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**Hudson Bay Programme
Final Science Report**

by
P.G. Sly



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HUDSON BAY PROGRAM: SCIENCE REPORT

INTRODUCTION

This report has been prepared as a working document for use by participants in the Hudson Bay program. It provides a summary of the information and understandings gathered during the science study phase of the program. No new research was undertaken during the science study. Rather, effort has been directed towards collection and synthesis of existing information (published and unpublished material). Collected materials have been compiled and annotated, and now comprise the most complete bibliography of the study region. The present report draws on material contained in the annotated bibliography and seven additional overview documents prepared for the program. All of these documents are listed in the bibliography provided at the end of this report. Each of the listed documents is supported by extensive citation and referencing. In this report, technical detail has been kept to a minimum and, for ease reading, citations have been omitted from the text. Species are referred to only by their common names. Readers are referred to the bibliography for appropriate source material.

The science study is one of two major activities that have been undertaken to provide information for use in an evaluation of cumulative impacts within and surrounding Hudson and James bays. The other major activity involves an extensive study of traditional environmental knowledge (TEK), largely the collective experience of the Cree and Inuit inhabitants of the region. Each of these two studies, in its own way, documents the state of the environment. For science, this includes: what exists and where; what processes occur and relate what to what; what trends are apparent in the information; what implications arise; what concerns may be attached to them; and what and how to focus on priorities. The science study provides a summary of natural conditions in the bioregion, it highlights human induced changes, and effects of change on human health, well being, and native economies.

For the purpose of this study, cumulative impact means significant changes in the lives of people and or conditions which result from human disturbance of the environment. This includes both living and non-living things. It also means the relations among and between bio-physical and socio-economic forms of impact.

The area covered by this report includes the entire Hudson Bay drainage basin which extends west to the Rocky Mountains in Alberta, east to the highlands of central Quebec, south towards the St Lawrence River drainage of Ontario, and north to the limits of drainage into Foxe Basin. Mostly, attention is directed to conditions in James Bay, Hudson Bay, Foxe Basin and Hudson Strait, and to those parts of the drainage basin which are most closely connected to these bodies of water. For convenience, these areas are called the bioregion. Settlements in these areas are most dependent on the natural resources of the bay for their health and well being.

GENERAL THOUGHTS

The bioregion covers a huge area, it supports a very small human population, and it is characterised by low biological productivity. However, the region is neither empty nor unused, rather it has a very low carrying capacity and people who depend on local food supplies require large areas to sustain hunting and trapping activities.

Although, scientifically, much is now known about the area, much also remains unknown. To be honest, it must be said that in many areas of scientific knowledge and understanding of the bioregion, scientists do not know what they don't know. In light of this statement it may be cautioned, also, that experience teaches "a little knowledge is a dangerous thing".

Climate dominates conditions in this northern environment and the lives of its people. The bioregion is subject to a cold climate, due its mid-continental location and the influence of Arctic marine waters. It is also subject to large natural variabilities which make it difficult to assess the extent to which man-made changes have begun to affect long term and spatially large scale environmental conditions.

The impacts of European and North American societies on native communities in the bioregion began in the seventeenth century. Cultural impacts have greatly increased, particularly in the past fifty years or so. During this period, a wide range of social, economic and environmental changes are known to have imposed stress on native communities, many of whose lifestyles and expectations were better adapted to prior conditions.

Native communities are likely to remain dependent on northern resources for a substantial part of their livelihood, for now and into the foreseeable future, and it is essential that the basis for their existence and well-being should not be compromised. This need (for sustainable development) is shared globally.

Scientific observations and experiments have shown that significant changes are occurring in the bioregion, that some are clearly related to human activity and that others may be. It is essential, now, to establish what kind of environment and society northern people wish for themselves ... as an expression of their own future. With this, science can be used to correct some of the past mistakes and to guide future planning and development.

The following summary is selective. It describes patterns of settlement and development in the Hudson Bay drainage basin, the natural environment of the bioregion, the different effects of development, and issues and problems that are now perceived. Priorities are considered, both in terms of human and broader environmental effects.

SETTLEMENT AND CULTURAL IMPACT

Figure 1 shows the extent of the Hudson Bay drainage basin, figure 2 shows the distribution of settlements, and figure 3 shows geographic features of the Hudson Bay bioregion. They provide the geographic setting for most of the following text. Indian settlements (mostly Cree) extend around the southern half of the bioregion, from the Churchill River to Great Whale River. Inuit settlements are present in the northern half of the bioregion.

North American Indians moved northward with the retreat of glacial ice and were the first to populate the region, perhaps more than 5000 years ago. Inuit, travelling eastwards along the Arctic coast, arrived in the bay about 3000 years ago. Early European explorers and traders seeking a northwest passage to the Orient entered the bay in the early 1600s, and explorers and traders moved northwest from the St. Lawrence and Great Lakes region a short while later.

Although many parts of the bay are relatively close to Europe, shipping within the region was severely limited by ice which restricted the movement of vessels to a few months of

the year. At first, European explorers and traders focused mostly on the availability of fur, and British and French interests competed for trade and territory. Movements within the region followed the major river and lake drainage systems and, largely because of difficult access, goods and people usually moved inland from the coast. Fast flowing rivers and the need to portage made it difficult to move large quantities goods and people between this region and the St. Lawrence drainage. Trading posts were established along the shore and around the bay, and often at the mouths of rivers which provided access to posts further inland. These sites were often shared by church missions, and later they became the focus for expanded government services and the settlement of native communities.

Contact with Europeans, unfortunately, brought disease to both Indian and Inuit communities and large numbers of native people died as a result of infections for which they had no immunity. Interestingly, however, contact did not result in the transfer of major new diseases into European society.

As the demand for whale oil grew, particularly during the eighteenth century, both Europeans and Americans became involved in whaling. Bowhead whales were the target of most of the commercial whaling in the bay, although beluga were also taken. Commercial whaling was discontinued just after the turn of the present century, when there were so few bowhead left that the practice was no longer economically viable. Native economies were affected in several ways by the whaling industry which offered limited employment but which also depleted an important source of food. The decline of this industry took several decades but while it was taking place, hunting and trapping of many fur bearing animals expanded dramatically. This maintained and, in several areas, increased trade and contact between natives and non-natives. Many hunters and trappers were non-natives.

Changes in the demand for furs reflected the whims of fashion and, later, the need for military clothing. Both resulted in excessive harvesting, and this was compounded by the need for trappers to kill, additionally, for dog food and for their own survival. Unsustainable harvesting practices, caused almost solely by pressures external to the native communities, resulted in the widespread depletion of essential food supplies. In no small way, these changes led to starvation and the loss of many self-supporting native economies throughout the region. Periods of severe climatic conditions also compounded the problems of survival for many native groups. Both Inuit and Cree were affected by these changes but the impact on the Inuit was probably greater because of a more limited food supply.

The Canadian Federal Government recognised the desperate condition of many native people during the 1950s and began a process of settlement, bringing what were essentially nomadic groups into central communities where medical and other forms of support could be provided. This process, unfortunately, further reduced the ability of native groups to manage their own affairs and made them even more dependent on government support.

At about this time, also, large piston-driven aircraft opened the market for transatlantic passengers and government services were expanded in expectation of the need for northern airport facilities. The introduction of long-haul jet aircraft services caused these expectations to be short-lived and at some places there was a related economic down-turn. However, concern for North American air defence also increased rapidly during the 1950s and 1960s, and numerous military posts were built throughout northern Canada, including the Hudson Bay bioregion. Military activities resulted in increased but temporary local employment and, in some cases, relocation.

The activities of North American society have continued to increase despite a decline in defence needs and generate increasing pressures on northern communities. Most recently, demands for water and for hydroelectric power have resulted in the construction of a number of very large reservoirs and large scale diversions of water from one basin to another. At present, only a small portion of the water in the Hudson Bay drainage basin is transferred out of the basin but proposals have been advanced for a massive southward diversion from James Bay. The initial effects of reservoir formation and water diversion have been particularly damaging to many Indian communities. The long term and more widespread effects, however, may be just as important for many Inuit communities around the bay.

Indian and Inuit societies have been directly affected by a wide range of northern construction and resource use activities, but both have been affected by more subtle and less evident forms of impact. In many ways the latter may have been of equal or greater importance. These impacts include restricted use of or access to resources, a greatly reduced role in the management of resource use, constraints on the development of native business, and exposure and pressure to accept concepts and expectations contrary to traditional beliefs. While many of the problems caused by the decisions of central government are increasing recognised, it will take time to resolve the issues and to find solutions acceptable to both native and non-native interests. In the meantime, stresses associated with cultural shock and frustrations with the inability to resolve key issues remain.

Poor health, violence and substance abuse may be symptomatic of these situations.

DEVELOPMENT

Five major drainage systems enter Hudson and James bays (figure 1) and, in total, they support a population of about 4.3 million. There are, however, no major centres of population (more than 5000 people) within 200 km of the bays. The total population of the bioregion, alone, is less than 45,000. Although the average income for all inhabitants of the Hudson Bay drainage area is only slightly less than the national average, there are large differences within it. The average income of people living around the southern part of Hudson Bay is about half that of people living in the Prairie regions of the Assiniboine and Red rivers (outside the bioregion).

Agriculture dominates the interior drainage of the Assiniboine and Red rivers but it is absent from almost all parts of the Hudson Bay bioregion. There is no indication that this industry has contaminated waters in the Hudson Bay bioregion. The demand for water supply is, however, an important factor which has contributed to water diversions between different parts of the Hudson Bay drainage.

Mining is extensive in several parts of the Canadian Shield, particularly in northern Manitoba (e.g. Lynn Lake, Flin Flon, Thompson), northern Ontario (e.g. Pickle Lake, Long Lac, Manitouwadge, Timmins, Kirkland lake), and western Quebec (e.g. Noranda, Matagami, Chibougamau) but large-scale mining is generally absent within the Hudson Bay bioregion. There are large peat deposits in many parts of the bioregion and extensive deposits of low grade coal are present in northern Ontario. Also, potential may exist for oil and gas development in Hudson Bay but no significant development of any hydrocarbon deposits has so far occurred in the bioregion. There are local problems of water quality that are associated with present or past mining practices but there is no evidence that mining has caused widespread environmental impact within the bioregion.

Timber cutting dominates the renewable resource based industries of Manitoba, Ontario, and Quebec, and logging is extensive throughout the boreal forest in each of these provinces. Again, however, most of the forest lies outside the area of the Hudson Bay bioregion. Only on the east shore of James Bay does this forest approach the shoreline of the bay, in the drainage of the Broadback, Rupert and Eastmain rivers. Logging practices can be highly degrading to the environments of streams, rivers, and lakes, to lake fisheries and both water quality and water quantity. In the bioregion, however, the impact of timber cutting is largely masked within the much larger impacts of water diversion and reservoir construction.

Much of the wood cut from the boreal forest is used in the pulp and paper manufacturing industries of northeastern Ontario and western Quebec. These industries have had three different types of impact on the downstream quality of surface waters. Until recently, large quantities of suspended solids were released from many plants and, near source, this depleted receiving waters of the oxygen required to support aquatic life. Mercury was used in industrial processes and its release into the environment was largely uncontrolled before the mid-1970s. Mercury remains a major contaminant of water, sediment, fish and wildlife in many parts of the drainage northwestern Ontario (e.g. Winnipeg River), and northwestern Quebec (e.g. Bell-Nottaway River). In human terms, the greatest problems associated with these releases have been the closures of native and recreational fisheries. A large number of complex organic chemicals are also released during the process of pulp and paper making. Some of the chemicals are formed during pulping and bleaching, and some occur naturally and are released as the woody material is broken down. Many of these compounds have low toxicities and, or, degrade fairly quickly; some, however, are highly toxic and persistent (e.g. dioxins and furans) and may become widely spread in the environment.

Without doubt, the single most important impact of development on the environment of the Hudson Bay drainage basin and the Hudson Bay bioregion has been the construction of reservoirs for hydroelectric power and diversion, and the effects of the diversions, themselves. Throughout western Quebec and northern Manitoba, an abundance of water has made it possible to embark on a number of massive hydroelectric power projects. Major diversions include those of the Churchill (1976) and the Eastmain (1980) rivers, and a number of smaller diversions were built earlier in northern Ontario (Lake St. Joseph, Ogoki, Long Lac, and Little Abitibi between 1939 and 1963).

Not many years ago, hydroelectric development was thought to be an "environmentally friendly" means of power production. This view is no longer so widely held. Both diversions and reservoirs can dramatically alter existing lakes and rivers, changing the sediment load, the flow of water, the availability of nutrients and biological productivity, and types and availability of fish and wildlife that live in and around them. Large scale hydroelectric power production may greatly alter flow, raising it in winter and reducing it at other times. Fluctuating water levels may create unstable ice conditions. Contaminants are produced when reservoirs flood areas of land which were previously covered by organic matter. The processes which cause the production of these contaminants are widespread in many of the reservoirs and diversions that have been constructed within the Hudson Bay drainage basin and, in particular, affect the availability of fish to native communities.

THE NATURAL ENVIRONMENT

Land

The Hudson Bay bioregion exists as a giant saucer over largely crystalline rocks of the Canadian Shield. Indeed, the Precambrian Shield extends continuously from one side of the bay to the other, beneath a cover of more recent rocks. Hudson Bay lies in a very large structural basin, in which Lower Palaeozoic and younger sedimentary rocks reach a maximum thickness of about 1800 m. A similar but smaller and linked structural basin underlies parts of northern Ontario and southwest James Bay, in which the sequence of sedimentary rocks reaches a maximum thickness of about 750 m. Foxe Basin is also underlain by a structural depression in the Precambrian surface in which younger sedimentary rocks have been deposited.

Much of the Precambrian Shield is composed of highly altered igneous and sedimentary material, and appears to have a largely crystalline composition. Within the Precambrian, however, there are distinct volcanic and sedimentary sequences, and a well defined fold belt extends northwards from northwest James Bay, through the Belcher Islands and northwards. Shield rocks are exposed along most of the Quebec shore of Hudson Bay and James Bay, along both sides of Hudson Strait, and much of Foxe Basin. Shield rocks also form most of the Keewatin shoreline north of the Churchill River. Younger sedimentary rocks (overlying the Precambrian Shield) form most of the shoreline of northern Ontario and Manitoba, and the island chain which separates Hudson Bay from Foxe Basin (including Southampton Island, Coats Island, and Mansel Island).

The combined effects of glacial and postglacial conditions have greatly influenced both landform and the distribution of surficial sediments within the Hudson Bay bioregion. Under conditions of maximum ice accumulation, three centres of ice (Keewatin, Baffin, and north-central Quebec) merged to form a continuous cover across the entire region. Glacial retreat began more than 10,000 years ago but the bay remained largely ice filled until about 8,000 years ago. The exact sequence of deglaciation is not yet established but it is possible that opening to the Atlantic Ocean through Hudson Strait occurred before the opening of Fury and Hecla Strait. If so, this may account for an apparent cooling which took place in Hudson Bay after it became ice-free.

Thin and discontinuous layers of modern marine sediments (gravel, sand and mud) overlie thicker sequences of glacial material over much of the floor of Hudson Bay, James Bay, and Foxe Basin. Around most of the shoreline north of the Churchill River and along the Quebec shore, accumulations of glacial and postglacial sediment are very limited and bedrock exposures are extensive.

Probably the most important geological influence on the bioregion has been the effect of postglacial uplift by which land has risen relative to sea level after removal of the glacial ice cover. Ice was more than a kilometre thick over much of the region. Land has risen around all parts of the bay and continues to rise. The rate of recovery is uneven but rates as high as 0.5 m per century occur. The effects of uplift are significant in the shallow areas of Foxe Basin, but of greatest importance along the Ontario shoreline of Hudson Bay and James Bay where old shorelines can be traced many kilometres inland and vast areas of wetland have formed. The effects of uplift also influence shoreline form and, in particular, the formation of channels and islands at the mouth of rivers.

Discontinuous permafrost occurs around the southern shore of Hudson Bay and parts of James Bay. Continuous permafrost begins north of the Nelson River on the west shore and the Little Whale River on the east shore of Hudson Bay.

Sea

There are four distinct bodies of water within the bioregion, Hudson Bay, James Bay, Foxe Basin and the Hudson Strait. Tidal exchange is limited between Hudson Bay and James Bay, but James Bay contributes large volumes of freshwater to Hudson Bay, mostly from runoff. James Bay contributes about 40 % of the total freshwater discharge received by Hudson Bay. The peak discharge into both bays normally occurs in May and June. During June and July, melting of sea ice results in the release of more freshwater. It is equivalent in volume to all of the discharge into the bay. Much of the freshwater entering Hudson Bay slowly mixes with ocean water. However, a persistent and relatively low salinity surface current flows northwards along the Quebec shore and into the Atlantic Ocean, along the south shore of Hudson Strait.

Waters in Hudson Strait and Foxe Basin are strongly mixed by tides. North Atlantic water enters Hudson Strait, particularly along the north shore, and penetrates into the southern part of Foxe Basin. Arctic water passes southeast through Fury and Hecla Strait into northern Foxe Basin, and much of this water mass enters Hudson Bay between the Keewatin shore and Southampton Island.

All deep water in Hudson Bay is colder than -10 C and is referred to as "Arctic" type water. This deep water may have entered the bay from the Arctic Ocean. Also, it may have entered the bay as Atlantic water but has been "reworked". Reworked means that the water has passed through at least one freezing cycle in which severe surface cooling results in massive salt rejection from the growing winter ice cover. Salt concentrations increase at depth in the water column as a result of rejection. The process is particularly severe in Foxe Basin where bottom water temperatures may be colder than -1.70 C. "Atlantic" type water is relatively warm (warmer than +10 C) but very little of it penetrates into Hudson Bay. The distributions of many marine organisms correspond closely to the occurrence of Arctic and Atlantic type waters in the bioregion.

In response to wind and tide, large scale surface water circulation in Hudson Bay is generally counter-clockwise. Vertical stratification in the water column is generally persistent. Stratification is typically caused by the presence of a warmer and less saline layer overlying a colder and more saline layer. Temperature differences are more pronounced in summer when surface temperatures may reach 5 to 80 C. Due to the effects of salt rejection, thermal gradients extend to greater depth in winter. Density differences which reflect the combined effects of temperature and salt concentration largely inhibit mixing between surface waters and those at greater depth.

Vertical stability is strong in summer and the surface layer extends to depths of 20 to 50 m as summer advances. The effect decreases in winter with reduced freshwater discharge and surface cooling. In coastal areas, low salinities are most evident off river mouths and freshwater discharge is an important mechanism that drives upwelling of marine waters. Freshwater plumes entering Hudson Bay and James Bay remain largely unmixed with marine waters for considerable distances. For example (in 1991), the plume of the La Grande River was 2 to 5 m thick, 20 to 30 km wide, and up to 70 km long.

Ice cover reduces the effect of wind on circulation in Hudson Bay and river plumes tend to be more spread out. The mean travel time for freshwater in the surface layer of the bay is

10 to 20 months, but the residence time for water in the deeper layer is 3 to 4 years (nearshore) and more than 6 years in mid bay.

Arctic type waters are nutrient-poor relative to Atlantic waters but they are nutrient-rich relative to much of the freshwater discharge. Because of the huge volume of Arctic type water within Hudson Bay it is an important source of nutrients, particularly in areas of coastal upwelling. Upwelling and freshwater discharge tend to maintain low surface temperatures in many nearshore areas and this may reduce rates of biological primary production. Offshore surface waters tend to warm more quickly and where nearshore surface waters are carried offshore, their nutrient availability may enhance primary production.

Freshwaters bring little dissolved nutrient into Hudson Bay but atmospheric sources may contribute significant quantities of nitrates and phosphates, as wet or dry fall. Nutrients are also released by the melting of winter ice. Nutrient levels in surface waters are thought to be low throughout the growing season and towards the end of summer primary production is likely to be limited by a lack of nutrients, especially where strong vertical density differences inhibit exchange between surface and deeper waters. Because primary production is low, Hudson Bay waters are generally very clear. The clarity allows light to penetrate to considerable depth, making it possible for primary production to occur immediately below the surface water layer.

Ice algae provide an extremely important component of primary production in the bioregion. Ice algae begin growing as ice forms in late fall. The algae stop growing as light levels drop but start again in the spring. Ice algae are concentrated immediately beneath the ice surface where both salt rejection and nutrient enrichment are occurring. As the ice melts in the spring, the ice algae may coexist for a short while with phytoplankton of the spring bloom.

Under natural conditions, most inflowing rivers bring little dissolved nutrient to enrich nearshore areas of the bioregion. However, they carry large quantities of particulate material, much of which is organic. Much of this organic matter settles in the estuaries of the inflowing rivers and along nearby tidal mud flats where it provides an important source of food for a number of benthic organisms.

Climate and vegetation

Climate over and around the Hudson Bay bioregion is dominated by sub-Arctic and low-Arctic continental conditions. Circulation is controlled by a generally persistent low pressure cell over Baffin Island and Davis Strait, and by high pressure areas that form over the Mackenzie and Keewatin districts of the Northwest Territories. These large scale pressure systems strengthen in winter, forcing cold, dry, polar air south over Hudson Bay. Hudson Bay has a limited ability to moderate the atmospheric temperature in surrounding areas. In summer, temperatures over the bay and coastal areas may be 100 C or less, inland they may reach 300 C, or more, at the same latitude. Storm systems mostly originate from the south during the summer. During the fall, stormy weather is caused by the reestablishment of cold northerly winds and their interaction with the relatively warm and ice-free waters of the bay. Foggy conditions are common in late summer and early winter, particularly in Hudson Strait.

Vegetation is substantially controlled by climate and most of the bioregion lies within Arctic and sub-Arctic climatic zones. Most of the region, south of the Seal River (west shore) to just north of the Little Whale River (east shore), has a sub-Arctic climate. Wetlands

dominate large parts of northern Ontario which lie within this area but, elsewhere, a mixture of tundra and sparse stunted trees is characteristic of taiga vegetation. To the north, tundra and barren grounds are dominant. Only in the southern part of James Bay does the bioregion lie within the boreal forest zone.

Mean daily air temperatures in January decrease northwest across the bioregion, from -200 C in southeast James Bay to -330 C in northern Keewatin. In July, mean daily air temperatures decrease northwards from 150 C in southeast James Bay to 50 C in Foxe Basin. Total annual precipitation also decreases northwards across the bioregion from about 900 mm in James Bay to about 200 mm in Foxe Basin, and snowfall patterns shown a similar distribution. The contribution of snowfall to total precipitation increases from about one-third to about one-half, northward across the bioregion.

At first, sea ice melts in-place, then through attrition and transport, and exposure to slightly warmer freshwater discharge. Clearing occurs first in James Bay and around the northwest (largely due to wind) and southeast (largely due to runoff) margins of Hudson Bay. Clearing begins during April and May, and by August most of the bay is ice-free. Ice begins to break up in Hudson Strait in late May but may be congested by ice from Foxe Basin later in June and July. Nearly all of the bioregion is ice-free by September. Sea ice begins to reform in Foxe Basin in October and covers most of Hudson Bay and James Bay by late November or early December. Early winter storms tend to mix bottom sediment with newly formed sea ice in the shallow parts of both Foxe Basin and James Bay. Ice movement continues throughout the winter, producing hummocky and fractured ice in Foxe Basin. Ice ridging is extensive in Hudson Strait.

Shorefast ice generally extends out to water depths of about 20 m but it may occur over much deeper water in eastern Hudson Bay. In some years, shore ice may be continuous from the northeast of James Bay to the Belcher Islands, and north to Cape Smith. Permanent areas of open water (polynyas) and shoreleads are produced by the interactions of wind and tidal currents, and occur between Churchill and Chesterfield Inlet (west shore), south and east of Southampton Island, east of Coats Island, and east of the Belcher Islands. Over much of Hudson Bay, winter ice tends to shift and reform, largely in response to wind action, and temporary openings can be widely distributed.

Food web

Primary production (ice algae, phytoplankton) forms the base of most of the marine food web in the bioregion. Detrital organic material is, however, an important additional food supply, particularly in some river estuaries and extensive nearshore mud flats. Figure 4 illustrates dependent relations among many marine species present in the bioregion. Ice algae are generally the earliest form of food available and are important to many species of zooplankton and larval fish. Sand lance and Arctic cod depend on the zooplankton and, in turn, form a major source of food for many predator fish, seabirds, and marine mammals. Capelin are present in the southern part of Hudson Bay where they may also be an important source of food. The Capelin is likely a relict species which entered Hudson Bay from the north Atlantic, before Arctic type waters came to dominate the bay. Capelin are not thought to migrate into Hudson Bay at the present time. Bottom dwelling organisms form an important part of the food web and these include sea snails, sculpins, sea urchins, starfish, mussels, and clams.

Year-to-year climatic variability is considerable throughout the bioregion and several compensatory mechanisms are naturally present within the food web to ensure species survival. Nevertheless, changes in the timing of events, nutrient and food availability, and

species interaction may significantly alter the numbers and distribution of top predators (on which humans depend).

Both the quantity of fish and the number of species decrease from the marine environment of Hudson Strait to the low salinity environment of James Bay. Numbers of fish also decrease with increasing water depth. Many species of fish are opportunistic feeders and some have behavioural or physiological adaptations to cold temperatures and salinity. Anadromous species spend part of their life in freshwater and part in salt water (e.g. herring, whitefish, Arctic char, and Atlantic salmon), and other species may have a particular tolerance only to low salinity and freshwater conditions (e.g. longnose sucker and brook trout, and walleye in James Bay and the Nelson River).

Ringed seals are the most abundant marine mammals in Hudson Bay. They depend on stable shore or sea ice to build dens for pupping, and they feed on a wide variety of fish and crustaceans. Bearded seals are larger and are present in the fast and shifting sea ice of Hudson Strait, Foxe Basin and eastern Hudson Bay. They are bottom feeders and depend on fish, crustaceans, and clams. Harbour seals are present in some estuaries on the west shore of Hudson Bay and may over-winter in presently accessible inland lakes. Seals have been reported from inland lakes in Quebec, where some have become land-locked as a result of postglacial uplift. Walrus are most common in Foxe Basin and small numbers also occur around the Belcher Islands. They feed mainly on clams (occasionally other seals) and use flat rocks or stable ice close to deepwater as sites for haul out.

The beluga is the most abundant species of whale throughout Hudson Bay and although some of the whales may remain in the bay year-round, most follow a well defined migration. Most winter in Hudson Strait but move to the south and southwest shores of Hudson Bay in May. Calves are born in June and July and adults move into river estuaries (particularly the Nelson and Churchill), where higher water temperatures are thought to promote moulting. The whales move on and offshore with the tide, feeding on fish, crustaceans, squid, and marine worms. They begin to migrate northwards in late August. The population of beluga found historically along parts of the Quebec shore does not appear to have become reestablished since commercial whaling ceased.

Bowhead whales migrate into the bay from Hudson Strait in April, and feed along the edge of the retreating ice where populations of small zooplankton (copepods) are rapidly expanding. The zooplankton feed on phytoplankton and these, in turn, are dependent on the release of nutrients from ice-melt and surface water enrichment by upwelling. Bowhead whales are present in small numbers and reach the western part of Foxe Basin by late August or September. Narwhals are present in the deeper waters of the bioregion. It is thought they may migrate through both Fury and Hecla Strait and Hudson Strait.

Polar bears are present throughout coastal areas of the bioregion. James Bay supports the most southerly population. They depend on the development of extensive shore and sea ice on which they hunt for seals (particularly ringed seals), generally in the same areas from year to year. The bears move onshore when the ice breaks up. During the summer months, females and cubs move inland and the males remain near the shore. Polar bears feed little during the summer, they rest to conserve energy and keep cool. In northern Ontario and Manitoba, dens may be dug into permafrost to aid thermal regulation and minimise the bears' exposure to insects. Polar bears may have more than one cub in the southernmost part of their range and these cubs mature most quickly. It is thought that weight may be an important factor in cub survival. Probably, the bears must reach a critical weight before they are able to break into the protective ice-coverings of seal dens.

Many species of seabirds occur throughout the bioregion but there are few breeding colonies. Five colonies of Thick-billed Murres occur along the southshore of Hudson Strait and Foxe Basin (Akpatok Island, Digges Island, and Coats Island). These birds feed on small fish and crustaceans and their populations appear to be very sensitive to both food supply and year to year changes in climatic conditions.

Common Eider ducks nest in colonies and breed on offshore islands throughout the bioregion. One group of eider ducks remains in the eastern Hudson Bay and Belcher Island area year round, and is dependent on polynya for overwinter survival. King Eider nest on the flat tundra around the northern part of the bioregion and some, also, may overwinter in Foxe Basin polynya; most migrate to overwinter outside the bioregion.

During the summer, large numbers of diving ducks are present in the coastal areas of Hudson Bay and James Bay. These include Surf Scoter, Black Scoter, and White-winged Scoter. Red-breasted Mergansers are widely distributed and Common Mergansers are present mainly in James Bay and southern Hudson Bay. Many species of ducks breed inland. During the summer moult and fall migration, large numbers of Greater Scaup, Lesser Scaup, and Common Golden Eye occur around southern Hudson Bay and James Bay.

Several species of surface feeding ducks are also present in the southern part of the bioregion during summer, these include Pintail, American Black Ducks, Mallard, Green-winged Teal, and American Widgeon.

The bioregion provides staging and breeding sites for Lesser Snow Geese (northern Ontario, Manitoba, and Keewatin shorelines of Hudson Bay, Southampton Island, and southwest Baffin Island). The James Bay area also supports most of the population of Atlantic Brant geese during spring and fall staging, and several different populations of Canada geese spend most of the summer months in western Hudson Bay, Southampton Island, and around Foxe Basin.

Waterfowl use many different types of coastal habitat and a great variety of small, migrant, shorebirds spend the summer months on the southern coast line of the bioregion. Shallow water shoals and reefs are used by diving ducks (eiders and scoters) which feed mainly on mussels. Marine worms and clams are abundant in many of the tidal mudflats of James Bay and southern Hudson Bay and support both diving ducks (feeding at high tide) and dabbling ducks (feeding at low tide). Eel grass beds in the low salinity waters of nearshore southern Hudson Bay and James Bay are of critical importance to migrating Brant geese. Other small organisms which also live in these beds support large numbers of scaup and mergansers. The tidal marshes and coastal wetlands sustain very large populations of breeding and grazing geese, and dabbling ducks.

The transient populations of geese, ducks, and shorebirds are specifically adapted to the use of different types of shore and coastal habitat, including the use of inland breeding sites. Adult survival and breeding success is critically dependent on timing (e.g. ice-out and food availability), and for some species specialised river and or inland lake habitat is essential (e.g. Harlequin duck).

ISSUES AND CONCERNS

As an example, table 1 provides a summary of some environmental impacts that may be caused by different types of development and, selectively, these can be expressed as issues and concerns. This report does not attempt to cover all the possible issues and concerns that arise from cumulative impact in the Hudson Bay bioregion. Rather, the following broad groups of topics have been selected for more detailed discussion. Specific examples are drawn from within the bioregion. No attempt has been made to rank either issues or the nature of concerns. Some, like the effects of mining or settlement, are of local importance. Some, like mercury contamination, are more widespread and already of major significance. Others, like climate change, remain more a potential than an existing problem but would be of enormous importance if they became a reality. The nature of problems associated with each group of topics is summarised in table 2; it should be noted, however, that most are related and many stem from a common origin.

Table 1.

DEVELOPMENT: SOME EXAMPLES OF SOURCE AND EFFECT

Effect (changes in):	Flow	Sediment	Debris & pollutants	Ice	Permafrost	Salinity	Buffer & Isolation	Vegetation
Source:								
Settlements			x				x	
Mines & other Industries	x	x	x				x	x
Military & other posts			x				x	x
Within reservoirs	x	x	x	x	x		x	x
Downstream channels	x	x	x	x	x		x	x
Downstream estuaries	x	x	x	x	x	x		x
Areas near to reservoirs				x			x	x
Nearshore & coastal	x	x	x	x		x		x
Roads, tracks, air/ sea lanes, corridors	x	x	x	x	x		x	x

Table 2.

CUMULATIVE IMPACT IN THE BIOREGION

Contamination of the food web

- resource industries
- reservoirs and diversions
- long range transport

Settlement and land use

- sewage disposal and solid wastes
- spills
- growth and new communities

Transport and travel

- over-ice travel
- roads, tracks, utility corridors, air and shipping lanes
- connectivity and exposure

Wildlife resource depletion

- competition for resources
- habitat degradation and change
- loss of isolation

Climate change

- changes in vegetation and rates of microbial processes
- species shifts and population changes
- weather effects on travel and access
- surface stability of permafrost, and sea level

Lifestyle and health

- wage economies
- employment
- traditional resource use
- management of resources use
- expectations and frustrations

Contamination of the food web

Resource industries

Past mining practices have led to locally increased levels of heavy metals (including copper, lead, mercury, and zinc) in water, sediments, and organisms, mostly as a result of poorly regulated effluent discharge, spills, and surface leaching. Acid mine drainage caused by the oxidation of tailings from sulphide ores has also been a problem. Present regulations impose strict standards which, if correctly enforced, greatly minimise the environmental impact of mining. It is almost impossible, however, to achieve zero impact because of the very nature of the activity. Numerous metal deposits are present in the bioregion and local mining activities could occur at several different localities under favourable economic conditions. Large scale mining operations are less likely because of economic constraints. Large scale mining outside the bioregion will continue for many years to come though, likely, with declining environmental impact (as a result of improved technologies and

practices). Thus, it is unlikely that future metal mining activities within or near the bioregion will have a significantly increased impact.

Large deposits of low grade coal and peat exist across much of northern Ontario and could be used to generate thermal power. At present, development is neither economically nor environmentally attractive, and it is unlikely that the resource will be used as a fuel at any time in the near future. No economically viable oil or gas deposits have been discovered in either the Hudson Bay or James Bay sedimentary basins. If such deposits were to be found, however, proximity to large southern markets would make them attractive to develop. Discounting spills and leakage which can be minimised but rarely eliminated, offshore structures should have little lasting impact on the environment. Dredging and disposal might be associated with development, and could have additional though probably local impact in the bioregion. On land, habitat modification for access, pipelines, and temporary settlements could have considerable impact on landform, permafrost, and wildlife. Native communities could be affected both by changes in the surrounding environment and by a range of economic and social factors, as well.

It is unlikely that new pulp and paper mills will be built within the bioregion but existing plants within the Hudson Bay drainage basin are expected to continue in operation for many years. Although the industry has become known as a major source of environmental contaminants, new effluent regulations have greatly improved waste characteristics, and mercury is no longer used. The effects of past industrial practices will be felt for many decades since it is not possible to recover most of the contaminants which have been released.

Although reduced by about 90 percent since 1960, suspended and dissolved solids released from pulp and paper mills continue to exert a relatively high demand for oxygen in receiving waters and may locally depress biological production. Recent regulations have also greatly reduced quantities of persistent organic pollutants in effluents, especially dioxins and furans. It is expected that these contaminants will be virtually eliminated from the effluents in the next few years. However, the extent to which plant toxins which naturally occur in the raw materials of pulp and paper making will be controlled by process technology remains less clear. Overall, the environmental effects of pulp and paper making are expected to further decline; and there is little evidence of any existing impact within coastal or nearshore areas of the bioregion.

Reservoirs and diversions

Many reservoirs and diversions have been constructed in areas previously covered by organic matter, either as living vegetation or as partly degraded peaty material, and mercury is naturally present in the soils and rocks of these areas. Natural microbial processes degrade the flooded organic matter and transform mercury into different forms of methyl mercury. Dimethyl mercury diffuses rapidly through the water and has little immediate effect as an environmental contaminant. It is dispersed and contributes to the increasing global atmospheric load of mercury. Monomethyl mercury remains longer in the water and it is taken up and bioconcentrated in phytoplankton. Monomethyl mercury accumulates at increasing concentrations, at higher levels in the food web. Evidence, so far, suggests that mercury rarely occurs in fish or wildlife at concentrations sufficient to be toxic to the organisms, although it likely contributes as one of many factors to their cumulative stress. Mercury, however, may accumulate in human tissue to levels that result in behavioural disorder and chronic dysfunction.

Over time, as microbes use up available organic matter in the flooded areas, rates of methylation decline. Estimates based on observations and laboratory studies suggest that

without confounding effects, levels of mercury in these environments should decline to acceptable levels over a period of 50 years or more. In northern rivers and lakes, low concentrations of nutrients and low temperatures result in low rates of growth throughout much of the food web. In turn, this results in long term exposure to any contaminants that are present. Thus, even before construction of reservoirs and diversions, naturally occurring levels of methyl mercury in fish and wildlife were already high. In terms of consumption, impoundments and diversions unknowingly made worse an already sensitive condition.

Long range transport

Atmospheric transport contributes significant quantities of heavy metals and persistent organic contaminants to the land and water surface of the bioregion. Discharge from its very large drainage basin may also add to that received directly at the edge of the bay and over the surface of its marine waters. Globally, loadings of mercury from atmospheric sources have doubled since the early 1800s, and are likely to double again by 2050. Many other heavy metals show a similar trend. Much of this contribution is derived from the burning fossil fuels and, in particular, coal. Air mass movements suggest that a large part of the atmospheric load received in the bioregion is carried over the pole from eastern Europe and Asia. Additional inputs are derived from other parts of north America and possibly central America. Global atmospheric transport adds more mercury to that already present in the flooded soils and rocks in northern reservoirs, likely extending the period during which bioaccumulation in fish and wildlife may exceed guidelines for human consumption.

Atmospheric transport also contributes many other organic contaminants associated with combustion, including polynuclear aromatic hydrocarbons (PAHs), pesticides (such as DDT and its breakdown products, and chlordane and toxaphene), and volatile components of other products such as polychlorinated biphenyls (PCBs). It is also possible that chemical compounds entering the Arctic Ocean from rivers in northern Russia may add to the availability of persistent organic contaminants which accumulate and concentrate at higher levels in the food web of the bioregion.

Using PCBs as an example, concentrations increase by about a factor of one thousand between fish and the top bird predator (Thick-billed Murres) in the bioregion. It is also probable that PCBs are concentrated an additional 1000 to 10,000 times between fish and water (based on comparable biomagnification in Pacific and Atlantic Ocean food webs). Thus, the increase in concentration between water and some top predator may be more than a million-fold.

Concentrations of most organic contaminants appear to be declining but, within the past decade, concentrations in the tissues of polar bears, beluga, seals, and seabirds were likely close to or somewhat above consumptive guidelines established for occasional ingestion of fish. Seals probably had slightly higher levels of PCBs than other marine mammals. In addition, concentrations of DDT and its related compounds tended to be a little higher than those of PCBs in animal tissues. The decline in concentrations of persistent contaminants in many marine mammals may not become generally evident for several years because of the longevity of these species.

In part because of the limited amount of information and in part because of a lack of obvious effects, there is little clear evidence to suggest marine mammals and seabirds in the bioregion have suffered from symptoms of either chronic or acute health problems that may be associated with persistent contaminants. Concentrations of PCBs in many Arctic species near the top of the food web appear to have been between 1 and 10 ppm, and this is

about an order of magnitude less than top predators in the Great Lakes' food web where obvious health problems have been documented. Subtle health effects occur at more comparable levels of contamination in the Great Lakes food web, but the extent to which similar comparisons can be made with the Arctic food web is uncertain.

Settlement and land use

Sewage disposal and solid wastes

Most sewage waste in northern communities is collected by some combination of gravity flow through pipes, or trucking (pump-out from holding tanks). In primary treatment, solids settle from the effluent and may be removed periodically from treatment lagoons. A limited amount of microbial breakdown is possible when waste retention times in ponds and wetlands are sufficient. In many communities, effluent is either discharged directly to the ocean or into landfill sites. Some heavy metals and organic contaminants are associated with sewage waste, but waste impacts are localised particularly because of the small size of most northern communities.

The spread of pathogens, however, is of immediate concern and the spread of microorganisms from waste pits into groundwater and surface water supplies has affected human health at a number of northern communities. Bacterial infections have occurred, especially where water supplies are untreated. Even where marine disposal is used, effluents may not immediately mix with ocean water. If entrained in a layer of freshwater, effluent may remain a significant source of infection as well as being unsightly and odorous.

Until recently, it was common practice to dispose of domestic equipment by leaving it on the ice prior to spring thaw. Quantities of industrial, construction, and military wastes were similarly disposed of or buried in pits on land where conditions permitted. Most of these practices have now ceased in any organised way but occasional dumping still occurs. Solid and liquid wastes at municipal landfill sites may seep or leach into surface waters and groundwater, and the marine environment. Because of soil conditions and low temperatures, decomposition of waste is rarely complete. Seepage from old military landfills may contain small quantities of heavy metals, fuels, lubricants, paints, solvents, PCBs and other hazardous materials. Similarly, contaminants may seep or leach from municipal landfill sites, as well. These may also include organochlorines bioaccumulated through the food web and retained in animal tissue waste. As with sewage, most problems are localised. Contaminants may also accumulate in protected bays and inlets where mixing by tidal currents and wave action is limited.

Spills

Almost all coastal communities receive fuel supplies by sea. Some inland communities can be reached by road and some are supplied by air. Oil spills do occur in shipment and because of cold temperatures and extended ice cover, degradation by natural microbial processes will take longer than in more southerly environments. Land based spills are usually associated with handling procedures. Less volatile petroleum products can seep into soils of sand and gravel where they may persist for a long time, oil spills can contaminate ground water and surface water. As settlements increase in size and number the potential for spills increases, and they may occur anywhere in the bioregion.

Growth and new communities

The idea of centralised service support has led to the growth and expansion of settlements around Hudson Bay. Many settlements were located not so much to minimise environmental impact but for ease of access and supply. With the recent increase in native populations, not only has the size and number of communities increased but also the complexity of their support services and infrastructure. Often, these now include airstrip and harbour facilities.

Settlements exert many different forms of impact on the surrounding environment, in addition to use of directly available resources and waste disposal. Noise from equipment (power plants, aircraft, vehicles, and boats) and the movement of people may disturb many species of wildlife. As settlements grow, so too does the area of their potential disturbance, and this may cause some sensitive species to relocate (possibly in less appropriate habitat). This concern is discussed further in relation to transport and travel.

Transport and travel

Over-ice travel

Traditional hunting and trapping activities comprise a significant part of both Indian and Inuit economies, and over-ice travel provides an essential link between centres of settlement and more remote areas where wildlife resources are available. Over-ice travel also links business and social activities in several communities around the bay. Ice conditions are of paramount importance for safe travel; in particular for seal and eider hunting, and for access to offshore islands for goose hunting.

Climate warming represents an uncertain but potentially major concern for future over-ice travel. Of immediate concern, however, are the effects of diversions and flow manipulations associated with hydroelectric power production. Major diversions have been built on both the Churchill River (Manitoba) and the Eastmain River (Quebec) and have reduced natural flows by upwards of 90 percent. As a result of this, ice-free conditions in the channels and estuaries of these rivers have likely decreased. On the other hand, large increases in the discharge of the Nelson and the LaGrande rivers have likely increased their role in spring break-up. Below the impoundments, short term variations in flow due to periodic power demand result in unstable ice conditions in the rivers, even in mid winter. Fluctuating water levels within the reservoirs also make ice conditions less predictable and travel dangerous. In effect, these changes create barriers to cross-drainage travel.

Winter discharge has been artificially increased as a result of hydroelectric power production and some freshwater plumes have expanded, under the sea ice, particularly in southeast Hudson Bay. In this part of Hudson Bay, increased discharge may result in coalescence of different river plumes under the ice, to the thickening and early formation of sea ice, and to reduction or closure of polynya. Earlier break-up in the spring may also occur. The extent of these changes is unclear and the lack of prior experience with such conditions affects the ability to predict safe travel.

Roads, tracks, utility corridors, air and shipping lanes

As communities in the bioregion grow and become more complex, more people travel between them and make increasing use of roads, tracks, and air and sea lanes. Also as connectivity increases, there are additional opportunities for communities to further increase in size and complexity. Community growth, unfortunately, also leads to increased

production of solid and sewage waste materials, and the likelihood of spills. At present, utility corridors have been built only to transport electric power, but it is possible that gas pipelines may also cross different parts of the bioregion in the future. Roads, tracks and utility corridors make access to the surrounding areas easier for more people. Potentially, this may further increase the effects of human disturbance and uncontrolled hunting, fishing, and trapping. Shipping may increase the need for ice-breaking, creating additional barriers to over-ice travel.

Connectivity and exposure

Improved connectivity results in greater mobility of people into and out of the bioregion. Visitors may increase the demand for non-essential facilities and services. Of most importance, however, is the direct exposure of native populations to non-native cultures, values, expectations, and economic pressures (including the influence of television). The degree to which connectivity and exposure affect native communities depends on many factors, not the least of which are opportunities to participate in the activities of non-native societies and abilities to deal with societal change.

Wildlife resource depletion

Competition for resources

Several different factors account for increasing competition for resources and their relative importance differs from area to area. Native populations have increased throughout the bioregion and, on this basis, it might be assumed that native hunting, trapping, and fishing are increasing. However, as a result of exposure to non-native foods, there have been dietary shifts and non-traditional foods now make up a significant portion of both Indian and Inuit diets. It is not clear if this trend will continue into the future as greater understandings develop about the importance of traditional foods in native diet. Observations do show, however, that some populations of fish and wildlife have become greatly reduced around northern settlements.

Non-native hunting, trapping, and fishing activities (particularly those associated with "sport and recreation") are competing for many of the same bird, fish, and mammal species that sustain native economies. Non-native activities, however, tend to be more wasteful of the resource and more disruptive. Proportionally, they may impact more heavily on the resource than native activities but this is unclear.

Interest in commercial fishing (e.g. Arctic Char) exists in some areas but past experience suggests that this resource will not usually support harvesting at levels which are commercially attractive. Mariculture (e.g. shellfish) and ranching (e.g. reindeer) may be viable means to supplement local dietary needs and may provide specialty food for export from the bioregion, but little is known about the impact of such activities on existing species. The extent to which enhanced cultivation can be sustained is unknown.

In virtually all ecosystems, predation is a natural function. It is performed to ensure vigorous production and replacement of organisms at lower levels within the food web. Subsistence hunting, trapping, and fishing activities fulfil this function, but the extent to which additional sport and commercial activities can occur and still produce a beneficial effect is uncertain. The uncertainty is increased when species response to natural climate variation is also taken into account.

Habitat degradation and change

Local habitat degradation and change is evident around most settlements, mine sites, and military posts. It has also occurred in parts of southeastern James Bay where timber cutting has taken place. Increased run-off, loss of vegetation, soil erosion and changes in nutrient availability have taken place but the extent to which these conditions have affected fish and wildlife is largely unknown.

Severe loss of habitat and extensive changes have occurred in areas affected by diversions and reservoir construction. In recently flooded areas such as those of the Churchill-Nelson diversion (Manitoba), nutrient levels tend to rise as dissolved mineral and organic materials are released from soils into the water. Within a few years, however, nutrient levels decline. They may fall below those originally existing because of the reduced size of the drainage area exposed to surface weathering. Nutrient levels largely control growth and productivity in lakes and streams. In areas of permafrost, flooding may result in increased rates of shore erosion and sedimentation within the newly formed reservoirs. Changes in water depth may alter circulation, and concentrations of dissolved oxygen and the temperature of bottom waters. Fluctuating water levels caused by the manipulation of discharge for power production (e.g. LaGrande system) may destroy critical breeding habitat for many species of birds, fish, and mammals.

Reservoirs trap nutrients and sediments and may cause major downstream changes in water quality and channel form. Where discharge is significantly reduced (e.g. Eastmain River), marine waters can penetrate further into river estuaries, and shoreline features may be modified in response to changes in the balance between sediment deposition and erosion. Both plant and animal species are likely to shift in response to these major environmental changes. Particular concerns exist with regard to species of ducks and geese that are dependent on eel grass beds, and these in turn are dependent on specific water level fluctuations and changes in salinity.

In many estuaries of the bioregion, the natural discharge of freshwater contains little dissolved nutrient but it is a significant supplier of particulate (detrital) organic matter from sources further inland. This organic matter is an important source of food for worms and clams which live in the bottom sediments of estuaries and mud flats, and which provide an essential source of food for many species of diving and dabbling ducks, and shorebirds.

The discharge of freshwater is also a key factor which drives the upwelling of marine waters in the nearshore. It is from marine sources that most dissolved nutrients are introduced into surface waters to sustain production of phytoplankton and zooplankton. The timing of this discharge and nutrient upwelling may be critical, also, to the success of many early life stages, particularly of larval fish, and subsequent support of higher levels of the food web.

Changes in sea ice stability and formation may also occur in response to increased freshwater discharge and the coalescence of freshwater plumes. The cover of offshore ice might form earlier and become thicker and more extensive in areas overlying extended freshwater plumes, but the extent to which direct and indirect plume effects may influence winter ice conditions remains undefined. It is not known if the formation of features such as polynya or areas of temporary open water are already being influenced by the manipulation of freshwater discharge. Mostly, it is thought that changes in plume formation do not extend far enough to be a significant influence on such features. However, if such changes were to occur they could be extremely important at sites used by over-wintering ducks and marine mammals.

Loss of isolation

For many species of animals, isolation is an important component of habitat selection. Similar physical and chemical conditions in proximity to settlement or other forms of human activity may be quite unacceptable to them. Female caribou, for example, tend to select isolated sites close to water to give birth to and rear their calves; many ducks and geese choose isolated inland lakes or tundra to raise chicks; and other species may be selective of isolated fast flowing rivers and streams (e.g. Harlequin ducks). Even outside the breeding period, many species may choose to avoid areas subject to any form of manmade disturbance.

For all such species, increasing human access by roads, tracks, utility corridors, and over-ice travel places additional stress on the occupancy of their range. It may cause them to move into less optimal habitat where other forms of stress (natural predation and climate, for example) may cause significant declines in population.

Climate change

Climate change is generally taken to mean global climatic warming but the existence of this phenomenon is not yet established. The bioregion lies between a region of unusually warm (western Northwest Territories) and cold (Baffin) conditions. Year to year variabilities are large, long term climatic records are sparse, and a clear understanding of interactions between natural processes (especially cloud formation and its effects on temperature) are not yet well established. Two things are clear, however:

- 1) In terms of the geological record, glacial (cold) and interglacial (warm) periods coincide with slight variations in the Earth's orbit and rotation, these variations persist, and the start of another cooling period may be relatively close (hundreds to thousands of years).
- 2) Global emissions of carbon dioxide have been increasing significantly for at least two hundred years and together with other "greenhouse gases" (e.g. methane), it is probable that air temperatures will rise. Temperature changes are likely to be greatest at high latitude. Within the bioregion, average annual temperatures might rise by 3 to 40 C, by 2050.

How climate will evolve in response to these potentially contrary conditions remains unclear. Likely, at least for the next several decades, warming will be of greater importance than cooling, though this is by no means certain. It is probable also, because of its size, that any actions which significantly increase the release of carbon dioxide or methane in the bioregion will be regarded as contributing to global climatic change.

Freshwater discharge is a major factor which influences ice formation and break up throughout the bioregion. It further complicates predictions of climate change because of the size of areas affected by the manipulation of river flow. Changes in freshwater discharge may also affect areas outside the bay, as a contributing rather than a controlling factor. The characteristics of surface nearshore waters south along the Labrador coast and beyond appear to be strongly influenced by local climatic conditions and much less so by the characteristics of discharge from Hudson Bay.

Changes in vegetation and rates of microbial processes

Recognising the uncertainties which surround predictions of future climate, it is reasonable to suggest that a general warming is occurring though with large year to year variability. Possible scenarios of warming indicate reduced precipitation and a greater rise of winter than summer temperature. These changes would likely be accompanied by a northward shift of the tree line, though it is not known by how much vegetation would lag climate change. Wetland areas would become drier and, likely would begin to support forest growth relatively quickly. Of particular importance, however, would be increased rates of microbial degradation in peat and wetland areas which would likely result in the production of more carbon dioxide and methane.

Species shifts and population changes

Studies on northern lakes in Manitoba and Ontario have already shown that ice-free periods are increasing and that changes have been occurring in the distributions of species able to migrate and extend their range northwards. The changes could affect a great diversity of birds, fish, and marine and terrestrial mammals, and may cause major difficulties for traditional hunting, trapping, and fishing activities. Also, it could be extremely difficult to predict the extent to which all forms of hunting, trapping, and fishing activities may impact on species already heavily stressed by changing climate and habitat. Changes would be felt throughout the food web and the nature and extent can only be guessed at. Even with an annual average temperature change of only a few degrees, the effects could be dramatic. In some scenarios, much of the bioregion may become ice-free, year-round. At the very least, this would imply major changes in the population and distribution of seals which depend on stable ice for pupping, and polar bears which hunt the seals.

There are complex and compounding effects which relate to increased levels of ultra violet (UV) radiation, caused by global emissions of ozone-depleting gases (e.g. chlorofluorocarbons or CFCs). One concern relates to the clarity of ocean waters. It appears that the effect of increased UV radiation may be felt by phytoplankton production in surface waters. Phytoplankton form the base of the food web, and measurable declines in productivity may occur in response to increased UV radiation. Despite worldwide recognition of problems associated with ozone-depleting gasses, many decades may pass before levels of UV radiation decline to more normal values.

Weather effects on travel and access

Ice cover throughout the region could be affected by climate warming. In one scenario, winter ice cover might be lost over much of the bay within 50 years or so. Between now and then, year to year variability will continue, making it difficult to predict travel conditions within the bioregion. Ice cover is of particular importance for surface travel but other changes might be expected, as well. Because of a longer open water season, frequency and severity of storms might increase, as might the formation of fog. Unstable weather and, possibly, more broken and reduced ice cover would affect all forms of travel within the bioregion.

Surface stability of permafrost and sea level

In response to climate warming, surface permafrost is likely to melt quite quickly, making much of the ground surface unstable for vehicles, housing, and other structures. Melting permafrost, also, is likely to increase rates of shore erosion and quantities of suspended sediment in lakes, rivers, and marine nearshore areas. Increasing quantities of sediment would cause more rapid alterations in river channels and shoreline features.

Postglacial uplift in the bioregion continues to raise the surface of the land, relative to sea level. However, in response to global warming, sea level is also expected to rise. At first, water is expected to expand slightly in volume, as a result of increased sea surface temperature. This could result in a rise in sea level by 10 to 20 cm, or perhaps more, during the next several decades. Around most of the bioregion, there would be little effect because rates of uplift would still exceed the rise in sea level. However, additional and less certain events could occur, including increases in the rate of melting of mountain glaciers and polar icecaps. Extremely large volumes of water are presently held in the polar icecaps and even slight increases in the rate of melting could cause sea level to rise by several metres over time periods beyond 2050.

The combinations of regional and bay-wide changes due to climate warming and variability could have far reaching effects, particularly on low-lying coastal areas. The changes could affect settlements, water supply, travel, access, vegetation, and the population and distribution of many species of birds, fish, and mammals which form a key part of the economic, social, and cultural life of the native people. Although the scope of such changes would be enormous, they would not occur in isolation from changes outside the bioregion. Further environmental, social, and economic changes might very well occur in response to decisions made and changes occurring, elsewhere.

The effects of climate change can not be viewed in isolation from the effects of large scale water diversion and impoundment within the bioregion. In some areas, it is possible that these separate factors will act together (increasing the amount of change). In other areas, they may act against each other (reducing the amount of change). Interactions between these two causative factors may differ seasonally, further compounding the difficulties which could be experienced in trying to establish cause and effect relations. Although it may be expected that the effects of global climatic change will be of overriding importance, the significance of this agent of change and other weather and climate related interactions due to development remain uncertain.

Lifestyle and health

Wage economies

Although problems exist with acceptance and application of wage economies in native societies, earned income is becoming an increasingly larger component of the overall native economy. Traditional hunting, fishing, and trapping activities are still important and, providing wildlife resources remain available, subsistence economies are likely to persist in many communities. Acceptance of a wage economy has been easier for younger than older members of many native societies and this aspect of cultural adaption will presumably continue for some time.

Employment

With the shift from a subsistence to a wage economy, and with the range of products available to communities throughout the bioregion, the ability to earn wages is increasingly important. Two factors, however, appear to mitigate against successful development of a balanced wage economy at the present time.

- 1) Rapidly expanding populations make it hard to provide enough jobs or jobs at an appropriate level of skill.

- 2) "Closed shop" or similar approaches by government and non-native business limit native employment and economic opportunities inside and outside the bioregion.

Within the bioregion, future opportunities may develop for a limited number of people. These could include: management of resource use (environment and wildlife), health care, ranching (some species of wildlife), and culturing of selected freshwater and marine species. For most people, however, opportunities outside the bioregion are not available and, with limited opportunities within the region, welfare becomes inevitable.

Traditional resource use

The use of traditional foods makes hunting, fishing and trapping valued activities, and provides accomplishment and self-esteem for the individuals involved, and an opportunity to share with others in the community. Hunting, fishing, and trapping also maintain the base of traditional skills and environmental knowledge (TEK) from which future society will be able to draw. However, it is also evident that many forms of traditional food may provide superior nutrition for Cree and Inuit people, and that their use is beneficial to both health and well being. At present, nutritional needs may not be adequately met by the selection and use of foods imported into the region.

Management of resource use

Until recently and because of regulations enacted under federal and provincial jurisdiction, many Indian and Inuit communities have been unable to manage their traditional resources effectively, or those in regions surrounding treaty lands. Native people have substantial knowledge and experience to draw on (TEK) and this is complementary to the information base normally used by science. Since it is likely that government funding will never be sufficient to provide all the information required by a comprehensive and detailed scientific approach to resource management in the bioregion, it is essential that ways be found to integrate TEK and science. To ensure this is effective, native involvement should be, at least, as an equal partner in the management of regional environmental and wildlife resources. The present separation of management responsibilities among different departments of several governments, often without native involvement and without appreciation that natural systems are oblivious of human jurisdiction, would seem the height of folly.

Expectations and frustrations

Many studies have found that conditions of health and well being among native people are lower than among other Canadians. This state is reflected by greater substance abuse, violence, and chronic health disorders such as obesity and high blood pressure.

Diet may be an important factor which influences health and one possible means to improve this may be to encourage greater use of traditional foods. If this is to occur, native people must have access to and manage the use of environment and wildlife resources over areas large enough to sustain their hunting, fishing, and trapping. Also, means must be found to make the productivity of flooded areas more available. Because of problems associated with reservoir fluctuations, in some instances, it may be more effective to apply culture techniques rather than traditional hunting, fishing, and trapping.

Probably the greatest problem is now associated with mercury contamination and the exclusion of historically important food resources from native diets. By what means can such food resources again become usable? Would it be possible and acceptable to include anti-toxins in diets which contain elevated levels of mercury? It is known that the

antagonistic effects of selenium and other group VI elements might provide a mechanism to do this but their potential and use needs to be properly evaluated.

Both Indian and Inuit societies have been greatly affected by the intrusion and imposition of non-native economic and cultural values. But, probably, the most important effects are related to dis-empowerment of decision-making. This has led to the removal of both individual and societal goals, loss of purpose, and loss of self-esteem. Problems associated with substance abuse and violence are almost certainly also closely related to the frustrations arising from these forms of cultural impact. One of the most effective ways of dealing with this situation is to re-empower individuals and their society, particularly with respect to the management of natural resource use.

CUMULATIVE IMPACTS: PRIORITIES

The following ideas are suggested to aid thinking about this topic.

- 1) Country foods remain a very important part of the economy and health of many Cree and Inuit communities. In monetary equivalence, they may represent as much as one-third of some local economies. As much as three-quarters of the time available to community members may be spent on activities directly and indirectly related to the use of such resources. Thus, the continuing ability to depend on locally available food resources represents an overwhelmingly important social, cultural, and economic fact of life, and one that provides meaningful occupation for a key segment of the population in each community. Changes made to societal fabrics of this type are likely to be beneficial only if opportunities for meaningful occupation increase.
- 2) We can't turn the clock back, and there is nowhere to hide from the process of human development.
- 3) Knowledge should be used to mitigate or correct existing problems.
- 4) Knowledge should be linked with the wishes of people living in the bioregion and as well as those from outside it, to develop the future goals of society and means for achieving them.
- 5) Not every community will share the same priorities although some are common to most communities. Thus priorities are not presented in order of importance but, rather, in terms of immediate and future need.
- 6) Overall, hydroelectric power development has the greatest environmental impact on the bioregion and potential exists for wider effects. Mitigative actions could probably reduce and localise most other sources of environmental impact.
- 7) The single most important step towards improvement of native well being would be a substantially greater role in the management of the use of all forms of resources in the bioregion.

"Now" priorities

- improved opportunities for native employment;

- substantially greater native roles in the management of environment and resource use;
- mitigative measures to deal with mercury contamination of traditional foods;
- mitigative measures to make better use of the potential productivity of reservoirs;
- development of culture and ranching techniques to increase local food supplies;
- improve sewage/ solid waste processing and prevent contamination of water supplies;
- mitigate/ minimise habitat loss or degradation due to change and manipulation of discharge (including protection of breeding, feeding, and staging areas for waterbirds and marine mammals);
- monitor and report critical ice conditions to improve safety of over ice travel;
- give priority to Cree and Inuit subsistence use of wildlife resources;
- minimise access and activities which decrease availability of isolated habitat.

Future priorities

- establish if development in the bioregion contributes significantly to global warming (e.g. carbon dioxide and methane) and or contamination (e.g. mercury), if possible mitigate existing contributions and do not add further contributions;
- establish to what extent global warming is affecting the bioregion, and what precautions should be taken or what actions may result in more beneficial use of the environment and wildlife resources;
- establish to what extent development within the bioregion affects areas outside it;
- through training, education, and communications, help native communities to better cope with societal and environmental change.

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