SUMMARY OF THE HUDSON BAY MARINE ECOSYSTEM OVERVIEW

by

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Preface:

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1.0 INTRODUCTION

Under Canada's *Oceans Act*, the Department of Fisheries and Oceans (DFO) has a mandate to lead and facilitate in the Integrated Management of Canada's estuarine, coastal and marine environments. To accomplish this, DFO plans to take an ecosystem-based approach to ocean management and to coordinate policies and programs across levels of government. Improved understanding and protection of the marine environment are key aspects of this program. Ecosystem-based management involves, in particular, a shift in research and management from the traditional single species approach to a more holistic approach, which emphasizes an understanding of the individual species, including humans, as a function of the ecosystem. The aim is to provide a clearer understanding of the way the different parts of the ecosystem interact with each other and their environment.

The Central and Arctic Region of DFO, which manages marine environments in Arctic Canada, has tentatively identified eleven marine regions in the Canadian Arctic (Figure 1). An overview of the Hudson Bay Marine Ecosystem, which includes both the Hudson Bay and James Bay/Eastern Hudson Bay regions, is being prepared to support the Department's coastal zone management initiatives in Hudson Bay and James Bay. It summarizes knowledge of the ecosystem and of factors that are stressing it. This report is a compilation of the chapter summaries from that overview. To improve the readability of this summary, reference citations have been removed from the text, and a list of key references has been provided in Section 6.

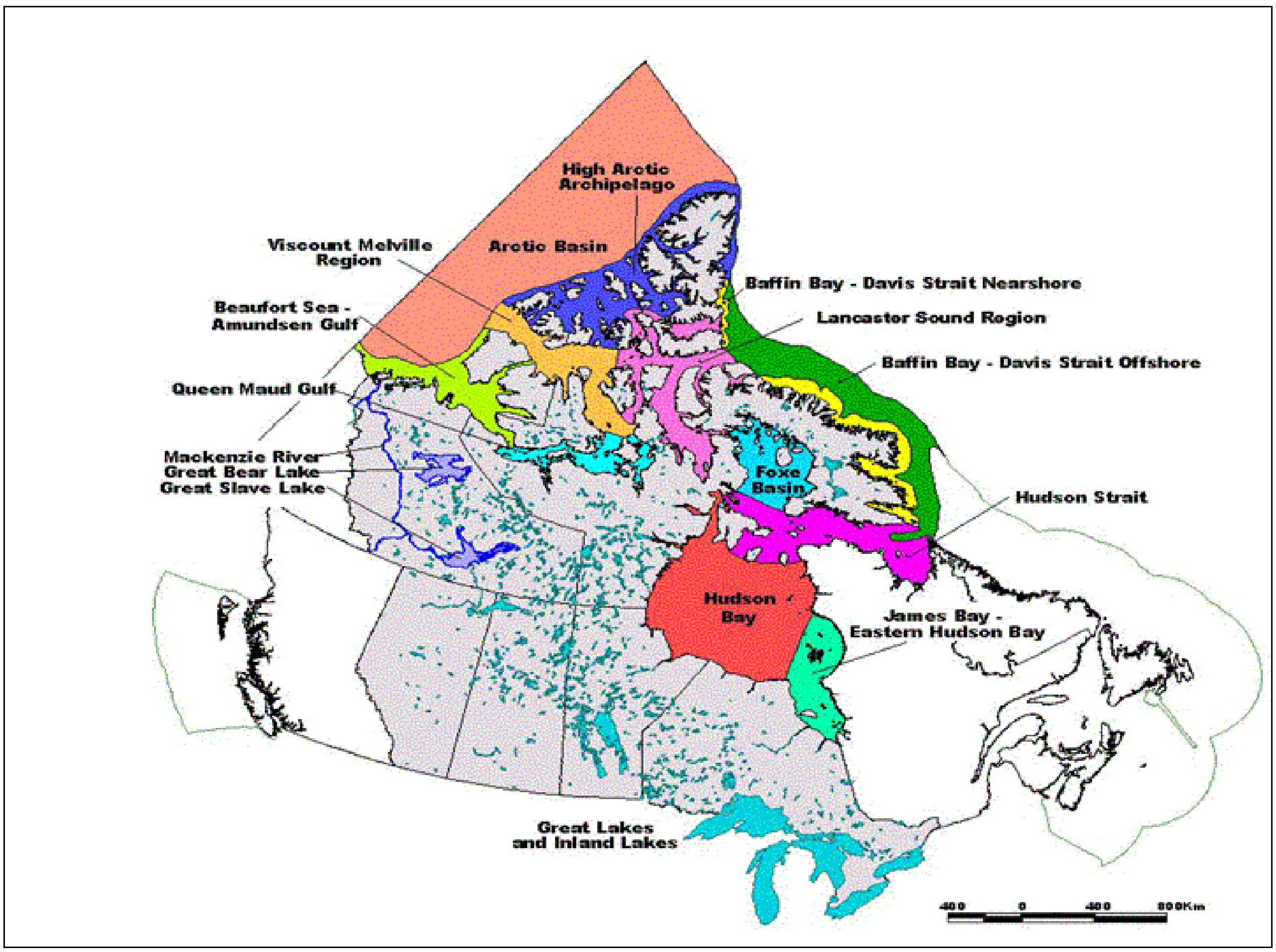

Figure 1. Marine ecoregions in Arctic Canada identified and under discussion by the Department of Fisheries and Oceans from an arctic science planning workshop in 2000 (D. Cobb, DFO, pers. comm.).

Figure 2. Map of Hudson Bay and James Bay (adapted from Canadian Geographic 1999). The northern boundary of the Hudson Bay marine ecosystem is shown with a heavy black line; a thin black line separates the Hudson Bay (north) and James Bay (south) marine regions of the ecosystem.

2.0 ECOLOGICAL OVERVIEW

The Hudson Bay marine ecosystem extends over a very large geographical area. It includes James Bay and Hudson Bay and is bounded in the east by the coast of Quebec, in the south by Ontario and Manitoba, and in the west by Nunavut. Its northern marine boundary has been set arbitrarily as a line that extends from Cap Aiviriuvik, Quebec (61°41'N, 77°58'W) to Cape Low, Southampton Island, via the southern tips of Mansel and Coats Island, and from Cape Welsford on Southampton Island to Cape Clarke on the Nunavut mainland via White Island (Figure 2). The ecosystem receives Arctic marine water from Foxe Basin and freshwater runoff from a catchment basin that is larger than those of the Mackenzie and St. Lawrence rivers combined (Figure 3). Because of its large extent, the ecosystem spans many different coastal ecozones. It offers a broad and varied range of habitats that are used year-round by a range of Arctic and Subarctic biota, and seasonally by many migratory fishes, marine mammals and birds.

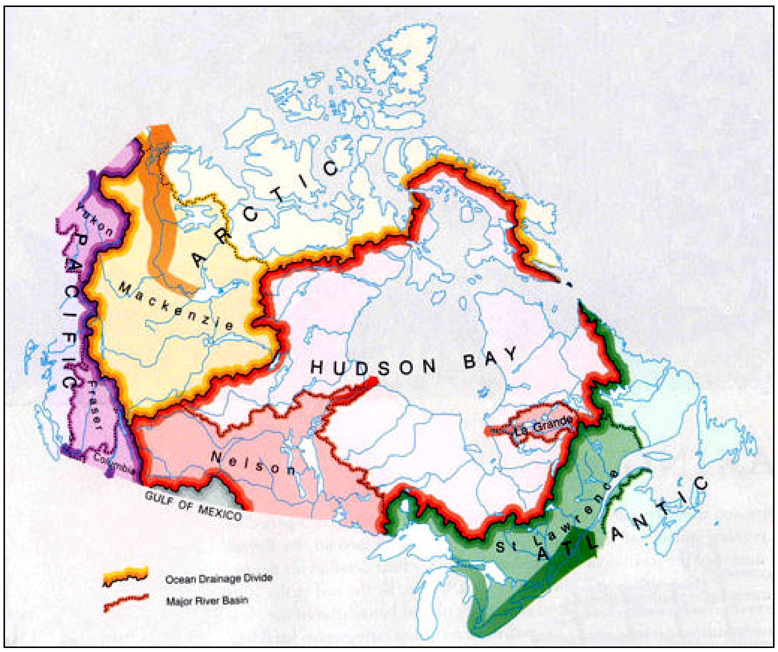

Figure 3. Hudson Bay watershed (from Canadian Geographic 1999).

Three key features characterize the Hudson Bay marine ecosystem. The first of these is the extreme southerly penetration of Arctic marine water, which enables polar bear to live and breed in southern James Bay at the same latitude as the holiday resorts in Jasper, Alberta. Second is the very large volume of freshwater runoff that enters it from the land--each year, James Bay has a net gain of 4.73 m of fresh water over its entire surface. And third, is the dynamic geomorphology of the coastal zone, which is still rebounding from the great weight of the Laurentide Ice Sheet that covered the entire area. New land is emerging from the sea at a rate of up to 15 horizontal m per year along the stretch of low-lying, marshy coast with it's wide tidal flats that continues almost uninterrupted from the Conn River in Quebec to Arviat in Nunavut.

Each of these key aspects of the ecosystem creates critically important seasonal habitat for large concentrations of internationally important migratory species. The sea ice supports seals upon which the polar bear depend; literally millions of geese and shorebirds feed and/or breed in the vast coastal saltmarshes; productive eelgrass beds provide food for multitudes of waterfowl on their way to and from breeding habitat in the Arctic Islands; and the large estuaries provide vital habitat for anadromous fishes and beluga whales. Indeed, the number of belugas in the area of the Nelson River estuary on 19 July 1987 was estimated at 19,500 animals! This is the largest single concentration of belugas in the world. While the key aspects of the Hudson Bay environment are interesting, the habitats they create are unique and irreplaceable.

The sections that follow describe the Hudson Bay marine ecosystem and how it interacts with its surroundings. They is based on existing knowledge and progresses from the physical, to the biological, and finally to the human features of the ecosystem. Each section is a chapter summary from the Hudson Bay Ecosystem Overview. Geological and climatic forces that have shaped and continue to influence the Hudson Bay basin will be discussed first, then oceanography within the basin, and finally use of coastal and marine habitats by biota including humans.

2.1 GEOLOGY

The Hudson Bay marine ecosystem and its coasts are situated on Precambrian Shield rock that is overlain, except in eastern James Bay, along the Quebec coast of Hudson Bay and the west coast north of Churchill, by thick sequences of platformal sedimentary rock. Two geological provinces of The Shield are represented (Figure 4). The Superior Province underlies eastern James Bay and forms most of the Quebec coast from the Nottaway River north to Korak Bay; the Churchill Province underlies southeastern Hudson Bay, the Quebec coast in the Richmond Gulf area and north of Korak Bay, and the west coast north of Churchill. The older crystalline, sedimentary, and volcanic basement and plutonic rock of The Shield is often deformed and (or) metamorphosed. The younger, calcareous rock of the Hudson Platform is generally flat-lying or little deformed. Most of the bedrock is covered by unconsolidated materials or by wetlands, except along the northern coasts of Quebec and the Keewatin.

This region was glaciated most recently by the Laurentide Ice Sheet, which was composed of glaciers that emanated from centres around, rather than in, Hudson-James Bay. Thick ice covered the entire marine ecosystem including the coasts, and affected most of its' present day features. Ice loading depressed the earth's surface so that the present-day coast was innundated by marine waters following glaciation. Subarctic oceanographic conditions, which persisted between about 6500 and 4000 yBP, were likely responsible for the relict Subarctic species that inhabit James Bay and southeastern Hudson Bay. Isostatic rebound continues at a rate of 0.7 to 1.3 m per century, so that most coastlines exhibit a variety of emergent glacial deposits. The southern extent of continuous permafrost along the region's coasts is unusual and strongly affects many other coastal themes such as soil development and shoreline vegetation (Figure 5).

There are three basic coastal types: low-lying, cliff and headland, and complex (Figure 6). The recently emerged, low-lying coastal sections occur more or less continuously from Arviat in Nunavut to the Conn River in Quebec; on the larger islands of James Bay; and along the southwestern shores of islands in northern Hudson Bay. Characterized by very gradual seaward slopes, they have shallow nearshore waters and extensive tidal flats that give way inland to low-lying, marshy coastal plains. Large rivers that carry much of the freshwater runoff that enters the marine ecosystem dissect the low-lying coastline (e.g. Nelson, Churchill, Albany, Moose, Nottaway). Access to and from the water along its shallow shores can be difficult and coastal travel in small craft is dangerous when winds rise. Most of the surface material is unconsolidated, and the coastal landscape evolves from one dominated by coastal landforms to one dominated by organic landforms. The extensive salt marshes and tidal flats provide vital habitat for many migratory waterfowl and shorebird species. They are one of the best examples of a fast-emerging, flat-lying shoreline in the world.

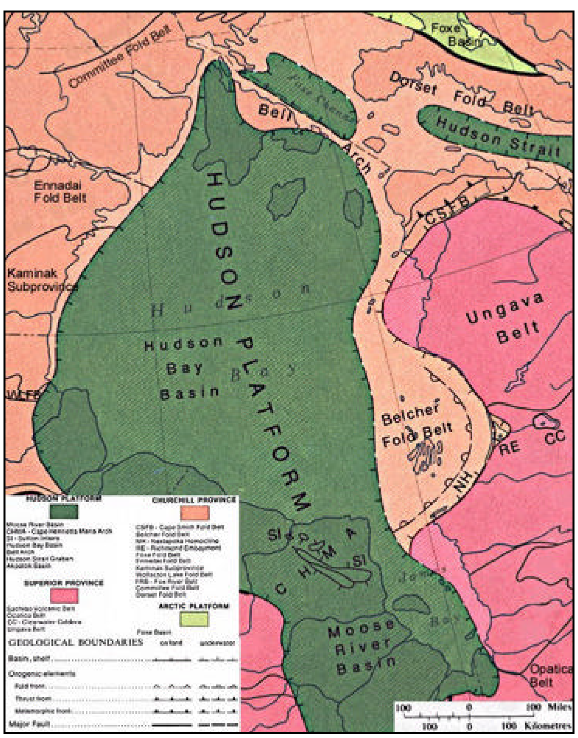

Figure 4. Geological Provinces and lithology (from National Atlas of Canada 4th edn. 1974).

Well developed cliff coasts and headlands occur in Quebec near Cape Smith and around most of the Hudson Bay Arc; along the mainland coast of Nunavut from Rankin Inlet to Chesterfield Inlet, Daly Bay to south of Wager, inside Wager Bay, and around Repulse Bay; and on the Ottawa and Belcher islands, White Island, and northeastern Southampton Island. In the Hudson Bay Arc elevations can reach 500 m and local relief 100 m, exposed bedrock is common, and tidal flats are lacking (Figure 7). Offshore, Manitounuk Island and the Nastapoka Islands are typical bold cuesta formations with low relief on the west side and steep slopes on the east. These formations are associated with broadly developed fault systems and fold blocks, and show a distribution similar to that of submerged canyons and cliffs. Local relief along the Nunavut coast between Rankin and Chesterfield inlets, and around Repulse Bay, seldom exceeds 30 m. South of Chesterfield Inlet, unconsolidated materials including

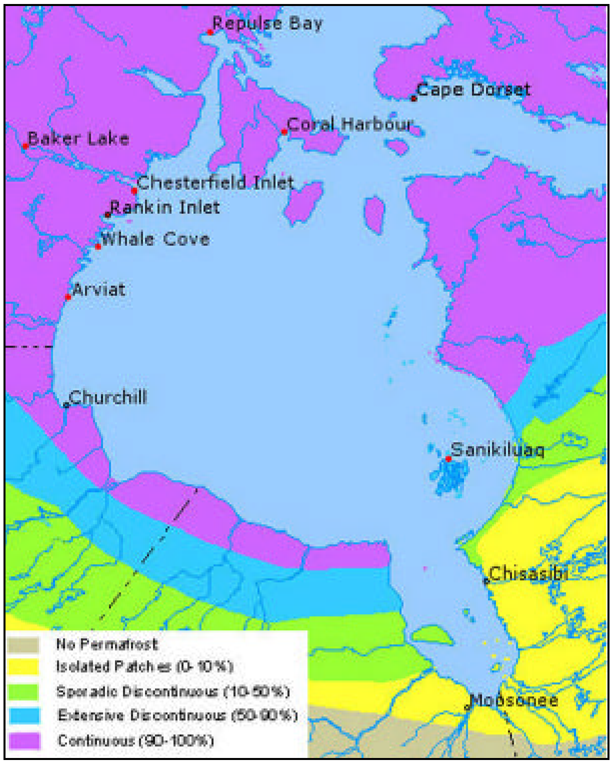

Figure 5. Permafrost (from National Atlas of Canada 6^{th} edn. 1998)

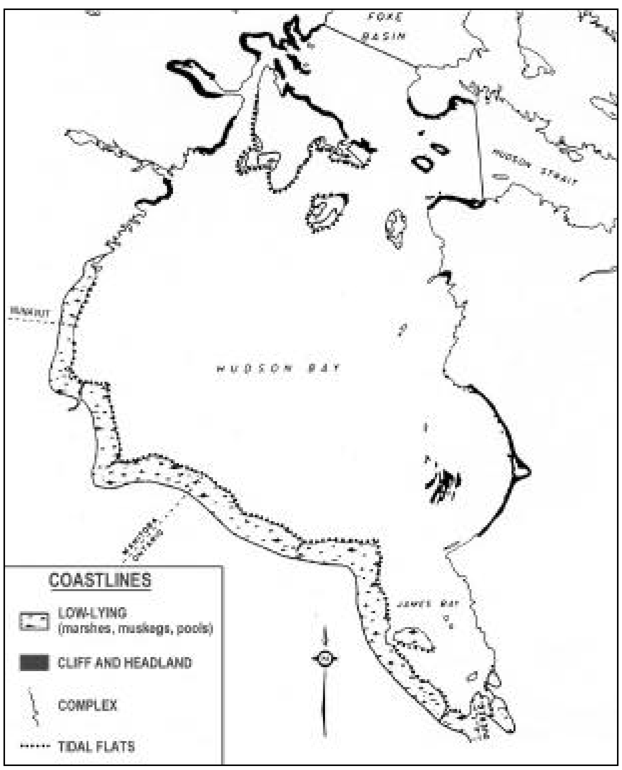

Figure 6. Coastal types bordering Hudson Bay and James Bay (adapted from EAG 1984).

well-developed networks of eskers are common and there are small tidal flats, marine spits and some rock. Gently rolling hills of Precambrian bedrock, often overlain by marine deposits that support tundra vegetation, form the coastline in the Repulse Bay area. Inside Wager Bay, on White Island and along the northeastern coast of Southampton Island the coastal terrain can be very rugged with steep cliffs rising abruptly 300 to 500 m asl and local relief >50 m. Elevations seldom exceed 200 m asl in the Belcher and Ottawa islands, where relief is generally low and the coastline rocky. Gilmour Island, which rises abruptly to 300 m asl is an exception. Continuous permafrost underlies the surface except along the Hudson Bay Arc and in the Belcher and Ottawa islands, where it is discontinuous. These coastlines are dry relative to the low-lying coasts, with decreasing organic cover and vegetation moving northward and on the islands, and a shallow active layer of soil that is often rocky. Trees occur north to about 57^{o}10'N along the east coast but are absent elswhere. These coasts have superb examples of emergent features, particularly the flights of raised marine beaches. They also support important cliff-nesting bird species that are not common elsewhere in the marine ecosystem. Grande riviére de la baleine is the only major river that dissects the cliff and headland coastlines.

Elsewhere in the region, bedrock folding, volcanism, and differential erosion of the exposed rock have created an intricate coastline of small headlands and bays. In Nunavut and along the Quebec coast north of Inukjuak, local relief in these coastal sections is generally <30 m and rocky shores are common. The surface is a mixture of exposed bedrock and unconsolidated materials, underlain by continuous permafrost. The active layer of soil is shallow but supports tundra vegetation; it is often rocky and may have barren areas. The terrain is typically well drained, relative to the low-lying coasts. Small tidal flats occur around many of the small bays and islands. In northeastern James Bay these coastlines are extremely irregular in shape and fringed by a myriad of small islands, skerries, and shoals. The surface is locally covered by thin glacial drift and emerged coastal deposits. There is little local relief and permafrost grades from sporadic near Kuujjuarapik to isolated in southern James Bay; soils are better developed and support trees. Tidal flats, some of them fringed inland by wide salt marshes, are found in most large embayments and around most offshore islands, and there are vast subtidal meadows of eelgrass (*Zostera marina* L.). Major rivers that dissect the complex coasts include the Eastmain, La Grande and Povungnituk in Quebec, and the Thelon and Kazan in Nunavut. These coastlines provide the greatest variety of landforms and biological habitats. Their tidal flats, coastal salt marshes, and subtidal eelgrass meadows have particular ecological importance.

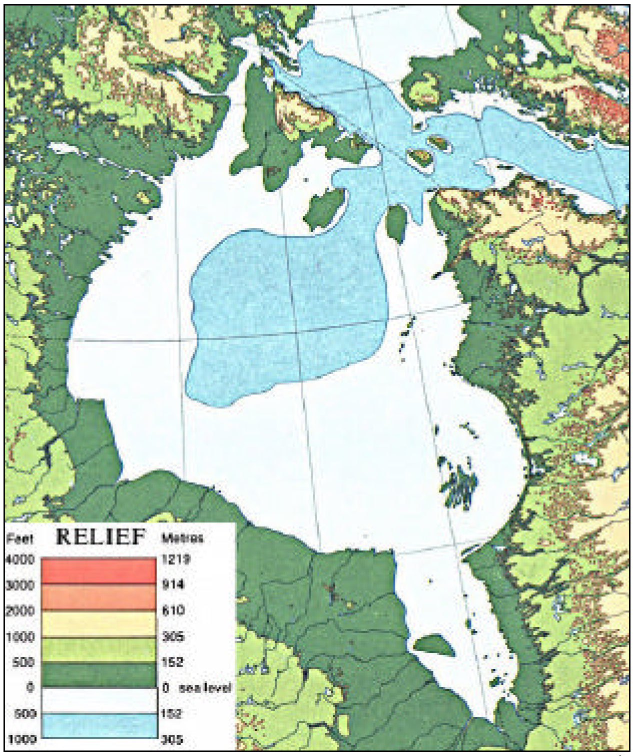

Figure 8. Relief (from National Atlas of Canada 4th edn. 1974).

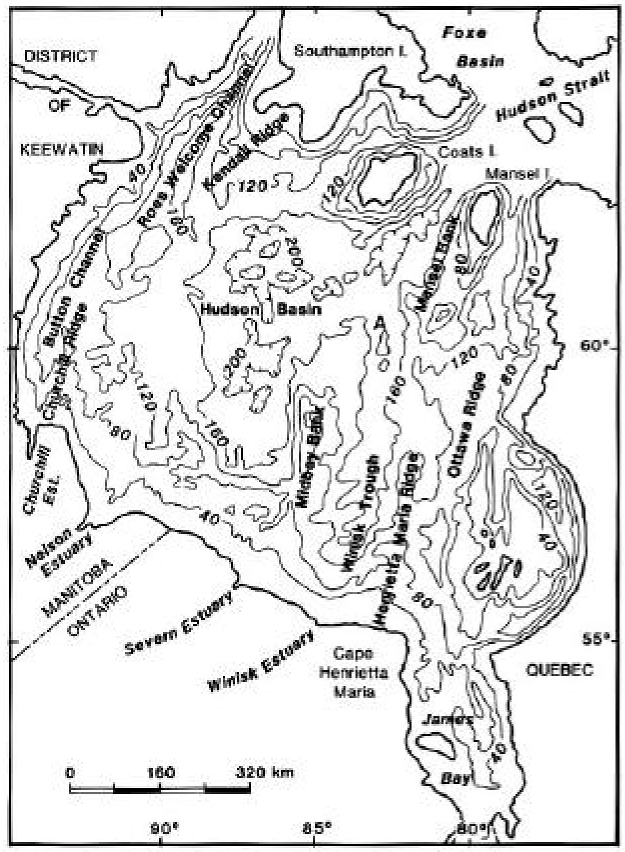

Figure 7. Bathymetry of Hudson Bay (from Pelletier 1986).

Hydroelectric developments have profoundly altered the hydrology--particularly the volume and seasonality of flow, of the Churchill and Nelson rivers in Manitoba and the Eastmain, Opinaca and La Grande rivers in Quebec. Ontario’s Moose River is also affected but to a lesser degree. The Nottaway, Broadback and Rupert rivers in Quebec may be affected by future hydroelectric development. The effects of these developments on the marine ecosystem are discussed in Section 3.2.

Bedrock and pre-glacial erosion have had a profound influence on shaping this regions' bottom topography, and the submarine geology and physiography tend to be extensions of coastal formations and features (Figure 8). Hudson Bay has a wide coastal shelf that slopes gradually to a relatively shallow seafloor, and sediments that grade from coarse gravels nearshore to fine silt and clay offshore. The Hudson Bay Arc area differs from the rest of Hudson Bay and James Bay in having exceptional, perhaps unique, enclosed bathymetric deeps (>200 m depth) that resemble the adjacent cuesta coastline. James Bay is seldom deeper than 50 m and extremely shallow for such a large marine area. The bottom sediment distribution is controlled primarily by the Late Wisconsin glaciation. The cover is generally thin and consists primarily of till or fine-grained glaciomarine deposits.

2.2 CLIMATE

The Hudson Bay marine ecosystem is abnormally cold relative to other areas at the same latitude, and extends through five ecoclimatic zones from humid high boreal in the south to low Arctic in the north. Its climate differs from north to south and east to west. The winters are long and cold; the summers are cool. The harshest climate is found in northwestern Hudson Bay where there is the greatest influence of cold Arctic air masses. Strong winds and persistent low temperatures are characteristic of this area (Figure 9). While neither is as extreme as in some continental areas, in combination they make it the coldest part of Canada based on wind

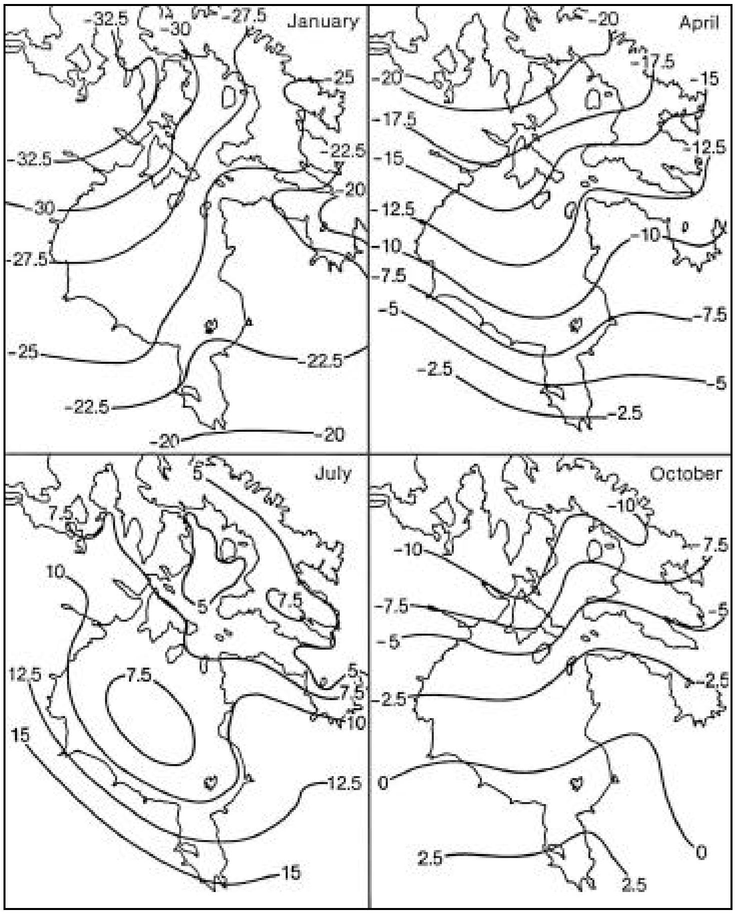

Figure 9. Mean daily air temperature (ºC) (from Maxwell 1986).

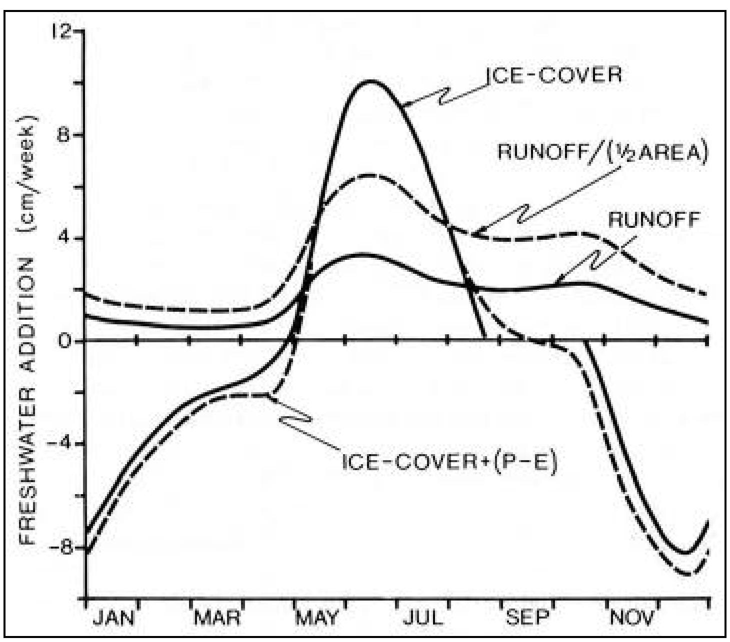

Figure 10. Freshwater addtion by ice cover, runoff (A), precipitation (P), and evaporation (E) for Hudson Bay, using a 1.6 m maximum ice-cover thickness (adapted from Prinsenberg 1988b).

chill. Other areas have either moderating southern or marine influences and do not exhibit the extremes of western Hudson Bay--particularly the high wind chills and frequent blizzards.

The marine environment depends strongly on local wind stress, runoff, radiation heat flux, and annual ice cover. There is an annual net gain of 473 cm of fresh water over the entire surface of James Bay, where precipitation is much greater than evaporation and runoff is high (Figure 10). This is much greater than the average for Hudson/James Bay, which has an annual net gain of only 64 cm over the entire marine surface. Hudson Bay loses more fresh water through evaporation than it gains from precipitation. Runoff has a strong influence on oceanographic and ice conditions, particularly in James Bay.

There is extreme variation in the range of average temperatures and average total precipitation in time, seasonally and annually, and in space throughout the region. There is a strong average precipitation gradient across the region, from less than 200 mm per year in the northwest to over 800 mm per year in the southeast. Evidence for change in these patterns related to global warming is discussed in Section 3.4.

The marine ecosystem has a strong influence on the surrounding land area, contributing particularly to the unusual southern extent of the permafrost (Figure 5). This influence is demonstrated by the presence of four ecozones along the coastline, each of which reflects the response of vegetation, soils, wildlife, and water to climattic and geological factors (Figure 11). Moving from south (Hudson Plains) to north (Northern Arctic) trends are apparent in the vegetation, which changes from boreal forest to tundra; the soil, which becomes increasingly cryolosic; and the wildlife, which become better adapted to cold and often undertake extensive seasonal migrations. The southward deflection of these broad east-west Ecozones in the Hudson Bay-James Bay area emphasizes the magnitude of the climatic effect of the extreme southerly penetration of Arctic waters in this marine ecosystem.

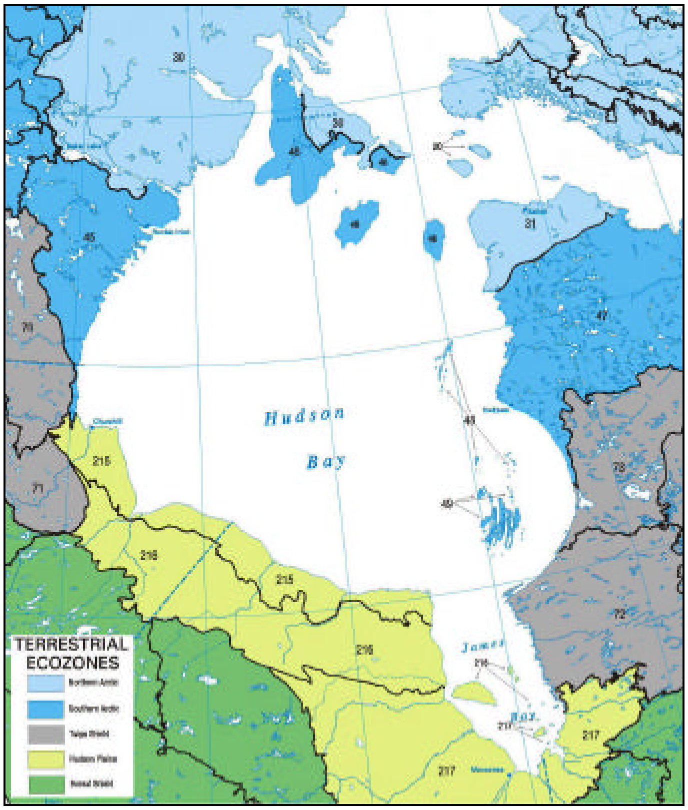

Figure 11. Terrestrial ecozones and ecoregions bordering Hudson Bay and James Bay (from ESWG 1995).

2.3 OCEANOGRAPHY

The Hudson Bay marine ecosystem consists of two oceanographically distinct marine regions (Figures 1 and 2). The water properties of these regions depend mainly on exchanges with Foxe Basin and Hudson Strait and the large freshwater input from both runoff and melting sea ice in the spring and summer. An understanding of their differences is critical to the design and integration of coastal zone management initiatives.

The northern area, or **Hudson Bay marine region**, is characterized by the presence of Arctic marine water and biota, complete winter ice cover and summer clearing, moderate semidiurnal tides of Atlantic origin, a strong summer pycnocline, greater mixing and productivity inshore than offshore, and low biological productivity relative to other oceans at similar latitudes. Hudson Bay lacks the typically subarctic species that are found in Hudson Strait but does support some of the relict warm-water species found in James Bay.

The southern area, or **James Bay marine region**, is closely coupled oceanographically to the Hudson Bay marine region but its waters are typically shallower and more dilute, being modified to a much greater extent by freshwater runoff from the land. Its species composition reflects these Arctic and freshwater influences and it supports a variety of warm-water species that are relicts of an earlier connection with the Atlantic and Pacific oceans. These plants and animals have disjunct distributions and are rare or absent elsewhere in Canada's Eastern Arctic waters. Southeastern Hudson Bay is included in this region with James Bay largely on the basis of biogeography. Strong density stratification limits mixing and leads to considerable surface warming by insolation in both marine regions.

Because of its remote location and the noncommercial nature of its marine resources, relatively few oceanographic field programs have been undertaken in the Hudson Bay ecosystem, where seasonal ice cover effectively prevents most year-round research and the shallow coastal waters make it very difficult to conduct bay-wide research from a single research platform. Consequently, characteristics of the circulation and water mass are not well known, especially outside the open water period.

In summer, surface water circulates cyclonically (counterclockwise) around Hudson Bay, and the deep water moves in the same general direction but is influenced by bottom topography (Figure 12). Cold, saline Arctic water from Foxe Basin enters Hudson Bay in the northwest via Roes Welcome Sound. As it flows eastward along the southern coast of Hudson Bay some of this water enters James Bay while the remainder is deflected northward to exit northeastward into Hudson Strait. A westward, wind-driven return flow across the top of Hudson Bay has been predicted by modelling studies, and there is a small--perhaps intermittent, intrusion of Atlantic water from Hudson Strait at the northeastern corner of Hudson Bay. Mathematical modelling suggests that the main reasons for this stable cyclonic circulation are the relatively weak coastal currents with limited coastal development to cause mixing, a relatively strong Coriolis effect that stabilizes the flow pattern by turning the freshwater outflow from rivers cyclonically around Hudson Bay, and strong density stratification due to intense freshening in summer. This circulation is maintained by inflow/outflow forcing that likely occurs year round, and reinforced during the open water season by wind and buoyancy forcing. The extreme southerly incursion of Arctic waters creates Arctic oceanographic conditions much further south than elsewhere along the North American continent, and is a key feature of the Hudson Bay marine ecosystem.

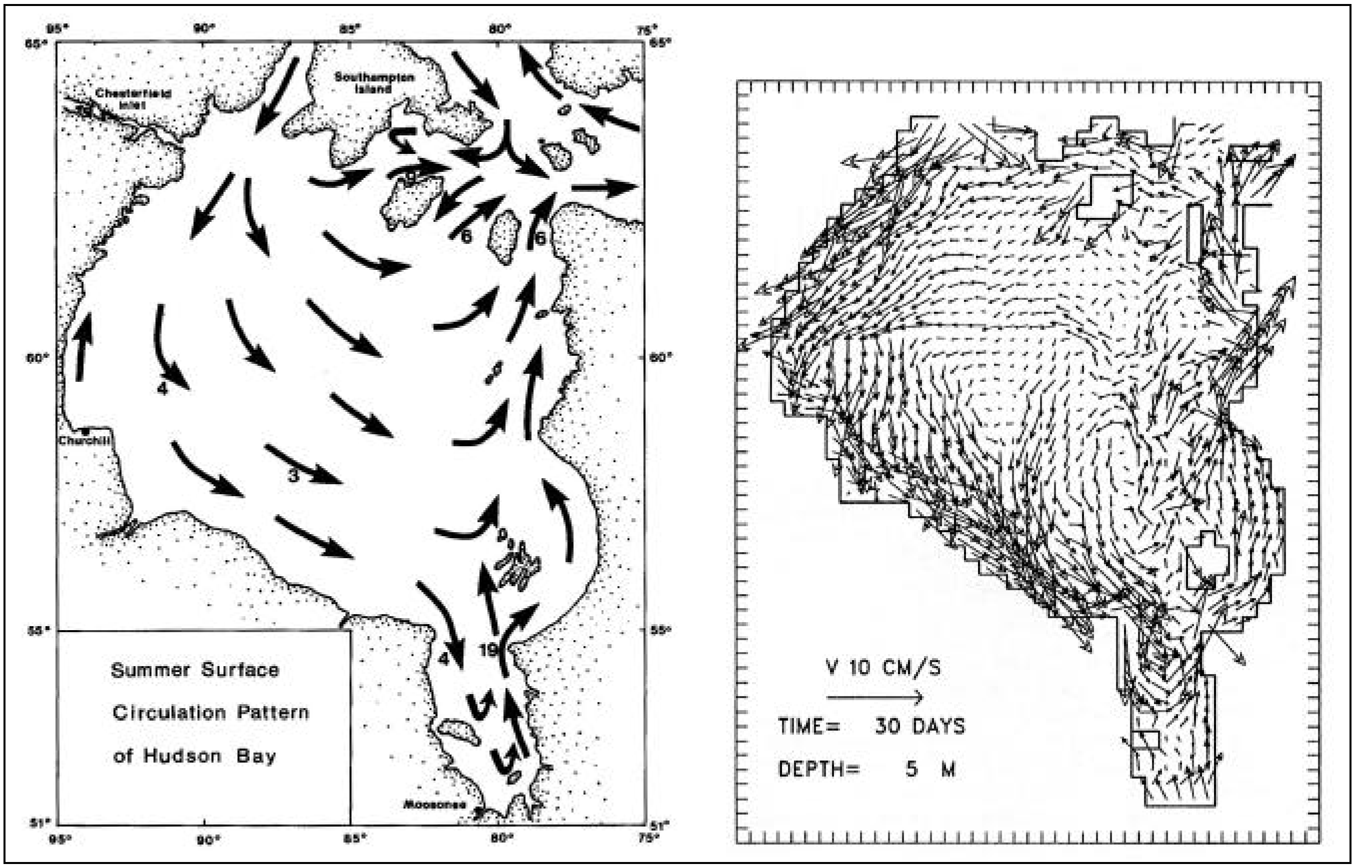

Figure 12. General surface circulation pattern for the summer condition of Hudson Bay and James Bay (Left) (from Prinsenberg 1986a; numbers are observed velocity values in cm •s^{-1}) compared with surface circulation determined from model results (Right) (from Ingram and Prinsenberg 1996 as modified by J. Wang from Wang 1993).

There is little Atlantic influence except in terms of the tides which enter Hudson/James Bay twice daily via Hudson Strait. These semidiurnal tides move as a Kelvin wave counterclockwise around the coastline and overshadow other tidal influences. They do not attain the extreme ranges in height found in Hudson Strait. Dangerous storm surges do occur in southern James Bay.

The Hudson Bay marine ecosystem is unusual among the world's oceans in that it is nearly covered by ice in winter and is free of ice in summer (Figure 13). In spring and summer, the cold saline surface water that enters the region is diluted by meltwater and runoff from the land, warmed by the sun, and mixed by the wind as it circulates through Hudson Bay and James Bay. This produces the strong vertical stratification of the water column that is characteristic of the ecosystem in summer, particularly offshore. This stratification slows vertical mixing, thereby limiting nutrient additions to surface waters and biological productivity. In winter, lower runoff, ice cover, and surface cooling weaken the vertical stratification and permit very slow vertical mixing. There is little coastal development or bottom relief to promote mixing or upwelling that might increase the availability of chemical nutrients in the surface waters. Temperature and salinity are relatively stable below a depth of 50 m, but small changes related to the seasonal disappearance of the pycnocline have been observed to 65 m in James Bay and 100 m in Hudson Bay (Figure 14). The water becomes progressively colder and more saline with depth, approaching the same deep water type at about 100 m where the mean temperature is less than -1.4^{o}C and salinity greater than 33 ppt. The deep water layer in James Bay is subject to considerable seasonal and interannual variation in temperature and salinity, due in part to the relative shallowness of the bay. Seasonal oceanographic variations are not well known there is no complete set of temperature-salinity transects that covers the entire area in any season, most sampling has been conducted during the open water season.

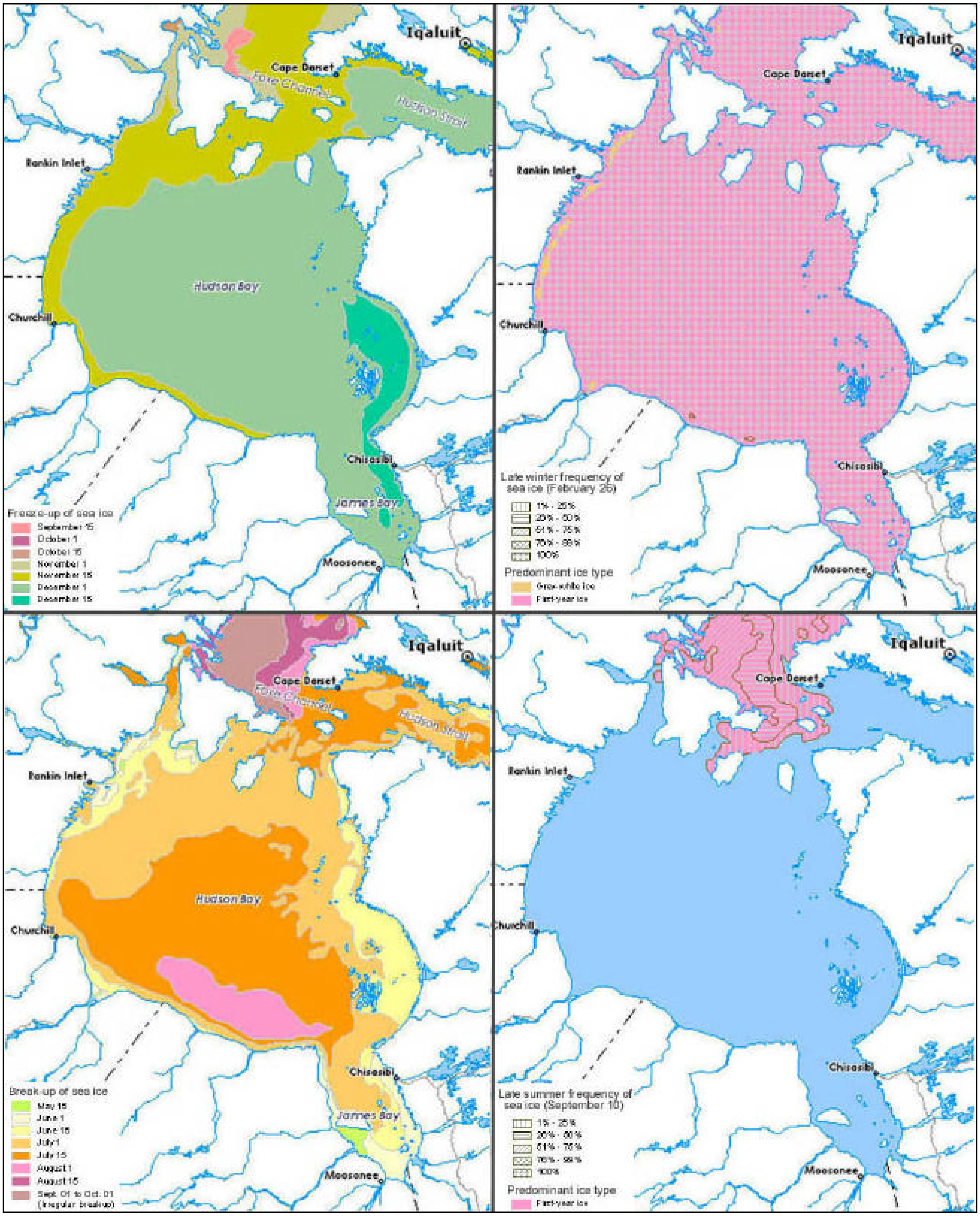

Figure 13. Patterns of sea ice freeze-up (top left) and breakup (bottom left) and frequency and type of late winter (top right) and late summer (bottom right) sea ice, based on 30 years of data (adapted from National Atlas of Canada 2003).

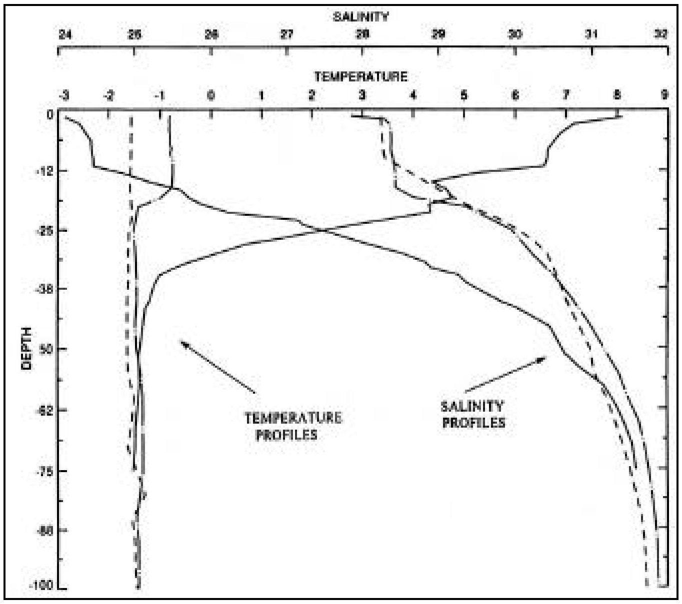

Figure 14. Representative vertical profiles of temperature and salinity in southeastern Hudson Bay at various times of the year (different years); April 15, 1982 (dashed line), May 16, 1982 (dashed-dotted line), August 15, 1976 (solid line) (from Ingram and Prinsenberg 1998:851).

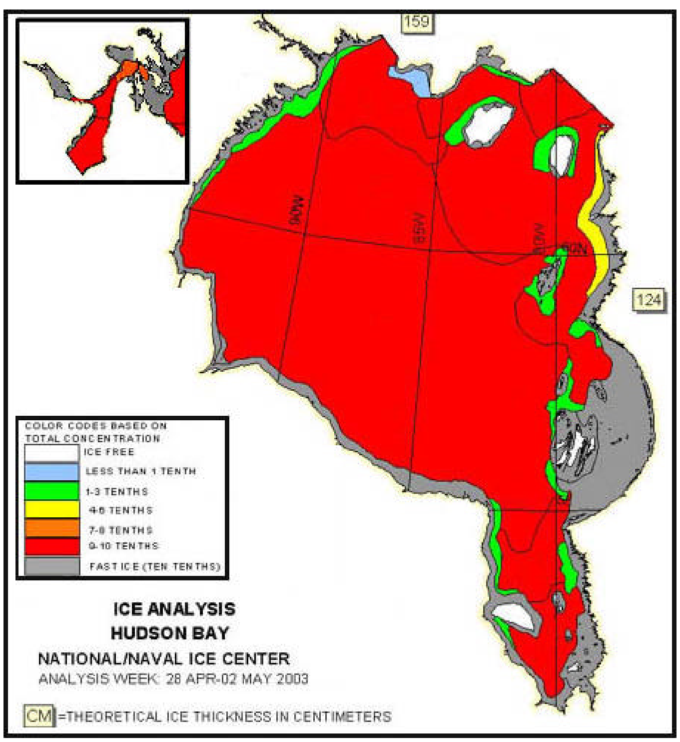

Figure 15. Sea ice concentration in the Hudson Bay marine ecosystem during the week of 28 April –2 May 2003 (from NOAA 2003).

The extreme southern presence of nearly complete ice cover with extensive areas of fast ice and polynyas strongly affects this region's physical and biological oceanography, the surrounding land, and human activities. Depending on weather conditions, the timing of freeze-up or breakup may be retarded or advanced by up to a month, but the basic pattern of ice formation remains similar. The reliance of Inuit and coastal Cree on sea ice for travelling and hunting is reflected in their detailed knowledge of its processes, characteristics, and annual cycles. The sea ice determines the ecology of the ice biota and it also influences pelagic systems under the ice and at ice edges. As the interface between air, ice, and water, ice edge habitats are areas of mixing that attract biota to feed. These areas are important sites of energy transfer within the ecosystem.

In winter and early spring the ice floes are kept in constant motion by the wind. Leads develop when the winds blow offshore and are quickly covered by new and young ice (Figure 15). These leads are important habitat for species such as the Hudson Bay eider that overwinter in the region and to migratory birds and mammals that arrive early in the spring. Recurring polynyas are present in the Belchers and near islands along the coast of southeastern Hudson Bay, in Roes Welcome Sound, at the northern tip of Coats Island, near Digges Island, and just off the southwest tip of Akimiski Island. The latter polynya is one of the most southerly in Canadian seas. These openings in the sea ice are vitally important to overwintering species and to early spring migrants. They are often areas of increased biological productivity. Old ice and icebergs are rare in Hudson Bay and rare or absent James Bay.

The importance of sea ice to the Hudson Bay marine ecosystem and its vulnerability to climatic warming have spurred efforts to develop a mathematical model that accurately simulates the region's sea ice dynamics.

The volume of freshwater runoff to this region from the land is very large and has an even greater effect on the oceanography of the James Bay marine region than is seen in the Hudson Bay marine region. It has a strong influence on the timing and pattern of the breakup of ice cover, the surface circulation, water column stability, species distributions, and biological productivity. Summer surface salinity values over most of this region are low relative to other marine regions (Figure 16). Extensive freshwater plumes are observed off its river mouths year-round (Figure 17). They spread further and deeper under the ice than under the ice-free conditions of summer, despite

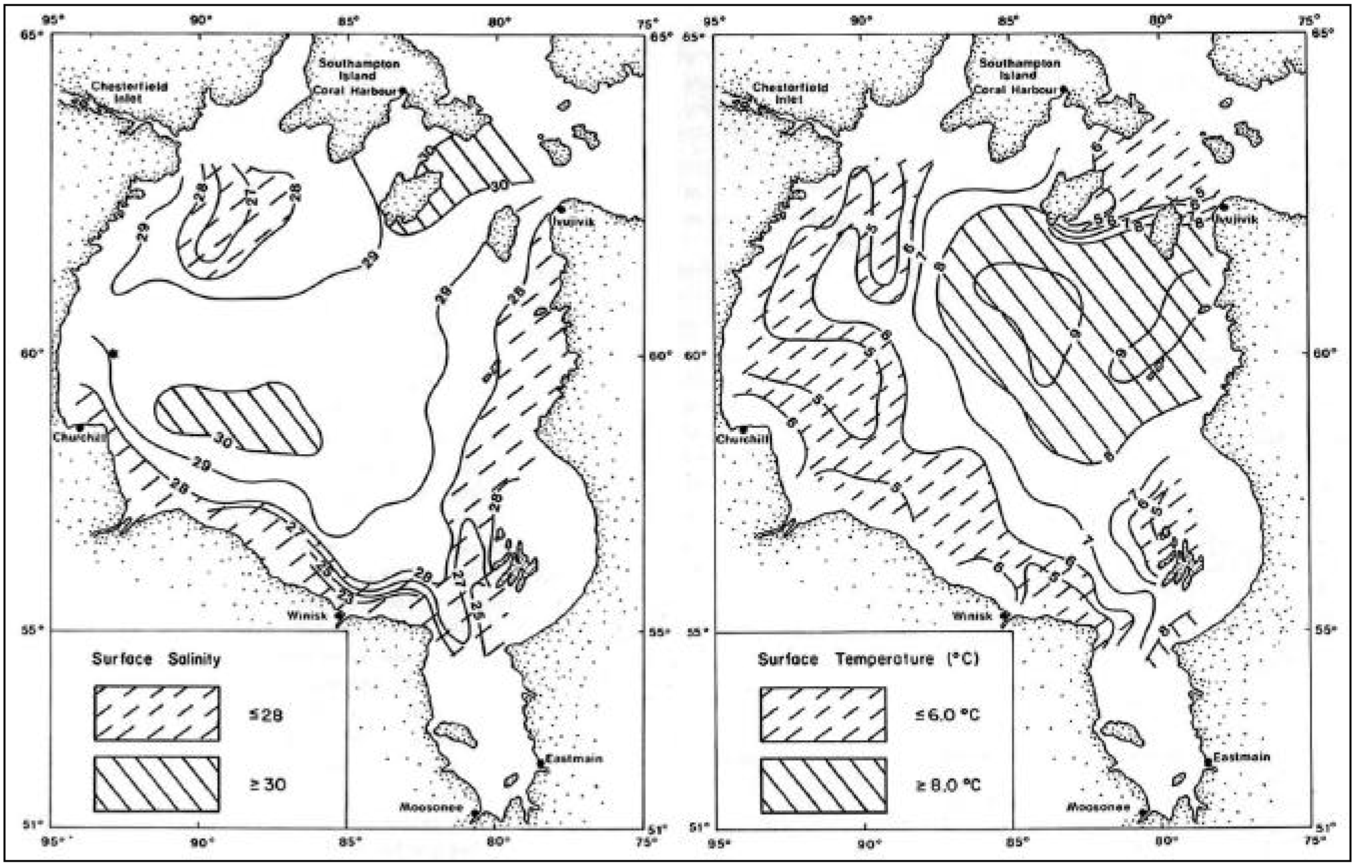

Figure 16. Surface salinity and temperature distribution of Hudson Bay in August-September 1975 (adapted from Prinsenberg 1986a:164-5).

runoff rates that are an order of magnitude lower. The effects of high runoff are most pronounced in eastern James Bay, along the southeastern coast of Hudson Bay and, perhaps, in Richmond Gulf. In southern and western James Bay, which are shallow and receive a great deal of sediment laden runoff, the water clarity is low relative to other parts of the marine ecosystem and to other Arctic marine regions generally.

In summer, there are distinct physical and biological oceanographic differences between inshore and offshore areas of this region. Inshore areas generally have lower water temperatures, salinities, and clarities and higher chlorophyll **a**, ATP, and pelagic biomass. These differences may be attributable to mixing processes which bring colder, deeper, relatively nutrient-rich water to the surface, and to dilution and nutrient addition by freshwater runoff. Vertical density stratification is particularly strong offshore in central Hudson Bay, where it effectively prevents mixing of the surface and deep waters and thereby replenishment of nutrients above the pycnocline.

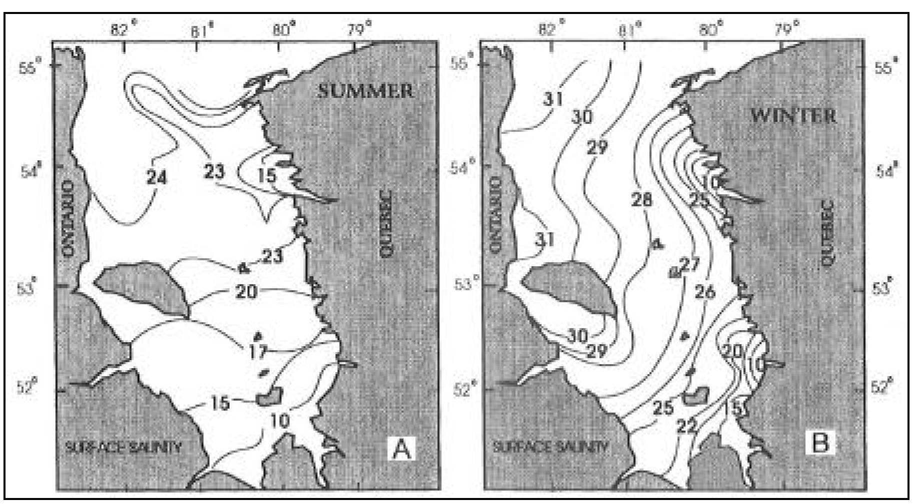

Figure 17. Surface salinities in summer (A) and winter (B) in James Bay (adapted from Ingram and Prinsenberg 1998:850).

Freshwater runoff affects the primary productivity negatively by increasing vertical stability of the water column, and positively through nutrient additions--either direct or due to deep-water entrainment. While river runoff carries large

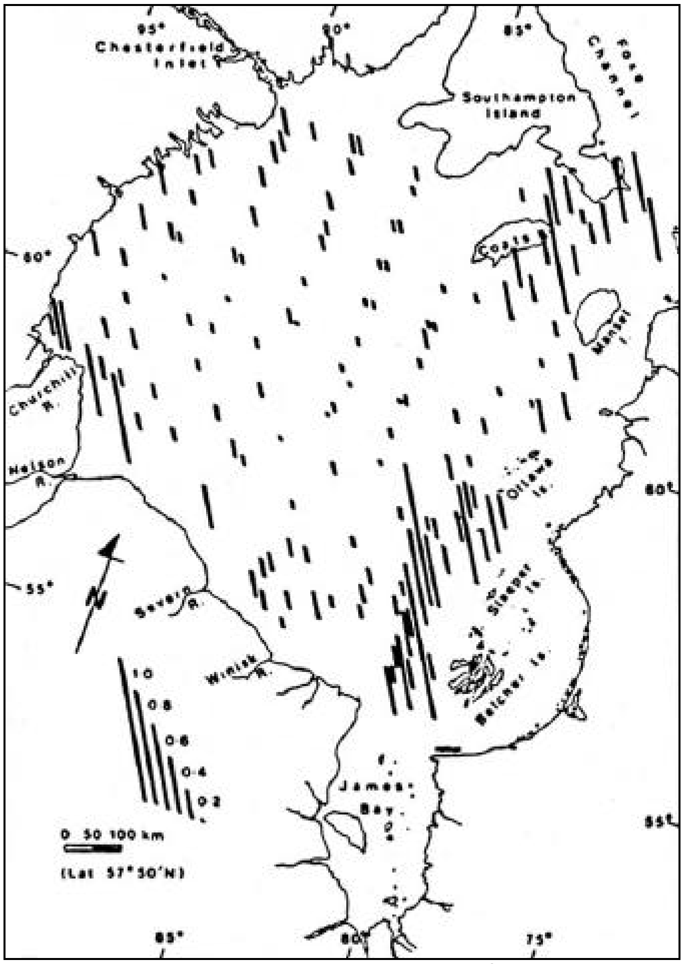

Figure 18. Surface chlorophyll a (mg•m^{-3}) distribution in Hudosn Bay, August-September 1975. Station location is base of bar (from Anderson and Roff 1980a:2247).

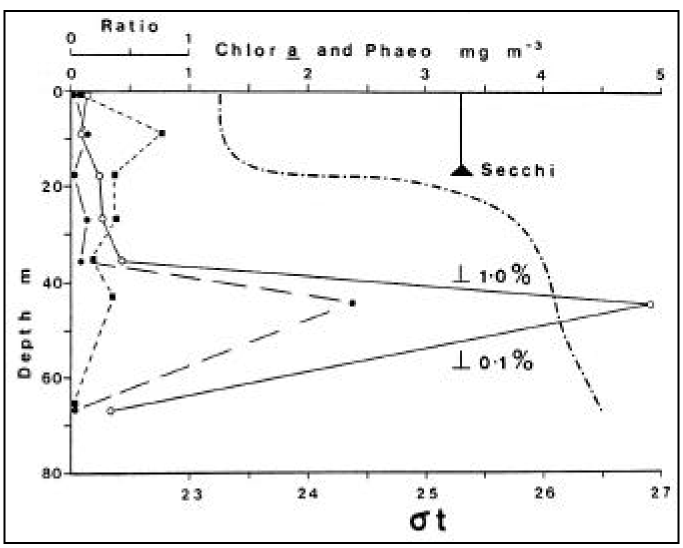

Figure 19. Seasonal variations of diatom counts, primary productivity rates, and ciliate counts at selected depths near the Belcher Islands (from Grainger 1982:790).

quantities of carbon and nutrients into the marine ecosystem, particularly during ice-breakup, the river waters are less concentrated in nutrients than Hudson Bay coastal waters.

Biological productivity appears to be low relative to other oceans at the same latitude and comparable to that of seasonally open-water areas of Canada's Arctic Archipelago. It appears to be greatest in coastal waters, particularly at embayments and estuaries, and near islands where there is periodic entrainment or upwelling of deeper, nutrient-rich water (Figure 18). Productivity above the pycnocline and under the ice may be limited by the availability of nutrients, particularly nitrogen. In summer there is a layer of maximum primary productivity below the pycnocline in Hudson Bay. The historical presence of large numbers of bowhead whales suggests that there is an area of higher productivity in northwestern Hudson Bay. The structure of the food web in the Hudson Bay marine ecosystem is not well known, nor is the flow of energy through that web.

2.4 PLANTS

While the marine flora of the Hudson Bay marine ecosystem has been subject to detailed study in areas subject to environmental changes from hydroelectric developments or habitat degradtion, it is still poorly known. This is particularly so for the area north and west of the Belchers, western James Bay, and Richmond Gulf; for the winter season; and for biological productivity and species distribution. Little is known of the species composition of the water column, seafloor, or sea ice; or how species distribution, abundance, or productivity changes with the seasons—particularly offshore.

Hudson Bay and James Bay are remarkable in having a diverse phytoplankton, impoverished bottom flora with few seed plants, and freshwater taxa offshore in the summer--most of which are related to the presence of annual ice cover. A subpycnocline chlorophyll *a* maximum occurs in the offshore waters of Hudson Bay in the summer (Figure 19). James Bay is unusual among Canada's Arctic marine regions in having rich eelgrass beds (Figure 21) and extensive saltmarshes (Figure 6) that provide critical habitat for migratory birds and other species (Figure 20). Significant degredation of saltmarsh habitats has occurred along the southwestern coast of Hudson Bay as the result of foraging by the burgeoning population of nesting lesser snow geese.

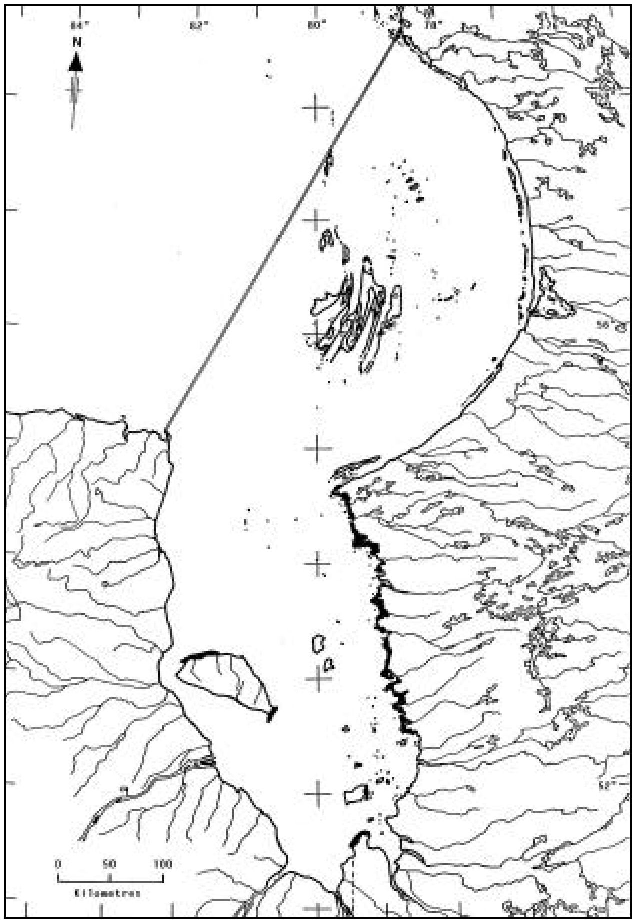

Figure 21. Distribution of eelgrass beds in the James Bay marine region (after Curtis 1973c, 1974/5; Dignard *et al*. 1991).

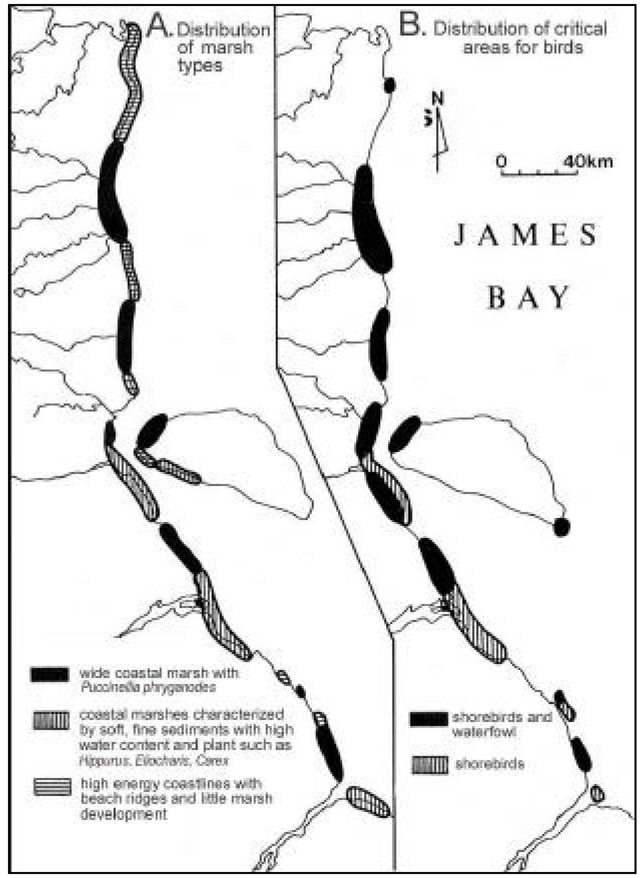

Figure 20. Distribution or marsh and coast types (A) and fall concentrations of shorebirds and waterfowl (B) on the west coast of James Bay (adapted from Martini et al 1980b).

2.5 INVERTEBRATES AND UROCHORDATES

Present knowledge of invertebrates in Hudson Bay and James Bay may better reflect the research interests of individual scientists than the actual occurrence of invertebrate species, since the magnitude of the task of surveying this region and the available research effort preclude even coverage for all areas and phyla. There is still a great deal of research to be done before we have a clear understanding of the occurrence and abundance of invertebrates in Hudson Bay and James Bay. Much of the invertebrate research has been conducted in summer in shallow subtidal (<50 m depth) and littoral zones; only a few studies have examined abundance.

Zoogeographically, many of the invertebrate species are regarded as Arctic forms that penetrate southward into Hudson Bay and James Bay, a reflection of their continuity with the primarily Arctic surface waters of the Canadian Arctic Archipelago and the surface of the Arctic Ocean. The invertebrate fauna of James Bay and southeast Hudson Bay also has Atlantic and Pacific affinities, reflecting a former connection with the faunas of those oceans and illustrating the area’s importance as a refugium. Estuarine species are distributed throughout James Bay and southeast Hudson Bay but are present in the highest density in or near river mouths, while the freshwater forms do not survive far from the rivers. The Arctic marine species become dominant moving away from the large estuaries. A number of species for which there is good sampling coverage appear to be relicts that survive in the warmer, less saline waters of James Bay but not in other Arctic marine regions. This is a very important aspect of the regional oceanography. Most of the remaining invertebrate species are widely distributed outside this region, generally in Arctic waters. The absence of *Calanus finmarchicus* is further evidence that there is now no direct penetration of Atlantic surface waters into Hudson-James Bay.

Few benthic species inhabit the intertidal zone on a permanent basis, likely due to ice scour, which can extend to a depth of 5 m. Invertebrates such as clams, mussels, snails, barnacles, worms, sea anemones, amphipods and sea squirts occupy the intertidal zone. Most benthic invertebrates live below the ice scour zone. They include the echinoderms, sea spiders, most polychaetes, clams and snails, shrimps and crabs, hydroids and bryozoans. Seafloor photographs taken during the 1961 cruise of the M.V "Theta" at a depth of 55 m show brittle stars, anemones, a shrimp, and a worm on the fine substrate of Omarolluk Sound in the Belchers. The central portion of Hudson Bay supports a meager fauna with echinoderms, especially brittle stars, polychaetes, sea anemones and decapods being predominant.

Molluscs common in the intertidal zone of Hudson Bay, which is generally depauperate, include the pelecypods *Hiatella arctica*, *Macoma balthica* and *Mytilus edulis*, the gastropods *Margarites costalis* and *Littorina saxitilis* and the chiton *Tonicella marmorea*. Molluscs are more common and abundant offshore, where most of the species are typically Arctic. Their distribution in the bay as well as species composition is correlated more to substrate type than to water depth. Common and abundant molluscs that are widely distributed in the bay include the pelecypods *Nucula belloti*, *N. pernula*, *Yoldiella lenticula*, *Musculus discors, Serripes groenlandicus*, *Macoma calcarea*, and *Chlamys islandica*. The pelycepod *Bathyarca glacialis* is abundant in the deep water of central Hudson Bay. Gastropods that have been reported from central Hudson Bay include *Lepeta caeca*, *Colus pubescens*, *Oenopota arctica* and *O. pyramidalis,* which are not very abundant. *Lepeta caeca* and *M. costalis* are common and abundant nearshore along both east and west coasts of Hudson Bay; *Boreotrophon fabricii* is also common along the west coast while 6 other species are common along the east coast.

Important benthic species in the Eastmain Estuary include the pelecypods *Macoma balthica* and *Mytilus edulis*, the gastropods *Cylichna alba* and *Margarites olivaceus*, the polychaetes *Terebellides stroemi* and *Aglaophamus neotenus*--the latter previously known only from the Atlantic coast, the cumacean *Diastylis rathkei*, and the amphipods *Atylus carinatus* and *Onisimus littoralis*. Distribution of the benthic organisms was positively related to the salinity gradient and the quantity of organic matter in the sediments. The dominant species of each group are very versatile in their occupation of different sediment types. Density of the benthic fauna in the brackish zone of the estuary was very low compared with freshwater or marine areas; the marine zone also had the most diverse benthic fauna.

The pelagic zone is characterized by comb jellies, arrow worms, copepods and amphipods, euphausids, and the pelagic sea butterflies. Grainger and McSween (1976) described the marine zooplankton of James Bay as being of "moderate quantity and fairly high diversity for northern waters, reflecting the range of habitat provided by the 2-layer estuarine structure ". In James Bay, the varying ratios of zooplanktonic species characteristic of fresh, brackish, and marine water reflect seasonal pulsations in the surface brackish water and saline bottom water within the bay. Many large and small species of crustaceans are important prey for larger animals including fish, birds, and mammals but none is known to be present in commercially exploitable quantities. The substantial bowhead population that once summered in northeastern Hudson Bay suggests that dense concentrations of Copepoda may be present in that area.

The ice fauna is not as well known as the ice flora. In April 1983, offshore the mouth of Grande rivière de la Baleine, it consisted largely of planktonic nematodes, rotifers, ciliates, and copepods--in order of abundance. The sea ice fauna was generally more dense although less diverse than the zooplankton occuring beneath the ice, both within and outside the river plume. The abundance was positively related to salinity, and to the presence of sea-ice microflora. Ice algae are an important food for the planktonic marine copepods *Calanus glacialis* and *Pseudocalanus minutes*. Because the standing stock of sea-ice fauna is greater under marine conditions, it could be decimated by a winter expansion of the freshwater plume. This could have important effects on the marine food chain in the affected area.

Ice scour limits most casual viewing opportunities for invertebrates, but SCUBA divers who venture below 5 m depth may see a variety of interesting species, particularly in the Belchers where the water is relatively clear and there is some bottom relief. Few species are of direct value to man, but many are indirectly valuable as food for fish, birds, and mammals. Belcher Islanders harvest and eat marine invertebrates to a greater extent than most other Inuit in Arctic Canada.

2.6 FISH

Knowledge of fishes in the Hudson Bay marine ecosystem is scant except for harvested anadromous species, and in the vicinity of estuaries that have been or may be affected by hydroelectric development. Lack of a proven, commercially viable offshore fisheries resource has limited offshore fisheries research and ice conditions have limited seasonal research. Relatively little is known of fishes along the Ontario coast or offshore.

At least 56,and perhaps 60, species of fish use waters of the Hudson Bay marine ecosystem—fewer than are present in Hudson Strait and along the Atlantic coast. James Bay and southern Hudson Bay support characteristic and unusual estuarine fish communities that consist of a mixture of Arctic marine, estuarine, and freshwater species. These communities include more freshwater and anadromous species and fewer Arctic and deepwater species than those in western and northern Hudson Bay. The entire ecosystem is relatively shallow and lacks the deepwater species that inhabit Hudson Strait.

The composition of the estuarine fish communities changes with latitude. They are best developed along the Quebec coast, from the Eastmain estuary northward to and including Richmond Gulf, where the waters are relatively warm, shallow, and dilute. To the south the Arctic marine species are poorly represented, and to the north and offshore there are fewer freshwater species. The ability to exploit the extensive brackish zone is an important ecological adaptation for both the freshwater and Arctic marine species. Their seasonal movements are often complex and are influenced by variations in temperature and salinity, and in their biological requirements (Figure 22). The estuaries provide important seasonal foraging and nursery habitat for many species, spawning habitat for some, and year-round habitat for fourhorn sculpin.

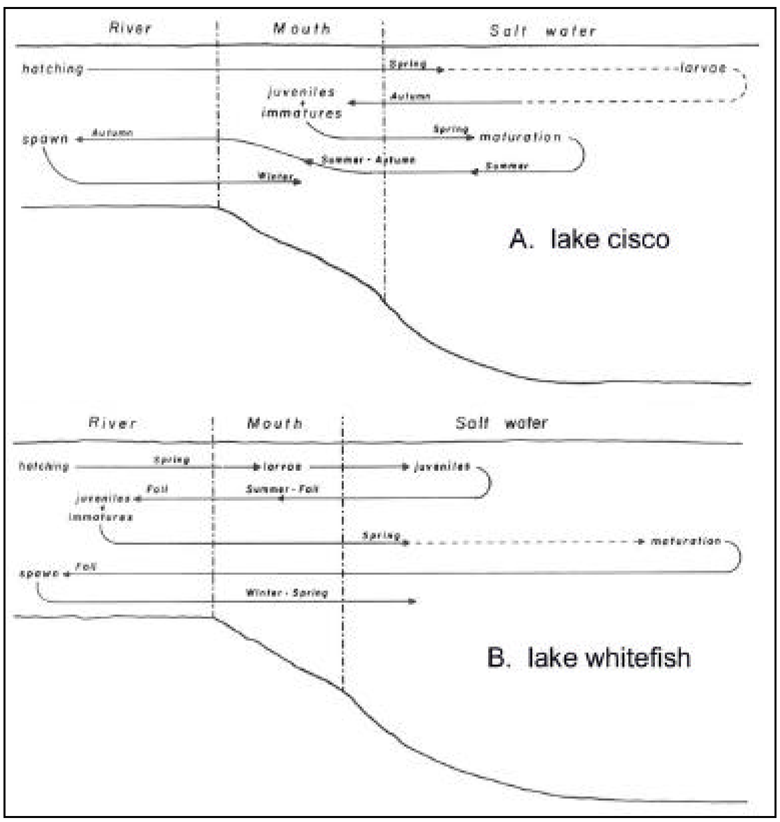

Figure 22. The life cycles of anadromous: A) lake cisco (*Coregonus artedi*), and B) lake whitefish (*C. clupeaformis*) in coastal James Bay (adapted from Morin *et al*. 1981:1605). Horizontal lines indicate movements of the fishes through the freshwater, river mouth, and saltwater zones from hatching to postspawning. Arrows indicate the direction of movements. The vertical arrangement of the lines is not related to the depth distribution of the fish.

Two recent changes in the zoogeography are of particular ecological interest. First, there may have been shift in species composition in northern Hudson Bay over the past two decades, with a decrease in the relative abundance of Arctic cod and an increase in that of American sand lance—possibly related to warming (Figure 23). Second, recent introduction of rainbow smelt (*Osmerus mordax*) into coastal river systems of Hudson Bay has the potential to damage coastal fisheries (Figure 24). The species is actively invading systems along the Hudson Bay coast and, elsewhere, has been implicated in the decline of native lake whitefish and cisco populations. Both of these developments merit further study.

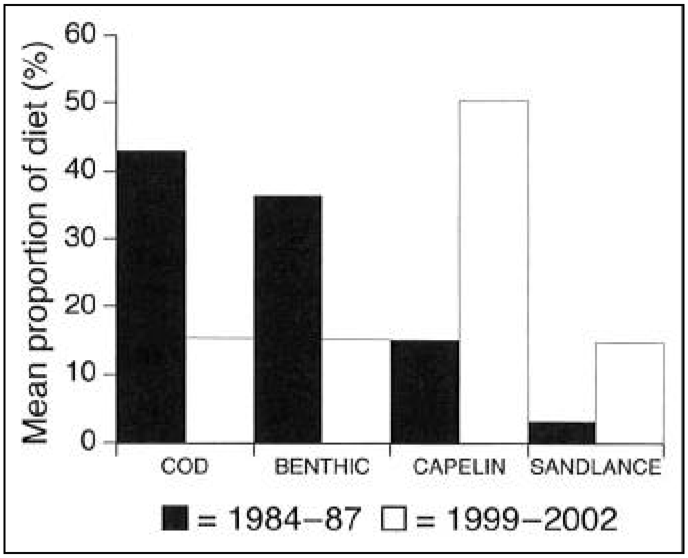

Figure 23. Proportion of fish prey types delivered to thick-billed murre chicks in 1984-87 and 1999-2002 (benthic = sculpins and zoarcids)(from Gaston *et al*. 2003:231). Values are means of annual proportions. Differences between periods for each prey type were significant at $p \leq 0.01$).

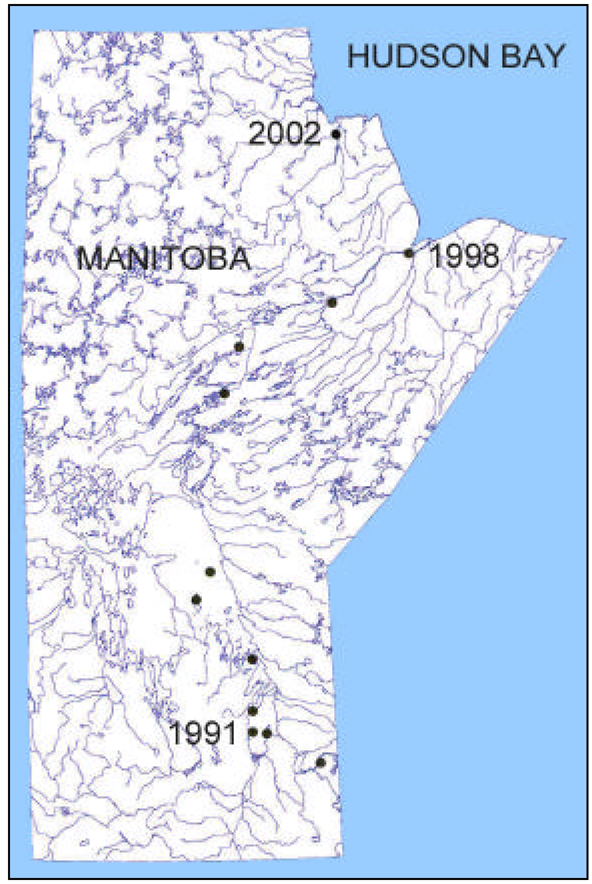

Figure 24. Spread of rainbow smelt in the Hudson Bay drainage (adapted from Stewart 2002).

2.7 MAMMALS

The extreme southerly presence of Arctic marine mammals is a distinctive characteristic of the Hudson Bay marine ecosystem. Its waters and/or ice habitats are used by at least five species of whales, by walruses, five species of hair seals, Arctic foxes, and polar bears. The beluga, narwhal and bowhead are migratory Arctic whales that frequent the region as ice conditions permit. Belugas are the only whales found commonly in James Bay and southeast Hudson Bay. Killer whales live at all latitudes and migrate into Hudson Bay in summer; the minke whale is a temperate-water species and rare summer visitor. There are also reports of sperm whales and northern bottlenose whales in Hudson Bay but their occurrence has not been confirmed and at best they are rare. Walruses, ringed seals, bearded seals, and harbour seals are resident while harp and hooded seals are seasonal visitors from the North Atlantic. Arctic foxes and polar bears frequent coastal areas in summer and ice habitats during other seasons.

The quality, extent and duration of the sea ice cover are vitally important determinants of the seasonal distribution and movements of these animals, and of their reproductive success. Heavy pack ice and landfast ice limit which species can survive and where they winter and reproduce. The duration of ice cover determines how long polar bears can hunt seals and whether seals can successfully reproduce and moult. While polar bears and Arctic foxes use these ice environments as a platform upon which to travel and hunt seals, the other species must maintain access to the surface to breathe. Ringed seals, and occasional bearded seals, are the only animals that can maintain breathing holes through the landfast ice. They use it as a stable platform upon which to haul out, build birth lairs, pup, and moult. They also inhabit consolidated and open pack ice, as do bearded seals and walruses. Harbour seals frequent areas where currents maintain open water year-round, typically in freshwater or estuarine rapids or small coastal polynyas or at the ice edge. Their reliance on ice makes ringed and bearded seals and polar bears vulnerable to changes in the ice environment of Hudson Bay and James Bay. The possible impacts of climate change are discussed in Section 3.4.

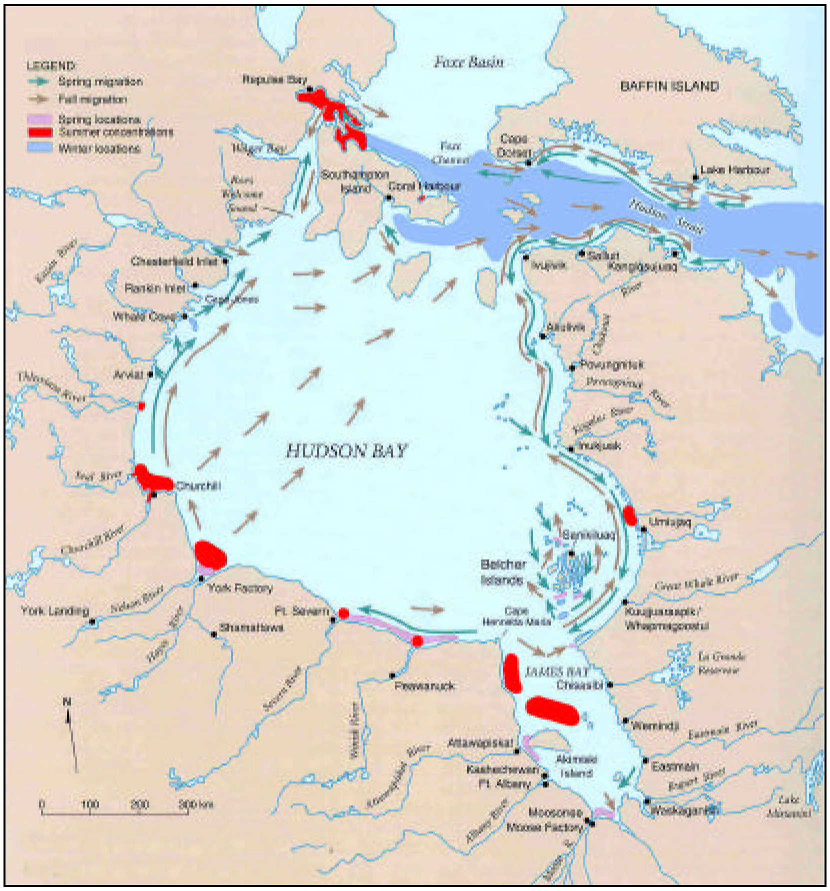

Figure 25. Information on the spring and fall movements of belugas and areas where they are first seen in the spring, concentrate in summer, and spend the winter compiled from traditional (McDonald *et al*. 1997) and scientific (Finley *et al*. 1982; Richard *et al*. 1990; Gosselin *et al*. 2002; Richard and Orr 2003) sources. Map modified from McDonald *et al*. (1997:88).

The other seal and whale species move into the region as ice conditions permit in the spring. The Arctic species, which winter mostly in the pack ice of Hudson Strait or Davis Strait arrive first, following leads or penetrating the pack as it dissipates. They are also the last species to leave in the fall. The seals and whales that winter in the North Atlantic arrive later in the season, once most of the pack ice has dissipated, and leave earlier in the fall. The timing of these movements can vary by a month or so from year to year, depending upon ice conditions.

Various populations of marine mammals have been identified in Hudson Bay and James Bay on the basis of seasonal distribution, genetics, contaminant loads or other factors. Some of these populations are shared with communities on Hudson Strait, Foxe Basin, Davis Strait, or the Atlantic coast. The genetic interchange among populations of each species, within and outside the region, is unknown.

Most movement data, polar bears excepted, comes from observations of species' arrival and departure times at harvesting locations. Since most harvesting is done near the coast, offshore movements are virtually unknown. The resident seal species move on or offshore to access seasonally preferred ice habitats. Some walruses remain at the ice edge or in the pack ice over the winter, while others move northeast into Hudson Strait. Two putative walrus populations have been identified in the region, one in South and East Hudson Bay and the other in Hudson Bay-Davis Strait. Narwhals from the Hudson Bay population and bowheads from the Hudson Bay-Foxe Basin population summer in northwest Hudson Bay, and may mix with other populations on their wintering grounds in Davis Strait. Belugas arrive at estuaries around Hudson Bay during or immediately after spring break-up (late May to late June) and generally leave by late August or early September (Figure 25). The largest summering concentration in the world occurs in the Nelson estuary area, and there are smaller concentrations at the Seal, Churchill, Winisk, Severn and Nastapoka estuaries. Use of these estuaries by belugas may be related to neonate survival and/or moulting. Recent studies of 5 belugas radio-tagged in late July and early August at the Nelson estuary demonstrated movement of belugas between summering areas—despite genetic and other evidence that these concentrations may constitute different stocks, northward migrations in the fall in central Hudson Bay and along its east and west coasts, and wintering in eastern Hudson Strait (Figure 26).

The seasonal movements and population dynamics of polar bears are better known. Long-term radio tracking studies of polar bears, particularly in western Hudson Bay, have identified distinct Southern Hudson Bay, Western Hudson Bay, and Foxe Basin populations. Bears from each of these areas show fidelity to maternity denning and summering areas but mix on the ice of central Hudson Bay in winter (Figure 27).

Bowheads are large (~20 m, 100 mt), long-lived (~200 y) baleen whales that feed on planktonic crustaceans, often at oceanic fronts where temperature, turbidity, or current patterns suggest there are areas of

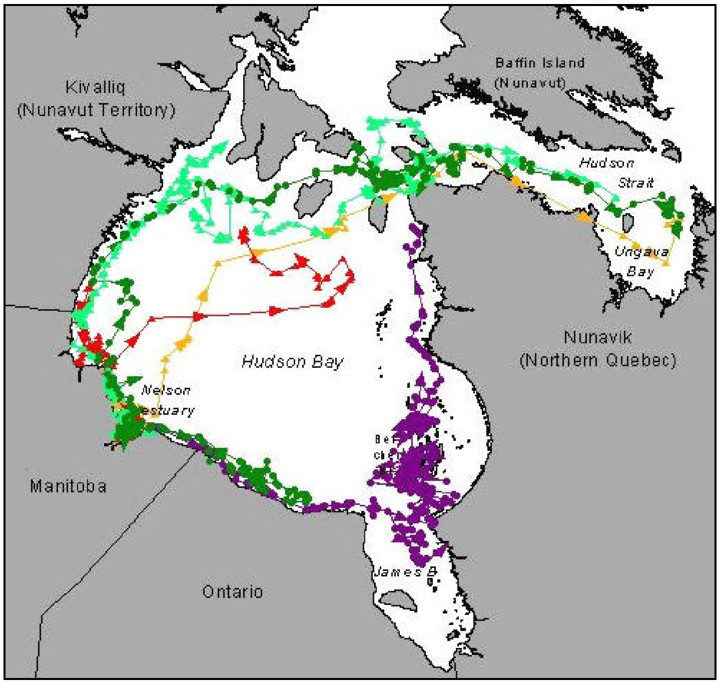

Figure 26. Map showing the seasonal movements of 5 belugas that were radio-tagged at the Nelson Estuary between 30 July and 5 August 2003 and followed until 27 November 2003 (Richard and Orr 2003). Arrows show direction of movement. Purple and dark green tracks were made by female belugas—a calf accompanied the former.

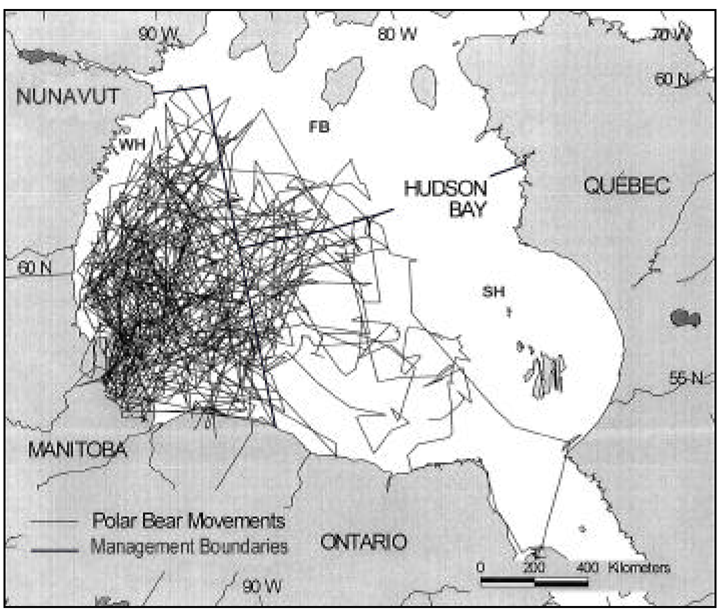

Figure 27. Movements of 41 adult female polar bears through a total of 46 bear years, between 1991 and 1998 (modified from Stirling et al. 1999:298). Management boundaries for the Western Hudson Bay (WH) and Southern Hudson Bay (SH) populations, and part of the Foxe Basin (FB) population are shown.

discontinuity or mixing. Their predictable concentration in these areas has made them very vulnerable to capture. Narwhals (~5 m, 1500 kg) and belugas (~3.5 m, 550 kg) are small toothed whales that eat a variety of fishes and invertebrates. These three species are well adapted to cold Arctic waters. They have a thick layer of insulating blubber under their skin, lack a dorsal fin, and are capable of breaking ice with their dorsal ridges or melons. Male narwhals are unusual in having a magnificent spiral tusk that can extend straight forward over 3 m. Killer whales are less well adapted for life in ice-filled waters with a large dorsal fin that limits their ability to break ice and is subject to damage. These large (~7.5 m) toothed whales prey on other marine mammals and on fishes. Like the polar bear, they are predators at the top of the food chain.

In the absence of humans, Altantic walrus populations likely require large areas of shallow water (80 m or less) with bottom substrates that support a productive bivalve community, the reliable presence of open water over these feeding areas, and suitable ice or land nearby upon which to haul out. They are very gregarious and for most of the year are associated with moving pack-ice. In Hudson and James bays the scarcity of ice in summer and fall forces them to haul out on land where they tend to congregate in a few predictable locations (*uglit* or *ubliqvik* = resting place on land).

Ringed seals (~1.25 m, 65 kg) are the most common and abundant marine mammals in Hudson Bay and James Bay. Their ability to maintain breathing holes in landfast ice enables them to occupy large areas that are inaccessible to other marine mammals except during the summer. In spring, the highest densities of breeding adults occur on stable landfast ice in areas with good snow cover, whereas non-breeders occur at the floe edge or in the moving pack ice. Bearded seals are larger (~2.2 m, 350 kg), with a patchy and relatively low density distribution that may be limited by dependence on areas of high benthic productivity for food. In winter they occur mostly in moving pack ice and open water where the water depth is less than 150 to 200 m. During the open water period they will enter estuaries and haul out on land, sometimes with harbour seals. There are resident populations of harbour seals in some fresh water drainages of the Hudson Bay watershed. Seals that winter in fresh water in the

Lacs des Loups Marins area may be a separate subspecies. The adults are generally sedentary and inhabit areas that have open water year-round. They tend to be solitary in the water but haul out in small groups on rocky shores, where they also pup. Their predictable availability at these locations makes them vulnerable to hunters. Harp seals are present in Hudson Bay from ice break-up in early June until just before freeze-up in early October. They are less common than ringed or bearded seals, but may have been more numerous and widespread in the past and may be re-occupying their former range. The hooded seal is a rare summer visitor to Hudson Bay.

The whales, most seals, and perhaps walruses can dive to the bottom to feed throughout James Bay and most, if not all, of Hudson Bay. The seal species eat a variety of fishes and invertebrates. Bearded seals are uncommon in areas frequented by walruses, suggesting that there is either inter-specific competition for benthic prey or predation by walruses. During the period of ice cover the polar bears eat mostly ringed and bearded seals. As top-level carnivores, they are susceptible to the accumulation of contaminants from their diet and vulnerable to changes in the availability of seals. Contaminant loads in polar bears are discussed in Section 3.3. Arctic foxes scavenge polar bear kills and prey upon ringed seal pups.

The whale species and the walrus all have relatively low reproductive rates, producing a single calf about every three years on average over their reproductive life. The rate of calf mortality is relatively low as the females feed and protect their young for the first several years of their lives. The vital rates of narwhals are uncertain because there is no accurate method to determine their ages. The seal species have a greater reproductive potential since they can reproduce annually. However, this potential is not always met; the actual pregnancy rate among ringed seals in western Hudson Bay can be 48-61%. The rate of mortality among seal pups is high, as they are eaten by polar bears and Arctic foxes, and weaned and abandoned after a period of weeks or a few months.

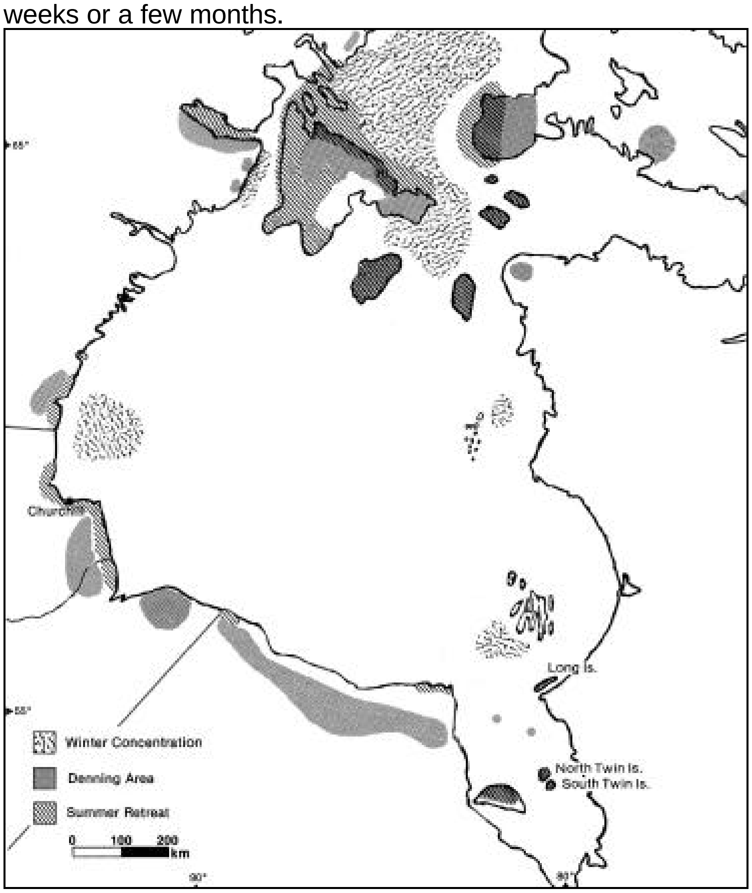

Figure 28. Denning habitats, summer retreats, and winter concentration areas of polar bears in the Hudson Bay and James Bay areas. Composite based on Jonkel *et al*. 1976; Urquhart and Schweinsberg 1984; Kolenosky and Prevett 1983; OMNR 1985; Lynch 1993; McDonald *et al*. 1997).

The annual ice melt generally forces polar bears in Hudson Bay and James bay ashore from mid-July through late August, when they are at their maximum yearly weight from feeding on fat, newly-weaned seals. They seem to come ashore in the same areas and show long-term site fidelity. The adult males tend to congregate on coastal capes and headlands, while the family groups tend to move inland near the denning areas (Figure 28). When the other bears move back onto the ice in November the pregnant females remain on land to dig maternity dens in deep snowdrifts or in the earth. The main maternity denning area for the Western Hudson Bay population is south of Churchill in Wapusk National Park. The use of earth dens on the islands in James Bay and along the Manitoba and Ontario coasts of Hudson Bay is unique. It may help these southernmost bears avoid overheating and reduce exposure to insects. They may also provide maternity dens early in the season in areas where snow banks have not developed adequately.

Polar bears in Hudson Bay and James Bay face a longer open water season and warmer summer than their counterparts in the High Arctic. They must conserve their energy to avoid starvation or overheating, and lose weight steadily from the time they come ashore until freeze-up in early November when they return to the sea ice to hunt. Despite the protracted periods of starvation these bears maintain a similar mean litter size to other polar bear populations and reproduce more frequently. The mean litter size for bears in Southern Hudson Bay is 2.04 (n = 161) and for bears in Western Hudson Bay is 1.84 (n = 274). Females emerge with their cubs in late February to mid-March and return to the sea ice to feed. While most polar bears wean their cubs after 2.5 years and have a 3-year breeding cycle, 40% of those in Hudson Bay wean their cubs after only 1.5 years and have a 2-year breeding cycle. The higher reproductive rates in the Western Hudson Bay population have been associated with higher growth rates, but the reasons for the higher growth rates are unknown.

Estimates of marine mammal populations in the region, based on systematic aerial surveys or counts at walrus haulouts, are summarized in Table 1. They are likely conservative as they were not corrected for animals submerged beyond view and all but the polar bears can hold their breath for over 20 minutes. The number of belugas summering in James Bay may have increased fourfold between 1985 and 2001, while numbers in eastern Hudson Bay declined by almost half. The increase in James Bay cannot be explained by reproduction alone, other contributing factors may include survey timing and immigration from Hudson Bay. The latter has important implications for population management and argues the need to improve understanding of the relationships between animals in these areas. In eastern Hudson Bay, the decline in numbers of belugas, offshore and at estuaries was accompanied by a decrease in the mean age of the catch. DFO has cautioned that continuing current levels of harvesting (>140 EHB beluga killed in 2001 by communities in Hudson Bay and Hudson Strait) could cause this population to disappear within 10 to 15 years.

Table 1. Population estimates of marine mammals in areas of Hudson Bay and James Bay.

Species	Area	Survey dates	Population estimate[a]	Reference
Beluga	James Bay	1985	1,842 [b]	Smith and Hammill 1986
		1993	3,141 (SE = 787)	Kingsley 2000
		2001	7,901 (SE = 1744)	Gosselin *et al*. 2002
	eastern Hudson Bay	1985	2,089 [b]	Smith and Hammill 1986
		1993	1,032 (SE = 421)	Kingsley 2000
		2001	1,194 (SE = 507)	Gosselin *et al*. 2002
	southwest Hudson Bay (Nelson, Churchill and Seal estuaries)	17-18 July 1987	23,000 belugas (95% CI 14,200-26,800)	Richard *et al*. 1990
	northwest HudsonBay (Repulse Bay, Frozen Strait)	late July 1982-84	mean estimates of 700 (95%CI 200-3,300) to 1,000 (95%CI 621-1,627)	Richard *et al*. 1990
Narwhal	northwest Hudson Bay (Repulse Bay area)	July 1984	1355 (90%CI = 1000-1900)	Richard 1991
		August 2000	1780 (90%CI = 1212-2492)	Richard pers. comm. 2002
Bowhead	northwest Hudson Bay (Whale Cove to north of Lyon Inlet)	12-17 August 1995	75 (S.E. = 27.5; 95%CI 17-133)	Cosens and Innes 2000
Polar bear	western Hudson Bay (WH)	1995	1200 (95%CI = 950-1450)	Lunn *et al*. 1997a
	southern Hudson Bay (SH)	1996	1000 (965-1095)	Calvert *et al*. 2002
	Foxe Basin (FB)	ca. 1996	2300 (SE = 350)	Derocher *et al*. 1998
Walrus	northern Hudson Bay	26 August 1977	2370 (haulout surveys)	Mansfield and St. Aubin 1991
	Coats Island	August 1990	1376 (direct count)	Richard 1993
	Nottingham Island	August 1990	461 (direct count)	Richard 1993
	Cape Henrietta Maria	August 1999	221 (direct count)	C. Chenier, DNR pers. comm. 2003
Bearded seal	western Hudson Bay, Nelson Estuary north to Rankin Inlet and offshore to 90º W longitude	7-14 June 1994	12,290 (SE = 2520); 0.122 seals/km² of ice	Lunn *et al*. 1997b
Ringed seal	Hudson Bay, not including James Bay	13-20 June 1974	227,500[c];	Smith 1975
	James Bay	1974	30,500 (extrapolated from Hudson Bay data)	Smith 1975
	western Hudson Bay, Nelson Estuary north to Rankin Inlet and offshore to 90º W longitude	1-4 June 1995	140,880 (SE = 8100); 1.690 seals/km² of ice	Lunn *et al*. 1997b
	southeast Hudson Bay, coastal waters between Long Point and Petite riviere de la Baleine extending 40 km offshore	20-30 May 1978	14400-21400, 1.44 to 2.14 seals/km² of ice	Simard *et al*. 1980

a = estimates were not corrected for seals in the water or whales submerged beyond view. b = Data collected in 1985 did not allow a line transect analysis, so the value is the product of the strip transect estimate and the mean ratio of line/strip transect estimates for the given stratum for the two following surveys. c = 1.48 seals/km² of landfast ice between Churchill and Chesterfield Inlet, 0.37 seals/km² of offshore consolidated pack ice, 0.11 seals/km² of broken ice and open water.

There is little scientific or traditional information to indicate large changes in the region’s other marine mammal populations over the past 20-50 years, but scientific survey information is very limited. The bowhead population remains severely depleted by commercial whaling that ended a century ago, and the historical range of walruses in James Bay and western Hudson Bay is much reduced. Hunting and disturbances caused by motorboats and snowmobiles may be causing narwhals and walruses to avoid areas near the communities.

The Committee on the Status of Endangered Wildife in Canada (COSEWIC) has given marine mammal species in Hudson Bay the following designations: **Endangered:** bowhead; **Threatened:** eastern Hudson Bay belugas; **Special Concern** (formerly Vulnerable): Lac des Loups Marins subspecies of harbour seal and polar bear; **Not at Risk:** western Hudson Bay belugas and hooded seals; **Data Deficient:** Atlantic subspecies of the harbour seal. Updates of the status of beluga, narwhal and Atlantic walrus populations in Canada are ongoing. The Committee on the International Trade in Endangered Species (CITES) has listed bowhead under Appendix I, which protects them from international trade. Belugas, narwhals and polar bears are listed under Appendix II, which is reserved for species that could be threatened with extinction if trade is not controlled and monitored, and Atlantic walrus are listed under Appendix III. A CITES export permit is required to transport products from these species across international boundaries. Marine Mammal Export permits are required from DFO to export marine mammal products from Nunavut. Harvesting levels are discussed in Section 3.1.

2.8 BIRDS

The Hudson Bay marine ecosystem provides resources of critical importance to migratory waterfowl and shorebirds, and to moulting ducks. Hudson Bay has the effect of funnelling southward migrating species of Arctic shorebirds and waterfowl into James Bay. With its rich coastal marshes, wide tidal flats and extensive eelgrass beds, James Bay is one of the most important stopping places for migrating Arctic-breeding shorebirds and waterfowl in North America. It is matched only by the Copper River delta and Bristol Bay in Alaska and, for shorebirds, by the upper Bay of Fundy. These birds, particularly the geese and ducks, have sustained, and continue to sustain, important subsistence harvests by Inuit and Cree.

The history of ornithological research in the Hudson Bay and James Bay dates back to the 1700's. Birds were a vital food of the early explorers and traders, who often recorded their observations or collected specimens. Indeed, the endangered (or possibly extinct) Eskimo curlew, *Numenius borealis* (Forster), was first described from specimens collected at Fort Albany; the blue morph of the snow goose, sandhill crane, sora, Hudsonian godwit, red phalarope, red-necked phalarope, northern harrier, whimbrel, horned grebe, and gyrfalcon were also first described from specimens collected in the Hudson Bay region--many of them by early employees of the Hudson's Bay Company. Despite the long history of research, there are a number of gaps in our knowledge of this region's bird fauna. Most studies have examined coastal areas during spring, summer, and/or fall. We do not know to what extent birds use offshore waters, overwinter in open water areas, or even what bird species inhabit long stretches of coastline.

At least 118 species of swimming birds, shorebirds, raptors, and scavengers frequent offshore, inshore, intertidal, or saltmarsh habitats of the Hudson Bay marine ecosystem. The area provides coastal breeding habitat for at least 99 species, including many that are primarily Arctic breeders--some of which are rarely seen in breeding condition outside the Arctic Islands. It also provides vitally important feeding, staging, and/or moulting habitats for many resident and transient species.

Because of their geographical location and transitional character, James Bay and southern Hudson Bay support some of the most southerly examples of Arctic-breeding species, and some of the most northerly examples of southern-breeding species--both of which offer interesting opportunities for study. Despite a rich avifauna most species are common and numerous elsewhere in Canada--the Hudson Bay eider is a notable exception.

The distribution of birds in the ecosystem is determined largely by habitat availability and climatic

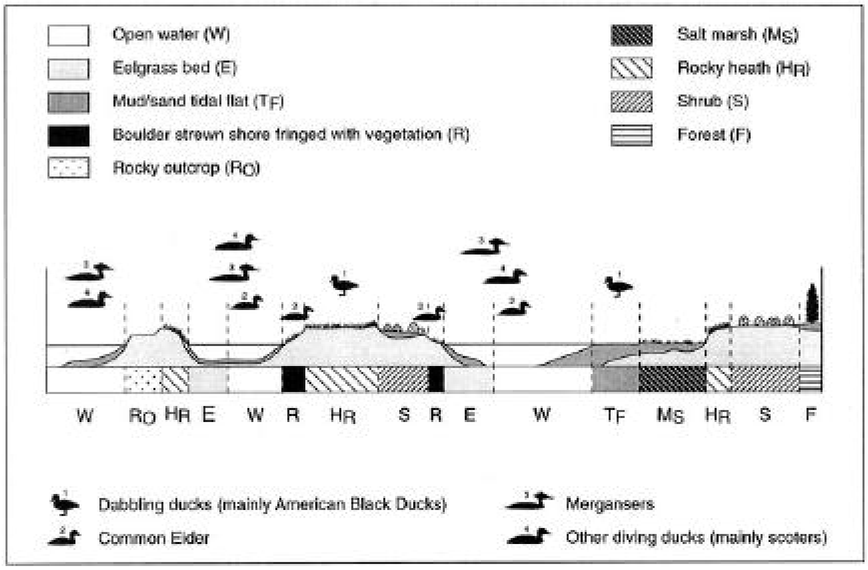

Figure 29. Use of habitats of the northeast coast of James Bay by ducks (from Reed *et al*. 1995).

factors, particularly temperature. Wide differences in coastal habitats and climates mean that species common in one area may be uncommon or absent in another. Low-lying rocky islands, wide tidal flats--often associated with wet lowland tundra, salt marshes, eelgrass beds, coastal cliffs, and open water (e.g. polynyas) are particularly important habitat (Figure 29). Biological oceanography is also important since it determines the local abundance of food for nearshore and offshore feeders.

Tidal flats in western James Bay, particularly north and south of the Albany River, provide resources of critical international importance for migrating Hudsonian godwit and red knot (Figure 21). In the fall, the knots and numerous other species of shorebirds make a direct flight from James Bay to the Atlantic seaboard or, in the case of Hudsonian godwit, to South America. They require fat built up from feeding along the James Bay coast to fuel them on the flight. During breeding season most of these shorebirds frequent coastal areas that have moist to wet vegetated tundra and sometimes salt marshes or higher, drier areas with low vegetation.

Rich and extensive beds of eelgrass along the northeast coast of James Bay provide food resources of critical North American importance to brant. The islands and coasts of James Bay offer breeding, feeding, and/or moulting habitat to a wide variety of species, many of them near the limits of their breeding distributions. Akimiski Island in western James Bay supports the most southerly breeding colonies of lesser snow goose, Ross's goose, and oldsquaw; the Twin Islands in Eastern James Bay also support a variety of typically Arctic-breeding species. Way Rock in Eastern James Bay supports perhaps the only breeding colony of the double crested cormorant on Canada's Arctic coast, and the American bittern is an unusually common breeder in the marshes of western James Bay.

Large areas of the Hudson Bay and James Bay coasts provide critically important habitat for migrating and moulting North American waterfowl. Waterfowl are also very important to the regional economy, both for subsistence and to attract sport hunters. Some species are colonial and can be very numerous in suitable habitats. At least 26 Anatid species breed along the coasts and frequent coastal marine habitats in summer, and a few overwinter. During the breeding season most of these waterfowl frequent low-lying, sometimes hummocky, moist to wet vegetated tundra, often near lakes or coastal river mouths. The eiders are exceptions and often nest on low-lying rocky coasts and islands, especially where mussel beds and reefs provide feeding grounds. After the young hatch they often congregate in flocks along the coasts.

The Canada goose breeds in large numbers though at low densities, in inland marshy areas and is a numerous spring and fall transient, particularly along the James Bay coasts. In the Belchers and on Akimiski Island these geese make extensive use of saline habitats and are characterized by very large salt glands, which develop to cope with the high salt intake. Many of the individuals marked at nesting areas in western James Bay winter in the Mississippi Valley, while those from the Belchers and the Quebec coast winter mainly along the Atlantic coast. Geese from Akimiski Island and southern James Bay apparently winter in the Tennessee Valley. Inuit and Cree have observed changes in the migratory patterns of both Canada and snow geese in Hudson Bay and James Bay.

The lesser snow goose breeds mainly in the Arctic and along the coasts of Hudson Bay. Its most southerly large breeding colony in Canada is located at Cape Henrietta Maria, and there is also a small breeding colony on Akimiski Island. During migration the entire Foxe Basin population of over a million birds stop to rest and feed at marshes on the west coast of James Bay. The region supports over 50% of the eastern Arctic breeding population of the lesser snow goose, *Anser caerulescens caerulescens* Linnaeus, which has increased significantly in the past 30 years. Breeding colonies are dotted along the Hudson Bay coast and the species is locally very numerous, so much so that overgrazing is degrading their prime habitats at La Perouse Bay, in the McConnell River Migratory Bird Sanctuary, and elsewhere. In summer, it is common to see adult geese waddling through Arviat trailing their broods.

The brant is a saltwater species that breeds in the Arctic and on Southampton Island, and is seldom seen in much of southern Canada. These geese graze extensively on beds of eelgrass along the coasts of James Bay in spring and fall (late September-early November). During the fall migration over 50% of the Atlantic brant population may use these habitats (Figure 20). The area of critical habitat south of Roggan River is nationally important because of the extensive eelgrass beds which attract up to 20,000 brant, many thousands of Canada Geese, and numerous ducks--principally black duck, in the fall. Many thousands of brant pass through southern James Bay (e.g. Netitishi Point) on their way south in late fall. They follow a relatively narrow migration corridor through Quebec enroute to and from their wintering grounds along the Atlantic coast of the United States.

The Hudson Bay subspecies of the common eider, *Somateria mollissima sedentaria* Snyder, is unusual in that it lives year round in Hudson Bay and James Bay. It breeds locally and commonly (colonial) along low-lying, tundra or rocky, coasts throughout this region and feeds almost exclusively on the blue mussel (*Mytilus edulis*). In the mid-1980s the breeding population in eastern Hudson Bay was estimated at 83,000 birds. These birds winter where open water and shallow depth coincide. Inuit report that they are present, sometimes in quantity, at almost every ice edge that is accessible from Sanikiluaq in winter, and in a number of polynyas (Figure 15). In the early 1990s many eiders were found frozen into areas where the water has usually remained open in winter. The Inuit attributed these kills to decreases in the area's winter currents over the past 5 to 10 years.

Two seabirds, the black guillemot and thick-billed murre, are harvested for subsistence. The black guillemot nests in small colonies on steep shores at Cape Henrietta Maria, along the Quebec coast from Chisasibi northward; on the Twin Islands, the Belchers, and other islands in southeastern Hudson Bay; on Southampton and Coats islands; and along the Keewatin coast north of Chesterfield Inlet. It is one of the most abundant and characteristic seabirds along the coasts of Hudson and James bays and on the outer islands almost to the head of James Bay. Most of the lowland coastal habitat is unsuitable for black guillemot breeding, since the species prefers to lay its eggs on bare rock or loose pebbles. The black guillemot is a year-round resident of the Belcher Islands area. There are breeding colonies of thick-billed murres on cliffs in northeast Hudson Bay. The species is uncommon but has been reported at the Belcher and Nastapoka islands in summer. Inuit report that murres winter in large numbers in areas of open water west of the Belchers.

There is a relatively dense, productive population of peregrine falcons nesting on coastal cliffs and islands near Rankin Inlet on the Kivalliq coast. They arrive on the breeding grounds in mid-May from wintering areas as far south as Uruguay. Nests are situated on cliff ledges, often near seabird colonies. Peregrines inhabiting coastal areas in summer prey on shorebirds, seabirds, and small mammals, which they kill with a blow from their feet following a spectacular dive. The population has relatively low pesticide residues and high reproductive success, but there is still measureable pesticide-related egg thinning. In 2002, there were 29 active nests and 24 young were fledged. The area has one of the highest and best-known concentrations of peregrines in the world and should be considered for protection. COSEWIC considers the subspecies to be of “Special Concern”.

Ross's and ivory gulls are rare spring visitors to Hudson Bay and James Bay. The Ross’s gull will nest at

Churchill and occurs in summer at the McConnell River in Kivalliq. The species usually nests in the Canadian high Arctic and in Siberia, may overwinter at Arctic polynias, and is rare in southern Canada. It has been designated as "Threatened" by COSEWIC. The ivory gull may occur more widely and in both summer and winter, but breeds further north. It has been designated a species of "Special Concern" by COSEWIC. The shorteared owl and yellow rail have also been designated species of Special Concern by COSEWIC.

The coastal wetland habitats are protected by a number of migratory bird sanctuaries and National and Provincial Parks (Figure 30). Two of these, the Southern James Bay Migratory Bird Sanctuary, which encompasses the Moose River and Hannah Bay Migratory bird sanctuaries, and Polar Bear Provincial Park, have been designated as Ramsar sites under the Convention on Wetlands of International Importance as Waterfowl Habitat (The Ramsar Convention). The former received this designation in recognition of its role as a late-fall staging area for large numbers of lesser snow geese (*A. c. caerulescens*), Canada geese, and dabbling ducks. It also holds substantial numbers of diving ducks offshore including scoters, scaup, and mergansers. Late fall storms bring spectacular migrations of waterbirds and shorebirds through the sanctuaries. Polar Bear Provincial Park regularly supports hundreds of thousands of ducks and geese, including a breeding colony of over 50,000 pairs of lesser snow geese at Cape Henrietta Maria. It also supports large numbers of waterfowl and shorebirds during migration, including a substantial portion of the central Arctic population of red knot and the entire central Arctic population of Hudsonian godwit during their fall migrations.

Figure 30. Map of Hudson Bay and James Bay showing locations of protected areas. The Cape Churchill and Cape Tatnam Wildife Management areas in Manitoba are not shown.

Two bird sanctuaries border on Hudson Bay, the McConnell River Migratory Bird Sanctuary which encompasses lowlands along the Kivalliq coast that are important nesting habitat for lesser snow geese and other waterfowl, and the Harry Gibbon's Bird Sanctuary which encompasses the Boas River Delta and associated sedge wetland tundra on Southampton Island where many lesser snow geese, some Canada geese and brant, and a few Ross's geese nest. Wapusk National Park, Manitoba's Cape Churchill and Cape Tatnam Wildlife Management Areas, and Ontario's Polar Bear Provincial Park also provide protection for a variety of bird species along the south coast of Hudson Bay.

There are smaller, long-established Migratory Bird Sanctuaries in southern James Bay at Akimiski Island and at Boatswain Bay, and a wildife sanctuary at the Twin Islands. The islands and shoals of James Bay are also part of the NWT's James Bay preserve which includes key migratory bird habitats such as the Twin Islands, Akimiski Island, and coastal reefs and islands between Rogan River and Rivière du Vieux Comptoir and in Boatswain and Hannah bays. However, the areas of greatest value to shorebirds, north and south of the Albany River in James Bay, have not yet been afforded statutory protection. Fortunately, they are not under any immediate threat. The Canadian Wildlife Service considers the Sleeper, North Belcher, and Salikuit islands to be sensitive habitats on account of their large indigenous populations of Hudson Bay eider.

2.9 HUMAN OCCUPATION

The prehistorical record of human occupancy of this region's coasts is relatively short due to glaciation. Paleo-Eskimos from Alaska colonized the islands and coasts of Hudson Bay after glaciation and gave rise to the Pre-Dorset (2000-800 BC) and later Dorset (800 BC-1500 AD) cultures (Figure 31). A later invasion of Alaskan Eskimos gave rise to the Thule culture (1000-1600 AD), direct ancestors of the modern Inuit. Each culture had a more advanced marine hunting technology than the last, and the Thule people actively hunted bowhead for food and building materials. Sites of prehistoric Inuit occupation are found along the Quebec coast from the Grande rivière de la Baleine northward, from Churchill northward along the west coast, on Southampton Island, and on the islands of southeastern Hudson Bay. They are relatively common but not unique to this region, which appears to have been marginal for these cultures. Some of the latest Dorset sites are located near the entrance to Richmond Gulf. In prehistoric times ancestors of the Cree occupied the northern woodlands of Quebec, Ontario and Manitoba west to near Churchill, while ancestors of the Chipewyans occupied the area near Churchill. The extent of coastal use by prehistoric Indian peoples is not well known.

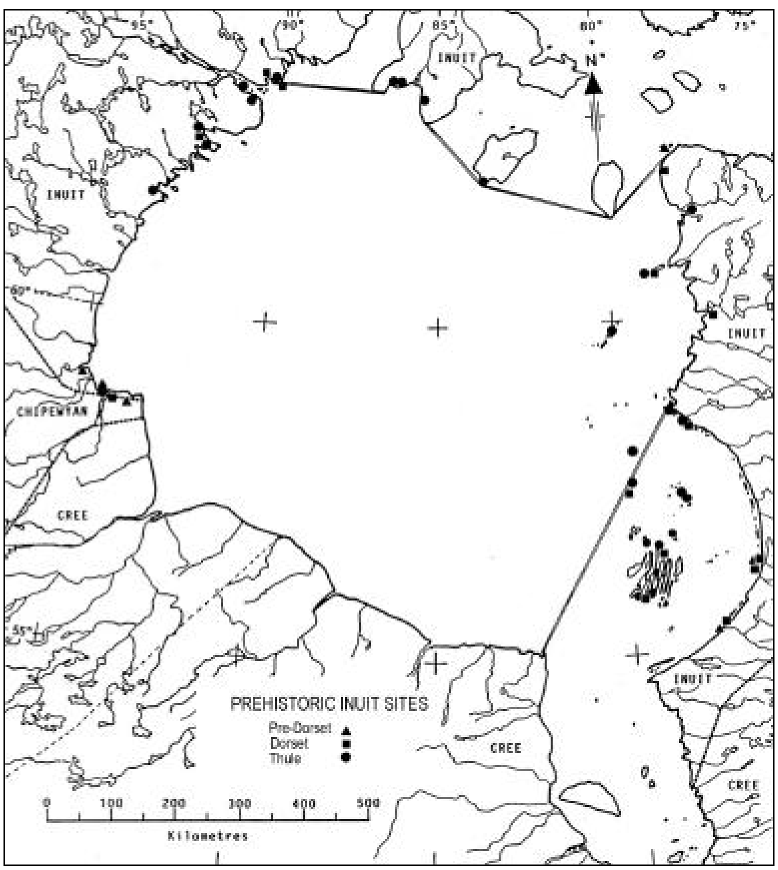

Figure 31. Sites occupied by prehistoric Inuit cultures (After Inuit Land Use and Occupancy Project 1976, vol. 2, p. 117-122) and approximate boundaries of Inuit, Cree and Chipewyan cultures during the first two centuries of white contact (After Canada 1980).

The region's historical record is long in North American terms. Early European exploration (1610-1632) of southeastern Hudson Bay and James Bay was in search of a Northwest Passage to the Orient (Figure 32). When no passage was found there was a brief hiatus, until about 1668 when interest in the lucrative North American fur trade prompted renewed explorations and, soon after, construction of Hudson's Bay Company trading posts at Fort Albany, Moose Factory and Fort Rupert (Figure 33). An intense struggle for the control of this region ensued between French and British interests, ending

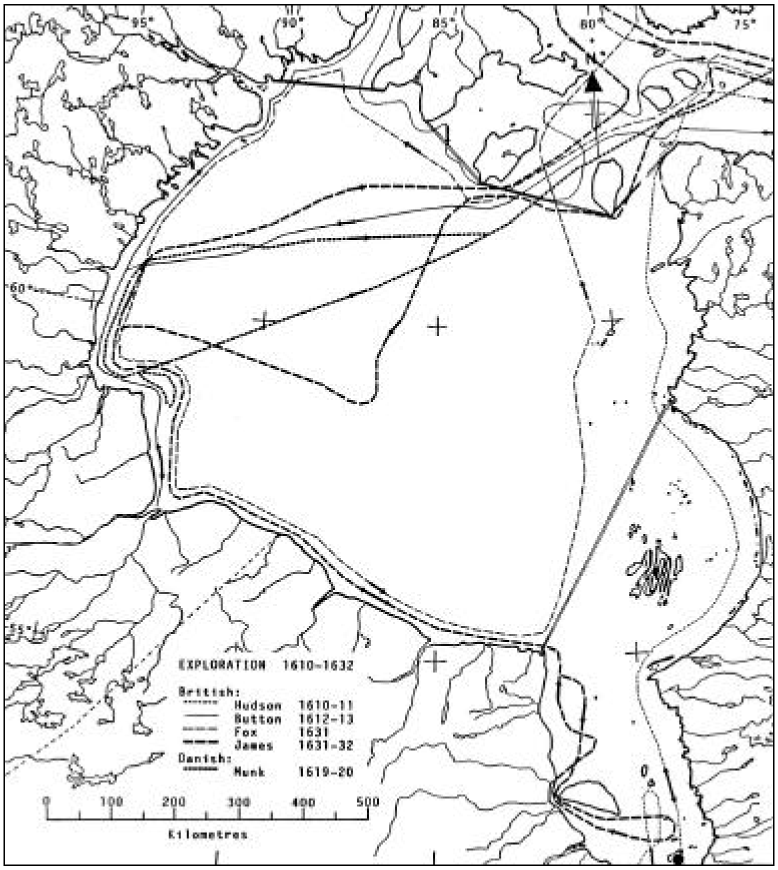

Figure 32. European exploration of Hudson Bay 1610-1632 (after Canada 1974). Solid dot marks Charlton Island where Hudson was abandoned by his crew.

only with the Treaty of Utrecht in 1713, wherein France relinquished all claims to Hudson-James Bay. All of the company's James Bay posts changed hands during the conflict, and for much of the period Albany was their only foothold in Hudson-James Bay.

Over the next 190 years the Hudson's Bay Company consolidated its hold on this region, establishing posts, developing the fur trade, and catching beluga whales at Grande rivière de la Baleine and Petite rivière de la Baleine. The coastline was mapped and, in the 1850's, the first church missions were established. While trade had been brisk with the East Main and West Main Cree since 1669, there was little contact between traders and Inuit until the 1840's.

The region continued to serve as an easy route to the interior until the advent of cheaper southern railway routes in the mid-1800s. The decline of York Factory as a port of entry coincided with growth of bowhead whaling in northwestern Hudson Bay. Between 1860 and 1915, New England and Scottish whalers nearly extirpated the bowhead population in northwestern Hudson Bay. Modern settlement began in 1912 with the establishment of a Hudson's Bay Company post at Chesterfield Inlet, and today there are settlements around the coast (Figure 2).

While the earliest explorers left little evidence of their visits, later explorers, fur traders, missionaries, and settlers had a marked effect on the cultures and economies of the aboriginal peoples. Centralized, permanent coastal settlements replaced temporary seasonal camps, and guns and motorboats the bows and kayaks. They were exposed to radically different concepts of time, work, and behavior and new languages, social activities, and diseases. Despite changing culture and technology, marine resource harvesting still plays an important part in modern Inuit culture and economy and, to a lesser extent, that of the coastal Cree. Land settlement agreements have confirmed Cree and Inuit title to large stretches of the Quebec coast, and Inuit title to large areas of Nunavut.

Some of the key differences between the modern coastal settlements are the railway links to Moosonee and Churchill, the all-weather road to Chisasibi and winter roads to the other James Bay communities, and the influences of radar base and hydroelectric construction. Kuujjuarapik and Chisasibi are unusual in that both Indians and Inuit inhabit them. Moosonee is Ontario's only saltwater port; Churchill is Manitoba’s only saltwater port.

Activities during the periods of exploration, fur trade, whaling, and settlement significantly affected the patterns and levels of marine resource use. While the whaling period was relatively restricted in geographic terms, its overall biological and cultural impacts on the Hudson Bay marine ecosystem were far reaching.

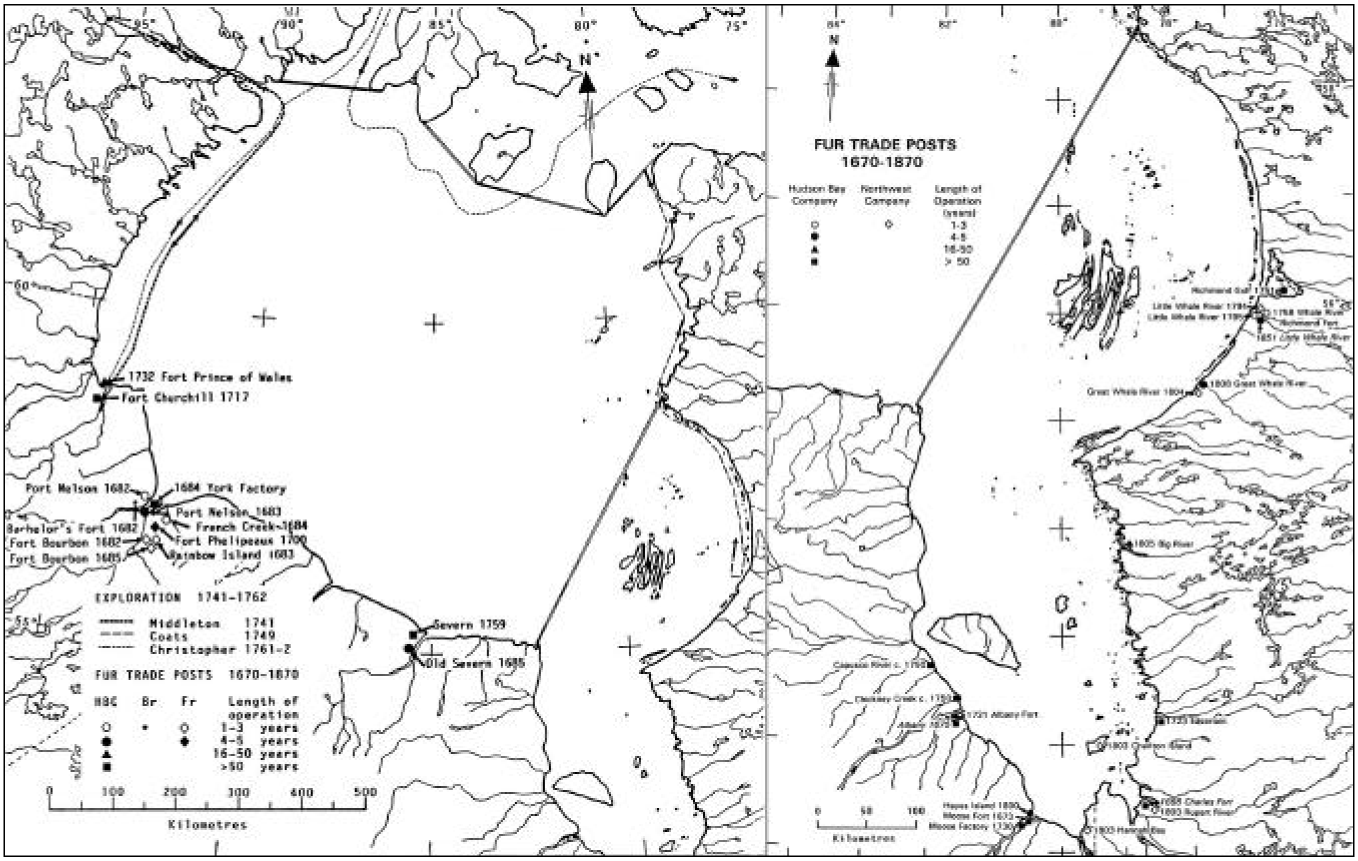

Figure 33. Posts of the Canadian fur trade, 1600-1870, and European exploration of Hudson Bay 1741-1762 (after Canada 1974).

3.0 ECOSYSTEM STRESSORS

Despite a history of resource harvesting and European habitation that dates back to the 1600's, the Hudson Bay marine ecosystem remains relatively pristine. The main human activities that have affected or may affect the natural condition of the region are related to resource harvesting, marine transportation, mineral or hydrocarbon development, and sewage disposal. Activities outside the marine ecosystem related to the diversion of freshwater and to industrial and agricultural development, may also affect the natural condition of the region. These ecosystem stressors are discussed in the following sections on harvesting, development, contaminants, and climate change. Readers are referred to Sly (1994) for an overview of land-based ecosystem stressors situated further afield in the Hudson Bay watershed.

3.1 HARVESTING

Traditional subsistence harvests of anadromous fishes, marine mammals, and waterfowl are vitally important to Inuit around Hudson Bay. Cree along the coasts of James Bay and southern Hudson Bay make greater use of migratory waterfowl, but harvest few marine mammals and different species of anadromous fishes. Inuit also harvest marine plants and invertebrates, and both cultures harvest some seabirds. These species have provided them with food, fuel, and materials to make clothing, shelter, and equipment. The hunt and sharing of its proceeds continues to be of great social, cultural, and economic significance to Inuit and Cree alike. Commercial whaling, particularly for bowhead and belugas, was instrumental in the European exploration and development of the region and dates back to the late 1600's in northern Hudson Bay. Bowhead populations and the eastern Hudson Bay beluga stock have not recovered from past commercial harvests for oil or baleen. European embargoes have nearly eliminated commercial sealing in the region.

The quality of quantitative harvest data depends upon the type of harvest (subsistence, commercial, sport), the species harvested, interest on the part of the compiler, and the community. Subsistence and sport harvest levels are not well documented for fish, bird, and seal species. The removal of these species is seldom monitored, as they are killed for personal use and the number that can be taken for subsistence has not been limited. Better records are available for the larger marine mammal species that are harvested for subsistence, and occasionally for sport. Concern over the ability of beluga, narwhal, bowhead, polar bear and walrus populations to support current rates of removal has resulted in regulation, and therefore monitoring, of at least some harvests of these species. The imputed value of subsistence harvests to Cree and Inuit living around Hudson Bay and James Bay, on a per capita basis, is substantial. A new study of subsistence harvesting in Nunavut was not available at writing.

Hunt management in the region is complicated by the migrations of many of the harvested species between jurisdictions. Harp and hooded seals excepted, few of the migratory marine mammals are vulnerable to harvest outside the coastal waters of Nunavut and Nuanvik. Migratory waterfowl and seabirds however, may be vulnerable to harvest from the High Arctic to the southern United States. Lesser snow goose populations, which have increased dramatically in response to changing agricultural practices in the southern United States and to effective conservation programs, present a particular challenge. Hunt managers are working to reduce their populations to an environmentally sustainable level, to avoid a population crash that would have strong adverse impacts on subsistence harvesters and likely increase harvests of other species.

Priority is given to Inuit and Cree subsistence harvesters when resources in Hudson Bay and James Bay are allocated. Where animal populations harvested by Nunavut and/or Nunavik are considered at risk of overharvesting, the total allowable harvest they can sustain and the basic needs level for native subsistence is determined. If there is a surplus in the allowable harvest it is allocated, in order of preference, to non-native residents for personal consumption, to sustain existing sport and commercial ventures, to provide for economic ventures sponsored by native organizations, and to other users.

The Nunavut Wildife Management Board (NWMB) makes all decisions relating to fish and wildlife in Nunavut, including setting quotas and non-quota limitations (e.g. fishing and hunting seasons, methods of harvest), approving management plans, and approving the designation of endangered species. While keeping many of the established harvest quotas, this co-management board has instituted a flexible quota system for polar bear hunts by Kivalliq communities and community-based management of the Repulse Bay narwhal hunt, to give communities greater responsibility and flexibility in the management of their renewable resources. Ultimate approval of the NWMB decisions rests with Ministers in the governments of Nunavut and Canada who can only reject or modify a NWMB decision if it interferes with Inuit harvesting rights, creates concern with respect to species conservation, or results in a public health or safety concern. The NWMB relies on the government departments for scientific research and advice, and for regulatory support and enforcement. Its decisions are implemented under legislation by the appropriate government department. People wishing to remove animal parts from Nunavut require a Wildlife Export Permit from the Department of Sustainable Development. A Marine Mammal Transportation Licence is required under the *Fisheries Act* to export marine mammal (whale, seal, walrus) parts out of Nunavut to other parts of Canada--with the exception of Indians or Inuks who harvest animals in one jurisdiction and are returning to their home in another jurisdiction.

Harvest management along the Quebec coast and its estuaries changed with signing of the James Bay and Northern Quebec Agreement (1976). Under this agreement, Inuit and Cree beneficiaries of the agreement are guaranteed certain levels of harvest, which are to be maintained unless their continuation is contrary to the principles of conservation. The Makivik Offshore Claim, which is under negotiation, will cover the coastal areas around western and northern Quebec. If approved, it may alter the management of fish and wildlife offshore the Nunavik coast in a fashion similar to the Nunavut agreement. The responsible department of the Federal or Provincial Government manages fish and wildlife hunts along the Ontario and Manitoba coasts.

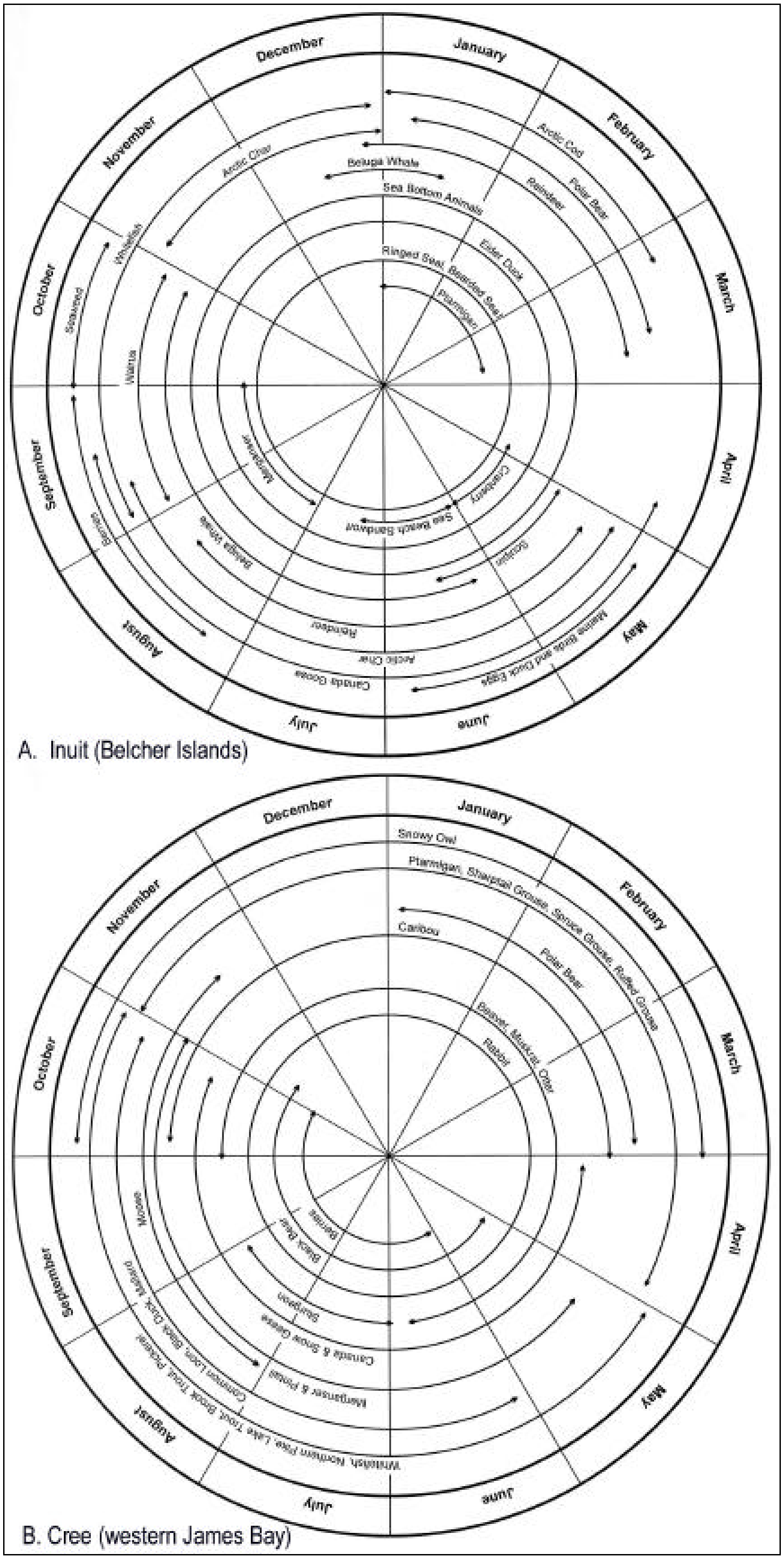

Figure 34. Seasonal foods of: A) Belcher Islands Inuit and B) western James Bay Cree (from McDonald *et al*. 1997).

3.1.1 Plants and Invertebrates

Inuit in the Belcher Islands harvest seaweed and kelp for food. There has also been interest in developing a commercial harvest for kelp in the vicinity of Whale Cove since the mid-1990s. Options under consideration have included processing kelp for health food, and composting it to produce methane gas and rich fertilizer. No license was issued for this fishery in 2003.

Inuit from the Belcher Islands harvest a greater variety of marine invertebrates for food than do the other communities in the region. Green sea urchin (*Strongylocentrotus droebachiensis*), brown sea cucumber (*Cucumaria japonica*), six-rayed starfish (*Leptasterias polaris*), and blue mussel (*Mytilus edulis*) are harvested yearround and there is recent interest in harvesting scallops (Figure 34). These species have been harvested in small quantities for local sale. Blue mussels are the only marine invertebrates harvested on a regular basis for subsistence by residents of western and northeastern Hudson Bay. They are readily available at extreme low tides at many locations along the coasts and make a tasty meal.

Exploratory fisheries have been conducted for shrimps, scallops, and clams but they have not been located in sufficient abundance to justify the establishment of an offshore fishery. The shellfish are small and slow growing relative to their southern counterparts. DFO has not issued Exploratory or Commercial Licences for shellfish in Nunavut, scallops excepted, since April 2003, as there is no Canadian Shellfish Safety Program inspection available to ensure that the harvest is safe to eat. In 2000, the NWMB approved a quota for 50,000 kg of green sea urchins (or 5,000 kg of eggs) to be taken in the Whale Cove area.

The impacts of marine plant and invertebrate harvests on the target species, their habitats, and other species that eat them or use the affected habitat have not been studied. Their ability to sustain harvests, and the rate of recovery of bottom habitats damaged by dragging or other methods of harvest, is unknown. The selective harvest of invertebrates in the Belcher Islands by divers is an exception, as it causes little damage to other species or habitats.

3.1.2 Fish

Most fish harvested from James Bay and Hudson Bay are taken from estuarine or coastal waters during the open water season by Cree and Inuit food fisheries. Neither culture has a tradition of offshore marine fishing. Fish are harvested for the food they provide, and as a traditional social and cultural activity. Anadromous Arctic charr are the fishes most sought after for subsistence by Inuit in Nunavut and north of Kuujjuarapik in Nunavik. They are available at predictable times and locations, grow quickly to a large size, and are free of parasites that infect people. Few of these fish are available to Inuit and Cree further south, so they harvest anadromous cisco, whitefish, longnose sucker, and brook trout. Most fish are caught using gillnets set near the communities, either along the coasts or at river mouths. Many of the same sites are fished commercially, sometimes at the same time and often with the same gear. Unlike commercial and sport fisheries, subsistence fisheries by registered native peoples are not restricted in terms of the fishing area, season, or harvest. Species caught incidentally, such as cod or sculpin are also eaten on occasion. Capelins are also harvested when they spawn at the shoreline in the Belchers. Subsistence harvests of cod and sculpin are much greater in eastern than in western Hudson Bay. Dogs are sometimes fed fish, usually freshwater coregonids but sometimes Arctic charr.

Commercially attractive marine fishes have not been found in sufficient quantity to support a viable marine fishery in Hudson Bay or James Bay. But, very little offshore fishing effort has been expended, certainly not enough to assess the seasonal presence of schooling fishes such as capelin and Atlantic cod. Small nearshore commercial fisheries for anadromous Arctic charr have developed along the Kivalliq coasts and at Puvirnituq. Kivalliq Arctic Meats in Rankin Inlet is a Federally Inspected meat processing plant with European Union Certification that processes fresh and frozen Arctic charr and caribou for sale directly to domestic and international markets. Fish harvested by Whale Cove and Chesterfield Inlet are frozen locally and then shipped to Rankin Inlet for processing; some fish are shipped fresh. Fish harvested at Arviat, Repulse Bay, and Coral Harbour are sold locally, and there is a small fish smoking plant at Puvirnituq. Historically, none of the Kivalliq fish processing operations has received enough fish to consistently meet operating expenses. Transportation is a particular problem for these fisheries both in terms of logistics and cost. Fishermen generally participate in the commercial fishery to supplement their incomes or subsidize subsistence harvests. Commercial harvesting of coastal marine and estuarine fish is also conducted on a small local scale at many communities along the Quebec coast, and fish are often marketed through local cooperatives. The main commercial fishery is conducted during August and early September when anadromous Arctic charr are netted at or near river mouths along the coast. Long standing

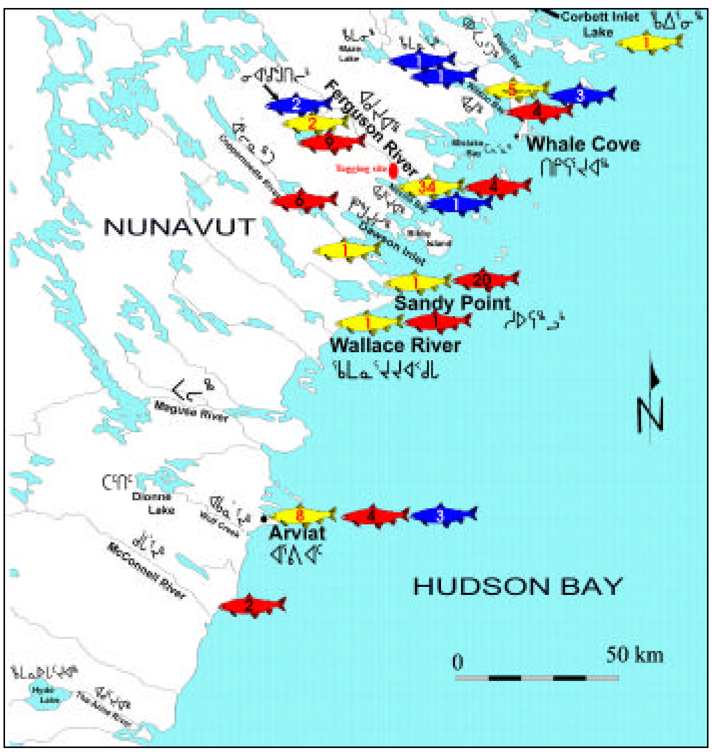

Figure 35. Movement of anadromous Arctic charrr along the Kivalliq coast of Hudson Bay (adapted from McGowan 1998:39). In June 1995, 493 Arctic charr were tagged during the downstream run from at the Ferguson River. This map shows the number of charr recaptured by fishermen at different locations in 1995 (yellow), 1996 (red), and 1997 (blue).

commercial harvest quotas at these locations are opened annually, as requested by the Hunters and Trappers Organizations, unless there is strong evidence of overharvesting. Most of these quotas target mixed stocks of charr (Figure 34). While ommercial and sport fisheries are closely regulated, overharvesting can occur in areas that also support large subsistence fisheries. One such area is the Diana River near Rankin Inlet, commercial fishing has been stopped and sport and subsistence fishing reduced to facilitate population recovery. There is no marine trophy fishery in Hudson Bay or James Bay, and most sport angling is by local residents.

3.1.3 Marine mammals

Commercial harvesting of belugas in western Hudson Bay began in 1688 and continued, sometimes on a large scale, until 1970. In the late 1940s, a Manitoba Company built a whaling plant at Churchill and began a commercial operation that lasted until 1968. Over 4,500 whales were processed for oil, leather, and mink food in the first decade of this operation. This population was estimated at 23,000 animals in July 1987 and was either extremely large prior to commercial exploitation, or has recovered well from that exploitation. This has meant that the Kivalliq communities have never had quotas on their subsistence harvests of belugas. Historically, the Hudson's Bay Company (HBC) conducted the main beluga fisheries in eastern Hudson Bay. These fisheries harvested a combined total of at least 8,294 whales from Grande rivière de la Baleine and Petite rivière de la Baleine between 1852 and 1868. The population was much reduced by harvesting and has not recovered. It is considered threatened and quotas have been placed on the subsistence harvest. In 2002, Quebec Inuit, unable to satisfy local demand under these quotas, purchased 2220 kg of *maqtaq* from the Arviat Hunters and Trappers Organization. Concerns were expressed within Arviat regarding the ramifications of commercialising the harvests; in particular, whether the population might decline or a quota might be imposed. A similar request for *maqtaq* was received in 2003. Belugas in James Bay were also harvested for subsistence and to supply the coastal HBC posts, but not with the same intensity. Currently there is no regular harvesting of belugas by Cree in James Bay.

Small-scale commercial harvests for belugas were conducted at Arviat and Whale Cove in the early 1960's. Seal meat was also processed for commercial sale by the fish plant at Daly Bay and later Rankin Inlet between 1964 and 1970. Product demand declined steadily and, in 1970, when mercury levels of 0.5 ppm (wet wt.) were found in the whale and seal meat the commercial harvest was stopped. Belugas were live-captured at Churchill for aquaria, beginning in 1967. Sixty-eight whales were taken before the Minister of Fisheries and Oceans issued a moratorium on this practice in 1992.

Only Inuit can hunt narwhals, and most are taken from the Hudson Bay population by Repulse Bay. The ivory commands high prices and is marketed internationally, while the *maqtaq* is consumed locally or traded to other Inuit communities. It is a highly valued food and demand often exceeds supply. The Hudson Bay narwhal population is unlikely to support the rates of removal seen in 1999 and 2001 over the long term, unless the natural rate of increase is greater than 5% per year. In 2002, the community-based management program responded to this concern by reducing the annual harvest limit for Repulse Bay from 100 to 72 narwhals.

Hudson Bay Inuit have a long tradition of harvesting bowhead whales and participated in the commercial harvests until the whale populations were depleted. Between 1860 and 1915, American and British whalers killed an estimated 566 whales in northwest Hudson Bay, and very nearly extirpated bowhead from the region. The species is considered endangered in Hudson Bay. Many Inuit still have a strong interest in harvesting bowheads for food and as part of their cultural heritage. Since 1979, a license from the Minister of Fisheries and Oceans has been required in order to hunt bowhead. In August 1996, hunters from Repulse Bay obtained a licence to hunt bowheads and killed an adult male, which was not secured and sank. The carcass resurfaced 46 hours later, by which time the meat was unfit for human consumption. Some of the *maktaq* was eaten but much of the whale was left to rot on the shore.

Arctic foxes and polar bears are harvested along the coasts and on the sea ice once they have developed their thick winter pelage. Female bears with cubs or in dens are avoided. Quotas have been placed on the number of bears that can be harvested from the Western Hudson Bay, Southern Hudson Bay, and Foxe Basin populations. They are divided among the harvesting jurisdictions frequented by bears from each population. Current harvest levels for each of these populations are believed to be sustainable. There is no open season for hunting polar bears in Manitoba. Only Inuit and Cree can harvest polar bears along the Quebec coast of Hudson Bay and James Bay. They take most of their bears from the Southern Hudson Bay population by Inuit residents of Inukjuak and Kuujjuarapik. Cree at Wemindji harvest a polar bear in some years, and those at Chisasibi harvest a few bears most years. Hunters from Sanikiluaq, in Nunavut, have historically harvested the greatest numbers of bears from the Southern Hudson Bay population. Only Treaty Indians who possess a valid trapping licence can hunt polar bears along the Ontario Coast. While the current levels of harvest are believed to be sustainable, the Southern Hudson Bay population would be over harvested if Ontario hunters took the number of polar bears to which they are “entitled”.

Walruses are harvested mainly for their ivory tusks, which are sold or carved for sale, and for their meat, which is eaten or fed to the dogs. Their seasonal availability varies between communities. Inuit and Indian natives of Canada can kill up to four walruses per year without a licence, except where community quotas limit annual catches; non-natives require a licence under the Marine Mammal Regulations or Aboriginal Communal Fishing Licence Regulation to hunt walruses. Since 1980, Coral Harbour has had an annual harvest quota of 60 walruses and Sanikiluaq of 10 walruses. The quota system is under review by the Nunavut Wildlife Management Board, which is considering new ways of managing the walrus hunt. Communities in Kivalliq and residents of Puvirnituq, Akulivik, and Ivujivik harvest walruses from the Hudson Bay/Davis Strait Stock. In Kivalliq, these harvests increase from south to north and hunters often have to travel north into the Coats Island area to hunt. In the east, most animals are killed during the open water season, often in September and October, near Nottingham and Salisbury islands. Hunters from Inukjuak, Kuujjuarapik, Umiujaq, and Sanikiluaq harvest walruses from the smaller South and East Hudson Bay Stock, mostly in September and October at the Sleeper Islands. To prevent outbreaks of trichinellosis, walruses harvested in Nunavik are screened for the parasite *Trichinella nativa* before being eaten. People can also contract this parasite from eating infected bearded seal or polar bear meat that has not been cooked sufficiently to kill the parasite. Sport hunts for walruses has been approved annually since 1996 in the Coral Harbour area. One walrus was taken between 1996 and 2001.

Ringed seals are a very important natural resource for Inuit and Cree along the coasts of Hudson Bay and James Bay. They are harvested year-round, but mostly from June through October. The largest harvests are taken in eastern Hudson Bay by Inuit from Sanikiluaq, Inukjuaq, and Kuujjuarapik. Catches from James Bay are generally small, the largest being from Chisasibi and Wemindji on the east coast and Attawapiskat on the west coast. This may reflect both the fact that Indians have not traditionally been hunters of sea mammals, and that seal densities may be lower and hunting conditions poorer due to the earlier breakup and later freeze-up. Bearded seals are also very important to Inuit. They hunted mainly during the open water season but also at the floe edge or in pack ice. Small numbers of harbour and harp seals are also taken. The harbour seal has a somewhat precarious existence, since its localized distribution makes it relatively easy to locate, and it is an easy target when hauled out on land or swimming in a shallow stream. An active campaign to discourage harvesting of seals in the lower Churchill River was initiated in 1999 at the request of DFO. Inuit and Cree around Hudson Bay and James Bay can harvest seals without a license; others require a license under the *Fisheries Act*. The seal meat is eaten or used for dog food, and the skins are used to make clothing and crafts.

Under the *Migratory Birds Convention Act, 1994,* subject to their existing rights and the regulatory and conservation regimes in the relevant treaties and agreements, Cree and Inuit may harvest migratory birds and their eggs, down, and inedible products year-round. This applies to both game birds, such as geese and ducks, and non-game birds, such as loons and guillemots. The down and inedible products may be sold but the birds and eggs can only be offered for barter, exchange, trade, or sale within or between Aboriginal communities as provided in the relevant treaties and agreements. While the subsistence harvest is essentially unregulated, Cree have a socially-enforced, traditional system for regulation of the goose hunt, comprising territories and rules which are designed to minimize disturbance of goose populations.

Migratory waterfowl comprise a significant portion of the diet of Cree and Inuit living along the coasts of Hudson Bay and James Bay, particularly in eastern Hudson Bay. Seabirds, in particular thick-billed murres and black gullemots, and resident waterfowl, such as the Hudson Bay eider duck, are also important but are harvested mostly in the Belcher Islands and along the northeast coast of Hudson Bay.

The subsistence harvest of waterfowl by Cree along the Ontario coast of James Bay and Hudson Bay consists predominately of Canada geese in the spring and lesser snow geese (blue and snow geese) in the fall. They also take large numbers of ducks and eggs. There is considerable variation in the annual harvests.

Canada geese dominate the subsistence harvest of waterfowl by Cree and Inuit along the Quebec coast and in the Belcher Islands. The majority of these geese are taken in the spring, except in Chisasibi and Kuujjuarapik, where the fall harvests are a bit larger. The harvest of lesser snow geese is smaller but still substantial. The majority of the Inuit harvest occurs in the spring, except in the Belchers where the majority of these geese are taken in the fall. Cree harvest snow geese mainly in the fall. Hunters from Wemindji and Chisasibi harvest well over half of the brant and loons taken from James Bay and Hudson Bay. The loons, mainly red-throated and common, are taken mostly in the spring and the brant in the fall. While fewer brant than other geese are harvested, the harvest is very significant in relation to the stock size and harvests by other user groups. Eiders make up the lions share of the duck harvest by Quebec Inuit, who also harvest mergansers, scoters, thick-billed murres, black guillemots, and snowy owls for food. The murres may also be vulnerable to harvest in Labrador and Newfoundland.

The common eider is the most important duck to Inuit living on the coast of Hudson Bay and is particularly important to people in the Belcher Islands. The species is harvested year-round for meat, skin and feathers, and nests are raided for eggs and nest down. Historically the skins have been used to make fine parkas and pants, and there has been a small export of eiderdown. In the Belchers, there is ongoing interest in the commercial harvest potential of eider down. The species' importance is reflected in the language of Belcher Island Inuit, which has a well-developed nomenclature to describe the stages of egg and bird development. Inuit in Kivalliq are far less reliant on waterfowl for food than those in Quebec.

Waterfowl are also harvested for sport and attract non-resident hunters to tourist camps along the Manitoba and Ontario coasts of Hudson Bay and the James Bay coast of Ontario. The fall harvest by their clients is substantial.

3.2 DEVELOPMENT

Despite its vast area, relatively few people live along the coasts of Hudson Bay and James Bay and very little development has occurred. Hydroelectric development is the activity with the greatest existing and potential impact on the marine ecosystem over the short, and perhaps, long term. Mineral developments, transportation, municipal waste disposal, and tourism also have the potential to impact the marine environment. Development of a pipeline to transport natural gas south from the Arctic or the impoundment of James Bay to provide water for the United States is unlikely but would have significant potential to affect the marine ecosystem.

Hydro-electric developments have altered the flow regimes of the La Grande and Eastmain rivers, which drain into James Bay, and of the Churchill and Nelson rivers, which drain into southwest Hudson Bay (Figure 36). The longterm impacts of these diversions on the marine environment are unknown and, in the case of the latter impossible to assess in the absence of baseline marine data.

In 1980, 80% of the flow from the Eastmain River was diverted into the La Grande River, and seasonal runoff was impounded so that it could be released to produce electricity in the winter. Under these regulated conditions the natural spring freshet into James Bay does not occur at either river. Because of the flow diversion, the plume from the Eastmain River is much reduced and there are intrusions of saline water up to 10 km upstream, year-round. While the size and shape of the summer plume from the La Grande River are essentially unchanged by development, the area of its under-ice plume has trebled (Figure 37). The winter discharge of freshwater from the La Grande River into James Bay increased from 500 m^3s^{-1} under natural conditions to over 4000 m^3s^{-1} following the diversion during peak power production. The plume can extend 100 km northward under the landfast ice of James Bay, and further increases in midwinter flow will lead to dilution of the nearshore surface waters in southeastern Hudson Bay.

Mercury levels in the La Grande system have risen considerably since that development began to operate but are now declining. Slightly elevated mercury levels have been found in the flesh of marine fishes within 10-15 km of the river mouth. The expected time before mercury concentrations fall back to the condition before the start of operations is about thirty years overall. This mercury problem will exist also for the Grande Baleine and NBR systems if and when the present plans are put into effect.

In 1976, 75% of the flow of from the Churchill River was diverted into the Nelson River to produce hydroelectric power. This has reduced runoff from the former while increasing it in the latter. The impacts of these changes on the estuaries cannot be assessed in the absence of pre-project data.

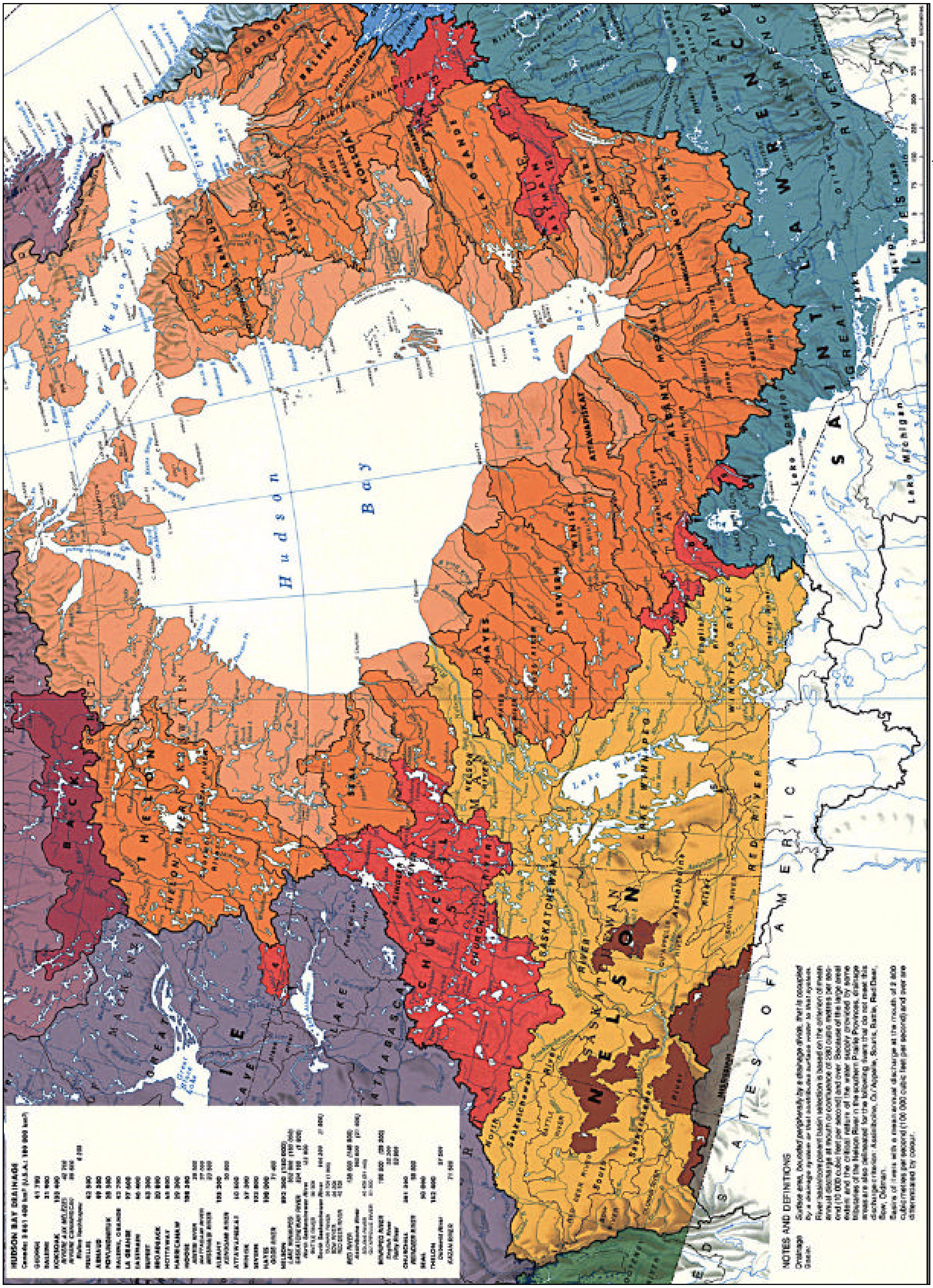

Figure 36. River drainages and hydroelectric diversions in the Hudson Bay watershed (from National Atlas of Canada 5th edn. 1986).

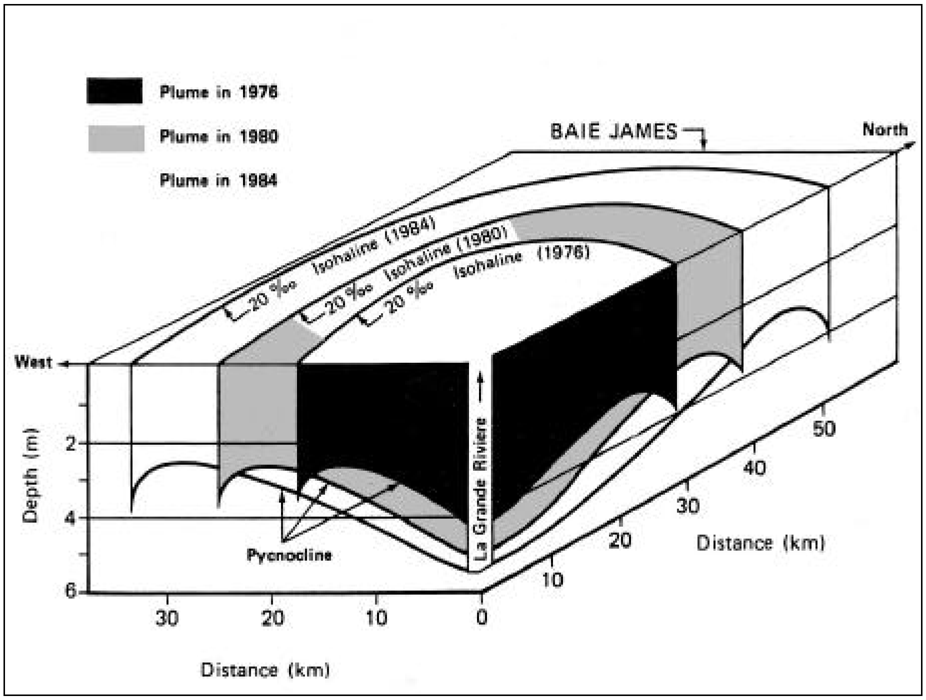

Figure 37. Schematic of the evolution of the La Grande River plume from 1976 to 1984 (from Messier *et al*. 1986).

The effects of hydroelectric development on the offshore surface waters are not well understood. Continued development may increase the winter surface salinity gradients and currents in James Bay. Modelling by Prinsenberg and Danard (1985) suggests that the surface temperature is buffered somewhat against man-made changes. They predicted that a decrease in surface temperature such as might be caused by hydroelectric development of surrounding watersheds would be gradually offset by the stabilizing effects of the colder water on the overlying air. This would act to decrease wind stress and increase the heat flux into the water. The reverse should be true in the case of an increase in water temperature. Ice-ocean modelling studies by Saucier and Dionne (1998) suggest that the bay-wide effects of the power plants are small compared with the natural variablility observed in the ice cover. The environmental impacts of altering the seasonal runoff regime on oceanographic conditions in the North Atlantic are uncertain and controversial.

Future hydroelectric development is planned by Quebec Hydro in southern James Bay (NBR), where much of the flow from the Rupert and Nottaway Rivers would be diverted into the Broadback River, and in southeast Hudson Bay (Grande Baleine), where 95% of the flow from the Petite rivière de la Baleine would be diverted into the Grande rivière de la Baleine. Manitoba Hydro is considering further developments on the Nelson River system, as is Ontario Hydro on the Moose River system. However, the flow regimes of these rivers have already been altered by existing developments.

There are no offshore mineral or hydrocarbon developments in Hudson Bay or James Bay and the only mine on the coast, for nickel at Rankin Inlet, has been closed since the 1960's. The region has a potential for discovery and development of hydrocarbons, base and precious metals, diamonds, asbestos, phosphate, gypsum, limestone, aggregate, and perhaps other minerals and materials. There has been some offshore mineral exploration and oil drilling in southwestern Hudson Bay but to our knowledge no oil or gas discovery has been made, and no exploration is ongoing.

Mineral deposits in the Kivalliq Region, primarily gold and base metals, may be developed over the next decade. While they are situated inland, any developments will likely require expediting services provided by the communities, improved port facilities, and servicing by shipping on Hudson Bay. They are likely to increase ship traffic on Hudson Bay, and the potential for the release of contaminants. Extensive surface exploration for uranium has also been conducted west of Baker Lake over the past several decades but no mine development is planned at present. Development potential along the Quebec coast of Hudson Bay, where exploration (primarily for gold and base metals but also for diamonds) is at an earlier stage, is less certain. If development occurs along the Hudson Bay Arc, it too may rely on the coastal communities and Hudson Bay shipping for logistical support. Mining developments inland from the James Bay coast would likely be less reliant on the coastal communities and transport supplies, materials and products by road or rail.

Hudson Bay's proximity to European markets was well recognized by fur traders and whalers, but it was not until the grain-producing capabilities of the Canadian prairies became apparent that a Hudson Bay shipping route was envisaged. Following completion of the railway link with western Canada, the route became a reality in 1931, when the first freighters loaded with Canadian wheat cleared Churchill Harbour. Today, annual vessel traffic within Hudson Bay includes European freighters that visit the Port of Churchill to load prairie grain and other commodities; ships or coastal barges that re-supply the other communities with food, dry goods, and fuel (sealift); and occasional luxury liners.

The impacts of marine transportation are low at present. Despite a regular traffic of ships to and from the region since the late 1600's, few natural alterations are apparent apart from the Port of Churchill, smaller docking facilities elsewhere, and a few marine hulks. Vessel traffic is largely confined to the open water season so there is seldom a requirement for ice-breaking, which can disrupt marine mammals and harvesting activities. Periodic dredging is required to keep the Churchill Harbour passable to large ships. In 1977-78, monitoring was carried out to ensure that cadmium levels, which were thought to be high in the sediment, did not exceed the ocean-dumping maximum of 0.6 ì g· g^{-1}. In the event, the levels were well within acceptable limits. There is some potential for spills of contaminants, such as oil during re-supply, and for the introduction of foreign organisms when bilges are cleaned. Community re-supply personnel are trained in emergency response procedures in the event of oil spills. In James Bay, the railway to Moosonee and seasonal or all-season (Chisasibi) roads to the other communities limit the need for sealift and thereby potential impacts from shipping.

The main impact of municipal developments on the marine environment are related to local transportation, by boat or on the ice by snowmobile or Bombardier, and the disposal of waste, both of which occur mainly in the immediate vicinity of the communities. While local boat traffic may affect marine mammals, in particular, these impacts cannot readily be separated from those of harvesting activities. They may have played a part in the abandonment of some *uglit* (haulouts) by walruses. Many of the communities lack sewage and wastewater treatement facilities, so bacterial and chemical contaminants may be discharged directly into the sea or flow overland to the water’s edge. Fortunately, the combined effects of low temperature and high salinity kill most organisms that cause human disease in a short time. Initiatives are underway at Rankin Inlet, and perhaps elsewhere, to improve sewage treatment.

The effects of marine ecotourism are likely low at present but may be increasing. The main activity takes place during the summer at Churchill where visitors come from around the globe to see beluga whales in the estuary, and polar bears and migratory birds along the coast. Outfitters at the other communities will take visitors on local sightseeing trips to see Arctic wildlife, walrus at Coats Island and polar bears at Wager Bay are particular favourites, and diving expeditions are available at Churchill and Sanikiluaq. Cruise ships also visit northwest Hudson Bay in the summer. Concern has been expressed that visitors to Coats Island and the Cape Henrietta Maria area may stampede walrus herds into the water and cause calf mortality.

In the 1970s, extensive studies were conducted in the Kivalliq Region to assess the feasibility of a pipeline to transport natural gas from the Arctic to southern markets. The project did not proceed, in part because the pipeline in the High Arctic could not be buried deeply enough to avoid damage from coastal iceberg scour.

A "Grand Canal" scheme has been proposed that would involve the construction of a dam across the mouth of James Bay so the bay could serve as a reservoir from which freshwater could be diverted south into the United States. The potential effects of such a project on the oceanography of Hudson Bay, productivity of James Bay, world climate, etc. cannot be adequately predicted and must not be underestimated. Modelling studies suggest that transforming James Bay into a massive freshwater lake would disrupt coastal currents, delaying ice melt and leading to colder wetter coastal conditions. They also suggest that the decrease in salinity would alter salt marsh vegetation in northern James Bay that migratory birds depend upon. These effects are just the tip of the ecological iceberg.

3.3 CONTAMINANTS

The watersheds draining to Hudson Bay are being changed by human activities, notably population growth and associated business activity, agriculture, hydroelectric development and climate change. In addition to alterations in watersheds, there is direct loading to the water surface of Hudson Bay by materials dispersed via atmospheric circulation. With the relatively limited attention contaminants have been given in Hudson Bay, existing analyses and those done in the coming few years have ‘benchmark’ quality that will help to assess the magnitude and significance of future changes.

3.3.1 Synthetic

Synthetic organochlorines and radionuclides produced by nuclear fission are two groups of contaminants found in the Hudson Bay marine ecosystem that result exclusively from human activities. They are products of 20th-century technology and have no natural sources or natural background concentrations. These compounds reach the Arctic by several means but one important pathway is via moving air masses (Figure 38). The have little or no history of use in the North but occur throughout the Arctic in air, water, sediment and aquatic life.

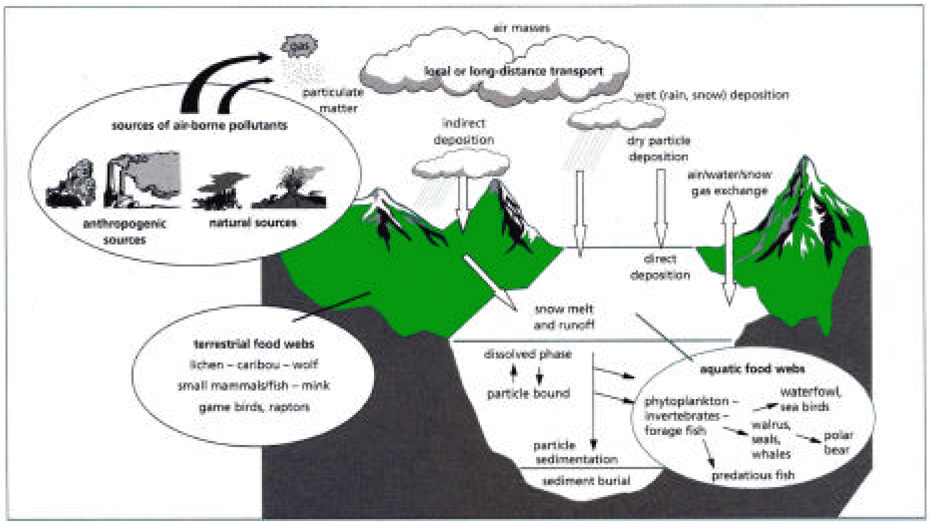

Figure 38. Schematic of pathways of transport and accumulation of persistent organic comtaminants and some metals to arctic and marine ecosystems (from Jensen *et al*. 1997, Figure 3.2.1, page 193).

Studies of the composition of the air from the Canadian North have consistently identified a wide range of synthetic organic compounds that originate thousands of km away. Organochlorine compounds differ somewhat from site to site even within the Hudson Bay/Foxe Basin/Hudson Strait area. Several contaminants move through food chains to become concentrated in animals at high trophic levels. With the exception of DDT, which seems to be declining in some species, temporal trends are still difficult to determine. With differences from one location to another, future work will have to be done on a site-by-site basis. Sentinel organisms and sites need to be selected for repeated monitoring over the coming years. Otherwise, even relatively large studies risk becoming too diffuse to detect temporal changes with high statistical confidence.

Few data exist describing organic contaminants in Hudson Bay sediments. But, high levels of both DDT (56 ng/g OC) and PCBs (920 ng/g OC) have been reported from eastern Hudson Bay relative to other Arctic locations.

Levels of both PCBs and HCHs in female ringed seals were quite similar across the range of Arctic locations sampled. The value for ÓPCB in seals from western Hudson Bay of about 700 ng/g in 1998-2000 may be compared with a value of 2100 ng/g for female seals from the same area in 1989-94. This implies a decrease in PCB contamination over the interval. The value for HCHs in blubber of seals from western Hudson Bay in 1998-2000 (about 100 ng/g wet weight) was one of the lowest found. PCB levels in blubber of belugas from Hudson Bay were higher than those in ringed seals. The mean concentration in male belugas from western Hudson Bay in 1992-95 was about three times higher than it was in the seals.

Concentrations of several organochlorine compounds in fat of mature polar bears from the Churchill area have been measured several times over the period 1969-1998 (Figure 39). Recent levels of ÓPCBs were under 3000 ng/g and all the other organochlorines reported were lower yet. The most consistent change is the decline in ÓDDT over the period from about 850 ng/g in 1968 to about 250 ng/g in 1999. CACAR II authors speculated that this decline is not typical of other Arctic data and might have been related to cessation of spraying DDT for the control of forest insects in the Hudson Bay watershed. ÓCBz appears to have increased between 1969 and 1984 and to have declined continuously since then. Similarly, levels of áHCH have declined since 1984 but levels of âHCH have not, with the result that the blend of the components ÓHCH has changed over the period.

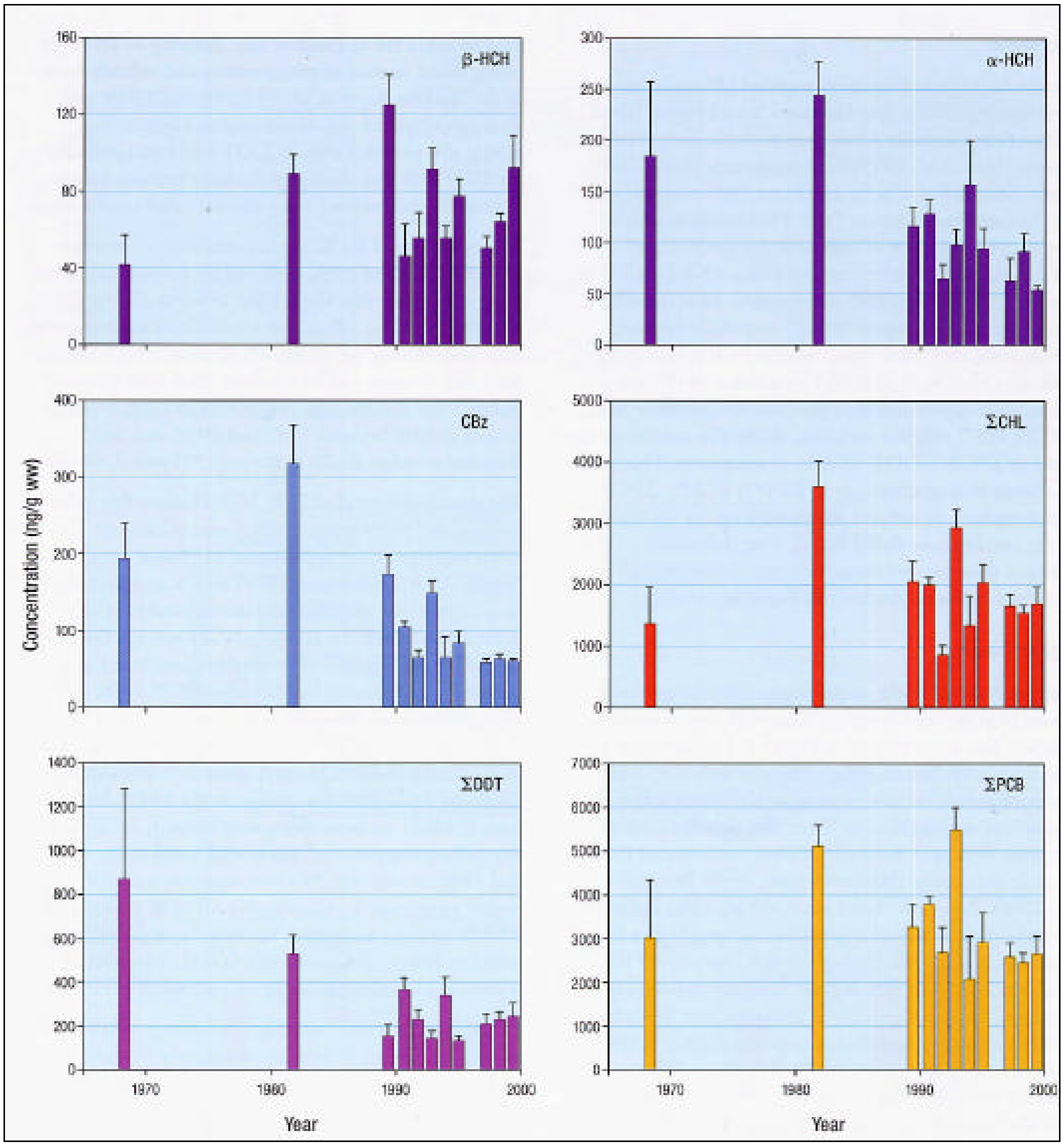

Figure 39. Organochlorine compounds (ng/g wet weight) in fat of polar bears from the Churchill area from 1968 to 1999. Samples from 1991-1999 are fat biopsies; earlier samples are adipose tissue (from CACAR II, Biological Environment, Figure 4.3.6, page 76).

Similarly, PCBs have declined during the 1990s but with a change in the composition of the mixture of PCB congeners in the bears. The proportion of less chlorinated congeners has increased while the proportion of highly chlorinated congeners has fallen with the result that no long-term trend in ÓPCBs since 1968 is evident.

Studies in areas outside Hudson Bay have revealed growing inputs of new stable chemicals like polybrominated diphenylethers. Future work on Hudson Bay biota should include assessment of these and other new chemicals.

The source of anthropogenic cesium-137 in this area was atmospheric testing of nuclear bombs, most of which ended in 1963 by international agreement. Little information exists on radionuclides in the aquatic biota of Hudson Bay. Levels of cesium-137 in animals today will have fallen below the values recorded in the early 1980s because the half-life of cesium-137 is only 30 years and inputs of new Cs-137 have fallen dramatically. The natural radionuclides polonium-210, radium-226, thorium-230, thorium-232, uranium-234 and uranium-238 were measured in a series of surface sediment samples collected in 1995 near Rankin Inlet. The highest levels of these radionuclides were usually found closest to the community of Rankin Inlet.

3.3.2 Naturally occurring

Human activities may also redistribute naturally occurring elements, including toxic heavy metals and metal-like compounds (e.g. arsenic), to the Hudson Bay marine ecosystem. Their presence is not, in itself, evidence of human activity because many elements are present naturally in soils and sediments. However, human activities often move elements about in the environment in ways and at rates not found naturally. The questions that arise in cases of suspected contamination by elements are whether the amounts found exceed natural background amounts and what the sources might be. Among the more toxic elements are cadmium, copper, chromium, lead, mercury, and zinc and the metalloids arsenic and selenium. In view of the potential for these elements to produce biological harm, Canada has established Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PEL) (Table 2). These guidelines describe levels that should not be exceeded in freshwater and marine sediments in order to avoid biological impacts.

Table 2. Interim sediment quality guidelines (ISQG) and probable effect levels (PEL) for seven elements in Canada (CCME 2001) and numbers of samples in Henderson (1989) in ranges defined by ISQG and PEL.

Element	ISQG ìg/g (dw) (whole sediment)	PEL ìg/g (dw) (whole sediment)	Number Below ISQG (in clay-size fraction)	Number above ISQG & below PEL (in clay-size fraction)	Number above PEL (in clay-size fraction)
Arsenic	**7.24**	**41.6**	**103**	**10**	**1**
Cadmium	**0.7**	**4.2**	**-**	**-**	**-**
Chromium	**52.3**	**160**	**0**	**78**	**36**
Copper	**18.7**	**108**	**0**	**112**	**2**
Lead	**30.2**	**112**	**5**	**108**	**1**
Mercury	**0.13**	**0.7**	**-**	**-**	**-**
Zinc	**124**	**271**	**4**	**110**	**0**

Chemical contaminants often become incorporated into aquatic sediments. Their horizontal and vertical distribution in the sediments provides a valuable record of where and when contamination has occurred. The Geological Survey of Canada (GSC) has collected seafloor sediments throughout Hudson Bay, using grab samplers. Henderson (1989) reported the data from these samples, which provide an overview of the surficial distribution of many important elements. These results cannot be compared directly with ISQG and PEL values because they refer only to the clay fraction and not in the unfractionated sediment, but the error is likely conservative since metals are usually more abundant in clay-sized particles than in larger particles. Vertical core samples of the bottom sediment have been used to examine the deposition history at a few locations.

The distribution of elements for which sediment quality guidelines have been established found little evidence of contamination. The highest concentrations of arsenic are mostly located in central Hudson Bay. The levels reported likely indicate a natural background for arsenic in fine sediment particles distributed by natural processes. Most of the sites with chromium over the PEL were offshore in southwest Hudson Bay, suggesting the possibility of chromium-enriched sediments originating from drainages entering Hudson Bay from the west. It is not known whether the existing levels in the sediment represent a risk to the biota of southwestern Hudson Bay. In general, the highest copper values were found off the west coast of Hudson Bay near the Churchill River. Copper enrichment has also been found in the sediment north of Arviat and between Chesterfield Inlet and Rankin Inlet. The distribution of copper may be explained by sediment transport offshore from Kivalliq. Only one site exceeded the PEL for lead. The core profile data suggest that Hudson Bay has received inputs of anthropogenic lead over the last century, probably from atmospheric fallout. There is no obvious clustering of high or low zinc values. Copper, lead, and zinc concentrations from bulk surficial sediment samples taken at five Ontario rivers immediately before they enter Hudson Bay or James Bay were well below those from the clay-size sediments from Hudson Bay.

No Interim Sediment Quality Guidelines have been established for aluminum, calcium, cobalt, iron, magnesium, manganese, molybdenum, nickel, or potassium. Several of these are major components of the

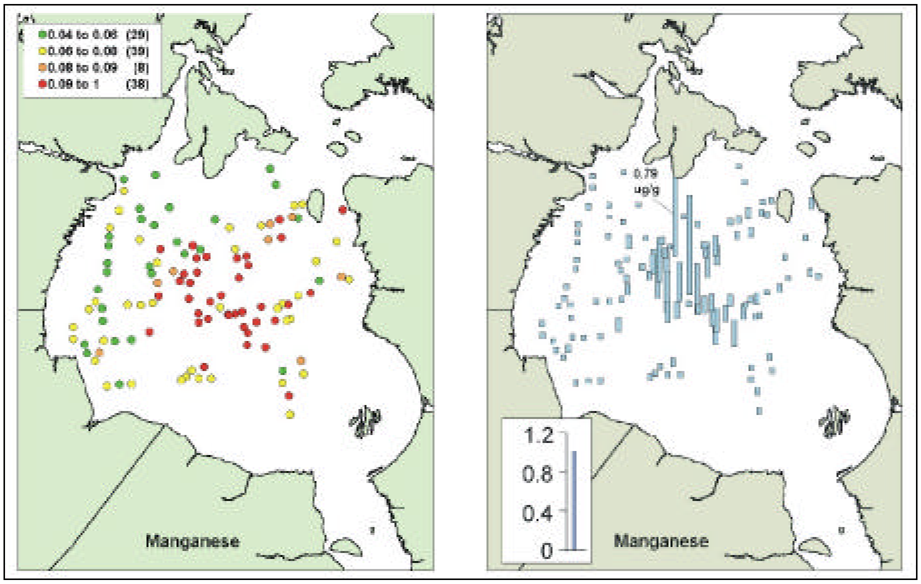

Figure 40. Manganese (ì g/g dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (right); same data shown as bars with bar heights proportional to concentration of manganese (right).

earth's crust and the concept of ISQG does not apply. Others are trace metals for which ISQG values have not been established. These elements, along with oxygen, silicon and sodium, are the major components of the earth's crust. Conditions in the deeper areas of central Hudosn Bay likely favour the diagenesis of manganese (Figure 40). The presence and levels of these elements in the sediments of Hudson Bay do not infer anthropogenic impacts.

Mercury is present naturally in the environment of Hudson Bay but is also added by a number of human activities. The GSC samples were not analyzed for mercury, so its distribution the surface sediment of the Hudson Bay seafloor is unknown. Given the problem with mercury in Arctic animals generally, an appropriate sub-set of sediment samples held by GSC should be analyzed for mercury. Mercury levels in core samples taken from southeast Hudson Bay and from VanVeen dredge samples taken near Rankin Inlet were well below the ISQG and PEL values. They do not portray a problem with mercury. Surveys of mercury in aquatic sediments have identified some high values in the drainages to the southwest of Hudson Bay (Figure 41). However, regional climate warming might result not only in habitat change but also in changing fluxes of materials to Hudson Bay. In the case of mercury, for example, warming of permafrost-dominated basins to the west of Hudson likely increases the erosion of particles and methylation of inorganic mercury, and hence biological accumulation of mercury. This might be detected most readily by sedimentation studies in selected estuaries.

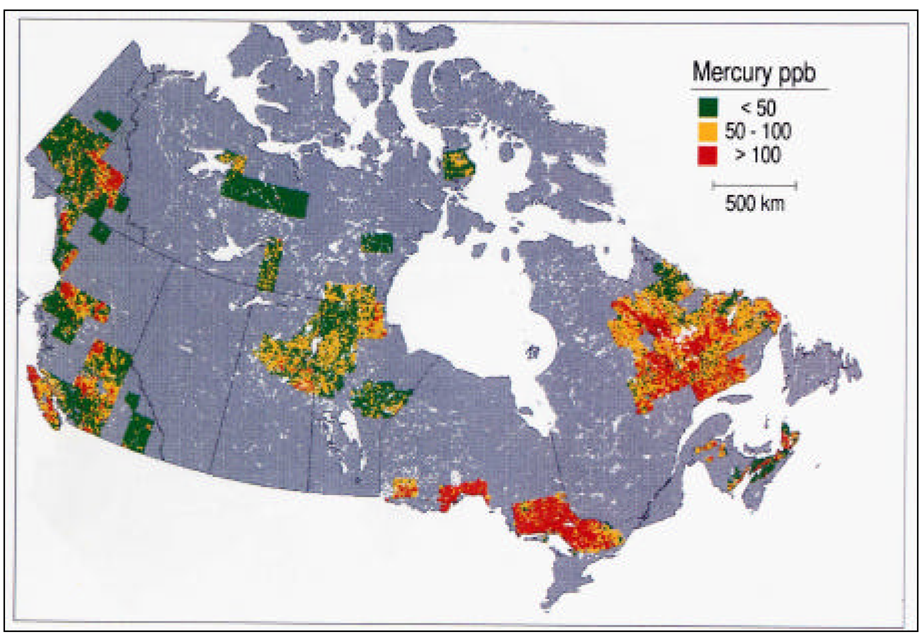

Figure 41. Mercury in lake and stream sediment samples (from Painter *et al*. 1994, page 226).

Despite the low levels of mercury in the sediments, there is a persistent problem with accumulations of mercury in marine animals high in the food chains. Two guideline figures are used in efforts to limit human intake of mercury. Concentrations should not exceed 0.5 ì g/g (wet weight) in fish sold commercially in Canada, and levels should not exceed 0.2 ì g/g in fish used for subsistence.

So little is known about mercury levels in marine fish of Hudson Bay that the few scattered reports available do little more than establish the need for a systematic survey of levels of mercury in marine fish and their supporting food chains. Levels are sometimes high enough to raise questions regarding subsistence consumption. However, mercury levels in anadromous charr are considerably lower than those in predatory landlocked fishes, such as lake trout, implying that feeding at sea supplies less mercury than feeding in lakes. There is evidence that hydroelectricity projects on the La Grande River have exported mercury downstream to marine habitat. A systematic survey of mercury in marine invertebrates and fishes will be required to determine the impacts of existing and future developments in the watershed, and the effects of climatic warming in western Hudson Bay watersheds.

Of all northern animals, marine mammals generally have the highest levels of mercury. Most chemical residue analyses have been done with ringed seals, beluga whales and polar bears. Ringed seal and beluga whale livers contains high levels of mercury but only a small proportion of it is present as neurotoxic methylmercury. Mercury levels seem to have increased since the mid- 1980s at Arviat and possibly at Sanikiluaq, although the latter collections were only four years apart (Figure 42). The whales harvested near Arviat summer downstream from the Churchill-Nelson hydroelectric development. The levels of mercury in the whales vary greatly among organs.

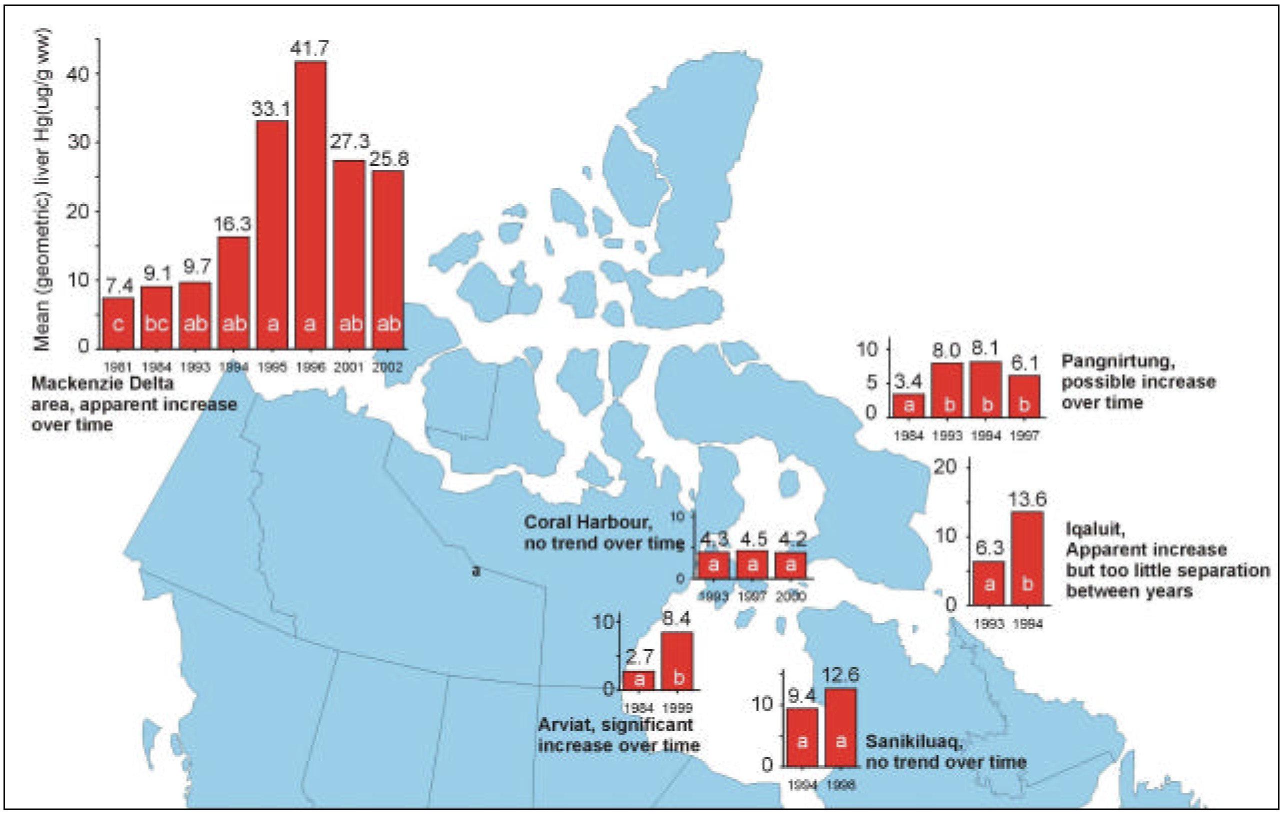

Figure 42. Mean concentrations of total mercury (ì g/g wet weight, adjusted for whale age) in liver of beluga whales from several sites in northern Canada from 1981 to 2002 (Figure modified from Lockhart *et al*., presented at Northern Contaminants Program symposium, Ottawa). Figures at the bases of the bars are years when samples were obtained; figures at the tops of the bars are least square geometric means; letters on the bars indicate statistical differences by Duncan's test.

Since the whales' major intake of mercury is from dietary methylmercury, the presence of a high proportion of apparent HgSe in the liver may represent a metabolic detoxification mechanism to bind the mercury as an inert form and render it non-toxic or at least less toxic. The levels of mercury in beluga, narwhal and ringed seal livers consistently exceeded those in walrus. One might expect polar bears to contain higher amounts of mercury than their prey but this is not the case. This apparent discrepancy is explained by the fact that the bears eat only the blubber of the seals, not the protein-rich organs like muscle and liver where more mercury is found.

The data from sediments available to date do not suggest a contamination problem with cadmium. The value given for cadmium in liver of seals from Arviat was about 12 ì g/g. This appears to be below the threshold for biological effects, which is 20-200 ì g/g. A small proportion of the seals would reach or exceed the lowest part of the effects range.

Levels of some organochlorines and mercury in some of the animals are high enough in some instances to pose a risk of biological injury. There is an almost complete lack of experimental work to find out whether existing levels are meaningful biologically. While this is understandable with some of the large species, toxicology experiments can and should be done with some of the smaller animals like fish and invertebrates and with common laboratory surrogates for the large mammals.

3.4 CLIMATE CHANGE

There is persuasive evidence that the climate is changing, in Canada and around the globe. However, statistical evidence for change in the Hudson Bay basin is limited, as there have been few regional studies and the wide variability of temperature and precipitation over time and space within the region makes relatively subtle long-term trends difficult to detect. Changes have been observed in air temperature and precipitation, and they are manifest in stream flow into Hudson Bay and in the sea ice and biota. There is evidence of warming in western Hudson Bay and cooling in the east, of earlier ice-breakup at lakes southwest of Hudson Bay, and of increasing annual precipitation with trends toward greater precipitation in spring, summer and autumn. River discharges are peaking earlier in the spring from Manitoba to Quebec, while their total discharge has decreased in central Manitoba and increased in the Kazan River, northwest of Hudson Bay.

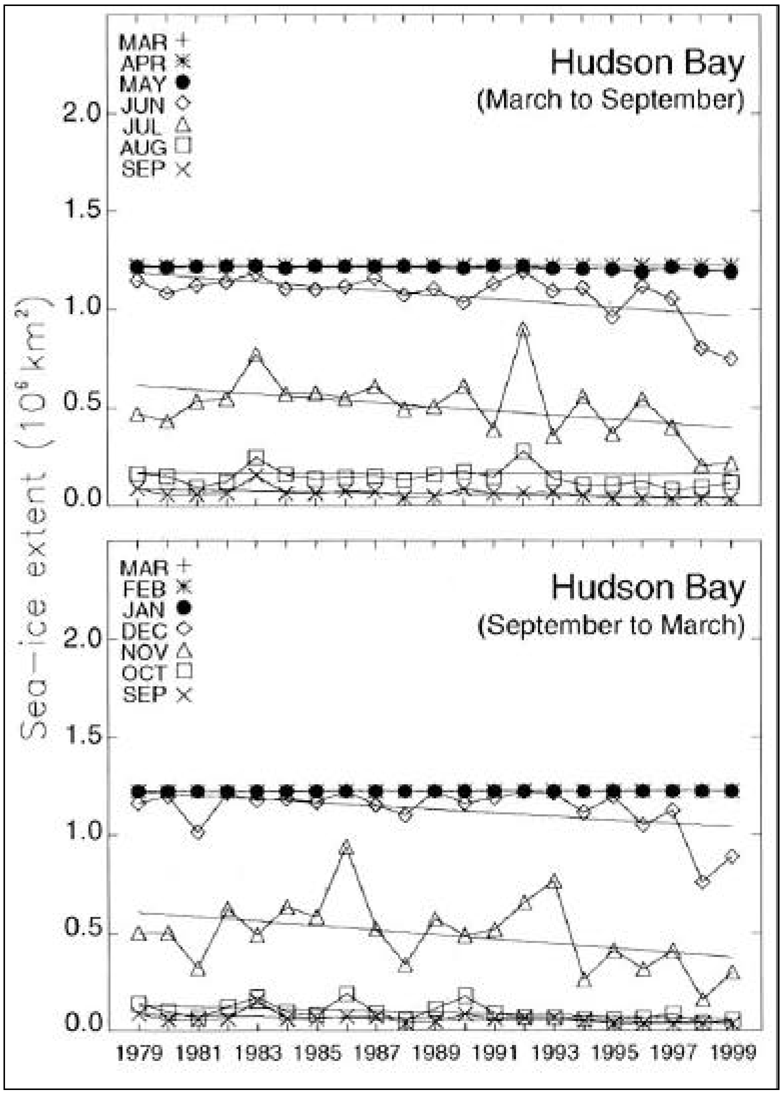

Figure 43. Time series of monthly sea-ice extents, arranged by month, the for Hudson Bay-James Bay-Foxe Basin-Hudson Strait area (from Parkinson and Cavelieri 2002:443). The top plot presents results from March-September, the bottom plot presents results for September-March. Lines of linear least-squares fit are included for each month.

Perhaps the most telling evidence of climate change in Hudson Bay is in the ice cover record derived from Satellite passive-microwave data (Figure 43). The extent of the ice cover in the Hudson Bay-James Bay-Hudson Strait-Foxe Basin area has been decreasing in June and July and in November and December, indicating that the ice is melting earlier in the spring and forming later in the fall. Over the 21-year period 1979-99, the yearly-average extent of sea ice concentrations with over 15% coverage was 798,000 km^2 with a decreasing trend of -4,300 ± 1,400 km^2a^{-1} (99%CI; P≤0.01). Most of the decline in the yearly averaged ice cover occurred in the 1990's. From 1979-96, the length of the sea ice season decreased in northwest Hudson Bay and along the southern coasts of Hudson Bay and James Bay, but increased in east central Hudson Bay and near the Belcher Islands and Akimiski Island (Figure 44). If the observed changes are tied most closely to Arctic warming that continues, then the ice cover is likely to continue to

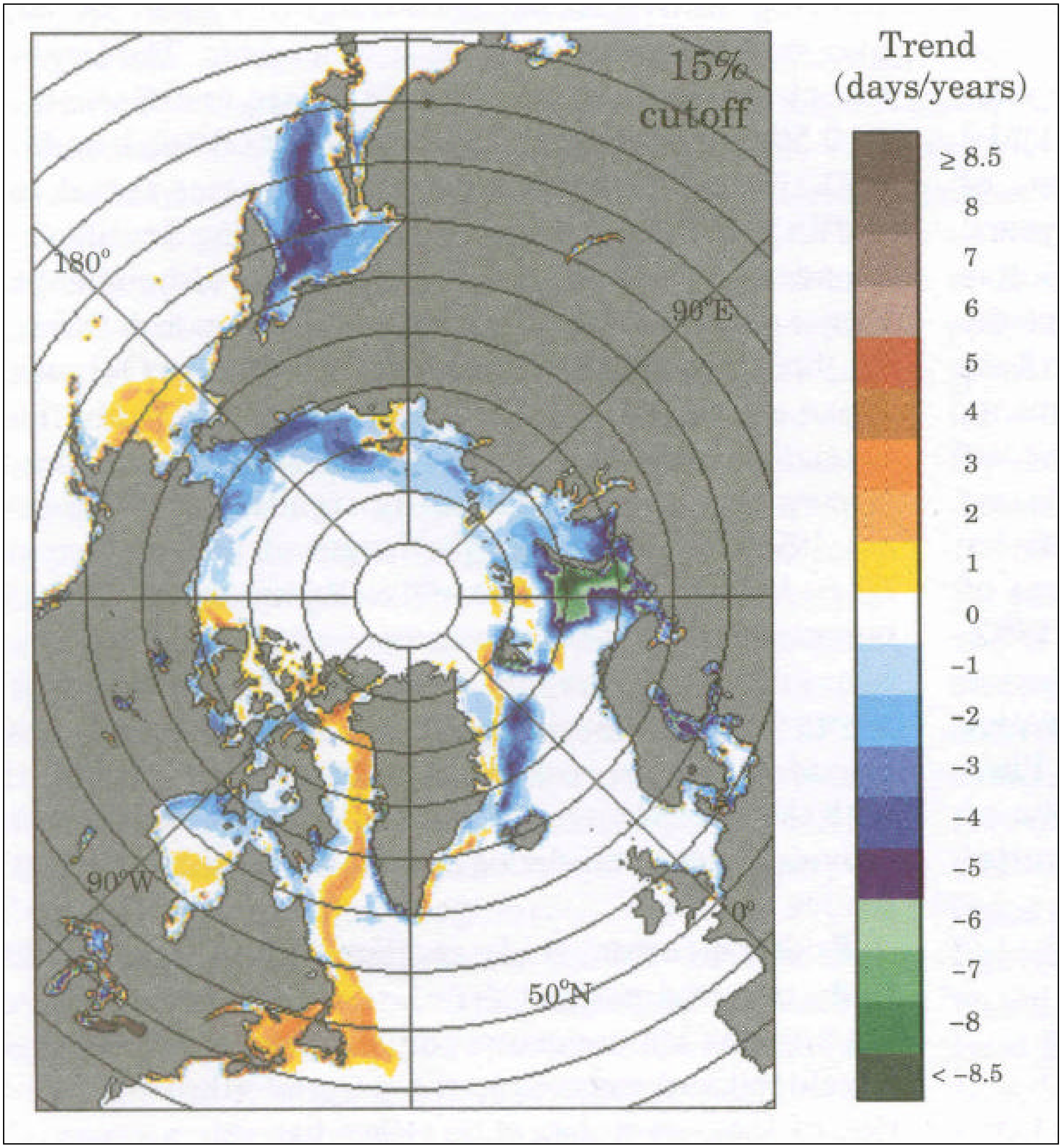

Figure 44. Trends in the length of the sea ice season from 1979 through 1996, calculated at each 10 km^2 grid cell as the slope of the line of linear least squares fit through the 18 years of season length data (from Parkinson 2000b:353). The length of the sea ice season was defined as the number of days with calculated ice concentration ≤15%. Ice concentrations were derived from satellite data.

decrease; but, if the sea-ice changes are tied more closely to oscillatory changes in the climate system, such as the North Atlantic Oscillation and the Arctic Oscillation, then sea ice cover will likely fluctuate. This uncertainty means that extrapolations of decreases seen in the sea ice cover in the 1990's should be done with caution. The impact of changes in ice cover on the freshwater budget and regional oceanography is difficult to predict, as ice thickness cannot yet be measured by satellite.

Climate change may also be affecting the polar bears in western Hudson Bay. As the top carnivores at the southern limits of their distribution, they are the "canaries in the coal mine" for regional climate change. Their dependence on ice cover makes them very vulnerable to changes in its quality, distribution, and duration. Recent declines in body condition, reproductive rates and cub survival, and an increase in polar bear-human interactions, suggest that these bears are under increasing nutritional stress. These changes have been correlated with earlier breakup and later freeze-up that have increased the ice-free period, reducing feeding opportunities and prolonging their fast.

While many scientists agree that there is a high probability of global warming during the next century, they are less certain about its rate, extent, and regional effects. Elaborate computer models have been developed to improve understanding of how the climate may respond to increases in greenhouse gas concentrations. These “general circulation models or GCMs” often simulate the type of climate that might exist if global concentrations of carbon dioxide were twice their pre-industrial levels. They use mathematical equations to represent physical processes of the climate system—particularly those involving radiation, heat and motion and the water cycle; and to calculate the interactions between these processes. Strictly speaking, they are not predictive models but rather a means of determining the sensitivity of the climate system to a change in one of its key elements.

Climate change scenarios derived from these models must be used with caution, as they are very sensitive to the choice of modeling parameters and different models can yield very different results. A model that more accurately represents the regional oceanography year round is being developed and will be embedded into a larger climate model to improve its predictive ability for Hudson Bay. Improvements are also needed to the atmospheric model, particularly with respect to low-level atmospheric fields (e.g. lower winds and higher temperature) and the effects of aerosols.

The GCM developed by the Canadian Centre for Climate Modelling and Analysis (CCC92) predicts a winter warming of up to 10°C and summer warming of 1-2 °C by 2100 in central Hudson Bay; smaller increases are predicted in winter (6-9°C) and greater increases in summer (2-5°C) along the coasts. Precipitation scenarios from this model suggest a general increase in precipitation in the Hudson Bay region of between 0 and 30% for a doubling of atmospheric carbon dioxide. Precipitation should increase throughout much of the region over most of the year, but mainly in summer and autumn. In winter and spring, northwestern Hudson Bay may receive less precipitation than at present. Glacial melting and thermal expansion of the world’s oceans caused by climate warming may slow, halt, or even reverse the rate of coastal emergence in Hudson Bay and James Bay by offsetting the effects of isostatic rebound. Results of 3-dimensional modelling analyses suggest that this rise will decrease the rate of coastal emergence by at least 75% for a 3°C warming of the earth’s surface. The physical impact of this change would be least along low-lying coastal sections of James Bay and southern Hudson Bay, where the fastest isostatic rebound is occurring.

The strong climatic linkages between Hudson Bay and its surroundings mean that coastal environments may be doubly impacted by climate change. They will be warmed more by overall global temperature warming and cooled less during the growing season by air originating over Hudson Bay. This will increase evapotranspiration from the wetlands; causing them to dry and reducing water yield for stream flow. It will cause permfrost degradation and favour northward movement of vegetation zones. The Arctic Tundra biome may shrink until it is confined largely to the Arctic Islands. Infilling by the taiga biome may not keep pace with the very rapid speed at which climatic warming is expected to occur. Within the existing treeline, the species composition of the forests is likely to change. More water may be stored underground and runoff may decrease. This could change the flow regime such that rainfall events rather than smowmelt dominate. Warmer drier soil conditions may cause the peat soils of wetland tundra to release rather than accumulate carbon dioxide from the atmosphere. The natural incidence of forest fires may increase. Climate change may simply cause a spatial shift of an ecozone or climate region, or it may create a new type not previously observed.

Recent studies suggest that ice cover in Hudson Bay and James Bay will be reduced by climate warming but do not agree on the extent of the reduction. Some GCMs suggest that Hudson Bay may become ice free in winter. A three-dimensional coupled ice-ocean model suggests that a simple 2°C increase in air temperature might reduce volume of the sea ice produced in Hudson Bay by 20%, increase summer sea surface temperature by 4°C, and cause a two-week advance of breakup and delay of freezup. A comparison of sea ice concentration to melting degree day data suggests that warming of 1° C could advance ice break-up as much as two weeks in parts of the Bay. Because melting sea ice contributes more fresh water to Hudson Bay than does runoff, any change in ice cover will alter the freshwater budget, with wide ranging effects on the oceanography and ecology.

The reduction or loss of seasonal ice cover has major implications for the Hudson Bay marine ecosystem. A progressive loss of ice cover would initially increase and eventually reduce or eliminate polynya and ice edge habitats that are important areas for the exchange of energy between ecosystems. It would increase surface salinity by reducing or eliminating salting out during freeze-up, and the dilution of surface waters by freshwater inputs from melting sea ice. With a thinner layer of low salinity water at the surface, and longer open water period, wind mixing should make more nutrients available to primary producers in the upper water column. More of the light incident at the surface would be available to primary producers. Damage to plants and bottom habitats caused by freezing and ice scour would decrease, and ice habitats and their associated biota would be reduced or eliminated. A shorter duration of ice cover when coupled with stronger winds would likely increase coastal erosion, although because much of the coastline is low-lying or rocky, these changes are unlikely to be severe as in areas with steep, unconsolidated shorelines such as the Beaufort Sea. More severe wave development would be favoured and storm surges could also become more frequent.

Climate change has the potential to affect the spatial distribution of biota in and around the Hudson Bay marine ecosystem. There may be shifts in the geographical distributions of individuals, species, and whole communities. Arctic biota that cannot adapt to warming will be selectively eliminated from the Hudson Bay marine ecosystem. Ice-adapted species, such as ice algae, sympagic amphipods, polar bears, and ringed and bearded seals, will the most affected. They may be reduced or eliminated. Breeding populations of polar bears could disappear from the region well before seals are seriously affected by reductions in seasonal ice cover. Warming may favour species such as belugas, bowheads, and harbour, harp and hooded seals that are not dependant upon ice habitats. The effects of ice habitat loss on narwhals are uncertain, given their great affinity for areas with seasonal ice cover, while the direct effects on walruses may be limited and not necessarily negative. Climatic warming may increase the opportunity for north temperate species to invade Hudson Bay. However, most aquatic species will have to do so via Hudson Strait, which may remain unfavourably cold. Relict species that live in James Bay may invade Hudson Bay. The lag between Arctic species receding and temperate species invading will likely reduce the biodiversity of southern Hudson Bay for some time.

While the end result of warming that is significant enough to reduce the ice volume in Hudson Bay and James Bay is likely an increase in biological productivity, the direction and degree of change at any time during the transition is impossible to predict given the complexity of the ecosystem. Climatic warming may cause shifts in the overall productivity of communities and species, and in the relative productivity of populations within a community. The overall marine production will rise and fall as species respond to climate change but should increase over the long term, as there will be more light and nutrients available for plant growth. The reduction or elimination of ice scour and surface freezing will enable more plants and invertebrates to colonize the nearshore zone. Offsetting these changes will be the loss of production by ice algae and ice-adapted biota. This will affect the sustainable harvest that individual species and particular locations can support. Each species' share of the available production will depend on how well it is adapted to the new climate conditions. The sustainable harvests of some species may increase while that of others may decrease or fall to zero. Scallops and mussels, for example, may grow faster and larger. Arctic charr may become more productive over the short term, in response to increased nearshore production, but over the long term may be replaced by other piscivorous fishes, such as northern pike and brook trout, that move northward to take advantage of new favourable habitats. The effects on other marine mammals species are less certain and could be positive.

Migratory birds visiting the Hudson Bay marine ecosystem are heavily dependant on appropriate time and space linkages for successful passage. Given the dependance of so many species on the timing of break-up and freeze-up, changes to either could have extremely wide-reaching effects. Likewise, any reduction in the size or quality of saltmarsh habitats that breeding waterfowl depend upon for food would adversely affect breeding success. Altering the rate of coastal emergence may reduce the extent of coastal salt marshes, as inland vegetation will tend to encroach on the marsh and new marsh will not be created at the same rate on the seaward side. Changes in coastal vegetation and wildlife could also reduce breeding success and cause species that breed on the tundra to relocate northward. Cliff-nesting seabirds would have earlier and longer access to marine resources. Changes in the relative abundance of prey species may cause some species, such as the thick-billed murre, to alter their diets and may attract other species, such as razorbill, to colonize the area. Birds using the Hudson Bay marine ecosystem on a seasonal basis may also be impacted by the effects of climate change in areas outside the region, where they lay down the fat stores necessary for successful breeding.

Climate change will effect major changes in the life style, housing, travel, harvesting, and health of people who live along the coasts of Hudson Bay and James Bay and use the resources of the marine ecosystem. It may fundamentally alter the resource base of communities, such that traditional knowledge is no longer applicable. Dietary and epidemiological changes may result and affect the health of area residents. Harvesters may have to adapt by targeting new species and developing new harvesting strategies. Inuit knowledge of sea ice conditions may have an important contribution to make in the interpretation (ground truthing) of remote sensing images for subtle changes in ice formation over time.

4.0 CONCLUDING REMARKS

One of the main stumbling blocks to the assessment of the cumulative impacts of stressors on the Hudson Bay marine ecosystem is the lack of information. Despite an impression to the contrary created by the many references to the region in the literature, in-depth information is only available for a few topics and areas at selected times of the year.

Most research has been conducted during the open water period near large estuaries, often immediately downstream from existing or proposed developments and seldom for more than a few sampling seasons. Few data have been collected during the period of ice cover (roughly mid November to mid-July), from offshore and shallow nearshore waters, or below 50 m depth.

Taxonomic coverage has been uneven and few studies have examined either trophic relationships or biological productivity. In consequence, there is little information on seasonal or inter-annual variation in the physical and biological systems. Indeed, we can only speculate as to what happens under the ice in winter, the importance of the spring ice algal bloom, how dependant beluga are on the large estuaries, and why bowhead whales concentrated in large numbers in northwestern Hudson Bay. Many vital pieces of information, such as the tolerance of beluga to changes in estuarine conditions, are also unknown. These gaps in research coverage make it difficult to identify and understand trends of change in the region, and to discern whether they result from variations in the natural environment or from human activities.

Research will be necessary to develop an understanding of how and why changes occur, and to understand and predict any cumulative impacts from development. Given the existing data there is a risk that important aspects of the oceanography may be ignored or misinterpreted in assessments. There may be great danger in applying what little knowledge we do have to other areas of the region, or in extrapolating it to other seasons or years.

Research coverage of the region has been limited by the difficulty and cost of sampling. Persistent, shifting pack ice; inclement weather; shallow shorelines; poor visibility; and remote location are only some of the factors that make sampling difficult. While funds have been allocated to studies immediately downstream from existing and proposed developments, elsewhere the research coverage has often been limited to the higher trophic levels. The demonstrated lack of commercially exploitable natural resources and the remote location have also limited research funding.

The magnitude of the information required, the importance of understanding the regional oceanography, and the constraints to research make it vital that research efforts be focussed to make best use of the available resources. One way of doing this is to improve communication, particularly between people with traditional ecological knowledge (TEK) of the region and members of the scientific community.

The knowledge of these two groups is complementary. The local people can offer the benefit of their long-term on-site observations; the scientists their research and interpretive skills. Improved communication between the groups should enable scientists to make better-informed research decisions, and to better support and address the concerns of area residents. Through such cooperation, the route to understanding important aspects of the regional environment may be shortened.

5.0 ACKNOWLEDGMENTS

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