XIX-62 Hudson Bay: LME #63

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The Hudson Bay LME is a vast, shallow, semi-enclosed LME, bordered by the Canadian provinces of Quebec, Ontario, Manitoba and Nunavut and with a surface area of about 1,743,895 km^2, of which 0.42% is protected (Sea Around Us 2007). It is connected to the Davis Strait, Labrador Sea and Atlantic Ocean through the Hudson Strait, and to the Arctic Ocean by the Foxe Basin and the Fury and Hecla Straits. The LME receives Atlantic and Arctic marine waters, and freshwater from a vast watershed extending from the Northwest Territories to Saskatchewan and Alberta. The coastal zone geomorphology (low-lying areas, cliffs and headlands, and bottom topography) is still rebounding from the great weight of the Laurentide Ice Sheet that once covered the entire region. A unique oceanographic feature of this LME is its Arctic climate and variety of ecoclimatic zones, ranging from humid high boreal in the south to low Arctic. The LME has long, cold winters and short, cool summers. It is the largest body of water in the world that seasonally freezes over in the winter and becomes ice-free in the summer and it is significantly colder than other marine regions situated on the same latitude. Strong winds during the open water season, persistent low temperatures and the influx in the spring and summer of fresh water from numerous rivers and melting sea ice characterise the LME. Annual ice cover fluctuates with oscillatory changes in the climate system produced by the North Atlantic Oscillation and the Arctic Oscillation. There is extreme variation in the range of average temperatures and average total precipitation, both seasonally and annually, throughout the LME. Book chapters and articles pertaining to this LME include Stewart & Lockhart (2004, 2005).

I. Productivity

Three key features characterise productivity of the Hudson Bay LME: (1) the extreme southerly penetration of Arctic marine water; (2) a very large volume of freshwater runoff; and (3) the dynamic geomorphology of the coastal zone, with its low-lying marshes and wide tidal flats. Polynyas (open water areas in the ice, which are known to be biologically important throughout the Arctic) are found predominantly along the north-west and east coasts of the LME, in the James Bay and in the vicinity of the Belcher Islands, situated in the Southeast of the LME. The areas of ice cover and polynyas strongly affect the LME's physical and biological oceanography, the surrounding land, and human activities. In summer there is a strong vertical stratification of the water column, particularly offshore. This slows vertical mixing, precludes the transfer of nutrients to surface waters and limits biological productivity. In winter, reduced runoff, ice cover and surface cooling weaken this vertical stratification. The large volume of freshwater influences the timing and pattern of the ice cover breakup, the surface circulation, water column stability, species distribution, and biological productivity. Areas to the North of James Bay are characterised by complete winter ice cover and summer clearing, moderate semidiurnal tides of Atlantic origin, a strong summer pycnocline, and lower biological productivity (Stewart & Lockhart 2004).

The Hudson Bay LME is considered a Class II (150-300 gCm^{-2}year^{-1}) productivity ecosystem. Productivity appears to be lower than that of other LMEs at similar latitudes, and is enhanced in coastal waters, near embayments and estuaries, and near islands where there is periodic entrainment or upwelling of deeper, nutrient-rich water. A remarkably diverse microalgal community, consisting of over 495 taxa, exists despite the northerly latitude, Arctic character, and low productivity of the Hudson-James Bay system

(Stewart and Lockhart 2005). Migratory fish, marine mammals and birds use the varied range of habitats year-round or seasonally. The ability to exploit the brackish zone is an important ecological adaptation for both the Arctic freshwater and marine species. Fewer species are found toward the North where Arctic species predominate. The LME and its ice habitats are used by five species of seals (bearded, ringed, hooded, harbor and harp), and by whales, including bowhead, beluga, narwhals, killer whales, minke, sperm whales and northern bottle-nose whales. There are walruses, Arctic foxes and polar bears in the LME coastal areas and ice habitats. The quality, extent and duration of the sea ice cover determine the seasonal distribution, movements and reproductive success of all these mammals. The polar bear population in the Hudson Bay region is at risk as ice cover recedes and seal prey are less available.

A precautionary approach to setting catch limits for polar bear in a warming Arctic was adopted at the 14th meeting of the IUCN Polar Bear Specialist Group in 2005. Knowledge gaps on the structure and function of the food web make it difficult to identify and understand trends of change and to discern whether they result from natural environmental variations or from human activities. The seasonal ice cover effectively prevents year-round, bay-wide research. Taxonomic coverage is uneven or incomplete, with few studies examining trophic relationships, biological productivity, and seasonal or inter-annual variation in the LME's physical and biological systems. Stewart and Lockhart (2005) who listed species that frequent Arctic marine waters: at least 689 invertebrate species, 61 fish species, marine mammals (5 species of whales, 5 species of seals, walrus, polar bear), and 133 species of seabirds. In addition, it is pertinent to highlight the importance and diversity of the ice algal community in Hudson Bay,including at least 155 taxa of which most (142) are diatoms.

Oceanic Fronts (Belkin *et al.* 2009) (Figure XIX-62.1): This LME appears relatively uniform as it features just a few comparatively weak fronts, mainly around its periphery. The most robust thermal front is observed in the far south, within James Bay, probably related to the enhanced freshwater discharge into the apex of James Bay that generates a collocated salinity front.

Similar estuarine fronts are likely to exist elsewhere off the bay's eastern, southern and western shores, peaking after spring freshets. A meandering front develops in the northern part of Hudson Bay between waters that flow into the bay from the northwest and resident waters. This front develops seasonally; its location and TS-characteristics ultimately depend on the seasonal ice cover melt since the latter determines the amount of fresh water released by the melting sea ice and eventually determines the salinity differential across this front.

Hudson Bay LME Sea Surface Temperature (Belkin 2009) (Figure XIX-62.2):
Linear SST trend since 1957: 0.59°C.
Linear SST trend since 1982: 0.28°C.

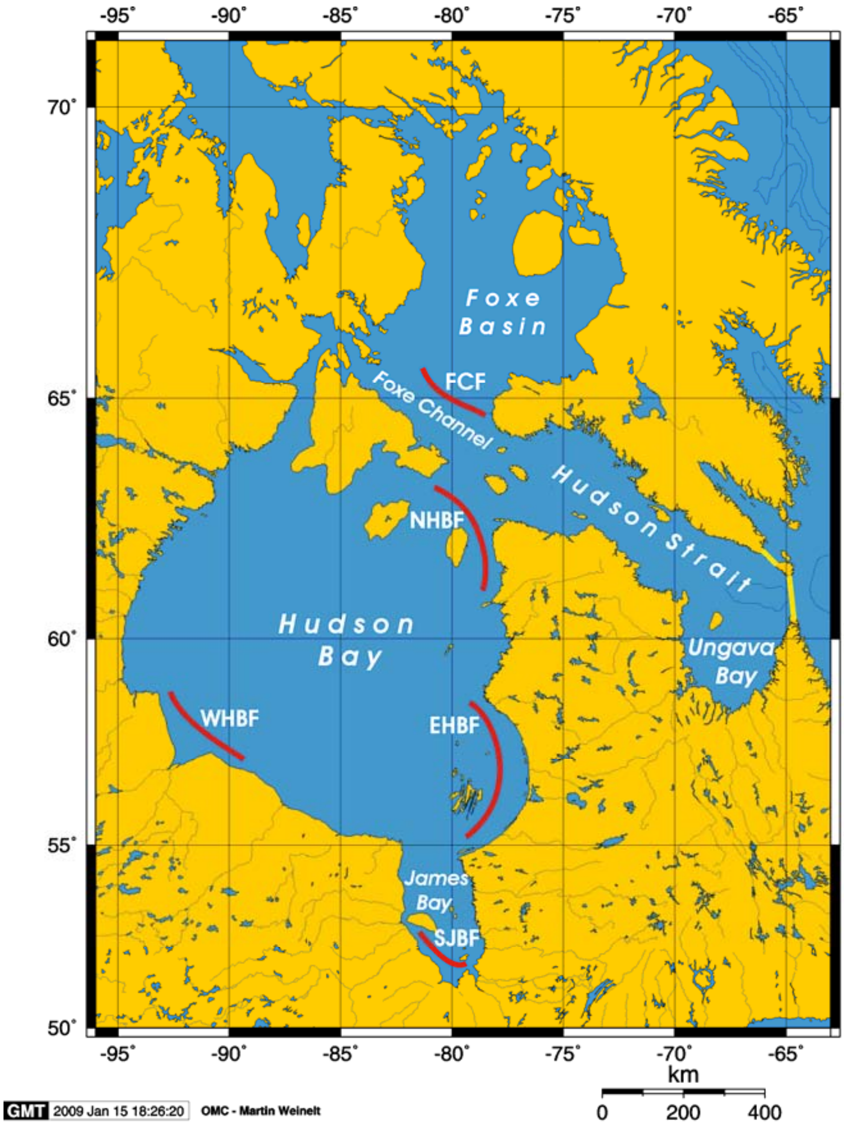

Figure XIX-62.1. Oceanographic fronts of the Hudson Bay LME. EHBF, East Hudson Bay Front; FCF, Foxe Channel Front; NHBF, North Hudson Bay Front; SJBF South James Bay Front; WHBF, West Hudson Bay Front. Yellow line, LME boundary. After Belkin *et al.* (2009).

The Hudson Bay warming was steady but moderate-to-slow. The all-time minimum of -0.1°C was achieved in 1972, in the end of a long-term cooling epoch. The post-1972 long-term warming resulted in an SST increase of >1°C over the next 20 years. The all-time maximum of 1.6°C in 1999 was an isolated event. The long-term decrease of river freshwater discharge into the Hudson Bay caused salinization of the upper ocean (Déry et al., 2005), so that there are two modern trends – warming and salinization – that have opposite effects on water density, which decreases with rising temperature and increases with rising salinity. Circulation in Hudson Bay flushes melt water out of the Bay into Hudson Strait and eventually onto the Newfoundland Shelf. Therefore the continuing warming of the Hudson Bay is bound to affect the Newfoundland Shelf. Significant asymmetry was found in temporal trends of landfast ice thickness between western and eastern sides of the Bay (Gagnon and Gough, 2005). First, "significant thickening of the ice cover over time was detected on the western side …., while a slight thinning … was observed on the eastern side" (Gagnon and Gough, 2005). Second, "this asymmetry is related to the variability of air temperature, snow depth, and the dates of ice freeze-up and break-up" (Gagnon and Gough, 2005). These results contradict numerical models of general circulation and field results obtained in other areas of the Arctic.

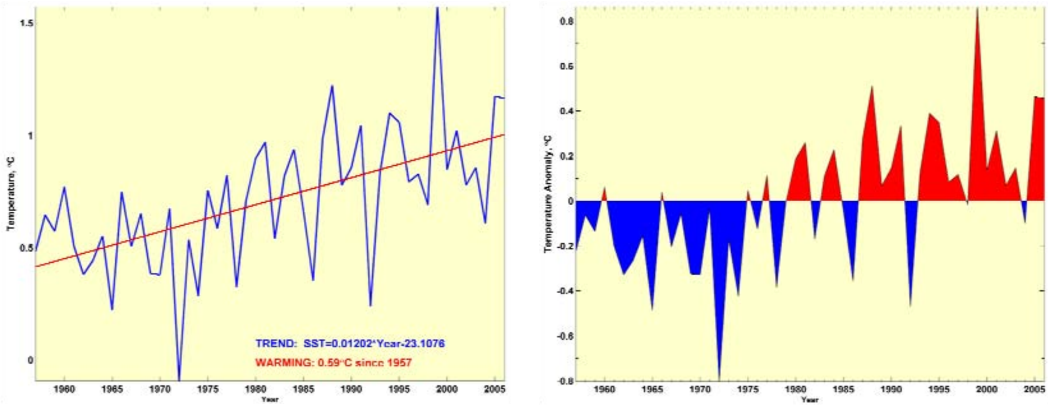

Figure XIX-62.2. Hudson Bay LME annual mean SST (left) and SST anomaly (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

Hudson Bay LME Chlorophyll and Primary Productivity

This LME is a Class II moderate-high (150-300 $gCm^{-2}year^{-1}$) productivity ecosystem (Figure XIX-62.3).

It is difficult to measure the contributions of phytoplankton, ice algae, benthic algae and benthic macrophytes to primary production in the marine ecosystem. Stewart and Lockhart (2005) point out the difficulty of sampling at breakup when the main phytoplankton bloom likely occurs.

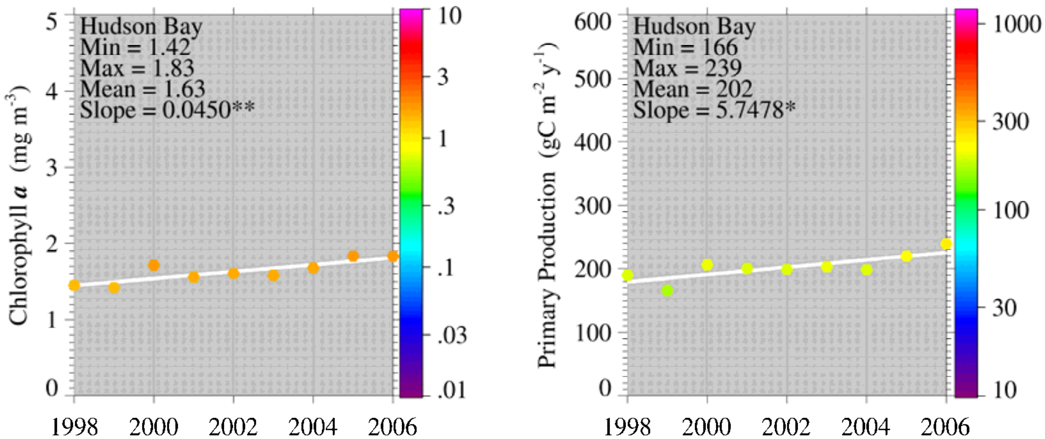

Figure XIX-61.3. Hudson Bay LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

A subpycnocline chlorophyll ***a*** maximum occurs in the offshore waters of Hudson Bay in the summer (Stewart and Lockhart 2005).

II. Fish and Fisheries

The Hudson Bay LME supports around 60 species of fish, consisting of a mix of Arctic marine, estuarine and freshwater species. This shallow LME lacks the deepwater species that inhabit the Hudson Strait. The typically Arctic mollusk species are more common and abundant offshore. The more significant marine resources are to be found in Foxe Basin, near the Fury and Hecla Strait. The Cree and Inuit catch most fish from estuarine or coastal waters during the open water season. Fishing is mainly for food, and as a traditional social and cultural activity. Exploited species include anadromous cisco, whitefish, longnose sucker, brook trout, capelin, cod, sculpin and blue mussels (*Mytilus edulis*). Indigenous peoples also catch seals, walrus and whales, and trap muskrat and beaver. Migratory waterfowl are a significant portion of the Cree and Inuit diet in the eastern Hudson Bay.

Of importance in this LME are largely unreported subsistence fisheries of the local Inuit and Indian populations, as described in Booth & Watts (2007). Twenty-four communities situated around the Hudson and James Bays make use of its resources, and the human population of these communities has grown from approximately 4,000 in 1950 to over 19,000 in 2001. Catches mainly target Arctic charr (*Salvelinus alpinus*) and Arctic cod (Boreagadus saida), although some other species are also taken, notably Atlantic salmon (*Salmo salar*) and Fourhorn sculpin (*Triglopsis quadricornis*). Estimated subsistence catches in 1950 were approximately 362 tonnes, and peaked in 1962 at 897 tonnes before declining to approximately 290 tonnes by the early 2000s (Figure XIX-62.4). A large portion of the decline over the last few decades is attributed to the fact that the snowmobile has replaced the dog sled as the major form of transportation, thus reducing the need for marine fish as dog food (Booth & Watts 2007).

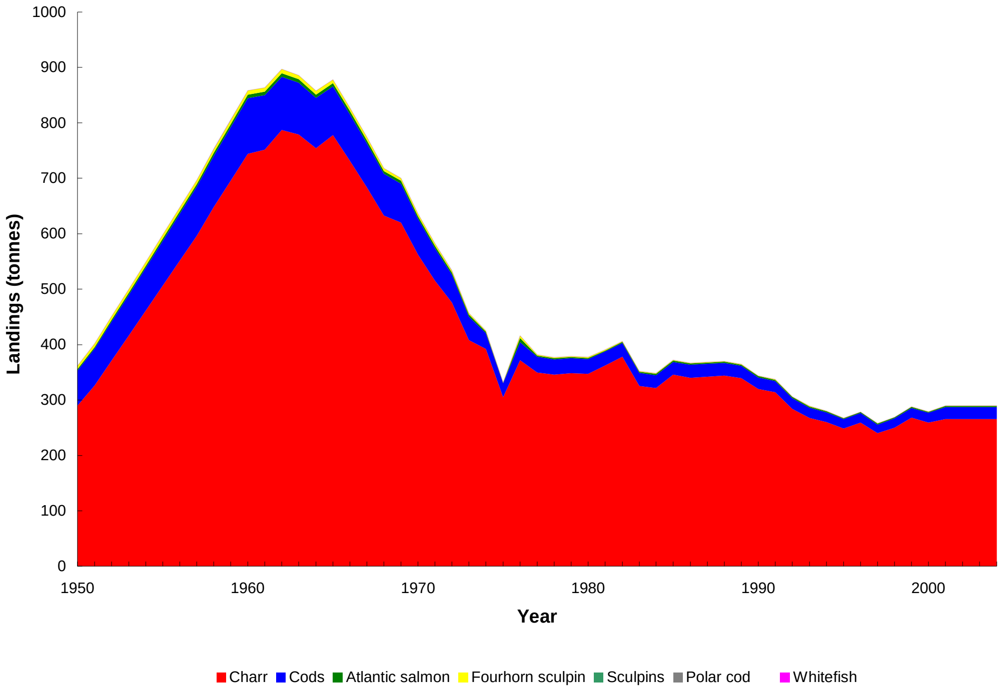

Figure XIX-62.4. Total estimated catches (subsistence fisheries) in the Hudson Bay LME by species (Sea Around Us 2007).
[No Figures 5, 6, 7, or 8]

Due to the tentative nature of these catch estimates, no indicators based on these data will be presented (but see Sea Around Us 2007).

III. Pollution and Ecosystem Health

Pollution: The Hudson Bay LME is relatively pristine. The human activities that can affect the natural environment of the LME are resource exploitation, marine transportation, mining, hydrocarbons, sewage disposal and the diversion of freshwater for industrial and agricultural purposes. The polynyas are thought to be affected by pollution as a result of the alteration in freshwater input to the southern Hudson Bay. Mercury levels in the La Grande River system rose considerably when a hydroelectric project began, but they are now declining. Slightly elevated mercury levels have been found in marine fish within 10 km to15 km of the La Grande River mouth. Marine mammals high on the food chain have the highest levels of mercury. Many Hudson Bay communities lack sewage and wastewater treatment facilities, and as a result, bacterial and chemical contaminants can be directly discharged into the sea. This is, however, offset by low temperatures and high salinity, which kill most pathogenic organisms. The impacts of marine ecotourism, while at present slight, are increasing. Visitors come to the port of Churchill (Manitoba) during the summer to see the beluga whales, polar bears and migratory birds. Cruise ships visit the northwestern Hudson Bay in the summer. Although there is a regular flow of ship traffic through the region, little has been altered along the coast except for the port of Churchill and for some small docking facilities. There is a risk of spills (oil, contaminants), and of introducing exotic species when bilges are cleaned.

Overall, the Hudson Bay LME is a relatively pristine environment. However, there is some evidence of the impacts of human activities on Hudson Bay with the presence in biota and sediments of synthetic persistent organic pollutants (POPs) which can reach the Arctic, and Hudson Bay, via long range transportation with moving air masses. Among the most toxic products found in Hudson Bay ecosystem, there are PCBs and radionuclides which result exclusively from human activities (Stewart and Lockhart, 2005). High levels of both DDT and PCBs have been reported from eastern part of Hudson Bay relative to other parts of the Arctic. High levels of PCBs were measured in human milk in coastal communities of northern Quebec (Cobb et al., 2001). In addition to POPs, toxic heavy metals have been found in this region. For example, a significant proportion of people living in coastal communities of northern Quebec has levels of blood mercury over the normal range (Cobb et al., 2001), whereas high levels of mercury have been observed in animals that are the highest in food chains, particularly some birds and marine mammals such as belugas and polar bears (Stewart and Lockhart, 2005)

Habitat and community modification: Low-lying rocky islands, tidal flats, tundras, salt marshes, eelgrass beds, coastal cliffs and open water polynyas are important habitats, used seasonally by migratory fish, marine mammals, migratory waterfowl and shore birds. The islands and coasts of James Bay provide critical habitats for breeding, feeding and moulting for a wide variety of species near the limits of their breeding distributions. Watersheds around the Hudson Bay LME are being altered as a result of population growth, business activity, agriculture, hydroelectric development and climate change. The pace of ecological change in the region seems to be accelerating if one draws upon the observations of indigenous populations who, for generations, have hunted and fished in this LME.

Hydroelectric installations have altered the timing and the rate of the flow of the La Grande and Eastmain Rivers, which drain into James Bay from the Province of Quebec, and of the Churchill and Nelson Rivers, which drain into southwest Hudson Bay from Manitoba. The long-term impacts of these diversions on the marine environment are currently unknown. Today the natural spring freshet into James Bay does not occur at the La Grande or Eastmain Rivers. The Eastmain River plume is significantly reduced, with saline intrusions occurring upstream over a distance of 10 km. The La Grande River now discharges 8 times more freshwater into James Bay, with the plume extending 100 km into the bay. Impacts might include changes in the duration of the ice-cover; changes in the habitats of marine mammals, fish, and migratory birds; changes in the system of currents flowing in and out of the Hudson Bay LME; changes in anadromous fish populations and in the seasonal and annual loads of sediments and nutrients; and changes in the biological productivity of estuaries and coastal areas.

There are concerns about probable climate change and sea level rise caused by global warming. Changes in air temperature, precipitation, stream flow, sea ice and biota are observed in the Hudson Bay LME, with evidence of warming in the western part, cooling in the eastern part, and an increasing trend of annual precipitation in the spring, summer and fall. The ice cover record (Stewart & Lockhart 2004) shows evidence of climate change. The loss of seasonal ice cover has major implications in the Hudson Bay LME: (1) an initial increase and subsequent reduction or elimination of polynyas and ice edge habitats that are important areas for the exchange of energy fluxes between ecotones; (2) an increase of surface salinity; (3) the dilution of surface waters by freshwater inputs from melting sea ice; (4) wind mixing, making more nutrients available to primary producers in the upper water column; (5) more surface light available to primary producers; (6) a decrease of damage to plants and bottom habitats caused by freezing; and (7) a reduction of ice habitats and their associated biota. Climate change has the potential to alter the spatial distribution of biota in and around the Hudson Bay LME, affecting ice-adapted species. However, the direction and degree of change is impossible to predict given the complexity of the ecosystem.

IV. Socioeconomic Conditions

The Hudson Bay LME is characterised by its remote location and by the non-commercial nature of its marine resources. European occupation began in the 1600s, with the exploration of the southeastern Hudson Bay and James Bay in search of a northwest passage to Asia. Today, the coastal areas of the Hudson Bay LME are populated by approximately 10,000 people living in 17 communities. Much of the local economy is based on subsistence hunting, trapping and fishing. Land settlement agreements with the Canadian government have given the Cree and Inuit title to large stretches of coast. Nunavut is the new Inuit territory, created in 1999. Many Inuit continue to harvest bowhead whales for food and as part of their cultural heritage. Ringed seals for the Inuit and the Cree, and bearded seals for the Inuit, are another very important natural resource. Waterfowl are also important to the regional economy, for subsistence and for sport hunting. The common eider is harvested year-round for its meat, feathers, skin, eggs and down. Some of the down is exported. Quotas exist for the number of bears that can be harvested. The sharing of the proceeds of hunting and gathering continues to be of great social, cultural and economic significance to both Inuit and Cree. There is a small fish smoking plant at Puvirnituq (Quebec). None of the Kivalliq fish processing operations has received enough fish consistently to meet operating expenses. The commercial exploitation of coastal marine and estuarine fish is conducted along the Quebec coast, and the fish is marketed through local cooperatives. Climate change could effect major changes in the lifestyle and resource use of the native peoples living in coastal areas, such that their traditional knowledge would no longer be applicable.

Several hydroelectric projects are in operation, or are planned, to divert or impound the renewable energy of the numerous rivers flowing into the Hudson Bay LME. At present there is no offshore mineral or hydrocarbon development, although exploration has taken place in the southwestern part of the bay. The region has a known potential for hydrocarbons, precious metals, diamonds, phosphates, gypsum and limestone. Construction, some tourism and government services are the other principal activities. A Hudson Bay shipping route is being envisaged to open up the Canadian prairies.

Churchill Harbor plays an important role in shipping, which is one of the most important activity that sustains the socio-economy of this region, along with tourism (e.g. polar bear watching).

V. Governance

The Hudson Bay LME waters are under Canadian federal jurisdiction. There is a federal responsibility to protect the integrity of the marine and fresh water ecosystems of the region. Under Canada's Oceans Act, the Department of Fisheries and Oceans (DFO) has a mandate to lead and facilitate the integrated management of all of Canada's estuarine, coastal and marine environments. The DFO is taking an ecosystem-based approach to integrated oceans management. In addition to the Oceans Act, several pieces of relevant federal legislation that apply to Arctic marine waters contribute to the conservation and protection of the Hudson Bay LME: the Fisheries Act, Canada Water Act, Canada Shipping Act, Arctic Water Pollution Prevention Act (up to 60°N), Species at Risk Act, Canadian Environmental Assessment Act, Canadian Environmental Protection Act. Main federal responsible authorities are Fisheries and Oceans Canada, Transport Canada, Environment Canada, Indian and Northern Affairs Canada.

The Nunavut Wildlife Management Board (NWMB) makes decisions relating to fish and wildlife in Nunavut. This includes setting quotas, fishing and hunting seasons and regulating harvesting methods, and approving management plans and the designation of endangered species (www.gov.nu.ca/nunavut/). Under the Northern Quebec Agreement (1976), Inuit and Cree are guaranteed certain levels of harvest which are to be maintained unless their continuation is contrary to Canadian principles of conservation. As opposed to the commercial and sport fisheries, subsistence fisheries by registered native peoples are not restricted by fishing area, season or harvest. The Cree and the Inuit may harvest migratory birds, and their eggs and down, year round. The NWMB has instituted a flexible quota system for polar bear hunts by Kivalliq communities and a community-based management of the Repulse Bay narwhal hunt, to provide communities with more responsibility in the management of their renewable resources. The NWMB relies on government departments for scientific research and advice, with scientists providing their research and interpretive skills. The local people contribute their on-site observations over time.

Wapusk National Park, Manitoba's Cape Churchill and Cape Tatnam Wildlife Management Areas, and Ontario's Polar Bear Provincial Park provide protection for marine mammals, birds and coastal wetland habitats along the south coast of the LME. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) provides assessment and makes recommendations about the status of species. Actually, species at risk are designated as such under the Species at Risk Act which is under the responsibility of Environment Canada (in general) and DFO (for marine species). The Committee on the Status of Endangered Wildife in Canada has designated the bowhead whale as endangered in the Hudson Bay LME and the beluga whale as threatened in the eastern part of the LME. There is ‘special concern’ for the Lac des Loups Marins subspecies of harbour seal and for the polar bear. The Ivvavik National Park and the Tuktut Nogait National Park include a marine component. The Canadian Arctic Resources Committee has proposed a Hudson Bay Programme, in an attempt to implement sustainable development policies in the region.

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