

The Northern Climate Exchange
Gap Analysis Project

An Assessment of the Current State
of Knowledge about the Impacts of
Climate Change in Northern Canada



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 Limited

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
Layout and design by Leaf Marketing & Coordination 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:

1. 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;
2. 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;
3. 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;
4. The report of a workshop on climate change research and priorities;
5. Two reports assessing the level of documented local and traditional northern knowledge about climate change;
6. Two reports assessing the completeness and value of the Infosources Database;
7. The NCE Knowledge Site, an Internet resource containing most of these products, — and more; and
8. 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

1	Introduction	1
	Project Objectives	1
	This Report and CD-ROM	2
2	Tools and Methods	5
	Literature Review	5
	Databases	5
	Traditional and Local Knowledge Assessments	5
	Northern Knowledge	6
	Matrices	6
	Independent Reviews	6
3	Results and Products	7
	Databases	7
	Northern Knowledge	10
	Traditional and Local Knowledge	13
	The Matrices	13
	Independent Reviews	18
4	Conclusions	23





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.

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.

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	



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 the events 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" readaptation 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 address 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).

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?

Figure 4: Sample lay-out of matrix

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

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.

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.

Figure 5: Sample cell from Boreal matrix

Topic: Boreal

COMPONENT	CLIMATE ASPECT: Impacts of Temperature Changes
Mammals	<p>State of Knowledge: FAIR</p> <ul style="list-style-type: none"> - 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)



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.





4

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.





Contents of CD-Rom

1 On-line Survey

2 Technical Reports

- *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

3 Internet Links

- Links to Internet locations of
 - › The Matrix Maker/Matrices
 - › The Infosources Database
 - › The Directory of Contacts
 - › The NCE Knowledge Site