Climate Change Impacts and Adaptation in Northern Canada

1997 - 2000

With special reference to the Infosources
Database of the Northern Climate
ExChange, February 2002

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1. INTRODUCTION

The purpose of this report is to provide a summary of research on Climate Change Impacts and Adaptation (CCIA) in northern Canada between 1997 and 2000. To some extent, it represents an update to *Canada's Arctic*, Volume II of the *Canada Country Study* (Maxwell 1997). In the report, when we speak of "North", we speak of Canada's three territories and the northern regions of the provinces together. Section 2 of the report outlines the impacts and adaptation research relating to the physical environment, to terrestrial and marine ecosystems, and to the socio-economic sectors. It follows the format of *Canada's Arctic* and refers specifically to the Infosources Database of the Northern Climate ExChange (NCE). This report follows the extensive Gap Analysis Project completed by the NCE in 2002. That project provided a detailed assessment of the current state of knowledge about the impacts of climate change in Northern Canada.

Climate variability and weather extremes are increasing in both northern and southern Canada. Although residents of southern Canada may not be concerned about climate change in the North, nor about the importance of increasing climate change research in the North, they should realize that their weather is largely influenced by climate conditions in the North. Northern Canada and the northern regions of Russia in Siberia show the most dramatic short-term effects of global climate variability. These effects have received a considerable amount of international attention (e.g., Stewart and Malcolm 1999) and include permafrost slumping, landslides along riverbanks, increased and more extensive forest fires, and longer ice-free seasons for northern rivers.

Sea level rise is another expected result of climate change, especially if climate-warming trends continue. Changes in sea level are especially important to vulnerable areas of coastline. Most of the Arctic coast of Canada is rising up as a result of geological forces. The area around Tuktoyaktuk, however, is sinking, due to both geological forces and sea level rise, and the resulting coastal erosion is threatening infrastructure and buildings near the coast. Sea level rise is caused both by seawater temperature changes (usually considered to be the major contributor to sea level rise), and by ocean water mass increase due to the melting of glaciers and ice sheets (Meier and Dyurgerov 2002) and the disintegration and melting of the West Antarctic Ice Sheet (O'Neill and Oppenheimer 2002).

Forest fire activity is on the increase in the North. Thunderstorms, formerly unheard-of in the far North, have been reported in the northern regions of NWT and Nunavut. One characteristic of climate variability is an increase in extreme events such as these. As has been pointed out in an article in *Canadian Geographic* by Lahey, "It is not a few degrees' rise in average temperatures that will affect people the most; it is the corresponding increase in extreme weather" (Lahey 2002). Lahey's article provides a good introduction to climate change science for the average person, including a discussion of the importance of mathematical computer models to describe present and future trends in climate change.

According to *Canada's Arctic* forecasts, the tree line may be expected to move northward from 5 to 7.5 km per year. Page xv of the Executive Summary speaks of "a northward shift of the tree line, by up to 750 km in eastern Keewatin." The exact time frame is not given, but most of the comments and forecasts refer to the year 2100. In 10 decades, 750 km means 75 km per decade, or 7.5 km per year! The southern boundary of the permafrost is also moving north: Table 2 on page 41 and Figure 28 on page 42 of *Canada's Arctic* refer to the northward movement of the southern permafrost boundary by perhaps hundreds of kilometres by year 2050.

Model-based projections from *Canada's Arctic* indicate a possible warming of from 5°C to 7°C for most of the Arctic Islands, and a warming of up to 10°C over central Hudson Bay. Such a warming would have a devastating effect on ice conditions, and therefore seal and polar bear habitat, in Hudson Bay. Precipitation in the North may also increase by up to 25%.

Many northern residents have reported that winters are getting warmer in the Northwest Territories. The season for ice roads is getting shorter by an average of two to eight weeks per year, which tends to cause thinner ice and contribute to more accidents. As well, the overall economic effect seems to be negative. Shorter seasons for ice road use, combined with longer periods between spring break-up and fall freeze-up of the rivers, mean more expensive air transportation for food and other perishable goods to mines and oil and gas facilities. There may be a positive economic impact on tourism, since longer ice-free periods lengthen the season for tourist activity on the Alaska, Klondike and Dempster highways.

Northerners have been reporting climate change trends through research based on local knowledge. For example, observations of climate change by the Inuit of Nunavut have been recorded and discussed by Huntington 2000 and, more recently, by Fenge 2001. Fenge reports, "already Inuit are altering their hunting patterns to accommodate changes to the ice regime and distribution of harvested species." A detailed table in Fenge's article tabulates observations of environmental change by Inuit and Cree in different regions of the eastern Canadian Arctic on various aspects of weather, sea and river conditions, and wildlife.

As of February 2002, the NCE Infosources Database contained 1,834 entries related to CCIA in northern Canada. This summary report is based on the status of the database at that time. Of this number, 183 entries were for 1997, 146 were for 1998, 137 were for 1999, and 160 were for 2000, for a total of 626 entries out of the 1,834 total. This indicates that approximately 1/3 of the database entries cover publications for the four-year period 1997-2000 inclusive. Climate sciences, including CCIA studies, have become more and more popular in recent years.

2. CLIMATE CHANGE IMPACTS AND ADAPTATION IN CANADA'S NORTH

NCE Infosources Database for the period 1997-2000, as of February 2002. It is important to note that what the database reveals is not necessarily indicative of everything in the publications cited. The database is in the process of development and refinement, so the keywords, summaries, and indications of regions and geographical extent are not always complete. Also, it is important to understand that the Infosources Database is evolving, with entries being added on a continuing basis; it does not claim to represent a complete compendium of northern research.

The Executive Summary of *Canada's Arctic* provided a list of three areas (biophysical environment, socio-economic activities, and climate change impacts on them) and six concerns relating to future directions of sensitivity- and impact-related research for the Arctic. The concerns are, as quoted from the report:

a. **Environmental monitoring**: Commitment to continued monitoring of atmospheric and oceanographic variables throughout the Arctic is needed.

b. **Climate scenarios**: There is a need for more credible and detailed regional scenarios than are currently available from the General Circulation Models.

c. **Geographic emphasis**: The eastern Arctic is much less well studied than the other regions of the Arctic.

d. **Socio-economic sectors**: Existing and potential relationships between climate and socio-economic sectors in the Arctic are even less well understood than those between climate and the biophysical environment.

e. **Traditional ecological knowledge (TEK)**: TEK should be more effectively utilized, particularly in respect to quantifying terrestrial and aquatic environmental sensitivity to climate.

f. **Stakeholder involvement**: There is a pressing need for real partnerships between researchers and users in both developing and carrying out impact-related research for the Arctic.

For the purposes of this report, we have added the following concerns:

g. Adaptation studies relating to climate change.

h. Impacts of storms, extreme events.

i. Geographical emphasis on the provincial north regions.

All of these variables are tallied in Table 1 in terms of numbers of papers cited from database entries for the years 1997-2000. We have also added a tally of the emphasis on studies of physical phenomena (row J), land-based ecological studies (row K), and marine-based ecological studies (row L). Transportation and infrastructure development is of continuing importance throughout the North, and climate change impacts relating to this area are recorded from the database as row M. However, many other records, such as adaptation in row G, extreme events in row H, physical phenomena (e.g., relating to temperature, precipitation and flooding) in row J, and land use planning in row D, apply indirectly to transportation and infrastructure development.

Many database entries address more than one of the concerns and study areas. Some database entries, such as general conference proceedings, have not been recorded in the table, since insufficient summary information is given for allocating the entries to particular areas of concern.

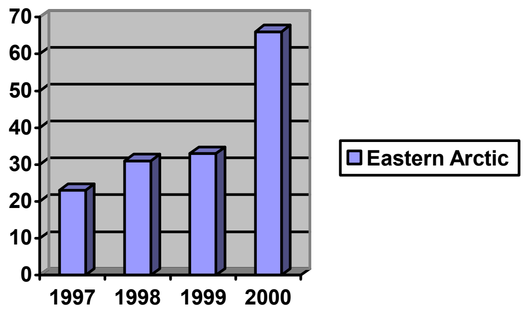
Table 1. Research Areas and Concerns Addressed by Database Entries, 1997 - 2000

	Year (entries)			
Concern	1997 (183)	1998 (146)	1999 (137)	2000 (160)
A. Monitoring	4	12	9	4
B. Modeling	39	9	8	5
C. East Arctic	23	31	33	66
D. Socio-econ	26	19	22	24
E. TEK	6	8	15	27
F. Community Involvement	4	3	7	15
G. Adaptation	12	8	8	12
H. Extreme Events	8	4	4	3
I. Provincial North	27	27	15	15
J. Physical	88	89	66	77
K. Land ecological	90	56	52	46
L. Marine ecological	10	8	9	18
M. Transport & Infrastructure	11	6	6	6

There are three trends apparent in Table 1, for rows C (eastern Arctic), E (traditional ecological knowledge) and F (community involvement). These trends are shown in Figures 1 and 2 for 1997-2000.

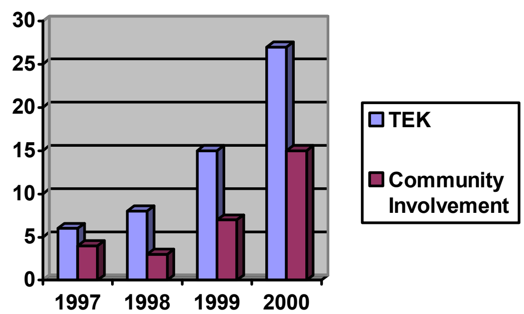
It is noteworthy that there is an increasing emphasis on eastern Arctic research from 1998 through 2000, according to the record of database entries. It is likely that the emphasis on creating the new eastern territory of Nunavut raised more research attention there in that time period.

Figure 1. Research Emphasis on the Eastern Arctic Region in Numbers of Database Entries, 1997-2000



The upward trend of Figure 1 indicates a probable increase in research in the eastern Arctic. This trend addresses the concern in *Canada's Arctic* about the need to increase emphasis on the eastern Arctic region.

Figure 2. Research Emphasis on TEK and Community Involvement in Numbers of Database Entries, 1997-2000



From Figure 2, we see that the Infosources Database indicates a dramatic increase in research emphasis in the areas of TEK and local knowledge, as well as stakeholder and community involvement in northern research. Thus, two more of the concerns stated in *Canada's Arctic* have been positively addressed in northern research between 1997 and 2000.

Generally speaking, there is a danger in reading too much into apparent trends from the database entries, since this summary does not go into research funding cycles and so on, which affect the emphasis on specific areas of research over short to medium time scales. However, based on the database entries numbered in Table 1 alone, there may have been a decrease in emphasis on environmental monitoring and on climate scenarios or modeling. This goes against the recommendations for increased future research emphasis in *Canada's Arctic*. However, much recent modeling research does concern the gap perceived in 1997, i.e., the need to increase research into the development and testing of regional climate models. From the table, it is observed that there may also be a decrease in research emphasis in Canada's provincial north.

Special mention is due to the Mackenzie Basin Impact Study and its final report, which was published by Environment Canada in 1997. The final report covers virtually all aspects of CCIA research relating to water, land, vegetation, wildlife, and people. It provides an excellent compendium of research results in all three areas of physical environment, terrestrial ecosystems, and the socio-economic sectors.

2.1 Physical Environment

Research on the physical environment of Canada's North, as recorded in the Infosources Database at the Northern Climate ExChange, includes research into the same areas as discussed in *Canada's Arctic*, namely:

- Hydrology
- Permafrost
- Sea Ice and Icebergs (including glaciology)
- Sea Level and Coastal Processes
- Freshwater ice (including freshwater lakes and riverine processes)

The results of the various research projects included in the database do not conflict with the observations and discussion of research in *Canada's Arctic*. Rather, they add to the body of knowledge in each of these research areas. The numbers of research entries in the physical environment category were entered in row J of Table 1. The references given in the following discussion are meant to be examples, and are not intended to be totally inclusive.

Research Hotspots

Some hotspots for research at the beginning of the 21st Century are in areas of the effects of climate variability and change on gas hydrates, on permafrost, on sea ice and ice sheets, on coastal erosion, and on various aspects of precipitation and river and lake hydrology. From a geographic point of view, the hotspot seems to be the Mackenzie Basin.

Fresh water is becoming the key resource of the 21st Century. Research relating to fresh water in all its aspects, including water for community use, water for transportation, water for hydro power development, and water for industrial processes and agricultural uses, is becoming more and more important. A warming climate has great impacts on water resources.

Other new research is in the development and/or refinement of models for physical processes (e.g., snow cover), so that they can be integrated with the best General Circulation Models (GCMs). The development of Regional Climate Models is one area of emerging research. GCMs are not able to represent climate scenarios in regions very accurately.

The ongoing emphasis on permafrost research is in part spurred on by resource development in Canada's North and the corresponding need to understand permafrost systems better in order to carry out reliable design and construction of community and regional infrastructure in the face of ongoing climate change.

Recent Research Findings

Research has expanded over the 1997-2000 period in the areas of climate modeling, both in terms of new models to describe particular physical processes, such as ocean-ice-atmosphere interactions, and in terms of refinements and new model experiments based upon the Canadian Global Climate Model known as CGCM1 (Hengeveld 2000).

Hengeveld's work has summarized climate projection results using the CGCM1. These results provide information on projected changes in temperature and precipitation, and on potential changes in ocean circulation patterns, sea level, sea ice, and climate extremes, as well as possible trends in regional, seasonal, and even daily patterns in climate behaviour.

Changes in permafrost and freshwater systems are very important in the North. Dyke et al 1997 have published a very interesting discussion of permafrost in the Mackenzie Basin, its influence on land-altering processes, and its relationship to climate change. Their research covers such aspects as the settlement or sinking of land where permafrost has melted, and the potential for increased landslides and riverbank slumping when permafrost melting occurs.

The Mackenzie Basin Impact Study: Final Report, published by Environment Canada in 1997, should be consulted for many other discussions of climate change impacts on the physical landscapes of the North.

Monitoring of climate change impacts is one area that continues to be very important since *Canada's Arctic* (Maxwell 1997). The monitoring of permafrost conditions in global climate observations has been the topic of research by Burgess et al 2000, based upon an international network, the Global Network for Permafrost (GTNet-P).

Lents 1999 has published interesting results of research that looks at the monitoring of changes in thickness and extent of the ice cover in the Arctic Ocean, using direct measurement techniques based on the scattering and loss in intensity of underwater sound. One purpose of the work is to provide baseline data to be used in databases that support models for ocean-ice-atmosphere interactions.

Improvement in our Understanding of CCIA Issues

As pointed out by Cohen 1999, the Intergovernmental Panel on Climate Change (IPCC) has clearly stated that increasing concentrations of greenhouse gases will cause climate warming. The IPCC reports published during the late nineties and many other CCIA workshops provide adaptation and response recommendations to governments and communities (e.g., IPCC 2001).

Understanding of the physical environment has now improved to the point where the research findings can be used in engineering design (Etkin 1998). In addition, our understanding of permafrost behaviour and of river and sea ice behaviours in a warming climate has improved. As a result of improved understanding of gradual sea ice disappearance, the Government of Canada has new and expanded information upon which to base policy generation on a number of issues, including Arctic sovereignty and sea-lane transportation through an open Northwest Passage within a few decades.

It is now understood that a reduction of permafrost due to climate change impacts is expected to lead to increased erosion and danger of landslides, as well as breakdown of ice-rich landscapes. The reduction of permafrost in peatlands and wetlands leads to increases in methane production, and hence to increases in greenhouse gas (GHG) emissions. The reduction of permafrost can also cause an increase in GHG emissions due to the freeing of methane from gas hydrate resources that are normally trapped in permafrost.

Research on the physical characteristics of climate change has allowed a better understanding of declines in freshwater due to the melting of sea ice, and due to the melting of the icebergs that break off from glaciers on the seacoast. Also, sea ice has been observed to decrease by approximately 3% per decade between 1978 and 1996. The results of climate modeling are quite variable, but they all show a clear trend toward the continuing melting of sea ice. By the year 2080, sea ice may completely disappear during the summer months.

We now have a better understanding of various issues surrounding CCIA in the freshwater ecosystems of Canada through the work of many Canadian scientists, such as Schindler 1997. This understanding is necessary for infrastructure development, such as reservoir construction, and for water conservation practices in communities and in agricultural practices.

Major Players

The major players include teams working with the following principal investigators: Schindler, D.W. (University of Alberta), Sharp, M. (University of Alberta), Whitfield, P.H. (Environment Canada), Barber, D. (University of Manitoba), and Marsh, P. (University of Saskatchewan). Key players in the physical sciences relating to CCIA also include three of the six recently appointed Northern Chairs sponsored by the Natural Sciences and Engineering Research Council (NSERC), namely Burn, C. (Carleton University), England, J. (University of Alberta), and Wolfe, B.B. (Wilfrid Laurier University). The many researchers involved in the ongoing Mackenzie GEWEX Study are also key players (see Appendix A and www.usask.ca/geography/MAGS/).

The science-based federal government departments as well as Indian and Northern Affairs Canada will continue to carry out CCIA-related research (Northern Affairs Program 2000), and will continue to collaborate on various CCIA initiatives in the physical sciences.

2.2 Terrestrial and Marine Ecosystems

In Canada's Arctic, this research area concentrates on climate change impacts on wildlife species and habitat. This is also true for the entries recorded in rows K and L of Table 1. There is a strong connection between ecosystem research and research on the physical environment, since wildlife habitat and feeding depends to a large extent on precipitation and river levels, and on ice formation and melting. In general, database entries dealing with freshwater fish were recorded in row K as part of the land-based ecology grouping, rather than row L on marine-based ecology.

Research Hotspots

Popular research areas relate to the impacts of climate variability and change on marine mammals and their habitat, on coastal changes and erosion as they impact terrestrial and marine ecosystems, and on interactions with contaminants and pollution, on boreal forest ecosystems, and on wetland, peat land and tundra ecosystems. Research in the Mackenzie Basin area has become very important, especially research relating to knowledge about various ecosystems in advance of hydrocarbon and mineral resource development.

Research including Traditional Ecological Knowledge (TEK) will continue to be very important, including community stakeholder involvement through various western science – community partnerships.

A warming climate has great impacts on water resources and on freshwater ecosystems. CCIA research in these areas is the objective of much of the research of Schindler 1997 and Schindler et al 1997, as examples.

Other new research is in the development and/or refinement of models for biological processes (e.g., carbon and nitrogen storage), so that they can be integrated with GCMs and Regional Climate Models.

Recent Research Findings

The research findings mentioned here are representative of the very extensive literature in the area of biological impacts of climate change on the sea, on the land, and on their inhabitants. This literature has been recorded in considerable detail in the Infosources Database of the NCE.

The impact of climate change on marine mammal populations is very important, and a considerable amount of research has taken place in this area. For example, Harwood et al 2000 have studied the variation in reproduction and body condition of the ringed seal in western Prince Albert Sound in the NWT. Climate variability leads to considerable variability in ringed seal health.

As another example of research in this area, Tynan and DeMaster 1997 have reported on interesting observations and predictions of climate change and their potential effects on marine mammals. They report that the changes in extent and concentration of sea ice may alter the seasonal distributions, geographic ranges, patterns of migration, nutritional status, reproductive success, and the abundance of some species.

The Mackenzie Basin Impact Study: Final Report, published by Environment Canada in 1997, should be consulted for many other discussions of climate change impacts on the terrestrial ecosystems of the North, including impacts on vegetation and wildlife.

One fruitful area of research has been the study of long-term changes in climate using algae in lake sediments as indicators (Smol and Cumming 2000). They have studied past climatic trends using the observed interactions between algae from lake sediments and their environments. From this it is possible to infer historical trends for climatic variables such as temperature.

The ongoing International Tundra Experiment (ITEX), which concentrates on climate change impacts on plant species on the tundra, is included in Appendix A. The results to date can be summarized as follows. Leaf development and flowering are speeded up for nearly all study species in a warmer climate, and seed weight and germination increase. Evergreen perennial plants respond very slowly or not at all in vegetative growth, and suffer a competitive disadvantage in communities where aggressive deciduous species, such as dwarf birch, will expand rapidly in biomass and standing crop. Recruitment of new plant individuals is extremely slow in undisturbed tundra (except perhaps in the polar deserts of the High Arctic); instead a loss of species and biodiversity is observed as long as the warming trend persists. Long-term monitoring of manipulated and unmanipulated plots in arctic Alaska corroborates the adequacy of these first ITEX results. Thus, a disintegration of the plant communities in the tundra that we are familiar with today is expected, and this must entail drastic changes also for animal populations.

Schindler 1997 and Schindler et al (1997), as well as other more recent and ongoing works of the Schindler team, report on the many physical, chemical and biological characteristics of freshwater systems.

Improvement in our Understanding of CCIA Issues

Permafrost areas are seen to be reducing in size, and are changing from continuous to discontinuous characteristics in many geographic areas. It is now understood that a reduction of permafrost due to climate change impacts is expected to lead to damage to vegetation, with severe changes to ecosystems and animal life.

Our understanding of CCIA issues relating to the sea and the land, and to wildlife and its habitats, is increasing rapidly. For example, ringed seals are the preferred diet of polar bears. Seal hunting by polar bears is becoming more difficult with climate warming. The ice, where the seals feed and give birth, melts earlier. As the birthing period nears, the polar bears often find themselves starving because the ice is already gone, along with the seals. This leads to reduction in birth weight and lower chances of survival for their young.

Climate warming, along with the associated changes in precipitation, can influence the migration patterns of birds and animals. For example, in the event of great depth of snowfall, or the melting and re-freezing of the snow surface of grazing lands, caribou are forced to migrate further afield to seek new grazing lands. In some cases these impacts are so great that starvation of large caribou herd populations results.

Major Players

The major players in the biological sciences research aspects of CCIA include the following principal investigators and their teams: Hik, D. (University of Alberta), Schindler, D.W. (University of Alberta), Smol, J.P. (Queens University), Douglas, M.S.V. (University of Toronto), Henry, G. (University of British Columbia). Other major players include three of the six recently appointed NSERC Northern Chairs, namely Wolfe, B.B. (Wilfrid Laurier University), Payette, S. (Universite Laval), and Dick, T.A. (University of Manitoba).

Other major players include the many researchers working within the International Tundra Experiment (ITEX) (refer to Appendix A) and Tundra Northwest. The science-based federal government departments as well as Indian and Northern Affairs Canada will continue to carry out CCIA-related research, and will continue to collaborate on various CCIA initiatives in the environmental sciences.

2.3 Socio-Economic Sectors

The information in Table 1 indicates that the number of socio-economic research projects recorded (rows D and M) tends to be considerably less than the number of studies on either the physical or ecological environments.

As in *Canada's Arctic*, the socio-economic sectors covered by the Infosources Database include

- Oil and gas
- Transportation
- Building and construction
- Recreation and tourism
- Settlements, country food and human health
- Agriculture and Forestry
- Fisheries
- Defence

Defence has very little representation in the NCE Infosources Database. However, much of the research on the physical environment (Section 2.1), e.g., research relating to glaciology and to sea and river ice, relates either directly or indirectly to defence.

Research Hotspots

One hotspot of social and economic research is the community-based recording of local knowledge on CCIA issues, such as sea ice retreat and changes in wildlife migration patterns and habitats. This TEK research provides valuable input to comparative studies of CCIA in the physical and environmental sciences.

As with the physical and biological CCIA research areas, freshwater availability and use is key to community sustainability in the North and to economic development through industry and agriculture. The rivers are still the highways of the remote northern communities and are often the sources of small-scale hydropower and food. Potable water resources are necessary for continued health and well-being.

Other research hotspots include research into various aspects of community sustainability, including subsistence economies, food contaminants, housing for remote Aboriginal communities, culture and language, education, and spirituality. Traditional Knowledge (TK) and partnerships involving western science and TK through such funding mechanisms as the Community University Research Alliance approach sponsored by the Social Sciences and Humanities Research Council will continue to play an important role in all aspects of socio-economic research in the North.

Recent Research Findings

Inuit peoples have documented their findings through video recordings and research documents prepared by the International Institute for Sustainable Development 2000, and by Huntington 2000. In particular, changes in sea ice characteristics and sea ice seasons have been recorded, as well as slumping and melting permafrost on land.

Engineering research into northern housing systems, supported by the Canadian Mortgage and Housing Corporation in Yellowknife, NWT, has led to improved housing design for harsh environments, as well as improved small-scale water and waste treatment systems.

The work of Schindler and his team (e.g., Schindler 1997) is very important to show the impacts of climate change on such aspects as reservoir construction, and to show the land-water interactions that result from human habitation and interactions between climate change and other human stresses on the environment.

Fast and Berkes 1999 have published an important discussion of CCIA issues relating to subsistence societies in the Canadian North, which continues to be relevant today. Their findings are grouped into three categories, as quoted here: "(1) climate change may affect the distribution of animals and other resources on which the subsistence economy is based; (2) climate change may affect the use of traditional knowledge and local adaptations; and (3) climate change may affect the health of northern populations through dietary dislocations and epidemiological changes." They go on to recommend that research should be undertaken "(1) to link the available biological/ecological information on the impacts of climate change on local resource use and the northern economy; (2) to develop adaptive management strategies with emphasis on the resilience of social and ecological systems, and on flexibility to respond to uncertainty and largely unpredictable climate change; and (3) to study the issue of the health of northern populations relative to the potentially significant implications climate change has for the long-term availability of country food."

Improvement in our Understanding of CCIA Issues

The documentation of local knowledge on CCIA issues has served to support the findings of the physical and environmental sciences, as well as the predictions of computer models of climate change. It is anticipated that the ongoing work of J. Kruse of the University of Alaska, F. Berkes of the University of Manitoba, and D. Schindler of the University of Alberta will greatly improve our understanding of the CCIA issues that affect arctic community sustainability.

Through the research on sea ice and precipitation from TEK, physical science, and environmental science perspectives, understanding of the impacts of climate change is improving, so that adaptation strategies can be developed. The effects of climate change impacts on sea ice bring changes to the lifestyles of coastal communities, with further dramatic changes expected if the Northwest Passage becomes ice free for a significant portion of each year during the coming decades. Precipitation changes affect the habitat and life expectancy of wildlife, as well as the integrity of community reservoirs. Permafrost degradation affects the length of ice road seasons, and the design and construction of roads, pipelines, buildings, and other infrastructure.

Our understanding of climate-related health issues is being improved through the work of L. Chan and his colleagues at the Centre for Indigenous Nutrition and Environment (CINE) at McGill University, and various researchers working through the national Northern Contaminants Program and the Sustainable Forest Management Network at the University of Alberta.

It is now understood that a reduction of permafrost due to climate change impacts is expected to lead to damage to infrastructure, such as buildings, roads and pipelines. Permafrost reduction also impacts agriculture in the sub-arctic regions.

Major Players

The major players in socio-economic research into CCIA issues include the following principal investigators and their teams: Berkes, F. (University of Manitoba), Fast, H. (Department of Fisheries and Oceans), Kruse, J. (University of Alaska), Schindler, D.W. (University of Alberta), and Chan, L. (McGill University, and one of the new NSERC Northern Chairs).

Significant institutional players include the International Institute for Sustainable Development in Winnipeg, Manitoba; the research division of the Canada Mortgage and Housing Corporation in Yellowknife, NWT; CINE; and the Sustainable Forest Management Network at the University of Alberta.

3. ON-GOING RESEARCH AND PLANS FOR FUTURE RESEARCH

Many of the entries in the NCE Infosources Database contain website addresses that are linked to ongoing research in the climate change area. Several projects, such as the project on sustainable communities in the Arctic led by J. Kruse from the University of Alaska Fairbanks, are in process. In addition, some ongoing and proposed research programs are listed in the Appendix. They should be considered as representative examples rather than comprising a complete list.

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APPENDIX

Ongoing Research

Note: These references are representative examples rather than a complete list.

1. Institute for Aboriginal Peoples Health (IAPH)

www.cihr-irsc.gc.ca/institutes/iaph

The IAPH is one of Canada's Networks of Centres of Excellence (NCE) (www.nce.gc.ca). Several of the NCEs carry out northern research through their researcher networks, although there is no NCE yet that focuses primarily on northern research. The IAPH specializes in health research as it affects Aboriginal people all across Canada. It is not dedicated specifically to health research in northern communities, but northern research plays a part in its overall mandate. Global Change research will undoubtedly play a part in the ongoing programs at the IAPH. The IAPH funds the Aboriginal Capacity and Developmental Research Environments (ACADRE) Network at the University of Alberta (www.acadre.ualberta.ca). The ACADRE Network will no doubt carry out some research in the future that is relevant to the health aspects of Climate Change Impacts and Adaptation in the North.

2. Sustainable Forest Management Network

sfm-1.biology.ualberta.ca

The Sustainable Forest Management Network at the University of Alberta is one national Network of Centres of Excellence that carries out some northern research, which includes climate related research.

3. The Mackenzie GEWEX Study

www.usask.ca/geography/MAGS

The following is quoted directly from the website: "Canada has the largest amount of fresh water of any country in the world. This resource is however subject to large fluctuations due to natural climatic variations and there are concerns about how anthropogenic forcing may alter the Canadian climate. For example, climate observations suggest that substantial warming has occurred over the last few decades over north-western Canada, and this warming has affected water resources. It is critical that approaches be developed to be able to assess our water resources within the context of the overall climate system and its variability and possible change. It is therefore only natural that Canada be very concerned with water and energy cycles, and consequently Canada has long been involved with the World Climate Research Programme's (WCRP) Global Energy and Water Cycle Experiment (GEWEX)."

4. Northern Rivers Ecosystem Initiative

www3.gov.ab.ca/env/water/nrei/northern_rivers-alberta.html

The Northern Rivers Ecosystem Initiative (NREI), which began in 1998, is a co-operative, five-year endeavour by three governments (Canada, Alberta, and Northwest Territories) to address the recommendations of the Northern River Basins Study. The recommendations include various follow-up actions to protect northern rivers involving both policy initiatives and scientific research.

The first progress report for the NREI was released by Federal Environment Minister David Anderson; Premier of the Northwest Territories and Minister of Resources, Wildlife and Economic Development Stephen Kakfwi; and Alberta Environment Minister Gary Mar on February 25, 2000. The report highlights the progress to date for each of the commitments made by governments, and the continuing challenges the initiative faces.

Link here to Northern Rivers Ecosystem Initiative Progress Report. (1.27 mb .pdf format)

5. Northern Ecosystem Initiative

www.pnr-rpn.ec.gc.ca/nature/ecosystems/nei-ien/dh00s00.en.html

To date, climate change research has been largely focused on atmospheric and physical processes. Ecosystem impacts and responses are not as well understood. The Northern Ecosystem Initiative (NEI) supports projects that improve our understanding of how northern ecosystems and communities are affected by climate change.

6. Northern Science and Technology in Canada: Federal Framework and Research Plan, April 1, 2000 – March 31, 2002

www.inac.gc.ca/nstp/nst_e.html

The report bearing this title was released in August 2000, and represents an ongoing effort to coordinate and integrate the Northern Science and Technology (NS&T) efforts of the many departments of the Government of Canada through interdepartmental action plans. Climate change represents one key area of federal NS&T activity. It is envisioned that the federal planning efforts in NS&T will be continued beyond March 31, 2002.

7. Arctic Monitoring and Assessment Program (AMAP)

www.amap.no

The AMAP was established in 1991 through the Arctic Council with responsibilities to monitor the levels of, and assess the effects of, anthropogenic pollutants in all areas of the Arctic environment, including impacts on humans. Climate change remains one of the ongoing concerns of AMAP.

8. Arctic Climate Impact Assessment (ACIA)

www.acia.uaf.edu

The ACIA is an international project of the Arctic Council and the International Arctic Science Committee (IASC). It is focused on the evaluation and synthesis of knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences in the circumpolar Arctic. The aim is to provide useful and reliable information to governments, and to the Arctic peoples and their organizations.

9. Conservation of Arctic Flora and Fauna (CAFF)

www.caff.is

CAFF is a Working Group of the Arctic Council. Its mission is to conserve Arctic biodiversity and to ensure the sustainable use of Arctic renewable resources. Climate variability and climate change are of importance since they have the potential to affect biodiversity and sustainability.

10. The International Tundra Experiment (ITEX)

www.systbot.gu.se/research/ITEX/ITEX.html

The International Tundra Experiment, ITEX, was established in 1990 as a MAB-NSN initiative (Man-And-the-Biosphere, Northern Sciences Network). Since then the program has grown rapidly and is today one of the most active international field programs in arctic ecology. The purpose of ITEX is to monitor the performance of plant species and communities on a circumpolar basis in undisturbed habitats with and without environmental manipulations. At present, there are over 20 active ITEX field sites throughout the circumpolar Arctic and in some alpine areas, operated by field parties from 13 countries. Additional sites and countries are under progress.

11. Canadian Arctic Shelf Exchange Study (CASES)

www.giroq.ulaval.ca/cases

The CASES Research Network was funded in March 2001 by the Natural Sciences and Engineering Research Council of Canada (NSERC). CASES is a major project to address the understanding of the links between freshwater and sea ice, sea ice and climate, and sea ice and biogeochemical fluxes, in order to assess the effects of present variability in sea ice cover on Arctic marine ecosystems and regional climate. The CASES initiative mobilizes a large proportion of the Canadian and foreign expertise in Arctic oceanography in Canada. The network comprises 42 Canadian Arctic researchers and over 30 Arctic specialists from nine foreign countries (USA, Japan, UK, Denmark, Russia, Poland, Norway, Belgium and Spain).