



# WEST KITIKMEOT SLAVE STUDY STATE OF KNOWLEDGE REPORT - 2007 UPDATE

**Prepared For:**

**West Kitikmeot Slave Study Society**

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**April 2008**

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## **1.0 INTRODUCTION TO STATE OF KNOWLEDGE FOR WEST KITIKMEOT AND SLAVE GEOLOGICAL PROVINCE**

### **1.1. Purpose**

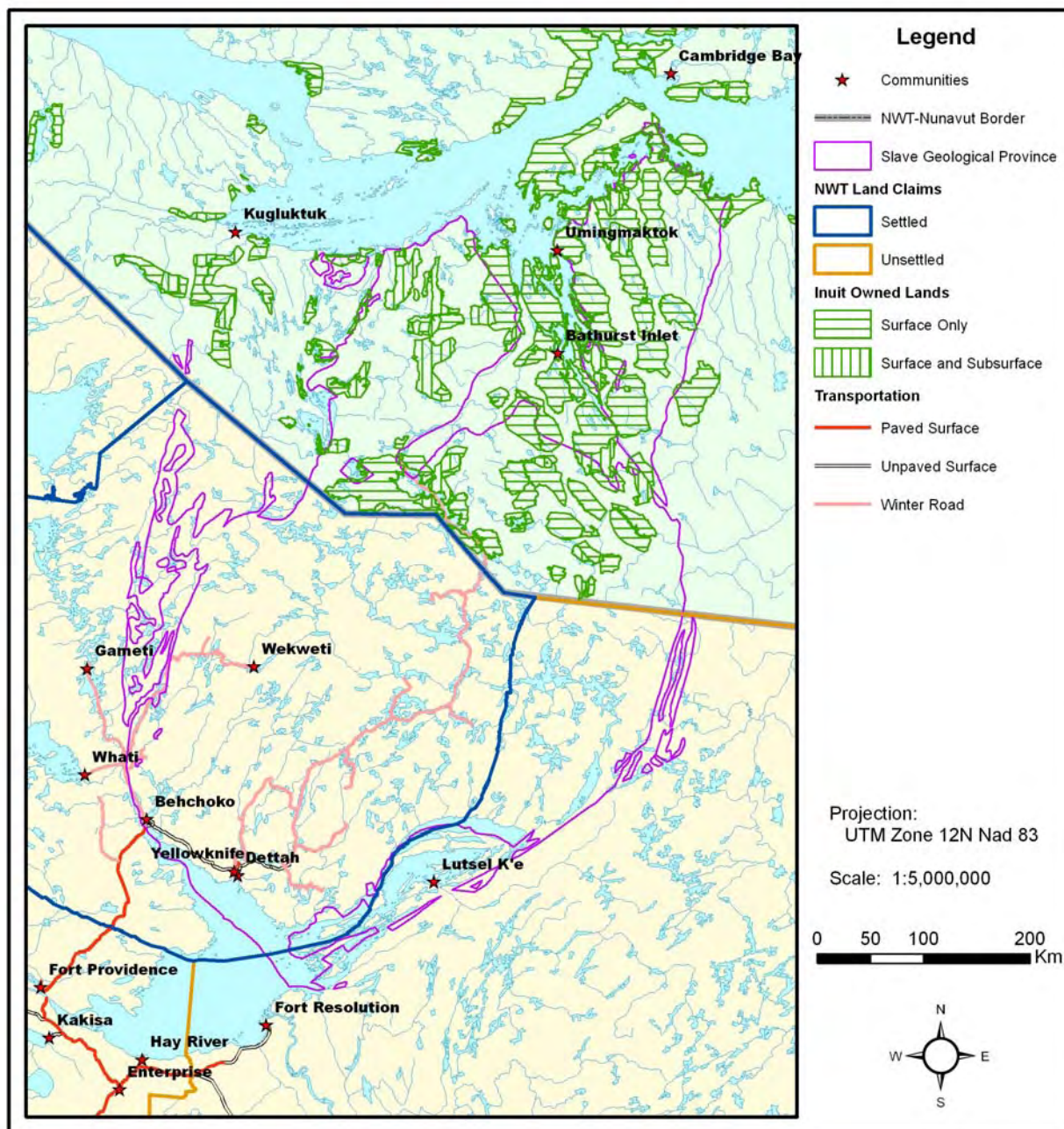
This is the third *State of Knowledge Report* prepared for the West Kitikmeot/Slave Study Society (WKSSS). The first *State of Knowledge Report* (Sly *et al.*, 1999) brought together and interpreted written knowledge on the study area up to the beginning of April 1, 1996. A revised report extended the knowledge base to that existing at the end of December, 2000 (Sly *et al.*, 2001). This updated report compiles and adds information predominantly from December 2000 to December 2006. The term “WKSS area” is used throughout this report to refer to the West Kitikmeot and Slave Geological Province and the surrounding area (see Figure 1).

A considerable amount of new information has become available since completion of the first two reports; the text and many figures and tables have been revised and added to, accordingly. In this revision, additions and changes have been made throughout the report. In particular, new information has given greater depth to our discussions of climate change and its potential effects, contaminants and traditional foods, exploration and development, and caribou. Recent studies on flora and fauna and traditional knowledge (TK) have also added to many aspects of the report. Socio-economic data have been updated and the products of community monitoring work have provided a broader appreciation of the changing situation of Aboriginal people in the study region.

Although this revised report contains few major new insights, improved understandings have given greater depth to many of the previous discussions. The report has been considerably enriched by the products of many studies sponsored by the WKSSS (since April, 1996). To the extent that new information from them has become available, it has also advanced consideration of some of the information needs previously defined by the WKSSS Board. Information about climate change and how it may affect the study area, contaminants and diet, exploration and development, and social and societal change have also helped to strengthen the focus of discussion of sustainable development.

The objective of this report remains the same as previous reports. It is intended to help readers to develop a “big picture” of the area and its people, and to provide an understanding of what and how change is taking place. Readers are encouraged to consult the references provided for more specific information. The report also highlights areas where understandings are incomplete and more research is needed.

**Figure 1 Overview of the West Kitikmeot Slave Study (WKSS) area**



Source: NWT Digital Atlas [CD-ROM], 2002. World Wildlife Fund (WWF) – adapted from

### 1.1.1 Indigenous Peoples and Place Names

Over the past two decades, many communities in the Northwest Territories have taken steps to revive traditional indigenous names. This document is revised to reflect names that have received official approval.

#### Peoples

| Official Name | Former Name   | Indigenous Language |
|---------------|---------------|---------------------|
| Dene Sųłıné   | Chipewyan     | Dene Sųłıné         |
| Métis         | NA            | Michif              |
| Qıırmıut      | Copper Eskimo | Inuinnaqtun         |
| Tłıchq        | Dogrib        | Tłıchq              |
| T'atsaot'ine  | Yellowknives  | Tłıchq              |

#### Land Claim Regions/Communities

| Region                                  | Communities                                             |
|-----------------------------------------|---------------------------------------------------------|
| Tłıchq, Northwest Territories           | Behchokō, Gamètı, Wekweètı, Whatı                       |
| Akaičho Treaty 8, Northwest Territories | Deninu Kue, Detah,  ıtsel K'e, and Ndilo                |
| West Kitikmeot, Nunavut                 | Bathurst Inlet, Cambridge Bay, Kugluktuk<br>Umingmaktok |

#### Community Names

| Official Name  | Former Name    | Ind. Language | Meaning of Indigenous Name                          | Approved |
|----------------|----------------|---------------|-----------------------------------------------------|----------|
| Bathurst Inlet | Kinggauk       | Inuinnaqtun   | "Like a nose"                                       | 17/04/80 |
| Behchokō       | Rae-Edzo       | Tłıchq        | "Mbehcho's place"; Edzo is the name of a Dene Chief | 06/09/92 |
| Cambridge Bay  | Ikaluktutiak   | Inuinnaqtun   | "Good fishing place"                                | 01/04/84 |
| Detah          |                | Tłıchq        | "Place beside a body of water"                      | 11/01/71 |
| Gamètı         | Rae Lakes      | Tłıchq        | "Rabbit net lake"                                   | 06/07/78 |
| Kugluktuk      | Coppermine     | Inuinnaqtun   | "Place of rapids"                                   | 01/01/96 |
|  ıtsel K'e     | Snowdrift      | Dene Sųłıné   | "Place of small fish"                               | 01/07/92 |
| Ndilo          | Rainbow Valley | South Slavey  | "End of the island"                                 | NA       |
| Umingmaktok    | Bay Chimo      | Inuinnaqtun   | "Place of many muskox"                              | 09/03/79 |
| Wekweètı       | Snare Lakes    | Tłıchq        | "Rock lake"                                         | 29/12/78 |
| Whatı          | Lac La Martre  | Tłıchq        | "Marten lake"                                       | 01/01/96 |
| Yellowknife    | Somba K'e      | South Slavey  | "Money place"                                       | 15/05/80 |

## **1.2. Description of Study Area**

The WKSS area extends across the northern boreal forest and deep into the tundra, from Great Slave Lake north to the coast of the Arctic Ocean. It covers a vast area of land and water in and around the West Kitikmeot sub-region of Nunavut, and the Slave geological province that extends into both Nunavut and the Northwest Territories (NWT) of Canada (Figure 1). The WKSS area has been occupied and used by Athapaskan and Inuit peoples for thousands of years but until little more than 200 years ago, the presence of Europeans was negligible. The earliest forms of European influence were related to the fur trade and the establishment of trading posts. In more recent times religious institutions, governments and the mineral industry have shaped development in the area. In particular, this has been through the establishment of churches and schools, fixed communities, roads, operating mines, hydroelectric dams and other forms of infrastructure. There are 12 communities in the WKSS area, with populations that range from less than 100 people to more than 19, 000 (Yellowknife).

### **1.2.1. Human Environment**

Inuit, Dene and Métis of the area continue to travel widely over the land, and traditional place names reflect Aboriginal use and habitation of this area over a very long period of time. There is no part of the land that has been outside the experience of Aboriginal peoples and, as they have said, *“our footprints are everywhere.”* Hunting, trapping, fishing and other on-the-land activities are widely practiced by most Aboriginal residents. Snowmobiles, aircraft, vehicles and boats are now used more often than the more traditional dog teams, canoes and foot travel. Non-aboriginal residents, most of whom live in Yellowknife, also participate in many of the same activities. Aboriginal people using the area include the Tłıchǫ people of Rae-Edzo, Wha Ti, Gameti and Wekweti, the T'atsaot'ine of Dettah and Yellowknife (including Ndilo), the Dene Sųłıné of Łutselk'e, and the Inuit of Kugluktuk, Umingmaktuk, Bathurst Inlet and Cambridge Bay.

All of the WKSS area is subject to Aboriginal comprehensive land claims, some of which remain unresolved or under negotiation. The largest of these claims has been completed, and under the Nunavut Land Claims Agreement the territory of Nunavut was officially established on April 1, 1999. This has divided the study area roughly in two. The Nunavut boundary largely follows the tree line with some areas of overlap defined with other claimant groups. The Tłıchǫ Treaty 11 Council signed a comprehensive land claim agreement over much of the southwest portion of the area on August 25, 2003. Claims by the Dene Sųłıné and T'atsaot'ine covering the southeast of the study area remain under negotiation.

### **1.2.2. Physical Environment**

The WKSS area includes large parts of two of Canada's major ecozones: the Taiga Shield and the Southern Arctic, with the tree line running northwest to southeast between them. Permafrost

underlies most of the area. Although tree cover is extensive in the southern part of the region, there has been little commercial forestry other than some small firewood operations and local sawmills. The density of roads is relatively light. More than half of these are ice roads over frozen lakes and land that are usable for less than a third of the year.

Barren-ground Caribou are present throughout the WKSS area and most belong to the Bathurst Caribou herd that roams freely, calving, migrating and wintering throughout the area and beyond. In addition, there are Grizzly Bears, Muskoxen, Gray Wolves, Moose and a variety of furbearers. Huge populations of migratory waterfowl, shorebirds and songbirds spend the summer months throughout the Canadian North. Many of them are found in the WKSS area, part or all of that time. Many of the lakes and rivers also support significant fisheries. The largely pristine environment and abundance of wildlife have attracted tourists and sportsmen. These visitors support an important tourism and outfitting industry, and the “Northern Lights” have become a special attraction.

There are no large protected areas within the WKSS area, although the Thelon Game Sanctuary and Queen Maud Gulf Migratory Bird Sanctuary adjoin its eastern edge. The area has a few small Territorial Parks and several campgrounds. Various organizations have defined special areas within the WKSS area as being worthy of consideration for protection. Most are to be considered in the process of land claim agreements. Recently, as part of the Akaitcho land claim negotiation process, the Łutselk’e Dene First Nation has formally indicated that it will be seeking long-term protection for an area north of their community referred to as Thaydene Nene (SENES 2006). The area includes two blocks of land: a formerly proposed National Park within the East Arm of Great Slave Lake and a larger parcel of land that essentially comprises the Thelon watershed, connecting the area of interest for a National park with the Thelon Game Sanctuary.

### **1.3. Potential Development**

By comparison with central and southern Canada, the WKSS area is largely undeveloped. However potential for development is high, particularly for diamonds, gold, uranium, and base metals (e.g., zinc). Gold mining has been a major factor, particularly in southern parts of the WKSS area where there have been a number of producing gold mines. Numerous mineral deposits occur throughout the WKSS area, chiefly gold, diamonds, and base metals. There are a few existing small hydroelectric developments and other potential sites have been identified. With the discovery of diamonds in the WKSS area at Lac de Gras in the early 1990’s, one of the world’s largest staking bonanzas began. Within a few years, virtually the entire area was subject to mineral claims. Mineral exploration activity has been high, and a number of sites are in production or the advanced stages of development.

Diamonds are the most active commodity in the WKSS. In the NWT portion, the Ekati diamond

mine, owned by BHP Billiton Diamonds Inc. and Dia Met Minerals, began production in 1998, the Diavik diamond mine began production in January 2003, the De Beers Snap Lake diamond mine is under construction and expected to go into production in 2007, and the De Beers Gachokué diamond project is undergoing an environmental assessment. In Nunavut, the Tahera Jericho diamond mine opened in August 2006.

In 2005, Diavik produced approximately 8.3 million carats and over its 16 to 22 year life, it is expected to produce over 100 million carats of diamonds. The next phase of this mine is scheduled to begin production in late 2007 (Diavik, 2006).

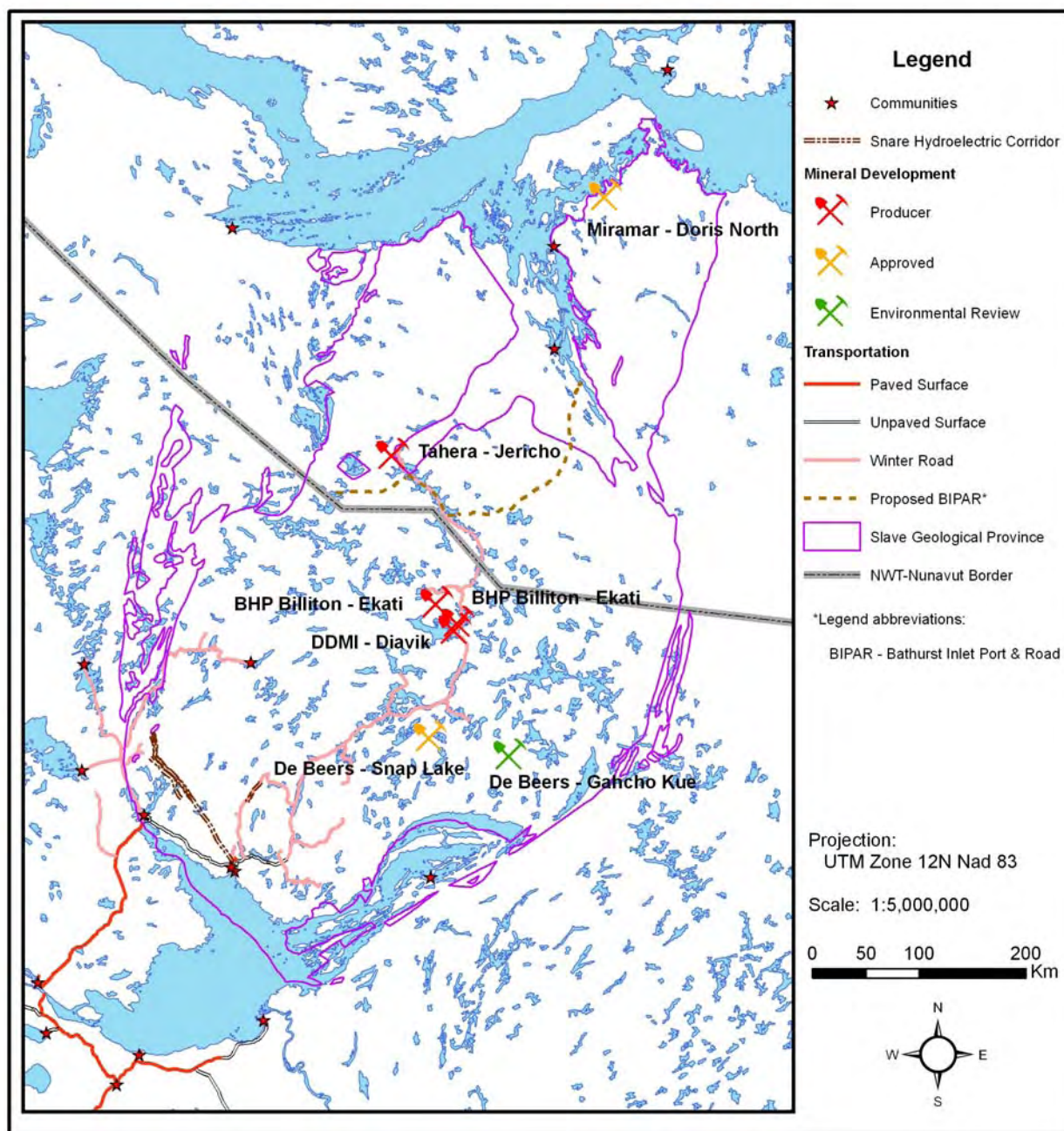
De Beers has begun construction of an underground mine at their Snap Lake project, with full production expected for 2007. De Beers is also in the exploration stages of its Gachokué project, located south of Lac de Gras, 80 km southeast of the Snap Lake Diamond Project and (approximately 300 km northeast of Yellowknife). If the project proceeds toward mine development, it is expected that permitting and stakeholder consultation will take a further three to four years, followed by three years for mine construction (DeBeers, 2006).

Active exploration is still occurring over much of the area, with numerous advanced exploration sites active via mineral claims, leases, and prospecting permits. Interest in uranium has been particularly high since 2005. Within the WKSS region uranium exploration is occurring in the southeastern section, just on the boundary of the SGP and the Thelon Game Sanctuary. Uravan Minerals Inc. owns 263 contiguous mineral leases and mining claims covering 646,823 acres of prospective uranium property (the “Boomerang Property”) located in the Thelon Basin (Uravan Minerals Inc., <http://www.uravanminerals.com/>). Ur-Energy Inc. has established a “Thelon Project” which is comprised of three properties, each of which was acquired based upon the presence of key geological vectors and encouraging supporting data from 1970’s era exploration by Urangesellschaft Canada Ltd. The 76 claims of the Thelon Project cover 175,000 acres (UR Energy Inc., [http://www.ur-energy.com/projects/canada/thelon\\_basin.htm](http://www.ur-energy.com/projects/canada/thelon_basin.htm)).

Figures 2 and 3 provide an overview of the industrial activity with the WKSS region.

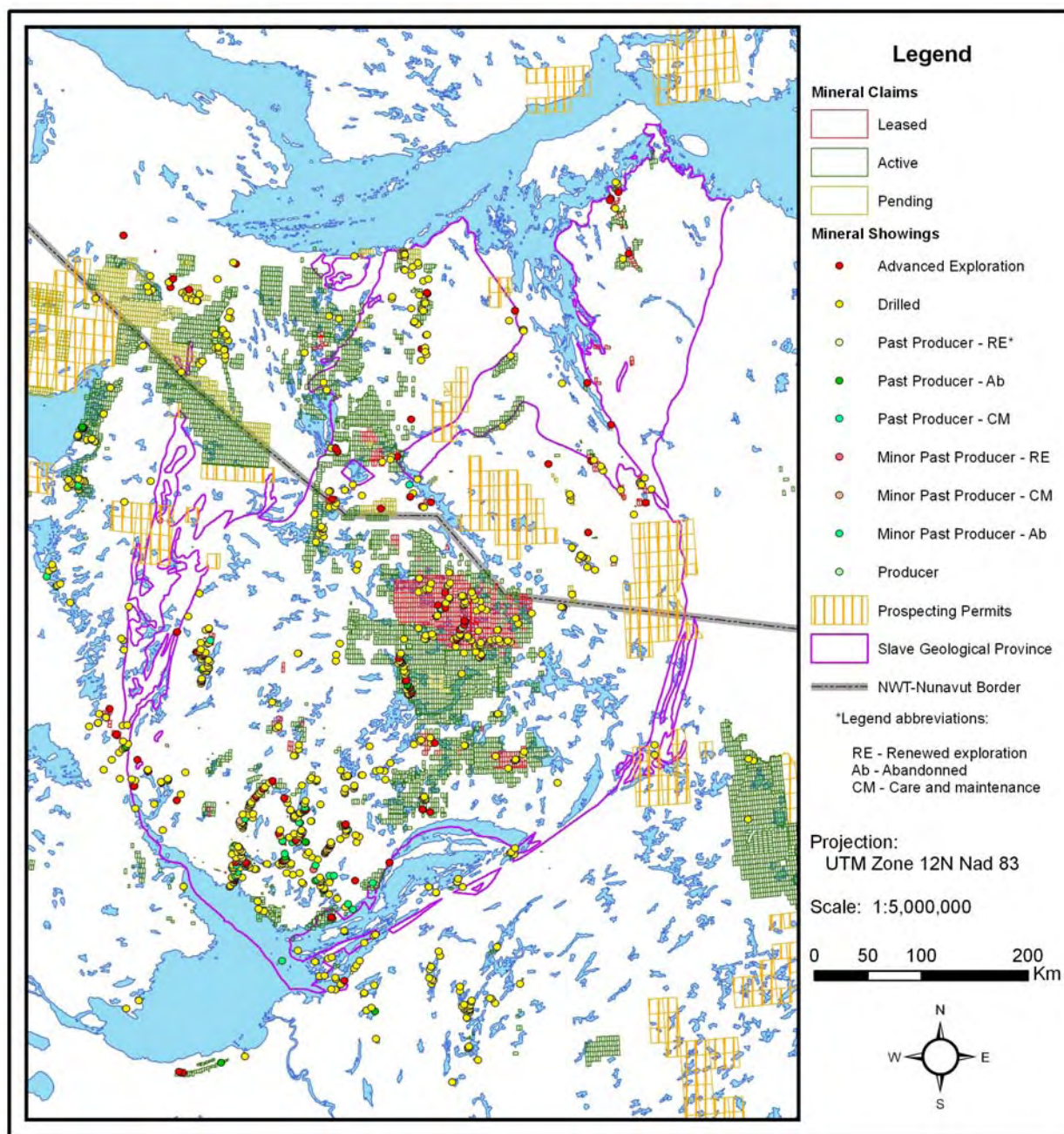


**Figure 2 Current and proposed industrial activity and related development**



Sources: NWT Digital Atlas [CD-ROM]. 2002. World Wildlife Fund (WWF) and Indian and Northern Affairs Canada Mineral Development Division ([http://nwt-tno.inac-ainc.gc.ca/ism-sid/index\\_e.asp](http://nwt-tno.inac-ainc.gc.ca/ism-sid/index_e.asp)) – accessed March 2007

**Figure 3 Mineral exploration activity in the WKSS area**



Sources: NWT Digital Atlas [CD-ROM]. 2002. World Wildlife Fund (WWF) and Indian and Northern Affairs Canada Mineral Development Division ([http://nwt-tno.inac-ainc.gc.ca/ism-sid/index\\_e.asp](http://nwt-tno.inac-ainc.gc.ca/ism-sid/index_e.asp)) – accessed March 2007



During early stages of the diamond staking rush, concerns were voiced by many organizations and individuals, especially Aboriginal and environmental groups. The concerns were about the pace of exploration and possible effects of a series of projects occurring over a relatively short time period in this large and relatively pristine area. As the extent of exploration and possible development have become clearer, all parties, including industry and governments, have recognized the need for an improved information base. This is needed to help minimize environmental problems and to maximize community benefits, and to forecast likely future changes. This need is particularly evident for information about the effects of multiple developments on the environment and the people in the area.

NWT residents and other interested parties have long-standing concerns about the potential cumulative effects of resource development activities on the environment of the NWT. Many of these concerns relate to uncertainties about the effectiveness of government monitoring and management of natural resources, and the lack of coordination among existing environmental research and monitoring programs (NWT CIMP and Audit Working Group, 2005).

These combined impacts may be significant even though the individual impacts of each action, when evaluated independently, are considered insignificant. Cumulative impacts therefore represent the most appropriate measure as to whether or not subsequent activities should be allowed to occur. Although the incorporation of cumulative impacts is a relatively new development in regulatory processes, the concept is strongly integrated into the holistic environmental thinking of Aboriginal people. Such thinking places an emphasis on the sustainability of the total environment and on each of its interconnected parts (SENES, 2005).

One step toward addressing these concerns has been the development of a regional plan of action for the SGP (SGP Project Group 2002). As provided by the SGP Project Group's purpose statement:

*“The Regional Plan of Action for the Slave Geological Province will make recommendations to decision-makers to facilitate the protection of ecological integrity, the building of sustainable communities (including social and economic dimensions), and responsible economic development within a sound environmental management framework.”*

Related to the SGP plan of action and the broader Cumulative Effects Assessment and Management Framework (<http://www.ceamf.ca/>), general monitoring programs have been discussed for both the NWT and Nunavut. These are the Cumulative Impact Monitoring Program (CIMP) and the Nunavut General Monitoring Program (NGMP), respectively. These two programs are discussed in Section 5.

## 1.4. Role of the West Kitikmeot/Slave Study

The West Kitikmeot/Slave Study was jointly announced by the Federal Minister of Indian Affairs and Northern Development, and the Minister of (then) Renewable Resources, GNWT on December 9<sup>th</sup>, 1994. The study was to examine the potential effects of development in the area of the West Kitikmeot and Slave geological province. It was to last five years, with funding provided by the federal and territorial governments. Government funding would match the combined contributions of industry, Aboriginal and environmental partners (to a maximum of \$750,000 each). The five year study ended its initial research program on March 31st, 2001.

During its initial five-year mandate, the WKSS produced research reports, using both traditional and scientific knowledge, on topics such as caribou and other wildlife, community health, vegetation and water. These reports provided necessary baseline information for the Partners to make informed decisions. In order to meet its objectives, the WKSS (WKSS, 2006):

- Gave traditional and scientific knowledge equal value
- Developed a clear set of guidelines for TK research
- Developed a holistic Research Framework and set of research questions for guiding its research based on gaps in existing information
- Developed criteria for approving proposals based on research questions, quality of research and ability to meet WKSS objectives
- Ensured the accessibility of all research results and data to the public; held public meetings throughout the WKSS area; produced regular updates through wide distribution of newsletters and annual reports
- Provided training opportunities and benefits for WKSS communities
- Involved independent experts in the review of research proposals and reports
- Produced and updated a State of Knowledge report on the WKSS area which pulled together information from over 800 documents and identified information gaps remaining at the end of the study
- Established a forum for the partners to share their diverse information and perspectives

At the same time that the West Kitikmeot/Slave Study was announced, the Minister of Indian Affairs and Northern Development formally appointed an environmental assessment panel for *BHP Billiton Diamonds Inc.'s NWT Diamonds Project*. The panel heard many concerns from a broad range of individuals and organizations, including all the communities potentially affected by the project. Some of these concerns related to the possible effects of the BHP Billiton Diamonds Inc. project in combination with a number of other mineral-related developments proceeding in the area. In its final report, the panel made numerous recommendations regarding the project, and several related to the study of cumulative effects of the project in combination with other developments. The panel also directed an eight-part recommendation to the WKSSS about studies related to the cumulative effects of development in the study area.

#### **1.4.1. Partnership Approach**

A partnership approach to research was strongly supported by all the founding partners (the Partners) of the WKSSS:

- Tẖcẖ Treaty 11 Council
- Łutselk'e Dene First Nation
- Inuit Organizations
  - Kitikmeot Hunters and Trappers Association
  - Nunavut Tunngavik Incorporated
  - Kitikmeot Inuit Association
- Nunavut Co Management Organizations
  - Nunavut Impact Review Board
  - Nunavut Wildlife Management Board
  - Nunavut Water Board
  - Nunavut Planning Commission
  - Metis of the Study Area
- Environmental Organizations
  - Canadian Arctic Resources Committee
  - Ecology North
  - World Wildlife Fund
  - Canadian Nature Federation
- Industry
  - Northwest Territories and Nunavut Chamber of Mines
- Government of Canada
  - Department of Indian Affairs and Northern Development
- Government of the Northwest Territories
  - Department of Environment and Natural Resources
- Government of Nunavut
  - Department of Sustainable Development

#### **1.4.2. Vision and Objectives of the West Kitikmeot/Slave Study Society**

Wishing to ensure their independence, the partners incorporated themselves as a registered society dedicated to achieving a common vision:

*“.. to achieve sustainable development in the WKSS area which represents aboriginal cultural values, so that the land is protected, culture is preserved, and community self-sufficiency/reliance is enhanced.”*

Using this vision as a basis, the partners set the WKSSS goal:

*“.. to collect and provide information for the West Kitikmeot/Slave area to assist*

*informed decision making by the Partners, and to facilitate sustainable development.”*

and objectives:

- "provide a basis for the identification and assessment of cumulative effects for planning and development purposes.*
- provide a forum in which to share information on issues, while respecting the diversity of interests: aboriginal, industry, environmental organizations, governments, and the public.*
- provide the information necessary to enhance the understanding of potential impacts of exploration and development on ecological processes and communities.*
- support a central role for both traditional knowledge and scientific knowledge, and facilitate the linkage of research carried out in these systems.*
- ensure the accessibility of study research results and information to all Partners and the public, while respecting the confidentiality of certain information.*
- “provide an information base necessary for study partners to make sound resource management decisions.*
- maximize community research training opportunities and the use of community resources in all study research.”*

### **1.4.3. Research Agenda**

Since 1999, other initiatives have been set up to discuss a number of different programs and organizations related to the research done by WKSS (WKSS, 2006)

- ways to set up a regional monitoring agency in the SGP area
- ways to implement cumulative effects monitoring in the NWT under the Mackenzie Valley Resource Management Act
- ways to set up a Cumulative Effects Assessment and Management Framework in the NWT

In 2001-2002, WKSS developed an interim plan for cumulative effects research and monitoring in the SGP. Since that time, WKSS has continued to fund several key projects during the interim period, until regional monitoring systems are in place. Recently, WKSS updated its research priorities (WKSS, 2006).

In the process of developing the research questions, the Board felt that it would be helpful to knit

together all the information collected on the study area. This revised *State of Knowledge Report* brings the knowledge base up to date, and like previous reports, it is intended as an aid to the partners and to any organizations or individuals interested in a holistic picture of the study area.

### **1.5. State of Knowledge Report: West Kitikmeot and Slave Geological Province**

In planning this *State of Knowledge Report* the partners set a number of objectives:

**Holistic** - The report should provide a complete overview of the natural and socio-economic environment of the area of the West Kitikmeot/Slave Study, and the stresses that are affecting it. Many people have knowledge about the land and the people of some part of the study area, or knowledge about some specific conditions. But it has not been easy to get a “big picture”

**Comprehensive** - Review as much of the material written about the study area as possible. This material covers the natural and socio-economic environment from both scientific and TK bases.

**Accessible** - As far as practical, the jargon associated with science and research would be translated into words understandable by the average reader.

**Integrate knowledge** - Traditional and scientific knowledge would be presented together in the report, to provide a greater understanding of each of the areas discussed.

**Research questions** - The report should assess the WKSSS research questions in relation to any data gaps identified. It would make recommendations to the board regarding changes and additions to the current set of questions based on the synthesis of existing information.

**Opportunities for learning more** - The report should be accompanied by a comprehensive bibliography. This would list as many as possible of the sources of the written knowledge about the region.

The partners believe that information and knowledge about the region are a very important part of achieving sustainable development. The better everyone understands the environment and the complexity of pressures acting on it, the better the decisions they will make. This *State of Knowledge Report* is intended to support the role of the WKSSS in communicating knowledge and adding to understanding of the region.

As with both the first and second report, the outline and content has been reviewed by the study’s

partners to ensure that it covered all major areas of concern, and that it would be useful to people living in the area as well as to the broader public. The report is based on a review of many hundreds of documents. The intention has been to update the second report and to draw from published and documentary materials as late as possible, within the extended period of the West Kitikmeot/Slave Study. The first draft of this report was completed at the end of December, 2006.

Unfortunately, there are still topics covered by this report for which little or no information is available from the WKSS area. This is particularly true for TK information. While efforts were made to list all TK-related studies in the region (or relevant to the region) since 2001, it was not possible to provide an overview or evaluation of study methods, results or recommendations for future research. Similarly, it was not possible within the scope of this project to provide a comprehensive overview of the ethnographic literature related to peoples of the region. Nor was it possible to fully discuss contributions made by WKSS-supported projects. A separate project would be required to properly account for the body of research and documentation related to indigenous peoples and their knowledge in the WKSS region. This would significantly enhance the value of earlier WKSS studies by showing their broader implications, so that key lessons learned can be applied elsewhere.

## **1.6. Science and Traditional Knowledge**

The survival of Aboriginal peoples living in the NWT has historically depended on their knowledge and understanding of the environment. This TK has been passed on from one generation to the next and is based on thousands of years of observation and validation (SENES, 2005). Despite the cultural, societal and technological changes that have occurred during the modern era, TK continues to serve as an invaluable resource to Aboriginal people that maintain a strong connection to the land. This knowledge also has the potential to provide information and perspectives that can improve decisions made by institutions responsible for managing the environment and its resources. Secondary benefits associated with the effective and respectful use of TK include capacity building in Aboriginal communities and helping to create an awareness of, and appreciation for, TK by non-Aboriginal communities (SENES, 2005).

Much of science and TK can be thought of as “two sides of the same coin”. The term “knowledge” (both scientific and traditional) embraces not only information but an understanding of it and an ability to use it. Both science and TK seek to develop understandings of cause and effect. Scientific methodology is often thought of as an exploration of information that occurs in ever more detail, and follows a path that splits into smaller and smaller components (analysis). However, understanding is also gained as different pieces of information are brought together to construct a greater whole (synthesis). The difference between science and TK lies not in these two approaches. Both can explore information from the “top-down” or “bottom up”. Rather, the distinction lies in the types of information that are used. Both scientific



and TK contribute to an understanding of the environment in the WKSS area.

Science tries to gather specific and measurable information (data), and to limit external influences so that experiments can be repeated and ideas demonstrated by replication of results. These forms of objective information provide the basis for most of science. Science usually tries to demonstrate that ideas are false. General acceptance is gained only when ideas can no longer be proven wrong (Gunn *et al.*, 1988; Sly, 1995; Zamparo, 1996). Scientific knowledge is almost always published in scientific journals where it can be reviewed, critiqued and tested by other scientists, around the world. In TK, on the other hand, more of the information is qualitative (not in numeric form). It is also derived from experience, observations, and experiments by trial and error (Gunn *et al.*, 1988; Sly, 1995; Zamparo, 1996). In the words of a Kluane First Nation member, TK is “not really ‘knowledge’ at all; it’s more a way of life” (cited in Nadasdy 2003, 63). Traditional knowledge grows and evolves as information is handed down by people, from generation to generation. Each generation may contribute to its enrichment, and contributions are usually characterized by general acceptance in a community. Scientific knowledge also grows and evolves over time as experiments are carried out and data are collected, and new hypotheses are developed and tested. Both TK and scientific knowledge must be shown to be valid over time before they are accepted.

In science, it is usual that only part of the "puzzle" is known to an observer and it is not until information is shared between different minds that a larger and a clearer picture can emerge. The scientific record is often brief or non-existent at many places in the north, and little or no scientific research may be available to show how various parts of the ecosystem link together. Many aspects of TK have potential to reflect past conditions (before scientific record), to fill some of the vast gaps (spatial) in the present scientific record, and to contribute collectively to knowledge of the WKSS area environment. For example, very little has been published about the coastal ecosystems of the Coronation Gulf and almost nothing is known about freshwater contributions to this marine environment.

Traditional knowledge has untold value to a people’s heritage. It has value both as an understanding of self sustained living (in the study area), and in a variety of other ways that it may contribute to understanding of the environment. Likewise, science can contribute to sustainable development and to further understanding of the environment and its use. There are also points of overlap in the information available from both science and TK. Most TK still remains in oral form, though communities in the WKSS area have been making efforts to revitalize and document this knowledge so that it can be used as a tool in addressing the challenges of social and environmental change.

Incorporating TK into formal environmental decision-making often draws attention to fundamental differences between “traditional” and “scientific” knowledge systems (SENEC,

2005). The following statement from the Dene Nation summarizes many of the differences that are commonly cited:

*Science aims to explain things by breaking them down into parts. In the holistic view of [traditional knowledge], everything is interconnected and every action affects the entire ecosystem. The time frame of scientific observations is defined and brief compared with TK observations which span a person's lifetime and even generations. Science and TK both have a special language, so that information can be lost in translation. A difference is that scientific observations are quantifiable and recorded in writing, whereas TK is oral and qualitative (Dene Nation, 1999).*

Historically, TK was not used in the regulatory process. This is changing with most process participants appearing to recognize TK as a potentially important source of information for decision-making. Traditional knowledge has played an important and, in some cases, central role in NWT land use planning, where this planning has taken place. It has also been used as the basis for decisions during regulatory processes and genuine efforts are being made to ensure that it is considered during Environmental Assessments. The first NWT Environmental Audit completed by SENES in 2005 identified numerous challenges to the process, including the need for increased emphasis to be placed on documenting TK and ensuring that it is passed between generations. In addition, participants in the environmental management regime should be given the training necessary to ensure they have the capacity to collect and use TK effectively. Further, the expectations of all parties should be clearly stated in processes involving the exchange of TK.

WKSS Partners agreed that scientific and TK have equal value and should be linked where possible to provide a broader understanding of any research question. This vision has influenced the research conducted in the study area. The Traditional Knowledge Steering Committee (TKSC) was appointed by the WKSSS Board in 1996. It comprised representatives of each of the Aboriginal partners and was mandated to monitor and encourage the use of TK in all research conducted in the WKSS area.

During the initial study period, several diverse projects were conducted within the WKSS area. These include comparisons of Tłıchǫ Elders' knowledge of caribou migration with scientifically gathered satellite radio collar data (Gon *et al.*, 1997); the integration of scientific and traditional ecological knowledge on the health of wildlife in the Kugluktuk area (Elkin *et al.*, 1999a); and the health of people in the community of Łutsel K'e (Łutsel K'e Dene First Nation, 1998). A sampling of some of the other projects sponsored by WKSS that have been conducted since 2001 are listed below (WKSS, 2006):

- *Traditional Ecological Knowledge in the Kache Kue Study Region* (2001)
- *Community-Based Monitoring* (2001, 2002)

- *Traditional Knowledge in the Kache Tué Study Region: Phase Three - Towards a Comprehensive Environmental Monitoring Program in the Kakıñëne Region* (2002)
- *Dogrib Knowledge On Placenames, Caribou And Habitat* (2002).
- *Ni hat'ni – Watching the Land: Results and Implications of Monitoring Activities in the Traditional Territory of the Łutsel K'e Denesóhne* (2003, 2005)

A number of additional TK projects were initiated by communities of the WKSS region with the aim of strengthening the role of the community as monitors and stewards of the land, including reports on cumulative effects, water protection, traditional land use, fishing knowledge, and planning for comprehensive community-based monitoring programs. The new government of Nunavut in 1999 has taken responsibility for TK research in the region; unfortunately any new studies undertaken with Qitirmiut since that time were not easily accessible at the time of this update.

Unfortunately it has not been possible within the scope of this report to fulfill the objective of providing equal weight to scientific and traditional knowledges. Although indigenous residents possess extensive knowledge of the WKSS region, most of this is undocumented. It is important to note that indigenous knowledge is at the root of much scientific knowledge, particularly that which relates to the environment, as scientists moving into a new area tend to rely heavily on what aboriginal people know to establish a pool of knowledge (Agrawal 1995; Anderson 1999: 158-163; Bravo 2000: 473-474; Ellen and Harris 2000: 11). Also, more recently, many northern scientists have actively relied on knowledge held by Inuit and Dene as a basis or support to their work (e.g., Gunn et al, 1997; Gunn 2003; Gunn and Fornier 2000). Thus there may well be much TK running as an unacknowledged undercurrent through much of the science presented in this report.

#### **1.6.1. Definition and Ownership of Traditional Knowledge**

There are many definitions of TK and other similar terms (Johnson, 1992; Legat, 1991; Stevenson, 1996). One of the first tasks undertaken by the TKSC was to develop a definition of TK for use in the study and to set out guidelines for this research. The TKSC definition of TK used in this report is as follows:

*“Traditional knowledge is knowledge that elders hold from experience and is passed down to them through the generations. It is continuous and grows. Interpretation of knowledge is important. Traditional knowledge is not just the past, but the future combined with the past” (WKSSS, 1996).*

The Committee also stressed the importance of community control over TK research and the data collected. This is reflected throughout the guidelines developed for the West Kitikmeot/Slave Study TK researchers.

The NWT Environmental Audit conducted by SENES in 2005 (SENES 2005) found that within the NWT there is no single institutional body responsible for the collection and use of TK. Thus, a situation has been created wherein the term “traditional knowledge” has been defined differently by Boards, cultural institutes, Aboriginal groups and government programs. However, notwithstanding differences, TK definitions are generally consistent with the following example which is sufficiently generic to include the biophysical, cultural and spiritual dimensions of TK:

*Traditional knowledge is broadly defined as a cumulative, collective body of knowledge, experience, and values held by societies with a history of subsistence* (Ellis, 2005).

Despite the variety of existing definitions the audit found that most participants in NWT environmental management processes have a common understanding that TK includes the full range of knowledge, experience and values possessed by Aboriginal people.

Recently indigenous theorists such as Maori author Linda Tuhiwai Smith (1999) and Kanienkehaka author Taiaiake Alfred (2005) have insisted that while there may be commonalities experienced in the history and impacts of colonization, generalizations about indigenous knowledge are inappropriate given the wide diversity of indigenous peoples. This diversity has been recognized in definitions of indigenous knowledge and ways of knowing specific to each people. This does not negate the general definition above, but rather enhances it with a more nuanced understanding of regional and local cosmologies. For example, the Government of Nunavut has formally adopted a specific conception of Inuit knowledge drawn from Inuit perspectives and language, *Qaujimajatuqangit* (Wenzel 2004). This concept should be distinguished from definitions of TK developed by the Dene Cultural Institute and Dene Nation. The concept of *Qaujimajatuqangit* has been applied in studies related to the Qitirmiut people of the West Kitikmeot Region (Thorpe et al 2001, Collington 2006). In their study of Qitirmiut Knowledge about caribou, Thorpe et al define Inuit *Qaujimajatuqangit* (IQ) as “what has always been known ...”what [Inuit] must or have to know” (2001, 4).

### **1.6.2. Sources and Limitations of Traditional Knowledge Used in This Report**

One of the objectives of the West Kitikmeot/Slave Study has been to collect TK related to the research priorities set by the Partners, and to link it with western scientific knowledge. The review for the first *State of Knowledge Report* covered TK documentation up to 1996 (Jenness, 1922; 1924; 1946; Helm, 1961; 1994), as well as older work that included ethnological research and land use studies in the WKSS area (Freeman, 1976; NPC, 1997; Riewe, 1992; Spacial Data Systems, undated). An additional 21 published documents were used in the preparation of 2001 edition of this *State of Knowledge Report*, (Andrews, 1998a; 1998b; Berkes, 1997; Bussey, 1998; 2000; Cluff, 1997; Cournoyea, 1997; Elkin *et al.*, 1999a; Fitzpatrick, 1999; Gon *et al.*, 1997;

Gunn *et al.*, 1997; Legat, 1998a; 1998b; Łutselk'e Dene First Nation, 1998; Parlee, 1997; Stevenson, 1997; 2000; Thorpe, 1997, 1998a; 1998b; Thomson, 1999; 2000). These documents report on TK research in the WKSS area, and were produced after 1996.

TK is an ancient field of inquiry, passed on orally and in practice since time immemorial. Documentation of indigenous knowledge goes back several centuries. Since the arrival of missionaries, traders, explorers and scientists, attempts have been made to document what both Inuit and Dene know about their surroundings. Early documentation of “what Dene know” occurred as early as 1790 with the explorer Samuel Hearne, the Oblate priest and ethnographer Emile Petitot in the early 1800, the naturalist John Russell in the late 1800s, and by the anthropologist John Alden Mason in the early 1900s – to name a few. The first documentation of “what Inuit know” occurred in the Kitikmeot with ethnographers Jenness, Rasmussen and Stefansson in the late 1800s and early 1900s, who at times travelled alongside biologists who took a keen interest in Inuit knowledge. Although most of these past researchers reflect the thinking of the times, and may tell us more about European attitudes than those of the people and knowledge they aimed to document (Bravo 2000: 470; Bravo and Sörlin 2002: 18; Pálsson 2002), others make sense of differences between Aboriginal and European approaches (for example, the naturalist John Russell when trying to understand why one Dene leader did not want him taking caribou hides back south with him). Current researchers may therefore be able to see trends over time in the actions Dene and Inuit take based on their knowledge. .

However, there have been two more recent trends in TK research. Firstly, since the 1980s, academics working with Dene have focused on knowledge and participatory and collaborative research (Ryan and Robinson, 1990 and 1992; Johnson and Ruttan, 1993). DeLancey (1984) used participatory and collaborate research with a focus on TK while in Fort Good Hope. Since the mid 1980s Joan Ryan initiated TK research using a participatory method in the Gwich'in community of Fort McPherson and in 1989 in Whatì (1990, 1992, 1995). Looking further back, the Tłıchǵ of Whatì insisted that both June Helm and Joan Ryan participate in the community if they wished to do research. Both continued to work and communicate with both the political and educational sections of the Tłıchǵ government until the mid 1990s – a span of 40 years. Furthermore since the 1980s archaeologists such as Chris Hanks and Tom Andrews have been both participating with communities and using TK to enhance their line of inquiry.

The second relatively recent trend is marked by attempts to use knowledge originating with the Dene and Inuit for policy decisions, environmental impact assessments and environmental monitoring. This has been a long time coming as Sandlos (2003) discusses in his article on the politics of early biological surveys in northern Canada. Reflecting on this new mode of TK use, Nadasdy (2003), Cruikshank (1998) and others have highlighted the many challenges associated with incorporating TK within bureaucratic and scientific frameworks.

There have been a number of academic publications on the nature and significance of TK in relation to scientific knowledge, particularly as a tool for cooperative resource management (Anderson and Nuttall 2004, Andrews, Tom 2002, Armitage 2005, Bateyko 2003, Berkes 2005, Berkes et al 2005, Ellis 2005, Huntington et al 2002, Sloan 2004, Nadasdy 2003, Scott 2004, Stevenson 2006). Other writings have focussed on the ethics, protocols and methodologies of TK research, including protection of intellectual property rights (Aurora Research Institute 2003, Faye 2001, Folliott 2004, Huntington et al 2004). Many contemporary inquiries involving TK have been related to a mix of environmental, social and political issues, including:

- Climate change/ecological change/monitoring (Berkes and Jolly 2001, Ford et al 2006, Krupnik and Jolly 2002, Parlee and Manseau 2005, Riedlinger et al 2001, Thorpe 2001, Thorpe 2000, Thorpe et al, 2000).
- Cultural landscapes and placenames (Collingon 2006, Prince of Wales Northern Heritage Centre [ongoing web database], Whaèhdòò Nàowoò Kò/Dogrib Treaty 11 Council 2002).
- Ethnography, cultural practices, material culture (Andrews 2006, Christensen 2003, Nuttall et al 2005, Santo 2004, Searles 2002, Stern and Stevenson 2006, Stewart et al 2004).
- Governance (Abele and Graham 2003, Billson 2001, Dahl et al 2000, Jull 2001, Kulchyski 2005, Simpson 2004).
- Identity formation and consciousness (Dorais 2005, Sharp 2001, Wenzel 2004).
- Oral narratives (Bennett and Rowley 2004, Blondin 2006).
- Resource development (Dragon 2005).
- Social impacts and healing (Government of the Northwest Territories 2006, Kral 2003, Oosten 2002).
- Teaching traditional knowledge (Takano 2005, Thorpe and Eyegetok, 2000a and b).
- Wildlife and resource management (Gilchrist et al 2005, Kendrick et al 2005, Parlee et al 2006, Thorpe et al 2001, Thorpe 2002, Wenzel, George 2004).

This recent phase of TK research in the North is remarkable for its thematic diversity. Identity development, governance and resource management have been critical fields in an era of self-government and cooperative resource management. Of particular note is the introduction of studies that specifically address the role and knowledge of women (Parlee 2006, Sloan 2004). Barren-ground caribou research has been a strong priority given reports of significant population decline (Dragon 2005, Kendrick et al 2005, Parlee and Manseau 2005, Thorpe et al 2001, Whaèhdòò Nàowoò Kò/Dogrib Treaty 11 Council 2002). Also, the field of TK research has been increasingly concerned with applications of TK in the context of ecological and social change, including climate change and ecological change caused by industrial development. Discussions continue about the adaptivity of TK in response to these dynamics. TK researchers are exploring research and knowledge mobilization methods that incorporate new technologies

including GIS mapping (Folliott 2004) and the internet (Christensen 2003). They are also experimenting with hybrid forms of research bringing together scientific and TK methods (Huntington et al 2004). There is an emergent school of thought that is drawing upon critical theory in the analysis of TK and its role in indigenous communities (Alfred 2005, Smith 1999, Scott 2004).

Traditional knowledge research continues to evolve and change, and only recently have projects focused on documenting specific aspects of TK. Prior to this, researchers tended to gather general information and their projects lacked clear goals and objectives. Current studies are almost exclusively community-based and are conducted by Aboriginal cultural organizations or Band Councils. Some are collaborative and involve research partnerships between communities and outside organizations such as governments or universities. Many of these projects are conducted with the assistance of a trained researcher using the *Participatory Action Research Method* which is designed to ensure that the community maintains control of all aspects of the project (Johnson, 1993; Legat, 1997; Ryan, 1993; 1995). Issues of intellectual property and ethical standards for collecting information are a significant part of any research design.

Traditional knowledge projects have been conducted in a number of Dene and Inuit communities outside the WKSS area, but cultural and linguistic differences among communities make information from these studies of uncertain value to the West Kitikmeot/Slave Study. For the purpose of this report, the focus is on projects conducted in communities within the WKSS area. This focus has helped to better assess data gaps within the region.

A number of organizations have conducted TK research that relates to the WKSS area. However, the use of some of this material is restricted due to concerns for intellectual property rights. Permission was requested to use these resources for earlier editions of this report, but if approval was not granted, the material was not included. The 2006 update draws exclusively upon on materials that have been released to the public since 2001.

Invaluable knowledge is contained within many audio and video recordings housed in various archives in the NWT, Nunavut, and other provinces. Some recordings are also held by community groups. Many of these have not been transcribed, or the results reported cover only a portion of the topics discussed on the tapes. Some collections are also restricted. No attempt has been made to access such original material but where documents based on research were available the results have been included in this report. Fortunately, a number of recent projects are transcribing, translating and integrating archived information. It is hoped that all the information will someday be available.

The Internet has quickly become a convenient means by which both traditional and scientific knowledge can be shared. Preparation of the *State of Knowledge Report* has included review of



source information on the “world wide web (www)”. This has been an important source of information for reports, project summaries, and the invaluable data contained in both government and non government databases pertaining to the WKSS area. Researchers wishing to directly access some of this information should visit the West Kitikmeot/Slave Study site at: <http://www.wkss.nt.ca> and the Prince of Wales Northern Heritage Centre web site at: <http://www.pwnhc.learnnet.nt.ca>.

In the course of the West Kitikmeot/Slave Study, researchers have been able to make some important additions to documented TK of the WKSS area. The West Kitikmeot/Slave Study has made an important contribution to the written body of TK. However, it is widely recognized that existing documentation represents only a fraction of knowledge embodied in oral traditions. An enormous amount of work and time will be required before any significant amount of the TK of the study area is written down.

### **1.7. Learning More**

It is never possible to have complete information, and interpretation of what is available will vary depending on one’s perspective. This report is intended to provide a comprehensive and, as far as it is possible, an unbiased view of the study area for readers. However, the amount of written material reviewed comes to many thousands of pages. Condensing it into such a brief description can only be done by keeping the information compact, simplifying, making choices and leaving many things out. For readers wishing to know more about any of the information presented, source materials are cited and referenced. The details lie in these other documents. This report sets the scene and, hopefully, it can strike the spark to fire each reader’s personal interest to discover more about this rich land and its people.

### **1.8. Report Structure**

Following this introduction, Section 2 provides a description of the environment and ecosystems of the study area. These include freshwater and marine environments, the terrestrial environment and human elements of the study area. Section 3 gives a descriptive summary of factors that act to stress the environment and people of the study area. These factors may be external or internal to the WKSS area. Section 4 describes in more detail the effects that result from various forms of stress. Many effects occur as a result of multiple rather than singular forms of stress. Section 5 discusses our evolving understanding of the concept of sustainable development. It points to the role that this concept can play in guiding future decision-making which will affect the region. Section 6 outlines additional information that may be required in support of present and near future decision-making. Section 7 provides recommendations for further research. Section 8 provides the full list of text references cited in the document. Appendices A, B, and C provide; respectively, a glossary and abbreviations, symbols and notations used, and a listing of the common and scientific names of flora and fauna of the WKSS.

## **2.0 ECOSYSTEMS AND THE ENVIRONMENT OF WEST KITIKMEOT / SLAVE STUDY REGION**

### **2.1. Introduction**

#### **2.1.1. Science and Traditional Knowledge**

Much of science and TK can be thought of as “two sides of the same coin”. The term “knowledge” (both scientific and traditional) embraces not only information but an understanding of it and an ability to use it. Both science and TK seek to develop understandings of cause and effect. Scientific methodology is often thought of as an exploration of information that occurs in ever more detail, and follows a path that splits into smaller and smaller components (analysis). However, understanding is also gained as different pieces of information are brought together to construct a greater whole (synthesis). The difference between science and TK lies not in these two approaches. Both can explore information from the “top-down” or “bottom up”. Rather, the distinction lies in the types of information that are used. Both scientific and TK contribute to an understanding of the environment in the WKSS area.

Science tries to gather specific and measurable information (data), and to limit external influences so that experiments can be repeated and ideas demonstrated by replication of results. These forms of objective information provide the basis for most of science. Science usually tries to demonstrate that ideas are false. General acceptance is gained only when ideas can no longer be proven wrong (Gunn *et al.*, 1988; Sly, 1995; Zamparo, 1996). Scientific knowledge is almost always published in scientific journals where it can be reviewed, critiqued and tested by other scientists, around the world. In TK, on the other hand, more of the information is qualitative (not in numeric form). It is also derived from experience, observations, and experiments by trial and error (Gunn *et al.*, 1988; Sly, 1995; Zamparo, 1996). In the words of a Kluane First Nation member, TK is “not really ‘knowledge’ at all; it’s more a way of life” (cited in Nadasdy 2003, 63). Traditional knowledge grows and evolves as information is handed down by people, from generation to generation. Each generation may contribute to its enrichment, and contributions are usually characterized by general acceptance in a community. Scientific knowledge also grows and evolves over time as experiments are carried out and data are collected, and new hypotheses are developed and tested. Both TK and scientific knowledge must be shown to be valid over time before they are accepted.

In science, it is usual that only part of the “puzzle” is known to an observer and it is not until information is shared between different minds that a larger and a clearer picture can emerge. The scientific record is often brief or non-existent at many places in the north, and little or no scientific research may be available to show how various parts of the ecosystem link together. Many aspects of TK have potential to reflect past conditions (before scientific record), to fill some of the vast gaps (spatial) in the present scientific record, and to contribute collectively to

knowledge of the WKSS area environment. For example, very little has been published about the coastal ecosystems of the Coronation Gulf and almost nothing is known about freshwater contributions to this marine environment.

Traditional knowledge has untold value to a people's heritage. It has value both as an understanding of self sustained living (in the study area), and in a variety of other ways that it may contribute to understanding of the environment. Likewise, science can contribute to sustainable development and to further understanding of the environment and its use. There are also points of overlap in the information available from both science and TK. Most TK still remains in oral form, though communities in the WKSS area have been making efforts to revitalize and document this knowledge so that it can be used as a tool in addressing the challenges of social and environmental change.

Incorporating TK into formal environmental decision-making often draws attention to fundamental differences between “traditional” and “scientific” knowledge systems (SENES, 2005). The following statement from the Dene Nation summarizes many of the differences that are commonly cited:

*Science aims to explain things by breaking them down into parts. In the holistic view of [traditional knowledge], everything is interconnected and every action affects the entire ecosystem. The time frame of scientific observations is defined and brief compared with TK observations which span a person's lifetime and even generations. Science and TK both have a special language, so that information can be lost in translation. A difference is that scientific observations are quantifiable and recorded in writing, whereas TK is oral and qualitative (Dene Nation, 1999).*

Historically, TK was not used in the regulatory process. This is changing with most process participants appearing to recognize TK as a potentially important source of information for decision-making. Traditional knowledge has played an important and, in some cases, central role in NWT land use planning, where this planning has taken place. It has also been used as the basis for decisions during regulatory processes and genuine efforts are being made to ensure that it is considered during Environmental Assessments. The NWT Environmental Audit identified numerous challenges to the process, including the need for increased emphasis to be placed on documenting TK and ensuring that it is passed between generations (SENES 2005). In addition, participants in the environmental management regime should be given the training necessary to ensure they have the capacity to collect and use TK effectively. Further, the expectations of all parties should be clearly stated in processes involving the exchange of TK.

### **2.1.2. Concepts of Scale**

Concepts of scale in space and time are important for perspective. The WKSS area is large and about half of it lies north of the tree line. It extends south from the Coronation Gulf to Great

Slave Lake, a distance of about 800 km. It extends eastward from near the eastern shore of Great Bear Lake to the Queen Maud Gulf on the Kent Peninsula, a distance of about 600 km (Figure 1). This roughly rectangular area covers more than 300,000 km<sup>2</sup> of the western mainland of the NWT and Nunavut. For comparison, this area is nearly two-thirds of the size of the province of Alberta.

From a geological perspective, the area is both remarkable and unique for what is preserved in the rocks of this part of the Earth's surface. Also, for what may be interpreted as a record of the Earth's history over an immensely long period of time, of more than 4 billion years (Ga) (Skinner & Porter, 1992).

### **2.1.3. Life and the Environment**

In many other ways, however, the area is not greatly different from the regions that surround it. The major seasonal migrations of animals and people into and out of the area indicate that the web of life is closely knit throughout the WKSS area. Thus, while our attention remains focussed on the WKSS area, care has been taken to set this within appropriate regional and, or, global contexts.

The land, freshwater (lakes and rivers), marine coast (Coronation Gulf), snow and ice cover, and even the air may each be considered as separate environments within the WKSS area. They are also parts of a larger whole to which they are intimately connected (such as the continental land mass or Arctic Ocean). Because plants grow in one place, they may be thought of as being associated with only one environment. But processes that enable them to spread to new areas, such as dispersals of seeds or living material by wind, water or the movements of animals, often extend parts of their life cycle through different environments. As with most living things, it is usual that one form of environment is dominant in their existence. It is usual to associate various animal and plant communities with a dominant environment. Biological environments can also exist at very small scales. For example, some small organisms may live almost an entire life time on a single plant or animal host. As a matter of convenience, most environments may be described by their chemical and physical characteristics. For each species, however, there is a set of temporal, physical, chemical and biological characteristics that collectively define its position or niche within the environment. No two species occupy the same niche when both are present in the same environment, although one may be replaced in its absence, by another.

Habitat describes something more specific than environment, both in time and space. It usually describes a place where the characteristics of the environment support special needs associated with particular animal activity. The area over which we can find a species is called its distribution, or range (Miller, 2005). Survival of a species may depend on its range, and the existence of precisely the right conditions at a specific time and, often, in a specific place. Denning habitat for wolves, calving habitat for caribou, and spawning habitat for fish may each be considered critical habitat. Other forms of habitat may be considered less critical. For

example, there may be plenty of space or time is less restricted for a required activity, such as a moulting or staging area for geese, or grazing area for Muskoxen.

A community, or biological community, consists of all the populations of the different species living and interacting in an area. When a different communities interact with one another and their physical environment, an ecosystem is formed.

Ecosystems characterize functional relations among and between organisms (both plants and animals) and the environment. Although many species of animals do not fit neatly into such groupings, the earth's ecosystems can be categorized into components of biomes (terrestrial regions such as deserts, forests, grasslands, etc.) and aquatic life zones (lakes, streams, coral reefs, etc.). Birds, for example, are mostly described as members of aquatic or terrestrial ecosystems. Humans are considered a terrestrial species although, very definitely, we are part of most ecosystems and our presence is global. Between ecosystems, there are widely differing degrees of connectedness both in space and time. After snow forms in the atmosphere and falls onto the land and melts, it runs off into rivers and lakes; after black-flies and mosquitoes emerge from their aquatic larval stages they become the torment of many animals in terrestrial ecosystems; yet the life cycles of many fish species remain entirely within freshwater ecosystems. Nevertheless, over time, all are interconnected globally as an integrated whole.

Each population in an ecosystem has a range of tolerance to variations in its physical and chemical environment. The existence, abundance and distribution of a species in an ecosystem depends on whether the levels of physical and chemical factors fall within this range (Miller, 2005).

Ecosystems are dynamic and, in many of them, cyclical change is a common feature. Some of the changes occur at more or less regular intervals, such as the cycles of Lynx and Snowshoe Hare that repeat at intervals of about 8 to 11 years. Other, less regular and less frequent population fluctuations also occur in many other terrestrial animals. Fire and periods of glacial advance and retreat provide examples of even more dramatic changes in the environment that occur over much longer time intervals. Over thousands of years, ecosystems naturally evolve, perhaps in response to slow and continual genetic change or to events such as species introductions and environmental catastrophes. The response of ecosystems to various forms of change is often unpredictable.

Ecosystems vary greatly in complexity. Most ecosystems depend on the growth of plants. Primary production is the process that converts carbon dioxide and water into organic matter in the presence of sunlight and plant growth is sustained by the availability of nutrients (Cunningham & Saigo, 1992). Because northern ecosystems are greatly influenced by low levels of annual received solar radiation and low nutrient availability, they are often characterized by

relatively small numbers (low diversity) of highly specialized plants and animals. The carrying capacity of northern environments is therefore much less than those in more southerly parts of Canada. Migration is practiced by caribou and many other species, especially birds. It enables relatively large groups of animals to maintain an adequate diet throughout the year, even though food supplies may not be continuously available in the same place. Humans used to migrate as well but now much of their dietary requirement is met by the import of food supplies to resident populations. This is expensive (both in terms of the energy required to move food and the monetary cost of doing this). Because of economic and cultural considerations and preferences, a substantial part of human food requirements is still met from the local harvest of country food.

Ecosystems can be characterized by the environment with which they are associated and by the biological communities that comprise them. The food web describes patterns of energy flow that occur within ecosystems and which involve all stages in the life and death of plant and animal communities. Within the food web there are many food chains, each of which links the flow of energy between important members of a community. As some animals eat other animals and some animals eat plants, the energy from organic matter in many small organisms becomes progressively concentrated in fewer but larger organisms. Most of the energy is stored in plant and animal material (biomass). Some is also used by organisms as they consume food and convert organic matter from lower to higher levels (trophic levels) in the pyramid-like structure of the food web. Energy transfer through food chains is not very efficient, as with each transfer some usable energy is degraded and lost to the environment as low-quality heat. In actuality, only a small portion of what is eaten and digested is converted into an organism's biomass. The amount of usable energy available to each successive trophic level declines (Miller, 2005).

Microbial populations exist in vast numbers but little is known about their contributions to northern food chains (in the WKSS area or globally). In simple aquatic ecosystems, phytoplankton are the primary producers (floating microscopic plants) and they occur at the base of most food chains. At the next level, zooplankton (including small crustacea) are the grazers that consume phytoplankton. At a higher level, fish exist as predators (small fish eating the zooplankton and big fish eating small fish). Detritivores (such as worms and larvae) consume decaying organic matter and are themselves consumed by larger forms. These relationships ensure a highly efficient use of all available food material. In simple terrestrial ecosystems, green plants are again the primary producers. These are grazed by herbivores that in turn support various predators. Bacteria and fungi are major contributors to processes of decay in both aquatic and terrestrial ecosystems. Several species of insects, birds and mammals consume decaying organic matter (including carrion). They effectively use all available food material and return nutrients to the land and, or, water. In this way, much of the energy and nutrients that are stored in organic matter are converted by detritus feeders into forms suitable for use by plants. Humans are the top predator in many food chains.

The food chains in many northern ecosystems are short. For example, the dependence of Lynx on Snowshoe Hare or wolves on caribou. With short food chains and many species that are highly specialized, the extent to which northern ecosystems seem to have a built-in redundancy appears to be very limited. A diverse ecosystem will be resilient as it contains many species with overlapping functions that can partially replace one another. The more complex the networks in an ecosystem, the more resilient it is to disturbances. Northern ecosystems have limited diversity. Could the Lynx survive without the Snowshoe Hare? What would happen to the vegetation without the Snowshoe Hare? Conversely, also, what would happen without the Lynx?

Both in terms of the environment and its related ecosystems, much of what we experience at the present has been influenced by what has happened in the past (*e. g.* the effects of glaciation). Much of what happens now will affect the future (*e. g.* developments associated with human activities). The resilience (ability to remain whole) of ecosystems under the influence of human activities are difficult to assess. A good understanding of both systems and their components are required for management to ensure continuity and integrity of the environment.

## **2.2. Physical and Climatic Aspects of the WKSS Area**

### **2.2.1. Climate**

Weather describes the day-to-day experience of atmospheric conditions (wet-dry, warm-cold, cloudy-sunny, windy-still) that may vary over distances of only a few tens of kilometres. Climate describes weather and its seasonal variations over larger areas and for time frames extending over several years. Climate is driven mostly by solar heating (Lockwood, 1979; Smith, 1981) and the Arctic air mass is the dominant feature of Arctic and sub-Arctic regions of North America. There is an additional but lesser influence from the Pacific air mass in the western Arctic and sub-Arctic (Rouse *et al.*, 1997). In the WKSS area, climate is dominated by the persistence of large scale atmospheric structures, particularly the Arctic High Pressure Cell. This is centred north of Alaska and its clockwise circulation generates a northerly air flow across the region (Mysak, 1993). During winter, the formation of ice cover stops much of the moisture exchange between the ocean and atmosphere. Cold temperatures also reduce atmospheric humidity by lowering the condensation point. During the summer, the air warms and can contain much more moisture. More moisture also evaporates from the open waters of the Arctic Ocean and Beaufort Sea and is carried south. This results in a summer precipitation peak throughout the WKSS area. As the air is forced to rise with the increasing height of land south of Coronation Gulf, it cools and condensation occurs. This causes a modest increase in precipitation.

Unfortunately, climate records from locations within the WKSS area are relatively short. Often they are of differing length, some lack continuity, and some are not directly comparable. The information presented in the Table 1 is based on data provided by Environment Canada climate normals (EC, 2006). Traditional knowledge is the only source of long term information on

climate patterns, as evidenced by research completed by Thorpe (2001), Cruikshank (2001), and Woo et al (2007).

**Table 1 Climate Normals in the WKSS Area (1996-2005)\***

| Location      | Time Period (years) | Mean Temperature (°C) |       |       | Precipitation (mm) | Rainfall as a % of Precipitation(mm) |
|---------------|---------------------|-----------------------|-------|-------|--------------------|--------------------------------------|
|               |                     | January               | July  | Year  |                    |                                      |
| Cambridge Bay | 1996-2005           | -31.9                 | 9.24  | -13.6 | 140.4              | 53                                   |
| Gameti        | 2001-2005           | -26.8                 | 17.4  | -5.2  | 251.1              | 53                                   |
| Kugluktuk     | 1996-2005           | -26.7                 | 11.5  | -10.2 | 234.2              | 62                                   |
| Łutselk'e     | 2000-2005           | -25.5                 | 16.2  | -5.16 | 293.0              | 58                                   |
| Wha Ti        | 1996-2005           | -25.8                 | 15.92 | n/a   | n/a                | n/a                                  |
| Yellowknife   | 1996-2005           | -26.2                 | 17.41 | -3.7  | 291.5              | 59                                   |

\*Data from Gameti and Łutselk'e were not available for this entire time period

As a result of inherent limitations in available data, both measured and estimated values from several sources have been included to provide an overall representation of climate across the WKSS area (AES., 2000; Acres Consult., 1982; Aston, 1977; BHP Billiton Diamonds Inc. & Dia Met, 1995; Kalin, 1987; Milburn *et al.*, 1994; Zoltai *et al.*, 1980). By using all available data, it is possible to make general comparisons. There is a distinct temperature gradient across the WKSS area which generally moderates towards the southwest (CCELC., 1989). Three climatic zones are represented. Kugluktuk lies near the southern edge of Low Arctic climatic conditions. To the south of it, sub-Arctic climate extends to an imaginary line extending between Rae and Reliance. Boreal climate extends further south from this narrow band along the north shore of Great Slave Lake.

The average winter temperature (November - March) increases from -32° C at Cambridge Bay to -26° C at Yellowknife. The average summer temperature (June - August) increases from 9° C at Cambridge Bay to 17° C at Yellowknife. Possibly due to some influence from Pacific air masses, the January temperature at Kugluktuk is slightly warmer than most other areas north of Yellowknife. July temperatures are warmest at Yellowknife. July temperatures at Bathurst Inlet are warmer than surrounding areas and these support more varied plant and animal communities (Hancock, 1979; PC., 1978; Zoltai *et al.*, 1980). Annual total precipitation is low throughout the region, increasing from about 140 mm at Cambridge Bay to about 290 mm at Yellowknife.



Typically, 50 to 60% of the total annual precipitation is in the form of rain (mostly between June and October). About one quarter of the WKSS area lies above the Arctic Circle and from Bathurst Inlet, north, the region experiences 24 hr sunlight in June but 0 hr in December. Yellowknife receives 20 hr of sunlight on the longest day in June but only 6.5 hr on the shortest day in December.

Because Great Bear and Great Slave lakes are very large, they can influence local weather conditions and, to some extent, the climate of surrounding areas. Lake effects are most noticeable as delayed warming in the spring. Then, air passing over the still-frozen lake surface may be significantly colder than over inland areas. Because of vegetation and irregular ground, most inland surfaces have a lower reflectance and warm more quickly. In the fall, the reverse happens. Air passing over open water may keep areas near the shoreline warmer than areas away from the lakes. Lake effects may also include occasional local summer thunderstorm activity and a slight increase in precipitation, due to greater moisture content in the atmosphere over the lakes.

There is considerable year-to-year variability in precipitation at many sites. For example, limited records of precipitation at Kugluktuk indicate that annual precipitation has ranged from a minimum of about 105 mm to a maximum of about 390 mm (records between 1935 and 1980). Further, it is also recognized that significant errors may exist in measurements of cold season precipitation (Spence, 1995). All locations are characterized by substantial variations in temperature. Winter temperature extremes range from about -5° C to more than -50° C at Cambridge Bay, and from about 3° C to -50° C at Yellowknife. During summer, extremes range from about -2° C to nearly 29° C at Cambridge Bay, and from near freezing to about 32° C at Yellowknife. Information prepared for the Contwoyto Lake area (records between 1956 and 1981) indicate that maximum and minimum January averages lie between -27.9 and -35.1° C; that maximum and minimum July averages lie between 14.9 and 4.8° C; and the maximum and minimum average annual temperatures range between -7.8 and -15.8° C (AES., 2000; Tahera Corp., 2000). Climatic conditions at Bathurst Inlet, Contwoyto Lake and Kugluktuk are generally similar to those at Cambridge Bay. Those at Yellowknife are significantly different. Winds at Cambridge Bay are most frequently northerly throughout the year, except in July when they are westerly. At Yellowknife, winds are most frequently northerly in January, March and May, southerly between June and September, and easterly at other times.

Some of the WKSS area climate data also suggest that a slight annual warming may have occurred over the period of record. Assessments of regional climatic variation in the Mackenzie Valley (Skinner & Majorowicz, 1999) and Shield areas (Schindler, 1997) are consistent with this. Over a larger area, records suggest that most recent warming appears to be greatest during winter and spring over northwest North America, and during spring and summer over the Arctic Ocean (Serreze *et al.*, 2000). The latter suggestion is also supported by reports of changing sea

ice conditions, from Inuit at Sachs Harbour, Banks Island (IISD., 2000).

Variations in climate are a major factor affecting the availability of food supplies for many northern species. If extreme or prolonged unfavourable conditions in climate manage to push levels of physical and chemical factors out of a species' range of tolerance, stock survival may be threatened. Climate records, therefore, provide some of the most valuable information that can be used to characterize large scale changes in the environment.

## **2.2.2. Geology**

### *2.2.2.1. Formation of the Crust*

Rocks of the WKSS area are very old, relative to the age of the Earth (about 4.6 Ga (Smith, 1981)). They provide special insight into early evolution of the crust. Interpretations gained from studies of the rocks, their age and distributions, have led to a greater understanding of mineral occurrences and potential for resource development. These include, associations of gold and base metals with volcanic rocks, rare earth minerals with some granitic intrusions, and diamonds with kimberlites.

The Earth is made up of a series of rock layers of different physical and chemical compositions, and the outermost layer, the crust, is composed of massive plates. The thickness of rock forming oceanic crust is about 8 km (basic or basaltic rock), and that of less dense continental rock is typically 30 to 70 km (acidic or granitic rock). The plates “float” on an underlying layer known as the mantle (Skinner & Porter, 1992; Smith, 1981). Over immense periods of time, the plates move, sometimes fusing together and at other times pulling apart. Cratons are the oldest and most geologically stable parts of continents, and the Slave craton is the most ancient part of the Canadian Shield (Percival, 1996).

Geological provinces characterize regions of the Shield that have different geological histories (Percival, 1996). The WKSS area is predominated by the Slave Province and its characteristic geology (Figure 2). Slave Province (Card & King, 1992; Clowes, 1996; Percival, 1996; St-Onge & Lucas, 1996) is composed mostly of late Archean rocks, with small exposures of early Archean rock such as the Acasta granitic gneiss (4.0 Ga). This gneiss formed within the crust. It is remarkable because it suggests that formation of the crust and its differentiation into acidic and basic igneous rocks occurred early in the Earth's history (Skinner & Porter, 1992). Bear Province consists of early Proterozoic sedimentary and volcanic rocks, and where these younger rocks overlie the western part of Slave Province they were folded into a ancient mountain chain and later eroded. Elsewhere in Bear Province, the rocks are relatively flat lying.

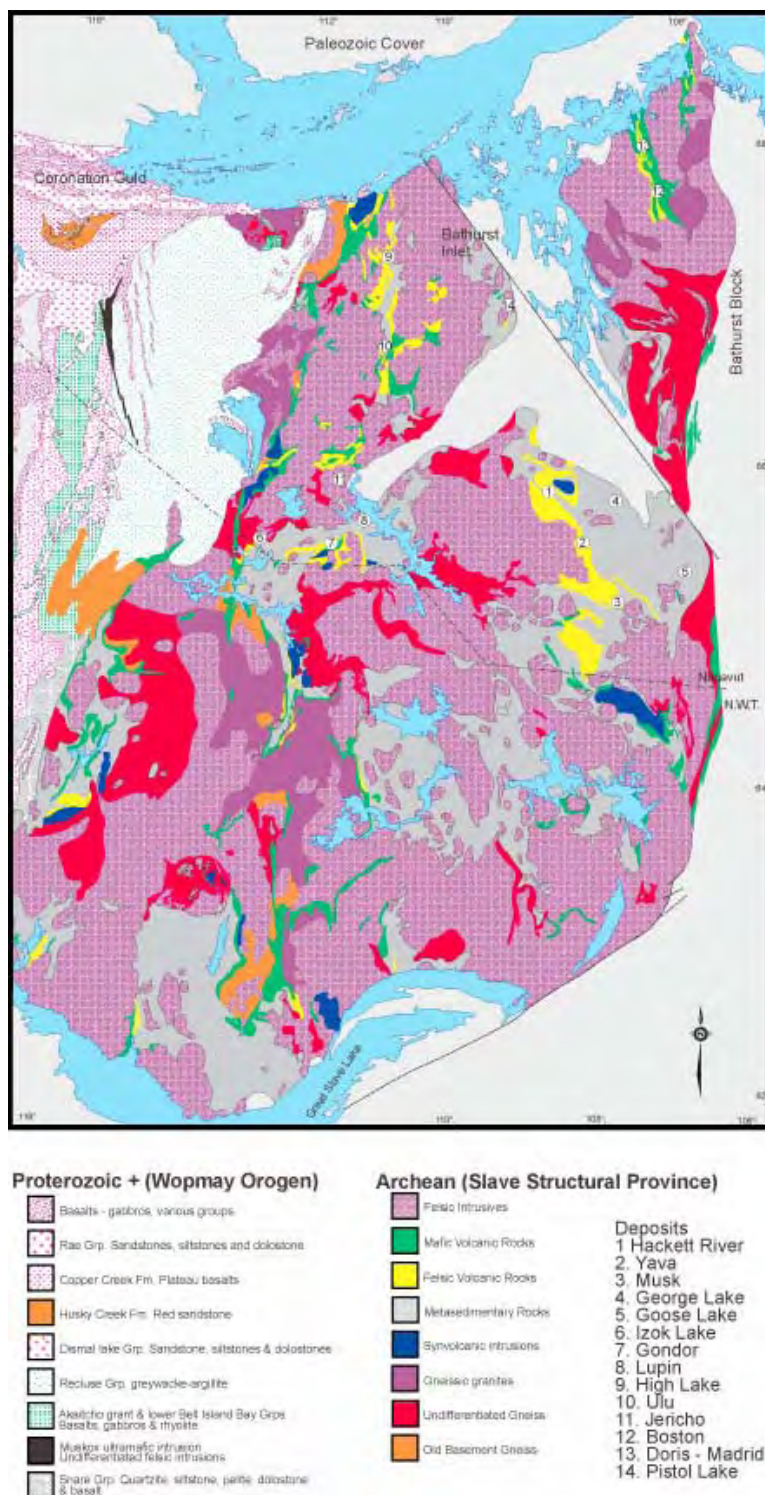
Rocks of the Slave Province cover an area of nearly 200,000 km<sup>2</sup> and comprise fragments of old continental crust that were welded together by late Archean time (Relf *et al.*, the eastern part

(Bleeker & Davis 1999). During Archean time, crustal movements (pull-apart) occurred within Slave Province. While igneous rocks were eroded and their debris laid down as new sediments, rifting influenced the process of reworking. Many rock structures have a northerly alignment (Padgham, 1990). Lead and Nd isotope measurements indicate large scale differences in igneous source materials. The Pb geochemical signature is the stronger (Bleeker *et al.*, 1999a; Yamashita *et al.*, 1999). The radiogenic Pb ( $^{238}\text{U}/^{204}\text{Pb}$ ) and non-radiogenic Nd signatures (Northrup *et al.*, 1999) indicate the extent to which early mantle material was mixed with juvenile crust. West of the Pb isotope line, Archean mantle material is a significant contributor to the crustal granites.

The Slave craton became a core onto which other parts of the crust later became attached and bound together. About 2.0 Ga, this plate moved eastward to collide and fuse with another part of the crust, the remnants of which form the western part of Rae Province. During collision, the eastern edge of Slave craton moved downward. Heat and compression changed the then existing igneous and sedimentary rocks into metamorphic rocks. This occurred along the collision boundary of the Taltson-Thelon front and caused the plates to fuse together (Gibb *et al.*, 1980; St-Onge & Lucas, 1996).

The Bear Province just to the west is the remnant of another part of the crust which moved eastward towards the Slave craton. As that collision began, the western margin of the Slave craton is thought to have been subducted (drawn down) beneath the advancing “Bear plate”. The western margin of the “Bear plate” is, itself buried beneath accretion of yet younger crustal material (Halls, 1982; Stockwell *et al.*, 1970). Movements of the Earth’s crust associated with this collision and later deformation in the Wopmay orogen also caused massive faulting along the eastern boundary of Slave Province (Bathurst and McDonald faults).

**Figure 4 Geology of the Slave Province and surrounding**



Source: Hoffman, P., and Hall, L., 1993, Geology, Slave craton and environs, District of Mackenzie, Northwest Territories: Ottawa, Geological Survey of Canada Open File 2559; Map, Scale: 1: 1,000,000 available on CDROM and paper map. (From: [http://ess.nrcan.gc.ca/2002\\_2006/nrd/slavecomp/bedrock\\_e.php](http://ess.nrcan.gc.ca/2002_2006/nrd/slavecomp/bedrock_e.php))

#### 2.2.2.2. *Igneous, Sedimentary & Metamorphic Rocks of Slave Province*

Little is known about the early history of the crust, but granitoid rocks (e. g., Acasta gneiss and the Eokuk Uplift area (Emon *et al.*, 1999)) formed part of the Earth's surface before 3.0 Ga. As rifting and stretching of the crust occurred, volcanic sequences and sedimentary basins developed over the granitoid rocks (Padgham, 1990; Bleeker *et al.*, 1999b). Sediments of the Yellowknife Supergroup are about 2.7 Ga and occur in five large and several smaller sedimentary basins that are partly bounded by volcanics. Sediments include coarse conglomerates, sandstones (typical of rapid erosion) and finer materials, and coarse to fine grading sequences deposited under water. Some volcanics are interbedded with the sediments and have features typical of both underwater formation (e. g. pillow lavas) and subaerial exposure (e. g. tuffs and ashes).

A great variety of rock types are present in the WKSS area and, based on mineral content, some deposits may have formed under oxic conditions. Stromatolites occur in some formations and these probable fossil lifeforms suggest biochemical photosynthetic activity (Cunningham & Saigo, 1992; Skinner & Porter, 1992). Other rock types are more consistent with an early atmosphere that is thought to have had lower levels of oxygen than at present. In some, there is evidence of intense chemical weathering by high levels of atmospheric CO<sub>2</sub> (Corcoran *et al.*, 1998).

The Yellowknife Supergroup is intruded by several younger granites, and rare earth pegmatites (Davis & Bleeker, 1999). Post-Yellowknife Supergroup sedimentary rocks also occur. In these, there are fragments of material from both the Yellowknife Supergroup and later granites (Padgham, 1990). Dyke swarms of basic igneous rock tend to be of much younger age. Many are likely associated with effects of various “plate” movements and development of the Great Slave Lake shear zone and McDonald fault. The Blatchford, Indin and Hearne intrusives age between 2.2 and 2.0 Ga (Bethune *et al.*, 1999), Contwoyto, Lac de Gras and Beechey swarms age between 2.0 and 1.8 Ga, the Mackenzie dyke swarm dates at about 1.2 Ga, and some dykes are as young as 0.8 Ga (Padgham, 1990; St-Onge & Lucas, 1996; Stockwell *et al.*, 1970).

#### 2.2.2.3. *Igneous, Sedimentary & Metamorphic Rocks of Bear Province*

Bear Province forms a wedge shaped area along the northwest margin of Slave Province (DEMPR., 1995). It also includes a small area of rock immediately west of the southern part of Bathurst Inlet. Bear Province covers an area of about 65,000 km<sup>2</sup>. Along the eastern margin, quartzites, dolomites, and siltstones of the northward trending Snare and Epworth groups are interbedded with andesite volcanics (including tuffs, surface flows and pillow lavas). These rocks are typical of accumulations in a crustal trough. The trough is thought to have developed in response to subduction, about 2.0 Ga. Sediments were faulted and folded as the trough closed,

and the mountain building processes continued in the Wopmay orogen. Under increasing heat and pressure, these rocks became metamorphosed and intruded by granitic material (Hepburn metamorphic and pluton belt). Some of this material may have originated as a result of melting of parts of the subducted margin of Slave Province. Further west, rocks of the Great Bear magmatic zone, including the McTavish volcanics and plutons of the Great Bear batholith (about 1.8 Ga in age), may be characteristic of a magmatic arc (*e. g.* the present Aleutian Island chain). In the northern part of Bear Province (outside the orogen) and following these events, land became elevated and subject to subaerial weathering. Derived materials were deposited under largely marine conditions and include conglomerates and quartzites, and later dolomites and siltstones of the Hornby Bay group. Later still, thick basalt flows formed at the base of the Coppermine group (which may date as late 1.0 Ga). Afterwards, red sandstones were deposited. The basic rocks of the Muskox intrusion (south of Kugluktuk) and the Mackenzie dyke swarm are likely of similar age (Halls, 1982; Stockwell *et al.*, 1970).

#### *2.2.2.4. From the Cambrian to the Start of Glaciation*

Almost all of the rocks that occur in the WKSS area are of Precambrian age (greater than about 0.6 Ga). It is likely that this part of the Earth's crust has been relatively stable since well before the beginning of the Cambrian period (0.6 Ga). Shallow seas existed at the northern and western edges of the WKSS area. Mainly marine sediments of Cambrian to upper Devonian age (dolomites, shales and sandstones) and lower Cretaceous age (shales and sandstones) occur over much of the Mackenzie River valley (DEMPR., 1995; Douglas *et al.*, 1970). Lower Palaeozoic sediments, mostly Ordovician and Silurian dolomites with some shales and sandstones, cover much of Victoria Island. Precambrian quartzites in Wellington Bay may, however, indicate that the Slave Province extends beneath the southern part of the island. Shallow marine conditions have occasionally extended over parts of Slave and Bear provinces since the Precambrian, but most of the deposited sediments were removed by subsequent erosion (DEMPR., 1995; Douglas *et al.*, 1970). For the most part, only Quaternary sediments, remain. These are of late glacial to recent in age and overlie previously existing erosion surfaces that date to the late Tertiary period (perhaps as little as 30 Ma). Recently, fossil materials of continental origin (pollen, wood, fish and micro-fossils of Cretaceous to early Tertiary age, about 50 to 120 Ma) have been found. The fossil materials occur in fragments of rock that fell back into the kimberlite pipes as they were intruded into the Lac de Gras area (Nassichuk & McIntyre, 1996). These kimberlites were intruded into a continental environment during the early Tertiary (about 52 Ma). Kimberlites intruded in the Contwoyto area appear to be older and have an age of about 172 Ma (Kerr, 1998).

#### *2.2.2.5. Metals Mineralization*

Mineralization in Slave Province is mostly associated with major crustal deformations that occurred during the oldest part of the Precambrian period (Archean, 2.5 to 4.0 Ga) and the later part of the Precambrian (Proterozoic, less than 2.1 Ga). In the WKSS area, this approximates the

time period before and after plate collision with the Rae Province. Understanding geological evolution of the region, therefore, contributes significantly to the success of resource exploration.

Archean mineral occurrences include gold, base metal-silver, and rare earth elements (Brophy 1991; 1993; DEMPR., 1995; Goff 1990; 1994; Igboji, 1996; Igboji *et al.*, 1997; INAC., 1998; 1999a; 2000a; Kusick & Goff, 1995; Padgham, 1990). Many gold occurrences formed early and before emplacement of the late granitoides. Gold may occur as lode deposits in shear zones in volcanics (*e. g.* Boston, Giant, and Con), with sulphide replacement in stratiform iron formations (*e. g.* George Lake) or uniformly distributed in stratiform iron deposits (*e. g.* Lupin), in quartz veins associated with volcanic sequences (*e. g.* Discovery and Colomac), and in smaller quantities in other associations. Gold is typically alloyed with small quantities of silver.

Occurrences of volcanogenic massive sulphide (Atkinson, 1990; Brophy 1991; 1993; DEMPR., 1995; Goff 1990; 1994; Igboji, 1996; Igboji *et al.*, 1997; INAC., 1998; 1999a; 2000a; Kusick & Goff, 1995; Padgham, 1990) are widespread. They are generally rich in zinc, lead and silver but poor in copper and gold (*e. g.* Gondor, Hackett River, Izok and Musk). The deposits are often associated with calc-alkaline volcanics but no zoning is apparent. Metal contents, suggest these volcanics are closely linked to the granites that intrude the Yellowknife Supergroup.

Rare earth element-rich pegmatites were intruded at a late stage and contain lithium minerals, ferromanganous phosphates, niobium-tantalum and beryllium minerals (Yellowknife basin, Mackay-Aylmer basin, and Torp Lake basin) (Brophy 1991; 1993; DEMPR., 1995; Goff 1990; 1994; Igboji, 1996; Igboji *et al.*, 1997; INAC., 1998; 1999a; 2000a; Kusick & Goff, 1995).

Proterozoic mineralization is largely associated with deep crustal fracturing that extended into the Earth's mantle, and often with extremely basic intrusive rocks of hyperalkaline to mafic or ultramafic composition (Brophy 1991; 1993; DEMPR., 1995; Goff 1990; 1994; Igboji, 1996; Igboji *et al.*, 1997; INAC., 1998; 1999a; 2000a; Kusick & Goff, 1995; Padgham, 1990). Fracture filling by copper sulphide occurs in the Coppermine basalt (Wreck Lake). Diabase dykes host small amounts of native silver (Hope Bay) and diabase dykes and carbonatites host nickel-copper-cobalt (Copper Pass). Polymetallic vein deposits occur at Contact Lake, Echo Bay, and Eldorado (arsenic, bismuth, cobalt, copper, nickel, silver and uranium). An extensive suite of rare earth mineral occurs at the Blatchford intrusive complex and at Thor Lake. Layered ultramafic rocks of the Muskox intrusion host chromite-sulphide seams and some copper, nickel, platinum and palladium. Uranium (as pitchblende and with hematite) was mined at Rayrock (south of Rae Lakes) but does not appear to be present within the Slave Province.

Over long periods of time, the movements of water within rock may result in dissolution, migration and redeposition (precipitation) of metals. Some of the copper from the Coppermine River may have been derived from underlying basalts. However, unlike some mineral deposits in

the younger Palaeozoic formations south of Great Slave Lake (*e. g.* Pine Point, (Anderson & Macqueen, 1982; Gibbins, 1988)), few if any remobilized metals in the Slave Province appear to occur in economic quantities.

#### 2.2.2.6. Kimberlites

Kimberlites are a very special kind of rock (DEMPR., 1995; Kjarsgaard, 1996a; 1996b. Pell, 1997). They appear to be restricted to areas of the crust that are older than 1.5 Ga. They contain diamonds only in areas where the crust is relatively thick (thicknesses of more than 40 km have been reported from the Slave Province).

The Lac de Gras area is underlain by a well defined low seismic velocity anomaly at depths of 350 to 600 km. Genetic relations between an inferred mantle plume and kimberlites are not resolved (Bank *et al.*, 2000). Anomalous rock and mineral fragments present in some kimberlites confirm that parts of the mantle underlying the Slave Province lie within the diamond stability field. For example, Jericho diamonds are likely derived from reservoir rocks at a depth of 130 to 190 km (Kopylova *et al.*, 1998). The kimberlite pipes of Slave Province likely belong to several generations (Griffin *et al.*, 1999). Dates from Lac de Gras give ages of 47-52 Ma (Eocene), 73-75 Ma (Cretaceous), the Jericho site is dated at 172 Ma (Jurassic), and Drybones and Cross pipes at 440 and 450 Ma (Silurian-Ordovician boundary).

Diamonds are a form of pure carbon. They do not form in kimberlite but in peridotite or eclogite (mantle rocks) and at depths of about 150 km below the Earth's surface. Internal "plumes" move these mantle rocks upwards so that fragments of them may be held in kimberlite "reservoirs" beneath the crust. Depending on temperature and pressure, carbon may be present in mineral form as either graphite or diamond. The right conditions to retain carbon as diamonds exist only beneath areas of thick crust. Kimberlite reservoirs are rich in CO<sub>2</sub> and H<sub>2</sub>O that fluidize and help to carry fragments of both mantle and crustal material to the surface. Generally, in the process of transport, the mantle fragments break into small pieces and the diamonds are released into the matrix of kimberlite. Exactly what triggers the explosive release of kimberlite to the surface is not known. But, when it happens, the event occurs extremely rapidly (otherwise the diamonds would be destroyed by oxidation during this upward movement). The kimberlite moves upward as a mixture of gaseous CO<sub>2</sub>, water vapour and rock fragments. Near the surface, where confining pressures drop rapidly, the exploding mixture blasts out an inverted cone (diatreme). At depth, kimberlites probably move upwards at velocities of 10 to 30 km·hr<sup>-1</sup>. Near the surface they may reach velocities of a few hundred km·hr<sup>-1</sup>. The pipes connect kimberlite reservoirs directly with the surface. Unlike most volcanic eruptions, however, the explosive release appears to be a one-time event and of short duration. Kimberlite pipes are thought to be aligned with deep seated structures. The pipes do not appear to be randomly distributed but neither are they closely related to surface geology.



#### 2.2.2.7. Quaternary Deposits

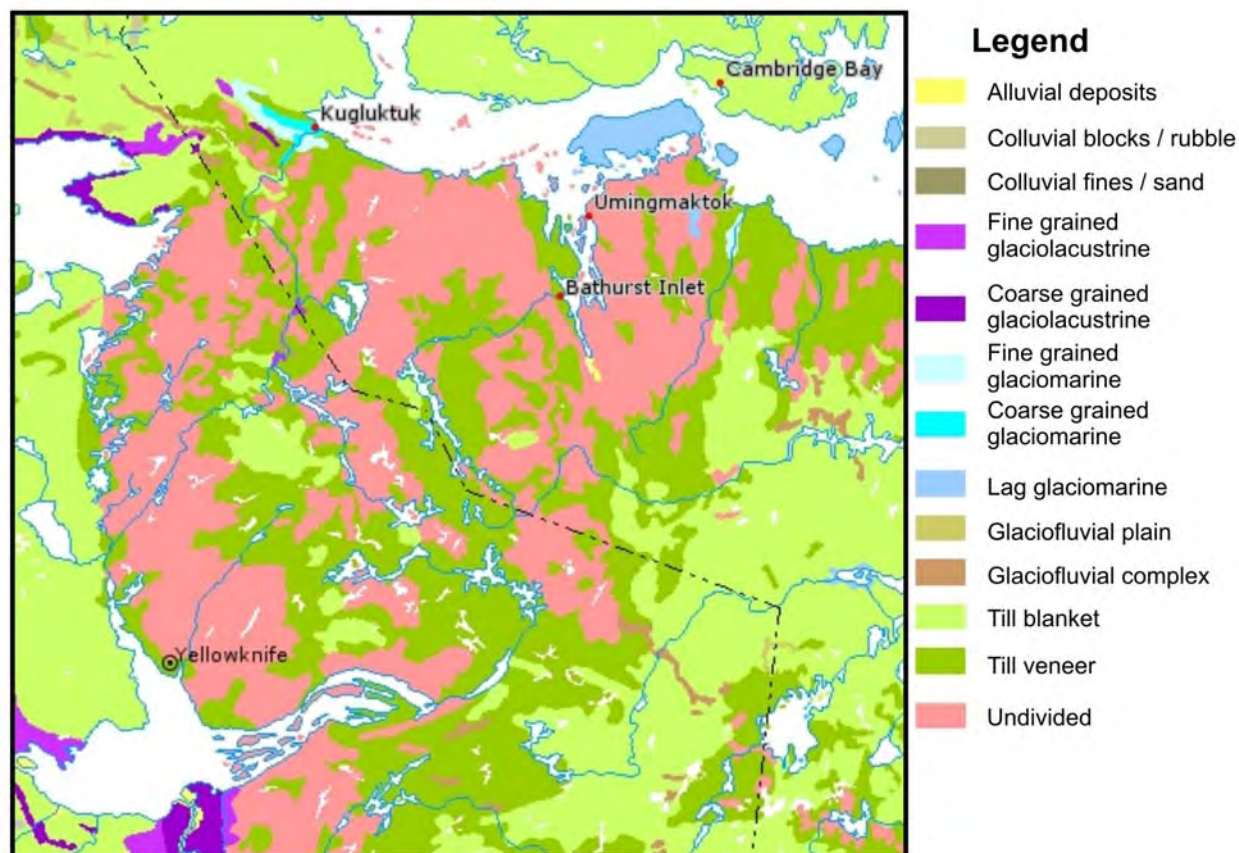
The Quaternary is the most recent period of geological time (beginning about 2 million years ago) and it has been marked by strong and periodic changes in global climate. Four major glaciations occurred during this period. Each time, advancing ice scoured the surface so that, over most of the WKSS area, evidence remains only of the last Wisconsinan glaciation and its retreat. Surficial glacial deposits within the region are identified in Figure 5.

Wisconsinan ice spread westward from the Keewatin area across the WKSS area, as part of a much larger mass covering the entire Shield (Dyke & Dredge, 1989; Prest, 1970). It spread in a generally radial pattern from a regional dome centred in the headwaters of the Thelon River drainage (Prest, 1970) and covered all of the WKSS area. Glacial ice probably reached its maximum extent about 20,000 BP. By 11,000 BP, the high ground in west Victoria Island was largely free of ice, as was much of the mainland west of Dismal lakes and north of Hottah Lake (Vincent, 1989). Ice retreated eastward across the region and by 10,000 BP areas west of a line between the Tree River and Yellowknife were ice free. The region was completely ice-free by about 8,500 BP. During glacial retreat, water levels rose in the Great Bear Lake basin.

Rapid melting, downward from the surface of the glacial ice, may have begun as early as 15,000 BP. Marginal retreat of the ice edge, however, did not accelerate until about 12,000 BP. By about 12,000 BP, a huge lake extended north along the ice front from Lake Athabasca to Great Bear Lake (Craig, 1965; Klassen, 1989; Prest, 1970). Lacustrine sediments from this glacial lake (glacial Lake McConnell) extend to elevations of about 260 m. Surface drainage patterns were more or less established in their present form by 8,500 BP. As the thickness of ice cover decreased, the land surface, long depressed by the weight of ice, began to rise. At first, sea level rose relative to the land because the rate of melt was so rapid, and lowland areas on both Victoria Island and the mainland surrounding Coronation Gulf were inundated by marine waters (Craig, 1965; Prest, 1970). The marine incursion extended far into Bathurst Inlet and reached locations that are now as much as 225 m above sea level. Evidence for this persists in thin layers of marine silt and clay which lie directly on bedrock or on thin layers of glacial till which also overlie bedrock. Evidence is also present in the form of raised glaciomarine and marine deltas, and as raised sand and gravel beaches. After glaciation, isostatic recovery (uplift of the land) was very rapid. For example, at Bathurst Inlet the rate of uplift was about 10 m per century for the first 1 to 2,000 years after ice-free conditions. The rate of uplift has slowed and is presently about 0.5 m per century in the southern Bathurst Inlet area (Prest, 1970). Even at its maximum extent during the Wisconsinan glaciation, glacial ice became progressively thinner west of Bathurst Inlet. Because of this, the amount of surface depression and later isostatic recovery also decreased west of the inlet.

Many smaller glacial lakes formed temporarily (St-Onge, 1980) as ice fronts partially dammed

**Figure 5 Predominant surficial glacial deposits within the WKSS area**



Source: Digital Atlas of Canada - <http://atlas.nrcan.gc.ca/site/english/maps/index.html> (accessed Jan. 2007)

the rapidly expanding melt waters, including those in the basins of the Richardson, Coppermine, Burnside, Back, and Thelon rivers. High level beach deposits of sand and gravel exist in many lake basins and marine coastal areas. Both thin lacustrine silty clays and river terraces of silty sands and gravels mark episodes of previously higher postglacial water level.

Although glacial ice has scoured and eroded the pre-existing Shield landscape, it is thought that only a few metres of bedrock may have been removed (Prest, 1970). Preservation of much of the original vent structure of many kimberlite pipes in the Lac de Gras area supports this view (Nassichuk & McIntyre, 1996). Glacial till is an unsorted mixture of coarse angular to sub-angular rock fragments in a finer matrix of sandy or silty-clayey material. It developed at the base of the glacial ice sheet and has a thin and patchy distribution over most of the WKSS area. It is occasionally overlain by glaciomarine and glaciolacustrine materials. Areas of fluted and drumlinized till are also common throughout the WKSS area. They are thought to have been caused by the movement of ice over till material and may be several metres thick. Hummocky moraine is thought to have been formed under “dead ice”. It covers a large area east of Bluenose Lake, and smaller areas north of the Rae River and around Aylmer Lake, Contwoyto Lake and

Lac de Gras (Kerr, 1998; Map 1253A; Prest, 1970).

The most significant glacial features of the region are the presence of numerous and extensive esker and kame complexes. Many of these are continuous over several tens of kilometres (Map 1253A; Prest, 1970). These deposits, of generally sandy material, were formed by under-ice meltwater streams or marginal pondings, and now occur as prominent ridges over bedrock (or thin glacial till). North of a line between Kugluktuk and Clinton-Colden Lake, these features trend southeast-northwest. South of this line but north of a line from Hottah Lake and Clinton-Colden Lake, the trend is more nearly ESE-WNW. Further south again, the trend is more nearly east-west (Map 1253A). Near the ice margin where the ice was relatively thin, and roughly following the east shore of glacial Lake McConnell, eskers are rare or poorly developed. Likewise in the area midway between the south end of Bathurst Inlet and the east end of McLeod Bay (Great Slave Lake), where under-ice drainage diverged beneath the middle of the melting ice dome, eskers and kames are poorly developed (Map 1253A; Prest, 1970).

Different types of Quaternary sediment can give rise to a variety of landforms and these, in turn, may provide different forms of habitat for use by a wide range of plant and animal species. This is most evident in the well-drained eskers which overlie bedrock or poorly drained glacial till. Geochemical differences can also exist between glaciolacustrine, glaciomarine and other till materials, and these may be reflected by differences in vegetation.

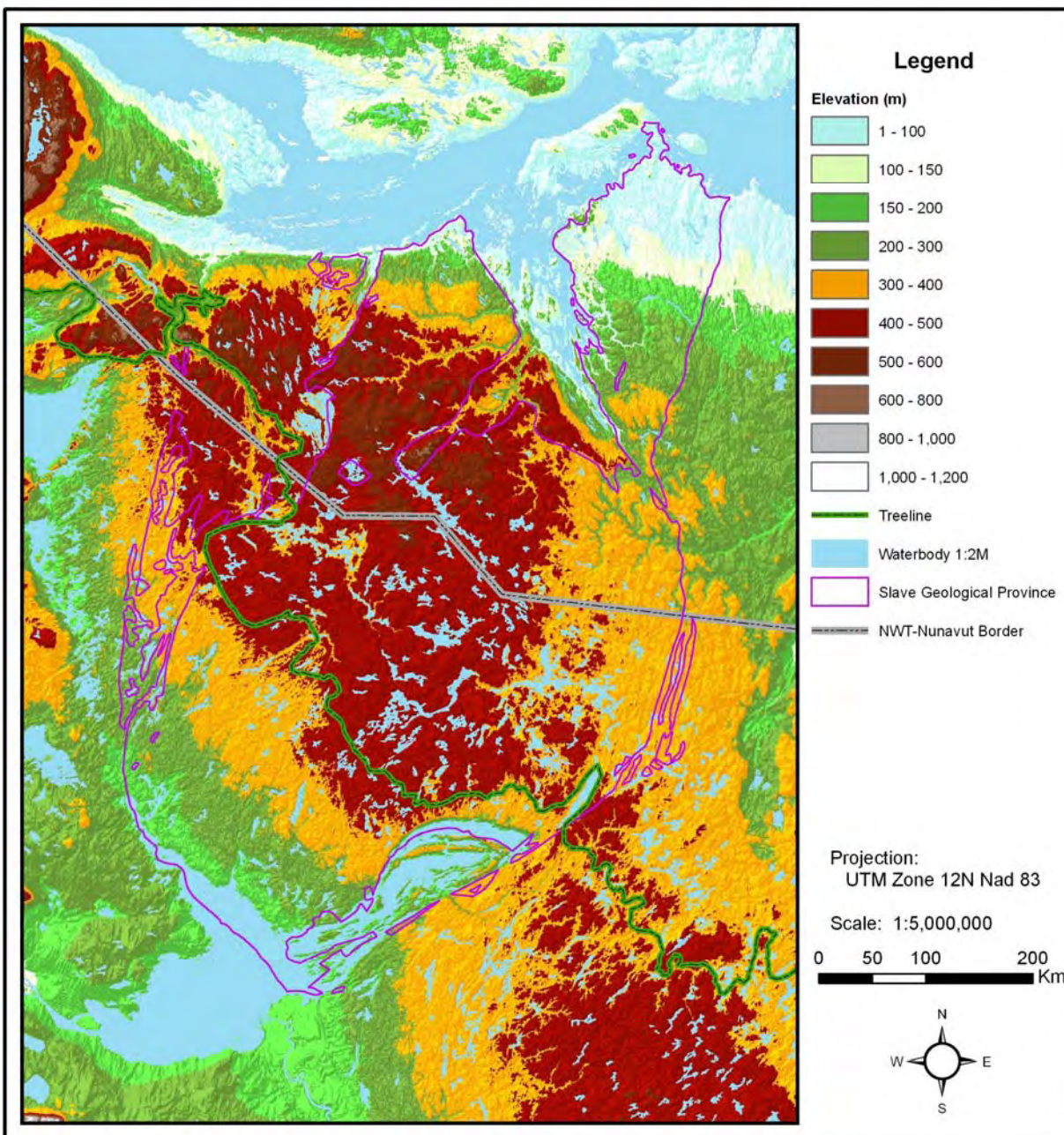
### **2.2.3. Physiography (landform)**

The WKSS area is characterized by mostly low to moderate relief and large areas of exposed or thinly covered bedrock (BHP Billiton Diamonds Inc. & Dia Met, 1995; Bostock, 1970; Dyke *et al.*, 1989). Although glacial erosion and deposition have strongly influenced formation of the present landscape (Figure 5), some bedrock surfaces may reflect the effects of much earlier erosion (Figure 4). The oldest erosion surfaces may be of Precambrian age (Bostock, 1970; Dyke *et al.*, 1989). An overview of the topography of the WKSS region is shown in Figure 6.

On the northern part of the mainland, the Horton Plain rises to greater elevations. The Melville Hills (formed by an inlier of Precambrian rock) reach more than 850 m, west of Bluenose Lake. Although the bedrock geology suggests continuity with that of Victoria Island, the landscape is different. There is little surface ponding on the plain and drainage is more strongly developed. The Horton Plain is separated from the Victoria Lowlands by Dolphin and Union Strait (Bostock, 1970).



**Figure 6 Elevation and surface water cover in the WKSS region**



Source: Adapted from the *NWT Digital Atlas* [CD-ROM], 2002. World Wildlife Fund (WWF)

The Coronation Hills have a lower elevation (generally less than 500 m). They cover a smaller area between the northeast shore of Great Bear Lake and the mouth of the Coppermine River (Bostock, 1970). Here, the presence of different sedimentary and igneous Precambrian rocks with variable resistance to erosion provides locally complex relief. Channels in the lower reaches of some rivers may be unstable where they cross early postglacial deposits, such as the valley terraces and delta area of the Coppermine River. Falls or rapids may be formed over resistant bedrock (Ellis, 1962; Raffan, 1979; Wedel *et al.*, 1988) and may limit flood plain development to a short distance south from the present coastline, such as on the Tree River (Robertson & Dowler, undated). East of this area, the Coronation Gulf has formed in what may be a submerged river valley that previously drained west into Amundsen Gulf. Glacial scour has deeply channelled parts of the floor of the gulf. From the mainland, many low islands extend eastwards along the shore as expressions of resistant bedrock (including the Coppermine sills). Depths in the gulf are typically 70 to 130 m and they reach a maximum of about 220 m. Extensive areas of shallow water extend between many islands and along the south coast.

Elevations over the eastern parts of the Great Bear Plain and the Great Slave Plain are generally less than 300 m. However, along the north shore of the McVicar Arm (Great Bear Lake) they reach a maximum of 700 m, and to the southwest of Hottah Lake they reach about 450 m. Both regions were covered by glacial Lake McConnell (Klassen, 1989; Prest, 1970). At present, Great Bear and Great Slave lakes have separate drainage. Both drain into the Mackenzie River but the level of the two lakes (about 156 m) differs by less than 0.5 m. The Precambrian Shield is exposed along the east shore of both lakes. Elsewhere, generally flat-lying or gently dipping sedimentary rocks of much younger age are present.

The deeply indented shoreline of Bathurst Inlet and the strong relief of this area reflects glacial scour along the Bathurst fault. It also reflects the distributions of many different types of Precambrian sedimentary and igneous rocks, and other structural controls (PC., 1978; Zoltai *et al.*, 1980). High falls occur where drainage crosses resistant rock formations and fault lines. The most extensive area of high ground (rising to about 500 m) forms the divide between the Hood and the Burnside rivers.

The Bear-Slave Upland conforms, mostly, to the remaining areas of the Bear and Slave geological provinces (Bostock, 1970). Elevations rise to 300 m over a distance of 40 to 60 km inland from the coast and to greater heights along the western boundary of Slave Province. Most of the region is above 300 m, and elevations locally exceed 650 m around the northeast shore of Contwoyto Lake. Numerous lakes cover 10 to 30 percent, or more, of the surface in this area of moderate bedrock relief. Rounded hills are formed by resistant bedrock such as granitoids and metamorphosed sandstones. Lakes and rivers develop along jointing and fault lines, and over softer bedrock that includes some volcanic material and kimberlites. Low ridges of exposed bedrock occur over intrusive dykes that are often aligned in a northerly direction. Eskers of

glacial sand and gravel also occur as long ridges, and these trend more nearly northwest-southeast.

Glacial scour along the faulted and sheared southeast boundary of Slave Province has produced dramatic erosional features in the area of the East Arm Hills of Great Slave Lake (Mondor, 1982). Although many of the southwest - northeast trending islands have strong relief, the underwater features are even more pronounced and depths reach nearly 300 m in McLeod Bay and more than 600 m in Christie Bay.

The Kazan Upland (Bostock, 1970) is generally similar in appearance to the Bear-Slave Upland and has formed over Shield rocks of Rae Province. The Back Lowland (Bostock, 1970) is also formed over Precambrian rocks of Rae Province but this region has significantly lower elevations (less than 300 m). Postglacial marine inundation of the Back Lowland was more extensive than over the Bear-Slave Uplands. It typically extends 130 to 150 km south from the present coastline over a gently undulating surface.

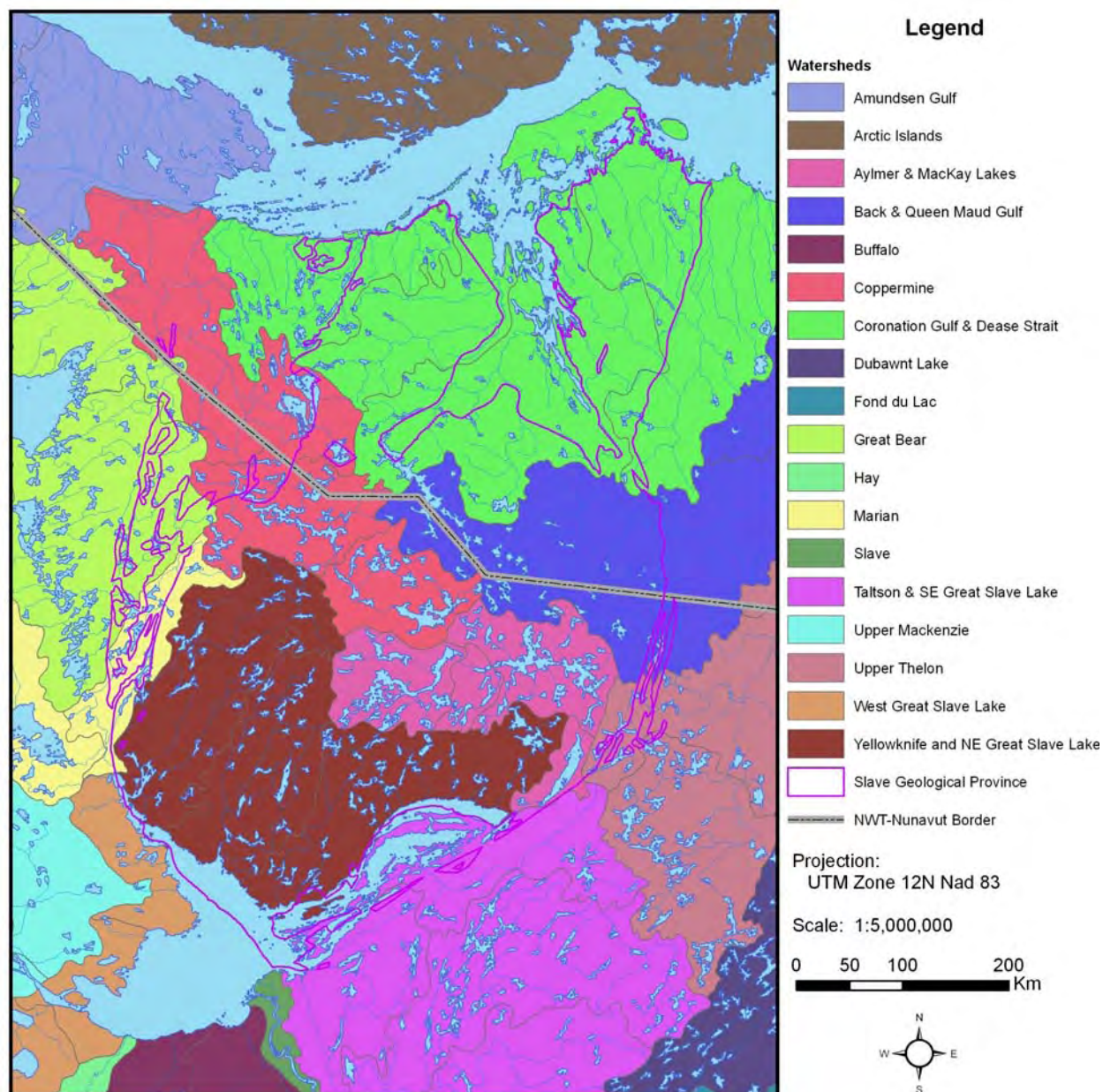
#### **2.2.4. Hydrology, Ice Cover and Coastal Conditions**

The major watersheds of the WKSS area are shown in Figure 7. Most of the rivers draining to the Arctic coast are relatively short, as are those entering Great Bear Lake. The Coppermine River has the longest drainage. It flows northwest across the Bear-Slave Upland and passes through numerous lakes and across a great variety of bedrock types. The Burnside River dominates the drainage of Bathurst Inlet. Most of the water entering Great Slave Lake is derived from areas to the south of the lake, in the Slave River drainage (with headwaters in the Rocky Mountains). The Lockhart River, with headwaters above Mackay Lake, is the most important source of water entering the East Arm of Great Slave Lake. The North Arm is fed by drainage from Lac Grandin and Lac la Martre, and from the Snare River and Lake system. The Camsell River which flows north through Rae, Hardisty and Hottah lakes provides the largest input to Great Bear Lake.

Water quality (McNeely *et al.*, 1979) is generally good throughout the WKSS area (HBT-Agra, 1993; Puznicki, 1996; MRBB 2003; SENES 2005). Although monitoring at Snare Rapids has shown a slight increase in concentrations of sulphate and nitrate ions since 1994, sulphate in precipitation is only one-fifth of the guideline level for sensitive environments ( $7 \text{ kg SO}_4 \cdot \text{ha}^{-1} \cdot \text{a}^{-1}$ ). At Snare Rapids, the 1996 average annual pH of precipitation was about 5.1 and typical of unpolluted background conditions (DRWED., 1998). Over many areas of the Shield, surface waters are slightly acidic but over areas of carbonate rock, alkalinity and calcium concentrations may increase. For example, pH values increase from 6.6 to 8.0 in the Coppermine River where high values are associated with dolomitic rocks in the northern part of the drainage. Seasonal increases in alkalinity may naturally occur during the July-September period. These are associated both with biological productivity and the influence of bedrock (Wedel *et al.*, 1988). Sediment loads, both bed and suspended sediment loads, increase dramatically with surface and



**Figure 7 Watersheds of the WKSS region**



Source: Adapted from the *NWT Digital Atlas* [CD-ROM], 2002. World Wildlife Fund (WWF)

bank erosion during spring runoff. They may temporarily limit supplies for potable water, as at Kugluktuk on the Coppermine River. Concentrations of some forms of contaminants, including several heavy metals and PAHs are also known to be associated with fine sediments and their quantities may increase, seasonally, with the load of suspended sediments. Movement of bed materials may also significantly alter channel forms and affect water transport, such as on the Mackenzie River. In most areas, conductivity, nutrient concentrations, and trace metal concentrations are low (Puznicki, 1996; Wedel *et al.*, 1988).

Based on a SW to NE survey of 24 shallow (less than 25m), small to medium size lakes (50-500 ha), summer surface water temperatures decrease latitudinally from about 14.5° C near Yellowknife to about 11.5° C at the tree line (near Beniah and Lockhart lakes), and to about 7.5° C near Contwoyto Lake (Pienitz *et al.*, 1997). Summer transparency is generally high except where lakes receive coloured waters from surrounding forested areas or peatlands. Conductivity is low in most lakes of the WKSS area and declines to very low values north of the tree line (Pienitz *et al.*, 1997; Puznicki, 1996). Most lakes in the WKSS area have very little buffering capacity, and pH tends to be quite variable and within the range of pH 6 to 9 (Pienitz *et al.*, 1997).

As in the rivers, concentrations of major ions strongly reflect geology and vegetation. On a relative basis,  $\text{Ca} > \text{Na} > \text{K}$ . Values of Ca are very low in areas of granitic rock but increase in areas of carbonate-rich sedimentary rock and some volcanics and mafic intrusions (Pienitz *et al.*, 1997). Concentrations of dissolved nutrients (N, P, Si and inorganic C) are low in lakes throughout the WKSS area and extremely low in most tundra lakes. Locally, hot-spots of nutrients and pathogens may be associated with seepage or discharge of sewage materials from some communities, camps and resorts. Dissolved organic C in tundra lakes increases slowly towards the tree line, from minimum values of less than 2  $\text{mg l}^{-1}$ . There is a significant increase southward from the tree line, where DOC values rise from about 5 to more than 9  $\text{mg l}^{-1}$  near Yellowknife (Pienitz *et al.*, 1997). Most DOC is derived from decaying vegetation and brown acidic run off from forested and peatland areas may also carry relatively high concentrations of dissolved Fe. On a regional basis, lake alkalinities tend to rise with increasing temperature but dissolved nutrients decrease due to biological processes of removal (Schindler, 1997).

Metal concentrations in lake sediments strongly reflect local geology and natural occurrence. Most fall within the range typical of freshwater sediments (Puznicki, 1997). Relatively high concentrations of As, Cd, Cu, Fe, Mn and Ni exist in some lake sediments and other metal anomalies have been detected in a few lakes (Puznicki, 1997). In the lower Slave River, As, Cu, and Zn and some other metals have been detected at concentrations above guidelines for LEL. These are also thought to be mostly of natural origin and adapted to by biota McCarthy *et al.*, 1997a). Some concentrations of PAHs (from both natural and anthropogenic sources) in suspended sediments also exceed LEL (Ontario) but remain well below SEL (Ontario). Overall,



the Slave River at Fort Smith and below is considered to be of near pristine water quality (McCarthy *et al.*, 1997a). The biological availability of metals in sediments depends on many factors and total metal concentrations are of limited value in estimating potential health hazard. However, on a site-specific basis and where there is human use of food or water from lakes containing high metal concentrations in sediment, further assessment of metal availability may be needed. Hot-spots of heavy metal contamination may exist as a result mining and other industrial activities.

There are major differences in the seasonal flow of most rivers in the WKSS area. Near zero flow occurs during late winter in many water courses (Acres Consult., 1982; HBT-Agra, 1993). This is partly because precipitation is lowest during winter but, also, because thick ice forms and freezing may take place to the bottom of some channels. Evaporation is also a significant factor across much of the WKSS area, accounting for 25% or more of the total precipitation in areas north of the tree line and where permafrost restricts seepage to a minimum. Over much of the region, lake evaporation may be as much as 50% of total precipitation (Acres Consult., 1982; BHP Billiton Diamonds Inc. & Dia Met, 1995). Because ground remains frozen for much of the year and because large areas of bedrock are exposed, surface runoff is high, typically 50 to 75% of total precipitation (Acres Consult., 1982). Lake storage (Acres Consult., 1982; HBT-Agra, 1993; Wedel *et al.*, 1988) provides an extremely important natural buffer that reduces variations in flow throughout the region, especially on the Coppermine, Camsell, Snare, and Lockhart rivers. However there is also considerable year-to-year flow variability, even on rivers well buffered by lake storage. For example, since 1966, maximum flow conditions on the Coppermine River have ranged from about 120 to 535 m<sup>3</sup>·sec<sup>-1</sup> (July period), and low flow conditions from about 25 to 45 m<sup>3</sup>·sec<sup>-1</sup> (Acres Consult., 1982; Wedel *et al.*, 1988). Hydro development has occurred on the Snare, Taltson, and Yellowknife River systems. Expansion of the Taltson River system is being further investigated. A Memorandum of Understanding between the Akaitcho Territory Government, NWT Métis Nation and the NWT Energy Corporation was signed in June 2003 (<http://www.nwtec.ca/taltson/index.html>).

Potential for additional development has been identified on other rivers, including the Barnston, Coppermine, Hoarfrost, and Lockhart systems (HBT-Agra, 1993; Glacier Power Ltd, 1997; UMA Group, 1979; Wedel *et al.*, 1988).

Although most of the WKSS area lies within cold climate regimes, precipitation is light and evaporation can be a major influence on the availability of surface water. Catchment studies in the Yellowknife River basin show that seasonal energy budgets differ from sites in the eastern sub-Arctic where there is more precipitation (Spence, 2000; Spence *et al.*, 2000). Exposed rock keeps water at the surface and allows high evaporation rates during late spring and early summer. In normal years, this may produce a moisture deficit by early July. Rock fractures enhance infiltration (few large fractures provide greater infiltration than many small fractures). Soil cover

increases infiltration and retention. Collectively these conditions decrease runoff and down slope availability of water. The drying of soil-bedrock contact zones, as water is drawn to the centre of soil covered areas, causes further disconnect in the hydraulic system (Spence *et al.*, 2000). Thus the annual moisture deficit of soil-covered hillslopes has a major influence on runoff response during summer and fall.

Lake storage deficits influence the volume and time of upstream discharge into mainstream flow (Spence, 2000). In the Yellowknife area, snowmelt occurs during mid-April to mid-May. Rates of evaporation increase to early summer. Moisture levels in peatlands begin to fall in late June and water tables reach their lowest levels in August. With thin soils, there is little storage buffer (Spence, 1995; 2000). With light summer rains, evaporation is high and evaporation rates do not begin to decrease until August. Because of this, the storage deficit only begins to recover after mid to late August. In upland areas, evaporation accounts for about 16% of available snowmelt, and only 70% goes into runoff. Of this, more than 50% goes to replace the storage deficit in receiving areas. Less than 10% of the meltwater is carried into mainstream flow. Some headwater lakes do not outflow every year and some flow only for a few days a year. Thus the previous year's storage deficit has a large influence on mainstream discharge in the following year. High discharge may occur only for a short period, and estimates of evaporation are a crucial component of water budgets (Spence, 2000; Spence *et al.*, 2000). Also, and as with precipitation estimates (Spence, 1995), there are concerns that generally applied measurements of evaporation (Gibson *et al.*, 1998) may fall short of requirements of water budgets for the WKSS area.

Small inland lakes and sheltered points of inflow to larger lakes are the first to become ice-free and break-up begins about mid-May in the most southerly part of the WKSS area. The last frost is about May 30th and a general date for break up in the western part of Great Slave Lake is about June 1st. Break up near Yellowknife occurs about June 15th (Sirois *et al.*, 1995). The last frost in the McLeod Bay area is about June 20th and ice may persist there until early July (Sirois *et al.*, 1995). Ice may also persist into July in parts of Great Bear Lake. The first frost in the Great Slave Lake area occurs about September 10th (Sirois *et al.*, 1995) and ice cover develops first on small inland lakes. It begins in early October near the Arctic coast. Lac de Gras is usually frozen by mid-October and the large bays of Great Slave Lake are usually ice covered by early November. The lake is completely covered by mid-December. The process of freezing on Great Bear Lake is similar and occurs a little earlier.

Surface and near surface flow in Dolphin and Union Strait is generally from west to east but reversals occur after periods of strong wind (Can Arctic, 1989). Queen Maud Gulf also receives cold water drifting south along the east coast of Victoria Island. At the eastern end of Dolphin and Union Strait, tidal streams produce polynya in June. These areas of open water expand slowly and ice fracturing begins in early July. The strait is largely ice free by late July or early

August. In the Coronation Gulf, break-up starts in the west and progresses eastward. Extensive surface ponding occurs and much of the sea ice melts in-place. Once started, disintegration becomes rapid and is assisted by inflow from the Coppermine River. The gulf is usually ice-free by late July. Most ice also melts in position in Dease Strait which becomes generally ice-free by late July or early August (Can Arctic, 1989).

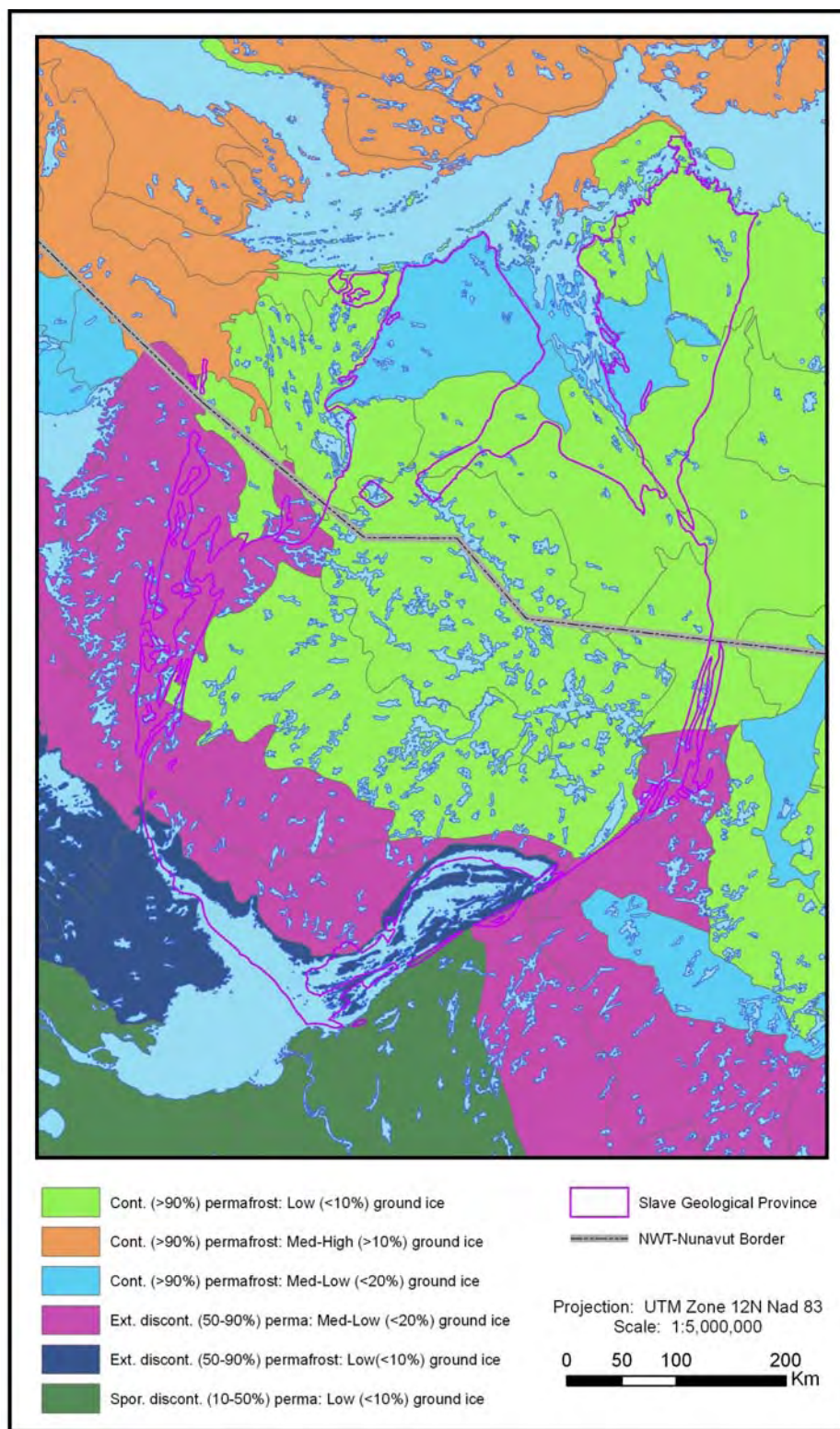
Ice re-forms in October, beginning in the east (Can Arctic, 1989). Freezing begins about October 1st on the Kent Peninsula. The mean date of freeze-up is October 10th at Cambridge Bay and October 24th at Coppermine (1930 to 1985 record). The ice pack remains mobile in Amundsen Gulf most of the winter and, in mild winters, polynya may persist off the western part of the Wollaston Peninsula. At the east end of Dease Strait, the ice is frequently rough and ridged but over most of Coronation Gulf it is relatively smooth (Can Arctic, 1989).

### **2.2.5. Permafrost and Massive Ground Ice**

Permafrost occurs in soil and rock that remains at or below freezing for a long period of time, at least for two winters and the intervening summer. Most permafrost has existed for much longer. Permafrost continues to develop when winter heat loss at the ground surface exceeds summer heat gain. It can move downward to a depth at which heat loss in the frozen ground is balanced by heat flow from the ground beneath. Where the mean annual ground surface temperature has remained generally less than  $-5^{\circ}\text{C}$  over periods of thousands of years, permafrost may be several hundred metres thick (Brown, 1970; French, 1989; Harris, 1987; Map 1246A). Figure 8 shows the distribution of permafrost throughout the WKSS region. In the continuous permafrost zone, thick and cold permafrost exists almost everywhere. Ground temperatures generally increase from north to south and the northern limit of discontinuous permafrost corresponds with a mean annual air temperature of about  $-6$  to  $-8^{\circ}\text{C}$  (Brown, 1970; French, 1989). Within regions of discontinuous permafrost, there may be both large and small areas without permafrost or lenses of unfrozen ground between layers of frozen ground.

The distribution of permafrost can be influenced by several factors (Brown, 1970; French, 1989; Harris, 1987; Map 1246A). Permafrost is often found beneath peatlands, because of their insulating effect. It is also found on north-facing slopes, or in areas where vegetation cover increases shade and reduces the insulation effects of winter snow cover. However, where heat from unfrozen surface water is sufficient, it can prevent formation of permafrost in the underlying ground. Permafrost is usually absent beneath large lakes and rivers, even within areas of otherwise continuous permafrost. Soil moisture in permafrost exists in the form of ground ice that is often present in excess amounts (*i. e.* more than the soil would normally contain when thawed). Melting of this ice, as a result of some form of disturbance, can lead to soil instabilities and thus to a concern for terrain stability and infrastructure integrity. The quantity and distribution of ground ice depends largely on soil texture, environmental conditions and glacial history (Burgess, 1988).

**Figure 8 Permafrost distribution in the WKSS region**



Source: Adapted from the NWT Digital Atlas [CD-ROM], 2002. World Wildlife Fund (WWF)

Massive ground ice can occur in association with both glaciolacustrine and glaciomarine sediments (Dredge *et al.*, 1999). It is a relict feature formed in late glacial or early postglacial times. Massive ground ice, up to 10m thick occurs in hummocky tills, eskers and some outwash deposits where it may directly overlies bedrock or be separated from it by a thin layer of sediment (1 to 2m thick). It may also be present as (frozen) slightly saline saturated sediment of marine origin. Massive ground ice can originate as glacial ground ice that was buried in-place. If the sediment cover coarsens-upward it may indicate a shallowing of water cover, over time. The ice may also originate as glacial meltwater that subsequently froze in place in eskers or kettle holes. Wedges may be present as remnant casts of early postglacial ice-wedge forms (Dredge *et al.*, 1999). Massive ground ice of freshwater origin has very low electrical conductivity and low concentrations of most major ions (especially Al, Fe and Si). These characteristics suggest that no significant enrichment has occurred by subsequent downward percolation of surface water (Wolf, 1998). For the most part, the presence of massive ground ice is not a cause of developing thermokarst features. Massive ground ice has been reported in hummocky till from the Contwoyto Lake and Lac de Gras areas (Dredge *et al.*, 1999; Wolf, 1998). It is likely present in other parts of the WKSS area where late glacial conditions allowed rapid cover of residual forms of glacial ice and frozen meltwater. Massive ground ice is best preserved in areas of permanently frozen ground.

All of the WKSS area lies within the permafrost zone (Brown, 1970; French, 1989; Map 1246A; Figure 8). Continuous permafrost exists north of a line extending generally southeast-northwest from Artillery Lake to the Dease Arm of Great Bear Lake. Permafrost extends to depths of as much as 90 m at Yellowknife, and to more than 100 m at the site of the Eldorado mine on the east shore of Great Bear Lake. Near Lac de Gras, it occurs to depths of more than 270 m (BHP Billiton Diamonds Inc. & Dia Met, 1995; Map 1246A) and near Contwoyto Lake it is estimated to occur to a depth of about 540 m (Tahera Corp., 2000).

#### **2.2.6. Soil Development**

Soil development is influenced by the characteristics of source material, climate and hydrology. Source materials in the WKSS area include bedrock, till (mostly silty sand with rock fragments), and glaciolacustrine and marine clays (Acton, 1989a; 1989b; Map 1253A). Till geochemistry is highly variable throughout the WKSS area and it often reflects the composition of underlying bedrock. Granitic bedrock is usually poor in nutrient elements and gives rise to more acidic conditions than basic rocks such as basalt. Where tills contain materials from several different sources, they may give rise to less acidic soils but these generally remain nutrient poor. Glaciolacustrine sediments are usually rich in clay minerals that contain more nutrient elements (exchangeable cations such as Ca, Mg, K and Na). Contents of Ca and Mg are often highest in marine clays (Zoltai *et al.*, 1980).

Soils develop in the active layer in which seasonal thaw occurs. This thin layer at the ground surface is often only a few tens of centimetres thick, although local conditions make this highly

variable. Dredge *et al.* (2000) cite a range between 15 and 120 cm, with the greater depth occurring in areas devoid of vegetation cover. Generally, the thickness of the active layer decreases northwards (Brown, 1970; French, 1989; Map 1246A). Soils that develop within regions of permafrost are collectively termed Cryosolic (CSSC., 1978). Turbic Cryosols (TCs) are strongly affected by the physical movements of the ground, caused by annual freeze-thaw cycles. Orthic TCs describe soils which frequently develop over well drained till or hummocky till (Zoltai *et al.*, 1980). They are characterized by a thin layer of granular material of slowly decomposing rock fragments, just below the more organic-rich surface layer. Brunisol TCs lack this thin granular layer but often show evidence of soil movement due to frost heave. They form over less well-drained till. Regosol TCs occur where there is strong soil movement. Typically, this carries organic material to depths within the soil and fresh mineral and rock fragments are brought to the surface (*e. g.* “mudboils”). Peatlands (CCELC., 1988; Tarnocai, 1989) generally occur in areas of poor drainage where plant matter accumulates to form organic soils. These are often more than 0.5 m thick and overlie permafrost. The organic matter is usually derived from *Sphagnum* moss on the more elevated parts of a peatland and from sedge meadows in the lower parts. Decomposition tends to be least complete in the raised *Sphagnum* areas. Peat soils are strongly acidic (pH 3 to 5). Where soils develop on well drained sand or gravel (*e. g.* kames, eskers, and some river terrace deposits), there may be little evidence of cryoturbation. Soil horizons become well differentiated (Zoltai *et al.*, 1980).

Rates of soil development relate to the physical and chemical breakdown of rock and mineral particles and release of nutrient elements, and to the accumulation of decomposed organic matter. They are closely associated with both vegetative growth and decomposition by communities of soil biota (Nadelhoffer *et al.*, 1992), particularly bacteria and fungi. However, information is limited about species diversity and population size of these Arctic and sub-Arctic communities. Rates of soil development are therefore also related to the combined effects of both temperature and soil moisture regimes (CSSC., 1978; CCELC., 1988; Tarnocai, 1989; Zoltai *et al.*, 1980). Layers of decomposed rock material tend to be best developed in moist but well drained soils. In these soils, the thickness of surface organic matter tends to be least because this is where recycling of organic matter and nutrients is most rapid. Rates of soil development throughout the WKSS area are very slow, typically in the order of a few millimetres per century, but peat materials may accumulate much more quickly. Soil development and nutrient availability are significant factors that influence the distribution and growth of higher plants.

## **2.3. Biological Aspects of the WKSS Area**

### **2.3.1. Biomes and Ecozones**

The SGP lies across the intersection of two ecozones: the Southern Arctic and the Taiga Shield. Ecozones are areas of similar land features, vegetation and climate and are subdivided into ecoregions and ecodistricts to further define common landscape characteristics (Wiken 1986; see

Figure 9). The unique features of the WKSS include the transition from the boreal forest around Great Slave Lake to tundra conditions in the northern portions. This combination of features supports a wide diversity of large and small mammal species, waterfowl nesting and terrestrial game and song birds despite a severe climate for much of the year. The short, productive summers are vital for the continuation of migrating and resident species that rely on the largely undisturbed ecosystem for critical portions of their life cycle.

A brief description of the four major ecoregions of the two ecozones is presented below from general summaries provided by Environment Canada<sup>1</sup> (Wiken 1986). These summaries are very descriptive, but provide details of the physical features of the region (Table 2). Most of the detailed information has been taken from national maps, and hence have poor resolution since few data recording stations are present in the WKSS, however it is important that these initial data be documented as a first step toward recording changes in the area due to climate change and development. Improved methods of recording physical parameters, with much higher resolution and precision, are needed to provide better baseline data, particularly on climate related parameters (temperature, wind-speed, precipitation, humidity, snow depth, etc.).

With respect to improving the vegetation classification information available for the WKSS region a four year baseline study was carried out to classify and map land and water cover types (Matthews et al. 2001). The objectives of the study were:

1. to produce a geometrically corrected land and water classification for the West Kitikmeot /Slave Study area;
2. to describe and map the classes using Landsat Thematic Mapper (TM) satellite imagery and field data;
3. to analyze the classification for its accuracy; and
4. to produce hardcopy maps of the area, a digital database of the classification, and an accompanying report.

The study area extends from the arctic coast of Coronation Gulf, to the taiga forest below the treeline, to the south. It includes parts of two terrestrial ecozones, the Southern Arctic and the Taiga Shield ecozones. Figure 10 shows the classification identified.

#### *2.3.1.1. Southern Arctic Ecozone*

The Southern Arctic ecozone lies from the Richardson Mountains in the Yukon to Ungava Bay in Québec. The portion of the ecozone that lies to the west of Hudson Bay forms a major portion of the northern section of the WKSS. The ecozone is characterised by the most extensive vegetative cover and highest diversity of species of the three arctic ecozones. The short growing

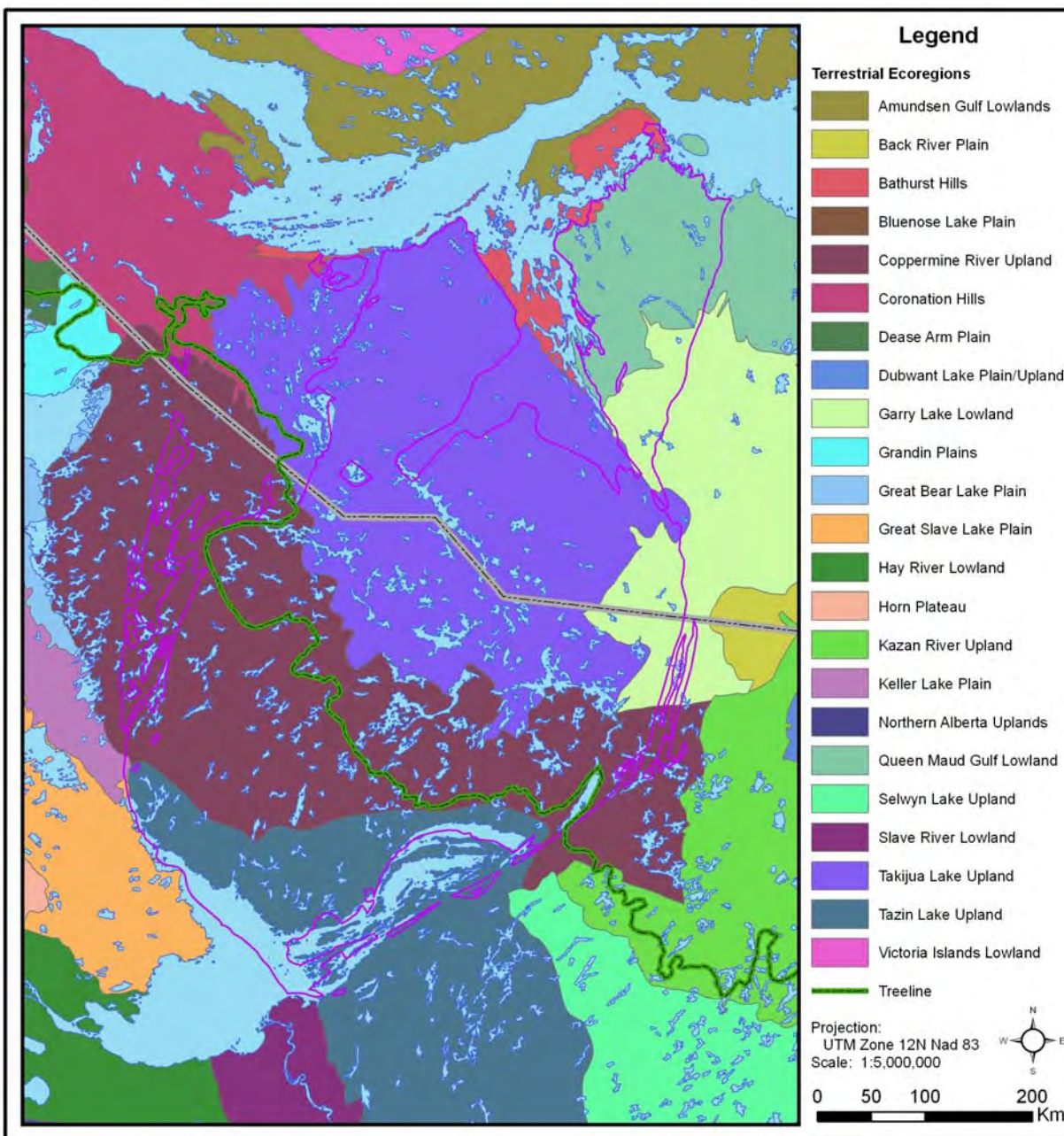
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<sup>1</sup> <http://www.ec.gc.ca/soer-ree/English/Framework/Nardesc/TOC.cfm>



season lasts up to 750 growing degree days. The vegetation varies from the taiga forest in the south to the treeless tundra in the north. Vegetative cover is comprised of a wide variety of plant species, including dwarf birch, willow and Labrador tea.

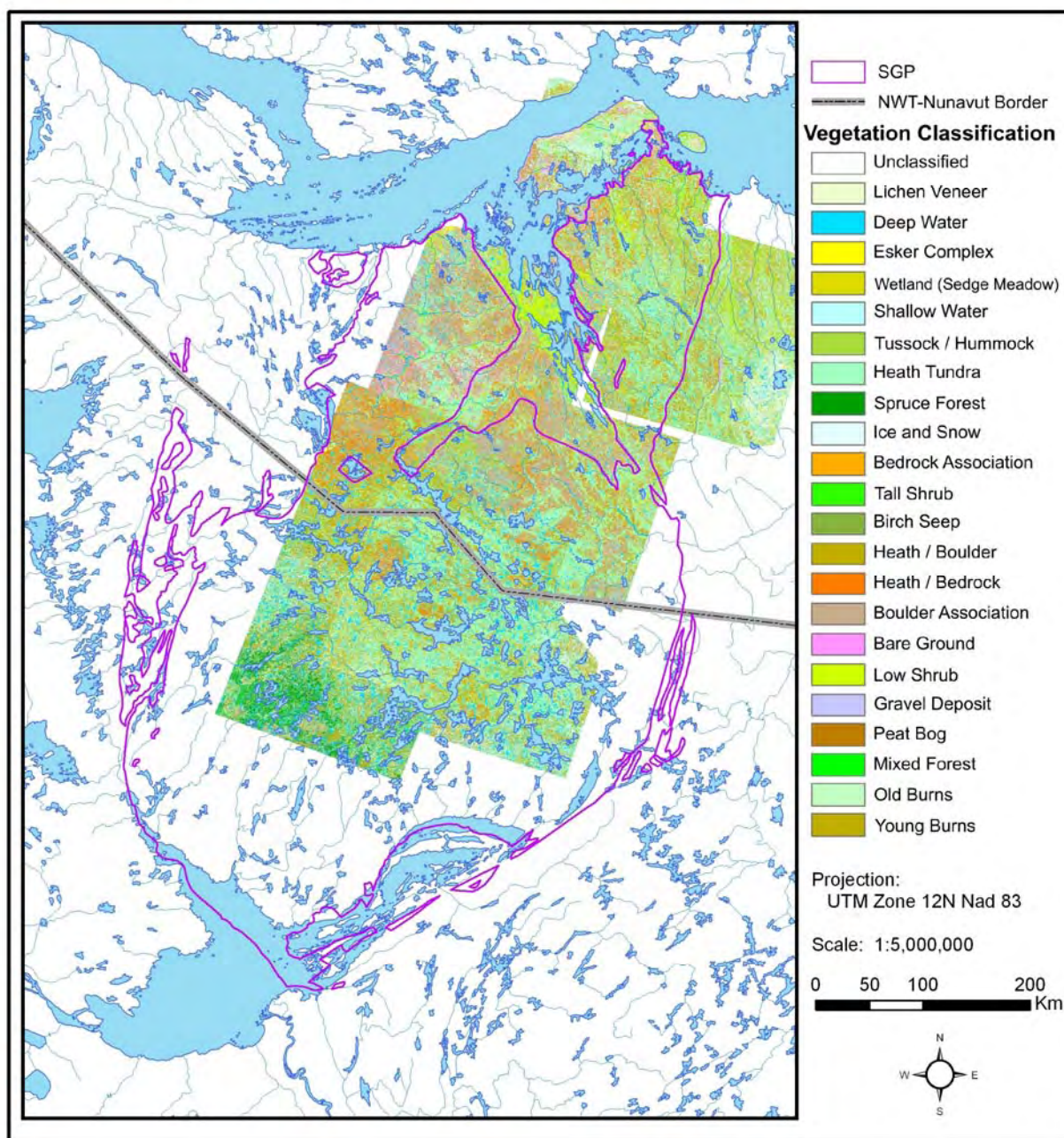
**Figure 9 Ecoregions and delimitation of trees of the WKSS area**



Source: Adapted from the NWT Digital Atlas [CD-ROM], 2002. World Wildlife Fund (WWF)



**Figure 10 Vegetation Classification for the WKSS Region**



Source: Adapted from, Matthews, S., H. Epp, and G. Smith. 2001. Vegetation Classification for the West Kitikmeot / Slave Study Region. Final Report To The West Kitikmeot / Slave Study.

**Takijuk Lake Upland Ecoregion** - This ecoregion forms the largest part of the Southern Arctic ecozone in the Slave Geologic Province and its features provide much of the character of the northern portion of the WKSS. The ecoregion covers  $11.7 \times 10^6$  ha, of which 36% is covered by water. Elevation ranges from sea level to 655 m (Table 2). Vegetative cover consists primarily of dwarf birch, willow, Labrador tea and *Vaccinium* species. Spruce occurs in the southern portions of the ecoregion.

**Queen Maud Gulf Lowland Ecoregion** – This ecoregion lies on the upper rim of the Slave Province but it provides some habitat for the Ahik and Dolphin and Union barren-ground caribou herds. It has the lowest mean temperatures within the WKSS and the lowest rates of precipitation (Figures 11 and 12). It has a low arctic ecoclimate. About 25% of its land area is covered by water. The Queen Maud Bird Sanctuary, a major nesting area for waterfowl, is in this ecoregion but lies to the east of the WKSS study area.

#### *2.3.1.2. Taiga Shield Ecozone*

The western section of the Taiga Shield forms a large portion of the southern half of the WKSS, including the land around the eastern end of Great Slave Lake. It is characterized as a combination of the Taiga Forest and the Canadian Shield.

**Coppermine River Upland Ecoregion** - This ecoregion covers an area of  $13.6 \times 10^6$  hectares, most of it in the Slave Geologic Province. Over 40% of the area is covered by water. The main feature of the vegetation is the tree line, which covers the transition from boreal forest to the tundra. Large rock outcrops form broad uplands and plateaus. Permafrost shows considerable variation, with continuous in the eastern sections to discontinuous in the west (Table 2).

**Tazin Lake Upland Ecoregion** - This ecoregion extends into Alberta and Saskatchewan, with about 77% of its total area in the NWT. It surrounds the East Arm of Great Slave Lake, and forms the habitat of the important birding area on the north shore of Great Slave Lake, and includes the city of Yellowknife. About 30% of the ecoregion is covered by water. The climate is defined as subhumid and high boreal. Permafrost is extensive but discontinuous with low ice content.

The major physical characteristics of the two ecoregions (Table 2) show the variation in landforms among the ecoregions. For example elevation ranges from sea level in the Southern Arctic ecozone to elevations of >640 m in the Taiga Zone. Permafrost is also variable, ranging from discontinuous around Great Slave Lake to largely continuous in the north. Average monthly precipitation and temperatures (Figure 12) show the difference of the warmer, wetter southern areas relative to the northern portions of the WKSS.

**Table 2 Summary of physical features of the two ecoregions of the two major ecozones that comprise the West Kitikmeot Study area.**

| Parameter                     | Taiga Shield Ecozone                                                                                         |                                                                           | Southern Arctic Ecozone                                                                 |                                                          |
|-------------------------------|--------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------|
|                               | Coppermine River Upland                                                                                      | Tazin Lake Upland                                                         | Takijuq Lake Upland                                                                     | Queen Maude Gulf Lowland                                 |
| Elevation (m) <sup>1</sup>    | Min = 149<br>Max = 672<br>Mean = 371                                                                         | Min = 142<br>Max = 643<br>Mean = 303                                      | Min = 0<br>Max = 655<br>Mean = 404                                                      | Min = 0<br>Max = 433<br>Mean = 85.7                      |
| Landform <sup>2</sup>         | 85% - Plain<br>15% - Hilland                                                                                 | 87% - Hilland<br>13% - Plain                                              | 100% - Plain                                                                            | 94% - Plain<br>6% - Hilland                              |
| Surface material <sup>2</sup> | 67% - Mineral soil<br>23% - Rock<br>10% - Organic soil                                                       | 48% - Mineral soil<br>46% - Rock<br>6% - Organic Soil                     | 62% - Mineral soil<br>33% - Rock<br>5% - Organic soil                                   | 65% - Mineral soil<br>24% - Rock<br>11% - Organic soil   |
| Land Cover Types <sup>3</sup> | 79% - Transitional Forest<br>19% - Tundra<br>1% - Mixed forest<br>1% - Sparse plant cover<br>generally < 25% | 72% - Transitional Forest<br>20% - Coniferous Forest<br>8% - Mixed forest | 64% - Tundra<br>30% - Sparse plant cover<br>generally < 25%<br>6% - Transitional Forest | 56% - Tundra<br>46% - Sparse plant cover generally < 25% |
| Permafrost <sup>4,5</sup>     | 54% - Elm<br>40% - Cl<br>6% - Cml                                                                            | 68% - Elm<br>28% - Sl<br>4% - El                                          | 93% - Cl<br>7% - Cml                                                                    | 98% - Cl<br>2% - Cml                                     |

Overall Source: Marshall, I.B., P. Schut, P. and M. Ballard (compilers). 1999. *A National Ecological Framework for Canada: Attribute Data*. Environmental Quality Branch, Ecosystems Science Directorate, Environment Canada and Research Branch, Agriculture and Agri-Food Canada, Ottawa/Hull (Website: [http://sis.agr.gc.ca/cansis/nsdb/ecostrat/data\\_files.html](http://sis.agr.gc.ca/cansis/nsdb/ecostrat/data_files.html))

<sup>1</sup> - <http://sis.agr.gc.ca/cansis/nsdb/ecostrat/elevation.html>

<sup>2</sup> - Shields, J. A., C. Tarnocai, K.W.G. Valentine, and K. B. MacDonald. 1991. *Soil Landscapes of Canada - Procedures Manual and User's Handbook*. LRRC Contribution Number 88-29, Land resource Research Centre, research Branch, Agriculture Canada, Ottawa, 74pp.

<sup>3</sup> - Energy, Mines and Resources Canada and Forestry Canada. 1993. Canada: Vegetation cover. National Atlas of Canada, 5<sup>th</sup> Edition. Map MCR 4182. National Atlas Information Service and Petawawa national Forestry Institute, Ottawa

<sup>4</sup> Permafrost Legend

Cl - Continuous (>90%) Permafrost: Low (<10%) Ground Ice

Cml - Continuous (>90%) Permafrost: Medium-Low (<20%) Ground Ice

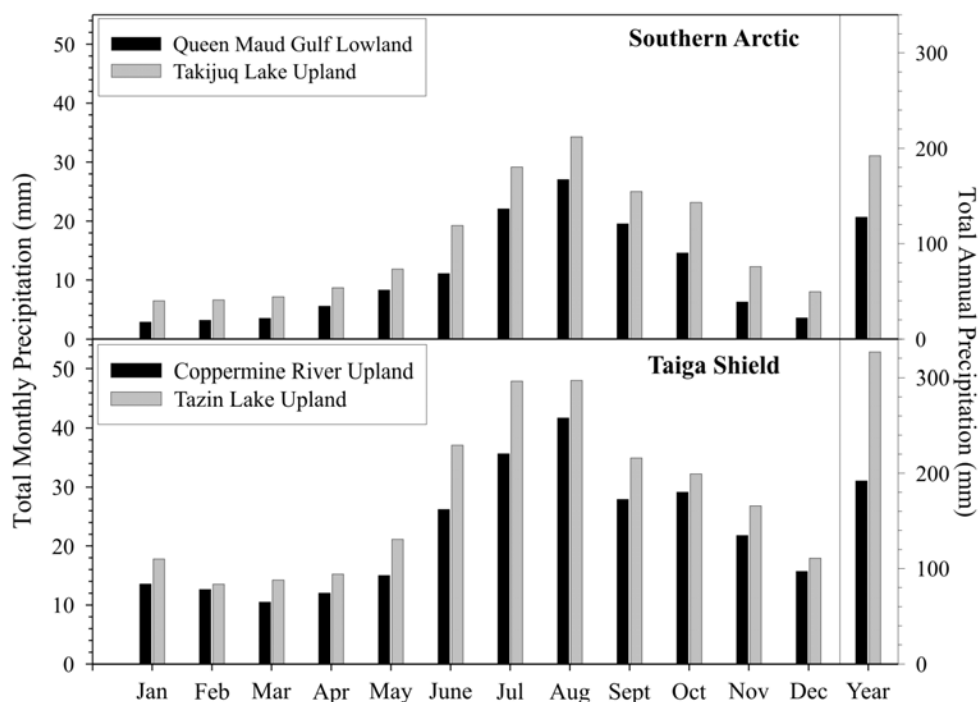
El - Extensive Discontinuous (50-90%) Permafrost: Low (<10%) Ground Ice

Eml - Extensive Discontinuous (50-90%) Permafrost: Medium (10-20%) Ground Ice

Sl - Sporadic Discontinuous (<10%) Permafrost: Low (<10%) Ground Ice

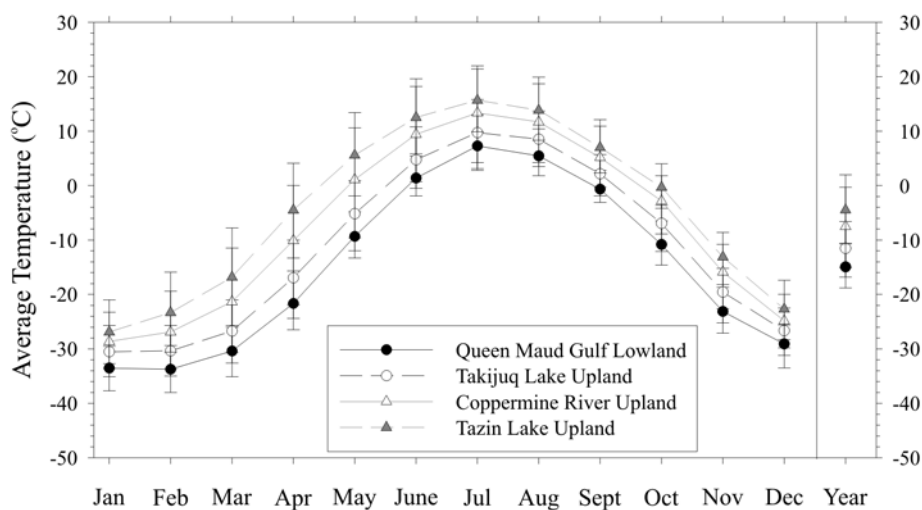
<sup>5</sup> - Natural Resources Canada. 1995. "Canada - Permafrost". National Atlas of Canada, 5<sup>th</sup> edition, Map No. MCR 4177. Canada Centre for Mapping, Geomatics Canada and Terrain Sciences Division, Geological Survey of Canada, Ottawa. Map 1:7.500.000 scale

**Figure 11 Monthly and annual precipitation in the four major ecoregions**



Source: Environment Canada. 1994. *Canadian Monthly Climate Data and 1961-1990*  
 Environment Canada, Atmospheric Environment Service, Downsview, Ontario.

**Figure 12 Monthly and annual average temperatures for the four major ecoregions**  
 Bars indicate average minimum and maximum values.



## **2.3.2. Marine Ecosystem**

### **2.3.2.1. Nutrients and Primary Production in Marine Areas**

Between Victoria Island and the mainland Nunavut, cold and nutrient poor Arctic water of the Coronation Gulf supports low biological productivity. Despite low temperatures and strong seasonality, biological productivity in such a polar ecosystem is reportedly similar to those of lower latitudes (Smetacek and Nicol 2005).

In the Coronation Gulf waters, tidal ranges and flows are small and there is probably little movement of deep oceanic water or the exchange of associated nutrients into its surface. Nutrient levels in runoff from the Shield are generally very low but some marine upwelling may occur in response to the outflow of a few larger rivers (Sly, 1995). Rivers that flow into the gulf include the Rae, Richardson, Coppermine and Tree. This could locally increase nutrients and biomass in surface waters. However, any upwelling that is generated by the offshore movement of a plume of freshwater is likely to be greatly limited by the short period of high river discharge which is typical of many river basins in the WKSS area. In most of the coastal rivers, winter discharge is negligible and runoff is small relative to the volume of receiving water, but the seasonal meltwater discharge may be sufficient to locally depress salinities. Although detailed information is lacking, particulate organic matter from land drainage may be an important addition to some estuaries such as the Coppermine River (Ellis, 1962; Wedel *et al.*, 1988).

Polynyas are suspected for the Coronation Gulf but have yet to be charted. Polynyas are areas of open water surrounded by sea ice, and maintained free of ice by currents, tides, upwellings and winds. They can vary in size from few kilometres to immense areas (Fortier, 2006). In spring, the absent or thin ice cover allows for the penetration of light as soon as the winter night ends, which triggers the early blooming of algae that are at the basis of the marine food chain. In areas of polynyas, the interval between the ice cover break-up in mid-summer and the return of the polar night is nearly two months. Hence, the season during which solar radiation reaches the surface layer to trigger algal production could be from two months in non-polynyas areas to as long as four to six months in polynyas areas. Recurring polynyas are suspected to be focal points for intense primary production and transfer of solar energy fixed by algae to Arctic cod, marine birds, seals, whales, polar bear and humans.

Based on evidence from other areas in the Arctic, atmospheric fluxes may be an important source of nitrate, nitrite and phosphate nutrients (Sly, 1995). Almost certainly, surface and near surface concentrations of nutrients remain low throughout the growing season, and levels of nitrate are probably very low at the end of summer.

Water clarity varies considerably (Ryder, 1972; Bodaly *et al.*, 1989; Coronation Gulf Air Photo

Coverage, various dates). River plumes, particularly during the spring melt, and wave erosion can greatly increase nearshore turbidity and limit primary production in surface waters. Water clarity may be high in other areas, thus allowing light penetration to considerable depth. Chlorophyll *a* is a green pigment that can be used to indicate the presence of plant growth. In very clear water it is possible for light intensity to be greater than the optimum for aquatic plant growth. It is not known if there is a related chlorophyll *a* maximum at depth, as there is in some other parts of the Arctic and sub-Arctic. In some areas, light intensity rather than nutrient availability may limit the growth of aquatic plants (Sly, 1995).

Biomass concentrations of microorganisms in sea-ice biota can far exceed those attained in seawater (Smetacek and Nicol, 2005). Although quantitative data are not known from this area, ice algae are a very important part of marine food web, contributing on average 57% to the total Arctic marine primary production (Sly, 1995; Gosselin *et al.* 1997; Krembs and Deming 2006). Ice algae start growing as ice begins to form but stop as light levels decrease below critical values during the early part of winter. In the spring, ice algae resume growth. Ice algae are concentrated at the base of the floating ice where salt rejection and ice formation create a thin layer of nutrient enrichment. They include both pelagic and benthic forms, and benthic forms may become dominant as spring advances and ice break-up begins. At the peak of ice-algal production in spring, the solid ice cover is transformed into pack ice with individual floes that transport organisms, organic matter and sediment over long distances before melting and discharging their contents into the marine water.

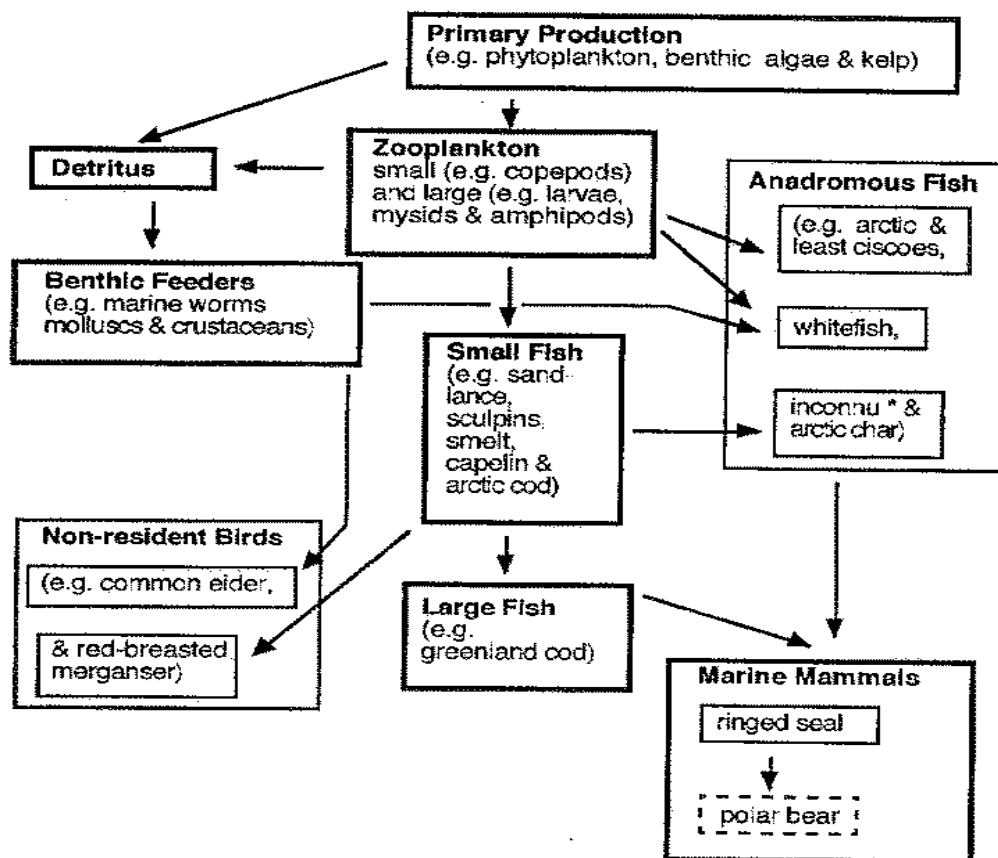
As marine sea ice melts in place, airborne introductions of microorganisms and trace elements particularly iron may produce early spring blooms of both freshwater algae in shallow ponds that form on the surface of the sea ice, and marine algae (Smetacek and Nicol 2005). Melting ice also reduces for the time being the salinity of near surface water and increasing density stratification may cut off the upward supply of nutrients to surface waters. In general, the nutrient supply for the spring bloom of surface phytoplankton is quickly exhausted hence the stimulating effect of meltwater on productivity. Light is a major factor controlling productivity, and ice algae are an important part of the total primary production.

Primary production is strongly pulsed in response to light. In comparable areas of the Arctic, partial cropping by pelagic species allows more than 40% of the energy from phytoplankton to enter food chains through benthic components of the food web (Sly, 1995). Partial cropping can occur in the water column if populations of browsing and grazing organisms do not increase rapidly enough to consume all the available food. Unconsumed plant material then settles to the bottom. Little is known about this part of the Arctic food web which is often reflected in the abundance of benthic organisms on both rocky and sandy bottoms (*e.g.* mussels, clams, Brown Sea cucumbers and sea urchins (Stewart *et al.*, 1993; Bright *et al.*, 1995; Zoltai *et al.*, 1980).

### 2.3.2.2. Structure of the Marine Food Web

The general structure of the food web present in the area between Victoria Island and the mainland is shown in Figure 13 (EC, 1991; Sly, 1995; Jensen *et al.*, 1997). It is greatly simplified and may exclude components that have particular, yet little understood significance. For example, ciliates may be an important link in the energy flow between nanoplankton and microphyto-plankton (including: bacteria, organic detritus, small diatoms and small flagellates) and larger omnivorous zooplankton (*e.g.* amphipods). Locally, contributions of organic matter from terrestrial sources may be significant in coastal areas such as Cambridge Bay (Bright *et al.*, 1995).

**Figure 13 Simplified food web of the marine ecosystem**



Recent research quantified biomass and diversity in marine bacteria collected from Resolute Bay, Nunavut (Tam *et al.* 2003). Bacteria have central global roles in decomposition, food chain, and biogeochemical cycling. Estimated viable marine bacterial numbers from 0.7 to  $1.8 \times 10^6$  cells/L. Calculation of the bacterial diversity in the marine samples was significantly greater than that of freshwater samples. Despite the extreme temperatures and nutrient limitations, microbial life was found abundant in the Arctic.



Marine food-web structure for the Coronation Gulf can only be speculative at this time. In Arctic Ocean as pointed earlier, sea-ice and light availability cause seasonal pulses of pelagic primary production (Gosselin *et al.* 1997), which are the food sources for ice-associated, pelagic and benthic organisms. The Arctic benthos is among the ultimate recipients of carbon fixed in primary production in the overlying water mass and flux of sinking material. The food that is provided for the benthic community depends on nutrient availability and primary production in the water column. This food input occurs in the form of direct sedimentation of phytoplankton, or through fecal pellets, zooplankton carcasses, molts and marine snow. In areas of high nutrient availability and primary production, and simultaneously low zooplankton grazing, the benthos is expected to be provided with a rich food sources. In these high productivity systems, bottom-up processes are thought to drive the pelagic and benthic community and food-web structures (Iken *et al.* 2005). Such high productivity systems appears thus far to be found in shallow Arctic continental shelf regions compared to Arctic deep-sea regions (Iken *et al.* 2005), which shallow regions may apply to the Coronation Gulf.

Furthermore, structures in benthic components of the food web are not shown in Figure 13 because, information is lacking for the Coronation Gulf. Benthic omnivores such as the Four-horned Sculpin occur throughout the area and are an important species in some coastal areas (Zoltai *et al.*, 1980; Bright *et al.*, 1995). Primary production at the base of the food web is supported both by ice algae that provide a crucial early pulse in the production cycle, and by marine phytoplankton (Sly, 1995; Smetacek and Nicol 2005). The ingestion of algal material by large numbers of copepods likely triggers an early start in their reproductive cycle. Copepod eggs and nauplii are a key component in the diet of many larval fish, in particular, the larvae of Sand Lance and Arctic Cod. Survival of fish at these early stages may be more dependent on availability of ice algae than the spring phytoplankton bloom. Amphipods, a major group of consumers, also feed on ice algae and on phytoplankton. The Sand Lance uses both planktonic and benthic sources of food. In turn, it is an important source of food for Arctic Cod, which also feeds extensively on pelagic crustaceans. Arctic Cod and Capelin support many large predators, including Greenland Cod, Ringed Seals, and birds (Klohn-Crippen, 1993; Krembs and Deming 2006).

Estuarine and nearshore environments are important for anadromous fish such as Arctic Char that are tolerant of a wide range of salinities, and semi-anadromous fish such as Arctic Cisco, Least Cisco, Lake Whitefish and Broad Whitefish (Ellis, 1962; McCart and Den Beste, 1979; McCart, 1986; Bodaly *et al.*, 1989). During the ice-free season, these fish benefit from higher primary production of these environments. Arctic Char (Robertson and Dowler, undated; McCart and Den Beste, 1979; McCart, 1986; Stewart *et al.*, 1993; Sirois *et al.*, 1995) are a key species in the coastal rivers of both Victoria Island and the mainland. In summer, stocks of Arctic Char may mingle together at sea where a high proportion of their diet consists of amphipods and small

fish. Anadromous fish return annually to over-winter and spawn in accessible freshwaters. These waters remain slightly warmer than salt water and provide thermal protection (McCart and Den Beste, 1979; McCart, 1986; Stewart *et al.*, 1993; Sly, 1995). For some anadromous species, the rising spring discharge assists in passive downstream migration of juvenile stages. The juveniles may depend upon the availability of early-life stages of zooplankton for first feeding at downstream sites.

#### 2.3.2.3. Population Size and Distributions of Marine Fish and Mammals

Very little is known about the size of populations or distributions of fish and marine mammals between Victoria Island and the mainland. Anadromous fish are present in several rivers entering these waters, including the Coppermine and Tree rivers, rivers entering the Wellington Bay and Cambridge Bay areas of Victoria Island, and rivers entering Bathurst Inlet (Ellis 1962; McCart and Den Beste, 1979; Zoltai *et al.*, 1980; McCart, 1986; Bodaly *et al.*, 1989; Bright *et al.*, 1995; Robertson and Dowler, undated). Sand Lance, Capelin and Arctic Cod are more widespread. At the mouth of the Coppermine River, water temperatures are about 10° C from late June to late July and may reach a maximum of about 18° C, but conditions are not stable and freshets of warm water may kill fish in the delta. Anadromous fish move out of the river as soon as ice conditions permit and most populations are greatest in the delta after July. Capelin spawn on sandy beaches in the delta in mid-July and are important in the diet of several anadromous species. Return migrations begin in September. Boreal Smelt are known to spawn in several rivers and streams entering Coronation Gulf (Zoltai *et al.*, 1980).

Arctic Flounder (feeding on isopods and gastropods), Starry Flounder (feeding on crustaceans and smaller fish such as Capelin) and Saffron Cod (feeding on crustaceans, worms and smaller fish) have also been caught at Kugluktuk (Ellis, 1962). Several species of sculpin (over 14 Arctic species, including Four-horned Sculpin), Shannies (7 Arctic species) and Eelpout (10 Arctic coast species) are present in Coronation Gulf, and small numbers of Bering Flounder and Starry Flounder have been reported from Bathurst Inlet (Zoltai *et al.*, 1980). Both of these flounders are thought to be relict species which became separated from parent stocks about 5000 BP when climate change resulted in regional cooling of Arctic waters. Survival of these relict populations may depend on particular marine conditions caused by the influence of a shallow sill at the north end of Bathurst Inlet (Zoltai *et al.*, 1980). Greenland and Toothed Cod, and Pacific Herring have also been reported west of Coronation Gulf (Stewart *et al.*, 1993).

The Ringed Seal is present in Bathurst Inlet, in Cambridge Bay, and along the south shore of Coronation Gulf, and the Bearded Seal is also occasionally present (Zoltai *et al.*, 1980; Bright *et al.*, 1995; NPC., 1997). Mollusc (bivalve) populations, however, may be too small to support Walrus. Although relations between Polar Bear distributions and habitat in this area are not known, this animal is present in both the Amundsen Gulf (Thorpe and Kadlun, 2000), Queen Maud Gulf (NPC, 1997), M'Clintock Channel and Gulf of Boothia (Barber and Iacozai, 2004)

areas, but generally absent from Coronation Gulf and Dease Strait. The extensive development of thick and continuous ice in Coronation Gulf may restrict winter access to much of the area by seals (and whales) and, hence, the gulf may lack suitable food resources for Polar Bears. The lack of snow cover also restricts potential Polar Bear denning habitat.

#### 2.3.2.4. *Birds of the Coastal Region*

Coastal-marine bird species are present for only a few months of the year, during the open-water season, and the most diverse community probably occurs around Bathurst Inlet (Zoltai *et al.*, 1980). Yellow-billed Loons are widely distributed (Godfrey, 1986; Kalin, 1987). They are present in large tundra lakes and coastal marine waters. These loons nest on freshwater lakes from the tree line north to the coast, and feed mostly in the marine nearshore. King Eider (Barry, 1986) occur on small islands in Bathurst Inlet, inland on grassy tundra (without shrubs and where predators are easily visible), and on some of the islands in Coronation Gulf. Both solitary and semi-colonial nesting occurs (Bromley, 1998). It is thought that King Eider males tend to leave the region (migrating east to west) before ice formation but late leaving females and young may be trapped in an early freeze-up. Colonies of Common Eider (Pacific race (NPC., 1997)) nest on small sand and gravel islands (isolated from Arctic Foxes) in ice-free areas of Dolphin and Union Strait, Coronation Gulf, Bathurst Inlet and in Elu Inlet (Barry, 1986; Bromley, 1998). They also migrate westward before freeze-up. Glaucous Gulls often nest close to Common Eiders and are an important predator on young Eider Ducks (Bromley, 1998). Red-breasted Mergansers are more common than the Yellow-billed Loons. Near the coast, they share similar habitat and may be present in rivers, as well (Zoltai *et al.*, 1980). Small numbers of Herring Gulls and Glaucous Gulls occur throughout the region. Both nest in coastal areas and Herring Gulls also nest inland. Small colonies of Arctic Terns are present in a few areas (Bromley, 1998). Loons, mergansers, and Arctic Terns feed extensively on small fish and invertebrates in shallow coastal waters. In the marine environment, many species of sea ducks also feed on invertebrates in the water column and eiders feed on bivalve molluscs (Blue Mussel and clams).

Several species of wading birds (shorebirds), including phalaropes, plovers, and sandpipers (Godfrey, 1986; Zoltai *et al.*, 1980) are present where mud flats and marshlands provide a sufficient source of small invertebrate foods, including molluscs, gastropods and dipteran larvae.

### 2.3.3. Freshwater Ecosystem

#### 2.3.3.1. Nutrients and Production in Freshwater

The freshwater ecosystem includes species adapted to a wide range of aquatic environments. These range from extremely large deep lakes (*e.g.* Great Bear Lake (Johnson, 1975) and Great Slave Lake (Rawson, 1950)) to many smaller and shallow lakes, ponds and marshes, and to rivers and streams with great seasonal variations in flow and water level. As in the marine environment, nutrient concentrations are very low to low throughout the growing season and net annual production is generally less than in Arctic marine waters.

Most of the primary production in large deep lakes comes from phytoplankton. Annual primary production values range from less than 4 g C m<sup>-2</sup> in the East Arm of Great Bear Lake, 15 g C m<sup>-2</sup> in McLeod and Christie bays (East Arm of Great Slave Lake), 30 g C m<sup>-2</sup> in the western basin of Great Slave Lake, to about 40 g C m<sup>-2</sup> in Yellowknife Bay (Johnson, 1975; Fee *et al.*, 1985). Nutrient concentrations in Canadian Shield drainage are generally low and primary production from phytoplankton is also low in many small lakes. There may be significant variations in year to year primary production. This is particularly so in bays and deltas that are influenced both by variations in run-off and nutrient contributions from surrounding watersheds, and by climatic variations. Rawson (1956) noted greater phytoplankton growth in Great Slave Lake during years with warm springs and a larger inflow from the Slave River. Seasonal distributions of phytoplankton in Yellowknife Bay reflect the relative influence of water from the main lake and the Yellowknife River (which contains effluent discharge from Yellowknife (Moore, 1980; Fee *et al.*, 1985).

In clear shallow lakes more light can penetrate to the bottom and a significant part of the bed may be covered by benthic algae. In clear lakes and streams, some algae (periphyton) may also be attached to hard surfaces. Primary production from both of these algal forms may be equal to or greater than that of phytoplankton (Johnson, 1975). *Chrysophyta* are the most important phytoplankton in turbid lakes. In addition, in very shallow lakes, primary production from rooted aquatic plants (macrophytes) can be several times greater than that of phytoplankton (Johnson, 1975).

A recent analysis (Vadeboncoeur and Steinman, 2002) of approximately 30 studies worldwide that have partitioned primary production between benthic and pelagic components shown that a pelagic-only focus can seriously underestimate whole lake primary production. Benthic primary production can be especially important in oligotrophic systems where nutrient limitation to the phytoplankton can favour benthic production by enhancing light penetration to benthic algae that derive nutrients from the sediment where concentrations are much higher.

The small surface area and shallow mean depth of many lakes further indicate that lake-catchment interactions are also important determinants of lake ecosystem structure and function. Catchment characteristics have been demonstrated to influence lake geomorphology, chemistry and phytoplankton biomass (Riera *et al.*, 2000) as well as distribution of invertebrates and fish (Magnuson *et al.*, 1998; Lewis and Magnuson, 2000). Therefore, developing food web dynamics requires an understanding of the influence of catchment characteristics as well as the functional significance of linkages between benthic and pelagic habitats.

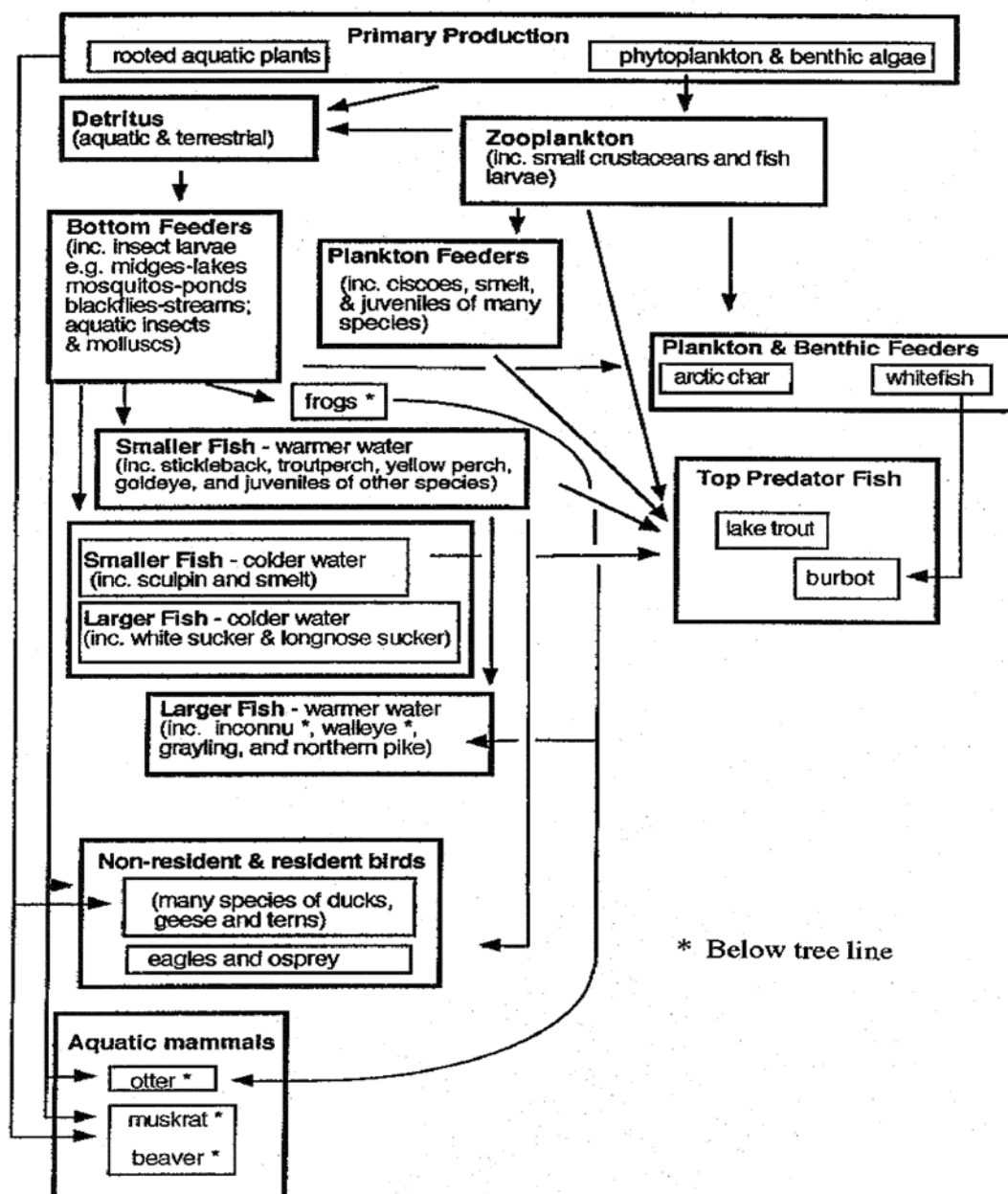
The biomass of fish is low in most streams, rivers, ponds and lakes of the WKSS area. In natural systems (not subject to heavy fishing pressures), it tends to be concentrated in relatively small numbers of large old fish. These represent the conversion and storage of many years of primary production (Ryder, 1972; Johnson, 1973; McCart and Den Beste, 1979; McCart, 1986). Terrigenous inputs of organic matter and nutrients are very important, and so are atmospheric inputs of nutrients (Sly, 1995). Latitude ranges from about 62° N to nearly 70° N across the WKSS area and this results in additional differences in growth potential related to temperature, light, and ice cover (Brylinsky and Mann, 1973; Ryder *et al.*, 1974; Schlesinger and Regier, 1982; Pienitz *et al.*, 1997). Except in large lakes, the effects of nearshore ice scour are much less than in marine coastal areas. This allows rooted aquatic vegetation to become established, except in areas of high turbidity (mostly due to suspended sediment). Because concentrations of all forms of plankton are low, water clarity is generally very high. Secchi depths range from about 13.7 m in Great Bear Lake, to 10.7 m in Great Slave Lake, and to 4.5 m in Lac la Ronge. These values are typical of large boreal lakes (Ryder, 1972).

Also, as in the marine environment, partial cropping allows a significant amount of the primary production to pass into the food web through its benthic components. This occurs when secondary feeders such as zooplankton grazers under utilize primary production. Under utilization in the water column can occur over large areas if phytoplankton densities are too low or too patchy to support significant assemblages of zooplankton. Locally, it may occur if warming or an influx of nutrient-rich waters creates a brief pulse in primary production. In general and across regions of broadly similar climate, most variabilities in productivities of aquatic ecosystems are linked to nutrient availability and feeding efficiencies in different parts of the food web (Brylinsky and Mann, 1973). Climatic factors, and differences in glacial and postglacial development of the region have probably influenced the distributions of some species (Brylinsky and Mann, 1973; McCart and Den Beste, 1979; McCart, 1986).

#### **2.3.3.2. Freshwater Food Web and Fish Distributions**

Figure 14 provides a greatly simplified summary of the structure of the region's freshwater food web. Phytoplankton include drifting green and blue-green algae, and diatoms (Fee *et al.*, 1985; Johnson, 1975; Moore, 1978; Rawson, 1956). Algae also may be present as benthic and attached forms (Bodaly *et al.*, 1989). Larger floating plants include Chickweed, and rooted aquatic plants

Figure 14 Simplified food web of the freshwater ecosystem



(macrophytes) include Yellow Pond-Lily and Water Milfoil. Emergent and wetland species include bulrushes, cattails, rushes, and horsetails (BHP Billiton Diamonds Inc. & Dia Met, 1995; Zoltai *et al.*, 1980).

Zooplankton include a great variety of small organisms that derive most of their food from living or dead phytoplankton, or other zooplankton (Fee *et al.*, 1985; Healey & Woodall, 1973; Moore, 1977). In tundra streams, larval drift is comprised mostly of insects (Diptera) and small crustaceans (BHP Billiton Diamonds Inc. & Dia Met, 1995). Species composition increases significantly in boreal areas of the WKSS area. Many of the same species of cladocerans, cyclopoids, and calanoids occur widely across northern Canada. Shrimp-like amphipods (*e. g.* *Gammarus* and *Pontoporeia*) and mysids are also typical of larger lakes (Fee *et al.*, 1985; Healey & Woodall, 1973; Johnson, 1973; 1975; Rawson, 1950; 1956). Chironomids (dipteran larvae), oligochaete worms, sphaeriid bivalves, and small gastropods (snails) are typical benthic feeders (BHP Billiton Diamonds Inc. & Dia Met, 1995; Fee *et al.*, 1985; Healey & Woodall, 1973; Rawson, 1956). The larval and nymph stages of many aquatic insects are also adapted to stream habitats (*e. g.* blackfly, mayfly and stonefly) and pond habitats (*e. g.* caddisfly and mosquito). The insects feed on detritus including fungi and bacteria and other organisms including diatoms (Moon, 1970; Moore, 1977; 1979). Frogs can provide an important link between insects and higher parts of the food web but they are only present in streams and wetlands south of the tree line (*e. g.* Boreal Frog and Wood Frog). Many species of aquatic invertebrates are environmentally sensitive and their abundance can be a useful indicator of changing conditions. Climate and habitat naturally limit the number of species and their distributions in the WKSS area, including those in the aquatic environment. Because of this, measures of density rather than diversity or the use of indicator species are most appropriate as indicators of stress, (*e. g.* pollution (Moore, 1977)).

Away from the effects of postglacial marine inundation along the Arctic coast, the structure of fish communities is somewhat unpredictable (Bodaly *et al.*, 1989; McCart, 1986; McCart & Den Beste, 1979). A number of small fish species provide a key link between upper and lower parts of the food web (BHP Billiton Diamonds Inc. & Dia Met, 1995; Scott & Crossman, 1973). Troutperch is common in the warmer waters of streams and shallow lakes where it feeds on insects and zooplankton. Ninespine Sticklebacks occur in similar areas and feed on insects and crustaceans. Lake Chub has a similar diet but also feeds on algae (BHP Billiton Diamonds Inc. & Dia Met, 1995; Scott & Crossman, 1973). Goldeye grows to larger size, its diet includes other small fish and it is adapted to turbid conditions in warmer and shallow water. It is an important species along the south shore of Great Slave Lake (McCart, 1986; McCart & Den Beste, 1979). Yellow Perch has a similar diet and is also limited to warmer but less turbid lake waters in the upper part of the Mackenzie basin where it occurs in small numbers (its range also coincides with more abundant populations of Walleye). Slimy Sculpins are adapted to colder waters and occur in streams and in lakes to depths of 30 m or more. The Four-horned Sculpin is a widely



distributed glacial relict species and may be present to depths greater than 350 m. It is also widespread in the marine environment but it is not migratory. Both sculpins are bottom feeders (McCart, 1986; McCart & Den Beste, 1979). Longnose Suckers are larger bottom feeders. They are present to moderate depths and widely distributed in most of the WKSS area.

The juveniles of many fish species feed on zooplankton of various sizes but they are also subject to cannibalistic feeding by adults of their own species. Juveniles tend to be distributed peripherally, especially in large lakes, where mergansers and terns may be important predators. However, survivors grow rapidly to join the population of adult fish.

Boreal Smelt and ciscoes are key plankton feeders in many lakes and rivers (Zoltai *et al.*, 1980). The Arctic Cisco is widely distributed in the lower parts of many rivers, along the coast between the Mackenzie River and the Kent Peninsula, and along much of the southern part of Victoria Island (McCart, 1986; McCart & Den Beste, 1979). The Least Cisco is present in mainland rivers and lakes, and extends south to Point Lake in the Coppermine River drainage and to Contwoyto Lake in the Burnside River drainage (BHP Billiton Diamonds Inc. & Dia Met, 1995; Ellis, 1962; McCart, 1986; McCart & Den Beste, 1979). The Lake Cisco occurs throughout the WKSS area, except in the coastal areas north of Contwoyto and Dismal lakes and north of the Great Bear Lake drainage. Some populations of ciscoes may migrate within drainage basins and spawning tends to occur on sand or gravel in tributary areas. In some shallow lakes, benthic algae and periphyton may also provide a significant part of the diet for migratory coregonids, particularly anadromous ciscoes (Bodaly *et al.*, 1989).

The Inconnu is a major predator of smaller fish and is present in much of the Mackenzie River drainage, including Great Bear Lake and Great Slave Lake. This species is anadromous in the lower reaches of the Mackenzie River and both freshwater and anadromous forms are migratory (Bodaly *et al.*, 1989; Howland *et al.*, 2000; McCart, 1986; McCart & Den Beste, 1979). Inconnu are relatively fast growing and spawn in areas of fast flowing water. In the lower Mackenzie drainage, spawning may be 6 weeks earlier than at the southern limit of its range (Howland *et al.*, 2000). Inconnu from the lower Mackenzie make extensive use of the delta for feeding and overwintering but there is little mixing with upstream stocks. Few Inconnu in the Lower Mackenzie move above Norman Wells and those in the Liard River remain below Great Slave Lake (Howland *et al.*, 2000). Inconnu that feed and overwinter in Great Slave Lake, move into the Slave River during late August and September. They spawn in the Fort Smith area during October and return to the lake in November. Inconnu also migrate into the Buffalo, Little Buffalo, and Taltson rivers, and some upstream migrations may be barrier-limited (Howland *et al.*, 2000).

Walleye is another predatory species. Its preference for warmer (and more turbid) waters restricts it to areas south of the tree line. Its abundance generally increases within the Boreal climate zone

(Scott & Crossman, 1973). Walleye are present throughout much of the Mackenzie drainage basin but abundance is low in Great Bear Lake and to the north of it. The most significant populations of this species are present in Great Slave Lake (excluding McLeod Bay and Christie Bay), Lac Grandin, Lac la Martre, Kakisa Lake, Tathlina Lake and in the Taltson River (Bodaly *et al.*, 1989; McCart, 1986; McCart & Den Beste, 1979). Walleyes spawn on coarse bottom sediment soon after ice break-up. Northern Pike occur throughout the mainland. They also prefer warmer and shallower lake waters, and their diet consists mostly of small fish. Northern Pike spawn after ice break-up, in weedy nearshore areas. Arctic Graylings are generally slow growing and spawn in small tributaries shortly after break-up. They are present in many mainland rivers and streams, and some lakes. Their diet includes small fish, stream drift and surface insects. In Great Slave Lake, Arctic Graylings are present mostly along the rocky northern shore.

Three species of whitefish are present (Bodaly *et al.*, 1989; Healey, 1975; Healey, 1980; McCart, 1986; McCart & Den Beste, 1979; Muth, 1969). The Broad Whitefish is present in the Mackenzie River, north from Fort Simpson and in the coastal drainage of mainland streams, but it is not present on Victoria Island. Round Whitefish and Lake Whitefish occur throughout most of the region, but the Round Whitefish is absent on Victoria Island. All of these whitefish species are cold-adapted but Lake Whitefish and Round Whitefish tend to be separated, within lakes, by their preferences for feeding on different benthic communities. Though both species include small molluscs and benthic invertebrates in their diet. Round whitefish occur mostly at shallow depths. Lake Whitefish are dominant in large lakes and optimum growth rates occur in areas with a climate equivalent of about 890 to 1220° C degree days. Whitefish spawn on coarse bottom materials in cooling near-surface waters before ice begins to form.

Lake Trout is the most widespread fish species in the region (Bodaly *et al.*, 1989; Johnson, 1973; 1976; McCart, 1986; McCart & Den Beste, 1979; Rawson, 1951; Scott & Crossman, 1973). It is long-lived (to 60 years or more) and can grow to be one of the largest fish (to 0.5 m or more) in the WKSS area. The species takes longer to mature with increasing latitude. For example, first spawning may not occur until 12-14 years old, as in Great Bear Lake (McCart & Den Beste, 1979). It uses a wide variety of food sources, with preference for amphipods and mysids, and small fish, and prey size increases as the fish gets bigger. Where available, ciscoes may form much of its diet. Lake Trout disperse widely to overwinter, and may move 100 km or more in some river-lake systems (McCart & Den Beste, 1979). At break-up, they may concentrate to feed in surface waters. Lake Trout move to deep water as surface waters warm (above 10° C). Spawning occurs on coarse material in shallow water, usually in late September or during October.

Arctic Char (Ellis, 1962; McCart, 1986; McCart & Den Beste, 1979; Muth, 1969; Robertson & Dowler, undated; Scott & Crossman, 1973) occur both as landlocked populations (*e. g.* Keyhole Lake, Victoria Island) and as anadromous populations (*e. g.* Nauyuk Lake, Kent Peninsula).

Anadromous populations grow faster because their diet is enriched with marine organisms. Arctic Chars are particularly adapted to severely changing stream conditions and, in freshwater, their diet is composed mostly of insects and crustaceans. The anadromous habitat of Arctic Chars may be limited in parts of Coronation Gulf and Bathurst Inlet, by physical constraints such as falls or rapids (*e. g.* Tree River (Robertson & Dowler, undated)). Arctic Char spawn in shallow water on coarse bottom materials shortly before ice begins to form.

Burbot is a cold water species that occurs to depths of 100 m or more and is an important predator in most large lakes and rivers in the region (McCart, 1986; McCart & Den Beste, 1979; Scott & Crossman, 1973). Burbot feed on whitefish, ciscoes, sculpins, sticklebacks, mysids, amphipods and small molluscs).

Because of energetic constraints, populations of some fish species may not spawn every year or spawning may not occur in the same year as an anadromous return. This reflects limited food supply and an inability to convert sufficient energy into reproductive materials (McCart, 1986; McCart & Den Beste, 1979). For example, Arctic Char and Lake Trout may spawn every other year or once in every three years at some high latitude sites. In addition and across much of the WKSS area, constraints in food supply may be reflected by seasonal variations in diet and trophic relationships (Little *et al.*, 1998). Many species of fish are opportunistic feeders. For example and in place of their preferred diet or dominant food source, some invertebrate feeders consume small fish and some plant material. Northern Pike may include rodents, snakes and small birds in their diet (Little *et al.*, 1998). In the Lower Slave River, there are some dietary overlaps between Walleye and invertebrate feeders during the spring, and between Walleye and northern Pike during the summer. Several benthic invertebrate feeders also have dietary overlap during the spring and summer but, in most species, feeding declines rapidly during the fall. Shallow water prey species include Emerald Shiner, Ninespine Stickleback, Troutperch, and y-o-y (young of the year) Lake Chub, Goldeye, Lake Whitefish, Longnose Sucker, Northern Pike and Walleye. Deepwater prey species (particularly during the spring) include Arctic Lamprey, Burbot and Lake Chub (Little *et al.*, 1998).

In terms of human use, the most important fish species are Northern Pike, Broad Whitefish, Lake Whitefish, Round Whitefish, Lake Trout and Arctic Char. Arctic Graylings have been a part of the domestic fishery (McCart, 1986; McCart & Den Beste, 1979).

Unlike the marine environment, most mammals (excluding humans) are not significant top predators in lakes and rivers, and otters and muskrats are largely limited to areas south of the tree line.

#### **2.3.3.3. *Birds of the Freshwater Areas***

Open water is crucial for staging ducks, and many lakes provide an important migratory corridor

north to the shores of Coronation Gulf and Bathurst Inlet, and across to Victoria Island (Alexander *et al.*, 1991; BHP Billiton Diamonds Inc. & Dia Met, 1995; Bromley & Buckland, 1995; Bromley & Stenhouse, 1994; McCormick & Bromley, 1990). During the spring migration, between mid-May and early June, a total of 65,000 birds of 34 species have been reported south from Yellowknife to the Beaulieu River (Alexander *et al.*, 1991; Bromley & Buckland, 1995; Sirois & Cameron, 1989). These include Greater Scaup and Lesser Scaup and Canada Goose which, together, make up nearly half of all the birds observed; Mallard and Tundra Swan, each about 10% or more of the birds present; Surf Scoter, American Widgeon, Northern Pintail and Lesser Snow Goose, each about 5% or more of the birds present; and small numbers of Red-breasted Merganser, Common Loon, White-winged Scoter, and Bufflehead. The north shore of Great Slave Lake is also a major stop-over for spring migrants, with 90,000 birds of 29 species recorded in some years (Alexander *et al.*, 1991; Bromley & Buckland, 1995). Inland, in the Artillery Lake area (Alexander *et al.*, 1991; Sirois & McCormick, 1991), surveys have reported 39,000 to 49,000 waterfowl (70% geese, but with large numbers of ducks and tundra swans). Other important staging areas include the Slave River delta, the Mackenzie River near Fort Providence, and the Snowdrift and Thelon rivers (Alexander *et al.*, 1991; McCormick *et al.*, 1990). At these sites, geese and many ducks feed on over-winter berries and the green shoots of sedges. Berries on exposed hilltops and south-facing slopes of upland tundra provide particularly important spring feeding sites for geese. Diving ducks feed on insects, crustaceans, molluscs, and small fish.

### ***Important Bird Areas***

Important Bird Areas are sites that provide essential habitat for birds in Canada. The designation of Important Bird Areas has been developed through the collaboration of the Canadian Nature Federation and Bird Studies Canada<sup>2</sup> and is linked to parallel programs in the U.S. and Mexico. The goal of the program is to identify and conserve a network of sites to ensure the long-term viability of naturally occurring bird populations<sup>3</sup>. Although a total of 17 Important Bird Areas are in the NWT, only two Important Bird Areas are present in the WKSS, both on the shores of Great Slave Lake. The importance of the areas is determined by the number of species that visit the site, and how significant the number is globally and continentally for the species. The Important Bird Areas on Great Slave Lake fall within the migration routes of several waterfowl species that use the areas for staging in spring and fall but also provide nesting habitat for several species during the summer. Combined, the two sites provide a significant portion of the habitat globally for 3 species of waterfowl and congregatory species and continentally for 2 congregatory species.

### ***South Shore Great Slave Lake Important Bird Area***

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<sup>2</sup> <http://www.bsc-eoc.org/iba/IBAsites.html>

<sup>3</sup> <http://www.bsc-eoc.org/iba/ibacriteria.jsp>

This Important Bird Area covers a relatively small area (425 km<sup>2</sup>) but supports sizeable populations of lesser snow geese, tundra swans and waterfowl during spring and fall migration (Table 2). The area includes the Slave River delta and shoreline. The number of tundra swans reported in 1979 represents over 3% of the North American population. The delta provides habitat for numerous breeding ducks, such as lesser scaup, mallard and blue-winged teal. The numbers of tundra swans and lesser snow geese during spring and fall migration exceed the Important Bird Area threshold for global significance since they represent a significant portion of the global population. A major concern of this Important Bird Area is the loss of fluctuations of water levels caused by the damming of the Peace River near its source.

**Table 3 Summary of major bird species observed in the South Shore Great Slave Lake Important Bird Area.**

| Species                         | Season           | Number               | Criteria of Significance | Date        |
|---------------------------------|------------------|----------------------|--------------------------|-------------|
| Lesser Snow Geese (white phase) | Spring migration | 23,520 ind.          | Global                   | 1983        |
| Shorebirds                      | Fall migration   | 3,000 ind.           |                          | 1979        |
| Tundra Swan                     | Fall migration   | 7,700 ind.           | Global                   | 1979        |
| Tundra Swan                     | Spring migration | 4,200 - 5,400 ind.   | Global                   | 1979 - 1983 |
| Waterfowl                       | Breeding         | 5,200 pairs          | National                 | 1978        |
| Waterfowl                       | Fall migration   | 17,080 ind.          | Continental              | 1979        |
| Waterfowl                       | Spring migration | 21,000 - 73,200 ind. | Global                   | 1979 - 1983 |

Source: IBA Canada (2004)

#### *North Arm, Great Slave Lake Important Bird Area*

The Important Bird Area on the North Shore of Great Slave Lake covers an area of about 1100 km<sup>2</sup> and consists of a number of freshwater rivers and marshes, as well as islands and bays along the shoreline of Great Slave Lake. The area is an important area for northward-migrating waterfowl, particularly during late spring. Waterfowl may number over 100,000 in the spring. Part of the Important Bird Area designation is from the area supporting a large portion of the global population of Short-grass Prairie Canada Goose and waterfowl (Table 3). In addition, a large proportion of the national populations of Black tern and scaup species also migrate through the region. The forests of the region are productive for breeding boreal ducks, and gulls and terns nest on islands during the summer.

## Waterfowl Surveys

The Canadian Wildlife Service and the U.S. Fish and Wildlife Service conduct the Waterfowl Breeding Population and Habitat Survey across North America every year to determine the breeding success of waterfowl in all major nesting habitats. The data are used to set harvest rates of the individual species for the fall of the year. Surveys have been conducted for about 50 years during June and July because the prairies and the NWT are major contributors to waterfowl numbers (CWS 2006; U.S. Fish and Wildlife 2006a).

**Table 4 Summary of major bird species in the North Arm, Great Slave Lake Important Bird Area**

| Species                                  | Season                   | Number           | Criteria of Significance | Date of Survey |
|------------------------------------------|--------------------------|------------------|--------------------------|----------------|
| Arctic Tern                              | Breeding                 | 300 pairs        |                          | 1986           |
| Black Tern                               | Summer<br>(non-breeding) | 300 ind.         | National                 | 1989           |
| Canada Goose<br>(Short Grass<br>Prairie) | Spring<br>migration      | 20,500 ind.      | Global                   | 1990           |
| Caspian Tern                             | Breeding                 | 77 pairs         |                          | 1986 - 1987    |
| Common Tern                              | Breeding                 | 300 pairs        |                          | 1986           |
| Northern Pintail                         | Spring<br>migration      | 5,700 ind.       |                          | 1990           |
| Scaup species                            | Spring<br>migration      | 12,000 ind.      | National                 | 1990           |
| Surf Scoter                              | Spring<br>migration      | 1,280 ind.       |                          | 1990           |
| Tundra Swan                              | Spring<br>migration      | 584 - 2,050 ind. |                          | 1986 - 1990    |
| Waterfowl                                | Spring<br>migration      | 100,000 ind.     | Global                   | 1990           |

Source: IBA Canada (2004)

There are two transects (Strata 16 and 18) in the surveys that overlap the southern portion of the WKSS area and hence give a good record of the numbers and species of waterfowl present over the last 50 years. Stratum 18 covers the Slave River and delta and the two Important Bird Areas in Great Slave Lake (Figure 15). Stratum 16 covers the eastern arm of Great Slave Lake and extends to the eastern portion of Great Bear Lake. Together, the two areas provide detailed

information on the status and availability of waterfowl in the area.

The 2006 survey reported that the conditions for waterfowl habitat throughout much of the NWT were good, with some areas in the western and southern NWT only fair because of dry conditions (Wilkins et al. 2006). When the southern portion of the NWT was surveyed in early June all wetlands were ice-free, and the spring was about two weeks earlier than normal (U.S. Fish and Wildlife 2006a).

The survey reported good populations of dabbling and diving duck in the WKSS sections, with abundant scaups and goldeneye (Figure 16). No blue-winged teal, northern shoveller, northern pintail or eiders were present in the area. The most numerous species present were scaups (147,100 in Stratum 16) and scoters (67,000 in Stratum 16). Total ducks numbered 554,000 in the two strata, most of which were the diving species (397,000). No Canada geese were observed nesting during the survey. The survey indicates that the southern portion of the WKSS continues to be excellent habitat for nesting waterfowl, although annual changes in precipitation, spring thaw and general climate conditions cause significant variability between years (US Fish and Wildlife 2006a, b; CWS 2006).

The surveys provide excellent long-term monitoring of the populations because the same methods and survey routes have been used for about 50 years. The data provide a good estimate of the availability of many species to resident and subsistence hunters, relative to previous years. Many species are well below their long-term average levels which have been calculated from the first surveys in the 1950s (Figure 17). For example, mallards in northern Alberta and the NWT are about 66% lower than the long-term average, and the northern pintail is 72% lower. Other species, like the canvasback (-71%) and long-tailed duck (-53%) are well below long-term averages for the species. The canvasback, goldeneye and bufflehead are well above the long-term average. Overall, the total number of ducks is about 28% lower than the historic levels while Canada geese remain about the same (Wilkins et al. 2006; U.S. Fish and Wildlife 2006b).



**Figure 15** Strata used by the Canadian Wildlife Service and U.S. Fish and Wildlife Service to annually survey waterfowl breeding populations and environmental conditions in late spring and early summer. Stratum 16 and 18 cover a large portion of the southern section of the WKSS area.

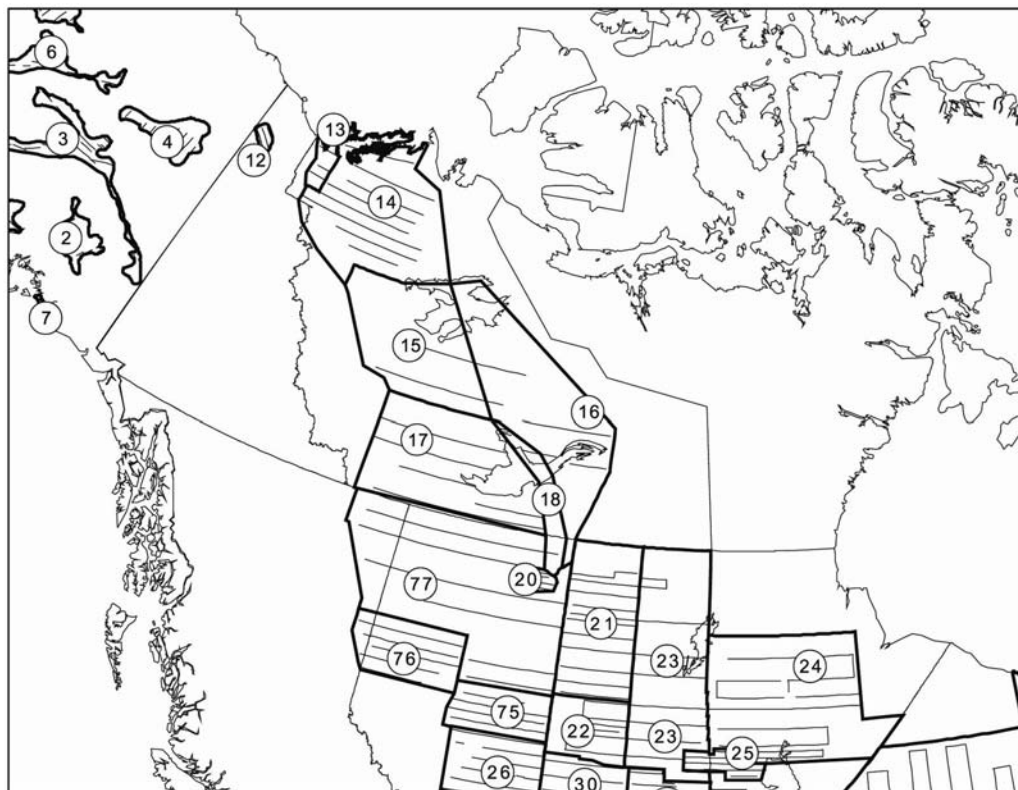


**Figure 16 Summary of numbers of waterfowl during nesting in Survey Strata 16 and 18 that form the southern portion of the WKSS. Zeroes refer to no individuals observed.**

Source: CWS (2006); US Fish and Wildlife (2006a)

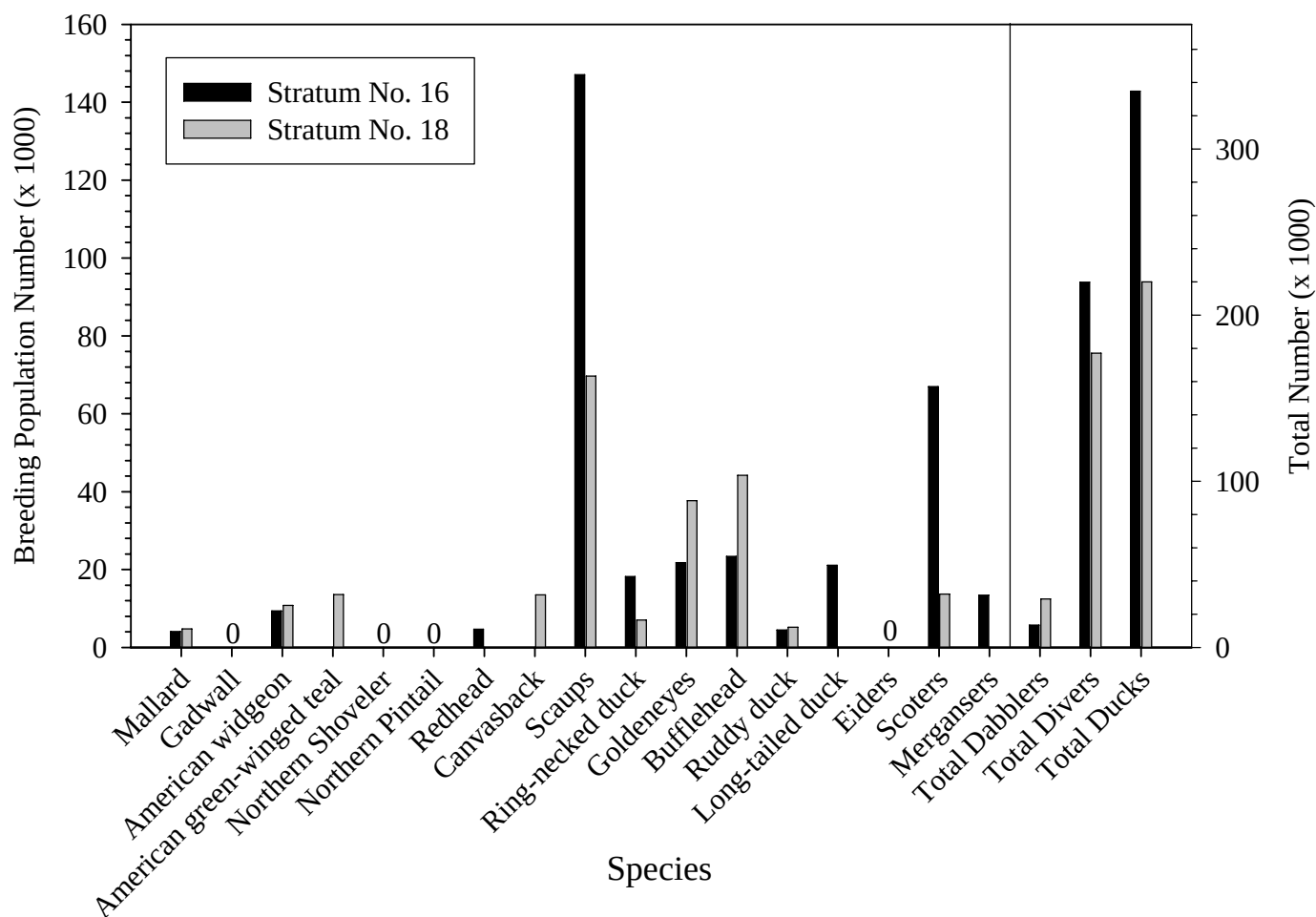
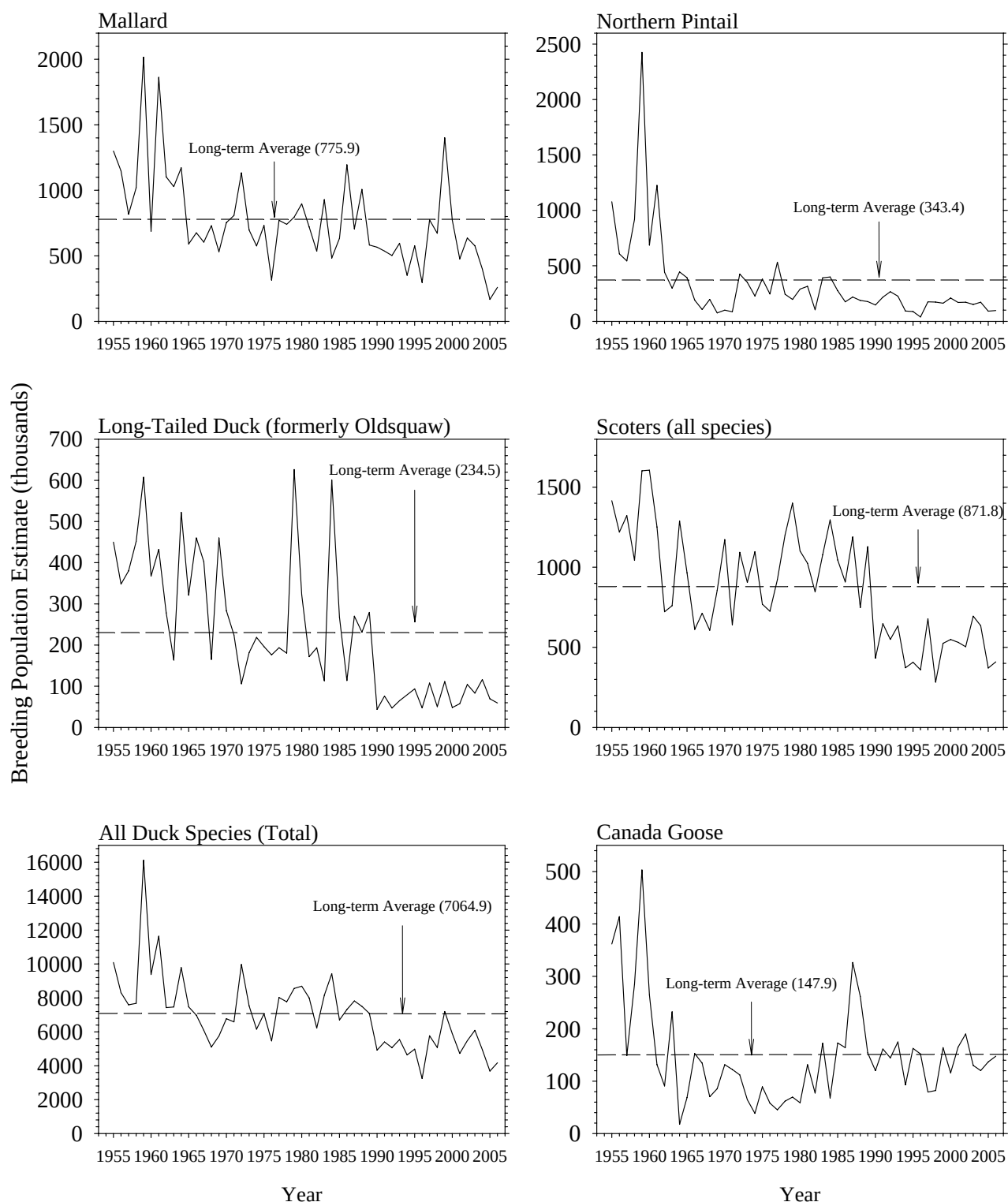


**Figure 17 Long-term trends of major waterfowl species in the NWT and northern Alberta. Long-term averages have been calculated since 1955.**



Source: Wilkins et al. (2006)

#### **2.3.4. Terrestrial Ecosystem**

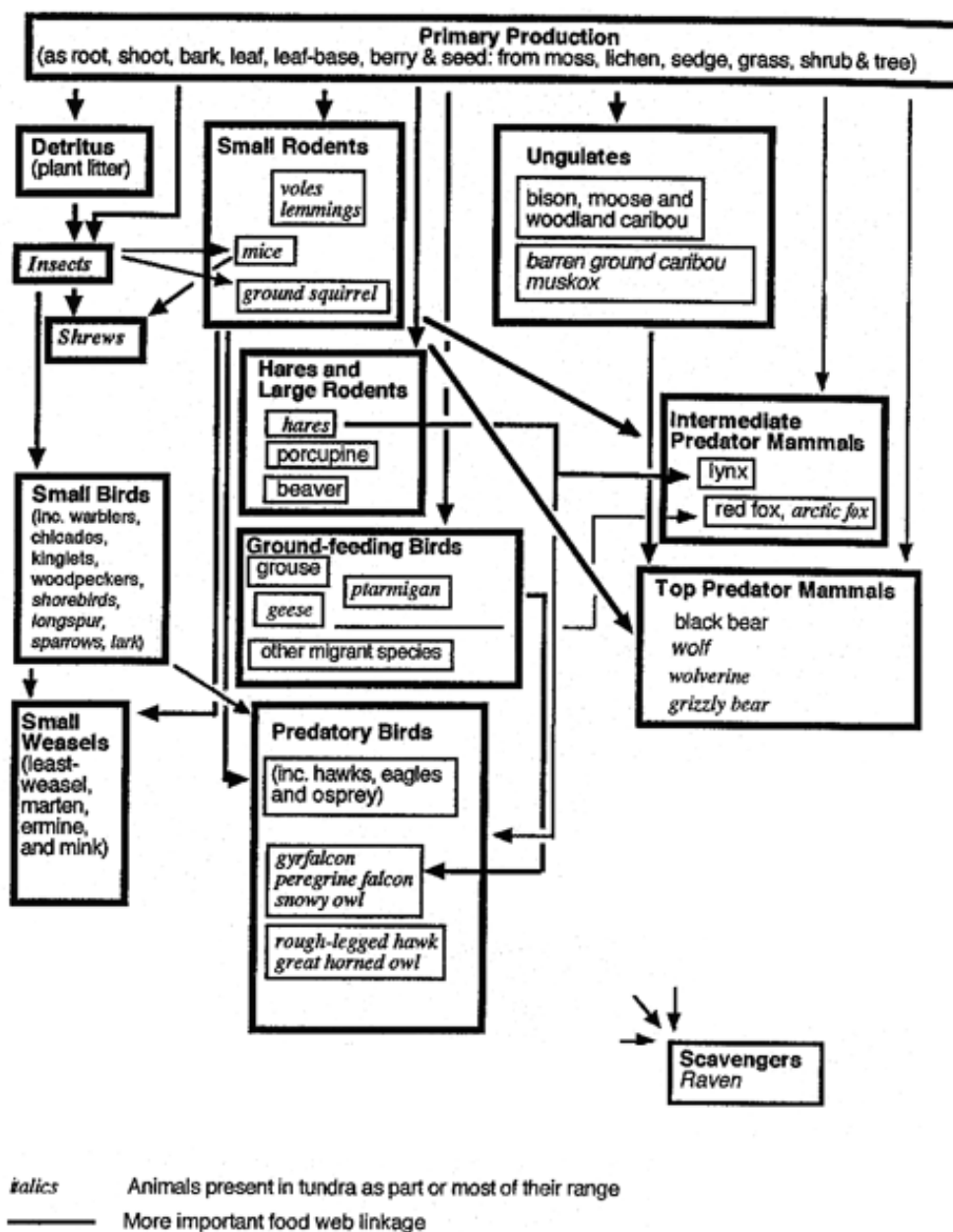
Climatic conditions are most extreme in the terrestrial environment and adaptations in terrestrial ecosystems also tend to be more pronounced than those in marine and freshwater ecosystems. Many plant and animal species are not present over all of the WKSS area, and several plants are unique in their adaptation to low temperature and an extremely short growing season (Billings, 1992). Often plants are present only in dwarf form at the northern part of their range. Figure 18 provides a general summary of the terrestrial food web in which insects (many with early life stages in aquatic forms), mammals, and birds are the dominant groups. Many food chains are short and link plants, insects and birds, or plants and different groups of mammals.

The 2001 SOK report (Sly et al. 2001) provides a good overview of the general biology of the wildlife in the WKSS. Species such as barren-ground caribou and moose are valuable traditional food species in some parts of the WKSS while others (e.g., wolves, grizzly bears) are significant predators of game animals and occupy the important top predator role in the ecosystem. The large predators are often termed “umbrella” species because they are good indicators of the “health” of the overall system and require large areas of undisturbed habitat to maintain populations.

Relatively little scientific information or recorded TK relating to wildlife in the WKSS was available until the WKSS-funded studies in the late 1990s. Some background studies on major species like caribou, moose and muskox were available as part of larger studies on the species in the NWT, which included the eastern Arctic at that time. Studies submitted as part of the earlier WKSS program included studies of the summer movements (Gunn et al. 2001) and the nutrition available to caribou on the calving ground (Griffith et al. 2002) of the Bathurst herd, summer behaviour of caribou near the Lupin mine (Gunn 1998), vegetation reclassification in the WKSS (Matthews et al. 2001), grizzly bear nutritional ecology (Gau and Case 1998) and habitat selection (McLoughlin et al. 1999). A significant part of the WKSS studies was the recording of TK about barren-ground caribou (e.g., reports by the Dogrib Treaty Council 2001 and on the Tuktu and Nogak Project recorded by Thorpe et al. 2001). Data for the 2001 SOK were taken largely from WKSS studies, reports from GNWT Environment and Natural Resources (ENR; formerly RWED) and the scientific literature. Information for the WKSS is unique in that it combines scientific data with TK studies to understand the status of the populations within region.

Since the 2001 SOK review, several major studies have been completed, both within and outside the NWT. In 2002, a review of information available for the Bathurst herd was prepared for the North Slave Metis Alliance (Gartner Lee Ltd 2002).

Figure 18 Simplified food web of the terrestrial ecosystem



An overall five year strategy for the management of caribou herds was released by ENR (2006). This partnership between federal and territorial agencies and new aboriginal organisations created under the land claims agreements is resulting in renewed interest in the status of wildlife within the land claims areas and the development of new projects which will be conducted in the next few years. It also assists in the incorporation of TK into management decisions relating to resource land use issues.

Studies outside the NWT include a number of assessments on the cumulative effects of development on caribou on the North Slope of Alaska (NAS 2004) and reviews of the impacts of developing the area over the last 40 years. Individual wildlife species, and the impacts of development, have also been widely studied in northern Alaska (e.g., see papers in Truett and Johnson 2000). These studies provide important information for the potential changes caused by mines and other developments such as roads and expanded communities.

#### *2.3.4.1. Nutrients and Plant Growth*

Plant growth occurs within the active layer of soil, in which some seasonal decomposition occurs. Climate has a strong effect on below-ground tundra soil respiration and CO<sub>2</sub> release during both winter and summer, but vegetation type is of greatest influence during the summer (Grogan & Chapin, 1999). In winter, most litter degradation occurs at the beginning and at the end of the season when soil temperatures are -5° C or warmer. This is enhanced by early snowfall (providing moisture and thermal insulation). Vegetation type affects the quality of litter. Depending on soil and vegetation type, 25 to 50% of annual CO<sub>2</sub> production from soil degradation may occur during the winter period (Grogan & Chapin, 1999). Simple models of C and N interactions between plants and soils with a closed N-cycle show convergence. That is, rapid plant growth with highly efficient N-use results in litter with a high C:N ratio but a low rate of mineralization. Slow plant growth with poor N-use efficiency results in litter with a low C:N ratio but high mineralization rate (Tateno & Chapin, 1997). Seasonal dynamics of tundra litter and soil are similar and N availability to plants is likely greatest at snowmelt. However, if soil temperatures are too low for active root growth or microbial activity, much of the available N is probably lost in runoff to aquatic systems. This is consistent with N-limitation observed in tussock tundra (Hobbie & Chapin, 1996).

Growth is nutrient limited in most high latitude areas, especially by the availability of nitrogen (Billings, 1992). Generally, about half of the nitrogen requirements are met by N-fixation from the atmosphere and precipitation provides an important additional source. Cyanobacter are major N-fixers. They are present both as free living bacteria at the soil surface and as symbionts in lichen (Chapin & Bledsoe, 1992). Lichens appear to be little specialized for temperature. Although optimum conditions for N-fixation are 15 to 25° C, some nitrogenase activity can occur at temperatures just below freezing (Chapin & Bledsoe, 1992). Snow Fleas can be an important consumer of vegetation and soil fungi, contributing to soil formation in woodland

areas (Bastedo, 1999). However, most decomposition occurs as a result of bacterial action and, relative to soils in more temperate climates, other forms of soil biota are mostly lacking.

Decomposition rates are slow and nutrient turn-over times are long. In wetter soils considerable quantities of nutrients are held in only partly decomposed organic matter and may become lost in permafrost. Although microbial respiration is measurable below freezing, cellulose degradation occurs mostly above 10° C (Nadelhoffer *et al.*, 1992). Rates of litter decomposition are greatest for deciduous shrubs and grasses, lower in evergreens, and they are least in mosses, lichens and woody tissues. Symbiotic relations exist between some fungi and the roots of higher plants. In mycorrhizal networks of Arctic soils, fungal activity in the roots of plants produces compounds of nitrogen and phosphorus that can be used as nutrients by the host plant. Carbohydrates produced by the host plant are used by the fungi. *Sphagnum* moss derives much of its nutrient requirement from percolating water (Tenhunen *et al.*, 1992). As Arctic soils age and thicken, the distance from the mineral horizon may become critical, especially for the availability of phosphorus. Coastal salt marshes occur rarely along the Arctic shoreline (particularly because of ice-scour) but, where present, phosphorus is more available and plant productivity may be much greater than on the surrounding land area (Chapin & Bledsoe, 1992).

Plants place a heavy demand on nutrient availability early in the season, and phosphorus supplies can be severely depleted within the first two weeks of plant growth (Kielland & Chapin, 1992). Phosphorus cycling may occur as much as 200 times and nitrogen cycling as much as 10 times in a growing season (Nadelhoffer *et al.*, 1992). High nutrient demands at the start of the growing season and frequent nutrient cycling are not peculiar to Arctic and sub-Arctic plants. However, the conditions under which they occur (short growing season and very limited nutrient supply) present special difficulties, and adaptations occur in several species of plants. For example, extensive surface or near-surface root mats allow plants to absorb nutrients from large areas and to avoid root saturation in wet soil. Adventitious rooting, such as from the roots or stem in Black Spruce (“candelabrum” spruce), can also compensate for root death due to increased soil saturation (*e. g.* rising water level) or nutrient and moisture competition from surrounding ground cover (*e. g.* *Sphagnum*).

Over most of the WKSS area, plant production is dependent on conditions during at least two growing seasons. The number of buds that form depend on conditions in one season and their growth depends on conditions in the following season (Wielgolaski *et al.*, 1981). At the end of each growing season, deciduous plants move carbon and nutrient resources from leaves to storage in stems and roots, or swollen leaf-bases (Berendse & Jonasson, 1992). These reserves provide a key source of energy to support rapid development at the very start of the next growing season (Kielland & Chapin, 1992). Evergreens store carbon and nutrients in leaves and shoots above ground. They continually remobilize them from senescing tissue throughout the growing season. Winter tissue loss may be critical to the survival of evergreens. Carbon is stored mostly

as polysaccharides (such as starch) in lichens and mosses, and as sugars in shrubs.

#### 2.3.4.2. Plant Distributions

Globally, climate is the dominant control on what and where plants can grow, and both physical and chemical conditions greatly influence vegetation type and form (Bliss & Matveyeva, 1992; Kielland & Chapin, 1992; Wielgolaski, 1981; Wielgolaski *et al.*, 1981). The seasonal time available when temperatures are sufficient to support plant growth is particularly important. There is a general relationship between mean annual temperature and the number of species of vascular plants. Based on general latitudinal relationships, diversities of about 100 plant species (per 10,000 km<sup>2</sup>) may be present in the Cambridge Bay area and more than twice this number around Yellowknife (Billings, 1992). At high latitudes, vascular plants become progressively less important in plant communities. The proportion of below-ground to above-ground plant tissue increases with the severity of climate (Wielgolaski, 1981; Wielgolaski *et al.*, 1981). Underground rhizomes provide plant storage and vegetative propagation in monocotyledons. Their erect and blade-like leaves are well suited to capture low-angle solar radiation in the tundra environment. Tap roots, as in some species of forbs, provide another means of plant storage. Low spreading cushion-plants (*e. g. Dryas* sp.) are typical of more windy and exposed tundra locations. Above the tree line, dwarfism occurs in several species of vascular plants (Wielgolaski, 1981; Wielgolaski *et al.*, 1981).

Deciduous plants have higher photosynthetic rates than evergreens and maximize growth above ground, and are therefore more sensitive to light shading (Sveinbjornsson, 1992). Soil temperature is usually more important than air temperature, especially for deciduous plants. Moisture is very important for both deciduous and evergreen plants. It may restrict the number of species capable of establishing themselves in a given area. Saturated and acidic soils generally favour the growth of *Sphagnum* moss, and tussock sedge develops in moist but less saturated conditions (CCELC., 1989, Nadelhoffer *et al.*, 1992; Wielgolaski, 1981; Wielgolaski *et al.*, 1981, ESWG 1996). Lichens are more competitive in areas where soil moisture contents are low, such as in rocky or well drained areas. They are also competitive where conditions are windy and summer drought occurs, or where most of the biomass of vascular plants is below the ground surface (Wielgolaski, 1981; Wielgolaski *et al.*, 1981). Crustose lichens colonize many forms of bare substrate, often as a thin film of brightly coloured organic matter on bare rock. Under more favourable conditions, foliose lichens form thicker and slab-like forms. Fruticose lichens are more plant-like in appearance and may grow to a height of several centimetres. Several species of this form provide important grazing for caribou. In northern boreal forest areas, trees may also provide a substrate for hanging lichens (bearded lichens). Nutrient availability can be an additional influence that favours selected species. Evergreens have lower absorption rates and Black Spruce are tolerant of nutrient-poor and light-shaded conditions. White Spruce are more competitive where nutrients and shade are less limiting.



Vegetation differs in each of the two major ecozones that comprise the WKSS (ESWG, 1999). The Southern Arctic Ecozone is characterized by treeless tundra. This zone covers the area north of a line running from the headwaters of the Lockhart drainage to the mouth of the Coppermine River, then generally westwards towards the northern limit of the Great Bear Lake drainage. Wet meadows of cottongrass, sedge and grass are typical of sedge tundra, and tussock tundra forms in areas where standing water may occur early in the growing season. Organic soils develop in poorly drained areas of sedge and tussock tundra. Elsewhere, Alpine or Bog Bilberry, Labrador Tea and Lingonberry (Rock Cranberry or Cowberry) are typical of areas with moist and acidic soil. Shrub tundra is typical of sheltered sites with both good drainage and sufficient moisture. Where protected from the wind, as on esker slopes and river banks, Green Alder, birches and willows may grow to as much as 2 m in height. Dwarf shrub tundra occurs over well drained but exposed upland areas where vegetation is typically comprised of Dwarf Birch, Crowberry (Curlewberry), Bilberry, Alpine and Red Bearberry and Narrow-leaved Labrador Tea. Mountain Avens occurs on thin gritty and generally non-acidic soils where winter snow cover is minimal or absent. Herbaceous tundra vegetation is more limited in extent and is characteristic of warm but often frequently disturbed sites. For example, where soil movements are due to slope failures and creep or animal denning, as occur along stream banks and the south slopes of eskers. There, plant communities may be enriched with a variety of species including River Beauty, Tundra Wormwood, Liquorice-root, Prickly Saxifrage and Variegated and Water Horsetail (Appendix C).

South of this climatic zone, the Taiga Shield Ecozone supports taiga vegetation (ESWG, 1999). This typically includes open conifer stands of Black Spruce, Tamarack and White Spruce. At lower levels, ground cover includes Dwarf Birch and willow, Labrador Tea, cottongrass, moss and lichen. Drier sites favour White Spruce and low covers of Lingonberry, Common Bearberry, Crowberry, Dwarf Birch, moss and lichen. Sedge tussock and *Sphagnum* moss predominate in poorly drained areas. Balsam Poplar, White Spruce and Paper Birch occur in more sheltered river valleys. To the west of Great Slave Lake, slightly warmer winter temperatures and increased precipitation favour increasing tree size and vegetation cover. The tree line approximates much of the taiga-tundra boundary north of the Lockhart River drainage. The rest of the region lies within the Boreal climate zone (CCELC, 1989) in which forest cover is generally closed and where the dominant tree species are Black Spruce, Jack Pine (over rocky and sandy soils), and some Paper Birch. The lower cover is comprised of feather moss, Bilberry, Labrador Tea, Lingonberry and lichen. White Spruce is a climax species but it may be poorly represented where there is frequent reoccurrence of fire. Balsam Poplar, and Trembling Aspen are characteristic of warmer but moist sites. Over poorly drained areas, Black Spruce, Tamarack, Labrador Tea, Bilberry, Bog Rosemary, and Cloudberry predominate.

Northern ponds age over very long periods of time, in part by the addition of sediment but mostly by the accumulation of dead and partly decayed plant material. Slowly, the processes of

accumulation begin to form a bog or fen. Tundra bogs and fens lack trees and may consist mostly of mosses, sedges, and low shrubs. Boreal bogs and fens, however, are characterized by large carpeted areas of wet and spongy *Sphagnum*, sedges, and conifers (CCELC., 1988; 1989). Black Spruce is common in more southerly areas. Bogs are more lacking in nutrients than fens. Sedge and Black Spruce associations are typical of areas at the outer edge of a bog, where inflowing water carries some mineral-derived nutrient from the surrounding areas (CCELC., 1988; Damann & French, 1987; Glaser, 1987). *Sphagnum* and Black Spruce associations are typical of the more central parts of a bog, remote from nutrient inputs. Both bogs and fens change over time. For example, as plant materials accumulate and if precipitation exceeds evaporation, the central part may rise relative to the edge. This forms a raised bog and, sometimes, it encloses areas of open water. In large part, this is because *Sphagnum* has a great capacity to absorb and hold moisture. Palsa bogs are also raised but they are usually without water-filled openings. They develop where the accumulation of plant fibre provides enough insulation to accelerate permafrost formation beneath the bog (CCELC, 1989). Over most of the WKSS area, the cover of peatland (both bogs and fens) is less than 5%. But, between Great Slave Lake and Great Bear Lake this may increase to as much as 25% (Tarnocai, 1989).

#### 2.3.4.3. *Insects in the Terrestrial Food Web*

Almost all animals consume plant material in at least part of their diet. Most prefer live material high in nutritive value. For example, chemical energy stored as carbohydrates in leaf-base, roots, berries and seeds, or specific nutrients like protein in plant enzymes (Jefferies *et al.*, 1992). Some insects also feed on living green plant tissue and others derive most of their food from decomposing plant material and associated fungi and bacteria. Many insects prefer deciduous trees and shrubs because they are less protected by natural plant chemicals than evergreen plants (Bryant & Reichardt, 1992). However, some insects like the Spruce Budworm have adapted to evergreen plant defense.

The number of insect species declines northwards across the WKSS area, particularly north of the tree line. About 20,000 insect species are estimated to be present in boreal areas, half that number at the tree line, about 1,000 species at the northern edge of the taiga, and 300 or less in the tundra (Moon, 1970). Many insects spend much of their life-cycle in water which provides a temperature-moderated environment for over-winter survival of eggs and larvae. More than 60 species of blackfly occur in the boreal forest ecozone where most are associated with well oxygenated, clear, and cold stream waters. The blackfly “season” for the adult stage may extend from April to October. Although the number of blackfly species decreases northwards, they are one of the most abundant insects throughout the WKSS area. Mosquito larvae are more typical of pond and slow moving waters. Many insects have special adaptive behaviours. For example, in extreme northern areas, mosquito larvae may bunch together and “follow the sun” to maximize heat-gain (Moon, 1970). In their larval forms, the widespread distributions of stonefly and caddisfly are important in the food chains of many fish species. As adults, they are important in

the food chains of several birds. Caterpillars are an important component of some terrestrial food chains, and boreal forest areas support many species of beetles, butterflies and moths, bees and wasps, and flies. North of the tree line, however, there are no dragonflies or ants, few butterflies, and only one species of bee. Species of the order *Diptera* are the most abundant insects in taiga and tundra areas (Moon, 1970).

#### 2.3.4.4. Parasites in Large Mammals

The study of parasites in large mammals in the WKSS has expanded significantly in the past few years, largely as a result of the effects of the warming climate on the prevalence of parasites such as lungworm in muskoxen (Kutz et al., 2005). The presence of parasites can be a major factor in determining the body condition and overall health of animal populations. For example, a major cause of mortality in some southern moose populations is the presence of the liver fluke (*Fascioloides magna*) and the meningeal (brain) worm *Parelaphostrongylus tenuis* which may cause a continuing decline in the population (Murray et al., 2006). Disease caused by the presence of high parasite loads in individual animals, or high prevalence of parasites in a population, can significantly affect the health and status of the population and reduce the numbers below sustainable levels.

A major thrust of the research on parasites in large mammals is the changing dynamics of the host-parasite systems in the presence of climate change. Some parasites, such as the protostrongylids that parasitize major large mammal species throughout North America, release first-stage larvae in the faeces of the host. These larvae invade an invertebrate intermediate host, such as a snail, develop to the third larval stage and then infect another definitive host (Jenkins et al., 2005). A significant constraint on the transmission of these parasites in the north has been the climate, where extreme temperatures and short growing seasons restrict the transmission of the larvae into new hosts (Kutz et al., 2005). Kutz et al. (2002) studied the development of the larval stage of the muskoxen lungworm *Umingmakstrongylus pallikuukensis* near Kugluktuk, NU and found that the normal time for the parasite to develop from the first to third stage was four to six weeks, and largely depended on the air and soil temperature. The onset of changing climate has increased the rate of development of the intermediate stages and possibly reduced the life cycle of the parasite from two to one year (Kutz et al., 2005). A warmer climate is also expected to help the free-living larval stages and gastropod intermediate hosts. Currently, the prevalence of *U. pallikuukensis* has reached 100% of the muskoxen in some populations (Kutz et al., 2001).

Three examples of parasites that have been recently studied as emerging issues in wildlife are the nematode lungworm (*U. pallikuukensis*) in muskoxen, the sheep lungworm *Protostrongylus stilesi* which has emerged in muskoxen living in range which overlaps with that of Dall sheep, and a nematode that lives in the abomasum of muskoxen and may be an important regulator of the Banks Island muskox population (Kutz et al., 2004). It is expected that wildlife disease caused by these parasites will continue to develop as a major issue in the presence of warming

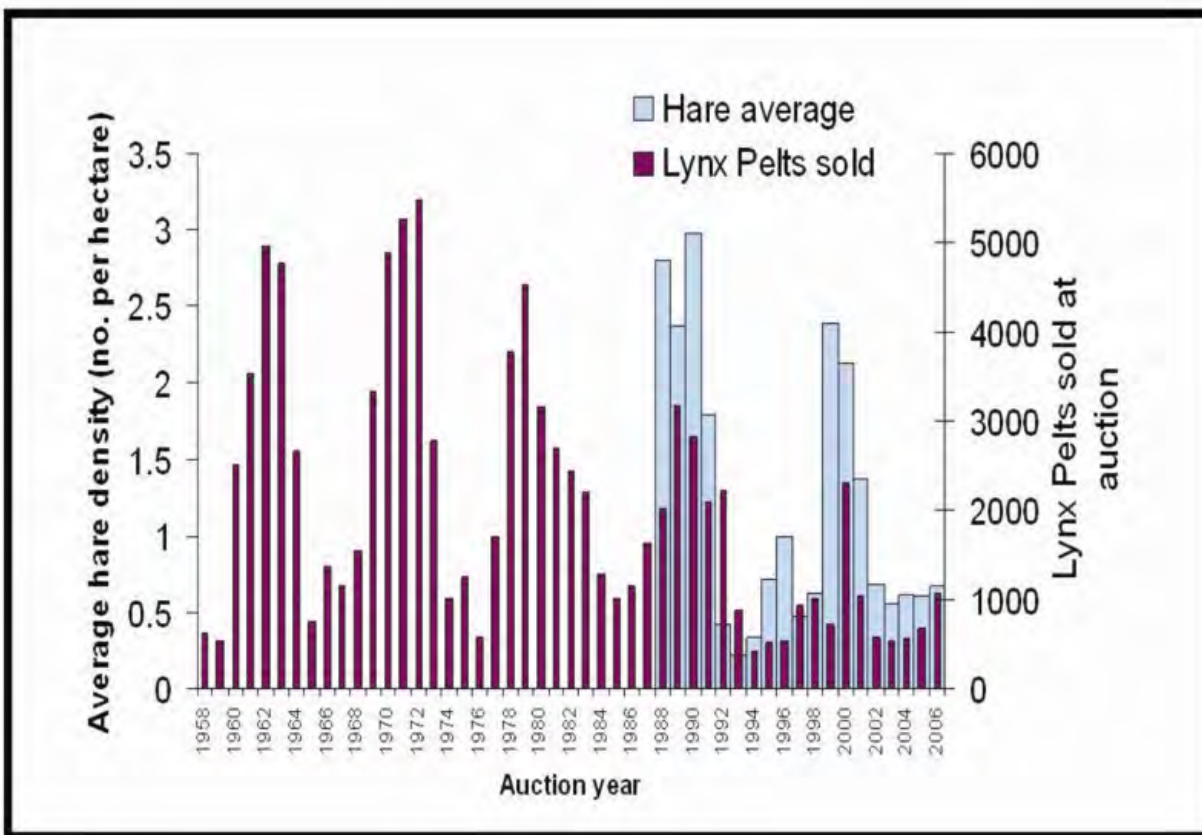
climate since high infestation may result in significant declines in the northern populations of some large mammals (Kutz et al., 2004) .

#### 2.3.4.5. *Small Mammals in the Terrestrial Food Web*

Small mammals are another key component of northern ecosystems and they are widely distributed. Distributions of lemmings, mice, shrews and voles are summarized in Table 5. These are based on summer night trap data from many sites in the WKSS area between 1990 and 1998 (Carrière, 1999). Data are consistent with previous collections (Shank, 1993). As with many plants and animals, several species have developed unique physical and, or, behavioural adaptations to increase survival under the harsh conditions of their environment. For example, the Collared Lemming (Victoria Collared Lemming) is the only rodent to moult (having different summer and winter coats) and the claws on their front feet become modified for winter digging (Engstrom, 1997). Insects (as larval grubs in soil or as adults) form a major part of the diet of shrews. Shrews remain active all year. The diet of Deer Mice, Arctic Ground Squirrels and Northern Red-backed Voles also includes some insects (Engstrom, 1997; Fuller, 1984). Voles (including Meadow Voles, Northern Red-backed Voles, Taiga Voles and Tundra Voles north of the taiga) and lemmings (Brown Lemming, Victoria Collared Lemming, and Northern Bog Lemming) are largely herbivores. They feed mostly on roots, seeds, willow bark, and sedges. Seeds and nuts provide much of the diet of Red Squirrels that occur throughout most forested areas (Collins, 1959; Moon, 1970; Wilkinson, 1970) (Appendix C).

Both Snowshoe Hares and Arctic Hares are herbivores. They feed mostly on grasses, twigs, shrubs and bark. The Snowshoe Hare extends north to the edge of the taiga, and the Arctic Hare is limited to areas north of the tree line. The caloric value of different plant food sources to rodents and hares varies among species. In general, flowering plants are about twice as nutritious as grasses and sedges, and nearly three times more nutritious than mosses (Jeffries *et al.*, 1992). In the NWT, and in the WKSS area, Snowshoe Hare populations have experienced a 9-11 year cycle in numbers since records exist. Numbers have been estimated using the hare pellet method (Krebs et al., 2001) since 1989. Hare cycles have been inferred using fur return data for its main predator, Lynx. In the NWT, peak numbers of Snowshoe Hares have been observed near the turn of each decade (e.g., in years 1979, 1989, 1999) (S. Carriere, pers comm., see Figure 19). In some parts of the WKSS area, densities of Snowshoe Hare have been estimated to exceed 100·km<sup>-2</sup>, 2 to 3 years after a population minimum (Krebs et al., 1987; Poole, 1989; 1992; Poole & Boag, 1988). However, from more recent studies on hares in the Mackenzie Bison Sanctuary, populations ranged from a peak of 5.3 - 6.2·km<sup>-2</sup> (1988-1990) to a low of 0.6 - 1.0·km<sup>-2</sup> during 1992-93 (Poole, 1997).

**Figure 19 Annual Hare cycle for the NWT compared with the annual sale of Lynx pelts at auction**



Source: Figure provided by GNWT Department of Environment and Natural Resources (February 2008; pers. comm. Suzanne Carrière and Francois Rossouw)

Many rodents seem to increase with the availability of plant food but may “crash” with its depletion. However, food supply may not be the only factor influencing these fluctuations and their cause or causes remain uncertain. For example, densities of Victoria Collared Lemmings may vary from less than 100·km<sup>-2</sup> to more than 5,000·km<sup>-2</sup> during a "cycle" (Engstrom, 1997). Populations of small rodents such as voles and lemmings frequently follow a 3 to 5 year "cycle". Their cycles may have a 10-times to 50-times range in abundance (Shank, 1993). Fluctuations in the peak of small mammal populations seem to occur at the same time in several locations. Taiga Shield sites (Yellowknife, Tibbitt Lake and Gordon Lake, Fort Smith shared common population highs in 1998 and 2002. the Southern Arctic sites (Daring Lake) peaked in 1994 and 2002 (S. Carrière, pers. comm.).

**Table 5 Distribution of small mammals in northwest Canada**

| LOCATION               | SMALL MAMMAL SPECIES     |             |                       |             |               |                           |                      |                         |       |
|------------------------|--------------------------|-------------|-----------------------|-------------|---------------|---------------------------|----------------------|-------------------------|-------|
|                        | VOLES                    |             |                       |             | LEMMINGS      |                           |                      | MOUSE                   | SHREW |
|                        | Northern Red-backed Vole | Meadow Vole | Chestnut-cheeked Vole | Tundra Vole | Brown Lemming | Victoria Collared Lemming | Northern Bog Lemming | White-footed Deer Mouse | Shrew |
| Fort Smith             | xxx                      | x           | x                     |             |               |                           |                      | xx                      | xx    |
| Fort Liard             | xxx                      | xx          | x                     |             |               |                           |                      | xx                      | xx    |
| Fort Simpson           | xxx                      |             |                       |             |               |                           |                      | xx                      | x     |
| Norman Wells           | xx                       | x           | x                     |             |               |                           |                      |                         | x     |
| Yellowknife            | xx                       | x           |                       |             |               |                           |                      | xx                      | x     |
| Kugluktuk              | xxx                      | x           |                       | x           |               | x                         |                      |                         | x     |
| Hope Bay               | xxx                      | x           |                       | x           | x             | x                         | x                    |                         |       |
| Melville Sound islands | xxx                      |             |                       |             |               | x                         |                      |                         |       |

Abundance: xxx = dominant; xx = common; x = present

Porcupine occur in the most southerly part of the region. They feed on leaves, twigs and buds in summer, and the inner bark of conifers and poplars in winter (Moon, 1970). Beavers build lodges and dams on ponds and small lakes, or den along the banks of slow flowing streams. They have a preferred diet of deciduous bark. In favourable habitat, their range extends north of the tree line. Dene note in addition to the bark and twigs of willow, poplar and birch, that leaves and stems of a variety of aquatic plants are eaten and food is either eaten on the spot or cached (Johnson & Ruttan, 1993). “Starvation food” for beaver is the inner bark of Tamarack and spruce.

South of the tree line, a number of weasel-like mammals act as key predators of small rodents, the young of small and large rodents and hares, small birds, and the eggs and young of birds. Their diet may also include insects and small quantities of plant material, particularly seeds, berries, and willow (CCELC., 1988; Collins, 1959; Jenness, 1924; Moon, 1970; Wilkinson, 1970)). Marten (American Sable) occurs in wooded areas where voles, mice and hares, and carrion form most of their diet (densities may be about one Marten/2 km<sup>2</sup> or greater). Marten eat fish killed by other animals or that they can catch in shallow water (Johnson & Ruttan, 1993). The occasional squirrel is eaten and so are lemmings. Eggs, berries and roots are also eaten, and Marten are known to cache food (Johnson & Ruttan, 1993). Populations of Marten tend to rise and fall with the availability of hare (Johnson & Ruttan, 1993). Mink are important predators on mice, Muskrats and fish. They are usually found near streams and marshes (densities about two Mink/km<sup>2</sup>). The small Least Weasel is present in open woodlands below the tree line. Ermine (Short-tailed Weasel) is present throughout the region. All are active year-round but population densities are generally low (typically some tens of animals per km<sup>2</sup> in good habitat).

As with some species of aquatic birds, there seems to be evidence for range expansion in small mammals. For example and based on comparison of survey records from the Thelon River valley since the mid-1930's, Beaver, Porcupine, Red Squirrel and River Otter appear to be colonizing new areas (Norment *et al.*, 1999). Likely, “northward” range expansion is occurring in many plant and animal communities, in response to changing climatic conditions.

#### 2.3.4.6. *Birds in the Terrestrial Food Web*

Tree and shrub insects are an essential food for many migratory woodland birds. These include several species of warblers, and also woodpeckers, flycatchers, Boreal Chickadee and Ruby-crowned Kinglet. Insects and seeds from grasses, sedges and shrubs in taiga and tundra areas provide summer food for several species of finches and sparrows. These include American Tree Sparrow, Harris’ Sparrow, Savannah Sparrow, White-crowned Sparrow. Horned Larks and Lapland Longspurs are often the most common migrant birds in northern taiga and tundra (BHP Billiton Diamonds Inc. & Dia Met, 1995; Collins, 1959; Moon, 1970; Wilkinson, 1970). Several other species of perching birds are present in the WKSS area. Recent environmental studies for mine developments are providing information about abundance and habitat use of many species at selected sites (*e. g.* BHP Billiton Diamonds Inc. & Dia Met, 1995; Diavik, 1997). Traditional knowledge studies are further expanding the information base, and recently American Robins and Barn Swallows have been reported as far north as Banks Island (IISD., 2000).

Arctic browsing birds feed extensively on woody and herbaceous matter (Wakelyn *et al.*, 1999). The Spruce Grouse and Ruffed Grouse have a similar diet of berries, spruce and pine needles, poplar buds, and insects (Collins, 1959; Moon, 1970, Wilkinson, 1970). The Spruce Grouse occurs in areas of generally close (spruce) forest cover. Small numbers of Ruffed Grouse are present in areas of more open deciduous cover. Willow Ptarmigan and Rock Ptarmigan include sedge, shrub flowers and berries, willow and birch leaves, buds and seeds, and insects in their diet (Wakelyn *et al.*, 1999). These birds are present year round. In summer, the range of Willow Ptarmigan extends north into the tundra. The Rock Ptarmigan is present in the tundra and barren areas north of the taiga. Typically, ptarmigan densities are a few birds/km<sup>2</sup> (Poole & Boag, 1988).

In spring, most geese pass north through the WKSS area and there is little nesting in the region. The North Arm (Great Slave Lake) - Lac la Martre - Hottah Lake area may be a corridor for limited migration through Great Bear Lake. Except where staging or moulting, the population densities of geese are low. In the southern part of the region, river valleys and inland lakes with early break-up are important sites for staging and moulting (Bromley & Buckland, 1995; McCormick & Bromley, 1990; McCormick *et al.*, 1990; Sirois & McCormick, 1991). In the north, shrubless tundra provides geese with habitat that is generally isolated from most predators during the seasonal moult. Hilltops and south facing slopes provide sites of early snow melt and

opportunities to crop over-winter berries and sedge shoots (Bromley & Buckland, 1995). A few species nest in coastal parts of the WKSS area and the Kent Peninsula is an important summer ground for geese. However, populations are very much larger to the east (Bromley & Stenhouse, 1994). More than a million geese may be present in the Queen Maud Bird Sanctuary and east along this coastal region (Gunn *et al.*, 2000). There, postglacial marine sediments (relatively Ca-rich) support vast areas of tussock vegetation. Geese begin to arrive in the southern part of the WKSS area about mid-May (Aniskowicz, 1993), and in Coronation Gulf area by about May 20th (Bromley, 1998). Departures begin from the gulf by about August 15th, and from the north and east shores of Great Slave Lake by the end of September (Aniskowicz, 1993). They feed mostly on sedges and grasses (Bromley & Buckland, 1995; Jefferies *et al.*, 1992). Canada Geese nest throughout the region. Tundra Swans, Greater White-fronted Geese, Lesser Snow Geese, Ross' Geese and Brant Geese (Pacific race) are present along both shores of Coronation Gulf.

Several species of large predatory birds are present in the region, and most are migrants (BHP Billiton Diamonds Inc. & Dia Met, 1995). Osprey, Great Horned Owl and, occasionally, Northern Goshawk, Sharp-shinned Hawk and Red-tailed Hawk all occur south of the tree line (Bromley & Buckland, 1995). Bald Eagles, Northern Harriers, Merlins and American Kestrels are present in both boreal and taiga areas. Peregrine Falcons, Golden Eagles, Rough-legged Hawks and Gyrfalcons occur throughout the WKSS area (Bromley & Buckland, 1995). Great horned Owls feed on a wide range of small mammals and birds. Red-tailed Hawks prefer areas of woodland cover and Rough-legged Hawks are present over much of the tundra. Both feed extensively on voles, mice, and lemmings (Bromley & Buckland, 1995). Rough-legged Hawks and other nomadic avian predators locate nesting sites in areas of prey abundance, such as voles (Bromley & McLean, 1986; Krebs *et al.*, 1987; Shank & Poole, 1994). The maximum density of Rough-legged Hawks is about one nest/50 km<sup>2</sup> (Bromley & McLean, 1986). Peregrine Falcons feeds on a variety of small birds and occasionally on ptarmigan, grouse, voles, mice, lemmings. They nest on river and coastal cliffs and ledges, and on rock outcrops in upland areas (Anon., 1993; Shank & Poole, 1994). Their territorial requirements are similar to Rough-legged Hawks and nesting density varies, depending on prey availability (maximum of about one nest/50 km<sup>2</sup> (Bromley & McLean, 1986)). Gyrfalcons are present year-round, most commonly nesting at low densities (maximum of about one nest/175 km<sup>2</sup>) within 20 km of the coast (Anon., 1993; Bromley & McLean, 1989). The distance between Gyrfalcon nests seems to be least in areas of highest mean July temperature. This may reflect the influence of food availability on breeding success. Rock Ptarmigan and Arctic Hare form the main source of food for Gyrfalcons in May and June, and Arctic Ground Squirrels in July and August (Bromley & McLean, 1986; Poole & Boag, 1988). Except under extreme winter conditions (including lack of prey), the Snowy Owl remains mostly within the WKSS area but it moves south from the coast in winter. It also feeds extensively on ptarmigan, voles and lemmings. In many different species, nesting practices may be adapted to take particular advantage of prey availability. Prey switching by generalist predators may also affect the reproductive success of waterfowl.



Population cycles occur in ptarmigan. Although they share much of the same food source as lemmings, fluctuations in the two groups may differ considerably. For example, population changes in Willow Ptarmigan (Bromley, 1998) seem to approximate a 10 rather than the 3 to 5 year "cycle" that is typical of many groups of small mammals (Shank, 1993). Sometimes, the cyclic effect is transferred up the food chain. Snowy Owls are particularly sensitive to such changes because their preferred diet includes both lemming and ptarmigan. Although the staple diet of Gyrfalcons is ptarmigan, cyclic fluctuations in availability of this prey do not seem to have much effect on Gyrfalcon populations which remain fairly stable. Fluctuations in food supply may, however, influence year-to-year reproductive success (Bromley, 1998).

Common Ravens are present throughout the region, year round. As scavengers, they are particularly important consumers of carrion. Ravens and gulls (especially California, Glaucous, Herring and Mew gulls) are extremely adaptive. They are opportunistic feeders and these species increase in numbers near human settlements where organic wastes are easily available.

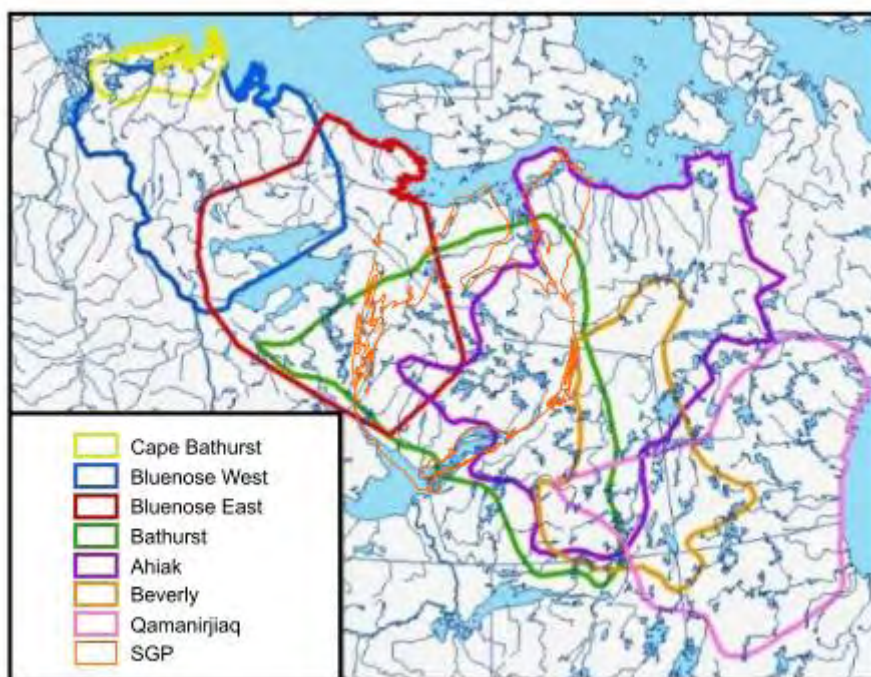
#### **2.3.4.7. Ungulates in the Terrestrial Food Web**

Four major groups of ungulates (hoofed mammals) are present in the WKSS area: caribou, moose, muskoxen, and bison. Each of these is described below. Given the particular importance of caribou from a social and cultural perspective, and the current concern regarding declining herd populations, greater detail is provided for caribou than for the other ungulates.

#### **Caribou**

Caribou are of critical importance throughout much of the NWT and Nunavut. Of the four subspecies that occur in Canada, the WKSS region intersects the ranges of herds belonging predominantly to the Barren-ground east of the Mackenzie River (*Rangifer tarandus groenlandicus*) and Peary (*Rangifer tarandus pearyi*) subspecies. The intersection of ranges of the Barren-ground herds are shown in Figure 20. As discussed below, the Peary Caribou occupy the northern edge of the WKSS.

**Figure 20 Barren-ground Caribou annual ranges based on satellite collared cows**



Source: Modified from <http://www.nwtwildlife.com/NWTwildlife/caribou/distribution.htm> - GNWT Environment and Natural Resources (accessed January 2007)

The Peary Caribou is small and light-coloured (CWS., 1997), and is present in low numbers across much of the high Arctic. The most southerly part of its range includes the northwest part of Victoria Island. The Arctic-island Caribou is similar in appearance to Barren-ground Caribou but a little smaller. It is present over much of Victoria Island, King William Island and the northern part of the Boothia Peninsula (Gunn, 1998; Hall, 1989; Jacobson, 1979; NPCTT., 1996; NPC., 1997). Caribou from the Dolphin and Union herd of Arctic-island Caribou migrate across the seasonal ice cover of the Coronation Gulf to a winter range on the northern mainland (NPCTT., 1996; NPC., 1997; Gunn *et al.*, 2000). Northwest of Great Bear Lake, Dene of Fort Good Hope and Colville Lake report two different types of Barren-ground Caribou. One is smaller than the other and it more closely resembles the Peary Caribou (Johnson & Ruttan, 1993).

Barren-ground Caribou are the most numerous and widespread sub-species of caribou in the WKSS area; however, their status remains a major concern within the NWT and Nunavut. Four major herds are found within the WKSS (Figure 20): two have declined significantly in the last ten years, and the current status of the other two is unknown, but the herds are suspected to be declining. Barren-ground caribou are an important social and cultural component in the lives of NWT and Nunavut residents, and the impact of smaller herds is felt particularly by subsistence hunters who must replace caribou with less nutritious and expensive store-bought food.

To protect the herds, the GNWT is implementing new controls on harvesting in the NWT, by restricting commercial hunts and reducing the number available to non-resident and resident hunters. This issue is of vital importance to the government and people of the NWT and new studies are being conducted by the Dept. of Environment and Natural Resources to understand the reasons behind the trends. Barren-ground caribou are known to undergo major natural fluctuations that are linked to large-scale changes in climate, such as the Arctic Oscillation and the North Atlantic Oscillation (GNWT 2006a).

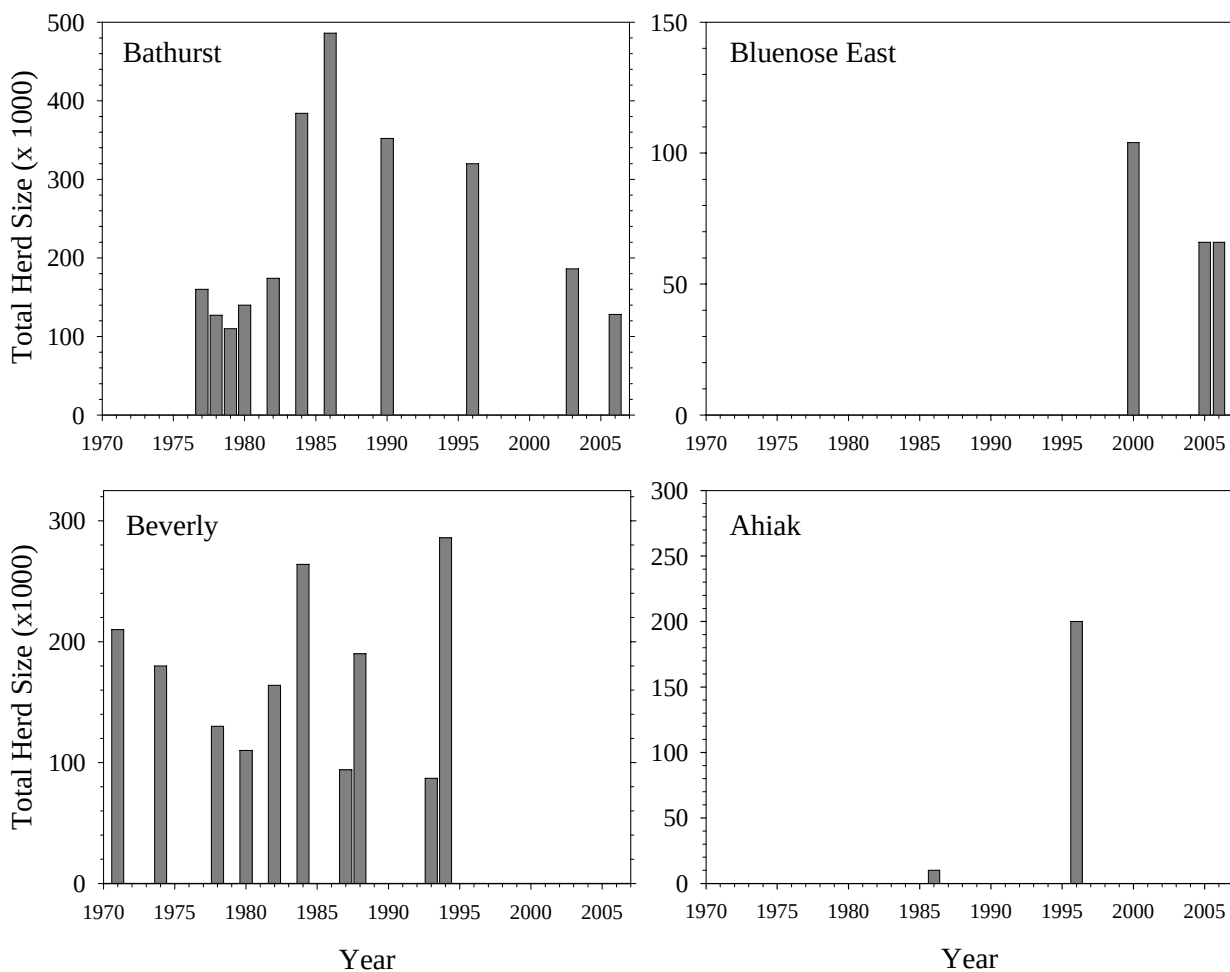
Recent studies by ENR have shown that the Bathurst herd, the major herd in the WKSS, has declined by an average 5% per year since reaching a peak size in 1986 (Table 6; Figure 21). Gunn et al. (2005) surveyed the herd in 2002 and determined that the ratio of calves to cows was low and the average calf survival rate was about half the value from 1985-1996 when the herd was at its peak. Total herd size in 2002 was estimated at 186,000. Warmer summer temperatures which resulted in more insect activity, and hence more stress on females, and delayed snowmelt that caused poor conditioning in females after calving (hence poor calf survival) may have been involved in low calf numbers. This corresponds to studies showing that calving success in barren-ground caribou of the herds is related to the condition of the females in the preceding fall (Cameron et al. 1993). The survey in 2006 estimated the total herd size at 128,000 (Nishi et al., 2008). ENR is preparing a report on the herd from surveys conducted in 2006, which should provide current data on the male:female sex ratios and cow:calf ratios, and provide some indication of whether the herd is continuing its decline, remaining stable or increasing. ENR has been monitoring winter body condition through harvesters and body condition was poor in the winter of 2006-06, which resulted in a very low recorded rate of calf survival in the spring of 2006 (9 calves/100 cows)(B. Croft, pers. comm.).

**Table 6 Summary of population size, range and management boards for the four major barren-ground caribou herds in the WKSS area.**

| Herd                                         | Calving Grounds                                                                                                            | Wintering Grounds                                                                                                                                                                                          | Population Size   | Date of Last Survey | Trend                                       | Management Boards                                                                                                                                                                                                              |
|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|---------------------|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ahiak<br>(formerly the Queen Maud Gulf herd) | <ul style="list-style-type: none"> <li>South of Queen Maud Gulf</li> </ul>                                                 | <ul style="list-style-type: none"> <li>On the tundra of the Thelon Game Sanctuary</li> <li>Possibly south to Saskatchewan border</li> <li>Overlaps with Bathurst and Beverly herds</li> </ul>              | Estimated 200,000 | 1996                | unknown                                     | <ul style="list-style-type: none"> <li>Wek’eezhii Renewable Resources Board</li> <li>Nunavut Wildlife Management Board</li> <li>Beverly/Qamanirjuaq Caribou Management Board</li> </ul>                                        |
| Bathurst                                     | <ul style="list-style-type: none"> <li>Between the Hood and Burnside Rivers, west of Bathurst Inlet (1986-2007)</li> </ul> | <ul style="list-style-type: none"> <li>Currently from east side of Great Bear Lake to Saskatchewan border</li> <li>Overlaps with Beverly and Bluenose-east herds</li> </ul>                                | 128,047           | 2006                | Declining on average 5% per year since 1986 | <ul style="list-style-type: none"> <li>Wek’eezhii Renewable Resources Board</li> <li>Nunavut Wildlife Management Board</li> </ul>                                                                                              |
| Bluenose-east                                | <ul style="list-style-type: none"> <li>Near Rae and Richardson R. west of Kugluktuk</li> </ul>                             | <ul style="list-style-type: none"> <li>North, south and east of Great Bear lake</li> </ul>                                                                                                                 | 66,186            | 2006                | Declined by 36% since 2000                  | <ul style="list-style-type: none"> <li>Wildlife Management Advisory Council (NWT)</li> <li>Sahtu Renewable Resources Board</li> <li>Wek’eezhii Renewable Resources Board</li> <li>Nunavut Wildlife Management Board</li> </ul> |
| Beverly                                      | <ul style="list-style-type: none"> <li>West of Baker Lake</li> </ul>                                                       | <ul style="list-style-type: none"> <li>South and east of Great Slave Lake extending into Manitoba and Saskatchewan</li> <li>Overlaps with Bathurst (west), Ahiak (north) and Qamanirjuaq (east)</li> </ul> | 276,000           | 1994                | Suspect declining, but no recent data       | <ul style="list-style-type: none"> <li>Beverly/Qamanirjuaq Caribou Management Board</li> <li>Nunavut Wildlife Management Board</li> </ul>                                                                                      |

Source: ENR 2006; GNWT 2006a

**Figure 21 Herd size of the four main barren ground caribou herds in the WKSS**



Source: CARMA (2006)<sup>4</sup>, GNWT (2006a)

<sup>4</sup> <http://www.rangifer.net/carma/>

The Bluenose East herd, whose wintering ground lies on the western edge of the WKSS, has also shown significant decline since 2000 (Table 6). Patterson et al. (2004) used 33 collared caribou to estimate a herd size of 104,000 in a survey of the calving grounds in June 2000. It was concluded that the herd was large enough at that time to support the harvest level of about 5,000 animals/year (5% of herd). The authors indicate that the herd size of 100,000 is probably the largest number that could be supported in the current range and that studies should be conducted to measure the body condition of the animals more closely. The group CARMA (Circumarctic Rangifer Monitoring & Assessment Network) has begun to develop standard a set of measurements (e.g., back fat, kidney fat, intestinal fat, bone marrow fat content) to determine the body condition of harvested caribou to provide continuous monitoring of the status of the herd (Kofinas et al. 2002), however the significance of the individual measurements between herds is unclear. A report submitted to the Joint Review Panel for the Mackenzie Gas Pipeline contained the results of a 2006 survey of the Bluenose-east herd which placed the herd size at 66,000 individuals, which is the same level as in 2005 (Figure 21). Neither the Ahiak or Beverly herd have been surveyed for at least 10 years, and their current status is unknown.

A fifth herd, the Dolphin and Union herd, overwinters at the northern rim of the WKSS and may mix with the Ahiak and Bathurst herds. This herd of barren-ground caribou has been ranked as “sensitive” (WGGSNS 2006) due to a unique set of ecological and biological characteristics. The herd undergoes calving, summering and rutting on southern Victoria Island but migrates across the Dolphin and Union Strait to overwinter on the mainland, where they are harvested by several communities. Individuals of the herd have size and pelage characteristics of the Peary caribou to the north, but also some characteristics of the larger herds (Ahiak, Bathurst) to the south. This combination of features gives the individuals in the herd unique morphology, which is supported by genetic analysis (COSEWIC 2004). From the taxonomic, behavioural, historical and Inuit traditional knowledge the herd is unique, and is ranked separately from other herds by COSEWIC.

The COSEWIC assessment report for the Dolphin Union herd (COSEWIC 2004) gives very few reliable estimates of the herd size, but several estimates place the numbers at approximately 28,000 in 1998. This is much higher than the 3400 level in 1980, but much lower than historical levels (ca. 100,000). Part of this estimate is based on harvest rates by northern communities of approximately 3000 caribou annually, which would require a fairly large herd size to support. Threats to the herd include extreme climate, which might result in winter storms during calving or ice storms that limit feeding, over-harvesting, drowning during migration and forage depletion in fall staging areas (COSEWIC 2004). Climate change could enhance many of these threats by causing thin ice and open water during migration over the Dolphin and Union Strait, and by increasing the number of ice storms and extreme weather events that can cover summer and winter forage. Because of its unique character and the possibility of major losses from an uncertain environment, the herd has been assessed as “Special Concern”, which is defined as “a

wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats” (COSEWIC 2004).

### ***Barren-ground Caribou Management***

As a consequence of the current decline of most of the major herds, the strategy to manage and understand the stresses on barren-ground caribou herds has become of critical interest to all residents. The proposal to build the Mackenzie Gas Project, in addition to the creation and expansion of diamond and precious metal mines, and proposals to expand current all-weather roads, has led to the need for information on the effects of the expanding development on wildlife. This push for development places significant stress on the resources available for research and on the knowledge available to understand potential effects from the development. For example, there is no clear single reason for the decline the major herds (e.g., Bathurst, Porcupine) despite being heavily studied over several years. The Porcupine herd in the north Yukon has also been declining since 1989, and has been heavily studied during that time, yet there is no known specific reason for the decline. Major spring storms have caused significant calf mortality in the Porcupine herd in at least two recent years (Russell and McNeil 2005).

In north Alaska, the need for information on wildlife species in the area of the North Slope, which has been heavily developed for oil extraction over the last 40 years, resulted in a large number of environmental studies up to 1998, 44% of which related to the four barren-ground caribou herds in the area, 2% were related to moose, and 4% on vegetation (Berger et al. 2001). Studies showed that linear development of the pipelines and oil fields had a number of effects of caribou behaviour, including providing open areas to help caribou avoid insects on roads and gravel pads (Haskell et al. 2006) to apparent long-term changes in the distribution of females with calves away from the oil fields (Nelleman and Cameron 1998; Cameron et al. 2005). These studies indicate that the response of caribou to the changes caused by development are varied, however the overall net impacts to the herds are uncertain.

### ***Barren-ground Caribou Management Plan***

Since the 2001 SOK was released, several changes have occurred in the management of the barren-ground caribou herds. In 2006, GNWT’s Environment and Natural Resources released a five-year NWT Barren-ground caribou management strategy (ENR 2006) which outlines the status of the herds within the NWT, the co-management boards associated with each herd (Table 6) and the provincial/territorial governments which oversee herd management. The strategy recognizes the social and cultural importance of barren-ground caribou to residents, and the importance of local and TK and western science in managing the herds. It is a significant document because it summarises a strategy to assess the current status of the herds, gaps in current knowledge and a strategy to collect needed information (see Table 7). It also outlines

other areas, such as education and community outreach, that will help to collect local and TK to help understand the herds and to communicate new information to hunters and communities.

The plan outlines a five strategy of data collection and communication to help manage the herds (Table 7). Under Strategy 5 (to determine the status of all NWT herds), several studies were conducted in 2006 to understand the current status of several herds and to monitor indicators of herd health. In terms of herds present in the WKSS, population counts of the Bathurst and Bluenose East herds were conducted (Table 6), while reconnaissance surveys of the Ahiak and Beverly calving grounds were conducted and tracking programs for the Bluenose East, the Bathurst and the Beverly herds were maintained or initiated. Detailed assessments of the number of breeding females in the Bathurst herd, and late winter counts of calf survival for the Bluenose East and Bathurst herds help to determine the ability of the herds to rebound over the next few years. Early results from the 2006 survey of the Cape Bathurst herd showed very few calves were present in the herd, which means few yearlings in 2007 to begin reproducing and help the herd increase. The significance of the data is that the herd (currently 1800) will stay at current levels or continue to decline. Similar data were collected for the Bathurst and the Bluenose-east herds. Data from the other 2006 surveys will be available in 2007.

Individual management plans have been released for the Bathurst and Beverly herds. These plans are important as they outline the current status of the herd, the roles that individual agencies play in funding and conducting research and actions to be taken when the herds are declining, or considered to be “low”. For example, the Beverly/Qamanirjuaq plan, prepared by the Beverly/Qamanirjuaq Management Board, states that a herd size of 150,000 should be considered to be “critical”, which is the level at which the size of the herd can not support the current levels of subsistence harvest. The critical level requires action on the parties to the agreement for studies and conservation. The plan for the Bathurst herd, developed by a committee made up of user communities and resource management agencies, used more general terms of “declining” or “low” to require action by the Parties. However, since a population survey of the Beverly/Qamanirjuaq herds has not been conducted since 1994 (a survey is likely in 2007), it is unlikely that actions linked to the “critical level” will be carried out. There is a slight difference in the philosophy of the co-management of the herds, with the Beverly and Qamanirjuaq Caribou Management Board (BQCMB) asserting the need for more TK to determine the status of the herd (Kendrick 2003), and using a “subsistence needs level (SNL)” or the total number of caribou to sustain the basic subsistence needs of traditional hunters.



**Table 7 Strategies outlined in the NWT Caribou Management Plan in 2006**

| Strategy No.                              | Action                                                                                                                                                                                                                                                                  |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1. Engaging All Partners</b>           |                                                                                                                                                                                                                                                                         |
| 1                                         | <ul style="list-style-type: none"> <li>Work with co-management and other public processes to effectively identify caribou conservation issues and options for caribou conservation.</li> </ul>                                                                          |
| 2                                         | <ul style="list-style-type: none"> <li>Track the implementation of existing management plans, update management plans where needed and develop management plans for herds where they do not exist.</li> </ul>                                                           |
| 3                                         | <ul style="list-style-type: none"> <li>Establish inter-jurisdictional agreements where needed to enhance coordination and cooperation.</li> </ul>                                                                                                                       |
| 4                                         | <ul style="list-style-type: none"> <li>Enhance and promote the exchange of information on the status and use of caribou across the circumpolar north.</li> </ul>                                                                                                        |
| <b>2. Information for Management</b>      |                                                                                                                                                                                                                                                                         |
| 5                                         | <ul style="list-style-type: none"> <li>Implement monitoring actions to determine the status of all NWT caribou herds and to understand factors driving changes in herd status.</li> </ul>                                                                               |
| 6                                         | <ul style="list-style-type: none"> <li>Identify and implement studies necessary to understand caribou ecology, including the role of predators.</li> </ul>                                                                                                              |
| 7                                         | <ul style="list-style-type: none"> <li>Develop population models that incorporate key demographic data, traditional knowledge and community-based knowledge to evaluate proposed management options.</li> </ul>                                                         |
| <b>3. Managing Human Impacts</b>          |                                                                                                                                                                                                                                                                         |
| 8                                         | <ul style="list-style-type: none"> <li>Evaluate the impacts of harvesting (including predation) on herd declines and recovery and implement strategies to reduce harvest impacts.</li> </ul>                                                                            |
| 9                                         | <ul style="list-style-type: none"> <li>Identify, monitor and mitigate impacts of exploration and development activities and improve understanding of the mechanisms for any impacts.</li> </ul>                                                                         |
| 10                                        | <ul style="list-style-type: none"> <li>Develop models to assess cumulative effects of human and natural impacts.</li> </ul>                                                                                                                                             |
| <b>4. Public Education and Compliance</b> |                                                                                                                                                                                                                                                                         |
| 11                                        | <ul style="list-style-type: none"> <li>Develop and implement a public information and education program.</li> </ul>                                                                                                                                                     |
| 12                                        | <ul style="list-style-type: none"> <li>Promote hunting excellence.</li> </ul>                                                                                                                                                                                           |
| 13                                        | <ul style="list-style-type: none"> <li>Document and publicize community based hunting rules.</li> </ul>                                                                                                                                                                 |
| 14                                        | <ul style="list-style-type: none"> <li>Enhance compliance programs.</li> </ul>                                                                                                                                                                                          |
| <b>5. Addressing Hardships</b>            |                                                                                                                                                                                                                                                                         |
| 15                                        | <ul style="list-style-type: none"> <li>Work with the Department of Industry, Tourism and Investment and impacted communities to identify hardships and identify possible solutions, including alternate meat sources and alternate harvesting opportunities.</li> </ul> |
| 16                                        | <ul style="list-style-type: none"> <li>Work with the Department of Industry, Tourism and Investment, outfitters and other commercial ventures to identify ways to maintain viability of businesses through changes in caribou numbers and distribution.</li> </ul>      |

Source: GNWT ENR 2006

### ***Bathurst Caribou Management Plan***

In 2004, the Bathurst Caribou Management Planning Committee (BCMPC) released a Bathurst Caribou Management Plan that outlines a strategy for the long-term conservation of the Bathurst herd (BCMPC 2004). The Planning Committee is comprised of members of federal and territorial agencies, NWT First Nations and organizations from the Kitikmeot and Nunavut territorial government. The plan was prepared over several years with public input, at a time when the herd was under significant decline.

The primary objective of the plan is to monitor the size of the herd and to collect information on caribou movements, herd health, incidence of diseases and to collect data on several parameters such as calf survival every year and the male:female ratio every six years. This is fundamental information that is necessary to understand the current status of the herd. When the herd is declining, additional data on pregnancy rates, predation rates by wolves and grizzly bears are collected and monitoring of the harvest is increased. When the herd size is low, monitoring is increased and the hunting by residents and non-residents and for commercial purposes is restricted. In 2006, NWT hunting regulations restrict hunting by residents to two male caribou only. Other objectives of the plan include monitoring of migration routes of the herd, to determine the impact of development, and to develop policy. No specific herd size is mentioned in the plan as to when the herd is considered to be “low” and hence when new actions are to be put in place.

### ***The Beverly and Qamanirjuaq Management Plan***

In 2005, the Beverly and Qamanirjuaq Caribou Management Board (BQCMB) released a management plan for the Beverly and Qamanirjuaq herds that is designed to cover the years from 2005-2012 (BQCMB 2005). The BQCMB is comprised of representatives from Manitoba, Saskatchewan, the NWT and Nunavut and the federal government. The purpose of the Plan is to outline ways to safeguard the herds. The plan recognizes the economic value of the Beverly and Qamanirjuaq herds at about \$17 million as well as the cultural and social importance of the herds to the residents within the range of the herds (BQCMB 2005).

The Plan outlines a strategy that is defined by three major stages: Core Management, (the herds are increasing or stable), Enhanced Management (the herds are declining or decreased below commercial and subsistence needs) and Critical Threshold Management, where the herds are below subsistence levels. A major tenet in the plan is the use of the Precautionary Principle which states that “in the absence of complete information where there are threats of serious or irreparable damage, lack of complete information or certainty shall not be a reason for postponing reasonable conservation measures (BQCMB 2005). The last survey of the size of the herds was in 1994, when the Beverly herd was 276,000. Collars have been placed on about 20

females in anticipation of a herd survey in 2007, however some of the females apparently were from other herds, and more collars were placed on caribou in July 2007. Poor weather in June 2007 prevented completion of a survey to estimate herd numbers. An action plan, which will be undertaken if the herd size is below 150,000 has not been developed by the BQCMB.

### ***Moose***

Relative to more southerly distributions in Canada, Moose population densities are low in the WKSS area. Moose occur in small family groups or as individuals. In good habitat, Moose require a browsing range of about 12 to 50 km<sup>2</sup> per individual (Bromley & Buckland, 1995). They feed on young deciduous vegetation, particularly willow, and semi-aquatic vegetation in ponds and shallow lakes. Moose are present year-round in all forested areas and especially in the Lac Grandin - Lac la Martre - Rae area, south of Yellowknife; and the lower Taltson River, east of the Slave River delta. During the summer, individuals may move far into the tundra where they feed on willows in sheltered river valleys (Bromley & Buckland, 1995; Jacobson, 1979). They tend to move into the bog and forest, and glaciolacustrine wildlife zones during winter. Moose prefer quiet surroundings (sound is important for sensing the presence of predators such as wolves). They move away from wintering caribou which noisily scrape and crater snow cover to graze on the underlying vegetation (Johnson & Ruttan, 1993). Moose are locally abundant in areas of forest regrowth (after burns) where they feed on new shoots (Bromley & Buckland, 1995; Jacobson, 1979).

In forested areas, Moose prefer different types of habitat at different times of year (Johnson & Ruttan, 1993). In summer, they can be found in cool and wet areas where there are a variety of aquatic plants, grasses and willows to feed on. By remaining in water, they also reduce harassment from insects. At other times and under conditions of light snow cover, Moose may move to higher ground where they feed on Labrador Tea and grasses. In winter, Moose may move to valley areas and to creeks and islands where they feed on a variety of willows. The use of burned areas by Moose appears to be dependent on the intensity and type of burn. For example, crown fires burn the tops of trees, surface fires burn only light ground cover, but severe fires burn everything including organic soil (Johnson & Ruttan, 1993). Moose are attracted first to areas that have had lighter burns and which develop nutrient-rich new growth. Large burned areas may not provide useful habitat if wind-blown snow becomes hardened and Moose can not feed on the underlying vegetation.

The mating season is from mid-September to late October (Johnson & Ruttan, 1993). During the rut, bulls will travel long distances in search of a mate. They are territorial once mating has occurred. Calving takes place from mid-May to early June and a variety of habitats are suitable for this (Johnson & Ruttan, 1993).

A survey of moose density in 2004 provided some baseline data on the numbers of moose in the North Slave Region of the NWT (Cluff 2004). The aerial survey of the western and north shores of Great Slave Lake reported moose densities of 3.99 and 2.75 moose/100 km<sup>2</sup>, and a calf:cow ratio of 16:100 and 64:100 in the Taiga Plain and Taiga Shield ecozones, respectively. These surveys should be expanded and compared to data across the NWT to provide more data on the density and condition of the moose population.

### **Muskoxen**

The Muskoxen population was severely depressed throughout the WKSS area as a result of unregulated hunting for hides during the late 1800's and early 1900's (Barr, 1989; 1995). Overall numbers are low but there has been some recovery since about 1970 (Bromley & Buckland, 1995). The Muskox is now recolonizing its historic range (Barr, 1989; 1991) which probably covered much of the tundra. In the mid-1970's, surveys recorded concentrations of Muskoxen on the Horton Plain north of Great Bear Lake and west of Kugluktuk (Jacobson, 1979). Later surveys (Graf & Shank, 1989; Gunn, 1995) recorded other groups concentrated in areas around the Back River and Contwoyto Lake. In 1991, about 1,400 Muskoxen were observed between Contwoyto Lake and Bathurst Inlet. Small numbers have also been reported in the Lockhart River drainage, above Artillery Lake. At least 1,000 animals were reported by a 1994 survey in the Thelon Game Sanctuary. In 1998, 537 Muskoxen were recorded in a stratified aerial survey of an area of about 50,000 km<sup>2</sup> east of Great Slave Lake. The data support a population estimate of about 1606 Muskoxen in this area and suggest that their population has increased in this area since 1989, and spread westwards (unpublished data, DRWED, Yellowknife). Recent estimates suggest that as many as 4,250 mainland Muskoxen may be present on their summer range along the Queen Maud Gulf (Gunn *et al.*, 2000). Herds are usually small, 5 to 25 animals, though some of 100 or more have been reported. Concentrations reflect local conditions and range from about one Muskox/50 km<sup>2</sup> (Artillery Lake), one Muskox/12 km<sup>2</sup> (Victoria Island), one Muskox/6 km<sup>2</sup> (Queen Maud Bird Sanctuary), to one Muskox/3 km<sup>2</sup> (Bank's Island).

Calving occurs in late March or early April and, in some herds, there are migratory patterns. For example, west of Kugluktuk, a mainland herd concentrates in the broad valleys of the Rae and Richardson rivers, from late October to March. There, snow is less wind-packed and Muskox forage on stands of willow and birch (Gunn & Fournier, 2000). At the end of March, snow becomes crusty and more dense with daytime heating. Muskox leave the valleys to calve on wind blown slopes that are free of snow, and where foraging is less energetically demanding and the herd is better able to protect calves from predator attack. Studies show that the proportion of calves in the herd drops from nearly 17% in July to 8-9% by November (Gunn & Fournier, 2000). Later, the herd moves slowly north to the coast and then begins to slowly return south in August (a round migration of nearly 300 km). West of Bathurst Inlet, Inuit hunters report that Muskoxen migrate to the coast in June and return to higher rocky areas in July. This migration

probably follows the availability of willow leaves that open earlier on the coast than inland (Gunn & Fournier, 2000). In the Queen Maud Gulf area, calves represent nearly 15% of the herd in August, and to the west of Bathurst Inlet calves represent about 12% of the herd population. Parasitic lungworms appear to be a particular problem in the Muskox population just west of Kugluktuk (Gunn & Fournier, 2000; Hoberg *et al.*, 1995). In these animals, pregnancy and calf survival rates appear to be low, and Grizzly Bears may cull badly infected Muskox. The valley population near Kugluktuk has varied from about 1,295 in 1983, to 1,800 in 1986, and to 974 in 1994 (Gunn & Fournier, 2000). Further potential for growth of the WKSS area Muskox population, as a whole, is uncertain (Bromley, 1998).

Muskoxen feed on grasses, sedges and willows, and like caribou they maximize nutritional intake by selective feeding (Jefferies *et al.*, 1992). Calves are born several weeks before plant growth begins and cows lose considerable weight during the first 6 weeks of lactation. Both males and females increase weight rapidly after the start of plant growth. During the growing season, Muskoxen spend about half their time feeding. Both males and females reach peak condition by the time of the rut, in August. Muskoxen are adapted to digest the high fibre content of over-winter grasses and sedges. They seek areas where snow has been blown away and where it is relatively easy for them to reach food. Freezing rain or deep snow, however, may severely limit their ability to forage. Their winter diet consists mainly of grass and sedge leaves, and leafless willow twigs. About half as much time is spent foraging in winter as in summer.

Nutrient cycling between plants and animals (by ingestion and excretion) contributes to the growth of forage, for both Muskoxen and caribou. But because caribou retain ammonium by recycling urea (for protein reserves), nutrient feedback may be more significant for Muskoxen that also feed more intensively (and thus fertilize) at one site (Gunn, 1998; Jefferies *et al.*, 1992). In addition, excreted materials may directly or indirectly enter the aquatic environment where they also enrich nutrient availability.

## **Bison**

Wood Bison are present in the Mackenzie Bison Sanctuary on the west shore of Great Slave Lake. Plains-wood Bison are present in the Slave River delta and Wood Buffalo National Park. Conservation programs maintain these herds that are near the northern limit of their present range (Jacobson, 1979). Large areas of sedge prairie (seasonally drained lakes that lack tree growth), between forest stands, provide grazing for the bison. Although these herds presently exist outside the WKSS area, slight changes in climate could extend their range into the study area.

### **2.3.4.8. Intermediate and Top Predators in the Terrestrial Food Web**

Predators play an important role in the arctic terrestrial ecosystem by controlling small game

populations and by acting as one of the major controlling factors on large herbivores, such as barren-ground caribou.

Lynx are active all year. They are heavily dependent on Snowshoe Hare for their food supply and distributions of the two species are similar. However, they are also known to kill and eat small mammals, grouse, ducks, and even caribou calves (Poole, 1989; 1992). Lynx numbers increase with the abundance of hares but declines abruptly at the end of each hare "cycle". At the end of the hare "cycle", Lynx mortality is high (particularly kits) and this is largely due to starvation. Natural mortality is thought to account for about 75% of long term total mortality in the Lynx population (Poole, 1997). At that time, both male and female Lynx disperse widely over distances of several hundred kilometres. One straight line radio-tracked distance of 930 km has been recorded (Poole, 1997). Some Lynx may move into areas where the hare-Lynx "cycle" is not in-phase with that generally existing over much of the WKSS area (Poole, 1989). Densities vary from a low of about one Lynx/33 km<sup>2</sup> to a high of one Lynx/3 km<sup>2</sup> (Poole, 1992). One recent cycle followed the hare population peak of 1988-90 and collapse of 1992-1993 (Poole, 1997). Few Lynx occur north of the tree line (Bromley & Buckland, 1995; Jacobson, 1979). They are widespread in the bog and forest, and glaciolacustrine wildlife zones.

Both Red Fox and Arctic Fox are opportunistic feeders (Bromley & Buckland, 1995). Small rodents form much of their diet but they will also eat berries and other vegetation. They scavenge wolf kills, particularly in winter. In addition, both foxes feed on Willow Ptarmigan and Snowshoe Hare in winter, and waterfowl and their eggs and young in summer. Red Fox also kill Muskrat in the spring. Arctic Foxes are considered a more specialist feeder and much of their diet consists of lemmings. Red Foxes are present year round and in small numbers (typically about one Red Fox/10 km<sup>2</sup>) over most of the WKSS area, including open forest and some of the tundra wildlife zones. They are most abundant in bog and forest, and glaciolacustrine wildlife zones which support substantial growths of willow. Arctic Foxes may move south from tundra to forest-tundra and open forest wildlife zones in winter. Both foxes prefer to den in sandy ridges and densities vary greatly with the availability of food supply and the time of year. Both foxes range widely (Jacobson, 1979).

Two of the major predators in the WKSS area, the grizzly bear and the wolverine, are considered to be "sensitive" species (WGGSNS 2006) because of their low reproductive rate and need for large areas of undisturbed land.

Although widely distributed through the NWT and the WKSS area, the grizzly bear (*Ursus arctos*) is classified under the category of "Special Concern" by COSEWIC (2002). A full review of grizzly bear biology and considerations for management of the species is available in the species status report (COSEWIC 2002). The designation is based on the slow reproductive rate of the species which leads to a very slow recovery in the population and the low densities

present in the north. Grizzly bears tend to build dens under tall shrubs in eskers (McLoughlin et al. 2002), which cover a relatively small portion of the taiga. First parturition in females in the WKSS occurs at about 8 years of age, with birth intervals of about 3 years (McLoughlin et al. 2003), however the occasional loss of litters increases the interval between litters to almost 4 years. Litter sizes of the population in the WKSS region were relatively large in the late 1990s, suggesting an increasing population (McLoughlin et al. 2003), however the authors indicate a large uncertainty in the data and the trend in the population is uncertain. Approximately 4800 bears are in the NWT.

The bear is particularly sensitive to human caused mortality and its behavior brings it into conflict with people (GNWT 2006b, after COSEWIC 2002). The loss of the grizzly in southern Canada was largely due to the loss of suitable habitat with the increase in human population. Northern populations, such as those in the WKSS area, are at the northern edge of their range and have very large home ranges due to the low levels of productivity in the system. At the far edge of their range, such as in the Mackenzie Delta, they may remain in their den for up to 200 days per year (GNWT 2006b), hence the bears must store enough energy reserves to last 6 or 7 months. The species remains at heightened conservation status because of the large undisturbed ranges needed to maintain the population. The population is very sensitive to over-harvesting, which might occur as illegal harvesting, or due to negative interaction (i.e., removal of nuisance bears) as development increases.

A survey of parasites in grizzly bears in the central Canadian Arctic reported the presence of gastrointestinal coccidia and a protostrongylid larva (Gau et al. 1999), which is the same group of parasites that include lungworm and brainworm in muskoxen and Dall's sheep. The study reported that higher levels of parasites in autumn might indicate that the bears voided gastrointestinal parasites prior to hibernation (Gau et al. 1999).

Another predator in the Taiga Shield and Southern Arctic ecozones is the grey wolf (*Canus lupus occidentalis*) which is considered to be "secure" (WGGSNS 2006) due to the presence of several stable populations and the ability of the species to recover quickly from declines. Major threats to the species are low populations of ungulates, such as barren-ground caribou which are a major food source, over-harvesting and disease. COSEWIC determined in 1999 that the northern populations of the gray wolf are stable, and hence not at risk, but the arctic form was designated as "data deficient" indicating that not enough data were available to make the assessment. Wolves tend to build dens along eskers or near the tree line, where they have access to caribou during the summer, when the pups cannot travel long distances (Heard and Williams 1992; Walton et al. 2001). Male wolves in the central Arctic were observed to have summer home ranges of 2,022 km<sup>2</sup>, with the range of the female at 1.130 km<sup>2</sup> (Walton et al. 2001). A study of wolves in the WKSS area in the late 1990s (McLoughlin et al. 2004) confirmed the importance of eskers for denning, and found little relationship with other variable, such as vegetation type, in

the selection of denning areas. The loss of eskers due to development, particularly because of the need for fill material in some industries, may significantly erode the suitability of habitat for the wolf. Also, the presence of caribou at the time of denning is critical for wolf survival and change to the distribution or timing of caribou movements may significantly impact the size of the wolf population (Walton et al. 2001). A study of a mature breeding female wolf during the summer reported that the wolf covered an area of 341 km over a 14 day period. The study suggests that the female abandoned its pups, possibly in the care of another female, to forage for caribou over a very long distance (Frame et al. 2004). These studies demonstrate the complexity of managing wildlife populations given the variety of behaviors presented by individual animals.

A study of microsatellite markers in wolves from sites in the NWT, but not the WKSS area, showed differences in the genetic structure between populations caused by the presence of large geographical features, such as the Mackenzie River and Amundsen Gulf (Carmichael et al. 2001), indicating little movement between some populations. The appearance of Banks Island wolves in the samples from Inuvik/Tuktoyaktuk showed that some mixing does occur, possibly from events such as the migration of the Dolphin-Union caribou herd across the Amundsen Gulf. The study generally supports the concept of management of discrete wolf populations, each of which has its own genetic structure and habitat and resource use.

The wolverine (*Gulo gulo*), is ranked as “Sensitive” (WGGSNS 2006) even though the NWT population appears to be stable, and has supported a steady harvest rate for several years. The major threat to the species is the same as with other predators: a slow rate of reproduction and the potential for the loss of undisturbed habitat. This loss of habitat is the major cause of the loss of the wolverine population in eastern Canada (COSEWIC 2003). A major concern for the species is the onset of development, which may reduce the amount of suitable habitat, but also cause the loss of adults that are attracted to camps and landfills. Harvest rates of the wolverine may have to be reduced in the future if the NWT population shows evidence of decline due to habitat loss.

A study of wolverine mortality across western north America, including the NWT, used data from radiomarked wolverines to show that human-caused mortality in the form of hunting and trapping was the major cause of death followed by predation and starvation (Krebs et al. 2004). The study recommended harvest controls in the vulnerable northern populations as a means to manage the major cause of mortality in the population. This recommendation is supported by genetic studies of NWT wolverine populations showing that, although wolverines inhabit large home ranges, they remain within the same general area and that the populations generally remain discrete from neighboring populations (Wilson et al. 2000). Studies of the genetic structure of wolverine populations support the view that males provide most dispersal between populations and hence may be responsible for maintaining genetic diversity (Wilson et al. 2000; Tomasik and Cook 2005), however a study in Alaska using microsatellite markers (Dalerum et al. 2007) found



little evidence for male-biased dispersal and provided other explanations for the genetic diversity of wolverine populations. These questions are significant because they may provide answers on the most appropriate methods of managing this sensitive species.

Two studies have been published recently reporting the concentration of essential and non-essential elements (Hoekstra et al. 2003a) and organochlorine contaminants (Hoekstra et al. 2003b) in wolverine from Kugluktuk, NU. Many elements were below detection limits in liver and kidney, however Cd, Cu, Fe, total mercury, Mn, Pb, Se and Zn were detectable in more than 50% of the samples tested. In general, the concentrations of elements were lower than in arctic fox collected at Holman and Arviat, and remained below concentrations that might be considered hazardous to the animal (Hoekstra et al. 2003a). Major organochlorine groups (PCBs, DDT, chlordanes and HCH) were observed in wolverine tissues but at low concentrations (Hoekstra et al. 2003b). In addition, very low concentrations of some forms of the compounds indicate that wolverines possess the ability to metabolise certain chemical structures. The study also concluded that, although the levels remain relatively low, the pattern of chemicals indicated that the wolverine probably were exposed to the compounds through the consumption of food from the marine system, and not the terrestrial system.

The cumulative impacts of development on barren-ground caribou and the major predators in the WKSS was investigated using models of vegetation distribution, interspecific interactions and human disturbance (Johnson et al. 2005). Data of several levels of human disturbances were entered into the models and the seasonal changes for each species predicted. The grizzly bear and wolf showed strong negative response (i.e., avoidance) to human disturbance, while the caribou showed a significant effect in the post-calving period. The study is important because it demonstrates that disturbances related to human activities can affect the distribution and movement of major species, and hence reduce the availability of high quality habitats that are necessary for the maintenance of the populations.

### **2.3.5. Status of Terrestrial Species in the WKSS**

The 2001 SOK report provided a descriptive summary of the major species present in the WKSS, but little assessment of the status of the species, or an evaluation of species that may be at risk due to low population size or the loss of habitat. This information is necessary to protect sensitive or species at risk of extirpation, thereby maintaining the biodiversity

In 2000, Resources, Wildlife and Economic Development (RWED; now Environment and Natural Resources) began a process to assess the status of all organisms within the NWT using the best available information (RWED 2000). The process, termed the NWT General Status Ranking program, used expert opinion and TK to assess the general status of all mammals and bird species, and many plants, within the NWT and to suggest candidate species for more detailed assessment. The goal of the program is to help maintain the “biodiversity of the natural system by ensuring that no species becomes extinct as a consequence of human activity”.

The general status rank of each species was determined by:

- The size of its population, which includes the number of individuals, but also the number of occurrences of where it exists and where it is distributed,
- The trends in the population (increasing, stable or decreasing) and the trend in its distribution (shrinking or expanding),
- The threats to the population (factors affecting the individuals or populations of the species) and threats to the habitat of the species that would result in population declines.

A score was assigned for each of the major categories to determine whether a species falls into several major categories ranging from “At Risk” to “Secure”. Species for which little information is available are classified as “Undetermined”. For the 2000 assessment, a total of 407 species were assessed. This included 73 mammals, 247 bird species and 8 reptiles/amphibians, or 100% of the known species of those groups. Forty out of >1200 known plant species were assessed, or about 3% of the expected number of plants.

In 2006, the Working Group of General Status of NWT Species (WGGSNS) released and updated the assessment which re-evaluated the data for all species and expanded the number of plants and insects assessed. The database consists of 65 terrestrial mammal species and 273 bird species in the NWT. A total of five amphibians and 1 reptile species were evaluated, as were 1107 plant species. Species are arranged by ecozones, making it possible to determine the status of species currently present in the WKSS (i.e., Taiga Shield and Southern Arctic ecozones).

#### **2.3.5.1. Mammals**

The 2006 assessment found one mammal species that should be considered to be in the highest category of concern (At Risk): the wood bison (*Bos bison athabascaae*) (Table 8). The assessment also determined that six mammal species in the WKSS are considered to be “Sensitive”, with one species, the fisher, downgraded in conservation status from “May Be At Risk” in the 2000 assessment to rank of “Sensitive” in 2006 (Table 8). This new categorization is based on new information for the species. Four of the mammal species are considered by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) to be of “Special Concern” based on a review of their biology, habitat and overall status in Canada (see below). Harvesting is a major stress to many populations, and development may also affect the species’ need for isolated, undisturbed habitat (COSEWIC 2003).

#### **2.3.5.2. Terrestrial Birds**

Except for the Eskimo curlew (*Numenius borealis*) that has not been seen in the NWT for several years (assigned to “At Risk”), four bird species found in the WKSS are categorized as “May Be

At Risk” (WGGSNS 2006). The rusty blackbird has been upgraded to “May Be At Risk” from the 2000 assessment, and the species is one of several in the WKSS that are considered to be declining (Table 9) and has been assessed by COSEWIC as a species of special concern (COSEWIC 2006). The common nighthawk (*Chordeiles minor*) has been assessed as Threatened in Canada according to COSEWIC (2007), but was considered “secure” (WGGSNS 2006) in the NWT. Some waterfowl species, such as the northern pintail and long-tailed duck, that have been a large part of traditional diets and are now considered to be “sensitive” because of long-term population declines.

Three grouse species are present in the Taiga Shield portion of the WKSS and the populations of all three species are considered to be secure. Data from Christmas Bird Counts and Breeding Bird Surveys show relatively consistent numbers for both the ruffed grouse (*Bonasa umbellus*) and spruce grouse (*Falciapennis canadensis*), although harvest rates in communities vary due to local population fluctuations. These changes are probably due to changes in local conditions that impact all populations at some time, such as climate conditions and the number of predators. A decline in the sharp-tailed grouse (*Tympanuchus phasianellus*) population nationally is a significant concern, although the NWT population appears to be stable and is broadly distributed in the taiga and boreal ecozones. Other game birds, such as the willow ptarmigan (*Lagopus lagopus*) and the rock ptarmigan (*Lagopus muta*) appear to be stable and have the ability to recover quickly from population lows.

Populations of raptors (falcons, eagles, hawks) in the WKSS appear to be stable (WGGSNS 2006), and the peregrine falcon that was ranked as “May be At Risk” in 2000 has been upgraded to “Sensitive” because of an increasing population since the mid-1980s (WGGSNS 2006). This decision to re-categorise the subspecies “anatum” is partly due to studies showing little genetic difference between the “anatum” and “tundra” forms, suggesting that all the populations in the NWT may be of the same subspecies. The “anatum” form was listed by COSEWIC as being endangered in 1978, then threatened in 1999 (COSEWIC)<sup>5</sup>. This species is clearly sensitive to man-made stresses including DDT, that led to a major crash in the population in the 1970s, and the loss of habitat. The DDT threat is now reduced, but the species requires large tracts of land and food base to remain healthy. Within the NWT and the WKSS, other populations of raptors, including the bald eagle (*Haliaeetus leucocephalus*) and golden eagle (*Aquila chrysaetos*), red-tailed hawk (*Buteo jamaicensis*) and rough-legged hawk (*Buteo lagopus*) are currently stable.

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<sup>5</sup> <http://www.cosewic.gc.ca> – report accessed on website in January 2007

**Table 8 Summary of mammals found in the WKSS that have elevated conservation status, based on the 2006 general status ranking of NWT species**

Only those species found in the Taiga Shield and/or the Southern Arctic ecozones (underlined) have been included from the NWT assessment. COSEWIC = Committee on the Status of Endangered Wildlife in Canada<sup>6</sup>.

| Common Name                                      | Scientific name                                                                         | General Status Rank    | COSEWIC Status                              | Present in Ecozones                                                                                                                                 |
|--------------------------------------------------|-----------------------------------------------------------------------------------------|------------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Wood Bison                                       | <i>Bos bison athabasca</i>                                                              | At Risk                | threatened - 1988 (revision - 2000)         | Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                                                                |
| Barren-ground Caribou (Dolphin Union population) | <i>Rangifer tarandus groenlandicus x pearyi</i> ( <i>R. t. pearyi x groenlandicus</i> ) | Sensitive              | Dolphin Union pop = Special Concern (2004)  | Northern Arctic, <u>Southern Arctic</u>                                                                                                             |
| Wolverine                                        | <i>Gulo gulo</i>                                                                        | Sensitive              | western population = Special Concern (2003) | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains |
| Fisher                                           | <i>Martes pennanti</i>                                                                  | Sensitive <sup>1</sup> |                                             | Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                                                                |
| Grizzly Bear                                     | <i>Ursus arctos</i>                                                                     | Sensitive              | Special Concern - 2002                      | Northern Arctic, <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                    |
| Polar Bear                                       | <i>Ursus maritimus</i>                                                                  | Sensitive              | Special Concern (2002)                      | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u> , Taiga Plains, <u>Taiga Shield</u>                                                      |
| Little Brown Myotis (bat)                        | <i>Myotis lucifugus</i>                                                                 | Sensitive              |                                             | Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                                              |

<sup>1</sup> – changed from “May Be At Risk” in 2000; the change was based on new information for the fisher.

<sup>6</sup> <http://www.speciesatrisk.ec.gc.ca/>

**Table 9 Summary of birds found in the WKSS that have elevated conservation status, based on the 2006 general status ranking of NWT species and COSEWIC**

Only those species found in the Taiga Shield and/or the Southern Arctic ecozones (underlined) have been included from the NWT assessment. COSEWIC = Committee on the Status of Endangered Wildlife in Canada<sup>7</sup>.

| Common Name                 | Scientific name                | General Status Rank         | COSEWIC Status          | Present in Ecozones                                                                                                            |
|-----------------------------|--------------------------------|-----------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Eskimo Curlew               | <i>Numenius borealis</i>       | At Risk <sup>1</sup>        | Endangered – 1978, 2000 | <u>Southern Arctic</u>                                                                                                         |
| Rusty Blackbird*            | <i>Euphagus carolinus</i>      | May Be At Risk <sup>2</sup> | Special Concern 2006    | <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                |
| Common Nighthawk            | <i>Chordeiles minor</i>        | Secure                      | Threatened - 2007       | Taiga Shield, Taiga Plains, Boreal Plains                                                                                      |
| Northern Pintail            | <i>Anas acuta</i>              | Sensitive                   |                         | North. Arctic, <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains |
| Lesser Scaup                | <i>Aythya affinis</i>          | Sensitive                   |                         | Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                         |
| Brant                       | <i>Branta bernicla</i>         | Sensitive <sup>5</sup>      |                         | Arctic Cordillera, North. Arctic, <u>Southern Arctic</u>                                                                       |
| Long-tailed duck (Oldsquaw) | <i>Clangula hyemalis</i>       | Sensitive                   |                         | Arctic Cordillera, North..Arctic, <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u>                 |
| White-winged Scoter         | <i>Melanitta fusca</i>         | Sensitive                   |                         | <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                |
| Black Scoter                | <i>Melanitta nigra</i>         | Sensitive <sup>1</sup>      |                         | Taiga Plains, <u>Southern Arctic</u>                                                                                           |
| Surf Scoter                 | <i>Melanitta perspicillata</i> | Sensitive                   |                         | Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                         |
| Common Eider                | <i>Somateria mollissima</i>    | Sensitive <sup>1</sup>      |                         | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u>                                                                     |
| King Eider                  | <i>Somateria spectabilis</i>   | Sensitive                   |                         | Arctic Cordillera, North. Arctic, <u>Southern Arctic</u> , <u>Taiga Shield</u>                                                 |
| American Golden-Plover      | <i>Pluvialis dominica</i>      | Sensitive                   |                         | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u>               |
| Black-bellied Plover        | <i>Pluvialis squatarola</i>    | Sensitive                   |                         | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u>                                                                     |
| Ruddy Turnstone*            | <i>Arenaria interpres</i>      | Sensitive                   |                         | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u>                                                                     |

<sup>7</sup> <http://www.speciesatrisk.ec.gc.ca/>

**Table 9 (cont'd)**

| Common Name             | Scientific name                | Classification         | COSEWIC Status                                                | Present in Ecozones                                                                                                              |
|-------------------------|--------------------------------|------------------------|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Sanderling              | <i>Calidris alba</i>           | Sensitive              |                                                               | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u>                                                                       |
| Dunlin*                 | <i>Calidris alpina</i>         | Sensitive              |                                                               | Northern Arctic, Southern Arctic, <u>Taiga Shield</u>                                                                            |
| Least Sandpiper         | <i>Calidris minutilla</i>      | Sensitive              |                                                               | <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Plains                                     |
| Semipalmated Sandpiper  | <i>Calidris pusilla</i>        | Sensitive              |                                                               | Northern Arctic, <u>Southern Arctic</u> , Taiga Plains, Taiga Shield                                                             |
| Long-billed Dowitcher   | <i>Limnodromus scolopaceus</i> | Sensitive <sup>1</sup> |                                                               | <u>Southern Arctic</u>                                                                                                           |
| Hudsonian Godwit*       | <i>Limosa haemastica</i>       | Sensitive <sup>1</sup> |                                                               | <u>Southern Arctic</u> , Taiga Plains                                                                                            |
| Whimbrel                | <i>Numenius phaeopus</i>       | Sensitive              |                                                               | <u>Southern Arctic</u> , Taiga Shield                                                                                            |
| Red Phalarope           | <i>Phalaropus fulicaria</i>    | Sensitive              |                                                               | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u> , Taiga Plains                                                        |
| Red-necked Phalarope    | <i>Phalaropus lobatus</i>      | Sensitive              |                                                               | Northern Arctic, <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains |
| Lesser Yellowlegs       | <i>Tringa flavipes</i>         | Sensitive              |                                                               | <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                  |
| Buff-breasted Sandpiper | <i>Tryngites subruficollis</i> | Sensitive <sup>1</sup> |                                                               | <u>Southern Arctic</u> , <u>Taiga Shield</u>                                                                                     |
| American Bittern        | <i>Botaurus lentiginosus</i>   | Sensitive              |                                                               | Taiga Plains, <u>Taiga Shield</u> , Boreal Plains                                                                                |
| Peregrine Falcon        | <i>Falco peregrinus</i>        | Sensitive <sup>3</sup> | anatum = Threatened (2000); tundrius = Special Concern (1992) | Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Plains                                                              |
| American Tree Sparrow   | <i>Spizella arborea</i>        | Sensitive              |                                                               | <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera                                 |

**Table 9 (cont'd)**

| Common Name                  | Scientific name                                              | Classification         | COSEWIC Status                                     | Present in Ecozones                                                                                                                  |
|------------------------------|--------------------------------------------------------------|------------------------|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| White-throated Sparrow       | <i>Zonotrichia albicollis</i>                                | Sensitive              |                                                    | Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                                                 |
| Harris's Sparrow             | <i>Zonotrichia querula</i>                                   | Sensitive              |                                                    | <u>Southern Arctic</u> , Taiga Plains, <u>Taiga Shield</u>                                                                           |
| Barn Swallow                 | <i>Hirundo rustica</i>                                       | Sensitive              |                                                    | Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                               |
| American Pipit (Water Pipit) | <i>Anthus rubescens</i> (formerly <i>A.spinoletta</i> )      | Sensitive              |                                                    | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera |
| Boreal Chickadee             | <i>Poecile hudsonica</i> (formerly <i>Parus hudsonicus</i> ) | Sensitive              |                                                    | Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                               |
| Blackpoll Warbler            | <i>Dendroica striata</i>                                     | Sensitive              |                                                    | <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                      |
| Olive-sided Flycatcher       | <i>Contopus cooperi</i> (formerly <i>C.borealis</i> )        | Sensitive              | Draft assessment report in preparation - May 2007. | Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera, Boreal Plains                                               |
| Pied-billed Grebe            | <i>Podilymbus podiceps</i>                                   | Sensitive <sup>1</sup> |                                                    | <u>Taiga Shield</u> , Boreal Plains                                                                                                  |
| Short-eared Owl              | <i>Asio flammeus</i>                                         | Sensitive              | Special Concern - 1994                             | <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains, <u>Taiga Shield</u>                                                         |

**Legend**

\* - increased risk of becoming extirpated (locally extinct) or extinct

1 – heightened status because of small distribution in NWT

2 – status elevated from “Sensitive” in 2000 assessment

3 – status reduced from “At Risk” in 2000 assessment

4 – changed from “Undetermined” in 2000 assessment

5 – changed from “Secure” in 2000 assessment

The WGGSNS also noted the expansion of some species into the NWT, although much of the evidence is anecdotal. For example, the WGGSNS noted increased numbers of the black-billed magpie (*Pica hudsonia*), which suggests a northward extension of its traditional range. However Godfrey (1986) noted that the range of this species had expanded eastward and northward since the early 1900s, and increasing numbers in the NWT continue this trend. One implication of this change in distribution is due to the predatory nature of the magpie, which may prey on the eggs and nestlings of other bird species. Increased numbers of this, and other, species may significantly alter the numbers of other species, such as songbirds, that are at the northern edge of their range.

#### 2.3.5.3. Insects

The 2001 SOK report (Sly et al. 2001) indicated that about 20,000 insect species are estimated to be in boreal areas, half that number at the tree line, about 1,000 species at the northern edge of the taiga and 300 or less on the tundra. The WGGSNS roughly estimated that from 9,000 to 22,000 insect species are present in the NWT, of which 141 species, or about 1%, were assessed in 2006. Of those species, a total of 90 butterfly species, 41 dragonfly and 6 tiger beetle species were assessed. Two butterfly species found in the WKSS, the Beringian Fritillary (*Boloria natazhati*) and the Eyed Brown (*Satyrodes eurydice*) are considered to be “Sensitive” due to their small numbers, while all other species found in the WKSS are considered to be “Secure”.

A major human health and wildlife disease concern is the presence of the West Nile virus in the NWT because of its ability to cause illness and death in humans and wildlife. The mosquito-borne virus, which is found in members of the corvid family of birds (crows, ravens, magpies and jays) has not been detected in the NWT but GNWT Environment and Natural Resources, in conjunction with the Department of Health and Social Services, is participating in a country-wide surveillance program in 2007 to continue to monitor for its appearance (<http://www.hlths.gov.nt.ca>).

#### 2.3.5.4. Plants

Vascular plants remain one of the most difficult groups to assess because of the lack of information on their distribution. Of the 1135 plant species assessed, 17 species found in the WKSS are included in the category of “May Be At Risk” (WGGSNS 2006). The categorization is primarily based on the low numbers of individuals of these species and their limited distribution within the NWT

The WKSS is not particularly rich in rare vascular plant species because it is a relatively young landscape. The study area was covered by ice up to about 8000 years ago and all plants present have pioneered from unglaciated regions of North America. (Pielou 1999). More information on



these vascular plants species in the WKSS. More information on vascular plants in the WKSS may change the general status ranks of many species to a lower conservation status.

There are also 97 plant species in the NWT that are considered to be “alien” and hence not normally found in the NWT. This number will probably increase in the future as habitat disturbance increases, and climate change moderates extreme temperatures and lengthens the growing season. . Alien plant species in the WKSS are mostly found in or near communities, mine sites, all weather road right-of-ways, on portages along ice roads, and along seismic lines.

There has also been no specific attempt to assess the status of medicinal plants, or those used as traditional foods. (by sorting the species by medicinal or traditional foods, one can create a list with associated status. The only medicinal plant ranked as “May be at Risk” and present in the WKSS is Several Vein Sweetflag, as known as Rat Root. Only one site is known from herbarium collections in the NWT, however more sites are expected to exist, including in the WKSS, that are known to Elders knowledgeable in traditional medicine.

**Table 10 Summary of plant species assessed to be under the category “May Be At Risk” by WGGNS (2006). Only those species present in the Taiga Shield and/or Southern Arctic ecozones are presented.**

| Common Name               | Scientific name                                                                                             | Classification              | COSEWIC Status | Present in Ecozones                                                                                   |
|---------------------------|-------------------------------------------------------------------------------------------------------------|-----------------------------|----------------|-------------------------------------------------------------------------------------------------------|
| Several Vein Sweetflag    | <i>Acorus americanus (Acorus calamus)</i>                                                                   | May Be At Risk <sup>1</sup> |                | <u>Taiga Shield</u>                                                                                   |
| Yukon Fleabane            | <i>Erigeron yukonensis</i>                                                                                  | May Be At Risk              |                | <u>Southern Arctic</u> , Taiga Plains, Boreal Cordillera                                              |
| Pygmy Aster               | <i>Eurybia pygmaea (Lindl.) Nesom. (Aster pygmaeus Lindl. ;Aster sibiricus var. pygmaeus (Lindl.) Cody)</i> | May Be At Risk              |                | Northern Arctic, <u>Southern Arctic</u>                                                               |
| Small-Flower Bitter Cress | <i>Cardamine parviflora</i>                                                                                 | May Be At Risk              |                | <u>Taiga Shield</u>                                                                                   |
| Red Pigweed               | <i>Chenopodium rubrum</i>                                                                                   | May Be At Risk              |                | Taiga Plains, <u>Taiga Shield</u>                                                                     |
| Swedish Dwarf Dogwood     | <i>Cornus suecica</i>                                                                                       | May Be At Risk <sup>1</sup> |                | <u>Taiga Shield</u>                                                                                   |
| Mackenzie Sedge           | <i>Carex mackenziei (Carex norvegica)</i>                                                                   | May Be At Risk <sup>1</sup> |                | Taiga Plains, <u>Southern Arctic (only in extreme NW of the Southern Arctic – no records in WKSS)</u> |
| Few- Seeded Sedge         | <i>Carex oligosperma</i>                                                                                    | May Be At Risk              |                | <u>Taiga Shield</u>                                                                                   |
| Three-seed Sedge          | <i>Carex trisperma</i>                                                                                      | May Be At Risk <sup>1</sup> |                | <u>Taiga Shield</u>                                                                                   |
| Moss Heather              | <i>Harrimanella hypnoides (Cassiope hypnoides)</i>                                                          | May Be At Risk <sup>1</sup> |                | Arctic Cordillera, Northern Arctic, <u>Southern Arctic</u>                                            |
| Beach Pea                 | <i>Lathyrus japonicus</i>                                                                                   | May Be At Risk <sup>1</sup> |                | <u>Southern Arctic</u> , Taiga Plains                                                                 |
| Spinulose Wood Fern       | <i>Dryopteris carthusiana</i>                                                                               | May Be At Risk <sup>2</sup> |                | Taiga Plains, <u>Taiga Shield</u> , Boreal Cordillera                                                 |
| Slender Rock-brake        | <i>Cryptogramma stelleri</i>                                                                                | May Be At Risk <sup>3</sup> |                | <u>Southern Arctic</u> , Taiga Cordillera, Taiga Plains                                               |
| Dane's Gentian            | <i>Gentianella tenella</i>                                                                                  | May Be At Risk <sup>1</sup> |                | Northern Arctic, <u>Southern Arctic</u>                                                               |

Table 10 (cont'd)

| Common Name                    | Scientific name                                         | Classification                | COSEWIC Status | Present in Ecozones                                                                                              |
|--------------------------------|---------------------------------------------------------|-------------------------------|----------------|------------------------------------------------------------------------------------------------------------------|
| Alternate-Flower Water Milfoil | <i>Myriophyllum alterniflorum</i>                       | May Be At Risk                |                | <u>Southern Arctic</u> , Taiga Plains (only near G Bear L in the Southern Arctic – If not part of WKSS - delete) |
| Drummond Bluebell              | <i>Mertensia drummondii</i>                             | May Be At Risk                |                | Northern Arctic, <u>Southern Arctic</u>                                                                          |
| Horenmann Willow Herb          | <i>Epilobium hornemannii</i>                            | May Be At Risk <sup>1</sup>   |                | Taiga Cordillera, <u>Taiga Shield</u>                                                                            |
| White Adder's mouth            | <i>Malaxis monophyllos</i>                              | May Be At Risk <sup>1,2</sup> |                | <u>Taiga Shield</u>                                                                                              |
| Seaside Plantain               | <i>Plantago maritima</i> ( <i>Plantago juncooides</i> ) | May Be At Risk                |                | Northern Arctic, <u>Southern Arctic</u> , Taiga Plains                                                           |
| Water Pigmy-weed               | <i>Crassula aquatica</i>                                | May Be At Risk <sup>1</sup>   |                | <u>Taiga Shield</u>                                                                                              |
| Prairie-Smoke                  | <i>Geum triflorum</i>                                   | May Be At Risk <sup>1</sup>   |                | Taiga Plains, <u>Taiga Shield</u> , Boreal Plains                                                                |
| Richardson Alumroot            | <i>Heuchera richardsonii</i>                            | May Be At Risk <sup>1</sup>   |                | Taiga Plains, <u>Taiga Shield</u>                                                                                |
| White Mountain Saxifrage       | <i>Saxifraga paniculata</i> ( <i>Saxifraga aizoon</i> ) | May Be At Risk <sup>1</sup>   |                | Arctic Cordillera, Northern Arctic, <u>Taiga Shield</u>                                                          |
| Purslane Speedwell             | <i>Veronica peregrina</i>                               | May Be At Risk                |                | Taiga Plains, <u>Taiga Shield</u> , Boreal Plains                                                                |

### Legend

- 1 – heightened status because of small distribution in NWT.
- 2 – status changed from “undetermined in 2000 assessment, based on new information.
- 3 – changed from “Sensitive” in the 2000 assessment, based on new informatio

## 2.4. People and Land: A History

Each of the three sub-regions of the WKSS area has been used and occupied for thousands of years. The WKSS area is the traditional homeland of various Aboriginal peoples and is the new home of non-Aboriginal immigrants who have come from many parts of the world. The Aboriginal groups of the WKSS area describe themselves and, or, are identified by Euro-Canadians as:

- 1) The *Qitirmiut* who live in Kugluktuk, Cambridge Bay, Bathurst Inlet and Umingmaktok in the West Kitikmeot sub-region, Nunavut Territory.
- 2) The *Tłı̄chǫ Dene* of Gamètì, Wekweètì, Whatì, Edzo and Behchokǫ in the Treaty 11 sub-region, NWT.
- 3) The *Dene Syłné* of Łutselk'e and "T'atsaot'ine" of Ndilo and Dettah in the Treaty 8 sub-region (an area that also includes Yellowknife, the capital of the NWT).

### 2.4.1. Archaeological Record

*"No person's sense of himself has to do only with the present, not with only his own people.... The past - even the remote past - enters the present, becomes part of it in stories, in myths, and in what is gathered together in the word 'culture'" (Brody, 1976).*

Indigenous peoples have their own ancient narratives of origins and migration (Cruikshank 1981). Recent archaeological methodologies have incorporated indigenous oral histories in the interpretation of material culture (Andrews and Hanks, 1987, Andrews, 1990, Andrews et al, 1997 and 1998, Hanks and Winters, 1986; Hanks, 1996a and 1996b). Tom Andrews is currently conducting research aiming to expand the legal definition of archaeological sites to include non-material sacred or spiritual sites that can provide new meaning to the material record.

The earliest known archaeological evidence of people in the WKSS area dates back to about 10,000 BP. Gordon (1996) identified four primary cultural traditions, the earliest being the Northern Plano tradition, dating from 7000 - 8000 BP (Before Present). The Shield Archaic tradition is the second distinct phase, dating from 6500 - 3500 BP, while the Pre-Dorset is the third phase, dating from 3500 - 2600 BP, followed by Taltheilei tradition from 2600 BP to historic times. Historic times started with Samuel Hearne recording his observations of his journey through the area in 1769 to 1772.

The Plano people likely came to this area from the south, having followed the retreating ice-sheets of the last glaciation. About 7,000 BP, bison-hunting people from the western plains moved north to inhabit areas in the vicinity of Great Slave Lake. These bison-hunters adapted to a new environment and came to rely on caribou for survival (Crowe, 1974). However, there is no evidence that these early hunting cultures are related to Dene cultures which have used and occupied the area in more recent times.

Between 4,000 and 5,000 BP when the climate became cooler, the first people from the west, known as the pre-Dorset culture, began to arrive in northern parts of the WKSS area. The pre-Dorset peoples came to the Thaydene area from the Arctic coast to the north along with the receding treeline. Gordon theorizes that the rapid cooling made their traditional harvesting of the sea more difficult so they adapted by moving inland, likely following the Bathurst caribou herd. These people were followed about 3,000 BP by an early Inuit culture known as the Dorset culture. *“Modern Inuit know of the Dorset people through stories passed down by their ancestors, who met and were absorbed or eliminated by the older culture. In the stories, the Dorset people are called Toonit, and while some of the tales have become fanciful over the years, many of the facts agree with the evidence of archaeology”* (Crowe, 1974). The Dorset culture was replaced by a whale hunting culture, the Thule Inuit, who came from the north coast of Alaska. These people arrived in northern Canada about 1,000 BP. The Thule people quickly spread across the Arctic. *“There is no certain time when the Thule way of life became the Inuit way, only a gradual change, greater in some places than others. Most people agree that by about A.D. 1700 (300 BP) the true Thule culture had become that of the modern Eskimo, the Inuit.”* (Crowe, 1974). Today, several Inuit sub-groups live throughout the circumpolar world. One of the many Canadian sub-groups is the Qitirmiut who live in the west Kitikmeot sub-region of the Nunavut Territory.

Archaeological evidence found near the tree line, from the lower Coppermine River east to Hudson Bay, indicates that the ancestors of the modern Dene of the Treaty 8 and 11 sub-regions may have arrived in the WKSS area about 2,500 BP. Clark argues that Dene (Athapaskan) prehistory is regionally diverse, “a thing of many strands” (1981, 119). Linguistic research indicates that a Proto-Dene language was undifferentiated until 500 BC or later; this precursor to contemporary Dene languages was centred in the present-day northern Dene territory, likely the mountainous areas in eastern interior Alaska, the Yukon and parts of northern British Columbia (Vanstone 1974; Workman 1978). More recently Gordon has argued that there was a consistent evolution through to historic times that clearly identifies the Taltheilei as ancestors of the modern Dene. These are divided into Early (2600 BP - 1800 BP), Middle (1800 - 1300 BP), and Late (1300 - 200 BP) phases, based on evolved tool styles and the carbon dating of stratified sites.

Dene people expanded southward and eastward after 500 BC (Krauss and Golla 1981, 68). This perspective is supported by a number of documented Dene narratives of migration and dispersal, and explaining the origins of the various Dene peoples. Abel cites geological and oral history evidence that eruption of the White River Volcano in the St. Elias Range at about 525 AD may have caused a major dispersal of Dene people (Abel 1993; Workman 1979).

The Late Phase Taltheilei were the last people to follow the annual herd migrations from the southern winter range deep into the forest as far south as the Churchill River and all the way to

the caribou calving grounds northwest of Baker Lake. The fur trade and the severe decimation of native peoples by European diseases ended thousands of years of following the caribou herds. The change did not happen suddenly as some Dene adapted to the fur trade while others remained more traditional caribou hunters, and even those groups that were more involved in the fur trade continued as caribou hunters.

Today, the Tłıchǫ, Dene Sų́líné and T'atsaot'ine people of WKSS area are among the most northerly of Dene-speaking peoples. Other closely related members of this language group live along the Pacific coast and in the southwestern United States (McFadyen, 1974).

#### **2.4.2. Before the Europeans**

In 1789, Alexander Mackenzie was told by some Dene Sų́líné that “*in ancient times their ancestors lived till their feet were worn out from walking*” (Mackenzie, 1801). The mobility and extensive travels of early Dene and Inuit are recurring themes in the oral histories of Aboriginal northerners. The Dene tell stories of the movements of their people from one area to another, and about the divisions that occurred in their populations. One Tłıchǫ story tells of two brothers who separated after their childhood, one traveling north to the Arctic coast and the other going south into the forests (Helm, 1966). The Inuit tell of the epic journeys that their ancestors made to distant lands (Freeman, 1976). The nomadic and highly mobile lifestyles of the ancestors of modern day Dene and Inuit required a strong ability to adapt, both to different climatic conditions and to the availability and distribution of food sources. They used tools made from stone, bone and wood, and they harvested a variety of fish, bird, large and small game, and flora resources. Caribou were a particularly important source of food, and many archaeological sites have been found at locations where migrating caribou could be intercepted (Arnold, 1989).

The northern Athapaskan people were not a homogeneous population. The largest most widely distributed group was the Dene Sų́líné. The latter name is derived from a Cree word meaning “pointed skins”. It describes the clothing once worn by these people (Smith, 1981). Sub-divisions of the Dene Sų́líné are the T'atsaot'ine (also known among early European traders as the Copper Indians) and the eastern Ethen-eldeli people (at one time known as the Caribou Eaters). The Dene Sų́líné were present over much of the Canadian Shield, from Coronation Gulf east to Hudson Bay (Gillespie, 1981). They occupied the northern transitional zone of boreal forest (taiga) and adjacent barren grounds (tundra). The Tłıchǫ, another northern Athapaskan sub-group, were present between Great Slave and Great Bear lakes, and from the lowlands on the east side of the Mackenzie River to Contwoyto, Aylmer and Artillery lakes (Helm, 1981). While each Dene band used well defined areas, land use was not exclusive.

Many distinct sub-groups of Inuit inhabit the Arctic regions. The Qitirmiut of the West Kitikmeot sub-region are neighbours of the Mackenzie Inuit (to the west) and the Netsilik Inuit

(to the east). The range of the Qitirmiut traditionally covered much of Victoria Island and southern Banks Island. On the mainland they extended south to Great Bear Lake, Contwoyto Lake and Beechy Lake (Back River), and east to the Perry River (Damas, 1984; Farquharson, 1976). Within the range of the Qitirmiut, there were many small, dispersed and mobile groups. Eight groups lived in the areas known today as Kugluktuk, the Dolphin and Union Straits, and Coronation Gulf. The groups were located near an important crossing for migrating caribou between the mainland and Victoria Island, and productive seal, waterfowl and fish populations (Farquharson, 1976). The Qitirmiut followed a seasonal cycle. Towards the end of May, they left snow house villages on the sea ice and moved to the land. The harvesting cycle involved hunting seals and fish jigging in spring; caribou hunting and fishing inland during the summer; fishing during the runs of Arctic Char and hunting during the fall migration of caribou; and winter sealing from camps on the sea ice (Damas, 1984).

The various Dene and Inuit sub-groups were recognized or described by the land or territory they used, their clothing, the resources harvested or other prominent lifestyle features. The various sub-groups shared a common interest in the barren-ground caribou. These caribou were central to the lifestyle of the Dene and an integral part of the seasonal cycle of the Qitirmiut. Caribou were the primary source of food, clothing and shelter. Estimates of usage for clothing, alone, numbered as many as twenty skins a year for each person (Arnold, 1989). People structured their seasonal harvesting cycle, movements, technology and socio-territorial organization around the barren-ground caribou. Caribou were the basis of many beliefs, stories and traditions among the Dene Sųłı́né (Smith, 1981). The Tłı̨chų also relied on caribou and had many stories attached to their relationship with them (Legat et al, 2001; Legat et al, 1995: 8-9). Thorpe et al (2001) extensively document Qitirmiut relationships with caribou.

Aboriginal people of the WKSS area have relied mainly on the Qaminurjuaq, Beverly and Bathurst herds of barren-ground caribou. These herds seem to have been large enough to feed sizable populations of people for a long time (Abel, 1993). In the hunting grounds, the Dene were closely tied to the ranges and migration routes of caribou (Arnold, 1989). Several methods were used to harvest caribou and one method, the caribou pound, yielded, when successful, enough meat to enable the Dene to live relatively sedentary lives for a time (Hearne, 1958).

The movements and distribution of the Dene varied according to activity, time of year and available food supply. To a large degree the movements mirrored those of the caribou herds on which they were dependent (Smith, 1981). Movements and distribution also shaped the size and composition of each Dene group. Nomadism allowed the harvesting of large areas with the benefits of abundant meat and fat in the summer and fall (but little in late winter), and resources of berries, migratory birds, fish, source material for stone tools (mainly chert and quartzite), birchbark, and spruce roots for fish nets and line.

People had to adapt to extreme seasonal changes. Winter, with little light and very short days, snow and ice covering land and lakes, and extreme cold, made it difficult for people to procure food even in the forest. Then in summer, where caribou crossed water, people held mass hunts and enjoyed times of abundance. To cope with this change people broke into smaller groups for the dim winters, and when caribou dispersed in the forest, the Dene dispersed as well. With few resources during the winter months, starvation was not unknown when caribou were not close at hand (SENES and Griffith 2006, 95).

The family was the basic social unit around which Dene bands were organized (Abel, 1993; Ryan, 1995). A man, his wife and unmarried children usually constituted the family. Other wives, married children and one or two older people may also have been considered as members, depending on the season and availability of food (McFadyen, 1974). Group associations reflected ties through blood and marriage. Men hunted, built shelters, made tools and weapons, and were responsible for the means of travel for hunting and seasonal migrations. Women were responsible for almost every other task, including the preparation of food and clothing and maintenance of shelter (Abel, 1993).

The families of the northern Dene have been described by size and composition as a “local group” (or closely related families) and the “regional band” (or families related by blood or through marriage). Local groups worked and lived cooperatively in the same household or in proximity to each other, for much of the time. They identified with the larger regional band which gathered infrequently. Relationships with others were fostered through marriage and adoption (Abel, 1993; Helm, 1981). Large gatherings usually did not extend beyond the regional band, possibly due to the potential for conflict. Extensive writings confirm that peoples of the region possessed sophisticated structures of leadership and governance (eg. Bates, 2006; Blondin, 1999; Briggs, 1970; Gillespie, nd; Legat et al, 2000; Mason, 1946; Sharp, 1977b; White, 2005).

Traditionally, the Qitirmiut had restricted and customary areas of land use although individuals might travel extensively for social and trading purposes (Farquharson, 1976). In the words of geographer Beatrice Collignon, “they were nomads of the land (nuna) and ice (hiku), and used these ecosystems alternately according to seasonal changes in hunting conditions.” (2006, 33). Qitirmiut groups were organized around the family unit and the size of groups also varied with the season and availability of food. When food was scarce or limited to fishing in lakes and hunting small game, groups may have consisted of only one family. In October, families gathered at the coast to hunt caribou and wait for the ice to freeze. This was often a time of hardship. When the ice-sheet became solid enough, people left the coast and established large camps numbering from twenty to more than one hundred people. Men would hunt seals and occasionally polar bears. Spring brought a move back to the mainland, and caching of food and equipment in preparation for the summer caribou hunt in inland areas. During this time, the



community would split up into very small groups, as small as a single family, rarely more than two or three. They would travel as far as possible inland on established routes, returning to the coastal caches in mid-summer to pick up stored meat. In fall, the families would return once more to the coast to await freeze-up. (Condon 1996, Collignon 2006)

The Qitirmiut were unique among central Inuit populations in that they were organized by small independent families. However, the importance of kinship relations is indicated in the precision and complexity of kinship terminology in the Inuinnaqtun language; according to Collignon, “until late in life, people are regarded not for themselves” but according to the relationship they and/or their namesake had with the speaker (2006, 178-179). The Qitirmiut practiced a system of mutual reciprocity where a gift was immediately repaid with a gift of equal value. Voluntary reciprocal relationships between families were established primarily through spousal exchange and singing and, or, dancing partnerships. The Qitirmiut were creative dancers, songwriters and poets and the communal dance house was central to Qitirmiut social life (Stevenson, 1997).

Within most Aboriginal families of the WKSS area, individuals were in a general sense, free to make their own choices and follow their own convictions (Jenness, 1922; McFadyen, 1974). Decisions pertaining to Aboriginal groups were made through a consensus of the individuals directly involved. Criticism, gossip and ostracism served to maintain social order and harmony. Disputes between individuals were often settled through compensation, vengeance or combat. Leaders were male. Dene leadership was established through consensual recognition that the individual was a superior producer-provider, and generous and committed to the welfare of the group (Helm, 1981). *"A man acquires influence by his force of character, his energy and success in hunting or his skill in magic. As long as these last him, age but increases his influence, but when they fail his prestige and authority vanish"* (Jenness, 1922).

Children among the Dene and the Qitirmiut of the WKSS area were valued and their presence heightened the status of women and the family. Children were rarely disciplined or treated harshly. The main role of elders was one of advisors and educators. During times of extreme hardship when food was scarce, members of the family unit, particularly the male hunters, were subject to tremendous stress. Mobility and strength were essential in the search for food. Family members unable to keep up may have been considered a liability, and left behind to die (Abel, 1993). Female infanticide was practiced among northern Dene (Abel, 1993). It may have been practiced among the Qitirmiut until the 1940's (Damas, 1984).

#### **2.4.3. Arrival of the Europeans and Métis**

The northern Dene and the Qitirmiut came into contact with Europeans at different times. In 1670, a British royal charter authorized the Governor and Company of Adventurers of England (Hudson Bay Company - HBC) to trade furs in the Hudson Bay region. The Dene Sųłné were the first of the northern Dene to come into contact with these European traders. Contact between

the Dene Sų́́né and European traders in the late 1600's began the longest, continuous, Dene-European relationship in northern history (Smith, 1981). In 1717, the Prince of Wales Fort was established at Churchill to facilitate trade with the Dene Sų́́né. Dene Sų́́né trappers traded with the Europeans, supplied food to the traders and served as intermediaries between the HBC and other northern Dene (Hearne, 1958). At the time of contact, the Dene Sų́́né peoples including the T'atsaot'ine and *Ethen-eldeli* sub-groups, may have numbered about 4,000 (430 T'atsaot'ine, 2,250 Dene Sų́́né and 1,250 *Ethen-eldeli* (Smith, 1981)).

At the urging of HBC traders who had learned of copper deposits and of the existence of the "Copper Indians" (the T'atsaot'ine) in the interior, the Dene Sų́́né were encouraged to bring copper or the people associated with it, to Fort Churchill for trade (Abel, 1993). The T'atsaot'ine did visit this fort (Gillespie, 1981) but they seem to have had infrequent contacts with the traders. Intermittent contacts may have been due to many factors such as distance of the HBC fort from their traditional range and tenuous T'atsaot'ine-Dene Sų́́né relationships. There may have been fear about harvesting copper from lands bordering those of the Inuit, a protectionist view of the copper that was known to be a source of power and prestige, and, or, avoidance of trader pressures to bring copper to Churchill (Abel, 1993; Gillespie, 1981). Traders made contact with the Tłı́chų around 1740 (Osgood, 1936).

From 1769 to 1772, the eastern Dene Sų́́né leader, Matonabee, guided Samuel Hearne of HBC overland to the Arctic coast. Hearne was the first European to travel overland, to describe Great Slave Lake, and to document contact with the Qitirmiut. In 1789, Alexander Mackenzie of the NWC met Tłı́chų and Slavey on the Mackenzie River, near the mouth of the Great Bear River. The Tłı́chų may have numbered close to 2,000 at that time (Crowe, 1974). Throughout the 1800's, the Qitirmiut, estimated to number some 1,000 at that time, were intermittently exposed to European traders and explorers (Crowe, 1974). During the latter half of the 19th century, however, there was little contact between the Qitirmiut and outsiders. Diamond Jenness (1922a and 1922b) and explorers Knud Rasmussen (1932) and Vilhjalmur Stefansson (1913) provide the main documented testaments to the Qitirmiut way of life in the early 20<sup>th</sup> century.

Between 1818 and 1855, in excess of 50 expeditions made-up primarily of Europeans, traversed the Canadian Arctic. Expeditions expanded European knowledge of the Inuit but a lack of documentation would suggest that few, if any, lasting relationships were established. Sir John Franklin, who visited the site of present day Bathurst Inlet in 1821 and 1826 made little contact with the Qitirmiut (Stevenson, 1997). In the 1830's, Chief Factor Warren Dease and Thomas Simpson of the HBC traveled down the Coppermine River and explored the coast to the east of the Kent Peninsula. They encountered small groups of Qitirmiut, the largest being a group of 30 people. The search for the Franklin expedition in the late 1840's and early 1850's created numerous opportunities for European and Inuit contact. In 1848, Rae explored the south and west

coasts of Victoria Island. In his search for the Franklin expedition, Collinson wintered in Walker Bay, Victoria Island in 1851/52 and in Cambridge Bay among 200 to 300 Inuit the following year.

The mid-18<sup>th</sup> century marked a little-known migration of French-Cree Métis from the Canadian Prairies, the Great Lakes region and Old Quebec. In the words of Emile Petitot, “these nomads [were] the descendents of French and French-Canadian voyageurs and coureurs de bois who preceded the Hearnese, Frobishers and Mackenzies in these lands, and afterwards became the first servants of the Northwest company” (Petitot, 1887: 267, 288). They were refugees from the social and economic upheaval further south, including trade rivalries, depletion of fur resources, and natural disasters (NSMA, 1999: 21). A large influx of French-Cree Métis accompanied the establishment of the first Northwest Company (NWC) trading post at Fort Providence in 1790 to serve as a meat provisioning post and to facilitate trade with the T’atsaot’ine and Tłı̨chǫ – by that time the Dene Sų́líné’s role in the Athapaskan fur trade had diminished (Helm, 1981). These were principally employed as middlemen with the indigenous trappers, and were fluent in the indigenous languages required to facilitate trade. According to Clem Paul, “Most of our parents spoke...a minimum of three languages. Some of them spoke as many as seven.... They were the link between the non-natives and the Dene people” (NSMA interview, 1999: 23).

The Cree heritage of these people probably facilitated their journey into the Cree-Dene Sų́líné borderlands. Eventually the Métis migrants integrated with Dene Sų́líné, T’atsaot’ine and Tłı̨chǫ social and economic networks (Abel, 1993: 76). In their roles as intermediaries between two cultures, Métis were also influential in helping to determine procedures for ensuring that fur harvesting practices were sustainable (NSMA 1999: 24). Though early Métis families intermarried with indigenous families, they evolved a distinct culture. Families were larger and less nomadic, and work was structured differently. While the patriarch would be away for long periods of time, his wife and children would remain near the trading post. Today, the North Slave Métis trace their roots to two founding families, the Laffertys and the Bouviers. Geneological research conducted by NSMA suggests that by the late 19<sup>th</sup> century, Métis families primarily tended to marry amongst each other (1999: 31).

The range of the T’atsaot’ine at the beginning of the 1800's was closely linked to the Bathurst Caribou herd. The T’atsaot’ine had a “warlike reputation” among European traders and their Dene neighbours, the Slavey and the Tłı̨chǫ (Gillespie, 1981). Akaitcho was an important T’atsaot’ine leader and had been involved in Sir John Franklin's first expedition between 1819 and 1822. Tensions between the Tłı̨chǫ and the T’atsaot’ine continued, and in 1823 the Tłı̨chǫ made a revenge attack. They killed an encampment of 34 people, estimated at one-fifth of the T’atsaot’ine population (Gillespie, 1981). Tłı̨chǫ oral history attributes subsequent amity between T’atsaot’ine and Tłı̨chǫ solely to Tłı̨chǫ leader Edze (Edzo). His oratory shamed and

terrified Akaitcho and the T'atsaot'ine into peace (Helm, 1981). The T'atsaot'ine perspective on this exchange is undocumented. After 1823, the Tłıchǫ occupied areas that the T'atsaot'ine had once dominated. By the 1830's, the T'atsaot'ine were no longer the power they had once been (Abel, 1993). The T'atsaot'ine gradually retreated from areas around the Yellowknife and Coppermine rivers to occupy the eastern end of Great Slave Lake (Gillespie, 1981).

In 1821, when the two rival trading companies (HBC and NWC) merged to create a fur trade monopoly in the north, and the York boat was introduced in 1822, trading operations were downsized and wages were reduced. As a result many French Métis relocated back to Red River. English-Scottish Métis were retained by the HBC. Those French Métis who remained acted as boatmen, guides, interpreters and labourers during the summer, and during the winter continued subsistence harvesting for their families. They also became skilled trappers, and were likely used traplines more intensively than did their Dene counterparts. NSMA notes that historical documents of this period refer to Métis as “halfbreeds,” or most often as Indians or Dogribs. North Slave Métis elders also tend to identify with the indigenous way of life; “all were the same” is the refrain (NSMA, 1999: 30).

After 1821 the trading post at Old Fort Providence was closed, leaving the Tłıchǫ and the T'atsaot'ine without a point of trade within their areas. The post at Fort Resolution, established in 1784 by the NWC, began to draw these Dene into a common range for trade. By the 1850's, trade posts were located at or near the site of many present day communities in the Treaty 8 and 11 areas (Hall, 1986). The prominence of trade posts began to grow in the latter part of the 19th century. The missionaries who arrived in the 1850's contributed substantially to this expanded role. For example, the Fort Rae post, established in 1852 on an island in the North Arm of Great Slave Lake, became a meeting place for the Tłıchǫ people and an important caribou meat provisioning centre for traders. In 1853, “over 13,000 lbs. of caribou meat, much of it dried, as well as 2,000 tongues” were listed on the fort inventory (Fumoleau, 1973: 351). Later, the fort also became a source of medical services, communications, and religious teachings. Between 1876 and 1902, the Fort Rae post became a major station in the trade of Muskox robes (Helm, 1981). NSMA identifies the history of Old Fort Rae as being significant for understanding the development of a distinct North Slave Métis culture and identity (1999: 33).

Relationships between the Dene and traders in the 1800's were highly inter-connected. The traders depended for survival on country foods and furs provided by the Dene. The Dene maintained a high level of independence, but were quick to find uses for European trade goods such as guns, ammunition, tobacco, tea, flour, axes, files, other tools, household utensils, and woollen clothes. The Dene found that some European trade goods were more durable, efficient and, or, easier to use than handmade items. This often made time available for other pursuits. “Free time” made it possible for art and craft activities to develop among the Dene. *“The nineteenth century was a time of a literal cultural flowering. Exquisite bead and quill work was*

*produced in quantities apparently unknown in the past ... the skills of women producing these beautiful items became highly valued ... ” (Abel, 1993).*

The Dene and European traders had differing ideas about their trade relationships. This was particularly the case with the expansion northward of the Hudson’s Bay Company in the late 19<sup>th</sup> century, which unlike the feudal French fur trade, operated according to capitalist principles of competition and profit (Tough, 1997). The HBC traders advanced credit to the Dene for winter supplies, based on a trapper's skills and previous successes. This system of credit required a trapper to return to the post to repay his debt. Among the Dene, a large debt was considered quite prestigious and not necessarily something that should or needed to be paid off at the end of each season. The English traders did not share such views (Hall, 1986).

Another example is provided by the high value and importance that European traders accorded to the accumulation of material goods, a value and importance which was not shared by the Dene. The Dene *“recognized the dangers of devoting too much time to fur trapping (to trade for material goods), for if game suddenly became scarce and there were no provisions in store, the possibility of starvation was very real indeed”* (Abel, 1993). Starvation was not the only concern. In the 1850's, scarlet fever ravaged a T’atsaot’ine band at Lac de la Mort. A decade or so later, influenza decimated about 30% of the Qitirmiut (Crowe, 1974).

Missionaries came into the WKSS area in the 1850's with the aim of converting the Dene to Christianity. Missions were established, and the missionaries traveled to Dene camps and to large Dene gatherings. They devoted much effort to learning indigenous languages in order to more effectively transmit their message. In subsequent decades, the roles of the missionaries expanded to include both education and care giving. Initially, the missionaries were drawn to the trade posts that enabled them to establish contact with Aboriginal people, to access supplies and to secure transport. In some parts of the WKSS area, missionaries were able to claim rapid success. For example, the Roman Catholic missionaries arrived at Fort Rae in 1859 and the first Tł̥chq̓ person was baptized into that faith in the same year. Within five years, 600 Tł̥chq̓ people had been baptized (Helm, 1981). However, the number of baptisms soon began to fall off, and the superficiality of these “conversions” became apparent (Abele 1993).

Records indicate that the seasonal cycle of the Dene was not substantially altered by early traders or missionaries (Abel, 1993; Helm, 1981; Ryan, 1995). Rather, trapping for trade and travel to the trade posts were integrated into this cycle. For example, the annual cycle of the Tł̥chq̓ in the latter part of the 1800's involved trading Beaver and Muskrat in June and July, drying fish and caribou hunting in late July and early August, stockpiling fish in September-October, trapping fine furs in November and December, seeking game in January and February, caribou hunting in March, and trading in April and May. By the latter decades of the 1800's, the Tł̥chq̓ were visiting the Fort Rae post at Christmas and Easter, and in June after the spring Beaver hunt. The

regularity of these visits by Tłı̨chǫ families resulted in large tribal gatherings at these times (Helm, 1981).

Unlike the Dene, the Qitirmiut had little or no direct contact with European travelers, traders or missionaries in the 1800's (Condon, 1996). Possibly the only group who may have had some exposure to the Europeans would have been the people of the area known today as Bathurst Inlet and Umingmaktuk. This group made more use of inland areas than other groups of Qitirmiut (Farquharson, 1976). Nevertheless, tons of valuable materials (copper, iron and wood) and manufactured goods entered Qitirmiut society from the British ship, *Investigator*, which was abandoned at Mercy Bay, Banks Island, by M'Clure (Stevenson, 1997).

In the latter decades of the 1800's, a series of events took place which set the stage for the tremendous changes which would occur in the WKSS area in the 20th century. The most significant of these events occurred between 1867 and 1870. They included the founding of the Dominion of Canada (1867), establishment of the first mission school in the NWT at Fort Providence (1867), and the transfer of title to Rupert's Land (the entire Northwest Territory) from the HBC to the new Government of Canada (1870). These events spawned an era of nation building, and the development and passage of legislation and policies to define the jurisdiction and authorities of the new government.

Among the new legislation and of particular relevance to the people of the WKSS area was the *Indian Act* (1876). The act defined Aboriginal people and the responsibilities of the Canadian Government. The *Northwest Territory Act* (1875) established administrative districts throughout the Northwest Territory. The District of Keewatin was established in 1876, the Districts of Assiniboia, Saskatchewan, Alberta and Athabaska in 1882, and the Districts of Mackenzie and Franklin in 1895. In 1898, Yukon became a separate territory and in 1905, the provinces of Saskatchewan and Alberta were formed. The *Northwest Territory Act* was amended in 1905 to give the Federal Government full responsibility for the remaining districts of the Mackenzie, Keewatin and Franklin. It also provided for the appointment of a Commissioner and a Council (of not more than four members (Carney, 1971)).

In the 1870s, the HBC lost its monopoly in the fur trade, and in the mid-1880s the steamboat was introduced to reduce transportation costs. These developments had a major impact on the fur trade, and particularly the Métis teams who had formerly manoeuvred the York boats along the rivers. The number of employees was reduced as a result of the new technology (Tough, 1997). Remaining Métis employees served as pilots, deck hands, and pulling barges at portages (NSMA, 1999: 40). The reduction of the number of fort employees significantly reduced the need for caribou meat, so Métis and Tłı̨chǫ were encouraged to trap and later to harvest muskox for their robes. By the turn of the century the area around Old Fort Rae had been stripped of fuel. In 1902 a new Fort Rae was established 18 miles north, and 14 years later only one

extended Métis family, the Laffertys, persisted in living at Old Fort Rae. By the turn of the century, Fort Rae had made the transition from provisioning post to fur trade post. During that time the Métis Erasmus family gained prominence as interpreters in the trade (NSMA, 1999: 42-43).

The economy and lifestyles of the Dene of the WKSS area underwent significant changes as the 20th century approached. These changes brought hardships and seriously threatened the survival of the Dene well into the new century. The Dene experienced game shortages, a declining fur trade, more competitive resource pressures and less amicable relationships with non-Aboriginal people. Dene also experienced uncertain relationships with the Government of Canada (Abel, 1993; Fumoleau, 1973). Little assistance was available to deal with these hardships. Annual visits by a medical doctor did not begin in the Tłıchǫ region until 1900 (Ryan, 1995). Appeals by missionaries to the Canadian Government to assist the Dene, were unsuccessful (Fumoleau, 1973). *“The Hudson’s Bay Company had always helped the Indians in time of famine. However, after 1870 it argued that the Canadian Government must assume responsibility for the NWT and its native people ... The Canadian Government did not feel any obligation toward people with whom it did not have a formal agreement”* (Fumoleau, 1973). The policy of the Canadian Government in the late 1800's has been described as “no-treaty-no-help” (Fumoleau, 1973). The Canadian Government seemed to have little interest in the north or in its people. It was not interested in entering into a treaty north of the 60th parallel.

By the turn of the century, Inuit people were being drawn into the fur trade for the first time. The international demand for white fox led to the establishment of permanent trading posts across the Arctic – a process of expansion that took only fifteen years (Usher 1970, 16). Inuit became accustomed to a variety of imported goods, and became skilled bargainers, playing competing traders off one another (Graburn, 1969). For practical reasons, Oblate Catholic and Anglican missionaries settled near the trading posts, along with RCMP officers, and began a fierce competition for Inuit converts. As in the fur trade, at least some Inuit tried to turn this rivalry to their advantage. However, despite the large number of apparent conversions, the elimination of shamanistic beliefs and practices proved to be quite difficult (Mitchell, 1996). Federal intervention in Qitirmiut territory at the turn of the century was minimal, principally motivated by American challenges to Canadian sovereignty in the Arctic following settlement of the Alaska/Canada boundary in 1903 (Coates, 1985: 141).

The Dominion of Canada began to govern the North more actively by the mid-1890s; the main vehicle for this was the “Unorganized Territories Game Preservation Act” restricting harvesting of animals and birds. The Canadian Government’s approach to northern administration, and to the people of the northwestern districts, finally changed with the discovery of oil in the Mackenzie River Valley and the discovery of gold in Yukon (Fumoleau, 1973). The resource potential of the northwest caused the government to actively pursue treaties with the northern

Dene and in 1899, Treaty 8 was signed. Northern “halfbreeds were offered scrip worth 240 acres of non-transferable land, though “scrip hunters” bought up many scrip certificates for a fraction of their value (NSMA, 1999: 44-45). Métis who took scrip relinquished their Indian status, and the differentiation of rights effectively fragmented the social structure of Dene-Métis communities (NSMA, 1999: 50).

#### **2.4.4. The 20th Century**

At the beginning of the 20th century, the business of building a new nation greatly influenced the WKSS area, as did other economic and political events occurring elsewhere in Canada and in the world. The gold rush in northern British Columbia and Yukon, mineral and oil exploration in the Mackenzie Valley, the growing presence of the Canadian Government in the northwest, and World War I were among these events. They brought an influx of non-Aboriginal traders, mineral explorers, scientists, law enforcement officers, missionaries and federal government agents into the region. With the newcomers came new social, economic and political pressures, and new expectations, systems and laws. The Canadian Government gave the North West Mounted Police (RCMP after 1921) the job of asserting Canadian sovereignty in the northern districts, establishing law and order, and enforcing government policy. The first RCMP detachment was established in the NWT at Fort McPherson in 1903. By 1921, there were six detachments, 12 by 1937 and 15 by 1944 (Barnaby, 1991).

In 1905, following the *NWT Amendment Act*, the Canadian Government appointed a non-resident council to guide development and express the nation’s interests in the Districts of Mackenzie, Keewatin and Franklin. The Government also pursued treaties as a means of furthering national interests and in 1921, Treaty 11 was signed. The Government viewed treaties as a mechanism for extinguishing land claims. Treaties also provided a cheap form of relief payment to Aboriginal people and facilitated the implementation of law and order, and government policies (Abel, 1993). Dene oral history may provide a more accurate version of the treaties. The Dene viewed treaties as international agreements that established relationships between themselves and the Crown. Treaties acknowledged Dene sovereignty and underlying title, while allowing Euro-Canadians access to the land. “*Dene were to retain control of themselves, their land, economy and political life; in return they promised to live in peace.....In return for living in peace, Dene would receive gifts of medical and relief aid for the sick, elderly, and destitute and emergency assistance.*” (Smith, 1999).

Treaties were expressions of good will whereby the Government promised to protect the land-based economy from outside pressures brought by settlers, trappers, and prospectors and to assist in times of hardship or sickness (Abel, 1993). For the Dene, ensuring continued access to hunting, fishing and trapping territories was the main motivation for entering into a treaty with the Government. In ensuing years, however, the Dene saw access to land and resources being threatened by government and non-Aboriginal interpretations of the treaties. The implementation of legislation also restricted or limited resource harvesting activities. The first legislation, the



*Game Act*, came into force in 1896 and this was followed by the *Migratory Birds Convention Act* in 1917, and the *NWT Game Act* in 1929 (Abel, 1993; Fumoleau, 1973). The Dene began to voice concerns to the first Indian agent, who was appointed to the northern districts in 1901. Lack of satisfactory resolution of concerns respecting resource harvesting eventually led to boycotts of Treaty 8 in Fort Resolution in 1920 and 1937. There were numerous other complaints and protests (Abel, 1993). In 1947, all Dene bands in the NWT lodged complaints to the Government about the *NWT Game Act* (Dene Nation, 1983).

While treaties were being signed and new Canadian laws implemented, the Dene of the WKSS area continued to be ravaged by starvation, sickness and disease. Epidemics and death from famine frequently followed diseases. Effects were to destroy families and profoundly undermine the skill and knowledge base of the people as well as their self-sufficiency and hopes for the future (Abel, 1993). Starvation and sickness drove Dene throughout the WKSS area to the trade posts in search of help. Little if any help was available. *“The complete inadequacy of northern medical services was demonstrated tragically in 1928. A severe strain of influenza was imported to Fort Smith that spring and developed into a full-blown epidemic reminiscent of the disastrous scarlet fever epidemic of 1865. The spring boats carried the virus from post to post down the Mackenzie; both Natives and non-Natives were snared in the same trap of contagion”* (Abel, 1993).

The early decades of the 20th century also brought Euro-Canadians scientists, adventurers, traders, missionaries and government agents into the west Kitikmeot subregion. The Canadian Arctic Expedition brought researchers and scientists to the lands of the Qitirmiut to investigate the people, flora, fauna and resources. The documents produced by the Expedition and others recorded during this time provided important insights into Qitirmiut society. *“The exploratory journey of Stefansson in 1910 to 1911 and the presence of the Canadian Arctic Expedition 1914 to 1917 were important factors, but the influx of goods brought by trading ships from the west and the establishment of a number of trading posts in the Coronation Gulf area during the early 1920's were the chief determinants of changes in material culture, economy, and social organization.”* (Damas, 1984).

After 1916, new trade posts sprung up in the Arctic coastal region to capitalize on the demand for Arctic Fox. In an attempt to maximize profits, many of these traders exploited Inuit trappers (Condon, 1994). The missionaries arrived about the same time, although the work of the churches was likely slowed by the murder of a Roman Catholic priest near Bloody Falls in 1913 (Damas, 1984). In the 1920's, mineral prospecting by aircraft began in the Arctic. The first settlement of Bathurst Inlet evolved from a mining exploration camp established there in 1929 (Pierce, 1994). The RCMP arrived in Cambridge Bay in 1926. A six-bed hospital operated at Kugluktuk between 1929 and 1931. This was undoubtedly influenced by a severe epidemic in 1928, which drove over half of the surviving population of Bernard Harbour to Kugluktuk.

Bernard Harbour was situated on the south shore of Dolphin and Union Strait, almost due north of Kugluktuk (Farquharson, 1976).

After only a short period of use, trade goods, particularly the rifle, steel trap and fish net, had begun to alter the seasonal cycle, land use and migration patterns of the Qitirmiut (Damas, 1984). By the mid-1920's many families were leaving sealing camps in early spring to remain inland until late fall. Jenness (1922) noted the rapid rate at which dogs became a major means of transportation. The dependance upon of dogs put greater pressure on caribou and fish resources and led to local shortages of caribou (Stevenson, 1997).

Traditional Qitirmiut society began to change as a result of contact with Euro-Canadians. *“The fur trade, the rifle and the fish net not only undermined traditional reciprocal rights and obligations, but they began to turn families into self-sufficient production units. Thus, the traditional foundation for sharing began to erode and socio-economic relationships became more inwardly focused.”* (Stevenson, 1997). Around the same time, missionaries outlawed spousal exchange and dance and/or song partnerships. These actions severely reduced traditional co-operative and reciprocal activities, and eventually extended family units began to replace voluntary partnerships.

Much of the literature about the WKSS area in the early to mid-20th century focuses on the interaction and the influence of the Anglican and Roman Catholic churches, Federal Government agents and the RCMP with the Aboriginal peoples. Mission-run schools were established early in the 20th century at central trade posts such as Fort Resolution (1903), Fort Smith (1915), and Fort Simpson (1918) in the western NWT, and at Chesterfield Inlet (Nunavut) and Churchill (Manitoba). These schools generally evolved from mission-run day schools to residential or boarding schools. They took young children far away from their families, in some cases, for years at a time. A major expansion of Canadian Government funding of mission schools was introduced in 1898. Possibly, this was in anticipation of the signing of Treaty 8. It was not until 1910 that a major revision of government policy was undertaken to address mounting complaints about the viability, efficacy and appropriateness of the church-run “Native boarding schools” (Abel, 1993). The policy gave the government a clear role in determining the curriculum, reducing the previous emphasis on religion. Schools were to provide *“an English education; to teach calisthenics, physical drill; fire drill; to teach the effects of alcoholic drinks and narcotics on the human system, and how to live in a healthy manner; to instruct the older advanced pupils in the duties and privileges of British citizenship, explaining to them the fundamental principles of the Government of Canada, and to train them in such knowledge and appreciation of Canada as will inspire them with respect and affection for our country and its laws.”* (Abel, 1993).

In recent years, the church-run residential schools have been more thoroughly documented in light of allegations of abuse (Barnaby, 1991; Chrisjohn, 1994; Peterson, 1994; Milloy 1999).

Much of the evidence is similar regardless of the origin of the child or the location of the school. *“Native schooling was not designed to enable graduates to assume positions of power, as these were reserved for hierarchies within the church, the company, and the government, all of whom were autocratic, conservative and fundamentally racist in character ... (Thus the Dene) never having been consulted about schooling, had nothing to say about the substitution of one paternalism for another, thereby leaving sectarian controversy which accompanied the rise of the federal system to the missionaries to resolve.”* This author's research was based on historical documents and education policies pertinent to the NWT (Carney, 1971).

Métis who had taken scrip were forced to pay for the privilege of having their children forcibly removed to attend residential school in Fort Resolution and Fort Providence. Even those such as Bob Erasmus who had employment had their houses confiscated by the Church because they couldn't make the payments (NSMA, 1999: 53). Despite the often traumatic experience of residential school, many Métis girls and some boys stayed to assist with cooking and cleaning after completion of the fifth and final year. Often these individuals went on to become nuns or priests.

In the early decades of the 20th century, day to day influence of federal agents on the lives of Aboriginal people in the WKSS area seems to have been less than that of other Euro-Canadians. The reasons for this are attributed to the wide range of their functions from health and education inspectors to treaty officials, and the extensive areas and widely dispersed populations for which they were responsible (Barnaby, 1991). The RCMP were regionally based, and played a significant role in the daily lives of northern people. The presence of the RCMP is described in the literature as a “mixed blessing” not only to Aboriginal people but also to the traders and the missionaries. The RCMP assisted in providing relief to those in need, enforced game laws, and protected the interests of Canada in the north. These responsibilities often brought the RCMP into conflict with northern people, both Aboriginal and non-Aboriginal (Abel, 1993).

World War II (WW II) stimulated additional and more rapid changes in the north. The discovery of silver at Great Bear Lake, oil at Norman Wells, and gold on the shores of Yellowknife Bay in the 1930's, fuelled greater interest in northern resources. Within the context of WW II, northern resources were viewed as critical to future national security (Abel, 1993). Gold discoveries at Yellowknife created a boom town by 1936 and four years later, it was a thriving community of about 1,000 people with the first municipal government in the district. Advances in communication and transportation technologies, a growing industrialization of the northern economy, falling fur prices and game shortages, and continued sickness and diseases particularly among the Aboriginal populations, posed new challenges for the people and the Government. *“The 1930's and 1940's saw the development of two northern solitudes: two independent economies, two very different societies and a significant power imbalance.”* (Abel, 1993). The solitudes separated those involved in the Aboriginal land-based harvesting economy and the non-

Aboriginal wage-based economy. These differences continued to be reflected in the marginal involvement of the Dene in the industrial economy, in decision making and perhaps, most importantly in the regulation of game and fish resources. *“Game regulations became the intersection at which Dene interests and value-systems collided most dramatically with outsider interests.”* (Abel, 1993).

North Slave Métis began to move to the Yellowknife area to take advantage of the gold boom, and two Métis enclaves formed in the School Draw and Willow Flats area. They were employed in freight hauling, fishing for the mine, and cutting wood. By 1940, the population of 50 Métis was overwhelmed by the swelling population of 1,000, mostly newcomers. By the late 1940s, the Yellowknife population grew to 3,000. Métis from Duck Lake and other outlying areas were ordered to relocate to Yellowknife and enrol their children in school. By the 1950s and 1960s, 12 to 15 families totalling 80 to 100 people lived in the two Métis neighbourhoods. As the number of newcomers expanded, so did the number of marriages outside the Lafferty-Bouvier dynasty, so that a large group of names were added to the pool of North Slave Métis families. Métis continued their traditional subsistence practices in the Yellowknife area, setting nets, snaring rabbits and foxes, hunting ducks, and picking berries. Warehouses were built for the purpose of processing country foods. These traditional practices were blended with wage labour. (NSMA, 1999: 57-59)

Despite the rapid changes occurring in the WKSS area, the seasonal activities of the Dene during and after WW II were reminiscent of those of previous generations. The Dene continued to be migratory. After spring break-up, they moved to traditional fishing sites for the summer. They gathered and dried foods for winter in late summer, and moved to traditional hunting grounds for the fall hunt. In December, they moved to the nearest post to trade furs and, after, they returned to winter camps until spring (Helm, 1981). Within this economic cycle, the general health of Aboriginal peoples continued to be poor. Influxes of newcomers brought with it numerous diseases that Aboriginal people had scant resistance to. Approximately 800 people died in the outbreak of measles and scarlet fever in 1867. An influenza epidemic hit the North in 1918. But the most devastating epidemic of influenza was transported by HBC supply boats in the spring of 1928, taking the lives of three to four people a day. High rates of tuberculosis also had a major impact throughout the early 1900s (Abel, 1993: 201). Between 1937 and 1941, the incidence of tuberculosis among Dene of the Mackenzie District was 14 times greater than the national average. The occurrence of pneumonia was more than double the national rate (Wherrett and Moore, 1945). In 1950, one in every five Inuit suffered from tuberculosis (Crowe, 1974).

The post-war years brought a recommitment from the Canadian Government to asserting sovereignty north of the 60th parallel, and to developing the north's non-renewable resources. Increases in government expenditures provide evidence of this commitment. In 1945, the Canadian Government's budget for the NWT was \$0.5 million and in 1961 it was \$41 million

(Carney, 1971). In the 1980's and 1990's Federal Government allocations to the GNWT exceeded \$1 billion annually, prior to the creation of Nunavut Territory. The 2001/2002 fiscal year budget for the new, smaller NWT stands at just over \$750,000,000. The budget for Nunavut Territory, for the same fiscal year, is \$667,000,000 (GNWT, 2000a).

In the post-war years, new national social programs became available in the WKSS area. In 1946, the Northern Health Service of the Department of National Health was established. It was to provide medical services and to address abysmal northern health conditions, particularly among Aboriginal peoples. Other forms of support such as food vouchers, social (financial) assistance, the family allowance (1945) and the old age pension (1948) were introduced or became more readily available. These forms of support quickly became incorporated into the northern economy and were eagerly used by the Dene and Inuit. Support was viewed as an economic resource, and one that was complementary to land-based harvesting practices (Ross, 1986). In 1956, Commissioner Gordon Robertson expressed concern about the wide-spread dependency on social support among Aboriginal people in the north (Abel, 1993). The wide-spread dependence on income support and social programs remains a concern throughout the NWT (DECE *et al.*,1995; Lutra, 1998).

In 1953, the Canadian Government restructured its administration of the northern districts. A Northern Administration Branch was created, in which the Territorial Division and the Lands Division were relevant to the Dene. The Arctic Division was relevant to the Inuit. Northern education was reorganized in 1955. Church run schools were phased-out, allowing government schools to refocus education. This provided an opportunity to reflect current social and economic circumstances and northern development policies of the Canadian Government (Abel, 1993). The new northern education program was designed to transform hunters into wage-earners. It was also intended to assimilate northern Aboriginal people into main stream Canadian society (Kakfwi, 1977). Family allowance supports became one of the instruments for encouraging the participation of Dene, Métis and Inuit children in education programs. To receive desperately needed cash, families sent their children to school. Some children attended schools near their family but many others went to residential schools in distant communities (Asch,1986; Barnaby, 1991; Carney, 1971). Dene and Inuit children of the post-war period were the first of their people to have the opportunity to achieve a high school education and pursue other post-secondary education. The parents of these children were the first to adopt a sedentary, community-based lifestyle, a trend that emerged in support of their children's education. It was also a trend that fundamentally altered the lifestyle of the Dene (Abel, 1993; Barnaby, 1991; Helm, 1981; Smith, 1981).

By the early 1960's, the effects of the Canadian Government's new northern policies were evident in the lifestyles of people throughout the WKSS area (Abel, 1993; Barnaby, 1991; Helm, 1981; Smith, 1981). Government nursing stations and elementary schools had been constructed

near churches, trading posts, RCMP detachments and government staff housing. "Stick-built" housing was also replacing the tents and, or, log dwellings of Aboriginal people. In the Tłıchǫ region, some Dene families began to live year-round at the present town site, rather than gathering at Rae once or twice a year and spending the winter on the land (Ryan, 1995). Electricity arrived in Rae in the 1950's and a connector road to the Mackenzie Highway opened in 1960. The Tłıchǫ community of Whatì, formerly a NWC trading post (1793 to 1817), began to form with the construction of a school in 1955. Gamètì and Wekwetì remained outpost hunting camps until government services and infrastructure began to arrive, respectively, in 1970's and 1980's. Łutselk'e began developing as a Dene Sųłné community when government services and permanent housing became available there in 1954. The Canadian Government designated the name "T'atsaot'ine A Band" to Dene Sųłnés in the Łutselk'e area in the 1960's and "T'atsaot'ine B Band" to the Tłıchǫ residing in and near the town of Yellowknife (Gillespie, 1981).

In 1965, concerns about the water supply and health of Rae residents spurred the Canadian Government to establish the new town site of Edzo and a new school was opened there in 1971. This "showplace community" was built despite Métis protests about the meaning of their old home, and the majority of Rae residents refused to relocate. Eventually the territorial and federal governments gave up attempts to relocate people and instead began to make improvements to the existing community (NSMA, 1999: 61). As the city of Yellowknife expanded and the value of land in Dene and Métis neighbourhoods increased, the government undertook to acquire these lands, calling the Aboriginal residents "squatters." In the early 1960s Dene were forcibly relocated to "Squaw Valley" at the end of Latham Island. If people refused to move, their homes were bulldozed. Métis were subjected to similar removal, but they were relocated to low-cost row housing in the newer part of town. The government was unable to overcome Métis resistance at Willow Flats, so they moved the Municipal dump next to their houses. As Métis were gradually dispersed, the community disintegrated and along with it buffers against racism and discrimination. (NSMA, 1999: 62-63)

The impacts of increased Canadian Government investment and new social policies were also felt by Qitirmiut of the west Kitikmeot subregion. In 1951, the Canadian Government took over the LORAN infrastructure for communication purposes and the Royal Canadian Air Force established a survival school at Cambridge Bay. Military and other government personnel arrived with the DEW-line, and a school was built in 1958. By 1955, Cambridge Bay had become a major supply and transportation centre for 12 DEW-line sites being constructed across the north. *"At the peak of this construction, some 200 Inuit were employed along this section, and Cambridge Bay became a focus of immigration from other settlements."* (Farquharson, 1976). The construction of a DEW-line site at Kugluktuk in the 1960's attracted Inuit to settle in the developing community. *"The extent of land use during the 1950's and early 1960's decreased, for most people lived in or near Coppermine at the time, and they still used dogs to*

*travel. The numbers of caribou and other game taken were not especially large. Then the snowmobile was introduced, and it changed the lifestyle and patterns of land use altogether. The necessity of maintaining a camp 20 to 30 miles out of town to be nearer good hunting territory became much less, so more people moved into the settlement. They are now able to travel farther and faster with the snowmobile and, despite the more concentrated settlement pattern, have returned to exploit most of the hunting area they left in the late 1950's."* (Farquharson, 1976).

The Qitirmiut population settled in the new communities in part because of the availability of wage employment and social services, but also because of declines in caribou populations and the uncertainties of the Arctic Fox fur trade (Damas, 1984). By 1959 the Federal government was actively supporting Inuit settlement in permanent communities, partly for administrative convenience and partly in order to assert sovereignty over the high arctic. Throughout the 1950s people in the areas around Cambridge Bay and Kugluktuk were moving into settlements. The move into Ulukhaktok and Bathurst Inlet did not begin until the end of the 1950s. This move had a major impact on the Inuit culture and way of life (Damas 2002; Collignon 2006). After experiencing the “urban” life, some families decided to move to camps on the land, spending only a few weeks every year in the settlement (Collignon 2006). Bathurst Inlet has remained, until very recently, an outpost camp with few services (Farquharson, 1976).

The growth of permanent communities together with the movement of land-based peoples into settlements, contributed to the development of cooperatives across the Canadian Arctic in the late 1950's. Cooperatives were an effort to link the land-based and the wage economies (Crowe, 1974). The Cambridge Bay fisheries and Kugluktuk arts and crafts cooperatives were established in 1961 and 1969, respectively. Mitchell argues that these cooperatives played a significant role in the emergence of class structures in the communities, and nurtured a new Inuit national consciousness (1996). Regional economic surveys in the 1950's and 1960's showed that few northern Aboriginal people held year-round or permanent wage jobs. The economic circumstances of Aboriginal peoples were very poor compared to those of non-Aboriginal people. Low participation of Aboriginal people in the wage economy was also influenced by limited opportunity, personal circumstance and lifestyle choice (Abel, 1993; DIAND., 1958-1969).

Governance in the NWT evolved with the development of the new communities. The first territorial council was appointed in 1905 but the first resident did not join the council until 1947. It was 1951 before the first members were elected. Fifteen years after Aboriginal people were allowed to vote in federal elections (1960), the first fully elected territorial council took office. This first fully elected council had a majority of Inuit, Dene and Métis members. It followed a consensus style of decision-making which is not found in any other legislative assembly in Canada. Since the 1960's, the Dene and Inuit have been working toward self-government. In response to grievances and growing concerns in and about the north, the Canadian Government

sponsored the Carrother's Commission to inquire into the political future of the NWT. In 1966, following this report, the seat of government was moved to Yellowknife. This began the devolution of power from Ottawa to the north.

In 1967, the Federal Government installed a Commissioner and administrative staff at the new capital of Yellowknife. Two years later, administrative responsibilities were transferred from the Government of Canada to the newly created GNWT. In the following decades, responsibilities for education, health, forestry, and some aspects of wildlife management and housing have been passed from the federal to the territorial government. Today, the Federal Government retains or shares responsibility with the GNWT and, or, Aboriginal organizations for non-renewable resources, fisheries and much of the regulatory processes related to the natural environment in the north. The institutions, structures and payroll of the GNWT bureaucracy grew steadily from its inception until the mid-1990's. In 1974, the GNWT employed 2,700 people (DP-GNWT., undated) and in 1995, this number was 6,128 (FMS-GNWT., 1995). After the creation of Nunavut, the GNWT employed only 3,351 people while Government of Nunavut employed 4,298.

Amidst the devolution of Federal Government responsibilities and the creation of the GNWT, Aboriginal peoples across Canada and in the NWT were evolving active political organizations. The establishment of the GNWT, concerns for Aboriginal participation in northern decision making, and the Federal Government's 1969 White Paper outlining the future of Aboriginal peoples in Canada were among the issues that lead to the formation of new Aboriginal political organizations. These included the Indian Brotherhood of the NWT in 1970 (now known as the Dene Nation), the Committee for Original Peoples Entitlement (COPE), the Métis Association of the NWT, and the Inuit Tapirisat of Canada (Abel, 1993). These political organizations worked to gain recognition of Aboriginal land rights, to regain control of resources, and to address issues of governance. Their efforts were manifested in a growing public awareness of Aboriginal peoples and of the north. Three years after the formation of the Indian Brotherhood, the Dene sought legal recognition of their prior interest in 450,000 square miles of traditional lands in the Mackenzie Valley. The initially positive response to the Dene's claim rendered by Judge William G. Morrow of the Supreme court of the NWT provided the basis for the Dene to pursue legal claim and recognition of Aboriginal rights to traditional lands, resources and governance. They were also successful in influencing the outcome of the 1975 Mackenzie Valley Pipeline Inquiry (Berger Inquiry) which recommended a moratorium for ten years on the first proposed oil pipeline, in light of unresolved rights and land disputes (Berger, 1977).

The 1970's and 1980's were decades of socio-cultural and political revitalization among northern Aboriginal peoples, and of the evolution of northern governments and institutions. The GNWT promoted establishment of municipal governments and today, locally elected councils function in virtually every community in the WKSS area. Dene communities also maintain a Chief and



Council as established by the Federal *Indian Act*. Education, health and social services begun in the WKSS area were expanded to include programs and services related to housing, municipal transportation, communications, and economic development. Many of these activities were driven by a need to catch-up and to introduce modern health care, recreation, schooling, transportation and jobs to the north (GNWT., 1991). Among Aboriginal peoples and their organizations, the need for self-determination again within their homelands was recognized. This encouraged greater use of Aboriginal languages and other expressions of Aboriginal cultures in the business of northern institutions, and supported the involvement of more Aboriginal people in the affairs of the state. In 1984, the *Official Languages Act* recognized Aboriginal languages along with French and English, as official languages of the NWT.

Throughout the 1970's and 1980's, Federal and Territorial Government investment and policies supported the development and expansion of community governments, public infrastructure, communication and education facilities and services and Aboriginal political organizations. They also supported community-based economic development in the form of renewable resource and tourism industries, and small businesses (SCNE., 1989). In these decades, four new mines opened in the NWT, adding to the three mines operating since the 1930's and 1940's. The mining industry continues to be the largest private sector employer and largest single influence on GDP (NWT-CM *et al.*, 1993). Throughout the 1970's and 80's, national and international resource developers continued to look north to exploit rich oil and gas deposits. In 1985, the first oil pipeline was built from Norman Wells to Alberta. Industrialization of the north has continued and in 1998, after almost a decade of intense exploration and development, the first diamond mine in Canada, the BHP Billiton Diamonds Inc. Ekati mine, opened in the traditional range of the Dene. Two additional mines are expected to open within the next few years.

The last two decades of the 20th century have been ones of tremendous political change in the WKSS area and NWT. To some extent, traditional land and resource uses of some Dene groups and the right to self-governance have been recognized in federal and territorial government legislation and policies. The first Aboriginal land claim agreement in the NWT was signed in 1984, between the Inuvialuit and the Government of Canada (*Inuvialuit Land Settlement Act*). The Federal Government began negotiating with the Dene and Métis in 1981 toward a comprehensive land claim settlement for the whole of the Mackenzie Valley. Nine years later, the Dene Nation rejected the proposed claim, partly due to the federal land claims 'policy-of-the-day' to extinguish Aboriginal rights. In 1990, the Gwich'in of the Mackenzie Delta and the North Slavey of the Sahtu Region withdrew their negotiating mandate from the Dene Nation. Each group requested that the Canadian Government negotiate regional land claim settlements. These claims were concluded in the Gwich'in area in 1992 and in the Sahtu Region in 1993. The Gwich'in and Sahtu agreements extinguished the Aboriginal rights of these Dene but provided certainty to the use and ownership of land. The agreements included a commitment for the Federal and Territorial governments to negotiate Aboriginal self government agreements with

these regional Aboriginal organizations (CWG., 1998). Some negotiations are nearing completion and others are in progress.

The failure to reach a comprehensive settlement in 1990 and maintain unity among northern Dene and Métis peoples, has weakened their political strength and fragmented the organizational force, but resource and governance issues continue to be pursued. Formal negotiations began with the Tłı̨chǫ in January 1994, the third regional land claim to be accepted for negotiation in the Mackenzie Valley. Interim agreements provide the Tłı̨chǫ with opportunities to participate on government bodies which assess and review development activities and regulate land and water uses in the North Slave region. In August 1996, the Tłı̨chǫ, the Canadian Government and the GNWT were signatories to a framework agreement that outlined the issues and time frames for concluding a land claim and self-government agreement. Agreement-In-Principle was signed in January 2000, and a final land claim and self-government agreement was signed on August 25, 2003 by the Tłı̨chǫ, the Canadian Federal Government and the GNWT. In 2000 negotiations began between government and the approximately 2,400 Akaitcho Treaty 8 Dene. After a break in 2002, negotiations resumed in January 2003 with emphasis on lands and governance issues and are ongoing. The thrust of these discussions is to achieve co-existence among Aboriginal and non-Aboriginal people in the Treaty 8 area. Co-existence is a philosophy based on the understanding that *“nothing will be done or allowed to interfere with their (Dene) way of living as they were accustomed to, and as their antecedents had done”* (NWT Treaty 8 Tribal Council, 1994).

The North Slave Métis Alliance was registered as a non-profit society on November 22, 1996 to represent descendents of indigenous Métis who lived in the North Slave region prior to 1921. The establishment of diamond mines and other development projects were the catalyst for the formation of the NSMA, which aimed to build unity among the various Métis groups in the region. A statement of claim for lands in the North Slave region, including Lac de Gras, was submitted to the federal government in 1998. This claim is ongoing.

Residents of the West Kitikmeot sub-region participated in a 1982 plebiscite which showed that 70% of eligible voters in Nunavut wished to divide the NWT into two parts (generally along the tree line), and to create a politically and culturally distinct territory for the Inuit. Five years later, the *Iqaluit Agreement* set out the principles by which an eastern and a western territory would be established. In 1990, the Tungavik Federation of Nunavut, representing Inuit throughout the NWT, reached an agreement-in-principle with the Government of Canada respecting Inuit land rights and governance. Four years later, the Nunavut land claim was legislated, recognizing traditional lands of the Inuit and the creation of the new territory of Nunavut on April 1, 1999. The West Kitikmeot sub-region is part of this new Inuit territory.

#### **2.4.5. Toward the 21st Century**

*“One factor of overriding importance is the rate of change in the North, especially since World War II. Each successive generation of Native people has grown up in very different circumstances. For example, elders alive today remember a childhood in which very occasional wage labour and the fur trade were the only significant sources of cash income, while most people made their living mainly from the land. The next generation - people who are in their thirties and forties now - remember being taken from their communities to residential schools for long periods of time and trying to learn the language and skills of their parents despite this. The children of the 1980's attend school (at least until high school) in their own communities, or they may be growing up in cities and large towns. They watch television, listen to popular music and face many different obstacles to learning about their heritage. The contrasts among the childhood experiences of these three generations illustrate the pace of change.” (Abele, 1989).*

As the 21st century begins, the prospect of change is a certainty shared by Aboriginal and non-Aboriginal residents of the WKSS area. New governance regimes are evolving in the two new territories, with the implementation of Aboriginal land claim settlements and self-government agreements. The wage or industrial economy is changing in response to reductions in government investment and proposed mineral, hydroelectric and infrastructure developments. Competing interests and changes in the natural environment influence both subsistence and land-based economies. Environmental and climatic change, new technologies, global market conditions, and changing harvester skills and interests pose complex questions and challenges for the future of resource harvesting. Amidst these changing conditions, many of the issues that existed at the turn of the 20th century persist today. These include access to and management of resources, equal participation in decision making, and ensuring the health and well-being of individuals and families. In the WKSS area, these concerns are made more urgent by the growing population, half of which is under 25 years of age.

The population of the NWT was 42,600 in 1976 and 64,402 in 1996. After division the total NWT and Nunavut population exceeded 70,000 (42,154 to NWT and 27,892 for Nunavut). According to Census Canada, the NWT posted a population decline of was -1.8% in 2001. In contrast, Nunavut's rate of growth was double the national average at, of 2.4%. Population projections based on the 2001 census indicate that more than 25,000 people live in the WKSS area (Table 7). This population is expected to increase to more than 32,000 by 2024. In the Treaty 8 and 11 and West Kitikmeot sub-regions, Dene and Inuit remain the majority in all communities except the capital of Yellowknife.

The people of the WKSS area are confronted with several unique and complex challenges. The population lives in a world of change and contrast, of new and old, both culturally and economically. Aboriginal and non-Aboriginal residents of the WKSS area have access to global communications and mass media, but also to elders who speak in forms of the Dene and Inuktitut

languages that are spoken by few other people. Communities other than Yellowknife can best be characterised as “mixed economies.” There exists a will to maintain and strengthen the traditional subsistence and trapping way of life among new generations; the continued economic importance of harvesting to Dene and Inuit have historically been downplayed, yet this remains one of the most important economic activities in communities in the WKSS area other than Yellowknife (Hicks and White, 2000; Tracey and Kramer, 2000). At the same time, there is a rapidly growing wage labour force rooted in the communities; training and education so that people can access work opportunities remains a major challenge (Abele 1989). For communities outside of Yellowknife, the majority of jobs are located outside the community; the two-week rotation schedule is a difficult reality for people who value family and traditional land-based practices. Whereas the unemployment rate in Yellowknife was only 5% in the winter of 2004, it was between 15% and 39% in the smaller communities (statistics are not available for Nunavut).

**Table 11 Population profiles for the WKSS area and communities**

| Area / Community                        | Population        |                   |                   | Percentage Aboriginal |      |                   |                   |                   |
|-----------------------------------------|-------------------|-------------------|-------------------|-----------------------|------|-------------------|-------------------|-------------------|
|                                         | 1996 <sup>1</sup> | 2001 <sup>1</sup> | 2005 <sup>2</sup> | 1981                  | 1991 | 1996 <sup>1</sup> | 2001 <sup>1</sup> | 2005 <sup>2</sup> |
| NWT Total                               | 39,672            | 37,360            | 42,982            | 43%                   | 47%  | 48%               | 50%               | 50%               |
| Nunavut Total                           | 24,730            | 26,745            | n/a               | 86%                   | 85%  | 84%               | 85%               | n/a               |
| Kitikmeot Region <sup>3</sup>           | 4,644             | 4,816             | n/a               | 91%                   | 87%  | 89%               | 90%               | n/a               |
| WKSS Communities                        |                   |                   |                   |                       |      |                   |                   |                   |
| Bathurst Inlet/Umingmaktok              | 51                | 5                 | n/a               | 100%                  | 100% | 100%              | 100%              | n/a               |
| Cambridge Bay                           | 1,351             | 1,309             | n/a               | 80%                   | 76%  | 76%               | 79%               | n/a               |
| Kugluktuk                               | 1,201             | 1,212             | n/a               | 93%                   | 93%  | 89%               | 93%               | n/a               |
| Treaty 11 - Tẖcẖo Region <sup>4</sup> | 2,471             | 2,410             | 2,893             | 92%                   | 90%  | 91%               | 93%               | 97%               |
| WKSS Communities                        |                   |                   |                   |                       |      |                   |                   |                   |
| Wekweti                                 | 135               | 131               | 138               | 100%                  | 98%  | 89%               | 92%               | 100%              |
| Gameti                                  | 256               | 274               | 302               | 95%                   | 100% | 92%               | 95%               | 100%              |
| Wha Ti                                  | 418               | 453               | 502               | 98%                   | 97%  | 94%               | 93%               | 96%               |
| Rae-Edzo                                | 1,662             | 1,552             | 1,951             | 91%                   | 92%  | 91%               | 94%               | 93%               |
| Treaty 8 - Yellowknives                 |                   |                   |                   |                       |      |                   |                   |                   |
| WKSS Communities                        |                   |                   |                   |                       |      |                   |                   |                   |
| Dettah                                  | 190               | 182               | 218               | 100%                  | 97%  | 97%               | 97%               | 97%               |
| Lutselk'e                               | 304               | 248               | 414               | 92%                   | 93%  | 92%               | 92%               | 94%               |
| Yellowknife                             | 17,275            | 16,541            | 19,429            | 14%                   | 17%  | 20%               | 22%               | 22%               |

**Notes:**
<sup>1</sup> Statistics Canada - <http://www12.statcan.ca/english/profil01/CP01/Index.cfm?Lang=E>
<sup>2</sup> GNWT Bureau of Statistics - <http://www.stats.gov.nt.ca/Profile/Profile.html>
<sup>3</sup> Eight communities total

<sup>4</sup> Four communities total

n/a - information not available

At the same time, governments lack a significant tax base from which to provide the wide range of programs and services that people in WKSS area communities have come to expect. The challenge of these issues is compounded by disturbingly high incidences of alcohol and drug abuse, illiteracy, boredom, unemployment, family violence, suicide and disease. For the large numbers of young people now growing up in WKSS area communities, these circumstances are disquieting. The National Roundtable on the Environment and the Economy (NRTEE), has determined that "...capacity building is the most important challenge facing Aboriginal communities in the north" (2001).

#### 2.4.6. Land and Heritage Sites: An Example of the Importance of Land to Aboriginal Peoples

Aboriginal people often refer to the important role that the land plays in their culture and survival, and non-Aboriginal people will likely relate to these statements from their own cultural perspective. They may think of the importance of wildlife used for food, the aesthetic qualities of

land and the attachment that is felt to familiar country, or country occupied for generations. However, the depth of meaning of the statement may be lost on most non-Aboriginal people unless they know more about the integral nature of land to Aboriginal culture. The land plays a role in the lives of Aboriginal people that is quite different from the experience of most non-Aboriginal peoples.

Among the Dene and Inuit the content of stories, songs or other forms of narratives are essential components of culture. Spirituality, values, history, governance, justice, and practical information needed for obtaining resources are examples of information contained within narratives. These are passed from one generation to the next through the oral tradition (Andrews et al, 1997; Legat, 1995; 1997).

Examples from recent Dene and Qitirmiut research show that many place names and associated narratives reflect the values and knowledge of indigenous people. Knowledge of these narratives, which accumulate over a life time, are essential to being or becoming a true and knowledgeable Dene or Qitirmiut (Andrews, 1990; Andrews et al, 1997; Collignon 2006; Dogrib Treaty 11 Council, 2002; Kitikmeot Inuit Association, nd; Kitikmeot Heritage Society, nd; Cruikshank, 1990; Savoie, Ed, 2001). Research with Tłı̨chǫ communities during 1996-2002 suggests that place names are important indicators of bio-geographical knowledge (Legat et al, 2000). Examples of the fundamental importance of places and place names for Dene are reflected in the legend of the culture hero Yamoria (Blondin, 1990). Through a series of heroic actions Yamoria brought order to the world, in part by separating animals and humans, and by ridding the land of giant animals that were harmful to people. The specific locations where these actions took place are remembered through place names assigned to each of them. When people travel past or camp at these places the stories associated with the place names are recounted and provide a time to reflect on or be taught the cultural values they convey. Some places are associated with particular stories that outline appropriate cultural behaviour. Those who are not behaving accordingly are reminded of this when they travel to or past these places. When away from them and acting inappropriately, the individual will think of the story and the place (Andrews, 1990).

Place names also provide practical descriptions for the location of resources such as caribou crossings, good fish lakes, places where a particular type of rock can be quarried for tools, or birch bark suitable for canoes. Some names simply provide a description of geographical features. For the Dene, traveling and living on the land is as important as it is to visit places where cultural narratives are expressed and knowledge imparted (Legat *et al.*, 2000).

Given the importance that the land holds for the Dene, only those who are truly knowledgeable of the land are thought qualified to speak about it (Zoe, 1995). Before doing so, elders establish their credibility to others in telling of their experience on the land, their knowledge of the rules set down by important historical leaders, and of key spiritual and, or, mythical events. In doing

so, they demonstrate that they are true holders of important knowledge which has been passed down through the generations.

Thorpe et al note that the meaning of Innuinaqtun terms related to the land are difficult to translate in English, since they embody a distinct conception of human-nature relationships. For example: “The term ‘*hila*’ is usually translated as ‘weather’ or ‘the outdoors,’ while it actually embodies much more than this: *hila* includes the relationships between Inuit, climate, weather, plants, wildlife, spirits, and the land. Similarly, the word ‘*nuna*’ is typically translated as ‘land,’ when most people say that *nuna* includes not only the land, but also the relationships between the land and other biological, spiritual, and physical elements of the tundra” (2001, 6). Similarly, in her study of Qitirmiut place names and land use, Collignon challenges the narrow conception that place names are key to knowledge of travel routes. When asked about this, elder participants asserted that “there is no need to know how to name the land in order to travel on it without getting lost” (2006, 107). Rather, Collignon found that place names are understood not so much on a “horizontal,” spatial plane as on a “vertical,” historical plane. Place names are “essential for making people feel at home in their surroundings, and for making these surroundings a human territory, where the culture may flourish” (2006, 110). Place names are linked to a spatial perspective that is “connected, relative and subjective” (2006, 158). That is, space is conceived as a collection of relationships that are dynamic and changing; moreover, knowledge about the land is “personal, specific, and connected to real situations” (2006, 167).

#### *2.4.6.1. Heritage Sites*

Given the importance of land to Aboriginal people, there are innumerable places within the WKSS area that are significant to Dene, Inuit, and Métis culture and history. Collectively, these are referred to as heritage sites. The use of the word heritage does not mean that the sites are only significant in an historical context. Many of these places continue to be used in some manner, as they have been over hundreds if not thousands of years.

Heritage sites are often named places and are documented through place names research. Such sites may be landmarks, sites associated with mythological or legendary events, or traditionally used places that also have archaeological remains. Place names research, archaeological surveys, oral traditions interviews, and a combination of all of these are the ways in which heritage sites can be documented within the WKSS area.

#### *2.4.6.2. Aboriginal Place Names*

Information on the place names of the NWT is held at the Prince of Wales Northern Heritage Centre (PWNHC) in Yellowknife. In the NWT, the importance of using Aboriginal place names to Aboriginal peoples can be seen in the recent change of many community names from Euro-Canadian ones to those that were traditionally used. For the past fifteen years the PWNHC has

been gathering and promoting the recording of traditional names for all geographic features (lakes, mountains, rivers, islands) throughout the north. Over the years traditional community names, many of which predate the community itself as they were used for nearby geographic features, have been recognized as official by the GNWT.

Traditional place names reflect the use of the land by Aboriginal peoples and are places of importance to them. Most non-Aboriginal people are unaware of the large number of named places that exist in the NWT. In the past, many Aboriginal names were not included on official maps and this resulted in a perception of under representation of the area's use by Aboriginal peoples. Documentation of traditional place names in the NWT, some of which are within the WKSS area, is taking on a new impetus (Andrews et al, 1997; 1998; Blondin, 1990; *Dene Mapping Project*, 1986). Not only do people want to see the names appear on maps but they also want to document the knowledge related to them. The GNWT recognized the importance of documenting and preserving traditional names and has sponsored more than 40 place name projects over the past 15 years. As well, several non government projects have also taken place. More than 15,000 traditional place names have been documented through recent place names projects (Freeman, 2000).

#### 2.4.6.3. Archaeological Sites

Archaeological sites in the NWT are protected by three laws. The *NWT Archaeological Sites Regulations* state that excavation or investigation of sites or collection and removal of artefacts cannot be undertaken without a permit. The *Territorial Land Use Regulations* state that land use permit holders shall not conduct land use operations within 30 metres of a known or suspected archaeological site or burial ground. Permit holders are to suspend operations if a site is found while working in an area and to report the find. The *Historic Resources Act* protects sites on Commissioner's Lands of the GNWT. Developments thought to threaten historic remains on such lands are subject to the Commissioner calling for the developer to undertake a study and, or, salvage of the remains. The importance of archaeological sites to Aboriginal peoples is clearly stated within most land claims agreements or negotiation documents (DECE., 1996).

The Archaeological Survey of Canada Sites Database is administered and maintained by the Canadian Museum of Civilization in Hull, Québec. It contains information on all sites reported in the NWT. The PWNHC in Yellowknife accesses this database and also maintains a file of sites reported by non-archaeologists. Within the WKSS area, the Archaeological Sites Database lists 1,041 known archaeological sites. This is thought to represent only a small fraction of the actual number of sites in the area (Andrews et al, 1998). The sites represent occupation of the area over as long as 7,000 years. Among the types of sites listed are burials, campsites, hunting localities, hunting blinds, lookouts, quarry sites, workshops, and forts.

There are numerous examples of the importance of using TK in identifying and interpreting



archaeological sites (Andrews et al, 1998; Blondin, 1990; NPC., 1997). The value alone in identifying numbers of sites through traditional and, or, local indigenous knowledge can be seen in the report of the West Kitikmeot Land Use Plan (Greer, 1997). Seven hundred archaeological sites were identified within the region. Of these, 61% were known sites obtained from the Archaeological Sites Database and the remaining 39% were identified by Inuit who knew of these sites from living and traveling in the area.

Recent archaeological surveys undertaken by the Tłıchǫ Treaty 11 Council and the PWNHC show the importance of archaeological sites and the information they contain on culture and history. During a survey of the Idaà trail (linking Great Slave to Great Bear Lake), Tłıchǫ elders and project researchers recorded 286 sites as well as 350 named places (Andrews et al, 1997; 1998).

#### 2.4.6.4. Graves

The Dene, Inuit, and Métis share concerns for the protection of graves. Dene and Métis graves, often with a cross and surrounded with a picket fence, are carefully maintained by people traveling past them. Offerings are presented to the dead and assistance may be asked for in hunting or some other activity. Graves may also be used as a meeting place for travelers and as a place where ceremonies are held to ensure safe travel. In the past, graves have been destroyed or damaged through development (Beilawski, 1993). Concerns that more graves may be destroyed was voiced by many Aboriginal people attending the Environmental Hearings for the BHP Billiton Diamonds Inc. Ekati mine (Legat, 1995). Graves are widely scattered across the land in areas where people lived and traveled. However, no systematic documentation of grave sites has been undertaken and very few graves have been recorded. Only graves that are sometimes recorded during archaeological surveys come under the protection of laws which pertain to archaeology. Graves in cemeteries are protected, but those found elsewhere, and not considered archaeological, are not protected. New legislation proposed by the PWNHC seeks to protect graves on Commissioner's Land (DECE., 1996).

It is important to Aboriginal people to identify grave sites so that they are not destroyed. Graves are present over a very large area and reflect the extensive land base on which people have lived and traveled. A recent survey of a portion of the traditional trail between Great Slave and Great Bear lakes yielded 189 graves (Andrews et al, 1998). Even though far away from present communities, graves are still a concern to people as the following statement of elder Laiza Koyina attests *“All the land over there is where the dead bodies are laid. Kǫk’etibà is where grandmother had died and they had to bring her across the lake and over by Kǫk’etibà. They carried her there and buried her. And so my younger brother, Johnny is buried there ... We have a lot of relatives who are buried in the barren land.”* (Legat, 1995).

## 3.0 THE DYNAMIC WKSS AREA ECOSYSTEM

### 3.1. Introduction

In terms of the environment, a stress is something that causes change. It may take the form of a sudden large event or an accumulation of many very small “happenings” which occur over time. Cumulative impact occurs when many stresses act together to cause change. Often their combined effects are greater than if each stress were to act separately. When stress exceeds some form of threshold, it alters the balance of life (e.g., ecosystems falling out of the range of tolerance for its species). Stress occurs naturally, such as when a wildlife population grows to exceed the carrying capacity of its range (*e. g.* caribou or geese). It also occurs when human development substantially alters the natural system (*e. g.* by contamination or exploitation). Stress has the potential to affect any part or all of the ecosystem and to be a major part of human experience.

Throughout the WKSS area, both natural and man-made stresses, and global and local stresses interact to cause change in many parts of the whole ecosystem. Relative to most parts of southern Canada, the WKSS area is much less disturbed or developed, but such comparison can be misleading. Even a small amount of development has the potential to affect sensitive environments of the WKSS area and their freshwater, marine and terrestrial ecosystems. Many of the resources of this region have already reached a moderate state of development and a few are at an advanced state (Figures 2 and 3).

For example, the NWT Cumulative Impact Monitoring Program (CIMP) Valued Components report provides an initial state of knowledge for identified criteria which encompass any part of the environment considered important based on economic, social, cultural, community, ecological, legal or political concern (INAC, 2005). With respect to the valued component of fish quality, this report indicated that stress from physical and chemical disruption can affect the overall health of fish by disrupting several key biological parameters, including storage and utilization of energy and ions, hormone and micronutrient homeostasis, throughout the NWT.

The Status of the Environment (SOE) portion of the NWT Audit conducted by SENES in 2005, found that overall quality in the NWT was favourable for most of these valued components. However, two disturbing trends were noticed: the recent large decreases recorded on the size of the caribou herds; and the need for action in the area of socio-economics and community wellness (SENES, 2005).

The mining industry is an example of development associated with a non-renewable resources. Many mines operate for less than 10 years although there are a few exceptions like Con (opened in 1938) and Giant (opened in 1948) that had lifetimes of more than half a century. Mineral resources of the WKSS area are extremely valuable. However, these resources have a limited lifetime and their rates of exploitation are largely determined by decisions made far outside the

region. Some renewable resources, such as fish and caribou, are relatively large but they are also significantly developed in terms of their potential long term yield. Other resources may support only very light use. For example, the number of Muskoxen is known to have been heavily depleted by past exploitation. For the foreseeable future, renewable resources are likely to remain a crucial part of Aboriginal and some domestic economies. They can only become more important in the future as non-renewable resources eventually become depleted.

The modern economy of the NWT has been dominated by these types of activities in the non-renewable resource sector. While some efforts are being made to diversify into other sectors, it is likely that non-renewable resources will continue to underpin the economy of the NWT for decades (SENES, 2005).

Multiple forms of stress affect the WKSS area and many of them result in cumulative impacts, but management of effect often requires that each form of stress be considered separately. Thus, in the following discussions, distinction is made between stress, its causes, and the effects of stress. It is also recognized that social and economic forces which drive development can not be divorced from its effects. They are often the source although they may not be the immediate cause of environmental change. People are a functional part of a dynamic biophysical environment, and land use cannot be planned and managed without reference to the human community; accordingly, social, cultural and economic endeavours of the human community must be central to land use planning and implementation (NPC, 2005).

As we have done throughout this report, social, economic and environmental factors need to be addressed together because people are an integral part of the environment. Stress does not affect all people equally or in the same way. There are obvious differences such as those depending on employment, education and economic standing. There are also cultural differences that exist among Aboriginal and non-Aboriginal communities and which can be equally significant in ways that give rise to different effects.

### **3.2. A Mixed Economy**

For centuries, family and group economies in the WKSS area have been influenced by the availability of and demand for resources, access to technologies and other circumstances such as climatic conditions. In the 20th century, these influences became more national and global in nature.

Since the late 1700s Europeans have periodically explored parts of the West Kitikmeot. However, within the last 60 years, outside ideas and institutions have significantly impacted the lives of Inuit in this region. Before contact with Europeans, there was some trade among Inuit groups, but, overall, people did not travel as far as during the later fur trading years, when trappers ranged over great distances (NPC, 2005).

The influences of both World War I and II, the "cold war", fur trading companies, the RCMP, church missions, the assertion of sovereignty in northern Canada, and increased mineral and hydrocarbon exploration and development activity had enormous impacts on life throughout the WKSS region. They spurred the establishment of DEW-line sites and transportation infrastructure throughout northern Canada, hastening the rate at which aboriginals had to adapt their traditional way of life in order to participate in the wage economy.

New economic circumstances (cash economy) created opportunities to take up seasonal construction work, and to supplement scarce game and low demand and, or, poor return from fur trapping. Health, education and social and government services that expanded in the WKSS area after WW II also offered opportunities to supplement intermittent wage employment and harvesting activities. To respond to new economic opportunities, some families abandoned the nomadic lifestyle and seasonal camps in favour of a community base. By the mid-1960s, the pattern of traditional camp life was declining as families began to move permanently into the communities (NPC 2005). For example, between 1996 and 2001, the population of Bathurst Inlet decreased from eighteen to five people. Social, health and education services encouraged a more sedentary lifestyle among Aboriginal people (Ryan, 1995). New technologies enabled harvesters to pursue traditional activities from a community base. Snow machines replaced dog teams, enabling harvesters to travel further and faster, and radio communications allowed harvesters to remain in contact with their families in the community. As new costs were incurred to support harvesting activities, wage employment became increasingly more vital as a means by which ties to the land and traditional activities could be retained (Usher, 1971). Government transfer payments were readily integrated into the wage and, or, harvesting economy of fledgling communities. Transfer payments were used by governments and recipients alike to respond to gaps in the economy whether as a result of depressed fur markets, poor harvesting conditions, inadequate housing or lack of employment (Abele, 1989). By the time the WKSS area communities were taking shape in the 1960's, wage employment and social and, or, transfer payments, like trapping in earlier decades, had been fully integrated into the economic cycle of the Dene, Inuit and Métis (Abel, 1993).

Today, the economy of the WKSS area has three elements. These are traditional activities, wage employment and government transfer payments. The combination of these three components is generally known as a "mixed economy". It is an economy which combines cash and non-cash inputs (Usher, 1989). A mixed economy combines cash inputs from wages with subsistence harvesting (mainly for food) and transfer payments (mainly as cost of living subsidies). While components of the mixed economy of the WKSS area typically function as integrated and intertwined elements, each community has its own economic cycle (Abele, 1989). For example, a truly mixed economy might generate cash inputs from seasonal wage employment in the construction, transportation or forestry sectors during the summer months. Cash inputs from

trapping may be generated in the fall and winter. Both non-cash inputs from harvesting activities and cash inputs from transfer payments may occur throughout the year. Hunting, fishing, trapping and arts and crafts are known as traditional "activities". Traditional activities typically form part of the mixed economy of Dene, Inuit, and Métis, particularly those living in small communities in the WKSS area (Hall, 1986). The relative importance of each component of the mixed economy varies among the 12 WKSS area communities. This is as a result of the availability and capacity of natural, human and physical resources.

The capital of the NWT, Yellowknife, has a wide range of full, part-time and seasonal jobs in mining, government and secondary service industries. It is the staging point for industrial developments in the WKSS area and for the supply and servicing of communities throughout the western NWT and the Kitikmeot sub-region of Nunavut. It has the largest and most diverse non-Aboriginal and Aboriginal populations in the NWT. Wage employment dominates the City's economy. Hunting and fishing are pursued by segments of the population for mainly recreation purposes. In 2001, the unemployment rate in Yellowknife was 5.0 (Statistics Canada (a), 2001), while it was 11.9 among Aboriginal people (Statistics Canada (b), 2001).

According to the 2001 census (Statistics Canada (a), 2001), business services provide 21% of employment, while 14% is provided by health and education; 10% is provided by wholesale and retail trade; 9% is provided by agriculture and resource based industries; 7% is provided by manufacturing and construction industries; 4% is provided by finance and real estate; and 35% is listed as other services.

Cambridge Bay, Kugluktuk and Rae-Edzo are medium-sized communities with populations of 1,000 to 2,000. Most of the residents in these communities have Aboriginal ancestry. These communities have developing business, government and transportation infrastructures that serve the needs of regional residents and industries. Households in these communities typically blend all elements of the mixed economy.

Table 13 shows the mixed economy in various WKSS Communities (Statistics Canada (a), 2001). On average, income is comprised of 84% earnings, 13% government transfers, and 3% other.

Unfortunately, data beyond total population is no longer available for the outpost camps of Umingmaktok and Bathurst Inlet (the 2001 Census population fell below the level where analysis is performed by Statistics Canada).

**Table 12 Mixed Economy in WKSS Communities (Statistics Canada, Community Profiles 2001)**

|                                                                             | <b>Kugluk-tuk</b> | <b>Cambridge Bay</b> | <b>Uming-maktok</b> | <b>Bathurst Inlet</b> | <b>Rae Lakes/Gameti</b> | <b>Beh-choko</b> | <b>Wha Ti</b> | <b>Yellow-knife</b> | <b>NU</b> | <b>NWT</b> |
|-----------------------------------------------------------------------------|-------------------|----------------------|---------------------|-----------------------|-------------------------|------------------|---------------|---------------------|-----------|------------|
| Persons 15 years of age and over with income <sup>(1)</sup>                 | 725               | 820                  | n/a                 | n/a                   | 165                     | 935              | 285           | 11830               | 15450     | 25770      |
| Median total income of persons 15 years of age and over (\$) <sup>(2)</sup> | 15624             | 20896                | n/a                 | n/a                   | 15392                   | 12544            | 13909         | 38927               | 17270     | 29030      |
| Composition of total income (100%) <sup>(3)</sup>                           | 100               | 100                  | n/a                 | n/a                   | 100                     | 100              | 100           | 100                 | 100       | 100        |
| Earnings - % of income                                                      | 80.3              | 87.2                 | n/a                 | n/a                   | 80.5                    | 78.5             | 79.2          | 92.2                | 83.8      | 89.2       |
| Government transfers - % of income                                          | 14.6              | 9.1                  | n/a                 | n/a                   | 17.7                    | 19.5             | 22.2          | 4                   | 12.9      | 7.3        |
| Other money - % of income                                                   | 5.1               | 4.1                  | n/a                 | n/a                   | 1.1                     | 1.9              | 0.7           | 3.8                 | 3.3       | 3.6        |

**Notes:**

(1) Refers to the total money income received during calendar year 2000 by persons 15 years of age and over.

(2) Refers to the median total income of persons 15 years of age and over reported for persons with income.

(3) The percentages shown provide the composition of total income are based upon aggregate source amounts (for example, employment income, government transfer payments or other income) that are generated, rounded and subjected to independent suppression for confidentiality reasons prior to calculation. Due to this calculation method, the sum of the percentages may not add to 100.0%.

Source: Statistics Canada – Community Profiles 2001 (<http://www12.statcan.ca/english/profil01/CP01/Help/Metadata/Income.cfm?Lang=E>)

In Kugluktuk and Rae-Edzo, 58% and 55% of the working age population, respectively, participated in the wage economy in 1999 (Table 14). In Cambridge Bay, Kugluktuk and Rae-Edzo about half of all employment is in the government sector (Diavik, 1997). Half or more of the working age population in these communities are involved in traditional activities on a full or part-time basis. In 1996 and 1997, 36% of the Cambridge Bay and 44% of Kugluktuk populations received or were a member of a household receiving income support (formerly social assistance), at some time during the year. In Rae-Edzo, 60% of the population was assisted with income support at some time in 1996 and 1997 (Lutra, 1998).

The remaining communities in the WKSS area are small, traditional communities. Typically, Aboriginal people are the majority population in these communities. Łutselk'e and Rae Lakes are typical of small, traditional WKSS area communities. Due to limited economic and government sector activity, these communities have few opportunities for generating wage income. Community economies are reliant on traditional activities, transfer payments and seasonal employment. For example, in 1996 and 1997, 95% of the Rae Lakes and 78% of Łutselk'e populations received or were a member of a household receiving income support at some time during the year (Lutra, 1998). In 1999, just over one-half (55%) of the working age population in Rae Lakes and 66% of the Łutselk'e population of this age participated in the wage economy (Table 13).

Harvesting of wild game and fish for domestic consumption (subsistence harvesting) has been described as the cornerstone of many community economies. It has also been described as the focal point of social and physical health and well-being throughout the Canadian north (Condon *et al.*, 1995; Fast & Berkes, 1994; Parlee, 1998). Annual household harvests of an estimated three to six caribou, together with fish and wild fowl and other available animal resources such as Moose or Muskox, make-up the bulk of the country foods harvested and consumed in WKSS area communities (BHP Billiton Diamonds Inc. & Dia Met, 1995). In Łutselk'e, caribou is the most commonly consumed country food. Ducks are consumed in the late summer while more fish are consumed in summer than in winter (Marlowe *et al.*, 2000). Virtually all Aboriginal households (91%) in the NWT consume meat and fish harvested from the land (BS., 1991) and all community residents in Łutselk'e consume meat and fish harvested from the land (Marlowe *et al.*, 2000). It is assumed that NWT country food harvesting and consumption patterns apply in most Dene, Inuit, and Métis communities of the WKSS area. Other studies conducted in the last decade corroborate these patterns of country food harvesting and consumption (Kuhnlein, 1991; Lawn & Langer, 1994; Rawson Academy, 1990; Receveur *et al.*, 1996). In the NWT and, or, Nunavut:

- 65% of Aboriginal households obtain half or more of the meat and fish consumed in the household through harvesting. Reliance on harvested resources is higher among Inuit (59%) households in Nunavut than in Dene and Métis households in the NWT (39%).

**Table 13 Revised profile of adults and general employment profiles in WKSS area communities**

|                                   | Yellowknife | Kugluktuk | Cambridge Bay | Behchoko | Wha Ti | Gameti | Wekweti | Lutselk'e | Dettah |
|-----------------------------------|-------------|-----------|---------------|----------|--------|--------|---------|-----------|--------|
| <b>Labour Force</b>               | 10470       | 675       | 780           | 550      | 190    | 90     | 55      | 115       | 120    |
| Participation Rate (%)            | 85          | 64        | 71            | 54       | 66     | 50     | 58      | 66        | 63     |
| Employment Rate (%)               | 81          | 50        | 61            | 44       | 48     | 42     | 53      | 51        | 50     |
| Unemployment Rate (%)             | 5           | 23        | 15            | 19       | 29     | 22     | 18      | 22        | 20     |
| <b>Profile of Employed Adults</b> |             |           |               |          |        |        |         |           |        |
| 15+ Years                         | 9945        | 795       | 875           | 450      | 140    | 75     | 50      | 90        | 55     |
| % Male                            | 52          | 50        | 51            | 59       | 57     | 60     | 50      | 50        | 55     |
| % Female                          | 48          | 50        | 49            | 41       | 43     | 40     | 50      | 50        | 45     |

Source: Statistics Canada – Community Profiles 2001 (<http://www12.statcan.ca/english/profil01/CP01/Help/Metadata/Income.cfm?Lang=E>)



- The proportion of meat or fish obtained by hunting or fishing increases with the number of persons living in the household. About 35% of Aboriginal households with one or two members obtain most meat and fish consumed through hunting and fishing. In Aboriginal households with seven or more members, this figure rises to 70%. The average size of Aboriginal households is 3.8 people in Treaty 8 and the West Kitikmeot sub-region, and 5.4 in Treaty 11 communities.
- The consumption of country food is greatest among low income households. Half of the Aboriginal households with incomes of less than \$40,000 obtain most or all of their meat and fish through hunting or fishing. This compares to only 34% of households earning \$80,000 or more. In small communities such as Rae Lakes, 81% of households have incomes of less than \$40,000 (SC., 1991).
- The amount of caribou consumed by Aboriginal people in northern Canada is declining. Data collected in 1989/90, when compared to 1967/68, show a two to fourfold reduction in caribou consumption over this period. The average intake of caribou by males in Rae-Edzo fell from 135 grams per day to 42 grams per day during this same period (Tracy & Kramer, 2000)

Harvesting activities provide food and reduce economic stresses in Aboriginal households. Assigning a monetary value to traditional activities has been the subject of some research and discussion in recent decades. The average annual replacement or the imputed value of wild meat and fish harvesting to Aboriginal households in the NWT and, or, Nunavut (exclusive of added-value country food processing) has been estimated at \$10,000 (Usher, 1989). Returns from trapping are generally less than the investment in that activity. For instance, each trapper in Rae-Edzo received an average of \$394 (1996) from the sale of furs, as part of the total community income of \$50,000 from trapping. Exclusive of personal time and equipment investments, government subsidy of the fur industry in Rae-Edzo for 1996 was \$66,000 (DRWED., 1996). Harvesting activities also have cultural significance, as an expression of identity and as a component of life on and connection to the land (Hall, 1986).

Government policies and investment strategies have a significant influence on the mixed economy in the WKSS area. Between the 1950's and the mid-1990's, public sector investment in the north continued to grow. For at least three decades, the federal and territorial governments offered subsidies to encourage and support traditional activities. For example, the *Outpost Camp Program* started in 1976, provided funding for transportation, building materials and fuel to enable families to live on the land for much of the year (Usher, 1989). Over this period, significant Federal Government funding was invested in economic development strategies and sector-specific initiatives designed to diversify the economy and to create jobs in regional centres

and small communities. Government-funded initiatives were designed to stimulate and enhance the viability of local employment in community cooperatives, tourism, arts and crafts, commercial renewable resource and small business ventures. Infrastructure was also funded to encourage industrial and non-renewable developments (DEDT., 1990). In the WKSS area, the results of these investments are evident in the Ekaluktutiak (fisheries) Cooperative in Cambridge Bay that employs about 25 local people (mainly Aboriginal). Kitikmeot Foods Ltd, a country foods processing plant in the same community, provides another 10 full-time jobs and supplements the income of some 125 local suppliers of Muskoxen, caribou, and fish (Lutra, 1996). Several tourism operations based on game and fish resources, such as the sport fishing lodge in Wha Ti and big game hunting outfitting from Wekwetì, developed from these investments (Diavik, 1997). Tourism businesses in Tłı̄chǫ communities and Yellowknife have created 186 person-years of employment (North Group & Norecon, 1996).

Government investments in public health, social, education and municipal infrastructures and services throughout the NWT and Nunavut continue to create the vast majority of full-time job opportunities in the WKSS area communities. Public investment in services and infrastructure is declining along with the government's role in economic development and job creation.

The third element of the mixed economy in the WKSS area, government transfer payments, has continued to play a prominent role since being introduced in the post-war years. The GNWT reports that in the 12 years between 1982 and 1993, annual social assistance payments increased from \$8.1 million to \$30 million and the number of social assistance recipients rose by 63% (DECE., 1995). The use of social assistance in WKSS area communities has followed a similar trend. Dependency on social assistance is greatest among those who are unemployed and have a low level of education. While the demand for income support continues in the absence of income alternatives, fiscal restraint and changing social policies with government are lowering income support payments to WKSS area communities. (Diavik, 1997; Lutra, 1998). However, the percentage of the population in most WKSS area communities that receives income support, continues to be high (Lutra, 1998).

The evolution of the mixed economy has created a variety of stresses for individuals and families in the WKSS area. Today, much of the stress may be a result of the extent to which the three elements of the economy can be blended to ensure viable family and community economies. Not all families or WKSS area communities share the capacity or have access to the resources for economic sustainability.

### **3.3. Human Pressures on the Environment and Ecosystem**

#### **3.3.1. Summary of General Forms of Environmental Stress in the WKSS Area**

Stress in the environment is related to both natural and man-made causes, and often it is difficult

if not impossible to separate their effects. One or more forms of stress may occur at a single site or many sites, and stresses may be continuous or discontinuous. Some forms of stress are so widespread as to be global in their presence and effect. Without assigning any particular cause, most forms of environmental stress are related to one or more of the following:

**Nutrient stress:** changes in nutrient availability.

**Exploitation stress:** disruption of food web structures by the loss or reduction in numbers of top consumers (excluding humans).

**Exotic stress:** disruption of food web structures by the presence of non-native microbes, plants or animals.

**Toxic stress:** presence of biologically harmful contaminants in significant quantities (including both non-radioactive and radioactive contaminants).

**Habitat stress:** loss or change of habitats, or connections between habitats (in space and, or, time).

**UV radiation stress:** changes in received UV solar radiation at the Earth's surface (stress is usually associated with an increase in received radiation).

**Climatic stress:** changes in temperature and, or, precipitation.

### 3.3.2. Examples of Direct Causes of Environmental Stress in the WKSS Area

Even though the WKSS area is distant from most major centres of development, human activities are a cause of many forms of environmental stress (EC., 1991). Based on the previous Section (3.3.1), examples of the causes of stress that may occur in the WKSS area include:

**Causes of nutrient stress:** Excess quantities of nutrients may be released from domestic sewage or animal wastes, or from wetland storage due to changes in drainage, or from bank erosion or soil loss. However, decreased recycling from grazing animals such as Muskoxen could result in nutrient depletion.

**Causes of exploitation stress:** Advances in equipment may make it easier to hunt and trap wildlife, to store and process this food, and improvements in transportation may make it easier to export product (external demand for country foods is increasing). Exploitation can be exacerbated by poor hunting practices, and by inadequate storage or processing facilities that lead to waste. Fluctuations in demand imposed by cultural fashions or beliefs can also lead to periodic extreme demand for hunting and trapping of some fur-bearers (including poaching).

**Causes of exotic stress:** Intentional or accidental introductions of non-native species can modify existing ecosystems in many different ways. For example, an escape of non-native strains of hatchery fish could influence the genetic composition of native stocks. Or, the introduction of microbial disease or non-native parasites could occur at any trophic level and result in significant changes in the food web.

**Causes of toxic stress:** Contaminants that are toxic, persistent and which bioaccumulate in the food web include pesticides, PCBs, and methyl mercury. Most of these are

carried in the atmosphere and brought into the WKSS area from outside sources. Locally, heavy metals may be released from mining operations, and a wide range of contaminants may be released from municipal and military waste sites and spills. Mine wastes may locally add to the low levels of radiation present in the WKSS area from both human activities and natural sources, within and outside the region.

**Causes of habitat stress:** Logging removes forest cover and construction causes habitat loss or change and, in particular, increased vehicular access may reduce the availability of many forms of preferred habitat. Fire can be destructive of terrestrial habitats, and manipulation of water levels and flow can affect availability of aquatic habitats (*e. g.* for hydroelectric power or water supply).

**Causes of UV radiation stress:** Ozone gas is naturally present in the upper atmosphere but a wide range of manufactured gases react photochemically with it and destroy ozone. The loss of ozone in the upper atmosphere allows greater penetration of UV radiation. Most manufactured gas emissions occur outside the WKSS area but they circulate globally. The process of ozone depletion is greatest at high latitudes.

**Causes of climatic stress:** Global climate may be influenced by emissions of greenhouse gases if their quantities are sufficient to modify the physics and chemistry of the atmosphere and its circulation. Total combustion in the WKSS area is small relative to industrial areas of similar size in southern Canada, but it does contribute to global emissions and potential climate change. Natural and human-induced processes could greatly increase greenhouse gas release from peatlands under some conditions of climate change, thereby adding to further climate change.

Looking forward, climate change is expected to have a profound effect on the WKSS region and all of Canada's North. The potential effects extend to all components of the environment ranging from: loss of permafrost conditions in some parts of the NWT; increased erosion of river banks and shorelines; changes in the duration, extent, and quality of sea ice cover; changes in vegetation coverage and animal habitat; increased mobility of nutrients and organic and inorganic contaminants; and, changes in the quality and availability of traditional foods (SENES, 2005). To improve the understanding of the effects of climate change on such components, additional research is required.

### **3.3.3. Development as a Cause of Environmental Stress in the WKSS Area**

Human development creates many different forms of stress on the environment and this section considers existing sources of stress in the WKSS area (see Figure 2). Global emissions may affect all parts of the WKSS area and are a source of two major external causes of stress: global climatic change, and long range transport of atmospheric pollutants (EC., 1991). Within the WKSS area, activities resulting in more localized effects of stress include: mining, settlement

and construction of supporting infrastructures, transportation, hydro development, domestic and commercial hunting, fishing and trapping, tourism and recreation. Other forms of development such as pipeline corridors, ranching and aquaculture might affect the region. For the foreseeable future, forestry is likely to be only of local significance and agriculture unlikely to be any significance. The environment is also subject to natural forms of stress, particularly those that are weather or climate related such as fire (mostly from lightning strikes), precipitation, and surface snow and, or, ice conditions.

General relationships exist between various types of activities and environmental effects but site conditions may further influence the extent of stress. Where several activities occur at one site they may cause multiple forms of stress. For example, mine sites usually create local effects but where mines are grouped together there may be cumulative effects. Atmospheric emissions may cause an additional regional stress where mining and smelting occur together. Also, the effects of hydroelectric development may differ greatly, depending on the type and operation, size and environmental setting.

#### *3.3.3.1. External stress - Global Climate Change*

Complex global interactions between oceans and the atmosphere, and large scale changes in land use and increasing quantities of "greenhouse" gas emissions (particularly carbon dioxide and methane), have the potential to influence global climate. The scales and types of interaction may vary between different regions, and it is difficult to differentiate between natural conditions and those caused by human activity. Some of the gases are released by biochemical processes occurring naturally in the environment, and feed-back exists between many of these processes and climate (Cohen *et al.*, 1994; Ovenden, 1989; Rudd *et al.*, 1993). Thus, the extent to which trends in recorded climate represent early stages in climatic change or fluctuations within the range of natural variation remains uncertain (Allen *et al.*, 2000; Hulme *et al.*, 1999). However, a significant warming of the average annual surface air temperature has occurred over much of the WKSS area during the past several decades (Cohen *et al.*, 1994). Model predictions of greenhouse gas emissions indicate that emissions will almost certainly continue to increase over the next 50 years or so (Anon., 2000e), and climate models (CCPB., 1991; Cohen *et al.*, 1994; EC., 1991; Maxwell, 1987; 1992) predict that future near surface air temperatures are likely to increase in response to the emissions and that changes are likely to be greatest at high latitudes.

The Arctic Climate Impact Assessment (ACIA) provides a comprehensively researched, fully referenced and independently reviewed evaluation of climate change and its impacts for the region and for the world. The Overview Report entitled "Impacts of a Warming Arctic" (November 2004) concludes that:

*"The Arctic is now experiencing some of the most rapid and severe climate change on Earth. Over the next 100 years, climate change is expected to accelerate, contributing to*

*major physical, ecological, social and economic changes, many of which have already begun. Changes in arctic climate will also affect the rest of the world through increased global warming and rising sea levels.”*

In the last few years, climate change has become a much debated topic. Although, some skepticism is apparent, most climate scientists agree that human activities have influenced recent temperature increases and will lead to significant temperature increases during this century (Miller, 2005). A recent report published by British economist Nicholas Stern indicated that in higher latitude regions, such as Canada, climate change may lead to net [economic] benefits for temperature increases of 2-3°C, through higher agricultural yields, lower winter mortality, lower heating requirements, and a possible boost to tourism (Stern, 2006). However, it also states that these regions will also experience the most rapid rates of warming, thus causing damage to infrastructure, human health, local livelihoods, and biodiversity (Stern, 2006).

Many communities have begun to record their observations of how climate change is affecting their environments and their lives. These observations generally agree with the scientifically measured trends, although the scientific record gives a stronger impression of cooling in the eastern Arctic than the reports of local observers. This may be because local observers have given more emphasis to recent years, which have been unusually warm. The scientifically measured trends, on the other hand, cover a span of 50 years and include a greater number of cold years (CCME 2003).

Changes in Northern Canada's climate are affecting many aspects of the environment, such as ice and terrain conditions and the supply of game, wild plants and fresh water. As a result, native peoples are finding it harder to rely on the TK and practices they have used for so long to survive in a region that is usually frozen for more than half the year. In recent years the Kitikmeot Inuit have noticed dramatic changes in the local climate and environment. Winters and summers have become warmer, and sea and lake ice have been melting earlier in the spring. Fall freeze-up, which occurred in August or September a few decades ago, now happens mostly in October or November. The weather has also become more variable, and short-term temperature swings that cause repeated thawing and freezing have become more common. With a more variable climate, weather and ice conditions have become harder to predict, and that has made it more difficult and dangerous for hunters and others traveling on the land and ice (CCME 2003).

### **3.3.3.2. External stress - Long Range Transport of Atmospheric Pollutants**

The movement of air currents in the Northern Hemisphere is such that the air gravitates towards the Arctic and eventually carries pollutants into Northern Canada. Subsequently, these pollutants become trapped in the cold temperatures and can enter the food chain (SENES, 2005).

Long range transport of atmospheric pollutants is the main contributor to toxic stress in the

WKSS area (EC., 1991; Jensen *et al.*, 1997; Pfirman *et al.*, 1994). Several persistent organic contaminants for which there is no significant regional source of emission have been identified at low concentrations in the food web (EC., 1991). These include DDT and its derivatives, PCBs, and other organochlorines. Other substances, such as mercury, and some radioactive materials occur both as an external source of loading and as a “local” input from within the region. Many contaminants have been identified from distant sources in North America, Asia, and elsewhere (Macdonald *et al.*, 2000).

The Northern Contaminants Program (NCP), managed by INAC was established in response to studies that showed the presence of contaminants in the Arctic ecosystem. Phase I of the program (1991-1997), focused on determining the main sources of contaminants and their transport pathways and fate in the Arctic, as well as their levels and spatial and temporal distribution within Arctic ecosystems and humans. Many of these contaminants have no Arctic sources and yet some are found at high levels in animals at the top of the Arctic food chain and in humans. The three main contaminants groups of concern are persistent organic pollutants (POPs), heavy metals and radionuclides. Phase II of this program (1998-2003) funded research on northern contaminants issues, in addition to supporting the Centre for Indigenous Peoples' Nutrition and Environment (CINE) and the participation of Aboriginal organizations in the NCP. The emphasis of Phase II was on expanding human health research, developing effective community dialogue, and continuing work on international agreements to control contaminants.

Industrial gas emissions from sources distant to the WKSS area are also of special concern at high latitudes, where loss of naturally occurring ozone in the upper atmosphere results in decreased adsorption of UV radiation and an increase in the amount received at the Earth's surface (EC., 1991). Reflected radiation from ice, water and snow surfaces may add to the amount of exposure in the terrestrial environment, and the aquatic environment also receives increasing amounts of UV-B radiation.

#### **3.3.3.3. Internal Stress - Mining**

The earliest mine in M̃qwhì Gogha Dè Ñt̃l̃l̃èè was staked in 1916 with shafts sunk in 1921 (Mackenzie Scott, 2001). Mining has been a major part of development in the region for more than 50 years. During the exploratory and staking phase, ground and vegetation disturbance may occur over wide areas and may persist for many decades (Vavrek *et al.*, 1999). Modern mining techniques are less disruptive than in the past but their stress on the environment may last for decades or more (Acres Internat., 1993; Bright *et al.*, 1996; Gunn *et al.*, 1998; Klohn Leonoff, 1992). Mine development involves the set-up of heavy equipment, supplies and storage, ore processing, accommodation and transportation facilities, waste disposal, and various forms of decommissioning.

Currently, four gold mines within the vicinity of Yellowknife are closed and undergoing various phases of abandonment and restoration. These are the Giant, Con, Colomac, and Ptarmigan mines. In Nunavut, on the north end of Contwoyto Lake, the Lupin gold mine stopped production in 1998, reopened in 2000 and closed again in 2005. In June 2006, Wolfden Resources acquired Lupin from Kinross Gold Corporation and commenced an assessment of the potential to re-start operations.

The BHP Billiton Diamonds Inc. Ekati diamond mine (Lac de Gras) began production in 1998, the Diavik diamond mine (Lac de Gras) opened in 2003, the Jericho diamond mine (Contwoyto Lake) opened in 2005, the De Beers Snap Lake Mine is currently under construction, with start-up expected for 2007, and the De Beers Gacho Kué project is undergoing an environmental assessment. There are several other potentially viable base metal, gold and silver, and kimberlite deposits in the region, and some of these have been known for two or more decades (e.g., Izok Lake zinc deposit), but viability and lifetime depend on world commodity prices, and it is difficult to predict when any of these additional resources will become economically worthwhile to develop (see Figures 2 and 3).

It is expected that current levels of mining activity will continue, for at least the next two to three decades. Depending on the type of ore, mining may directly create nutrient stress (*e. g.*, soil disturbance and presence of organic wastes), toxic stress (*e. g.* metals release, acidification, and low level radioactive waste), and habitat stress. If there is increased access to areas around mine sites, exploitation stress (*e. g.* fish and wildlife) may also be important. Most forms of stress are local but cumulative effects from toxic stress are possible over wide areas.

#### **3.3.3.4. Internal Stress - Hunting, Fishing and Trapping**

Most hunting in the WKSS area is for Barren-ground Caribou and the total annual take from the Bathurst Caribou herd was estimated to be between 14,500 and 18,500 in the late 1980's (Aboriginal, resident and non-resident hunters). This is thought to represent less than 6% of the population of the herd (Case *et al.*, 1996; D'Hont, 1998). Other frequently killed big game in the WKSS area, include Moose and Woodland Caribou, and lesser numbers of wolves and bears (Chalmers, 1990). For many years it has been illegal to hunt Muskoxen but, recently, a quota of 124 Muskoxen has been set and this covers much of the WKSS area (D'Hont, 1998).

During 1988 and 1989, resident hunters (mostly non-Aboriginal) took about 1,400 Barren-ground Caribou, 140 Moose, 60 Woodland Caribou, 20 Black Bears, and 19 wolves in the WKSS area (Chalmers, 1990). During 1996 and 1997, resident hunters took a similar number Barren-ground Caribou, 60 Moose, 8 Woodland Caribou, 12 Black Bears and 60 wolves (D'Hont, 1998). An additional 684 Barren-ground Caribou and 3 wolves were taken by non-resident hunters. It has been estimated that 5 to 10 Grizzly Bears were also killed annually (for food or because of nuisance) prior to setting a commercial quota of 10 bears, in 1987. In 1997, 8



Grizzly Bears were taken under the quota and an additional 11 were killed in defence of life and property (D'Hont, 1998). About 90 Wolverines were taken during 1992 and 1993 and about 142 during 1997 and 1998, mostly by Aboriginal hunters and trappers in the Kugluktuk and Umingmaktok-Bathurst Inlet areas (D'Hont, 1998; Lee, 1994). Resident hunters took 13 Wolverines and non-resident hunters took 6 Wolverines, during 1996 and 1997 (D'Hont, 1998). Between 600 and 700 Lynx were taken in 1987 and 1988, shortly after the minimum of the hare cycle (Poole, 1992). Other fur-bearers were also taken by trappers.

In 1988 and 1989, resident hunters also took about 860 ducks, 150 geese, and more than 8,500 game birds (grouse and ptarmigan) in the WKSS area. In 1996 and 1997, 1,400 ducks and 6,000 game birds were taken by resident hunters (D'Hont, 1998; Lee, 1994). The total annual take by hunting and trapping is variable relative to the total population of a target species, and the size of domestic or subsistence harvests is not known with any certainty. However and as discussed further, traditional foods form an extremely important part of the diet of almost all Aboriginal people in the WKSS area.

Recreational, domestic and commercial fishing activities occur throughout the region (McCart & Den Beste, 1979). Lake Trout, Arctic Char, Grayling, and Northern Pike are key species for recreational and tourist fishing, and trophy fish are particularly important for the tourist industry (McCart & Den Beste, 1979). All available species are utilized by the domestic freshwater fishery and this represents a significant part of the Aboriginal economy. Domestic fisheries on Great Bear Lake and Great Slave Lake include whitefish, Lake Trout and other species, and domestic fisheries also exist on many other lakes and rivers. Commercial fishing on Great Slave Lake targets Lake Whitefish (with some by-catch of Lake Trout) and, at various times, there has also been commercial fishing on lakes in the Lockhart and Camsell River, and Lac la Martre drainages. The largest commercial fishery for Arctic Char in Nunavut began as a Federal government test fishery at Cambridge Bay, in the 1960's. The fish plant at Cambridge Bay is supplied by catches of migrating Char in both Victoria Island and mainland rivers. Usually, the Paliryuak, Holovik and Lauchlan rivers are fished for a few days during mid-July and early August, and the Ellice, Ekalluk and Jaco rivers are fished for a few days between mid-August and early September (Stewart *et al.*, 1993). Weather and ice-conditions are a significant factor affecting this fishing activity. Blue Mussels, clams, Green Sea Urchins and Brown Sea Cucumbers occur at low densities in the Coronation Gulf area but are little utilized. Domestic fisheries for Arctic Char occur at Kugluktuk and Bathurst Inlet.

#### **3.3.3.5. Internal Stress - Settlement**

Yellowknife is the largest centre in the region and had a mixed European and Aboriginal population of about 19,000. The predominantly Aboriginal communities of Cambridge Bay, Kugluktuk, Dettah, Łutselk'e, Rae-Edzo, Rae Lakes, Snare Lake, Umingmaktuk (and Bathurst

Inlet), and Wha Ti add about another 8,000 people, for a total of more than 25,000. With the current heated economy, the population of Yellowknife is expected to increase to about 25,000 by the year 2010. With expected increases in the other communities, the total population of the region will then be about 32,000; this would be an increase of about 36% over 15 years. Yellowknife provides government and major health services for that part of the WKSS area within the NWT. It is also a centre for mining, tourism and trapping. Cambridge Bay provides regional services of government to those parts of the WKSS area (West Kitikmeot) now in Nunavut. Most other communities are heavily dependent on hunting, fishing and trapping, and mining is an additional activity for the communities at Rae-Edzo, Gameti, Kugluktuk, Łutselk'e and Wha Ti.

At each of the communities there is increasing needs for housing, access roads, supplies and storage, power, water, waste treatment and disposal, and transportation facilities. The most common forms of stress associated with increasing size of settlements include nutrient, toxic, and habitat stress.

#### **3.3.3.6. Internal Stress - Transportation**

All-weather (mostly gravel) and winter roads link many northern Mackenzie Valley communities, and several other communities around Great Slave Lake, and southern communities (Figure 1). Winter roads also link Rae-Edzo with Wha Ti and Gameti, and Yellowknife with the Lac de Gras diamond field and the Lupin mine (Contwoyto Lake). Extensions also provide access to the Kennady Lake and Snap Lake diamond sites. Recently, a winter road has reconnected the Colomac mine (Indin Lake) with Yellowknife, for emergency pumping of the tailings pond to avoid overflow during the spring melt. Development of the Jericho diamond mine may extend the winter road beyond the Lupin mine. With the probable opening of a number of future base metal mines north of Yellowknife, additional road development, such as the proposed Bathurst Inlet Port and Road project, could take place to support bulk transport of ores and mineral concentrates. A new winter road could link the proposed Izok Lake base metal mine and other potential mines in the West Kitikmeot sub-region with a deepwater port near Kugluktuk or Bathurst Inlet (see Figure 2). Numerous potential routes for transportation corridors to service anticipated future development in the WKSS are under consideration (DT., 1999; 2000). Road transport can be subject to various forms of interruption (*e. g.* road bed stability and weather effects). Ferry services, and or, ice bridge access at Fort Providence (linking Hay River and Yellowknife) may be interrupted by ice formation on the Mackenzie River in early winter and by break-up in the spring. With renewed interest in the construction of the Dehcho Bridge over the Mackenzie River, these latter noted interruptions may be eliminated.

Almost every community in the WKSS area has flight connections with Yellowknife, and most

are provided with airstrips and some sort of terminal facility. Float planes also serve many communities in the region (and seasonal lodge operations). Air transport is an essential service throughout much of the region and further upgrades in facilities to improve operations and support larger aircraft have been proposed (DT., 1995). Yellowknife reported nearly 47,000 air movements, Hay River nearly 8,000, Cambridge Bay nearly 5,500, and Kugluktuk more than 2,700 air movements in 1991. Smaller communities such as Łutselk'e, Fort Resolution and Wha Ti reported air movements in the 500 to 1,000 range, and many others had a few hundred air movements a year.

Roads, rail, airport and docking facilities all directly modify habitat; and roads, in particular, make wider areas accessible for hunting and fishing. Noise associated with transportation, fuel spills, and the increased possibility of fire may be additional forms of environmental stress. Increased shipping raises the potential for accidental spills and loss, and disruption of sea ice cover (NPC., 1997; NPC TT., 1996). If manipulations of water level and flow are used to improve road use (DT., 1995), they may add to habitat stress.

#### **3.3.3.7. Internal Stress - Hydroelectric Development**

Limited hydro development has occurred on the Snare and Yellowknife rivers, primarily to meet local domestic needs, and on the Taltson River. In future, there is a proposal to raise the level of Indin Lake by 3 m (HBT-Agra, 1993; Lloyd, 1996), development has been proposed on the Lac la Martre River, and an expansion of the Taltson River project is also being investigated. Other potential hydro developments have also been considered on the Back, Burnside, Coppermine and Hood rivers, largely in support of possible mine developments (Goff, 1990; HBT-Agra, 1993; Igboji *et al.*, 1997; UMA Group, 1979; Wedel *et al.*, 1988). Development of sites on the lower Lockhart River have also been proposed. For most mines, hydro development is not viable on an individual basis but future development might take place if a group of mines could be served together (spaced reasonably close together and operating over a similar time period).

Hydro development may involve regulation of flow, changes in water level (including flooding), diversion, and construction of barriers. It may also cause changes in the natural regime (*e. g.* a shift or spread of peak discharge events). Transmission corridors that carry power from generation sites to user sites also create many of the same environmental stresses that are associated with road transportation. Many changes create stress on both terrestrial and aquatic habitats and their effects are long term, and some are more or less permanent.

#### **3.3.3.8. Internal Stress - Tourism and Recreation**

Tourism is the third largest industry in the WKSS area and two-thirds of the 1992 value of \$135 million came from non-residents. In total there are about 30 tourist lodges and camps, 25 of which are located around Great Bear Lake and Great Slave Lake. In the WKSS area there are

nearly 40 outfitters. In 1994, 6 tourist companies work out of Yellowknife, providing tourist and recreational services to non-resident visitors. More than one hundred other businesses provide accommodation and other tourism-related services ((North Group & Norecon, 1996) Section 3.2). Tourism has grown rapidly in the region and, although only a small percentage of visitors travel beyond Yellowknife, wildlife viewing and wilderness travel are locally as important as tourist fishing or hunting. Non-residents are increasingly involved in wilderness trekking and canoeing, and resident use of the Ingraham Trail (Yellowknife) for cabin and lake recreation is also high. Yellowknife received about 30,000 visitors in 1994.

Few park areas exist within the WKSS area(Hamre & Cozzetto, 1999a; 1999b). Existing and proposed parks, reserves and historic sites in Nunavut and the NWT include Mount Pelly (Cambridge Bay), Bloody Falls (Kugluktuk), Hidden Lake (near Yellowknife), Fort Smith Mission, Twin Falls Gorge (near Hay River), and Mills Lake near Fort Providence (Hamre & Cozzetto, 1999a; 1999b; NPC., 1997; Seale & Cozzetto, 1997; 1998). The Coppermine River has been proposed as a National Heritage River, and Parks Canada has also considered both the Bathurst Inlet and East Arm (Great Slave Lake) as areas of special interest (Hamre & Cozzetto, 1999a; 1999b; Hancock, 1979; HBT-Agra, 1993; PC., 1978; Seale & Cozzetto, 1997; 1998). Parts of the boundary for the Tuktut Nogait Park have been established but discussions between the Federal Government, Nunavut and the Sahtu Dene and Métis continue with regard to its southern and eastern boundaries. At present, there are no national parks within the WKSS area.

Most recently tourism has been growing at the rate of a little over 1% a year. Road improvements will aid tourism. Many forms of stress are associated with support facilities and transportation (as with fishing, hunting and trapping), but noise and disturbance add to habitat stress, and local exploitation of fish or wildlife may be a concern (Hamre & Cozzetto, 1999a; 1999b).

#### *3.3.3.9. Projections of Future Development*

A study of future development in the WKSS area (1994) presented three scenarios for the year 2010, based on low, moderate, and high levels of activity in the region (Bernard *et al.*, 1995; MRD., 1996). The scenarios, largely driven by mining development, are still valid today. However, given that mining is most responsive to international market conditions that are notoriously difficult to predict, it is difficult to know which is most probable.

The underlying characteristics of development during this time period appear to be that mine employment is likely to increase rather than decrease, but this may not occur at a steady rate. Mining activities are greatly influenced by fluctuations in international mineral and metal markets. Also, even though opportunities are likely to increase, there may still be more people available for employment than work available. Population increases in Yellowknife and Aboriginal communities in the WKSS appear to differ. Both will increase but increases in

Aboriginal communities are likely to be largely independent of employment opportunities (*e. g.* mining, and government administration). More hydroelectric development may occur on the Snare River, or via an expansion of the existing Taltson River system, but additional larger developments on other rivers are unlikely unless they are required in support of new mining activities. Winter roads to the Arctic coast and associated port facilities may be required in support of mine development, particularly of base metal mines (*e. g.* Izok Lake, High Lake and Hackett River). The availability of high grade ore at Izok Lake might also justify upgrading to an all weather road. Exploration and development of Arctic oil and gas is not likely to occur in the WKSS area but there may be indirect effects. For example, in relation to transportation and the use of existing or potential road and sea corridors.

The Mackenzie Valley Environmental Impact Review Board (MVEIRB) and the Nunavut Impact Review Board (NIRB), and regional Land and Water Boards provide screening of proposed development in the WKSS area. Activity in the WKSS region accounts for about 40% of the proposals considered by the boards. This provides a strong indication of the present and near future importance of the WKSS area to the NWT and Nunavut economies. Most activities are associated with mine development. Remaining activities are mostly associated with road work and construction of other forms of infrastructure.

### **3.4. Activities as a Cause of Human Stress in the WKSS Area**

Just as many forms of human activities create stress in the natural environment, such activities may also cause stress within society. These stresses may be produced as a result of the interactions between and among people, and as a result of human interactions with other components of the ecosystem. Societal stress may reflect both participation and, or, non-participation in various economic, social and, or, cultural activities. For Aboriginal people, societal stress has most often meant loss of culture, and poor physical and mental health.

In the last three decades, industrial developments in the Canadian north have encouraged efforts to identify and understand activities that stress human populations and their environment. Indicators, valued social components (VSCs), and expressions of stress in local populations have varied both in number and nature. Data are currently collected for more than 60 measures by various agencies and/or monitoring programs in the NWT, predominantly in response to diamond mining activity. Most of the data focus on human health indicators, including some looking at broader factors contributing to individuals' state of health. Most of the data are collected through government agencies, for monitoring impacts and social trends associated with the operating diamond mines. A few community wellness monitoring programs have also been initiated; one of these is a community based research and monitoring program (initiated by the community of Lutsel K'e) looking at broader issues of community wellness, as opposed to individual health statistics. Two others (led by BHP Billiton Diamonds Inc. and Diavik Diamond Mines Inc) focus on a selected number of health indicators to assess overall community wellness.

No baseline data have been determined for these monitoring programs (NWT CIMP and Audit Working Group 2005). The GNWT Department of Health and Social Services is also engaged in tracking social indicators. Twenty social indicators were developed by a GNWT interdepartmental working group in response to a 2002 Social Agenda Working Group recommendation regarding the need to identify a set of social indicators that could be used to describe and monitor social conditions in NWT communities (SENES 2005). The 20 social indicators are based on the general areas of population health, education, crime and safety, housing, families and children, income and employment, and Aboriginal culture. The 20 social indicators and the general area that they address are identified in Table 15.

**Table 14 Social Indicators for NWT Communities**

| Area of Focus         | Indicator                                                                                |
|-----------------------|------------------------------------------------------------------------------------------|
| Population Health     | • Incidence of Heavy Alcohol Use                                                         |
|                       | • Death Rates From Accidents, Suicides and Homicides                                     |
|                       | • Sexually Transmitted Infection Rate (three year average)                               |
| Education             | • Percentage of Population 15 Years and Older with at Least High School                  |
|                       | • High School Graduation Rate                                                            |
| Crime and Safety      | • Violent Crime Rate by Detachment                                                       |
|                       | • Rate of Juvenile Crime                                                                 |
|                       | • Shelter Admissions                                                                     |
| Housing               | • Percentage of Households in Core Need                                                  |
|                       | • Percentage of Households with 6 or More Persons                                        |
| Families and Children | • Percentage of Lone Parent Families                                                     |
|                       | • Children Living in Low Income                                                          |
|                       | • Child Protection Investigations                                                        |
| Income and Employment | • Population Dependency Ratios                                                           |
|                       | ◦ Less than 15 Years of Age                                                              |
|                       | ◦ 60 Years of Age and Over                                                               |
|                       | • Population Mobility                                                                    |
|                       | • Average Employment Income                                                              |
|                       | • Income Disparity                                                                       |
|                       | ◦ Percentage of Families with Income Less Than \$30,000                                  |
|                       | ◦ Percentage of Families with Income Greater Than \$75,000                               |
| Aboriginal Culture    | • Employment Rate                                                                        |
|                       | • Percentage of Aboriginal People 15 Years and Over Able to Speak an Aboriginal Language |
|                       | • Use of Harvested Meat and Fish                                                         |

Source: NWT Bureau of Statistics <http://www.stats.gov.nt.ca/Social/home.html>.

Indicators of stresses within human populations can be subjective, and may be useful and meaningful only if standards and values are shared. Further, individuals and groups may cope or manage stresses differently, as a result of a number of socio-economic and cultural factors. Communities and individuals in the WKSS area may share commonalities but have differences

in standards, values, expectations and, or, coping mechanisms and support. The Dene, Inuit and Métis do not necessarily share the same values any more than individuals of European origin.

The use and meaningfulness of indicators are also influenced by:

- Reliability and, or, consistency (comparability) and quality or validity of data collected over time (*e. g.* lack of longitudinal studies and the difficulties discerning naturally occurring change across populations from change resulting from project or development-influenced activities);
- intervening variables (*e. g.* community attitudes about professionals in the community may influence reporting of crimes, visits to the health centre, or attendance at school);
- cultural and personal bias (*e. g.* the number of children in day care may be viewed as enabling women to participate in wage economy but for others, it may indicate a lack of family responsibility or less value being accorded to children);
- community perspectives (*e. g.* communities with similar economies and populations may have different values and attitudes for example, about people receiving income subsidies);
- small populations or numbers of participants (*e. g.* small numbers may limit the availability and meaningfulness of information or pose threatens to individual privacy); and,
- natural occurring change across populations and changes the are isolated from project or development-influenced changes.

For these reasons, efforts to collect, interpret and analyze information on interactions between and among people and their environment, cannot be identified or predicted with precision. Combining traditional, community and scientific knowledge is the current approach to improving both the quality of information about, and the understanding of these stresses.

NWT and Nunavut Aboriginal communities have common interests in land and resources, and a shared desire to control the social, economic, cultural and political conditions that characterize their communities. Some Aboriginal communities are actively asserting control through the implementation of land claims and impact benefit agreements (IBAs), participating in non-renewable resource development; developing structures for self-government, or conducting research. Participatory research has been shown to have positive long term benefits to at least some members of a community (Ryan and Robinson, 1990 and 1992; Ryan, 1995). Furthermore, individuals trained by Joan Ryan in late 1980s, and those trained during the WKSS research are gainfully employed and continued to be active socially and politically within their community.

Tłı̨chǫ communities have conducted a series of participatory archaeological and TK research

projects. Research led by Thorpe among Qitirmuit communities was community controlled and collaborative, and incorporated training.

Community control and collaboration has been integral to a project in Łutselk'e that monitors socio-economic impacts of mineral resource development. This project, which began in 1996, has used a collaborative or action research methodology to increase the community's capacity to benefit from development while mitigating negative effects. The project has been undertaken in phases. In the first phase of the project, community perceptions of community health, monitoring and indicators were determined. Community health was defined as the 'Dene way of life'. Three themes or journeys toward community health - self-government, healing and cultural preservation - and a number of sub-themes were identified. The themes express the community's desire for control or self-determination, concerns regarding social issues, and the desire to protect language and culture (Parlee, 1998). The Łutselk'e monitoring project followed a four-step process: 1) gathering information through home-visits; 2) summarizing information and communication; 3) evaluation of information with a committee; and 4) reporting. Data collection has been the focus of the second phase of the project.

Some common themes have emerged from the various efforts to identify stressors, particularly on non-industrial, Aboriginal populations. Economic activity and population growth are two activities producing stress. Aboriginal participation in wage employment has been identified as a key indicator of stress or change.

Low participation of Aboriginal people in the wage economy contributes to poorer socio-economic circumstances among this segment of the NWT and Nunavut population. This is not a recent occurrence. Since regional economic studies were conducted in the 1950's and 1960's, subsequent economic studies have consistently found that compared to non-Aboriginal northerners, Dene, Métis and Inuit in the NWT and Nunavut have less participation in, and derive fewer benefits from the wage economy (SENES 2005, DEDT., 1990; DIAND., 1970). In WKSS area communities:

- Most non-Aboriginal people of working age (15 or more years of age) are active in the wage earning labour force (89%) compared to only 65% of Aboriginal people of similar age.
- About two-thirds of all employed persons in the NWT were born and raised outside of the territories.
- The average income of individuals living in the predominantly non-Aboriginal community of Yellowknife was \$39,086 while average incomes of adults in other WKSS area communities ranged from \$12,126 (Rae Lakes) to \$28,915 (Cambridge Bay) (SC., 1996).
- The majority of people not working and wanting a job have Aboriginal ancestry.



Literacy and numeracy skills lead to self-sufficiency and individual participation in family, school, work and community life. In the NWT and Nunavut, persons who have not achieved grade 12 are considered to have low literacy levels. Adults with low levels of formal education and training are less likely to participate in the wage economy; more likely to be receiving income support; and are more often involved in high risk behaviours or to live in high risk circumstances than those with higher levels of education (Lutra, 2000a). In 1999, 19% of adults in Yellowknife and 65% of adults in other WKSS communities have not achieved grade 12 (BS.,1999). In WKSS communities (excluding Yellowknife) 78% of adults who are not working and want a job, had not achieved grade 12. A minimum of 12 years of education is required for most entry level jobs in the 21st century.

Since formal education has been available in the NWT and Nunavut, high school graduation rates have continued to be low. In the NWT the high school graduation rate was less than half the rate recorded for Canada in 1994-95 through 1996-97 but has been increasing over the years to a rate of 45.3% in 2003-04, as compared to about 76% nationally (SENES 2005). The reasons for early school leaving are complex and inter-related, and based on circumstances in the home, school and, or, community, as well as in the personal lives of students (Lutra, 1992). Some students are particularly challenged in the school environment. An estimated 46% of students in the NWT require but are not receiving additional supports (*e. g.* beyond the regular school program) (DECE., 2000). Other students lack motivation and interest in school due to poor relationships in and outside of the educational environment. Others lack encouragement to pursue education (Lutra, 1994).

The interactions of non-Aboriginal and Aboriginal values and expectations in the school environment also influence educational and economic successes. These interactions have been examined in terms of school relationships (D. Wall Res. Group, 1996), the history of educational experience in the north (Barnaby *et al.*, 1991; Carney, 1971), teaching techniques (*e. g.* which separate skills for earning a living from learning about, for example, moral values, scientific or religious ideas, human relations, and the relations of human beings to the rest of the natural world) (Abele, 1989), and the influence of culture or teaching and learning styles (Bright, 1999). In some manner, these and other factors have been identified as stressors in the human environment, particularly as society places greater emphasis on achieving higher levels of formal education. Education and training institutions are criticized for trying “to make native people fit into economic and political institutions transplanted from the south” rather than responding to economic needs and the well-being of people within their particular context (Abele, 1989). To minimize stresses associated with lack of success in formal education and training programs, holistic programs, culturally appropriate curricula, community-based training, individual training programs, and the training and hiring of teachers of Aboriginal descent have been advocated and, or, implemented (Bright, 1999; DECE., 1994).

While communities have replaced seasonal camps as the centre of activity and of emotional, social and political life for Aboriginal people in the WKSS area, the lifestyle and expectations associated with harvesting and camp life have not necessarily been abandoned. Like the camps of long ago, there are strong ties among community members that are strengthened by family alliances, and traditionally valued ethics such as cooperation and voluntary, non partnership-based sharing (Collings *et al.*, 1998). Today, youth seek good paying wage employment but fear alienation from their community if they pursue it. Adults fear for the continuity of culture, family and community if young people leave communities in search of higher education and wage employment (Condon, 1990; Condon *et al.*, 1996). For these reasons (and others), employment opportunities in hydrocarbon and mining industries have created stresses for individuals in the WKSS area and elsewhere in northern Canada (IWGMI various dates; Lutra, 1995; Pierce & Hornal, 1994).

Recruitment and, or, training initiatives have been introduced to develop familiarity and comfort in a distant workplace. Long distance rotational commuting has been implemented to enable Aboriginal employees to return home, hunt for food and otherwise participate in family and community life before returning to work (Pierce & Hornal, 1994). Still, communities worry that employment demands will result in a loss of traditional skills or “brain drain”, creating stresses that impact on the social health and well-being of both families and communities (Tłı̨chǫ Treaty 11 Council, 1995).

In the absence of ongoing and viable community-based wage earning opportunities, traditional activities have sustained populations in the WKSS area. “*The north may well be the only place where a poor man’s table is laden with meat*” (Usher, 1976). This may not be the case in the future. Recent studies show that few youth (15 to 24 years of age) in the NWT and Nunavut participate in, or wish to pursue traditional economic activities (Condon *et al.*, 1995). Inuit youth view hunting, fishing and other subsistence activities as leisure (Stern, 2000). Less than 2% of NWT individuals of this age trap. About 7% of NWT youth earn income from arts and crafts activities (Lutra, 1996). Individuals who trap and earn less than \$2,000 annually, when offered wage employment, see paid work as a superior method of gaining an income (Stabler *et al.*, 1990). Recognizing the desire among youth for wage employment, some Aboriginal elders in the WKSS area have given conditional support for mining activities on their traditional lands (BHP Billiton Diamonds Inc. & Dia Met, 1995). These same elders recognize that many young people will not be able to sustain themselves in the future from traditional activities.

The ability to meet basic living needs continues to be a source of stress among populations in WKSS area communities. For decades, social assistance and income subsidies have been available to offset the lack of paid work and adequate input from traditional activities. Today, the majority of persons seeking assistance, do so for economic reasons, particularly where wage

income is insufficient relative to the high cost of living and, or, there are inadequate jobs for local residents. Many of these low income families participate in the service sector or in traditional activities such as arts and crafts production. A smaller number have social needs (*e. g.* disability or illness) which prevent them from participating in the wage and, or, traditional economy. In 1996 and 1997, 36% of the NWT and, or, Nunavut population received or were a member of a household receiving income support (Lutra, 1998).

For the Aboriginal populations of the NWT and Nunavut, housing conditions continue to improve. Bigger houses along with smaller household size have decreased the risk of infectious disease (*e. g.* tuberculosis) while improved sanitation has decreased exposure to several micro-organisms. Still, the growing populations of the NWT and Nunavut have created demands for more housing and for income to construct and maintain shelter. In 1992, almost 3,600 or 24.1% of NWT and Nunavut households were in need of affordable, suitable (*e. g.* number of bedrooms) and, or, adequate housing (*e. g.* running water, indoor toilet, shower and, or, bath). In 1996, 4,346 or 23.2% of NWT and Nunavut households were in need of major repair (NWT HC., 1996) and in 2000, 20% of households in the NWT were in this category (NWT HC., 2000). Securing affordable, suitable and adequate housing in Aboriginal communities may be more challenging in the WKSS area due to larger than average-size households. In Tłı̄ch̄ Treaty 11 communities, the average household size ranges from 3.9 people (Wekweti) to 4.7 people (Wha Ti) (SC., 1996). The lack of adequate and suitable housing has been identified in numerous studies as contributing to the incidence of family violence, increasing the rate of crime, affecting performance in school, and influencing the physical and mental health of household members (SENES 2005). Globally applied land-use planning and housing practices may also contribute to societal stress. These practices place more importance on functional services than the social, cultural and environmental needs of the people (*e. g.*, traditional kinship groupings, open space for gathering and access to the land and water) (Pin Mathews Architects, 1997).

Although food security has improved, the 1991 Aboriginal Peoples Survey found that its availability was a problem for an average of 15% of Aboriginal adults in Nunavut regions (20% in Baffin and 12% in Kitikmeot and Keewatin). The availability of food was a problem in particular communities rather than in whole regions. In the WKSS area, the availability of food was a problem for about 20% of Aboriginal adults in Wekweti and 5% to 6% of Aboriginal adults in Rae Lakes and Wha Ti. Studies show that dietary practices and food security (*e. g.* reasonable access to a nutritionally adequate and culturally acceptable diet) are affected by the high cost of food (which is 85% higher than in the nearest, large southern Canadian city), fear about the ability to feed the family, fear about the safety and supply of country food, lack of money to buy food, and inadequate food to eat. These problems are most serious among families on income support (Lawn & Langer, 1994).

A study into the health of NWT students found that students, particularly Aboriginal students at

all grade levels, are missing essential nutrients in their diets and tend to eat more "junk foods" than young people in the rest of Canada. Students most frequently lack foods from milk and, or, milk products (although many may have an intolerance for dairy products) and fruit and, or, vegetable groups as well as calcium, and vitamins A, C and D. Students' sugar consumption is also much above the national average. The lack of vitamin A and calcium, and the high use of sugar in the diet of Aboriginal families has been corroborated in other studies. It is a particular concern for women of child-bearing age and those who are pregnant or lactating, as well as for the health of young children (Peart & King, 1995).

A study in the community of Łutselk'e on TK and health (Łutsel K'e Dene First Nation, 1998) examined the relationship between knowledge of the land, knowledge of traditional food sources and preparation, and the health of community members. This relationship was not surprising but elders in the community also saw a link between hard work, especially that of a traditional lifestyle, and a long life. For them the solution to health problems in the community rested, in part, on teaching work skills to the younger generation so they too could work hard and be healthy. Tłıchq elders, leaders and hunters have also stressed the importance of having knowledge of caribou and the environment to maintain a healthy community and a healthy environment (Dogrib Treaty 11 Council, 2001).

Socio-cultural stressors have had both positive and negative impacts on the health and well being of Aboriginal people. Life expectancy for Canadian Inuit more than doubled between the 1940's and the 1990's (Bjerregaard & Young, 1998). Still, people in the NWT and Nunavut live four to five years less than the average Canadian and are twice as likely to die of injuries than other Canadians. Alcohol is a contributing factor to most accidents and injuries (DHSS *et al.*, 2000)

The rapidly growing, young population in WKSS area communities has generated many social, cultural and economic stresses. Like the rest of Canada, birth rates in the NWT and Nunavut have been declining over the past ten years. Still, in 1998 NWT birth rates were 18.6 per 1,000 population, almost twice the national average of 11.8 per 1,000 population (DHSS *et al.*, 2000) and the average birth rate in Nunavut was 29.8 per 1,000 population for the five years between 1992 and 1996. During this period, average birth rates in Cambridge Bay and Kugluktuk were 26.8 and 26.1 respectively per 1,000 population. (BS., 1998). In the Tłıchq community of Rae-Edzo, the average birth rate rose from 25.8 per 1,000 in 1986 to 30.8 in 1996, but it fell in Wekwetì from 23.5 per 1,000 population in 1986 to 14.8 in 1996. Teen births create additional socio-economic stresses. Children born to teenage mothers are more likely to live in households with lower levels of education, literacy and income (DHSS *et al.*, 2000). In the NWT, average teen birth rates between 1992 and 1996, were 2.75 times more likely to give birth than women of the same age in the rest of Canada (DHSS *et al.*, 2000). Compared to in-migration (estimated at about 2% per year since the 1976 Canada Census), birth rates have the greatest influence on population growth.

Children and youth under the age of 20 years make up 40% of the NWT population. In Treaty 8 and 11 communities, children 14 years of age or younger make up 32% and 36% of the population, respectively. Children make up about 38% of the population in the West Kitikmeot subregion. Youth (between 15 and 24 years of age) in the various WKSS area communities make up 15% to 20% of the population. The youthfulness of the population is creating economic pressures, as well as inordinately high demands on housing, education and social services and infrastructure. Recent studies are showing evidence of despair, hopelessness and powerlessness among youth (Lutra, 1996). About 22% of the individuals receiving social assistance in the NWT and Nunavut in January 1995 were between the ages of 18 and 25 (Lutra, 1996). It has been estimated that between 20% and 30% of NWT and, or, Nunavut children live in poverty (DECE., 1994) although a definition of child poverty in the NWT does not exist. Child poverty has economic, psychological and social costs. About 3% of NWT preschool-aged children are in care mainly due to neglect and parental alcohol abuse. Between 1994/95 and 1998/99, an average of 275 children in WKSS area communities (in the NWT) were taken into care (DHSS *et al.*, 2000). Children may be taken into care because of poor parenting, neglect, abuse and, or, developmental delays (Lutra, 1996; The Child Welfare League, 2000).

Inter-generational conflict also creates stresses within WKSS area communities. English is the language used in most Aboriginal households in the NWT but elders are most likely to use their Aboriginal language. “...over the next 15 to 20 years, English may well become the language of choice for almost all NWT’ residents” (DHSS., 1999). Loss of Aboriginal language means that children may have difficulty understanding and learning from their grandparents, and have different values and ways of thinking and acting (Bright, 1999). Lack of continuity creates stresses for and among individuals, families and communities.

## 4.0 STRESS EFFECTS

### 4.1. Introduction

Previous sections of this report have described the present environment of the WKSS area, its ecosystems and parts of their food webs. Many different types of stress affect the WKSS area and these have been summarized together with likely causes of stress in Sections 3.1 and 3.2. The types and extent of many human activities in the WKSS area have been described in Sections 3.3 and 3.4. This section now considers the effects of stress on ecosystems and the environment in more detail. Where information is sufficient, emphasis is also given to the most important cause and effect relationships.

In reality, most situations are a reflection of multiple effects that have occurred in response to a combination of causes; although there is often a common underlying “trigger”. For example, when international mineral or metal market conditions are thought to be suitable, management of a company may make an economic decision to open a mine. By association, this decision may also initiate road, air or marine construction, increase local and regional wage employment and the growth of settlements, increase vehicular traffic, and open wilderness areas otherwise isolated from human contact to greater use. Further, all development occurs against a background of societal change that includes the impacts of western culture and values on many Aboriginal people. It also occurs against a background of continuing environmental change that is largely driven by both climatic and geological processes over which people have little control (Andrews & Pelletier, 1989; Maxwell, 1987; 1992, ACIA 2005, Stern 2006). Without control, historical context may be particularly useful in adaptation to changing situations, such as those that may arise as a result of probable climate change (Robinson & Cohen, 2000). Generally, ecosystems evolve and adapt to most natural forms of stress but because of the scale, rapidity and variety of change, human activities may overwhelm the short term adaptive capacity of natural ecosystems. Already, there are concerns for number of species present in the WKSS area. Short term adaptive capacity may also become a concern in parts of human society, itself.

It is not possible to predict the future but it is known that many forms of development have potential to cause significant environmental impact, and many species of fish, birds and mammals (including people) may be affected. Several species are particularly adapted to the northern environment and in the extreme, if they are lost, they could not be replaced. Lesser effects, such as those that might influence behavioural characteristics (*e. g.* prey behaviours and breaks in the continuity of inter-generational learning) could also have major impacts on species survival. Such losses could pose great stress on many northern communities that continue to depend on them as a source of food, and in other ways as entities deeply embedded in Aboriginal culture and belief. Also, though not fully understood, there are significant interdependencies among and between plants and animals, and between them and the surrounding environment, such as between biota and fire. Each needs the other to maintain a balanced ecosystem, and this

includes the roles of natural parasites and predators in the terrestrial, freshwater and marine ecosystems.

While such concerns do not imply that there should be no development, they do imply that it is more than just prudent to proceed with caution. With developments there are varying degrees of environmental risk and uncertainty, and it is essential that effects monitoring should be reliable and sufficiently sensitive to make timely change in human activity. Effects monitoring needs to be based on concepts of "biological integrity" (Cairns, 1986) rather than the "most sensitive species" (Karr, 1991), and the early response to stress by aquatic ecosystems make them a valuable indicator of change. For example, changes in species composition of the phytoplankton community may occur in response to several types of stress and the incidence of morphological abnormalities in benthic invertebrates is strongly influenced by pollutants (Schindler, 1987). However, in many northern ecosystems where species diversity is low, changes in abundance may be a more useful indicator of stress response. Further, effects monitoring means not only the local effects of development but, also, the cumulative effects of development (both direct and indirect effects) over a region (such as the WKSS area). Many stress effects in the environment are also related to stress effects in people though, often, such effects and their extent are different in human communities. Thus, it is important that the impact of development on the environment should not be considered in isolation from its impact on people.

Stress has the potential to cause change in the environment. Whether or not the resultant changes are considered as "positive" or "negative" depends on how they are viewed as an influence on human activities. Some of the effects of past development in the WKSS area have been severe, particularly where activities were not sufficiently controlled (noted later in this Section). For the future, however, sustainable development seeks to reduce stress and to keep human activities and environmental change within limits that do not radically alter or impair future use of renewable resources.

In keeping with this approach to sustainable development, a number of conservation measures have also been undertaken or are under consideration in the NWT and Nunavut. In the WKSS area, Parks Canada has identified the North Water polynya at the east end of Dolphin and Union Strait as an area of special biological interest, and is working with the community of Lutsel K'e to advance the protection of Thaydene Nene, a culturally and environmentally significant area to the southwest of the Thelon Wildlife Sanctuary (Beckmann, 1994; CWS., 1993; Hamre & Cozzetto, 1999a; 1999b; Seale & Cozzetto, 1997; 1998; SENES 2006). The Wollaston Peninsula (Arctic Island Caribou calving), and the Melville Sound and Kugluktuk areas (Gyrfalcons and Peregrine Falcons) have been proposed for consideration as wildlife conservation areas (DRR., 1995; Ferguson, 1987). In addition, there are other federal sanctuaries and conservation areas that may be an external influence on wildlife within the WKSS area. These include the Thelon Wildlife Sanctuary, Wood Buffalo National Park (also designated as a RAMSAR site under the

1978/1981 Ramsar Convention on the Conservation of Wetlands of International Importance), Queen Maud Bird Sanctuary, and Tukturnogait National Park (CWS., 1993; Hamre & Cozzetto 1999a; 1999b; Seale & Cozzetto, 1997; 1998). Parks Canada also has interest in Bathurst Inlet (as a natural area of Canadian significance). The Ellice River uplands just east of Bathurst Inlet (Bathurst Caribou herd calving) and the Horton Plain west of Kugluktuk (Bluenose Caribou herd and year-round Muskox range) have been proposed for consideration as wildlife conservation areas (DECE., 1994; DRR., 1995).

## **4.2. Stress Effects Due to Human Activities**

### **4.2.1. Global Climate Change**

#### *4.2.1.1. Natural Processes and Human Influence on Climate*

A number of factors influence the temperature of the Earth's atmosphere and climate, the most predictable of which relates to astronomical cycles. Well defined irregularities in the Earth's orbit around the sun and a slight wobble in the planet's axis result in small but significant changes in received radiation, especially toward the poles. These cycles (Milankovitch cycles) have periodicities which extend over extremely long periods of time, from about 20,000 to more than 100,000 years (Chin & Yevjevich, 1974). Many cycles closely correlate with major climatic changes evident throughout the Pleistocene glacial period. At present, the most significant astronomical influence on climate is the movement of the Earth's axis. The axial tilt reached its maximum about 11,000 BP and will reach its minimum about 10,000 years in the future when differences in seasonal contrast will be least. Because of this and if it were the only influence or even if it were to be the most significant influence, the Earth would be expected soon to enter a cooling phase or to have already entered it (Chin & Yevjevich, 1974).

Mean summer and autumn temperatures have generally declined over much of the northern hemisphere since 1940 even though mean annual temperatures have increased (Cohen, 1997; Cohen *et al.*, 1994). A seasonal decline of this sort is probably consistent with the effects of climate change expected to occur as a result of reduced axial tilt. However, there is no evidence to support this particular association as a cause and effect relationship, and there is no certainty that this hemispheric temperature trend will continue. Indeed, from geological data and based on variations in average annual global temperature between glacial and post glacial periods, it would be almost impossible to determine the signature of this form of astronomically driven climate change over time intervals of much less than several centuries (perhaps a tenth of a degree in 2 or 3 centuries). Therefore any temperature change brought about by axial tilt would be most likely to occur as a slow and underlying long term geological fluctuation. Based on the known astronomical associations between the Earth's planetary motion and glacial events, existing interglacial warm climatic conditions are expected to last several thousand more years



(Broecker, 1998).

There are other factors that may alter both received solar radiation and atmospheric response to it (Lockwood, 1979). The causes of many unusual warm and cold periods which have occurred throughout historic time appear to reflect a combination of astronomical cycles, solar fluctuations (particularly sunspots (Bartusiak, 1989)), volcanic activity, ocean-atmosphere interactions and the carbon dioxide content of the atmosphere (Anon., 2000c; 2000f; Gribbin, 1983; Shindell *et al.*, 1999; Skinner, 1985).

Sunspot cycles correspond to the formation of large dark patches on the surface of the sun. They are caused by variations in solar magnetism and the number of patches increase to a maximum during the peak of a cycle. The cycles occur over intervals of 8 to 15 years and average about 11 years (Mitton, 1977). But recorded sunspot intensity (number of sunspots occurring during the peak of a cycle) also varies over longer periods of 80 to 90 years (Immen, 1995; Mitton, 1997). It has been suggested that variations in the output of solar energy associated with sunspot cycles would be too small to affect the Earth's climate (Broecker, 1999). However, it also seems that the release of solar energy is neither as constant as once thought, nor is it only related to solar brightness. Variations in brightness are likely to affect the Earth's near surface atmospheric temperature, but variations also occur in the release of UV radiation. This likely affects high altitude wind and ozone concentrations in the atmosphere. The discharge of subatomic particles in association with strong variations in the Sun's magnetic field may influence the Earth's cloud cover and rainfall (Broad, 1997). For example, there is some correspondence between sunspot cycles and water levels in the Great Lakes region of North America. Certainly, some of the variations in the record of dust and chemical content of glacier snow, the width of tree rings, and some plant and animal cycles in both terrestrial and aquatic environments seem to reflect solar cycles (MacLuich, 1974; Reckahn, 1986).

Recent evidence suggests that bright patches (faculae) that occur together with the more obvious dark patches during sunspot cycles, override the dark effect and actually increase rather than decrease solar output during the sunspot peak (Broad, 1997). This might explain why northern Europe (and North America) cooled considerably during a period of extended low sunspot activity between 1640 and 1720. From the early 1900's to about 1940, the length of sunspot cycles was short and the Earth's near surface temperatures increased. Between 1940 and 1980, the length of cycles became longer and atmospheric temperatures declined. However, sunspot cycles became shorter again after 1980 and this has coincided with further increases in the Earth's near surface temperature. On this basis, it is quite possible that variations in solar output account for much of the rise in the Earth's near surface temperature between about 1860 and 1980 (Anon., 2000d). Based on more specific measurements of variation in the solar magnetic field and its effects on the Earth, solar output could account for almost all of the warming experienced between 1860 and 1930. Since 1970 solar influence can account for only about one

third of the global warming that has occurred (Anon., 1999a).

In addition to the effects of direct solar heating at and near the Earth's surface, measurements show that 10 to 20% of the change in energy output of solar cycles occurs in the form of UV radiation (Shindell *et al.*, 1999). Under natural conditions, much of this radiation is absorbed by ozone in the upper atmosphere and this process warms the ozone and raises the temperature of the stratosphere. However, and due to the release of certain types of man made chemicals, ozone depletion has been particularly noticeable since the early 1970's (UNEP., 1989). This has resulted in stratospheric cooling. Model studies suggest that changes in stratospheric temperature affect planetary waves in the atmosphere and, in turn, modify tropospheric circulation over the Earth's surface. Another effect is also linked to ozone depletion and reduced stratospheric heating. In polar regions and at very high altitudes (about 21 km above the Earth's surface), ice crystals can form polar stratospheric clouds at extremely low moisture contents when temperatures fall to about -78° C or lower. These clouds may further contribute to changes in the stratospheric heat balance (Shindell *et al.*, 1999). Ozone depletion and its effects on stratospheric heating in response to UV radiation, are likely to persist over many decades to come (EC., 1991; UNEP., 1989).

At the Earth's surface, heating and cooling are more rapid in areas without cloud cover (Anon., 2000c) but, in the atmosphere, water vapour is the dominant carrier of heat transferred from the equator to the poles. Models suggest that with higher temperatures in the troposphere, evaporation from the ocean increases and leads to more wet days a year at high latitudes and heavier rains at mid and lower latitudes. There is some evidence to suggest that El Niño and La Nina events may be becoming stronger (Anon., 2000f). Increased quantities of water vapour in the atmosphere also act as a feedback mechanism and add further to the greenhouse effect (Ramanathan, 1998). Under the influence of warming and increased water vapour in the tropical troposphere, more moisture may also transfer into the stratosphere and, additionally, contribute to stratospheric cloud formation (Kirk-Davidoff *et al.*, 1999). The extent to which ozone depletion has actually reduced stratospheric heating is poorly quantified. The influence of variations in the solar discharge of subatomic particles and variations in solar magnetism on climate are less certain.

Volcanic activity may also contribute to climatic variation and, when eruptions are powerful enough to inject dust and SO<sub>2</sub> into the upper atmosphere, stratospheric dispersals can result in hemispheric cooling that lasts for periods of several years (Gribbin, 1983). Conditions such as this are thought to have occurred following the massive volcanic explosions of Tambora (1815) and Kratakau (1883). Other effects may be possible, such as the release of heat or nutrients to the marine environment from underwater volcanic activity, corresponding changes in oceanic conditions including thermal structure and productivity, and subsequent exchanges between the ocean and atmosphere. Volcanic activity that releases large quantities of CO<sub>2</sub> and little dust to the

atmosphere would cause atmospheric warming, if sustained over long periods of time. The geological record from marine sediment cores indicates that natural increases in phytoplankton would also act to remove the CO<sub>2</sub> by photosynthesis. However, there is a considerable lag (measured in tens of thousands of years) between these mechanisms of release and increased sequestering of CO<sub>2</sub> (Anon., 2000b). Although statistical relationships do exist between climate features such as the El Niño Southern Oscillation (ENSO) and high atmospheric concentrations of volcanic aerosols, they appear to be no greater than would be expected from random associations (Self *et al.*, 1997). Under some circumstances, volcanic activity can be an important influence on climate. But, usually, large scale vulcanism is an infrequent event and its effects on climate are not long lasting. Man made aerosols (*e. g.* from combustion) also produce climatic cooling but the effect is considerably less than the warming of greenhouse gas emissions (Charlson, 1997).

Based on evidence by association, it seems most probable that variations in total solar output (particularly brightness) have been a major influence on climate over the period for which records are available. It is also possible that global warming could have been greater without the influence of recent ozone depletion. Climate, however, is not simply the response of the atmosphere to received solar radiation. The composition and behaviour of the atmosphere is closely coupled to the oceans that cover about 85% of the Earth's surface and to plant material present on land and in the sea. Thus there are many other feed-back mechanisms which have potential to further alter atmospheric response to solar variations.

Warming at the Earth's surface will tend to decrease the density of all surface waters. It will intensify the hydrological cycle by which water is evaporated and transferred to the atmosphere as water vapour. This process will also result in the transport of more freshwater (as precipitation) to higher latitudes (Broecker, 1998). Global oceanic circulations are linked and deep Atlantic waters that move southward into the "polar raceway" of the Antarctic Ocean become redistributed to the Indian and Pacific oceans, and from the Pacific to the Arctic Ocean. Differences in the density of the water masses have a major influence on these movements. It is thought that circulation in the North Atlantic may be particularly sensitive to changes of the inflow and mixing with Arctic Ocean water (Broecker, 1997; 1998).

Although deep waters of the North Atlantic are much warmer than those of the Arctic Ocean, their higher salt content makes the density of the two water masses more nearly the same. Atmospheric warming that increased freshwater discharge from the Arctic Ocean would alter the salinity and density of mixed Atlantic and Arctic waters that form the deep return flow of the Atlantic "conveyor belt". There is concern that salinity of these mixed ocean waters could be sufficiently reduced to modify density and effectively shut down major components of circulation in the North Atlantic (Broecker, 1997; 1998). Under this condition, the transport of warm surface waters in the North Atlantic drift would also decline and regional cooling would

affect large areas of western and northern Europe. Models of ocean circulation based on a 50% increase of precipitation and runoff over evaporation (Broecker 1997), or an atmospheric warming of about 4 to 5° C, support this (Broecker, 1998). Reduced warmth in the North Atlantic would affect evaporation and air temperature. It could also affect the position and behaviour of large scale atmospheric phenomena such as the North Atlantic Oscillation (NAO), and the El Niño Southern Oscillation (ENSO) of the Pacific Ocean.

There is evidence to suggest that changes in the characteristics of the Atlantic deepwater return flow may be occurring, already. Salinity measurements of deep water between the Shetland and Faroe islands in the Northeast Atlantic have been made since 1893. Until recently, the salinity of this mixed Arctic and Atlantic water has been highly constant, and sufficient to provide a calibration standard (Anon., 1999b). But over the past two decades, salinity has declined by 0.01 g·kg<sup>-1</sup> of seawater and the temperature of deep water has increased (the -0.5° C temperature depth dropped by 60 m between 1988 and 1997 (Anon., 1999b)). Flow reversals have also occurred. For example, in 1982 and 1983, deepwater flowed south from Greenland into the Norwegian Sea but ten years later the flow was reversed (Anon., 1999b). Feedback mechanisms may be occurring in the North Atlantic and related processes could have far reaching but as yet little understood impacts on climate in the western Arctic, including the WKSS area. On the other hand and although it is not known to what extent similarities may be drawn between present climate and the mid-Holocene high (see later comments in this Section), available evidence does not indicate that this warm period was suddenly terminated by rapid and detrimental climate change. Since present Arctic and sub-Arctic climate is not yet as warm as it was during the mid-Holocene, it would seem that threshold conditions (if they occur) would be at a level, at least, above the mid-Holocene high.

Human activities release large quantities of “greenhouse gases” into the atmosphere where their influence may partially override other tendencies towards global cooling (such as reduced solar output). Greenhouse gases include water vapour, CO<sub>2</sub>, CH<sub>4</sub>, NO<sub>x</sub>, CFCs, and O<sub>3</sub>, (CCPB., 1991). These gases allow passage of short wave radiation from the sun but block long wave radiation, much of which is re-emitted from the Earth’s surface. This traps heat near the ground, but it may also contribute to further reductions of temperature in the upper atmosphere and increases in the frequency of stratospheric cloud formation (a process that is also poorly quantified (Kirk-Davidoff *et al.*, 1999; Shindell *et al.*, 1999)). As previously noted, changes in stratospheric heating are thought to influence atmospheric circulation (and perhaps to intensify polar vortices).

The gases differ greatly in effect (EC., 1991; UNEP., 1989) and although water vapour is the most important greenhouse gas (Broecker, 1996), its concentration in the atmosphere is highly variable. Of the other major constituents and given that present trends in atmospheric composition do not change during the rest of this century, CO<sub>2</sub> will likely contribute to more than 70% of the greenhouse effect. Methane, which is about 20 times more effective than CO<sub>2</sub> as a

greenhouse gas, could contribute to about 17% of potential warming. Nitrous oxides are more than 300 times as effective as CO<sub>2</sub> as a greenhouse gas and could contribute nearly 8% of potential warming. Chlorofluorocarbons (CFCs) and related aerosols range from about 4,000 to about 24,000 times more effective than CO<sub>2</sub> as greenhouse gases, and will likely contribute to about 3% of the warming effect (Mitchell, 2000)

The release of CH<sub>4</sub> from peatlands and wetlands is expected to increase as a result of temperature induced microbial activity (Nadelhoffer *et al.*, 1992), and rising temperatures could also affect gas hydrates that are buried in sediments. However, there is no evidence that hydrates became a significant source of greenhouse gas at the end of the Younger Dryas (11,800 BP) when global temperatures increased rapidly (Broecker, 1996). Present conditions appear to be no more favourable for their release. Estimates suggest that global levels of CH<sub>4</sub> have increased considerably over the past three centuries and that much of the increase has been due to industrial and agricultural activities (Ovenden, 1989). During past interglacial periods, this gas contributed about one-quarter of the greenhouse effect of CO<sub>2</sub>. Methane breaks down in the atmosphere to produce water vapour and, for each 1° C increase in temperature, water vapour will increase by about 6 %. The effect of water vapour on climate is complex. In very general terms, the effect depends on two things: how much water vapour is carried into the stratosphere where high level cloud formation may cause cooling at lower levels in the atmosphere; and how much enters lower levels in the atmosphere where cloud formation can trap heat near the Earth's surface. Model studies suggest that water vapour has a major influence on global climate. In part, this is because of feedback. During glacial maxima, the effects of water vapour could have been considerably greater than those of CO<sub>2</sub> (Berger & Loutre, 1997).

Changing patterns in land use, deforestation, intensive agriculture and the spread of desert lands may all contribute to increased greenhouse gas concentrations in the atmosphere, both by greater gas release or by reducing the ability of ecosystems to sequester such gases (Anon., 1998; 1999c). Over the past 150 years or so the net production of terrestrial ecosystems is thought to have increased significantly in response to greater availability of C. But the response by vegetation to further increases of CO<sub>2</sub> could decline, as the fertilization effect becomes saturated (Kuicao & Woodward, 1998). Difference in regional effects may become very significant (Betts *et al.*, 1997). Present understanding of feedback mechanisms in the C cycle are not yet sufficient to adequately quantify terrestrial biospheric processes (Rodhe *et al.*, 1997).

Human activity has very likely contributed to recent warming trends in global climate and signatures of climate change are present in a wide array of climate data. It is difficult to separate and quantify the extent of human related effects (Allen *et al.*, 2000; Corti *et al.*, 1999), but natural conditions remain dominant. For example, Hulme *et al.* (1999) suggest, based on simulations of precipitation runoff, that natural conditions predominate. Corti *et al.* (1999) suggest that recent warming of the northern hemisphere is mostly related to the thermal structure

of circulatory regimes in the atmosphere.

Despite uncertainties, some things are known with a very high degree of probability. They are that the combustion of fossil fuels is a major source of greenhouse gas emissions from human activities. Based on the modelling of a great number of possible scenarios there is almost no likelihood that the release of CO<sub>2</sub> from this source to the atmosphere will cease to increase for at least the next 50 years, despite the best likely applications of conservation and control technologies (Anon., 2000e). Therefore if human activities have contributed to some part of recent global warming (particularly over the past 20 to 30 years) it is almost certain that the effects of this contribution to warming, whatever they are, will also continue and increase. What may happen in the latter part of the 21st century is much less clear, most likely greenhouse gas emissions will begin to decline but it is uncertain by how much (Anon., 2000e). As a reflection of greenhouse gas emissions, the forecast of global warming to the middle of the 21st century appears to be robust but the extent of warming after atmospheric equilibrium composition is reached is uncertain. It is even less certain that, when achieved, equilibrium will be maintained (Allen *et al.*, 2000). Estimates, that are heavily weighted by projections of fossil fuel combustion, predict concentrations of atmospheric CO<sub>2</sub> will double by 2050. The mean annual global temperature will rise between 1.5 and 4.5° C (CCPB., 1991). However, the rise in temperature is expected to be uneven and the greatest increase is expected to occur at high latitudes.

The geological record provides a means of extending the record of observed climate change and perhaps gaining some further insight into cause and effect relations. After some time lag, cooling in the North Atlantic during the Younger Dryas period, between 17,700 and 11,500 BP, seems to have resulted in cooling of the northern Pacific Ocean and western North America (Benson *et al.*, 1997). In part, this lag may reflect processes associated with the circulation of water between the Atlantic and Pacific oceans (Broecker, 1997; 1998). Geological evidence, based on comparisons of core data from ocean sediments and glacial ice cores suggests that other links between climate and ocean response in the North Atlantic are possible. Over the past 110,000 years, conditions have switched between moderate and intense cold in Greenland. These changes occurred over periods of a few years to decades, every thousand years or so (Broecker 1997). During 6 of these very cold events (Heinrich events), icebergs dropped debris from Greenland off the coast of France, and it is thought that Canadian ice sheets also, alternatively, stored and released freshwater to interrupt Atlantic Ocean circulation (Broecker 1996). Asian winds (producing dustfall from the Golbi Desert in Greenland) and surface salinities of the Pacific Ocean have also undergone large synchronous changes over periods of a few decades (Broecker, 1997).

Near the end of the Younger Dryas (at the end of the last glacial period), and based on N isotope data from ice cores, temperatures were about 15° C colder than now on the Greenland ice cap

(Severinghaus *et al.*, 1998). Warming at the end of the Younger Dryas was abrupt and could have occurred in as little as 3 years, or less, during which snowfall also doubled (Beaulieu, 1997). This warming may have been as much as 7° C and coincided, to within a decade or so, with a rapid rise of CH<sub>4</sub>. The cause of this warming is not known but it demonstrates that extremely rapid hemispheric change can occur in global climate.

Average annual global temperatures are probably as warm now as at any time in the past 4,000 to 5,000 years (Maxwell, 1987; 1992). Temperatures in the northern hemisphere are likely their warmest in 400 years (Serreze *et al.*, 2000), but similarities between present climate and the mid-Holocene high are limited. Global coastlines, then and now, were similar and so were surface sea temperatures, but the axial tilt of the Earth was different during the period of the mid-Holocene high (Pelletier, 2000). At that time, increased solar radiation was received during summer in the northern hemisphere, the temperature contrast between land and sea was greatest in summer, and monsoon circulation was enhanced relative to the present. Comparisons have also been suggested between present climatic conditions and the Medieval warm period, between 1,000 and 1,300 AD. However, there appear to be significant differences, as well, between this past and the present climate. Data suggest that the Medieval warm period was characterized by 2 or 3 warm periods that lasted only 20 or 30 years each, and that this warming was somewhat patchy (Crowley & Lowery, 2000). Composites of the Medieval warm period may not be closely comparable to the more constant and widespread warming of the present.

Over the past century, the global mean surface air temperature has warmed by 0.3 to 0.6° C (EC., 1991; Serreze *et al.*, 2000), and 0.2 to 0.3° C of this warming has occurred during the past 40 years (Serreze *et al.*, 2000). Precipitation has also increased in Canada, north of 55° N, since the 1960's. Much of this has been associated with position of the Atlantic cyclone track. The greatest increase in air temperature over northwest North America has been during winter and spring, but over the Arctic Ocean the increase has been greatest during spring and summer. There has been a pronounced warming over much of North America since the 1970's but, at the same time there has been a cooling over the North Atlantic (Serreze *et al.*, 2000). Based on records since about 1960, annual average temperatures have increased by 0.25° C per decade in the western Canadian Arctic. They have also decreased by a similar amount in the eastern Canadian Arctic (northern Quebec, Labrador and Baffin Island). The NAO is a component of the Arctic Oscillation. The strong northerly flow across eastern Canada is characteristic of the positive phase of the NAO when both the Icelandic Low and Azores High pressure atmospheric systems intensify. This condition has existed over the past 2 decades. There is evidence that the Arctic Ocean has been warming and the length of the seasonal melt has increased (Serreze *et al.*, 2000). During the mid 1990's, the surface area of Arctic sea ice decreased at a rate of about 2.9% per decade. Outflow of Arctic surface water through the Fram Strait has increased, and underlying warmer but more saline Atlantic water has extended further into the Arctic Ocean (Serreze *et al.*, 2000).

In the middle Mackenzie River basin, average annual surface air temperatures have increased by about 2° C between the Alberta-BC border and Rae Lakes, and by about 1.5° C at Norman Wells and the East Arm of Great Slave Lake, over the period 1900-1990 (Skinner & Majorowicz, 1999). Ground surface temperatures show an even greater rise over this same period. On a regional basis, temperature records of groundwater in wells at depths greater than 50 m indicate that significant warming has occurred over the past half century. Ground surface temperatures have increased by about 5° C or more in prairie grassland areas and by 3° C or more in boreal areas (UNEP., 1989). Locally, warming has been greatest where there has been land disturbance, such as pipeline construction and timber cutting (Skinner & Majorowicz, 1999). Warming has not been constant. Widespread warming is thought to have occurred across much of the Arctic during the period between 1820 and 1920. This may coincide with globally low atmospheric concentrations of volcanic aerosols (Serreze *et al.*, 2000). In the middle and lower Mackenzie Valley, there was general warming between 1890 and 1940, cooling between the 1940's and 1970's, and a further warming has occurred since then (Skinner & Majorowicz, 1999). The WKSS area has experienced modest warming but less than in the Mackenzie River valley and Yukon regions (Cohen *et al.*, 1994; Cohen, 1997; Hardy & Bradley, 1996).

Precipitation records from the WKSS area span a short period of time and evidence from proxy data is very limited. Based on analysis of tree rings from stands of White Spruce near Inuvik, growth (ring width) appears to be more influenced by availability of moisture than an increase in temperature (Szeicz & MacDonald, 1996). Growth has been greatest during periods of increased precipitation (and, or, least evaporation during the previous season). Over the past 900 years or so, growing conditions appear to have been best between: 1185-1205, 1215-1260, 1510-1560, 1725-1740, 1770-1780, and 1925-1940 AD. Poor growth occurred between 1125-1170, 1260-1300, 1395-1405, 1585-1610, 1700-1710, and 1820-1855 AD. During dry and cold conditions, Arctic outflows may have followed a more meridional atmospheric circulation, although generally drier periods seem to have existed in both northern Quebec and northwest Canada between 1260-1300 and 1600-1850 AD. Moisture levels were probably high between 1170 and 1250 AD (Szeicz & MacDonald, 1996).

Geological evidence from sediments indicates that lakes of the Great Basin area of central North America have responded to climatic events of global scale. Broecker (1996) has suggested that, under the influence of increased heating, massive cumulus clouds would have formed in the tropics and fed vast quantities of moisture high into the atmosphere towards the end of the last glaciation. The high level lake stages which developed about 14,000 BP would have been, therefore, an expression of greatly increased precipitation, associated with that moisture. The geological record suggests there is broad coherence of climate among many sites in western North America and that this may be related to sea surface temperature in the tropical Pacific (Laird *et al.*, 1998). Well developed regions of low atmospheric pressure off both the east and west coasts of North America are associated with drought in the northern Great Plains (Laird *et*



*al.*, 1998). Extreme droughts were common at Moon Lake in North Dakota prior to 1,200 AD, and at both this region and in the upper Mackenzie valley, moisture levels increased after about 1,200 AD. Apart from this association, there is little evidence for a relationship between climatic conditions in northwest Canada (WKSS area) and those of the northern Great Plains. While proxy precipitation data from North Dakota can be extended northwards into Saskatchewan (and possibly into the extreme southeastern part of Alberta), the 2,300 year record from the Moon Lake region (Laird *et al.*, 1996) shares little in common with events in the middle and lower Mackenzie Valley. The Moon Lake data appear to be strongly influenced by seasonal incursions of air masses from the Gulf of Mexico whereas the northern Mackenzie Valley region has remained under the influence of Arctic and north Pacific air masses. This is consistent with present air mass time-frequencies at Inuvik (Rouse *et al.*, 1997), in which Arctic air is present 100% in winter, 85% in spring, 55% in summer and 88% in the fall, and Pacific air makes up the balance.

Natural variability in climate is known to be considerable throughout the WKSS area and predates any effect that may be occurring from the release of greenhouse gases. Rapid warming (15,000 to 10,000 BP) brought an end to the last glacial period and the WKSS area became ice-free about 8,500 BP. Locally, the cooling effects of large lakes may have persisted for an additional time. The warming was followed by cooling and then warming again about 5,000 BP (mid-Holocene high). Shortly before 3,000 BP there was another period of cooling (Bryson & Wendland, 1967; Maxwell, 1987; 1992). Diatom assemblages from lake sediments in the Lac de Gras area (Pienitz *et al.*, 1999) show clear evidence of warming and more humid conditions between about 5,000 and 3,000 BP. This mid-Holocene warm event is widespread across northern North America but unrelated to Milankovitch cycles. It has been suggested that retreat of the Arctic front allowed greater influence of Pacific air masses at that time (Pienitz *et al.*, 1999).

Within recorded history, large variations in winter and summer temperature are already known to exist across much of northern Canada. There are considerable variations in precipitation, and year-to-year differences in ice cover and thickness may vary by as much as 30% (Ball, 1983; Catchpole, 1985; Dunbar, 1985; Fisher & Koerner, 1983; Koerner & Fisher, 1981; Wilson, 1985). In addition to year-to-year variations about some mean value (*e. g.* annual temperature or total precipitation), there may be changes in the frequency of extreme events such as storms, coastal surges, drought, and fire. There are few certain relationships between possible climate change and specific weather events.

Separation of natural and human-induced effects within recent climatic data is not distinct (Allen *et al.*, 2000; Corti *et al.*, 1999) and although there is a present warming trend the extent to which it will continue is uncertain. The likelihood that future conditions might become similar to those of the late Tertiary Period of geological history (Matthews, 1989) is conjectural. Changes that

may be associated with precipitation (quantity and form) are uncertain (Cohen *et al.*, 1994). Based on analogy with palaeoclimatic information, some increase in precipitation is probable at high latitudes and this would most likely occur during the open water season (as at present).

Palaeobotanical evidence such as tree ring data and pollen distributions, relict stands of trees that became established under previous and more benign climatic conditions north of the present tree line, and relict peatlands, suggests that there have been significant vegetational changes both before and throughout the period of human occupation. Geological evidence also indicates that brief but rapid changes in climate have occurred even during glaciation. It has been suggested that these may have been related to the global evaporation-precipitation balance (including continental run-off). In particular, it seems possible that changes in the rate of production of cold and deep North Atlantic Ocean water might move climate from one quasi-stable state to another (Broecker *et al.*, 1985).

In summary, two factors are most likely to influence climate in WKSS area over the 21st century. If the recent trend of solar activity remains the same it will contribute to global warming. However, solar activity might increase, or it could decrease (and cause less heat to be received at the Earth's surface). The effects of warming from greenhouse gases is almost certain to continue. The influence of many other factors on climate in the WKSS area are not predictable but could cause either significant warming or cooling. On balance, it seems most likely that climate will continue to become warmer, at least to the middle of the 21st century, and that this warming will be accompanied by a modest increase in precipitation (mostly during summer). There is nothing to suggest that climate will become less variable. Rather, collective evidence suggests that it may become more variable as greater quantities of water vapour transport more heat poleward.

A wide range of effects from climate warming could occur in the WKSS area. Potential environmental effects that represent a relatively quick response to climate warming include: more freezing rain and changes in snow cover and runoff, delayed ice formation, less stable ice cover and earlier break-up, increased wave activity due to extended open water conditions, and increased evaporation. Soil moisture is likely to decrease but fire frequency is likely to increase and to occur earlier in the season (Kane *et al.*, 1992; Kadonaga, 1997). Environmental effects showing a slower response include: thinning of permafrost and changes in its distribution, changes in types and distributions of vegetation, (Billings, 1992; Jefferies *et al.*, 1992)), rising sea level (globally, the expansion of warmer water could rise sea level by about 0.4 m within a few decades (Schneider, 1998). Over a long period, melting of polar ice caps could cause much more severe coastal flooding. Examples of specific effects are discussed in more detail.

#### **4.2.1.2. Effects of Climate Change - Permafrost**

With climate warming (as higher maximum summer and fall temperatures, and an extension of

the period of above-freezing temperatures or both), changes could be expected over large areas of permafrost which are presently within 1 to 3° C of melting or where mean annual air temperatures are greater than -6° C (Rouse *et al.*, 1997). General predictions suggest that much of the permafrost in the discontinuous permafrost zone will gradually disappear over periods of decades to centuries. Instabilities associated with thawing soils, such as ground settlement and slope failure, will likely increase (Burgess, 1998). The southern limit of the discontinuous permafrost zone will likely shift northward. In the continuous permafrost zone, the thickness of the active layer will probably increase and permafrost thickness will gradually decrease.

Specific responses of permafrost and the active layer (rate and magnitude) are difficult to predict (Williams, 1979). They are strongly influenced by water balance and will respond to changes in both temperature and precipitation, and feedback mechanisms. Permafrost conditions are also influenced locally by vegetation, soil moisture, snow cover, and fire (Harris, 1987; Maxwell, 1992; Rouse *et al.*, 1997). Surface organic layers can buffer the ground (Tenhunen *et al.*, 1992) from increasing air temperature and increased snow cover can insulate the ground from geothermal heat loss. Models of the effects of climate warming on peatlands in the Mackenzie River basin suggest that permafrost will persist under protective peatlands north of about Latitude 65 °N. Moisture levels in these northern peatlands are likely to decrease (Nicholson *et al.*, 1997).

Permafrost underlying moss bogs may be less well insulated from effects of warming than under fens where vascular plant structures provide mechanisms for greater evaporative loss. Soils with low moisture contents warm more quickly than those with high moisture contents but the drier the surface of peatlands, the greater their ability to insulate underlying permafrost (Rouse *et al.*, 1997). Fire may decrease the thickness of insulation over permafrost and melting may result in collapse of the peatland cover. In areas subject to periodic fire, lowering and recovery of peatlands after fire may be an event that is recurrent over periods of 600 to 2,000 years (Rouse *et al.*, 1997).

#### 4.2.1.3. Effects of Climate Change - Vegetation

The response to climate warming by Arctic and boreal vegetation is difficult to predict (Rouse *et al.*, 1997; Starfield & Chapin, 1997). If warming occurs, both as an earlier spring and later fall, present plant community structures may shift northward. However, if warming extends only in the fall, other changes could occur and these might include a shift to species better adapted to the new conditions (Sveinbjornsson, 1992). Present evidence suggests that warming will be greater in winter than summer but that winter temperatures will not rise above freezing (Cohen *et al.*, 1994). Fall extension of the open-water season seems likely, and this could cause more freezing rain and early winter snow. Under such conditions, soil moisture might increase favouring expansion of moss over lichen. If the summer growing period does not significantly increase, vascular plants will not colonize northward. If summer temperatures rise by only a small amount,

evaporation is likely to rise by only a small amount, and with a longer period of open-water annual precipitation could increase. With more soil moisture and less frequent fire, spruce canopy closure (and loss of lichen) might also increase near the tree line. Tussock vegetation is also very sensitive to changes in soil moisture (*e. g.* in response changes in precipitation, or wind and evaporation). With increasing temperature, rates of peat accumulation would likely increase in tundra areas where it would act as a carbon sink (Oechel & Billings, 1992). In more southerly areas, however, peatlands could become warmer and drier, and increasing microbial activity would likely cause them to become a carbon source (for greenhouse gases). The presence of deciduous species within the boreal forest areas (between Great Slave Lake and Great Bear Lake, and along the East Arm of Great Slave Lake (Hartley & Marshall, 1997)) may increase. Some vegetation anomalies north of the present tree line (Johnson, 1979; Kershaw & Rouse, 1976; Timoney, 1995) may also reflect areas of favourable soil (which partly compensate for net radiation effects) and previous vegetational advances under more favourable climatic conditions. Vegetation anomalies south of the tree line (Johnson, 1979; Kershaw & Rouse, 1976; Timoney, 1995) reflect areas of unfavourable soil and the effects of fire.

Based on accumulating evidence and models of warming due to a doubling of CO<sub>2</sub> in the atmosphere, it seems likely that normal successional change will be influenced by warm but not very humid conditions. Over the next 50 to 500 years, model studies suggest that grasslands could replace parts of both presently forested areas and tundra uplands in the WKSS area (Starfield & Chapin, 1997). However, if the Pacific airmass becomes a more significant component of the climatic regime, rising humidity would enhance tree growth both near the tree line and possibly at some coastal and near coastal sites. Vegetation response will be very sensitive to water balance in the environment. Vegetation response will lag climate warming and based on an increase of 3° C per century, it would take at least 150 years for forest cover to begin extension into the tundra (Starfield & Chapin, 1997). Conifer species would be early colonizers and only later would deciduous species begin to replace them. The predicted sensitivities of peatlands and river systems to climate change are shown in Figures 22 and 23.

Other factors may be important, too. For example, it is probable that timber harvest, moose and predator control practices and fire would have greater effect on vegetation than climate change (Starfield & Chapin, 1997). Also and under the present scenario of climate warming in response to a doubling of atmospheric CO<sub>2</sub>, it is possible that the Spruce Weevil will expand its range northwards. It could occupy most areas in the Mackenzie River basin that are presently forested with White Spruce. Weevil infestations in pine forests require a minimum of 720 degree days above 7.2 °C (Sieben *et al.*, 1997)).

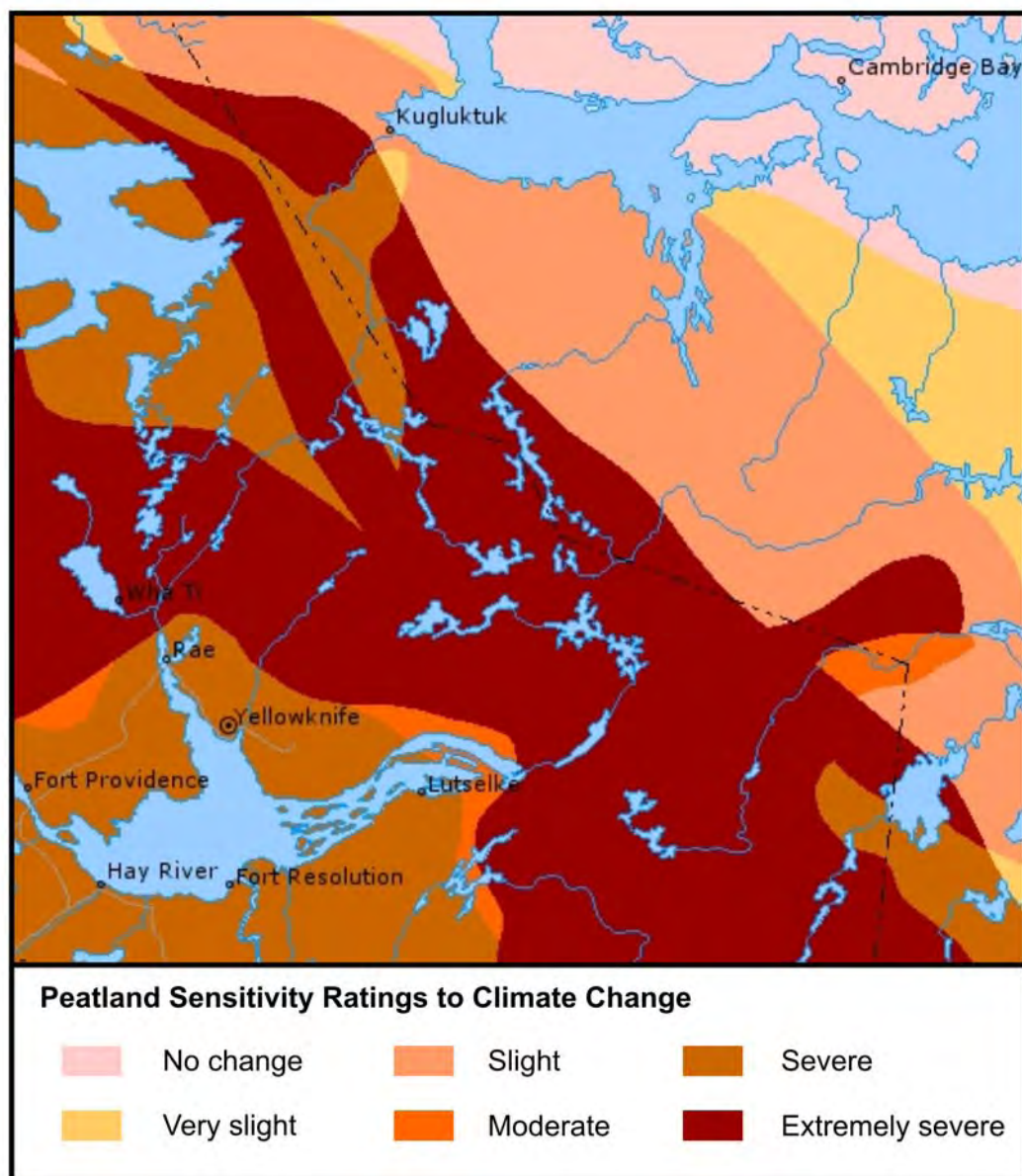
Although White Spruce and Black Spruce did not die-off during cold summers during the mid 1800's, both suffered from poor growth and recruitment at the tree line. After 1880, both species did well under the influence of warming. During the 1960 and 1970's, cooling again limited

growth and recruitment. Most recently, White Spruce and Black Spruce have shown good growth and recruitment in response to warming since the 1980's (MacDonald *et al.*, 1998). However, there is little evidence of a significant northern advancement of the tree line (since 1880).

Satellite data from 1981 to 1991 indicate that plant growth has increased with a longer growing season (mean annual hemispheric warming). This has been most significant between 45° and 70° N where spring warming has also occurred together with an early decrease in snow cover (Myneni *et al.*, 1997). Experimental studies indicate that it may be easier for trees to colonize shrub tundra than either heath or tussock tundra and that White Spruce is likely to be one of the most successful colonizing species (Hobbie & Chapin, 1998a). The location of the present tree line probably results, in part, from unsuccessful recruitment (temperatures are too cold to permit germination). Once established the survival of seedlings is further influenced by both availability of nutrients and competition. Many stands of Green Alder and Balsam Poplar on the tundra are likely relict populations from mid-Holocene warming (Hobbie & Chapin, 1998a).

Carbon and peat accumulation rates over the past 1,200 years have been less in northwest Canada than in northeast Canada, particularly because of low and variable summer precipitation. Recent accumulation rates are similar for areas of rich fen and peat plateau (about 14g C·m<sup>-2</sup>·a<sup>-1</sup>), and rates for poor fen and ombrotrophic bogs are higher (20 to 22g C·m<sup>-2</sup>·a<sup>-1</sup>). The annual

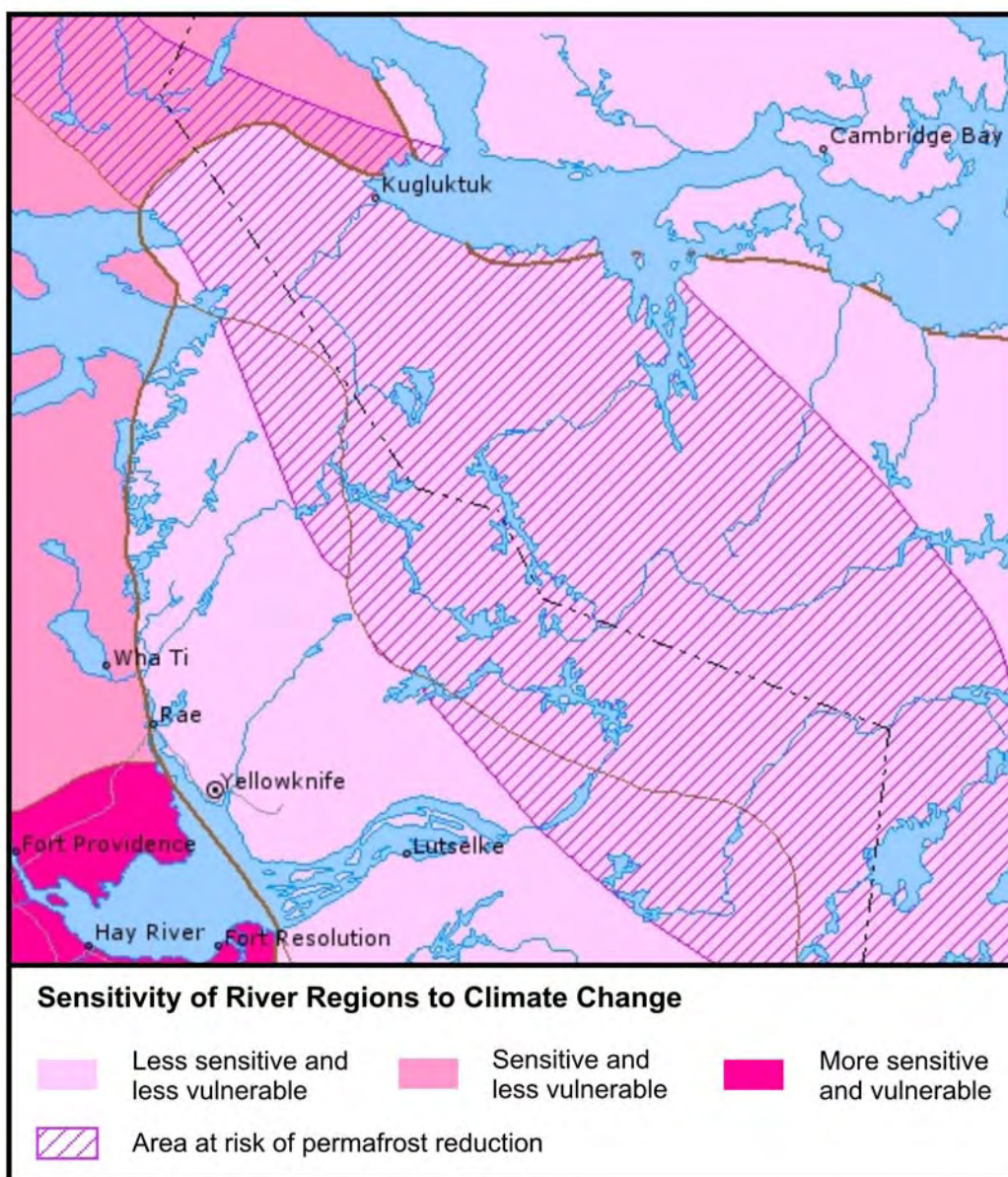
**Figure 22 Peatland sensitivity to climate change**



Source: Digital Atlas of Canada ([http://atlas.nrcan.gc.ca/site/english/dataservices/free\\_data.html](http://atlas.nrcan.gc.ca/site/english/dataservices/free_data.html))



**Figure 23 Sensitivity of river regions to climate change**



Source: Digital Atlas of Canada ([http://atlas.nrcan.gc.ca/site/english/dataservices/free\\_data.html](http://atlas.nrcan.gc.ca/site/english/dataservices/free_data.html))

average rates of peat accumulation range from 0.28 to 0.56 mm over discontinuous permafrost in northwest Canada (Robinson & Moore, 1999). The tree line is a surrogate for the long term average position of the Arctic Front in July, and over the past hundred years, or so, the front has moved north in many areas. Although forest cover lags this change, areas of tundra have changed from a net sink for atmospheric CO<sub>2</sub> (30 to 100g C·m<sup>-2</sup>·a<sup>-1</sup>) to a source of CO<sub>2</sub> (by a similar amount). About 20% of the CO<sub>2</sub> released from peatlands passes first through the aquatic environment before being finally released back into the atmosphere (Serreze *et al.*, 2000).

Growth experiments indicate that a 4° C atmospheric temperature rise will increase C turnover but little effect is expected on the tundra C balance (Hobbie & Chapin, 1998b). A temperature rise in the growing season will have little effect on total biomass, N content or N uptake in the main plant and soil pools. Rather, tundra productivity seems to be controlled by nutrient availability and length of growing season. Warming stimulates early photosynthesis and above ground biomass (*e. g.* Dwarf Birch) and redistributes N from understory shrubs (*e. g.* Cranberry) thus mediating N availability within the plant community (Hobbie & Chapin, 1998b). Warming also stimulates respiration during the growing season and this is likely associated with root-N uptake for above ground biomass (*e. g.* Dwarf Birch). Experiments with different species of grass indicated that the effects of increasing CO<sub>2</sub> on litter decomposition and N release may be strongly influenced by the root:shoot ratio. In addition, this depends on species traits and nutrient availability. The effects of rising CO<sub>2</sub> on litter decomposition and N-release are species specific (Frank *et al.*, 1997).

General models indicate that uptake of CO<sub>2</sub> in tundra systems can be related to annual precipitation and the mean July temperature ((Christensen *et al.*, 1999), but actual conditions may be more complex. It is uncertain if tundra ecosystems will act, overall, as a sink or source under climatic warming, and it is likely that fluxes of CO<sub>2</sub> and CH<sub>4</sub> are more strongly influenced by soil and vegetation type than by direct temperature change (Hobbie & Chapin, 1996). For example, sedges may assist release of CH<sub>4</sub> by conducting it from anaerobic soil to the atmosphere. Greenhouse gas experiments with elevated temperature and humidity had little influence on release of CH<sub>4</sub> (Verville *et al.*, 1998). Models based on North Slope (Alaska) tussock tundra, predict that rising air temperature and CO<sub>2</sub> content will increase ecosystem C storage. Because N is redistributed from soil to plants, photosynthesis exceeds respiration but consequent increases in C storage are constrained by the C:N ration in vegetation. It is possible that drier soil will decrease C storage because of greater soil respiration. With drier soil, N redistribution from soil to plants is limited by competing processes (*e. g.* N mineralization). Consequent loss of N from the system would contribute to declining C storage. On a percentage basis, modelling suggests that between 1829 to 1990 (from a cool to a warm period) the flux of CO<sub>2</sub> went from -5.4% to +2.3%. There is a high probability of transient events for ecosystem C loss (McKane *et al.*, 1997). Long term sequestering of C in Alaskan tundra was reversed by warm and dry conditions in the early 1980's but the effect diminished. There is now a summer



CO<sub>2</sub> sink in some areas. This reflects metabolic readjustment to decadal or longer climate change (nutrient cycling/physiological acclimation, population/ community reorganization). On an annual basis, however, the tundra has been a net source of CO<sub>2</sub> (40g C m<sup>-2</sup> a<sup>-1</sup> due to “winter” release). Further warming that follows the existing season trend would likely enhance this (Oechel *et al.*, 2000).

Across the WKSS area, *Typhea* marshes and *Salix* swamps give way to sedge and bryophyte fens and bogs to the north. Globally, wetlands are thought to contribute more than 20% of the flux of CH<sub>4</sub> to the atmosphere, and high latitude peatlands contribute about one third of this. Variations in water content and peat temperature regulate aerobic and anaerobic conditions, and the resultant microbial production or consumption of CH<sub>4</sub>. Storage of CH<sub>4</sub> in pore water, in the top half-metre of many peatlands is considerable. For example, at Fort Simpson, the summer flux of CH<sub>4</sub> is about 18 mg CH<sub>4</sub> m<sup>-2</sup> d<sup>-1</sup> (Liblik *et al.*, 1997). In some fens, O<sub>2</sub>-rich groundwater may facilitate CH<sub>4</sub> oxidation in water which reduces its flux to the air. With permafrost melting, the flux of CH<sub>4</sub> would initially increase particularly as a result of collapse structures in plateau bogs and palsas. It would later decline as sites dry out and stabilize to lower water tables (Liblik *et al.*, 1997). Permafrost in peatlands confines water flow to the thin active layer. With a doubling of CO<sub>2</sub>, the water table might drop 10-20 cm in summer. The southern boundary of peatlands could move 200-300 km northwards so that peat plateau and thermokarst pools develop as far north as Inuvik. Low boreal bogs could evolve as far north as the south shore of Great Slave Lake. Warming would not likely influence subsurface peats (greater than 30-40 cm depth). Raised water levels would increase rates of peat accumulation and reduce the thickness of the aerobic zone. Warming the peatland, therefore, may have little effect on decomposition. Fluxes of soil CO<sub>2</sub> are linearly related to water table depth but fluxes of CH<sub>4</sub> are more nearly exponentially related. Warm moist conditions increase photosynthesis and results in N redistribution from soil. Warm dry conditions make photosynthesis only partly compensate for greater respiration, and N is lost to the system. Many peatlands may show little response to increasing levels of CO<sub>2</sub> without both nutrients and moisture (Rouse *et al.*, 1997).

#### 4.2.1.4. Effects of Climate Change - Fire

The frequency of fire is closely related to a weather index (Johnson, 1979; Kershaw & Rouse, 1976) and when fires significantly exceed this relationship, often the cause is human activity. Fire is the dominant form of disturbance in lichen woodlands (Johnson, 1983). The fire season usually extends from late May to the end of August, and the largest burns occur in years with warm, dry summers. Therefore, any climatic shift towards such conditions is likely to increase the occurrence of fire and to advance the start of the fire season (Kadonaga, 1997). In northern Quebec (Payette *et al.*, 1989), the average size of burns in the northern boreal forest is about 80 km<sup>2</sup>, about 0.8 km<sup>2</sup> in tundra areas, and 80 % of all fires are less than 1 km<sup>2</sup>. In the same region, the fire rotation period is about 100 years in northern boreal forests and more than 9, 000 years in shrub tundra. Near the tree line (+/- 20 km), it is about 7, 800 years. Within forested areas of the

Great Slave Lake region, the reoccurrence of fire decreases northwards towards the tree line (e.g. 40 years at 400 km, 50 years at 250 km, and 100 years at 100 km) and fire rarely extends more than 75 km beyond the tree line (Timoney, 1995).

Studies of fire on the Beverly Caribou range (Ferguson, 1983) indicate that surface soil temperatures and net radiation are greatest shortly after burns. Then, conditions may be near optimum for germination of dormant Black Spruce seeds (requiring temperatures between 17 and 28° C). Very early in recovery, grasses and germinating seeds exist under conditions of low moisture content (Kershaw & Rouse, 1976). Soil moisture generally increases over time and by about 12 years after fire, moss becomes the dominant form of vegetation. This gives way to lichen, 25 to 30 years after a fire, with *Cladonia* slowly being replaced by other species of lichens (50 or more years after a burn (Case *et al.*, 1996)). In the final phase of recovery, the plant community consists of vascular plants and moss but when fire occurs more frequently than about once in 100 years, a closed canopy does not develop and spruce-lichen cover is maintained. Winter grazing caribou avoid areas where burns are too recent for lichen cover to have become re-established, or where a lack of fire has allowed extensive canopy development. This is confirmed by TK research with communities including the Tłı̨chǫ (Dogrib Treaty 11 Council, 2001) in which elders discuss locations of fire and why caribou avoid these locations.

In areas of frequent fire, seed banks in the soil are quickly exhausted. Most pine and spruce seedlings appear 3-10 years after a fire and little further recruitment occurs in this even-aged population, until it becomes capable of seed-bearing after another 50 to 75 years. Forest layering begins close to the new parent trees and few seeds are carried more than 100 m (Luc & Luc, 1998). Tree density at recovery sites is much lower than before a fire, and the resulting open forest or lichen heath is more typical of tundra than boreal conditions. A short fire interval and unfavourable climate can rapidly change boreal forest to taiga and species shifts may occur. For example, at Chisasibi in northern Quebec, the average fire cycle is about 109 years but in areas with a 40 year frequency density is greatly reduced and Jack Pine dominates Black Spruce (Luc & Luc, 1998). The longer lived spruce only becomes dominant in areas with greater than average fire interval.

Ground fires reduce C storage and peat accumulation, and increase the likelihood of permafrost melt (Robinson and Moore, 2000). At some fire sites, there may be a lag between fire and the effects of permafrost degradation. For example, germination may be successful and seedlings begin to recolonize a burned area. Initially, seedlings grow well and are protected by surrounding trees, but surrounding mature trees may not survive the delayed effects of soil disturbance associated with melting permafrost. If protection is lost, the young trees lose winter insulation as the snow depth decreases and they become more exposed to wind damage. Deformities, such as die-back and cushion-form development in young trees, may indicate multiple stress effects associated with fire near the tree line (Arsenault & Payette, 1997).

Because boreal forests are comprised of a few but widespread species, biodiversity is a poor indicator of richness during recovery from fire. Rather, patchiness and canopy development are more useful indices of recolonization. During the pioneer stage of recovery, vegetation patchiness and species abundance tend to be linearly related. With expansion and stabilization the relationship is lost by many species as they cover more of fewer patches (Fortin *et al.*, 1999).

Areas downwind from a burn are also stressed because of low moisture content in the atmosphere (Kershaw & Rouse, 1976). Regrowth is more rapid after an early summer burn than one in late summer. Fire and animal herbivory tend to select for short lived and quick growing deciduous trees. Long periods between fire allow replacement by slower growing but more competitive species. Light seeds favour wind dispersal of willow and Balsam Poplar as early colonizers, though Black Spruce is most tolerant of nutrient-poor soil, and water transport favours heavier seeds (*e. g.* birch). Frequent fires select for grasses and could eliminate evergreens as a seed source at the tree line if they do not reach seed-bearing age before a return of fire. Burns over permafrost may destabilize soil structure and increase summer melt, and require vegetative regrowth to begin at the earliest phase of colonization. On ice-rich permafrost slopes, active layer detachment slides frequently increase after fires.

Based on palaeo-environmental data, fire frequencies in the Porter Lake area (east of Great Slave Lake) have varied considerably over time (Johnson, 1983). The present fire frequency (return period) is about 100 years, at 400 BP it was about 250 years, and at 2,500 BP it was about 400 years. However, under warmer and drier conditions about 1,000 BP, fire frequency was about 50 years. These variations indicate that a changing fire regime, could dramatically effect the environment of the WKSS area.

At sites not affected by fire, vegetation may persist with little response to climate change. Where fires occur, however, recovery may result in major changes in species composition and structure of plant communities. Climate warming models based on a doubling of atmospheric CO<sub>2</sub> result in increased burn severity (by 40 to 50 %) and an increase in burned areas (by about 40%). Recent warming trends are thought to have nearly doubled the size of burned areas in Canadian boreal forests (Starfield & Chapin, 1996). Model studies of boreal forest areas in northern Alberta (Hartley & Marshall, 1997) also suggest that there will be a significant increase in burns, even under low fire scenarios. Under continued warming, productivity is likely to increase for several decades but both coniferous and deciduous species will decline below peak values by the mid 2000's.

It is likely that increases in the frequency of fire will affect distributions of wildlife (Kadonaga, 1997). Species that prefer areas of mature forest (*e. g.* Marten) may significantly decline but species that prefer areas of early regrowth may increase (*e. g.* Moose). Because of their ability as

opportunistic feeders, Red Fox may also increase in areas where the effects of fire prevent plant succession to the stage of mature community structure (Latour & Maclean, 1997).

#### 4.2.1.5. Effects of Climate Change - Grazers and Browsers

Grazers and browsers typically remove about 10% of the net above ground annual primary production, and there is little evidence that normal summer grazing has any long term effect on the availability of suitable vegetation (Jefferies *et al.*, 1992). Even intensive grazing by caribou occurs only for short periods. Temporary densities of up to 50 caribou·km<sup>-2</sup> over areas of several hundred to a few thousand square kilometres are common on calving grounds, but only for a week or so. During the June calving period, selection of plant material seems to be influenced by weather conditions. With an early spring, the Bathurst herd favoured wet graminoid plant communities but under late spring conditions they shifted to lichen-heath communities. Lichen (mostly *Cladonia*) remained the dominant forage with lesser quantities of early-greening graminoids in early spring or mosses in late spring (Griffith *et al.*, 2000). Highly nutritive cottongrass becomes available to caribou cows shortly after, rather than before, calving (Gunn & Dragon 1999).

Caribou do not appear to be closely associated with a specific forage base because fecal deposition is not closely coupled to plants (Jeffries *et al.*, 1992), although this may reflect a short term rather than long term relationship (Gunn *et al.*, 2000). By frequently moving as they graze, animals allow vegetation to recover within a few seasons, and vascular plants usually recover well within one growing season. Animals that feed more intensively and in small patches (*e. g.* geese), may migrate annually to new forage areas (Jefferies *et al.*, 1992). Groups of Barren-ground Caribou are also known to migrate to “fresh” summer grounds (unused for several decades or longer), but the reasons for such change are not well understood (Gunn *et al.*, 2000). They are presumed to be in response to limitations in quality food supply (Jefferies *et al.*, 1992; Miller, 1991).

It is not known how climatic change will affect present range use by different herds of caribou or Muskoxen but it has been suggested that snow depth on the range of the Bathurst Caribou may increase by 10 to 20 % (Brotton *et al.*, 1997). With rising temperatures, there will be a tendency for some areas, particularly in southern parts of the Barren-ground Caribou range to shift from forest to grassland conditions. This will be most noticeable where revegetation occurs at sites of increased fire frequency. Rising temperatures and possible changes in the water balance may also modify tundra vegetation. The effect is most likely to occur as a redistribution of patchiness as some areas of wetland dry out and other areas become wetter as a result of permafrost melting. A shift of range could occur but most herds will probably also make different use of their existing ranges. It is not clear how an earlier loss of snow cover and earlier availability of cottongrass that is so important to post-calving cows, will influence caribou migration and the time of calving.

Similarly, the northward movement of Muskox from the Rae and Richardson rivers area that appears to be associated with early availability of willow leaves (Gunn & Fournier, 2000), could continue to follow the same pattern but over slightly different time frames. Or, there might be a range shift to benefit from newly developing communities of tundra vegetation. A range shift in this herd of Muskoxen will, however, give rise to a specific concern. At present, the herd appears to be isolated from other Muskoxen in the WKSS area.

This herd is known to suffer from a severe infestation of the parasitic lungworm *Umingmakstrongylus pallikuukensis* (Hoberg *et al.*, 1995). This particular parasite has not been reported from other herds of Muskoxen in the WKSS area. The molluscan slug *Deroceras reticulatum* acts as an intermediate host and the parasite is thought to be ingested with forage and cycled back into the environment from fecal material. Hoberg *et al.* (1995) have suggested that this parasite may be a Pleistocene relict that has persisted only in the area now ranged by the Kugluktuk herd, or which was carried as a residual by Muskoxen from the Bluenose Lake area as they recolonized their previous range. Any further shift in the range of this herd, that increases the likelihood of overlap or mixing with other mainland herds, could have a devastating effect on Muskox recovery throughout the WKSS area and beyond. However, if this particular parasite is a Pleistocene relict and it only occurs in the herd near Kugluktuk, there is hope to believe that the herd would not naturally spread it further as a result of climatic warming. The mid-Holocene warming that lasted more than 1500 years provided conditions which were warmer than present, and at least as warm as may be expected from the effects of greenhouse gas warming over the next 50 years. If the herd remained isolated during the mid-Holocene warming, natural isolation may persist.

Population cycles in many species of animals (*e. g.* lemmings and Snowshoe Hare) appear to be linked, at least to some extent, to the availability of food and in particular to plant availability. Population dispersals (*e. g.* Lynx) may also be linked to areas that do not share the same cycle. For both caribou and Muskoxen, winter grazing (thus general condition or survival) has the potential to be of even greater influence on population size than predator control. Winter grazing by caribou may also have a greater impact on vegetation than summer grazing, and lichen “pastures” can take 20 to 40 years or more to recover from intensive use (Henry & Gunn, 1991). Lichen woodlands may reflect the effects of both winter browsing and summer fire (Henry & Gunn, 1991; Johnson, 1983). Increased fire frequency near the tree line is probable in response to climate warming and this may influence sites of the annual rut along the tree line (Gunn & Dragon, 2000). No significant shift of the tree line or rutting activity is anticipated.

Browsing removes woody shoots on deciduous plants and this causes compensatory growth. In the process, carbohydrates are used to create more tissue but leaves remain largely unprotected by plant toxins (secondary metabolites formed from carbohydrates (Bryant & Reichardt, 1992)). Vegetation switching in the summer diet allows browsed plants (mostly deciduous) to recover

and to create more carbohydrates, due to their high rates of photosynthesis. Severe defoliation by insects does not reduce shoot numbers and thus carbohydrates can be converted into plant toxins (as a deterrent and to decrease food value of the leaves (Bryant & Reichardt, 1992)). Many plants have developed an evolutionary response to browsing. For example, taiga willow and birch have greater plant chemical defence against browsing hare than tundra willow and birch (Bryant & Reichardt, 1992). There are, therefore, close relationships between plants and animals which are particular to different climatic conditions within the WKSS area. If climate change occurs slowly, these plant and animal systems should adjust easily to the change. If changes are rapid, major problems could occur. For example, taiga browsers (with greater tolerance of plant toxins) could replace tundra browsers, leaving less plant material to support some tundra species (Bryant & Reichardt, 1992).

In addition to the quantity and quality of winter food, its access and availability for both caribou and Muskoxen appears to be particularly sensitive to climatic conditions. Myneni *et al.* (1997) have noted vegetation response to warming in areas west of Bathurst Inlet (1981-1991 satellite data), and this is corroborated by local observations of residents from both Kugluktuk and Bathurst Inlet (Thorpe & Kadlun, 2000). Caribou travel on hard surfaces with minimal snow cover but the energetic cost of walking on crusted snow increases dramatically (DRR., 1996). Lower water levels would be less energy-demanding for caribou at river and lake crossing but changing ice conditions could have considerable influence on safe crossing of lake ice and sea ice, particularly at Bathurst inlet and between Victoria Island and the Kent peninsula (NPCTT., 1996; NPC., 1997, Thorpe & Kadlun, 2000). Freezing rain or heavy snow can present a major problem for Muskoxen that have a limited ability to dig through such cover (Barr, 1991). When coastal waters were ice-free, catastrophic losses were recorded in the east Greenland Muskox herd (during 1938 and 1939, 1953 and 1954) and also on Melville and Bathurst islands (1973-74). High Arctic die-offs also occurred in the mid-1990's (Gunn, 1998). The ability of caribou, Muskox and Snowshoe Hare to outrun predators is also very dependent on surface condition.

In northern ecosystems, there are many points in the scales of both time and space where animal populations are particularly vulnerable to stress. Populations with high rates of reproduction and rapid growth are most capable of sustaining high rates of predation but have large nutritional needs. Where vegetation provides lower levels of nutrition, animals have lower rates of reproduction and growth, and survive by minimizing exposure to predation. Although general models of population response to stress are simplistic and ignore many of the complexities of natural systems, they can reflect a range of naturally occurring survival strategies. For example and with regard to grazing (Ferguson, 1996), if some form of stress is widespread but largely unaffected by population density (*i. e.* a density-independent stress such as increased snowfall or summer drought), chances of survival increase if a large population is widely dispersed. Somewhere, under the least unfavourable conditions, there will be survival. On the other hand, under density-dependent control (*e. g.* a limited food supply) populations may be able to survive

best as very small groups where the effects of grazing are within the reduced but sustainable yield of habitat. Somewhat comparable strategies for survival may have been used by Aboriginal people, as well. It is not known to what extent either "strategy" may have been significant but it is certain that herds of caribou and Muskoxen have survived past climatic extremes and isolation. They successfully recolonized large areas of northern Canada after glacial retreat (Barr, 1989; 1991; Hall, 1989; Urquart, 1981).

#### *4.2.1.6. Effects of Climate Change - Freshwater Species*

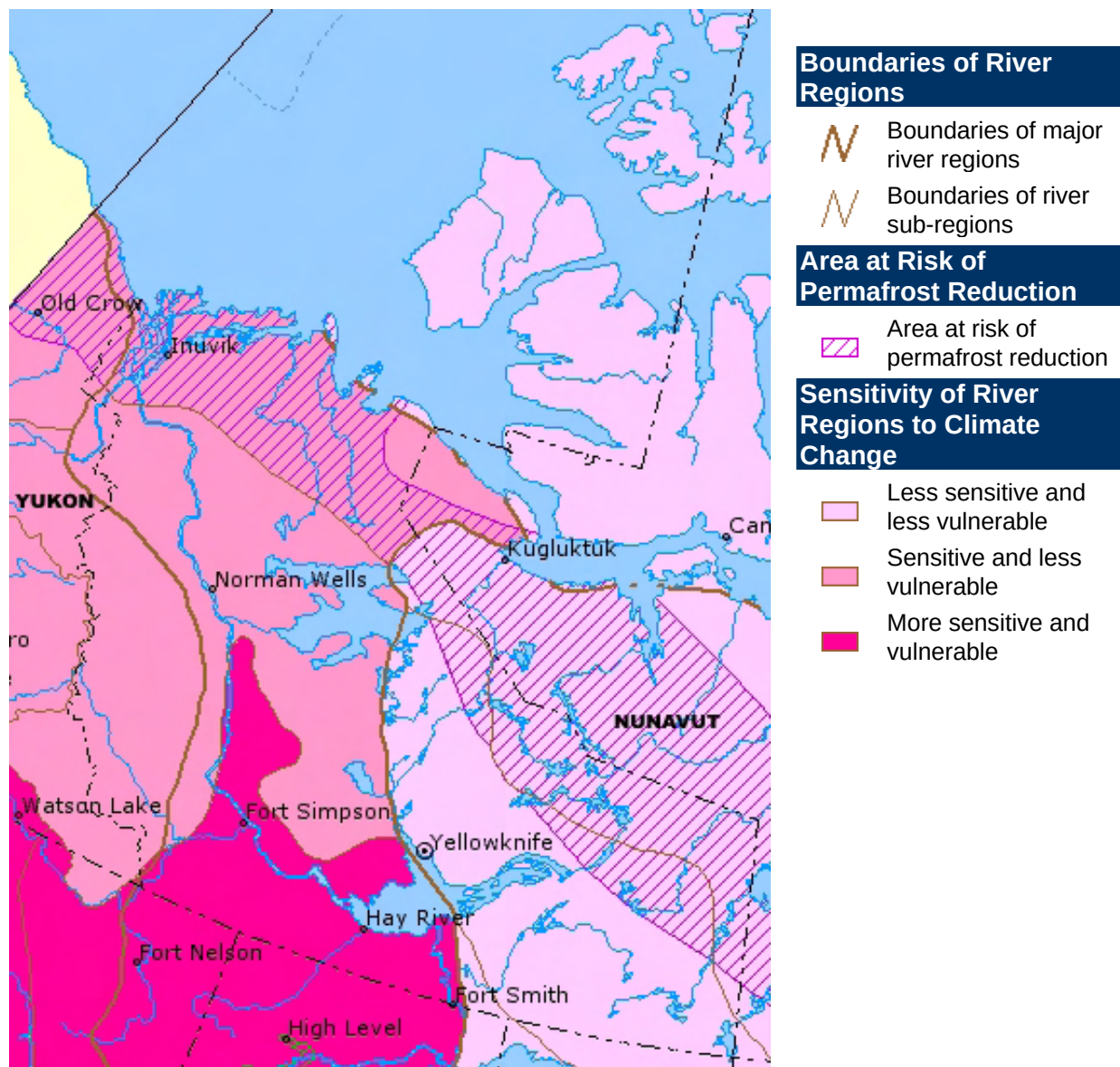
The greatest effects of a changing climate are expected in the higher latitudes, where melting ice and large tracts of drying tundra cause significant changes to the natural hydrologic cycle and carbon exchange. Overall, it has been estimated that the air temperature over the arctic landmass has increased at a rate of 0.40°C per decade since the 1960s. ACIA reports that average winter temperatures in the western Canadian Arctic have increased by 3 to 4°C in the last 50 years, and that precipitation appears to have increased by 8% across the Arctic (ACIA 2004). ACIA predicts that total annual precipitation will increase by 20% in the Arctic by the end of the century. These prolonged changes to the climate are expected to have major effects on northern aquatic regimes. Figure 23 shows a sensitivity projection for river regions in response to climate warming. Climate warming has the potential to cause substantial changes to flow in rivers and degradation of permafrost (Ashmore and Church 2000).

Based on studies in boreal lakes, longer ice-free periods, higher evaporation rates and increased water residence times, and increasing nutrient concentrations and productivity appear to be most evident in relatively small and shallow lakes (Schindler, 1997; Schindler *et al.*, 1990). Reduced runoff and lower water levels (Spence, 2000; Spence *et al.*, 2000) could be extremely detrimental to biological communities in deltas and associated perched lakes (Schindler, 1997). Lake alkalinities are likely to rise with climate warming (Schindler, 1997) and permafrost melt may contribute to nutrient additions (Evans, 2001). During the growing season, concentrations of nutrients such as DOC, P and Si are likely to decline as a result of increased biological activity and demand (including primary productivity). The combined effects of a longer ice-free season, an increase in thermocline depth and an increase in epilimnion temperature will act together to greatly increase degree-day values and the length of the growing season in the aquatic environment (Schindler, 1997). In turn, this will influence rates of hatching and development, reduce lifespans and change species distributions. Distributions of fish, amphibians, aquatic insects, and plants may respond to climate warming by northward range extension (where barriers do not limit species migration and colonization). Species displacement by more competitive forms may also occur (Regier & Meisner, 1991).

Major community species shifts are possible at all trophic levels (Schindler, 1997). Several forms of microscopic plants are sensitive to changes in both water quality and temperature. The remains of diatoms (composed of silica) which accumulate in the bottom sediments of lakes and

ponds can provide particularly detailed records of environmental change. Evidence of past changes in both boreal (Pienitz & Smol, 1993; Pienitz *et al.*, 1995) and high Arctic environments is well established (Douglas *et al.*, 1994, Quinlan *et al.*, 2005). However, at higher levels in the food web, the extent of change is more difficult to assess (and to attempt prediction) because of the significance of site-specific conditions, and the extent to which connectedness is maintained among and between areas of critical habitat.

**Figure 24 Sensitivity Projection for River Regions in Response to Climate Warming**



Source: Digital Atlas of Canada, Natural Resources Canada - <http://atlas.gc.ca/site/english/maps/climatechange/potentialimpacts/sensitivityriverregions>.

The extent to which cold-water species in large lakes would be affected by anticipated climate



warming is uncertain (Melville, 1997). Recent studies at Toolik Lake (Alaskan Arctic) indicate that, over a 16 year period, there has been a 3° C rise in the July epilimnion temperature (McDonald *et al.*, 1996). Because of this warming and based on bioenergetic models, y-o-y Lake Trout need 8 to 10 times more food to sustain their development. But because the lake is nutrient limited, like almost all high latitude lakes, there is little evidence of increased primary production. Typically, y-o-y Lake Trout remain in littoral habitat where protection from predation is least, but where temperatures are highest and the need for food greatest. It is likely that many of the y-o-y Lake Trout from this habitat no longer survive their first winter and, therefore, warming without increased nutrient supply could greatly reduce Lake Trout populations (McDonald *et al.*, 1996).

#### **4.2.2. Long Range Transport of Atmospheric Pollutants (LRTAP)**

##### **4.2.2.1. Processes Affecting Received UV-B Radiation**

Ozone in the atmosphere is present both at great height (high level) and close to the ground (low level). It is produced naturally as a result of photo-oxidation, particularly in the stratosphere (15 to 50 km above the Earth's surface). Emissions from combustion sources increase the amount of low level ozone. Near the ground, ozone acts as a pollutant and can negatively affect both plant and animal health. At high levels in the atmosphere, however, ozone forms a filter, shielding the Earth's surface from harmful components of solar radiation (EC., 1991).

Atmospheric circulation redistributes pollutant gaseous and fine particulate emissions, globally. By means of both vertical and horizontal movements, air-masses are progressively move poleward on both sides of the equator and then back towards the equator. Several ozone-depleting gases (mostly man-made and from regions of mid and low latitude) are carried to higher latitudes, and a number of persistent chlorinated and other halogenated compounds are of particular concern. These include CFCs 11, 12, and 113 (lifetimes about 75 to 110 years), carbon tetrachloride (lifetime about 67 years), methyl chloroform (lifetime about 8 years), and halon 1301 (lifetime 110 years). Nitrous oxides (from combustion and fertilizer sources) can also destroy ozone but usually break down within the troposphere and before being carried up into the stratosphere (EC., 1991).

In the stratosphere and in the presence of sunlight, chlorine (from CFCs and other man-made chemicals) undergoes a catalytic reaction with ozone, to form oxygen and chlorine monoxide. The chlorine monoxide repeatedly disassociates and chlorine continues to split many more molecules of ozone. The natural formation of high level ozone and its depletion (particularly by pollutants) occur simultaneously but, because of the quantity of ozone-depleting gases and their long lifetimes, rates of depletion can exceed formation. Ozone depletion in the stratosphere is seasonal and it is most severe at high latitudes (EC., 1991).

During each northern or southern winter, cold and relatively dense polar air masses tend to separate from the rest of the global circulation, forming what is known as a polar vortex (Alt, 1983; EC., 1991). The Arctic vortex is less coherent than the Antarctic vortex. This is largely because of the greater influence of land mass relief on atmospheric circulation in the northern hemisphere. Received solar radiation declines greatly in polar regions with the advance of each winter period and ice crystals form in the stratosphere as temperatures drop to very low levels. With the loss of sunlight during winter, photo-chemical processes cease and ozone-depletion declines to a minimum. At the same time, chlorine and other halogens become attached to the ice particles in the stratosphere. This process results in a seasonal concentration of ozone-depleting substances over each pole. It is exacerbated by any condition that increases the formation of polar stratospheric clouds. With increasing sunlight during the spring, photochemical reactions increase in the stratosphere and the cycle of ozone depletion begins again. Rates of depletion are most rapid in spring. Because the Arctic vortex has been less stable than the Antarctic vortex, ozone depletion over the south pole has been 4 to 5 times more severe than over the north pole. Over regions north of latitude 50° N and between 1978 and 1987, concentrations of high level ozone decreased by about 2.5%. Between the late 1970's and early 1990's ozone-depletion over the Arctic increased to about 10% (IASC., 1995). Depletion increased to about 40% during the 1996-1997 period (Hansen & Chipperfield, 1998).

Recent studies have raised additional concern, particularly about feedback mechanisms in the atmosphere (Shindell *et al.*, 1999; Walker, 2000). Tropospheric warming appears to cause the position of the Arctic vortex to move north and to form a more stable feature, less influenced by planetary relief (Shindell *et al.*, 1999). Warming at the Earth's surface also intensifies tropical heating and may raise additional water vapour into the stratosphere (Broecker, 1996). Together, increased moisture and a more stable vortex would tend to increase the development of polar stratospheric clouds. Nitric acid is a natural constituent of stratospheric chemistry. It reacts with chlorine to form chlorine nitrate that, in turn, reduces the amount of chlorine available for ozone-depletion. With more moisture, stratospheric ice particles could increase in size and if sufficiently large they would fall under their own weight (stratospheric precipitation). Ice particles removed from the stratosphere would also remove nitric acid, and this might make more chlorine available and further increase ozone depletion (Walker, 2000). Northward movement and greater stabilization of the Arctic vortex might therefore intensify stratospheric ozone-depletion, creating similar conditions in both polar regions.

Ozone depletion is not permanent and natural regeneration will eventually replace lost ozone. However, there will be a lag time of several decades between reduction of pollutant emissions and exceedence of their atmospheric lifetimes, and increasing quantities of newly formed stratospheric ozone (UNEP., 1989).

Solar UV is received as short (C), medium (B) and long wave (A) radiation. The UV-C is

potentially lethal but high level ozone absorbs almost all of it. UV-B (280 to 320 nm) is less severe in its effects but more of it penetrates the ozone layer. UV-B represents about 1% of the total received radiation (Vincent & Pienitz, 1996). Much of the UV-A passes through the ozone layer but this radiation is relatively harmless. Depletion of stratospheric ozone is therefore likely to increase the quantity of UV-B received at the Earth's surface. The extent of further increase is uncertain (Walker, 2000). However, recent models simulating changes in stratospheric ozone depletion and the effects of greenhouse gas emissions provide an estimate of increases in the amount of UV-B radiation that may be received during springtime, between 60° and 90° N (Taalas *et al.*, 2000). Based on these simulations, UV-B dosage will increase by about 90% from the period 1979-1992 to 2010-2020. The corresponding (northern) hemispheric dose will increase by about 14% over the same period but by only 2% from 1979-1992 to 2040-2050, indicating the longer term effect of emission control (Taalas *et al.*, 2000).

#### 4.2.2.2. Effects of Increasing Amounts of Received UV-B Radiation

Increased dosage of UV-B radiation (as a result of ozone depletion) may give rise to a wide range of health related problems in both plants and animals. These include: sunburn, cataracts, skin cancer, dysfunction of the immune system, growth impairment, and loss of fecundity (EC., 1991). Humans produce melanin, and many species of invertebrates, algae and fish taken from high latitude and polar waters have mycosporine-like amino acids that absorb UV-B (Karentz *et al.*, 1991; Leavitt *et al.*, 1997). The extent to which photosynthesis in plant communities may be affected by increased UV-B radiation in the WKSS area is not known, nor is the extent to which some plant species may be more susceptible to damaging effects than others. However, there is considerable potential for harm in terrestrial (Oechel & Vourlitis, 1994) and aquatic ecosystems (Rampino & Etkins, 1990; Smith, 1989; 1990; Smith & Baker, 1979; Smith *et al.*, 1992).

In some recent years, more than 50 % of the high level ozone layer has been lost in the Antarctic during the spring, and this has been associated with a significant increase in UV-B penetration of the atmosphere. In clear water (fresh and marine), UV-B can penetrate deeply into the photic zone and studies on marine algae show that photosynthesis may decrease by 6 to 12% (Ryan, 1992). About 10% of received UV-B can penetrate 2 m of ice and studies indicate that the photosynthesis of ice algae may decrease by 5%. Pigmentation in plants and animals absorbs UV-B but the extent of this protection is not known.

Dissolved organic carbon (DOC) is a surrogate for the brownish water colour associated with dissolved organic matter that provides an important protective screen for UV-B radiation (Leavitt *et al.*, 1997; Pienitz & Vincent, 2000; Pienitz *et al.*, 1999; Schindler *et al.*, 1996). In lakes, the protective effect is greatest below the tree line. It decreases above the tree line where concentrations of DOC in water are usually less than about 5 mg l<sup>-1</sup>. The depth to which photosynthesis can occur is limited by the penetration of sunlight in water. Because of increasing water clarity above the tree line, photosynthetic depth increases from about 1.5 m in

the boreal forest (500 km below the tree line), to about 5 m at the tree line. It is more than 10 m, 500 km above the tree line (based on data from northern lakes, mostly in Quebec (Vincent & Pienitz, 1996)). Likewise and with declining concentrations of DOC, water is increasingly transparent to UV-B radiation. UV-B penetration depths increase from less than 10 cm (500 km below tree line) to nearly 150 cm (500 km above the tree line). In northern lakes, small phytoplankton and benthic algae are important sources of primary productivity and studies on cyanobacteria have shown them to be very sensitive to changes in UV-B, particularly at low temperature (Vincent & Pienitz, 1996).

Changes in lake and river DOC may respond to variations in the UV dose received by vegetation but during the past 10,000 years or so, climate (temperature) has been by far the most important influence on DOC (Pienitz & Vincent, 2000). This effect is most dramatic in the sediment record from lakes at the tree line (near Lac de Gras), where interpretations show that DOC increased from average values of about 1.8 mg l<sup>-1</sup> before the mid-Holocene warming, to about 5.8 mg l<sup>-1</sup> during this warming, and have averaged about 1.4 mg l<sup>-1</sup> from about 3,000 BP to the present. The advance of Black Spruce forest during the mid-Holocene warming contributed much to the DOC increase. Maximum values dropped from about 7 mg DOC l<sup>-1</sup> to about 1 mg DOC l<sup>-1</sup> at the tree line from slightly before 3,000 BP to the present, and reflect a return to dwarf and shrub vegetation (Pienitz & Vincent, 2000). The variations in DOC are equivalent to changes in UV exposure over two orders of magnitude. They are much greater than expected from the actual variation in received UV radiation that is occurring as a result of ozone depletion (Pienitz & Vincent, 2000). Leavitt *et al.*, (1997) studied lakes in the Canadian Rockies between 51° N and 53° 30' N. From sediment data, they were able to demonstrate that the depth of UV-B penetration increased dramatically between 1850 and 1900. This increase was associated with changes in DOC rather than received radiation. The DOC variations (1850-1900) coincide with drought at lower elevations and cooling near the tree line. Because DOC is at low concentrations, many lakes from the tree line northward are extremely sensitive to the effects of changing DOC on penetration of UV-B (Leavitt *et al.*, 1997)

Solar radiation is not constant. Emitted UV radiation varies (Mitton, 1977) and it may be several decades before regulation and control of emissions of ozone depleting gases allow recovery of the stratospheric ozone layer to be well established. For the next several decades, potential exists for decreased production at the base of the freshwater food web above the tree line. This would be due to further increases in UV-B, and reduced DOC if increased evaporation exceeds precipitation. Likewise and although the extent of effect is uncertain, increasing cataract and skin cancer (in humans and other animals) and reduced photosynthetic efficiency (in terrestrial and aquatic plants) may be anticipated (EC., 1991; Oechel & Vourlitis, 1994; Vincent & Pienitz, 1996).

### **4.2.3. LRTAP, Organic, Metal and Radionuclide Contaminants**

#### **4.2.3.1. LRTAP - Persistent Organic Pollutants (POPs) and Effects**

In March 2003, the second Canadian Arctic Contaminants Assessment Report (CACAR Phase II) reporting on research under phase 2 of the NCP, was published. NCP findings have provided substantiation for the calls for action on international controls of contaminants. POPs and Heavy Metals Protocols under the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CRTAP) have been signed by 36 countries, including Canada, since June 1998. Negotiations for a legally binding global instrument on POPs under the United Nations Environment Programme have now also been completed with the signing of the POPs Convention in Stockholm, Sweden on May 23, 2001. Both of these conventions entered into force in 2004.

Results from the CACAR Phase II indicated that the Canadian northern atmosphere contains lower levels of POPs and heavy metals than those found over most other circumpolar countries (SENEC, 2005). Levels of most contaminants are declining slowly right across the circumpolar Arctic. However, it is still too early to tell whether mercury levels are increasing or decreasing. Most POPs are declining in the Canadian northern atmosphere, with the exception of dieldrin and endosulfan. Decreases in the hexachlorocyclohexanes (HCHs) and toxaphene are undoubtedly a result of international controls on their use. Lindane is expected to continue to be transported northward for some years from residues in Canada, France and China.

Several new contaminants not previously studied under the NCP are now being found in the Canadian northern atmosphere but it is still too early to tell whether levels are increasing. These include the brominated flame retardants, chlorinated paraffins and chlorinated phenols. The flame retardants are widely used and may be of concern in the future as they easily enter the food web. More research is required in this area.

Organic contaminants in the WKSS area include pesticides and other persistent substances. The most common pesticides include DDT and its degradation products (DDD and DDE), dieldrin, heptachlor epoxide, chlordane, toxaphene (a mixture of PCCs), and HCH (Gregor, 1990; Gregor & Gummer, 1989). Other persistent substances include chlorobenzenes, PAHs, PCBs, PCDDs and PCDFs (EC., 1991).

DDT is now used primarily for malarial control (outside North America). Chlordane is used in termite control and as a broad spectrum insecticide. HCB is used as a fungicide to treat seeds and as an industrial chemical. Toxaphene has been used as an insecticide on cotton, cereal grains and some fruits and vegetables (Tesar, 2000). Total HCH includes g-HCH (Lindane) and is still used as a pesticide in North America and Europe, and HCH isomers (especially a-HCH) are prominent in seawater (Muir & Norstrom, 2000). PCBs are still widely used as heat exchange

fluids in heavy electrical equipment (including in North America) and there are residuals from earlier usage as additives in print, paint and plastics. PCBs continue to be released into the environment as a result of poor waste management, recycling and reclaiming practices (Muir & Norstrom, 2000; Tesar, 2000).

Some of the lowest loadings of persistent organic contaminants in North America occur in the western Canadian Arctic (Swyripa *et al.*, 1994). Concentrations of persistent organic contaminants are low throughout most of the WKSS area but their spatial distributions and temporal trends are not well defined. Based on sediment data from Great Slave Lake and Lake Ontario, northern contaminant levels are about two hundred times less than in the Great Lakes region of southern Canada (Mudroch *et al.*, 1992).

There are many sites where small quantities of waste materials may contain contaminants (particularly along the shores of the Coronation Gulf), and there are few larger point sources of persistent contaminants such as municipal and industrial wastes, military wastes from DEW-line sites (on Victoria Island), and disposal in the Coronation Gulf (NPCTT., 1996; NPC., 1997). Releases and loadings from tributary sources are thought to be small. For most contaminants found in biota from this region, there are no major sources within several thousands of kilometres (EC., 1991). A large part of the contaminant burden in fish and wildlife found in the WKSS area has been, and continues to be, contributed by the long range transport of atmospheric pollutants (LRTAP). These pollutants disperse into aquatic and terrestrial ecosystems by various transfer mechanisms.

Most persistent organic contaminants carried in the air are transferred to the Earth's surface attached to dust particles, and attached or dissolved in rain, snow and ice particles (and as cold condensates). Direct transfer by absorption also occurs (Jensen *et al.*, 1997; Macdonald *et al.*, 2000; Muir *et al.*, 1999b). Some portion of these contaminants is retained in the terrestrial environment and enters the terrestrial food chain, but relatively high concentrations of contaminants are associated with melt and runoff (Freitas *et al.*, 1997). These are carried into rivers and lakes where a further portion enters the aquatic food web, but only a small amount becomes associated with bottom sediments (Paterson *et al.*, 1998). Although many physical processes in lakes affect contaminant transfer and availability, studies on northern lakes indicate that lake size has little effect on concentrations of SPCBs in water or fish (Paterson *et al.*, 1998). For the most part, Arctic and sub-Arctic lakes act as a conduit rather than a sink for persistent organic contaminants (Freitas *et al.*, 1997).

Airborne contaminants may reach the sea surface directly or by runoff and erosion from the land. Numerous transfers continue to move persistent organic pollutants through different parts of the Arctic and sub-Arctic ecosystem (Freitas *et al.*, 1997; Jensen *et al.*, 1997). In this multistep process, seasonal revolatilization is indicated by elevated levels of organic contaminants in

summer air (Barrie *et al.*, 1997). Burial of contaminants in Arctic ocean sediment is limited by the very low concentration of suspended particulate material. Many chemicals remain in suspension (in dissolved phase). Because of the effectiveness of global atmospheric and oceanic circulatory systems there is no absolute resting place for persistent contaminants. Rather, they become ever more dispersed. However, in practical terms and apart from volatilization, there are few mechanisms available to remove contaminants once they do become buried in deep lakes or Arctic ocean sediments. Concentrations of HCH in Canadian Arctic waters seems to be related to the combined effects of outgasing of HCH isomers (particularly  $\alpha$ -HCH) and the extent of polar ice cover (Muir & Norstrom, 2000).

Most persistent organic contaminants that continue to transfer between different living and non-living components of the environment slowly degrade, as a result of physiochemical and biochemical processes (usually to less toxic forms). These changes may require considerable time. In the WKSS area, many of these organic contaminants are also likely to be persistent for 50 years or more (Tesar, 2000).

Persistent organic contaminants have a wide range of physicochemical characteristics. These greatly affect how contaminants are transported in the environment, and the effects of various transfer mechanisms on them (Jensen *et al.*, 1997; Macdonald *et al.*, 2000; Muir *et al.*, 1996, 1999b). For example, in a warm atmosphere (at 20° C), naphthene, HCB and HCH are mostly present in gaseous form whereas DDT and benzo *a* pyrene remain in particulate form (left-hand panel). At much lower temperatures (and relative to  $\gamma$ -HCH), several contaminants including  $\alpha$ -HCH, pyrene, toxaphene, dieldrin and endosulphan partition more strongly than others to the liquid phase (centre panel). Physicochemical properties also influence how effectively contaminants can be scavenged from the atmosphere by precipitation of rain and snow (right-hand panel). Snow scavenging is thought to be one of the most important mechanisms for transferring organic contaminants to the Arctic terrestrial ecosystem (Hoff *et al.*, 1999). Snow is generally a much more effective scavenger than rain (Gregor, 1990; Gregor *et al.*, 1996) and the transfer of DDT,  $\gamma$ -chlordane, dieldrin and toxaphene by this means, can be many tens to hundreds of times greater than for  $\gamma$ -HCH. Snow sampling provides a good indication of potential contaminant loading to the Arctic but few contaminants exhibit a simple pattern of seasonal deposition (Strachan *et al.*, 1997).

Air mass and wind direction records indicate that the WKSS area lies under the influence of Arctic air for most of the year. But there are significant incursions of Pacific air over the northern half of the area, particularly during summer. In addition, incursions of warm continental air may also cover the southern part of the area during summer. Further, distributions of persistent organic contaminants within parts of the Mackenzie River system may not reflect conditions that otherwise appear to influence the rest of the WKSS area. This is because much of the headwater drainage of the Mackenzie River system lies in the Rocky Mountains. These mountains lie under

an air mass trajectory regime very different from that which directly affects the WKSS area. The Athabasca River, for example, rises from the Columbia icefield where Pacific and Asian air masses have an annual frequency of about 68% and North American continental air about 32% (Donald *et al.*, 1999). However, during the May-July period (when precipitation is highest and atmospheric pesticide concentrations are greatest), the North American air mass (which may draw from as far south as Mexico) is dominant for 54% of the time (Donald *et al.*, 1999).

Weather event back-casting and models of atmospheric circulation (Pudykiewicz & Dastoor, 1996), and identity of dry-fall and “finger-printing” of contaminants, strongly imply atmospheric transport from distant sources in North America, Europe and Asia. Because of atmospheric processes, some contaminant loadings tend to be event-related, particularly with snowfall. Some loading are also specifically related to the occurrence of Arctic haze (Anon., 1990; Pfirman *et al.*, 1994; Wadleigh, 1996). This haze is concentrated in the lowest 5 km of the atmosphere and reaches maximum development during February and March (Muir *et al.*, 1992) but it was not reported prior to the 1950's (Lockhart *et al.*, 1992). Brown snow in the Keewatin district, for example, is thought to comprise loess from western China and soot from coal combustion in China and Russia (Gregor & Gummer, 1989; Welch, *et al.*, 1991). Atmospheric transport of SDDT and PCBs may include sources as far away as Mexico and Central America. Loadings of PCBs are greatest from dry fall (Barrie *et al.*, 1992). Long range atmospheric transport is also a source of PCDDs and PCDFs.

The composition of PAHs in snow is typical of emissions from combustion in mid-latitudes of the northern hemisphere. Increasing concentrations of PAHs in the upper layers of soil, snow and lake sediment from northern Canada follow global trends (Gregor *et al.*, 1994). In rivers, it is very noticeable that concentrations of PAHs are closely associated with the availability of particulate organic matter. Where the quantity of this material is small, concentrations of PAH tend to be highest (Jefferies *et al.*, 1994). For example, concentrations of suspended organic matter in the Burnside, Thelon, Ellice and Coppermine rivers were 0.93, 1.3, 8.4 and 26.4 mg·L<sup>-1</sup>, respectively; and concentrations of PAHs in this material were about 750, 350, 100, and 50 ng·g<sup>-1</sup> dry weight in these same rivers (August 1993 data (Jefferies *et al.*, 1994)). In the Mackenzie River, seasonal concentrations of PAHs also increase in association with suspended sediments between May and September (Jeffries *et al.*, 1997).

Sediment samples from Great Slave Lake suggest that there are multiple sources of PAHs to this lake and that loadings have increased significantly since the 1960's (Evans *et al.*, 1996). Sources include long range atmospheric transport, local inputs (*e. g.* Hay River) and inputs from the Peace-Athabasca drainage basin (Mudroch *et al.*, 1992). In the Slave River, PAHs are associated with both natural oil seeps and manmade sources (tar sands and other industrial activities). Of 16 PAHs generally present in industrial wastewaters and known or suspected to be carcinogenic most were present in the Slave River at at very low concentrations at or near detection limit



(McCarthy *et al.*, 1997a). Pyrene, benzo *a* pyrene, fluorene, fluoranthene and benzo *ghi* perylene were associated with suspended sediments and did exceed LEL but not SEL (Ontario). Based on *Daphnia magna* (zooplankton) and *Hyaella azteca* (amphipod) tests, PAHs in the Slave River are not thought to adversely affect biota (McCarthy *et al.*, 1997a). A wide range of persistent organic contaminants are present in the lower Slave River (including chlorinated phenolics, dioxins and furans that are likely from distant upstream pulp and paper mills) but with very low concentrations, at or near analytical detection limits (Evans *et al.*, 1996; McCarthy *et al.*, 1997a). PAHs are the dominant form of contaminant in Great Slave Lake and probably over much of the WKSS area, and the greatest concentrations of chlorinated organic compounds are present as PCBs (Evans & Headley, 1993; Evans *et al.*, 1996).

Ocean water quality between Victoria Island and the mainland may be influenced by low concentrations of contaminants from the Mackenzie River system. River loadings from northern Russia are another potential source of contaminants (Jensen *et al.*, 1997). This is because of eastward circulation in the stable polar mixed layer of the Arctic Ocean, that has low density and residence times of up to 20 years (Barrie *et al.*, 1992). In Arctic marine waters, particulate concentrations are very low and contaminant scavenging and settlement to the sea floor is minimal. Both seasonal volatilization that causes contaminants to pass from the sea to the atmosphere and ice-rejection (cryoconcentration) may act as “contaminant pumps”. Together, these processes contribute to a systematic build up of contaminants in the Arctic environment. Concentrations of HCH are associated with latitude. Elevated concentrations have been found in many northern freshwaters (Bidleman *et al.*, 1994a; 1994b; Freitas *et al.*, 1997; Mackay *et al.*, 1994).

Contaminant loadings and their levels in non-living components of the environment are only “part of the picture”. The other part relates to what happens to them in Arctic and sub-Arctic food chains that are characterized by slow-growing and long-lived species and by a human population that exists as the top predator, and is still dependent on local fish and wildlife for a significant part of its food requirement.

Animals, throughout the food web, have excretory processes that can remove many types of contaminants. However, persistent organic contaminants occur at increasing concentrations at higher levels in the food web as a result of bioaccumulation (EC., 1991; Hargrave *et al.*, 1996). Most tend to accumulate to higher concentrations in fat and some body organs (particularly the liver). Persistent organic contaminants in muscle tissue are generally at lower concentrations. Persistent organic contaminants that concentrate strongly in fatty tissues, such as SDDT and SPCBs, show the highest degree of bioaccumulation in food chains (Kidd *et al.*, 1998).

Trophic levels in the upper panel, have been derived from observation. Although information is not sufficient to allow direct comparison among trends in freshwater and terrestrial ecosystems,

general similarities exist (EC, 1991; Jensen *et al.*, 1997; Wong, 1985). Equivalent PCB concentrations in phytoplankton at the base of aquatic food webs are generally less than 1 ng·g<sup>-1</sup>, as are those in terrestrial lichens (WKSS area). Caribou graze on vegetation, much as zooplankton graze on phytoplankton, and tend to have PCB concentrations similar to those at the second trophic level. Wolves (which prey on caribou) and Lake Trout (which feed on amphipods and may also feed on other fish) have PCB concentrations which place them at or slightly above the third trophic level.

In the lower panel,  $\delta^{15}\text{N}$  represents parts per thousand difference from atmospheric standard, and tissue  $^{15}\text{N}/^{14}\text{N}$  is an effective means of characterizing trophic levels, that increase at each trophic transfer (Atwell *et al.*, 1998). Values of  $\delta^{15}\text{N}$  are more effective as a means of characterizing the trophic level of a group than an individual (Atwell *et al.*, 1998). Concentrations increase with each trophic level in the food web. Variations about the trend line are most likely related to differences in the lengths of individual food chains (including differences in diet) which can be both site and species specific (Anon., 1994; Evans *et al.*, 1996; Kidd *et al.*, 1998). It may be possible for concentrations of suspended sediment to influence the availability of some organic contaminants (including PAHs). For example, toxaphene is higher in fish from the East Arm of Great Slave Lake, where the concentrations of suspended sediment are lowest. The East Arm is also likely to be least influenced by input from the Slave River, although it is thought to be one of the larger sources of contaminant input to the lake (Evans *et al.*, 1999).

Some migratory birds (*e.g.* Oldsquaw, Pintail, Semipalmated Plover and Water Pipit) carry elevated body burdens of contaminants (*e.g.* SDDT and PCBs) from their wintering grounds. A similar relationship has been reported in Herring and Mew gulls, and Caspian and Black terns from Great Slave Lake (Weyland, *et al.*, 2000). However, concentrations of persistent organic contaminants in the eggs of Willow Ptarmigan from coastal areas of the western Arctic were mostly below analytical detection limits (Wakelyn *et al.*, 1999). Data show that contaminant levels in browsing and grazing birds are minimal. Levels increase dramatically in most water birds and the highest contaminant levels occur in fish-eaters that are also at a higher trophic level. When birds fall prey to other species, their contaminant concentrations are added to those of existing regional sources. This additive effect is particularly noticeable in top raptor species (*e.g.* Peregrine Falcons, an endangered species (EC., 1991; Shank & Poole, 1994)) that migrate and carry elevated body burdens from their wintering grounds (Johnstone *et al.*, 1994; 1996).

In general, contaminant levels in avian omnivores are greater than terrestrial omnivores. In some Mink, however, concentrations of PCBs, dioxins and furans may be relatively high. The reasons for this are not entirely clear (Deh Cho First Nations, 1999). The diet of Mink includes fish and small mammals (*e. g.* Snowshoe Hares and Northern Red-backed Voles) that are mostly at a lower trophic level than the fish (Poole *et al.*, 1997; 1998). A wide range of persistent organic contaminants were detected in wild Mink from the lower Slave River, the East Arm and outlet of

Great Slave Lake, and the lower Liard and lower Mackenzie rivers. In Mink liver samples, the highest group means were 9.5 ng SDDT·g<sup>-1</sup> and 73.1 ng SPCB·g<sup>-1</sup>. Concentrations of SDDT, SPCB, SChlordane and Dieldrin declined on northerly and westerly gradients. Mink are known to be very sensitive to contaminants. Generally, the contaminant levels were one to two orders of magnitude lower than observed to cause reproductive impairment, reduced kit survival or lethality in adults (Poole *et al.*, 1997; 1998). In Beaver and Muskrat that have a largely vegetarian diet, concentrations of most contaminants (both organic contaminants and heavy metals) are very low (Kennedy *et al.*, 1999).

With the exception of toxaphene, most western Arctic marine and freshwater fishes contain levels of organochlorine contaminants that are lower, often by more than ten times, than levels in marine and freshwater fishes from southern Canada (EC., 1991; Norstrom & Muir, 1988). Elevated concentrations of HCH and toxaphene have been reported in Pacific Herring and Arctic Cod. In much of the Arctic, levels of toxaphene are higher than PCBs in fish (EC., 1991; Norstrom & Muir, 1988). The effects of toxaphene (and many other persistent organic contaminants) on fish and wildlife are not well understood. Toxaphene concentrates in fatty tissues and is not released back into the body unless an animal is nutritionally stressed and fat reserves are remobilized as an energy source. Experimental studies in fish suggest that this process could lead to lethal effects under starvation and changes in fertility and egg viability (Delorme *et al.*, 1999).

Chlordane and PCBs account for about 80% of the organochlorine present in the fatty tissue of marine mammals (Norstrom *et al.*, 1988). Concentrations of PCBs in Beluga Whales are nearly ten times greater than in Ringed Seals, and Beluga Whales from the western Arctic tend to have higher levels than those from the eastern Arctic. However, concentrations are still two to three times less than those of Beluga Whales from the Gulf of St. Lawrence (Muir *et al.*, 1990). Concentrations of about 5,000 ng·g<sup>-1</sup> for PCBs, 3,500 ng·g<sup>-1</sup> DDT and 6,000 ng·g<sup>-1</sup> have been reported in Beluga Whale blubber in the western Canadian Arctic (Muir *et al.*, 1996; 1999a; 1999b).

There are geographic and temporal differences in the trends of concentrations of persistent organic contaminants in the Arctic. Concentrations of both chlordane and PCBs increased by about 50% in Beaufort Sea Beluga Whales between 1983 and 1994. Concentrations of SDDT were similar in 1972 and 1994 (but declined from 1972 to 1983, and then increased). Concentrations of toxaphene decreased by about 25% between 1983 and 1984 (Muir *et al.*, 1999a; 1999b). These variations probably reflect the combination of direct loadings of contaminants to the Beaufort Sea area and indirect loadings from more distant sources in the Mackenzie River drainage.

Concentrations of SHCH are highest in Polar Bears and seals in the Canadian Arctic, and are

coincident with levels in ocean water (Muir & Norstrom, 2000). There has been no change in SHCH concentrations in seals from the mid 1980's to mid 1990's. In Polar Bears from the Amundsen Gulf -Beaufort Sea, west Viscount Melville Sound, and Queen Maud Gulf-Larsen Strait areas, recent concentrations of SPCB ranged between about 4,600 and 8,600 ng·g<sup>-1</sup>, Schlordane between about 1,500 and 2,100 ng·g<sup>-1</sup>, DDE between 52 and 112 ng·g<sup>-1</sup> and dieldrin between 85 and 147 ng·g<sup>-1</sup> (Muir *et al.*, 1999a; 1999b). Concentrations of SPCBs are lower in seals from the Canadian Arctic than in the Greenland, Scandinavian and Russian Arctic, and this may reflect differences in diet (Muir *et al.*, 2000). Small pelagic fish (*e. g.* Arctic Cod) form much of the diet of seals in the Canadian Arctic but piscivorous fish, at a higher trophic level (*e. g.* *Gadus* spp.), likely comprise more of the diet of seals elsewhere in the Arctic (Muir *et al.*, 2000). Concentrations of SPCBs increased in Polar Bears from the Eastern Canadian Arctic between the 1970's and 1980's but are now in decline (Muir & Norstrom, 2000).

Because Ringed Seals are near the top of the marine food web and accumulate contaminants over several years, they can be useful indicators of ecosystem health. Concentrations of many contaminants are lower in female than male seals because lactation has the effect of lowering contaminant residues (Stern *et al.*, 1999). Long term records of DDT and PCBs in Canadian Arctic wildlife (including Ringed Seals) began in the late 1960's (EC., 1991), and periodic sampling of biota indicates that levels of SPCB have generally declined by half since the early 1970's. Concentrations of SPCBs in seals from Holman declined by more than two-thirds between 1972 and 1991. Most declines occurred before 1981. Since then, a further but slight reduction has occurred in the less chlorinated congeners (Stern *et al.*, 1999). The decline in concentrations of SDDT has been more continuous (Muir *et al.*, 1999a; 1999b). Across the Canadian Arctic, concentrations of SDDT in seals are generally less now than two decades ago. Concentrations of many other persistent organic contaminants are slowly falling and levels of a-HCH have declined since the 1980's (possibly related to the phase out of technical-HCH in India (Bidleman *et al.*, 1996). Extremely low concentrations of PCDDs and PCDFs have been reported from fish and wildlife in the western Arctic (Anon., 1994; Herbert *et al.*, 1996 ). Concentrations of PCBs and some other persistent organic contaminants may, however, continue to increase in lake sediments, at least for a few more years. Concentrations of similar contaminants in lakes from more southerly regions of Canada have begun to decline as the contaminants are released through the process of volatilization (Gregor *et al.*, 1994). Because of the colder climate, this process is slower in northern regions. Thus, there is a lag between declines noted in more temperate areas and those expected to occur in the WKSS area.

Other factors also influence the residual period of contaminants in both terrestrial and freshwater environments (Donald *et al.*, 1999). Persistent organic contaminants are retained in deposits of glacial snow and ice that form headwaters tributary to the Mackenzie River system, at high elevations in the Rocky Mountains, where transfer from the atmosphere may have been "enriched" by cold condensation (Donald *et al.*, 1999). In mid latitudes and near sites of use,

many pesticides peaked in the 1960's and almost all have declined since the 1970's. In headwater glaciers, SDDT, dieldrin, SChlordane all reached maximum concentrations and flux values during the 1980's, a decade after they were banned in North America. Both Lindane and SChlordane had peaks in 1960 and 1980, and the flux of HCB reached a maximum in the 1990's. The concentrations of this contaminant may still be rising (Donald *et al.*, 1999). Continued use outside North America could delay declines in contaminant concentrations of glacial ice in headwater areas. Regional climatic changes, perhaps external to the WKSS area, will also regulate storage (in glacial ice) and release (as glacial melt water). Pulses of contaminant release into the downstream environment will particularly affect the aquatic ecosystem and could persist for many decades yet to come (Donald *et al.*, 1999).

Outside North America, major production of HCH ceased in China in 1985, in the USSR in 1992, and it has remained in “low-level” use in India (for public health protection). During the past decade, levels of a-HCH have declined rapidly in the atmosphere, particularly as a result of degradation under tropical and temperate climatic conditions. As a result of this loss, a-HCH, at higher latitudes, now represents more of the total global inventory. Contributions from atmospheric transport to higher latitude is thought to be of less importance (Wania, *et al.*, 1999a). However, the net direction of air-sea flux in Arctic waters has reversed. Ocean waters and lakes are now a diffuse source of HCH resulting in further redistribution at low concentrations. This process is controlled by temperature and the relative concentrations of HCH in air and water, in response to Henry's Law constant (Li *et al.*, 1999). The effects of climate can also be seen to have a selective effect on PCBs. As with HCH, only a small amount of the global PCB inventory is thought to be transported to high latitudes but, during this movement, there is a shift towards lighter and more volatile congeners (Wania *et al.*, 1999b).

Based on present knowledge and risk assessments that address a wide range of toxic responses, concentrations of most contaminants are thought to be at levels well below thresholds which affect the health of fish and wildlife. Uncertainties remain with respect to the effects of some classes of contaminants, including those known as endocrine disruptors. These contaminants are thought to have potential for causing a wide range of defects, particularly during the early stages of embryo development. Concentrations of SDDT and SPCBs in some bird eggs may be high enough to lower reproductive survival, particularly as a result of eggshell thinning (*e. g.* Peregrine Falcons (Johnstone *et al.*, 1994; 1996)). The concentration of SPCBs in some Polar Bears may be high enough to interfere with vitamin A and thyroid hormone transport (Norstrom *et al.*, 1999). The effects of toxaphene, at high concentrations, remains uncertain (Delorme *et al.*, 1999). In many top Arctic predators including humans, b-HCH is a major contaminant and both a- and b-HCH are significant endocrine disruptors.

For the foreseeable future, concentrations of most persistent organic contaminants are not expected to increase much above present values. This depends to a large extent on their control

and regulation in many developing countries including Mexico and other countries in South America.

#### 4.2.3.2. LRTAP- Mercury and Effects

Mercury occurs in rocks and soils. Both inorganic and organic forms are naturally present, and very small quantities of metallic Hg can occur in both liquid and gaseous phase under most environmental conditions. It is highly mobile in the environment, and is rapidly dispersed in both gaseous and vapour forms. Mercury usually enters the food web in minute quantities. Bioconcentration of Hg is selective and related to food web structures. Microbial processes act to methylate and demethylate Hg. Monomethyl mercury is the most toxic form of the metal. Photochemical processes affect Hg in the troposphere. At high latitudes, Hg concentrations seem to follow trends that are similar to those of ozone. With the onset of polar sunrise and advancement of polar spring, photo-oxidation is thought to convert Hg from gaseous to particulate form. Particulate Hg has a shorter residence time in the atmosphere and concentrations of Hg decline in the air during the April to June period (Schroeder *et al.*, 1997; 1999a; 1999b). High levels of Hg have been reported in snow on the frozen Beaufort Sea, between mid February and early May (Welch *et al.*, 1999a; 1999b). Concentrations of Hg in snow melt also increase with latitude. They are high in the western Arctic between April and June.

Mercury and several other trace metals are naturally present in fossil fuels. Combustion provides an important mechanism for their release, as contaminants, into the environment. In North America, combustion from fossil fuels contributes more than one-third of Hg emissions to the environment (Natan *et al.*, 2000). Even with improved fuel technology, increasing energy demand is unlikely to result in significantly reduced global Hg emissions from this source. On the other hand, regulations and controls are reducing the emissions of Hg from other sources, particularly waste incineration. Most of the electrical power generated in the mid-west United States and in Alberta, is derived from combustion of fossil fuels, particularly coal (Keating *et al.*, 2000). It is likely that emissions from these power plants can be carried directly into the WKSS area during the summer. These emissions also add to the global inventory of atmospheric pollutants. On a percentage basis, global Hg loadings comprise Asia 46%, Western Europe 16%, North America 15%, Eastern Europe and former USSR 13%, and Africa 5% and central and South America nearly 3% (Pirrone *et al.*, 1996). Significant quantities of Hg are also released into the environment as a result of microbial processes and the degradation of organic matter in flooded soils. Newly formed reservoirs and diversions can be a major source of methyl mercury (MeHg) to the aquatic environment and the atmosphere, as in many parts of the Hudson Bay drainage basin (Anon., 1987; Brouard *et al.*, 1990; Jackson, 1987; 1989). Mercury is widespread as a global contaminant.

Global loadings of Hg have generally increased over the past two centuries and during the early

1990's, concentrations in the atmosphere of the northern hemisphere were increasing by about 1.5% annually (Slemr & Langer, 1992). These observations are supported by dated soil, peat, and lake sediment core profiles. The profiles indicate there has been a doubling in such concentrations since the start of the 19th Century (Slemr & Langer, 1992; Lockhart *et al.*, 1994). Lockhart *et al.* (1999b) analyzed metal profiles in sediment cores from several northern lakes and determined that Hg (and possibly Pb) increased in relation to the effects of long range transport. Lead, however, often reflects regional rather than global patterns of loading, as seen in Scandinavian data (Renberg *et al.*, 2000). Lockhart *et al.* (1999b) estimated that the flux of Hg increased by about x 0.3 at Lake Belot, x1.5 at Great Bear Lake and by x 3.9 at Ste Therese Lake, since the 1950's. Lockhart *et al.* (2000) confirmed the reliability of the sediment core data. Concentrations of other metals have also increased as a result of human activities in the environment but Hg is most widespread and of greatest concern (Jackson, 1987).

Historically, Hg emissions and deposition in North America are thought to have been greatest when it was widely used for metal extraction in the early mining industry. Pirrone *et al.* (1998) estimated that anthropogenic emissions peaked at about 1,708 t<sup>-1</sup>a<sup>-1</sup> in 1879, that following a decline they peaked again at about 940 t<sup>-1</sup>a<sup>-1</sup> (1920), and that between 1970 and 1989 emissions have been about 325 to 330 t<sup>-1</sup>a<sup>-1</sup>. More recent estimates (quoted by Schroeder, 1999a) suggest that most North American emissions might be less than this and that total Global emissions are higher. Due of the mobility of Hg in the environment, lower North American emissions may not, of themselves, significantly benefit the northern environment. Also, because of its high volatility, Hg is easily remobilized from temporary sinks in the environment and re-emissions from old mine sites, waste dumps and other sources are likely to add to current and future emissions for some time Pirrone *et al.* (1998). Total anthropogenic emissions of Hg from developed countries have remained more or less stable over the past decade but emissions from other parts of the world have increased by 2.7 to 4.5% annually. On a global basis, anthropogenic emissions are thought to have peaked in 1989 and may be declining, again, by about 1% per annum (Pirrone *et al.*, 1998). Although emissions from some types of sources may decline, emissions from others may increase. It seems probable that global Hg emissions will tend to rise, at least to some extent, over the next several decades. It is unclear, however, whether they will closely follow the projected rise of carbon dioxide from combustion of fossil fuels. If so, that could amount to a near-doubling of the Hg loading from global emissions over the next 50 years.

In general, slow growing animals that are high in the food web, accumulate most Hg. However, there are many exceptions to this and they are mostly related to food selection. Age may or may not be a factor related to body burdens of Hg. Polar Bears, for example, are higher in the food chain than the seals that they feed on but they may have lower body burdens of SHg (Atwell *et al.*, 1998). This is thought to be because the bears select for skin and blubber, rather than seal meat. Muscle and organ tissues generally have a higher Hg content than skin and blubber. Selective feeding, however, may also result in increased concentrations of persistent organic

contaminants in the Polar Bears, relative to seals.

Measurements indicate that there is an increase of 3 to 5% in  $\delta^{15}\text{N}$  at each trophic step in the food chain, and many Arctic sea birds at a similar trophic level and with similar  $\delta^{15}\text{N}$  values have different concentrations of Hg (Atwell *et al.*, 1998). These differences, likely, reflect availability of Hg in their wintering grounds. For example, King Eider and Common Eider from Holman have less Hg but more Se in their livers than eiders from the central and eastern Canadian Arctic, and levels of Cd are also lower (Wayland *et al.*, 1999). Since much of the body burden of Hg in birds is also keratin-bound, contaminant levels can be significantly reduced during the process of moulting (Atwell *et al.*, 1998). In the WKSS area, as in other areas of the Canadian Arctic, long range atmospheric transport contributes small but significant quantities of Hg and other metals such as Zn, Cd and Pb to both aquatic and terrestrial ecosystems (EC., 1991; Jackson, 1987).

Mercury levels can be high in top-predator fish under natural conditions (*e. g.* Lake Trout). No consistent relationship exists between concentrations of Hg in fish and concentrations of Hg in ambient waters or bottom sediments (Johnson, 1987; Lockhart *et al.*, 1999a). In some freshwater systems, where concentrations of Hg in fish are relatively high, there may be a weak relationship between geology or lake characteristics such as water colour (a surrogate for DOC), and Hg in biota. Selenium in the environment may have some influence concentrations of Hg in fish (*e. g.* in fish from the Mackenzie River (Lockhart *et al.*, 1999a; 1999b)). But, Se in fish seems to have little effect on the concentration of Hg in fish.

There is a close relationship between concentrations of Hg in fish tissue and its rate of loading to the environment (Andersson *et al.*, 1991; Anon., 1991; Muir *et al.*, 1986; Slemr & Langer, 1992; Wagemann *et al.*, 1990). This is most evident in top-predator fish (*e. g.* Lake Trout). For example, in the Hudson Bay region, many fish important to the diet of Cree and Inuit (*e. g.* Lake Trout, Walleye, and Northern Pike) had high concentrations of Hg before the impact of hydroelectric development (Perusse, 1990). Mercury concentrations were close to Health and Welfare Canada guidelines for sport fish consumption ( $0.5\text{mg}\cdot\text{g}^{-1}$ ) and exceeded those for unlimited consumption ( $0.2\text{mg}\cdot\text{g}^{-1}$ ). Reservoir flooding caused levels of MeHg to increase and, as a result, more fish had Hg levels in excess of the consumption guidelines. However, because of differences in the structure of the food web, concentrations in Lake Whitefish remained, generally, within the guidelines.

A somewhat similar situation may exist in the WKSS area but supporting data are limited. Concentrations of Hg in Northern Pike from both the Hay River and Slave River have been reported to be about  $0.3\text{mg}\cdot\text{g}^{-1}$ , and concentrations in both Northern Pike and Walleye from Resolution Bay exceed  $0.2\text{mg}\cdot\text{g}^{-1}$ . In this area, to the west of the Slave Delta, the “finger print” of both metal and organic contaminants also appears to be distinct from other parts of the lake (Boucher *et al.*, 1997). Concentrations of Hg in Lake Trout were about  $0.3\text{mg}\cdot\text{g}^{-1}$  from Colville



Lake and  $0.1 \text{ mg}\cdot\text{g}^{-1}$  from lake Belot. However, concentrations of mercury in Lake Whitefish from Colville Lake were much lower, about  $0.02 \text{ mg}\cdot\text{g}^{-1}$ . These data indicate that existing levels of Hg in some country foods are already close to critical levels for unlimited consumption (Muir *et al.*, 1994). Concentrations of Hg from the breast muscle of birds indicate that although browsing and grazing birds have only low levels of contamination (generally less than  $150 \text{ ng}\cdot\text{g}^{-1}$  or  $0.15 \text{ mg}\cdot\text{g}^{-1}$ ), other types of feeders and especially fish-eating ducks may have much higher levels of Hg contamination (some reaching  $1.9 \text{ mg}\cdot\text{g}^{-1}$ ).

Concentrations of Hg in muscle tissue from Beluga Whales from the western Canadian Arctic (about  $1.5 \text{ mg}\cdot\text{g}^{-1}$ ) are a little higher than those from the eastern Canadian Arctic, and seem to reflect natural conditions (Jensen *et al.*, 1997). Organic Hg in muscle tissue of both Beluga and seals is mostly in the form of MeHg and this represents about half of the SHg in an individual. The toxic effect is therefore less than if all Hg was present as MeHg (Wagemann *et al.*, 1999a; 1999b). Concentrations of Hg in surface marine waters tend to be lower in the eastern than the western Canadian Arctic, and may reflect both the influence of regional geology on runoff and differences in atmospheric loadings. At a lower level in the food web, the mean concentration of Hg in Ringed Seals is about  $0.4 \text{ ug}\cdot\text{g}^{-1}$  in both the eastern and western Canadian Arctic (Wagemann *et al.*, 1996).

Changes over time strongly imply an increase in global emission, and between 1984 and 1993 to 1994 concentrations of Hg in livers from Beluga Whales increased by about 2-fold (Wagemann *et al.*, 1996). Elevated levels of mercury in marine mammals are often associated with naturally elevated levels of Se (Kari & Kauranen, 1978; Wagemann *et al.*, 1990). In these animals, Se seems to act as a protective mechanism and to reduce potential toxicity to the animals (Anon., 1983; Lockhart *et al.*, 1999a; 1999c; Pelletier 1985; 1986; Speyer, 1980; Srikumar & Akessen, 1992; Turner & Swick, 1983; Wren *et al.*, 1986). It is thought that demethylation of mercury occurs in the liver. Mercury and Se combine in 1:1 ratio to form insoluble amorphous particles of mercuric selenide and these accumulate as individuals age (Wagemann *et al.*, 1999). Mercury present in the brain and spinal chord of Beluga appears to be only in the inert form of mercuric selenide, and not in the toxic form of MeHg (Lockhart *et al.*, 1999d). However, the extent to which Se may also protect human consumers, such as Aboriginal hunters, is poorly understood (EC., 1991; Valentine *et al.*, 1992).

Mercury is potentially less of a contaminant problem in the terrestrial environment, where food chains are often shorter than in the aquatic environment (*e. g.* lichens - caribou - wolf). Concentrations of Hg in the livers of Barren-ground Caribou from Inuvik, the Beverly herd, and Cambridge Bay were about 0.5, 0.4 and  $0.2 \text{ mg}\cdot\text{g}^{-1}$ , respectively (Elkin *et al.*, 1996a; 1994), but concentrations in muscle tissue would be expected to be considerably less.

Although present concentrations of Hg in fish and wildlife from the WKSS area are generally

within consumption guidelines, concentrations will probably increase and Hg contamination is likely to remain a concern for the foreseeable future, particularly in some freshwater and marine species.

#### 4.2.3.3. LRTAP - Radionuclides and Effects

Radionuclide sources in the WKSS area include natural deposits, atmospheric fallout from nuclear weapon testing conducted from the 1940s through 1980, transportation accidents, and industrial process by-products (e.g., testing during the laying of pipe). However, the most common source of radionuclides in any Arctic environment is through accidents resulting in releases including those involving stockpiles of radioactive waste (AMAP 2002). While it is unclear how much radioactivity is distributed through the environment in the WKSS area, radioactivity levels measured in terrestrial animals and fish indicate that radioactivity is not a concern (SENES 2005). An investigation of radionuclide levels in fish near the former Port Radium radium/uranium/silver mine site on Great Bear Lake showed low levels in lake trout and lake whitefish muscle and liver samples and herring whole body samples (SENES 2004). An assessment of the whole body dose to these species using measured levels in the lake water and sediment in combination with fish tissue data demonstrated that the combined dose from internal and external exposures were well below acceptable levels.

Some mining activities have produced local "hot spots" and, locally, elevated levels of  $^{226}\text{Ra}$  have been associated with uranium mining and processing (Port Radium and Rayrock (Veska & Eaton, 1991)). Studies at Łutselk'e showed evidence of impacts from past uranium mining at nearby Stark Lake, and the presence of low concentrations of Rn in some buildings (Łutselk'e Environmental Committee *et al.*, 1999; Papik *et al.*, 1999). Follow-up studies indicated that the background gamma radiation at Łutselk'e averaged about  $0.8 \text{ m Sv a}^{-1}$ , about twice the global average but well within the range of normal conditions. Radiation hotspots (10 to 100 times greater than community background) were present at the old mine site and required remedial action (because local residents do not enter the mine area, this is considered more of an environmental than a health concern). Concentrations of gamma radionuclides ( $^{137}\text{Cs}$ ,  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{235}\text{U}$ ) were similar at the community water intake, Stark Lake, and Great Slave Lake and well below health concern (Papik *et al.*, 1999). Radiation levels were somewhat above health guidelines in the community hall, indicating a need for remedial action, and the source of this radiation is thought, most likely, to be natural. Concentrations of some metals (Al, Cu, Fe, Sr and U) in a stream near the Stark Lake mine were above environmental guidelines but this, also, may be a natural condition (Łutselk'e Environmental Committee *et al.*, 1999).

Where there is little evidence of local "radiation hot spots", dispersal by atmospheric transport may be considered the most important anthropogenic influence. Lichens are an effective trap for many atmospheric contaminants, including radionuclides, and provide a major source of these

materials at the base of the terrestrial food web. Concentrations of naturally occurring  $^{40}\text{K}$  (with a relatively long half-life) are similar in Barren-ground Caribou from Inuvik, Cambridge Bay and Pond Inlet (Baffin Island), and in Moose from southern Manitoba. However, concentrations of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$ , that have been derived from atmospheric tests of nuclear devices, increase from west to east across the Arctic. The presence of these isotopes in Canada is largely due to atmospheric transport (Elkin *et al.*, 1994; 1996b; Jensen *et al.*, 1997). During the 1950's and 1960's, Barren-ground Caribou had concentrations of  $^{137}\text{Cs}$  at levels 10 to 100 times greater than those in southern beef cattle. Since the moratorium on atmospheric tests in 1963, however, accumulations of radionuclides from long range atmospheric transport have greatly declined in the caribou (Smith *et al.*, 1996). Concentrations of  $^{137}\text{Cs}$  (half-life about 30 years) in Barren-ground Caribou from Inuvik ( $2.8 \text{ Bq}\cdot\text{kg}^{-1}$ ), Cambridge Bay ( $20.3 \text{ Bq}\cdot\text{kg}^{-1}$ ) and Pond Inlet ( $36.5 \text{ Bq}\cdot\text{kg}^{-1}$ ) are considered low and of no health concern (Elkin *et al.*, 1994; 1996b). The aquatic food chain also provides a significant pathway for human intake of  $^{137}\text{Cs}$  (Van Oostdam *et al.*, 1999) and values of up to up to  $20 \text{ Bq}\cdot\text{kg}^{-1}$  have been reported in Arctic fish. Small quantities of  $^{134}\text{Cs}$  (less than  $0.7 \text{ Bq}\cdot\text{kg}^{-1}$ ), with a half-life of about 2 years, may reflect the residual effect of the Chernobyl accident in 1986 (EC., 1991; Elkin *et al.*, 1996b).

#### *4.2.3.4. Climate Change, Atmospheric Pollutants and Environmental Indicators Noted by Aboriginal People*

Studies conducted in the past several years have begun to document TK in Dene and Nunavut communities. Parlee *et al.* (2000) have reported that elders have extensive knowledge of the Kache Kue, a traditional area of the Dene around the East Arm of Great Slave Lake. The area extends, approximately, from Gordon Lake to Lac de Gras, to Artillery Lake, and to the south of Łutselk'e. Elders have stated that there have been significant shifts in the distributions of some animal species, that some behavioural patterns (including seasonal migrations) have changed, that the populations of some species have changed significantly (not as a result of Dene hunting or trapping), and there have been changes in the quality or condition of some species. In particular, the numbers of White-fronted Geese have declined significantly (and are no longer hunted), and patterns of Barren-ground Caribou migration have changed and there may be fewer caribou using this part of their winter range.

The *Tuktu and Nogak Project* (Thorpe, 1997; 1998; Thorpe & Kadlun, 2000) included the Nunavut communities of Cambridge Bay, Umingmaktok, Bathurst Inlet and Kugluktuk. It has documented evidence of extensive recent environmental change. Snow and ice melt earlier and freeze later in this region, and melting occurs first within the communities. Freeze-up used to be complete by early September but now this may not occur until late October or even early November. Weather is not consistent and conditions are difficult to predict, and it has become more stormy and windy. Ice is thinner and the development of early leads in sea ice may affect caribou crossings. Caribou do not like to climb out of the water onto ice, which is dangerous and difficult for them. Currents make openings unpredictable in parts of Elu and Bathurst inlets.

More caribou are thought to be drowning but this may also reflect increased observations by hunters who now travel further with snowmobiles. Sporadic freeze-thaw conditions are increasing and this may affect the availability of vegetation for a variety of browsing and grazing animals. More water is present on the ground surface in spring and the number of Ground Squirrels seems to have declined, coincident with this. The number of plant varieties on Victoria Island has increased, and shrubs are growing larger all over the region, especially willows and alders. Caribou are showing a preference for richer vegetation. They are also seeking shade and some are moving to the coast to keep cool in summer, and to be in areas where insect populations are lower. Caribou are thought to eat mushrooms to maintain body moisture.

Traditional knowledge has also documented major climatic change at Holman, on the west coast of Victoria Island. There, it was normally safe to travel on sea ice by mid October, but now this travel is not safe until the end of October (Thorpe & Kadlun, 2000). There is less snow pack, and the condition of seal pups and Polar Bears has declined (pups have less time to bask and fatten-up on the sea ice and are less available to the bears).

Further north, elders at Sachs Harbour on Banks Island, have also reported that weather has become much less predictable. The autumn freeze-up may now be up to a month later than usual, and the spring thaw is earlier. The community depends heavily on seals for food, and the multi-year sea ice is smaller and drifts further from the community in summer, taking the seals with it. The winter sea ice is thinner and broken, and more dangerous to travel on. Fall storms have become more frequent and severe (and thunder and lightning have been observed for the first time). Permafrost has been melting during summer, causing large scale shoreline slumping, lake drainage, and damage to buildings. For the first time, Barn Swallows and (American) Robins have been seen on the island, salmon have been caught in nearshore waters, and large numbers of flies and mosquitoes have also appeared (IISD., 2000).

Many of these observations also complement reports of environmental change based on TK from the central and eastern Arctic (Arragutainaq *et al.*, 1995; McDonald *et al.*, 1995; 1997). For example, TK from across the Canadian Arctic is consistent with climate records that document warming in the western Canadian Arctic and cooling in the eastern Canadian Arctic. The boundary between these warming and cooling areas passes within Hudson Bay. Across the Arctic, there is greater variability in the weather, sudden changes are more frequent and difficult to predict, and there are indications of change that may relate to the influence of atmospheric pollutants and increases in received UV radiation.

### **4.3. Stress Effects on People**

Section 4.2 describes the environmental effects that may be associated with different forms of stress. It is clear that most environmental effects can impact on people in the WKSS area. For example, a late freeze up or early melt due to climate change, increases the hazards of over-ice

travel and interest in replacing seasonal roads with all-weather roads. Climate change as a factor contributing to major shifts in the population, migration and seasonal range of Barren-ground Caribou, can increase the distance that hunters must travel from communities and the likelihood of harvesting restrictions. Environmental effects can contribute to limits on fish consumption if the levels of some pollutants (e.g. mercury) rise further, and to higher living costs and food security issues.

Social, economic and cultural circumstances are also associated with different forms of stress that have effects for individuals, families and communities in the WKSS area. The population health approach adopted by the Public Health Agency of Canada (1999) provides an analytical framework for understanding the stress effects that can result from various determinants and, or the interaction of them. Health Canada lists nine main groups of determinants that effect human health and well-being. They are: income and social status, social supports and networks, employment and work conditions, physical environments, education, healthy child development, biology and genetic endowment, health services and personal health and coping skills. Inuit and First Nations groups have expanded these determinants to include culture, gender, local/community control and multi-generational trauma and powerlessness associated with residential schools and other colonial forces (ITK, 2006). These determinants can also impact social and economic security.

In the WKSS area, human populations may experience stress effects for example, from the increasing number of young people seeking employment and a place within mainstream society and within their particular cultural community but without the skills and supports needed to meaningfully participate in either sphere. The effects of these trends are evident in the escalating rates of high-risk social behaviours and youth crime. Consumerism is rising, but so too is the gap between expectations and the means of achievement, and between people who have resources and those who do not. The effects of these trends are demonstrated in rising rates of homelessness and marginalized people in large and small communities. The loss of TK and practices, and less appreciation of the contribution these traditions make to sustainable development combined with risky behaviours and problems meeting basic needs can contribute to the stresses of marginalization and alienation of segments of vulnerable segments of the population within the WKSS area.

Determining the extent to which people in the WKSS area are effected by stresses in their environment is as complex as identifying the stressors themselves. Stress effects are dynamic and variable. They are both perceptual and real, expected and unexpected. Depending on individual, family and community circumstances, some effects may occur only after multiple changes in the environment while others may result from a single event. Further, stress effects may be different at different times and affect people in different ways. Stress effects on people are discussed in

this section with respect to exposures to contaminants and infection, economic and social security, culture and traditions, and power and control.

#### **4.3.1. Human Exposures to Contaminants and Infection**

In the central and eastern Canadian Arctic, differences in contaminant concentrations in Cree and Inuit populations can reflect differences in diet (Sly, 1995). For example, elevated levels of Hg have been associated with consumption of freshwater fish, whereas elevated levels of persistent organic contaminants tend to be associated more with consumption of marine mammals. Some concentrations of organic contaminants (*e. g.* PCBs) are also known to be higher in communities of the eastern Arctic than in more southerly parts of Canada (Dewailly *et al.*, 1989). However, differences in contaminant concentrations are likely to be less significant in most people living in the WKSS area. This is because contaminant concentrations in many country foods tend to be lower and because diets of Dene, Métis and Inuit peoples are more similar.

It is thought that the nutritional value of many country foods is a more important factor than concern about contaminant effects (Kinloch *et al.*, 1992). But, while assessments of the relative benefits and risks of depending on country foods for a major portion of dietary requirements are ongoing (Dewailly *et al.*, 1996), it is prudent to be aware of potential implications for both positive and negative effects. Traditional foods provide a significant source of vitamins A, E and C, Fe and Zn, and are generally superior to store-purchased foods for the intake of proteins, vitamins E and C, Fe, Mg, K, P and Zn (Kuhnlein *et al.*, 2000). Store purchases include milk, eggs, chicken and hamburger meats but carbohydrates form a major part of most Kitikmeot diets. Relative to other northern communities in the Inuvialuit and Nunavut, Kitikmeot communities may make somewhat less use of traditional foods. The average intake of both traditional and store foods falls short of standard nutrient levels for vitamins A and E, Ca, folic acid, fibre and some nutrients (Kuhnlein *et al.*, 2000). Recent studies have not indicated how nutrient deficits might best be corrected but it is clear that further reductions in the use of traditional foods would likely increase them.

The principal pathway by which persistent organic contaminants enter human populations is through the food supply. Concentrations of persistent organic contaminants have been measured in human tissues (including samples from northern Canada) and, in general, contaminant levels are highest in tissues with a high lipid (fat) content. Fatty tissue is used by the body as a convertible energy store and for insulation. The presence of organochlorines in fatty tissue reflects accumulation in response to exposure over an extended period of time. Concentrations of organochlorines in blood samples are indicative of their equilibrium between fatty tissue and blood. Concentrations of MeHg in blood suggest response to more immediate exposure. Children may be more affected by these contaminants than adults. Recent health studies in Nunavik (Dewailly *et al.*, 2000) suggest that some Inuit children may be particularly susceptible to middle ear infection (*Otitis media*). This is thought to be a result of pre-natal exposure to DDE, HCB and dieldrin. Susceptibility may be reduced by breast-feeding during the first trimester. Any

potential problem would be further reduced in women of reproductive age by maintaining a diet of traditional food high in nutrients but low in organochlorine contaminants (Dewailly *et al.*, 2000).

Concentrations of contaminants in humans have the potential to reach high levels as a result of accumulation and biomagnification at lower levels in the food web. At very low concentrations, the effect of contaminants on human health become close to natural background conditions. A lack of effect can be expressed as a health guideline for unlimited or occasional consumption, or (more precisely) as an acceptable or tolerable daily and annual intake value. Contaminant levels in most sources of country food in the western Canadian Arctic and sub-Arctic are one hundred to a thousand times less than levels considered critical for human health.

Harvest times and availability vary across the WKSS area and some species, such as Moose, are not usually available to Inuit and, likewise, seals are not available to Dene and Métis. In Behchoko and Łutselk'e, the leading country foods provide 25 to 30% of dietary energy requirements in fall and winter. Comparable values for the Kitikmeot sub-region are from 11 to 29%. In the Kitikmeot sub-region, caribou, Arctic Char, Muskox and Lake Trout are the most important traditional foods in both summer and winter. These are consumed by at least half the population. In summer, considerably more traditional foods are available, and Eider Duck, Ringed Seal, Blueberries and geese also figure prominently in community diets. However, only caribou and Arctic Char represent more than 10% of food use.

Traditional foods are generally considered to be an important source of nutrients for most Aboriginal communities in the WKSS area (Gilman *et al.*, 1997, Kuhnlein *et al.*, 2000; Van Oostdam *et al.*, 1999). The extent to which each source may yield its maximum value depends both on the freshness and preparation of the food, and what part is consumed (*e. g.* the vitamin contents of muscle tissue, organs and blood differ significantly). Diets that include caribou, seal, Arctic Char and berries are an excellent source of the nutrients listed in this table, and also provide many other nutrients and minerals (Gilman *et al.*, 1997, Kuhnlein *et al.*, 2000; Van Oostdam *et al.*, 1999).

In most WKSS area communities, the intake of organic contaminants remains well below Health Canada guidelines. Chlordane and toxaphene, however, somewhat exceed provisional TDI values for average and high dietary intake at Cambridge Bay, and are mostly associated with consumption of marine mammal fat (Kuhnlein *et al.*, 2000). Tolerable daily Intake (TDI) values are based on risk analyses rather than the background levels of a contaminant.

Concentrations of Cd and Pb also tend to be less in country foods from western Arctic but concentrations of Hg may be higher in country foods from the western Arctic. As a result of residual effects, concentrations of As in berries may be high at some existing and abandoned

mine sites, where they can exceed health guidelines. Recently released studies from the Kitikmeot area (Kuhnlein *et al.*, 2000) indicate that the average intakes of As, Cd, Hg and Pb remain below the TDI levels. However, for a few individuals who have a high consumption of caribou and Arctic Char, As and Pb may somewhat exceed provisional TDI values (Kuhnlein *et al.*, 2000).

Out of 1,012 dietary reportings from 16 communities, there was no exceedence for CBZ, DDT, dieldrin, HCH, or PCBs. Chlordane, toxaphene, Cd and Pb accounted for less than 1%, each, of exceedences. Although high concentrations of Cd have been found in human blood samples, these appear to be directly related to smoking and not to the effects of diet. Levels of Cd in smokers can be 5 to 6 times higher than in non-smokers and represent a serious health concern (Rey *et al.*, 1997). About 1% of exceedence was attributed to As and about 4% to Hg. Chlordane and toxaphene were mostly associated with consumption of Beluga muktuk and blubber, and with Arctic Char and Burbot. Arsenic was mostly associated with consumption of cisco, and Hg was associated with a broad spectrum of country foods. Overall, the information presented in this table substantiates the general safety of country foods consumed by these communities. It is further supported by the recent caribou and Moose sampling program completed in the Sahtu Region (Berti *et al.*, 1998; Sahtu Dene Council *et al.*, 1999).

Natural radiation is, by far, the most significant source at each community and, on an annual basis, all of these doses are far below accepted health standards. These data, however, do not characterize the effects of exposure to radiation “hotspots” such as occur at some abandoned mine sites (*e. g.* Rayrock (Veska & Eaton, 1991)).

There are additional concerns that involve the possible spread of infectious diseases and parasites, both of which may be related, in some way, to climate warming. Some diseases may be “imported” by people and animals moving into the WKSS area. For example, in Canada as a whole, the reported incidence of malaria has risen by about 3 fold since 1984 (Kelleher, 2000). While most of this increase is related to travel rather than to invasive infection that too has increased. Malaria was present in the Great Lakes region of southern Canada at the time of European settlement but it is not presently a significant health problem in that region. Reasons for this remain unclear. Certainly the drainage of large areas of marsh and wetland have contributed to the decline of malaria but significant areas of marsh and wetland remain. Possibly, agricultural run-off and, or, effluent discharge (Evans, 2001) may be additional factors. Malaria is not expected to become a serious threat in the WKSS area but other diseases, especially those carried by insects, birds and rodents could become invasive under climate warming. Also, there is concern that warming might increase the incidence of existing parasitic infections. Little is known of the potential for increased disease and infection in fish and wildlife of the WKSS area.



#### 4.3.2. Economic Security

Economic security is the main pillar of human existence. At a fundamental level, economic security is achieved through access to, and adequacy of food, clothing and shelter. Economic security is impacted by a range of individual, local and global circumstances such as personal interests, skills and self-confidence; access to and use of resources; and government policy, investment, market conditions and technologies. Nevertheless, the single most important determinant of economic security is human effort or work.

In hunting and gathering economies, access to land and harvestable resources is basic to economic security. In wage-based economies, paid work or access to the currency of exchange is fundamental to economic security. Although more people seek wage employment particularly in industrial sectors, the WKSS area continues to have a mixed economy. In a mixed economy, access to land and harvestable resources and paid employment or cash inputs are necessary for economic security. In this type of economy, economic security is affected when for example industrial activity threatens access to land and harvestable resources. Development that threatens subsistence harvesting or fails to preserve or enhance environmental quality is neither sustainable nor healthy (Wisner, 1996). It can deny the very underpinning of sustainable communities (Freeman, 1997) and can undermine cultural identity and compromise societal values. Unsustainable development offers little long-term economic security. Conversely, strong subsistence communities reduce the need for social support programs, encourage the transfer of TK (Wisner, 1996), strengthen social cohesion (Duhaime, *et al.*, 2004), and enhance physical and mental health (Samson and Pretty, 2005). In effect, subsistence economies that use TK and practices act to conserve the biodiversity of the environment (Michael, 1997) and promote economic security.

Most people in WKSS communities continue to harvest and eat food from the land (DCAB, 2005) but between 1998 and 2003, hunting and fishing activities declined in all communities except Behchoko (DHSS *et al.*, 2006). Over the past half-decade, monitoring reports show that diamond mine workers are spending less time on the land involved in traditional pursuits; less time with elders; and less time teaching traditional skills to their children. Most mine workers admit to knowing less about the history of the land (Lutselk'e, 2006; YKDFN, 2005). Several studies contend that subsistence harvesting is the cornerstone of the northern economy and the health of Aboriginal communities (Fast & Berkes 1994; DCAB, 2006; Duhaime, *et al.*, 2004; Usher, 2003). Others argue that land claim agreements that provide a land base and secure access to harvestable resources are fundamental to the economic security of Aboriginal communities (ARA Consulting Group Inc., 1995; ITK, 2006). While mine workers appear to be moving away from hunting and fishing, these resources continue to be central to economic security in local households. Access to healthy land, water and harvestable resources sustains these practices and their contribution to economic security.

Over the past century, industrial or non-subsistence land and resource uses that have conflicted with subsistence harvesting have threatened the economic security of northern Aboriginal people at various times (Abel, 1993; Watkins, 1977). The effects of the last two decades of escalating industrial activity in the WKSS area also increase potential land and resource conflicts and pose challenges for economic security (Kendrick, 2003). Further, reduced harvesting activities effect the capacity of people to meet basic needs and potentially threatens individual identity, cultural expression, and physical and emotional health and wellness. Economic insecurity can contribute to social insecurity, high-risk social behaviours (Berger, 1977; Condon, 1990; Condon *et al.*, 1996; Hall, 1986), and undesirable changes in diet, health status (Receveur *et al.*, 1996; Samson and Pretty, 2005).

In large and small, and Aboriginal and non-Aboriginal WKSS area communities, cash inputs are necessary to meet human needs and aspirations. In a blended economy, paid work and/or income assistance are the source of cash inputs. Historically access to paid full or part-time work in the WKSS area favoured skilled, educated workers from southern Canada and elsewhere in the world. These imported workers attracted to the NWT by lucrative wages and benefits (housing, travel and cost of living subsidies) were often in a better position to cope with cash demands than indigenous workers (Legislative Assembly NWT, 1996). Uneven access to paid work, housing, and other benefits contributes to disparities and inequities in human relationships and socio-economic circumstances within the WKSS population.

Industry and annual monitoring reports on employment in the diamond mines in the WKSS area indicate that Aboriginal people and other northerners are employed in mine or mine related work (BHP Billiton Diamonds Inc. & Dia Met, 2000; Diavik, 1997, DCAB, 2006). Aboriginal communities monitoring the effects of the Diavik Diamond Mine found that virtually all mine workers work in entry-level or semi-skilled positions (DCAB, 2006). Many of these workers do not benefit from on-site training and/or career advancement opportunities due to low literacy and education levels or lack of opportunity to learn the skills to advance in supervisory and management positions. Mine employment is also effected by work-based issues including prejudicial attitudes in the workplace and difficulty adjusting to strict rules and codes of conduct. The turnover among Aboriginal workers at industrial workplaces is high (DCAB, 2006).

Greater access to, and success securing employment positively effects economic security. Access to paid employment in WKSS area communities is facilitated by the higher levels of formal education now being achieved by northerners of working age. Education is a high priority for mine workers (DHSS *et al.*, 2006). More Aboriginal people particularly Aboriginal women are achieving higher-levels of education perhaps due to more understanding of the relationship of education/ training, and lifestyle and work choices; more desire to compete for wage employment; and greater demand for skilled employees particularly Aboriginal and northern workers, by all sectors of the WKSS economy including Aboriginal land claim organizations and

corporations (BHP Billiton Diamonds Inc. & Dia Met, 1995; BS., 1984, 1989, 1994; DE., 1989a, NWT BS., 2006). Despite trends toward higher education, youth unemployment in the WKSS area continues to be high due to a lack of employment skills and poor self-esteem among this segment of the population (DCAB, 2006).

In WKSS area communities, wage employment has come to have more prestige than making a living from the land (SWC-NWT, 1995; DCAB, 2006). Industrial activity provides new opportunities in the WKSS area for building positive self-esteem and contributing to economic security. Industrial employment often involves long distance commuting and rotational work arrangements. Studies since the 1980s have identified long distance, rotational industrial employment as having both advantages and disadvantages (NOGAP, 1986):

#### ADVANTAGES

- Home communities are buffered from direct contact with industry-induced influences.
- Workers in a controlled situation have fewer options for tardiness and absenteeism.
- Workers have blocks of time for hunting or resource harvesting.
- Cultural interaction is facilitated and community support systems remain intact.
- Income is provided to pursue traditional harvesting activities.
- Dependence on government transfer payments is lessened.
- Training is provided and job skills are developed.
- Workers are better able to provide food, housing and clothing for families.

#### DISADVANTAGES

- Emotional stress and worry resulting from worker-family separation.
- Worker loneliness and family stress may result from unfamiliarity with the workplace.
- Absence causes family stress.
- Less time, overall, may be available for hunting, trapping and fishing.
- Increased income may be spent on alcohol and drugs, causing related social problems.
- Diet may change when away from home.
- Prejudice and discrimination may occur at the worksite.
- Increase wage income breaks down traditional modes of sharing and support.
- Wage income changes distribution of income and may create poverty.
- Periodic “boom and bust” events create unstable sources of employment and income.
- Child neglect and discipline problems may increase in the absence of one parent.
- Conflicts may increase between parents, about child rearing, management or household issues.
- Attraction to apparently lucrative jobs may increase rates of school drop out.

- Traditional skills may be lost.
- Benefits from wage labour may not be realized due to lack of money management skills.
- Mental and physical health problems may be associated with wage culture.
- The cost of living may increase in response to an increase in community income.

Information collected through employee surveys, community reports, and approximately six years of statistical monitoring of the socio-economic impacts of diamond mining in the WKSS area seem to confirm effects of long distance rotational employment on northern families and communities identified in the 1980s. Mine workers themselves may however, be unaware of the full effects of this way of working. For example, excessive alcohol consumption (i.e. five or more drinks on one occasion) was more common among diamond mine workers in 2005 than in 2000 (DHSS *et al.*, 2006). Mine workers for the most part, report no change or stronger relationships with their spouses despite escalating family violence statistics in the WKSS area. Similarly, mine workers particularly in small communities believe that mine employment has positively impacted on their children (DHSS, *et al.*, 2006) even though statistical monitoring reports show high rates of child investigations and children coming into care in the WKSS area (DHSS, *et al.*, 2006).

If quality of life is measured by the ability to purchase consumer goods, travel to southern Canada, or support family members, then mine workers report positive effects from industrial employment over the past half decade (DCAB, 2006). At the same time, industrial employment income produces negative effects for mine workers with problems managing money. These industrial workers spend recklessly or beyond their means and experience high debt loads. This causes family members to experience the stresses of ‘feast or famine’ circumstances. When income is spent on alcohol and drugs, violence and financial stress can increase in families.

A shift toward wage employment, particularly industrial employment in non-renewable resource industries in the WKSS area has potential effects for long-term economic security. A downturn in industrial activity resulting in job losses could undermine the ability of individuals to meet basic needs especially if they are unable for reasons of skills or availability, to access other cash inputs or harvest resources from the land. The withdrawal of the oil industry from the Beaufort-Mackenzie Delta Region in the 1970’s provides an example of extreme ‘boom and bust’ effects on the economic security of local communities. Further, a restrained fiscal environment and stringent social policies within government diminishes opportunities for income supports (Lutra, 1998). Reduced cash inputs are a source of stress with particular consequences for dependent and vulnerable people (e.g. those requiring income subsidies for social reasons such as disability or illness) and people unable to secure employment. Young people are also at particular risk. The large number of young people receiving income subsidies (Lutra, 1998) together with low involvement in either the wage and, or, traditional economy are concerns in WKSS area

communities and elsewhere in the NWT (DCAB, 2006).

Studies have identified the availability of increased wage employment and cash income earning opportunities as ready deterrents to the need for income subsidies. Recent monitoring studies do not support this hypothesis (DHSS *et al.*, 2006). Other experiences also challenge this assumption. For example, over the four-year period of the Fort Good Hope-Chevron Canada Resources joint venture for oil and gas exploration, the small Dene and Métis community in the NWT experienced a dramatic increase in social assistance payments (Little *et al.*, 1994). The reasons for these increases may have included lack of skills or confidence to take up guaranteed jobs, increased costs in the community, unrealistic job expectations, a lack of sharing of wage earnings, and, or, poor money management or budgeting skills.

The use of income support in WKSS communities in the NWT has declined over the past decade due initially to changes in social policy and more recently to employment opportunities (DHSS *et al.*, 2006). However within small WKSS communities in the NWT, the average monthly income assistance rates while declining, remains high compared to Yellowknife and non-WKSS communities in the NWT. For example, in the six small WKSS communities, average monthly income assistance rates declined from 88.8 per 1,000 persons in 2000 to 56.2 per 1,000 in 2004. Over this same period in other non-WKSS NWT communities including Yellowknife, the average monthly income assistance rates fell from 44.9 to 30.8 per 1,000 persons (DHSS *et al.*, 2006). Income support rates within small WKSS communities in the NWT that are almost double those of non-WKSS communities, might suggest that economic security for many individuals is not met through industrial activity. For these individuals, the effects of personal choice and preferences, and the availability of social supports such as education, training and childcare (Alternatives North, 2006) may be the more critical factors impacting economic security.

#### **4.3.3. Social Security**

Social security is freedom from poverty and exposure, and the absence of fear or anxiety for personal safety. Social security and economic security are inter-dependent. For example, loss of work can trigger changes in diet or shelter arrangements to effect individual safety and security. Uncertain economic circumstances can alienate individuals from their family, community or culture to effect social cohesion or expose people to risky social activities.

The nature, structure and organization of work effects social security. These effects may differ for men and women, and among cultures. For example prior to the fur trade, Dene men and women maintained relatively egalitarian relationships (Abel, 1993). The nature and organization of work associated with the fur trade shifted the focus of Dene society to the labour traditionally done by men. With the collapse of the fur trade and the introduction of social assistance after WW II, government identified Dene women as the household head and recipients of income subsidies (Abel, 1993; Ryan, 1995). In the last half of the 20<sup>th</sup> century, government jobs in

education, care giving and family services available in WKSS area communities tended to be taken up by women to reinforce their role as providers of social and economic security (BS., 1984, 1989, 1994; DE., 1989a; DE., 1989b, Lutra, 2000). Although Aboriginal men continued to hunt, fish and trap from a base in the community, the role of men as main providers was largely displaced. The effects of changing roles of men and women have undermined personal security, self-esteem and identity. The prevalence of suicide and alcohol and drug abuse (including fetal alcohol spectrum disorder) increased. Crime and family violence also increased as a result of acculturative stress and breakdown of the traditional family unit (Bayly *et al.*, 1985; Bjerregaard & Young, 1998; Chambers *et al.*, 1993; GC., 1993).

Industrial employment in the diamond mines is once again altering the roles of men and women and impacting social security in the WKSS area. Communities recognize that men are mainly attracted to mine employment; have regained self-esteem through employment; and are proud of their role as ‘breadwinners’ (DCAB, 2006). However, the stress effects of separation and adjustment from a single to two-parent family to accommodate rotational work cycles of mine workers places tremendous stress on the family unit and the responsibilities of the ‘stay-at-home’ adult. Family separation and loneliness are major factors contributing to workers’ decision to leave mine employment (DCAB, 2006). Family separation is also likely a factor in the increase of single-parent families in small WKSS communities from 20% to 30% between 1996 and 2001 (DH&SS, *et al.*, 2006). The separation of mine workers from the family unit and family responsibilities together with binge drinking, gambling and drug abuse including (ab)use of highly addictive substances such as crack cocaine and crystal methamphetamine upon the return of some mine-workers to the community, are also factors in family breakdown and high rates of family violence (DCAB, 2006). Lack of engagement of returning mine workers in subsistence harvesting activities or lack of service to the extended family and community unit may be other reasons for family breakdown.

Family violence is a serious and pervasive problem throughout the NWT and Nunavut (Chambers *et al.*, 1993; DHSS, 1999; GC., 1993; Zellerer, 1996). Family violence is an abuse of power within family or dependent relationships. It can take many forms from physical and sexual violence and abuse to financial, emotional and psychological abuse. A wide range of issues are associated with family violence including patriarchy and power, traditions, spirituality or lack thereof, changing family relationships and lifestyles, leadership roles, the influence of religious institutions, alcohol and other additions, cultural values of non-interference, a lack of community sanctions, and conditioning to family violence (Chambers *et al.*, 1993; Zellerer, 1996). Women of all ages, backgrounds and occupations are most likely to be the victims of abuse. Stresses associated with depression among women have been linked to persistent family violence (Bjerregaard & Young, 1998). Many people do not want to recognize, talk about, or report the problems of family violence (Chambers *et al.*, 1993; GC., 1993; Zellerer, 1996). As such, most cases of family violence are not reported to the police. Child abuse including child sexual abuse

is probably the most pervasive and under-reported of violent and abusive acts in the family. Children who experience violence in the home are more likely to become abusers themselves (DHSS *et al.*, 2000).

In 2005 rates of violent crime in the NWT and Nunavut were more than seven times higher than in southern Canada (SC, 2006). Victims of violent crimes in the northern territories are more likely than victims in the provinces to know their perpetrators. Between 2002 and 2004, the rate of violent crime in Yellowknife increased by 50% from 32 to 48 violent crimes per 1,000 persons, and fluctuated in smaller WKSS communities in the NWT from a high of 78 to a low of 59 violent crimes per 1,000 persons. The use of alcohol or other drugs is associated with most violent crimes in the NWT (DHSS *et al.*, 2006). Spousal assault, sexual assault and other acts of violence within the family unit, are among the violent crimes taking place in WKSS communities. Nunavut has 6.5 times the national rate of reported spousal abuse cases (Pauktuutit, 2006). The effects of sexual assaults and violence seriously undermine the social security of victims. Victims fleeing violence in the family are often left without the resources to provide for basic needs. Family violence contributes to depression and other mental wellness problems among Inuit women (Stout Dion, 1996). People impacted by family violence also lack the security, dignity and confidence to meaningfully participate in their families and communities (ITK, 2006).

Reported incidents of spousal assaults and other violent crimes fluctuates. For example, between 1998 and 2004, the number of reported spousal assault cases in Yellowknife rose to 123 in 1999 then dipped to a low of 59 in 2004. Similar trends have been observed in small WKSS communities in the NWT where reported spousal assaults reached a high of 59 in 2002 then fell to a low of 28 in 2004. The reason for variance in reporting of these crimes is complex but likely does not suggest any decrease in these crimes. The Government of the NWT suggests that reporting of spousal assaults is effected by employment. It suggests that the number of reported spousal assault cases in smaller WKSS communities (i.e. in 1998 and 2002) coincided with the completion of diamond mine construction and the subsequent termination of employees (DHSS *et al.*, 2006).

Youth (persons 12 to 17 years of age) crime in WKSS communities is an expression of the state of social security among this segment of the population. Between 2001 and 2003, there was a dramatic increase in the number of youth charged with a criminal offence in smaller WKSS communities in the NWT (e.g. 50 per 1,000 people in 2001 and 204 per 1,000 in 2003). Over this period, youth in Yellowknife charged with a criminal offence changed very little from 65 per 1,000 in 2001 to 72 per 1,000 in 2003 (DHSS *et al.*, 2006). Mainly as a result of changes to the federal *Youth Criminal Justice Act* (April 2003) that emphasize alternatives to the formal justice system, youth crime rates declined in 2004 to 153 per 1,000 people in smaller WKSS communities in the NWT and 61 per 1,000 in Yellowknife (DHSS *et al.*, 2006). Youth crimes

resulting in charges in 2004 are likely of a more serious or repetitive nature. Yellowknife youth and youth-serving agencies identify several factors that contribute to crime including drugs and alcohol, boredom and unhealthy family environments (Auchterlonie, 2004).

WKSS communities monitoring the effects of industrial employment report changes in youth behaviours. Youth are less connected to their families, their culture or their communities; uncertain about their future (and have few employment opportunities); bored and engaging in unhealthy, high-risk behaviours; disrespectful of others (e.g. parents, elders, other adults and youth); not attending school and/or disruptive at school; and not living at home or are living in unhealthy environments (DCAB, 2006). Sharp increases in youth crime and sexually transmitted infections corroborate these observations (DHSS *et al.*, 2006).

The destabilizing effects of unhealthy family environments can have wide-spread and long-term impacts on individuals, families, communities and cultures. A main effect of uncertain or unhealthy family environment is the breakdown of social cohesion or social ties produced through involvement in family and community activities whether social, cultural, economic or political (Duhaime *et al.*, 2004). Throughout this century, both Dene and Inuit have experienced famine, epidemics and death at rates that have undermined social cohesion, security and continuity and challenged the health and well-being of families and cultures. Northern people no longer disappear into southern Canadian institutions (e.g. with mental illness or tuberculosis) or far-off residential schools for months or years at a time as was the case in earlier decades. Still, these practices have undermined trust within families, fragmented family relationships, and contributed to feelings of isolation and apathy towards the family unit. Broken or fragile family relationships have strengthened individual dependencies on external systems for security and support. Dependency on economic and social relationships which extend beyond and, or supersede those of the family unit, have weakened individual and collective capacity to manage stress and accommodate change. For example, many parents rely on schools to discipline and socialize their children or social workers to resolve family problems. Individuals may have fewer cooperative relationships with family members, be less consistent in their care and protection of weaker members, and less responsible for contributing to the social and economic security of others. Statistics showing high levels of child abuse, elder abuse, youth crime and suicide are evidence of the weakened state of family units in the NWT and, or, Nunavut (Chambers *et al.*, 1993; GC, 1993; ITK, 2006).

Growing populations, more transience among youth and the stresses of meeting basic needs also significantly stress and fragment social cohesion and undermine supportive human networks and relationships. Like youth, Inuit women feel less connected to others today than in the past and have fewer resources to support each other (Brockman-Haworth and Hashmani, 2005). Literature respecting hydrocarbon activities in the Beaufort-Mackenzie Delta in the 1980s suggest that industrial work activities may further weaken family units as workers become alienated from



their home community, and less inclined to care for and protect family members (NOGAP, 1985). Over the last half decade mine workers from small WKSS communities appear to be less connected to family and community support systems and less optimistic about their future (DHSS, *et al.*, 2006).

In recent decades, northerners have become increasingly concerned about the state of mental health within northern communities (ITK, 2001) but efforts to understand it have been overshadowed by a focus on alcohol abuse, crime and family violence. The high rates of suicide and suicide attempts, key indicators of mental health, have forced some focus on mental wellness particularly in Inuit communities (Stevenson and Ellsworth, 2004). Suicide among Inuit youth, 16 to 30 years of age, is about six times higher than among youth elsewhere in Canada (ITK, 2006). Typically, suicide is viewed as a result of depression and hopelessness that is exacerbated by a lack of economic and social security. Suicide among Inuit youth has been described as a cry for help from individuals suffering from the effects of *‘inter-generational tension, intra-family violence, altered and destructive relationships between husbands and wives, family break-up and generally an increase in disruptive domestic life in Inuit communities’* (GC, 1993). Individuals caught between the values and expectations of traditional and modern day culture and lifestyles are considered most vulnerable (Lutra, 1996). Depression and separation from home and family associated with industrial employment may also increase vulnerability to suicide although little current evidence exists to substantiate this notion. Statistical monitoring in WKSS communities in the NWT provides no evidence to understand the effects of industrial employment on suicide rates or the overall state of mental wellness (DHSS, *et al.*, 2006).

One of the most pervasive factors affecting the social security of northern people is alcohol and drug abuse. Substance abuses contribute to poor mental and physical health, high rates of crime including violence and injury, high conviction rates, and the high number of Aboriginal people incarcerated. Uses of alcohol, drugs and tobacco in the NWT and WKSS area communities are well above national averages. Alcohol and, or, drugs account for as much as 88% of unlawful offences in some WKSS area communities (Diavik, 1997). Alcohol and, or, drugs are involved in accidents and, or, injuries and a significant number of violent deaths (BHP Billiton Diamonds Inc. & Dia Met, 1995; Diavik, 1997; DHSS., 1999; Lutra, 1996). The main medical conditions in WKSS area communities, cancer, respiratory and nervous system, injury and poisoning, may also be linked to the high use of alcohol, drugs and, or, tobacco (BHP Billiton Diamonds Inc. & Dia Met, 1995; Diavik, 1997; DHSS., 1999; Lutra, 1996).

A growing body of research citing the lengthy history of abuses, guilt, shame, powerlessness and loss of self-esteem associated with the colonial experience in the north is identified as a root cause of violence and substance abuse (Chambers *et al.*, 1993; SWC-NWT., 1995; GNWT., 2001). In other words, the collective or cumulative effects of acculturation that result in loss of identity, self sufficiency, self-worth and well being may underlie many of the problems

associated with substance abuse, violence and injuries (Stieb & Davies, 1995). Reversal of these effects may greatly reduce these problems (Chambers *et al.*, 1993; SWC-NWT, 1995). Still, a history of alcohol abuse in the NWT and Nunavut has led to perceived high rates of fetal alcohol spectrum disorder (FASD) among children and youth (Kowalsky & Verhoef, 1999). Other effects of substance abuses are emerging through monitoring of industrial employment (DCAB, 2006; DHSS, *et al.*, 2006) although lack of rigorous analysis limits the extent to which increases or decreases in alcohol and drug consumption effect more or less employment, economic benefit or social security.

Numerous studies have linked the social security of Aboriginal people particularly women, to the health of the traditional economy. The rationale for these linkages is that harvesting activities not only provide basic economic security but also shape societal relationships, cultural expression and individual identity and security. *“Aboriginal women’s human security is tied to the land, and the cultural traditions derived from fishing, hunting and gathering necessary to foster a safe and healthy life for the future generations of their people”* (Deiter and Rude, 2005). *“For First Nations people, the core of social life is not the traditional nuclear family unit but the extended family, the band and the community”* (Rude and Dieter, 2004).

Country foods offset the cost of imported foods, provide important nutritional value, and promote and sustain family and community social structures and values (Collings, 1997; Pierce & Horal, 1994)). For example, caribou hunting helps people maintain their cultural identity and connections, as the hunt often is a group activity. Sharing country food harvested helps to structure and maintain social alliances (Condon *et al.*, 1995; Hall, 1986). Country food such as caribou, is also a relatively inexpensive source of nutrition. Caribou has a high nutrient density and, when used in its entirety, provides most required nutrients (Christensen, 1989). The only essential nutrient which caribou is deficient in is vitamin D. In earlier times, people used other food sources such as fish liver oil to balance this need in their diet. Studies in Dene and Métis communities of the NWT indicate that country foods provide 10 to 27% of the intake of total food energy, 35 to 61% of protein intake, 4 to 17% of fat, 34 to 64% of iron, 34 to 65% of zinc, 5 to 82% of vitamin A, and 3 to 9% of calcium. Changes in food harvesting and, or, consumption patterns may account for findings in several WKSS area communities that the intake of both vitamin A and calcium was below levels recommended for adult health (CIPNE *et al.*, 1996).

While Aboriginal households continue to consume country foods, the dietary circumstances of many are poor (CINE *et al.*, 1996). Poor dietary circumstances may be due to a number of factors, including: loss of TK about nutritional values; lack of familiarity about the nutritional values of presently used foods; improper use and preparation of foods; inadequate supply and, or, low consumption of country foods among household members most vulnerable to dietary deficiencies (*e. g.* young children and women of child bearing age (Christensen, 1989). However, no substantive data have been published to indicate how or if industrial activities such as mining

are impacting on food security or health and well-being of Aboriginal northerners (Davidson, 1994). It is known, however that dietary changes resulting from a reliance on food purchased from stores along with an increasingly sedentary lifestyle have compounded problems of health and wellness in many Aboriginal communities. These changes have increased the likelihood of obesity, diabetes, high blood pressure and dental caries (Bjerregaard & Young, 1998; Stieb & Davies, 1995; Sampson and Pretty, 2005).

Access to affordable and suitable housing has long been an issue in NWT and Nunavut. Shelter concerns have not abated with more wage employment. Shelter remains one of the most pressing issues affecting Inuit mental wellness and physical health (ITK, 2006). Inadequate shelter arrangements contribute to the risk of transmitting infectious diseases, the potential for personal injury, inter-personal stresses, family violence, and access to the basic supports needed to function and thrive in modern society. Socio-economic monitoring of WKSS communities in the NWT show that overcrowding is declining in some communities (DCAB, 2006) but it is clear that industrial activity has not had the positive impact on housing that was expected (DHSS, *et al.*, 2006). Further, there is a rising incidence of homelessness in larger WKSS communities, particularly Yellowknife. While the interaction of several factors combine to produce homelessness including poverty, addictions, and violence, little is known about the effects of homelessness in northern climates as it is a relatively recent phenomena.

#### **4.3.4. Culture and Traditions**

The culture of a people is their way of life reflected in social, economic, political, intellectual and spiritual activities, and expressions of values and beliefs are unique to each culture. Berkes *et al.* (1998) have stated that although the “language” of TK may differ significantly among Aboriginal peoples (metaphorical imagery and spiritual expression may indicate differences in context, motive and conceptual underpinning), the concepts of traditional (ecological) knowledge are comparable. Thus, some ecosystem-like concepts incorporate spirits of animals and other natural objects, and enhance feedback in TK in ways comparable to adaptive management. Historically, the cultures and traditions of both Dene and Inuit were founded on an interdependence with the animal, plant, spiritual and human worlds. Language, individual and collective beliefs and practices together with socio-economic and political organization focused on the maintenance of harmony and balance among these elements. A sense of place and role, and fulfillment of individual responsibilities ensured collective security. The shared goal of survival shaped the moral code of ethics of sharing, respect, non-interference and the use of persuasion rather than authoritarianism (Ross, 1992). Northern cultures have endured a series of disruptive events and influences whether through church, school, state, industry or natural circumstances, which have systematically or haphazardly undermined age-old beliefs and traditions (Abel, 1993; Bjerregaard & Young, 1998; Chambers *et al.*, 1993; GC., 1993; Ryan, 1995)

Today, individual and collective activities within contemporary WKSS area communities do not

always encourage or enable the expression of culture or traditions. Institutions, structures and systems rooted in European traditions, whether municipal models of governance or institutionalized care of the elderly or preschoolers, have stymied, frustrated, contradicted and, or, diluted many traditional practices. As a result, a good number of northern people lack connection not only to their own feelings, history and experiences but also to any collective set of values and beliefs (Chambers *et al.*, 1993). This is a source of stress among people of all ages and the effects of these stresses may be manifested in various ways.

A body of research suggests that a healthy traditional economy can and does restore a cultural connection among Aboriginal peoples. As the “store” or “bank” for Aboriginal people, the land provides for economic security as well as social and cultural strength. It is the land, its resources and the cultural, heritage, historic, and burial sites on it, that offer a sense of identity, belonging and place in the world that is missing in many contemporary northern communities. (Condon *et al.*, 1995; Parlee, 1998b). As relationships to the land are threatened by industrialization and development, the effects of these stresses on Aboriginal culture and traditions of the WKSS area increase (Parlee & Łutselk’e First Nation, 1997).

#### **4.3.5. Power and Control**

The extent to which individuals and groups are able to make and influence decisions that affect their lives, lies at the heart of power and control. The power base of the Dene and Inuit, has and continues to be derived mostly from the land and its resources. Aboriginal people in northern Canada including the WKSS area, have experienced more than a century of efforts to alienate and remove their people from the land. For example, through game legislation and harvesting regulation, treaties, community and settlement efforts, and expropriation of land and resources for industrial development (Abel, 1993; Fumoleau, 1973). The overall effects have been to marginalize Aboriginal people, who have had little control over decisions respecting the use of lands and resources. Most have derived little or no benefits from the use of lands and resources (Berger, 1977) and an inability to prevent damage to the environment may have as much impact on the community as the impact of the damage itself (Beilawski, 1993, 2003).

Aboriginal people became organized politically during the 1970's and have fought for recognition of their rights to land, resources and governance. They have significantly influenced development, through, for example, the Mackenzie Valley Pipeline Inquiry. They have also entered into agreements, such as impact benefit agreements, to assert power and control over the use and benefits of lands and resources. These efforts seek to address long held concerns of Aboriginal peoples in the WKSS area that are generally shared by other Aboriginal Canadians, that:

- *“resources and habitat have been exploited for the profit of southerners, with little socio economic advantages to themselves;*

- *they have experienced little if any participation in decision-making processes.*
- *They have seen few plans to protect the lands which they have inhabited for countless generations.*
- *They have seen few plans for long term benefits through employment in spin-off industries which could be created by the projects in question” (Malcolm, 1995).*

Future industrial resource development in the WKSS area has the potential to increase stress effects on people in the region. Efforts to ensure Aboriginal participation and access to benefits, may reduce these stresses. The literature currently does not document the extent to which stresses are being created, managed or reduced as a result of new approaches to Aboriginal involvement in power and control of land and resource uses.

#### **4.3.5.1. Respect for Land Ownership and Treaties**

Some Tłıchǵ elders have stated that treaties signed in good faith have not been lived up to. Outsiders do not appear to respect the Tłıchǵ’s ownership of the land, nor the animals that live on it. Given these experiences they are concerned about mining development . They are frustrated that they cannot trust what they are told by outsiders. Elder Pierre Wedzin states: *“They [Whites] look up to money as if it were their god. They are impossible. ... If we think there is no hope, there will be no hope as the white man is very ambitious. They work, and we cannot see them with our own eyes. They work with hard rocks, but to them it’s as if it were pliable wood. ... We as a people depend on words [which are sacred and carefully chosen], yet those who have come [representing Whites] aren’t the boss” (Legat & Zoe, 1995).*

Aboriginal people have expressed their frustration in having to deal with so many departments and individuals on issues related to government or business. It makes it difficult for them to determine who has real authority and what rules and agreements are actually in place. Elder, Andrew Gon states:

*“Why do they have so many people for k’ade [in positions of authority] ... Why do they have k’ade for different things and they all think different.... They don’t talk the same way. They all work different ways....” (Legat & Zoe, 1995).*

#### **4.3.5.2. Demonstrating Respect for the Land**

Tensions may arise when developers or others using the traditional lands of Aboriginal people act in ways that are not considered respectful. Many Aboriginal people believe that the land and animals are aware of human actions. Among the Tłıchǵ, animals must be treated according to

*ekw'i naàw* - the rules of people. The outcome of breaking these rules is serious and can result in ill fortune or the guardian spirit of the animals causing them to move to another area. It is understandable that people who depend on many animals would be concerned about the impacts of people who do not know the rules (Legat *et al.*, 1994).

Offences to the land have been observed through past mining operations. The physical damage resulting from mining operations, the lack of reclamation or clean up when mines close, and the continued harm to people and animals through contaminants is an ongoing concern. Elder Andrew Gon states: *“They have been working at Watiza (a deserted mine site)... They have been working there with the nàedili [poison] and they never clean it and they just leave it like that. They never bother to clean it and they have been spilling nàedili on the land. It is just like there is a big hole in the land. All those people have been working on the land; all the people who were working there are no longer living. It is just like they have been killing people, it is the same. To this day they have never bother to ndè segaleà-lè [clean it up]; what about if the animals goes on that land and eats it and drinks the water. Maybe the animals have been traveling around in this area, and we eat them. Maybe if we kill the animal and eat it we might get sick because of that”* (Legat *et al.*, 1994).

#### **4.4. The Future**

With the large number of youth entering the work force each year, residents of the WKSS face every new venture inside their community and on the land, with a mixture of hope and apprehension. They hope for real and lasting benefits that will create much needed jobs for young people, increase income, and provide new training and education and business opportunities. At the same time, northerners worry about the adverse effects of development on the land, the wildlife, the water and, on the beliefs, values and identity of the people. These conflicts create tremendous stress. The stress effects on northern populations may be both positive and negative but the rapidly changing circumstances in the north severely limit any certain prediction of how these stresses will play out in the WKSS area.

## 5.0 SUSTAINABLE DEVELOPMENT IN THE WKSS AREA

The stated vision of the WKSS Partners is to achieve sustainable development in the WKSS area *“which respects aboriginal cultural values, so that the land is protected, culture is preserved and community self sufficiency and, or, reliance is enhanced.”* The Partners firmly believe that providing useful information to decision-makers is an essential ingredient for achieving sustainable development. This chapter will discuss some other tools available to assist in achieving sustainable development in the WKSS area.

### 5.1. Sustainable Development and Stewardship

The World Commission on Environment and Development coined the term *Sustainable Development* in 1987 (WCED., 1987), and defined it this way: *“Sustainable development means development which meets the needs of the present without compromising the ability of future generations to meet their own needs.”*

This concept provides a foundation on which it is possible to integrate social, economic and cultural development with environmental considerations. Sustainable development depends on the ability of the ecosystem (including people) to remain stable and in balance. It implies careful use of resources, both renewable and non-renewable, and that the ecosystem should not be degraded.

Long before the term *sustainable development* was used, the idea of stewardship, or wise use, has been a guiding philosophy for many peoples. Stewardship is a recognition that, in terms of the natural environment, people don’t own anything. Rather, an opportunity exists to use the environment in ways that support and please people, and this opportunity transfers from one generation to the next. Since people now have the ability to greatly change the environment and ecology of the planet (including the WKSS area), a high degree of stewardship exists. In the long term, stewardship rather than ownership may be of greatest importance in the wise use of renewable resources; as stated by Leopold (1949) *“We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect”*.

#### 5.1.1. Stewardship and Aboriginal Culture

Many aspects of the traditional economy are present in the modern concept of sustainable development (INAC., 2000b). To Aboriginal people in North America, the notion of land extends beyond the physical landscape and it includes the living environment and people. As stated by Rosalie Tailbones: *“It’s the land that keeps things for us. Being our home it’s important for us to take good care of the dwelling, the land, for wherever you go is home”*; or, as noted by Madeline Drybones *“The land we live on is our home”* (Legat *et al.*, 2000). Here occupancy is seen as inextricably linked with the responsibility for stewardship. Aboriginal concepts may not preclude resource use but rather support wise use (Berkes *et al.*, 1998; Sly,

1995)

Prior to the contact period between Europeans and Aboriginal peoples, Aboriginal “rules” for stewardship of land, animals and people kept people in balance with natural resources (Legat, 1998a; Johnson & Ruttan, 1993; Zamparo, 1996). This was essential, since people’s survival depended on such reciprocal relationships. Traditional knowledge provided the basis of such rules, and beliefs and myths gave reinforcement to the approach. Values and beliefs leading to moral code or environmental ethic are an important part of TK.

One of the most important aspects of this form of stewardship was respect, and this included not only respect for other people but, of equal and sometimes of greater importance, respect for the land and the animals and their spirits. Such respect ensured that nothing was wasted, animals were killed only for necessities, and that as far as possible the kill was quick and clean. Also, disturbance of other animals was kept to a minimum. The role of TK reinforced by belief made the practice of Aboriginal stewardship very effective. Contemporary relationships (between people and their use of resources are generally weaker.

Many Aboriginal communities pursue a mixed economy to gain cash to support traditional activities (*e. g.* hunting, trapping, fishing, crafts, carving and other domestic activities), aiming for sufficiency rather than accumulation. Subsistence activities are an important part of “the reason for being” and they are the hub around which other economic activities move. Subsistence activities are of vital importance in maintaining cultural identity and self-worth, and sustainable use of resources is not just a biological issue but one that involves social, economic, legal and many other issues (Freeman, 1997). Constant levels of take are rare, because Arctic and sub-Arctic ecosystems are naturally highly variable and many activities are sustainable only when they respond to the rhythm of the environment (which also includes people (Freeman, 1997). A renewable harvest that meets some distant consumer demand, rather than being consistent with local productivity, is not sustainable.

Generations of people have made their living in the WKSS area by harvesting country foods (such as ducks, geese, fish, caribou, Moose and Muskoxen), and if future generations are to continue this practice, carrying capacities should not decline and neither should abundance of the wildlife resource.

To be viable, wildlife populations must be large enough and sufficiently dispersed to withstand losses due to weather, starvation, fire and disease. For some wildlife, isolation is important, even though a particular habitat may be required for only a very short period of time (*e. g.* calving grounds of Barren-ground Caribou). Further, all species of a community should continue to interact with one another to maintain system integrity. This includes predator-prey relationships such as those among caribou, wolves and carrion-eaters.



Some species are naturally more abundant or have higher rates of replacement than others and resource use can reflect this. There are special concerns, however, for species of low abundance. Once extinct, species can not be brought back (*e. g.* Woolly Rhinoceros, Mammoth, and Sabre-tooth Cat that were present in the glacial refugium of the northern Mackenzie Valley only 10,000 to 14,000 years ago (Harrington, 1978; Kurten, 1988)). Also, even if similar replacement groups of wildlife could be introduced, they might not carry appropriate adaptations or behavioural characteristics. Adaptations like the winter changes that occur in the burrowing feet of Collared Lemmings or the hooves of Barren-ground Caribou, behavioural responses learned as juveniles in wolves and Muskoxen, or the migratory instincts of Arctic Char are not likely to evolve over short periods of time.

To maintain a balance within the ecosystem, development should occur in ways that meet the needs of both people and the ecosystem. For example, mining is a short term activity, perhaps a few decades in duration at most locations, but technologies exist to return many areas to a productive form (though perhaps different from an original state). This type of activity should represent only a temporary loss of natural renewable resources if its development, including reclamation and closure, is well managed. In most areas, including the WKSS area, development occurs not as a single activity but in the cumulative form of many activities. Knowing the potential effects of various activities and having a greater understanding of the environment and the effects of these activities will certainly help to reduce the negative effects of development.

### **5.1.2. Cumulative Impacts**

Environmental impacts from multiple activities that overlap in space and time are referred to as cumulative impacts. They are defined as changes to the environment caused by the combination of past, present and reasonably foreseeable future actions. These combined impacts may be significant even though the individual impacts of each action, when evaluated independently, are determined to be insignificant. Cumulative impacts therefore represent the most appropriate measure as to whether subsequent activities should be allowed to occur (SENES 2006b).

The foundation of cumulative effects assessment (CEA) is environmental monitoring information. This “raw” information needs to be of sufficient quality and quantity to identify historic, current and future potential cumulative impacts with a reasonable degree of certainty. It also needs to be in a consistent format and readily accessible to facilitate efficient use. In addition to environmental monitoring information, organizations responsible for environmental management require a unique set of skills and analytical tools to effectively identify and interpret cumulative impacts.

With the increased pace of industrial development in the WKSS region in the past decade; predominantly in the non-renewable resource sector, the need for effective tools to assess and

manage cumulative impacts has been highlighted. Some of these tools are discussed further on in this section.

As general terms, both environmental impact and cumulative impact have been used many times already in this report but further clarification is useful to more fully appreciate their significance in relation to sustainable development. Temporal and spatial scales of effect increase as the level of impact rises from an individual of a species, to a population of that species, to the community in which that population is a member, to an entire ecosystem. The implication to be drawn from this is that any attempt to characterize or monitor change must be appropriate to the scale of effect as well as the level within the ecosystem at which the effect is occurring. Indicators of stress effects at the level of an individual are not likely to be well suited to characterize stress effects in a community and the adage that “*you can’t see the forest for the trees*” exemplifies the need for appropriately integrated forms of indicators suited to different levels in the ecosystem.

The state of human communities can be degraded, conserved and enhanced just as the state of animal communities, or the environment in which both exist. Many forms of response to stress, whether environmental or human, are non-linear and effects may not be easily discerned until some type of threshold has been crossed, resulting in a new state of being. All such changes relate to both singular and multiple impacts. Once an environmental threshold has been crossed, change is not exactly reversible although something similar to a pre-existing condition may be re-established. This applies just as much to the human condition as to other living components of the environment. It is important to be able to recognize early warning signs appropriate to various thresholds.

As a further complication, and because the process of reversing degradation across a threshold is moving against natural tendencies toward disorder, more energy and effort are required to correct an undesirable condition than to create it, hence the precautionary principle.

The adoption of “themes” could provide an effective means of cumulative effects monitoring because, by their nature, they are an integrated form of indicator. Themes include trends in the natural environment, economy, community characteristics and human health (NPC., 1997). The health of the environment could be indicated by selected measures of water and air quality, and population and habitat characteristics of selected fish and wildlife (including birds). The economy could be reflected by selected measures of natural resource harvesting, wage employment, commercial and industrial activity and consumption. The community might be characterized by some measures of demographics, services, health care, education, community activities and culture. Health, social equity, safety and security could provide additional indicators of the quality of life.

#### 5.1.2.1. The Global Context: UNEP - GLOBIO Study

The GLOBIO (Global Methodology for Mapping Human Impacts on the Biosphere) consortium aims to develop a global model for exploring the impact of environmental change on biodiversity (UNEP, 2001). The purpose of the model is to provide an analytical framework for bringing together biodiversity and environmental change data in support of the integration of the environmental assessments in which UNEP is involved. By estimating biodiversity impacts from human activities, overviews of past, present and potential future impacts can be derived.

Two excerpts from the findings from the GLOBIO sub-regional study completed for the Arctic in 2001 are provided below. Although much of the information for the study has been drawn from northern Scandinavia and Russia (west of the Ural mountains), many aspects of the methodology used by the GLOBIO study are generally applicable to the needs of cumulative impact assessment in the WKSS area. The study used a scenario in 2050 applying reduced, stable, or increased rates of infrastructure growth as compared to the growth between 1940-1990:

*Continued growth at current rates in infrastructure, gas, oil, and mineral extraction will, within 20-50 years, seriously impact wildlife populations, vegetation, and ecosystem function across 50-80% of the Arctic. Migratory species, like birds, will carry the impacts with them far beyond the Arctic region. Furthermore, the cumulative impacts are likely to affect many of the indigenous cultures in the Arctic, which are depending upon natural resources for their traditional lifestyles.*

*The extent of the impacted areas, even with conservative estimates assuming 50% reduction in development rates, ostensibly illustrates the severity of the environmental threat to the Arctic. Although the Arctic is among the least developed areas of the world, the extent of the impact zones is much larger. Changes in the hydrology of the tundra may also affect climate patterns as these areas hold some of the world's greatest carbon reserves.*

*Among the most crucial inputs to GLOBIO are realistic scenario-models for development in infrastructure. There are obvious differences in the rates of such development including both socio-economic (urbanization trends) and natural factors. This part needs to be thoroughly developed for the global scenario work, and currently requires specific attention. New landscape disturbances, which are disconnected to existing infrastructure and may arise in regions previously undeveloped also needs to be addressed in the methodology ahead. For example, this analysis does not include the many mining, power line, and road facilities currently planned for in previously undeveloped regions of the Arctic (e.g., Nunavut and Labrador of Canada).*

It is important to note that predicting regional characteristics of the WKSS area would require significant change to existing components of the GLOBIO study (e.g., as most taiga and tundra environments are characterized by only a few species of highly specialized plants and animals, density (abundance) is a more useful indicator of ecological health than diversity). The development of roads and various forms of infrastructure, and increasing zones of influence along road and pipeline corridors provide a powerful image of increasing cumulative impact over time. This form of output would be just as appropriate for the WKSS area as it has been for the GLOBIO study.

### 5.1.3. Planning for Sustainable Development

Limiting the extent of environmental impacts is clearly a very important part of the process of sustainable development, but more is also required. Sustainable development seeks to meet broad community objectives by creating positive conditions that are beneficial to people. Using an earlier example, mining has the potential to be disruptive of the local environment, while also having the potential to provide for present and future betterment of both Aboriginal and non-Aboriginal societies in the WKSS area. The potential for betterment, however, depends just as much on how economic gains affect and are used within communities as it does on the ways in which development takes place. To achieve sustainable development it is necessary not only to respond to activities as they occur, but to direct development towards an objective. In its most basic form, development should meet three essential and equal objectives. Ideally, none should be pursued to the detriment of another:

|                         |                                                                    |
|-------------------------|--------------------------------------------------------------------|
| an economic objective   | production of goods and services                                   |
| a social objective      | maintenance and enhancement of quality of life (including culture) |
| an ecological objective | maintenance, and, or, enhancement of environmental conditions      |

Objectives have to be realistic and in the WKSS area it is important to know, for example:

- what short term products and services are possible and desirable;
- what long term products and services are possible and desirable;
- what are the infrastructure needs for communities;
- what are the educational needs for the future of communities;
- what forms of decision-making would improve community involvement;
- what can be done to improve community wellness; and
- what level of dependence on country foods is desirable.

Although these and similar sets of information would be an invaluable guide, sustainable development requires something more, again. Process is another component of sustainable development and has a major influence on the extent to which people are willing to support the concept. Information and expert support have to be readily available to all parties, there has to be sufficient time for discussion, and above all, decision-making should be transparent. Objectives should be formulated around some form of overall vision of what people want, and the clearer the vision and the more people that share it, the stronger it becomes. The use of visioning and forward-looking objectives as part of the overall approach is possibly one of the most challenging issues to be faced in adopting the concept of sustainable development.

In several ways, already, there have been significant advances within the WKSS area toward sustainable development. Many steps have been taken, particularly over the past decade, such as devolution of legislative and administrative authority, land claim agreements, co-management agreements and impact-benefit agreements.

Sustainable development is a vision which must be constantly striven for. If sustainable development will be achieved through human decisions and actions, then good tools will be needed to make good decisions.

## **5.2. Tools for Achieving Sustainable Development in the WKSS Area**

### **5.2.1. External Stresses: Actions by Northern and Aboriginal People**

Global climate change is likely the greatest environmental threat facing the WKSS area. It is also one of the greatest threats facing the world as a whole. The potential for ecological disruption is at a scale entirely greater than the sum of all current and proposed development in the WKSS area. It is beyond the direct control of the residents of the region, or even of Canada itself, and can be dealt with only in international meetings at the highest levels. There is global concern because a prompt and significant response by the international community appears to have stalled. The 1997 *Kyoto Agreement*, to reduce global greenhouse gas emissions required developed countries to cut emissions by 2012, while allowing developing countries to make individual commitments. It would have allowed for emission trading. The United States has not ratified the Treaty and recent indications suggest that US legislation to reduce CO<sub>2</sub> emissions from power plants will not receive key support. In Canada, many provincial governments (that are responsible for energy policy) remain uncertain of future policy directions. In Alberta, for example, increased power production from coal-fired plants is expected to raise emissions over the next decade to about 40% above the 1990 level.

A study of traditional ecological knowledge (Thorpe & Kadlun, 2000) known as *Tuktu and Nogak* (caribou and calf) has begun to document Inuit knowledge of the caribou. In this study, elders have also described the effects of climate change on caribou and other species, their distributions, land use and feeding patterns, population changes, the influence of ice conditions

on migration routes, behaviour, vegetation changes and numerous other characteristics of the environment in and around Bathurst Inlet. Again, the study has pointed to the disconnect in information transfer between youth and elders. At Bathurst Inlet, the *School of Tuktu* (Thorpe, 1998) has been used as an aid to record Inuit knowledge of caribou and also to involve youth through participation in an Elder-Youth camp. This and similar activities in other Aboriginal communities provide an important move to avoid the darkness of forgetting and the future exclusion of TK from sustainable development.

A recent example of northerners, including people from the WKSS area, taking action on external stresses may be seen in the *Whitehorse Declaration on Northern Climate Change* (Circumpolar Climate Change Summit and Exposition, 2001). In this declaration, experts take responsibility and seek to focus the attention of policy and decision-makers on key northern issues, and the need for effective actions – locally, regionally and globally. It reflects increasing concern, particularly among northern residents, at the rapidity of climate change and the extent to which it may affect sensitive Arctic and sub-Arctic environments.

*“Whereas we recognize that residents of the Circumpolar North are witnessing disturbing and severe climatic and ecological changes; and,*

*Whereas we recognize that this interdisciplinary issue requires an unprecedented level of collaboration by all nations and all sectors of their societies; and*

*Whereas we recognize that Northern residents need to take stronger measures to reduce their own greenhouse gas emissions, and we also recognize that, regardless of the success of these measures, the Circumpolar North will remain highly reliant upon global actions to reduce greenhouse gas emissions;*

*Therefore, we the undersigned participants at the Circumpolar Climate Change Summit, held in Whitehorse, Yukon, Canada, on March 19th to 21st, 2001, declare that the following actions need to be taken to address climate change and its impacts in the Circumpolar North:*

- 1. We must develop a strong northern message on the effects of climate change and present this message nationally and internationally;*
- 2. We must use traditional knowledge and improve our scientific capacity to understand climate change impacts on northern ecosystems, economies, cultures, traditions and communities;*
- 3. We must develop tools that will enable communities to better understand climate change, reduce their greenhouse gas emissions, and adapt to changing climatic and environmental conditions;*

4. *We must ensure that all new and existing policies, standards, regulations, legislation, and management agreements become consistent with the goal of reducing greenhouse gas emissions and our vulnerability to climate change;*
5. *We must establish effective incentives and remove the many barriers to improved energy efficiency and the widespread use of renewable energy; and,*
6. *We must ensure that all institutions, businesses, governments, families and individuals take far stronger measures to reduce greenhouse gas emissions.”*

The threat posed by atmospheric transport of pollutants is another major concern in the WKSS area, and there are two main issues associated with LRTAP. The first relates to mercury. While levels of many persistent organic contaminants are showing signs of decline in the WKSS area (or, at least, they are no longer showing a significant increase), levels of mercury may not be in decline. Mercury contamination is of most particular concern in some species of fish (such as Lake Trout and Walleye) which are an important traditional food for many Aboriginal people in the WKSS area. High levels of mercury are also present in seals and Beluga. Mercury contamination is spread through the processes of LRTAP and fuel combustion for power generation is one of the most important sources of emission. Mercury from coal and oil is released together with greenhouse gas emissions and, if CO<sub>2</sub> emissions continue to increase, it may be expected that concentrations of mercury will also increase. Control technology is not yet capable of providing sufficiently reduced levels of greenhouse gas and heavy metal emissions from the combustion of fossil fuels.

While persistent organic contaminants are not generally thought to be a health concern in the WKSS area (Papik, 1998), they provide a good example of the effectiveness of northern aboriginal interventions and lobbying. Studies undertaken as part of the first phase of the *Northern Contaminants Program* made a significant contribution to the *UN protocol on Long Range Transport of Pollutants* that was signed in Denmark in 1998. NCP findings have provided substantiation for the calls for action on international controls of contaminants. POPs and Heavy Metals Protocols under the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CRTAP) have been signed by 36 countries, including Canada, since June 1998. Over the period of ongoing negotiations, Aboriginal concerns and involvement have received significantly greater recognition (Fenge 1998; 2000). As noted by Fenge (2000):

*“Although few in number, Inuit and other indigenous peoples in the Arctic have influenced international negotiations towards a global convention on persistent organic pollutants (POPs) out of all proportion to their numbers through research, public education, and co-ordinated*

*advocacy and lobbying. This fact is important internationally, for what they have done in the global POPs process - to the benefit of all Canadians - can be repeated in other global environmental negotiations that address Arctic concerns such as climate change, ozone depletion, and perhaps even biodiversity conservation. In particular, the Canadian Federal government should learn an important lesson: northern indigenous peoples lobbying from their unassailable high moral ground can, in partnership with the federal agencies, achieve foreign policy objectives that Canada alone may not”.*

The NCP works closely with the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP). The goal of this cooperative program among the eight Arctic countries, Arctic Aboriginal organizations and a number of observer countries and organizations is to monitor and assess anthropogenic pollution in the circumpolar Arctic. The results of NCP projects represent the main Canadian contribution to AMAP, and those of NCP Phase I formed an integral part of the comprehensive AMAP Assessment Report: Arctic Pollution Issues, published in 1998.

In March 2003 the second Canadian Arctic Contaminants Assessment Report, reporting on research under phase 2 of the NCP, was published. Phase 2 results also made a substantial contribution to the second AMAP assessment reports published over the past three years.

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### **5.2.2. Environmental Management**

There are stresses associated with exploration and mining, transportation and waste management, and concerns are routinely raised at public hearings regarding effects of such activities on the environment. There are also legacies from past activities which remain to be addressed and conditions raised to current standards.

Environmental management and approaches to improving community well-being in the WKSS area are evolving as a result of a number of processes, notably negotiation and settlement of aboriginal claims, initiatives such as the NWT Cumulative Effects Assessment and Management Framework (CEAMF), the NWT Cumulative Impact Monitoring Program (CIMP), the Nunavut General Monitoring Program (NGMP), monitoring on the Coppermine River, and land use planning. The processes include establishment of co-management bodies for land use planning; permitting, assessing, reviewing and monitoring development proposals, and managing wildlife, water and protected areas. Legislation envisions cumulative impact monitoring



programs in the WKSS area and regular audits to evaluate cumulative effects of development and the effectiveness of institutions are included in the *Mackenzie Valley Resource Management Act* (MVRMA) passed in 1997 (MVRMA, 1997).

An overview of the various environmental management tools is provided in the following sections.

#### 5.2.2.1. Co-Management Boards

Co-management boards in the WKSS area are generally structured so that half of their membership are nominated by the government (combination of territorial and federal as appropriate) and the remaining half by claimant groups. In all cases the Minister (of DIAND) appoints the members and retains the right to approve, reject or send back the recommendations of a co-management body. However, the Minister must provide reasons where his decision varies from the recommendations of a board.

The appointment of Aboriginal chairs has raised the stature of co-management in many northern communities. It has certainly helped all parties to appreciate and work towards better ways of communicating and involving northern communities. Over time, a level of trust has begun to develop in many boards and this is seen to be an extremely valuable outcome (Morgan & Henry, 1996). For the most part, decisions reached by the co-management boards have been supported by the organizations represented and to this extent, the boards have achieved something more than an advisory capacity. It is also recognized that trust and respect is something hard to gain and easily lost. Also, several boards have requested that agencies keep the same people as their representatives, in part because of trust but also because of the process of cultural understanding that is evolving at the board level.

The Nunavut Wildlife Management Board was established in 1994 and is responsible for policy and management of wildlife throughout Nunavut, and for some species (*e. g.* caribou) there are specific management boards. Other co-management institutions include: the Nunavut Planning Commission that is responsible for planning and regulation of land use, the Nunavut Impact Review Board that is responsible for environmental assessment and review of projects in Nunavut, the Nunavut Water Board that is responsible for water use, and the Surface Rights Tribunal that deals with entry and compensation to holders of surface rights (NPC., 1997).

The MVRMA is intended to be the vehicle for establishing co-management boards throughout the NWT, with the exception of the Inuvialuit Settlement Area which pre-dates the Act. The MVRMA establishes co-management boards for land use planning, land and water management, and environmental assessment and review within settlement areas. The Act enables co-management boards to be established throughout the entire geographic area under the Act, and to cover activities in as yet unsettled areas and activities which may affect more than one settlement

area. To date, all claim areas except Akaitcho Treaty 8 have either nominated members or are in the process of selecting nominees.

Responsible management can only take place where information and an understanding of it are sufficient to make good decisions, and it can only be effective when it involves all of the interested parties; in the WKSS area, they include both Aboriginal and non-Aboriginal peoples. Across the North, there are many examples of evolving co-management (Berkes, 1994; Berkes *et al.*, 1991; Feit, 1988; Haugh, 1994; MacLachlan, 1994). They include resource management boards that issue licenses and set quotas, and many of these have strong representation from local trappers, hunters and outfitters associations (Gunn *et al.*, 1988). However, many of the present and future issues can not be resolved by one agency alone (even though it represents multiple interests).

#### ***5.2.2.2. Environmental and Cumulative Impacts; Assessment, Review and Monitoring***

Environmental assessment in the WKSS area has experienced a rapid evolution in the past few years. The MVRMA and the NLCA established approaches to land, water and environmental management that consider environmental, social, cultural and economic impacts (including cumulative impacts) of non-renewable resource development. These tools are seen as providing a foundation for ensuring that non-renewable resource development occurs in a way that promotes sustainable development.

Environmental assessment has moved from a regulatory process led by DIAND to a multi-stage process where proposals receive preliminary screening by regional land and water boards. If proposals meet certain criteria they are sent to impact review boards (MVEIRB and NIRB) for environmental assessment. The environmental assessment may recommend a full environmental review panel. Where projects are anticipated to have broader impacts (e.g., significant transboundary concerns), they may also require review under the *Canadian Environmental Assessment Act* (1995) or by the National Energy Board.

The importance of environmental monitoring has been made evident in key areas over the past three decades. Responses to the problems of acid rain, ozone depletion, climate change, deforestation, and a host of other global ecological issues would not have been possible without the long-term monitoring that alerted us to the existence of these serious problems in the first place. Meaningful social policy development is equally dependent upon accurate, long-term indicators.

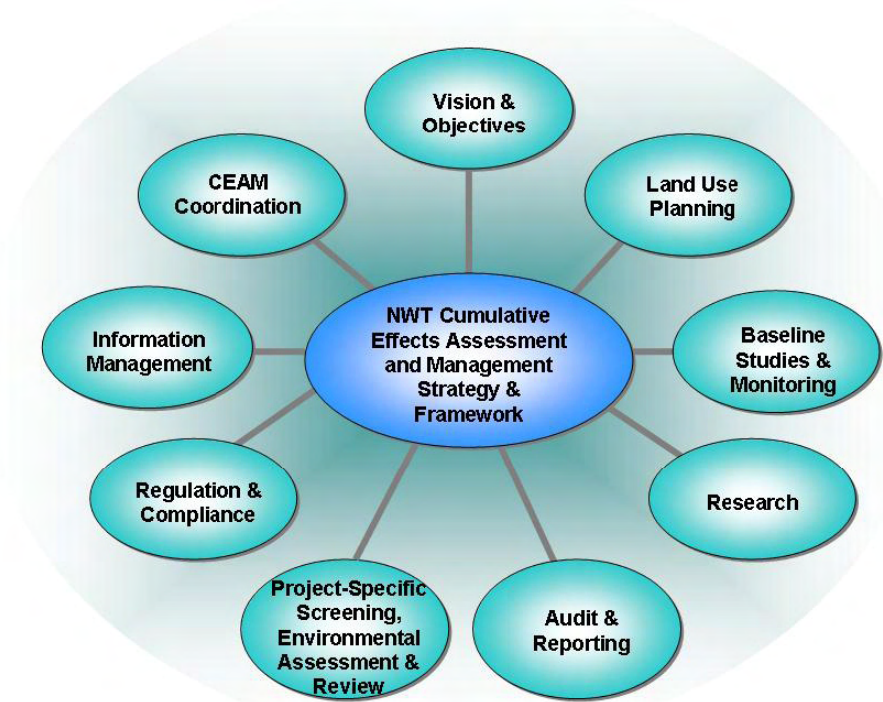
#### ***Cumulative Effects Assessment and Management Framework (CEAMF)***

Following the comprehensive study for the Diavik Diamonds Project, the Federal Ministers of Indian Affairs and Northern Development and the Environment initiated a process to develop the

NWT Cumulative Effects Assessment and Management Framework (CEAMF). The process was led by a Steering Committee made up of representatives from Aboriginal organizations, industry, environmental non-governmental organizations (ENGOS), the federal and territorial governments and the Mackenzie Valley Environmental Impact Review Board (MVEIRB). CEAMF uses a broad definition of ‘environment’, which includes social, cultural and economic aspects in addition to natural and biophysical, is used. The NWT CEAM Framework consists of nine components that capture the key functions necessary for CEAM and the principal linkages among them (NWT CEAM Steering Committee 2006). These components, listed below, are shown graphically in Figure 24.

- Vision and Objectives
- Project-Specific Screening, Environmental Assessment and Review
- Land Use Planning
- Regulation and Compliance
- Baseline Studies and Monitoring
- Information Management
- Research
- Coordination
- Audit and Reporting

**Figure 25 NWT Cumulative Effects Assessment and Management Framework**



Source: NWT CEAM Steering Committee. 2006. A Blueprint for Implementing the Cumulative Effects Assessment and Management Strategy and Framework in the NWT and its Regions. ([www.ceamf.ca](http://www.ceamf.ca))

A plan for implementing CEAMF in the NWT as a whole and throughout its regions was developed in April 2003 in a document entitled, “*A Blueprint for Implementing the Cumulative Effects Assessment and Management Strategy and Framework in the NWT and its Regions*”. The Blueprint is a ‘living document’ based on the Steering Committee’s assessment of the current state of the nine components of the CEAM Framework in the NWT (NWT CEAM Steering Committee 2006). It is designed to ensure that:

- The NWT’s regime for environmental and resource management is able to implement each component of the CEAM Framework;
- The institutions and decision-making processes responsible for each component of the CEAM Framework can complete their respective tasks effectively and efficiently; and
- The components of the CEAM Framework function as an integrated system.

In relation to the nine components of the CEAM Framework, the Blueprint sets out short- and long-term recommendations for achieving full implementation of CEAMF. In addition, it includes ‘regional plans of action’, ‘traditional knowledge’, and ‘community and organizational capacity development’ as elements that are essential for the implementation of the CEAM Framework as a whole. Additional information on the NWT CEAM Strategy and Framework and related initiatives and reports, including the Blueprint, is available at <http://www.ceamf.ca>. The original Blueprint has since been updated several times (NWT CEAM Steering Committee 2003, 2004 and 2005) following annual Gatherings where the status of the implementation of the Blueprint is reviewed (NWT CEAM Steering Committee 2006).

As identified above, regional plans of action have also been developed through the CEAM process. Of relevance to the WKSS area is the “*Regional Plan of Action for the Slave Geological Province*”. Developed in 2002, it contains a series of proposed recommendations and short-term actions focused specifically on that area of Nunavut and the NWT. The purpose of the Regional Plan of Action for the SGP is to make recommendations to decision-makers to facilitate the protection of ecological integrity, the building of sustainable communities (including social and economic dimensions), and responsible economic development within a sound environmental management framework (SGP Project Group 2002). In particular, the Regional Plan of Action is intended to facilitate:

- Mechanisms to make well-informed decisions about the environment and human activities, particularly in cases involving transboundary issues;
- Systematic and coordinated approaches to cumulative effects assessment and management;
- Common principles and links between environmental management processes including land use planning, land and water management, cumulative impact

- monitoring, and environmental audit; and
- Improved certainty, clarity, efficiency, transparency and accountability of processes, roles and responsibilities at all levels.

While the CEAM process, including the regional plan of action for the SGP, remains ongoing, there have been no significant advances with respect to full implementation and effectively assessing and managing cumulative impacts in the WKSS area.

### ***Cumulative Impact Monitoring Program (CIMP)***

The NWT Cumulative Impact Monitoring Program (CIMP) was developed as an initial response to the Government of Canada's responsibility to lead an environmental monitoring and assessment program as per the *Mackenzie Valley Resource Management Act*, the Gwich'in Comprehensive Claim, the Sahtu Land Claim Agreement, and the Tlicho Agreement. Based on these legislated requirements, the NWT CIMP must achieve the following:

- Evaluate trends in environmental quality, identify monitoring priorities and facilitate coordination among existing monitoring programs in the NWT;
- Build capacity for NWT communities to prepare, implement, and report on cumulative monitoring programs;
- Contribute to informed decisions regarding environmental resource management, economic development and land and water uses in the NWT; and
- Minimize duplication of public and private monitoring programs and enhance and encourage cooperation and coordination of efforts in a reduction of overall costs.

To ensure that decision-making on potential monitoring programs was inclusive of all groups, a CIMP Working Group was formed. The Working Group includes representation from all of the Land Claim groups (Inuvialuit, Gwich'in, Sahtu, Tlicho), the NWT Metis Nation, the North Slave Metis Alliance, the Dehcho First Nation, the Government of the Northwest Territories (GNWT) and the Government of Canada (as represented by the department of Indian and Northern Affairs Canada (INAC)). The Akaitcho were invited to attend, but have declined participation, although they receive all Working Group correspondence. Environment Canada, the Mackenzie Valley Environmental Impact Review Board (MVEIRB), and the federal Department of Fisheries and Oceans (DFO) participate as observers on the Working Group. A CIMP Secretariat, charged with managing the administrative functions of the program, is supported by INAC (SENES 2006b).

After conducting a series of public meetings, the Working Group developed a list of Valued Components (VCs) to guide the direction of the CIMP. Since 1999, the CIMP Working Group has funded a total of 54 environmental monitoring and capacity building initiatives. Furthermore,

the CIMP has produced a “State of Knowledge” report each year for the past three years that details the state of knowledge for each VC, incorporating information and initiatives that are taking place throughout the NWT.

Thus far, federal funding for the CIMP has been intermittent and provided on a yearly basis. The absence of long-term stable funding has hampered the design and implementation of a fully functional program. To address this issue, INAC recently submitted a Treasury Board Secretariat request for the full costs of implementing the program. If approved, this request would make \$3.1 million available to the CIMP (and NWT Environmental Audit) each year for five years.

### ***Nunavut General Monitoring Program (NGMP)***

The authors of the NLCA recognized the importance of general monitoring and intended that it be a cornerstone of the land use planning and environmental impact assessment processes in Nunavut (NPC 2005). Section 12.7.6 of the NLCA states that:

*There is a requirement for general monitoring to collect and analyse information on the long term state and health of the ecosystemic and socio-economic environment in the Nunavut Settlement Area. Government, in co-operation with the NPC, shall be responsible for developing a general monitoring plan and for directing and co-ordinating general monitoring and data collection. The NPC shall:*

- (a) in accordance with the plan, collate information and data provided by industry, government departments and agencies, amongst others;*
- (b) in accordance with the plan, report periodically on the ecosystemic and socio-economic environment of the Nunavut Settlement Area; and*
- (c) use the information collected under Sub-sections (a) and (b) to fulfill its existing responsibilities under Article 11.*

The requirement for government to develop the NGMP was reinforced in the Contract Relating to the Implementation of the Nunavut Final Agreement). That Contract requires that INAC, in cooperation with the NPC, shall:

- identify government agencies involved in monitoring and data collection;
- establish a process to coordinate monitoring and data collection by government agencies;
- review existing ecosystemic and socio-economic monitoring programs in the Nunavut Settlement Area;
- develop a general monitoring program;

- provide information and data collected by government to NPC for collating;
- direct and coordinate general monitoring and data collection.

The Nunavut Impact Review Board also recognises that “a monitoring program is a crucial component of CEA [Cumulative Effects Assessment] and in many ways the ultimate test of sustainability practices. Monitoring programs enable us to understand how we are doing and whether we are achieving the goals and objectives articulated earlier in the process.” (NPC 2005).

As a first step towards establishing a general monitoring program for Nunavut, INAC and the NPC jointly sponsored a workshop in Cambridge Bay in April, 1997. The workshop was attended by community representatives, government, industry, and the public (NPC 2005). Workshop participants concluded that:

- Nunavut communities have a great deal of TEK that must be incorporated into the monitoring program. Active community participation in information gathering and analysis will be critical to the success of the NGMP.
- Monitoring indicators should be selected based on simplicity, policy relevance, validity, currency, availability, affordability, and sensitivity to change.
- Monitoring indicators should be organized into four main categories:
  - (1) Physical environment, relating to air, land, water, and wildlife,
  - (2) Economic, relating to key sectors of the Nunavut economy, including traditional land-based activities,
  - (3) Community life, relating to the social reality of Nunavut communities, and
  - (4) Culture and identity, indicators of traditional lifestyles.

Unfortunately, in the eight years since that workshop, INAC has made no progress whatsoever in meeting its NLCA implementation obligation to establish the NGMP. The Governments of Canada and Nunavut accepted an additional legal duty to create the NGMP when they approved two land use plans in 2000 requiring that the Program be implemented, yet nothing has been done in the years since that time to honour these commitments.

The draft West Kitikmeot Regional Land Use Plan (NPC 2005) states the following:

*Therefore, this plan provides that all steps necessary shall be taken to move the development of the NGMP forward:*

- (1) immediately upon approval of this plan;*
- (2) in a public multi-planning partner forum;*
- (3) including measurable cumulative effects indicators and thresholds;*
- (4) incorporating credible models for identifying the carrying capacity of*

*ecosystems, taking into account Nunavummiut values related to the limits of acceptable change.*

The lack of a general monitoring program has had serious negative consequences -- in the West Kitikmeot and throughout Nunavut -- for the development and monitoring of land use plans, for the assessment of cumulative effects, and for state of the environment reporting.

### ***Land Use Planning***

Land use planning is a central tool in managing any public or private land area. Land use planning can do many things, but in general it sets out a future vision for the protection, conservation and development of land and resources. Community-based land use plans allow institutions of public government to identify, conserve and protect areas of special values and resources. The areas protected could be important for resource or traditional use, environmental protection, social and spiritual significance, or a combination thereof (SENES 2005).

Fundamentally, there are five criteria that drive the allocation of public lands into different use categories or zones of activities. These are: physical feasibility and biological sustainability; economic efficiency; distributional equity; social and cultural acceptability; and operational practicality or administrative feasibility. The relative importance of these criteria varies significantly from jurisdiction to jurisdiction and planning decisions are often driven by the fundamental values of the particular area.

Land use plans strive to integrate opportunities for responsible economic development within a context of wise stewardship and protection of natural resources and the environment. They can also identify where development can occur, what types of activities should be allowed and at what level of development intensity. Public planning systems can range from simple delineation between protected areas (emphasizing protection) and general use land designations (where all uses are allowed subject to other forms of environmental approvals) to systems in which there is a more comprehensive suite of zones, guidelines and restricted use areas.

Approved land use plans provide information to the public, industry and government on which areas can be developed, which cannot be developed or which can be developed subject to certain conditions and other processes. The existence of land use plans can increase the public's comfort regarding the protection of environmentally significant features/areas and provides industry information on where it can operate.

Regional land use planning in the NWT has been in progress since 1984, when the Basis of Agreement on Northern Land Use Planning was signed by the federal and territorial governments, with the participation of the Aboriginal organizations which existed at the time.



The MVRMA, enacted in 1998, also established land use planning requirements (SENES 2005). In Nunavut, Section 11.4.1 of the NLCA directs the NPC to establish broad planning policies, objectives and goals for the Nunavut Settlement Area and to develop land use plans that guide and direct resource use and development in the Nunavut Settlement Area. The primary purpose of land use planning under the NLCA is “to protect and promote the existing and future well being of those persons ordinarily resident and communities of the Nunavut Settlement Area taking into account the interests of all Canadians.” (NPC 2005).

Despite legislated land use planning requirements, little progress has been made in developing land use plans in the WKSS area. The only land use plan developed for the region to date is the West Kitikmeot Regional Land Use Plan (NPC 2005), and it remains only in draft form and it is not clear when it will be approved.

The lack of land use plans in WKSS area is adding increased complexity and uncertainty to the regulatory processes for resource management and environmental protection.

### ***Project-specific Oversight Agencies***

In addition to the monitoring and land use planning requirements discussed above, a number of other, non-legislated organizations have been created in the NWT in response to diamond mining in the WKSS area. Subsequent to the BHP Billiton Diamonds Inc. Panel Review an environmental agreement was negotiated between the Federal Government, the GNWT, BHP Billiton Diamonds Inc. and aboriginal organizations from the WKSS area. Among other things, it established an Independent Environmental Monitoring Agency (IEMA) as a watchdog over the environmental activities and reporting by the proponent. The IEMA monitors BHP Billiton Diamonds Inc.’s activities and reviews environmental management plans and reporting, but does not collect primary data. A similar agreement has been negotiated with Diavik, establishing an Environmental Monitoring Advisory Board (EMAB), and more recently, a similar agency for the De Beers Snap Lake diamond mine. These organizations are set up as registered societies funded by the proponents and managed by nominees of the signatories to the agreements. Monitoring activities do not extend to social or economic conditions although socio-economic monitoring is the subject of separate socio-economic agreements.

### **5.2.3. Industry-Aboriginal Agreements**

A variety of arrangements and agreements can be included within the framework of an Impact and Benefit Agreement (IBA). The term is most commonly applied to project-specific, private agreements between an Aboriginal community(s) and a resource development company. IBAs generally provide opportunities for a community to participate and receive economic benefits from a project, including participation in the management, monitoring and mitigation of social, cultural, economic and environmental impacts (Alex Kerr Compass Consult. & Michael Doggett

and Assocs, 2000a).

Economic benefits, capacity building, environmental protection, and maintenance of social and cultural fabric are required for effective participation of Aboriginal people in non-renewable resource development. In their review of IBAs as tools for securing Aboriginal participation in non-renewable resource development, Alex Kerr Compass Consult. & Michael Doggett and Assocs (2000a) concluded that IBAs are one tool for securing effective participation. IBAs provide economic benefits to Aboriginal communities through jobs and employment, business opportunities, and financial benefits (cash payments, profit sharing) and can contribute to local economic diversification. In these regards, the first benefit agreement (Ulu mine project) entered into by Nunavut (represented by the Kitikmeot Inuit Association) was particularly important because it set precedent on four principles (O'Reilly & Eacott, 2000):

*“Major developments on Inuit-owned lands would add “value” to affected community/regional economies.*

*Impact benefit agreements would be considered a strategic and long term economic development tool to help build corporate capacity for Inuit.*

*Impact benefit agreements should be considered an instrument for fostering good will and should provide the foundation for Inuit and developers to “work together” from project inception, through production, and finally to abandonment.*

*An Inuit content factor in considering and evaluating tenders for mine services meant there would be strong incentive for all potential contractors to maximize Inuit participation.”*

However, concerns have been raised about the use of IBAs as a mechanism for support of environmental monitoring and abandonment (IEMA., 1999; 2000). Also, IBAs may not provide the best mechanism for capacity building and environmental, social and cultural impacts monitoring and mitigation. Others tools to secure Aboriginal participation include tenure instruments (e. g. surface leases), regional agreements, and cooperative, multi-stakeholder initiatives.

#### **5.2.4. Round Tables**

In Canada the concept of the “Round Table” has been used as a vehicle to move toward sustainable development. A Round Table involves all sectors of the economy in developing ways to achieve sustainable development. At present neither territory has a round table in place, although the GNWT’s *Sustainable Development Policy* does envision an NWT Round Table.

The National Round Table on Environment and Economy released a report in 2001 of its Aboriginal Communities and Non-Renewable Resource Development Task Force which

includes recommendations specific to the North and to the SGP ([http://www.nrtee-trnee.ca/Publications/HTML/SOD\\_Aboriginal\\_E.htm](http://www.nrtee-trnee.ca/Publications/HTML/SOD_Aboriginal_E.htm)). The recommendations dealt specifically with cumulative effects assessment and management, sustainable aboriginal communities, and capacity building for aboriginal communities.

#### **5.2.5. Partnerships**

Partnerships are formal relationships that are formed for mutual benefit. Partnerships are formed for a variety of reasons including sharing responsibility without significantly increasing costs, accessing additional resources and increasing opportunities to address specific needs. Partnerships are the new way of doing business and addressing environmental and socio-economic issues in the WKSS area. Partnerships have been formed to respond to healing, disability, labour force development, and early childhood issues. Partnerships have involved public and Aboriginal governments, non government or voluntary organizations, and individuals. Partners share authority, risk, responsibility, accountability, investment and benefits. While more groups are entering into partnerships to achieve specific purposes, the lack of formal agreements, and different expectations and motivations have terminated many partnerships before any results could be achieved. Healthy, successful partnerships offer great potential for WKSS area communities, particularly with respect to deriving sustainable sociocultural solutions.

The WKSSS, itself, has been a Partnership negotiated entirely separately from the regulatory process to collect and provide information to decision-makers is an essential ingredient for achieving sustainable development on the environmental and socioeconomic cumulative effects of development in the WKSS area.

#### **5.2.6. Community Health and Well-Being**

Rapid and profound societal changes have occurred in the WKSS area over the past century. Societal change has stemmed from epidemics, acculturative stress, colonization, breakdown of the traditional family unit, the changing roles of men and women and more recently, industrialization. Many of these changes have undermined the security, health, well-being and culture of Aboriginal and other northern peoples. Institutions, structures and systems rooted in European traditions have stymied, frustrated, contradicted, diluted and, or, weakened Aboriginal cultures and communities. The social, economic, cultural and political characteristics of most WKSS area communities today are linked to this legacy. Acculturation has given rise to many effects and one of these has been the loss of the intergenerational transfer of traditional ecological knowledge that naturally occurred in the practice of traditional activities. There are concerns that youth lack connection with and respect for the land (Marlowe *et al.*, 2000; YDFN, 2005; Lutselk'e Dene First Nation, 2006; DCAB, 2006).

Responses to a legacy of poor socio-economic conditions have most often been project-specific and short-term in nature. Fragmented approaches and, or, resources (*e. g.* initiatives, programs,

services, funding) rather than long-term, holistic socio-economic development processes and supports have made few inroads into supporting healthy and sustainable communities. At the same time, communities in the WKSS area particularly Aboriginal communities have demonstrated a resiliency and adaptability that has enabled segments of the community to cope with and manage change (ITK, 2006, Duhaime *et al.*, 2004). Resiliency is illustrated in the continuing strength of Aboriginal languages in WKSS communities and a reverence from the land, subsistence traditions and the sense of identity that emanate from the natural environment (DCAB, 2006).

The continuation of a mixed economy particularly in smaller WKSS communities despite global and local pressures to embrace a market or wage economy, illustrates the desire for choice and diversity that accompany this type of economy. Respecting choices and diversity is challenging given the stresses associated with balancing and reconciling one set of values in a wage-earning society and another set of values tied to individual and, or, group use of natural resources. These challenges have contributed to numerous social problems in northern communities (George & Preston, 1987; Scott, 1992; Stephenson, 1991). At the same time, studies suggest that underlying these challenges is the capacity for resiliency and adaptability that have sustained Aboriginal peoples for centuries. Nevertheless, understanding and measuring the sensitivity of subsistence-based economies to change is problematic, *“precisely because subsistence is a flexible and resilient system. Its participants can and do adapt to change, whether adverse or beneficial. ...The better subsistence is understood and modelled, the more precisely these limits can be specified. The first need is an accurate model of the mixed, subsistence-based economy, and the second is a reliable set of indicators.”*(Usher *et al.*, 2003)

#### 5.2.6.1. Human Health

Human health has been identified as a concern in many parts of northern Canada, and particularly in relation to the value of traditional foods and exposure to persistent organic contaminants (Shearer, 1998). DIAND responded to concerns about widespread contamination of the northern ecosystem and risks to human health with the formation of an inter-governmental technical committee in 1985. The committee expanded to include northern Aboriginal partners in 1989, and developed a five year research and monitoring framework known as the *Northern Contaminants Program’s Strategic Action Plan*. The *Northern Contaminants Program* (NCP) became a part of the *Green Plan* of the Federal Government, and a component of the *Canadian Arctic Environmental Strategy* in 1991 (Jensen *et al.*, 1987). Government and Aboriginal partners have continued to manage the program and funding for this work. This program has been the principal source of support for most of the recent health-related northern environmental research.

Studies (under NCP) on benefit and risk associated with diets of traditional foods will be completed, soon, in the West Kitikmeot region (Kuhnlein *et al.*, 1999) and these, and those

already completed in many Dene communities, are expected to reinforce existing views that strongly support continued use of traditional foods as a highly valued source of nutrition. Throughout the north, special attention is being given to establishing what, if any, relationships exist between persistent organic contaminants and immune system effects such as child infections, and neural behaviour effects in children (Anon., 2000a). Fortunately, few of these effects are likely to be of major concern to Aboriginal communities in the western Arctic and sub-Arctic, where levels of persistent organic contaminants are generally low (Papik, 1998), although results should provide further insight into contaminant problems due to external influence.

Both government and Aboriginal communities have recognized the importance of communicating information from the *Northern Contaminants Program*, especially as it may create better appreciation of the potential health effects of contaminants. Contributions have been made through establishment of a contaminants curriculum in the high and junior-high school programs (Carpenter *et al.*, 1997), and through opportunities to provide information and feedback in Dene and Inuit communities (Mills, 1997; Mills *et al.*, 1999; Usher *et al.*, 1999). The need for contaminant and, or, health information and opportunities for questions and comments will continue to exist indefinitely and these initiatives provide an important means of developing understanding and confidence in northern health studies.

#### 5.2.6.2. Community Wellness

Health and well-being are generally understood as the state of being free from ailment or malaise. Good health and well-being denotes satisfaction, happiness, security and comfort. Community well-being is generally accepted as a reflection of physical and mental well-being among people and their communities. The GNWT identifies indicators of wellness as a strong sense of community, family life, culture and tradition; an emphasis on personal dignity, a state of well being; and zero tolerance for violence. In Aboriginal communities in the WKSS area, a more holistic view links individual and community wellness to the health and well-being of the environment, societal relationships, and cultural and spiritual values. For example, in Lutselk'e, community health is viewed as a way of life. Regardless of definition, community health and well-being are essential elements of sustainable communities.

Community wellness can be expressed through a variety of actions and behaviours. These include: strong generational bonding (elders and youth) and successful parenting; acceptance of the legitimacy or authority of traditional and cultural ways of being and doing (e. g. healing circles, community justice); acceptance of personal responsibility and use of healing processes where needed; participation and, or, contribution to collective good (e. g. individual sense of place in a group), gender parity, and family as a basic human unit. In Lutselk'e, wellness is expressed in large part by self-government, healing and cultural preservation activities as they reflect the community's desire for self-determination, addressing social issues and keeping the

Chipewyan culture and language strong (Parlee & Lutsel K'e First Nation, 1997).

Voluntary participation to help others, advance a cause or to help out in the community is an indicator of social cohesion and wellness (NWT Health and Social Services, 2005; Little et al., 2005; Imagine Canada and SC, 2004). People in the NWT and Nunavut have the highest informal rates of volunteering in Canada, building on traditions of helping and sharing with each other. Northerners also volunteer in more formal ways through groups and organizations. Volunteering engages individuals in their communities, builds social and cultural ties and fosters citizenship. Volunteering is a way to counter the effects for example, of youth alienation and Aboriginal language loss, and to foster opportunities for elders and youth to make healthy connections, concerns of WKSS communities monitoring the effects of industrial employment on social and economic security (DCAB, 2006). Engaging individuals and families in their communities is also a way to foster a sense of identity and place that is derived from participation in language and cultural practices. Industrial employment can effect volunteering and the benefits derived from it. Monitoring studies among Yellowknives Dene First Nation (2005)) and Lutselk'e Dene First Nation (2006) mine workers show that industrial employment reduces attendance at community cultural events (e.g. drumming, feasts, funerals) and family events.

The wide-ranging indicators or expressions of community wellness suggest that not all solutions fall within the 'powers' of an affected community. This is particularly true given the expanding involvement of global, multi-national corporations in the WKSS area. More often than not, solutions can only evolve as a result of constructive solution-making undertaken jointly by both Aboriginal and non-Aboriginal people. However, communities themselves must agree on those elements or ways of life that are important to them, and work together to achieve sustainable responses to those that are unacceptable or indicate lack of wellness. Support to help communities deal with complex, interrelated and deep-rooted wellness issues must be holistic, coherent, and long term in approach. Decades of top-down directives and funding for health and well-being have had little if any effect on rebuilding individual and community wellness in the WKSS area.

Social cohesion in northern communities requires a balance of two systems of solidarity: organic and mechanical (Duhaime et al., 2004). Organic solidarity is structured through access to formal economic, community and government institutions and the social ties developed through participation in the labour force, political involvement and access to schools, public housing, recreation, employment insurance. Mechanical solidarity is structured through access to community and/or family-based relations strengthened through subsistence harvesting activities, sharing harvested food, helping others, and coming together as a community to celebrate and mourn. When these two systems are in balance (i.e. when individuals have access to both forms of solidarity and when the systems are not working against each other), the society remains

relatively stable and can endure stress caused by economic recession, social deviance, trauma, or other factors. This research suggests that social inclusion can be measured through analysis of six indices – the presence of social capital, demographic stability, social inclusion, economic inclusion, community quality of life, and individual quality of life.

### **5.2.7. Human Capacity**

WKSS area communities lack adequate numbers of people with the skills, knowledge and, or specialized expertise to respond to the wide range of internal and external opportunities and demands that must be confronted daily. Lack of human capacity is a challenge for all sectors of the northern economy, in large and small communities, and in Aboriginal and non-Aboriginal communities. The challenges are greatest for those segments of WKSS society that may have limited resources or are perceived to have less value in society (Stephen, 2006). Lack of human capacity severely limits the ability of WKSS area residents to actively and knowledgeably participate in political, economic, social or environmental decision-making and take control of local affairs. For example, lack of capacity in WKSS area communities limits the extent to which residents can participate in technical processes and decision-making for example, with respect to the pace and scale of industrial developments, understand risks, monitor and assess impacts on humans and the environment, and, or, maximize opportunities and benefits. Although structures and mechanisms including self-government and environmental organizations are in place in WKSS communities to support participation in a broad range of decisions, lack of human capacity often limits the extent to which these structures can benefit and support the sustainability of local communities.

Building capacity or developing human potential at the community level is seen by northerners as “...a *fundamental prerequisite to deal with issues facing communities today*” (GeoNorth, 2000). Low literacy and education levels and a lack of skills and training (including leadership training) create barriers to building capacity in WKSS area communities (Economic Strategy Panel, 2000; GeoNorth, 2000; Lutra, 2000a). Health and wellness issues (e. g. alcohol abuse) affect peoples’ ability to benefit from education, training and employment opportunities (Dogrib Community Services Board, 1999; Economic Strategy Panel, 2000; DCAB, 2006).

The fragmentation or lack of resources to build and support capacity (e.g. programs, services, funding) creates stress within WKSS area communities. Building capacity requires a coordinated, holistic, community-based approach. Communities, Aboriginal organizations and all levels of government and industry need to be partners in building processes and mechanisms that build capacity. There is a need to assess progress and document what works, to share information with other communities and to increase understanding (GeoNorth, 2000). Finally, there is a need to engender community ownership and involvement in solutions and take pride in supporting each other and healthy outcomes (ITK, 2006).

## 6.0 INFORMATION NEEDS

### 6.1. Background

The WKSSS was set up to collect and provide information that would assist sustainable development in the WKSS area. The WKSSS is a partnership of aboriginal, co-management and environmental organizations, government and industry that finished an initial five-year research program in 2001. A comprehensive consultation process took place among the WKSSS partners regarding priority issues of concern to them. This consultation included two major workshops and ongoing meetings of the key partners during 1995. The discussions on research priorities led to a major workshop in February 1996 to develop a research strategy for the WKSSS (WKSSS, 1996). The workshop produced a list of 70 research priorities ranging from general areas of research such as *the impact of local and regional development on communities* to more specific topics such as *baseline information on Grizzly Bear*.

Since 2001 the WKSSS has continued to fund several key projects during the interim period until regional monitoring systems are in place. More than twenty reports have been funded, using both traditional and scientific research. Topics have included caribou and other wildlife, community health, vegetation and water quality.

To date the WKSS reports have provided an information base to be used in examining the long and short-term effects of development in the region. The Traditional Knowledge and Scientific Research projects funded by WKSS are listed below, and are all available via the website: <http://www.wkss.nt.ca>.

#### 6.1.1 Traditional Knowledge Research

##### Habitat

- Traditional Ecological Knowledge Research in the Kache Tse Study Region (Lutsel K'e Dene First Nation)
- Habitat of Dogrib Traditional Territory: Place Names as Indicators of Biogeographical Knowledge (Dogrib Treaty 11 Council)

##### Community-Based Monitoring

- Ni hat'ni - Watching the Land: Results and Implications of 2002-2003 and 2003-2005 Monitoring Activities in the Traditional Territory of the Lutsel K'e Denesoline (Lutsel K'e Dene First Nation)
- Final Report: Community Based Monitoring (Lutsel K'e Dene First Nation)
- Traditional Knowledge Study on Community Health (Lutsel K'e Dene First Nation)
- A Community-Based Monitoring System in the Slave Geological Province (Lutsel K'e Dene First Nation)



### Caribou

- Traditional Knowledge on the Relationship between Caribou Migration Patterns and the State of Caribou Habitat (Dogrib Treaty 11 Council)
- Tuktu and Nogak Project - Inuit Knowledge about Wildlife in Bathurst Inlet: Focus on Caribou and Calving Areas (Simon Fraser University and the Tuktu and Nogak Board)

## **6.1.2 Scientific Research**

### Habitat

- Habitat/Vegetation Classification for the West Kitikmeot/Slave Study Region (Northwest Territories Centre for Remote Sensing)
- Esker Habitat Studies in the Slave Geological Province (GNWT/DIAND)
  - Esker Habitat Characteristics and Traditional Use Study in the SGP

### Water

- Investigation of Aquatic Impacts of On-Ice Exploratory Diamond Drilling
- Reading Water Quality Record in West Kitikmeot/Slave Sediment (DIAND)

### Caribou

- An Estimate of Breeding Females in the Bathurst Herd of Barren Ground Caribou, June 2003 (GNWT/Integrated Ecological Research)
- Bathurst Caribou Calving Ground Studies (University of Alaska, GNWT, Canadian Wildlife Service)
  - Influence Of Nutrition And Human Activity On Calving Ground Location
  - Prevalence and Intensity of Gastro-intestinal Nematode Parasitism in the Bathurst Caribou Herd, 1998-99
- Seasonal Movements of the Bathurst Caribou Herd (GNWT)
- Summer Behaviour of Bathurst Caribou Herd (GNWT)
  - Summer Behaviour of Bathurst Caribou at Mine Sites and Response of Caribou to Fencing and Plastic Deflectors
  - Effect of Gravel Road and Tailing Pond Dust on Tundra Plant Communities near Lupin Mine, NWT

### Moose

- Survey of Moose Abundance in the Boreal Forest around Yellowknife, Northwest Territories (GNWT) Grizzly Bear
- Population Ecology of Grizzly Bears in the Slave Geological Province (University of Saskatchewan, GNWT)
  - Spatial Organization and Habitat Selection Patterns of Barren ground Grizzly Bears
  - Grizzly Bear (*Ursus Arctos*) Studies in the Northwest Territories: Nutritional Component

### Wolverine

- Wolverine Ecology, Distribution and Productivity in a Tundra Environment (GNWT)

### Wolves

- Esker Habitat Studies in the Slave Geological Province (GNWT, DIAND)
  - o Analysis of Esker Use by Wolves Denning in the Central Arctic, NWT

## **6.2. Collection and Use of Information**

The seeking of knowledge for its own sake creates an unending demand for information and one of the first questions that must be asked is what information is essential; thus, drawing attention to the concern that is to be addressed. Stress and effect matrices (or interactive matrices) are a valuable means of site-specific environmental impact assessment. They have also been used to characterize gaps in non-site-specific knowledge that are applicable to more general decision-making (CEAA., 1996; Geonorth & Axys Environ. Consult., 1997; WKSS., 1996; 1997).

If information is to be collected efficiently, the questions or concerns that are to be addressed must be clearly framed, first. Since it is not intended to frame a range of questions within this report, information gaps can be considered only in relatively broad terms. No attempt is made to suggest who should gather information. For example, TK may be able to contribute significantly to an overall understanding of the ecosystem and environment of the WKSS area, but this report can do little more than encourage such input. How information is collected is equally important. Broadly, there are two ways of looking at gathering information and, in general, use is made of whatever information is available.

- Collecting a range of generally standardized information that can be drawn upon in response to several different user needs (*e. g.* monitoring information).
- Collecting information that is specific to some requirement (*e. g.* survey information).

Much information already exists in the form of maps, aerial photographs and satellite imagery that could be used to address some of the gaps in knowledge identified by the WKSS. An increasing quantity of one-time and site-specific information is also being accumulated, especially in relation to proposed mineral developments in the WKSS area. In addition, a substantial body of environmental knowledge already exists in many other parts of Canada, much of which is closely applicable to the WKSS area. For example, water quality requirements for several key species of fish (*e. g.* Lake Trout) are known. Contaminant concentrations that are likely to be critical for many forms of wildlife are known. Guidelines have been established for human consumption of many country foods. Also, although understandings about long term exposure to low levels of contamination are less well established, several ongoing programs in wildlife, fisheries and human health are directed at key issues.

Most information needs that apply to the WKSS area fall into one of three general types: baseline information (covering any topic where little or no information presently exists), bridging information (building links between existing sets of information that are often very different and of only limited use), and trend information (continuing collection of data to show change over time). The use of meta data systems to record what forms of information are available and the use of geographic information systems to locate such information would make it easier for all users to search for information and to trace where it is stored. If such systems were available in the WKSS area, they would be very useful. Once implemented and fully operational it is expected that the CIMP and NGMP initiatives will contribute significantly to this information needs gap.

### **6.3. Socio-Economic Information**

Profound change continues to be a main characteristic of WKSS area communities. As discussed, the pace and extent of change contributes to stress effects that have both positive and negative outcomes. Some information is collected on these outcomes as a result of socio-economic monitoring agreements between government and the owner/operators of diamond mines in the WKSS area. In addition, some Aboriginal communities in the WKSS are undertaking their own monitoring activities and generating information about the changes taking place in their communities. While social, cultural and economic information about human populations is available, there are gaps in understanding of the effects of changes in the northern ecosystem for human populations. These gaps are exacerbated by a lack of information and, or analysis of the effects of change for various segments of the population given the lack of uniformity of effects. Gaps in understanding also exist as a result of limited analysis of the interaction of various socio-economic determinants. For example, analytical functions associated with socio-economic monitoring in the WKSS do not investigate linkages between alcohol use and participation in subsistence activities or family violence.

This report points to very troubling economic and social circumstances in many WKSS communities in the NWT. ‘Communities and Diamonds reports’ over a seven-year period indicate that a substantial number of people in WKSS communities in the NWT continue to face difficulties achieving basic social and economic security (DHSS *et. al.*, 2000, 2001, 2002, 2003, 2004, 2005, 2006). These trends are disturbing given emerging data that show an industrial workforce turning away from subsistence harvesting activities even though these activities and resources are a mainstay of local households. Lack of similar monitoring reports for WKSS communities in Nunavut limit any understanding of trends among Inuit populations. This is a significant gap in the state of knowledge in the WKSS.

This report also identifies new and disturbing social and economic behaviours emerging in the WKSS area. Local media reports identify the most visible of these behaviours as: gambling,

prostitution, organized illicit drug activity associated with highly addictive and dangerous drugs, homelessness and youth crime. These behaviours pose considerable risks to human health and well-being but little research exists to understand the reasons for these rising trends. No evidence exists for example as to whether rapid industrialization of the WKSS is related to these behaviours.

Monitoring and understanding of the socio-economic circumstances of some WKSS area communities continues to be hampered by incomplete baseline data. This problem is particularly acute when endeavouring to understand the circumstances in the small WKSS communities of Bathurst Inlet and Umingmaktuk in Nunavut, and Dettah and Ndilo in the NWT. Census Canada currently does not collect data for the latter three communities. It is noted that recent socio-economic monitoring of industrial employment, particularly associated with the Diavik Diamond Mine, on the communities of Dettah and Ndilo provides a glimpse of socio-economic circumstances in these communities (YKDFN, 2005). While this recent monitoring report provides some understanding of the impacts of change, the report is limited because it does not distinguish circumstances in each of the two communities.

In recent years, as a result of Aboriginal land claim agreements and the assertion of Aboriginal land and resource rights, more and more communities and, or, regions have entered into impact benefit and other formal agreements to ensure that benefits accrue to them from industrial developments. The literature (IWGMI, 1990-1996; Little *et al.*, 1994; ITK, 2006) seems to indicate that a great deal of faith is placed in these agreements. We know so little about the effectiveness of these “tools”. For example, government implementation of land claim agreements may be evaluated but Aboriginal implementation is not. Impact benefit agreements are private, so opportunities to understand whether these are effective don't exist. The experience of some partnerships has been documented but lessons learned or experiences are not well known. Best practices documentation is needed. Little is known about the extent to which these agreements are meeting expectations and, or, fulfilling agreed upon requirements. Questions relate to how Aboriginal communities can most appropriately participate in and benefit from development, and how best to ensure that benefits are shared equitably within communities. This knowledge will be important to ensure the health of the WKSS area people and their environment.

One of the objectives of this report was to present the results of TK research as well as to integrate it with scientific knowledge where possible. However, compared to scientific research, very little TK research has been done within the WKSS area. As stated early in the report, this is an emerging field of study. Therefore, it is not surprising that there is little information available that presents the current state of knowledge of the inhabitants of the area. Traditional knowledge has the potential to contribute information and understanding of almost every aspect of life (including the social, cultural, health and well-being of people) and the environment of the

WKSS area.

### **6.3.1. Traditional Economy**

The relative importance of traditional economic activities varies among households and communities in the WKSS area. There have been efforts in the last few decades to understand the role of the traditional economy within the context of overall socio-economic change. But, there is a lack of current documentation about the relationship of harvesting activities to the economic security of WKSS area communities at the beginning of the 21<sup>st</sup> century. Assessment of existing information and needs in relation to harvesting and changes in harvesting patterns (and success) and consumption would provide better appreciation of the role of the traditional economy. The relationships between harvesting, consumption and community health are clearly important. Any changes, such as a shift from subsistence to recreational hunting, need to be monitored and assessed, particularly as they may be affected by employment and development. Some studies initiated under the *Northern Contaminants Program* and some of the studies sponsored by the WKSSS (WKSSS., 1997) are contributing to a better understanding of traditional economies in the WKSS area (Anon., 2000a; Dewailly *et al.*, 1999; Jensen *et al.*, 1997; Kuhnlein *et al.*, 1999; Marlowe *et al.*, 2000; Parlee *et al.*, 2000) but they present only a partial “picture”. From information presently available, many similarities seem to exist between traditional economies in the western Canadian Arctic and those of Cree and Inuit communities, further to the east (McDonald *et al.*, 1997; Sly, 1995).

### **6.3.2. Social and Economic Benefits and Dis-benefits**

Health Canada contends that income and social status are thought to be the most important determinants of health (1999). There are three main reasons for this statement: 1) people at each level of the income scale are healthier and live longer than those at the level below; 2) countries with evenly distributed incomes have healthier populations than those with gaps between the rich and the poor; and 3) family income directly influences children’s physical and mental health, cognitive and social development, and academic achievement. For many decades, the benefits from economic development activities in the WKSS area have flowed mainly to non-Aboriginal people and to non-residents in the form of employment, higher incomes and status. It has been the view of many Aboriginal people that only dis-benefits such as alienation from and, or, harm to lands and animals, have flowed from economic development. These views were expressed for example in a study of the impacts of hydroelectric development on the Denesoline of Lutselk’e (Beilawski, 1993). The study revealed few if any benefits but several dis-benefits including impacts to traditional travel routes, and to the subsistence economy through changes to the habitats of game waterfowl and fur bearers. The study also raised safety concerns about the effects of changing ice conditions in flooded areas.

Since the 1970's, Aboriginal people in the WKSS area and elsewhere in the NWT and Nunavut have worked to ensure dis-benefits from economic, social and political developments are minimized and, or, mitigated and benefits maximized. Land claim and self-government

legislation, impact and benefit agreements with industry, monitoring and research are tools that assist communities and governments to management economic development and derive benefit from these activities. Lessons from the impacts of previous development activities provide a useful basis for negotiating benefits and minimizing dis-benefits. For instance, a study of the impacts of uranium mining (Dogrib Renewable Resources Committee and Dogrib Treaty 11 Council, 1997) provided information to enable the region to negotiate and implement more beneficial arrangements with diamond mines operating on Tli Cho lands.

In the 21<sup>st</sup> century where global, multi-national corporations play significant roles in economic development in the WKSS, it is challenging for small populations and local/regional authorities to influence and maximize local benefits and minimize dis-benefits from economic development in the WKSS area. Despite access to more and more influential tools than in the past, WKSS communities like others in the NWT face challenges engaging local citizens and governments in monitoring activities or taking action to correct negative impacts including those revealed in monitoring activities. Statistical monitoring reports produced by Aboriginal communities are evidence of this (DCAB, 2006). Further challenges are created by seemingly disparate and unconnected discussion, analysis and, or follow up on obvious dis-benefits of economic developments (DHSS *et al.*, 2006).

## **6.4. Physical and Environmental Information**

There are close relations between many of the knowledge gaps associated with each of the following sections, and a substantial amount of overlap exists. As noted in the previous section, there is also great potential for TK to contribute to virtually every aspect of environmental understanding. Studies conducted in other parts of the NWT such as the *Traditional Dene Environmental Knowledge Project* undertaken by the Dene Cultural Institute (Johnson & Ruttan, 1993) and in eastern Nunavut (McDonald *et al.*, 1995; 1997; Arragutainaq *et al.*, 1995) provide numerous examples of detailed knowledge of the environment that Aboriginal people possess and which will be of benefit to policy making. Other studies, relating to caribou, traditional territory and biogeographic knowledge, and community environment are currently ongoing in the WKSS area (Legat *et al.*, 2000; Marlowe *et al.*, 2000; Parlee *et al.*, 2000; Thorpe, 1998; Thorpe & Kadlun, 2000).

### **6.4.1. Water Quality**

Good water quality is important to the health of both the natural and cultural environments. The Canadian Council of Ministers of the Environment (CCME) has established Environmental Quality Guidelines (EQG) for protection of aquatic life in water and sediment and for a number of water uses. These guidelines are threshold concentrations of chemical, physical and microbiological substances that are deemed to be safe for most forms of freshwater aquatic life or for various types of uses (e.g., livestock watering, irrigation, recreation and aesthetics,

community water supply) (SENES 2005).

Traditional knowledge of the effects of contaminants on wildlife and the physical and emotional health of people in the WKSS area is not well documented. For example, impacts were noted by Denesoline when flooding from hydroelectric projects caused a decrease in waterfowl, diseased and inedible fish and loss of drinking water in some areas (Beilawski, 1993). Water quality monitoring at selected abandoned mine sites and those that have received remedial treatment would also help to provide a greater sense of security. Changes in water quality have had negative impacts where effluent from a uranium mine was discharged into a lake and killed some vegetation around the lake and made the fish inedible (Tłıchq Renewable Resources Committee and Tłıchq Treaty 11 Council, 1997), and heavy metals (*e. g.* Discovery mine (Lafontaine, 1994)) have polluted fish in tributaries and downstream lakes.

Water quality monitoring continues to be carried out by federal, territorial and municipal governments at long-term sites and by industrial proponents at new developments. Federal, territorial and regional legislation is in place to regulate the discharge of wastewaters to the natural water bodies. Also, water licences are required by communities and industries for the use of water and discharge of wastewater. The licences set limits on the amount of water that can be used and on the quality and quantity of wastewater that can be discharged. When developments are proposed, environmental and health impact assessments must be carried out and submitted to the appropriate authorities for review.

Overall, water quality in the WKSS area largely reflects natural conditions. There are localized areas with elevated metals or nutrients attributable to wastewater discharges or industrial effluents but the effects are not obvious at the regional level. Stricter regulations and technological improvements have resulted in reductions in contaminant loads entering the environment and in improvements in receiving water quality (MRBB 2004). Current initiatives to remediate abandoned mine sites and former military sites in the area also contribute to improvements in environmental quality near these sites. Similarly, the creation of monitoring oversight committees on new developments which involve Aboriginal people will help ensure that future impacts are minimized (SENES 2005).

#### **6.4.2. Surface Hydrology**

Information about patterns of surface drainage in the WKSS area is available. However, the number of places reporting climatic information, stream flow, water levels, and well data are very limited. Information is sufficient to support site-specific information requirements at only a few locations in the WKSS area. For some requirements (*e. g.* water levels in Great Slave Lake) information from areas outside may be more important than from within the WKSS area (*e. g.* upper Mackenzie River basin). Even at a general level, knowledge of the water balance in the

WKSS area and the influence of groundwater, including changes in permafrost, on surface drainage are poorly known and require substantially better understanding (Spence *et al.*, 2000, MRRB 2004, SENES 2005). In anticipation of the effects of climate warming, better and more widely distributed measurements of precipitation and evaporation are also required (Gibson *et al.*, 1998; Spence, 1995). However, instrumentation for long term recording is expensive and costly to operate and maintain in remote areas under extreme climatic conditions. Because of this, there may be value in the use of proxy data that is much more easily obtained and which can be used to “fill-in” gaps in data from existing survey sites. Most information needs with respect to the use of water resources are likely to be site-specific.

#### **6.4.3. Baseline Habitat and Landuse**

Habitat and land use are dynamic components of the environment and permafrost is particularly sensitive to any natural or manmade change that may affect its thermal stability. At a local scale, change may be rapid (*e. g.* slope failure, shifting of a river channel, construction of a highway) but large regional changes (*e. g.* movement of the tree line) are characteristically slow. Baseline information is useful as a means of comparison at both local and regional scales. Apart from site-specific information needs, local scale information is often most appropriate in support of studies aimed at understanding some form of process. Most regional scale studies need to be set in a different context. For example, information about precipitation and snow cover, permafrost, vegetation, water balance, soil moisture, fire, and range use and condition (*e. g.* for caribou, Muskoxen, and other harvest species) might be developed and compared with satellite and (limited) “ground truth” information to develop predictive tools for improved long term resource use and conservation strategies. These could be particularly useful in relation to various scenarios of the effects of climatic change (*e. g.* the northward range shift that appears to be occurring in many species of plants and animals).

Much remains unknown or poorly understood about the terrestrial ecosystem and the structure of its food web. In particular, the inter-connectedness of prey species (*e. g.* caribou and Muskoxen) and predators (*e. g.* wolves and bears), and partially dependent scavenger species (*e. g.*, foxes, Wolverines and Ravens). Also, the feed-back mechanisms between predators, grazers and plant growth, and fire and vegetational succession. The extent to which habitat (such as areas used by calving caribou) may limit present or future wildlife populations (particularly economically important species) is not known. In Barren-ground Caribou, herd mixing and range overlap also add considerably to difficulties in studying population dynamics. These and many other gaps in knowledge (including quantitative information about environmental processes) limit the ability to model northern ecosystems and to simulate their responses to various types of development and the effects of global climatic change.

The marine environment and ecosystem of the area between Victoria Island and the mainland is virtually unknown and it is difficult to assess what knowledge is required (with respect to the potential impacts of both development and climate change). At least, biological communities,



food web structures, and some estimates of productivity should be established, and little is known of the seasonal changes in physical and chemical oceanographic conditions of this area. Relationships between ice cover (including ice form, thickness and stability), seasonal caribou migrations (particularly between Victoria Island and the mainland), seal and Polar Bear distributions are poorly documented. More is known about the freshwater environment and ecosystem but information is fragmentary and needs to be updated, particularly to track the effects of potential climatic change. Little is known about anadromous fish stocks or those that migrate within the WKSS area, and the ecosystems and environments of taiga and tundra streams and rivers (including estuarine areas) are poorly understood.

In terms of people and their environment and given the size of the WKSS area, little heritage site and or archeological research has been undertaken. Further research is required to identify the locations of traditional trails, landmarks, sacred sites, graves, and other types of Aboriginal cultural sites. Research utilizing TK and a place names approach has proven to be of great value in identifying places of cultural, historical, and environmental significance as well as past and present land use within the WKSS area (Andrews & Zoe, 1997; Andrews *et al.*, 1998).

#### **6.4.4. Habitat Loss, Fragmentation and Alienation**

Loss of habitat, loss of connectedness between habitats, and alienation of wildlife may be some of the most difficult knowledge gaps to address. Also, some types of habitat are of limited availability in the WKSS area. For example, wetlands suitable for staging shorebirds and waterfowl are limited in extent and any loss could have a major impact on species distributions. Research is needed to better document habitat resources and their use. It is evident that urban development and many other human activities (*e. g.* mining, transport, recreation, and hunting) can have a significant impact on wildlife. However, broad generalizations can not be applied equally to all wildlife or to each form of activity, or to each location. Some species are more “sensitive” than others and their adaptive behaviours may differ. Some human activities have a greater impact than others, and locations are further specific in whether or not they are unique in terms of time and place.

While it is certainly useful to know more about the response of some species to human activity (*e. g.* caribou), it would seem most practical to accept that development will continue and to determine the best ways to minimize its effects on a site-specific basis. Empirical information based on better documentation of the effects of some existing activities (such as mining, hydroelectric power generation, and road and air transportation) would provide better appreciation of the “footprints” of development and the actions required to mitigate its impact. At a more general level of human behaviour, many precedents for mitigative action already exist. For example, experienced Aboriginal hunters have long applied techniques that minimized disturbance and have killed only what wildlife was essential for food, and experienced travelers seek to avoid confrontation with wildlife.

Further, TK research on the response of key species to the impacts of development may help mitigate negative impacts. Tłıchǵo elders, for example, have provided insight into the effects of some seemingly innocuous aspects of exploration and mining such as flagging tape (causing caribou to change their routes of travel (Legat & Zoe, 1995). Loss of habitat has occurred with hydroelectric development and Dene tell of the loss of shorebird, fur bearer, and large game habitat in flooded areas (Beilawski, 1993). Obtaining a greater understanding of the habitats in the path of development through TK may help mitigate the extent of future effects.

#### **6.4.5. Wildlife Mortality**

To ensure the long term availability of wildlife resources, the amount and composition of annual harvests (*e. g.* from trapping, fishing and hunting) and the size and condition of target stocks (fish, birds and other wildlife) need to be known promptly and with sufficient accuracy for well based and timely decisions to be made about resource use. This requires gathering of common information from different sources. Information is only sufficient to demonstrate broad cause and effect changes in populations due to natural mortality (including starvation, disease, condition and predation), harvesting, and climate change or variability. Although there is probably more known about the Bathurst Caribou herd than any other stock in the WKSS area, information about this herd is barely sufficient to meet these requirements. With climate warming, species shifts and invasive occurrences have potential to spread parasites and infections to new areas; the potential for damage from such effects is high.

Little is known about mortality of wildlife resulting from impacts of development within the WKSS area. A few insights were provided by Aboriginal people who noted an increase in diseased fish and higher incidence of dead animals in contaminated lakes (Beilawski, 1993; Tłıchǵo Renewable Resources Committee and Tłıchǵo Treaty 11 Council, 1997). Research using TK may better improve understandings between the causes and effects of such occurrence and help to mitigate the impacts of future development.

Some forms of management and TK research, could be used together to benefit mechanisms for improved sharing and exchange of information. They could offer ways to make management of resources more effective and responsive to environmental conditions. This could be of particular benefit where jurisdiction is shared or overlapping, where species are migratory, or where there is significant degree of resource interdependence such as associated with predator-prey relations.

#### **6.4.6. Human Health**

Human health research falls largely outside the responsibility of WKSS communities (*e. g.* *Northern Contaminants Program* and extension) and ongoing work continues to relate the effects of persistent organic pollutants and health in Aboriginal communities. Fortunately, levels of many of these pollutants are no longer increasing in the northern environment and most do not

pose a health issue in WKSS area communities. However and in recognition of effects that may be associated with climate change and global emissions, Hg remains a significant concern in the environment. Since many WKSS area communities retain a strong dependence on traditional foods, every opportunity should be taken to seek a better understanding of Hg and the environment, and the interactions between Hg and Se in animal and human metabolism. Other important health issues relate to health and smoking, causes of high rates of diabetes, and nutrient deficiencies in Aboriginal diets. While Federal agencies remain largely responsible for research related to many of these concerns, opportunities exist for some initiatives by territorial and municipal governments and by non-governmental agencies (including contributions that may be made through TK research).

Valuable insights have been gained about health and wellness in communities through TK research sponsored by the WKSSS. An opportunity to build on this work also exists.

#### **6.4.7. Cumulative Effects**

The sum of all human development gives rise to cumulative effects. Over time, some effects eventually decline, such as pollution from old mine sites. But, for the most part, there is an additive effect as one after another, forms of development and human activity modify the natural environment. The distributions and abundance of plants and animals may change, hunting, trapping and fishing pressures increase, access to natural resources becomes easier, communities become larger and connected by more roads, and levels of pollution rise. Social, cultural and economic changes occur and these further affect the health and well being of human populations. Because of complex interactions among different effects, cumulative impacts become greater than the impacts of an individual development. Modelling cumulative effects such as those from climate change, or multiple developments within a region, is complex. Cumulative effects and their impacts can be assessed and computer models can be used to project future trends, but they require that objectives (what such models are intended to show) are clearly defined. They also require that a “vision” (e.g., a land use plan) be in place for the region of concern. The objectives will determine what information would be most appropriate to show some form of impact, and the level of accuracy and resolution that may be associated with an analysis. Cumulative effects and their impacts can be addressed separately as an environmental issue (*e. g.* the relationship between manmade eutrophication and the discharge of phosphorus as a nutrient pollutant). Cumulative effects and their impacts also can be addressed by linking various socio-economic and environmental indicators (*e. g.* GLOBIO pilot study).

### **6.5. Summary of Information Needs**

This report shows, in general terms, that much is already known about both human and environmental conditions in the WKSS area. Detailed knowledge is also available about some specific sites and topics. However, gaps in knowledge often make it difficult, if not impossible, to link things together or to track information over time. Much of the information available has

not been used or considered useful mainly due to lack of rigorous analysis. TK is severely limited by the small amount that has reported and which is available outside Aboriginal communities. The following summary provides a focus for concerns about information that are specific to this report and which have been described in this section. Concerns are particularly related to the ability to define trends in time or changes in space that are occurring in the WKSS area.

### **6.5.1. Socio-economic Information**

**A. Concerns about the effects of industrialization and wage employment at the community level:** Development in the WKSS area, and most particularly the influence of mining and associated activities, continues to have wide ranging effects on Aboriginal communities and resource-use practices. Many of the effects occur indirectly, but primarily, as result of mining development. Many occur as a result of political and administrative decisions that are also related, at least to some extent, with resource extraction and development. Since it is unlikely that these underlying causes of socio-economic stress can be significantly altered in the near or foreseeable future, it is probable that many decisions will seek to provide treatment of symptoms rather than causative factors. To do this as effectively as possible, it is essential that immediate cause and effect relationships are clearly defined, understood, and quantified. It will also be necessary for much of the information to be updated on an ongoing basis. Community involvement will be a major factor in determining not only that information is useful and reliable, but also that decisions which are based on it can be made to work in the affected communities. The WKSS supported socio-economic studies at Lutselk'e and this initial work has given valuable insight into the complexities of evolving human stress (Parlee, 1998b; Parlee & Marlowe, 1999; Marlowe *et al.*, 2000). Recent monitoring data produced by government and Aboriginal communities in the NWT provides the potential for comparable information to be rendered for other Aboriginal communities in the WKSS area. Similar information is needed for Inuit communities in the WKSS area in Nunavut. Specific attention should be accorded to:

**1. Increasing Industrialization:** The extent to which increasing industrialization and industrial employment in the WKSS area is impacting on individual, family and community life and on Aboriginal cultures and the blended economy.

**2. Resource Harvesting:** The influence of industrial employment on renewable resource harvesting participation levels and practices (e. g. the traditional economy), and the implication this has for sustainable WKSS area communities.

**3. Socio-economic Security:** The influence of industrial employment on socio-economic security of traditionally isolated Aboriginal populations including impacts on social cohesion and resiliency.

**4. Rotational Work:** An update and re-evaluation of the effects of rotational work on

individual, family and community life with particular emphasis on family cohesion and harmony.

**5. Negative Activities:** A more clear understanding of gambling, prostitution, organized illicit drug activities, and youth crime particularly increasing rates of crime among young girls in the WKSS area.

**B. Concerns about the effects of industrialization and wage employment at a regional level:**

Management decisions applied for the betterment of Aboriginal communities need to be based on information that may be specific to some communities and on information that reflects a broader and more regional perspective. In particular, decisions should be supported by an appreciation of the extent to which industrialization may affect communities and affect segments of the population differently, and the extent to which changes in one community may affect another. In addition to an overview (synthesis) of information needs outlined above (A), information is also needed about:

**1. New Approaches:** The extent to which socio-economic stresses are being created, managed or reduced as a result of new approaches to Aboriginal involvement in or authority for land and resource use (e. g. land claims agreements, impact benefits agreements).

**2. Lessons Learned:** The documentation and communication of the benefits and disbenefits of mining and other developmental activities including lessons learned.

**3. Resiliency and Adaptability:** Not enough information has been produced about those determinants in the WKSS that most often positively impact on the capacity of human population to cope with and adapt to change.

### **6.5.2. Traditional Knowledge Information**

Throughout this revised State of Knowledge Report we have noted examples of TK studies that have broadened our understanding of the land, water, plants and animals of the WKSS area. These studies have given us a unique aboriginal perspective on the environment and their importance cannot be understated. Issues of funding for TK research, of community control and ownership of the information gathered, and of access to the information by “outsiders” still remain as obstacles but are slowly being overcome.

The rapid changes that have been occurring in many WKSS communities are seen as a contributing factor in the loss of traditional land-based knowledge. The traditional land based way of life is now intimately linked with a wage economy. The challenge is to document and communicate TK in a way that is relevant and intelligible to new generations, so that it can contribute to capacity-building in Dene and Qitirmiut communities, enhance well-being, and facilitate wise decision-making.

### 6.5.3. Health and Environmental Information

**A. Human health:** Activities under the Northern Contaminants Program have helped to draw attention to a number of health concerns, in particular those related to nutritional needs, contaminants in traditional foods, alcohol, smoking and diabetes. Many traditional foods are recognized as an important source of nutrients for Aboriginal people. Thus, continued monitoring of some species (e. g. Lake Trout, Burbot, Ringed Seals, and some water birds) is necessary to ensure that intake levels of Hg and organic contaminants do not exceed health guidelines. Studies on some marine mammals suggest that much of the Hg taken in through the food chain may be stored in some body organs, in a more or less inert form of HgSe material. This process needs to be better understood, not only in terms of its significance to marine mammals but also in human terms. For example, Se is considered to be a toxic substance but does it also act to detoxify Hg in humans? Concerns about alcohol, smoking and diabetes require more attention and are a particular reflection of social, economic and cultural conditions. In particular, it is important to monitor change resulting from for example, public awareness campaigns launched by the GNWT and Health Canada.

The state of human health and well-being continues to shift as WKSS residents move from rural and, or, land-based to urban and, or, industrialized lifestyles. The process begun by BHP Billiton Diamonds Inc. and the GNWT to monitor the socio-economic effects of the Ekati Mine is a good beginning for helping residents, governments and industry understand changes occurring in the human environment. It is important to expand this effort and engage WKSS communities in monitoring and communication activities.

As noted throughout the report, managing changing human health and other socio-economic circumstances within the WKS area is hampered by lack of good quality baseline data. Statistics Canada and the GNWT conduct a variety of surveys (e. g. Canada Census and the NWT Labour Force Survey) but data may not be available in a timely manner or in an appropriate format. Further, the NWT and Nunavut are often excluded from national surveys (e. g. International Adult Literacy Survey) due to high administrative costs and population size. Investing in regular surveys and making data available in a timely and appropriate manner requires immediate attention.

**B. Concerns about contaminant trends mostly associated with local sources:** These concerns are in addition to ongoing requirements to ensure that sources of drinking water meet health standards for community supply, or that country foods are safe for human consumption. Presently available information is too limited to track trends over time and changes in the areas of effect that may be associated with site-specific sources of contamination. It would not be practical to attempt to monitor conditions at numerous sites of concern in the WKSS area. Rather, sites could be chosen to be representative of different types of contaminant sources and periodically monitored for selected characteristics of water quality, and for contamination in

biological indicator species. The information could be used as a form of alert at these or similar sites elsewhere in the WKSS area. Also, information could be used to show how long contaminant effects are likely to remain significant. Possible examples might include:

- 1. Sewage Discharge:** Nutrient, heavy metal and microbial contamination at sites receiving sewage discharge from permanent settlements, camps and lodges.
- 2. Mine effects:** Sites affected by acid drainage, metals toxicity, or radioactivity from mining activities (e.g. waste rock, tailings and treatment ponds).
- 3. Dumps and Disposal sites:** Metals and organic contaminants associated with municipal dumps and military disposal sites.
- 4. Slave River:** Metals and several organic contaminants including PAHs (water/suspended matter) have been reported from the Slave River which contributes large quantities of water from drainage external to the WKSS area. This river acts as a point source to Great Slave Lake.

**C. Concerns about contaminant trends associated with atmospheric transport from distant sources:** Several species of fish and wildlife are now known to accumulate persistent contaminants. Species high in the food chain generally have the highest contaminant concentrations and those that accumulate contaminants over many years can be selected to provide information about long term contaminant trends. Because the concentrations of most persistent contaminants are extremely low in water and suspended matter, it is more appropriate to use biological indicators in which contaminant levels are higher and easier to measure. Further and because of mobility and, or, feeding patterns, many species also provide a natural spatio-temporal integration of contaminants. Trend data provide background and comparative information. Trend data are needed in addition to any ongoing programs that sample contaminants in fish and other wildlife to ensure the safety of country foods for human consumption.

**1. Trend sampling:** Sampling for trend data should, at a minimum, provide information about Hg, SDDT, SHCH, SPCBs and toxaphene. Annual sampling of selected species such as Lake Trout, Burbot and Ringed Seals (each group of similar age and, or, size, and of the same gender) could occur at sites selected to broadly characterize different environments of the WKSS area (including those that may be in remote locations).

**2. Snow Sampling:** Snow is important as a scavenger of persistent organic contaminants in the atmosphere that are carried into the WKSS area by long range transport. Concentrations are influenced by processes such as atmospheric chemistry, patterns of atmospheric circulation and contaminant emissions to the atmosphere. These processes are of relatively short duration

(measured in weeks rather than years). Thus, contaminant concentrations in snow will have greater variability and are likely to be less than those which accumulate in biota near the top of the food chain. “Memory effects” in snow and biota are also different. Snow samples may, however, provide valuable additional information (especially where select biota are not readily available for sampling).

**D. Concerns about physical effects of climate change:** There are few sites of long term weather recording in the WKSS area. More are required to provide a comprehensive understanding of climatic conditions that range from boreal to. As with water quality concerns, it will not be practical to significantly increase the number of recording stations in this area. However, it may be possible to use other forms of (naturally integrated) data to characterize long term changes and trends in climate, and its effects.

**1. Proxy Data:** Temperature/depth relationships in lakes respond to summer heating and annual measurements (e. g. in late July) can be used as proxy data to show year-to-year and spatial changes occurring in different parts of the WKSS area. Ground surface temperatures can be used in a similar way. Where deep groundwater wells are available, temperature differential within them can be used to estimate trends in time. Ice thickness is closely related to winter cooling and can be measured in both freshwater and marine environments. Freeze-up and break-up are also related to the respective rates of fall cooling and spring warming. Much of this information could be readily obtained, each year, from many different locations across the WKSS area. Consistent measurements of such proxy data could provide much more detailed information on climatic variability, and trends and change than is presently available.

**2. Permafrost:** Permafrost conditions are affected by temperature, but other factors such as the influence of vegetation may significantly modify permafrost response to warming. There may be a significant lag between increasing air temperature and permafrost response. Throughout the WKSS area, vegetation may respond as much or more to changes in precipitation, as to changes in temperature. Sites could be selected to monitor trends and changes in permafrost conditions and vegetation. However, because site-specific factors such as slope, orientation and soil cover can be very significant, complementary information may be required to provide a regional characterization of change. Remote sensing data (e. g. indicating seepage moisture and plant growth) would provide important additional information about the uniformity and extent of change.

**3. Water Balance:** Climate change could have a major affect on water balance in the WKSS area and the extent of effect may differ, significantly, in different parts of the area. Greater knowledge of relationships between precipitation (snow and rain), seepage, run-off, and evaporation is required. Also, it is necessary to have a better understanding of the potential contribution of permafrost-melt to the water balance. It is likely that extensive field



measurements could be applied only in a few major, or typical, watersheds. Thus it would be useful to know to what extent proxy data might be useful as an indicator of water balance in different drainage basins (e. g. discharge duration of headwater lakes, duration of over-bank flow, duration of no-flow conditions). If suitable, proxy data could be applied to the management of water use in the WKSS area.

**E. Habitat change and range use:** Climate change will affect vegetation (on land and in water) over wide areas, especially as a result of changes in temperature and precipitation. Habitat may be changed, also, as a result of human activities such as road building, mining development, and the growth of communities. Habitat change (e. g. fragmentation, plant colonization, reduced ice or water cover) may very well alter its use and thus the distribution of many species (including people). Many changes will be readily visible on the ground but financial constraints limit the extent to which site-specific information gathering will be possible. Aerial and satellite remote sensing techniques offer the only practical means of determining and quantifying change over large areas. At present, the WKSS area lacks consistent baseline information about the distribution of habitat types and resource use.

**1. Surveys and Observations:** Aerial survey techniques have been used as a means of monitoring wildlife habitat and range use in the WKSS area, particularly in relation to Barren-ground Caribou, and satellite data have been used to characterize habitat. These studies need to be continued but greater understanding is required of fragmentation effects associated with human activities in the environment, and the extent to which halo effects (including wildlife mortality) occur around different types of development. Empirical observations of the effects of different types of development, settlement, roads and other forms of infrastructure provide essential information for construction of better models of both environmental and cumulative impacts.

**2. Indicators:** Environmental indicators need to be developed to simplify the display of information about habitat change and range use. For example, shorebird habitat is very limited in the WKSS area. Climate change could result in a loss of much of this existing habitat. It could also result in opening of new shoreline habitat in areas that are now under some other environmental condition. If climate change continues at the present (rapid) rate, it may be easier to track habitat change from remotely sensed information than to rely on trying to locate the birds based on the use of sightings, alone. Environmental indicators would help to reduce the complexity of habitat change and range use.

**3. Changes in the freshwater food web:** Very little is known about the likely affects of climate change on the freshwater food web, and especially changes that may occur in fish stocks. Warming could reduce water levels and flow, advance spawning periods and increase nutritional needs. Warming is likely to favour some species but to create habitat that is less favourable to

others.

**4. Dams, Diversions and Water Control:** The effects of dams, diversions, and water level manipulations on water quality and aquatic (and semi-aquatic species) is poorly documented in the WKSS area. Information about such effects is available from sites in Northern Manitoba, Ontario and Quebec, and much of it is applicable to the WKSS area. However, there are also significant differences; in particular, the WKSS area receives much less precipitation and the regional water balance is very different. Although the scale of potential hydro development is likely to be very different in the WKSS area, nevertheless the potential for environmental impact is considerable. This is particularly so where Aboriginal communities are dependent on local resources for traditional food, as has been documented on the Talston River (Beilawski, 1993).

**F. Wildlife management:** This applies, mostly to human use of renewable resources by hunting, trapping and fishing. Animal populations vary from year to year as a result of many natural factors and in particular weather, food supply, natural predation and disease; human use of the resource is an additional factor. Good information about each of these factors is essential to ensure long term availability of the resource.

**1. Health of Animal Populations:** Climate change may increase incidence of disease and, or, parasitic infections in birds, fish and other wildlife (including both marine and terrestrial mammals). Sample information is used to provide indications of animal populations and their condition in relation to nutrition and disease. This monitoring is an essential part of resource management. With increasing appreciation of the value of traditional foods in Aboriginal diets, however, more of this monitoring information may be needed.

**2. Predators and Prey:** Natural predator-prey interactions exist between many species (e. g. Lynx and Snowshoe Hare, wolves and caribou, and Grizzly Bear and caribou) but the nature and extent of many of these interactions is poorly defined. Major wolf kills have occurred in some parts of northern Canada as a means of allowing a larger take by hunting for some target species, such as caribou. These actions have occurred without clear understanding of the roles played by predators in maintaining the health of prey, or the effects of climatic variability on predator-prey relations. There is little understanding of the effects of large scale killing on behavioural learning and societal structure within wolves. Even less is known about most other predator-prey relations.

**3. Resource Use:** With the potential for increased human use of bird, fish and other wildlife resources (as traditional food), it becomes increasingly important to have good information about the extent to which hunting, trapping and fishing affect the populations of target species. Also, the extent to which any of these activities may be selective of certain groups of a population (such as breeding females or pre-breeding males). Because fishing can have an overwhelming

influence on fish populations, fisheries management is particularly sensitive to the need for good information about both stock size and condition, and catch.

**4. Caribou Populations:** Several herds of Barren-ground Caribou have summer and winter range within the WKS area. The herds are defined on the basis of their separate calving grounds. However, the range of each herd varies and at some times of the year members of different herds may mix together (range-overlap). Caribou populations are difficult to estimate and population estimates are affected by inclement weather during surveys and the lack of demographic information on the herds. More and better information about the populations and herd fidelity are particularly important for resource management.

**G. Interactions Between Terrestrial and Aquatic Ecosystems:** Very little is known about the interactions between terrestrial, freshwater and marine ecosystems of the taiga and tundra environments. Nutrient cycling, the roles of microbial populations, and the limiting effects of temperature and moisture content are poorly understood.

**H. Freshwater and Marine Environments:** Very little is known about taiga and tundra stream ecologies in the WKSS area, and this includes food web structures, and the distributions, behaviours and populations of migratory and anadromous fish species. Very little is known about the marine environment between Victoria Island and the mainland. Information is needed on almost every aspect of this environment. Bathurst Inlet is likely an area of special environmental interest. Also, because there are rapidly growing communities at Kugluktuk and Cambridge Bay, areas around these sites are likely to experience most stress from human activity.

**I. Cumulative Impacts:** Techniques for cumulative impact assessment are not yet generally established but a number of initiatives have been taken to apply this form of assessment within the WKSS area. Assessment techniques will link the impacts of multiple developments. For example, they could provide an understanding of the wider (regional) impact of mine development at multiple sites. It is essential that cumulative impact assessment take a holistic approach and that attempts do not proceed piece-meal. It is also likely that different parts of a cumulative impact assessment may proceed separately first, at least to some degree, but that they be designed to fit together in a larger whole.

**1. Environmental Information:** Cumulative impact assessment may include environmental information such as on water and air quality (e. g. from sewage disposal and contaminant emissions), changes in water quantity (e. g. effects of water withdrawal on water resources), construction of roads and other structures, changes to habitat and range use (e. g. from structures and road construction), wildlife avoidance (e. g. from noise and activity), and increased natural resource use (e. g. increased hunting, trapping and fishing by camp populations and greater access to wilderness areas).

**2. Socio-economic Information:** This may include socio-economic impacts such as on use and, or, understanding of Aboriginal languages and cultural practices (e. g. from more global or mainstream assimilation practices), changes in family relationships and structures (e. g. due different work schedules and income earning roles); and changes in and applicability of skills and knowledge (e. g. more industrial and less harvesting or land-based skills).

**3. Traditional Knowledge Information:** Traditional knowledge may provide an important component in many aspects of cumulative impact assessment. Cumulative Impact assessments, eventually, may also link the effects of global components such as climate change, with those of more local and regional origin. They may also begin to integrate some of the links that exist between environmental change and societal change.

**4. Access to information and Meta Data:** Whatever the undertaking of cumulative impact assessment in the WKSS area, it will need the support of many different government agencies, industry and other organizations. It will need to make use of consistent forms of data, particularly data describing trends over time and changes in space. Examples of such information include: water quality monitoring, temperature and precipitation recording, and habitat surveys. Meta data, which define what types of information are available about which areas and when, and where the data is available, could contribute significantly to the selection and use of information. Establishment of a meta data system to catalog existing and future available data would be very helpful but cost and skill requirements may suggest use of existing expertise (external to WKSS area) rather than creation of a separate system. The fact that substantial quantities of information have only recently become available about the WKSS area means that early use of a meta data system could be highly beneficial in terms of both cost and service.

## **7.0 RESEARCH GAPS AND NEEDS**

A great deal of specific research and some long-term monitoring has been conducted throughout the WKSS region, and these activities have provided a broad understanding of the state of the environment. Overall, environmental quality in the region can be said to be favourable for most components. However, in some cases it remains difficult to determine the current condition of an environmental component or evaluate trends due to a lack of adequate baseline data.

For cases where data are sufficient, several instances of unfavourable conditions and deteriorating trends can be identified. As noted in the recent NWT status of the environment review (SENES 2005), two of the most disturbing trends are: the recent large decreases recorded for the size of caribou herds that many people living in the WKSS region rely on as a major source of subsistence; and, the need for action in the area of socio-economics and community wellness. With changes to the environment from climate change and the potential for increasing development near calving grounds, the need for accurate data on the status of the individual caribou herds and their habitat is becoming increasingly important.

With respect to socio-economics and community wellness, while traditional economic indicators show that the population and economy are growing, there is no commensurate progress in community wellness with numerous measures of social well-being being found to be less favourable than national averages. The social problems identified appear even more pronounced in the smaller communities and are more associated with the Aboriginal population. This situation requires action by government agencies that have health and social service mandates.

Looking forward, climate change is expected to have a profound effect on the Canadian North. The potential effects extend to all components of the environment ranging from: loss of permafrost conditions in some parts of the WKSS region; increased erosion of river banks and shorelines; changes in the duration, extent, and quality of sea ice cover; changes in vegetation coverage and animal habitat; increased mobility of nutrients and organic and inorganic contaminants; and, changes in the quality and availability of traditional foods. Additional research is required in a number of areas to improve the understanding of the effects of climate change on all components of the environment.

Based upon the key issues identified above, and gaps more specifically identified in the text and by the WKSSS, the following sections provide recommendations for priority research areas.

### **7.1. Climate Change**

Climate change continues to be one of the critical issues affecting the WKSS area. As such, the following recommendations are made:

- Comprehensive monitoring and research programs should be established; independently or in collaboration with other agencies, to begin monitoring of specific components of the WKSS area environment.
- Policies should also be in place to manage effects as they occur through education, communication and protection of resources.
- Programs should be put in place to continually monitor populations of major species through trapping and harvest records, or direct measurement of the populations.

## 7.2 Community Wellness

The available data indicate the need for action in the area of socio-economics and community wellness. The following findings for the WKSS region require that government agencies that have health and social service mandates take action and develop effective implementation plans:

- While traditional economic indicators show that the WKSS area population and economy are growing, there is no commensurate progress in community wellness.
- Numerous measures of social well-being are found less favourable than national rates.
- The social problems identified appear even more pronounced in the smaller communities and are more associated with the Aboriginal population.

Building upon the “monitoring” agencies established by the socio-economic agreements signed for the Diavik Diamond Mine and the DeBeers Snap Lake Diamond Mine, research should be conducted to answer the following questions:

- What is the current state of knowledge with respect to social, cultural and economic indicators, thresholds and limits of acceptable change in the study area?
- What are the institutional or political challenges to examination of the social and cultural effects of development, and the application of the information that is available? What are the opportunities available to do so?
- What are the cumulative social, cultural and economic effects (negative/positive) of development in the study area on families and communities?
- What are the impacts of a two-week-in, two-week-out work schedule on families and communities?

### **7.3. Wildlife**

Recent large decreases have been recorded for the estimated sizes of caribou herds in the WKSS region. In addition to the implementation of the various management plans developed, the following recommendations are made:

- Further research and resources are required to gather information that would enable an estimate of the current condition of herds on an annual basis or whether the major herds are increasing or decreasing.
- Increased support for research into improved methods of assessing herd condition and pressure on government agencies to expand research programs are required.

In the area of monitoring, agencies such as the U.S. Fish and Wildlife and Canadian Wildlife Service provide valuable information from monitoring and research programs on the status of waterfowl and shorebirds.

- Support is required to ensure continuation of the program, which is critical to setting harvest rates nationally and internationally.
- Since virtually no information is available on landbirds and songbirds, survey routes should be established throughout the WKSS area to begin monitoring the health of these important components of the terrestrial ecosystems.

In the context of continued industrial development in the WKSS region, more research is required in the following area:

- Effects of new/additional developments and associated linear features (e.g., roads) and increased traffic on the behaviour, movements and condition of wildlife.

### **7.4. General Monitoring**

As discussed in the text, the lack of implemented and operational general monitoring programs has serious negative consequences in the WKSS area. The absence of such programs inhibits the the development and monitoring of land use plans, the assessment of cumulative effects, and state of the environment reporting. To overcome this significant gap the following is required:

- Further development and implementation of the CIMP
- Development and implementation of the NGMP

In establishing these regional monitoring programs the following is also recommended:

- Identification of potential organizational models for the program.
- Development and implementation of “VC Advisory Groups”.
- Selection of appropriate “prototype” VCs that should be used to guide the design and initial development of the program.
- Identification of conceptual approaches for the design and operation of a cumulative impact Information Management System.

## **7.5. Cumulative Effects Assessment and Management**

In order to effectively assess and manage cumulative effects that may occur in the WKSS area as a consequence of the increased non-renewable resource activity the following recommendations are provided:

- The West Kitikmeot Regional Land Use Plan should be finalised and implemented.
- A land use plan for the rest of the WKSS area (NWT portion of the SGP) should be developed.
- Research on thresholds and limits of acceptable change should be conducted to respond to the following questions:
  - o What is the current state of knowledge with respect to the concepts of resilience, carrying capacity, thresholds and limits of acceptable change, and how can this knowledge be applied in the study area?
  - o How can water quality data be standardized and tracked (information management) to detect changes? When do changes become significant or unacceptable? Do we know enough about “end use” to decide this?



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- Traditional knowledge & Lifestyles: V1 (1.2, 5); V2 (1.2, 4.1-4.3); V3 (1.2); V4 (4.1, 4.2, 4.8).
- Wildlife: V1 (4.7, 5.1); V2 (3, 4.2, 4.3); V3 (6,7, 9.2); V4 (4.1, 4.2, 4.8, 10.6).
- Water Quality and Environmental Issues: V1 (1.5, 2.2, 2.5-2.7, 3.7, 4, 5.1, 5.4), V2 (1-4), V3 (1, 3-10); V4 (1-3, 4.1, 4.2, 4.8, 4.9).
- Archaeology: V1 (5.1); V2 (4.8); V4 (4.1, 4.2, 4.15).
- Social Issues: V1 (1.4, 2, 4, 5); V2 (1,4); V3 (10.9); V4 (4).
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## APPENDIX A: GLOSSARY AND ABBREVIATIONS

**Acculturation:** Mutual influence of different cultures in close contact. Often applied to the impacts of non-Aboriginal culture on Aboriginal peoples.

**Acid/basic (rock).** In geological terms and referring to igneous rocks, acidic rocks are silica-rich (having free-quartz) and basic rocks are silica poor. See also Igneous rocks.

**Acidification:** Production of acidic material as a result of rock and mineral weathering (often associated with metal mining activities where sulphides, exposed to the air, become oxidized).

**Active layer:** Surface soil layer that seasonally thaws and freezes.

**ADFG:** Alaska Department of Fish and Game.

**Adventitious rooting:** Lateral rooting from stem tissue (above or below ground). See also Candelabrum spruce.

**AES:** Atmospheric Environment Service.

**Aerobic:** Life and life-related processes occurring in the presence of free oxygen (gaseous or dissolved).

**Algae:** Large group of non-vascular marine and freshwater aquatic plants of unicellular and multicellular forms (Sub-division of Thallophyta), including: yellow-green, blue-green, green, red, and brown algae. See also Cyanobacter.

**ALUR:** Arctic Land Use Research Program.

**Ambient:** Surrounding conditions (*e. g.* background air or water quality).

**Amphipods:** Small shrimp-like crustaceans (Order Amphipoda) having some appendages specialized for swimming. See also Mysids.

**Anadromous:** Migratory species of fish that spawn (lay eggs) in freshwater.

**Anaerobic:** Life and life-related processes occurring in the absence of free oxygen.

**Andesite:** Fine-grained, darkish, igneous rock containing plagioclase feldspar, ferro-magnesian minerals and a very small amount of quartz.

**Anoxic:** Having an oxygen deficiency.

**Annual precipitation (wet):** Total annual received moisture as snow, ice, rain, and fog-droplets.

**Annual received solar radiation:** Solar radiation (part or all of the spectrum) received over a year.

**AP:** Acid potential; extent to which acidic material is likely to be produced (by weathering). See also NNP and NP.

**Aquiculture:** Artificial culture of biota (mostly fish) in freshwater.

**Atmospheric:** Referring to the gaseous layer surrounding the planet.

**Attached algae:** Single-celled or colonial photosynthetic organisms (plants) that remain attached to some form of substrate.

**Aurora Borealis:** “Northern Lights”; light produced by excitation and ionization in the upper atmosphere in response to solar magnetic radiation.

**Banded ironstones:** Sedimentary rocks containing alternating thin layers of iron. See also sedimentary.

**Basalt:** Fine-grained dark igneous rock containing olivine, pyroxene and plagioclase feldspar but lacking free silica. See also diabase.

**Base-metal:** Mining term including copper, lead and zinc ores.

**Batholith:** A very large mass of igneous rock intruded into the Earth's crust (may be hundreds or thousands of square kilometres in area). See also pluton.

**Benthic:** Referring to bottom-dwelling and, or, bottom-feeding biota.

**BHC:** Benzene hexachloride. See also HCH.

**BHP:** Broken Hill Properties.

**Biota:** Living organisms (including plants and animals).

**Biomass:** The mass (usually as weight) of living organisms (or a specific group of organisms).

**Bioaccumulate:** Uptake and retention of chemical substances by an organism.

**Bioconcentration:** Concentration of a chemical substance in a whole organism or specific tissue from it (*e. g.* blood serum, muscle, kidney, liver or fat).

**Biological communities:** Groups of plants or animals living together.

**Biomagnification:** Increasing concentrations of a substance in a food chain. At each higher level, concentration relative to biomass (of that level) increases. Members of higher trophic levels consume members of lower trophic levels and, in the process, they retain persistent contaminants.

**Biomass:** Quantity of living matter in a defined space.

**Biome:** A large region that is defined by the characteristics of biological communities living in it. Climate is frequently a controlling factor (*e. g.* tundra biome). See also Ecozone.

**Bivalves:** Animals of the Phylum Mollusca, having shells composed of two parts (*e. g.* mussels).

**Blood serum:** Clear fluid containing antibodies but without clotting agents

**Bog:** A wet peatland in which the soil is composed of organic matter, and the soil water is acidic (containing organic acids) and generally lacking in plant nutrients. See also Peatland.

**Boreal:** Northern; usually referring to forested areas within the Boreal Climate zone (in which coniferous species are frequently dominant).

**BP:** Years Before Present.

**BS:** Bureau of Statistics (GNWT).

**Caloric value (nutritional):** Food value, especially as a source of energy for body heat, growth, activity.

**Canadian Shield:** Vast area of ancient igneous and metamorphic rocks that forms much of central and northern Canada.

**Candelabrum Spruce:** Adventitious rooting of black spruce. This occurs where lichen ground cover develops around a tree, and cuts off supply of nutrients and moisture to the tree's roots in the underlying soil. Extensive development of the candelabrum may occur where a tree has multiple stages of adventitious rooting (seeking to outreach the surrounding cover of lichen). See also Adventitious rooting.



**Cached food:** Uneaten or partly eaten food that is hidden or stored for future use.

**Carbonate rocks:** Sedimentary rocks, such as limestone and dolomite, containing significant quantities of carbonate minerals (*e. g.* calcium and magnesium carbonates). See also Sedimentary.

**CARC:** Canadian Arctic Resources Committee.

**Carrying capacity:** The population of a specific group or groups of animals that can be supported by a given area of land (usually applied to grazing and or browsing species dependent on ground vegetation, and expressed as a long term average).

**CBC:** Canadian Broadcasting Corporation.

**CCELC:** Canadian Committee on Ecological Land Classification.

**CCPB:** Canadian Climate Program Board.

**CDA:** Canadian Department of Agriculture.

**CEAA:** Canadian Environmental Assessment Agency.

**CEAM:** Cumulative Effects Assessment and Management.

**CEAMF:** Cumulative Effects Assessment and Management Framework.

**Century:** 100 years.

**CFCs:** Chlorofluorocarbons; volatile but stable and non-toxic fluids used as refrigerants. Highly effective as ozone-depleting gases when released into the atmosphere. Halons (*e. g.* Halon 1301) are similar compounds containing bromine and chlorine. They are an efficient fire extinguisher.

**Chironomids:** Midges (Family Chironomidae) present as small worm-like larvae in soft sediments of freshwater lakes, streams, and rivers.

**Chlordane:** An organohalide (chlorinated) insecticide.

**Chlorinated dioxins:** See PCDDs.

**Chlorophyll *a*:** Green pigment in living plants, necessary for photosynthesis.

**Chromite:** A ferrous chromite mineral (oxide of iron and chromium).

**Ciliates:** Microscopic protozoans (Class Ciliata) characterized by hair-like features that cover all or part of the body at some period of their life. A very small type of zooplankton.

**CIMP:** Cumulative Impact Monitoring Program

**CINE:** Centre for Indigenous Peoples' Nutrition and Environment (Montréal).

**Climax population:** Population structure of a mature biological community (*e. g.* a forest).

**Closed canopy:** Forest cover lacking open spaces between the trees.

**Condensation point:** Temperature at which vapour condenses into droplets (gas to liquid).

**Congener:** Member of the same family of the chemical periodic system.

**Coniferous:** Trees and shrubs that usually keep their leaves year-round (evergreen).

**Copepods:** Small, sometimes parasitic, crustaceans (Sub-class Copepoda) living in either fresh or salt water; a type of zooplankton.

**Coregonids:** Ciscoes and whitefish (Family Coregonidae). Pelagic and benthic fish of the freshwater environment but with tolerance of low salinity. Stocks may migrate to spawn in rivers and lakes.

**COSEWIC:** Committee on the Status of Endangered Wildlife in Canada.

**Country foods:** Uncultivated foods obtained by fishing, hunting or gathering.

**CPHA:** Canadian Public Health Association.

**CINE:** Centre for Indigenous (Peoples') Nutrition and Environment, McGill University, Montreal. See also CIPNE.

**CPS:** Canadian Parks Service.

**Craton:** A core of extremely ancient crustal rock that has been geologically stable for a long time (*i. e.* it has not been subject to selective elevation or subsidence, or to orogenic processes such as mountain-building).

**Crust:** The Outer hard rock layer of the Earth, composed of rocks that are less dense than those in the underlying mantle.

**Crustaceans:** Members of the Class Crustacea, including crabs, lobsters, shrimps, and water fleas; most are aquatic.

**Cryoturbation:** Slow movement of frozen ground caused by various cold effects (including freeze-thaw, ice deformation and plastic flow).

**Crysollic (order):** Soils in which structures are affected by permafrost that is present at a depth of 1 m or less. Turbic Cryosols are intensely disturbed.

**CSHD:** Climate System, History and Dynamics (research program).

**CSSC:** Canadian Soil Survey Committee.

**Cultural eutrophication:** Intentional or unintentional nutrient enrichment of a body of water by additions of nutrients such as nitrogen and, or, phosphorus (*e. g.* from industrial or community sources).

**CWG:** Constitutional Working Group.

**CWS:** Canadian Wildlife Service.

**Cyanobacter (Cyanophyta):** Very small plant-like (algal) photosynthetic organisms, with blue (phycocyanin) and green (chlorophyll) pigmentation. See also algae.

**DCC:** Department of Culture and Communications (GNWT).

**DDE:** See DDT.

**DDT:** Dichloro diphenyl trichlorethane; an organic insecticide, often present with toxic breakdown products known as DDD and DDE; no longer in general use in Canada).

**DE:** Department of Education (GNWT).

**DECE:** Department of Education, Culture and Employment (GNWT).

**Deciduous:** Trees and shrubs that drop their leaves after each growing season.

**DEDT:** Department of Economic Development and Tourism (GNWT).

**Degree days:** Number of days x temperature above some temperature, such as 0°C (*e. g.* 45 days having an average temperature of 4° C is equivalent to  $45 \times 4 = 180$  degree days). See also Growing degree days.

**DEMPR:** Department of Energy Mines and Petroleum Resources (GNWT).

**Detritivore:** Organism that feeds on detrital material, particularly organic matter in the sediments of freshwater and marine environments.

**DEW-line:** Distant Early Warning (radar) line; part of the post-WW II North American air defence network.

**DHSS:** Department of Health and Social Services (GNWT).

**Diabase:** An intrusive igneous rock with composition similar to basalt, but having a coarser crystalline structure.

**Diamond:** An extremely hard, crystalline form of pure carbon.

**DIAND:** Department of Indian Affairs and Northern Development.

**Diatom:** Microscopic unicellular or colonial algae (Phylum Chrysophyta) whose cell walls contain silica. Diatoms are a rich source of food for many forms of freshwater and marine life.

**Diatreme:** An explosive vent associated with eruptive geological processes.

**DIF:** Department of Information (GNWT).

**DINA:** Department of Indian and Northern Affairs. See also DNANR, INAC and IAND.

**DJ:** Department of Justice.

**DMCA:** Department of Municipal and Community Affairs (GNWT).

**DNANR:** Department of Northern Affairs and Natural Resources. See also DINA, INAC and IAND.

**DOE:** Department of Environment. See also EC.

**Dolomites:** See carbonate rocks.

**DP:** Department of Personnel (GNWT).

**DRR:** Department of Renewable Resources (GNWT).

**Drawdown:** Lowering of water levels in artificial impoundments.

**DRWED:** Department of Resources, Wildlife, and Economic Development (GNWT).

**Dry-fall:** Precipitation of dry particulate material from the atmosphere (often, low concentrations of fine “dust”).

**DSS:** Department of Social Services (GNWT).

**DSS:** Department of Supply and Services. See also, MSSC.

**DT:** Department of Transport (GNWT).

**Dyke swarms:** Clusters of narrow and steeply inclined intrusions of igneous rock (similarly oriented) into existing crustal rock (near flat-lying intrusions are termed sills).

**EC:** Environment Canada. See also DOE.

**Eclogite:** A metamorphic rock (originally an igneous rock but partly reformed under high temperature and pressure), containing garnet and pyroxene.

**Ecosystem health:** Ecosystem health refers to the state of physical, chemical and biological processes that support all living organisms, and to the condition of organisms and their communities as well. A pristine state or condition exists where there is little impact from human activities. Degradation occurs where human activities cause lasting negative effects (*e. g.* as a result of contamination, habitat loss or over-harvesting). Activities that improve degraded conditions may achieve restoration (return to near-natural states or conditions) or rehabilitation (return to a well functioning ecosystem but that may differ

somewhat from its original structure). Characteristics of healthy ecosystems include: no loss of species diversity, normal patterns of behaviour, no excessive decline or proliferation of organisms (excluding natural fluctuations), no significant increase in disease or deformities, generally stable community structures, and robust and self-regulating interactions between and among plants and animals. The health of individual organisms and communities of organisms requires a healthy environment (summarized from EC., 1991).

**Ecozone:** A large region that may be defined by one or more characteristics of the environment such as landform, geology, soil, vegetation and climate. Zones characterized by terrestrial features may or may not coincide with those defined by climatic or other features (*e. g.* some vegetation and climate zones may be comparable but landform and climate zones may differ significantly). Ecozones based on animal and, or, plant communities (*e. g.* tundra wildlife ecozone) are similar to biomes.

**Electrostatic precipitation and baghouse filter:** Pollution control technologies used to remove particulates from gaseous emissions. Electrostatic precipitators use charge attraction, and baghouse filters use large volume screens to remove particulates.

**El Niño:** An event off the coast of Peru (that may last for many months) when warm surface waters move westwards across the Pacific Ocean and dramatically influence global weather conditions. As a result of complex and not well understood interactions between the ocean and atmosphere, warmer than normal weather across much of central and northern North America is thought to be associated with some El Niño events. See, also La Nina.

**EMR:** Energy, Mines and Resources. See also NRC.

**Endangered species:** Any species of plant or animal whose existence is threatened through all or a significant part of its range, often owing to the actions of human beings.

**EPB:** Environmental Protection Branch.

**EPS:** Environmental Protection Service.

**Esker:** A feature of the postglacial landscape. Deposits of sand and gravel, originally laid down in the bed of streams flowing under glacial ice, appear as long winding ridges on top of the ground, as areas become ice free. See also Kame.

**Ethnographic/Ethnological:** Study of the culture of a society (by means of participant observation).

**Eutrophication:** The natural aging (geological) of a body of water as it fills with sediment and nutrient loadings increase from the surrounding area. These changes result in long term shifts in species composition and, generally, higher biological productivity. See also Cultural eutrophication.

**Extinction:** Complete loss of some species throughout all of its occurrence (*e. g.* Sabre-Tooth Cat and Mammoth).

**Extirpated:** The total loss of an animal or plant species in a significant part of its total range (such as a large island or some other large area, *e. g.* WKSS area Muskoxen during the

first half of this century).

**Feather moss:** Thick carpet moss of the boreal forest floor (*Hylocomium* spp. and several other species).

**Fecal coliform:** Types of bacteria associates with animal feces.

**Feed-back:** When the output of some process applies a new influence to that process, feedback occurs (e. g. when solar radiation warms the ground it may release greenhouse gases trapped within the ground, or increase microbial activity that also releases more greenhouse gases). These gases may trap more heat in the atmosphere and further raise global temperatures. In most situations, natural feed-back is self-limiting and there is some upper limit to effect.

**Flux:** Movement.

**FMS:** Financial Management Secretariat (GNWT).

**FOC:** Fisheries and Oceans Canada

**Forage:** Plant materials used by grazing animals.

**Forbs:** Any form of herb, except grasses. See also Herb.

**Fruticose and other lichens:** Fruticose lichens have plant-like growths of low tufts and stalks (sometimes extending as much as 10 to 15 cm above the ground), and cover large areas of the tundra and taiga. Other groups of lichens include crustose lichens that spread as a thin crust over rocks and other bare substrates; foliose lichens that form flat lobes and scales (often on rotting vegetation); and bearded lichens that hang from forest vegetation.

**FS:** Forestry Service (US).

**FWS:** Fish and Wildlife Service (US).

**Gas hydrates:** Gas trapped in permafrost ice.

**Gastropods:** Molluscs having one-piece (univalve), straight or spiral shells, or having no shells or greatly reduced shells (Class Gastropoda). Most move by means of a broad, muscular, basal foot. Many forms are commonly called snails.

**GC:** Government of Canada.

**GDP:** Gross Domestic Product (a measure of economic activity).

**Geological time scale:** This covers time from the oldest known rocks to the present. Units of time are not divided equally and differentiation becomes more detailed as the rocks become younger. The longest intervals of time are termed Eons, the oldest of which are collectively termed the Precambrian. From the Precambrian, on, time is further divided into Era and Periods. Further subdivision into Epochs occurs in the Tertiary and Quaternary Periods. In the WKSS area, there are only a few traces of rocks formed between the end of the Precambrian and the late Quaternary Period.

**Glacial refugium:** A region where species adapted to more temperate conditions were able to survive during periods of glaciation, and from which they later spread to recolonize the postglacial environment.

**Glacial till:** An unsorted mixture of clay, sand, gravel and larger particles left as residual material after melt and retreat of glacial ice. A form of sedimentary rock.

**GNWT:** Government of the North West Territories.

**Granite gneiss:** A rock with the composition of granite but in which there is mineral orientation and structural banding and swirls. The rock has been largely reformed under intense metamorphic heat and pressure, to the extent that its original form may not be discernible.

**Granitoid:** A granite-like rock. Granites are coarse grained, light coloured igneous rocks that contain plagioclase feldspar, mica and quartz.

**Graphite:** A soft, gray-black and flaky mineral form of pure carbon.

**Gray water:** Household and vessel effluent water that does not include sewage waste, mostly from washing and cleaning activities.

**Greenhouse gas:** A gas that absorbs solar radiation (directly, or reflected from the Earth's surface) and which causes the temperature of the atmosphere to increase (*e. g.* carbon dioxide). A greenhouse-like effect.

**Growing degree days:** Number of days  $\times$  temperature above 5° C (*e. g.* 45 days having an average temperature of 7° C is equivalent to  $45(7-5) = 90$  degree growing days (most plant growth is minimal below 5° C). See also Degree days.

**GSC:** Geological Survey of Canada.

**Halogenated organic compounds** Also called organohalides; organic compounds in which halogen elements are bound into the molecular structure. Halogens include bromine, chlorine, fluorine and iodine.

**HBC:** Hudson Bay Company. See also NWC.

**HC:** Health Canada.

**HCH (Alpha-, beta-, gamma-, technical-):** HCH is an insecticide. The gamma-isomer of HCH is also known as Lindane (a widely used insecticide). The degradation product of this isomer is Alpha-hexachlorocyclohexane. Most HCH is applied as technical HCH (a mixture of alpha-, beta- and gamma-HCH; the mixture is mostly alpha-HCH). See also, BHC.

**Hematite:** An iron oxide mineral (ferric oxide).

**Heptachlor epoxide:** Organohalide (chlorinated) insecticide.

**Herbivore:** Organism whose principle diet is plant material.

**Herb:** A seed-bearing non-woody vascular plant whose above ground parts die-off at the end of the growing season. See, also Forbs.

**Herd:** A group of animals of the same species that generally stay together or that share a common range for most of their lifetime. Herds usually comprise many smaller groups (*e. g.* family groups). See also, Population.

**HRD:** Human Resources Development.

**Hummocky moraine:** Generally coarse material “dumped” from stagnant melting glacial ice, producing an irregular surface over the till material.

**Hyperalkaline (rocks):** Igneous rocks containing unusually high concentrations of alkaline elements (*e. g.* Ca, K and Na). High Ca is mostly associated with basic rocks, high K with acidic rocks, and high Na with rocks of intermediate composition.

**INAC:** Indian and Northern Affairs Canada. See also DIAND, DNANR and IAND.

**IAND:** Indian Affairs and Northern Development. See also DIAND, DNANR and INAC.

**IASC:** International Arctic Science Committee (Norway).

**Ice algae:** Species of algae specifically adapted to living in close association with ice. Ice algae are present in ice and surrounding surface waters and photosynthesize under relatively low light conditions of Arctic and sub-Arctic fall and spring.

**ICI:** Inuit Cultural Institute.

**IEMA:** Independent Environmental Monitoring Agency, Yellowknife.

**Igneous rocks:** Rocks formed, within the earth's crust, after cooling of molten material. Slow cooling produces coarse crystalline structures; rapid cooling produces fine crystalline structures. See also Metamorphism.

**IISD:** International Institute for Sustainable Development, Winnipeg.

**Inliers:** A region of older rocks surrounded by younger rocks.

**In situ:** In place.

**Invertebrates:** Animals having no backbone.

**Isomers:** Groups of compounds that have the same molecular composition but different molecular structure.

**Isostatic recovery:** Upward movement of the Earth's surface in response to the decreasing weight of overlying ice, during periods of glacial melt. There is a lag between melt and uplift.

**ISTC:** Industry, Science and Technology Canada.

**IWD:** Inland Waters Directorate.

**IWGMI:** Intergovernmental Working Group on the Mining Industry.

**Kame:** A sedimentary deposit, often of sandy gravel, formed in a ponded area on the surface (or the edge) of melting glacial ice. After ice retreat, the kame surface remains higher than the surrounding area. See also Esker.

**KIA:** Kitikmeot Inuit Association.

**Kimberlite:** Compositionally, kimberlites reflect peridotite and eclogite source materials. Texturally, they are composed of broken rock fragments set in a matrix of much finer material and appear similar to some volcanic rocks. Kimberlites may or may not contain diamonds.

**La Nina:** Under a La Nina event, colder than normal water spreads west from Peru across the Pacific Ocean and may dramatically influence global weather conditions. As a result of complex and not well understood interactions between the ocean and atmosphere, Arctic air may penetrate more deeply into North America (El Niño and La Nina can be thought of as somewhat opposite conditions, with La Nina tending to be the weaker. The reality is much more complex). See also El Niño.

**Larval fish:** An early stage in development, immediately following the hatch of fish eggs. Larval fish are very small and form part of the zooplankton community.

**LD:** Lands Directorate.

**LEL:** Lowest effect level; a guideline value indicating that at least one chemical parameter has potential to adversely affect aquatic biota. LEL does not imply that there will be an adverse effect nor does it require biological assessment which would be necessary to establish an adverse effect. LEL provides a warning. See also SEL.

**Lipids:** Organic compounds that are insoluble in water, consisting of fats, oils, and greases.

**Loading:** The amount of a substance (*e. g.* a contaminant) introduced into the environment over some period of time (*e. g.* expressed as:  $\text{kg}\cdot\text{a}^{-1}$ ).

**Lode deposits:** A formation of highly concentrated minerals or metal within a rock.

**Loess:** Fine-grained, yellowish-brown, wind-blown deposit (many loess deposits were formed by wind erosion of glacial sediments exposed by retreating ice).

**LORAN beacon:** Beacon that is part of a long range radio navigation system.

**Magmatic arc:** An oceanic region of magmatic activity (usually as a long arc) close to a subduction zone (where the edge of one plate moves beneath another).

**Magmatism:** Formation of molten rock as a result of increased heat and, or, pressure within the Earth's crust.

**Magnetite:** Iron oxide mineral (chemically, a ferrous and ferric oxide mixture).

**Mantle:** A thick layer of rock surrounding the Earth's core; at depths greater than 100 - 350 km (and depending on rock composition and temperature), rocks become easily deformed (the Asthenosphere).

**Marble:** Metamorphosed limestone (rock in which mineral calcite has recrystallised under heat and pressure).

**Mariculture:** Artificial culture of biota (mostly fish or shellfish) in marine waters.

**Marshland:** A wetland area without trees, in which there is some movement of water (cattails and rushes are often the dominant vegetation).

**MC:** Museums Canada.

**Melanin:** A dark brown or black pigment.

**Metabolism (biological):** All the physical and chemical processes that convert food into living matter, and reserves and waste matter, and energy for all vital processes.

**Metamorphism (rocks):** Changes in structure and mineral content that occur in any solid rock, under the influence of high temperature and pressure (rocks which completely melt and recrystallize become igneous rocks). See also, Igneous rocks.

**Methylation (mercury):** Natural microbial processes by which a methyl ( $-\text{CH}_3$ ) group is attached to a metal or metalloid in an inorganic compound. Anaerobic conditions favour production of methyl mercury. In neutral or alkaline waters, volatile dimethyl mercury ( $(\text{CH}_3)_2\text{Hg}$ ) is formed and most passes quickly into the atmosphere. Under more acidic conditions, monomethyl mercury ( $\text{CH}_3\text{Hg}^+$ ) is formed. This soluble form is more readily incorporated into the food web through bioaccumulation. Both methylation and demethylation processes may proceed simultaneously within different microbial communities, in the same sediment.

**MHA:** Métis Heritage Association of the Northwest Territories.



**Microtines:** Voles.

**Milankovitch cycles:** Long term periodicities in inclination and motion of the Earth around the sun that relate to changes in received solar radiation. Average periodicities for precession, tilt, and orbital eccentricity are 23,000, 41,000, and 100,000 years (low eccentricity) and 400,000 years (high eccentricity), respectively; frequencies of these effects, in combination, extend over even longer periods of time.

**Mineral horizon:** Layer containing a mineral concentration.

**Moho or Mohorovic discontinuity:** Zone of seismic discontinuity at the base of the Earth's crust.

**Monocotyledon:** A flowering plant with long and narrow leaves that have a parallel vein structure, and fibrous roots (*e. g.* grasses).

**Moulting:** Process of shedding and regrowth of hair, fur, feathers, or an exoskeleton.

**MRD:** Mineral Resources Directorate.

**MSSC:** Ministry of Supply and Services Canada. See also DSS and SSC.

**MVEIRB:** Mackenzie Valley Environmental Impact Review Board, Yellowknife.

**Mysids:** Small, shrimp-like crustaceans with a carapace over most of the thorax and that have two-branched appendages (Order Mysidacea). Mysids tend to be larger than amphipods. See also Amphipods.

**NAO:** North Atlantic Oscillation; a long term fluctuation in the distribution of large scale atmospheric pressure systems over the North Atlantic.

**NATMAP:** National Mapping (Canadian geological research program).

**Nauplii:** First larval stage in development of some crustaceans; the body is typically unsegmented, with only three pairs of appendages and an unpaired median eye. See also Zooplankton.

**NCP:** Northern Contaminants Program (DIAND and partners).

**NED:** Northern Environment Directorate.

**NFA:** Nunavut Final Agreement.

**Net annual production:** Total production, less material used in respiration.

**N-fixation:** Process by which atmospheric nitrogen is used by some bacteria and blue-green algae to form amino acids (some of these organisms are free living and some are symbionts living in association with plants, *e. g.* in root nodules).

**NGMP:** Nunavut General Monitoring Program.

**NNP:** Net Neutralizing Potential, the balance between AP and NP (values may be positive or negative). See also AP and NP.

**NP:** Neutralizing Potential, the ability of material to neutralize acids (relating to mine wastes). NP values generally apply to the natural bedrock surface at the site of mine wastes. See also AP and NNP.

**NPC:** Nunavut Planning Commission.

**NRC:** Natural Resources Canada. See also EMR.

**NREDB:** Natural Resources and Economic Development Branch.

**NSMA:** North Slave Métis Alliance

**Nutrients:** Biological health and growth are largely controlled by availability of major nutrients (e. g. phosphorus, nitrogen, organic carbon, and silica) and numerous other minor nutrients.

**NWC:** North West Company. See, also HBC.

**NWT:** North West Territories.

**NWT-CM:** NWT Chamber of Mines.

**NWT-HC:** NWT Housing Corporation.

**Ostracism:** To socially ignore someone or, in a more extreme situation, to banish, exile, or cast someone out from a community.

**Orogen:** Large elongated region of the Earth's crust that has been intensely folded, faulted and thickened as a result of crustal movements.

**Ozone:** A strongly oxidizing gas (molecular formula O<sub>3</sub>).

**PAHs:** Polycyclic aromatic hydrocarbons; a group of compounds formed as a result of incomplete combustion of fuel (including wood, oil and coal). The compounds have a wide range of toxicities.

**Passerines:** Perching birds.

**Passive migration:** Movement of an organism with the natural flow of a river or coastal current, with little or no additional effort to accelerate transportation.

**PC:** Parks Canada.

**PCBs:** Polychlorinated biphenyls; stable, heat transfer fluids, lubricants and flame retardants, PCB congeners have a wide range of toxicities and persistence.

**PCCs:** Polychlorinated camphenes. See also Toxaphene.

**PCDDs:** Polychlorinated dibenzo-*p*-dioxins; group of isomers formed as by-products in manufacture of chlorophenol and phenoxy compounds (including some pesticides and wood preservatives), and possibly from municipal incineration. Also, like some of the chlorinated dibenzo furans, PCDD may be produced as a by-product of chlorinating in the pulp and paper industry. PCDDs range widely in toxicity (2,3,7,8 tetrachloro dibenzo-*p*-dioxin is the most toxic isomer). See also PCDFs.

**PCDFs:** Polychlorinated dibenzo-*p*-furans (closely related to PCDDs). Present as a by-product or contaminant in PCBs and produced, unintentionally, in some chlorinated processes (e. g. pulp and paper manufacture) and in association with some combustion. 2,3,7,8 tetrachlorodibenzo-*p*-furan (TCDF) is the most toxic of these compounds.

**Peatlands:** Areas dominated by the formation of organic soil in which much of the material is only partly decomposed (also known as muskeg). See also Wetlands.

**Pegmatites:** Igneous rocks (usually late in an intrusive sequence) in which the crystalline structure is extremely coarse.

**Pelagic:** Actively moving in open water (not drifting).

**Peridotite:** Coarse grained igneous rock consisting mostly of olivine (with or without pyroxene).

**Permafrost:** Permanently frozen ground.

**Pesticides:** Chemicals that are manufactured to kill different types of pests (including insects, worms, mice, rats and other organisms). Insecticides specifically target insects and are a common type of pesticide.

**pH:** A log. scale that measures the concentration of hydrogen ions; 1.0 is extremely acidic, 7.0 is neutral, and 14.0 is extremely basic.

**Photic zone:** Uppermost layer of a water body in which penetration of daylight is sufficient to support photosynthesis.

**Photochemical reaction:** Chemical reaction produced by light energy.

**Photo-oxidation:** Chemical oxidation induced by light.

**Photosynthesis (plants):** Synthesis of chemical compounds by organisms containing chlorophyll (plants) in light. The synthesis of carbohydrates from carbon dioxide and a hydrogen source such as water, with the simultaneous liberation of oxygen.

**Phytoplankton:** Free-floating or suspended microscopic plants in marine and freshwater environments. See also Plankton.

**Pillow lavas:** Lava extruded under water at the Earth's surface. Rapid cooling causes the lava to develop characteristic pillow shaped forms as it solidifies into rock.

**Pitchblende:** Mineral of uranium oxide (also called uranite).

**Plankton:** Depending on particle size, plankton (phytoplankton and, or, zooplankton) can be grouped as pico (0.45 to 1.2 mm), nano (1.2 to 5.0 mm), ultra (5 to 20 mm), and micro or net plankton (greater than 20 mm).

**Plume:** Tongue-like body of freshwater and, or, suspended sediment that is sometimes present where a river enters a lake or the sea. Plumes occur where there is a difference in density between inflowing and receiving waters. Plumes may be present on the surface, at some mid-depth or at the bottom of the receiving body of water. Plumes of gas and particulate emissions from industrial sources also enter the atmosphere and may travel hundred of kilometres from source.

**Pluton:** Any large body of intrusive rock, regardless of shape (a batholith may comprise multiple plutons).

**Polar vortex:** Circulation of the atmosphere around the polar regions (Arctic and Antarctic).

**Polynya:** Areas of open water that remain uncovered by seasonal ice (for most or all of the year). These areas are usually kept open by current circulation and vary considerably in size. The features are generally stable and develop in the same place each winter.

**Polysaccharide:** Large carbohydrate molecule made up of many monosaccharide units. Insoluble and unsweet, and important for energy storage (*e. g.* starch, glycogen) and as reinforcing material in plants (cellulose).

**POPs:** Persistent Organic Pollutants.

**Population:** All members of some specifically defined group (*e. g.* males and females, juveniles and adults; or the group might include only adult males). Population can apply to a species, a community or some larger grouping of animals and plants, or both. See also Herd.

**Primary production:** Amount of organic matter produced by photosynthesis.

**Pyrrhotite:** Mineral of iron sulphide (ferrous sulphide).

**Quartzites:** Metamorphosed sandstone (rock in which mineral quartz is dominant and has recrystallised under heat and pressure).

**Radiometric dating techniques:** Age determination based on the extent to which isotopic decay has occurred in some radioactive element. Rates of decay are more or less constant and the half-life of a radioactive element is the time taken for half of this isotopic decay to occur (*e. g.*  $^{40}\text{K}$  has a half life of 1.3 Ga but  $^{14}\text{C}$  has a half life of only 5.7 ka).

**Radionuclides:** In this report, radionuclides include those of cesium ( $^{134}\text{Cs}$ ,  $^{137}\text{Cs}$ ), lead ( $^{210}\text{Pb}$ ), polonium ( $^{210}\text{Po}$ ), potassium ( $^{40}\text{K}$ ), radon ( $^{222}\text{Rn}$ ), radium ( $^{226}\text{Ra}$ ), strontium ( $^{90}\text{Sr}$ ), thorium ( $^{232}\text{Th}$ ) and uranium ( $^{235}\text{U}$ ).

**Range:** Area normally occupied by some group of animals, for part of all of a year. If not specified, the range is assumed to be the total annual range (*e. g.* the range of the Bathurst Caribou herd includes winter grounds, calving areas, summer feeding grounds and rutting areas).

**Range extension:** An increase in the area occupied by some group of animals (*e. g.* in response to changing and more favourable climatic conditions).

**Raptors:** Any bird of prey (predatory bird).

**Rare earth (elements):** Rare lanthanide elements such as cerium and hafnium (having atomic numbers between 58 and 72, inclusive).

**RCMP:** Royal Canadian Mounted Police

**Respiration (microbial):** Gas exchange between an organism and its surroundings.

**Rhizome:** Underground part of a plant stem that provides storage, usually horizontal, and from which new buds and leaves may develop away from the parent plant (vegetative propagation).

**Sandstone:** Sedimentary rock composed of sand grains that have become fused or cemented together.

**SC:** Statistics Canada.

**SCNE:** Special Committee on the Northern Economy.

**Secchi depth:** Measure of transparency based on the depth at which a white disk can be seen, when lowered into water.

**Sedge meadow:** Open areas of sedge vegetation. See also Tussock sedge.

**Sedimentary (rock):** A rock formed in response to the processes of erosion (by wind, water and ice) and deposition on the land or under water. “Soft” sediments (*e. g.* mud, sand and gravel) are not cohesive but if consolidated by overlying material or cementation, over a long period of time, they develop into “hard” rocks (including mudstones, limestone, and sandstone).

**SEL:** Severe effect level; a guideline indicating that at least one chemical parameter exceeds a level at which biological assessment is required to establish the effect of a sediment contaminant on aquatic biota (and remediation implemented). This is a sediment quality

guideline that was established by the Ontario Ministry of Environment in 1992. The guideline value does not indicate that the sediment will have an adverse affect on biota; rather it indicates that biological testing must be undertaken to establish to what extent there may or may not be an adverse affect. See also LEL.

**Senescing tissue:** Old tissue (that may often die-off in plants).

**Shales:** Mud (mixture of silt and clay) that has been metamorphosed and developed fine partings perpendicular to formative pressures.

**Shrub:** A low woody plant without a well defined (single) stem.

**Siltstone:** Metamorphosed silt (but without well developed fine partings).

**SMB:** Surveys and Mapping Branch.

**Solifluction:** Slow downslope movement in soil.

**SSC:** Supply and Services Canada. See also MSSC.

**Staging:** Seasonal behaviour, particularly in ducks and geese, in which groups of birds gather to feed and rest before leaving on migration.

**Stocks:** A subset of the population of a species; often used in reference to fish. See also Herd.

**Stratiform deposits:** Layered deposits (applied to mineral layers in some ore deposits).

**Stratosphere:** Atmospheric layer between about 10 and 25 km above the Earth's surface, in which the temperature is relatively constant, ranging from about -45° C to -75° C.

**Subducted:** Downward movement of the edge of a plate on the Earth's crust beneath an adjacent plate, as one plate moves towards the other.

**Substrate:** Stable base onto which an organism can become attached (*e. g.* shell of another organism, wood, sediment, rock or even ice).

**Sugar:** Simple carbohydrate formed of monosaccharide units that can be readily metabolized to support plant growth or animal activity.

**Sunspots:** Regions of high magnetic field on the sun. Groups of sunspots vary in size (lasting hours to weeks). Sunspot (magnetic) activity increases to a maximum about every 11 years.

**SWC:** Status of Women Council.

**Syntheses (biological):** Processes by which plants and animals make essential compounds.

**Taiga:** Transitional vegetation zone between a closed canopy boreal forest and treeless tundra. It is characterized by small groups of scattered trees within tundra vegetation and, occasionally, patches of tundra within open canopy boreal forest. Taiga vegetation more or less coincides with the sub-Arctic Climate zone.

**Tailings:** Waste materials left after extraction of ore from host rock; a waste product of mining.

**TDI (PTDI and PDI):** Tolerable Daily Intake (an adopted value) and Provisional Tolerable Daily Intake (a provisional value). Amount of a substance (contaminant) that a person may be exposed to, every day of their lifetime, with minimal or no appreciable health risk. Values of TDI are based on epidemiological and toxicological research that establishes at what level there is no observed adverse effect, and to which a safety factor has been applied. Consumption advisories are issued when PDI values exceed TDI.

Probable Daily Intake (PDI) values are calculated from information about contaminant concentrations (*e. g.* in food), quantity of food (containing a contaminant) and the body weight (of a person eating the food). Well defined analyses of risk form the basis of both TDI and PDI values

**Terrane:** A large piece of the Earth's crust having distinct geological characteristics.

**Terrigenous:** Referring to the land (*e. g.* terrigenous environment).

**TKSC:** traditional knowledge Committee of the West Kitikmeot/Slave Study.

**Toxaphene:** Chlorinated camphene; an insecticide (which may consist of a mixture of more than 170 compounds). See also PCCs.

**Tree line:** Northern edge of the Boreal Forest that may, in part, lie within the taiga. See also Taiga.

**Trophic levels:** Successive levels in the food web. Primary production of plants (including phytoplankton) occurs at the base of the food web, and predator species characterize the upper levels. Some food chains are longer than others and have more trophic levels.

**Tuff:** Rock formed from the hardening of volcanic ash and ejecta.

**Tundra:** Treeless vegetation cover (including sedges, grasses, low shrubs, lichens and mosses) that coincides closely with the Low Arctic Climatic Zone.

**Tussock sedge:** Distinctive clumps of sedge vegetation that form under poorly drained conditions. See also Sedge meadow

**Ultramafic:** Extremely basic rocks, very dark in colour, that are mostly comprised of ferromagnesian minerals (*e. g.* olivine and pyroxene) and a small amount of plagioclase feldspar.

**UNEP:** United Nations Environment Program.

**USDA:** United States Department of Agriculture.

**USDI:** United States Department of Interior.

**USEPA:** United States Environmental Protection Agency.

**UV radiation:** Ultra violet radiation is a form of short wave electromagnetic radiation with wave lengths between about 0.1 and 0.4 mm. It merges into the spectrum of visible light (that has wave lengths up to about 0.8mm).

**Vascular plants:** Plants having internal structures (vascular bundles) that allow water to be transported within the plant (*e. g.* from roots to leaves).

**Vitamins:** Organic compounds that are vital in diet, in small amounts, for normal health and growth. Not all organisms require the same vitamins. Some vitamins are synthesized by the animals that need them but some have to be taken into the body as food. Vitamins A, D, E and K are fat-soluble, and vitamins B and C are water soluble.

**Volatilization:** Released as vapour; changing rapidly from a liquid to a gas.

**Volcanic massive sulphides:** Large deposits of sulphide metal ores (*e. g.* iron, copper, zinc, lead and arsenic) associated with the formation of volcanic rocks.

**Weather index:** In WKSS area, east of Great Slave Lake, almost all natural fires occur as a result of lightning strikes. By comparing fire history with environmental conditions, it is

possible to characterize fire potential (*e. g.* risk related to moisture content of soil and vegetation) and weather conditions that are likely to start and support a fire (*e. g.* air temperature and moisture, and wind conditions). Fires that do not match weather index conditions for fire are likely due to some other cause.

**WKRLUP:** West Kitikmeot Regional Land Use Plan (*draft*).

**WKSS area:** The West Kitikmeot and Slave geological province and surrounding region, including the Bear geological province and part of the Mackenzie Valley. The main focus of this report is on the West Kitikmeot sub-region of Nunavut (that includes part of the Slave geological province) and the eastern part of the Northwest Territory (which includes the remainder of the Slave geological province).

**WKSSS:** West Kitikmeot Slave Study Society, Yellowknife, NWT.

**WMO:** World Meteorological Organization, Geneva.

**WRD:** Water Resources Division.

**WS:** Wildlife Service.

**WWI / WWII:** First World War (1914-1918) / Second World War (1939-1945).

**Zooplankton:** Animal plankton (*e. g.* nauplii, ciliates, small crustaceans and fish larvae). See also plankton.

## APPENDIX B: SYMBOLS, NOTATIONS AND USAGE

|                                      |                   |
|--------------------------------------|-------------------|
| Ag.....                              | Silver            |
| As.....                              | Arsenic           |
| Au.....                              | Gold              |
| Be.....                              | Beryllium         |
| Bi.....                              | Bismuth           |
| C.....                               | Carbon            |
| Ca.....                              | Calcium           |
| Cd.....                              | Cadmium           |
| Co.....                              | Cobalt            |
| Cr.....                              | Chromium          |
| Cs.....                              | Caesium           |
| Cu.....                              | Copper            |
| F.....                               | Fluorine          |
| Fe.....                              | Iron              |
| Ga.....                              | Gallium           |
| K.....                               | Potassium         |
| Mg.....                              | Magnesium         |
| N.....                               | Nitrogen          |
| Na.....                              | Sodium            |
| Ni.....                              | Nickel            |
| O.....                               | Oxygen            |
| P.....                               | Phosphorus        |
| Pb.....                              | Lead              |
| Pd.....                              | Palladium         |
| Po.....                              | Polonium          |
| Pt.....                              | Platinum          |
| Ra.....                              | Radium            |
| Rn.....                              | Radon             |
| S.....                               | Sulphur           |
| Si.....                              | Silicon           |
| Th.....                              | Thorium           |
| U.....                               | Uranium           |
| Y.....                               | Yttrium           |
| Zn.....                              | Zinc              |
| As <sub>2</sub> O <sub>3</sub> ..... | Arsenious oxide   |
| CaCO <sub>3</sub> .....              | Calcium carbonate |
| CO <sub>2</sub> .....                | Carbon dioxide    |
| H <sub>2</sub> O.....                | Water             |



|                                            |                                                                                                                                                                         |
|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SO <sub>2</sub> .....                      | Sulphur dioxide                                                                                                                                                         |
| MeHg .....                                 | Methyl mercury                                                                                                                                                          |
| a.....                                     | Year                                                                                                                                                                    |
| Bq.....                                    | Becquerel, number of disintegrations per second from a radioactive source.                                                                                              |
| °C .....                                   | Degree Celsius                                                                                                                                                          |
| d.....                                     | Day                                                                                                                                                                     |
| g.....                                     | Gram                                                                                                                                                                    |
| Ga.....                                    | Giga years (billion years, or 10 <sup>9</sup> years)                                                                                                                    |
| ha.....                                    | Hectare (10,000 square metres)                                                                                                                                          |
| ka.....                                    | Kilo years (one thousand years, 10 <sup>3</sup> a)                                                                                                                      |
| kg.....                                    | Kilogram (one thousand grams, 10 <sup>3</sup> g)                                                                                                                        |
| km .....                                   | Kilometre (one thousand metres, 10 <sup>3</sup> m)                                                                                                                      |
| l .....                                    | Litre                                                                                                                                                                   |
| m .....                                    | Metre                                                                                                                                                                   |
| mg .....                                   | Milligram (one thousandth part of a gram, 10 <sup>-3</sup> ), <i>e. g.</i> weight of contaminant in some form of concentration.                                         |
| mm .....                                   | Millimetre (one thousandth part of a metre)                                                                                                                             |
| ng.....                                    | Nanogram (one billionth part of a gram, 10 <sup>-9</sup> ), <i>e. g.</i> weight of contaminant in some form of concentration.                                           |
| nm .....                                   | Nanometre (one billionth part of a metre, 10 <sup>-9</sup> ), <i>e. g.</i> wavelength in part of the electromagnetic spectrum (1000 nm = 1mm).                          |
| t .....                                    | Metric tonne (1000 kg).                                                                                                                                                 |
| ug.....                                    | Microgram (one millionth part of a gram, 10 <sup>-6</sup> ), <i>e. g.</i> weight of contaminant in some form of concentration.                                          |
| um .....                                   | Micrometre (one millionth part of a metre, 10 <sup>-6</sup> ), <i>e. g.</i> wavelength in part of the electromagnetic spectrum.                                         |
| % .....                                    | Per cent (parts per hundred), a useful form of common comparison.                                                                                                       |
| S .....                                    | The sum of; <i>e. g.</i> SPCB means all PCB congeners (that are present ).                                                                                              |
| Bq·kg <sup>-1</sup> .....                  | Becquerels; disintegrations per second, per kilogram of material containing a radioactive substance ( <i>e. g.</i> a radioactive isotope of caesium in caribou tissue). |
| ha <sup>-1</sup> .....                     | Quantity of something per hectare ( <i>e. g.</i> lemmings).                                                                                                             |
| kg·d <sup>-1</sup> .....                   | Loading of something expressed in kilograms per day ( <i>e. g.</i> some form of industrial contaminant).                                                                |
| kg·ha <sup>-1</sup> ·a <sup>-1</sup> ..... | Loading of something expressed in kilograms per hectare per year ( <i>e. g.</i> sulphate ions, as an indication of atmospheric contributions to acidification).         |
| km <sup>-2</sup> .....                     | Quantity of something per square kilometre ( <i>e. g.</i> hares).                                                                                                       |
| m <sup>-2</sup> .....                      | Quantity of something, per square metre ( <i>e. g.</i> annual production of plant                                                                                       |

|                          |                                                                                                                               |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------|
|                          | matter).                                                                                                                      |
| mg·l <sup>-1</sup> ..... | Parts per million of something expressed as weight per volume ( <i>e. g.</i> suspended organic matter in water).              |
| ng·g <sup>-1</sup> ..... | Parts per billion of something expressed as weight per weight (mass).                                                         |
| mg·g <sup>-1</sup> ..... | Parts per million of something expressed as weight per weight (mass).                                                         |
| mg·m <sup>-3</sup> ..... | Parts per billion of something per cubic metre expressed as weight per volume ( <i>e. g.</i> some pollutant in air).          |
| Sv.a <sup>-1</sup> ..... | Sieverts or dose equivalent (defined as absorbed radiation dose times the Relative Biological Effectiveness factor) per year. |

## APPENDIX C: COMMON AND SCIENTIFIC NAMES

### Mammals

No formal inventories of mammalian species, or any other group, have been conducted in the WKSS but the following lists summarise what is known about the resident mammalian species in the Taiga Shield and Southern Arctic ecozones and hence may be present in the WKSS. Genus and species names are taken from the Mammal Species of the World, 3<sup>rd</sup> Edition (2005) (Wilson, D. E., and D. M. Reeder (eds). 2005. Mammal Species of the World. Johns Hopkins University Press, 2,142 pp.), the world authority on mammal nomenclature and taxonomy. The latest systematics can be found at <http://nmmhgoph.si.edu/msw/> or <http://www.bucknell.edu/msw3/>.

#### Large Mammals

|                                                    |                                                 |
|----------------------------------------------------|-------------------------------------------------|
| Wood Bison                                         | <i>Bison bison athabasca</i>                    |
| Barrenground caribou<br>(except Dolphin-Union)     | <i>Rangifer tarandus groenlandicus</i>          |
| Barrenground caribou<br>(Dolphin Union population) | <i>Rangifer tarandus groenlandicus x pearyi</i> |
| Woodland caribou                                   | <i>Rangifer tarandus caribou</i>                |
| Moose                                              | <i>Alces americanus</i>                         |
| Muskox                                             | <i>Ovibos moschatus</i>                         |
| Black Bear                                         | <i>Ursus americanus</i>                         |
| Grizzly Bear                                       | <i>Ursus arctos</i>                             |
| Polar Bear                                         | <i>Ursus maritimus</i>                          |
| Wolverine                                          | <i>Gulo gulo</i>                                |
| Lynx                                               | <i>Lynx canadensis</i>                          |
| Coyote                                             | <i>Canis latrans</i>                            |
| Gray Wolf                                          | <i>Canis lupus</i>                              |
| Arctic Fox                                         | <i>Vulpes lagopus</i>                           |
| Red Fox                                            | <i>Vulpes vulpes</i>                            |
| Beaver                                             | <i>Castor canadensis</i>                        |
| North American Porcupine                           | <i>Erethizon dorsata</i>                        |

#### Small Mammals

|                      |                          |
|----------------------|--------------------------|
| Northern River Otter | <i>Lontra canadensis</i> |
| Marten               | <i>Martes americana</i>  |
| Fisher               | <i>Martes pennanti</i>   |
| Least Weasel         | <i>Mustela nivalis</i>   |
| Ermine (Stoat)       | <i>Mustela erminea</i>   |
| Mink                 | <i>Neovison vison</i>    |
| Arctic Shrew         | <i>Sorex arcticus</i>    |
| Masked Shrew         | <i>Sorex cinereus</i>    |
| Pigmy Shrew          | <i>Sorex hoyi</i>        |
| Dusky Shrew          | <i>Sorex monticolus</i>  |
| Water Shrew          | <i>Sorex palustris</i>   |
| Tundra Shrew         | <i>Sorex tundrensis</i>  |
| Barren Ground Shrew  | <i>Sorex ugyunak</i>     |
| Snowshoe Hare        | <i>Lepus americanus</i>  |
| Arctic Hare          | <i>Lepus arcticus</i>    |

|                                    |                                                    |
|------------------------------------|----------------------------------------------------|
| Meadow Jumping Mouse               | <i>Zapus hudsonius</i>                             |
| Southern Red-backed Vole           | <i>Clethrionomys gapperi</i>                       |
| Northern Red-backed Vole           | <i>Clethrionomys rutilus</i>                       |
| Tundra or Root Vole                | <i>Microtus oeconomus</i>                          |
| Meadow Vole                        | <i>Microtus pennsylvanicus</i>                     |
| Taiga Vole (Chestnut-cheeked vole) | <i>Microtus xanthognathus</i>                      |
| Eastern Heather Vole               | <i>Phenacomys ungava</i> ( <i>P. intermedius</i> ) |
| Nearctic Collared Lemming          | <i>Dicrostonyx groenlandicus</i>                   |
| Richardson's Lemming               | <i>Dicrostonyx richardsoni</i>                     |
| Brown Lemming                      | <i>Lemmus trimucronatus</i>                        |
| Northern Bog Lemming               | <i>Synaptomys borealis</i>                         |
| Muskrat                            | <i>Ondatra zibethicus</i>                          |
| Deermouse                          | <i>Peromyscus maniculatus</i>                      |
| Northern Flying Squirrel           | <i>Glaucomys sabrinus</i>                          |
| Woodchuck                          | <i>Marmota monax</i>                               |
| Least Chipmunk                     | <i>Tamias minimus</i>                              |
| Arctic Ground Squirrel             | <i>Spermophilus parryii</i>                        |
| Red Squirrel                       | <i>Tamiasciurus hudsonicus</i>                     |

## Birds

No rigorous inventory of bird species of the WKSS has been conducted but WGGSNS (2006) lists the following species as being present in the Tundra Shield and Southern Arctic ecozones (WGGSNS 2006). Resident species are those that nest in the WKSS and the list does not include transient species, or those that migrate through the area.

Nomenclature (genus and species names) is taken from the American Ornithologists' Union (AOU), which is the official source on bird taxonomy, in April 2008. A checklist of North American species, with current scientific names, including all supplements, can be found at <http://www.aou.org/checklist/index.php3>.

### Order Anseriformes – Swans, geese and ducks

|                             |                           |
|-----------------------------|---------------------------|
| Northern Pintail            | <i>Anas acuta</i>         |
| American Wigeon             | <i>Anas americana</i>     |
| Northern Shoveler           | <i>Anas clypeata</i>      |
| Green-winged Teal           | <i>Anas crecca</i>        |
| Blue-winged Teal            | <i>Anas discors</i>       |
| Mallard                     | <i>Anas platyrhynchos</i> |
| Gadwall                     | <i>Anas strepera</i>      |
| Greater White-fronted Goose | <i>Anser albifrons</i>    |
| Lesser Scaup                | <i>Aythya affinis</i>     |
| Ring-necked Duck            | <i>Aythya collaris</i>    |
| Greater Scaup               | <i>Aythya marila</i>      |
| Canvasback                  | <i>Aythya valisineria</i> |
| Brant                       | <i>Branta bernicla</i>    |
| Canada Goose                | <i>Branta canadensis</i>  |
| Cackling Goose              | <i>Branta hutchinsii</i>  |
| Bufflehead                  | <i>Bucephala albeola</i>  |
| Common Goldeneye            | <i>Bucephala clangula</i> |
| Snow Goose                  | <i>Chen caerulescens</i>  |

|                        |                                  |
|------------------------|----------------------------------|
| Ross's Goose           | <i>Chen rossii</i>               |
| Long-tailed duck       | <i>Clangula hyemalis</i>         |
| Tundra Swan            | <i>Cygnus columbianus</i>        |
| Harlequin Duck         | <i>Histrionicus histrionicus</i> |
| White-winged Scoter    | <i>Melanitta fusca</i>           |
| Black Scoter           | <i>Melanitta nigra</i>           |
| Surf Scoter            | <i>Melanitta perspicillata</i>   |
| Common Merganser       | <i>Mergus merganser</i>          |
| Red-breasted Merganser | <i>Mergus serrator</i>           |
| Ruddy Duck             | <i>Oxyura jamaicensis</i>        |
| Common Eider           | <i>Somateria mollissima</i>      |
| King Eider             | <i>Somateria spectabilis</i>     |

### **Order Caprimulgiformes – Nighthawks, Poorwills**

|                  |                         |
|------------------|-------------------------|
| Common Nighthawk | <i>Chordeiles minor</i> |
|------------------|-------------------------|

### **Order Charadriiformes – Shorebirds, Gulls and Auks**

|                                       |                                 |
|---------------------------------------|---------------------------------|
| Dovekie                               | <i>Alle alle</i>                |
| Black Guillemot                       | <i>Cephus grylle</i>            |
| Thick-billed Murre (Brünnich's murre) | <i>Uria lomvia</i>              |
| Killdeer                              | <i>Charadrius vociferus</i>     |
| American Golden-Plover                | <i>Pluvialis dominica</i>       |
| Black-bellied Plover                  | <i>Pluvialis squatarola</i>     |
| Black Tern                            | <i>Chlidonias niger</i>         |
| Herring Gull                          | <i>Larus argentatus</i>         |
| California Gull                       | <i>Larus californicus</i>       |
| Mew Gull (short-billed gull)          | <i>Larus canus</i>              |
| Glaucous Gull                         | <i>Larus hyperboreus</i>        |
| Bonaparte's Gull                      | <i>Larus philadelphia</i>       |
| Ross's Gull                           | <i>Rhodostethia rosea</i>       |
| Long-tailed Jaeger                    | <i>Stercorarius longicaudus</i> |
| Parasitic Jaeger                      | <i>Stercorarius parasiticus</i> |
| Pomarine Jaeger                       | <i>Stercorarius pomarinus</i>   |
| Caspian Tern                          | <i>Hydroprogne caspia</i>       |
| Common Tern                           | <i>Sterna hirundo</i>           |
| Arctic Tern                           | <i>Sterna paradisaea</i>        |
| Sabine's Gull                         | <i>Xema sabini</i>              |
| Spotted Sandpiper                     | <i>Actitis macularius</i>       |
| Ruddy Turnstone                       | <i>Arenaria interpres</i>       |
| Sanderling                            | <i>Calidris alba</i>            |
| Dunlin                                | <i>Calidris alpina</i>          |
| Baird's Sandpiper                     | <i>Calidris bairdii</i>         |
| Red Knot                              | <i>Calidris canutus</i>         |
| White-rumped Sandpiper                | <i>Calidris fuscicollis</i>     |
| Stilt Sandpiper                       | <i>Calidris himantopus</i>      |
| Pectoral Sandpiper                    | <i>Calidris melanotos</i>       |
| Least Sandpiper                       | <i>Calidris minutilla</i>       |
| Semipalmated Sandpiper                | <i>Calidris pusilla</i>         |
| Wilson's snipe                        | <i>Gallinago delicata</i>       |
| Common snipe                          | <i>Gallinago gallinago</i>      |

|                         |                                |
|-------------------------|--------------------------------|
| Short-billed Dowitcher  | <i>Limnodromus griseus</i>     |
| Long-billed Dowitcher   | <i>Limnodromus scolopaceus</i> |
| Hudsonian Godwit        | <i>Limosa haemastica</i>       |
| Eskimo Curlew           | <i>Numenius borealis</i>       |
| Whimbrel                | <i>Numenius phaeopus</i>       |
| Red Phalarope           | <i>Phalaropus fulicarius</i>   |
| Red-necked Phalarope    | <i>Phalaropus lobatus</i>      |
| Lesser Yellowlegs       | <i>Tringa flavipes</i>         |
| Greater Yellowlegs      | <i>Tringa melanoleuca</i>      |
| Buff-breasted Sandpiper | <i>Tryngites subruficollis</i> |

#### **Order Ciconiiformes – Herons, Storks and Allies**

|                  |                              |
|------------------|------------------------------|
| American Bittern | <i>Botaurus lentiginosus</i> |
|------------------|------------------------------|

#### **Order Coraciiformes - Kingfishers**

|                   |                          |
|-------------------|--------------------------|
| Belted Kingfisher | <i>Megaceryle alcyon</i> |
|-------------------|--------------------------|

#### **Order Falconiformes – Diurnal Birds of Prey**

|                         |                                  |
|-------------------------|----------------------------------|
| Northern Goshawk        | <i>Accipiter gentilis</i>        |
| Sharp-shinned Hawk      | <i>Accipiter striatus</i>        |
| Golden Eagle            | <i>Aquila chrysaetos</i>         |
| Red-tailed Hawk         | <i>Buteo jamaicensis</i>         |
| Rough-legged Hawk       | <i>Buteo lagopus</i>             |
| Northern Harrier        | <i>Circus cyaneus</i>            |
| Bald Eagle              | <i>Haliaeetus leucocephalus</i>  |
| Osprey                  | <i>Pandion haliaetus</i>         |
| Merlin                  | <i>Falco columbarius</i>         |
| Anatum Peregrine Falcon | <i>Falco peregrinus anatum</i>   |
| Tundra Peregrine Falcon | <i>Falco peregrinus tundrius</i> |
| Gyrfalcon               | <i>Falco rusticolus</i>          |
| American Kestrel        | <i>Falco sparverius</i>          |

#### **Order Galliformes – Partridges, Pheasants and Grouses**

|                     |                                 |
|---------------------|---------------------------------|
| Ruffed Grouse       | <i>Bonasa umbellus</i>          |
| Spruce Grouse       | <i>Falcipennis canadensis</i>   |
| Willow Ptarmigan    | <i>Lagopus lagopus</i>          |
| Rock Ptarmigan      | <i>Lagopus muta</i>             |
| Sharp-tailed Grouse | <i>Tympanuchus phasianellus</i> |

#### **Order Gaviiformes - Loons**

|                    |                       |
|--------------------|-----------------------|
| Yellow-billed Loon | <i>Gavia adamsii</i>  |
| Common Loon        | <i>Gavia immer</i>    |
| Pacific Loon       | <i>Gavia pacifica</i> |
| Red-throated Loon  | <i>Gavia stellata</i> |

#### **Order Gruiformes – Cranes, Rails and Allies**

|                |                                   |
|----------------|-----------------------------------|
| Sandhill Crane | <i>Grus canadensis</i>            |
| Yellow Rail    | <i>Coturnicops noveboracensis</i> |
| American Coot  | <i>Fulica americana</i>           |
| Sora           | <i>Porzana carolina</i>           |

### Order Passeriformes – Perching Birds

|                        |                                                              |
|------------------------|--------------------------------------------------------------|
| Horned Lark            | <i>Eremophila alpestris</i>                                  |
| Bohemian Waxwing       | <i>Bombycilla garrulus</i>                                   |
| Rose-breasted Grosbeak | <i>Pheucticus ludovicianus</i>                               |
| American Crow          | <i>Corvus brachyrhynchos</i>                                 |
| Common Raven           | <i>Corvus corax</i>                                          |
| Gray Jay               | <i>Perisoreus canadensis</i>                                 |
| Black-billed magpie    | <i>Pica hudsonia</i>                                         |
| Le Conte's Sparrow     | <i>Ammodramus leconteii</i>                                  |
| Lapland Longspur       | <i>Calcarius lapponicus</i>                                  |
| Smith's Longspur       | <i>Calcarius pictus</i>                                      |
| Dark-eyed Junco        | <i>Junco hyemalis</i>                                        |
| Swamp Sparrow          | <i>Melospiza georgiana</i>                                   |
| Lincoln's Sparrow      | <i>Melospiza lincolni</i>                                    |
| Song Sparrow           | <i>Melospiza melodia</i>                                     |
| Savannah Sparrow       | <i>Passerculus sandwichensis</i>                             |
| Fox Sparrow            | <i>Passerella iliaca</i>                                     |
| Snow Bunting           | <i>Plectrophenax nivalis</i>                                 |
| American Tree Sparrow  | <i>Spizella arborea</i>                                      |
| Clay-colored Sparrow   | <i>Spizella pallida</i>                                      |
| Chipping Sparrow       | <i>Spizella passerina</i>                                    |
| White-throated Sparrow | <i>Zonotrichia albicollis</i>                                |
| White-crowned Sparrow  | <i>Zonotrichia leucophrys</i>                                |
| Harris's Sparrow       | <i>Zonotrichia querula</i>                                   |
| Common Redpoll         | <i>Carduelis flammea</i>                                     |
| Hoary Redpoll          | <i>Carduelis hornemanni</i>                                  |
| Pine Siskin            | <i>Carduelis pinus</i>                                       |
| Red Crossbill          | <i>Loxia curvirostra</i>                                     |
| White-winged Crossbill | <i>Loxia leucoptera</i>                                      |
| Pine Grosbeak          | <i>Pinicola enucleator</i>                                   |
| Barn Swallow           | <i>Hirundo rustica</i>                                       |
| Cliff Swallow          | <i>Petrochelidon phyrhronota</i>                             |
| Bank Swallow           | <i>Riparia riparia</i>                                       |
| Tree Swallow           | <i>Tachycineta bicolor</i>                                   |
| Red-winged Blackbird   | <i>Agelaius phoeniceus</i>                                   |
| Rusty Blackbird        | <i>Euphagus carolinus</i>                                    |
| Northern Shrike        | <i>Lanius excubitor</i>                                      |
| American Pipit         | <i>Anthus rubescens</i>                                      |
| Eastern Yellow Wagtail | <i>Motacilla tschutschensis</i>                              |
| Black-capped Chickadee | <i>Poecile atricapillus</i>                                  |
| Gray-headed Chickadee  | <i>Poecile cincta</i>                                        |
| Boreal Chickadee       | <i>Poecile hudsonica</i> (formerly <i>Parus hudsonicus</i> ) |
| Yellow-rumped Warbler  | <i>Dendroica coronata</i>                                    |
| Magnolia Warbler       | <i>Dendroica magnolia</i>                                    |
| Palm Warbler           | <i>Dendroica palmarum</i>                                    |
| Yellow Warbler         | <i>Dendroica petechia</i>                                    |
| Blackpoll Warbler      | <i>Dendroica striata</i>                                     |
| Cape May Warbler       | <i>Dendroica tigrina</i>                                     |
| Ovenbird               | <i>Seiurus aurocapillus</i>                                  |
| Northern Waterthrush   | <i>Seiurus noveboracensis</i>                                |
| American Redstart      | <i>Setophaga ruticilla</i>                                   |

|                                 |                               |
|---------------------------------|-------------------------------|
| Orange-crowned Warbler          | <i>Vermivora celata</i>       |
| Tennessee Warbler               | <i>Vermivora peregrina</i>    |
| Wilson's Warbler                | <i>Wilsonia pusilla</i>       |
| House Sparrow (English Sparrow) | <i>Passer domesticus</i>      |
| Ruby-crowned Kinglet            | <i>Regulus calendula</i>      |
| Red-breasted Nuthatch           | <i>Sitta canadensis</i>       |
| European Starling               | <i>Sturnus vulgaris</i>       |
| Western Tanager                 | <i>Piranga ludoviciana</i>    |
| Hermit Thrush                   | <i>Catharus guttatus</i>      |
| Gray-cheeked Thrush             | <i>Catharus minimus</i>       |
| Swainson's Thrush               | <i>Catharus ustulatus</i>     |
| Varied Thrush                   | <i>Ixoreus naevius</i>        |
| American Robin                  | <i>Turdus migratorius</i>     |
| Olive-sided Flycatcher          | <i>Contopus cooperi</i>       |
| Western Wood-Pewee              | <i>Contopus sordidulus</i>    |
| Alder Flycatcher                | <i>Empidonax alnorum</i>      |
| Yellow-bellied Flycatcher       | <i>Empidonax flaviventris</i> |
| Least Flycatcher                | <i>Empidonax minimus</i>      |
| Eastern Phoebe                  | <i>Sayornis phoebe</i>        |
| Say's Phoebe                    | <i>Sayornis saya</i>          |
| Eastern Kingbird                | <i>Tyrannus tyrannus</i>      |
| Warbling Vireo                  | <i>Vireo gilvus</i>           |
| Red-eyed Vireo                  | <i>Vireo olivaceus</i>        |
| Philadelphia Vireo              | <i>Vireo philadelphicus</i>   |
| Blue-headed Vireo               | <i>Vireo solitarius</i>       |

**Order Pelecaniformes – Pelicans, Cormorants, Frigatebirds and allies**

|                        |                                  |
|------------------------|----------------------------------|
| American White Pelican | <i>Pelecanus erythrorhynchos</i> |
|------------------------|----------------------------------|

**Order Piciformes - Woodpeckers**

|                                |                           |
|--------------------------------|---------------------------|
| Northern Flicker               | <i>Colaptes auratus</i>   |
| Pileated Woodpecker            | <i>Dryocopus pileatus</i> |
| Black-backed Woodpecker        | <i>Picoides arcticus</i>  |
| American Three-toed Woodpecker | <i>Picoides dorsalis</i>  |
| Downy Woodpecker               | <i>Picoides pubescens</i> |
| Hairy Woodpecker               | <i>Picoides villosus</i>  |
| Yellow-bellied Sapsucker       | <i>Sphyrapicus varius</i> |

**Order Podicipediformes - Grebes**

|                   |                             |
|-------------------|-----------------------------|
| Horned Grebe      | <i>Podiceps auritus</i>     |
| Red-necked Grebe  | <i>Podiceps grisegena</i>   |
| Eared Grebe       | <i>Podiceps nigricollis</i> |
| Pied-billed Grebe | <i>Podilymbus podiceps</i>  |

**Order Strigiformes - Owls**

|                               |                          |
|-------------------------------|--------------------------|
| Boreal Owl (Richardson's Owl) | <i>Aegolius funereus</i> |
| Short-eared Owl               | <i>Asio flammeus</i>     |
| Snowy Owl                     | <i>Bubo scandiacus</i>   |
| Great Horned Owl              | <i>Bubo virginianus</i>  |
| Great Grey Owl                | <i>Strix nebulosa</i>    |
| Northern Hawk Owl             | <i>Surnia ulula</i>      |



## BUTTERFLIES

Butterflies (Order: Lepidoptera) present in the Tundra Shield and Southern Arctic ecozones, as summarized by the Working Group on the General Status of NWT Species (WGGSNS 2006).

### Family: Hesperiiidae

|                        |                                 |
|------------------------|---------------------------------|
| Arctic Skipper         | <i>Carterocephalus palaemon</i> |
| Dreamy Duskywing       | <i>Erynnis icelus</i>           |
| Persius Duskywing      | <i>Erynnis persius</i>          |
| Common Branded Skipper | <i>Hesperia comma</i>           |
| Grizzled Skipper       | <i>Pyrgus centaureae</i>        |

### Family: Lycaenidae

|                     |                              |
|---------------------|------------------------------|
| Arctic Blue         | <i>Agriades glandon</i>      |
| Brown Elfin         | <i>Callophrys augustinus</i> |
| Western Pine Elfin  | <i>Callophrys eryphon</i>    |
| Eastern Pine Elfin  | <i>Callophrys niphon</i>     |
| Hoary Elfin         | <i>Callophrys polia</i>      |
| Spring Azure        | <i>Celastrina ladon</i>      |
| Western Tailed Blue | <i>Everes amyntula</i>       |
| Silvery Blue        | <i>Glaucopsyche lygdamus</i> |
| Northern Blue       | <i>Lycaeides idas</i>        |
| Dorcas Copper       | <i>Lycaena dorcas</i>        |
| American Copper     | <i>Lycaena phlaeas</i>       |
| Greenish Blue       | <i>Plebejus saepiolus</i>    |
| Cranberry Blue      | <i>Vacciniina optilete</i>   |

### Family: Nymphalidae

|                            |                            |
|----------------------------|----------------------------|
| Meadow Fritillary          | <i>Boloria bellona</i>     |
| Arctic Fritillary          | <i>Boloria chariclea</i>   |
| Bog Fritillary             | <i>Boloria eunomia</i>     |
| Freija Fritillary          | <i>Boloria freija</i>      |
| Frigga Fritillary          | <i>Boloria frigga</i>      |
| Dingy Fritillary           | <i>Boloria improba</i>     |
| Mountain Fritillary        | <i>Boloria napaea</i>      |
| Beringian Fritillary       | <i>Boloria natazhati</i>   |
| Polaris Fritillary         | <i>Boloria polaris</i>     |
| Silver-bordered Fritillary | <i>Boloria selene</i>      |
| Common Ringlet             | <i>Coenonympha tullia</i>  |
| Disa Alpine                | <i>Erebia disa</i>         |
| Red-disked Alpine          | <i>Erebia discoidalis</i>  |
| Branded Alpine             | <i>Erebia fasciata</i>     |
| Reddish Alpine             | <i>Erebia lafontainei</i>  |
| Taiga Alpine               | <i>Erebia mancinus</i>     |
| Ross's Alpine              | <i>Erebia rossii</i>       |
| Four-dotted Alpine         | <i>Erebia youngi</i>       |
| Variegated Fritillary      | <i>Euptoieta claudia</i>   |
| Viceroy                    | <i>Limenitis archippus</i> |
| White Admiral              | <i>Limenitis arthemis</i>  |
| Mourning Cloak             | <i>Nymphalis antiopa</i>   |
| Milbert's Tortoiseshell    | <i>Nymphalis milberti</i>  |

|                       |                           |
|-----------------------|---------------------------|
| Compton Tortoiseshell | <i>Nymphalis vaualbum</i> |
| Sentinel Arctic       | <i>Oeneis alpina</i>      |
| White-Veined Arctic   | <i>Oeneis bore</i>        |
| Chryxus Arctic        | <i>Oeneis chryxus</i>     |
| Jutta Arctic          | <i>Oeneis jutta</i>       |
| Macoun's Arctic       | <i>Oeneis macounii</i>    |
| Melissa Arctic        | <i>Oeneis melissa</i>     |
| Polixenes Arctic      | <i>Oeneis polixenes</i>   |
| Philip's Arctic       | <i>Oeneis rosovi</i>      |
| Uhler's Arctic        | <i>Oeneis uhleri</i>      |
| Northern Crescent     | <i>Phyciodes cocyta</i>   |
| Green Comma           | <i>Polygonia faunus</i>   |
| Hoary Comma           | <i>Polygonia gracilis</i> |
| Grey Comma            | <i>Polygonia progne</i>   |
| Satyr Comma           | <i>Polygonia satyrus</i>  |
| Eyed Brown            | <i>Satyrodes eurydice</i> |
| Red Admiral           | <i>Vanessa atalanta</i>   |
| Painted Lady          | <i>Vanessa cardui</i>     |

**Order: Papilionidae**

|                            |                           |
|----------------------------|---------------------------|
| Canadian Tiger Swallowtail | <i>Papilio canadensis</i> |
| Old World Swallowtail      | <i>Papilio machaon</i>    |

**Order: Pieridae**

|                    |                            |
|--------------------|----------------------------|
| Christina Sulphur  | <i>Colias christina</i>    |
| Giant Sulphur      | <i>Colias gigantea</i>     |
| Hecla Sulphur      | <i>Colias hecla</i>        |
| Johansen's Sulphur | <i>Colias johanseni</i>    |
| Labrador Sulphur   | <i>Colias nastes</i>       |
| Palaeno Sulphur    | <i>Colias palaeno</i>      |
| Clouded Sulphur    | <i>Colias philodice</i>    |
| Booth's Sulphur    | <i>Colias tyche</i>        |
| Large Marble       | <i>Euchloe ausonides</i>   |
| Northern Marble    | <i>Euchloe creusa</i>      |
| Arctic White       | <i>Pieris angelika</i>     |
| Mustard White      | <i>Pieris oleracea</i>     |
| Cabbage White      | <i>Pieris rapae</i>        |
| Western White      | <i>Pontia occidentalis</i> |
| Spring White       | <i>Pontia sisymbrii</i>    |

**PLANTS**

The plant species listed here are considered by the Working Group on the General Status of NWT Species to be within the Tundra Shield and Southern Arctic ecozones and may be within the WKSS boundary (WGGSNS 2006).

**Order: Alismatales**

|                    |                           |
|--------------------|---------------------------|
| Northern Arrowhead | <i>Sagittaria cuneata</i> |
|--------------------|---------------------------|

**Order: Apiales**

|                      |                             |
|----------------------|-----------------------------|
| American Thoroughwax | <i>Bupleurum americanum</i> |
|----------------------|-----------------------------|

Bulbous Water-hemlock  
 Mackenzie's Water-hemlock  
 Yakutsk Snow-parsley  
 Cow parsnip  
 Water Parsnip  
 Wild Sarsaparilla

*Cicuta bulbifera*  
*Cicuta virosa* (*Cicuta mackenzieana*)  
*Cnidium cnidiifolium* (*Conioselinum cnidiifolium*)  
*Heracleum maximum* (*Heracleum lanatum*)  
*Sium suave*  
*Aralia nudicaulis*

**Order: Arales**

Several Vein Sweetflag (Rat Root)  
 Wild Calla (Water Dragon)  
 Star Duckweed  
 Turion Duckweed

*Acorus americanus* (*Acorus calamus*)  
*Calla palustris*  
*Lemna trisulca*  
*Lemna turionifera* (*Lemna minor*)

**Order: Asterales**

Yarrow spp.  
 Common Yarrow

*Achillea lanulosa* ssp *occidentalis*  
*Achillea millefolium* (includes *Achillea lanulosa* & *Achillea nigrescens*)  
*Achillea nigrescens* ssp *nigrescens*  
*Achillea sibirica*

Yarrow spp  
 Siberian Yarrow  
 Pale False Dandelion  
 Alpine Pussytoes

*Agoseris glauca*  
*Antennaria alpina* (syn *A. canescens*, *A. compacta*, *A. crymophila*, *A. pallida*, *A. pedunculata*, *A. stolonifera*, *A. subcanescens*, *A. ungavensis*)

Pussytoes spp  
 Pussytoes spp  
 Everlasting spp  
 Everlasting spp  
 Fries' Pussytoes

*Antennaria angustata* (see *Antennaria monocephala*)  
*Antennaria canescens* (see *Antennaria alpina*)  
*Antennaria ekmaniana* (see *Antennaria friesiana*)  
*Antennaria elegans* (see *Antennaria rosea*)  
*Antennaria friesiana* (incl *neoalaskana* ssp *neoalaskana*, *A. ekmaniana*, *Antennaria alaskana*)  
*Antennaria glabrata* (see *Antennaria alpina*)  
*Antennaria isolepis* ssp *pulvinata* (see *Antennaria rosea*)

Everlasting spp  
 Everlasting spp

*Antennaria microphylla* (*Antennaria nitida*)  
*Antennaria monocephala* (incl. *angustata* & *philonipha* & *pygmaea*)

Small-leaf Pussytoes  
 Pygmy Pussytoes

*Antennaria monocephala* (includes *Antennaria angustata*; *A. philonipha*; *A. pygmaea*)

Pygmy Pussytoes

*Antennaria neglecta* (*Antennaria campestris*)

Field Pussytoes  
 Everlasting spp  
 Showy Pussytoes  
 Rosy Pussytoes

*Antennaria oxyphylla* (see *Antennaria rosea*)

*Antennaria pulcherrima*

*Antennaria rosea* (incl *alborosea* & *elegans* & *incamata* & *isolepis* & *oxyphylla* & *subviscosa*)

Everlasting spp  
 Everlasting spp  
 Narrowleaf Arnica  
 Leafy Arnica  
 Snow Arnica  
 Long-leaved Arnica  
 Field Sagebrush

*Antennaria subscaescens* (see *Antennaria alpina*)

*Antennaria ungavensis* (see *Antennaria alpina*)

*Arnica angustifolia* (*Arnica alpina* var. *tomentosa*)

*Arnica chamissonis*

*Arnica frigida* (*louiseana*) ssp *frigida*

*Arnica lonchophylla*

*Artemisia campestris* (incl *Artemisia borealis*, *A. canadensis*) ssp *borealis*

*Artemisia canadensis*

Wormwood spp

|                                              |                                                                                                                                    |
|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Prairie Sagebrush                            | <i>Artemisia frigida</i>                                                                                                           |
| Three-fork Sagebrush                         | <i>Artemisia furcata</i> ( <i>Artemisia hyperborea</i> )                                                                           |
| Wormwood spp                                 | <i>Artemisia richardsoniana</i>                                                                                                    |
| Tilesius Sagebrush                           | <i>Artemisia tilesii</i>                                                                                                           |
| Alpine Aster                                 | <i>Aster alpinus</i>                                                                                                               |
| Aster spp                                    | <i>Aster junciformis</i> (See <i>Symphyotrichum boreale</i> )                                                                      |
| Nodding Beggarticks                          | <i>Bidens cernua</i>                                                                                                               |
| Drummond Thistle                             | <i>Cirsium drummondii</i>                                                                                                          |
| Leafy Thistle                                | <i>Cirsium foliosum</i>                                                                                                            |
| Elegant Hawksbeard                           | <i>Crepis elegans</i>                                                                                                              |
| Dwarf Alpine Hawksbeard                      | <i>Crepis nana</i>                                                                                                                 |
| Arctic Daisy                                 | <i>Dendranthema arcticum</i> ( <i>Chrysanthemum arcticum</i> )                                                                     |
| Bitter Fleabane                              | <i>Erigeron acris</i> (including <i>E. jucundus</i> = <i>E. acris</i> ssp. <i>debilis</i> )                                        |
| Dwarf Mountain Fleabane                      | <i>Erigeron compositus</i>                                                                                                         |
| Angular Fleabane                             | <i>Erigeron elatus</i>                                                                                                             |
| Smooth Fleabane                              | <i>Erigeron glabellus</i>                                                                                                          |
| Large-flower Fleabane                        | <i>Erigeron grandiflorus</i>                                                                                                       |
| Low Fleabane                                 | <i>Erigeron humilis</i>                                                                                                            |
| Hyssop-leaved Fleabane                       | <i>Erigeron hyssopifolius</i>                                                                                                      |
| Short-ray Fleabane                           | <i>Erigeron lonchophyllus</i> ( <i>Trimorpha lonchophylla</i> )                                                                    |
| Philadelphia Fleabane                        | <i>Erigeron philadelphicus</i>                                                                                                     |
| One-flower Fleabane                          | <i>Erigeron uniflorus</i> ( <i>Erigeron uniflorus</i> ssp. <i>eriocephalus</i> ; <i>E. eriocephalus</i> )                          |
| Yukon Fleabane                               | <i>Erigeron yukonensis</i>                                                                                                         |
| Pygmy Wood Aster                             | <i>Eurybia pygmaea</i> (Lindl.) Nesom. ( <i>Aster pygmaeus</i> Lindl. ; <i>Aster sibiricus</i> var. <i>pygmaeus</i> (Lindl.) Cody) |
| Siberian Aster                               | <i>Eurybia sibirica</i> ( <i>Aster sibiricus</i> )                                                                                 |
| Grass-leaved Goldenrod                       | <i>Euthamia graminifolia</i> ( <i>Solidago graminifolia</i> )                                                                      |
| Low Cudweed                                  | <i>Gnaphalium uliginosum</i>                                                                                                       |
| Broadleaf Gumweed                            | <i>Grindelia squarrosa</i>                                                                                                         |
| Umbellate Hawkweed                           | <i>Hieracium umbellatum</i> ( <i>Hieracium scabriusculum</i> )                                                                     |
| Tartarian Lettuce                            | <i>Lactuca tatarica</i> ( <i>Lactuca pulchella</i> )                                                                               |
| Entire-leaf Daisy                            | <i>Leucanthemum integrifolium</i> ( <i>Chrysanthemum integrifolium</i> )                                                           |
| Boreal Groundsel                             | <i>Packera hyperborealis</i> ( <i>Senecio hyperborealis</i> )                                                                      |
| Rayless Mountain Groundsel                   | <i>Packera indecora</i> ( <i>Senecio indecorus</i> )                                                                               |
| Balsam Groundsel                             | <i>Packera paupercula</i> ( <i>Senecio pauperculus</i> )                                                                           |
| Rocky Mountain Groundsel (Cleftleaf Ragwort) | <i>Packera streptanthifolia</i> ( <i>Senecio streptanthifolius</i> )                                                               |
| Arctic Sweet Coltsfoot                       | <i>Petasites arcticus</i> ( see <i>P. frigidus</i> var. <i>palmatus</i> ; See <i>P. frigidus</i> )                                 |
| Arctic Sweet Coltsfoot                       | <i>Petasites frigidus</i> ( <i>arcticus</i> & <i>hyperboreus</i> & <i>palmatus</i> & <i>sagittatus</i> & <i>vitifolius</i> )       |
| Sweet Coltsfoot spp                          | <i>Petasites palmatus</i> ( see <i>P. frigidus</i> var. <i>palmatus</i> ; See <i>P. frigidus</i> )                                 |
| Arrow-Leaved Sweet-Coltsfoot                 | <i>Petasites sagittatus</i> (see <i>P. frigidus</i> var. <i>sagittatus</i> ; See <i>P. frigidus</i> )                              |
| Sweet Coltsfoot spp                          | <i>Petasites vitifolius</i> (see <i>P. frigidus</i> var. <i>xvitifolius</i> ; See <i>P. frigidus</i> )                             |
| Goldenweed                                   | <i>Pyrocoma uniflora</i> ( <i>Haplopappus uniflorus</i> , <i>H. lanceolatus</i> subspp)                                            |

|                              |                                                                                                                                                                                                                                                            |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Narrow-leaf Saw-wort         | <i>Saussurea angustifolia</i>                                                                                                                                                                                                                              |
| Marsh Ragwort                | <i>Senecio congestus</i>                                                                                                                                                                                                                                   |
| Desert Ragwort               | <i>Senecio eremophilus</i>                                                                                                                                                                                                                                 |
| Black-tip Ragwort            | <i>Senecio lugens</i>                                                                                                                                                                                                                                      |
| Alpine Multiray Goldenrod    | <i>Solidago multiradiata</i>                                                                                                                                                                                                                               |
| Sticky Goldenrod             | <i>Solidago simplex</i> (var. <i>nana</i> = <i>Solidago decumbens</i> )                                                                                                                                                                                    |
| Boreal Aster                 | <i>Symphyotrichum boreale</i> ( <i>Aster franklinianus</i> , incl <i>Aster junciformis</i> )                                                                                                                                                               |
| Alkali Aster                 | <i>Symphyotrichum ciliatum</i> ( <i>Aster brachyactis</i> )                                                                                                                                                                                                |
| Lindley's Aster              | <i>Symphyotrichum ciliolatum</i> ( <i>Aster ciliolatus</i> )                                                                                                                                                                                               |
| White Heath Aster            | <i>Symphyotrichum ericoides</i> ( <i>Aster pansus</i> ) var <i>pansus</i>                                                                                                                                                                                  |
| White Prairie Aster          | <i>Symphyotrichum falcatum</i> (incl and <i>Aster falcatus</i> )                                                                                                                                                                                           |
| Dandelion spp                | <i>Taraxacum alaskanum</i> (See <i>Taraxacum phymatocarpum</i> )                                                                                                                                                                                           |
| Dandelion spp                | <i>Taraxacum dumentorum</i> (See <i>Taraxacum officinale</i> )                                                                                                                                                                                             |
| Dandelion spp                | <i>Taraxacum hyperboreum</i> (See <i>T. officinale</i> )                                                                                                                                                                                                   |
| Dandelion spp                | <i>Taraxacum integratum</i> (See <i>T. officinale</i> )                                                                                                                                                                                                    |
| Dandelion spp                | <i>Taraxacum lacerum</i> (See <i>T. officinale</i> )                                                                                                                                                                                                       |
| Dandelion spp                | <i>Taraxacum lapponicum</i> (See <i>T. officinale</i> )                                                                                                                                                                                                    |
| Common Dandelion             | <i>Taraxacum officinale</i> (including <i>T. carthamopsis</i> ; <i>T. maurolepium</i> ; <i>T. lapponicum</i> ; <i>T. lacerum</i> ; <i>T. pellanum</i> ; <i>T. pseudonorvegicum</i> ; <i>T. integratum</i> ; <i>T. dumentorum</i> ; <i>T. hyperboreum</i> ) |
| Northern Dandelion           | <i>Taraxacum phymatocarpum</i> (including <i>T. hyparcticum</i> ; <i>T. pumilum</i> ; <i>T. mackensiense</i> ; <i>T. alaskanum</i> ; <i>T. arcticum</i> )                                                                                                  |
| Northern Dandelion           | <i>Taraxacum phymatocarpum</i> ( <i>phymatocarpon</i> & <i>hyparcticum</i> & <i>alaskanum</i> & <i>pumilum</i> )                                                                                                                                           |
| Dandelion spp                | <i>Taraxacum pseudonorvegicum</i> (See <i>T. officinale</i> )                                                                                                                                                                                              |
| Holman Dandelion             | <i>Taraxacum pumilum</i> ( <i>T. holmenianum</i> ) Also see <i>T. phymatocarpum</i>                                                                                                                                                                        |
| Dark Purple Groundsel        | <i>Tephrosia atropurpurea</i> ( <i>Senecio atropurpureus</i> ; <i>S. frigidus</i> )                                                                                                                                                                        |
| Seashore Chamomile           | <i>Tripleurospermum maritima</i> ( <i>Matricaria ambigua</i> and <i>Matricaria maritima</i> )                                                                                                                                                              |
| <b>Order: Callitrichales</b> |                                                                                                                                                                                                                                                            |
| Northern Waterstarwort       | <i>Callitriche hermaphrodita</i>                                                                                                                                                                                                                           |
| Large Waterstarwort          | <i>Callitriche heterophylla</i> ( <i>Callitriche anceps</i> )                                                                                                                                                                                              |
| March Waterstarwort          | <i>Callitriche palustris</i> ( <i>Callitriche verna</i> )                                                                                                                                                                                                  |
| Four-leaved Maretail         | <i>Hippuris tetraphylla</i>                                                                                                                                                                                                                                |
| Common Maretail              | <i>Hippuris vulgaris</i>                                                                                                                                                                                                                                   |
| <b>Order: Campanulales</b>   |                                                                                                                                                                                                                                                            |
| American Harebell            | <i>Campanula rotundifolia</i>                                                                                                                                                                                                                              |
| Arctic Harebell              | <i>Campanula uniflora</i>                                                                                                                                                                                                                                  |
| Water Lobelia                | <i>Lobelia dortmanna</i>                                                                                                                                                                                                                                   |
| Kalm's Lobelia               | <i>Lobelia kalmii</i>                                                                                                                                                                                                                                      |
| <b>Order: Capparales</b>     |                                                                                                                                                                                                                                                            |
| Saltwater Cress              | <i>Arabidopsis salsuginea</i> ( <i>Thellungiella salsuginea</i> )                                                                                                                                                                                          |

|                                |                                                                                                                                 |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Rock Cress spp                 | <i>Arabis alpina</i>                                                                                                            |
| Arctic Rockcress               | <i>Arabis arenicola</i>                                                                                                         |
| Limestone Rockcress            | <i>Arabis divaricarpa</i>                                                                                                       |
| Drummond Rockcress             | <i>Arabis drummondii</i>                                                                                                        |
| Western Hairy Rockcress        | <i>Arabis hirsuta</i>                                                                                                           |
| Holboell Rockcress             | <i>Arabis holboellii</i>                                                                                                        |
| American Wintercress           | <i>Barbarea orthoceras</i>                                                                                                      |
| Smooth Rockcress               | <i>Braya glabella</i> (incl <i>Braya purpurascens</i> , <i>Braya glabella</i> ssp. <i>purpurascens</i> , <i>Braya henryae</i> ) |
|                                | <i>Braya humilis</i> (incl <i>Braya richardsonii</i> )                                                                          |
| Alpine Northern Rockcress      | <i>Braya pilosa</i>                                                                                                             |
| Hairy Rockcress (Pilose Braya) | <i>Braya purpurascens</i> (see <i>B. glabella</i> )                                                                             |
| Purple Braya                   | <i>Cardamine bellidifolia</i>                                                                                                   |
| Alpine Bittercress             | <i>Cardamine digitata</i>                                                                                                       |
| Richardson's Bittercress       | <i>Cardamine parviflora</i>                                                                                                     |
| Small-flowered Bittercress     | <i>Cardamine pensylvanica</i>                                                                                                   |
| Pennsylvania Bittercress       | <i>Cardamine pratensis</i>                                                                                                      |
| Cuckooflower Bittercress       | <i>Cochlearia officinalis</i>                                                                                                   |
| Scurvy Grass                   | <i>Descurainia incana</i> ( <i>Descurainia incisa</i> , <i>Descurainia richardsonii</i> )                                       |
| Green Tansy Mustard            | <i>Descurainia pinnata</i>                                                                                                      |
|                                | <i>Descurainia sophioides</i>                                                                                                   |
| Pinate Tansy Mustard           | <i>Draba alpina</i> ( <i>Draba micropetala</i> , <i>Draba pilosa</i> )                                                          |
| Northern Tansy Mustard         | <i>Draba aurea</i>                                                                                                              |
| Alpine Whitlow-grass           | <i>Draba borealis</i>                                                                                                           |
| Golden Draba                   | <i>Draba breweri</i> ( <i>Draba breweri</i> var. <i>cana</i> , <i>Draba cana</i> , <i>Draba lanceolata</i> )                    |
| Boreal Whitlow-grass           | <i>Draba cinerea</i>                                                                                                            |
| Brewer's Whitlow-grass         | <i>Draba corymbosa</i> ( <i>Draba macrocarpa</i> , <i>Draba bellii</i> )                                                        |
|                                | <i>Draba crassifolia</i>                                                                                                        |
| Gray-Leaf Whitlow-grass        | <i>Draba fladnizensis</i>                                                                                                       |
| Flat-top Whitlow-grass         | <i>Draba glabella</i> ( <i>Draba daurica</i> , <i>Draba hirta</i> )                                                             |
| Snowbed Whitlow-grass          | <i>Draba incerta</i>                                                                                                            |
| White Arctic Whitlow-grass     | <i>Draba juvenilis</i> ( <i>Draba longipes</i> )                                                                                |
| Rock Whitlow-grass             | <i>Draba lactea</i>                                                                                                             |
| Yellowstone Whitlow-grass      | <i>Draba nemorosa</i> ( <i>D. nemorosa</i> var. <i>leiocarpa</i> )                                                              |
| Long-stalk Whitlow-grass       | <i>Draba nivalis</i>                                                                                                            |
| Milky Whitlow-grass            | <i>Draba norvegica</i> ( <i>Draba rupestris</i> )                                                                               |
| Wood Whitlow-grass             | <i>Draba pilosa</i> (See <i>Draba alpina</i> )                                                                                  |
| Yellow Arctic Whitlow-grass    | <i>Draba praealta</i>                                                                                                           |
| Norwegian Whitlow-grass        | <i>Draba subcapitata</i>                                                                                                        |
| Mustard family                 | <i>Erysimum cheiranthoides</i>                                                                                                  |
| Tall Whitlow-grass             | <i>Erysimum inconspicuum</i> ( <i>Erysimum coarctatum</i> )                                                                     |
| Ellesmere Whitlow-grass        | <i>Erysimum pallasii</i>                                                                                                        |
| Worm-seed Wallflower           | <i>Eutrema edwardsii</i>                                                                                                        |
| Shy Wallflower                 | <i>Halimolobos mollis</i>                                                                                                       |
| Pallas Wallflower              | <i>Lepidium bourgeauanum</i> (See <i>L. ramosissimum</i> )                                                                      |
| Edward Mock Wallflower         | <i>Lepidium ramosissimum</i>                                                                                                    |
| Soft Rockcress                 | <i>Lesquerella arctica</i>                                                                                                      |
| Bourgeau's Peper-Grass         | <i>Parrya arctica</i>                                                                                                           |
| Branched Pepperwort            | <i>Parrya nudicaulis</i>                                                                                                        |
| Arctic Bladderpod              |                                                                                                                                 |
| Arctic False-Wallflower        |                                                                                                                                 |
| Naked-stemmed Wallflower       |                                                                                                                                 |

Persistent-sepal Yellowcress  
 Bog Yellowcress  
 Water Awlwort

*Rorippa calycina*  
*Rorippa palustris* (*Rorippa islandica*)  
*Subularia aquatica*

**Order: Caryophyllales**

Creeping Sandwort  
 Alpine Chickweed

*Arenaria humifusa*  
*Cerastium alpinum* (including ? *Cerastium arcticum*  
 and *Cerastium nigrescens*)

Field Mouse-ear Chickweed  
 Bering Sea Chickweed  
 Nodding Chickweed  
 Regel's Chickweed  
 Slender Mountain Sandwort

*Cerastium arvense*  
*Cerastium beeringianum*  
*Cerastium nutans*  
*Cerastium regelii* (incl. *Cerastium jenisejense*)

Seabeach Sandwort  
 Mountain Stitchwort  
 Rock Stitchwort  
 Elegant Stitchwort

*Eremogone capillaris* (*Arenaria capillaris*)  
*Honckenya peploides* (*Arenaria peploides*)  
*Minuartia biflora* (*Arenaria sajanensis*)  
*Minuartia dawsonensis* (*Arenaria dawsonensis*)  
*Minuartia elegans*

Ross' Stitchwort  
 Boreal Stitchwort  
 Yukon Stitchwort  
 Blunt-leaved Sandwort  
 Large-Leaved Sandwort  
 Tufted Pearlwort

*Minuartia rossii* (*Arenaria rossii*)  
*Minuartia rubella* (*Arenaria rubella*, *Arenaria verna*)  
*Minuartia yukonensis* (*Arenaria laricifolia*)  
*Moehringia lateriflora* (*Arenaria laterifolia*)  
*Moehringia macrophylla* (*Arenaria macrophylla*)  
*Sagina caespitosa*

Snow Pearlwort  
 Knotted Pearlwort  
 Procumbent Pearlwort  
 Moss Champion  
 Drummond's Champion  
 Arctic Champion

*Sagina nivalis* (*Sagina intermedia*)  
*Sagina nodosa*  
*Sagina procumbens*  
*Silene acaulis*  
*Silene drummondii* (*Melandrium drummondii*)  
*Silene involucrata* (syn *Melandrium affine*, *M.*  
*furcatum*, *Lychnis brachycalyx*, *L. gillettii*, *Silene*  
*tayloriae* (as *S. involucrata* ssp *tenella*)

Menzies Pink Champion  
 Creeping Champion  
 Sorensen's Champion  
 Taimyr Champion

*Silene menziesii*  
*Silene repens*  
*Silene sorensenii*  
*Silene taimyrensis* (*Silene ostenfeldii*, *Melandrium*  
*ostenfeldii* & *Melandrium taimyrense*, *Melandrium*  
*dawsonii* )

Peel River Champion

*Silene tayloriae* (*Melandrium tayloriae*) also see *Silene*  
*involucrata*

Apetalous Champion  
 Chickweed spp

*Silene uralensis* (*Melandrium apetalum*)  
*Stellaria arenicola* (see *Stellaria longipes* ssp.  
*arenicola*)

Boreal Stitchwort (Northern Stitchwort)  
 Fleshy Stitchwort  
 Trundra Starwort  
 Saltmarch Sandwort  
 Longleaf Stitchwort  
 Long-stalked Stitchwort

*Stellaria borealis* (may incl. *Stellaria calycantha*)  
*Stellaria crassifolia*  
*Stellaria crassipes* (see *Stellaria longipes*)  
*Stellaria humifusa*  
*Stellaria longifolia* (*Stellaria atrata*)  
*Stellaria longipes* (*S. laeta*, *S. monantha*, *S. stricta*, *S.*  
*subvestita*, *S. edwardsii*, *S. ciliatosepala*, *S. crassipes*)  
*Wilhelmsia physodes*

Arctic-Flower (Merkia)  
 Thick-leaved Orache

*Atriplex dioica* (syn *Atriplex subspicata*)

Gmelin's Orache  
 Lamb's Quarters  
 Berlandier's Goosefoot  
 Strawberry-blite (Strawberry Goosefoot)  
 Oakleaf Goosefoot  
 Narrowleaf Goosefoot  
 Red Pigweed (Coast-Blite Goosefoot)  
 Rocky Mountain Goosefoot

Hooker's Bugseed  
 Nuttall's Povertyweed  
 Horned Sea-blite  
 White Sea-blite  
 Water Blinks

*Atriplex gmelinii*  
*Chenopodium album*  
*Chenopodium berlandieri*  
*Chenopodium capitatum*  
*Chenopodium glaucum*  
*Chenopodium leptophyllum*  
*Chenopodium rubrum*  
*Chenopodium salinum* (*Chenopodium glaucum* var. *salinum*)  
*Corispermum hookeri* (*Corispermum hyssopifolium*)  
*Monolepis nuttalliana*  
*Suaeda calceoliformis*  
*Suaeda maritima*  
*Montia fontana* (syn *Montia lamprosperma*, *Claytonia fontana*)

**Order: Cornales**

Dwarf Dogwood (Bunchberry)  
 Red Osier Dogwood  
 Swedish Dogwood

*Cornus canadensis*  
*Cornus sericea* (*Cornus stolonifera*)  
*Cornus suecica*

**Order: Cyperales**

Saltmarsh Bulrush

Circumpolar Sedge  
 Black-and-White-Scale Sedge  
 Water Sedge  
 Northern Clustered Sedge  
 Wheat Sedge  
 Scabrous Black Sedge  
 Dark-brown Sedge  
 Golden Fruit Sedge  
 Bebb's Sedge  
 Two-colour Sedge  
 Bigelow's Sedge

Brownish Sedge  
 Buxbaum's Sedge  
 Silvery Sedge  
 Hairlike Sedge  
 Capitata Sedge  
 Creeping Sedge  
 Low Northern Sedge  
*Carex* spp  
 Crawford sedge  
 Northern Sedge  
 Lesser Panicle Sedge  
 Softleaf Sedge  
 Bristle-leaved Sedge  
 Dryspike Sedge  
 Short-Leaf Sedge

*Bolboschoenus maritimus* (*Schoenoplectus maritimus*;  
*Scirpus paludosus*; *Scirpus maritimus*)  
*Carex adelostoma* (*Carex morrisseyi*)  
*Carex albonigra*  
*Carex aquatilis*  
*Carex arcta*  
*Carex atherodes*  
*Carex atratiformis* (*Carex raymondii*)  
*Carex atrofusca*  
*Carex aurea*  
*Carex bebbii*  
*Carex bicolor*  
*Carex bigelowii* (*Carex consimilis*, *Carex lugens*,  
*Carex cyclocarpa*, *Carex yukonensis*, *Carex anguillata*)  
*Carex brunnescens*  
*Carex buxbaumii*  
*Carex canescens*  
*Carex capillaris*  
*Carex capitata*  
*Carex chordorrhiza*  
*Carex concinna*  
*Carex consimilis* (see *Carex bigelowii*)  
*Carex crawfordii*  
*Carex deflexa*  
*Carex diandra*  
*Carex disperma*  
*Carex eburnea*  
*Carex foenea* (see *Carex siccata*)  
*Carex fuliginosa* (*Carex misandra*; *Carex fuliginosa*)



|                                     |                                                                                                                                                                                                                 |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Garber's Elk Sedge                  | <i>Carex garberi</i>                                                                                                                                                                                            |
| Glacier Sedge                       | <i>Carex glacialis</i>                                                                                                                                                                                          |
| Gravel Sedge                        | <i>Carex glareosa</i> ( <i>Carex glareosa</i> Wahlenberg subsp. <i>glareosa</i> ; <i>Carex amphigena</i> (Fernald) Mackenzie; <i>C. cryptantha</i> T. Holm; <i>C. glareosa</i> var. <i>amphigena</i> Fernald) ) |
| Northern Bog Sedge                  | <i>Carex gynocrates</i>                                                                                                                                                                                         |
| Arctic Marsh Sedge                  | <i>Carex holostoma</i>                                                                                                                                                                                          |
| Arctic Harefoot Sedge               | <i>Carex lachenalii</i> ( <i>Carex bipartita</i> )                                                                                                                                                              |
| Lapland Sedge                       | <i>Carex lapponica</i> ( <i>Carex canescens</i> ssp. <i>Subloliacea</i> )                                                                                                                                       |
| Slender Sedge                       | <i>Carex lasiocarpa</i>                                                                                                                                                                                         |
| Shore Sedge                         | <i>Carex lenticularis</i>                                                                                                                                                                                       |
| Bristly-stalk Sedge                 | <i>Carex leptalea</i>                                                                                                                                                                                           |
| Mud Sedge                           | <i>Carex limosa</i>                                                                                                                                                                                             |
| Rye-grass Sedge                     | <i>Carex loliacea</i>                                                                                                                                                                                           |
| A Sedge                             | <i>Carex lugens</i> (see <i>Carex bigelowii</i> )                                                                                                                                                               |
| Mackenzie Sedge                     | <i>Carex mackenziei</i> ( <i>Carex norvegica</i> Willdenow ex Schkuhr, Besch. Riedgrä )                                                                                                                         |
| Boreal Bog Sedge (Magellan's Carex) | <i>Carex magellanica</i> ( <i>Carex paupercula</i> )                                                                                                                                                            |
| Sea Sedge                           | <i>Carex marina</i> (syn. <i>Carex amblyorhyncha</i> )                                                                                                                                                          |
| Seaside Sedge                       | <i>Carex maritima</i>                                                                                                                                                                                           |
| Norwegian Carex                     | <i>Carex media</i> ( <i>Carex alpina</i> Liljeblad var. <i>inferalpina</i> Wahlenberg, <i>C. angare</i> Steudel; <i>C. norvegica</i> Retzius subsp. <i>inferalpina</i> (Wahlenberg) Hultén )                    |
| Fragile-seed Sedge                  | <i>Carex membranacea</i>                                                                                                                                                                                        |
| False Unicinia Sedge                | <i>Carex microglochin</i>                                                                                                                                                                                       |
| Nard Sedge                          | <i>Carex nardina</i>                                                                                                                                                                                            |
| Scandinavian Sedge                  | <i>Carex norvegica</i> (see <i>Carex media</i> )                                                                                                                                                                |
| Few-seeded Sedge                    | <i>Carex oligosperma</i>                                                                                                                                                                                        |
| Rock Dwelling Sedge                 | <i>Carex petricosa</i> ( <i>Carex franklinii</i> )                                                                                                                                                              |
| A Sedge                             | <i>Carex physocarpa</i> (see <i>Carex saxatilis</i> )                                                                                                                                                           |
| Short-stalk Sedge                   | <i>Carex podocarpa</i>                                                                                                                                                                                          |
| Ramenski Sedge                      | <i>Carex ramenskii</i>                                                                                                                                                                                          |
| Loose-flowered Sedge                | <i>Carex rariflora</i>                                                                                                                                                                                          |
| Richardson Sedge                    | <i>Carex richardsonii</i>                                                                                                                                                                                       |
| Ross' Sedge                         | <i>Carex rossii</i>                                                                                                                                                                                             |
| Pumpkin-fruited Sedge               | <i>Carex rotundata</i>                                                                                                                                                                                          |
| Snowbed Sedge                       | <i>Carex rufina</i>                                                                                                                                                                                             |
| Rock Sedge                          | <i>Carex rupestris</i>                                                                                                                                                                                          |
| Sartwell's Sedge                    | <i>Carex sartwellii</i>                                                                                                                                                                                         |
| Russet Sedge                        | <i>Carex saxatilis</i> ( <i>Carex physocarpa</i> )                                                                                                                                                              |
| Bulrush Sedge                       | <i>Carex scirpoidea</i>                                                                                                                                                                                         |
| Dry-spike Sedge                     | <i>Carex siccata</i>                                                                                                                                                                                            |
| Hoppner's Sedge                     | <i>Carex subspathacea</i>                                                                                                                                                                                       |
| Weak Arctic Sedge                   | <i>Carex supina</i>                                                                                                                                                                                             |
| Many-headed Sedge                   | <i>Carex sychnocephala</i>                                                                                                                                                                                      |
| Sparse-flowered Sedge               | <i>Carex tenuiflora</i>                                                                                                                                                                                         |
| Three-seed Sedge                    | <i>Carex trisperma</i>                                                                                                                                                                                          |
| Bear Sedge                          | <i>Carex ursina</i>                                                                                                                                                                                             |
| Northwest Territory Sedge           | <i>Carex utriculata</i>                                                                                                                                                                                         |

|                                |                                                                                                                                       |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Sheathed Sedge                 | <i>Carex vaginata</i>                                                                                                                 |
| Little Green Sedge             | <i>Carex viridula</i> ( <i>Carex oederi</i> )                                                                                         |
| Williams' Sedge                | <i>Carex williamsii</i>                                                                                                               |
| Needle Spike Rush              | <i>Eleocharis acicularis</i>                                                                                                          |
| Common Spike Rush              | <i>Eleocharis palustris</i>                                                                                                           |
| Few-flowered Spike Rush        | <i>Eleocharis quinqueflora</i> ( <i>Eleocharis pauciflora</i> )                                                                       |
| One-Glume Spike Rush           | <i>Eleocharis uniglumis</i> ( <i>Eleocharis macrostachya</i> )                                                                        |
| Narrow-leaved Cotton-grass     | <i>Eriophorum angustifolium</i> (incl. <i>Eriophorum triste</i> )                                                                     |
| Short-antler Cotton-grass      | <i>Eriophorum brachyantherum</i> ( <i>Eriophorum opacum</i> )                                                                         |
| Sheathed Cotton-grass          | <i>Eriophorum callitrix</i>                                                                                                           |
| Chamisso's Cotton-grass        | <i>Eriophorum chamissonis</i> ( <i>Eriophorum russeolum</i> var. <i>albindum</i> )                                                    |
| Slender Cotton-grass           | <i>Eriophorum gracile</i>                                                                                                             |
| Scheuchzeri White Cotton-grass | <i>Eriophorum scheuchzeri</i>                                                                                                         |
| Cotton Grass spp               | <i>Eriophorum triste</i> (See <i>Eriophorum angustifolium</i> )                                                                       |
| Tussock Cotton-grass           | <i>Eriophorum vaginatum</i>                                                                                                           |
| Tassel Cotton-grass            | <i>Eriophorum viridicarinatum</i>                                                                                                     |
| Pacific Kobresia               | <i>Kobresia myosuroides</i> ( <i>Kobresia bellardi</i> )                                                                              |
| Siberian Kobresia              | <i>Kobresia sibirica</i> ( <i>Kobresia hyperborea</i> )                                                                               |
| Simple Kobresia                | <i>Kobresia simpliciuscula</i>                                                                                                        |
| Acerbic Bulrush                | <i>Schoenoplectus acutus</i> ( <i>Scirpus acutus</i> )                                                                                |
| Black-girdled Bulrush          | <i>Scirpus atrocinctus</i>                                                                                                            |
| Small-fruit Bulrush            | <i>Scirpus microcarpus</i> ( <i>Scirpus rubrotinctus</i> )                                                                            |
| Alpine Bulrush                 | <i>Trichophorum alpinum</i> ( <i>Scirpus hudsonianus</i> and <i>Eriophorum alpinum</i> )                                              |
| Tufted Bulrush                 | <i>Trichophorum caespitosum</i> ( <i>Scirpus caespitosus</i> )                                                                        |
| Crested Wheat Grass            | <i>Agropyron cristatum</i> spp <i>pectinatum</i> ( <i>Agropyron pectiniforme</i> )                                                    |
| Northern Bentgrass             | <i>Agrostis mertensii</i> ( <i>Agrostis borealis</i> )                                                                                |
| Rough Bentgrass                | <i>Agrostis scabra</i>                                                                                                                |
| Short-awn Meadow-foxtail       | <i>Alopecurus aequalis</i>                                                                                                            |
| Alpine Meadow-foxtail          | <i>Alopecurus alpinus</i>                                                                                                             |
| Broad-leaf Arctic-bent         | <i>Arctagrostis arundinacea</i> (See <i>Arctagrostis latifolia</i> ssp. <i>arundinacea</i> )                                          |
| Broad-leaf Arctic-bent         | <i>Arctagrostis latifolia</i>                                                                                                         |
| Pendant Grass                  | <i>Arctophila fulva</i>                                                                                                               |
| American Sloughgrass           | <i>Beckmannia syzigachne</i>                                                                                                          |
| Fringed Brome                  | <i>Bromus ciliatus</i>                                                                                                                |
| Pumpelly Brome                 | <i>Bromus pumpellianus</i> ( <i>Bromus inermis</i> var. <i>pumpellianus</i> )                                                         |
| Blue-jointed Reed Grass        | <i>Calamagrostis canadensis</i>                                                                                                       |
| Reed Bentgrass spp             | <i>Calamagrostis chordorrhiza</i> (see <i>Calamagrostis stricta</i> )                                                                 |
| Circumpolar Reed Grass         | <i>Calamagrostis deschampsoides</i>                                                                                                   |
| Holm's Reed Grass              | <i>Calamagrostis holmii</i>                                                                                                           |
| Lapland Reed Grass             | <i>Calamagrostis lapponica</i>                                                                                                        |
| Reed Bentgrass spp             | <i>Calamagrostis neglecta</i> (see <i>Calamagrostis stricta</i> )                                                                     |
| Purple Reed Grass              | <i>Calamagrostis purpurascens</i>                                                                                                     |
| Slim-stem Reed Grass           | <i>Calamagrostis stricta</i> ( <i>Calamagrostis inexpansa</i> , <i>Calamagrostis neglecta</i> and <i>Calamagrostis chordorrhiza</i> ) |

|                                           |                                                                                                                               |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Slender Wood Reed Grass                   | <i>Cinna latifolia</i>                                                                                                        |
| Short-Leaf Hair Grass                     | <i>Deschampsia brevifolia</i> ( <i>Deschampsia cespitosa</i> ssp. <i>brevifolia</i> )                                         |
| Tufted Hair Grass                         | <i>Deschampsia cespitosa</i> ( <i>Deschampsia caespitosa</i> , <i>Deschampsia glauca</i> )                                    |
| Hairgrass spp                             | <i>Deschampsia pumila</i> (see <i>Deschampsia caespitosa</i> )                                                                |
| Fisher's Tundra Grass                     | <i>Dupontia fisheri</i>                                                                                                       |
| Alaska Wild Rye                           | <i>Elymus alaskanus</i> [ssp. <i>latiglumis</i> ] ( <i>Agropyron violaceum</i> ; <i>Agropyron boreale</i> )                   |
| Thick-spike Wild Rye                      | <i>Elymus macrourus</i> ( <i>Elymus sericeum</i> ; <i>Agropyron sericeum</i> )                                                |
| Slender Wild Rye                          | <i>Elymus trachycaulus</i> ( <i>Agropyron trachycaulum</i> )                                                                  |
| Rough Fescue                              | <i>Festuca altaica</i>                                                                                                        |
| Baffin Fescue                             | <i>Festuca baffinensis</i>                                                                                                    |
| Short-leaved Fescue                       | <i>Festuca brachyphylla</i>                                                                                                   |
| Proliferous Fescue                        | <i>Festuca prolifera</i> ( <i>Festuca rubra</i> ssp. <i>arctica</i> )                                                         |
| Richardson's Fescue                       | <i>Festuca richardsonii</i> (incl. <i>Festuca rubra</i> ssp. <i>richardsonii</i> )                                            |
| Rocky Mountain Fescue                     | <i>Festuca saximontana</i>                                                                                                    |
| Small Floating Manna Grass                | <i>Glyceria borealis</i>                                                                                                      |
| American Manna Grass                      | <i>Glyceria grandis</i>                                                                                                       |
| Mackenzie Valley Manna Grass              | <i>Glyceria pulchella</i>                                                                                                     |
| Alpine Sweet Grass                        | <i>Hierochloe alpina</i>                                                                                                      |
| Vanilla Sweet Grass                       | <i>Hierochloe odorata</i>                                                                                                     |
| Arctic Sweet Grass                        | <i>Hierochloe pauciflora</i>                                                                                                  |
| Fox-Tail Barley                           | <i>Hordeum jubatum</i>                                                                                                        |
| Downy Lyme Grass                          | <i>Leymus innovatus</i> ( <i>Elymus innovatus</i> )                                                                           |
| American Lyme Grass                       | <i>Leymus mollis</i> ( <i>Elymus arenarius</i> )                                                                              |
| Ice Grass                                 | <i>Phippsia algida</i>                                                                                                        |
| Common Timothy                            | <i>Phleum pratense</i>                                                                                                        |
| Slender Short-awn Mountain-rice Grass     | <i>Piptatherum pungens</i> ( <i>Oryzopsis pungens</i> )                                                                       |
| Kentucky Bluegrass                        | <i>Poa alpigena</i> (see <i>Poa pratensis</i> )                                                                               |
| Alpine Bluegrass                          | <i>Poa alpina</i>                                                                                                             |
| Arctic Bluegrass                          | <i>Poa arctica</i> (includes <i>Poa brintnellii</i> ; <i>Poa lanata</i> ; <i>Poa williamsii</i> )                             |
| White Bluegrass                           | <i>Poa glauca</i>                                                                                                             |
| Hartz's Bluegrass                         | <i>Poa hartzii</i> ( <i>Poa ammophila</i> )                                                                                   |
| Mt. Washington Blue Grass                 | <i>Poa laxa</i> ssp. <i>flexuosa</i> ( <i>Poa flexuosa</i> )                                                                  |
| Fowl Bluegrass                            | <i>Poa palustris</i>                                                                                                          |
| Kentucky Bluegrass                        | <i>Poa pratensis</i> (incl. <i>Poa alpigena</i> ; <i>P. pratensis</i> ssp. <i>pratensis</i> and ssp. <i>colpodea</i> )        |
| Curly Bluegrass                           | <i>Poa secunda</i> (incl. <i>Poa scabrella</i> ; <i>Poa buckleyana</i> )                                                      |
| Boreal Alkali Grass                       | <i>Puccinellia agrostidea</i> (see <i>Poa arctica</i> )                                                                       |
| Anderson's Alkali Grass                   | <i>Puccinellia andersonii</i>                                                                                                 |
| Northern Alkali Grass                     | <i>Puccinellia angustata</i> (incl. <i>Puccinellia contracta</i> )                                                            |
| Arctic Alkali Grass                       | <i>Puccinellia arctica</i> (incl. <i>Puccinellia borealis</i> ?, <i>Puccinellia poaceae</i> , <i>Puccinellia agrostidea</i> ) |
| Goose Grass (Arctic Alkali Grass)         | <i>Puccinellia borealis</i> (see <i>Puccinellia arctica</i> )                                                                 |
| Prince Patrick Alkali Grass (Goose Grass) | <i>Puccinellia bruggemannii</i>                                                                                               |
| Northern Alkali Grass                     | <i>Puccinellia contracta</i> (see <i>Puccinellia angustata</i> )                                                              |
| Inland Alkali Grass                       | <i>Puccinellia interior</i> (see <i>Puccinellia nuttalliana</i> )                                                             |

Polar Nuttall's Alkali Grass

Creeping Alkali Grass

Floodplain Alkaligrass

Dwarf Alkali Grass

Tundra Alkali Grass

Arctic Tussock Alkali Grass

Vahl's Alkali Grass

False Melic Grass

Freshwater Cordgrass

Slender Wedgescale Grass

Narrow False Oat

Arctic Hairgrass (Mountain Hairgrass)

*Puccinellia nuttalliana* (*Puccinellia deschampsoides*,  
*Puccinellia borealis*?, and incl *Puccinellia interior*)

*Puccinellia phryganodes*

*Puccinellia poacea* (see *Puccinellia arctica*)

*Puccinellia pumila* (*Puccinellia kurilensis* )

*Puccinellia tenella* ssp. *langeana* (*Puccinellia langeana*)

*Puccinellia vaginata*

*Puccinellia vahliana* (*Colpodium vahlianum*)

*Schizachne purpurascens*

*Spartina pectinata*

*Sphenopholis intermedia*

*Trisetum spicatum*

*Vahlodea atropurpurea* (*Deschampsia atropurpurea*)

### Order: Diapensiales

Lapland Diapensia

*Diapensia lapponica* (*Diapensia obovata*)

### Order: Dipsacales

Twinflower

Mountain Honeysuckle

Northern Snowberry

Squashberry (High-bush Cranberry)

Wood Valerian

*Linnaea borealis*

*Lonicera dioica*

*Symphoricarpos occidentalis*

*Viburnum edule*

*Valeriana dioica* (*Valeriana eptentrionalis*)

### Order: Equisetales

Field Horsetail

Water Horsetail

Dwarf Scouring-rush

Variegated Horsetail

*Equisetum arvense*

*Equisetum fluviatile*

*Equisetum scirpoides*

*Equisetum variegatum*

### Order: Ericales

Black Crowberry

Bog Rosemary

Alpine Bearberry

Red Bearberry

Common Bearberry (Kinnikinnik)

Arctic White Heather

Leatherleaf

Moss Heather

Bog Laurel

Common Labrador Tea

Narrow-leaved Labrador Tea

Alpine Azalea

Purple Mountain Heather

Lapland Rosebay

Velvetleaf Blueberry

Small Cranberry

*Empetrum nigrum*

*Andromeda polifolia*

*Arctostaphylos alpina*

*Arctostaphylos rubra*

*Arctostaphylos uva-ursi*

*Cassiope tetragona*

*Chamaedaphne calyculata*

*Harrimanella hypnoides* (*Cassiope hypnoides*)

*Kalmia polifolia*

*Ledum groenlandicum*

*Ledum palustre* ssp. *decumbens* (*Ledum decumbens*)

*Loiseleuria procumbens*

*Phyllodoce caerulea*

*Rhododendron lapponicum*

*Vaccinium myrtilloides*

*Vaccinium oxycoccos* (*Oxycoccus microcarpus*,

*Oxycoccus quadripetalus*)

*Vaccinium uliginosum*

*Vaccinium vitis-idaea*

Alpine Bilberry

Rock Cranberry (Lingonberry)

One-flowered Wintergreen  
 One-sided Wintergreen  
 Pink Pyrola  
 Greenish-flowered Pyrola  
 Arctic Pyrola  
 Lesser Pyrola

*Moneses uniflora*  
*Orthilia secunda* (*Pyrola secunda*)  
*Pyrola asarifolia*  
*Pyrola chlorantha* (*Pyrola virens*)  
*Pyrola grandiflora*  
*Pyrola minor*

**Order: Fabales**

Meadow Milk-vetch  
 Alpine Milk-vetch  
 American Milk-vetch  
 Indian Milk-vetch

*Astragalus agrestis*  
*Astragalus alpinus*  
*Astragalus americanus*  
*Astragalus australis* (*A. aboriginorum*, *A. richardsonii*,  
*A. linearis*)  
*Astragalus bodinii* (*Astragalus yukonis*)  
*Astragalus eucosmus*  
*Astragalus laxmannii* (*Astragalus adsurgens*,  
*A. adsurgens* var. *robustior*, *A. laxmannii* var.  
*robustior*, *A. striatus*)  
*Astragalus richardsonii* (*Astragalus aboriginum*) See  
*A. australis*

Milk Vetch spp

*Astragalus tenellus*  
*Hedysarum alpinum*  
*Hedysarum boreale* (*H. boreale* ssp. *mackenziei*,  
*Hedysarum mackenziei*)

Loose-flowered Milk-vetch  
 Alpine Sweet-vetch  
 Boreal Sweet- vetch

*Lathyrus japonicus*  
*Lathyrus ochroleucus*  
*Lupinus arcticus*

Beach Pea  
 Cream Vetchling  
 Arctic Lupine  
 Arctic Locoweed  
 Oxytrope spp  
 Boreal Locoweed

*Oxytropis arctica* (incl. *Oxytropis bellii*)  
*Oxytropis bellii* (See *Oxytropis arctica*)  
*Oxytropis borealis* (incl. *O. borealis* var. *hudsonica*, *O.*  
*glutinosa*, *O. viscida*, *O. sheldonensis*, *O. leucantha*)  
*Oxytropis campestris* (*O. campestris* var. *varians*, and  
var. *roaldii*, *O. hyperborea*, *O. jordalii*, *O. sericea* var.  
*spicata*)

Field Locoweed

*Oxytropis deflexa* (*O. deflexa* var. *foliolosa*, var.  
*parviflora*, var. *sericea*)

Pendent-pod Locoweed

*Oxytropis hudsonica* (See *Oxytropis borealis*)  
*Oxytropis maydelliana*

Oxytrope spp  
 Maydell Locoweed  
 Blackish Locoweed

*Oxytropis nigrescens* (*O. nigrescens* var. *uniflora*, *O.*  
*arctobia*, *O. nigrescens* ssp. *pygmaea*, *O. nigrescens*  
ssp. *bryophylla*)

Showy Locoweed

*Oxytropis splendens*

Oxytrope spp

*Oxytropis varians* (See *Oxytropis campestris*)

Sticky Locoweed

*Oxytropis viscida* (See *Oxytropis borealis*)

American Purple Vetch

*Vicia americana*

Green Alder

*Alnus crispa*, ssp *crispa* (see *Alnus viridis*)

Speckled Alder (mountain alder, gray alder,  
 hoary alder)

*Alnus incana* (sp. *tenuifolia*)

Green Alder

*Alnus viridis* (incl *Alnus crispa*)

Arctic Dwarf Birch (Dwarf Birch)

*Betula nana* (*Betula glandulosa*, *Betula x eastwoodiae*)

Alaska Paper Birch

*Betula neoalaskana* (*Betula papyrifera* ssp

Water Birch

*nealaskana)*

*Betula occidentalis* (*Betula fontinalis*, *Betula x eastwoodiae*)

Paper Birch (white birch)

*Betula papyrifera* (*Betula papyrifera* var. *commutata*)

**Order: Filicales**

Fragile Fern

*Cystopteris fragilis*

Spinulose Wood-fern

*Dryopteris carthusiana* (*D. spinulosa*)

Fragrant Cliff Wood-fern

*Dryopteris fragrans*

Western Oak-fern

*Gymnocarpium disjunctum* (*Gymnocarpium dryopteris* ssp. *disjunctum*; *Dryopteris disjuncta*)

Nahanni Oak-fern

*Gymnocarpium jessoense* (*Dryopteris robertiana*)

Alpine Cliff-fern (Northern Woodsia)

*Woodsia alpina*

Smooth Cliff-fern (Smooth Woodsia)

*Woodsia glabella*

Rusty Cliff-fern (Rusty Woodsia)

*Woodsia ilvensis*

Rock Polypody

*Polypodium virginianum*

Siberian Polypody

*Polypodium sibiricum* (*Polypodium vulgare*)

American Parsley-fern (American Rock-brake)

*Cryptogramma acrostichoides* (*crispa*)

Slender Rock-brake

*Cryptogramma stelleri*

Northern Beech Fern

*Phegopteris connectilis* (*Dryopteris phegopteris*, *Thelypteris phegopteris*)

**Order: Gentianales**

Spreading Dogbane

*Apocynum androsaemifolium*

Gentian spp.

*Gentiana arctophila* (See *Gentianella propinqua*)

Northern Gentian

*Gentianella amarella* (*Gentiana acuta*)

Four-parted Gentian

*Gentianella propinqua* (syn *Gentiana propinqua* & *Gentiana arctophila*)

Dane's Gentian

*Gentianella tenella*

Sheared Gentian

*Gentianopsis detonsa* (*Gentiana richardsonii*) spp. *detonsa*

Sheared Gentian

*Gentianopsis detonsa* ssp. *Raupii* (see *Gentianopsis detonsa*)

Marsh Felwort

*Lomatogonium rotatum*

Bicknell Geranium

*Geranium bicknellii*

**Order: Haloragales**

Alternate-flower Water Milfoil

*Myriophyllum alterniflorum*

Spilked Water Milfoil

*Myriophyllum sibiricum* (*Myriophyllum exalbescens*)

Whorled Water Milfoil

*Myriophyllum verticillatum*

**Order: Isoetales**

Spiny-spored Quillwort

*Isoetes echinospora* (*Isoetes tenella*, *Isoetes muricata*)

**Order: Juncales**

Northern Green Rush

*Juncus alpinoarticulatus* (*Juncus alpinus* ssp. *nodulosus*)

Arctic Rush

*Juncus arcticus* (*Juncus arcticus* ssp. *alaskanus*;

*Juncus balticus* var. *alaskanus*)

Baltic Rush

*Juncus balticus* (see *Juncus arcticus*)

Two-flowered Rush

*Juncus biglumis*

Toad Rush  
 Chestnut Rush  
 Dudley's Rush  
 Thread Rush  
 Knotted Rush  
 Moor Rush  
 Northern White Rush  
 Vasey Rush  
 Arctic Woodrush  
 Northern Wood Rush  
 Greenland Wood Rush  
 Kjellman Woodrush  
 Common Wood Rush  
 Small-flowered Wood Rush  
 Spiked Wood Rush  
 Wahlenber's Wood Rush

*Juncus bufonius*  
*Juncus castaneus*  
*Juncus dudleyi*  
*Juncus filiformis*  
*Juncus nodosus*  
*Juncus stygius* (*Juncus stygius* ssp. *americanus*)  
*Juncus triglumis* (ssp. *albescens*; *Juncus albescens*)  
*Juncus vaseyi*  
*Luzula arctica* (*Luzula nivalis*; *Luzula tundricola*)  
*Luzula confusa*  
*Luzula groenlandica*  
*Luzula kjellmaniana*  
*Luzula multiflora*  
*Luzula parviflora*  
*Luzula spicata*  
*Luzula wahlenbergii*

**Order: Lamiales**

Northern Stickseed  
 Western Stickseed  
 Drummond Bluebell  
 Sea Bluebell  
 Northern Bluebell  
 Northern Bluebell  
 American Dragonhead Nettle  
 Northern Bugleweed  
 Corn Mint  
 Hooded Skullcap  
 Hairy Hedge Nettle

*Hackelia deflexa* (*Hackelia deflexa* var. *americana*)  
*Lappula occidentalis* (*Lappula redowskii*)  
*Mertensia drummondii*  
*Mertensia maritima*  
*Mertensia paniculata* (Incl var. *alaskana*)  
*Mertensia paniculata* (see *Mertensia paniculata*)  
*Dracocephalum parviflorum* (*Moldavica parviflora*)  
*Lycopus uniflorus*  
*Mentha arvensis*  
*Scutellaria galericulata*  
*Stachys pilosa* (includes *Stachys palustris*?)

**Order: Liliales**

Strict Blue-eyed Grass (Iris)  
 Wild Chives  
 Wild Lily-of-the-Valley  
 Starry False Solomon's Seal  
 Three-leaf False Solomon's Seal  
 Northern False Asphodel  
 Scotch False Asphodel  
 Mountain Death Camas

*Sisyrinchium montanum*  
*Allium schoenoprasum*  
*Maianthemum canadense*  
*Maianthemum stellatum* (*Smilacina stellata*)  
*Maianthemum trifolium* (*Smilacina trifolia*)  
*Tofieldia coccinea*  
*Tofieldia pusilla* (*Tofieldia palustris*)  
*Zigadenus elegans*

**Order: Linales**

Lewis Blue Flax

*Linum lewisii*

**Order: Lycopodiales**

Trailing Clubmoss

*Diphasiastrum complanatum* (*Lycopodium complanatum*)

Fir Clubmoss

*Huperzia selago* (*Lycopodium selago*)

Bristly Clubmoss

*Lycopodium annotinum*

Running Clubmoss

*Lycopodium clavatum* (see *Lycopodium lagopus*)

Tree Clubmoss

*Lycopodium dendroideum* (*Lycopodium obscurum*)

One-cone Clubmoss

*Lycopodium lagopus* (*Lycopodium clavatum*)

**Order: Myricales**

Sweet Gale

*Myrica gale*

**Order: Myrtales**

Fireweed

*Chamerion angustifolium (Epilobium angustifolium)*

River Beauty

*Chamerion latifolium (Epilobium latifolium)*

Arctic Willowherb

*Epilobium arcticum*

Dauria Willowherb

*Epilobium davuricum*

Willowherb spp.

*Epilobium glandulosum (See Epilobium ciliatum)*

Hornemann Willowherb

*Epilobium hornemannii*

Marsh Willowherb

*Epilobium palustre*

**Order: Najadales**

Seaside Arrowgrass

*Triglochin maritima*

Marsh Arrowgrass

*Triglochin palustris (Triglochin palustre)*

Slender Naiad

*Najas flexilis*

Alpine Pondweed

*Potamogeton alpinus*

Leafy Pondweed

*Potamogeton foliosus*

Fries Pondweed

*Potamogeton friesii*

Grassy Pondweed

*Potamogeton gramineus*

Blunt-leaf Pondweed

*Potamogeton obtusifolius*

White-stem Pondweed

*Potamogeton praelongus*

Richardson's pondweed

*Potamogeton richardsonii*

Flatleaf Pondweed

*Potamogeton robbinsii*

Straightleaf Pondweed

*Potamogeton strictifolius*

Yenisei River Pondweed

*Potamogeton subsibiricus (Potamogeton porsildiorum)*

Flatstem Pondweed

*Potamogeton zosteriformis*

Slender Pondweed

*Stuckenia filiformis (Potamogeton filiformis)*

Sheathed Pondweed

*Stuckenia vaginata (Potamogeton vaginatus)*

Pod Grass

*Scheuchzeria palustris*

Eelgrass spp.

*Zostera marina*

**Order: Nepenthales**

English Sundew

*Drosera anglica*

Round-leaved Sundew

*Drosera rotundifolia*

**Order: Nymphaeales**

Common Hornwort

*Ceratophyllum demersum*

Variegated Pond Lily

*Nuphar variegata (Nuphar variegatum, Nuphar lutea ssp. variegata)*

Pygmy White Waterlily (Small White Water-lily) *Nymphaea tetragona*

**Order: Ophioglossales**

Mingan Moonwort

*Botrychium minganense*

**Order: Orchidales**

Small Round-leaved Orchis

*Amerorchis rotundifolia (Orchis rotundifolia)*

Caypso

*Calypso bulbosa*

Long-bract Orchid

*Coeloglossum viride (Habenaria viridis var. bracteata)*

Early Coral Root

*Corallorhiza trifida*

Spotted Lady's-slipper

*Cypripedium guttatum*



Yellow Lady's-slipper  
 Pink Lady's-slipper  
 Sparrow's-egg Lady's-slipper  
 Lesser Rattlesnake Plantain  
 Northern Twayblade  
 White Adder's-mouth  
 Tall Northern Green Orchid

Blunt-leaved Bog Orchid  
 Hooded Ladies' -tresses

**Order: Papaverales**

Golden Corydalis  
 Pale Corydalis  
 Polar Poppy  
*P. radicum ssp polare*  
 Lapland Poppy  
 Arctic Poppy

*Cypridedium parviflorum* (*Cypridedium calceolus*)  
*Cypripedium acaule*  
*Cypripedium passerinum*  
*Goodyera repens*  
*Listera borealis*  
*Malaxis monophyllos*  
*Platanthera aquilonis* (*Habenaria hyperborea*,  
*Platanthera hyperborea*)  
*Platanthera obtusata* (*Habenaria obtusata*)  
*Spiranthes romanzoffiana*

*Corydalis aurea*  
*Corydalis sempervirens*  
*Papaver dahliaum* (*P. cornwallisensis*, *P. polare*) (see  
*Papaver lapponicum* (*Papaver hultenii*)  
*Papaver radicum* (incl. *Papaver polare*, *Papaver*  
*dahliaum*, *P. nudicaule* var *radicum*, *P.*  
*cornwallisensis*)

**Order: Pinales**

Common Juniper (Ground juniper)  
 Creeping Juniper  
 Tamarack  
 White Spruce  
 Black Spruce  
 Jack Pine

*Juniperus communis*  
*Juniperus horizontalis*  
*Larix laricina*  
*Picea glauca*  
*Picea mariana*  
*Pinus banksiana* (*Pinus divaricata*)

**Order: Plantaginales**

Hairy Plantain  
 Saline Plantain  
 Nipple-seed Plantain  
 Seaside Plantain

*Plantago canescens* (*Plantago septata*)  
*Plantago eriopoda*  
*Plantago major*  
*Plantago maritima* (*Plantago juncooides*)

**Order: Plumbaginales**

Western Thrift

*Armeria maritima*

**Order: Polygonales**

Meadow Bistort  
 Alpine Knotweed  
 Iceland Purslane  
 Mountain Sorrel (Scurvey Grass)  
 Water Smartweed  
 Pale Smartweed

Alaska Knotweed

Arctic Dock  
 Tierra del Fuego Dock

*Bistorta plumosa* (*Polygonum bistorta ssp plumosum*)  
*Bistorta vivipara* (*Persicaria vivipara*, *Polygonum*  
*viviparum*)  
*Koenigia islandica*  
*Oxyria digyna*  
*Persicaria amphibia* (*Polygonum amphibium*)  
*Persicaria lapathifolia* (*Polygonum lapathifolium*,  
*Polygonum scabrum*)  
*Polygonum humifusum ssp caurianum* (*Polygonum*  
*caurianum*)  
*Rumex arcticus* (*Rumex arctica*)  
*Rumex fueginus* (*Rumex maritimus* var *fueginus*)

Western Dock  
Triangular-valved Dock

*Rumex occidentalis* (*Rumex aquaticus*)  
*Rumex triangulivalvis* (*Rumex salicifolius*)

**Order: Primulales**

Sweet-flower Rock-jasmine  
Pygmy-flower Rock-jasmine  
Few-flower Shooting-star  
Sea Milkwort  
Tufted Yellow Loosetrife (Water Loosestrife)  
Slender Primrose  
Greenland Primrose  
Mealy Primrose  
Lake Mistassini Primrose  
Stiff Primrose  
Northern Starflower  
Arctic Starflower

*Androsace chamaejasme*  
*Androsace septentrionalis*  
*Dodecatheon pulchellum*  
*Glaux maritima*  
*Lysimachia thyrsiflora*  
*Primula borealis*  
*Primula egaliksensis*  
*Primula incana*  
*Primula mistassinica*  
*Primula stricta*  
*Trientalis borealis*  
*Trientalis europaea*

**Order: Proteales**

American Silverberry  
Buffalo-berry

*Elaeagnus commutata*  
*Shepherdia canadensis*

**Order: Ranunculales**

Red Baneberry  
Canada Anemone  
Cut-leaved Anemone (Hudson Bay Anemone)  
Small-flower Anemone  
Prairie Crocus

*Actaea rubra*  
*Anemone canadensis*  
*Anemone multifida*  
*Anemone parviflora*  
*Anemone patens* (*Pulsatilla patens* ssp. *Multifida*, *P. ludoviciana*, *Anemone patens* ssp. *multifida*)  
*Anemone richardsonii*  
*Aquilegia brevistyla*  
*Caltha natans*  
*Caltha palustris*  
*Delphinium glaucum*  
*Ranunculus aquatilis* (*R. a. var. eradicatus*, *Ranunculus trichophyllus*; *R. longirostris*; ? *Ranunculus circinatus*)  
*Ranunculus cymbalaria*  
*Ranunculus flammula* (*Ranunculus filiformis*, *Ranunculus reptans*)  
*Ranunculus gmelinii* (incl. *Ranunculus purshii*)  
*Ranunculus hyperboreus*  
*Ranunculus lapponicus*

Yellow Anemone  
Blue Columbine  
Floating Marsh Marigold  
Marsh Marigold  
Pale Larkspur  
White Water Buttercup

Seaside Buttercup (Crowfoot)  
Lesser Spearwort

Small Yellow Water-buttercup  
High-Arctic Buttercup (Arctic Buttercup)  
Lapland Buttercup  
Long-beak Buttercup (Eastern White Water-crowfoot)

*Ranunculus longirostris* (see *Ranunculus aquatilis* var. *subrigidus*; *Ranunculus aquatilis* var. *diffusus*)  
*Ranunculus macounii*  
*Ranunculus nivalis*  
*Ranunculus pallasii*  
*Ranunculus pedatifidus* (*Ranunculus affinis*, *Ranunculus arcticus*, *R. eastwoodianus*)  
*Ranunculus pensylvanicus*  
*Ranunculus purshii* (see *Ranunculus gmelinii*)

Macoun Buttercup  
Snowy Buttercup  
Pallas' Buttercup  
Northern Buttercup

Bristly Crowfoot  
Buttercup / Crowfoot spp

Dwarf Buttercup  
Sardinian Buttercup  
Cursed Crowfoot

Sulphur Buttercup  
Veined Meadow Rue

**Order: Rosales**

Water Pigmy-weed  
Skunk Currant  
Northern Black Currant  
Bristly Black Currant  
Canada Gooseberry  
Swamp Red Currant  
Saskatoon Berry, Serviceberry  
Silverweed  
Egede Cinquefoil  
Marsh Cinquefoil  
Shrubby Cinquefoil  
Yellow Mountain Avens  
Entire-leaved Mountain Avens

Mountain Avens spp  
Virginia Strawberry  
Yellow Avens  
Large-leaved Avens  
Prairie-smoke  
Tall Cinquefoil  
Two-flowered Cinquefoil  
Staghorn Cinquefoil  
Arctic Cinquefoil  
Snow Cinquefoil  
Norwegian Cinquefoil  
Pennsylvania Cinquefoil  
Pretty Cinquefoil  
Rocky Mountain Cinquefoil  
One-flowered Cinquefoil  
Vahl's Cinquefoil  
Pin Cherry  
Prickly Rose  
Raspberry spp  
Cloudberry  
Red Raspberry  
Dwarf Red Raspberry  
Arizona Cinquefoil  
Three-toothed Cinquefoil  
Steven Meadow-sweet (Spiraea)  
Northern Golden Saxifrage  
Richardson Alumroot  
Bare-stem Bishop's Cap  
Kotzebue's Grass-of-parnassus

*Ranunculus pygmaeus*  
*Ranunculus sabinei* (*Ranunculus pygmaeus* ssp. *sabinei*)  
*Ranunculus sceleratus* (*R. sceleratus* var. *multifidus*, *R. sceleratus* ssp. *multifidus*)  
*Ranunculus sulphureus*  
*Thalictrum venulosum*

*Crassula aquatica* (*Tillaea aquatica*)  
*Ribes glandulosum*  
*Ribes hudsonianum*  
*Ribes lacustre*  
*Ribes oxyacanthoides*  
*Ribes triste*  
*Amelanchier alnifolia*  
*Argentina anserina* (*Potentilla anserina*)  
*Argentina egedii* (*Potentilla egedii*)  
*Comarum palustre* (*Potentilla palustris*)  
*Dasiphora fruticosa* (*Potentilla fruticosa*)  
*Dryas drummondii*  
*Dryas integrifolia* (incl *Dryas chamissonis*, *Dryas sylvatica*, *Dryas crenulata*)  
*Dryas sylvatica* (see *Dryas integrifolia*)  
*Fragaria virginiana*  
*Geum aleppicum*  
*Geum macrophyllum*  
*Geum triflorum*  
*Potentilla arguta*  
*Potentilla biflora*  
*Potentilla bimundorum* (*Potentilla multifida*)  
*Potentilla nana* (*Potentilla hyparctica*)  
*Potentilla nivea*  
*Potentilla norvegica*  
*Potentilla pensylvanica*  
*Potentilla pulchella*  
*Potentilla rubricaulis*  
*Potentilla uniflora* (*Potentilla ledebouriana*)  
*Potentilla vahliana*  
*Prunus pensylvanica*  
*Rosa acicularis*  
*Rubus acaulis* (see *Rubus arcticus*)  
*Rubus chamaemorus*  
*Rubus idaeus* (*Rubus idaeus* ssp. *strigosus*)  
*Rubus pubescens* var. *pubescens*  
*Sibbaldia procumbens*  
*Sibbaldiopsis tridentata* (*Potentilla tridentata*)  
*Spiraea stevenii* (*Spiraea beauverdiana*)  
*Chrysosplenium tetrandrum*  
*Heuchera richardsonii*  
*Mitella nuda*  
*Parnassia kotzebuei*

Grass-of-Parnassus  
 Marsh Grass-of-parnassus  
 Yellow Mountain Saxifrage  
 Tufted Saxifrage  
 Nodding Saxifrage  
 Leafy Saxifrage  
 Stiff Stem Saxifrage  
 Yellow Marsh Saxifrage  
 Heart-leaved Saxifrage  
 Purple Mountain Saxifrage  
 White Mountain Saxifrage  
 Yukon Saxifrage  
 Alpine Brook Saxifrage  
 Prickly Saxifrage

**Order: Rubiales**

Northern Bedstraw  
 Bedstraw spp  
 Boreal Bedstraw  
 Bog Bedstraw  
 Bedstraw spp  
 Small Bedstraw

Fragrant Bedstraw

**Order: Salicales**

Balsam Poplar  
 Trembling Aspen  
 Alaska Willow  
 Littletree Willow  
 Arctic Willow

Northern Willow  
 Athabasca Willow  
 Bebb Willow (long-beaked willow)  
 Short-fruit Willow  
 Hoary Willow  
 Willow spp

Sandbar Willow  
 Willow spp  
 Alaska Bog Willow  
 Gray willow

Willow spp  
 Halberd Willow  
 Snowbed Willow (New England Dwarf Willow)  
 Willow spp  
 Yellow Willow  
 Blueberry Willow  
 Barren-ground Willow

*Parnassia montanensis* (see *Parnassia palustris*)  
*Parnassia palustris* (incl. *P. palustris* var. *montanensis*)  
*Saxifraga aizoides*  
*Saxifraga caespitosa*  
*Saxifraga cernua*  
*Saxifraga foliolosa*  
*Saxifraga hieraciifolia*  
*Saxifraga hirculus*  
*Saxifraga nelsoniana* (*Saxifraga punctata*)  
*Saxifraga oppositifolia*  
*Saxifraga paniculata* (*Saxifraga aizoon*)  
*Saxifraga reflexa*  
*Saxifraga rivularis*  
*Saxifraga tricuspidata*

*Galium boreale*  
*Galium brandegei* See *Galium trifidum*)  
*Galium kamtschaticum*  
*Galium labradoricum*  
*Galium tinctorium* (see *Galium trifidum*)  
*Galium trifidum* (includes *Galium brandegei* & *Galium tinctorium*)  
*Galium triflorum*

*Populus balsamifera*  
*Populus tremuloides*  
*Salix alaxensis* (*Salix longistylis*)  
*Salix arbusculoides*  
*Salix arctica* (*Salix anglorum*, *Salix crassijulis*, *Salix hudsonensis*)  
*Salix arctophila*  
*Salix athabascensis*  
*Salix bebbiana* (*S. rostrata*)  
*Salix brachycarpa*  
*Salix candida*  
*Salix cordifolia* (*Salix cordifolia* ssp *callicarpea*) (see *Salix glauca*)  
*Salix exigua* (*Salix interior*)  
*Salix fullertonensis* (See *S. niphoclada*)  
*Salix fuscescens*  
*Salix glauca* (*cordiflora* ssp *callicarpea* & *glauca* ssp *stenolepsis*?)  
*Salix gracilis* (see *Salix petiolaris*)  
*Salix hastata* (syn *Salix farriar* var. *walpolei* )  
*Salix herbacea*  
*Salix longistylis* (see *Salix alaxensis*)  
*Salix lutea*  
*Salix myrtilifolia*  
*Salix niphoclada*

Arctic Seashore Willow  
Willow spp  
Bog Willow  
Skeleton-leaved Willow  
Diamond-leaved Willow  
Polar Willow  
Mackenzie Willow

False Mountain Willow  
Tea-leaved Willow  
Balsam Willow  
Net-veined Willow  
Richardson Willow  
Scouler Willow (mountain willow, fire willow)  
Autumn Willow  
Wedgeleaf Willow  
Willow spp.

**Order: Santalales**

Northern Comandra spp.

**Order: Scrophulariales**

Hairy Butterwort  
Common Butterwort  
Flatleaf Bladderwort  
Greater Bladderwort  
Lesser Bladderwort  
Northern Groundcone  
Pale Indian Paintbrush / Painted Cup spp  
Elegant Indian Paintbrush / Painted Cup spp  
Northern Indian Paintbrush  
Ruap Indian Paintbrush  
Eyebright spp  
Arctic Eyebright  
Northern Mudwort  
Yellow Owl's Clover  
Capitate Lousewort  
Red-tip Lousewort  
Greenland Lousewort (Elephant Head)  
Hairy Lousewort  
Labrador Lousewort  
Woolly Lousewort  
Langsdorf's Lousewort (Arctic Lousewort)  
Lapland Lousewort  
Muskeg Lousewort  
*var. macrodonta* (Richards.)  
Sudetan Lousewort  
Little Yellow Rattle  
Long-leaf Speedwell  
Purslane Speedwell  
Marsh Speedwell

*Salix ovalifolia* (*S. ovalifolia* var. *arctolitoralis*)  
*Salix ovalifolia* ssp. *arctolitoralis* (See *Salix ovalifolia*)  
*Salix pedicellaris*  
*Salix phlebophylla*  
*Salix planifolia* (incl *Salix tyrrellii*)  
*Salix polaris*  
*Salix prolixa* (*Salix mackenzieana*, *S. eriocephala* *mackenzieana*, *S. rigida mackenzieana*)  
*Salix pseudomonticola*  
*Salix pulchra*  
*Salix pyrifolia* (*Salix balsamifera*)  
*Salix reticulata*  
*Salix richardsonii* (*Salix lanata* ssp. *richardsonii*)  
*Salix scouleriana*  
*Salix serissima*  
*Salix sphenophylla*  
*Salix tyrrellii* (see *Salix planifolia*)

*Geocaulon lividum*

*Pinguicula villosa*  
*Pinguicula vulgaris*  
*Utricularia intermedia*  
*Utricularia macrorhiza* (*Utricularia vulgaris*)  
*Utricularia minor*  
*Boschniakia rossica*  
*Castilleja caudata*  
*Castilleja elegans*  
*Castilleja hyperborea*  
*Castilleja raupii*  
*Euphrasia frigida* (*Euphrasia arctica*)  
*Euphrasia subarctica*  
*Limosella aquatica*  
*Orthocarpus luteus*  
*Pedicularis capitata*  
*Pedicularis flammea*  
*Pedicularis groenlandica*  
*Pedicularis hirsuta*  
*Pedicularis labradorica*  
*Pedicularis lanata*  
*Pedicularis langsdorfii* (*Pedicularis arctica*\_  
*Pedicularis lapponica*  
*Pedicularis macrodonta* (syn *Pedicularis parviflora*  
  
*Pedicularis sudetica*  
*Rhinanthus minor* (ssp. *borealis*, *Rhinanthus borealis*)  
*Veronica longifolia*  
*Veronica peregrina*  
*Veronica scutellata*

Alpine Speedwell

*Veronica wormskjoldii* (*Veronica alpina*)

**Order: Solanales**

Franklin's Phacelia

*Phacelia franklinii*

Bog Buckbean

*Menyanthes trifoliata*

Narrow-leaved Collomia

*Collomia linearis*

Richarson's Phlox

*Phlox richardsonii* (incl. *spp alaskensis*, syn *P. alaskensis* (*P. richardsonii ssp alaskensis*), *P. sibirica ssp alaskensis*)

Richarson's Phlox

*Phlox richardsonii ssp richardsonii* (see *Phlox richardsonii*)

Tall Jacob's Ladder

*Polemonium acutiflorum*

Northern Jacob's Ladder

*Polemonium boreale*

Showy Jacob's Ladder

*Polemonium pulcherrimum*

**Order: Theales**

Long-stemmed Waterwort

*Elatine triandra*

**Order: Typhales**

Narrow-leaf Bur-reed

*Sparganium angustifolium*

Northern Bur-reed

*Sparganium hyperboreum*

Bur-reed spp.

*Sparganium multipedunculatum* (See *Sparganium angustifolium*)

Small bur-reed

*Sparganium natans* (*Sparganium minimum*)

Broad-leaf Cattail

*Typha latifolia*

**Order: Urticales**

Stinging Nettle

*Urtica dioica* (*ssp gracilis*); *rtica gracilis*)

**Order: Violales**

Woolly Beach-heath (Sand Heather)

*Hudsonia tomentosa*

Sand Violet

*Viola adunca*

Smooth White Violet

*Viola macloskeyi* (*Viola pallens*)

Alpine Marsh Violet

*Viola palustris*

Kidney-leaf White Violet

*Viola renifolia*

**LICHENS**

This table lists the known species of lichen present in the Tundra Shield and Southern Arctic ecozones. The basic list was taken from the Working Group on the General Status of NWT Species (WGGSNS 2006). The names of some genera, Families and Orders have been modified from the WGGSNS 2006 database to conform with Lichens of North America (Brodo, I., S. D. Sharnoff and S. Sharnoff. 2001. Yale University), a standard text of lichen taxonomy and nomenclature. Some species have also been added, based on the distribution maps presented in the Lichens of North America text.

**Order: Agaricales**

Mushroom lichen

*Omphalina hudsoniana*

Greenpea mushroom lichen

*Omphalina umbellifera*

**Order: Caliciales**

Fragile coral lichen

*Sphaerophorus fragilis*

|                                      |                                             |
|--------------------------------------|---------------------------------------------|
| Coral lichen                         | <i>Sphaerophorus globosus</i>               |
| <b>Order: Lecanorales</b>            |                                             |
| Brown cobblestone lichen             | <i>Acaraspora fuscata</i>                   |
| Rimmed cobblestone lichen            | <i>Acaraspora glaucocarpa</i>               |
| Gray witch's hair                    | <i>Alectoria nigricans</i>                  |
| Green witch's hair                   | <i>Alectoria ochroleuca</i>                 |
|                                      | <i>Alectoria vexillifera</i>                |
| Gray horsehair lichen                | <i>Bryoria capillaris</i>                   |
|                                      | <i>Bryoria chalybeiformis</i>               |
| Pale-footed horsehair lichens        | <i>Bryoria fuscescens</i>                   |
|                                      | <i>Bryoria glabra</i>                       |
|                                      | <i>Bryoria lanestris</i>                    |
| Brittle horsehair lichen             | <i>Bryoria nadvornikiana</i>                |
| Spiny gray horsehair lichen          | <i>Bryoria nitidula</i>                     |
| Tundra horsehair lichen              | <i>Bryoria pseudofuscescens</i>             |
| Mountain horsehair lichen            | <i>Bryoria simplicior</i>                   |
|                                      | <i>Bryoria tenuis</i>                       |
| Horsehair lichen                     | <i>Bryoria trichodes</i>                    |
|                                      | <i>Bryoria vrangiana</i>                    |
|                                      | <i>Cornicularia aculeata</i>                |
|                                      | <i>Cornicularia divergens</i>               |
|                                      | <i>Cornicularia muricata</i>                |
|                                      | <i>Arctomia delicatula</i>                  |
|                                      | <i>Arctomia interfixa</i>                   |
|                                      | <i>Biatora vernalis</i>                     |
| Dot lichens                          | <i>Cladina arbuscula</i>                    |
| Reindeer lichen                      | <i>Cladina mitis</i>                        |
| Green reindeer lichen                | <i>Cladina rangiferina</i>                  |
| Gray reindeer lichen                 | <i>Cladina stellaris</i>                    |
| Star-tipped reindeer lichen          | <i>Cladina stygia</i>                       |
| Black-footed reindeer lichen         | <i>Cladonia aberrans</i>                    |
|                                      | <i>Cladonia acuminata</i>                   |
|                                      | <i>Cladonia alaskana</i>                    |
| Quill lichen                         | <i>Cladonia amaurocraea</i>                 |
| Lipstick powderhorn, pin lichen      | <i>Cladonia bacillaris</i>                  |
|                                      | <i>Cladonia bacilliformis</i>               |
| Toy soldiers                         | <i>Cladonia bellidiflora</i>                |
| Boreal pixie-cup                     | <i>Cladonia borealis</i>                    |
| Wooden soldiers                      | <i>Cladonia botrytes</i>                    |
| Split leg lichen, split leg soldiers | <i>Cladonia cariosa</i>                     |
| Crowned pixie-cup                    | <i>Cladonia carneola</i>                    |
| Powdered funnel lichen               | <i>Cladonia cenotea</i>                     |
| Mealy pixie-cup                      | <i>Cladonia chlorophaena</i>                |
|                                      | <i>Cladonia coccifera</i>                   |
|                                      | <i>Cladonia conista</i>                     |
| Bighorn cladonia                     | <i>Cladonia cornuta</i> ssp. <i>Cornuta</i> |
| Organ-pipe lichen                    | <i>Cladonia crispata</i>                    |
|                                      | <i>Cladonia cryptochlorophaea</i>           |
|                                      | <i>Cladonia cyanipes</i>                    |
|                                      | <i>Cladonia decorticata</i>                 |

|                                           |                                 |
|-------------------------------------------|---------------------------------|
| Lesser sulphur cup                        | <i>Cladonia deformis</i>        |
| Finger pixie-cup                          | <i>Cladonia digitata</i>        |
| Frosted cladonia                          | <i>Cladonia ecmocyna</i>        |
| Trumpet lichen                            | <i>Cladonia fimbriata</i>       |
| Smooth cladonia                           | <i>Cladonia gracilis</i>        |
|                                           | <i>Cladonia granulans</i>       |
|                                           | <i>Cladonia grayi</i>           |
|                                           | <i>Cladonia macrophylla</i>     |
| Large-leaved cladonia                     | <i>Cladonia macrophyllodes</i>  |
| Giant cladonia                            | <i>Cladonia maxima</i>          |
|                                           | <i>Cladonia merochlorophaea</i> |
|                                           | <i>Cladonia metacorallifera</i> |
| Sieve lichen                              | <i>Cladonia multiformis</i>     |
|                                           | <i>Cladonia norrlinii</i>       |
| Felt cladonia                             | <i>Cladonia phyllophora</i>     |
| Red-fruited pixie-cup                     | <i>Cladonia pleurota</i>        |
| Rosette pixie-cup, carpet pixie cup       | <i>Cladonia pocillum</i>        |
| Pebbled pixie-cup                         | <i>Cladonia pyxidata</i>        |
| Wand lichen                               | <i>Cladonia rei</i>             |
| Dragon cladonia, dragon funnel            | <i>Cladonia squamosa</i>        |
|                                           | <i>Cladonia stricta</i>         |
|                                           | <i>Cladonia subcervicornis</i>  |
|                                           | <i>Cladonia subfurcata</i>      |
| Antlered powderhorn                       | <i>Cladonia subulata</i>        |
| Greater sulphur-cup                       | <i>Cladonia sulphurina</i>      |
| Split-leg lichen, greater thatch soldiers | <i>Cladonia symphyrcarpia</i>   |
|                                           | <i>Cladonia thomsonii</i>       |
| Spotted black-foot                        | <i>Cladonia trassii</i>         |
| Crazy scale lichen                        | <i>Cladonia turgida</i>         |
| Thorn cladonia                            | <i>Cladonia uncialis</i>        |
| Ladder lichen                             | <i>Cladonia verticillata</i>    |
|                                           | <i>Leciophysma finmarkicum</i>  |
|                                           | <i>Collema bachmanianum</i>     |
|                                           | <i>Collema ceraniscum</i>       |
|                                           | <i>Collema glebulentum</i>      |
|                                           | <i>Collema limosum</i>          |
| Soil jelly lichen, tar jelly              | <i>Collema tenax</i>            |
| Jelly flakes                              | <i>Collema undulatum</i>        |
|                                           | <i>Leptogium arcticum</i>       |
|                                           | <i>Leptogium lichenoides</i>    |
|                                           | <i>Leptogium minutissimum</i>   |
|                                           | <i>Leptogium saturninum</i>     |
|                                           | <i>Leptogium tenuissimum</i>    |
| Chalky sunken disk lichen                 | <i>Aspicilia candida</i>        |
| Cinder lichen                             | <i>Aspicilia cinerea</i>        |
| Candy lichen, spraypaint                  | <i>Icmadophila ericetorum</i>   |
| Water fingers                             | <i>Siphula ceratites</i>        |
| Hidden goldspeck lichen                   | <i>Candelariella aurella</i>    |
| Tundra goldspeck lichen                   | <i>Candelariella terrigena</i>  |
| Common goldspeck lichen                   | <i>Candelariella vitellina</i>  |
| Black-eyed rim-lichen                     | <i>Lecanora circumborealis</i>  |



|                                   |                                  |
|-----------------------------------|----------------------------------|
| Mortar rim-lichen                 | <i>Lecanora dispersa</i>         |
| Wood-spot rim-lichen              | <i>Lecanora marginata</i>        |
| Granite-speck rim-lichen          | <i>Lecanora piniperda</i>        |
| White rim-lichen                  | <i>Lecanora polytropa</i>        |
| Fused rim-lichen                  | <i>Lecanora rupicola</i>         |
| Orange rock-posy                  | <i>Lecanora symmicta</i>         |
| Green rock-posy                   | <i>Rhizoplaca chrysoleuca</i>    |
| Brown tile lichen                 | <i>Rhizoplaca melanophthalma</i> |
| Gray-orange disk lichen           | <i>Lecidea atrobrunnea</i>       |
| Tile lichen                       | <i>Lecidea lapicida</i>          |
| Cabbage lungwort                  | <i>Lecidea tessellata</i>        |
| Textured lungwort                 | <i>Lobaria linita</i>            |
| Moon lichens, crater lichens      | <i>Lobaria scrobiculata</i>      |
| False sunken disk lichen          | <i>Sticta arctica</i>            |
| Arctic kidney lichen, green light | <i>Megaspora verrucosa</i>       |
| Alpine kidney lichen              | <i>Nephroma arcticum</i>         |
| Fringed kidney lichen             | <i>Nephroma expallidum</i>       |
| Powdery kidney lichen             | <i>Nephroma helveticum</i>       |
| Alpine bloodspot                  | <i>Nephroma parile</i>           |
| Rockmoss rosette lichen           | <i>Ophioparma ventosa</i>        |
| Brown-gray moss-shingle           | <i>Massalongia carnosa</i>       |
|                                   | <i>Pannaria pezizoides</i>       |
|                                   | <i>Parmeliella arctophila</i>    |
| Black-bordered shingle lichen     | <i>Parmeliella praetermissa</i>  |
| Green moss-shingle                | <i>Parmeliella tryptophylla</i>  |
| Gray witch's hair                 | <i>Psoroma hypnorum</i>          |
| Green witch's hair                | <i>Alectoria nigricans</i>       |
| Rock grubs                        | <i>Alectoria ochroleuca</i>      |
| Concentric ring lichen            | <i>Allantoparmelia alpicola</i>  |
| Rippled ring lichen               | <i>Arctoparmelia centrifuga</i>  |
| Arctic rag lichen                 | <i>Arctoparmelia separata</i>    |
| Arctic rag lichen                 | <i>Asahinea chrysantha</i>       |
|                                   | <i>Asahinea chrysantha</i>       |
|                                   | <i>Asahinea scholanderi</i>      |
| Northern foxhair                  | <i>Bryocaulon divergens</i>      |
| Spiny heath lichen                | <i>Cetraria aculeata</i>         |
|                                   | <i>Cetraria andrejevii</i>       |
|                                   | <i>Cetraria chlorophylla</i>     |
|                                   | <i>Cetraria commixta</i>         |
| Curled snow lichen                | <i>Cetraria cucullata</i>        |
|                                   | <i>Cetraria delisei</i>          |
| Iceland lichen                    | <i>Cetraria ericetorum</i>       |
|                                   | <i>Cetraria fastigiata</i>       |
|                                   | <i>Cetraria halei</i>            |
|                                   | <i>Cetraria hepatizon</i>        |
| True icelandic lichen             | <i>Cetraria islandica</i>        |
| Striped icelandic lichen          | <i>Cetraria laevigata</i>        |
|                                   | <i>Cetraria nigricans</i>        |
|                                   | <i>Cetraria nigricascens</i>     |
| Crinkled snow lichen              | <i>Cetraria nivalis</i>          |
|                                   | <i>Cetraria pinastri</i>         |

|                                                      |                                   |
|------------------------------------------------------|-----------------------------------|
|                                                      | <i>Cetraria sepincola</i>         |
|                                                      | <i>Cetraria tilesii</i>           |
| Snow-bed Iceland lichen                              | <i>Cetrariella delisei</i>        |
|                                                      | <i>Cetrelia alaskana</i>          |
| Mountain oakmoss lichen                              | <i>Evernia divaricata</i>         |
| Boreal oakmoss lichen                                | <i>Evernia mesomorpha</i>         |
|                                                      | <i>Evernia perfragilis</i>        |
| Varnished tube lichen                                | <i>Hypogymnia austerodes</i>      |
| Powdered tube lichen                                 | <i>Hypogymnia bitteri</i>         |
|                                                      | <i>Hypogymnia oroarctica</i>      |
| Monks-hood lichen, hooded tube lichen, puffed lichen | <i>Hypogymnia physodes</i>        |
| Heath tube lichen                                    | <i>Hypogymnia subobscura</i>      |
| Arctic tumbleweed                                    | <i>Masonhalea richardsonii</i>    |
|                                                      | <i>Parmelia almquistii</i>        |
|                                                      | <i>Parmelia alpicola</i>          |
| Mealy camouflage lichen                              | <i>Parmelia disjuncta</i>         |
| Elegant camouflage lichen                            | <i>Parmelia elegantula</i>        |
| Lustrous camouflage lichen                           | <i>Parmelia exasperatula</i>      |
|                                                      | <i>Parmelia fraudans</i>          |
|                                                      | <i>Parmelia infumata</i>          |
| Spotted camouflage lichen                            | <i>Parmelia olivacea</i>          |
| Smoky crottle                                        | <i>Parmelia omphalodes</i>        |
|                                                      | <i>Parmelia panniformis</i>       |
| Salted shield lichen, crottle                        | <i>Parmelia saxatilis</i>         |
| Northern camouflage lichen                           | <i>Parmelia septentrionalis</i>   |
|                                                      | <i>Parmelia solediosa</i>         |
| Bottlebrush shield lichen                            | <i>Parmelia squarrosa</i>         |
|                                                      | <i>Parmelia stygia</i>            |
|                                                      | <i>Parmelia subaurifera</i>       |
|                                                      | <i>Parmelia substygia</i>         |
| Hammered shield lichen                               | <i>Parmelia sulcata</i>           |
|                                                      | <i>Parmeliopsis aleurites</i>     |
| Green starburst lichen                               | <i>Parmeliopsis ambigua</i>       |
| Gray starburst lichen                                | <i>Parmeliopsis hyperopta</i>     |
| Varied rag lichen, ragbag                            | <i>Platismatia glauca</i>         |
| Coarse rockwool                                      | <i>Pseudephebe minuscula</i>      |
| Fine rockwool                                        | <i>Pseudephebe pubescens</i>      |
|                                                      | <i>Xanthoparmelia centrifuga</i>  |
| Tumbleweed shield lichen                             | <i>Xanthoparmelia chlorochroa</i> |
|                                                      | <i>Xanthoparmelia incurva</i>     |
|                                                      | <i>Xanthoparmelia separata</i>    |
|                                                      | <i>Xanthoparmelia taractica</i>   |
|                                                      | <i>Xanthoparmelia tasmanica</i>   |
| Common freckle pelt, felt lichen                     | <i>Peltigera aphthosa</i>         |
| Dog lichen                                           | <i>Peltigera canina</i>           |
| Alternating dog-lichen                               | <i>Peltigera didactyla</i>        |
| Scaly pelt                                           | <i>Peltigera lepidophora</i>      |
| Ruffled freckle belt                                 | <i>Peltigera leucophlebia</i>     |
| Veinless pelt                                        | <i>Peltigera malacea</i>          |
| Membranous dog lichen                                | <i>Peltigera membranacea</i>      |
|                                                      | <i>Peltigera occidentalis</i>     |

|                                               |                                    |
|-----------------------------------------------|------------------------------------|
| Many-fruited pelt                             | <i>Peltigera polydactyla</i>       |
| Field dog-lichen                              | <i>Peltigera rufescens</i>         |
| Scabby pelt                                   | <i>Peltigera scabrosa</i>          |
| Fan lichen                                    | <i>Peltigera venosa</i>            |
|                                               | <i>Solorina bispora</i>            |
| Orange chocolate chip lichen                  | <i>Solorina crocea</i>             |
| Common chocolate chip lichen                  | <i>Solorina saccata</i>            |
| Fringed chocolate chip lichen                 | <i>Solorina spongiosa</i>          |
| Powdery saucer lichen                         | <i>Ochrolechia androgyna</i>       |
| Arctic saucer lichen                          | <i>Ochrolechia frigida</i>         |
| Tundra saucer lichen                          | <i>Ochrolechia upsaliensis</i>     |
| Finger wart lichen                            | <i>Pertusaria dactylina</i>        |
| Arctic wart lichen                            | <i>Perusaria pangyra</i>           |
| Tiny button lichen                            | <i>Amandinea punctata</i>          |
|                                               | <i>Anaptychia kaspica</i>          |
| Golden moonglow lichen                        | <i>Dimelaena oreina</i>            |
| Pincushion shadow lichen                      | <i>Phaeophysica constipata</i>     |
|                                               | <i>Phaeophysica endococcinea</i>   |
| Dark shadow lichen, five o'clock shadow       | <i>Phaeophysica sciastra</i>       |
| Hooded rosette lichen                         | <i>Physcia adscendens</i>          |
| Hoary rosette lichen                          | <i>Physcia aipolia</i>             |
| Blue-gray rosette lichen, powder-back rosette | <i>Physcia caesia</i>              |
| Powder-tipped rosette lichen                  | <i>Physcia dubia</i>               |
| Black-eyed rosette lichen                     | <i>Physcia phaea</i>               |
| Bottlebrush frost lichen                      | <i>Physconia deterosa</i>          |
| Ground frost lichen                           | <i>Physconia muscigena</i>         |
|                                               | <i>Placynthium aspratile</i>       |
| Moss-thorns                                   | <i>Polychidium muscicola</i>       |
|                                               | <i>Fistulariella almquistii</i>    |
|                                               | <i>Fistulariella roesleri</i>      |
| Rock ramalina                                 | <i>Ramalina intermedia</i>         |
| Hooded ramalina                               | <i>Ramalina obtusata</i>           |
| Snowy map lichen                              | <i>Rhizocarpon chioneum</i>        |
| Yellow map lichen                             | <i>Rhizocarpon geographicum</i>    |
|                                               | <i>Stereocaulon alpinum</i>        |
|                                               | <i>Stereocaulon arenarium</i>      |
|                                               | <i>Stereocaulon condensatum</i>    |
| Finger-scale foam lichen                      | <i>Stereocaulon dactylophyllum</i> |
|                                               | <i>Stereocaulon glareosum</i>      |
| Grand foam lichen                             | <i>Stereocaulon grande</i>         |
|                                               | <i>Stereocaulon incrustatum</i>    |
| Easter lichen                                 | <i>Stereocaulon paschale</i>       |
| Snow foam lichen                              | <i>Stereocaulon rivulorum</i>      |
| Rock foam lichen                              | <i>Stereocaulon saxatile</i>       |
|                                               | <i>Stereocaulon symphycheilum</i>  |
| Woolly foam lichen, eyed foam lichen          | <i>Stereocaulon tomentosum</i>     |
| Variegated foam lichen                        | <i>Stereocaulon vesuvianum</i>     |
| Gray-rimmed firedot lichen                    | <i>Caloplaca cerina</i>            |
| Sulphur-firedot lichen                        | <i>Caloplaca flavovirescens</i>    |
| Tundra sulphur lichen                         | <i>Fulgensia bracteata</i>         |
| Gold-eye lichens                              | <i>Teloschistes arcticus</i>       |

|                                           |                                      |
|-------------------------------------------|--------------------------------------|
| Shrubby sunburst lichen                   | <i>Xanthoria candelaria</i>          |
| Elegant sunburst lichen                   | <i>Xanthoria elegans</i>             |
| Sugared sunburst lichen                   | <i>Xanthoria sorediata</i>           |
| Blackened toadskin                        | <i>Lasallia pensylvanica</i>         |
|                                           | <i>Umbilicaria arctica</i>           |
| Fringed rock tripe                        | <i>Umbilicaria cylindrica</i>        |
| Netted rock tripe                         | <i>Umbilicaria decussatus</i>        |
| Peppered rock tripe                       | <i>Umbilicaria deusta</i>            |
|                                           | <i>Umbilicaria havaasii</i>          |
|                                           | <i>Umbilicaria hirsta</i>            |
| Blistered rock tripe                      | <i>Umbilicaria hyperborea</i>        |
| Salty rock tripe                          | <i>Umbilicaria krascheninnikovii</i> |
|                                           | <i>Umbilicaria lyngei</i>            |
| Smooth rock tripe                         | <i>Umbilicaria mammulata</i>         |
| Plated rock tripe                         | <i>Umbilicaria mühlenbergii</i>      |
| Emery rock tripe                          | <i>Umbilicaria phaea</i>             |
| Petaled rock tripe                        | <i>Umbilicaria polyphylla</i>        |
| Nettled rock tripe                        | <i>Umbilicaria proboscidea</i>       |
| Roughened rock tripe                      | <i>Umbilicaria rigida</i>            |
| Punctured rock tripe                      | <i>Umbilicaria torrefacta</i>        |
|                                           | <i>Umbilicaria vellea</i>            |
| Blushing rock tripe                       | <i>Umbilicaria virginis</i>          |
| Arctic finger lichen                      | <i>Dactylina arctica</i>             |
|                                           | <i>Dactylina beringica</i>           |
|                                           | <i>Dactylina madreporiformis</i>     |
| Frosted finger lichen                     | <i>Dactylina ramulosa</i>            |
|                                           | <i>Thamnolia subuliformis</i>        |
| Whiteworm lichen                          | <i>Thamnolia vermicularis</i>        |
| Pitted beard lichen                       | <i>Usnea cavernosa</i>               |
|                                           | <i>Usnea dasypoga</i>                |
| Bristly beard lichen, shaggy beard lichen | <i>Usnea hirta</i>                   |
| Straw beard lichen                        | <i>Usnea scabrata</i>                |
|                                           | <i>Usnea subfloridana</i>            |
|                                           | <i>Usnea substerilis</i>             |
| Order: Leotiales                          |                                      |
|                                           | <i>Baeomyces carneus</i>             |
| Carpet beret lichen                       | <i>Baeomyces placophyllus</i>        |
|                                           | <i>Baeomyces roseus</i>              |
| Brown-beret lichen                        | <i>Baeomyces rufus</i>               |
| <b>Order: Lichinales</b>                  |                                      |
|                                           | <i>Ephebe hispidula</i>              |
| Rockshag lichen                           | <i>Ephebe lanata</i>                 |
|                                           | <i>Zahlbrucknerella calcarea</i>     |
| <b>Order: Ostropales</b>                  |                                      |
| Cowpie lichen                             | <i>Diploschistes muscorum</i>        |
| <b>Order Verrucariales</b>                |                                      |
|                                           | <i>Dermatocarpon cinereum</i>        |

Common stippleback leather lichen

*Dermatocarpon fluviatile*  
*Dermatocarpon hepaticum*  
*Dermatocarpon intestiniforme*  
*Dermatocarpon miniatum*  
*Flavocetraria cucullata*

## **Fishes**

Fish nomenclature and taxonomy updated in 2007 using the database at [www.fishbase.org](http://www.fishbase.org), which lists the latest species names from the American Fisheries Society.

### Freshwater Fish

Arctic Grayling  
Broad Whitefish  
Burbot  
Emerald Shiner  
Goldeye  
Inconnu  
Lake Chub  
Lake Cisco  
Lake Trout  
Lake Whitefish  
Least Cisco  
Longnose Sucker  
Ninespine Stickleback  
Northern Pike  
Round Whitefish  
Shortjaw Cisco  
Slimy Sculpin  
Troutperch  
Walleye  
Yellow Perch

*Thymallus arcticus*  
*Coregonus nasus*  
*Lota lota*  
*Notropis atherinoides*  
*Hiodon alosoides*  
*Stenodus leucichthys*  
*Couesius plumbeus*  
*Coregonus artedi*  
*Salvelinus namaycush*  
*Coregonus clupeaformis*  
*Coregonus sardinella*  
*Catostomus catostomus*  
*Pungitius pungitius*  
*Esox lucius*  
*Prosopium cylindraceum*  
*Coregonus zenithicus*  
*Cottus cognatus*  
*Percopsis omiscomaycus*  
*Sander vitreus*  
*Perca flavescens*

### Freshwater and Marine, and Marine Fish

Arctic Char  
Arctic Cisco  
Arctic Cod  
Arctic Flounder  
Arctic Lamprey  
Bering Flounder  
Bering Wolffish  
Boreal Smelt

*Salvelinus alpinus*  
*Coregonus autumnalis*  
*Boreogadus saida*  
*Liopsetta glacialis*  
*Lampetra japonica*  
*Hippoglossides robustus*  
*Anarhichas orientalis*  
*Osmerus mordax*

|                    |                                                |
|--------------------|------------------------------------------------|
| Capelin            | <i>Mallotus villosus</i>                       |
| Eelblenny          | <i>Lumpenus</i> spp and <i>Anisarchus</i> spp. |
| Eelpout            | <i>Lycodes</i> spp.                            |
| Arctic Flounder    | <i>Liopsetta glacialis</i>                     |
| Fourhorn Sculpin   | <i>Myoxocephalus quadricornis</i>              |
| Greenland Cod      | <i>Gadus ogac</i>                              |
| Pacific Herring    | <i>Clupea pallasii</i>                         |
| Polar Cod          | <i>Arctogadus glacialis</i>                    |
| Saffron Cod        | <i>Eleginus gracilis</i>                       |
| Pacific Sand Lance | <i>Ammodytes hexapterus</i>                    |
| Starry Flounder    | <i>Platichthys stellatus</i>                   |

### Invertebrates

|                             |                                                                         |
|-----------------------------|-------------------------------------------------------------------------|
| Ants, bees and wasps        | Order Hymenoptera                                                       |
| Beetles                     | Order Coleoptera                                                        |
| Bot flies (true flies)      | <i>Cephenemyia trompi</i>                                               |
| Blackflies (true flies)     | inc. sp of genera <i>Prosimulum</i> , <i>Cnephia</i> , & <i>Simulum</i> |
| Butterflies/moths           | Order Lepidoptera                                                       |
| Spruce budworm              | <i>Choristoneura fumiferana</i>                                         |
| Caddis flies                | Order Trichoptera                                                       |
| Calanoids                   | (Very small crustaceans, Order Copepoda)                                |
| Cyclopoids                  | (Very small crustaceans, Order Copepoda)                                |
| Dragonflies and Damselflies | Order Odonata                                                           |
| Hoppers (freshwater)        | <i>Gammarus</i> spp. (Order Amphipoda)                                  |
| Mayflies                    | Order Ephemeroptera                                                     |
| Mosquitoes (true flies)     | inc. <i>Aedes</i> , spp.                                                |
| Baltic Macoma               | (marine clam) <i>Macoms balthica</i>                                    |
| Mysids                      | <i>Mysid</i> spp. (Order Amphipoda)                                     |
| Blue mussel                 | <i>Mytilis edulis</i>                                                   |
| Freshwater shrimp           | <i>Pontoporeia</i> spp. (Order Amphipoda)                               |
| Snow Fleas                  | <i>Achorutes nivicola</i>                                               |
| Sphaeriid Freshwater clam   | F. sphaeriidae                                                          |
| Spruce/White Pine Weevil    | <i>Pissodes strobi</i>                                                  |
| Stone flies                 | Order Plecoptera                                                        |
| True Flies                  | Order Diptera                                                           |
| Warble fly (true flies)     | <i>Hypoderma tarandi</i>                                                |