The Northern Climate ExChange
Gap Analysis Project

Overview Report

Northern Climate ExChange
Northern Research Institute
Yukon College
Box 2799, 500 College Drive
Whitehorse, Yukon Y1A 5K4

Acknowledgements

The Northern Climate Exchange would like to extend its gratitude to the agencies and individuals whose contributions have made this project possible.

The project team consisted of representatives from a number of agencies, including:
Environment Canada
University of Alberta
Ryerson University
LegendSeekers Anthropological Research
GeoNorth Consulting

The project received funding from:
Government of Canada (Climate Change Action Fund)
Environment Canada - Canadian Wildlife Service (Yukon Region)
Government of Yukon
Yukon College

Cover photograph by Paul Gowdie
Other photographs courtesy of Yukon Government
Design and production by Leaf Solutions

Executive Summary

Beginning in 1999, the Northern Climate ExChange (NCE) coordinated a major project aimed at assessing the current state of knowledge about climate change and its impacts in northern Canada. With Environment Canada as its main partner, and with consulting help from the University of Alberta, Ryerson University, GeoNorth Limited, and LegendSeekers Anthropological Research, NCE set out to meet several major objectives, with an overall goal of determining where information on climate change is adequate and where there are gaps.

The NCE Gap Analysis Project has created several products that offer an assessment of the state of knowledge on climate change in northern Canada:

- The Infosources Database, a searchable on-line database of published climate change research related to the Canadian North, with some broader information about climate change in northern regions;
- The Directory of Contacts, an on-line database where people involved in or interested in climate change issues can self-register and make contact with others;
- A set of matrices or tables, accessible through a graphical interface called the Matrix Maker, that rate the level of available information about climate change as it relates to a range of natural, economic, and community systems;
- The report of a workshop on climate change research and priorities;
- Two reports assessing the level of documented local and traditional northern knowledge about climate change;
- Two reports assessing the completeness and value of the Infosources Database;
- The NCE Knowledge Site, an Internet resource containing most of these products, and more; and
- This overview report.

All products are available in this report, on the accompanying CD-ROM, or on the Internet through the Northern Climate ExChange web site at www.taiga.net/nce.

In general, the NCE Gap Analysis Project revealed:

- Inequalities in the amount of existing information across systems;
- Greater knowledge and confidence concerning baseline information and predicted temperature changes than for other climate components;
- Strong regional trends for compiled information, with some regions well studied and others barely touched;
- Relatively little local and traditional knowledge about climate change documented;
- More information about climate change impacts on biological systems with an economic component than those without obvious economic significance.

Table of Contents

Contents of CD-ROM:

- On-line Survey
- *An Assessment of Documented Traditional and Local Knowledge and Perspectives on the Impacts of Climate Change within Nunavut Territory, the Northwest Territories, Northern Alberta, Manitoba, Ontario, Quebec and Labrador*, GeoNorth Limited, Yellowknife, NWT
- *An Assessment of Documented Yukon First Nations Traditional and Local Knowledge and Perspectives on the Impacts of Climate Change within the Yukon Territory and Northern British Columbia*, LegendSeekers Anthropological Research, Whitehorse, Yukon
- *State of Knowledge – Impacts of Climate Change on Human Activity*, Frank Duerden, Ryerson University, Toronto, Ontario
- *State of Knowledge – Impacts of Climate Change on Biophysical Systems*, David Hik, University of Alberta, Edmonton, Alberta
- *A Northern Assessment of the Impacts of Climate Change: Defining our Knowledge Base and Research Priorities*, the report of a workshop held in Whitehorse, Yukon, September 20-21, 2000
- Links to Internet locations of
    - The Matrix Maker/Matrices
    - The Infosources Database
    - The Directory of Contacts
    - The NCE Knowledge Site

1 Introduction

Climate change is not a new concept. It began to be a public issue in the 1970s, was largely ignored during the 1980s, but has since moved to centre stage as a global issue. This is particularly true in the North, where climate change has become more a current issue than a future concern. The impacts of climate change are expected to be most extreme in the high latitudes of the world, and to affect these areas first. Indeed, some climate-related changes are already noticeable.

Because residents of northern Canada are seeing increasing evidence of climate change and experiencing the effects firsthand, their observations about these matters are a valuable resource. People living in small remote communities often have intimate knowledge of the climate, of changes that they have already observed, and of the potential impacts of climate change. As well, northerners want more information on climate change so that they can be prepared for what the future might hold.

Government agencies, universities and non-governmental organizations have already initiated many climate change research and monitoring projects in Canada and elsewhere. Individual communities, particularly in the North, are beginning to undertake their own projects related to climate change. Circumpolar organizations and indigenous peoples are taking their concerns about the impact of climate change to the world stage.

The substantial increase in climate change research in the past decade has made it difficult for researchers to keep track of all the various projects related to understanding, preventing, and mitigating climate change impacts. This situation has almost certainly led to overlapping research, unnecessary duplication of effort, and ineffective use of limited time and resources. In addition, there has been no overall vision guiding the allocation of efforts and resources.

Communication has been limited among the various groups and organizations involved in and concerned about climate change: researchers, communities, indigenous peoples, non-government organizations, industry, and many levels of government. This has made it difficult to exchange information, to correlate scientific knowledge and local information, and to return the results of research to the people experiencing the effects of climate change most directly. Sharing information among all of these different parties and interest groups can be a challenge, but it is essential. When knowledge is not shared, everyone's understanding of climate change and its impacts is diminished.

Project Objectives

Beginning in 1999 and carrying on into 2002, the Northern Climate ExChange (NCE) coordinated a major project aimed at assessing the current state of knowledge about climate change and its impacts in northern Canada. With Environment Canada as its main partner, and with consulting help from the University of Alberta, Ryerson University, GeoNorth Limited and LegendSeekers Anthropological Research, NCE set out to meet several major objectives:

- Determine what is currently known about climate change and its impacts in northern Canada, and incorporate this information into a database;
- Identify trends or patterns in the available information;
- Use this information to help identify research, monitoring, technological, and policy priorities; and
- Improve collaboration and coordination among and between researchers, communities, governments, non-government organizations, and residents of northern Canada.

The overall goal was to determine where information on climate change is adequate and where there are gaps. Documenting existing knowledge will provide sound baseline information on what is known about climate change and its effects on northern Canada. This information will assist those attempting to establish priorities for climate change research, monitoring, technological development, policy development, and other matters in Canada's North. It will also help to facilitate links between different people and organizations working towards similar goals.

Many individuals and organizations have helped in this project by sharing their knowledge and their ideas about how to proceed. The breadth of knowledge and diversity of perspectives represented by these different groups greatly strengthened the overall assessment.

This Report and CD-ROM

The purpose of this information package – the overview report itself and the CD-ROM attached to the back cover – is to deliver most of the fundamental information and products of the NCE Gap Analysis Project in a flexible and convenient form.

The report itself provides an overview of the project, the products, and the conclusions reached. The Internet addresses of the two on-line databases that are an integral part of the project are included in the text where the databases themselves are explained. Because the databases and the Northern Climate ExChange web site are, in themselves, vital appendices to this report and the project, their addresses are also listed on the report's title page.

The CD-ROM contains the full texts, along with bibliographies, of the four reports commissioned for this project:

- *An Assessment of Documented Traditional and Local Knowledge and Perspectives on the Impacts of Climate Change within Nunavut Territory, the Northwest Territories, Northern Alberta, Manitoba, Ontario, Quebec and Labrador*, GeoNorth Limited, Yellowknife, NWT
- *An Assessment of Documented Yukon First Nations Traditional and Local Knowledge and Perspectives on the Impacts of Climate Change within the Yukon Territory and Northern British Columbia*, LegendSeekers Anthropological Research, Whitehorse, Yukon
- *State of Knowledge – Impacts of Climate Change on Human Activity*, Frank Duerden, Ryerson University, Toronto, Ontario
- *State of Knowledge – Impacts of Climate Change on Biophysical Systems*, David Hik,

University of Alberta, Edmonton, Alberta

- *A Northern Assessment of the Impacts of Climate Change: Defining our Knowledge Base and Research Priorities*, the report of a workshop held in Whitehorse, Yukon, September 20-21, 2000

On the CD-ROM you will also find a copy of the original on-line survey used in collecting information and opinions about the state of climate change research.

Finally, the CD-ROM contains links to the Internet location of the Matrix Maker, a graphical interface linked to the matrices used to evaluate the state of knowledge about climate change in northern Canada, to the two databases associated with the NCE Gap Analysis Project – the *Database of Climate Change Information Sources for Northern Canada* and the *Directory of Contacts for climate change in the Canadian North*, and to the NCE Knowledge Site. Since the databases, the matrices, and the Knowledge Site are updated periodically, they are best used on the Internet where the latest versions are available.

2 Tools and Methods

From the beginning of this project, we were aware that a great deal of information about climate change in the North already existed, in a range of forms from local information held by northern residents to large multidisciplinary scientific research programs. Finding the best ways to collect and synthesize this information has been an organic process that has evolved as the project progressed.

Literature Review

Our first step was a review of all the documented information that we could find about climate, climate change, and its potential impacts in northern Canada. Information sources included journal articles, conference proceedings, databases, public lectures, researcher/expert surveys, research licence compendia, Internet sites, and experts from governments, universities and communities.

We also prepared a survey and distributed this to people involved in the realm of climate change research and knowledge, asking questions focused on the state of knowledge in their area of expertise.

Databases

Two databases are part of this project, both as tools and as products. They are the *Database of Climate Change Information Sources for Northern Canada* (referred to hereafter as the Infosources Database) and the *Directory of Contacts for climate change in the Canadian North* (referred to hereafter as the Directory of Contacts). Both are accessible through the Northern Climate ExChange web site (www.taiga.net/nce) and have become fundamental resources for the NCE.

The **Infosources Database** was begun in the mid-1990s as part of the Canada Country Study. It has been updated periodically since then, including in the course of this project, and continues to be updated frequently. The database is a compilation of published information and data related to climate change in northern Canada and in the broader circumpolar North. In general, the references have been collected through searches of standard reference indices, academic libraries, and Internet resources.

The **Directory of Contacts** is a database of people active or interested in the field of climate change study for northern Canada. This is not a comprehensive listing of experts since it relies entirely on self-registration. Instead, it is a guide to people who have expertise and interest in climate change issues in the North and who wish to get in touch with others working in the field.

Traditional and Local Knowledge Assessments

Since our initial literature review identified a bias towards information from scientific sources, independent surveys of documented local and traditional knowledge about climate change and its impacts were commissioned. GeoNorth Limited of Yellowknife examined information from Nunavut, the Northwest Territories, Labrador, and the northern regions of Alberta, Manitoba, Ontario, and Quebec. The Whitehorse-based firm, LegendSeekers, analyzed documented sources from the Yukon and northern British Columbia.

Northern Knowledge

Although the NCE Gap Analysis is primarily a literature review, we attempted as far as possible to test the results of that review against the knowledge of northerners and experts on the North. This input was gathered in a number of ways, including two workshops, a community tour, expert reviews of products, and an on-line survey, delivered through the NCE web site. Summaries of recommendations and responses arising from the workshops and community tour are included in Chapter 3 of this overview report. The on-line survey and the initial invitation to participate in it are reproduced on the accompanying CD-ROM. The results of the survey are incorporated into other products of the project.

Matrices

As indicated earlier, a huge amount of existing information was found on climate and climate change in northern Canada. In order to evaluate the quality of this information and identify gaps, we organized a subset of the information into 17 matrices or tables. One shows baseline data; the other 16 represent different natural, economic and community systems important to the North. The matrices include information from both a subset of the Infosources Database and from the two reports on traditional and local knowledge.

Figure 1: Systems represented in matrices

Natural Systems	Economic Systems	Community Systems
• Boreal	• Agriculture	• Community Health
• Freshwater	• Fisheries	• Energy Development
• Tundra	• Forestry	• Infrastructure
• Coastal	• Hunting and Trapping	• Transportation
• Marine	• Mining	• Waste Management
	• Tourism and Recreation	

These matrices are the central tool of the state of knowledge assessment. Main components of each of the systems were identified, and listed in the table rows. Listed in the columns are three aspects of climate change – temperature change, precipitation change, and other climate and indirect impacts – as well as the baseline matrix, which does not take climate change into

account. We examined the cross-relationship between these components and the general climate change projections, assessing the current state of knowledge for each of them. The draft matrices were sent out to experts and posted on the NCE web site for review of their accuracy and completeness. More detail about our methods and results can be found in Chapter 3 of this report.

Independent Reviews

Two independent reviews of the information contained in the Infosources Database were commissioned from respected academics. One evaluated the completeness of the database with respect to data on climate change and human activity in northern Canada. The second review addressed the completeness and usefulness of data related to the biophysical aspects of climate change.

3 Results and Products

The information developed in the course of the NCE Gap Analysis Project is available in a variety of formats so that as many people as possible can use it.

- The Infosources Database is available on the Internet, as is the Directory of Contacts. To find links to both databases, go to www.taiga.net/nce or activate the link on the CD-ROM accompanying this overview report.
- Reports about the workshops and the community tour are available in print from the Northern Climate ExChange or in downloadable format from the NCE web site at www.taiga.net/nce/projects.html.
- All products from this project are available on or through the NCE Knowledge Site, which is part of the NCE web site.
- The four reports commissioned directly for this project, along with the report of the workshop held as part of the project, are on the CD-ROM accompanying this overview report.
- The matrices can be viewed using our Matrix Maker. A link to the Matrix Maker is on the CD-ROM included with this overview report

The goal of distributing the material as widely as possible is to improve collaboration and coordination among researchers, local communities, organizations, and governments.

In this chapter, you will find a summary of each of the products created in the course of the Gap Analysis Project, along with an explanation of how the products were created. Also summarized below are the results of the workshops, community tour, and other background work.

Databases

Two databases were used as tools in the course of the NCE Gap Analysis Project. In the course of the project, both databases have been refined and expanded. They continue to grow and will serve in the future as important tools in directing and conducting climate change research.

Infosources Database

Currently, in the spring of 2002, the Infosources Database contains just over 1800 records, including conference proceedings, journal articles, books, theses, data collections, and information published through less traditional methods like videorecording or the Internet. Wherever possible, abstracts or summaries of the information are provided either directly or through hypertext links to the originating sources. The database is not static but continues to be updated and expanded frequently. The most recent version is available on the Internet at http://yukon.taiga.net/infosources/.

As well as scientific information, the Infosources Database includes documented sources of traditional and local knowledge on climate change. Many of these sources were added as a result

of two reports produced in the course of the NCE Gap Analysis Project. The LegendSeekers report provided sources from the Yukon and northern British Columbia, while the GeoNorth report provided documented sources from the Northwest Territories, Nunavut and the northern provinces. Both reports are summarized later in this chapter. The full versions of the reports, along with bibliographies, are reproduced on the CD-ROM accompanying this overview report.

The Infosources Database is searchable as a whole or by region. Although the focus is on northern Canada, some references applying to Alaska and northern Europe are included, and it is possible to search by those regions as well. Information providing a broader perspective on climate change science, without regional focus, is also catalogued and is best found through searching the database as a whole. A second search level offers searches by category, key word, or format, either within the regional results or through the database as a whole. Further refinements of the search engine will be added in the future.

Each record in the database includes information in the following categories, wherever relevant or available:

- Title
- Author/content
- Agency
- Publishing information
- Time span
- Date published
- Format
- Keyword(s)
- Region
- Web site
- Summary
- Comments (including information on where the record can be found, if available)

The database confirms that a large amount of information already exists on climate change impacts in northern Canada, and that research has taken place in many different regions on a wide range of topics. The sources and types of knowledge in the database include scientific, local and traditional knowledge, modeling, monitoring, field experiments and paleoclimate information. Not all of the records in the database were used in the gap analysis as information was often repeated in different formats.

Figure 2: Infosources Database records by region (March 2002)

Region	Number of Records
Yukon	148
North Yukon	80
Central Yukon	16
Southwest Yukon	49
Southeast Yukon	11
NWT	271
Nunavut	216

Northern Provinces	131
Hudson Bay	62
Northern Quebec/Labrador	78
Mackenzie Basin	154
Western Arctic	45
Central Arctic	39
Eastern Arctic	69
Greenland	21
Alaska	130
Northern Europe	25

Note: Many entries refer to more than one region.

Figure 3: Infosources Database records by category (March 2002)

Category	**Number of Records**
Climate	1478
Coast/marine	388
Fresh water	517
Human activity	408
Land	907
Studies	694
Wildlife	316

Note: Many entries refer to more than one category.

Directory of Contacts

In the course of the NCE Gap Analysis Project, a searchable on-line database of contacts in the field of climate change study for northern Canada was developed. The Directory of Contacts is based on self-registration via a sign-up screen accessible through the Internet at http://yukon.taiga.net/contacts. Currently, in March 2002, the database contains 113 entries, including both individuals and institutions.

The Directory of Contacts can return a full listing or it can be searched by name, field of interest, or region of interest. When registering, contacts fill out as much or as little information as they choose under the following headings:

- Name
- Organization/affiliation
- Contact information (address, phone, fax, e-mail)
- Field(s) of interest
- Geographic region(s) of interest
- Notes

The Directory of Contacts is a continuing work in progress and is intended to serve as a vehicle to help people in a variety of fields and organizations work together.

Northern Knowledge

The Northern Climate ExChange conducted two workshops and a community tour, all in the Yukon, during the period when the NCE Gap Analysis Project was underway. While only the workshop was explicitly part of the project, all of them produced useful observations and recommendations related to the state of climate change research and directions it should take in the future.

Workshop: Taking Action on Climate Change in the Yukon

During this May 2000 workshop, a breakout group on Research and Monitoring addressed topics particularly relevant to this report and to the NCE Gap Analysis Project. The group reported the following general comments or recommendations:

- The Northern Climate ExChange should be a catalyst for climate change knowledge and awareness in the Yukon.
- All products should be made accessible in a variety of formats, for a range of audiences.
- Continuity of the Northern Climate ExChange is expected and assumed.

The workshop group recommended creating an index of available data sets on climate and environmental change. The index would be made available in paper, electronic and web-based versions. The participants also recognized the degree to which government cutbacks over the past few years have affected monitoring and collection of data.

The group also recommended a number of ways in which the NCE could help promote partnerships. The suggestions included creating a database of experts, helping researchers communicate with one another, and building on scientific, local and traditional knowledge.

Finally, community-based research and monitoring was identified as a priority, and it was recommended that the NCE should help facilitate efforts in this area.

Community Tour: ExChanging Ideas on Climate Change in the Yukon

This community tour, undertaken in the summer of 2000, was designed to gauge how much people living in Yukon communities already knew about climate change. It was also meant to identify local issues, observations, and concerns related to climate change.

The tour showed clearly that climate change is no longer an abstract idea for many Yukoners. They are aware of the issue and often concerned about its impacts. However, public opinion varies both on how serious the issue is and on what to do about climate change. Some of the opinions heard on the tour include:

- “I am overwhelmed by conflicting information.”
- “It is going to happen anyway.”
- “It is going to be very hard on us.”
- “There is nothing I can do.”

- "Northerners aren't the cause of the problem."
- "It is not as bad as they say."
- "Some technology will be developed to fix the problem."

The tour confirmed that there is already a tremendous amount of local information on climate change, but little of it is documented. People have a wealth of anecdotal observations about the changes that they have observed. Many individuals are disturbed by what they consider to be severe climatic and ecological changes, describing them as unprecedented.

However, people had more questions about climate change than answers. Many individuals lamented the lack of studies addressing the probable impacts of climate change at local and regional levels, and that even fewer studies provide guidance on how to adapt to a changing environment.

Observations and concerns on climate change vary among communities. Subtle local and regional differences indicate that climate change will impact communities in different ways because of variations in culture, economy, and location.

Community observations of the impacts of climate change sometimes match the climate-model predictions, but not always. While both models and anecdotal information indicate that the Yukon climate is indeed changing, local knowledge tends to provide greater detail on local conditions and more context on local concerns.

Local observations on climate change are extremely valuable in helping to pinpoint areas for research. People who are close to the land can supply valuable information, particularly since even the most sophisticated computer models still lack local-scale climate data.

Finally, local communities are best positioned to understand and assess their own vulnerability to climate change and, therefore, define what should be done to address changing conditions at the local level. Community participation in research and decision-making is essential to long-term resource, environmental, and cultural sustainability.

Workshop: A Northern Assessment of the Impacts of Climate Change: Defining our Knowledge Base and Research Priorities

The following recommendations arose from this September 2000 workshop:

- Formalize a means for adding new records and information to the system (i.e. add a form to the website);
- Provide regular updates to communities when new relevant information is available, and provide some means for non-electronic distribution of information;
- Formalize a system by which communities can look for undocumented sources of information and discuss new issues/current events;
- Record case studies of how northern communities are responding to impacts of climate change;
- Provide checklists of climate-related considerations for communities (i.e. decision support

tools or a resource guide for communities to aid in long-range planning exercises);
- Keep track of information needs and formalize a system to document and distribute;
- Expand current NCE mailing list to a discussion list for assisting those who are looking for non-documented sources of information and soliciting feedback on current events and significant issues;
- List observations from NCE community tour on website in order to match community questions with researchers and to assist communities with similar issues to get in touch with each other;
- Provide an opportunity to keep track of people's questions, related to climate change, for which they have not been able to find information;
- Include recommendations for policy mechanisms within the final report;
- Include case studies or pilot projects on northern communities that are developing or implementing adaptation strategies;
- Include guidance on "what we should be doing" re adaptation and prevention;
- Describe the state of knowledge by sub-regions (traditional territory) as well as by natural and human systems;
- Provide a list of codes, standards and regulatory processes in place in the north where climate change should be considered (e.g. the Development Assessment Process);
- Provide a list of where we need to regain monitoring capacity and on what; and
- Identify collaborative research opportunities.

This workshop provided an opportunity for Northerners to learn more about climate change, and to help develop a regional response to minimizing vulnerability to its impacts. The aim was to initiate community involvement in order to address the evolving needs of northern communities, industries and governments in response to this issue. Some of the recommendations arising from the workshop have been incorporated into the NCE Gap Analysis Project. Others have been addressed through other NCE programs or media. Still others will be addressed as time and resources permit.

Traditional and Local Knowledge

People living in the North are already noticing differences in their environment related to climate change, including melting permafrost and changes in vegetation and wildlife. These direct observations add an important dimension to our understanding of climate change.

In two separate reports, commissioned for the NCE Gap Analysis Project, researchers surveyed documented sources of traditional and local knowledge on the impacts of climate change in northern Canada. The reports' compilers searched the Internet for references to traditional or local knowledge of climate and climate change. In addition, they searched sources such as existing databases, academic publications, conference papers, and video archives. As well, they contacted 52 northern experts for information, receiving 17 replies.

A quick summary of the findings in the two reports appears below. Both reports, with full bibliographies, are on the CD-ROM accompanying this overview report.

GeoNorth Limited of Yellowknife produced a report entitled *An Assessment of Documented Traditional and Local Knowledge and Perspectives on the Impacts of Climate Change within Nunavut Territory, the Northwest Territories, Northern Alberta, Manitoba, Ontario, Quebec and Labrador*. The authors were able to identify only 74 sources of documented information. These were used for a gap analysis applying the following criteria: region, format/medium, keyword, content, continuity, duration as of 2000, regional extent, and type of information.

The low number of sources clearly indicates the need for further research on local and traditional knowledge. There is so little documented information that it is difficult to assess whether specific areas of concern are understood poorly or adequately. Also, much of the existing documentation comes from larger sources or general reports on climate change and is incidental or descriptive rather than specific. Some regions have better documentation than others because they are home to regional "hot spots" for climate change research, such as the Mackenzie Basin.

LegendSeekers Anthropological Research of Whitehorse produced a report called *An Assessment of Documented Yukon First Nations Traditional and Local Knowledge and Perspectives on the Impacts of Climate Change within the Yukon Territory and Northern British Columbia*. Primarily the authors reviewed written publications that were based on oral history. This fairly broad search found little in the way of specific information on current patterns of climate change, though information on climate in earlier times is available. As in the previous report, the authors strongly support the need for oral history research on climate change topics.

The Matrices

The matrices, or tables, are the primary tool used in the NCE Gap Analysis Project to assess the distribution of existing research about climate change and to identify weak areas of coverage. They are based on a subset of the information in the Infosources Database, including references to local and traditional knowledge collected in the two reports, referenced above, which were prepared specifically for the NCE Gap Analysis Project. The completed matrices are on the Internet (see the CD-ROM accompanying this overview report for the Internet address), and accessible through a graphical interface called The Matrix Maker.

How the Matrices Work

There are 17 matrices, one showing baseline data and the other 16 based on different natural, economic and community systems important to the North. The main components of each of the systems were identified, and listed in the rows of the table. For example, the boreal matrix lists eight components: distribution, vegetation, mammals, birds, terrestrial invertebrates, carbon cycling, water and nutrient cycling, and permafrost and land stability. Listed in the columns are baseline knowledge (excluding climate change), impacts of temperature changes, impacts of precipitation changes, and other climate and indirect impacts (such as increased cloudiness or increased storm frequency).

Figure 4: Sample lay-out of matrix

Boreal Component	Baseline Knowledge	Impacts of Temperature Changes	Impacts of Precipitation Changes	Other Climate & Indirect Impacts
Distribution				
Vegetation				
Mammals				
Birds				
Terrestrial invertebrates				
Carbon cycling & nutrient cycling				
Water & nutrient cycling				
Permafrost & land stability				

We examined the cross-relationship between the components and the general climate change projections, assessing the current state of knowledge for each of them. The cells at the intersection of the rows and columns were filled in with information supporting this assessment (e.g. the impact of temperature changes on boreal forest distribution, or the current baseline knowledge of water quality). The information in the cells of the completed matrix includes the type of knowledge, location of studies, and time span of research, as well as current deficiencies in knowledge. It does not include information on how system components will be impacted by the predicted climate changes.

Each cell was also assigned a ranking of Good, Fair or Poor to denote the current state of knowledge of the specific topic/relationship. The rankings were assigned as consistently as possible, according to a standard protocol. Each ranking is based on the following sets of questions, relating to the three types of information found in the matrices:

- Does the existing knowledge allow for a solid understanding of this system component?
- With the existing knowledge and capacity, can we detect a change in this climate variable and confidently predict future changes?
- Is the mechanism by which the climate parameter influences the system component understood?

When appropriate, we also asked a number of more specific questions such as:

- Overall, is the existing knowledge applicable across Northern Canada?
- Is the existing knowledge mostly current?
- Has the research generally taken place over a sufficient period of time for detection of trends?
- Does most of the existing knowledge originate from and agree with a variety of sources, such as community experts, scientists, and government monitoring programs?

Based on this protocol, matrix cells were assigned rankings of *Good* (all of the applicable

questions could be answered yes), *Fair* (several but not all of the questions could be answered yes), or *Poor* (one, two, or none of the questions could be answered yes). In some cases we were unable to find any information regarding a system component and its possible response to climate change, making it impossible to determine a ranking. In such cases, the statement "no information compiled for this relationship" was inserted into the cell.

The draft matrices were then sent out to experts and posted on the NCE website for review of their accuracy and completeness. In the final version of the matrices, the rankings are colour-coded as a quick visual guide to the state of knowledge for each system.

Figure 5: Sample cell from Boreal matrix

Topic: Boreal

COMPONENT	CLIMATE ASPECT: Impacts of Temperature Changes
Mammals	**State of Knowledge: FAIR** - Study of marten, red fox and lynx in Mackenzie Basin under different fire regimes; relevant to predicting impacts of climate change (33) - Some study of forest fire effects on moose and snowshoe hare (26) - Observation by biologists and locals of species expanding their range northward in Yukon - (i.e. mule and white-tailed deer, elk and cougar) (65) - Some information on winter tick range moving north; much information for northern Alberta and B.C., less for Yukon (42); fair bit of study in Alberta on how they respond to temperature; range of tick surveyed in late 80s to determine temperature controls (8,37,65)

The rankings do not imply judgement on whether a topic area needs further research. They are solely based on the amount and quality of existing information. The rankings also do not indicate whether the predicted impacts of climate change on a system component are likely to be positive or negative.

Patterns Emerging From the Matrices

In general, analysis of the matrices shows that current information concerning northern systems, predicted climate changes, and the impacts of those changes on northern systems is poor. Although the number of references in the Infosources Database is substantial, many make only a passing reference to climate change. Impacts at the regional scale are very poorly understood and studies are not evenly distributed across the North. However, despite the lack of quality information in many areas, some general patterns do emerge from the extensive amount of

existing information.

Climate parameters: Temperatures and potential temperature changes are better understood than are precipitation and extreme events. Our more complete understanding of temperature regimes has provided greater confidence when predicting temperature changes versus changes in other climatic variables.

Climate monitoring: While existing climate stations give a fair picture of the entire North, they are widely distributed and information cannot be reliably extrapolated to specific regions. Efforts have been made to understand northern systems and to predict impacts in them, but these exercises have often used information extrapolated from studies conducted elsewhere, such as in temperate areas.

Ecological monitoring: Monitoring networks for such physical parameters as climate and hydrology need to be expanded to provide more accurate and site-specific baseline information regarding climate and physical conditions in northern Canada. Expansion will aid in the development of finer-scale regional circulation models that are better able to predict climate change and its impacts in northern areas.

System-level understanding: Most climate change research has focused on the physical environment, meaning features such as land, permafrost, and coastlines. We are better able to predict changes in physical systems than in biological systems or socio-economic ones. In general, complex systems that are influenced by many variables are more poorly understood than simpler systems. In addition, existing knowledge tends to be focused more on economically-significant system components, such as commercial fisheries and fish species, than on non-economic system components, such as general fish ecology. Finally, terrestrial ecosystems have received more research attention than have marine or aquatic ecosystems.

Socio-economic systems: The socio-economic impacts of climate change have received the least amount of research attention. In fact, most of the documented information on this topic merely confirms the lack of knowledge in this area.

Geographic distribution: The gap analysis revealed that information and research on climate change varies by geographic region and, in general, is sparse and unevenly distributed. For instance, the impacts of climate change on physical systems such as permafrost have received more study in the western Arctic (Alaska, the Yukon and Mackenzie Basin) than in the eastern Arctic (Nunavut).

Local and traditional knowledge: A great deal of local and traditional knowledge about climate change impacts exists, but relatively little of it has been documented. Traditional information about climate change can complement scientific information, offering a more regional, more holistic, and longer-term perspective. Local information and local experience can provide a level of regional detail beyond the capacity of current scientific models and analyses.

Interest in building partnerships among scientists, First Nations, and northern communities has increased in the past couple of decades, and most of the documented local and traditional

knowledge has been collected in regions where scientific research has been focused. Information about climate and climatic events such as floods, and extreme heat or cold is often included in such research, but it tends to be embedded in the written material about other topics and is consequently not easily found.

Harvesting: In northern Canada, with a few notable exceptions, only general studies of native harvesting exist. Few of them analyze locally harvested populations, and even fewer make connections between climate change and hunting success. Studies that have collected locally relevant information related to climate change include research on the Porcupine and Bathurst caribou herds. For these herds, the connections between changes to the land and impacts on harvesting are understood. Less is known about how climate change could affect the population dynamics, nutritional status, and economic systems of small communities.

Mining: It is recognized that climate change could affect both the operation and decommissioning of mines in the north. For example, there are concerns about the effects of increased precipitation and melting permafrost on mine tailings ponds. Very little serious research has been conducted in this area.

Hydrology and energy: The impacts of climate change on hydrology regimes have been investigated. Studies in the Mackenzie Delta-Beaufort Sea area looked at the possible impacts of climate change on offshore oil and gas exploration. In northern Quebec research has been conducted on the links between climate change and hydropower.

Sea ice: Sea ice plays a very important role in the North, affecting both its ecology and the northern way of life. While navigation in the Arctic Ocean might become easier if sea ice decreases, other possible effects are not well understood. There is little scientific agreement on how factors such as temperature, storms, and wave regimes could affect sea ice. Satellite photos have provided reliable information on ice extent and distribution over the past three decades. However, the thickness of ice and its physical and chemical properties are less well known. Many forms of marine life depend on sea ice for their survival and reproduction, but most studies have focused on how decreasing sea ice would affect larger animals such as ringed seals and polar bears. Little research has been done on smaller organism such as ice algae.

River and lake ice: Thinner ice has made winter travel across frozen lakes and rivers notably more difficult, whether traveling on foot, by snowmobile, or by ice road. This trend may be expected to continue. In the past, local knowledge of ice conditions has been invaluable, but environmental changes may make this source of expertise less reliable in the future.

Integrated studies: Long-term, regionally focused studies of climate change and its impacts on northern systems are scarce. The Mackenzie Basin Impact Study shows the value of regional studies that use various sources of knowledge and integrate systems. This one study added greatly to our understanding of climate change and its impacts in northern Canada, and provided a disproportionate amount of information for the gap analysis. Another example of this inclusive approach is the Northern Rivers Basin Study (Peace and Athabaska Delta). This type of work would be valuable for other northern regions as it provides a way to track trends and interrelationships, and includes social, political and economic perspectives.

Independent Reviews

The NCE Gap Analysis Project included two independent reviews of the contents of the Infosources Database. Professor Frank Duerden of Ryerson University in Toronto addressed the completeness of the references to human activity. Dr. David Hik of the University of Alberta in Edmonton looked at biophysical aspects.

Report: State of Knowledge – Impacts of Climate Change on Human Activity

Professor Duerden's report reviewed references to human activity in relationship to climate change in the Infosources Database at a time when the database contained 456 references to papers, books, statistics and research reports relevant to the question of climate change in northern Canada. Of these, 106 – or almost one-quarter – addressed some aspect of human activity. Although additional references were sought from a wide range of sources, including an Internet request aimed at the scientific community, very little new material was found at that time. Since then, however, the database has been expanded substantially.

For purposes of the review, human activity was defined broadly as economy and land use. References to human activity were included in the analysis only if they contained some discussion of the implications of climate change on the activity. This condition greatly reduced the possible number of sources, eliminating many that referred only to the impact of human activity on the climate. The remaining references were divided into various activities involving land use, economic impacts, infrastructure/community, or hazards and extreme events.

The review recognized the need for certain specific types of information to answer pragmatic questions such as how harvesting might be affected by climate change or whether melting permafrost will affect construction. The database was evaluated for completeness and for whether it provided the type of information needed for action or decision-making. The ease with which information could be retrieved was also evaluated.

Understanding the impact of climate change on various activities is very difficult, as the relationships are complex and interdependent. In general, the content analysis found that many of the studies were highly speculative and dogged by uncertainty about the nature and impact of climate change in the North.

Virtually nothing in the literature reviewed explicitly addressed the question of strategies for dealing with uncertainty. A tendency towards very general works was also noted. Only slightly more than half of the references (55) predict impacts in any sort of specific or rigorous manner. This lack of information partly reflects the fact that many works focus primarily on changes in the physical environment and references to human activity are secondary. These shortcomings present a particular problem for decision-makers in communities that need to address change.

Geographically, western regions had a disproportionately high number of entries in the database.

More than 40 percent of the place-specific references were for the Yukon. The Mackenzie Basin Impact Study generated numerous references for its region. However, Nunavut had relatively few entries at that time. Moreover, the majority of references are not specific to a region but deal with a broader area such as "the Arctic."

The review found that the NCE bibliography was a relatively good inventory of available information (and the number of references in the database has roughly quadrupled since the time of this review). Overall, however, quality information relating human activity and climate change impacts in northern Canada was found decidedly lacking. Currency was also an issue. Only 45 citations had been produced in the five years immediately preceding the evaluation, and most came from projects centred on climate change impacts in the western Arctic. There was also a decided lack of specific information as virtually nothing in the literature reviewed explicitly addressed the question of strategies for dealing with uncertainty.

Information needs and research priorities identified in the report:

- Most sources deliver a prevailing message of uncertainty about the impacts of climate change in the North. Strategies for dealing with uncertainty need to be addressed.
- Information from local sources such as land claims documentation should be made accessible to provide baseline information.
- Just as traditional knowledge from First Nations adds to our understanding of climate change, so could information from other northern practitioners and decision-makers in sectors such as transport and construction. Their needs and levels of knowledge should be identified.
- More geographically precise information is needed, and community-specific databases are needed.
- More information is needed on climate-change-related risks posed to communities, such as floods, landslides, and breakdowns in communications systems.
- Integrated regional studies, like the Mackenzie Basin Impact Study, should be encouraged.
- Because the process of change could be very specific to certain regions, information extrapolated from other environments will not necessarily be useful.

Report: State of Knowledge – Impacts of Climate Change on Biophysical Systems

This report was conducted at a time when the Infosources Database contained just over 450 entries relevant to the biophysical systems. The review focuses primarily on entries concerned with climate variability resulting from natural processes and human activity, ecological and physical impacts of these changes in the North, and vulnerability of natural, social and economic resources to the consequences of climate variability. It addresses four major issues:

- Is the Infosources Database representative of the available information?
- To what extent does it provide information for assessing specific climate change impacts on physical and human systems?
- Are the information sources regionally representative?
- Recommendations based on the Gap Analysis.

The assessment identifies several sources of uncertainty:

- Many of the overview studies in the database are highly speculative and based on limited details.
- Many of the detailed, technical studies were conducted at a specific site and cannot be easily extrapolated to a larger scale.
- The database provides a representative (rather than exhaustive) collection of information sources, so that the state of knowledge is more likely to be under-interpreted than over-interpreted.
- The range of possible climate change scenarios is not well understood, and potential responses of biological and physical systems remain rather tentative.

For all of these reasons, this assessment of knowledge gaps is generally conservative.

The utility and comprehensiveness of the Infosources Database were assessed by comparing it with two other research databases – the ISI Web of Science Database and the Arctic Science and Technology Information System. While recognizing that the Infosources Database is not comprehensive, the review concluded that its contents are generally representative of the state of northern climate change literature and likely sufficient to assess the knowledge gaps for northern Canada.

Using the matrices, the review assessed the state of knowledge by system and topic, beginning with two broad observations. First, the state of knowledge of baseline conditions and the potential impacts of climate change are highly variable by region, a function of past research efforts, which tend to be focused in smaller areas. Secondly, information about climatological, physical and biological processes is poorly integrated with socio-economic aspects of the northern environment. As a consequence, even where potential climate change impacts are reasonably well understood, the implications for human activities and well-being are not obvious.

More specific observations, based on the matrices, include:

- Climate data – there is a reasonable state of knowledge for basic temperature and precipitation data but relatively little information is available for other climate data, such as the effects of storms, extreme events, and UV radiation.
- Boreal forest/taiga – the state of knowledge is generally good, with significant gaps in the area of invertebrate pest species and the relationships between physical and biological processes.
- Coast – better baseline information is needed and more precise predictive models could be developed using local monitoring data.
- Tundra – baseline information is generally good but more information is needed about the effects of extreme conditions on large and small herbivores and about the hydrology of tundra environments.
- Freshwater – current knowledge is fair to poor and the potential impacts of climate change are poorly understood.
- Marine – baseline knowledge of marine mammals is relatively good but all other aspects of the marine physical and biological environment are insufficiently understood.
- Fisheries – baseline information is only fair in general and poor to non-existent in many regions.

- Forestry – while the state of knowledge is fair, understanding about impacts of climate change and cumulative impacts is poor.
- Hunting and trapping – while information about most species is good, there is little information about the potential impacts of climate change on harvesting and harvest-dependent communities.
- Agriculture – expansion of livestock production in parts of the North might be viable in a future climate but little information is available.

The issue of regional representation was the most difficult to assess because northern Canada is a vast region and considerable variability in local responses to climate change is anticipated. Regional and local information will be critical in assessing and planning for climate change impacts. There are references in the Infosources Database from all northern regions but they tend to be clustered around sites of more intensive research activity rather than being representative of an entire region.

One significant pattern emerges. Regions with a longer history of access from southern Canada tend to have a more complete set of baseline information. Most of the regional knowledge gaps are in areas that are either difficult to access or where no research infrastructure exists. Within specific regions:

- Yukon: reasonably good information in most areas; southeast Yukon is weakest in both baseline information and potential climate change impacts.
- NWT: the bulk of information comes from the Mackenzie Basin Impact Study and from ongoing research in the Inuvialuit region.
- Nunavut: a number of long-term studies, but specific knowledge gaps related to impacts of climate change on sea ice and marine mammals.
- Hudson Bay: no significant gaps but opportunities for further research, particularly integrated multidisciplinary research programs.
- Northern Quebec/Labrador: good baseline information for Northern Quebec but information lacking for Labrador.
- Arctic Ocean: many gaps in knowledge of both the physical and the biological environment.
- Northern Provinces: highly variable, partly because the region is outside the database's primary focus; increasing industrial activity in the region makes improving knowledge particularly important.

Recommendations based on the Gap Analysis:

1. There is an urgent need for more geographically specific data collection throughout the North. Integrated Regional Impact Studies (IRIS) provide a framework for conducting multidisciplinary, long-term research. Emphasis on building partnerships to establish a network of IRIS programs in northern Canada is essential, and would ensure that many of the identified knowledge gaps would be addressed in a systematic manner. The Northern Climate ExChange could play an important role in facilitating the establishment and development of IRIS programs.

2. It is possible that the NCE database will become outdated as other assessments become available, particularly large international programs. However, the NCE's Infosources Database should remain an important place for communities to find and share information on local and regional scales that are often overlooked by larger-scale assessments. Where possible it would be

useful to identify references to the scale of a community. A community-focused database will provide useful information that is unlikely to otherwise be widely available.

Conclusions

At the beginning of this project, we had four major goals. We set out to determine what is currently known about climate change and its impacts in northern Canada, and incorporate this information into a database. We planned to identify trends or patterns in the available information. We then intended to make use of this information to help identify research, monitoring, technological, and policy priorities. Finally, we hoped to improve collaboration and coordination among and between researchers, communities, governments, non-government organizations, and residents of northern Canada.

The first two goals have been met, at least within the scope of the NCE Gap Analysis Project. The Infosources Database incorporates the information collected in the course of the project, as well as hundreds of references collected outside the scope of the study. Frequent updates, as time and resources permit, are part of the effort to keep the database as current and complete as possible. In the future, as the amount of information about climate change in the North increases, it might be advisable to focus the database more closely, perhaps on information specific to regions and communities as one review has suggested. At this point, however, the quantity of information about climate change in the North and the level of regional focus do not require that shift.

Through the matrices, we have in large part achieved the second goal of identifying trends or patterns in the available information. The matrix analysis, based on a large subset of the information available at the time, identified a number of clear trends and a number of areas in which serious gaps in information existed. The full matrix analysis is available on the accompanying CD-ROM. Chapter 3 of this overview report contains a summary of the findings and a description of the process.

The broad patterns in our state of knowledge revealed by the matrices include:

- Inequalities in the amount of existing information across systems, with more information available about climate change impacts on physical processes, less information concerning biological systems, and even less concerning socio-economic systems;
- Greater knowledge and confidence concerning baseline information and predicted changes to temperature than for other climate components like rain, snow, and extreme events;
- Strong regional trends for compiled information, with some regions well studied and others barely touched;
- Relatively little of the local and traditional knowledge about climate change documented, with most of the documented knowledge coming from regions where scientific research has been focused;
- More information about climate change impacts on biological systems with an economic component, such as harvested fish species, than for those without obvious economic significance.

Although more information has been published and added to the Infosources Database since the matrix analysis, the broad patterns revealed by the analysis still hold true and the gaps remain.

With respect to the third goal, priority-setting, the NCE Gap Analysis Project has produced a synthesis of information that can be used as a baseline and a tool in determining future

directions. That determination, however, must be made through a broader public process than this project. Climate change is an issue of considerable public concern in Canada's North. Communities are already seeing climate-related changes with social, economic, and physical implications. Coastal erosion, degrading permafrost, disappearing sea ice, changing wildlife behaviour, new insect pests – these are not future possibilities for northerners but current reality. The setting of priorities for research and monitoring, technology development, and policy is a matter for all northerners and those involved in and concerned about the North.

Finally, the NCE Gap Analysis Project itself contributed to the fourth goal of improving cooperation and collaboration among the many groups, agencies, and individuals concerned about climate change in the North. The project pulled together a number of researchers and agencies within and beyond the North. Workshops and community meetings broadened the range of people involved in the discussion, although limited resources restricted these more public occasions to the Yukon.

Recently – and outside the immediate scope of the NCE Gap Analysis Project – the Northern Climate ExChange has taken further steps to improve collaboration by hosting the northern region of the Canadian Climate Impacts and Adaptation Research Network (C-CIARN North), in partnership with the Aurora Research Institute in the Northwest Territories and the Nunavut Research Institute in Nunavut. Focusing on the impacts of climate change and adaptation to a changing climate, C-CIARN North is a growing network of researchers and stakeholders spanning the North and linked with a national network. Its goal is to facilitate collaboration, reduce duplication in research, and help focus the efforts of researchers where they are needed most. The NCE Gap Analysis will be an important tool in determining where those efforts are needed. In a sense, C-CIARN North is the successor to the NCE Gap Analysis Project, taking over responsibility for maintaining products like the databases and furthering the goals of collaboration and priority-setting.

The NCE Gap Analysis Project remains a work in progress. Although the project itself is over, the information it identified and the products it created are part of a continuing process. Some, like the databases and the matrices, will grow and change as our knowledge of the issues related to climate change increases. Others, like the reports on the accompanying CD-ROM, will contribute to that future growth. Climate change, the impetus behind our work, is also a work in progress with no end in sight. To adapt to it, we must be prepared for change and open to change. The NCE Gap Analysis Project is a tool to help us develop that flexibility.

The Northern Climate ExChange

Gap Analysis Project

An Assessment

of Documented Traditional and Local Knowledge and Perspectives on the Impacts of Climate Change within Nunavut Territory, the Northwest Territories, Northern Alberta, Manitoba, Ontario, Quebec and Labrador

Natasha Thorpe

Dyanna Riedlinger
Shari Fox
With GeoNorth Limited
Yellowknife, Northwest Territories
October 2000

Table of Contents

List of Tables

List of Appendices

1.0 Introduction

This report is one important part of a comprehensive project being undertaken by the Northern Climate ExChange entitled, "*An Assessment of the State of Knowledge of the Impacts of Climate Change on Canada's North.*" It assesses the current state of knowledge of the impacts of climate change, with a goal of helping to establish priorities for climate change research, monitoring, technological development and policy development in Canada's North.

Until very recently, scientists have done almost all of the research on northern climate change and its potential impacts. However, people living in northern communities are already noticing the impacts of climate change (ICC 1996) as weather is the main factor controlling daily activity in their lives.

This close connection to the land gives local people a unique perspective from which to understand changes related to climate. Further, recent studies show that local observations and hypotheses parallel many of those made by scientists (e.g. McDonald *et al*. 1997; Fox 1998, 2000; Huntington 2000; Riedlinger 2000; Thorpe 2000).

For this report we analyzed the current state of knowledge of documented traditional and local knowledge on the impacts of climate change within the regions of Nunavut, the Northwest Territories, Northern Alberta, Manitoba, Ontario, Quebec and Labrador. In general, we examined the regional extent of this knowledge of climate change, and the topics covered by documented sources. We assessed how and by whom documentation is taking place, and we also looked at the kinds of traditional and local knowledge and observations that have been recorded, and identified potential gaps. Our conclusions and recommendations on the state of documented traditional and local knowledge of climate change are somewhat limited by the fact that we located only 74 sources. However, this shortage shows that further research on local and traditional knowledge is needed.

1.1 Defining "traditional and local knowledge": Semantics, Meanings and Terminology

This report addresses the knowledge and observations of climate change of local people, particularly indigenous people, living in the regions of Nunavut, the Northwest Territories, Northern Alberta, Manitoba, Ontario, Quebec and Labrador. Debates both inside and outside academia have focussed on finding an appropriate term and definition for the knowledge of indigenous people, or indigenous knowledge (IK). This knowledge has also been labeled traditional knowledge (TK), local knowledge (LK), traditional ecological knowledge (TEK), traditional environmental knowledge (TEK), folk ecology, ethno-ecology, customary law, and knowledge of the land (Johnson 1992). In addition, there has been a recent move to recognize specific groups. For example, the government of Nunavut is using the term Inuit Qaujimajatuqangit (IQ) in all of its government policies and practices to refer to Inuit knowledge. (Government of Nunavut, 1999).

However, despite these numerous terms, there is still no clear accepted definition of indigenous knowledge. One example is as follows:

> Traditional environmental knowledge, or TEK, can generally be defined as a body of knowledge built up by a group of people through generations of living in close contact with nature. It includes a system of classification, a set of empirical observations about the local environment, and a system of self-management that governs resource use. The quantity and quality of traditional environmental knowledge varies among community members, depending upon gender, age, social status, intellectual capability, and profession (hunter, spiritual leader, healer, etc.). With its roots firmly in the past, traditional environmental knowledge is both cumulative and dynamic, building upon the experience of earlier generations and adapting to the new technological and socioeconomic changes of the present (Johnson 1992: 4).

In this report, we used the terms traditional knowledge *and* local knowledge*. We used the word* traditional *with the utmost respect, recognizing that many of the sources we gathered are based on the knowledge of Elders. Such knowledge is the closest link to the past and incorporates the knowledge and skills of their ancestors with their rich life experiences through changing culture, language, and environmental and living conditions.*

Local knowledge *is often based on and includes* traditional knowledge*. We used* local knowledge *as a broader term that also recognizes knowledge developed over shorter time periods, such as that dealing with environmental monitoring (e.g. changes noticed in the last 5-10 years).* Local knowledge *also recognizes the knowledge of non-native long-time residents who have, in many cases, contributed to the studies we have included in the report.*

2.0 Methods

We searched numerous media to collect the information required for an annotated bibliography of all identified sources of traditional and local knowledge of climate change. Next, these media were collated and inserted into tables for purposes of a gap analysis.

2.1 Searching for Sources

i) Web searches*: The World Wide Web was searched thoroughly for any pages containing references to traditional and local knowledge of climate and climate change. Appendix A includes all of the web pages that were searched, though not all of them contained relevant information.*

ii) Databases*: We searched all existing databases containing information on Northern climate change, environmental change, indigenous knowledge, traditional and local knowledge, etc. Appendix A lists all the databases that were searched, though not all of them contained relevant information.*

iii) Contacting Northern Experts*: The authors tried to contact 52 colleagues and experts in Northern areas regarding any possible sources of information on this topic. Most contacts were made by e-mail, and a total of 17 replies were received. The list of contacts is not included, as individuals were not informed that their names would be included.*

iv) Literature searches*: The authors and GeoNorth team searched academic publications, conference papers and presentations, non-published material and obscure reports such as unpublished government or NGO reports for additional sources of information. All relevant sources have been annotated and included in the bibliography.*

v) Video library searches*: The GeoNorth team searched the video archives of the CBC and National Film Board of Canada for productions related to traditional and local knowledge of climate and climate change. Shari Fox searched the archives at the Inuit Broadcasting Corporation in Iqaluit for similar material.*

vi) Media sources*: An overwhelming amount of information appears in the popular media on climate change and its impacts on Northern areas, so we did not attempt to include such sources in our bibliography. However, we recognize that searches in newspapers, magazines, radio and television newscasts may reveal some relevant reports.*

2.2 Creating Tables for Analysis of Sources

The above searches resulted in 74 sources documenting traditional and local knowledge of climate change. The following eight criteria were used to place the sources in tables:

- region
- format/medium
- keyword
- content
- continuity
- duration as of 2000
- regional extent
- type of information

These tables helped us to analyze the relative strengths and weaknesses of the sources as well as the gaps and trends in the literature. Our broad conclusions and recommendations on what further research may be needed are hindered by the fact that there are so few existing references to local and traditional knowledge of climate.

We did not include all possible sources. For example, we omitted literature that identifies the need to look to traditional and local knowledge in order to understand change in the North. Second or third party accounts of traditional and local knowledge of climate change (e.g. accounts of Arctic missionaries or adventurers) were not sought out, but were included when found. In order to stay with the objectives of this report, we included only sources focussed strictly on traditional and local knowledge of climate change.

3.0 Results

A gap analysis was conducted according to the eight categories listed in the previous section. Results are shown below.

3.1 Region

Table 1a and 1b illustrate how well regions are covered in terms of documented local and traditional knowledge of climate change.

Table 1a. Regional Analysis

Region	**Number**
Not specific to one region	9
Western Arctic	13
Mackenzie Basin	8
Central Arctic	8
Eastern Arctic	5
Northwest Territories	6
Nunavut	25
Alaska	7
Hudson Bay	8
Northern Provinces	8
Northern Quebec / Labrador	2
Arctic Ocean	1

As illustrated in Table 1a, there were on average eight sources per region for the 11 identified regions when the category "not specific to a region" was excluded. Nunavut (25) and the Western Arctic (13) had more than the average number of sources.

In contrast, Alaska (7), Northwest Territories (6), Eastern Arctic (5), Northern Quebec/Labrador (2), and Arctic Ocean (1) fall below the average. The Central Arctic, Hudson Bay, Mackenzie Basin, and Northern Provinces equal the average (8).

Table 1b. Sub-Regional Analysis

Sub Region	**Number**
Inuvialuit	14
Gwich'in	2
Sahtu	3
Deh Cho	4
North Slave	3
South Slave	4
Kitikmeot	9
Kivalliq	7
Qikiqtani	5

Table 1b shows that in the sub-regions of Nunavut and the Northwest Territories, most references are for the Inuvialuit (14), Kitikmeot (9) and Kivalliq (7) regions. The fewest sources pertained to the South Slave (4), Deh Cho (4), Sahtu (3), North Slave (3), and Gwich'in (2) areas. On average there were six references per sub-region.

3.2 Format/Medium

Table 2 shows the formats or types of media that document local and traditional knowledge.

Table 2. Format / Medium Analysis

Format / Medium	**Number**
Book	14
Book section	12
Report	11
Journal article	10
Conference presentation	10
Thesis	4
Web Site	3
Project	3
Conference proceedings	3
Other	2
Video	1
CD ROM	1
Summary or periodic report	1
Dissertations, maps, bibliographies, posters, summary or periodic reports, computer models, brochures, fact sheets (digital and printed formats)	0

Most references were found in books (14), book sections (12), reports (11), journal articles (10), and conference presentations (10). Theses, websites, videos, conference proceedings, CD ROM, summary or periodic reports and projects produced four or less sources. There were no documented sources for dissertations, maps, periodic reports, bibliographies, computer models, brochures, and fact sheets.

3.3 Keyword

Table 3 summarizes the number of sources associated with 23 keywords provided by NCE. Most sources were associated with more than one keyword.

Table 3. Keyword Analysis

Keyword	Number
Traditional knowledge	64
Climate	62
Wildlife	31
Temperature	31
Land use	30
Human activity	30
Indicators	24
Water/Ice	21
Land	20
Mammals	19
Sea Ice	18
Vegetation	17
Marine	16
Snow	16
Economy	15
Coast	14
Precipitation	14
Lakes	11
Birds	10
Adaptation	10
Permafrost	9
Fish	8
Storms	8
Air	7
Sea level	7
Erosion	6
Transportation	5
Run-off	4
Flooding	3
Palaeoclimate	2
Invertebrates	2
Streams	2
Forests	2
Glaciers	2
Ground ice	1
Ice-cores	1
Peat	1
Landslides, chronology, pollen, tree-rings	0

More than 20 sources contained the following keywords: climate, indicators, temperature, land, wildlife, human activity, land use, water/ice, and traditional knowledge. There were 10-19 sources related to marine, snow, vegetation, lakes, sea ice, coast, precipitation, mammals, birds, adaptation, and economy. Fewer than 10 sources were associated with air, palaeoclimate, erosion, permafrost, glaciers, run-off, streams, forests, fish, invertebrates, transportation, sea level, peat, ground ice, ice-cores, storms and flooding. There were no sources for four keywords: landslides, chronology, pollen, and tree rings.

3.4 Content

Table 4 shows the eight categories that were used to summarize the state of knowledge in key areas of local knowledge.

Table 4. Local Knowledge Content Analysis

Category	Number
Weather and seasonal change	56
Wildlife	36
Human adaptations and impacts	48
Sea ice and oceans	40
Environmental change	32
Water (lakes and rivers)	23
Vegetation	16
Land processes and permafrost	14
Historical	9

The keywords with the most references were weather and seasonal change (56) and human adaptation and impacts (48). Other keywords with

numerous sources were wildlife (36), sea ice and oceans (40), water (23), vegetation (16) land processes and permafrost (14).

3.5 Continuity

Table 5 shows that continuity did not apply to the majority (53) of sources. Only nine sources were continuous and eight sources were discontinuous. A small number (4) were not recorded or unknown.

Table 5. Continuity Analysis

Category	Number
Continuous	9
Discontinuous	8
Not applicable	53
Not recorded / unknown	4

3.6 Duration

As of the year 2000, most sources reflected more than one year of research (7) or two years (6), as illustrated in Table 6. Few studies or projects (<3) lasted more than three years. This category did not apply to 42 sources.

Table 6. Duration Analysis

Length of time as of 2000	Number
Less than one year	4
One year	7
Two years	6
Three years	3
Four years	1
Five years	3
More than five years	3
Not applicable	42
Not recorded / unknown	5

3.7 Regional Extent

Table 7 shows the number of communities contributing to each source. Population levels within each community were not considered.

Table 7. Regional Extent Analysis

Regional Extent of Research	Number
One community	19
Two to five communities	12
Six to ten communities	6
Eleven to twenty communities	2
Entire regions as grouped in table 1a & 1b (e.g. Nunavut, Mackenzie Basin)	10
Not specific to a region	14
Not applicable	3
Not recorded / unknown	8

Most sources applied to one community (19) while twelve applied to between two and five communities. Six sources pertained to between six and ten communities while two sources covered between eleven and twenty communities. Many sources (14) were not specific to a region or, alternatively, covered an entire region (10).

3.8 Information Type

Table 8 illustrates the various types of information that informed each source.

Table 8. Type of Information Analysis

Type of Information	Number
Observational	38
Interviews	32
Archival records	17
Oral histories	11
Testimonies	10
Community workshops	7
Study reports / surveys	5
Digitized map information	5
Video footage	4
Archeological records	4
Language history	3
Participatory action research	3
Participant observation	3
Other	3
Presentations	1
Anecdotal	1
Grad theses	1
Narrative data	1
Not applicable	2
Not recorded / unknown	8

Observational information (38) and interviews (32) informed most sources. Archival records (17), oral history (17) and testimony (10) applied to numerous records while fewer sources came from community workshops (7), study reports/surveys (5), digitized map information (5), video footage (4) and archaeological records (4). Eight types of information informed three or fewer sources: history (3), participatory action research (3), participant observation (3), other (3), presentation (1), anecdotal (1), graduate thesis (1), and narrative data (1).

4.0 Discussion

This analysis of eight criteria is a starting point for identifying areas where documented sources of local and traditional knowledge are strong, weak, or have gaps in them. However, each "absolute" number must be taken with caution as it does not account for varying spatial and temporal scales, regional coverage and depth of information. In other words, we are comparing apples and oranges. As a result, the following conclusions should be used as one of many tools in identifying information gaps regarding local and traditional knowledge of climate change.

A search for documented local and traditional knowledge of climate change using the methods described in Section 2 yielded 74 sources. This low number indicates that very little local and traditional knowledge of climate change has been recorded, and does not necessarily reflect the actual state of knowledge of climate change. As outlined in the terms of reference for this report, we included only *documented* sources of traditional and local knowledge of climate change and this number does not adequately show the total state of knowledge in communities nor the levels or extent of local expertise.

Following are four of the reasons why local and traditional knowledge of climate change have not been more fully documented:

i) Interest in climate change is relatively recent. The number of references on traditional and local knowledge of climate change has increased since the late 1980s

ii) The validity and usefulness of traditional and local knowledge has not always been recognized. More recently the implementation of land claims, self-government and legal precedents (e.g. Delgamuukw) have both empowered community members to conduct their own research and increased recognition for their ways of knowing. Communities are now pursuing their own efforts to document their knowledge of climate change.

iii) In the last few years there has been more demand for local and traditional knowledge research and a concurrent rise in available funding for such initiatives. Both of these conditions have facilitated the recent documentation of local and traditional knowledge by researchers.

iv) The current number of references on traditional and local knowledge of climate change essentially reflects the level of collaboration between researchers and community members. Now most communities are starting to document this knowledge on their own, with less input from outside researchers. As both the funding and the demand for such projects continues to increase, community members will be better able to document their own knowledge in the future.

4.1 Region

These results suggest that Nunavut and the Western Arctic have a relatively high number of sources while the number is low for the Northern Provinces, Quebec, Labrador and the Arctic Ocean. This finding should be considered with caution as each region greatly differs in geography, size and population.

The relatively high numbers for the Western Arctic and Mackenzie Basin may reflect recognition of this region as a climatic "hot spot" or an area where impacts from climate change may be seen first. As a result, more research has taken place in these regions. As well, several key projects have contributed multiple sources to our database (e.g. the Mackenzie Basin Impact Study (MBIS) and Inuit Observations of Climate Change). Essentially, a few large projects can make regions stand out because of the limited number of sources in our database. MBIS, Northern River Basins Study, Inuit Observations of Climate Change Study and the Tuktu and Nogak Project are four examples of such studies.

With respect to sub-regions, the fact that most sources pertained to the Inuvialuit, Kitikmeot and Kivalliq regions may partially reflect the researchers' areas of familiarity.

We could more easily find sources for the regions in which we work and it was also easier to consult with other experts for obscure sources. The least number of sources pertained to the South Slave (4), Deh Cho (4), Sahtu (3), North Slave (3), and Gwich'in (2) areas.

4.2 Format/Medium

Analysis of the different sources revealed that there is little non-written material and a relative abundance of written material. This is a critical point as community members usually prefer communication through non-written materials such as videos or oral recordings. These approaches ensure that elders who cannot read English are included.

This finding highlights the need to determine which formats are best for providing information on documented traditional and local knowledge to community members. These preferred formats should then be used in future projects.

For example, most documentation is contained in books and reports, which are useful formats for preserving traditional and local knowledge. However, they may be more accessible to academics and outside researchers than they are to community members. One approach might be to require that researchers provide written summaries of their works to communities in the local language.

It appears that videos, web-based materials and oral testimonies are becoming popular, and these formats may be well suited for documenting traditional and local knowledge related to climate change.

4.3 Keyword

As stated earlier, traditional and local knowledge provide an important local/regional understanding of the environment. Accordingly, the keywords “wildlife,” “temperature,” “land use,” and “human activity” all have numerous sources.

Other keywords that we expected to produce a similar number of sources did not do so. However, this finding was less surprising when we considered that most of the references were from the Nunavut region, which is primarily above treeline.

Also, contrary to popular belief, our analysis showed that many Arctic communities are not familiar with glaciers. This keyword produced few sources, as did ice-cores, pollen, tree-rings, and palaeoclimate. These terms refer to tools used by Western scientists to evaluate climate and are not as relevant to local and traditional knowledge.

Two important points need to be raised here: First, a distinction needs to be made between how indigenous and local people in the North make, interpret, and talk about their observations, as compared to the more reductionist approach taken by scientists. Many Northerners do not think of their environment and changes occurring to it as an accumulation of parts. Rather, environmental characteristics, features, creatures and processes are tied together in complex interrelationships that are only beginning to be understood and documented in terms of climate change. Therefore, everything on this list is probably incorporated in some form at some scale in all traditional and local knowledge.

Second, quantification of these key words does not clearly indicate the sum total of northern traditional and local knowledge on climate change; rather this exercise reflects what questions are being asked by the people who are documenting the knowledge.

As has been noted several times already, the documentation of traditional and local knowledge of climate change in the North is a new endeavor, and very few sources of this type of work have been found. Research to date has only laid the foundation and is just beginning to ask questions about local observations. These questions have often been broad in scope and that is reflected in the keyword analysis. However, the stage is now set for more specific research.

Anyone familiar with northern communities will not be surprised that many of the keywords with the most sources are tied to community life and use of the land. People in the North often discuss their environment in a “big picture” way. For example, changes are often discussed in terms of the “sea ice environment” or “weather and seasonal change.” In addition, like any other population, local people in the North have been noticing and talking about the “big impacts” first, such as those that are tied to community living.

4.4 Content

We found that content analysis may be a more appropriate tool for identifying what has been done on traditional and local knowledge, as well as the gaps in this area. These categories reflect how we see traditional knowledge of climate change being documented, based on our own experience and knowledge with this issue. For example, most people in

the community are talking about "weather and seasonal change." This topic can be divided into more specific keywords such as climate, temperature, indicators, snow, precipitation, storms, and air.

This analysis showed a high number of sources for human adaptation and impacts. As noted earlier, the keyword analysis showed that most sources deal with impacts rather than adaptations. This finding speaks to the assertion that northerners are the first peoples to experience climate change, and they have already begun to discuss its impacts.

There are only nine references for the keyword "historical" which reflects the difficulties in accessing older local and traditional knowledge that is nested or embedded in materials found in archives, community libraries, hunting and trapping organizations, and heritage societies.

4.5 Continuity

This analysis showed that the number of sources for continuous and discontinuous sources was roughly equal, but this criterion was not applicable to most sources. While continuity and duration are concepts easily assigned to scientific studies, they are not so easily applied to local and traditional knowledge works. Many of the sources were not actual studies so duration was not applicable or was difficult to pinpoint. For example, when Inuit Elders give presentations on changes they are experiencing, this source cannot be analyzed in terms of continuity or duration. Community-based projects that are documenting this knowledge can be assigned duration, but continuity does not apply in the same way that it would for a scientific study since communities may not have a rigid timetable for documentation.

4.6 Duration

Since climate change has only been noticed in the last decade or so, most sources of documented traditional and local knowledge are relatively new. Therefore, it is not surprising that most research projects and studies are less than five years in duration. In fact, most are less that one year in duration, although they may develop into longer works.

4.7 Regional Extent

This analysis showed that most sources involved only one community, but such sources can be just as important as ones involving multiple communities. For example, there may be more local experts in one community than in five communities combined. Also, local experts may know much more about the surrounding region than do average community members.

4.8 Information Type

Analysis of the sources showed that most of them come from observations, interviews, and archives. Oral histories and testimonies, which are commonly used for local and traditional knowledge research, are also important. Surveys, digitized map information, video footage, and archaeological records provide fewer sources, though they would likely contribute useful information if used more often. Relatively few sources are informed by presentations, graduate theses, or anecdotal and narrative data.

5.0 Conclusions

Climate change is now one of the leading areas for research in the Canadian North. Evidence from both the scientific community and from within northern communities suggests that the impacts of climate change are already noticeable in high latitude regions. While western science-based research provides an extensive body of literature on climate change trends and impacts, contributions from traditional and local knowledge have received less attention.

Based on our analysis of 74 sources, we can draw the following conclusions:

- Our gap analysis uncovered so few sources that it is difficult to state whether specific areas of research on traditional and local knowledge of climate change are covered poorly or adequately.

- Much of the existing documentation comes from larger sources or general reports on climate change, and is incidental or descriptive. There are fewer examples of specific projects or substantial explorations of traditional and local knowledge of climate change.

- Some regions have better documentation than others on traditional and local knowledge of climate change. However this variation most likely reflects the existence of regional "hot spots" for climate change and the fact that key projects in certain areas have looked specifically at community perceptions of climate change.

- Documented traditional and local knowledge of climate change mainly reflects broad categories of impacts and change, rather than details and specifics. This may reflect the 'newness' of this area of research. However, the kinds of changes being documented reflect what is most noticeable in communities and what communities are saying about the changes. The documented sources of traditional and local knowledge of climate change mainly reflect community concerns about community livelihood and community life.

- Much of the work being done to document traditional and local knowledge appears to focus on current observations of change rather than the historical context for these changes.

- Most traditional and local knowledge of climate change is found in books, journals and reports.

- Many sources documented general observations of climate change in the North and were not specific to a region or community. However, specific studies and research projects were usually based on between one and five communities.

- Most studies of documented traditional and local knowledge are very short in duration, lasting less than five years.

- The 74 sources that we uncovered do not reflect the total knowledge base that can be found in the North. Rather this relatively low number reflects the fact that mainstream researchers are just starting to pay more attention to this new area of research. In addition, the small number of sources must be viewed in the context of the questions that were asked by the researchers.

In conclusion, while our analysis was not as useful in identifying specific regional or topical gaps, it did help identify that:

1. There is an overall need for more projects that specifically explore and document traditional and local knowledge of climate change in the North. Most of the information that we found was incidental or only briefly described changes. Substantial explorations of the issues were not found.

2. *What* is being documented and *where* it is being documented are both very important questions. However, the critical overriding issue is *how* to encourage or support documentation *with* and *in* Northern communities. A standard gap analysis identifying sources on traditional and local knowledge by region and topic is not particularly effective in focussing future research needs. Traditional and local knowledge of climate change is being documented largely because northerners are concerned and talking about it. Our analysis clearly identified a need for more projects at the community level, and for linking western science-based climate change research with this knowledge to move towards a more comprehensive understanding of the impacts of climate change on the North.

Also, community-based projects on documenting local and traditional knowledge should only be the first step. Relationships must be built between scientists and communities so that traditional and local knowledge of climate change is included in mainstream research. This process continues to be hindered by questions of how to integrate or bridge the gap between western science and local and traditional knowledge.

There are both conceptual and logistical challenges to linking these ways of knowing. Research that seeks to include a traditional and local knowledge component is often faced with barriers such as project-funding structures and timelines that can be inadequate for community-based or long-term research. These issues are particularly important when addressing traditional and local knowledge of climate change, as this research must cover a wide range of topics, not just one variable, over the long term. Both the conceptual and logistic aspects of increasing collaboration between scientists and communities are included in the recommendations we provide below.

6.0 Recommendations

Based on the above conclusions on the state of traditional and local knowledge of climate change in Nunavut, the Northwest Territories and Northern Alberta, Manitoba, Ontario, Quebec, and Labrador, we have developed a series of recommendations. They are intended to help further efforts to document traditional and local knowledge of climate change and increase collaboration between scientific and traditional and local experts. Together, this should create the capacity for sharing information and for feedback. These recommendations reflect the analysis we have conducted for the purposes of this report, as well as of our shared experiences as researchers actively working in this area:

1) **More research is needed that is specifically focussed on documenting traditional and local knowledge and interpreting this knowledge with local people.** This approach is different from research where such knowledge is a sub-component of a larger study.

2) **Although we are reluctant to say that a specific region is under-represented, very few sources for Northern Provinces and Northern Quebec/Labrador were found.** Local and traditional knowledge research is scarce in all regions and needs support and encouragement. Documenting traditional and local knowledge of climate change requires substantial commitments of both time and money for research. One way to address regional gaps may be to focus on climatic "hot spots" since there is already an emerging body of research in these areas. Another approach may be to encourage research in regions and sub-regions that are poorly represented, for example, the Northern Provinces and Labrador.

3) **Individual communities, in consultation with researchers, should identify priorities for future research topics on traditional and local knowledge of climate change.** The topics identified in our gap analysis may be more appropriate for describing the *kind* of research that is being done than for identifying where future studies should focus. For example, while invertebrates are an underrepresented keyword in our analysis, this does not mean that they should not be a research priority for all northern communities.

4) **Future research should focus on exploring traditional and local knowledge in more depth and detail.** This work could highlight the strength of local knowledge regarding regional climatic variables. Multi-year projects would help add depth to the research.

5) **More research is needed on *how* to bridge the gap between western science and local knowledge, both conceptually and practically.** This requires moving beyond simply recognizing that the gap exists, and will most likely require more creative approaches as well as efforts to build capacity within communities. Currently, there are good examples of this kind of research taking place.

6) **Documenting traditional and local knowledge of climate change requires creative methodologies.** As with other community-based research, methodologies and approaches are needed that retain the context of the knowledge. These methodologies may include time on the land, mapping, film and video.

7) **Project structures, funding requirements and timelines must reflect the needs of community-based research.** Promoting collaboration between science and traditional and local knowledge requires flexible approaches to research. Working with communities to understand climate change requires significant time, logistical and organizational contributions. More time can be needed to

ensure that traditional and local knowledge is documented in a manner appropriate to the community. Funding structures should be adaptable and reflect the unique needs of this kind of research.

8) **Future research in this area possibly could be promoted by developing a forum for tracking current research on climate change in the North.** A web-based database could help increase collaboration between researchers and communities. For example, if communities could access this database, they could invite researchers to engage in collaborative projects based on research priorities that they have already identified. This is one area in which the NCE is making progress.

9) **Scientists should be actively encouraged to communicate and collaborate with communities, and include traditional and local knowledge in their research.** This would include providing information and feedback to communities from these projects, and it would most likely require more funding and project support mechanisms. Encouraging scientific communication and collaboration could also help improve the links between traditional and local knowledge and the scientific community. (see recommendation 5)

10) **Continued support for projects that are initiated by communities is critical.** More opportunities should be created for communities to document and monitor climate-related changes in ways that are appropriate for and reflect their needs. This initiative could require more funding and better connections with researchers and research projects.

11) **A series of conferences, bioregion meetings, or "on the land summits" should be created.** These gatherings would bring together local experts and scientists to discuss climate change. Meetings could be organized around climate trends and impacts in a particular bioregion (i.e. Beaufort Sea), and could take place either as an organized conference or as an "on the land summit" – a meeting out on the land/ice/water. Summits organized for local participants only should be seen as having the same importance as meetings involving only scientists.

12) **More focus should be placed on adaptation strategies for climate change as northern Canada has little control over the impacts.** It may be important to focus research on practical adaptation strategies and processes. The emerging body of traditional and local knowledge can be used to help develop these mechanisms.

13) **Opportunities should be supported and created for northern communities to share their experiences and concerns related to environmental and climate change with local, national and international decision-makers.** These forums could help influence these decision makers by showing how climate change is affecting human livelihoods in the North. For example, such forums could support efforts to change international legislation on greenhouse gas emissions and provide funding for developing local adaptation strategies.

7.0 References

Agrawal, A. 1995. Dismantling the Divide Between Indigenous and Scientific Knowledge. *Development and Change*. 26:413-439.

Boas, F. 1888. *The Central Eskimo*. (Lincoln: University of Nebraska Press, Reprint 1964).

Cohen, S. J. 1997. What if and so what in northwest Canada: could climate change make a difference to the future of the Mackenzie Basin? *Arctic* 50 (4): 293-307.

Fast, H. and Berkes, F. 1998. Climate change, northern subsistence and land-based economies. In: Mayer, N. and Avis, W. (editors). *The Cross Canada Country Study: climate impacts and adaptation*. Ottawa: Environment Canada: 206-226.

Fox, S. 1996. *The Potential Impacts of Arctic Climate Change on Inuit/Wildlife Relationships: A Case Study of Igloolik NT, and the Atlantic Walrus (Odobenus rosmarus rosmarus)* (Waterloo: Bachelor of Environmental Studies Thesis; Department of Geography, University of Waterloo).

Fox, S. L. 1998. Inuit Knowledge of Climate and Climate Change*. (Waterloo: Masters of Environmental Studies Thesis, Department of Geography, University of Waterloo).*

Fox, S.L. 2000. Arctic Climate Change: Observations of Inuit in the Eastern Canadian Arctic. The Arctic Climatology Project : Arctic Meteorology and Climate Atlas, CD ROM. *A Joint Project of the Arctic and Antarctic Research Institute and the National Snow and Ice Data Center.*

Government of Nunavut. 1999. Report from the September Inuit Qaujimajatuqangit Workshop. Niaqunngnut, Nunavut, September 29-30, 1999. *Sponsored by the Government of Nunavut, Department of Culture, Language, Elders and Youth*

Grenier, L. 1998. Working with indigenous knowledge: a guide for researchers*. (Ottawa: International Development Research Centre).*

Hallen, B. and Sodipo, J.O. 1986. *Knowledge, Belief and Witchcraft; Analytic Experiments in African Philosophy* (London: Ethnographica).

Hountondji, P.J. 1983. *African Philosophy: Myth and Reality*. (London: Hutchinson University Library for Africa).

Huntington, H.P. 2000. Native Observations Capture Impacts of Sea Ice Changes. Witness the Arctic. Spring 2000, 8 (1): 1-2.

ICC and FJMC (Inuit Circumpolar Conference and the Fisheries Joint Management Commission). 1996. *A seminar on two ways of knowing: indigenous and scientific knowledge. November 15-17, 1996, Inuvik, NWT*. Prepared by: A. Fehr and Hurst, W. Aurora Research Institute, Aurora College, Inuvik, NWT.

Inuit Circumpolar Conference (ICC). 1996. *Inuit Statement Regarding COP2 Conference in Geneva*. ECO Newsletter, Issue #7.

Jacobs, J.D. 1989. Spatial representativeness of climatic data from Baffin Island, NWT, with implications for muskox and caribou distribution. *Arctic*. 42:50-56.

Johnson, M. 1992. *LORE; Capturing Traditional Environmental Knowledge*. (Ottawa and Hay River: Dene Cultural Institute and the International Development Research Institute).

Knudston, P. and Suzuki, D. 1992. *Wisdom of the Elders*. (Toronto: Stoddart Publishing Co. Ltd.)

Levy-Bruhl, L. 1923. *Primitive Mentality*. (New York: London, Allen, and Unwin).

Maxwell, B. 1997. *Responding to global climate change in Canada's Arctic*. Volume II of the Canada Country Study: climate impacts and adaptations. Ottawa: Environment Canada.

McDonald, M., Arragutainaq, L. and Novalinga, Z. 1997. Voices from the Bay: traditional ecological knowledge of Inuit and Cree in the Hudson Bay bioregion. (Ottawa: Canadian Arctic Resources Committee).

Riedlinger, D. 2000. Looking in New Directions to understand Arctic climate change: contributions of Inuvialuit knowledge to climate change research in the Western Arctic. In: J. Oakes, R. Riewe, M. Bennett, and B.Chisholm (Eds.) Pushing the Margins: Northern and Native Research. Winnipeg, MB University of Manitoba Native Studies Press. 432 pages.

Thorpe, N.L. 2000. Contributions of Inuit Ecological Knowledge to Understanding the Impacts of Climate Change on the Bathurst Caribou Herd in the Kitikmeot Region, Nunavut . *Master's in Resource Management research project no. 268, School of Resource and Environmental Management. Burnaby, BC: Simon Fraser University.*

Warren, D.M. 1991 Indigenous Knowledge Systems and Development. *Agricultural and Human Values* 8 (special issue).

Wavey, Chief Robert. 1993. International Workshop on Indigenous Knowledge and Community-based Resource Management: Keynote Address *in Traditional Ecological Knowledge; Concepts and Cases*. Inglis, J.T. ed. (Ottawa: International Program on Traditional Ecological Knowledge and International Development Research Centre) pp. 11-16.

Appendix A: Database / Web Search

Name	Location
Arctic Research Consortium of the U.S (ARCUS)	www.arcus.org/a.html arcus.polarnet.com
Arctic Borderlands Ecological Knowledge Co-op	www.taiga.net/coop/about.html www.taiga.net/sustain/lib/index.html
Aurora Research Institute	www.aurresint.nt.ca/
Taiga News (of the Taiga Rescue Network)	www.snf.se/TRN/TaigaNews
Arctic Institute of North America (AINA)	www.ucalgary.ca/UofC/Others/AINA
Arctic Science and Technology Information System (ASTIS)	www.aina.ucalgary.ca/ASTIS
Canadian Wildlife Service	www.cws.ca/
Dene Cultural Institute	www.deneculture.org/tradknow.htm
Department of Fisheries and Oceans	www.dfo-mpo.gc.ca/home-accueil_e.htm
Indian and Northern Affairs Canada (Northern Scientific Training Program)	www.inac.gc.ca/index_e.html
Association of Canadian Universities for Northern Studies (ACUNS)	www.uottawa.ca/associations/aucen-acuns/en/about.html
West Kitikmeot Slave Study Society (WKSS)	www.wkss.nt.ca
First Nations Periodical Index	moon.lights.com/index2.html
World Wide Web Virtual Library – environment	earthsystems.org/Environment.shtml
Nunavut Environmental Database	http://136.159.147.171/ned/
Arctic Roadmap	www.dartmouth.edu/acad-inst/arctic/roadmap.html
Inuit Circumpolar Conference, Canada	www.inusiaat.com
Arctic Council	arctic-council.usgs.gov/
Polar Web	www.urova.fi/home/arktinen/polarweb/polarweb.htm
Nunavut Research Institute (NRI)	www.nunanet.com/~research/
Inventory of Circumpolar Arctic Sustainable Development Initiatives	www.grida.no/parl.isdi
International Institute for Sustainable Development (IISD) Information Centre	iisd1.iisd.ca/ic/default.htm
Canadian Arctic Resources Committee (CARC)	www.carc.org
Canadian Polar Commission	www.polarcom.gc.ca/homepage.htm
Canadian Circumpolar Institute (CCI)	www.ualberta.ca/~ccinst/polar.html
Arctic Circle	arcticcircle.uconn.edu/ArcticCircle/

Northern Information Network (NIN)	nin.inac.gc.ca esd.inac.ga.ca/NIN
	www.nunavut.com/nunavut99/english/inuit-land.html
	www.greenpeace.org/~comms/97/arctic/library/region/people.html
Environment Canada Library	http://199.212.19.41/cgi-bin/bestn?id=8
	www.inac.gc.ca/pr/pub/indigen/ipsdca_e.html
Environment Canada (Green Lane)	www.ec.gc.ca/
Environment Canada (Ecosystem Initiatives)	www.ec.gc.ca./ecosyst/backgrounder.html
	www.atl.ec.gc.ca/nei/
	www.atl.ec.gc.ca/nei/pdf/bibliography.pdf
The international arctic environment data directory (ADD)	www.grida.no/add/
Akwesasne task force on the environment (ATFE)	www.slic.com/atfe/atfe.htm
AMP International	www.ampinternational.gl/
Climate change knowledge network	http://iisd.ca/climate/southnorthkn.htm

The Northern Climate ExChange
Gap Analysis Project

State of Knowledge

Impacts of Climate Change on Biophysical Systems

David Hik
University of Alberta
Edmonton, Alberta

Background and Context

For the past decade it has been apparent that the greatest impacts of climate change will be most evident in northern Canada and other Arctic regions. Nevertheless, there is still a great deal of uncertainty about the magnitude of these effects in different northern regions. These aspects of climate change science have been described in detail in the most recent report of the Intergovernmental Panel on Climate Change (IPCC, 2001), and are the subject of ongoing investigation by the Arctic Climate Impact Assessment (ACIA) [http://www.acia.uaf.edu/]. Other international organizations including the Arctic Monitoring and Assessment Program (AMAP), Conservation of Arctic Flora and Fauna (CAFF), World Wildlife Fund (WWF), and the International Arctic Science Committee (IASC), among others, are also actively engaged in assessments of climate change impacts in the Arctic.

In Canada, a comprehensive attempt to synthesize the potential effects of climate change on the people, economy and natural resources of northern Canada was published as part of the Canada Country Study on Climate Impacts and Adaptation in 1997. The federal Climate Change Action Fund (CCAF) has also provided several recent assessments of climate change impacts in northern Canada.

The Northern Climate Exchange (NCE) gap analysis project should be viewed as another contribution to these ongoing northern climate change initiatives. More specifically however, the NCE undertook to provide an assessment that will be directly useful for northern communities concerned about climate change impacts. Traditional, community and scientific sources of information were all considered. Since the people of small and remote communities characteristic of northern Canada hold considerable knowledge about climate change, the inclusion of this information in the NCE knowledge gap assessment will help to build a strong link between scientists, communities, First Nations, governments and industry.

This gap analysis is built around the consideration of five main factors including the identification of:

1) climate variability resulting from natural processes and human activity (such as greenhouse gas emissions);
2) ecological and physical impacts of these changes in the north;
3) vulnerability of natural, social and economic resources to the consequences of climate variability;
4) potential adaptation and mitigation strategies that might alter the consequences of climate change, and;
5) possible changes in the nature of human activities which generate changes in climate.

This review and assessment will focus primarily on the first three factors, based on the information available in the NCE gap analysis database. In the past decade, research efforts towards understanding, preventing and mitigating climate change impacts have greatly increased, but an overall vision of where to allocate limited resources is lacking. Consequently, the overall objective of this assessment was to identify knowledge gaps and to provide reliable information to governments, organizations and peoples of the Arctic. This is expected to lead to the development of a coherent strategy for ensuring that the required information is collected in order to sustain the environments, resources and peoples of northern Canada.

This report provides an overview and assessment of over 450 items contained in the NCE database on climate change and effects on physical and natural resources that affect human activity in northern Canada. The following six issues were addressed:

Issue 1. **Is the NCE database representative of the available information?**

Issue 2. **To what extent do the references in the database provide information needs for assessing specific climate change impacts on physical and human systems?**

Issue 3. **Are the information sources regionally representative?**

Issue 4. **Recommendations based on the Gap Analysis**

1. **NCE facilitation of monitoring programs at the community level**
2. **Options for maintaining a current database.**

Description of the Matrices

The matrices (or tables) developed as part of the NCE gap analysis are the primary method used to organize and compile the information about the state of knowledge of climate change impacts in northern Canada. Each matrix applies to a system relevant to northern Canada. Ten of the seventeen matrices were assessed in this summary, including:

Baseline Climate Data
Boreal Forest and Taiga Ecosystems
Fresh Water Ecosystems
Tundra Ecosystems
Coastal Ecosystems
Marine Ecosystems
Agriculture
Fisheries
Forestry
Hunting and Trapping

Projected scenarios of climate change, including seasonal temperature changes; precipitation changes (rain and snow); and other climate impacts (storms, floods, cloudiness, or increased levels of atmospheric greenhouse gases), were assessed for each system for both baseline data (without taking climate change into account) and potential climate change scenarios. The matrices are only a tool to detect the current state of knowledge of climate change impacts on the various systems operating in northern Canada, and this information does not answer the question of what the effects of climate change on these systems will be. Therefore, if the state of knowledge of 'precipitation changes' on marine mammals is deemed to be poor, this does not necessarily imply that the impacts of more rain or snow will be negative for these species (although this might be true).

The overall gap analysis project involved the identification of information sources and the subsequent synthesis of this information with respect to the impacts of climate change on northern Canada. Information sources included documented scientific, local and traditional knowledge from journal articles, conference proceedings, research licenses, databases, and consultation with local experts and researchers. The number of information sources available for each matrix evaluated are indicated below. There were 464 references in total, although there is some duplication of records among the different systems.

Table 1: References in each System Matrix (updated Jan. 2002)

Matrix	**No. References**

Baseline Climate Data	47
Physical Systems	
Boreal Forest/Taiga	64
Coast	32
Tundra	85
Fresh Water	58
Marine	53
Human Systems	
Fisheries	33
Forestry	35
Hunting/Trapping	40
Agriculture	17

Limitations of the NCE Database

The NCE database provides information about the state of knowledge, with a critical assessment of what information is still required. Being able to see where these knowledge gaps are will provide both confidence in current decision making processes, and identification of directions for future studies. This assessment of possible trends and the consequences of climate change will allow users to independently determine possible responses in other regions, but it is not a substitute for local information and research. If comparisons of responses are made between regions these must be undertaken carefully, recognizing the tremendous variability in conditions across northern Canada. Most importantly, this gap analysis may provide opportunities to identify research and monitoring needs, and allow communities, governments and researchers the opportunity to coordinate their efforts.

There are several sources of uncertainty that apply to this gap analysis. First, many of the overview studies included in the database are highly speculative and are based on limited details. Similarly, many of the detailed, technical studies were conducted at a specific site and cannot be easily extrapolated to a larger scale. Second, the database provides a representative (rather than exhaustive) collection of information sources, so that the state of knowledge is most likely to be under-interpreted rather than over-interpreted. Third, the range of possible climate change scenarios is not well understood, and potential responses of biological and physical systems remain rather tentative. For all of these reasons therefore, this assessment of knowledge gaps is generally conservative, however this limitation should be interpreted as a virtue rather than as a liability.

Issue 1: Is the NCE database representative of the available information?

There is a vast body of scientific literature available on the topic of northern climate change. The current NCE gap analysis database contains several hundred documents from various sources, but no database is ever complete. However, the NCE database provides a representative, if not entirely comprehensive, overview of the northern climate change literature.

This assessment is based, in part, on a comparison with two other research databases, the ISI Web of Science Database and the Arctic Science and Technology Information System database. A search of the ISI Web of Science Database (http://www.isinet.com) using the keywords "Arctic" and "climate change" identified more than 450 references to scientific papers published in the technical journals between 1975 and 2001. No papers using these key words were published before1989, but there has been a steady increase in these publications over the last decade (Table 2).

Table 2: Number of papers published in scientific journals identified in a search of the ISI Database using the keywords 'Arctic' and 'climate change' (updated Jan. 2002).

Year	Number of Papers	Year	Number of Papers
2001	**75**	**1994**	**26**
2000	**60**	**1993**	**26**
1999	**68**	**1992**	**12**
1998	**49**	**1991**	**10**
1997	**63**	**1990**	**2**
1996	**17**	**1989**	**1**
1995	**48**	**<1989**	**0**

A similar search of the Arctic Science and Technology Information System (ASTIS - http://www.aina.ucalgary.ca/astis/) using the key word 'climate change', identified a total of 286 publications for the period 1990-2001, 58 during the 1980's, 17 during the 1970's, and only 5 prior to 1970. This database emphasizes reports from government agencies, industry, First Nations, and universities in addition to some journal articles, conference papers, graduate student theses and books.

Most of the references in the NCE database are from 1990 or later, and therefore should provide a reasonable perspective on the available information, and are likely sufficient to assess the knowledge gaps for northern Canada, recognizing that other information may be available in some areas. This additional information will be particularly important to provide additional information about 'baseline' conditions for some systems in different regions, and this could include almost any information about each of these systems from earlier decades. In this sense, the NCE database is incomplete but there is probably little value in adding additional general references. Current information about climate change impacts is more relevant to assessing potential risks, as well as the development of strategies for adaptation and mitigation at a local level.

Issue 2: To what extent do the references in the database provide information needs for assessing specific climate change impacts on physical and human systems?

For each of the systems identified in Table 1, a matrix was constructed to identify the state of knowledge (good, fair, poor) for baseline conditions of various system components and climate change projections, as described in the project methodology. In general, baseline knowledge is rated 'good' to 'fair', whereas climate change projections are rated 'poor' to 'not rated' because of data deficiencies. A number of general observations can be made from the available information sources.

1. The state of knowledge of baseline conditions and the potential impacts of climate change are regionally highly variable. This is a function of past research efforts, which tend to be focused in smaller areas (for example, Mackenzie Basin, Kluane Lake, Mayo, Churchill), but that are poorly studied in the rest of the North. Baseline data provides good site specific coverage in some cases, but regional coverage is generally limited. Extrapolation from highly localized studies to a larger scale is often problematic.

2. Information about climatological, physical and biological processes is poorly integrated with socio-economic aspects of the Northern environment. As a consequence, even where potential climate change impacts are reasonably well understood, the implications for human activities and well-being are not obvious. Thus, in all systems there is great uncertainty about the impacts of climate change on complex interactions.

1. Climate Data

Climate data in northern Canada is available from relatively few stations compared to the area of this region. Most climate stations are located near communities and consequently there is poor coverage in other areas. Most records are less than 50-years in duration, and there is a worrying trend of shutting down many weather stations, further reducing the ability of climatologists to monitor and predict changes in climate. Since this weather data is essential for determining subsequent impacts on natural and physical resources, this trend must be reversed. Nevertheless, the NCE database indicates that there is a reasonable state of knowledge for basic temperature and precipitation data in northern Canada. However, other climate data, for example effects of storms, extreme events and UV- radiation, is relatively poor.

Recent predictions suggest that the future Arctic climate will be characterized by a 5-7°C warming in winter over the mainland and much of the Arctic Islands, with modest cooling in the extreme eastern Arctic. In summer, warming of up to 5°C is predicted for the mainland NWT, but only 1-2°C over marine areas. Annual precipitation may increase by 25 per cent, with increases in the frequency of rain in early autumn or spring. Only by monitoring these changes and the outcomes will it be possible to really assess the implications of climate change.

One gap that needs attention is the extent to which ongoing community and scientific monitoring will be prepared to detect these changes. In addition, baseline climate data for temperature is generally better than for precipitation or extreme weather events, and this trend is reflected in our state of knowledge of the various potential climate change impacts on a particular system.

2. Boreal Forest/Taiga

In general, the state of knowledge about the boreal forest is good. The distribution of trees and other plants in the boreal forest, along with historical changes at treeline, are quite well known in northern Canada. Understanding the impacts of climate change on boreal forest vegetation is less certain, particularly if physical processes such as permafrost and forest fires are considered. Also, there are still some difficulties in predicting effects of climate change on forest growth. For example, measurements of tree ring-width and maximum late-wood density of white spruce in North America (representing growth from 1700 to 1990) show increased net tree productivity from 1760-1950, but this increase has leveled off since 1940 perhaps due to other confounding factors such as increasing UV-B. This decreased sensitivity of responses of tree growth to temperature change is problematic because of the importance of tree ring data in reconstructing past climate. (Briffa et al. 1998).

Changes in animal populations are known from a number of long-term experimental studies. For example, in the Yukon the 10-year snowshoe hare cycle and its effects on other boreal species are well known (Krebs et al. 2001). Similarly, an analysis of lynx population cycles across Canada based on 21 time series from 1821 onward show that lynx population dynamics are associated with winter climatic conditions. The mechanisms behind this association are not known, but the influence of snow on hunting efficiency needs to be addressed (Stenseth et al. 1999). These relationships can be largely extrapolated across northern Canada.

In northern Quebec, trampling scars on roots and low branches of conifers were used to index caribou numbers within the Rivière George caribou herd from 1868-1992. The index shows a negative trend in population growth from about 1900 to 1950, with positive growth from 50's to 80's. There was also a small increase in numbers during the 20's to 30's that is not well documented in the historical record (Morneau and Payette 2000).

Overall, the largest gaps are for invertebrate pest species and the relationships between physical (permafrost, hydrology, fire) and biological processes in the boreal forest. Potential effects of climate change will not be the same in all regions, and more work needs to be done to integrate existing datasets.

3. Coast

Baseline information and projected impacts of climate change in coastal regions is generally poor. *There is some urgency in addressing these gaps* because thermal expansion of the ocean coupled with melting glaciers and ice sheets are projected to raise mean sea levels about 20cm in the Arctic Ocean from 2000-2049, and by 50 cm by 2100. Such changes in sea level are expected to have significant effects on the Arctic's coastal settlements, and costly measures may be needed to protect them from flood damage, if indeed they can even be protected. Obviously these predictions are based on assumptions applied to global circulation models, but many of these projections appear to be quite reasonable. In this case the model is based on 1950-1990 greenhouse gas emissions compounded by a 0.5% annual increase after 1990, and the projections

are compared with simulation using control greenhouse gas emissions from 1950 (Miller & Russell 2000).

There is a clear need to develop better parameterized models using data from local coastal monitoring sites, since models will continue to play a large role in predicting the fate of coastal regions.

4. Tundra

There is good baseline information for a number of tundra sites in the Arctic due to long-term research efforts sustained over many decades at a number of sites including Devon Island, Ellesmere Island, Bylot Island, among many others. Recent experiments conducted by the International Tundra Experiment (ITEX) have also provided considerable insight into the ecology and effects of climate change on tundra environments. There is some concern that taiga/tundra ecosystems may be reduced by as much as two-thirds of their present size if climate warming shifts the southern boundary of the tundra north. Indeed, the southern Arctic Ecozone may completely disappear from the Mainland. Similarly, the northern distribution of 25 mammal species are bounded by the Arctic Ocean. Of those, the collared lemming (*Dicrostonyx groenlandicus*), which is a keystone herbivore, expected to lose 60% of its habitat (Kerr & Packer 1998).

From 1950-1995 trends in both total accumulation of precipitation and daily precipitation intensity at climate stations have increased significantly in the Arctic, particularly in the Arctic islands. Heavy event precipitation has increased most during the winter months and less so during the summer (Stone et al. 2000). The implications for tundra species is still speculative, but under these conditions mainland caribou would probably lose weight because of heavier snow cover and the increase in insects harassing the herd. High Arctic Peary caribou and muskoxen may become extinct.

More information is needed about the effects of extreme conditions on the survival and condition of large and small herbivores in tundra environments. There is also a gap in our understanding of the hydrology of tundra environments.

5. Freshwater

The state of knowledge about freshwater environments in northern Canada is fair to poor, and potential impacts of climate change are also poorly understood. Among the possible consequences of a warmer atmosphere and longer thaw period is increased evaporation resulting in decreased rivers flows and levels. The river-ice season may be reduced by up to a month by 2050, and the season for large lakes by up to two weeks. Many alpine glaciers are retreating rapidly, with resulting changes in stream flow and sediment loading. Species in lakes and streams are predicted to shift northward by about 150 km for every degree of increase in air temperature. If this were to occur, Arctic char would have to compete with the expansion of southern species such as brook trout. In general, the consequences of these range expansions are unknown. There are also concerns that increased UV-B may lead to changes in species composition and

productivity since UV-B can interact with heavy metals to reduce nutrient uptake, enzyme activity, carbon fixation, and oxygen evolution in some phytoplankton species.

Overall, there are significant gaps at <u>all levels</u> in understanding of freshwater environments.

6. Marine

With the exception of baseline information about marine mammals, the state of knowledge about Arctic marine environments is generally poor. The primary concern in the Arctic Ocean is the potential loss of sea ice. Microwave satellite remote sensing indicates14% reduction in multiyear ice in winter (1978-1998), a rate of 7% per decade (Johannessen et al. 1999). Marine mammals such as polar bears, ringed seals, and bearded seals are totally dependent on the sea ice environment, and all three species are sensitive to likely impacts of climate change, and are predicted to decline. In contrast, the range and numbers of beluga and bowhead whales may increase. Reduction in sea ice extent, duration, thickness and concentration, as well as displacement of the marginal ice zone can adversely affect reproductive success, foraging success, migration patterns and survival of marine species.

***There is a need to identify critical habitat for marine mammals relative to sea ice characteristics. This will require close integration of physical and biological researchers, and the close involvement of communities dependent on these resources*.**

7. Fisheries

Baseline knowledge of fisheries is rated as only fair. This is in large part because most of the available information relates only to distribution of species. There is little known about fish habitat, food chains in northern waters, parasites, or harvest levels. For example, of the 29 species in the by-catch of the commercial turbot fishery in the eastern Arctic, there is almost no information on the age to maturity, growth rates, food consumed, parasites, or general habitat use of these species. In addition, most subsistence fisheries in the north are difficult to manage using traditional fisheries science models developed for large-scale commercial fisheries. Increases in community size and fishing effort using new fishing gear has made it difficult to set harvest levels based on historic consumption estimates. As well, the variable life histories and isolated locations of different fish stocks makes estimating population size by direct counts very inefficient and expensive.

Overall there is very little information about northern fisheries, and the state of knowledge is poor to nonexistent in most regions. The impacts of climate change on both freshwater and marine fisheries remain largely speculative.

8. Forestry

The state of knowledge about forestry in northern Canada is fair, but there is great uncertainty about the effects of climate change. Forest fires and northward shifts in species habitats could affect human use of

forests. Climate change could exacerbate current development pressures in more accessible areas, especially where there is potential for competition from agriculture. The geopolitical and economic context is important in assessing the impact of climate change on the use of forests. There is a good sense of potential land-use shifts, and a general understanding of possible physical changes to land-use, but it is not clear how political and economic factors may play into actual land-use changes.

Much more work is needed on cumulative effects of forestry in the north. Studies in northern Alberta and Quebec indicate that corridors, industrial activity and climate change will all impact the future viability of forestry in the north. The experience in the Yukon suggests that forestry activities will not remain a sustainable part of the economy in the long-term given the slow rates of forest regrowth following harvesting. Considerably more work on this topic, especially in the context of climate change, is required.

9. Hunting and Trapping

Northern subsistence economies are intimately linked to wildlife resources. Although the state of knowledge is generally good for most species, there have been few detailed studies relating harvesting to climate change. There a few communities where information is available (e.g. Old Crow), but these experiences are not easily applied to other situations with different environments, traditional practices, and climate impacts. Much of the information about traditional hunting and trapping in communities was originally collected to support land claims and for harvesting data community economic studies, and consequently is not generally available.

There may be a gap in knowledge in this area, and an assessment of the implications of climate change on the long-term availability of country foods should be assessed. For example, the loss of local waterfowl and fish populations could have serious implications because these resources are not likely be replaced by other wild food sources. In a broader context there are gaps in understanding the relationship between food quality, human health and resource management in northern communities.

10. Agriculture.

For the most part, agricultural activity in northern Canada is not viable on a large scale. The short growing season and poor soils limit the types of crops that could be grown, although there have been serious investigation of this potential by government agencies over several decades in Yukon and the Mackenzie valley. In some areas wheat production may be possible with expanded irrigation, but a lack of suitable markets and high transportation costs may limit its viability.

Game ranching has been discouraged, but the potential for more extensive livestock operations in the Yukon and NWT has not received as much attention and this is a knowledge gap.

Issue 3. Are the information sources regionally representative?

This issue was the most difficult one to assess because Northern Canada is a vast region and considerable variability in local responses to climate change are anticipated. However, many of the references in the database represent analyses conducted at a large geographical scale, often for the entire Arctic region. In different ways, all northern regions will be susceptible to the impacts of climate change and variability, affecting all natural resources and every major human activity in the Arctic. While some of these changes may bring economic benefits, these are likely to be offset by new problems.

Given that both geography and community settings vary widely in the North, providing information on probable regional or local impacts of climate change is critical. There are references in the NCE database from all northern regions, but these tend to be clustered from sites of more intensive research activity, rather than being representative of an entire region. In some cases it is possible to extrapolate from small-scales to larger-scales, but in general this approach is probably not very helpful.

Table 3 indicates the number of references that apply to each region in northern Canada. However, many of the references in the database are not specific to a single region, therefore they are often cross-referenced to several regions. When these references are divided into the various categories for climate, biological and human systems, it is apparent that many knowledge gaps remain.

Table 3: Geographic Focus of Database References

Location	No. Records
Yukon*	**93**
Northern Yukon	**72**
Central Yukon	**15**
SW Yukon	**44**
SE Yukon	**10**
NWT	**169**
Nunavut	**101**
Hudson Bay	**49**
Northern Quebec/Labrador	**64**
Arctic Ocean	**114**
Northern Provinces	**80**

***in the Yukon, many references apply to more than one region consequently total Yukon records are fewer than the sum of all Yukon regions.**

One significant pattern emerges from the assessment of regional gaps. In general, regions with a longer history of access from southern Canada tend to have a more complete set of baseline information that can be used to assess potential effects of climate change. In most cases these sustained research efforts have been facilitated by the presence of research infrastructure, especially field stations. This pattern was apparent in the past, and is also evident today. Most of the regional knowledge gaps are in areas that are either difficult to access, or where no research infrastructure is present. The high costs associated with northern research appear to be a significant barrier to more extensive studies in many areas.

1. Yukon

There is reasonably good information available for both baseline conditions and climate change impact assessments in most parts of the Yukon. In the southwest Yukon this is largely a result of more than 40-years of intensive scientific investigation based out of the Arctic Institute of North America's Kluane Lake Research Station. Over 1000 scientific publications on physical and biological processes and climate impacts have been published, providing a large body of knowledge. Many of the 'gaps' in this region are for more specific information about detailed responses of physical and biological systems to climate variability, and better integration with consequences of human activities such as forestry and mining. In the central Yukon, 20-years of work on permafrost in the Mayo region has provided a sound basis for assessing the effects of climate change on forests, lakes, hydrology and infrastructure. In the northern Yukon the Arctic Borderlands Ecological Knowledge Co-op, in conjunction with other agencies such as the Wildlife Management Advisory Council (North Slope), have taken a leadership role in facilitating and developing ecological monitoring projects. *Only in the southeast Yukon are more basic assessments of baseline information and potential climate change impacts lacking*. It is worth noting however, that there are sufficient differences between the ecology and climate of this region compared to other Yukon regions that the absence of local information is a significant gap.

2. NWT

The greatest body of information about potential climate change impacts in the NWT comes from the Mackenzie Basin Impact Study, completed in 1997. Physical and ecological processes in other parts of this region are not as well studied, although some monitoring programs have been initiated as sites such as Daring Lake. Ongoing studies in the Inuvialuit Region also have a long and ongoing history of scientific investigation that supplements traditional knowledge. For example, recent observations from Banks Island suggest that (1) late freeze-ups (3-4 weeks) and early spring breakups of sea ice are interfering with caribou migrations; (2) there is a deepening of permafrost layers; (3) storage caches dug into permafrost are more unreliable; (4) there is an increase in the frequency of severe thunderstorms; (5). ice floes are now absent in summer; (6). muskoxen are born earlier and polar bears are emerging earlier; and (7) fishermen are catching Pacific sockeye and pink salmon in nets (Riedlinger 1999).

3. Nunavut

There have been a number of long-term studies of physical and biological processes in Nunavut, including long-term mass balance studies of icecaps and glaciers, and biophysical studies of tundra environments at Truelove Lowland (Devon Island), Alexandra Fiord (Ellesmere Island) and Bylot Island. *Specific*

knowledge gaps in Nunavut are related to changes in the sea ice environment, and potential effects of climate change on marine mammals.

4. Hudson Bay

The environment of western Hudson Bay is reasonably well known as a result of detailed research efforts conducted out of the Churchill Northern Studies Centre for several decades. Changes in sea ice, permafrost, hydrology, treeline dynamics, polar bears, plant-herbivore interactions and climate variability have been studied extensively, and provide a very useful baseline for determining climate change impacts. There has been considerable work on the eastern coastline as well. Overall, there are many opportunities for further research in the Hudson Bay region, but there are no significant gaps in comparison to some other regions in northern Canada. ***This region would be a good place to establish integrated multidisciplinary research programs.***

5. Northern Quebec/Labrador

The availability of baseline data in northern Quebec is very good as a result of several decades of long-term research by University scientists based out of research stations maintained by McGill University and Laval University. In addition, hydroelectric developments since the 1960's have ensured increased monitoring activity in the region. ***There is less information available for Labrador, and this region is certainly a large gap.***

6. Arctic Ocean

Issues related to the Arctic Ocean are described under the Marine Systems summary above. *Overall, there are still many gaps in knowledge with respect to both the physical and biological environment of the Arctic Ocean*. Factors that influence high-latitude energy fluxes need to be addressed, including attempts to link global climate models with models of ocean dynamics. At a more regional scale, patterns of spatial variability of sea ice cover are poorly documented. Variability in sea ice will have a strong influence on both the rate and magnitude of climate change in the Arctic and globally and this should be a priority area for research.

7. Northern Provinces

Information from the northern provinces is highly variable, reflecting in part the lack of focus on this region in the database. Since these sub-arctic areas are also experiencing the greatest increase in industrial activity (forestry, oil and gas exploration and development, agricultural expansion) the potential effects of climate change need to be urgently considered. Overall there are several initiatives focused on cumulative

effects assessment in these regions (i.e. the Sustainable Forests Network at the University of Alberta), and these studies should provide useful information for assessing risks in the northern provinces.

Issue 4: Recommendations based on the Gap Analysis

1. NCE facilitation of monitoring programs at the community level

This analysis of the NCE database also indicates that the regions with the most complete baseline information and potential to assess climate change impacts are those with established and ongoing scientific and community-based monitoring and research programs in place. There is a critical need for interdisciplinary studies combining traditional, community and scientific knowledge. All partners are essential to the success of these programs.

Monitoring is required to obtain a description of the long-term processes that drive ecosystems, and can be used to assess the ecological integrity or the health of ecosystems. Some monitoring activities can be conducted over the short-term, but because many processes occur over longer periods (for example the 10-year snowshoe hare cycle, fluctuations in caribou numbers over many decades, and climate patterns associated with 30-50 year oscillations in oceanic regimes such as the Pacific Decadal Oscillation), commitments to monitoring programs must be long-term. Monitoring programs based out of communities could provide much of the required information and sustain these efforts over time.

In northern Canada, the impacts of global change are an issue of high priority for decision makers in the public and private sector, for scientists and for communities and the public. There is increasing awareness and concern about the possible extent and nature of changes related to climate variability and impacts on daily life. The answers to these questions are complex and require an assessment of possible impacts of global changes on environmental and socio-economic systems in a comprehensive and integrated manner. These assessments also need to be focused on a regional scale in order to derive meaningful and reliable results. This approach is known as an Integrated Regional Impact Study (IRIS).

Perhaps the best example of such a program is the Mackenzie Basin Impact Study (MBIS) that functioned from 1989-1997. The MBIS integrated studies of the physical and biological environment with human activities that depend upon these natural resources. The overall research program provided an integrated analysis of climate change impacts within the entire Mackenzie watershed. Other examples of Integrated Regional Impact Studies, at different scales, include the Wolf Creek study (Yukon) and the proposed Hudson Bay ecosystem study (Nunavut, Manitoba). All of these projects engage multiple partners including communities, government agencies, and research organizations.

There is an urgent need for more geographically specific data collection throughout the North. Integrated Regional Impact Studies provide a framework for conducting multidisciplinary, long-term research. Emphasis on building partnerships to establish a network of IRIS programs in northern Canada is essential, and would ensure that many of the identified knowledge gaps would be addressed in a systematic manner.

The NCE is not in a strong position to maintain global or national summaries of climate change impacts, and much of this work is being undertaken by other agencies such as IASC,

IPCC and ACIA. However, clear knowledge gaps have emerged from the NCE database at the scale of communities. Integrated studies need to be conducted at regional scales in all of northern Canada. Areas with fairly good coverage at present include Yukon, Mackenzie Basin, Hudson Bay and Northern Quebec. Regions lacking attention in the necessary monitoring and research include the eastern Arctic, Labrador, central NWT, and the Arctic Islands. Priorities for monitoring include atmospheric, oceanographic, and biological systems. Greater utilization of Traditional Ecological Knowledge; and the active involvement of northerners in climate impact research is essential. The NCE could play an important role in facilitating the establishment and development of *Integrated Regional Impact Studies.*

2. Options for maintaining a current database.

One problem with this gap analysis project is that new information is becoming available on a daily basis. While older references are relevant to establishing baseline information, only more recent items deal explicitly with climate change and the implications of climate change. Consequently, the pool of references with a specific analysis of climate change impacts is relatively small at this time.

It is possible that the NCE database will become outdated as other assessments (i.e. ACIA) become available. The ACIA program in particular is well funded and a part of larger international programs. However, the NCE database should remain a very important place for communities to find and share information, particularly information that is relevant at the local and regional levels, scales that are often overlooked by larger-scale assessments such as ACIA.

Rather than attempting to maintain a 'global' database, it would likely be most efficient to identify information at the level of individual communities or local regions. This has been attempted with the current references, however many of them cannot be identified at a more precise geographic scale. However, where possible it would be useful to identify references to the scale of a community. *A community-focused database will provide useful information that is unlikely to otherwise be widely available.*

The assessment of potential impacts of climate change would benefit from close integration with specific community concerns. For example, research on water resources could be integrated with applications to fisheries, development of hydroelectric power, commercial navigation, and water supply and waste management. As noted earlier, the NCE could play a valuable role in matching researchers to communities, and communities to researchers. In addition, it is essential that community-specific databases be established so that knowledge of climate change impacts can be readily adopted in decision-making processes related to adaptation and mitigation.

Literature Cited

Briffa, K. R., Schweingruber, F. H., Jones, P. D., Osborn, T. J., Harris, I. C., Shiyatov, S. G., Vaganov, E. A. & Grudd, H. 1998. Trees tell of past climates: but are they speaking less clearly today? Philosophical Transactions of the Royal Society of London: Series B 353, 65-73.

Johannessen, O. M., Shalina, E. V. & Miles, M. W. 1999. Satellite evidence for an arctic sea ice cover in transformation. Science 286, 1937-1939.

Kerr, J. & Packer, L. 1998. The impact of climate change on mammal diversity in Canada. Environmental Monitoring and Assessment 49, 303-325.

Krebs, C.J., S. Boutin & R. Boonstra. 2001. Ecosystem Dynamics of the Boreal Forest. Oxford University Press.

Miller, J. R. & Russell, G. L. 2000. Projected impact of climate change on the freshwater and salt budgets of the Arctic Ocean by a global climate model. Geophysical Research Letters 27, 1183-1186.

Morneau, C. & Payette, S. 2000. Long-term fluctuations of a caribou population revealed by tree-ring data. Canadian Journal of Zoology 78, 1784-1790.

Stenseth, N. C., Chan, K.-S., Tong, H., Boonstra, R., Boutin, S., Krebs, C. J., Post, E., O'Donoghue, M., Yoccoz, N. G., Forchhammer, M. C. & Hurrell, J. W. 1999. Common dynamic structure of Canada lynx populations within three climatic regions. Science 285, 1071-1073.

Stone, D. A., Weaver, A. G. & Zwiers, F. W. 2000. Trends in Canadian precipitation intensity. Atmosphere-Ocean 38, 324-347.

The Northern Climate ExChange
Gap Analysis Project

State of Knowledge

Impacts of Climate Change on Human Activity

Frank Duerden
Ryerson University
Toronto, Ontario

March 2001

1 Introduction

The possibility of rapid global climate change has raised concerns about the ability of populations to adjust to change. While considerable uncertainty exists about the future climate and its impacts on human activity, there is consensus that climate change will affect high latitude regions the most. Physical changes of the type associated with global warming lie outside the experiences of the contemporary population of the North, and well beyond the popular perception of the North as a cold climate land characterized by stable landscapes and unchanging environments. It is generally accepted that information is an important tool for resource management when dealing with uncertain environments, so consolidating information on climate change and its possible impacts in northern Canada could help increase awareness of current and future trends, identify possible impacts, and provide a sense of information needs.

This report is a critical review of data on climate change and human activity in northern Canada found in a Northern Climate Exchange database. The study was undertaken when the bibliography contained some 456 references, and all references were examined in detail. Over subsequent months, the number of citations has increased markedly, and consequently the analysis and discussion of information quality is based on a very highly representative sample of works that collectively describe our state of knowledge regarding climate change in the Canadian north. It contains some 456 references to papers, books, statistics, and research reports relevant to the question of climate change in northern Canada. The Microsoft Access format allows relatively easy interrogation of the database by keyword search, date of publication, degree of completeness, and geographical area. In addition, summary abstracts of each work provide a fairly detailed sense of content.

This report analyzes the 106 references in the initial database that address some aspect of human activity. While additional references were sought from a wide range of sources, very little new material was found. A request posted on the Internet asking for information from the scientific community yielded no responses.

2 Climate Change and Human Activity

The focus of this work is human activity, defined broadly as economy and land-use and identified specifically by a number of descriptors which in total describe the range of human activities in northern Canada (see Table 1 for classification and explanation). Discussion of the relationship between climate and human activity is ancient, and the resilience of this debate points to the difficulties of establishing the manner in which climate change may impact on land-use and economy.

While it is indisputable that climate provides the context and parameters for human activity, establishing with any certainty the manner in which activities may respond to climate change is fraught with problems. First, relationships between activities are complex, change in one activity may affect others through economic multipliers, varying perceptions of decision-makers, and a range of feed-back mechanisms. Second, the response to physical change may primarily be a function of political and economic contexts. For example, the northward shift of agricultural potential in parts of the Mackenzie basin does not necessarily lead to the conclusion that there will be increased agriculture; this is dependent on markets and the population's acceptance of agriculture as a land-use activity. Finally, for better or worse, the development of North America has been dependent on innovations that have ameliorated the impact of climate extremes, (such as central heating, irrigation, and air-conditioning)1, and technological change will play into the way different sectors respond to climate change. Producing the scenarios that become the data and information about the possible impacts of climate change is difficult because one uncertainty is predicated on another, our understanding of the probable future climatic context for human activities depending on the accuracy of physical prognosis regarding the nature of change.

[1] Ironically increased CO2 levels are partially attributable to our endeavours to modify the impact of climate.

3 Database Rationale

The concern that global warming could have a significant impact on northern Canada raises many uncertainties and points to the need for certain types of information. Some of the pragmatic questions at the community level are:

- How will harvesting be affected?
- Will possible changes in winter ice formation affect hunting practices and winter road construction?
- Will melting permafrost affect construction, and if so, what technologies do we have to deal with these problems?
- How will employment be affected?
- Will easier access to northern oil and gas widen the industrial base of some northern communities?
- Will the subsistence base of some communities collapse because adaptation lags behind rapid change?
- How should we modify traditional housing design in the face of a warmer and possibly wetter future?
- Should we prepare for increased flooding?
- Will there be more forest fires?
- Will slope instability and landslides disrupt transportation? Will climate change lead to more catastrophic storms?
- Have communities experienced climate-induced stress in the past? If so, how frequent and severe were they, and how did they cope?

It is expected that both the general population and the decision-makers in northern communities will use the information in this climate change database. For example, government agencies may have to respond to a range of issues such as concerns associated with easier navigation through Canadian Arctic waters, the dislocation of community economies, or the consequences of extreme events. Given these "user-needs," a climate change information system would have four roles:

1) providing information on possible trends\scenarios and information on approaches for addressing the possible consequences of climate change;

2) enabling users to investigate impacts, responses, etc. of others in similar circumstances. This approach would save both time and money, reducing the need for extensive primary research and allowing users to focus on the most likely approaches or solutions. Given the pace of change, time is an important consideration;

3) providing baseline data that enables users to build scenarios predicting local impacts. For example, detailed information on current populations, ecosystems and economy and on the relationship between the current climate and human activity could help a community anticipate the impacts of environmental changes;

4) identifying research needs. Reviewing current database records and cross-referencing them with areas where information is needed would help identify gaps in research.

Evaluating the database thus hangs on questions such as: how complete is it? Can it provide a basis for action or decision-making? Is there a reasonable “fit” between the current information on climate change in Canada provided by NCE and the intended users?

4 Methodology

Assessing a database has two components. First, it must be determined whether users can retrieve relevant information easily, and second, the quality of the available information must be assessed. This paper largely concentrates on the second task. In addition to the NCE database review, the completeness of the existing database was assessed by searching for other sources of information. The value of a database lies as much with its ability to serve the needs of users as it does in the quality of information it contains. Even if all available current information on a topic is captured, such information may fall short of user needs.

The following six steps were used to test the quality of information on climate change in northern Canada:

1) Evaluating how well descriptors in the database matched information needs;

2) Evaluating the extent to which references in the database matched information needs for very specific human activities;

3) Reviewing the quality of information contained in the various references. Is it speculative? Is it informative? Does it tell us about possible responses to change?

4) Assessing currency of data. Is it contemporary? Have prognoses and assessments become outdated?

5) Reviewing the scale and comprehensiveness of geographic coverage.

6) Evaluating the completeness of the database. Is substantial available information missing? (As opposed to desirable information that is unavailable).

5 Identification of relevant references.

The initial step was identifying works dealing with human activity. A key-word search was conducted using the following descriptors for human activity in the North: human activity, harvesting, agriculture, transport, energy, forests, economy, mining, infrastructure, construction, and recreation\tourism. References were found in the following categories:

Table 1: References Relating to Human Activities

Activity	References
Human Activity	93
Land	35
Wildlife	33
Economy	28
Land-Use	17
TEK	15
Transportation	5
Mining	15

(Note: The number of valid references exceeds the number of records (106) because many records contained multiple references to different activities)

While the search terms "TEK" and "human activity" helped to identify 106 potentially useful records, the terminology was found to be imprecise as many references did not indicate a clear link to human activity. Subsequently more detailed reference to the range of human activities relevant to the North was sought in the abstract of each of the records.

Users of the database would want to know the possible impact of climate change on well-defined sectors of activity, and consequently a more detailed list of terms was used to describe human activity in northern Canada (Table 2). This included land uses and economy, infrastructure, social aspects of settlement (population, health, well being) and threats to economy and well-being in the form of increased incidence of natural hazards that may result from climate change (floods, landslides etc).

Defining reference material appropriate for inclusion in the analysis was a little problematic, as a huge amount has been written on climate change in the North over the past thirty years. Arguably all of it could be considered valid as it describes "initial conditions" and could provide baseline information.

Given that the focus of this exercise is the relationship between climate and human activity, all valid references had to contain some discussion of climate change implications. Repetitive works were eliminated, as were general bibliographies (8), and new references added. Table 2 illustrates how the number of valid references decreased as definitions became more specific.

Table 2: References by Specific Activity

Descriptor	References
1)Sector\ Land-Use	
Harvesting (hunting\trapping\fishing)	19
Forest Use	12

Agriculture	12
Recreation	6
Energy (Oil and Natural Gas)	13
Mining	3
Construction	3
2)Economic Impacts	16
3)Infrastructure \Community	
Transport	12
Water Supply\Sewage	2
Health\Well-being	7
4)Hazards\Extreme Events	12
Total	127

6 Content Analysis

i) Overview

Formal studies commissioned by government agencies or interest groups have generated much of the focused information on human impacts of climate change in the Canadian North. At the largest scale are works such as IASC's spell out (1999) systemic overview of infrastructure and land-use and broad studies of possible changes in the Yukon (1998) and the Arctic (1998) produced as part of the Canada Country Study series. Reports focused at the regional level include the Mackenzie Basin Impact Study (1997), which recognized the complex integrated regional systems framework in which impacts have to be evaluated, and a review of stresses on Hudsons Bay produced by the Canadian Arctic Studies Committee. There are also a plethora of sectoral studies examining the impacts of change on specific aspects of life in the Arctic (for example, Fast and Berkes 1998).

Many of these studies are inevitably highly speculative and are often dogged by both uncertainty about the physical nature of changes and a lack of detailed data on economy and society necessary for modeling ways in which a predicted change in physical conditions would ultimately impact on way of life at the community level. Anticipated changes such as tree line advance, melting permafrost, or modification of a major ecoregion all have implications for human activity and are generally described at the gross scale. But significant impacts may vary markedly from community to community because of variations in local geography, economy and culture. There are fewer appropriate community level studies.

Individual works often refer to a range of activities, thus diluting what were already highly speculative impacts for any one sector. However, the accompanying analysis was sometimes particularly significant as it centered on the dynamics of land-use change and the ways in which some uses may displace others with climate shifts. For example forests may give way to agriculture and there may be changes in the nature of wildlife harvesting.

In this interplay between land-uses, behavioral and economic factors determine responses to climate change and may also give rise to land-use conflicts. For example climatic conditions could create new agricultural opportunities in the potentially more arable areas of the southern Yukon and parts of the Mackenzie system, but market conditions may discourage land-use change (MBIS). Northern agriculture would still be a costly proposition, despite relatively low transport costs, and it is difficult to compete with mass production in the south. Significant agricultural expansion could cause conflicts with wildlife harvesting because of land clearance and the notion that "wild" animals constitute pests in domesticated landscapes, exacerbating stresses and ecological modifications that were first triggered by climatic factors.

ii) Sectoral Review

a) Harvesting (hunting, trapping, fishing). Although there are numerous references to harvesting, few detailed studies relate harvesting to climate change. Some good local studies have provided important information for specific communities (Old Crow, Bathurst Caribou Herd, for example.) Such studies can offer other communities a sense of climate change\subsistence dynamics, but variations in northern geography and community circumstances make interpolation of experiences to other locations questionable.

There is a tendency towards very general works. For example, the Canada Country Series study of climate change impacts on harvesting (Fast and Berkes 1998) provides a generally useful overview. Much of the substantial data on native harvesting was gathered for purposes other than climate change (land claims, regional or community economic studies). Reviews of probable impacts on dietary habits are scant and highly speculative (see, for example,

Wein 1995). There is a general understanding of the physical changes that could impact harvesting (ecosystem shifts, shifts in tree-line, permafrost melt, ocean warming, decrease in sea-ice) at the macro-level, but the way in which physical changes would play into population dynamics and mixed economies at the local level is not as clearly understood. The few studies directly linking climate change and harvesting rely on information from widely known studies that sit in the public realm. Considerable baseline information has been gathered at the community level in the course of land claim negotiations or in support of other processes (environmental assessments, planning, etc.), but is not accessible. Overall there seems to be a high sense of awareness that harvesting will be impacted, but the precise nature of the impacts is not known.

b) Human Use of Forests. Forest fires and northward shifts in species habitats could affect human use of forests. Climate change could exacerbate current development pressures in more accessible areas, especially where there is potential for competition from agriculture. Geo-political and economic contexts are seen to be important in assessing the impact of climate change on the use of forests. There is a good sense of potential land-use shifts, and a general understanding of possible physical changes to land-use, but it is not clear how political and economic factors may play into actual land-use changes.

c) Agriculture. Most discussion concerns general land-use and the relationship between agriculture and other land-uses. The northern movement of agriculture could bring conflicts with forest use. An increased need for irrigation may constrain agricultural expansion. Although physical conditions may favour northern expansion of agriculture, a lack of markets and unfavourable local economic conditions may limit its spread. In the Yukon and parts of the Mackenzie Basin, considerable long-term baseline information gives a reasonable sense of how marginal lands would respond to warming. Where studies have focused on specific regions (eg Brklacich and Curran in MBIS, 1997), there is a cautious understanding of the way in which economic factors may constrain land-use change

d) Recreation\Tourism. The very limited amount of available information mainly appears in broad overview works dealing generally with climate change impacts (see, for example, Rothman and Herbert 1997). There is some discussion of emerging issues related to tourism and climate change (Wenzel, 1995, West, 1995).

e) Mining. The most significant questions relate to the ways permafrost melt and increased precipitation may impact existing mining operations and de-commissioned mines and affect future approaches to de-commissioning. Mining has long been an important industry in northern Canada, but there is little detailed relevant information on associated issues in the database.

f) Energy. (including oil and natural gas). Most references concern the impacts of climate change on energy production. This includes investigating impacts in the Mackenzie-Beaufort region under different climate change scenarios, and the impact of modified hydrology on hydro-electricity generation in Northern Quebec. A minor theme is the use of alternate energy sources in the North to ameliorate global warming through reduction of greenhouse gases.

g) Transport. Impacts vary with location, largely related to landscape changes. Increased landslides and slope instability could affect highway transport, as would the melting of permafrost beneath highway surfaces. Travel related to harvesting may become more difficult because of thinner lake ice (anecdotal evidence for this), more open water and changing shore-ice conditions. Over time northern transport systems have evolved to accommodate a range of climatic conditions, and from a baseline standpoint there is a good sense of current conditions. The literature addresses impacts on land transport from changes such as melting permafrost and increased incidence of landslides, but the prognosis regarding ocean transport is more guarded. Decreasing ice coverage is expected to make navigation on the Arctic Ocean easier, but there is currently considerable controversy among marine scientists about temperature trends (IASC 1999).

h) Economic. Impacts tend to be speculative. Improved accessibility in some areas (the Arctic Ocean, for example) could bring new opportunities (increased hydro-carbon development) and cause shifts in community economic bases as the nature of subsistence harvesting changes, possibly declining in some areas. There are virtually no community micro-studies directly related to climate change detailing economic structure and

interdependency, or examining the potential for labour to be absorbed into emerging sectors as economies shift. However a number of studies prepared for other purposes (pipeline impacts, planning, land-claims) detail the structure of dual economies that could conceivably provide baseline data. Much of this information is dated; not all of it is easily accessible.

i) Health\well-being. This topic is related to economic development. Climate change is generally viewed as an emerging stress that will exacerbate other factors impacting well-being in the North, such as rapid population increases in the eastern Arctic and the possible release of toxins into the food-chain associated with higher temperatures. It is speculated that people may eat less country food because of changing wildlife regimes, resulting in health problems.

j) Water-Supply\Sewage. While the characteristics of existing infrastructure in individual communities are documented, and some general observations on future scenarios was found, no formal information on climate change impacts in this area was uncovered.

k) Hazards. The range of extreme or catastrophic events associated with warming that may impact human activity is well documented, although there is no detailed assessment of risk (at the community level for example). Database records identify impacts such as rapid coastal erosion in the western Arctic, increases in run-off leading to flooding, more forest fires, landslides impacting on communications, and permafrost melting potentially affecting built structures and transportation. The MBIS study has the most comprehensive region specific information. With one notable exception (Aharonian, 1994) there is little formal information on the hazard history of northern communities in the contemporary literature. Detailed information on hazard history could be very useful as different experiences of past extreme events would probably be reflected in different responses to events associated with climate change.

> From the preceding review a general picture emerges of our knowledge of the ways in which climate change may impact on different aspects of human activity. Agencies, organizations and individuals concerned with climate change and its possible impacts need information that is rigorous (detailed, low on speculation) or prescriptive (suggesting possible adjustments or adaptive strategies). While most works identified in this study have some prognosis regarding climate change, many are speculative in tone. Only slightly more than half the references (55) predict impacts in any sort of a specific or rigorous manner, only eight dealt in any detail with either amelioration of climate change or specific approaches to adaptation. This lack of information partly reflects the fact that a number of works focus primarily on changes in the physical environment, and references to human activity are secondary. The preoccupation with predicting impacts rather than offering ways to react to changes, and the message that the climate may be changing, are both clearly important because they give northerners a sense of the conditions for which they should be preparing.

Is the lack of prescription a cause for concern? It certainly points to a major *formal* information gap on how various sectors should prepare for climate change, but it perhaps understates the extent to which consequences of change are understood. It is highly probably that those employed in various activities in northern communities may have a strong innate sense about the constraints under which particular activities function, and thus the manner in which they may be affected by changing conditions and possible appropriate responses to change. The validation of TEK as a source of information on northern environments over the last several years certainly supports this contention, and local and experiential knowledge may expand way beyond TEK into tertiary and industrial sectors. Thus while the review on page 8 indicates that relatively little is formally recorded about possible impacts on a number of sectors we can surmise that there is considerable reservoir of experience and understanding – local knowledge – that would play an important role in responding to climate change.

The lack of detailed information presents a particular problem for decision-makers in communities that need to address change. Except for those in the Mackenzie region, decision-makers can learn very little of direct application from the database. It is important to note, however, that this is not a failing in the database per se or of NCE's data-collection efforts. The search for additional sources of information yielded few results, and those additional works that were identified displayed the same lack of specificity as references identified by the NCE. It is perhaps not too

crass to characterize the message of many works as being “climate change is coming, there could be some considerable impacts, we really don’t know what they are but you should be ready for them…….”

7 Spatial Distribution of References.

Given that both geography and community settings vary widely in the North, providing information on probable regional or local impacts of climate change is important. However, as Tables 3 and 4 indicate, references tended to be at a gross geographic scale and information in the NCE database displays considerable spatial bias. This is somewhat to be expected when examining the impacts of change on human activity because the North's 90,000 inhabitants are mainly located in the west (the Mackenzie region and the Yukon), characterized by the most complete infrastructure (roads, pipelines, mining, oil and natural gas) and relatively large non-native populations. Even making allowances for these variations, the west is over-represented in the database. The Yukon, with only 30 percent of the North's population has more than 40 percent of the place-specific references, and one-third of these were based on one northern community, Old Crow. The numerous references in the database for the Mackenzie valley obviously reflect the rich range of source material produced by the MBIS project. Nunavut per se is very much under-represented. Many references are at a very general scale, examples include "Yukon", "Arctic", "Western Arctic" etc, or "the North." While this is a reflection of the fact that changes will be wide ranging, to a large extent it results from the paucity of sub-regional or local scale information about the north.

Table 3: Geographic Focus of Database References

Location	Occurrences
1) Arranged by Frequency	
Not Specific	44
Mackenzie Basin	19
Yukon	18
Yukon North	11
Alaska	6
N. Provinces	6
Arctic Ocean	5
N. Quebec/Labrador	3
Nunavut	2
Central Arctic	1
Yukon Central	1
2) Arranged by Location	
Not Specific	44
Yukon	18
Yukon North	12
Central Yukon	1
NWT	7
Mackenzie Basin	19
Nunavut	2

Western Arctic	3
Central Arctic	2
Northern Provinces	6
Alaska	6

Note: This table depicts the apparent spatial imbalance in the available information relating to climate change and human activity. This is attributable both to focused studies in the west examining climate change impacts and to the range of scales at which references have been classified. More than one-third of the references are not region-specific, and many relate to more than one region. Overall only 36 are affiliated with a single region, and some of these regions are vast (Alaska, for example), pointing to the need for more locally focused small-scale studies.

However impacts on human activity will be felt locally. Every community is unique with its own geography, culture and economy, so even identical changes in broad conditions such as advancing tree –lines, melting permafrost, retreating sea-ice and storm surges may impact any two communities in markedly different ways. For example, at the aggregate (or systemic) level we can make gross estimates of food harvests and relative dependency on country food, and thus perhaps model how depleting one species may impact on this part of the economy. But harvests vary in both type and volume, as does the local ecological context for the harvest. Local economies also vary, and communities with stronger or emerging industrial economies may be better able to tolerate change by offering alternate employment.

As a consequence of these various factors, communities will probably react in different ways to changes in environment or productivity of the land. In order to get a realistic sense of probable impacts, detailed information on initial (baseline) conditions in individual communities is required along with a sense of the ways that their local physical environment could be impacted by events associated with climate change, such as melting permafrost and changes in forest characteristics.

The numerous relevant references drawn from the Mackenzie Basin Impact Study (MBIS) come closest to providing an integrated and geographically useful database. MBIS recognized that the physical environment provides a context for human activity and that different activities are related and interdependent. The works associated with MBIS provide a multi-facetted and fairly well integrated perspective on climate change impacts in a large physical region defined by one unifying feature, its watershed. To a large extent MBIS is a good model for a climate change information base in terms of the types of information provided and appropriate geographic scale. (The Wolf Creek study performs the same function at a somewhat smaller scale, as did CARC's Hudson's Bay study.) Much of the information in MBIS is only useful for application in its own geographic area. This is not a weakness, rather it reflects the strengths of a regionally important information base. But it also underlines the general need for more geographically specific data collection throughout the North. [2]

[2] While MBIS is by far the best regional integrated source on climate change impacts it was a relatively low budget exercise, and to some extent this is reflected in its speculative nature and relative paucity of primary data.

8 Currency

While the NCE database captures information ranging back over thirty years, the more specific analyses linking climate change to human activity or to defined regions have been conducted in the last decade. This reflects the fact that concerns about climate change are relatively new.

Table 4: References by date of completion

Date of Completion	References
1990 and before	19
1991-95	40
Since 1996	54

While these trends are not unexpected, they do indicate that the number of studies linking human activity and climate change in the North is increasing. The recent studies are region or sector specific and have the greatest relevance, and continuation of this trend may help ameliorate the current substantial information deficiencies.

9 How Good is Our Formal Knowledge of Human Impacts of Climate Change in Northern Canada?

> From the preceding analysis, conclusions can be drawn about the specific structure of the NCE database and the state of knowledge regarding climate change impacts in northern Canada. In the first instance, the NCE bibliography is a good (if not quite complete) inventory of books, papers, data and reports on the impact of climate change on human activity that clearly sit within the public realm. As it stands, the database architecture could perhaps be improved to better reflect both the content of works related to human impacts and their geographic context. The addition of more key words (such as the ones used in this report) to describe specific activities would be very useful. More precise regional definition would also be appropriate, although it is conceded that this is rather problematic given that there is no precise geographic focus for many works.[3]

Regarding the overall state of knowledge, there is a real lack of quality information relating human activity and climate change impacts in northern Canada. The 106 citations identified dwindle significantly if their relevance and currency are considered. After adjusting for duplication, 91 records clearly referred to human activity, and a number of these were references to different activities in the same article or paper. Only 45 citations could be considered current, meaning produced in the last five years, and these also are the most relevant references, yielding practical focused information on climate change impacts. They are largely products of projects centered on climate change impacts (MBIS, the Canada Country Studies, for example).

Given the large size and geographic diversity of northern Canada, there is little formal information available on human activity and climate change. This situation is made worse by the fact that most of the information is specific to the western Arctic, and many works are at a broad scale. Understanding the impacts of change with any certainty is perhaps not a reasonable expectation at this stage, given that there is considerable uncertainty about what is happening to the North's physical environment upon which most human activities are based. Section 6 of this report summarizes the state of formal knowledge regarding climate change impacts and human activity in the Canadian North.

Different users require information at different scales, so a useful report provides the right information at the appropriate scale. While much work remains to be done in obtaining, consolidating and presenting information, a number of works exemplify ways of conveying climate change information at different scales that would be useful to specific users. Information can be classified at four distinct scales:

- large scale sectoral (IASC,1999 for example)
- regional\sectoral (Canada Country series)
- regional\integrated (MBIS)
- community level (Kofinas, 2000).

The value of these studies lies in their utility to different user groups. The IASC analysis, for example, has its greatest immediate value in providing a scientific overview to federal-level decision-makers charged with responsibility for broad sectors of the northern environment (inland waters, Arctic navigation, regulation of non-renewable resources) and a need to be aware of concerns that could arise from extreme events. The regional level analyses serve as a tangible basis for planning and drawing affected land-use interests together in contemplating climate change impacts, while community level studies recognize the fact that impacts and responses will depend very much on local geography, economy and community attitudes.

10 Information Needs

1. A reoccurring theme in climate change literature (either directly, or implied through general discussion) is uncertainty about the nature and impact of climate change in the North. Prescribing anything approaching reasonable responses to change is difficult if the real nature of that change is unknown. While information, such as that contained in the reviewed literature, may allow us to narrow down *possibl*e scenarios for different sectors or affected populations, the prevailing message is one of uncertainty. Virtually nothing in the literature reviewed explicitly addresses the question of strategies for dealing with uncertainty. Resource-management literature does address this question and some consideration should be given to putting it into frameworks appropriate to northern Canada.

2. While there is a lack of formal material (i.e., in the public realm) relating climate change and human activity, there is probably extensive "grey literature" of relevance. Also considerable local-scale information on land and environment has been produced over the past twenty years, largely in support of land claims. If this type of information were made accessible, it could serve as baseline data for building scenarios.

3. The expectations and levels of knowledge of those involved in decision making need to be identified. TEK is an accepted way of encoding knowledge and understanding processes and change for aboriginal populations. Is it not also reasonable to expect that long-time northern practitioners and decision makers involved with different sectors (such as transport, construction, or community infrastructure systems) would hold much detailed and useful informal knowledge regarding ways of responding to change? Their experiences, expectations and perspectives on adaptation to changing environments are perhaps the most valid, but are also the least likely to enter the world of print.[3]

4. Much more hard, geographically precise information is needed for building scenarios. Human impacts will be felt at the community level. Widely differing geographic contexts and economies mean that individual communities will react to change in different ways. Dedicated *community-specific* databases are required that include factors such as initial conditions, land uses, economic structures and locational conditions that could have bearing on climate change impacts. Examples of the latter include susceptibility to hazards and extreme events.

5. There is a lack of information on community risk. Catastrophic events such as floods, landslides, and communication ruptures could be the most visible and immediately costly impact of climate change. While there is some decent regional prognosis regarding hazard impacts (MBIS), generally in the North well-organized data are sparse, both temporally and spatially. Ideally data need to be consolidated to identify possible risks associated with climate change at the community level.

6. As the volume of information produced through MBIS illustrates, integrated studies with a regional focus have tremendous value, as long as the region has underlying physical unity. They provide a systemic basis for tracing\modeling physical impacts, and from the human activity perspective address both the political\economic context and the dynamic relationship between different activities. They have immediate practical relevance to subject populations for addressing issues arising from the probability of climate change. More integrated regional impact studies should be encouraged.

7. While investigating other regions that represent the types of physical environments that may emerge in the North may be useful, its value may perhaps be limited because the immediate problem will be one of dealing with the process of change rather than with the emergent stable environment. This process could be both protracted and characterized by unpredictable events.

[3] The number of references to "personal communication" in the database indicates that there is a wealth of experience to be drawn on from those involved in the day to day business of running the north in both the public and private sectors.

Bibliography

1) Sector\Landuse

Harvesting (hunting\trapping\fishing)

1995 Arragutainaq,L. et al.
Traditional ecological knowledge of environmental changes in Hudson and James Bay. Hudson's Bay Programme, CARC.

1995 Beamish, R. J.
Responses of anadromous fish to climate change in the North Pacific. In Human Ecology and Climate Change, People and Resources in the Far North, David Peterson and Darryll Johnson (Eds.) pp. 123-135.

1994 Berkes, F. et al.
Wildlife harvesting and sustainable regional native economy in the Hudson Bay and James Bay Lowland. Arctic 47, pp. 350-60.

1997 Bone, Robert, Shane Long and Peter McPherson.
Settlements in the Mackenzie Basin: now and in the future 2050. In Mackenzie Basin Impact Study Final Report, Stewart Cohen (Editor).

1997 Brotton, J. and Wall,G.
Climate Change and the Bathurst Caribou Herd in the NWT. Climate Change 35 No 1.

1998 Duerden, F. and Kuhn, R.G.,
Scale, context, and application of Traditional Knowledge of the Canadian North. Polar Record 34 (188):31-38.

1992 Ernek, P.
Traditional and contemporary Inuit knowledge of the impact of climate variations on wildlife. Paper presented at Canadian Arctic Global Change Workshop. University of Alberta.

1998 Fast, H. and Berkes, F.
Climate Change, Northern subsistence and land-based economies, Canada Country Study. Sectoral Issues. Ottawa.

1998 Gill, Mike, Canadian Wildlife Service, Whitehorse, (867) 393-6760 Yukon North Slope Long-term Research and Monitoring Plan,

1999 Griffith, Brad
Integrating the effects of climate and development on a subsistence resource for Arctic communities. President's seminar, Institute of Arctic Biology, University of Alaska, Fairbanks

1998 Huang, G.H., Cohen, S.J., Yin, Y.Y. and B. Bass
Land resources adaptation planning under a changing climate - a study for the Mackenzie Basin. In Resources, Conservation and Recycling 24(2): 95-119

1992 Kassi, Norma
Native perspective on climate change

In Impacts of Climate Change on Resource Management in the North, Geoffrey Wall, ed. (Department of Geography Publication Series, Occasional Paper No. 16, University of Waterloo, 1993): 43-49.

2000 (ongoing) Kofinas, Gary (c.)
Community-based Ecological monitoring project in the North Yukon

1997 Dale Rothman and Debora Herbert
The socio-economic implications of climate change in the forest sector of the Mackenzie Basin. Mackenzie Basin Impact Study. Stewart Cohen (Ed.): 225-241

199-
Russell, Don, and Joan Eamer
Caribou and Climate: A Slide Show

1998 Ryder, J.M.
Geomorphological processes in the alpine areas of Canada : the effects of climate change and their impacts on human activities. Geological Survey of Canada, Bulletin 524

2000 Snowshoe, Norman
Gwich'In Settlement Area Land Use Impacts, 2000. Panel Discussion on climate and impacts Workshop: Climate change impacts and adaptation strategies for Canada's northern territories

1995 Wein, E.E. and R.W. Wein
Predictions of Global warming influence on Aboriginal food use patterns in northwest Canada. The Northern Review 14 1995, pp. 86-94.

1995 Wenzel, George, W.
Warming the Arctic: Environmentalism and Canadian Inuit. In Human Ecology and Climate Change, People and Resources in the Far North, David Peterson and Darryll Johnson (Eds): 169-184

Forest Use

1994 Armstrong, Glen W.
Timber supply impacts of climate change in the Mackenzie Basin. In Mackenzie Basin Impact Study Interim Report #2, edited by Stewart J. Cohen. Ottawa: Environment Canada, 1994: 447-452.

1997 Dale Rothman and Debora Herbert
The socio-economic implications of climate change in the forest sector of the Mackenzie Basin. Mackenzie Basin Impact Study. Stewart Cohen (Ed.): 225-241

1998 Huang, G.H., Cohen, S.J., Yin, Y.Y., and B. Bass
Land resources adaptation planning under a changing climate - a study for the Mackenzie Basin. In Resources, Conservation and Recycling 24(2): 95-119

1998 Marshall, Jane
Yukon State of the Environment, Interim Report 1997, A focus on Air quality and climate change

1997 Maxwell, Barrie
Responding to global climate change in Canada's Arctic, vol. II of the Canada Country Study: Climate Impacts and Adaptations

1985 Miller, M.M.
Recent climatic variations, their causes and Neogene perspectives Late Cenozoic History of the Pacific Northwest, American Association for the Advancement of Science, Pacific Division. San Francisco: California Academy of Science, 1985, pp. 357-414.

1992 Roots, Fred
Climate change - its possible impact on the environment and the people of northern regions In Impacts of Climate Change on Resource Management in the North, Geoffrey Wall, ed. (Department of Geography Publication Series, Occasional Paper No. 16, University of Waterloo, 1993): 127-51.

1997 Rothman, D. and D. Herbert
The socio-economic implications of climate change in the forest sector of the Mackenzie Basin. In Mackenzie Basin Impact Study, Final Report. Stewart Cohen (Ed.): 225-241

1998 Schindler, D
Dim future for boreal waters and landscapes. Bioscience 48(3): 157-16

1993 Slaughter, Charles W.
Global warming considerations in northern boreal forest ecosystems. In Impacts of Climate Change on Resource Management in the North, Geoffrey Wall, ed. (Department of Geography Publication Series, Occasional Paper No. 16, University of Waterloo, 1993): 81-90.

1994 (published '97) Timoney, K.P., Peterson, G., Wein, R
Vegetation development of boreal riparian plant communities after flooding, fire, and logging, Peace River, Canada In Forest ecology and management 93(1-2): 101-120

2000 Yvonne Harris, coordinator
Yukon State of the Environment Report, 1999, Government of Yukon

Agriculture

1994 Armstrong, Glen W.

Timber supply impacts of climate change in the Mackenzie Basin. In Mackenzie Basin Impact Study Interim Report #2, edited by Stewart J. Cohen. Ottawa: Environment Canada, 1994: 447-452.

1997 Brklacich, M, and P. Curran
Carbon dioxide induced climatic change and agricultural potential in the Mackenzie Basin, In Mackenzie Basin Impact Study, Stewart Cohen (Ed.)

1996 Bootsma, Andre
Synthesis Paper: A Review of Impacts of Climate Variability and Change on Agriculture in Atlantic Canada. In Climate Variability and Climate Change in Atlantic Canada : Proceedings of a Workshop, Halifax, Nova Scotia, 3-6 December 1996: 79-89.

1997 Maxwell, Barrie
Responding to global climate change in Canada's Arctic, vol. II of the Canada Country Study: Climate Impacts and Adaptations

1994 Mills, Peter
Agricultural potential of northwest Canada and Alaska and the impacts of climate change In Arctic 47(2): 115-123

1994 Mills, Peter
The potential soil resources for northwestern Canada and the United States and the impact of climatic changeProceedings of the First Circumpolar Agricultural Conference, Whitehorse, Yukon, Septemnber 1992:195-204

1994 Riewe, Rick and Jill Oakes (Eds.)
Biological implications of global change: northern perspectives Edmonton, Canadian Circumpolar Institute, 1994. Vi, 114 p. (Environmental Research Series Occasional Publication 33)

1980 Rostad, H.P.W.
Agriculture in the Northwest and Yukon Territories, Canada West Foundation, Calgary

1992 Smith, C.A.S.
Agroclimate and soil resources of the Yukon, In Proceedings of the 1st Circumpolar Agricultural Conference, Whitehorse, Sept 1992

1988 Tarnocai, C. et al
Agriculture potential and climate change in the Yukon, In Proceedings of the Third Meeting on Northern Climate, Sept 7-9, 1988, Whitehorse:181-196

2000 Yvonne Harris (coordinator)
Yukon State of the Environment Report, 1999, Government of Yukon.

1997 Zebarth, B. et al
Effect of climate change on agriculture in British Columbia and Yukon, In Responding to Global Climate Change in British Columbia and Yukon, Volume I of the Canada Country Study. Bill Taylor and Eric Taylor (eds.)

Tourism/Recreation

1998 Huang, G.H., Cohen, S.J., Yin, Y.Y., and B. Bass
Land resources adaptation planning under a changing climate - a study for the Mackenzie Basin, In Resources, Conservation and Recycling 24(2): 95-119

1997 Rothman, D. and D. Herbert
The socio-economic implications of climate change in the forest sector of the Mackenzie Basin. In Mackenzie Basin Impact Study, Final Report. Stewart Cohen (Ed.): 225-241

1995 Wenzel, George, W.
Warming the Arctic: Environmentalism and Canadian Inuit, In Human Ecology and Climate Change, People and Resources in the Far North, David Peterson and Darryll Johnson (Eds): 169-184

1995 West, Patrick C.
Global warmingand conflict management: Resident native peoples and protected areas, In Human Ecology and Climate Change, People and Resources in the Far North, David Peterson and Darryll Johnson (Eds): 187-195

2000 Yvonne Harris (coordinator)
Yukon State of the Environment Report, 1999

Mining

1988 Eamer, Joan
The use of climate data in environmental impact assessment at Curragh Resources' lead-zinc mine. Published in Proceedings of the Third Meeting on Northern Climate, edited and prepared by Yarranton Holdings Ltd., under contract to the Natural Resources and Economic Development Branch of DIAND, 1988: 82-89.

1996 Eamer, Joan (c.)
Yukon State of the Environment Report 1995, Published by Environment Canada and the Yukon Government

2000 Yvonne Harris, coordinator
Yukon State of the Environment Report, 1999

Energy

1994 Anderson, William P.; DiFrancesco, Richard; Kliman, Mel
Potential impacts of climate change on petroleum production in the Northwest Territories, In Mackenzie Basin Impact Study Interim Report #2, edited by Stewart J. Cohen. Ottawa: Environment Canada, 1994: 433-441.

1996 (published '97) Arctic Pollution Issues: a state of the Arctic Environment Report, AMAP Secretariat, Oslo, Norway

1990 Collins, Robert
Yukon strategies to reduce greenhouse gas emissions, Published in Proceedings of the Fourth Meeting on Northern Climate, edited by G. Wall and L. Weber. Canadian Climate Program, 1990: 147-152.

1993 Croasdale, K.R.
Impacts of climate change on northern offshore petroleum operations, In Impacts of Climate Change on Resource Management in the North. Geoffrey Wall (Ed.)

1993 L.A. Mysak
Climate variability and change with respect to hydroelectric development in northern Quebec.Montreal : Great Whale Public Review Support Office, 1993. Background paper - Great Whale environmental assessment, no. 1

1997 Maxwell, Barrie
Responding to global climate change in Canada’s Arctic, vol. II of the Canada Country Study: Climate Impacts and Adaptations

1994 Riewe, Rick and Jill Oakes (Eds.)
Biological implications of global change: northern perspectives Edmonton, Canadian Circumpolar Institute, 1994. Vi, 114 p. (Environmental Research Series. Occasional Publication 33)

1997 Von Camp, J. And D. Bevington
Hydrogen: the key to sustainable energy for the remote north, Aurora Research Institute; South Slave Research Institute; Fort Smith, NWT

2000 Yvonne Harris, coordinator
Yukon State of the Environment Report, 1999

Oil/Gas

1994 Anderson, William P.; DiFrancesco, Richard; Kliman, Mel
Potential impacts of climate change on petroleum production in the Northwest Territories, In Mackenzie Basin Impact Study Interim Report #2, edited by Stewart J. Cohen. Ottawa: Environment Canada, 1994: 433-441.

1993 Croasdale, K.R.
Impacts of climate change on northern offshore petroleum operations, In Impacts of Climate Change on Resource Management in the North. Geoffrey Wall (Ed.)

1993 Mcgillivary, D.G., T.A. Agnew, G.A. McKay, G.R. Pilkington, M.C. Hill
Impacts of climate change on the Beaufort Sea-Ice regime: Implications for the Arctic Petroleum Industry. Climate Change Digest, AES, Downsview ON

1985 Miller, M.M.
Recent climatic variations, their causes and Neogene perspectives, in Late Cenozoic History of the Pacific Northwest, American Association for the Advancement of Science, Pacific Division. San Francisco: California Academy of Science, 1985, pp. 357-414.

Construction

1989 O'Donnell, Brian J.; Frankling, Freddie T., ed.
Climate change and its potential impact on the future of northern hydrocarbon development, Northern hydrocarbon development in the nineties: a global perspective: 156-161. Ottawa: Geotechnical Science Laboratories, Carleton University, 1989

1998 Ryder, J.M.
Geomorphological processes in the alpine areas of Canada : the effects of climate change and their impacts on human activities, Geological Survey of Canada, Bulletin 524

Transport

1994 Anderson, William P.; DiFrancesco, Richard; Kliman, Mel
Potential impacts of climate change on petroleum production in the Northwest Territories, In Mackenzie Basin Impact Study Interim Report #2, edited by Stewart J. Cohen. Ottawa: Environment Canada, 1994: 433-441.

1994 Aylsworth, J.M.; Egginton, P.A.
Sensitivity of slopes to climate change, In Mackenzie Basin Impact Study Interim Report #2, edited by Stewart J. Cohen. Ottawa: Environment Canada, 1994: 278-283.

1994 Cohen, Stewart J., ed.

Mackenzie Basin Impact Study Interim Report #2, Environment Canada, 1994. The Summary was also published in Environment Canada's Climate Change Digest.

1993 Croasdale, K.R.
Impacts of climate change on northern offshore petroleum operations, In Impacts of Climate Change on Resource Management in the North. Geoffrey Wall (Ed.)

1993 Lonergan, Stephen C.; DiFrancesco, Richard; Woo, Ming-Ko
Climate change and transportation in northern Canada: an integrated impact assessment, Climatic Change, August 1993: 331-351

1992 Lonergan, Stephen C.; Woo, Ming-Ko
Impacts of climate warming on transportation and the regional economy of Canada's North, The Canadian Geographer 36(1): 73-75.

Economic

1999 CAFF Steering Committee
Consequences of Climate Variability and Change in the Arctic Region. Arctic Climate Assessment.

1989 Clague, John J., comp.; Fulton, R.J., Ed
Quaternary geology of the Canadian Cordillera: Chapter 1.
Quaternary geology of Canada and Greenland; Geological Survey of Canada; Ottawa. The Geology of North America. Volume K-1; Geology of Canada.

1997 Cohen, Stewart (Ed.)

Mackenzie Basin Impact Study (MBIS), Final Report

1994 Cohen, Stewart J., ed.

Mackenzie Basin Impact Study Interim Report #2, Environment Canada, 1994. The Summary was also published in Environment Canada's Climate Change Digest.

1999 Griffith, Brad

Integrating the effects of climate and development on a subsistence resource for Arctic communities. President's seminar, Institute of Arctic Biology, University of Alaska, Fairbanks

1998 Huang, G.H., Cohen, S.J., Yin, Y.Y., and B. Bass

Land resources adaptation planning under a changing climate - a study for the Mackenzie Basin, In Resources, Conservation and Recycling 24(2): 95-119

1995 Kochmer, Jonathan P., and Darryll R. Johnson

Demography and socioeconomic of northern North America: Current status and impacts of climate change. In Human Ecology and Climate Change: People and Resources in the Far North. Edited by David L. Peterson and Darryll R. Johnson: 31-53

1993 Lonergan, Stephen C.; DiFrancesco, Richard; Woo, Ming-Ko

Climate change and transportation in northern Canada: an integrated impact assessment, Climatic Change, August 1993: 331-351

1992 Lonergan, Stephen C.; Woo, Ming-Ko

Impacts of climate warming on transportation and the regional economy of Canada's North, The Canadian Geographer 36(1): 73-75.

1997 Rothman, D. and D. Herbert

The socio-economic implications of climate change in the forest sector of the Mackenzie Basin, In Mackenzie Basin Impact Study, Final Report. Stewart Cohen (Ed.): 225-241

1997 Taylor, Eric and Bill Taylor (Eds)

Responding to Global Climate Change in British Columbia and Yukon, Aquatic and Atmospheric Sciences Division, Environment Canada, Pacific and Yukon Region, and the Air Resources Branch, British Columbia Ministry of Environment, Lands and Parks.

1997 Greenpeace USA

The threat of climate change to Arctic Human Communties

1992 Woo, M. and D.J. Gregor (Eds.)

Arctic environment: past, present, & future

1992 Woo, Ming-Ko; Rouse, Wayne R.; Young, Kathy L.; Lewkowicz, Antoni G.

Adaptation(sic) to permafrost in the Canadian North: present and future, In Impacts of Climate Change on Resource Management in the North, Geoffrey Wall, ed. (Department of Geography Publication Series, Occasional Paper No. 16, University of Waterloo, 1993): 51-54.

1997 Yin, Yongyuan

Integrated climate change impact assessment and sustainable land use in the Mackenzie River Basin, In Mackenzie Basin Impact Study, Final Report. Stewart Cohen (Ed.): 275-280

2000 Yvonne Harris, coordinator

Yukon State of the Environment Report, 1999

2) Infrastructure\Community

Water

2000 Bruce, James et al

Water Sector: Vulnerability and Adaptation to Climate Change. Background Paper for Regional Workshops

2000 Bruce, James et al

Water Sector: Vulnerability and Adaptation to Climate Change. Background Paper for Regional Workshops, Organized by Provincial Chapters of the Soil and Water Conservation Society

Population

1997 Bone, Robert, Shane Long and Peter McPherson

Settlements in the Mackenzie Basin: now and in the future 2050, In Mackenzie Basin Impact Study Final Report, Stewart Cohen (Editor),

1994 Cohen, Stewart J., ed.

Mackenzie Basin Impact Study Interim Report #2, Environment Canada, 1994. The Summary was also published in Environment Canada's Climate Change Digest.

1995 Kochmer, Jonathan P., and Darryll R. Johnson

Demography and socioeconomics of northern North America: Current status and impacts of climate change. In Human Ecology and Climate Change: People and Resources in the Far North. Edited by David L. Peterson and Darryll R. Johnson: 31-53

1995 Peterson, David, L. and Darryll R. Johnson (Eds.)

Human ecology and climate change: people and resources in the far north, Taylor and Francis Inc, Bristol, PA

1997 Watson, R.T. et al.

The Regional Assessment of Climate Change:An Assessment of Vulnerability. Report of I PCC Working Group II

Well-Being\Health

1997 Bone, Robert, Shane Long and Peter McPherson

Settlements in the Mackenzie Basin: now and in the future 2050 In Mackenzie Basin Impact Study Final Report, Stewart Cohen (Editor)

1997 Cohen, Stewart (Ed.)

Mackenzie Basin Impact Study (MBIS), Final Report

1995 Kochmer, Jonathan P., and Darryll R. Johnson

Demography and socioeconomic of northern North America: Current status and impacts of climate change. In Human Ecology and Climate Change: People and Resources in the Far North. Edited by David L. Peterson and Darryll R. Johnson: 31-53

1994 McGhee, Robert

Disease and the development of Inuit culture, Current Anthropology 35(5), p. 563-593

1997 Taylor, Eric and Bill Taylor (Eds)

Responding to Global Climate Change in British Columbia and Yukon, Aquatic and Atmospheric Sciences Division, Environment Canada, Pacific and Yukon Region, and the Air Resources Branch, British Columbia Ministry of Environment, Lands and Parks.

1997

The threat of climate change to Arctic Human Communities

1995

Wein, E.E. and R.W. Wein

Predictions of Global warming influence on Aboriginal food use patterns in northwest Canada. The Northern Review 14 1995, pp. 86-94.

Hazard

1994 Aharonian, D.

Land Use and Climate Change. An assessment of climate-society interactions in Aklavik NWT. MBIS Interim Report #2.

1994 Aylsworth, J.M.; Egginton, P.A.

Sensitivity of slopes to climate change. In Mackenzie Basin Impact Study Interim Report #2, edited by Stewart J. Cohen. Ottawa: Environment Canada, 1994: 278-283.

1997 Bone, Robert, Shane Long and Peter McPherson.

Settlements in the Mackenzie Basin: now and in the future 2050. In Mackenzie Basin Impact Study Final Report, Stewart Cohen (Editor).

1997 Cohen, S.J.

What if and so what in northwest Canada: could climate change make a difference in the future of the Mackenzie Basin? Arctic 50 (4) 1997, pp. 293-507.

1997 Cohen, Stewart (Ed.)

Mackenzie Basin Impact Study (MBIS), Final Report

1997 Grescoe, Taras

Temperature Rising. Canadian Geographic 117 (6) 1997, pp.36-45

1988 Hill, Philip R.

Effects of changing northern climate on the Beaufort Sea coast and related industrial development. Published in Proceedings of the Third Meeting on Northern Climate, edited and prepared by Yarranton Holdings Ltd., under contract to the Natural Resources and Economic Development Branch of DIAND, 1988: 163-180.

1999, Environment Canada - Canadian Wildlife Service, Ecological Monitoring and Assessment Network, Yukon Renewable Resources

Research and Monitoring Priorities in the Boreal Northwest, contact Mike Gill, Canadian Wildlife Service, (867) 393-6760

1997 Newton, J.

Coping with Floods: An Analogue for dealing with the Transitions to a modified climate in the northern sector of the Mackenzie, In Mackenzie Basin Impact Study, Final Report, Stewart Cohen (Editor): 219-223

1999 Prentice, Laura

Climate Change Fact Sheets

1998 Ryder, J.M.

Geomorphological processes in the alpine areas of Canada : the effects of climate change and their impacts on human activities, Geological Survey of Canada, Bulletin 524

2000 Snowshoe, Norman

Gwich'In Settlement Area Land Use Impacts, 2000. Panel Discussion on climate and impacts, In Workshop: Climate change impacts and adaptation strategies for Canada's northern territories

1997 The Threat of Climate Change to Arctic Human Communities

1986 Williams, Peter

Pipelines & permafrost : science in a cold climate, Ottawa : Carleton University Press

1999 Climate Change and Sea Ice

http://www.greenpeace.org/~climate/arctic99//reports/seaice3.html