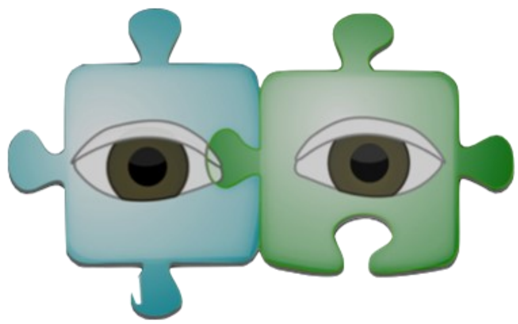
CLIMATE CHANGE IMPACTS ON THE HEALTH AND LIVELIHOODS OF

INDIGENOUS COMMUNITIES IN NORTHERN ONTARIO

by

Riley J. Belanger



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May 2021

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A Graduate Thesis Submitted in

Partial Fulfillment of the Requirements for the

Degree of Master of Science in Forestry

Faculty of Natural Resources Management

Lakehead University

May 2021

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ABSTRACT

Belanger, R.J. 2021. Climate Change Impacts on the Health and Livelihoods of Indigenous Communities in Northern Ontario. 125 pp.

Keywords: climate change, First Nation, Indigenous communities, Indigenous health, livelihoods, traditional activities, traditional foods, Two-Eyed Seeing

Climate change is expected to affect people's health and livelihoods in northern Indigenous communities more adversely than in others due to existing socio-economic conditions and direct reliance on the environment to support Indigenous livelihoods. The central research questions of this study are: How has climate change affected Indigenous livelihoods and Indigenous health in Northern Ontario communities, and how might these be affected into the future? These were answered by conducting research in two parts: a comprehensive literature review, and interviews with 15 members of a First Nation community. From the literature and interviews, Indigenous community members made significant observations related to climate change including increasingly unpredictable and intense weather, declines in ice cover duration and ice thickness, declines in the abundance of some traditional food species, and negative health outcomes. Several participants had experienced severe enough changes that their livelihoods had been diminished due to a decreasing ability to participate in certain traditional activities such as hunting, ice fishing, and trapping and a decline in harvest success for traditional foods like moose, fish, and blueberries. Projections of changes in environmental conditions and traditional food species abundance throughout this century demonstrated that in Northern Ontario, there will be continuing trends of declines in ice cover duration and ice thickness, increasingly intense weather, more frequent extreme weather events such as heat waves and forest fires, declines in water quality due to proliferation of waterborne diseases and the occurrence of cyanobacterial algal blooms, and declines in the abundance of moose and preferred fish species.

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ACKNOWLEDGEMENTS

I would like to thank my friends, family, and the members of my committee who gave me their continued support over these three long, difficult years. I sincerely appreciate that you never stopped believing in me and always gave me the encouragement I needed during my most challenging times.

I thank all the First Nation community members who participated in this study for sharing with me your invaluable, insightful, and wise perspectives. I hope that these perspectives help change the course of action in Ontario, Canada, and even globally so that there might one day soon be climate justice for all.

I would like to acknowledge all the young women out there, who, like me, have continuously struggled with impostor syndrome, never given ourselves the credit we deserve, or believed we have not truly earned our place in the world. I recognize that I have immense privilege for being where I am today due to having lifelong encouragement and support from my family, nearly endless opportunities, and facing few calamities in life, but I cannot and will not continue to overlook the hard work I have put in and the challenges I have overcome to arrive at this point in my life. To other young women reading this, I hope you will endeavour to do the same and always remind yourself that you are the one that has put in the work to get to where you are, and you deserve to be there just as much as anyone else.

1. INTRODUCTION

For the remainder of this century, climate change is the single greatest threat to humans and natural systems. Climate change will alter ecosystems, food systems, infrastructure, coastal, urban, and rural areas, human health, and livelihoods (IPCC 2014:76), but these impacts will not be distributed or experienced equally. For example, Northern Indigenous (First Nation, Inuit, or Métis) communities are expected to be some of the most impacted by climate change due to a direct reliance on the environment to support traditional aspects of livelihoods like hunting, fishing, gathering, and trapping. Traditional plant and animal foods, as well as fur-bearing animals, may change in abundance or distribution as a result of climate change, impacting Indigenous livelihoods. In addition, Indigenous Peoples' health may be especially vulnerable to some of the effects of climate change due to the limited adaptive capacity of many communities to respond to them (IPCC 2014:118). Issues such as food and nutrition, clean water, and energy insecurity, inadequate housing conditions, higher than average rates of illness, and limited access to medical services (CIER 2011:1), facing a large number of communities in Canada may contribute to limited adaptive capacities. Threats to health and safety may also rise with climate change as a result of increasing occurrences of waterborne illnesses, cyanobacterial algal blooms, extreme weather events such as heat waves, droughts, floods, and forest fires, and unstable ice conditions (e.g., IPCC 2014:69).

In Northern Ontario, each Indigenous community is unique in its geography, culture, access to services and supplies, and economy. Therefore, even within the region not every community will be impacted by climate change in the same ways.

Particular issues facing communities in this region that may limit adaptive capacities include an extraordinarily large number of long-term boil-water advisories (BWAs), poor socio-economic conditions, use of diesel generators for energy, and community remoteness leading to limited accessibility to affordable healthy groceries, housing supplies, fuel, and medical services. For instance, the majority of communities located in Ontario's Far North (North of approximately 50 °N, see MNRF 2019) are remote and depend heavily upon winter ice roads for physical and financial accessibility to goods and services, and declining winter road viability due to climate change may especially impact remote community members' livelihoods and health by further limiting access to these.

1.1. RESEARCH QUESTION AND OBJECTIVES

There is currently minimal understanding of how climate change may affect First Nation communities within Northern Ontario throughout the remainder of this century, particularly regarding their livelihoods and health. This study sought to improve this understanding by bringing together Indigenous knowledge in the form of community- and individual-level perspectives of climate change and Western knowledge in the form of analysed trends and modelled projections of the effects of climate change to answer the central research questions: How has climate change currently affecting Indigenous peoples' health and livelihoods and in Northern Ontario communities, and how might these be affected into the future? To answer these, the following two objectives were established:

1. Conduct a comprehensive literature review to determine how Indigenous community members' livelihoods and health have been affected by climate

change, and to analyse trends and modelled projections of the effects of climate change to predict how communities may be affected into the future.

2. Conduct interviews with a First Nation's community members to gain additional understanding of Indigenous perspectives and experiences with climate change.

1.1.1. EXPECTED OUTCOMES

Based on the review of observations from Northern Ontario communities and others located in neighbouring regions, it is expected that most participants in this study would have observed some changes in the environment that are attributable to the warming climate. These may include changes in temperature and weather, ice regimes, water levels and quality, and traditional food species abundance. It is also anticipated that these changes may have somewhat hindered people's ability to participate in traditional harvesting activities, decreased their harvest success of some traditional foods, or resulted in some adverse health effects.

2. METHODOLOGY

2.1. LITERATURE REVIEW

2.1.1. Two-Eyed Seeing Framework

Research conducted for this review was guided by the Two-Eyed Seeing framework. Two-Eyed Seeing is a term first introduced by two Mi'kmaq Elders, Albert and Murdena Marshall from Unama'ki (Cape Breton), Nova Scotia (Wright et al. 2019). The term refers to learning to see from one eye with the strengths of Indigenous knowledge and ways of knowing, and from the other eye with the strengths of Western knowledge and ways of knowing (graphically represented by top image on the cover page of the jigsaw puzzle pieces, where each knowledge system represents only one "piece" of knowledge as a whole, http://www.integrativescience.ca/). Drawing the two knowledge systems together allows for a better and more holistic understanding of the world for the benefit of all, including future generations (Bartlett et al. 2012, Iwama et al. 2009). Two-eyed seeing additionally recognizes Indigenous knowledge as its own distinct and whole knowledge system separate from but equally significant to Western science (Bartlett et al. 2012, Iwama et al. 2009). Elder Albert noted the importance of weaving back and forth between the two knowledge systems because one may have more applicable strengths than the other in different circumstances (Bartlett et al. 2012). With these shared strengths, Iwama et al. (2009) explained how research can be conducted to better understand and solve problems facing Indigenous communities, especially regarding the damage done to Indigenous health by the loss of traditional language and connectiveness. The approach differs significantly from unethical historical research methods involving Indigenous peoples, where they have been "researched to death" as subjects to study by non-indigenous researchers rather than people to work together with in mutually beneficial research relationships (Schnarch 2005:82).

Within the Two-Eyed Seeing framework, the following strategies were employed during the research process for this review. First, the sources analysed for this review included both quantitative observations and modelled projections of the effects of climate change (Western knowledge) as well as qualitative and quantitative Indigenous observations, experiences, and concerns for the future (Indigenous knowledge). It is important to note that with the latter, Indigenous knowledge had nonetheless been presented and analysed through a lens of Western scientific methods via the dissemination of results in peer-reviewed journal articles. As these are the standard form of literature to be reviewed in academic settings, it is highlighted that Western methods continue to dominate research and dissemination processes which makes it difficult to impossible to present or review Indigenous knowledge on separate but equal terms with Western knowledge. Despite this imbalance, Indigenous knowledge was incorporated into this review as much as possible. By attempting to bring the two knowledge systems together, this review has been able to provide a more complete understanding of how climate change is currently affecting Indigenous communities of Northern Ontario and how it may continue to affect them throughout the rest of the century. Most quantitative observations and modelled projections of the effects of climate change have been conducted outside of Indigenous contexts, without discussion of how these changes will affect Indigenous communities, traditional livelihoods, or Indigenous health.

The review and discussion of the effects of climate change on health has also been done through a lens of holistic health that includes physical, mental, emotional, and spiritual aspects. These four aspects are represented in the Cree medicine wheel (bottom image on cover page and Figure 1 below), where one is considered to be in good health only when all four aspects are in balance. The physical aspect refers to the health of one's physical body, which can be influenced by one's diet (healthy foods vs. unhealthy foods), the ability to freely hunt and harvest from the land (exercise), and the presence or absence of illnesses. Spiritual health refers to spiritual beliefs and practices, which can involve participation in ceremonies, belief in a higher power, or having a spiritual connection to the land. Emotional health refers to one's emotions and thoughts (which is more typically labelled as mental health in a Western context) such as optimism, hopefulness, and resilience when faced with adversity. Finally, mental health refers to one's knowledge, which can include the importance of knowing one's own traditional language, embracing cultural identity, and honing skills related to living off the land (Danto and Walsh 2017). Western science research methods tend to focus mainly on physical health, and in more recent years, sometimes on emotional health as well. As a result, few studies reviewed here discuss Indigenous health beyond the physical aspect.

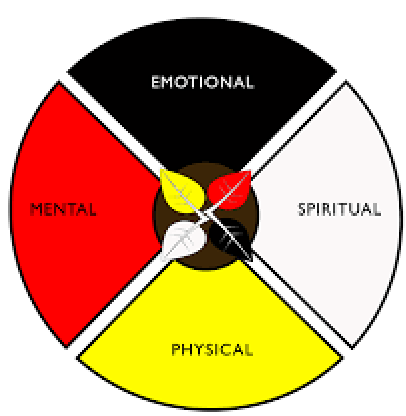

Figure 1. Four aspects of health represented by the Cree medicine wheel.

2.1.2. Research Methods

Guided by the research questions, “How has climate change affected Indigenous peoples’ traditional livelihoods and Indigenous health in Northern Ontario communities?” and “How is climate change expected to affect these into the future?” a review of primarily peer-reviewed literature, as well as some reports, government documents, books, websites, and relevant news articles, was conducted. The review was conducted over three phases.

The first phase began in February of 2019 and involved a keyword search of the Omni academic search tool online database to find existing literature reviews regarding the subject matter of the effects of climate change on Indigenous peoples in Canada. The following keyword terms were used in the search: “climate change” and (“First Nation”, “Indigenous”, or “Aboriginal”) and (“traditional activities” or “health”). This phase resulted in a list of 19 peer-reviewed journal articles. These reviews were analysed first to gain a general understanding of the most significant impacts of climate change on traditional lifestyles and Indigenous health across Canada. With this broad understanding, research topics could then be narrowed down to original studies analyzing specific effects of climate change occurring and projected to occur in Northern Ontario in the second phase.

The second phase involved analysing the reference lists in the articles retrieved in the first phase, in which relevant original studies and reports were found and reviewed. An additional keyword search in the online database was conducted to find more original research focusing on specific subjects; the following keyword terms were utilized in this search: “climate change” + [specific topic] + [location] +/- “First Nation”, “Indigenous”, or “Aboriginal”. The specific topic keywords included many of the subjects reviewed in this paper including, but not limited to, “traditional activities”, “traditional foods”, “health”, “freshwater fish”, “moose”, “waterfowl”, “berries”, “ice”, “winter roads”, “water”, “waterborne pathogens”, “cyanobacteria”, “extreme weather events”, etc. The location keyword used would generally start out at the smallest relevant scale and continually increase in scale if no relevant studies were found, for example, a search may have begun with the location “Northern Ontario” then to “Ontario” to “boreal forest” and finally, to “Canada”. Indigenous descriptors such as “Indigenous”, “First Nation”, or “Aboriginal” were included when searching for studies documenting Indigenous observations of climate change effects or research conducted with an Indigenous context. On some occasions, searches through physical literature and the Google Chrome internet browser were conducted to find additional relevant information within reports, government documents, news articles, books, and websites when peer-reviewed literature was lacking on a particular subject. This phase resulted in a list of 195 peer-reviewed journal articles, 20 reports, 3 government documents, 7 news articles, 5 books, and 2 websites for a total of 232 sources.

The third and final phase involved further analysis of all articles and other sources acquired during the second phase. Sources containing irrelevant or outdated information or information beyond the scope of this paper were excluded, resulting in a final list of 86 sources: 58 peer-reviewed journal articles, 12 reports, 3 government documents, 6 news articles, 5 books, and 2 websites. The majority of these sources focused on either Ontario or Northern Ontario, although some contained useful and relevant information from neighbouring provinces of Manitoba and Quebec. A few sources discussed subjects in other regions or Canada in a broad sense, and these occasionally provided important contextual or comparative information. All sources used in this review contained the most recent and up-to-date information where possible; all have been published after the year 2000, within two decades of creation of the review. Some articles contained information relevant to multiple sections of this review (e.g., articles discussing Indigenous community members’ wide-ranging observations of climate change) and as a result these may have been referenced numerous times throughout the review.

2.2. DATA COLLECTION

2.2.1. Context

This study was conducted as part of a larger Traditional Knowledge (TK) and Land Use and Occupancy documentation project that was initiated independently of this research, between the First Nation and a private consulting company. Leaders within the First Nation, such as members of the Elders Council, sought out to document the community's TK, as well as its members' land use and occupancy within their traditional territory. There are a number of reasons why Indigenous communities may seek to document this information, including but not limited to: creating physical documentation of TK for use by future generations and to ensure this knowledge is not lost, for environmental assessment and land use planning purposes to protect important cultural or harvest sites, or to establish legal Aboriginal title through the documentation of land use and occupancy on maps (Tobias 2000:28-36). Lakehead University was invited to collaborate and conduct research that would fit interests of both the First Nation as well as the university's graduate student researcher, the author of this paper.

The research topic of climate change was chosen during meetings with members from the three project participants: The First Nation, Lakehead University, and the consulting company. The First Nation leaders expressed interest in determining how climate change is affecting the lives of community members who participate in traditional activities, and the graduate researcher agreed that this would be a suitable topic to study due to personal interest in the subject.

2.2.2. Data Collection Methods

During discussions between the First Nation and the university, it was decided that semi-structured interviews would be the most appropriate data collection method for the overall project and research. Semi-structured interviews are typical when conducting TK and Land Use and Occupancy documentation projects in Canada, and templates for these types of projects are available from the Centre for Indigenous Environmental Resources (CIER), which have been adapted from materials within Terry Tobias' book 'Living Proof'. For the overall project, the interview process involved providing the participant with paper base maps of the First Nation's traditional territory area, which included features such as lakes, rivers, roads, and railways. The lead interviewer (a person unaffiliated with Lakehead University hired by the First Nation to conduct the interviews) then asked a series of questions regarding the participant's use and occupancy on the land, and each feature was marked on the map and given a number and code for digitizing purposes. The questions were developed from the questionnaire template which had been modified to be the most appropriate for the community. The questionnaire was mainly used as a guideline: sections that were irrelevant to a given participant could be excluded (i.e., questions regarding a traditional activity the participant did not practice), and participants were also free to exclude any information they did not wish to share, or to include any topics not present in the questionnaire. The main purpose of the project was to document the individual's own story about their time and experiences on the land throughout their life. For the first interviews conducted, frequently discussed topics not present in the questionnaire were then added to the template to be used for following interviews. Interviews were audio recorded. Participants were given the option to not have the interview recorded. However, all participants gave consent to be recorded. Audio recordings were later used to transcribe interviews. Features on the maps were digitized using ArcGIS software and stored in databases by the participating consulting company.

The original questionnaire template used for this project did not have a section regarding climate change. Adding a section of climate change-related questions to be used for this study was simple and allowed for a seamless continuation of the semi-structured interview. Following completion of the land use and occupancy sections of the questionnaire, participants were asked questions regarding any changes they had observed in the environment that were potentially attributable to climate change, and if these changes were affecting the practice of traditional activities or harvest levels of traditional foods. These included questions about any observable changes in the timing of seasonal or biological events, extreme or unusual weather events, precipitation amounts, ice thickness and quality on lakes and rivers, and water quality. Follow-up with these questions included inquiring if any of the changes had affected timing of harvests, harvest amounts, accessibility of harvesting areas, or the health and safety of people in the community. Responses to these questions were the only ones to be analysed for this study.

2.2.3. Study Setting

All interviews were conducted at the First Nation's band office, as this was an easily accessible location to most members of the community. Potential participants were given the option to choose an alternate location to conduct an interview, such as their home or a location closer to where they lived. Given that all participants were fluent in English, all interviews were conducted in English and a translator was not required. However, as decided by community leaders, an elder advisor was chosen to attend each interview to aid with cultural sensitivity and support throughout the interview process and to help the participants feel comfortable. This advisor is a member of the community's Elders' Council and is well-known to most community members.

Each interview took an average of one full workday (8 hours) to complete, with some interviews taking as little as half a day or as much as three full workdays on the extreme ends. Snacks and lunch were provided for all interviews, and breaks were taken as frequently as needed for each participant. The climate change section of interviews would generally take between half an hour to an hour.

Participants were given the option to conduct the interview individually or as a group. Nine participants were interviewed individually, and six were interviewed in groups of two; in all cases these were two siblings. Both scenarios presented their own benefits and difficulties for this study. For example, interviews with an individual were generally easier to transcribe as there would be just one voice talking at a time when listening to the audio recordings, whereas during interviews with a pair they would sometimes talk at the same time or finish each other's sentences, making it difficult to understand what was being said. On the other hand, when interviewing a pair, the two could occasionally help each other remember events and conditions from the past, such as the climatic conditions of when they were children. This potentially allowed participants to give more accurate responses to the questions regarding climate change.

2.3. PARTICIPANT SELECTION AND RECRUITMENT

2.3.1. <u>Research Participants</u>

Targeted research participants were members of the above referenced Northwestern Ontario First Nation. Ideal participants were elders and older adults, as these individuals would have likely observed the greatest amount of change throughout their lifetimes. However, adults of any age were welcome to participate so that the number of participants could be maximized. The goal for the number of participants for this study was a minimum of fifteen, but interviews were intended to continue beyond this number if there was interest. This number was chosen because it was reasonably achievable and similar studies have included between approximately 10 and 20 participants. The goal was reached; fifteen members of the First Nation participated in the project, of which were six elders (aged 65+) and nine adults (Age 18-64). Full participant age and gender distributions are found in Figures 2 and 3 below. More participants were scheduled to be interviewed in the project, but due to the COVID-19 pandemic, interviews were discontinued to protect the health of community members.

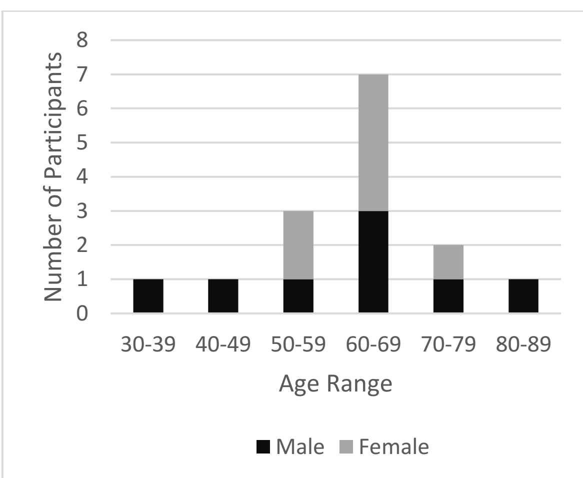

Figure 2. Ages of participants

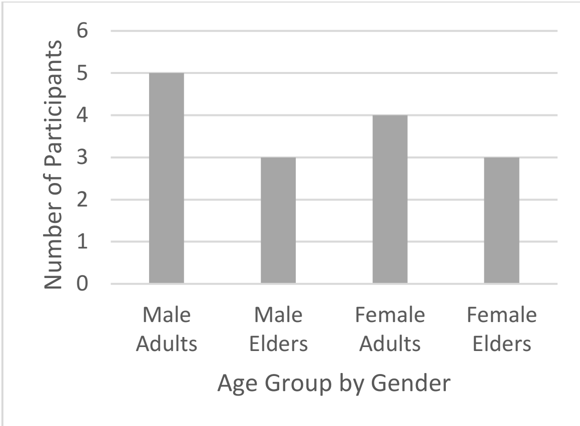

Figure 3. Age group and gender of participants (Adults 18-64, elders 65+)

2.3.2. Recruitment

Some members of the Elders' Council already had a high level of involvement in the development of the project prior to Lakehead University's involvement. During discussions it was agreed that these members would be first to participate in the data collection interviews as a sort of trial run before moving on to inviting other members of the First Nation to participate. This allowed for further development and refinement of the questionnaire and interview process to best fit the needs of the community. Recruitment beyond these first interviews involved members of the Elders' Council reaching out to other community members to let them know about the project and the interview process and giving them contact information to enquire about participating. A snowball sampling technique was used as well, where at the end of interviews participants would be asked to relay information about the project and contact information to others (such as family or friends) who may be interested in participating. Potential participants were never directly contacted by interviewers, and this was to avoid pressure to participate in the project.

2.4. ETHICAL CONSIDERATIONS

This study involved interviewing Indigenous people, a group that constitutes a vulnerable and historically marginalized population. As such, the principles and protocols outlined by both Lakehead University's Research Ethics Board (REB) and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans were followed at all times during the research process.

2.4.1. Potential Harms

There was no potential harm or risk (physical, psychological, injury to reputation or privacy, or breach of any relevant law) for participants or for third parties during this study. Deception was not used as part of this research, and thus did not present a risk to participants.

2.4.2. Potential Benefits to Participants and Society

Upon completion of the project, participants will be provided with a custom map of their land use and occupancy that has been created by the consulting company. A cultural values and TK library mapping and information management system will also be created for the community, for long term knowledge access, security, and storage, as to help prevent loss of knowledge overtime and across generations. Furthermore, the project will enhance the involvement of community members in decision-making within the First Nation's traditional territory. Land use and occupancy documentation will enable the community to participate and utilize this information to support informed consultation, planning and management, joint stewardship initiatives, and co-operative decision-making in resource planning, management, and development.

This research will help the community better understand how climate change is currently affecting individual members, as well as pinpoint which aspects of traditional livelihoods are being most affected or have the most potential to be affected by climate change in the future. This may aid the community in creating long-term plans to mitigate any potential negative outcomes of climate change, such as of shortages of traditional foods or reduced accessibility to harvest areas. This research will also contribute to the growing body of literature regarding how climate change is affecting Indigenous communities in Canada and worldwide.

2.4.3. Informed Consent and Right to Withdraw

Before the start of each interview, participants were given an information and consent form to read and sign. This form contained a description of the project and its purposes, interview procedures, information ownership and use, confidentiality, the right to withdraw, as well a checklist giving the participant the options to remain anonymous for the project and/or to not be audio recorded. The lead interviewer went through the form with participants and answer any questions regarding their rights as a participant or give clarification when necessary. When the participant agreed that they fully understood the form and the project including the university researcher's involvement in it, they would sign to give their consent to participate and the interview would begin.

All potential participants had capacity to consent, and thus were able to sufficiently understand the nature of the project, and the risks, consequences, and potential benefits associated with it. Participants had the right to withdraw from the project at any time without penalty of any kind and had the right to choose not to answer any questions asked during the interviews. Participants were given information on how to withdraw their information from the project and/or our study after completing an interview if they wished to do so.

2.4.4. Participant Anonymity

At the start of each interview, participants were assigned a personal identification number (PIN), starting with PIN 001, PIN 002, and so on. This PIN would then be used for that person for this project as well as any future traditional knowledge or land use and occupancy documentation projects the community conducts. These same PINs were used for our study for data organization and analysis. Each participant's PIN and associated information for the whole project was kept confidential in a secure database at the consulting company. For this study, only the PINs and audio recordings of participant responses to the climate change-related questions were kept for transcription and data analysis, and this information was stored on a password protected personal computer. More information on data storage and access is described in the next section. No identifying information will be used for any purpose for this study, meaning that participant names, the community's name, or any information that may identify the participant or community will not be used in publication or dissemination of this research.

2.4.5. Data Storage and Access

All data for this project including original paper base maps, scanned copies of base maps, audio recordings and their transcriptions (including the climate change section of the questionnaire), copies of information and consent forms, and electronic databases have been securely stored at the consulting company.

Copies of the climate change response audio files and transcriptions have been securely stored on a password protected personal computer throughout the research process. After completion of the research, this data was stored in a password protected memory stick for five years with the Principal Investigator at Lakehead University and destroyed afterwards, as per Lakehead University policy.

2.5. DATA HANDLING AND ANALYSIS

Audio recordings of participant responses to the climate-change related questions were transcribed verbatim using mostly manual techniques, and some automated techniques. For automated transcription, free trials to two cloud-based transcription services were tested using two participant audio recordings. Both programs had similar transcription accuracy, where a low to moderate number of corrections had to be made manually while reviewing the output transcriptions. Beyond the free trials, one service was slightly more cost-effective, so this program was used for transcribing two more participant audio recordings. Four audio recordings in total were transcribed using the automated techniques, and the remaining eleven were transcribed manually. Only recordings that were determined to be “high quality” were chosen for automated transcription, as it was known that this would result in fewer corrections needing to be made. High quality recordings were those where participants spoke clearly and at a moderate to high volume (or the recording device was placed closer to the participant) and where there were few occurrences of background noise or interviewers and participants talking at the same time. For this reason, any interviews with two participants were transcribed manually as there were frequent occurrences of more than one person talking at once. This method of using two transcription techniques allowed for the least time-consuming but most accurate transcription of audio recordings.

Once all audio recordings were transcribed, they were formatted for use in the qualitative analysis software NVivo. Transcriptions were automatically coded through NVivo using document formatting. A thematic analysis was then used to analyse the transcripts, identifying any recurring observations of changes in the environment, and impacts on traditional activities or harvest levels, health and safety, and overall experiences with climate change. Patterns that emerged from the transcriptions were categorized into themes and sub-themes which could then be used to draw general conclusions about the effects of climate change on members of the community.

3. LITERATURE REVIEW RESULTS

Through summary of peer-reviewed literature, reports, and other sources, this chapter aims to determine how climate change is already affecting livelihoods and the health of Indigenous community members across Northern Ontario, and how these may continue to be affected in the future as the consequences of climate change become more severe. Simultaneously, gaps in this knowledge will be highlighted and topics that may require further research attention will be identified. The results of this review have been divided into three sections. First, the effects of climate change in Northern Ontario will be reviewed, including existing trends and future projections of changes in weather and environmental conditions that are relevant to Indigenous people's livelihoods and health. In the following section, the current and future potential impacts of these changes on traditional food sources and Indigenous livelihoods will be reviewed. In the final section, the impacts of changing weather and environmental conditions on Indigenous people's health and safety will be covered. Summary tables containing this information will be provided at the end of each section (see Tables 1, 4, 5, and 6).

3.1. EFFECTS OF CLIMATE CHANGE ON WEATHER AND ENVIRONMENTAL CONDITIONS

3.1.1. Temperature

In Ontario, the average annual temperature increased by 1.4 °C from 1948 to 2008 (Ministry of the Environment 2011:10). Average temperature in Ontario has been projected to increase by 2.6 to 2.7 °C in the 2030s 4.0 to 4.7 °C in the 2050s, and 5.9 to 7.4 °C in the 2080s under different climate scenarios (Wang et al. 2015b). Similar projections were made for the 2071 to 2100 time period in Li et al. (2018). Rising average temperatures are the most direct result of greenhouse gas emissions, and these increases will have cascading effects on other aspects of weather and environmental conditions. For instance, rising temperatures will affect weather including precipitation in the form of rain and snow, wind speeds and gust frequency, storm intensity, and occurrence of unusual or extreme weather events such as heat waves, droughts, and forest fires (Li et al. 2018). Higher temperatures will also affect weather-related environmental conditions such as water levels, water quality and the duration of winter ice cover and ice thickness throughout Northern Ontario.

3.1.2. Precipitation

Regarding precipitation, the consensus among the scientific community is that globally, wet areas (e.g., coasts) will get wetter and dry areas (e.g., deserts) will get drier as the climate continues to change. Northern Ontario's climate, although being centrally located in Canada, is influenced by the Great Lakes and Hudson Bay and, as such, receives a moderate amount of precipitation, most of it falling as snow during the winter months. For example, annual precipitation amounts (rain and snow combined) across Northern Ontario cities range from 624 to 1045 mm, compared to coastal cities on Vancouver Island, British Columbia receiving 705 to 3505 mm or prairie provinces like Saskatchewan receiving 325 to 529 mm (Current Results 2021). Amounts are not projected to change significantly throughout the rest of the century. For example, Wang et al. (2015b) projected an increase in annual precipitation from baseline levels of 4.5 to

7.1% in the 2030s, 4.6 to 10.2% in the 2050s, and 3.2 to 17.5% in the 2080s for Northern Ontario.

The frequency and intensity of heavy rainfall events have also been observed to increase in the region (Adamowski and Bougadis 2003) and are expected to further increase in the future (Wang et al. 2015c). In Northern Ontario, increases in precipitation are projected to be mostly in the form of winter snow and spring rain (Wang et al. 2015b). However, increases in temperature and the resulting increases in evaporation may not be offset by even the largest estimated increases in precipitation (Stonefelt et al. 2000, Fontaine et al. 2001 cited in Assembly of First Nations 2008:22). For instance, Flannigan et al. (2016) estimated that average precipitation rates would have to increase by 15% to offset the moisture loss resulting from every 1 °C increase in temperature in a given region. With a maximum projected increase in average temperature of 7.4 °C in the 2080s, precipitation would have to increase by 111% by then to offset evaporation rates. As a result, lake levels and overall freshwater availability may be significantly reduced throughout Northern Ontario.

3.1.3. Water Quality

Water quality can be affected by climatic factors such as temperature and precipitation, and non-climatic factors such as soil erosion, sedimentation, and anthropogenic pollutant inputs. Changing climatic conditions in Northern Ontario may therefore diminish water quality throughout the region. Specifically, rising temperatures and changes in precipitation regimes as projected may affect the concentration and movement of waterborne pathogens as well as the occurrence of toxin-producing cyanobacterial algal blooms.

Waterborne pathogens are climate-sensitive. For instance, some pathogens proliferate and thrive at higher temperatures, while others may start to die off or inactivate (Health Canada 2005 in Assembly of First Nations 2008:20; Schijven and de Roda Husman 2005 and Semenza et al. 2012 cited in Schijiven et al. 2013). Furthermore, changes in precipitation quantity, intensity, frequency, and duration as a result of climate change may increase the risk of waterborne disease (Harper et al. 2011). Low water levels during periods of drought result in higher concentrations of some pathogens in water, increasing the risk of becoming ill when utilizing the water source (Schijiven et al. 2013). Conversely, during periods of heavy rainfall or rapid snowmelt, water levels rise and water moves more quickly, sometimes resulting in significant overland water runoff. This can increase water turbidity and result in the transportation of pathogens, contaminating water sources (Harper et al. 2011; Health Canada 2005 cited in Assembly of First Nations 2008:28), especially when runoff moves raw sewage into drinking water sources (Assembly of First Nations 2008:4, Charron et al. 2005:81). Even when water treatment systems are in place, higher turbidity can make water treatment more challenging (Aramini et al. 2000 cited in Harper et al. 2011), potentially overwhelming these systems during periods of heavy overland water flow.

Cyanobacteria (also called blue-green algae) are microscopic, single-celled photosynthetic bacteria that can produce harmful or even deadly toxins that affect the nervous system, liver, or skin of animals and humans (Assembly of First Nations 2008:26). Nutrient concentrations and ratios in water and climatic conditions (primarily temperature, precipitation, and wind) have been identified as the two most important factors in predicting cyanobacteria blooms at large, regional scales. At the small, lake-level scale other factors may play equally important roles (Persaud et al. 2015) but these are highly complex and not yet fully understood (Favot et al. 2019). In Ontario, reports of algal blooms, including ones where cyanobacteria were dominant, were found to have increased significantly between 1994 and 2009 (Winter et al. 2011). In their study, Winter et al. (2011) examined reports of algal blooms across the 5 regions of Ontario's Ministry of the Environment (MOE): Northern, Eastern, Southwestern, West Central, and Central. The total number of reports of all algal blooms was highest in the Northern region, and this region also had the highest rate of increase in the number of blooms reported each year for total and cyanobacteria, from 0 to 22 reports of total blooms and 0 to 15 cyanobacterial blooms per year from 1994 to 2009. Most lakes with reported cyanobacteria blooms across Ontario were characterized by elevated phosphorus concentrations, however 26% of lakes were classified as oligotrophic, i.e., having low nutrient concentrations (Winter et al. 2011). In these lakes, changing climatic conditions must have contributed to bloom occurrence. Similarly, Favot et al. (2019) determined that an increase in cyanobacterial bloom occurrence in a single Northern Ontario lake was likely a result of warmer air temperatures, an increase in the length of the ice-free season, and declines in wind speed (reduced mixing of stratified water layers). With predicted increases in air temperature and resulting increases in water temperature and evaporation rates, cyanobacteria algal blooms may continue to become more widespread, frequent, and severe throughout Northern Ontario. Increased development and associated anthropogenic nutrient inputs in Northern areas will further contribute to this. Wind speeds are expected to increase in Ontario (Cheng et al. 2012) which may offset increasing bloom frequency and severity through increased water mixing.

3.1.4. Ice Cover Duration and Ice Thickness

Changes in the duration of winter ice cover and ice thickness are largely associated with climatic factors such as air temperature, and to a smaller extent, wind and precipitation type and amount. Non-climatic factors also play a role in lake ice cover duration, including lake volume and surface area, and water inputs from inflowing rivers. (Brown and Duguay 2010). There is considerable research into historical trends and projections of changes in duration of inland lake ice cover and ice thickness at the large-scale for the Northern Hemisphere (e.g., Dibike et al. 2011) and Canada (e.g., Duguay et al. 2006). At the smaller scale, Minns et al. (2012) have projected climate change effects on the duration of ice cover (the number of days between fall ice freeze-up and spring ice break-up) and ice thickness for lakes across Ontario. Within the 2071-2100 time period, the duration of lake ice cover was projected to decrease by a minimum of 10.0 to 20.2 days and by a maximum of 20.6 to 28.8 days from historical durations across Northern Ontario under worst-case climate scenarios (projections were also made for the time periods 2011 to 2040 and 2041 to 2070 and for conservative climate scenarios, see Minns et al. 2012). Decreases in ice cover duration tended to be more pronounced following a southward gradient.

Regarding ice thickness, Minns et al. (2012) projected changes for a single “representative” mid-latitude (50°) Ontario lake under different climate scenarios for the period of 2041 to 2070 only. Using 1971 to 2000 climate averages, this representative lake would have an ice cover duration of about 150 days between ice freeze-up and break-up dates. By the 2041 to 2070 period, ice cover duration was projected to decrease to 138 and 126 days under conservative and worst-case climate scenarios, respectively. Ice thickness was modelled in an assumed pattern of growth from the first day of freeze up toward a plateau in late winter, and then decay until the day of break-up. In all scenarios, ice thickness growth and decay followed the same patterns, but shorter ice cover durations under the climate change scenarios resulted in critical ice thickness thresholds being met for shorter durations throughout the ice-cover season and a decreased peak ice thickness (Minns et al. 2012)

3.1.5. Extreme Weather Events

Climate change is expected to affect the frequency and intensity of extreme weather events. These events are unusually severe or unseasonal weather based on a given location's typical weather history. In Northern Ontario, the most common extreme weather events include heat waves, cold snaps, floods, and droughts. Forest fires may not be considered an extreme weather event, but they will be included here because they increase in frequency and intensity during periods of high temperature extremes and/or low precipitation extremes and can have similar socio-economic impacts as extreme weather events. Rising average temperatures and shifting wind patterns are contributing to an increasing frequency and duration of extreme weather events such as these in Ontario (Ministry of the Environment 2011:27).

Throughout the year, all regions of Ontario experience periods of extreme heat and extreme cold, typically referred to as heat waves and cold snaps. Even small changes in average temperature can result in a disproportionate change in the frequency of daily temperature extremes (Dotto et al. 2010:74). With a rise in average temperature such as the maximum predicted increase of 7.4 °C by the 2080s in Northern Ontario (Wang et al. 2015b), heat waves can be expected to increase in frequency, duration, and intensity throughout the region.

Li et al. (2017) modelled future temperatures for Ontario and projected a relative increase in annual mean temperature of 40.0-101.1%, 64.6-264.8% and over 443.15% for meteorological stations located in Southern, Central, and Northern Ontario, respectively. This implies that while Northern Ontario may not experience the highest absolute temperatures, it will experience the highest rate of temperature increase out of all three regions. Analyses of projected heat wave events from 2070 to 2100 indicated that these will become more intense, more frequent, and longer lasting throughout Ontario. The northernmost station included in the study was projected to experience the highest number of and longest lasting heat waves (Li et al. 2017). No studies have investigated potential changes in cold snaps in Ontario, however, it can be inferred that they will likely have the opposite outcome of heat waves and be fewer, less intense, and shorter in duration.

Floods occur in all regions of Canada, in rural and urban areas, and they can happen at virtually any time of year (Dotto et al. 2010:49). Flood conditions can cause damage to infrastructure and pose risks to human health and safety in developed areas (Dotto et al. 2010:49-50, IPCC 2014:123). Floods are strongly influenced by human activities impacting catchment areas which makes it difficult to attribute changes in flooding to climate change, however, increasing trends in extreme precipitation in some areas may increase the risk of flooding on a regional scale (IPCC 2014:53). The frequency and intensity of flood events are expected to increase in some regions throughout Canada as changes in temperature and precipitation occur (Burrell 2011, Dotto et al. 2010:49, Thistlethwaite and Henstra 2017). The extent to which these are expected to increase in Northern Ontario is not well researched. However, the frequency of heavy rainfall events and average precipitation are projected to increase in Ontario, which may result in increased flood frequency and intensity throughout the province, particularly in the spring during periods of high surface runoff.

Conversely, droughts can occur during periods of below-average precipitation and/or high temperatures. Droughts stress water availability for human and environmental needs; they result in lower lake and reservoir levels, reduced stream flows, and diminished groundwater supply. Like floods, the potential future occurrence of droughts in Northern Ontario is not well-researched. Projections of precipitation and water resources have demonstrated that in Canada, Northern areas will become wetter and southern areas will become drier (Maloney et al. 2014, cited in Yusa et al. 2015). In addition to higher precipitation amounts, northern areas will experience thawing of permafrost and increases in snow, ice, and glacial meltwater (INAC 2006, cited in Assembly of First Nations 2008:22). From these it might be inferred that Northern Ontario will be less at risk for the occurrence of drought conditions, but projected increases in average temperature and the resulting increase in evaporation rates are not taken into account. Therefore, it is difficult to say how drought frequency and intensity may change in the region for the remainder of this century.

Forest fires are a natural phenomenon in the boreal forest. Weather conditions are the driving force behind the ignition and spread of forest fires. Fires can be started from either lightning strikes or human activities such as recreation or industrial activities (Wotton et al. 2005). Their intensity and rate of spread are largely determined by wind speed and the moisture content of forest fuels (e.g., dead woody debris and leaf litter) which is related to temperature and precipitation (Dotto et al. 2010:42, Wang et al. 2015a, Wotton et al. 2003).

In Ontario, it is predicted that there will be a greater number of fires as well as an increase in the amount of forest area burned with every fire season (Ministry of the Environment 2011:59-60). This is largely due to projected increases in average temperatures resulting in lower moisture content of fuels, making them more conducive to fire spread; any projected increases in precipitation amounts will not be enough to offset this moisture loss (Flannigan et al. 2016, Wotton et al. 2003, Wotton et al. 2005, Wotton et al. 2017). It has been predicted that by 2090, the total number of fires will increase by 50% from baseline levels in Ontario, with a majority of this being contributed by lightning-caused fires. However, estimates of lightning-caused fires were conservative, as these projections did not account for any changes in lightning activity, which the authors stated is expected to increase in the province (Wotton et al. 2005).

Table 1. Summary of climate change effects on weather and environmental conditions in Northern Ontario.

		Trends and Projections for Northern Ontario	Source(s):
General Weather Patterns	Temperature	• Average temperature increase of 1.4 °C from 1948 to 2008 • Projected increase of 2.6 to 2.6 °C in the 2030s 4.0 to 4.7 °C in the 2050s, and 5.9 to 7.4 °C in the 2080s	Ministry of the Environment 2011 Wang et al. 2015b
	Precipitation	• Increase in annual precipitation from baseline levels of 4.5 to 7.1% in the 2030s, 4.6 to 10.2% in the 2050s, and 3.2 to 17.5% in the 2080s • Increased heavy rainfall frequency	Wang et al. 2015b Adamowski and Bougadis 2003 Wang et al. 2015c
Environmental Conditions	Freshwater Availability and Quality	• Possible decrease in freshwater availability • Decreasing water quality through projected increasing occurrence of waterborne pathogen contamination and cyanobacterial algal blooms	Schijiven et al. 2013 Harper et al. 2011 Favot et al. 2019 Persaud et al. 2015 Winter et al. 2011
	Ice Cover Duration and Ice Thickness	• Decrease in ice cover duration by as much as 29 days • Decreasing ice thickness, critical ice thickness thresholds met for shorter periods of time	Minns et al. 2012
Extreme Weather Events	Heat Waves	• Projected increases frequency and intensity of heat waves due to rising average annual temperatures	Li et al. 2017 Dotto et al. 2010
	Floods	• Possible increase in flood events due to increases in winter and spring precipitation and heavy rainfall events	Dotto et al. 2010 Thistlethwaite and Henstra 2017
	Droughts	• Possible increase in drought events due to rising temperatures	Yusa et al. 2015
	Forest Fires	• Observed and projected increases in forest fire frequency and intensity due to rising temperatures and moisture loss	Dotto et al. 2010 Wang et al. 2015a Wotton et al. 2003

3.2. IMPACTS ON TRADITIONAL FOOD SOURCES AND LIVELIHOODS

Many Indigenous communities of Northern Ontario have mixed economies combining wage employment and traditional livelihoods consisting of fishing, hunting, gathering, and trapping for food and income. The effects of climate change discussed in the previous section may alter traditional food species abundance and distribution, diminish people's ability to participate in certain harvesting activities, and compromise winter ice roads that support livelihoods. Therefore, some aspects of traditional livelihoods may be significantly impacted across the region as the effects of climate change become more apparent and severe throughout this century. Through a review of Indigenous observations and modelled projections, this section will cover the current trends and future predictions concerning the effects of changing environmental conditions on key traditional foods, the ability of people to participate in traditional harvesting activities, and winter ice roads in Northern Ontario.

There are large number of traditional animal and plant foods harvested by Indigenous community members across Ontario. Important traditional food species groups that will be discussed in the following paragraphs are listed in Table 2 with examples of species commonly harvested in the region.

Table 2. List of common traditional foods of Northern Ontario (non-exhaustive)

Species Group	Species
Large Mammals	• moose (*Alces americanus*) • white-tailed deer (*Odocoileus virginianus*)
Freshwater Fish	• lake trout (*Salvelinus namaycush*) • lake whitefish (*Coregonus clupeaformis*) • pickerel (or walleye; *Sander vitreus*) • northern pike (*Esox lucius*) • smallmouth bass (*Micropterus dolomieu*)
Migratory Waterfowl	• mallards (*Anas platyrhynchos*) • Canada geese (*Branta canadensis*) • snow geese (*Chen caerulescens*)
Game Birds	• ruffed grouse (*Bonasa umbellus*) • spruce grouse (*Falcipennis canadensis*) • sharp-tailed grouse (*Tympanuchus phasianellus*) • willow ptarmigan (*Lagopus lagopus*)
Berries and Other Food Plants	• blueberries (*Vaccinium angustifolium* and *V. corymbosum*) • raspberries (*Rubus ideaus*) • saskatoon berries (*Amelanchier alnifolia*) • wild strawberries (*Fragaria vesca*) • cranberries (*Vaccinium oxycoccos* and *V. vitis-idaea*) • choke cherries (*Prunus virginiana*) • pin cherries (*Prunus pensylvanica*) • wild rice (*Zizania* spp.) • beaked hazel (*Corylus cornuta*) • maple (*Acer* spp.) and birch (*Betula* spp.) syrup • Labrador tea (*Rhododendron groenlandicum*) • wild mint (*Mentha canadensis*)

3.2.1. Moose

Moose survivability and vigour are affected by changes in climate directly through physiological mechanisms such as increasing difficulty in thermal regulation as average air temperatures rise, and indirectly through potential changes in habitat and food sources, increasing parasitism from winter ticks (*Dermacentor albipictus*) and diseases carried by white-tailed deer such as meningeal brain worm

(*Parelaphostrongylus tenuis*), greater competition for habitat from white-tailed deer, and increased predation by wolves (*Canis lupus*; CIER 2007, Murray et al. 2012, Rempel 2011, Weiskopf et al. 2019).

Moose abundance in Ontario has been predicted to decrease overall at the southern limits of their range and increase in the northern extents toward the end of this century (Murray et al. 2012, Rempel 2011). However, populations in some areas of their southern extents may remain stable or increase due to variances in small-scale environmental conditions (Murray et al. 2012). Projected declines have been attributed to lower habitat carrying capacity, higher heat stress, higher parasite loads, and increased wolf predation resulting from climate change (Rempel 2011). Hunting opportunities for moose will therefore likely decrease at their southern range limit throughout this century.

A number of Indigenous communities in Northern Ontario and Manitoba have observed changes in moose abundance, distribution, and meat quality (potentially related to animal vigour). The communities of St. Theresa Point First Nation, MB and Poplar River First Nation, MB have both observed a decline in the number of moose in the area (CIER 2006). Members of Weenusk First Nation, Ontario have observed variations in moose distribution rather than a direct change in population numbers (Lemelin et al. 2010). Other communities have noted that while moose populations are stable, the meat quality and health of moose has declined, which is believed to be possibly caused by climate change. For example, community members of Fort Albany, ON mentioned that moose meat tastes different than it used to (Tam et al. 2013). In addition, members of Black River First Nation, MB described finding “blisters” under the skin of moose which made them question the quality of the meat, sometimes resulting in it being thrown away to avoid potential illness. Members of Black River are now eating less traditional foods than they used to because they no longer trust that these foods are safe to eat (CIER 2007).

3.2.2. Freshwater Fish

Freshwater fish species can be categorized into three groups: cold-water, cool-water, and warm-water species. In Northern Ontario, cold-water species include lake trout and lake whitefish; cool-water species include pickerel and northern pike; and warm-water species include smallmouth bass. Since different fish species are suited to specific water temperatures, they will be directly affected by warming air temperatures and the resulting increase in water temperatures (Van Zuiden et al. 2016). Fish may also be affected by other factors resulting from climate change such as droughts, changes in water flow, and increased sediment mobilization (Rowland et al. 2013). Other non-climatic factors that affect freshwater ecosystems include hydroelectric developments, forestry operations, mining, and road and transmission line developments. While these are not a directly result of a changing climate, there is growing demand for these in Canada and a warming climate may present opportunities for new developments in more northern areas (Rowland et al. 2013). All these factors combined stress freshwater fish populations, particularly cold-water species, and will put them at increasing risk of extirpation as average temperatures rise (Murray 2016).

Presently, the proportion of lakes in Ontario dominated by warm-water, cold-water, and cool-water fish species are 4.8%, 13.2%, and 82%, respectively. It has been projected that nearing the end of this century, lakes dominated by warm-water species will increase by 10-40%, lakes dominated by cool-water species will decrease by up to 27%, and lakes dominated by cold-water species may decrease by up to 80% and will comprise only 0.2-1.8% of total lakes (Biswas et al. 2017). Similar projections have been made for freshwater fish in Central and Southern Ontario (Edwards et al. 2016) and across Canada (see Chu et al. 2005). Van Zuiden et al. (2016) projected that smallmouth bass occurrence rates will increase by approximately 306%, and pickerel occurrence rates will decline by approximately 22% by 2070. By 2070, the co-occurrence of pickerel and smallmouth bass was predicted to increase by 11%, creating increased competition between the species particularly in Central and Northern Ontario (Van Zuiden et al. 2016).

It can be expected that there will be a northward range expansion of both cool-water and warm-water fishes, and cold-water fishes may become extirpated in lakes at the southern extent of their ranges in Ontario (Biswas et al. 2017, Chu et al. 2005). The invasion of warm-water fishes like smallmouth bass into presently cool- and cold-water lakes as the climate warms can compound the decline of other fish, as bass tend to outcompete others like lake trout and pickerel for prey species and habitat (Murray 2016, Reeves 2016, Van Zuiden et al. 2016).

Several Indigenous communities in Northern Ontario and Manitoba have observed modest changes in freshwater fish. These have included the appearance of new fish species, shifts in abundance of some native species, differences in meat quality, and changes in average fish size. While these observed changes have not yet been substantial, community members have expressed a growing concern over how other observed changes in aquatic environments may potentially affect local fish populations in the future. Community members of both Fort Albany (Tam et al. 2013) and Weenusk (Lemelin et al. 2010) in Ontario have observed the appearance of yellow perch (*Perca flavescens*) in areas where they were not found previously. Observations of carp (Cyprinus spp.) were also reported in Weenusk (Lemelin et al. 2010). Similarly, members from York Factory Cree Nation, MB have noted the appearance of catfish (species or genus unidentified) in the area (CIER 2006). It is difficult to conclude if the appearances of new species around these communities are a direct result of changes in climate since fish invasions can also be facilitated by human activities (e.g., purposeful introductions, dumping live bait). Regardless, changes in aquatic environments can result in water bodies becoming more capable of supporting the survival of introduced invasive fish species.

Changes in the abundance of native fish species have been reported in some communities. In St. Theresa Point, MB, fish populations were reported to be declining (CIER 2006), though the exact species were not identified. Members of St. Theresa Point, as well as Poplar River, MB, noted that all fish in general were observed to be smaller in size (CIER 2006). Some community members have seen a decline in the quality of fish meat, sometimes resulting in it needing to be discarded because it was not suitable for consumption. For example, in Barren Lands, MB, fish meat was found to be softer and rotting more quickly, particularly in lake trout (CIER 2006). Members of Poplar River and York Factory, MB similarly described a general decline in the quality of fish meat (CIER 2006). Participants from multiple communities expressed great concerns about observed changes in local lakes, rivers, and creeks and how these may potentially affect fish populations over time. For instance, members of Fort Albany have articulated concerns over changes in water temperatures, water levels, and changes in precipitation and their effects on fish (Tam et al. 2013). One community member noted that increased water temperatures will lower the oxygen levels of the water and fish will no longer be able to survive (Tam et al. 2013).

3.2.3. Migratory Waterfowl and Game Birds

Regarding migratory waterfowl and game birds, there is little to no research of the projected effects of climate change on these in Ontario. Some research has been conducted for waterfowl species in other areas of Canada (see Zhao et al. 2016 and Whithey and van Kooten 2014).

Changes in migratory waterfowl have been observed by a few Indigenous communities. These include changes in abundance, the timing of migration, meat quality, and competition and predation from new species. In Fort Albany, study participants reported a decline in Canada geese numbers, whereas snow geese were said to have disappeared from the area entirely during the hunting season (Tam et al. 2013). In Weenusk, ducks were observed to be decreasing in number or disappearing entirely as well (Lemelin et al. 2010). The timing of goose migration was also reported to vary more from year-to-year in Fort Albany. Participants find that they are no longer prepared for the arrival of geese, and sometimes community members miss opportunities to hunt them. This change in timing was associated with earlier springs and overall warmer seasons. One member from Fort Albany stated that the community relies on geese for food, and the decline in their numbers has caused people to turn to more less-preferred store-bought foods (Tam et al. 2013). A change in the taste of goose meat was also reported in Fort Albany (Tam et al. 2013) and Bunibonibee, MB (CIER 2006).

Participants in Fort Albany had observed new bird species like pelicans (*Pelecanus spp.)* and pigeons (*Columba spp*.), which has raised concerns about competition for food sources and interactions between them and the native bird populations (Tam et al. 2013). An increase in the number of bald eagles (*Haliaeetus leucocephalus*) was also reported by participants, which they associated with the decline in geese in the area. They said that eagles in the harbour will ward off geese and prevent them from landing around the community (Tam et al. 2013). An increase in the number of eagles was also seen in Weenusk, ON (Lemelin et al. 2010).

Minimal observations of changes in game birds have been documented. In Fort Albany, community members indicated that sharp-tailed grouse and ptarmigan were no longer seen around the community (Tam et al. 2013). The same has occurred in Poplar River, MB, where ptarmigan used to be plentiful in the area but are no longer seen at all (CIER 2006). In Barren Lands, MB, the ptarmigan abundance has decreased (CIER 2006). Conversely, grouse and ptarmigan populations were observed to be increasing in Weenusk (Lemelin et al. 2010).

3.2.4. Berries and other Food Plants

There is currently little to no research that addresses how climate change may affect berry and food plants in Ontario. However, CIER (2007) briefly discussed the role climate plays in the production of berries through a review of some literature as well as interviews with experts on climate change in the boreal forest region; these are located in Table 3 below. From this information, it can be inferred that a reduction in the amount of precipitation in the forms of either snow or rain in a region or increases in temperature resulting in moisture loss could result in a decline in the number of blueberries produced. CIER (2007) also gave some speculations into how other food and berry plants may respond to changes in climate (Table 3).

Table 3. Possible climatic interactions and impacts of climate change on blueberries and other food plants (CIER 2007).

	Climate Change Influence or Impact	Original Source
Blueberries	• Flower buds of blueberries are produced in the fall, and the plants need to be covered in enough snow to protect the buds from frost damage	Hall et al. 1979
	• Late frosts or dry conditions in the spring may stop plants from flowering, which would reduce the number of berries produced	Benoit et al. 1984
Other Food Plants	• Plants may "move" into new territories as habitats change over time through creeping roots and seeds carried by wind, water, or animals. • As the climate changes, it may be possible for plant species to survive as they relocate; however, if changes occur too rapidly, then certain species may be at risk of extinction. • Plants with heavy seeds, such as choke cherries and plums (Prunus nigra), will be at the most risk of extinction because seeds are not easily carried by wind.	CIER 2007

Some of the most common observations of changes in food plants in Ontario and neighbouring provinces is the drying up of blueberries in the summer months before they have had a chance to ripen and be picked, and overall reduced blueberry abundance. When going berry picking, members of many communities are finding berries that are smaller than usual, and often dried and shriveled up. This has been observed in Poplar River and York Factory, MB, (CIER 2006), Black River, MB (CIER 2007), and the Cree Nation of Wmindji in Eastern James Bay, QC (Berkes pers. comm. 2007 cited in CIER 2007). In Black River, almost all study participants said that there used to be plenty of berries in the area, and it has been increasingly difficult to find berries and other fruits (CIER 2007). Similarly, members from York Factory (CIER 2006), Weenusk, ON (Lemelin et al. 2010), and Fort Albany, ON (Tam et al. 2013) reported an overall decline in the number of berries around the communities. Members of Black River noted that when they are unable to harvest wild berries, they sometimes buy frozen or canned berries.

The participants from Black River indicated that climate change could be one cause of the changes in traditional food plants, but they noted that development activities such as logging and hydro dam construction could be important factors as well. However, several of them made specific connections between the changes in weather they have noticed and how they could be affecting food and medicine plants. For instance, it was mentioned that reduced snowfall amounts in the winter could be leading to reduced moisture availability for plants during the growing season (CIER 2007). Members of Fort Albany made similar connections: some people associated the decline in berries to warmer temperatures, stronger sun intensity, and reduced precipitation, while others said that soil contamination and other pollution in the area could be a factor as well (Tam et al. 2013).

Table 4. Summary of projections and Indigenous observations of changes in key traditional foods (some observations from neighbouring provinces of Manitoba and Quebec).

Species Group	Projections and Observations for Northern Ontario	Source(s)
Moose	• Population numbers projected to decrease in southern extents of range and increase in northern extents • Declines attributed to lower habitat carrying capacity, higher heat stress, higher parasite loads, and increased wolf predation resulting from climate change • Indigenous observations of declining moose abundance, changes in distribution, and declining meat quality	Murray et al. 2012 Rempel 2011 Lemelin et al. 2010 Tam et al. 2013 CIER 2006 CIER 2007
Freshwater Fish	• Possible northward range expansion for all fish species • Extirpation of cool- and cold-water fish species at southern extents of ranges due to rising water temperatures and increased competition from invasive species • Increasing abundance and invasion of warm-water fish species into presently cool- and cold-water lakes • Indigenous observations new/invasive fish species, shifts in native fish species abundance, declines in meat quality, and declines in fish size	Rowland et al. 2013 Biswas et al. 2017 Murray 2016 Reeves 2016 Lemelin et al. 2010 Tam et al. 2013 CIER 2006
Waterfowl and Game Birds	• Little to no research on these in Ontario • Waterfowl population dynamics driven by wetland availability; a decline in wetland area in the region due to rising temperatures may affect waterfowl abundance • Indigenous observations of changes in migration patterns, meat quality, and increased competition and predation from new bird species	Zhao et al. 2016 Whithey and van Kooten 2014 Lemelin et al. 2010 Tam et al. 2013 CIER 2006
Berries, other food plants	• Little to no research on these in Ontario • Climatic factors involved in blueberry production may include snow depths, late frosts, and spring rain conditions • Plants may “move” into new territories as habitats change over time through creeping roots and seeds carried by wind, water, or animals • Plants with heavy seeds will be at higher risk of extirpation because seeds are not easily carried by wind • Indigenous observations of decreased blueberry abundance and abrupt drying of berries before they have had a chance to ripen and be harvested	CIER 2007 CIER 2006 Lemelin et al. 2010 Tam et al. 2013

3.2.5. Livelihoods

Changing weather and environmental conditions have also affected Indigenous community members' livelihoods in a number of ways beyond direct changes in traditional foods. For instance, changes in ice conditions, weather, and water levels have made it more difficult to access harvesting areas or participate in certain harvesting activities. Changing ice conditions have also compromised the winter ice roads that provide many benefits to remote communities in Ontario's Far North.

Winter ice cover of sufficient thickness on lakes and rivers is necessary for traditional activities that supply food sources and income, such as ice fishing and trapping. The projected changes in lake ice regimes discussed previously will negatively affect Indigenous livelihoods as carrying out these activities become increasingly difficult and dangerous. As temperatures rise throughout this century, decreasing ice cover duration will reduce the amount of time critical ice thickness thresholds (e.g., for on-foot, snow-machine, or vehicle travel) are met, contracting the timeframe where these winter activities are possible and safe.

Changes in ice regimes and resulting impacts on livelihoods have been discussed by numerous Indigenous community members in Northern Ontario. Firstly, several communities in the region have reported that ice only becomes about as half as thick as it used to, and the duration of ice cover in the winter has been much shorter. It was stated by study participants that ice cover used to normally last for six to eight months of the year, and more recently the duration of ice cover has been reduced by about two months on average. For these communities, changes in ice regimes have impacted traditional activities, particularly regarding personal safety due to increasing risks of falling through ice (Golden et al. 2015). Similarly, in Fort Albany, ON, ice on lakes and rivers has been observed to begin developing later than normal and not becoming as thick as it used to. For example, ice on one lake near the community used to be thick enough to walk on in October, but now the ice only begins forming in December. Participants also noted that ice on the Albany River used to become very thick, and in recent years the ice has been much thinner. These changes in ice have negatively impacted some aspects of community members' livelihoods; for instance, some participants noted that they are not able to go trapping when the rivers do not completely freeze, as they are not able to cross them to get to their traplines (Tam et al. 2013).

Regarding changing weather and water conditions, members of Fort Albany discussed how these have affected certain harvesting activities. For instance, participants stated that weather patterns were much more predictable in the past, and that they have relied on this predictability to plan and follow through with activities like hunting trips. Members have found that weather has become more variable, unpredictable, and severe, which has increased the risks of going on hunting trips and forced some hunters to change or cancel plans (Tam et al. 2013). Furthermore, participants noted that water levels around the community have been lower than normal. It was explained that when the water levels in the river are too low, they are unable to travel upstream to their hunting grounds where they go moose hunting, and this decreases the amount of moose meat they are able to harvest for the year.

Winter ice roads are used in northern regions of Canada and Alaska to allow for more economical transportation of heavy equipment, fuel, and supplies to remote communities, as well as to facilitate social connections between communities (Barrette and Charlebois 2018, Hori et al. 2018b). There are about 3160 km of winter road networks in Ontario that provide many socio-economic benefits to remote communities in the north (Barrette and Charlebois 2018, Reid 2015).

The seasonal length of winter roads in Northern Ontario is typically about ten to twelve weeks (Reid 2015) and depends on climatic factors like air temperature, precipitation (both rain and snow), and wind. Warming temperatures have already impacted ice regimes and winter road seasonal length in Northern Ontario; the season has contracted by over a week on average and is projected to shorten by at least two more weeks in the next few decades (Garrick 2010 cited in Reid 2015). With further warming, these changes may lead to significantly reduced longevity, quality, and viability of winter roads within this century (Hori et al. 2018a, Reid 2015). This occurrence will have several social, economic, and cultural implications for remote Northern Ontario communities that rely on winter roads, as they are vital to livelihoods by providing access to goods, groceries, fuel, and heavy equipment at a significantly reduced cost compared to other transportation methods (Golden et al. 2015, Hori et al. 2018b).

Many observations have been made by Indigenous community members regarding how climate change has affected winter roads in Northern Ontario. These have included a shortened winter road season and reduced road quality, which has resulted in significant economic repercussions. For instance, the James Bay winter road connects Fort Albany to the community of Moosonee, a town with rail access. The winter road allows community members to travel to Moosonee to purchase necessities like food, furniture, and housing supplies at lower prices compared to having them transported by air to Fort Albany. Most participants asserted that climate change is negatively affecting the winter road. They stated that warmer winter temperatures, reduced amounts of snow, earlier spring melt, late freeze-up all have made the winter road less stable. They also remarked that the winter road used to last longer, and that it would freeze by the end of November and last until the end of March (Tam et al. 2013).

For multiple other remote Northern Ontario communities, changing ice conditions have also significantly affected community members' winter road use (Golden et al. 2015). For one, those in charge of winter road construction have had to adjust the type and weight of equipment used over the years due to changes in ice strength-bearing capacity. In the 1980s, 18 tonne snowploughs were standard equipment, which changed to 10 tonne equipment in the early 2000s, and finally to ¾ and 1 tonne trucks fitted with ploughing equipment presently. The reduction in equipment size has increased the time needed to complete and maintain the winter road and shortened the timeframe where winter road conditions are safe and reliable. The diminished winter road access has significantly increased the price and decreased the availability of goods such as fuel and groceries, as well as large equipment like vehicles and machinery which cannot be transported by air (Golden et al. 2015).

For fuel (gasoline and diesel), the decreased availability has had multiple consequences for communities. First, the increased cost makes it less economical to carry out traditional harvesting activities where gasoline is required for vehicles like snow machines, and in some cases, it is not even worth the cost to go on hunting or fishing trips when gas prices are high; as one community member stated, "It is not worthwhile to go moose hunting as it is expensive… the ride is very expensive… it comes out about the same as to buy food from the store than to go hunting" (Golden et al. 2015:408). Secondly, most communities in Ontario's Far North rely on diesel generated electricity to power appliances, heating and cooling systems, and water treatment plants. Many homes are equipped with wood stoves for heating, but larger buildings (schools, nursing stations, and band offices) and some homes are not. With extremely low temperatures in the winter, not having access to heat due to a fuel shortage can be life-threatening and disrupt community life in general. Moreover, in some communities the water quality is so poor that bottled water must be delivered by either transport trucks or air cargo, which has further driven up costs of potable water when winter road transport is disrupted (Golden et al. 2015).

In the winter of 2020 to 2021, unusually warm weather led to a greatly shortened winter road season in Northern Ontario. A warm start to the season resulted in winter road use being delayed by more than a month than usual. Typically, some communities would be able to have light traffic (i.e., personal vehicles) on winter roads by the end of December, and for the 2020-2021 season it was not possible until a cold snap occurred in February. The cold snap allowed most communities to finally open the roads to at least partial loads, but seven still had their roads remain under construction (CBC 2021b). Indigenous leaders of Northern Ontario have described the continuous delaying of winter road construction due to warming temperatures a “developing crisis” for northern communities (CBC 2021a).

Table 5. Summary of the effects of climate change on Indigenous livelihoods in Northern Ontario.

Effect of Climate Change	Impacts on Livelihoods	Source(s)
Reduced Ice Cover Duration and Ice Thickness	• Critical ice thickness thresholds take longer to be reached and are met for shorter durations • Reduces the amount of time winter harvesting activities like ice fishing and trapping are possible and safe to carry out • Many observations of decreasing ice thickness and shorter ice cover duration in Northern Ontario which have affected community members' livelihoods	Minns et al. 2012 Golden et al. 2015 Tam et al. 2013
Unpredictable Weather	• Weather patterns were much more predictable in the past, and this predictability was relied upon to plan and follow through with harvesting activities like hunting trips • Increased risks associated with longer trips, some hunters have been forced to change or cancel plans which can be difficult to work around when time is restrained by employment commitments • Increasingly extreme and unusual weather and wind patterns may further contribute to this unpredictability	Tam et al. 2013
Reduced Water Levels	• Some community members have stated that when river water levels are too low, they are unable to travel upstream by watercraft to access good moose hunting areas • This has decreased the amount of moose meat they are able to harvest when water levels are low	Tam et al. 2013
Reduced Winter Road Seasonal Length	• Winter roads allow for more economical transport of heavy equipment, fuel, supplies, and groceries to remote communities • Reduced seasonal length and declining road quality has impacted communities financially because goods must otherwise be transported by air • Increased cost of goods resulting from decreased winter road viability has contributed to food and energy insecurities in many communities • Increased fuel costs or limited fuel availability has impacted people's ability to conduct harvesting activities when gasoline is required for snow machines, all-terrain vehicles, or motorized watercraft	Barrette and Charlebois 2018 Hori et al. 2018b Reid 2015 Golden et al. 2015 Tam et al. 2013

3.3. IMPACTS ON INDIGENOUS PEOPLE’S HEALTH

Climate change may affect the health of Indigenous peoples of Northern Ontario in a number of ways. Reduced consumption of traditional foods and diminished livelihoods, decreasing water quality, rising temperatures, increasing occurrences of droughts and flooding, and declining winter road viability all have the potential to affect the different aspects of people’s health: physical, emotional, mental, and spiritual. This section will review how climate change has affected and may continue to affect community members’ health throughout the century while considering important contexts of health issues presently facing many communities in Northern Ontario.

3.3.1. Decreased Harvest and Consumption of Traditional Foods

For Indigenous peoples of Canada, traditional foods can make up a substantial portion of food intake, and they are a key factor in maintaining a good balance in all aspects of health (CIER 2007, Guyot et al. 2006, Riedlinger 2001). Consumption of traditional foods by Indigenous peoples in Canada is significantly lower now than it was prior to European colonization, but they are still an essential component of Indigenous cultures (Prowse et al. 2009, Willows et al. 2019). Knowledge of these foods and the actions of harvesting and consuming them connect Indigenous peoples to their traditional territories, foster a sense of Indigenous identity, and promote good holistic health (Willows et al. 2019).

Among some Indigenous populations, the transition to a predominantly Western diet of store-bought processed foods has led to higher-than-average rates of nutrition-related chronic diseases such as obesity, insulin resistance, type 2 diabetes, and cardiovascular disease due to these foods generally being low in nutritional value but high in sugars, saturated fats, and sodium (Guyot et al. 2006, Willows et al. 2019). Additionally, the replacement of traditional foods with store-bought foods has led to a decrease in the physical activity required to procure traditional foods, further increasing the risk of metabolic health conditions (Willows et al. 2019). In remote Indigenous communities, rates of metabolic health problems are especially high due to extremely high food costs and limited availability of fresh, whole foods since they must be transported by air during most of the year. Processed foods tend to be lower in cost and have a much longer shelf life compared to fresh foods (Willows et al. 2019), often making them the only practical store-bought food options for people living in these communities.

Traditional foods provide essential nutrients such as protein, vitamin D, iron, and magnesium, that may not be found in store-bought foods in sufficient amounts to maintain good health (Willows et al. 2019). Wild food and berry plants also contain vital nutrients, including vitamins A and C, carbohydrates, and fibre, providing various health benefits. For example, fibre promotes smooth functioning of the digestive tract and to reduce the risk of colon cancer, hazel nuts contain heart-healthy monounsaturated fatty acids, and cranberries can treat and reduce recurrence of urinary tract infections. Volatile oils and tannins found in Labrador tea and wild mint tea also have beneficial effects on the digestive system when consumed in moderation (Marles et al. 2012:39). In addition to the physical and nutritional health benefits of traditional foods, the actions of procuring, preparing, and consuming them is integral to maintaining good mental, emotional, and spiritual well-being. For instance, berry picking the and collection of other food plants are important social activities for many, contributing to good emotional and spiritual health (CIER 2007; Marles et al. 2012:39). When traditional knowledge is passed down from one generation to the next through hunting, gathering, and food preparation activities, it provides a sense of cultural and spiritual identity and promotes good mental health (CIER 2007). Traditional foods are also simply more preferred for consumption taste-wise by many Indigenous community members (CIER 2007; Guyot et al. 2006).

Further reduced consumption of traditional foods due to changing environmental conditions and food species' abundance may exacerbate existing food and nutritional insecurities and physical health problems in Indigenous communities of Northern Ontario. Additionally, shifts in harvest practices, loss of traditional knowledge and culture, and increased consumption of less-preferred store-bought foods may affect the emotional and spiritual well-being of people. For instance, experiences of emotional health issues have been documented from Inuit hunters; these have occurred in response to an inability to hunt with changing ice conditions, reflecting a decreased ability to provide food for family and a loss of cultural identity and livelihood (Cunsolo et al. 2012, Cunsolo et al. 2013, and Pearce et al. 2010, cited in Ford et al. 2014).

3.3.2. Decreasing Water Quality and Availability

Fundamental to understanding the effects of changing water quality and availability is the context of water in Indigenous communities of Northern Ontario. This context includes the history of drinking water advisories in Ontario, the spiritual and cultural significance of water, and how water is used by Indigenous communities and individuals.

For Indigenous communities, water has a variety of uses beyond drinking and typical household use such cleaning and sanitation, cooking, and bathing. It is also important for recreation, fishing, hunting, and travelling by watercraft, all of which can be essential components of traditional livelihoods. Furthermore, water has significant spiritual and cultural importance. Water is regarded as a primal substance that is at the centre of all the interconnections of life by many Indigenous peoples (Blackstock 2002 cited in Sanderson et al. 2015). For Indigenous cultures in British Columbia, the link between water, spirituality, healing, and cleansing is inherent in cultural practices and stories passed down from generation to generation (Blackstock 2002 cited in Sanderson et al. 2015). Elders of the James Bay Cree Nation have described water as a reflection of the health of the earth and human beings, and others from the Haudenosaunee Iroquois Nation consider water to be a living entity (Lavalley 2006 cited in Assembly of First Nations 2008:13). Water is the source of life, and anything that affects the water will affect everything else in the ecosystem, including humans.

For many communities across Canada, and particularly in remote Northern Ontario, a long history of drinking water advisories has jeopardized the use and significance of water. Drinking water advisories are used as a preventative measure to protect public health and are issued when there is microbial and/or chemical contamination in a drinking water source (Health Canada 2009). There are three types of advisories: boil-water, do-not-consume, and do-not-use advisories. Boil-water advisories (BWAs) are issued when water can be brought to a boil (or disinfected with bleach) to render it safe for human consumption. Do not consume advisories are issued when a contaminant in the water cannot be removed by boiling. Finally, do not use advisories are issued when a contaminant in water cannot be removed by boiling and that may cause skin, eye, and/or nose irritation when exposed through any use (Health Canada 2009). In Ontario, the majority of drinking water advisories that have been issued are BWAs, and they have been mostly a result of equipment malfunction due to insufficient operator training (Galway 2016). A large number of these advisories are currently still in place and are considered long-term (lasting more than one year). The longest-running BWA has been in place since 1995, in Neskantaga First Nation of Northern Ontario (CBC 2015).

The current Prime Minster of Canada, Justin Trudeau, vowed to end BWAs on First Nations reserves within 5 years of becoming Prime Minster in an 88-page plan dedicating $1.8 billion to water system and wastewater system infrastructure over this timeframe (CBC 2015). As of December 1, 2020, 97 long-term drinking water advisories across Canada have been lifted. However, 59 advisories still remain in effect, and 43 of these advisories are in Ontario (Government of Canada 2020).

Drinking water advisories place significant burdens on affected communities. When a BWA is issued, water must be boiled to use for drinking, making ice, brushing teeth, food preparation, and infant formulas, which becomes incredibly time-consuming especially during long-term advisories. Purchasing bottled water is a further economic burden, particularly in remote communities where the cost of goods is extremely high. When bottled water may be unaffordable, people may resort to drinking untreated water, increasing their risk of illness. Finally, BWAs may put individuals under constant underlying anxiety about their drinking water quality (Galway 2016).

Lower water levels, rising air and water temperatures, and changes in spring runoff and heavy rainfall events predicted for Ontario may reduce drinking water availability, increase the risk of waterborne pathogen contamination in drinking water sources, and increase the occurrence of toxin-producing cyanobacterial algal blooms. For communities with already stressed or inadequate water treatment systems in Northern Ontario, these changes could further reduce clean water availability and put community members at increasing risk of becoming ill from waterborne pathogens or cyanobacterial toxins.

3.3.3. Increasing Frequency of Extreme Weather Events

Rising average temperatures and increasing occurrences of extreme weather events are expected to affect the health and safety of Indigenous community members. Extreme weather events such as heat waves and forest fires have been projected to increase in frequency and intensity in Northern Ontario, and the occurrence of other events such as droughts and floods may change as well. Possible consequences for human health and safety resulting from an increase in the frequency of these extreme weather events will be explored below.

To begin, heat waves can be dangerous to human health for several reasons: They can result in illnesses such as heat cramps, heat exhaustion, and heat stroke which can be life-threatening (Dotto et al. 2010:72, Fortune et al. 2013). The people most vulnerable to illness and death due to high temperatures are the elderly, the very young, and those with weakened immune systems. Also, relatively vulnerable are those who are pregnant, overweight, living in poverty, without air conditioning (Dotto et al. 2010:72) or workers in manual labour occupations or industries with substantial outdoor work (Fortune et al. 2013). The latter could include Indigenous people that spend a significant of time outdoors while practicing traditional activities to support their livelihood.

Increasing rates of illness and mortality during heat waves have already been documented among the occupationally active (aged 15-64) across Ontario (Fortune et al. 2013) and elderly (65+ years) in Southern Ontario (Smoyer et al. 2000). Increasing incidences of heat waves in Northern Ontario may have serious implications for many communities. For instance, many communities are not connected to an electricity grid and rely on diesel generators for their power supply. These communities may experience electricity blackouts and shortage of capacity during periods of high energy use (Dotto et al. 2010:68, McCarthy 2016). As temperatures warm, there may be an increasing need for air conditioning in northern communities, which may increase energy demand beyond what can be supplied and cause further blackouts, leaving people without much-needed cooling during heat waves and putting them at risk of heat-stress and death. Another reason is that infrastructure in northern communities is not built to accommodate for hot weather. For example, many buildings in Nunavut are designed to remain insulated from the cold and do not have windows that open (Akearok et al. 2019).

Many communities in Ontario and neighbouring provinces have reported observing changes in yearly temperatures; in general, temperatures have risen year-round, resulting in hotter summers and milder winters. For example, in Fort Albany, ON, community members have stated that winters have become warmer and shorter in duration overall (Tam et al. 2013). Further, they have observed that spring and summer temperatures seem to be higher than usual; the summers feel hotter and more humid, and the sun’s rays feel stronger (Tam et al. 2013). One participant even stated “we never used air conditioning before, but now it is a necessity” (Tam et al. 2013:447). Similarly, members of Black River First Nation, MB, have observed milder winters and warmer summers. It was mentioned that the increasing temperatures have been causing community members to get sick (CIER 2007).

Moreover, flooding events in Northern Ontario may become more frequent as the number heavy rainfall events increase and more snowfall and faster rates of snowmelt result in excessive spring runoff. Flooding can have many negative consequences for communities, including (cited in Thistlethwaite and Henstra 2017):

- Population displacement (Levine et al. 2007)
- Destruction of infrastructure (Kidd 2011)
- Business interruption (Ingirige and Wedawatta 2011)
- Threats to physical health and safety (Burton et al. 2016, Carroll et al. 2010)

- Mental (emotional) health-related illnesses such as post-traumatic stress disorder, depression, and anxiety (Lamond et al. 2015, Stanke et al. 2012).

One of the most prominent flooding events in Northern Ontario was the 1986 Winisk flood. On May 16, 1986, the community of Winisk was washed away as a result of a spring ice jam on the Winisk River. The jam caused flood waters and large ice chunks to reach as far as six kilometers inland and displaced almost every community structure into Hudson Bay. There were several injuries and two deaths associated with this flood. Due to the community's remote location, relief efforts were difficult and many residents were stranded in canoes for days while waiting for rescue. Winisk was abandoned and the community was rebuilt several kilometers up-river on higher ground and renamed Peawanuck, the location of Weenusk First Nation. Following this disaster, several recommendations were made to avoid similar situations in the future: better surveillance of river conditions, implementing early flood warning systems, improved emergency transportation infrastructure, and a pre-planned escape route. If the risk of major floods increases due to climate change, many Northern Ontario communities may have to take precautions such as these to mitigate such disasters.

Droughts are another extreme weather event that have negative impacts on human health. They may affect respiratory health, mental (emotional) health, illnesses resulting from exposure to toxins, food and water security, rates of injury, and infectious diseases including food-, water- and vector-borne diseases (Yusa et al. 2015). Droughts are a relatively rare occurrence in Northern Ontario, but in areas where drought is infrequent, there is generally lower adaptive capacity to deal with them, making their impacts more severe when they do occur (Nova Scotia Dept. of Agriculture and Fisheries 2001, cited in Yusa et al. 2015).

While precipitation in Northern Ontario has been projected to increase slightly throughout this century, it will likely not be enough to offset the moisture loss resulting from projected rising temperatures. Therefore, there is a possibility that droughts may become more frequent in Northern Ontario. Communities may be ill-prepared to handle drought conditions if they do occur, leading to negative health outcomes.

Finally, forest fires are a common disaster event in the boreal forest of Northern Ontario that can negatively affect the health of Indigenous community members. As average temperatures have risen in the region, forest fires have become more frequent, intense, and hazardous to human health and property (Dotto et al. 2010:41). When a forest fire occurs within close proximity of a community, the most vulnerable or sometimes all residents must be evacuated while the fire is being contained and extinguished. These evacuations can cause stress and anxiety due to concerns for safety and possible destruction of homes or other property from fire damage. Smoke conditions and reduced air quality can further put the respiratory health of residents at risk. With a projected increase in the frequency and severity of forest fires in Northern Ontario, it can be expected that Indigenous communities will be placed at further risk to their negative health effects.

3.3.4. Declining Duration and Viability of Winter Roads

The declining duration and viability of winter roads may impact various aspects of health of Indigenous peoples of remote Northern Ontario. The increasing costs of goods and supplies associated with late winter road openings and early closures may add to financial stress for families living in these communities. For example, the shorter winter road season in Fort Albany, ON has placed financial strain on many community members and raised concerns about personal safety while using the road (Tam et al. 2013). Winter roads also facilitate social connections between communities and reduce feelings of isolation (Barrette and Charlebois 2018, Hori et al. 2018b). Further reductions in winter road viability may compound declining emotional health associated with isolation and increase the risk of falling through ice while using the roads.

Table 6. Summary of climate change impacts on Indigenous community members' health and safety.

Changing Weather and Environmental Conditions	Impacts on Health and Safety	Source(s)
Reduced Consumption of Traditional Foods	• Harvesting and consuming traditional foods contributes to good overall health and well-being compared to most available market foods • Reduced availability of these foods due to climate change may exacerbate existing food and nutritional insecurities and physical health maladies • Decreased consumption of traditional foods and diminished livelihoods may contribute to emotional, mental, and spiritual health declines	Willows et al. 2019 Guyot et al. 2006 Marles et al. 2012 CIER 2007 Ford et al. 2014
Reduced Water Levels and Quality	• Many Northern Ontario communities are already facing drinking water quality issues in the form of Boil Water Advisories • Lower water levels, rising air and water temperatures, and changes in spring runoff and heavy rainfall events may further reduce clean drinking water availability, increase the risk of waterborne pathogen contamination, and increase the occurrence of cyanobacterial algal blooms, both of which can cause illness and death	Health Canada 2009 Galway 2016 Schijiven et al. 2013 Harper et al. 2011 Favot et al. 2019 Winter et al. 2011
Increasing Temperature and Occurrences of Heat Waves	• Heat waves can result in dehydration, heat cramps, heat exhaustion, and heat stroke which can be harmful or deadly to human health • Indigenous community members may be especially vulnerable to increasing incidences of heat waves due to existing health conditions, poverty, energy insecurities, inadequate infrastructure, and participation in outdoor activities • Many Indigenous observations of increasing temperatures with impacts on health and increasing requirements for air conditioning	Dotto et al. 2010 Fortune et al. 2013 McCarthy 2016 Akearok et al. 2019 Tam et al. 2013 CIER 2007
Possible Increase in Flooding and/or Drought Frequency	• Flooding events threaten physical health and safety and can result in mental health-related illnesses such as post-traumatic stress disorder, depression, and anxiety	Thistlethwaite and Henstra 2017
Increasing Forest Fire Frequency and Intensity	• Forest fires can affect respiratory health from smoke conditions and result in mental health issues associated with evacuations, stress, and destruction of homes	Dotto et al. 2010
Reduced Winter Road Viability	• Added financial stress through increased cost of goods • Increased social isolation resulting in diminished mental health • Increased risk of falling through ice	Tam et al. 2013 Barrette and Charlebois 2018 Hori et al. 2018b

3.4. LITERATURE REVIEW CONCLUSION

There are only two studies found that have explored the general impacts of climate change facing individual Northern Ontario communities (see Lemelin et al. 2010, Tam et al. 2013). One study has investigated the impacts of changing ice conditions on numerous communities (see Golden et al. 2015). This low number of studies containing direct Indigenous observations of climate change within the region has limited the perspectives and experiences that could be reviewed here. Additional perspectives were gained from communities in Manitoba (see CIER 2006, CIER 2007) to help compensate for this limitation, as it was expected that these communities would be experiencing similar impacts of climate change to those located in Ontario. From these Indigenous perspectives, it was demonstrated that some of the most significant impacts facing communities are changing ice conditions and declining winter road viability, declines in traditional food species' abundance or changes in their distribution, and and increasingly unpredictable and intense weather.

There is plenty of literature addressing possible outcomes of climate change in Ontario through modelled projections regarding changes in ice regimes, moose and freshwater fish abundance, precipitation patterns, temperature and heat wave events, and forest fires. However, few of these studies have included contexts of how these outcomes may affect Indigenous peoples.

Since discussions of potential climate change impacts on Indigenous communities are minimal in these projections, I offer some of my own speculations of potential future impacts of climate change derived from the literature that does exist. Based on Indigenous observations and modelled projections, it seems likely that Indigenous community members will see declines in the abundance or changes in the distribution of important traditional foods like moose and fish, decreasing the amount they will be able to harvest over time. This may result in declines in all aspects of health among impacted individuals. Furthermore, projected declines in winter ice cover duration ice thickness may significantly diminish people's ability to participate in traditional activities like ice fishing and trapping, affecting livelihoods through decreases in harvest and income. Likewise, as weather becomes increasingly unpredictable and intense throughout the century, it may become more difficult to plan and take part in other traditional activities such as hunting and open-water fishing. Finally, declining winter road viability will substantially impact livelihoods and health in remote communities in Northern Ontario by diminishing people's ability to reap the economic benefits of these roads, further limiting the availability of healthy groceries and fuel, and creating increased feelings of isolation.

There are several possibilities for future research that could be conducted to greatly benefit Indigenous communities in Northern Ontario. These include: studies investigating the effects of climate change at the community-level for more Northern Ontario communities; exploring how climate change may impact emotional, mental, spiritual, and physical health, as these are regarded by some Indigenous groups as being equally important to one's well-being; and projecting changes in the abundance of a larger number of traditional foods such as waterfowl, game birds, and food plants.

4. STUDY RESULTS

Four major themes of participant observations of climate change emerged from the thematic analysis of interview data in NVivo. The first theme is the timing of seasonal events, which includes subthemes of ice formation and ice breakup, the first and last snowfall, snowmelt, spring fish spawning, seasonal goose migration, moose rut, and the ripening of blueberries. The second theme is weather and weather-related environmental conditions, which includes subthemes of temperature, rain, snow, water qualities, spring runoff, unusual weather events, and ice thickness and quality. The third theme is traditional food species, which includes subthemes of their abundance and distribution, health and vigour, and how changes in these have affected participants' and other community members' harvest levels of these foods. The fourth and final theme is community members' health and includes subthemes of sunburns, skin cancer, Lyme disease, and other general health concerns.

There was a wide variation in the number of traditional activities that each participant took part in. Participants' observations of changes in the environment or traditional food species may have been significantly influenced by the types of activities they take part in. For example, participants who regularly go ice fishing or travel over ice to traplines each winter are assumed to be more likely to have observed trends in ice conditions throughout their lifetime. To provide valuable context, Table 7 lists the number of participants that have regularly taken part in certain harvesting activities for most of their lives (i.e., an activity that they take part in yearly or seasonally).

Table 7. Number of participants that have regularly taken part in each type of traditional activity throughout their lifetimes.

Activity	Type	Number of Participants
Fishing	Open-water fishing	13
	Ice fishing	3
Hunting	Moose	6
	Waterfowl	3
	Game birds	6
	Small mammals	4
Trapping	Any	4
Gathering	Blueberries	10
	Other berries	4

4.1. TIMING OF SEASONAL EVENTS

Most participants reported a change in the timing of some physical and biological seasonal events. These included the timing of fall ice freeze-up and spring melt on lakes and rivers, the first and last snowfall or spring snowmelt, spring fish spawn, seasonal goose migration, moose rut, and the ripening of berries. These events were reported to be occurring either earlier or later than normal, or in some cases becoming more erratic from one year to the next.

4.1.1. Ice Formation and Ice Break-up

Five participants discussed a change in the timing of ice formation in the fall and ice break-up in the spring. The subject of changes in ice thickness and quality is reported in its own section below. Some participants noted the occurrence of either (or both) a later freeze-up in the fall and an earlier melt in the spring, while others noted observing a later spring melt only (Figure 4).

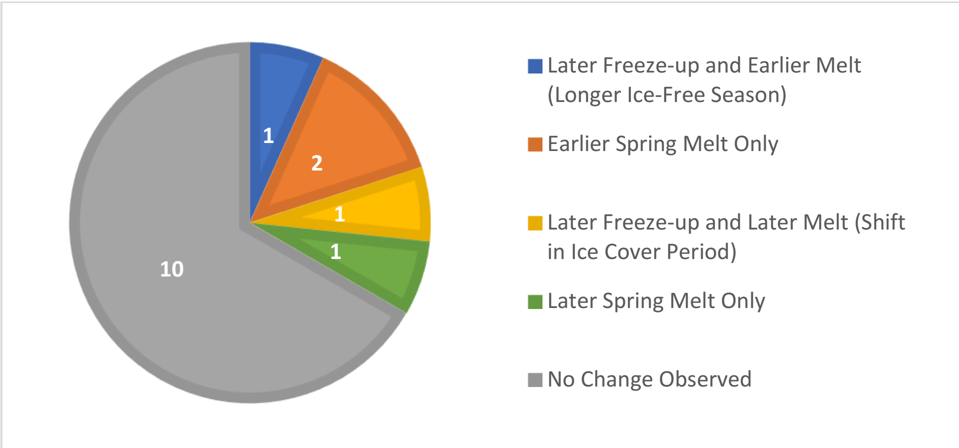

Figure 4. Observations of changes in the timing of ice freeze-up and ice melt.

Participant #1 stated that ice freeze-up is occurring later in the year, sometimes by up to a month or a month and a half from normal. He also said the spring ice break-up has been occurring much earlier than normal. Overall, the lakes and rivers are frozen for a shorter time in the winter: "It gets cold, and the ice might skim over, but you're not getting really cold weather to make the ice thick. Until later on, and then it really gets cold, it's just later. You know, but that's usually in January. So you get January and February and then all of the sudden we're - we're getting into the-- warm weather's starting to get springtime again" (participant #1). Regarding a particular lake this participant normally crosses in the winter for trapping, he stated that in previous years it used to be frozen enough to walk over by the second or third week of October, and in more recent years it doesn't freeze up until the second week of December. Likewise, participants #4 and 14 reported that the ice has been breaking up earlier in the springtime. Participant #4 specifically noted that as a child he remembers the ice would start coming off the lakes right around his birthday, but now it happens about two weeks earlier than that. Participant #14 also explained how the earlier spring ice melt has reduced the time he is able to go ice fishing on rivers, "…it would be frozen solid until the 3rd week of April. I think that was some of the best ice fishing - that's when I'd used to go - the 2nd week of April, go ice fishing. I think some places you don't want to be out there now".

Conversely, other participants have been noticing a later spring ice break-up in recent years. For example, participant #3 had noticed this during his yearly steelhead trout fishing in the spring. He also heard from other steelhead fishermen in the area making the same observation: "Years ago, the steelhead fishermen would be out two weeks prior than what we would go out now. You hear it from all the older gentlemen that fly-fish out on these rivers in town here, and they're saying that it's later, the ice comes out two weeks later than it used to" (participant #3). Similarly, participant #10 observed ice staying on the lakes and rivers for longer, but noted it also takes longer to freeze up in the Fall, possibly suggesting an overall shift in the ice-cover season but no significant change in the total length of time the ice is out.

4.1.2. First Snowfall and Snow Melt

Three participants had noticed a change in the timing of the first snowfall and snow melt in the spring. Participants #1, 8, and 9 believed that the first snowfall of the year, on average, is happening later than usual. Participant #1 went into further depth on the subject, stating that when he was a child the first snowfall would usually occur around the end of October (at Halloween), but this snow wouldn't stay on the ground, it was more of a warning that winter is on its way. Once it would get colder the snow would begin to stay. Regarding the first snowfall in more recent years, he said "now, it can come anytime" (participant #1), suggesting that now you really can't be sure when the snow might come, and the timing is more erratic from year to year. In the springtime, he stated that most of the snow would be gone by April: "I mean, there would still be snow in the bush and in the swamps and stuff like that, you wouldn't - it would never, ever snow past April" (participant #1). Nowadays, he said, you can still be getting snowfall in June or a big heavy snow in October that stays, and that everything is "all mixed up".

4.1.3. Fish Spawning

Ten participants reported observing a deviation in the time that pickerel normally spawn in the spring, which was often associated with the observed timing of ice break-up and water temperature. Out of the participants who have observed a change, some stated that the fish are spawning earlier than normal, others thought that spawning is occurring later, and the rest believed that it now varies more from year-to-year and it could occur either earlier or later than normal (Figure 5). The differing observations may simply be a result of participants observing fish spawn at different lakes and river systems, or the timing varies from year to year making it difficult to pinpoint an earlier or later spawn overall. Most referred to a particular large lake within the community's traditional territory that is popular among Indigenous and non-Indigenous fishers, and others referred to smaller lakes they visit regularly in the area. There may have been inherent variation in the spawn times of fish between different lakes, and the lakes could be experiencing different effects of climate change and other environmental factors due to geographical differences. One participant believed that lake trout have been spawning later in the fall and stated that they used to spawn in late September, but more recently they have been spawning in mid October.

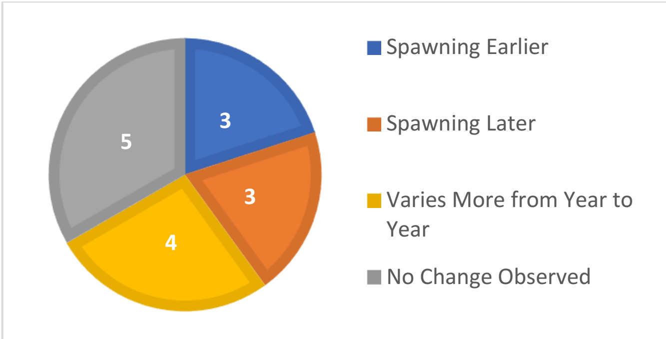

Figure 5. Observations of changes in the timing of spring fish spawn.

Three participants believed that the fish spawn is happening earlier than normal. Participant #1 and 14 both stated that fish spawn would always occur within a three-day period, from May 12th to the 15th, "we used to be able to set our clocks by it for fishing" (participant #1). These three participants believed that the fish have been spawning about one to three weeks earlier than normal on average, or in an extreme case, participant #1 had observed the fish spawning as early as April 1st immediately after the ice came off the lake. For participant #14, the earlier and somewhat unpredictable timing of fish spawning has interfered with his spring fishing trips: "every year I'd go out, to catch fish, the last few years I'm too late. I've missed it. The time's changed".

On the other hand, another three participants thought that spring fish spawn seemed to be occurring later than usual. Participants #8 and 9, in their group interview, both agreed that the changes in the seasons have affected the timing of fish spawn. They stated that fish would spawn in April in the area where they were as children, and in more recent years the spawn is happening later in the spring. Participant #3 discussed how the opening weekend for pickerel fishing season set by Ontario's Ministry of Natural Resources and Forestry is based on historical spawn times, and that normally by opening weekend the fish would have already finished spawning in the rivers and returned to the lakes. He stated that "the ice comes out late, so the fish enter the river late, and by the time they make it to their spawning grounds, opening season's already happened, and you're getting hundreds of fishermen along this river pulling up these monster fish and taking them out, before, like pre-spawn, and I think that's really bad for our lake" (participant #3). Due to the later spawn time no longer corresponding with historical data and opening season, concerns were raised over the sustainability of pickerel in this popular fishing lake. Participant #3 thought that opening weekend should change to reflect the later spawn times and to help conserve the pickerel population.

The remaining participants associated the timing of fish spawn to seasonal conditions like air and water temperature and timing of ice melt on lakes, "the fish will spawn according to the weather. The seasonal conditions" (participant #10). These participants said that since the weather and seasonal conditions vary more from year to year, that the fish spawn follows suit and also varies in its timing. For example, when asked if a change in the length of seasons has affected the timing of fish spawn, participant #5 responded: "Oh, I believe so. Yeah. It changes how quickly the ice comes off the lakes, which I think changes the spawning season. By how much? I'm not too sure". Likewise, participant #4 said that the timing of fish spawn can vary from year to year because it depends on the temperature of the water, and that a late ice break-up would result in a late spawn. This participant also brought up the date of opening weekend for fishing, "they always make opening season the first Saturday after the 15th, and that should really vary according to the seasons. It's like, say, if it's going to be a late breakup, they should hold back the season opening for a week, but they don't" (participant #4). He further brought up the important point that it would be difficult to establish this because so many people plan their vacations for opening weekend well in advance, such as booking spots at resorts and taking time off work, which are not easily changeable if the opening date is pushed back, "that's not going to happen. You can't control people; when they say it's open, it's open and they're going fishing" (participant #4). Participant #2 mentioned that due to the increasing variability in the timing of fish spawning, you can't really count on an exact date anymore and this has affected when it is a "good" time to catch fish.

4.1.4. Moose Rutting Season

Questions regarding changes in moose rutting were not originally a part of the questionnaire guide, but the subject was brought up by a couple of early participants, so it was added to the questionnaire for the remaining interviews. In the end only the two early participants, #3 and 5, reported observing a significant enough change in the timing of moose rut to warrant a discussion. However, another participant wasn't sure if he had noticed a change in the timing of moose rut, he thought it would definitely be a temperature-dependent event and thus could be affected by climate change.

Participant #3 explained that historically, the peak of rut for moose would be September 23rd to the 27th every year. The past year, however, he felt that the peak of rut was closer to late August and early September, which is quite earlier than normal. Just like participant #4, he also related the timing of moose rut to the seasonal change in temperature and described that varied or unusual fall temperatures could be changing affecting when it occurs. For the year when he noticed the rut occurred very early, he said that it was an unusually cold week which may have triggered the early response from moose. The following three or four weeks were quite warm, and then when the temperature dipped again, he said it was like there was a second rut that happened in about mid-October. The unusual fluctuations in temperature triggering these responses were somewhat concerning to him, as he stated that an early rut event would cause moose calves to be born too early in the following spring and put them at risk: "if there's still an abundance of snow when the calves are born in the spring, they're not going to be able to move" (participant #3). Participant #5 mentioned he was not personally an avid hunter, but many of his friends are. He has heard them complaining about the moose rut happening earlier than normal due to the changing seasons. They would say, for example, that if the rut starts early, at the very beginning of hunting season, all the hunters will be able to get a bull moose right away before they have had a good chance to mate, so the sustainability of the moose population was worrying to them.

4.1.5. Goose Migration

Two participants mentioned observing variations in the timing of Canada geese migration. One noticed that some years the geese seem to be migrating later than normal on their return from the south in the spring, which has affected some community members' hunting trips. For example, normally hunters would go out on goose harvesting trips at a certain time in the spring, and in recent years when they go the geese have not arrived yet, requiring them to wait longer for them to return, "Like people I work with, they're hunters, right? They go out way up to, way, way up there, umm, Fort Severn. They go up there and by the time they get over there, which is normal for them, there's supposed to be geese, and they said they didn't see any. So, they have to go back again maybe a month later, and that's when they're there" (participant #11). The other participant had observed that geese seem to be migrating earlier than usual in the fall.

4.1.6. Berry Ripening

Yearly berry-picking was a common activity partaken by most participants. Blueberries are the main type people would harvest in the summertime, with some also going for wild raspberries and wild strawberries on occasion. Six participants reported observing a change in the timing of berry ripening in recent years, and the majority stated that they are ripening earlier than normal, while the rest had observed them ripening later (Figure 6).

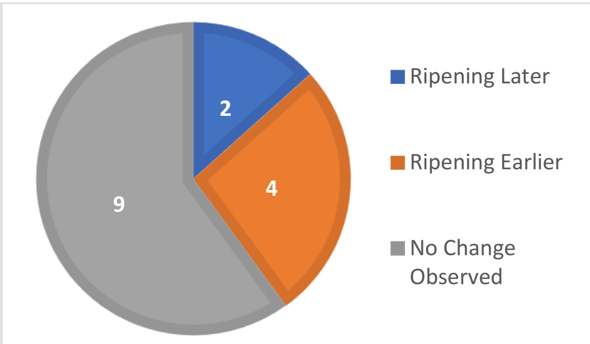

Figure 6. Observations of changes in the timing of berry ripening.

Participant #11 and 15 described seeing berries ripen about two to three weeks later than they normally would. For example, participant #11 remembered picking berries from about late July until the middle of August in the past, and more recently has been able to harvest up until the first week of September. Participants #1, 3, 8, and 9 agreed that berries seem to be ripening a lot earlier in the summer. In addition, they all stated that the berries are drying up and dropping from the plants much more quickly after ripening, which in other words means there has been a shorter window of opportunity to harvest berries. These participants attributed the early ripening and drying up of berries mainly to insufficient amounts of rain, as well as hotter summer temperatures. For instance, participant #1 talked about how he and his family would pick berries over a few weeks in the middle of August, and now he is noticing the berries ripening as early as the beginning of July. He further explained that the berries don’t stay on the plants as long either, “they’re not out there in the sun very long, because they dehydrate, and dry right up”, “they’re totally dehydrated and burnt, because of the sun, and there’s no moisture” (participant #1). Participants #8 and 9 similarly stated that in recent years the berries have been ripening around the end of July and they start dropping from the plants by the middle of August, which a couple weeks earlier than normal for them. They thought that this may be due to a lack of water, in the forms of both rain and snow (spring runoff). Moreover, participant #3 described how he and his family had missed their berry harvest one recent year because when they went out, at a time they would normally have nothing but success, most of the berries had already dropped from the plants. He said “everywhere we went they were like burned out and you could see like shriveled up berries underneath the plants. And it’s like, and we were like ‘we missed berry picking season’ like... I mean that, that’s a huge effect because, as like traditionally Indigenous people were always on time for harvests, and with these timeframes fluctuating so much now, how can you judge to hit that harvest on time?”, and “like now we missed out on a year’s worth of berries because they were gone early. And I think that has to do with warmer summers. Like the different rays, what’s affecting my skin is affecting those blueberries” (participant #3).

Other participants that did not observe an overall average shift in the timing of berry ripening still associated the timing with weather conditions. For example, participant #2 responded that the time berries ripen can be different from year to year depending on what the weather has been like. Likewise, participant #7 explained how berry ripening depends on the amount of rain the plants receive and that if it doesn’t rain enough the berries will not ripen properly. This scenario results in berries that are dry and shriveled up that look almost “burnt,” as she described.

4.2. WEATHER AND WEATHER-RELATED ENVIRONMENTAL CONDITIONS

4.2.1. Temperature

Most participants (n=10) noted a change in the average temperature throughout recent years compared to the past, and these observations were generally related to summer and winter temperatures. Almost all (n=9) who reported an observation stated that summers have been warmer in recent years, and out of these eight, two said winters have also been warmer, four said winters have been colder, and two said winter temperatures haven’t changed significantly. One participant reported warmer winters but no change in summer temperatures (Figure 7). Furthermore, several participants explained that temperatures seem to fluctuate from day to day a lot more than they used to. For example, participant #5 stated that in the past, temperatures would gradually change with the seasons but now there can be a huge difference in temperature from one day to the next. Similarly, participant #15 said during the winters for about the last ten years the days will alternate between cold and warm temperatures and these fluctuations do not allow ice to stay frozen solid. Participant #5 related the fluctuating temperatures to a change in prevailing winds over the years. “The winds are changing. It seems like they'll come from the north a lot and then they'll come from the south. And before you would just get mostly northern winds, northern winds and then southern would come. But now it seems to drop back and forth a lot quicker. I don't know if that's from climate change or what. And those will bring on the different temperatures and like it'll make those temperature swings significant” (participant #5). Additionally, participant #5 brought up that the warming temperatures would likely affect fire seasons in the region, and that the fire season may start to happen earlier than normal.

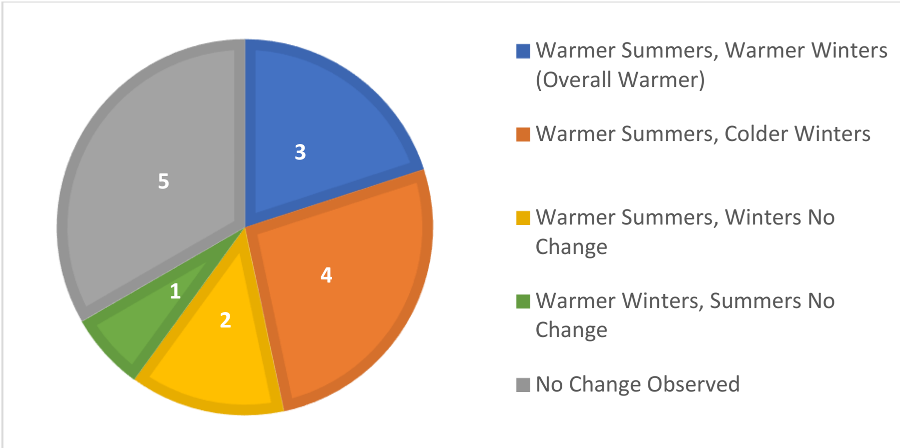

Figure 7. Observations of changes in seasonal temperatures.

4.2.2. Rain

There was a fairly wide variance in observations of changes in rain among interviewees, but no single consistent observation from a majority (Figure 8). Some noted an overall difference in the amount of rainfall that occurs, both an increase and a decrease. Others had observed changes in the amount of rain that falls during a single rain event and the number of rain events, but not necessarily a difference in the total amount of rain received over a season. For example, participant #2 felt that the area was receiving more rain on average, while participant #12 observed that overall, it seems to be drier now than it used to be, a factor she related to an increase in the number of forest fires in the region. Participants #8 and 9 described that while the amount of rain received on average is probably the same as normal, it seems that periods of wet or dry are becoming more extreme, i.e., when it rains, it rains a lot, but then it will be a long time before it rains again and everything will get really dry in between, rather than there being smaller but more frequent rains. Participant #1 described a similar observation, when he noted that the rain seemed softer and more gentle when he was young, and now it seems to rain a lot harder than it used to: “You wouldn't see this violent rain blowing sideways and all different directions. Now when it rains, it's really changed, compared to what it used to be" (participant #1). In contrast, participant #10 had observed the opposite, and stated that "there is no more real more, heavy duty rain that we used to have. We have rain alright, but the rain is more like drizzle, not like a downpour that we used to have" (participant #10).

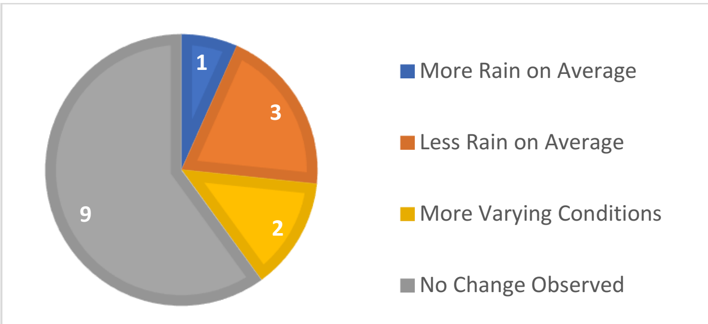

Figure 8. Observations of changes in rainfall amounts.

4.2.3. <u>Snow</u>

The majority of participants (n=11) observed a change in the amount of snow that falls in the winters throughout their lifetimes. Most (n=9) reported that there has been a decrease in the amount of snow the area receives, while the remaining two had observed more snow compared to the past (Figure 9). There was some discussion of how snow depths affect ice thickness and the amount of slush on lakes and rivers as well; it will be included in the Ice Thickness and Quality section below.

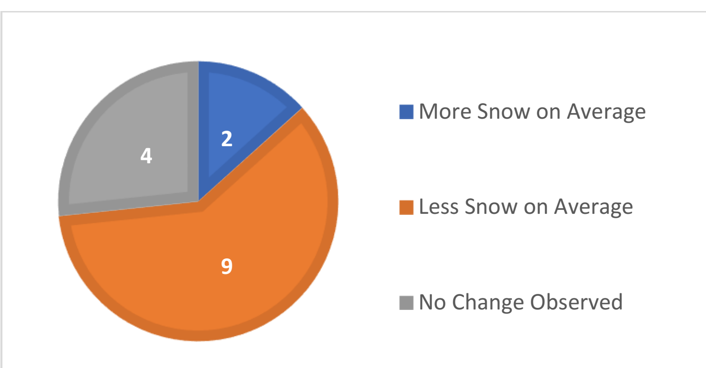

Figure 9. Observations of changes in snowfall amounts.

Firstly, those who had observed a decrease in snow mostly referred to remembering larger snowbanks or deeper snow cover on top of the ice on lakes while ice fishing and trapping when they were younger. Almost all these participants discussed how snow depths might be affecting wildlife, particularly large mammals like deer and moose. They explained how that when the snow is moderately deep, it gives moose an advantage against predators like wolves because the moose can easily run through the deep snow with their long legs, while the wolves can't. Then when there is little snow, the advantage is reversed and it goes to the wolves, who can now more easily chase and catch a moose, "when there's less snow, the moose are more vulnerable. When there's high snow the moose are not vulnerable. 'Cause the wolves can run when there's no snow, but if it's deeper, the moose can run" (participant #12).

Secondly, of the two participants that had observed an increase in the amount of snow, one described how too much snow can also be bad for moose. He explained that when the snow is too deep, "[the moose] are exerting too much energy, and they're running themselves thin" (participant #3). Similarly, participant #2 thought that unusually deep snow may be contributing to the death of a large number of deer in his area: "At my buddy's property out there he had a really high concentration of deer there, like he was getting all the big bucks, lots of does, and then I guess about 4 years ago that really heavy snow we had and the cold killed almost all of them off, there was hardly any deer that's on his property now. I think the ones […] on my trapline, most of them are gone too" (participant #2).

4.2.4. Water Qualities and Spring Runoff

Several changes in water qualities were reported among nine participants. These included observations of an increase in algae growth, generally lower water levels in lakes and rivers compared to the past, small water bodies like creeks drying up completely, and warmer water temperatures (Figure 10). Changes in spring runoff were also brought up by eight participants, regarding how the amount of spring runoff has affected spring water levels, occurrences of flooding, and water availability for ecosystems during the growing season.

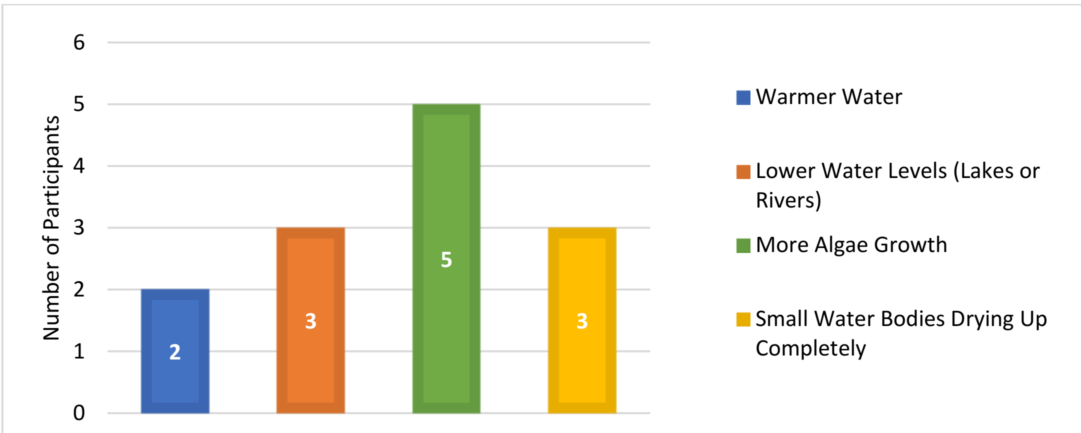

Figure 10. Observations of changes in water qualities; responses from nine participants with more than one response per participant possible

Almost all of the participants that had seen an increase in algae in water bodies associated the excess growth with lower water levels and water becoming stagnant, as well as increased water temperatures. For example, from participant #5: “it's like when the water gets really stagnant and it's been hot for days, weeks, and then you get that algae build up on the lakes, and when I was younger, I don't remember noticing that”; and from participant #1: “because the water’s lower, it doesn’t move as much. I would imagine that any water, that’s sitting and not moving, that would get stagnant, [and get] an algae bloom growing in it.” Additionally, some had noticed that lakes with more algae growth began to get a fishy smell and taste: “I know there is algae in the water because you can taste it in the springtime, when the snow is melted off the ice, it gets really fishy tasting. You have to put it through a real good filter like a Brita filter or a Zero filter to get the fishy taste out of it” (participant #1). This was unusual, as he had been able to drink the water from the lake his entire life without needing to treat or filter it. Participant #5 also mentioned that where he grew up there were a few small lakes he would go swimming in, he said, “and now when I go to them it's like, man that smells fishy. You don't even want to really go in there.” He also stated that he hears about swimmer’s itch becoming more common now, which he thought may be due to the increasing water temperatures and algae growth.

The few that had observed lowering water levels thought that the phenomenon had to do with climate change. For example, participant #5 stated, “I think the water levels are dropping slightly. Probably everywhere, due to climate change, which you can see in our rivers.” Participant #10 had also noticed that at a dock on the lake at a family member’s camp would be underwater almost every spring, but for the past ten years the dock has been sitting about five feet above the water. Participant #1 had similarly mentioned that the lake he gets his water from has been extremely low in the summertime. This caused him a lot of concern because it is a spring-fed lake, and the thought there may be something wrong with the entire water system in the area. Related to lowering water levels, some participants had noticed certain small water bodies including creeks and ponds drying up completely. Participant #15 thought that this was a result of less snowfall in the area. Regarding increasing water temperatures, little was discussed beyond how the higher temperatures seem to be affecting algae growth. However, participant #1 did mention that he thinks warmer water in lakes and rivers would affect fish populations and their food sources over time.

Eight participants had observed a change in the overland water runoff that occurs when snow begins to melt in the spring. Four had observed less runoff in recent years, one had observed more, and three said that there has been more variation in runoff from year to year (i.e., sometimes more than normal, sometimes less; Figure 11). Participants provided a number of different explanations for these changes, mostly related to temperatures and amounts of snowfall received over the winter. For example, when participant #14 was discussing how river water levels no longer get high like they used to, he suggested that this may be due to the reduced amount of snowfall in the area. He further explained that the increasing number of warm days in the winter may be causing snow to melt over a longer period of time, reducing the amount of peak spring runoff and water flows. Similarly, participant #10 explained how the river next to his childhood home used to come up to about five feet from their door in the springtime, but the water no longer gets that high. He stated that the water levels decreasing may be due to the area receiving less snowfall as a result of climate change. Moreover, participants #1 and 11 believed that the reduced spring runoff has been partially due to higher temperatures causing snow to evaporate directly into the atmosphere rather than melt into the ground or as runoff. A few participants discussed that in recent years the water levels in the spring will only rise slightly and then they will go down very quickly again as summer arrives, "[the water] goes into the lakes - a little bit of highwater in the springtime. And whether through evaporation or running down the rivers, boom it's gone. and if you get into summer, your bush is dry, because it's all run off, and there's no rain no water in the lakes, and the sun gets so hot it just keeps evaporating the water out of the lakes. The water goes down. You notice that - look at some of the rocks around some of the shores and see where it's stained on the rocks where the water table usually is" (participant #1). The reduced spring run off and increased evaporation rates had raised concerns about reduced water availability for the growing season and an increased risk of forest fires. One participant even claimed that the changes in runoff and precipitation have caused some rivers to change routes through soil erosion.

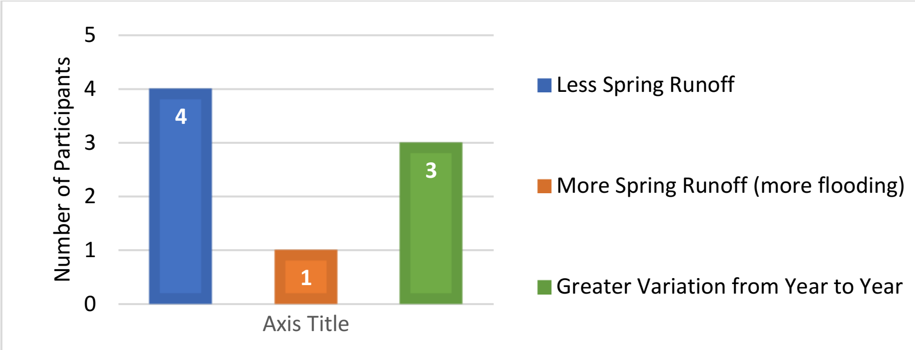

Figure 11. Observations of spring runoff

On the other hand, some other participants had observed either more spring runoff and flooding occurring or simply more variation in runoff from year-to-year. Participant #6 stated that when she was young there was hardly ever any flooding but has been observing an increase in flooding events, especially during spring runoff due to increasing occurrences of ice jams. Participant #5 described seeing more variation in runoff and flooding in the past few years. For example, he stated that “this year’s […] spring runoff was actually really good. Runoff was good for homes and communities because it was cool at night. Warm during the day, but not too warm. And it didn't cause any flooding. But the last previous two years to this year, it was super fast, and it caused lots of flooding.”

4.2.5. Unusual and Extreme Weather Events

Twelve participants discussed changes in unusual and extreme weather events that have been occurring in recent years. There was a wide variation in responses from interviewees, and most discussed more than one observation (Figure 12). These included observations of stronger and more frequent winds (n=5), unusual occurrences of freezing rain and sleet (n=3), overall stronger and more intense storms (n=8), storms approaching more quickly (n=2), and more sudden variation in weather extremes from day to day (n=2). In addition, a few participants made general remarks that the weather has just overall become more unusual in recent years, such as events sometimes occurring in the “wrong” season (n=3).

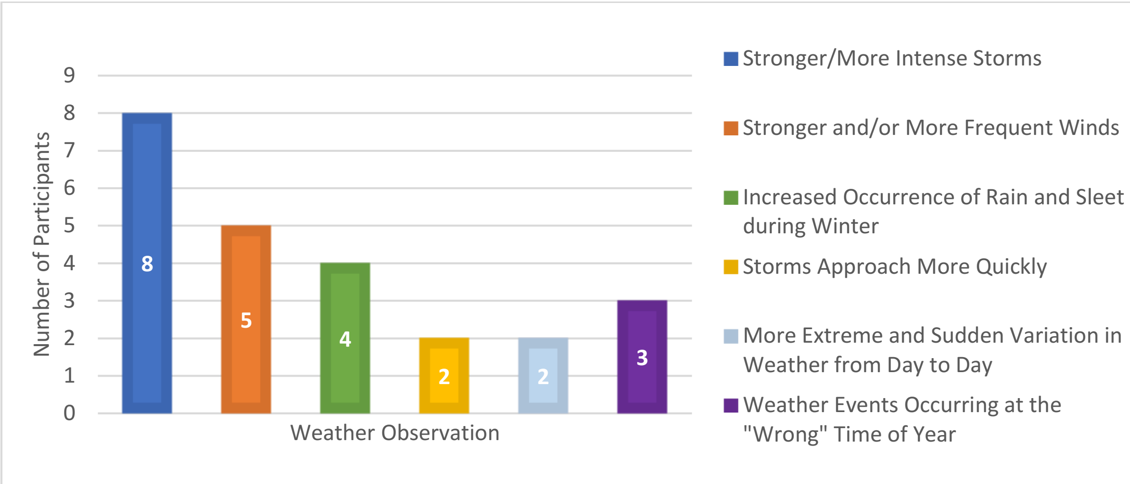

Figure 12. Observations of changes in weather; responses from twelve participants with more than one response per participant possible.

Regarding winds, one participant mentioned seeing more cases of extremely high winds in recent years than he has ever seen before: “I see places that are completely blown down, like a sheer wind went through it. Along that [road name], I’m sure a tornado went through there, like all the trees are busted about 6-foot-high all the way down, like huge trees all over the road” (participant #2). Another participant similarly described seeing unusually strong winds, almost like tornados, that were capable of flipping transport trucks over and knocking down all the trees over a large area, something she never saw when she was younger (participant #15). Moreover, participant #1 brought up that the stronger winds in the last few years have started creating waterspouts on lakes, also something he never saw when he was young: “The air sucks the water right up from the lake. And it comes down. I’ve seen two on [lake name] in my lifetime, and one -- I think it was last summer. You’ll be just sitting there on a nice calm day, and all of a sudden out of the calmness you’ll just notice the water starting to suck up and where's the wind and everything coming from? It's really spooky."

One participant additionally described how the changing winds have affected his fishing while on the water: "high winds on [lake name] have put me on the islands more than I want to be" and "I would've swamped the boat if I had stayed out, so I had to pull off onto an island to wait it out. I know I haven't spent many, many years fishing on [lake name] but in the years I have, there was a lot more calmer days in the first few years... and now it's like it was hard to find a non-windy day to go." He further explained, "I'll go out up to 25 km/hr before I start getting scared, but this year there was lots of 40, 50, 55 km/hr winds" (participant #3).

Several participants had reported an increase in unusual freezing rain and sleet, which some said had affected wildlife and interfered with their travel on the land. For example, one participant explained that in the past when the first snowfalls would occur, it would be cold enough that there would be solid snowflakes, but with the warming climate in recent years, it is more like "half snow, half rain, when it comes" and then it sticks to tree branches and freezes solid (participant #1). He further described the most recent freezing rain event that occurred in late October of 2019, where trees became so heavy with frozen sleet that many broke from the weight and a lot of bush was pushed down as well. When travelling on a trail afterwards, he stated that the smaller bush and branches were pushed down and intertwined so much it was "like trying to get through a jungle," and "you couldn't even walk where you would normally" (participant #1). Participant #3 similarly described observing more of what he calls "slush storms," when a freezing rain occurs and it freezes and builds up on tree branches, causing them to snap under the excess weight.

Participant #3 further pointed out his concerns about the effect ice build up from freezing rain and sleet would have on the environment and wildlife. Other participants mentioned the effects on wildlife as well, with one stating that ice build up on tree branches would likely make it more difficult for animals to access food sources like the buds on tree branches, and another explaining that freezing rain forms an ice crust on top of snow which makes it difficult for animals to dig to get at food sources under the snow, or it can cut up the legs of animals like moose, causing pain and a risk of infection. All participants who had observed an increase in these freezing rain or sleet events that cover everything in a layer of ice remarked that these were extremely rare or non-existent when they were young.

There was a strong consensus among participants that all storms in general (rainstorms, thunderstorms, windstorms, ice storms, and snowstorms) are stronger or more intense now than they used to be. Some further described that storms also seem to approach much more suddenly than normal, and that the weather can vary between extremes from day to day, rather than gradually changing.

A few specific remarks were made regarding storms: for example, one participant explained how his job sometimes involves weather-related calls for repairs, and recently has noticed that he and his team have been receiving many more calls for weather-related incidents involving ice storms, windstorms, and lightning in recent years. He further stated that lightning storms specifically seem to be much more powerful and do more damage than they used to (participant #5). Another participant described storms as becoming more violent, as he stated “it just seems that the earth is… the weather is more violent now. It’s almost like it’s angry” (participant #1). Both of these participants also described storms as approaching more suddenly or unpredictably, and these storms having affected their fishing trips while on the water. As participant #1 explained, “well, [the thunderstorms], they’re quicker. They definitely come up quicker than they did before. Before, you used to say, ‘you know what, I’m sitting here across the lake in my boat, and I see the storm brewing over there, I got an hour to get home. So, I'll take a few more casts, and away I'll go.' Now? You see that, you better get the hell off the lake quick." Participant #5 similarly stated that "these storms just come out of nowhere, and you got to be prepared to head for cover" while on the lake.

Participants #5 and 10 further described seeing a large variation in weather extremes from one day to the next, whereas changes in weather used to be more gradual: "I mean one day, it's nice, super duper hot, and the next, you know, you're shovelling snow" (participant #10), and "the weather can change dramatically in 24 hours. And I don't remember that being like that as a child. And maybe the last 10 years, I notice that it's been quite a bit more significant and getting worse the last few years" (participant #5).

In addition to affecting fishing activities, various participants made remarks about the effects of these severe storms on their safety while travelling and on wildlife or ecosystems as a whole. Regarding the more recent changes in weather and storms, participant #10 stated, "I don't think that it not only affects animals, I believe it affects everybody that's alive. You know? 'Cause we're dependant on the animals to survive. If there's no animals, you know - how are we going to survive?".

Finally, a few participants made general remarks about how the weather has just overall become more unusual and referred specifically to some events occurring in the "wrong" season. For example, two participants had recently observed rain and thunderstorms during the winter, something that is highly unusual for the region. Another participant also mentioned seeing unusual snowstorms occurring as late in the year as June, when normally the last snowfall of the year would occur much earlier. Most participants made some sort of observation that the general weather and storms have become increasingly unusual and extreme. The increasing occurrences of unusual and extreme weather appear to be some of the most problematic effects of climate change on the community's traditional activities, particularly for fishing and travelling. The changes in weather also raised concerns about how wildlife and ecosystems will be affected, and how this will in turn affect humans.

4.2.6. Ice Thickness and Quality

Nine participants reported changes in the thickness and quality of ice on lakes and rivers and how these pertain to the safety of travelling over ice (Figure 13). Six claimed that ice is generally thinner now than it used to be. For example, participant #1 has an all-season camp (or cottage) next to a lake that he said he used be able to walk straight across in the winter, but in more recent years the ice no longer gets thick enough to walk on towards the centre of the lake. Similarly, participant #10 has a camp next to a large river and said "this whole river system used to freeze solid. And now, I'd say [since] about thirty, thirty-five years ago, the centre of the river's always open." Additionally, he said that this makes it more difficult to get across the river: "We used to cross the river anywhere in the wintertime. But now you gotta choose specific spots." In general, participants believed that the ice is becoming thinner because of rising temperatures, but one person mentioned that the depth of snow also plays a role due to its insulating properties.

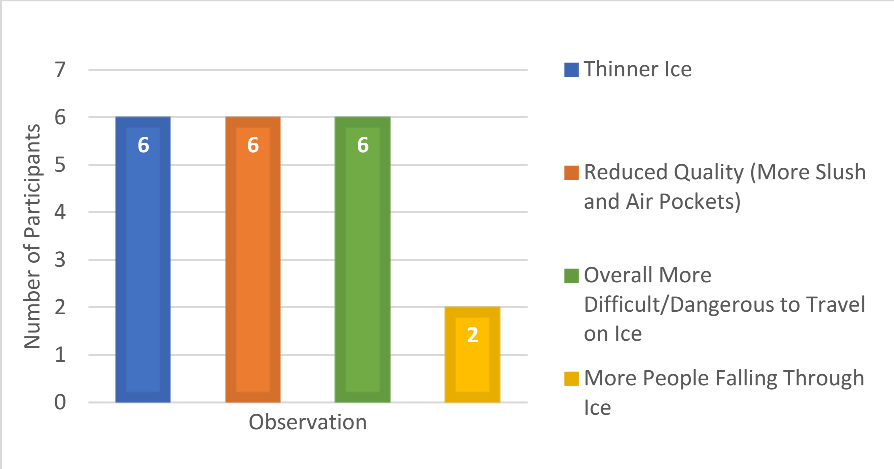

Figure 13. Observations of changes in ice thickness and quality; responses from nine participants with more than one response per participant possible.

Regarding ice quality, most participants referred to the content of slush and air pockets within ice, as well as ice colour and the occurrence of "rotten ice." They explained that ice with many layers of slush and air pockets is unpredictable and potentially dangerous to travel over, whereas solid, blue or black ice is stable and safer. Six participants said that ice quality has reduced over the years, which was generally associated with overall warmer temperatures and large fluctuations in temperature. It was described how the warmer temperatures tend to turn the snow on top of ice to slush, and the fluctuations in temperature are what create the low-quality layers of ice, air pockets, and slush, "with the warm, cold, warm, cold, you get the air pockets in between the layers of ice, and some of those air pockets are big enough for you to just fall right in" (participant #3).

One participant mentioned that the warming temperatures have been increasing the occurrence of rotten ice or candle ice: "… They call it 'candling' when ice gets to a certain state where it's - it's - you can push on it and it goes down and breaks all into like, candles, ice candles". He explained that he believes the way the hot sun hits black ice now it begins melting and candling very quickly, and if someone walks on this type of ice they will fall right through.

Moreover, an ice road is built on one of the major lakes used in the territory every winter to allow for improved ice-fishing access. One participant had discussed how unusually deep snow produced a large amount of slush on the lake in one recent year, which made it practically impossible to plow the road. This led to increased difficulty for many community members to access their ice fishing shacks, as well as getting the shacks off the lake in time before the ice melted: “The ice shacks out on [lake name] are...people aren’t able to get them off right now because there’s so much slush” (participant #3).

Due to the thinner and lower-quality ice, six participants stated that now it is more difficult and/or more dangerous to travel over ice to access harvesting areas like traplines or to go ice fishing. Some went into further detail about needing to take longer, alternate routes to access harvesting areas, and avoiding travelling over ice entirely because it is not worth the risk of falling in or losing equipment. Two participants reported that they have been hearing of more incidences of people and equipment falling through the ice in recent winters, even in the middle of winter when the ice should be the most stable: “The OPP (Ontario Provincial Police) just went out on the lake and rescued some people the other day, and this is the middle of winter!” (participant #3). This has made him increasingly uncomfortable with going out on the ice in recent years, and he says he will only go out on it now if it has been extremely cold for a long period of time.

4.3. CHANGES IN SPECIES ABUNDANCE, DISTRIBUTION, AND HEALTH AND THEIR EFFECTS ON HARVEST

A few observations were made about changes to the abundance, distribution, and health of some traditional food species (plants and animals) that participants believed could be a result of climate change. A few participants remarked that there seems to be fewer wildlife species in general. More specifically, some have observed seeing fewer moose, geese and ducks, partridge (or grouse), fish, and blueberries (Figure 14). Participants attributed these declines at least partially to climate change and the resulting changes in weather and environmental conditions.

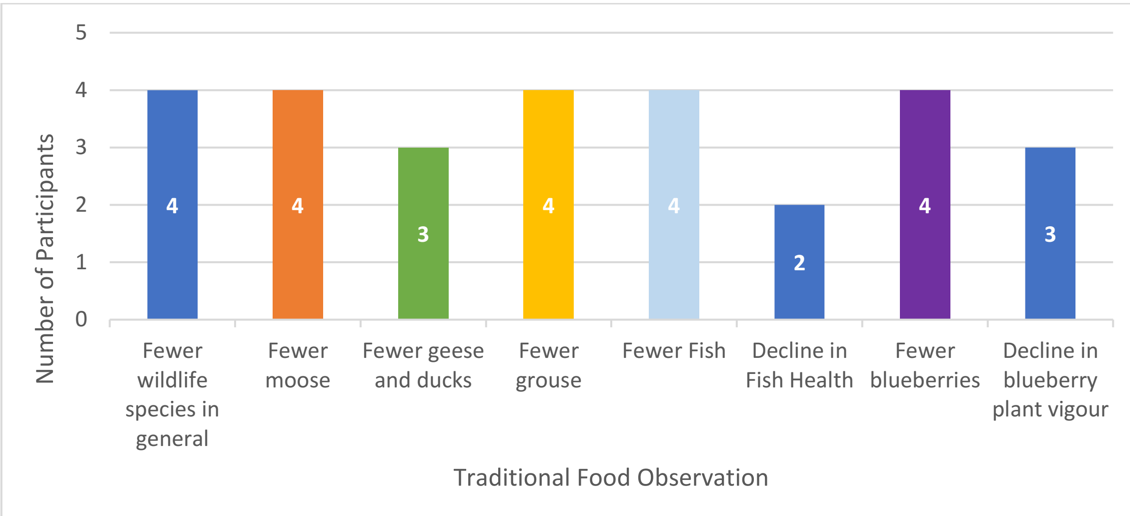

Figure 14. Observations of changes in traditional food species' abundance and health or vigour; responses from 12 participants with more than one observation per participant possible.

One participant attributed the decreasing blueberry abundance to a decrease in rain. Some also thought that forestry activities may be playing a role in the decline of traditional foods as well, such as logging activities decreasing moose habitat and herbicide spraying killing blueberry plants. One participant suggested that clear cut areas should receive prescribed burning rather than herbicide sprays to manage tree growth, as this would help rather than hinder blueberry production. Another participant believed that the decrease in moose numbers may be due to clear cutting of high ridges where they tend to stay in the winter (moose wintering areas), and that forestry operations should avoid cutting these areas.

It was mentioned that white-tailed deer populations appear to be increasing in the area, and that they may be moving farther north as the climate changes. This movement was associated with potential negative impacts on moose numbers due to increased competition for habitat, increased wolf predation, and the transmission of meningeal brain worm from deer to moose.

Regarding animal health, two participants stated that they were seeing significantly large increase in the number of diseased pickerel they catch while fishing. It was determined that the disease was likely dermal sarcoma, a virus that results in the growth of tumours on the skin of pickerel. One participant thought that the increased prevalence of the disease could be due to warmer water temperatures and thus may be affected by climate change.

One participant mentioned the effects of warming temperatures on the fur quality of animals targeted for trapping. He stated that the best time for trapping is in the middle of winter when it is the coldest because that is when the animals have “prime fur,” and once it begins warming up the animals start shedding. Once it begins getting cold, he stated, “they just automatically start growing their hair to keep themselves warm. But if it was going to remain warm, their fur would be still not very thick and pretty ugly looking” (participant #4). He was concerned that as winters continue to get warmer, trapping may become a less viable source of income. Many participants explained that it is already very difficult to earn an income with trapping, and most of the time they barely break even after equipment and fuel expenses.

The decreasing abundance and health of traditional food species has affected some participants’ harvest success. For some, it has been more difficult to successfully hunt a moose in recent years because there are fewer available to hunt. Another participant explained that blueberries are harder to find and not as plentiful as they used to be. Similarly discussed earlier in the timing of berry ripening section, many participants associated the earlier ripening and quickly drying fruits with a decrease in moisture (rain and snow) and increased temperatures, which has reduced the amount of berries community members have been able to harvest. An increase in the number of diseased fish being caught has also reduced the number of fish some community members will harvest and eat.

4.4. COMMUNITY MEMBERS' HEALTH

Participants were asked if they had observed any changes in the health of themselves or others in the community. Specifically, it was asked if there had been an increase in cases of Lyme disease from ticks (as there has been a large increase in the number of ticks in the area in recent years), sunburns, skin cancer, heat stroke, or any other illnesses that may have been caused by recent changes in the environment.

The most common observation (n=6) was that sunburns are much more common now than they used to be. Many participants explained that as children they could be outside all day without wearing sunscreen in the summers and they would maybe get a tan but never a sunburn. In recent years, they find that they and their family members burn very easily after just a short time outside and must take extra precautions for long days in the sun like using sunscreen frequently and wearing hats, sunglasses, and long-sleeved shirts to avoid getting a sunburn. Some associated sunburns with the sun's rays feeling more intense: "and even if it's not record-breaking temperatures, it's like the UV rays are more intense or something" (participant #3).

Moreover, one participant expressed that in general Indigenous people are becoming sick with more illnesses and conditions and thinks that climate change could likely be playing a role.

Some other minor observations about health of community members were made. For example, two participants said that they are hearing about people getting skin cancer more often possibly due to the higher rates of sunburns, but not specifically within the community. Similarly, one participant claimed to be hearing about increased cases of Lyme disease occurring across Canada and associated this with the increasing number of ticks in the area, “I know that the ticks are moving further and further north every season. I think it's from climate change, for them to be going further north” (participant #5). Another participant felt that people in the community are becoming more susceptible to heat stroke and dehydration because of extremely high summer temperatures in recent years. Finally, one participant brought up her concerns regarding the effects of changing air, water, and seasons on a person’s overall wellness, including their physical and emotional health. She was particularly concerned for the future generations, “I worry about the future and I worry about the future of our young people coming up. Scary, actually” (participant #15).

5. DISCUSSION

This study sought to provide a holistic understanding of how climate change is affecting and may continue to affect the livelihoods and health Indigenous community members of Northern Ontario by utilizing the Two-Eyed Seeing framework. This was achieved by meeting the two initial objectives: 1) conducting a comprehensive literature review, and 2) conducting interviews with members of an Indigenous community. Indigenous perspectives of climate change were acquired through the conduction of semi-structured interviews with members of a Northern Ontario First Nation as well as a review of articles and other sources that have documented Indigenous observations in Northern Ontario and surrounding regions. With an understanding of how some communities are being affected by specific effects of climate change, trends and projections of these effects were analysed to predict how communities may be impacted further throughout the remainder of this century.

As expected based on existing literature, participants interviewed in my study had reported several observations of changing weather and environmental conditions resulting from climate change and discussed how changing conditions have affected traditional food species' abundance and harvest success (livelihoods), and community members' health. The majority of these observations are in alignment with existing trends and projections. Similar observations have also been made by a number of other communities in Northern Ontario and other regions. Similarities and differences from this study and the existing literature, as well as some recommended actions for communities to mitigate the negative impacts of climate change contained within the literature will be discussed below.

5.1. WEATHER AND ENVIRONMENTAL CONDITIONS

The First Nation community members that participated in my study made several fairly consistent observations of changes in weather and environmental conditions including higher temperatures, a shorter ice cover duration, reduced ice thickness, reduced snowfall amounts, increased occurrences of unusual weather, stronger and more frequent winds, and declining water levels and quality. Regarding rain and spring runoff amounts, the largest number of respondents reported a decline in these, but there was still a wide variance in observations which makes it difficult to draw any conclusions about how climate change may be affecting rain and spring runoff within the community's traditional territory from this information alone. Analysing meteorological records of precipitation in the area may aid in predicting how rain amounts change over time, and how spring runoff may be influenced by changes in rain and snow within the community's traditional territory.

Aside from declines in rainfall, snowfall, and a subsequent decline in spring runoff, the above observations are in line with existing trends and projections for the region. Average annual temperatures have risen and are projected to continue rising throughout this century (Ministry of the Environment 2011:10, Li et al. 2018, Wang et al. 2015b). Ice cover duration and ice thickness throughout the winter have been projected to continue declining (Minns et al. 2012) which will in turn affect the seasonal length and viability of winter roads (Barrette and Charlebois 2018, Hori et al. 2018b, Reid 2015).

Contrary to community observations of declines in rain and snowfall, precipitation has been projected to increase slightly (3.2% to 17.5% by the 2080s) in

Northern Ontario, particularly in the form of snow and spring rain (Wang et al. 2015b) which may increase spring runoff amounts. The number of heavy rainfall events has risen (Adamowski and Bougadis 2003) and has been projected to increase further (Wang et al. 2015c) as well. Some participants did believe heavy rainfall events were increasing in frequency but there have been longer dry periods between events, resulting in more extreme conditions but no change in average annual precipitation. The variation between observations made and trends and projections may suggest that small scale differences in precipitation changes may occur throughout the region, even if large-scale regional increases are projected.

Declining water levels in lakes and rivers have been observed by participants of my study as well as members of Fort Albany, ON (Tam et al. 2013). Participants of my study did not mention that lower water levels were affecting their health or livelihoods, but many concerns were raised including how lower water levels may affect water availability during the growing season, water quality for drinking and recreation, fish survivability, risk of forest fires, and the risk of flooding in the future. As well in Fort Albany, the lowered water levels have made it more difficult to access moose hunting areas, as community members travel upstream by watercraft to get to these areas. As a result, there has been a decline in the amount of moose meat people are able to harvest, which has affected not just individual hunters, but the entire community because many families share game meat with each other (Tam et al. 2013). No studies were identified that research possible changes in water levels and freshwater availability in Northern Ontario resulting from climate change. Some sources have suggested that any projected increases in precipitation will not offset the moisture loss resulting from higher temperatures (e.g., Flannigan et al. 2016 and Stonefelt et al. 2000, Fontaine et al. 2001 cited in Assembly of First Nations 2008:22), which may result in lower water levels and a decline in freshwater availability for human and environmental needs.

Regarding water quality, several participants in of my study reported observing an increase in algae growth in some water bodies. Some participants mentioned that the increased algae growth has resulted in a change in the taste of water, which has necessitated the use of water filtration systems where they were not required before. All types of algal blooms, including toxin-producing cyanobacterial algal blooms have been projected to increase in occurrence throughout Northern Ontario due to rising temperatures and changes in precipitation regimes (Winter et al. 2011). Furthermore, with observed and predicted increases in temperature, heavy rainfall events, and spring runoff in Northern Ontario, waterborne pathogens may proliferate and more easily move over land from contaminated areas such as sewage lagoons to water extraction sources. It can therefore be expected that the risk of contracting waterborne illnesses will likely rise for communities in the region, particularly for those with inadequate water treatment systems. It has been recommended in the literature that one way to avoid potential waterborne pathogen contamination of water use sources is constructing sewage lagoons in locations where there is low risk of contamination associated with high overland water movement (Assembly of First Nations 2008:4, Charron et al. 2005:81).

One observation made by some members of the community in my study but not others in the literature was an increase in wind speed and the frequency of windy days. Little research has been done to investigate how winds may change in Northern Ontario, except for a single study where wind gust frequency was projected to increase across all regions of Ontario. Northern Ontario specifically was projected to see the highest rate of increasing wind gust frequency among all regions, especially for extremely high wind gust speeds of ≥70 km/hr (Cheng et al. 2012). The increasing wind speeds and frequency of windy days observed by community members had occasionally interfered with fishing on lakes, therefore an increase in wind gust speed and frequency as projected may further increase difficulty in fishing or reduce the number of days it is possible to go fishing safely.

Community members from my research and other studies did not make any observations of specific extreme weather events such as heat waves, droughts, or forest fires. Two participants of my study believed that floods seem to occur more frequently now than they used to due to an increase in spring runoff amounts and increasing occurrences of ice jams. Additionally, some concerns were raised about rising temperature and its possible effects on human health and forest fire activity. Extreme weather events in general are expected to become a more common occurrence (Ministry of the Environment 2011:27); in particular, heat waves (Dotto et al. 2010:74, Li et al. 2018) and forest fires (Dotto et al. 2010:42, Ministry of the Environment 2011:59-60, Wang et al. 2015a, Wotton et al. 2005, Wotton et al. 2003) have been projected to increase in frequency and intensity. Droughts have the potential to become more frequent in the region due to rising temperatures and resulting increases in evaporation rates (Flannigan et al. 2016 and Stonefelt et al. 2000, Fontaine et al. 2001 cited in Assembly of First Nations 2008:22). Similarly, floods may occur more frequently as a result of increases in snowfall and spring rain (Wang et al. 2015b) and increasing frequency of heavy rainfall events (Adamowski and Bougadis 2003, Wang et al. 2015c). Communities that do not regularly experience certain extreme weather events tend to have low adaptive capacity to handle them (e.g., Nova Scotia Dept. of Agriculture and Fisheries 2001 cited in Yusa et al. 2015) and may be at a heightened risk of negative health and safety outcomes if these events do begin to occur more frequently.

Winter roads are not particularly relevant to the participants of this study, as the community has all reason road access (although members may still use winter roads for social events or traditional activities in other communities). However, declines in winter road viability have significantly impacted a large number of remote communities in Northern Ontario, and this trend is expected to continue throughout the century, which warrants discussion.

Some adaptation strategies against changing winter road conditions and alternatives to winter roads have been discussed by Hori et al. (2018b), Barrette and Charlebois (2018), and Reid (2015). These strategies can include altering the methods of winter road construction, such as putting bridges in at problematic river crossings, relocating road segments, building and maintaining multiple routes in case one becomes unusable, and artificially increasing ice thickness with water spraying and surface flooding (Barrette and Charlebois 2018, Reid 2015). However, water spraying and surface flooding may increase the risk of spring flooding in some communities (Hori et al. 2018b). Another strategy involves traffic management, such as only using the roads at night when the ice is stronger, enforcing speed limits, and providing winter road safety training to road users (Barrette and Charlebois 2018, Hori et al. 2018b). Alternatives to winter roads can include continued use of air transportation and barge transportation for coastal communities, and expanding rail transportation (Hori et al. 2018b, Reid 2015), but these are costly alternatives to be used year-round. Another suggested alternative that is more environmentally friendly and economical is the use of airships for transportation of goods (Hori et al. 2018b, Reid 2015).

One final alternative to winter roads would be the construction of all-season roads, but these can have immense social and economic implications for remote communities, both positive and negative. Some positive aspects may include improved access to goods at reduced costs, increased opportunities for employment, and easier travel between communities. Some negative aspects include “opening up” the areas to recreational land users, providing easier access to drugs and alcohol, and fragmentating the few remaining untouched landscapes in the north (Reid 2015). All-season roads will also provide increased opportunities for development for industries such as mining, forestry, and hydroelectric in the north, which can be a positive or negative aspect. Some communities may welcome the opportunities for employment and economic stimulation, while others may find it undesirable to have industry development on their traditional territories. The construction of all-season roads may also simply not be practical in many cases due to the large number of river crossings and wetland areas in the Far North (Reid 2015).

5.2. TRADITIONAL FOODS

Participants of this and other studies have reported a large number of observations related to declines in traditional food species’ abundance, and these observations have been in line with trends and projections where the literature exists for particular species. Most respondents in my study reported declines in moose numbers; other declines were reported for waterfowl, game birds, fish, blueberries, or all wildlife species in general. Some observations were made related to traditional foods’ health and vigour among participants, and similar observations have likewise been made by other community members.

Declines in moose abundance or changes in their distribution have also been observed in St. Theresa Point First Nation, MB, Poplar River First Nation, MB (CIER 2006), and Weenusk, ON (Lemelin et al. 2010). Moose numbers in Ontario have been projected to decrease overall at the southern limits of their range toward the end of this century, primarily due a decrease in vigour associated with the effects of climate change (Murray et al. 2012, Rempel 2011). Additionally, as white-tailed deer distributions move northward into moose habitat, moose may also be moving northward to avoid deer which could be one possible reason for their observed decrease in number. Declines in moose health and vigour potentially related to climate change have been observed in Black River First Nation, MB (CIER 2007) and Fort Albany, ON (Tam et al. 2013).

CIER (2007) described some adaptation strategies regarding changes in moose for Black River First Nation, which may be applicable to the First Nation that participated in this research. It was recommended that the members of Black River continue practicing good stewardship of moose populations by putting as little hunting pressure on moose as possible, in addition to keeping track of the number of moose hunted and avoiding hunting female moose. It was mentioned that if moose do move farther north due to climate change as predicted, then community members may also have to travel farther north to hunt them. Some implications of this include a higher financial burden to harvest moose (e.g., needing more supplies and gas, as well as potential lost wages for extra time away from work) which may make it no longer financially worthwhile to hunt them. It may also mean that the community would have to hunt in other First Nations' traditional territories, in which case permission would be needed to hunt there. A final strategy would be to hunt different animals as species distributions change; for example, if white-tailed deer also move northward into habitat currently occupied by moose, then the community may choose to hunt more of them as a substitution (CIER 2007). In my study, one participant also suggested that forestry companies should avoid harvesting moose wintering areas (high ridges) to help alleviate some of the pressure on population numbers.

A few observations have been made by participants of this study and others regarding freshwater fish. The observations that have been made generally related to declines in abundance and health. Freshwater fish have been projected to decline in number at southern extents of species' ranges, particularly for cold- and cool-water fishes. Conversely, warm-water fishes may increase in abundance and have their range expand northward (Biswas et al. 2017, Chu et al. 2005, Van Zuiden et al. 2016). Cold-water fishes like lake trout and lake whitefish, and cool-water fishes like pickerel tend to be most favourable for consumption by people. A reduction in the number of these fish species or their movement northward will impact Northern Ontario communities that rely on them for their livelihoods, whether that be subsistence or commercial fishing. Communities could potentially shift to harvesting and consuming more warm-water species like smallmouth bass to substitute the other declining species, but these are not as favourable.

Two participants in my study stated that they have been catching an unusually large number of diseased fish in recent years, which they thought may have been in part due to climate change. The disease was identified as the virus dermal sarcoma, and sources do suggest that water temperature may affect the expression of this virus (e.g., Paul et al. 2008). These participants would not harvest or eat fish that were heavily diseased. In the Manitoban communities of Barren Lands, Poplar River, and York Factory, declines in fish meat quality were also observed; for example, lake trout meat was found to be softer and rotting more quickly than normal (CIER 2006). This has sometimes resulted in meat being discarded because it was not suitable to be eaten. These observed declines in fish health and vigour may be associated with climate change and warming water temperatures, but little to no research has investigated this occurrence. Further declines in fish health as the climate continues to change may result in Indigenous communities and individuals harvesting and consuming less fish, impacting most or all aspects of their health.

There appears to be ample research into the effects of climate change on freshwater fish abundance and distribution in Ontario and Canada. Efforts now should likely be placed on conserving important fish species, especially cold-water species like lake trout and lake whitefish so that they may continue to be harvested in the future.

Regarding waterfowl and game birds, declines in abundance and meat quality and changes in migration patterns were reported by community members in this study and several others including Fort Albany, ON (Tam et al. 2013), Weenusk (Lemelin et al. 2010), Bunibonibee, MB, and Barren Lands, MB (CIER 2006). Participants referred specifically to Canada geese, duck species, sharp-tailed grouse, and ptarmigan species. In this study, one participant mentioned that changes in the timing of Canada goose migration had affected some community members' hunting trips. Hunters had travelled a long distance by bush plane for goose hunting and due to a late migration, the hunters had to return home and make a second trip to the hunting area. For situations like this, needing to take more than one hunting trip by plane or any other modes of transportation could put significant additional financial burden on community members to be able to successfully harvest traditional foods.

There were no studies identified that have researched the possible effects of climate change on waterfowl and game bird species in Northern Ontario. Except for some waterfowl species in the Prairie Pothole Region (e.g., Zhao et al. 2016 and Whithey and van Kooten 2014), the body of knowledge across Canada is minimal. The previous referenced studies have determined that waterfowl population dynamics are driven by wetland availability, as these are important habitats for ducks and geese. Northern Ontario is covered by a large amount of wetland area and a change in availability may also affect waterfowl abundance in this region. For example, predicted rising average temperatures may result in a significant reduction in moisture, leading to a decline in wetland area and thus waterfowl abundance. As waterfowl and game birds are important traditional food sources to Indigenous communities in the region, this may be an important topic for investigation.

Regarding berries and other food plants, blueberries were the most commonly harvested and consumed among participants of this study and other community members throughout Northern Ontario and neighbouring regions. Several observations were made related to their declining abundance and vigour, which were generally associated with rising temperatures and declines in moisture. It was also mentioned by some participants in my study that non-climatic factors may be playing a role in loss of blueberry plant vigour, such as the use of aerial herbicide sprays in forestry operations. One participant had suggested that forestry companies should employ the use of prescribed burns instead of herbicide sprays to manage undesirable vegetation growth, as this would help rather than hinder blueberry production.

In several cases within this study and others, declines in blueberry plant abundance and vigour have decreased blueberry harvests. As a replacement, canned or frozen blueberries have sometimes been purchased instead (CIER 2007). Needing to buy berries rather than harvesting them may place additional financial strain on Indigenous families, especially for those who harvest and sell blueberries as part of their livelihood. No studies were identified that investigate the effects of climate change on blueberries or other food plants in Northern Ontario or other regions within Canada.

5.3. HEALTH

Some observations and concerns related to community members' health were reported by participants of this study. Observations made included that it is now easier to get a sunburn, and people may be becoming more susceptible to dehydration and heat stroke due to rising temperatures. Other general health concerns were raised, such as possible increased risks of skin cancer, rising cases of Lyme disease in Canada due to the northward range shift in certain tick species, possible declines in emotional health due to the effects of climate change, and Indigenous people becoming more ill in general with climate change potentially playing a role. The participant who discussed the latter also associated things like high rates of diabetes among Indigenous populations with a drastic change in diets over the years. While not directly related to climate change, the diets of people may be further affected by changes in traditional food species' abundance and distribution as an indirect consequence of climate change, potentially increasing the occurrence of diabetes and other metabolic health conditions.

The increased risk of getting a sunburn is a health concern that was not mentioned by participants of other studies. In the community of Black River First Nation, MB, one member did suggest that rising temperatures were causing people to become ill, but they did not say with what symptoms or conditions (e.g., heat cramps or heat stroke). Other than these, observations of changes in health by Indigenous community members were limited in the literature. This may be largely be because the focus of other studies has primarily been the effects of climate change on traditional foods, traditional activities, or winter roads. It is also possible that noticeable climate change impacts on health are currently minimal, or that observed changes in health have not been associated with climate change as a potential cause, especially since most impacts of climate change on health would be indirectly caused (e.g., climate change affecting traditional foods, which then affects Indigenous people's health).

Research of climate change impacts on Indigenous people's health are also limited in Western literature, especially beyond the physical aspect of health. As a result, most of the potential impacts on Indigenous people's health discussed in this paper are speculations that have been made by linking together separate but related subjects in the literature. For example, many sources have explored the positive associations between consumption of traditional foods and the health of Indigenous Peoples (e.g., CIER 2007, Guyot et al. 2006, Marles et al. 2012, Riedlinger 2001, Willows et al. 2019), and others have investigated potential changes in the abundance and distribution of important traditional foods under climate change scenarios (e.g., Biswas et al. 2017, Murray et al. 2012, Rempel 2011), but without discussions of how these changes might affect Indigenous communities. Similarly, some studies have explored how limited access to potable water and long-term boil-water advisories impact people's health in Indigenous communities (e.g., Galway 2016), and others have projected changes in waterborne pathogen contamination (e.g., Harper et al. 2011, Schijiven et al. 2013) and the occurrence of cyanobacterial algal blooms (e.g., Favot et al. 2019, Persaud et al. 2015) without Indigenous contexts. These connections were also made regarding diminished livelihoods, declining viability of winter roads, and increasing frequency of extreme weather events such as heat waves, droughts, floods, and forest fires.

Mere speculation of the impacts of climate change on health of Indigenous people is an insufficient method of assessing and creating solutions to these impacts. However, I believed that making these connections and having this discussion was warranted due to the lack of individual studies directly investigating possible health outcomes associated with the effects of climate change.

5.4. PARTICIPANT PERCEPTIONS OF CLIMATE CHANGE EFFECTS

There are several factors that may have influenced each participant's perceptions of the effects of climate change, and thus their reported observations presented in this study. Possible factors include the participants' ages, the type of traditional activities they take part in and how often, personal daily exposure to and experiences of climate change effects (“the local warming effect”), and access to information about climate change. These factors and how they may have influenced participant perceptions will be discussed in the following paragraphs.

Adults of any age were welcome to participate in this research, however the targeted demographic for participant selection was older adults and elders. This is because it was assumed older individuals would have been able to notice more trends in changing environmental or other conditions simply due to their life experience compared to younger individuals. Participants’ ages ranged from their 30s to 80s, but the majority were between their 50s and 70s. Contrary to my assumption, the two younger participants in their 30s and 40s reported many changes in the environment and traditional foods, like that of any of the other older participants. The number of participants is too small of a sample size to make any definite associations between age and observations of climate change. However, one possibility for the younger participants’ large number of observations is that the effects of climate change have become most pronounced due to the acceleration of warming global temperatures within their lifetimes.

The traditional activities participants took part in had a much more noticeable effect than age on the number of climate change observations reported by each participant. The participants who regularly (i.e., yearly or seasonally) took part in a larger number and type of traditional harvesting activities made more observations than those who took part in few activities or only took part in activities on rare occasions. In addition, there was a strong association between the number of observations made for a particular effect of climate change and any traditional activities that might have been relevant to that observation (e.g., moose hunters often observing changes in moose abundance compared to minimal changes observed by non-moose hunters). Table 8 below lists the number of participants that have made observations of changes in the environment or traditional foods as well as the number of participants who take part in activities that may be relevant to each observation.

Table 8. Comparison of the number of participants who made a particular climate change observation and the number who took part in relevant traditional activities.

Results Section	Observation	# of Participants That Made an Observation	Relevant Traditional Activity/Activities	# of Participants That Take Part in Relevant Activities
Timing of Seasonal Events	ice freeze-up and break-up	5	• ice fishing • trapping	6
	fish spawning	10	• open-water fishing • ice fishing	13
	goose migration	2	• waterfowl hunting	3
	moose rut	2	• moose hunting	6
	blueberry ripening	6	• blueberry harvesting	10
Weather and Environmental Conditions	water qualities	9	• open-water fishing	13
	ice thickness and quality	9	• ice fishing • trapping	6
Traditional Food Species' Abundance and/or Vigour	moose	4	• moose hunting	6
	fish	5	• open-water fishing • ice fishing	6
	waterfowl	3	• waterfowl hunting	3
	game birds	4	• game bird hunting	6
	blueberries	5	• blueberry harvesting	10

Regarding Table 8 it is important to note that it was not necessarily only the participants who took part in the relevant traditional activities that made the observations; for example, nine participants observed changes in ice thickness and quality, but only 6 took part in relevant activities. The table simply highlights the trend that more observations of a particular climate change effect were positively associated with increased participation in traditional activities. Figure 15 below visually represents this association.

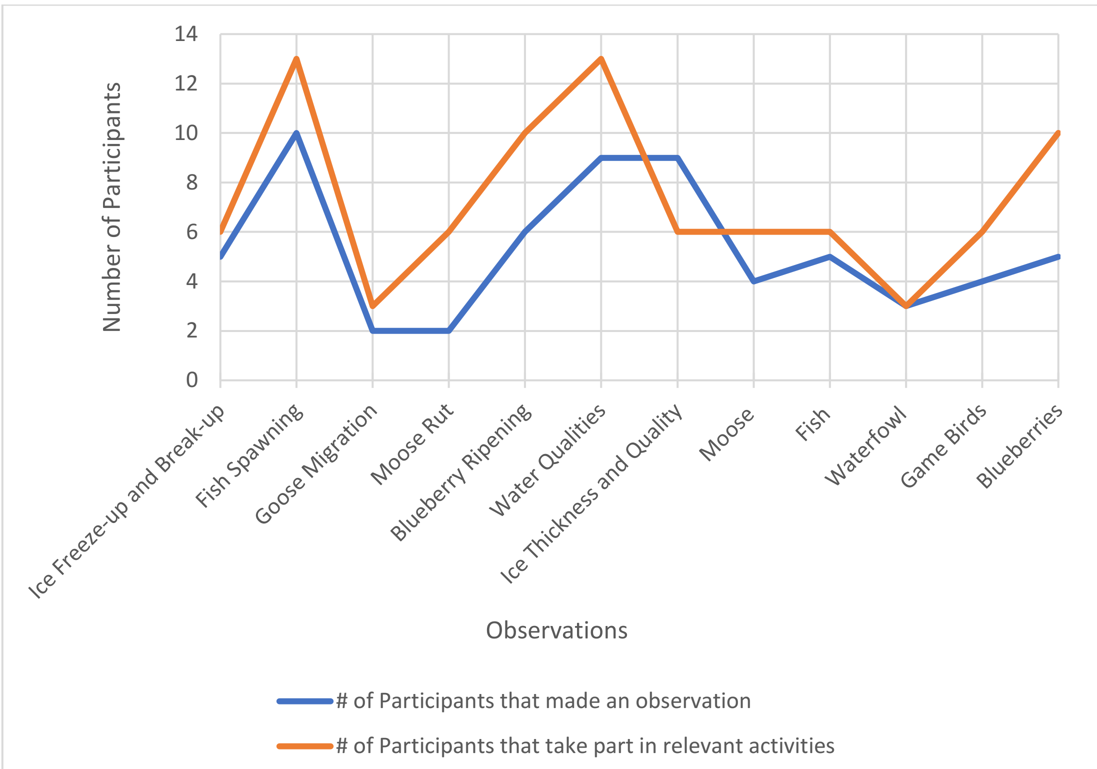

Figure 15. Visual representation of the positive association between regular participation in traditional activities and the number of observations made for a particular climate change effect.

Participants' daily exposure to weather effects in the most recent years prior to being interviewed for this study may also have played a role in their overall perspectives of climate change. A psychological phenomenon called the local warming effect refers to the judgements a person makes about climate change based on whether the current day seems warmer or colder than usual (Li et al. 2011, Zaval et al. 2014). It has been demonstrated that when making judgements of climate change, individuals may use less relevant but available information such as the current day's temperature rather than more reliable but less accessible information such as global climate change patterns (Zaval et al. 2014). The local warming affect may influence an individual's risk assessment of climate change. For example, on warmer than usual days, individuals tend to perceive climate change as a greater threat and have stronger emotional responses to it due to the realisation of the consequences that may arise from climate change locally and globally (Li et al. 2011, Reser et al. 2014).

Among the participants interviewed for my study, it is entirely possible that psychological phenomena such as the local warming effect influenced their responses to questions about climate change. For instance, participants very often referred to specific events that have occurred within the last few years or even the last few weeks from when they were interviewed when making judgements on climate change effects (interviews took place between 2019 and 2020). Additionally, many participants explicitly noted that they did not remember events and conditions from when they were very young with absolute certainty (e.g., stating that they were "pretty sure" rather than certain regarding specific environmental conditions observed during their childhood), which may have made more recent memories take priority over long-term memories when making judgements.

Regarding the above findings of Zaval et al. (2014) where it was demonstrated that information less available to an individual such as global climate change patterns will not take priority when making climate change judgements, I would like to discuss the availability of such information to the participants of my study, and how this may have influenced their perspectives. Firstly, climate change was a concept each participant was adequately familiar with (i.e., interviewers did not have to explain what climate change was or what its effects are to any of the participants). Throughout the interview process, it was occasionally mentioned in conversation by some participants that they were not regular users of modern technology such as smart phones or personal computers. This is understandable considering the ages and lifestyles of most participants.

Based on my own speculation, the minimal use of technology among participants may have limited their external perspectives of climate change to those of others within the community, within news sources, or on television. Some participants did mention that some of their observations of climate change were derived from observations that other community members have made, therefore their own judgements may have been influenced by the perspectives of others in the community. As a result, it is possible that perspectives of climate change among participants may have been limited in scope to local or regional effects of climate change, and more in-depth knowledge of global patterns of climate change were minimal. It is unknown if this truly is the case among participants since it was not explicitly discussed as part of the interview, but if it is the case then the limited scope of climate change knowledge could have influenced psychological phenomena like the local warming effect when participants were making judgements of climate change effects during interviews.

5.5. STRENGTHS AND LIMITATIONS OF RESEARCH

There were some limitations of the research conducted in this study, for both the literature review and community interviews. Regarding the literature review, there was a considerable scarcity in literature that focused specifically on Northern Ontario. The majority of articles and other sources reviewed covered Ontario as a whole, and in most cases of these, there was a bias in data collection points that favoured southern

Ontario. Additionally, data collection points located in Northern Ontario (for articles focusing on either Ontario or Northern Ontario) were quite limited to its southernmost extents, and there were almost no data collected in Ontario's Far North. This is somewhat understandable considering the limited accessibility of remote areas and the vast amounts of undeveloped land within Northern Ontario. However, these studies that exclude large areas from data collection may present results that do not accurately reflect changing conditions across the entire region. It is a major shortcoming that these areas are often overlooked when conducting research that may have important implications for the Indigenous communities located within them.

Furthermore, Indigenous contexts and perspectives were frequently lacking in the literature, particularly in peer-reviewed journal articles. Most of the Indigenous perspectives reviewed in this study have come from sources that are not peer-reviewed, such as reports, government documents, news articles, and books. For instance, many studies have projected the effects of climate change on moose abundance (e.g., Murray 2012, Rempel 2011), one of the most important traditional foods to Indigenous communities in Northern Ontario and throughout the boreal forest, yet they have not discussed the implications of their results to these communities. Without the inclusion of Indigenous perspectives in climate change projections, many speculations had to be made about the potential impacts of climate change on Indigenous communities in the literature review, and these speculations may not accurately reflect community members' true concerns regarding climate change.

There were also some limitations regarding the results of my interviews with members of a Northern Ontario First Nation. Firstly, it was explicitly stated by several participants that with the observations they made, it was sometimes difficult to say whether the observed effects were a direct result of climate change or a result of other factors. For example, multiple participants explained that they were unsure if the declines in fish abundance they have observed were solely due to climate change, or if pollution, invasive species, and/or overharvesting by recreational (non-Indigenous) fishers were playing a role as well. Similarly, some participants thought that declines in moose abundance may be partially due to the clearcutting of important moose habitats, or that the reduced vigour of blueberry plants may be due to herbicide sprays used to manage vegetation growth in cut areas. Regardless, participants believed climate change was at least playing a role in almost every observation they made in changes in weather, environmental conditions, traditional foods, and community members' health.

Secondly, many participants expressed that due to their age, they sometimes had a hard time remembering events or environmental conditions from when they were younger. This sometimes resulted in a lack of confidence when comparing past conditions or events to more current ones, using terms such as "I'm pretty sure" or "I think so, but I'm not sure". These types of answers were still recorded as an observation unless there was significant doubt (otherwise there would have been almost no results to these interviews), and as a result there is a possibility that some participants' observations do not accurately reflect real changes. In many cases, however, there were largely consistent observations among participants (e.g., changing ice conditions, declines in snowfall amounts, storms becoming more intense than they used to be, etc.) and these would be more likely to accurately reflect true conditions.

Inconsistent observations, such as those made for rainfall amounts or the timing of spring fish spawning, may be due in part to unclear memories. They may also be a result of increasing variation in conditions from year to year, causing some participants to believe there is a change in one direction, and others in another direction (e.g., some years there is more rain than normal, so some participants think there is a trend of increasing rainfall every year, or vice versa for less rain). Another possible reason for inconsistent observations is that the community's traditional territory covers a large area and there may be geographical differences between the areas each participant typically uses, resulting in inherent variations in climatic conditions between these areas.

There were also a number of strengths to both portions of this research. I believe that following the Two-Eyed Seeing framework by incorporating aspects of Indigenous and Western knowledge into the literature review provided a more complete and holistic understanding of the current and potential impacts of climate change on Indigenous communities of Northern Ontario than either knowledge system would have alone. As stated by Elder Albert who introduced Two-Eyed Seeing, it is important to weave back and forth between the two knowledge systems when conducting research because one may have more applicable strengths than the other in different circumstances (Bartlett et al. 2012). This became quite evident in my review, where the different strengths of each knowledge system were unmistakeable.

The incorporation of Indigenous knowledge in the form of direct observations and perceptions of climate change from Indigenous community members gave real, concrete attestation of how they are already being affected. Without the involvement of Indigenous perspectives, mere speculations would have to made regarding how climate change might be affecting communities, which might not be entirely beneficial to them. With this insight of how community members are experiencing climate change, more relevant and useful predictions could be made about how communities might be affected into the future with the strengths of Western science. For instance, some of the most impactful climate change effects reported by Indigenous community members in the literature were changing ice conditions and declines in traditional food species' abundance. With this knowledge, the strengths of Western science could be utilized to understand how ice conditions or traditional food species' abundance and distribution might change over time via the development of models that can project future conditions. Presently, there is a large disconnect in the literature between Indigenous knowledge and Western knowledge regarding climate change effects. A valuable addition to future research would be the inclusion of Indigenous perspectives when discussing the implications of projected changes, especially for changing conditions that are likely to impact Indigenous communities.

Another strength of this research was the community-based approach taken throughout the research process. Firstly, it was due to the interest of some of the First Nation's leaders that initiated the research subject of how climate change is affecting community members. Within this approach, it was the community members who were able to choose a research subject that would benefit them, rather than a researcher imposing a research subject that may or may not be beneficial. It is important that research benefits all involved parties, and the research conducted here was nonetheless beneficial to the researcher was well due to personal interest in the subject and potential contribution to the growing body of literature on the subject.

The community-based approach to this study allowed community leaders to have significant, if not the majority of the input on how research would be conducted. For example, the community leaders were involved in the development of data collection methods (semi-structured interviews), the questionnaire used during interviews, and choice of interview location (the community's band office). Additionally, leaders were able to be among the first participants of interviews to allow for refinement of the interview process and to ensure the questionnaire used was culturally appropriate. For example, removing questions from a questionnaire template that were irrelevant to the community, such as those regarding caribou (*Rangifer tarandus*), or adding questions that were relevant to community members. The high level of involvement of community leaders in the research process potentially maximized the benefits to participating in the research.

6. CONCLUSIONS

Although the number of studies investigating the effects of climate change at the individual- and community-level are limited in Northern Ontario (two from existing literature, and now a third from my research), these perspectives have been a valuable starting point for understanding how Indigenous communities' livelihoods and health may be impacted by climate change within this century. Presently, it appears that some of the most impactful effects of climate change in Northern Ontario are changing ice regimes due to rising temperatures leading to reduced winter road viability and diminished ability to participate in winter harvesting activities; shifts, expansions, or contractions of traditional food species' range, declines in their abundance due to declining ecosystem resilience, changes in the timing of biological events like fish spawning, moose rut, waterfowl migration, or blueberry ripening, and increasingly unpredictable weather all leading to increasing difficulty to plan and follow through with hunting, fishing, and gathering activities and reduced harvest success for community members; and negative health outcomes such as increasing risks of sunburns, dehydration, heat stroke, and other illnesses associated with rising temperatures.

Based on Indigenous observations and of climate change and projections in the literature, I expect that throughout the remainder of this century, members of the community that participated in my research may see: a decline in hunting opportunities for moose, especially considering the community's traditional territory is located within the southernmost portion of moose range extent; a decline in fishing opportunities for cold- and cool-water fish species such as lake trout, lake whitefish, and pickerel due to both declines in their abundance and increased prevalence of diseased fish; a decline in gathering opportunities for blueberries; and an overall decline in the amount of traditional foods consumed by communities members as a result of these declining opportunities to harvest them.

As a non-remote community that is in relatively close proximity to one of the region’s main services centres, most community members have good physical and financial accessibility to market foods, therefore food security is not expected to be significantly affected by declines in harvest opportunities (although this may vary between individuals depending on their own circumstances). However, the physical, mental, emotional, and spiritual well-being of community members (current and future generations) may be substantially impacted due to declines in physical activity associated with harvesting activities, losses in the nutritional benefits of traditional foods, loss of traditional knowledge and intergenerational sharing of this knowledge, and loss of spiritual connection to the land and traditional foods.

Some proposed adaptation strategies have been suggested within the literature and from community members in this study to address changes in traditional foods and impacts on harvests. These included harvesting new or more abundant species to substitute others that are declining (e.g., choosing to hunt deer instead of moose), practicing good stewardship of important traditional food species, increasing the use of new equipment and technology to access harvesting areas, and adopting better natural resource management practices that help conserve traditional food species and ecosystem vitality, such as avoiding clearcutting important habitats and substituting the use of herbicide sprays with prescribed burns to manage vegetation growth.

Here I offer some suggestions for future research that might be highly beneficial to expand the understanding the impacts of climate change on Indigenous communities’ livelihoods and health in Northern Ontario. First, conducting additional community-level studies investigating climate change impacts will allow these communities to better understand how they might be uniquely affected and build adaptive capacity suited to their own needs. In addition, these studies might help address small-scale differences in climate change effects across the region that cannot be achieved with regional climate change models, such as with changes in precipitation regimes. Secondly, including Indigenous perspectives in studies projecting climate change effects will further contribute to this understanding, particularly for subjects already known to be affecting communities such as changes in ice regimes or important traditional foods. Indigenous perspectives may also offer insights of how these changes might affect the well-being of community members regarding all aspects of health. Finally, some subjects that are lacking in the literature for Northern Ontario may be of interest for future research: occurrences of waterborne illnesses, droughts, and floods; changes in the abundance of traditional foods such as waterfowl, game birds, small mammals, berries, and other food plants; the relationship between climate change and the health or vigour of traditional foods; and Indigenous perspectives of alternatives to winter roads like the construction of all-season roads, and potential effects of these alternatives on health, lifestyles, and economies within presently remote communities.

It has been demonstrated that the most pressing concerns of climate change effects on Indigenous communities of Northern Ontario will likely exacerbate existing issues such as food and nutrition, clean water, and energy insecurity, poor access to medical services, and inadequate housing and other infrastructure, especially for remote communities. Therefore, it is recommended that addressing these issues become a priority among all levels of government (e.g., community-level to federal-level) so that communities will have strengthened adaptive capacity to respond to the effects of climate change in the coming years, and the most severe negative outcomes are minimized.

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