'empêche pas l'accès pour l'exploration minière.	Exploration
9	S'assurer que la performance de la technique de restauration soit robuste face aux changements climatiques avant d'émettre un certificat de libération.	Restauration
10	Produire un guide visant à établir des façons de faire pour mieux intégrer les changements climatiques dans les études techniques.	Exploitation Restauration
11	Utiliser les connaissances des communautés locales, notamment des communautés autochtones, pour mieux comprendre l'impact des changements climatiques sur les milieux et les impliquer dans le suivi local des changements climatiques.	Exploration Exploitation Restauration
12	Utiliser les données météorologiques existantes recueillies sur les sites miniers actifs pour le développement de scénarios climatiques adaptés au secteur minier.	Exploitation Restauration

Recommendations with respect to climate change for the mining sector in Quebec (Bussière et al. 2017)

APPENDIX 14



Territoire qui ne respecte pas les critères d'aménagement durable des forêts

Territoire de sensibilité très élevée

- 1.1 - Contraintes très importantes du milieu physique
- 1.2 - Capacité de production insuffisante pour un aménagement durable des forêts
- 1.3 - Capacité de production insuffisante pour faire face au risque de feu
- 1.4 - Insuffisance d'habitats denses et hauts

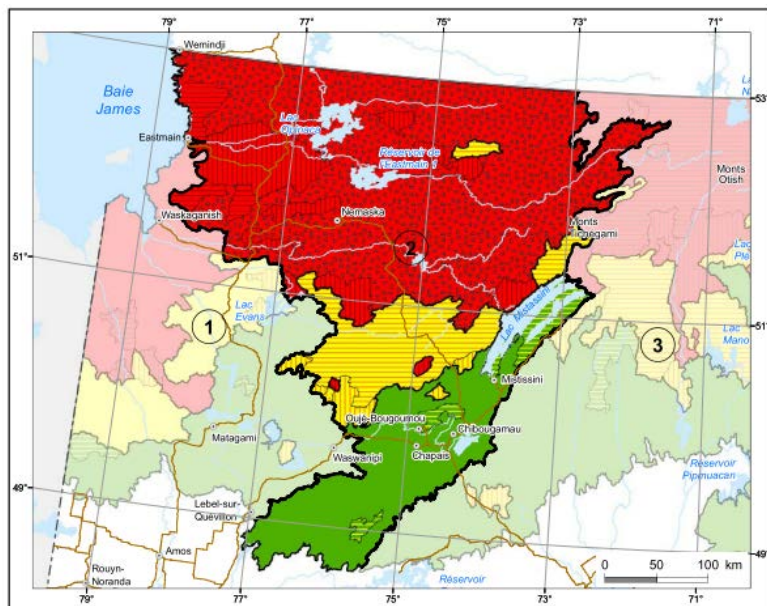
Territoire qui respecte les critères d'aménagement durable des forêts

Territoire de sensibilité moyenne à élevée

- 2.1 - Contraintes importantes du milieu physique
- 2.2 - Impact élevé des perturbations naturelles récurrentes par le feu
- 2.3 - Insuffisance d'habitats denses et hauts en raison d'une seule année de feu
- 2.4 - Habitats denses et hauts fragmentés

Territoire de sensibilité faible

- 3.1 - Quelques facteurs préoccupants pour l'aménagement durable des forêts
- 3.2 - Peu risqué pour l'aménagement durable des forêts



Maps showing zones where sustainable development of forestry is not possible considering the sensitivity and sustainable development of the forests (MERN 2013)

APPENDIX 15

TABLE 14: Strategic and operational-level climate change adaptation options that may be considered to meet the goals of sustainable forest management, as defined by the Montreal Process (Source Ogden and Innes, 2007a).

Adaptation goals	Conserve biological diversity	Maintain productive capacity of forest ecosystems	Maintain forest ecosystem health and vitality	Conserve and maintain soil and water resources
Strategic-level adaptation options	- Minimize fragmentation of habitat and maintain connectivity - Maintain representative forest types across environmental gradients in reserves - Protect climate refugia at multiple scales - Identify and protect functional groups and keystone species - Maintain natural fire regimes - Provide buffer zones for adjustment of reserve boundaries - Create artificial reserves or arboreta to preserve rare species - Protect most highly threatened species <i>ex situ</i> - Maintain natural fire regimes - Develop a gene management program to maintain diverse gene pools	- Practice high-intensity plantation forestry in selected areas to promote the growth of commercial tree species, especially in areas where an increase in disturbance is anticipated - Enhance and minimize disturbance to forest soils - Assist in tree regeneration - Employ vegetation control techniques to offset drought - Plant genetically modified species and identify more suitable genotypes - Enhance forest growth through forest fertilization - Actively manage forest pests - Underplant with other species or genotypes where the current advanced regeneration is unacceptable as a source for the future forest - Selectively remove suppressed, damaged or poor-quality individuals to increase resource availability to the remaining trees (pre-commercial thinning) - Reduce the rotation age followed by planting to speed the establishment of better-adapted forest types - Control those undesirable plant species that will become more competitive in a changed climate - Relax rules governing the movement of seed stocks from one area to another - Include climate variables in growth and yield models in order to have more specific predictions on the future development of forests - Design and establish a long-term multi-species seed-lot trial to test improved genotypes across a diverse array of climatic and latitudinal environments	- Breed for pest resistance and for wider tolerance to a range of climate stresses and extremes in specific genotypes - Reduce non-climatic stresses to enhance ability of ecosystems to respond to climate change by managing tourism, recreation and grazing impacts - Reduce non-climatic stresses to enhance ability of ecosystems to respond to climate change by regulating atmospheric pollutants - Reduce non-climatic stresses to enhance ability of ecosystems to respond to climate change by restoring degraded areas to maintain genetic diversity and promote ecosystem health - Adjust harvest schedules to harvest stands most vulnerable to insect outbreaks - Plant genotypes that are tolerant of drought, insects and/or disease - Reduce disease losses through sanitation cuts that remove infected trees - Used prescribed burning to reduce fire risk and reduce forest vulnerability to insect outbreaks - Employ silvicultural techniques to promote forest productivity, and increase stand vigour (i.e. partial cutting or thinning) by lowering susceptibility to insect attack - Shorten the rotation length to decrease the period of stand vulnerability to damaging insects and diseases and to facilitate change to more suitable species	- Avoid constructing roads in landslide-prone terrain where increased precipitation and melting of permafrost may increase hazard of slope failure - Enhance and minimize disturbance to forest soils - Maintain, decommission and rehabilitate roads to minimize sediment runoff due to increased precipitation and melting of permafrost - Minimize the impacts on infrastructure, fish and potable water of changes in the timing of peak flow and volume in streams resulting from more/earlier snow melt
Operational-level adaptation options	- Allow forests to regenerate naturally following disturbance, favouring natural regeneration wherever appropriate - Control invasive species - Practice low-intensity forestry and prevent conversion to plantations - Assist changes in the distribution of species by introducing them to new areas			

Climate adaptation options for forestry management (Furgal & Prowse 2008)

APPENDIX 16

TABLE 5: EXISTING MONITORING AND ADAPTATION ACTIVITIES IN MISTISSINI, WASKAGANISH AND WHAPMAGOOSTUI	
COMMUNITY	MONITORING AND ADAPTATION ACTIVITIES
Mistissini	- The ice is monitored in the main channel by a tallyman. It was not performed in 2009 because of late freeze-up. - Water temperature in the lake is monitored by the local Environment Coordinator
Waskaganish	- Niskamoon provided \$ 100,000 for an ice-monitoring program. A team was hired to monitor the ice and put signs on the ice. There is a monitoring report. - Public safety is looking at water and ice security. It is getting harder to travel. It is harder to perform search and rescue operations. The First Nation is considering acquiring an hovercraft.
Whapmagoostui	- Monitor ice conditions in collaboration with the Inuit fire department - Search and rescue provide data on ice conditions - There is already some efforts being made to trace routes along the bay and rivers for snowmobiles to cross but only on an ad-hoc basis.

Existing adaptation strategies in three Cree communities (CTA 2011)

APPENDIX 17

MISTISSINI CLIMATE CHANGE WORKING ON AN ACTION PLAN- septembre 2010

OBSERVATIONS	IMPACT	Type of Impact	POSSIBLE SOLUTIONS	RESPONSIBILITY
- Late freeze-up/ early break-up - Changes in snow quality and quantity - Changes in ice quality	Dangerous travelling conditions	Safety Food Security Economic Health	- Monitoring - Awareness/Training programs - Safety leader with each travelling party - Life jackets in winter	Fire department is monitoring after freeze up Band Council can request funds
	Shorter hunting season	Food Security Health		
	Less land use means less control	Political/Cultural		
	Travel to blinds unsafe	Safety Economic	- Build goose ponds and flyways in safer locations - Study on Goose Pond (Ducks Unlimited)	
More violent weather	Impact on infrastructures (community and on the land) Overflowing sewage and rain drainage system Silt in the lake from development Diminishing quality of tap water after rain (report from Rod Quinn)	Infrastructure Economic Health	- Monitoring better weather (wind measures and maybe a weather station in Mistissini) - Evaluation of sewer and rain drainage system	Env. Coordination
More forest fires	Loss of property, resources Health hazard	Safety Economic Health	- Monitoring - Insurance program? - Preparedness programs	SOPFEU CRA works with the First Nation Council on the Emergency plans for each community – it will be presented to the communities
- Less ducks - Less partridge - less rabbits - less muskrats - beaver not as fat - worms in caribou - Less fish - Less berries	Traditional food diet affected	Food security Health		
Arrival of geese unpredictable	Planning affected	Food Security Health	Monitoring	
Changes in medicinal plants (quality and quantity)	Loss of healing practices (Cultural)	Cultural	- Recording healing practices - Murray's camp - CIHR Team in Aboriginal Anti-diabetic Medicines: http://www.taam-emaad.umontreal.ca/index.htm	

Draft of a climate change action plan for Mistissini (CTA 2011)

APPENDIX 18

WHAPMAGOOSTUI CLIMATE CHANGE WORKING ON AN ACTION PLAN – SEPTEMBER 8-9, 2010

OBSERVATIONS	IMPACT	TYPE	POSSIBLE SOLUTIONS	RESPONSIBILITY
- Late freeze-up/early break-up - Changes in snow quality and quantity - Changes in ice quality (thinner) - Bad ice along the coast - Weather harder to predict	Dangerous traveling conditions	Safety Food security	- Monitoring of ice conditions along main traveling path on the bay and inland - Promoting the use of flotation suit for people traveling by skidoos on the Bay - Developing an awareness program in the community and in the school - Building more Landing strips in camps	Police and Safety department are marking ice path on an ad-hoc basis. The program could be made permanent if we secure funding
	Shorter hunting season	Economic		
	Less land use means less control	Political Cultural		
	Access to camp in spring is dangerous because of thin ice	Safety Economic		
- Change in river level - Sand bar in the River - Beluga are rare in the river	Dangerous traveling conditions	Safety	Installing channel marker in the River	
	Lost of a resource ?	Food security?		
- Skinnyer Caribou - Less snow geese	Access to resources	Food security	- Exchange with other communities - Sending hunting parties to get caribou for the communities	Done on an ad-hoc basis by some hunters
- More polar bear - More black bear - Change in black and polar bear behaviour	Danger to people and property (camp)	Safety	Monitoring polar bear around the community	
- No more seals - Whitefish and trout are smaller - More sucker fish	Lost of resources	Food security		

Draft of a climate change action plan for Whapmagoostui (CTA 2011)

APPENDIX 19

WASKAGANISH CLIMATE CHANGE PROJECT: WORKING ON AN ACTION PLAN – OCT. 25-26, 2010

OBSERVATIONS	IMPACT	TYPE	POSSIBLE SOLUTIONS	RESPONSIBILITY
Thinner Ice	Dangerous traveling conditions	Safety Food security Health	- Monitoring of ice conditions along main traveling path on the bay and inland - Promoting the use of flotation suit for people traveling by skidoos on the Bay (Whapma) - Developing an awareness (certification?) program in the community and in the school - Ice roads follow-up website	Band Council CTA Committee with elders, tallyman
Earlier Break-up Late Freeze-up	Shorter hunting season	Economic Food security Health		
More open water in the Spring	Less land use means less control	Political Cultural		
	Access to camp in spring is dangerous because of thin ice	Safety Health Economic		
Stronger Wind	Dangerous traveling conditions	Safety Food security Health	Warning system	
	Impact on infrastructures	Infrastructure		
	Shorter ice cover	Coastal erosion	Infrastructure	- Protection of coast around village and camps - Relocation of camps
Less Caribou Change in geese behaviour	Access to resources	Food security Health	Exchange with other communities	
More polar bear Change in black bear behaviour	Danger to people and property (camp)	Safety	Monitoring polar bear around the community	

Draft of a climate change action plan for Waskaganish (CTA 2011)



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Ouranos was born from the shared vision of the Government of Quebec, Hydro-Québec and Environment Canada, with financial support of Valorisation-Recherche Québec in 2001. Incorporating a network of some 450 scientists and professionals from various disciplines, the consortium focuses on two main themes: climate science and vulnerabilities, impacts and adaptation. Its mission is the acquisition and the development of knowledge on climate change and its impacts, as well as socio-economic and environmental vulnerabilities, in order to inform policy makers about climate change and advise them on how to identify, evaluate, promote and implement local and regional adaptation strategies.