

XIX-60 Scotian Shelf: LME #8

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The Scotian Shelf LME is bordered by the Canadian province of Nova Scotia and extends offshore to the shelf break, more than 200 nautical miles from the coast. The area of this LME is 283,000 km², of which 0.87% is protected, and contains one major estuary, the St. Lawrence (Sea Around Us 2007). To the north the LME is separated from the Newfoundland Labrador Shelf LME by the Laurentian Channel, while to the south it extends to the Fundian Channel (Northeast Channel). The Scotian Shelf LME has a complex topography consisting of numerous offshore shallow banks and deep mid-shelf basins. It can be divided into eastern and western subsystems. The eastern Scotian Shelf LME includes Emerald Bank. The Nova Scotia Current hugs the coastline in a southwestward direction and enters the Gulf of Maine through the Northeast channel (Zwanenburg *et al.* 2002, Zwanenburg 2003). Book chapters pertaining to this LME are by Zwanenburg *et al.* (2002) and Zwanenburg (2003).

I. Productivity

The Scotian Shelf LME is considered a Class II, moderately high productivity ecosystem (150-300 gCm⁻²yr⁻¹). Productivity is influenced by changes in environmental conditions and temperature. A decrease in ambient temperature is noted on the eastern Scotian Shelf for the period 1980-1992 (Zwanenburg *et al.* 2002). The recent changes to research vessel survey protocols broaden the collection of ecosystem monitoring data to include abundance and distribution of phytoplankton, zooplankton, as well as an increased suite of physical oceanographic parameters. A monthly Continuous Plankton Recorder Survey is being conducted in collaboration with the Allister Hardy Foundation, Plymouth, England. There has been an exponential increase in grey seal abundance since the 1960s. Harp, hooded and harbour seals are found in the Gulf of St. Lawrence and so are Beluga whales.

Oceanic fronts (Belkin *et al.* 2009) (Figure XIX-60.1): The Shelf-Slope Front (SSF) along the Scotian Shelf/Slope bounds this LME and is associated with the southward cold, fresh Labrador Current, augmented by fresh discharge from the Gulf of St. Lawrence. The Gulf component is strongly seasonal and reflects in the SSF characteristics (Linder & Gawarkiewicz 1998). The newly-identified Gully Front (GF) is observed at 43.5°N over the Gully, the largest canyon that incises the Scotian Shelf and Slope. Medium-scale thermohaline fronts in the southern Gulf of St. Lawrence are generated seasonally by spring freshet, followed by summertime warming. The Cabot Strait Front (CSF) is also related to the Gulf of St. Lawrence fresh outflow. The Cape North Front (CNF) develops north of Cape Breton Island.

The Scotian Shelf LME SST (Belkin 2009) (Figure XIX-60.2):

Linear SST trend since 1957: 1.15°C.

Linear SST trend since 1982: 0.89°C.

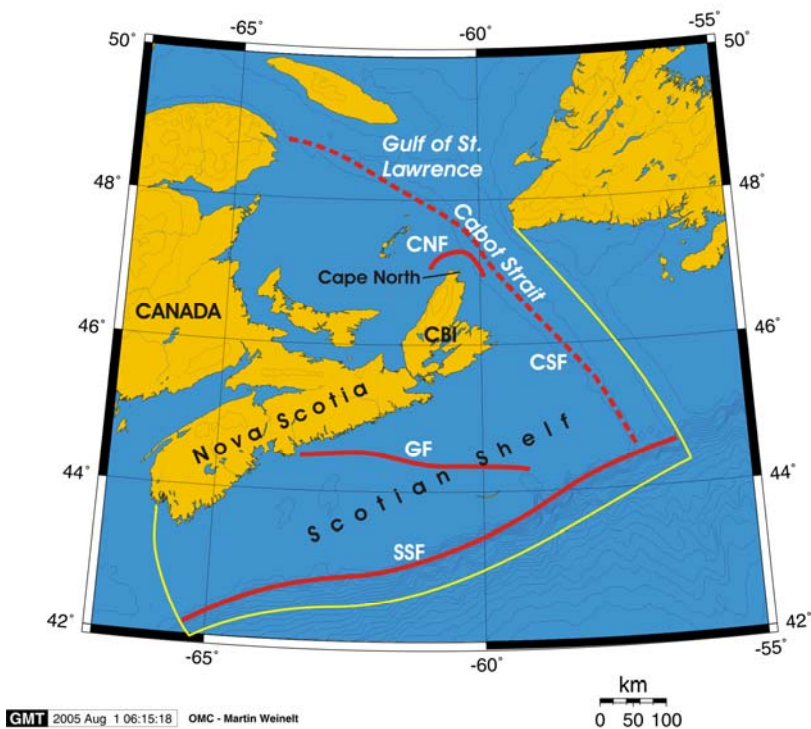


Figure XIX-60.1. Fronts of the Scotian Shelf LME. CNF, Cape North Front; CSF, Cabot Strait Front (most probable location); GF, Gully Front; SSF, Shelf-Slope Front. Yellow line, LME boundary. After Belkin *et al.* (2009).

The thermal range of the Scotian Shelf LME differs from that of the Northeast U.S. Continental Shelf LME. The Scotian Shelf long-term regression trend in mean annual SSTs ranges from a low of 7.4% in 1957 to 8.5% in 2006. Whereas, the SST regression trend increases from 11.5°C in 1957 to 12.5°C in 2006 within the Northeast Shelf LME. The multidecadal mean annual low values in SSTs are, however, similar in both LMEs, having occurred in 1965 likely under the influence of the Northeast Atlantic Slope Current. As in the Northeast Shelf LME, 1965 can be taken as a true breakpoint between two regimes characterized, respectively, by long-term cooling before 1965 and long-term warming after 1965. The post-1965 warming amounted to approximately 2°C over 40 years, making the Scotian Shelf as a geographic whole, one of the fastest warming LMEs. Note that smaller processes like the rapid cooling of the eastern Shelf during the 1980s, drive significant changes in the biota. Generalizations about the entire Scotian Shelf do not examine important differences between the eastern and western sections of this LME.

Over the late 1990s, the Scotian Shelf interannual variability was in sync with the Northeast U.S. Continental Shelf LME as evidenced by the simultaneous minimum in 1997, maximum in 1999, minimum in 2004, and the sharp increase in 2004-2006, in both LMEs. The most recent SST increase in 2004-2006 led to the all-time maximum of >9.0°C in 2006 over the Scotian Shelf, consistent and concurrent with the near-all-time maximum of 13.0°C over the Northeast U.S. Shelf Continental LME and the all-time maximum of 6.4°C over the Newfoundland-Labrador Shelf LME, both in 2006. The above simultaneity suggests large-scale forcing on the order of 2,000 km as a dominant factor over these distinct but adjacent ecosystems.

The minima of 1986 and 1997 may have been related to passages of the decadal-scale Great Salinity Anomalies (GSA) associated with low temperatures (Belkin et al., 1998; Belkin, 2004).

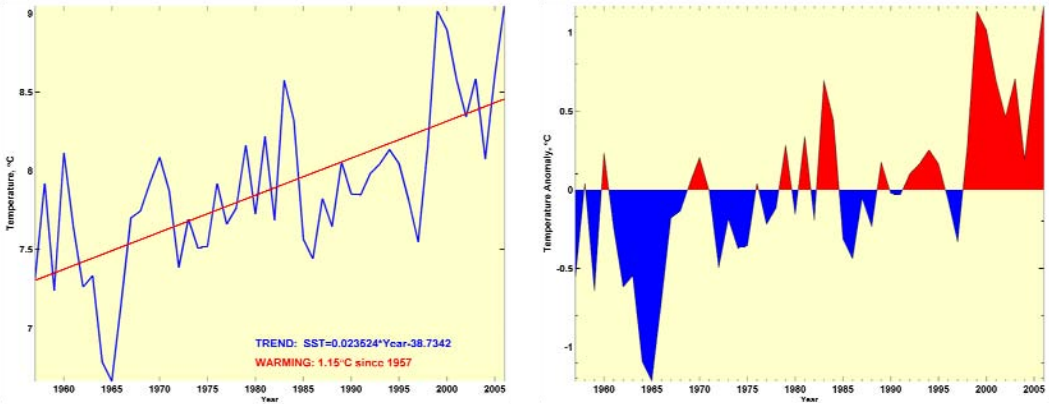


Figure XIX-60.2. Scotian Shelf LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

Scotian Shelf LME Chlorophyll and Primary Productivity

This LME is a Class II, moderately-high productivity ecosystem ($150\text{-}300\text{ gCm}^{-2}\text{yr}^{-1}$) (Figure XIX-60.3).

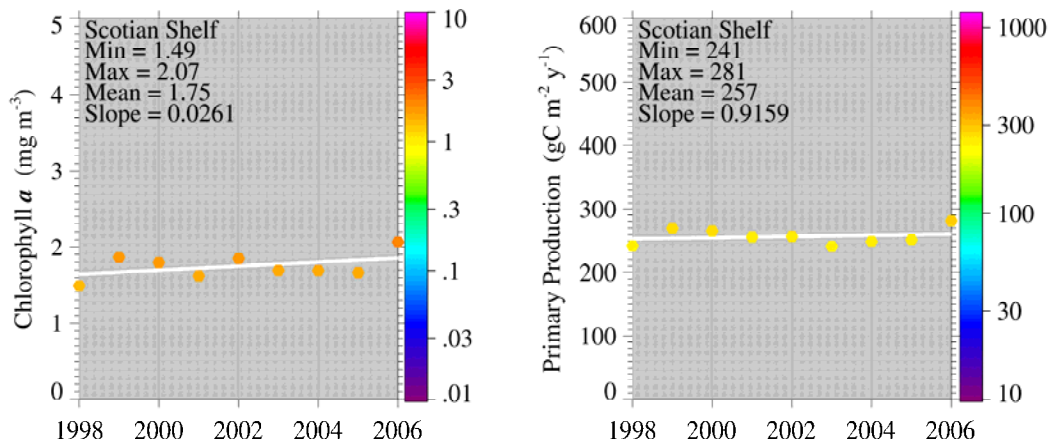


Figure XIX-60.3. Scotian Shelf LME annual trends in chlorophyll a (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

Commercially exploited species include cod, haddock, pollock, silver hake, halibut, white hake, and turbot. Pelagic species include the Atlantic herring and the Atlantic mackerel. Invertebrates include snow crab, northern shrimp and short fin squid. Both snow crab and northern shrimp prefer cold water and the increased landings for both those species coincide with the cooling of the eastern shelf (Zwanenburg 2003). Systematic fishery surveys of the shelf made between the 1960s and the present are the most consistent source of information available concerning this LME.

Total reported landings recorded a peak of 889,000 tonnes in 1970 and declined to less than a quarter of this level or 213,000 tonnes in 2004 (Figure XIX-60.4). Major changes include a dramatic decline in landings of cod, silver hake and redfish. However, the value of the reported landings reached its peak of US\$1.2 billion (in 2000 US dollars) in 2000, as a result of high value commanded by its landings of crustaceans (Figure XIX-60.5).

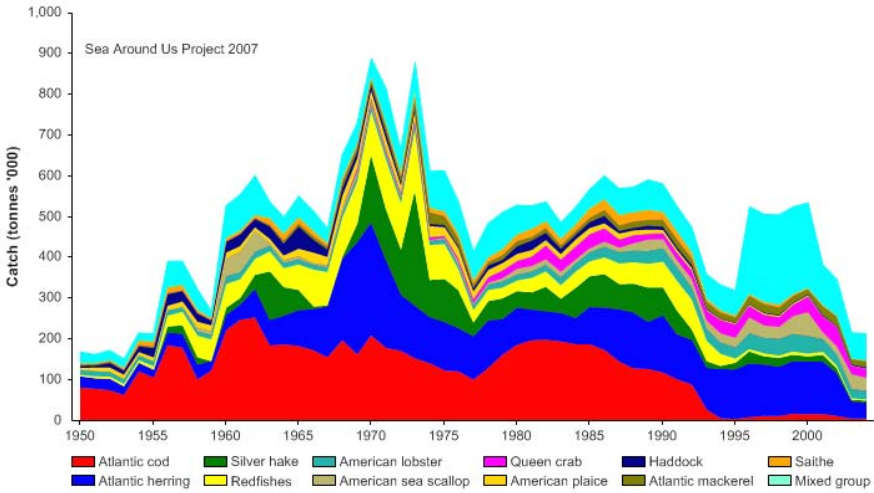


Figure XIX-60.4. Total reported landings in the Scotian Shelf LME by species (Sea Around Us 2007).

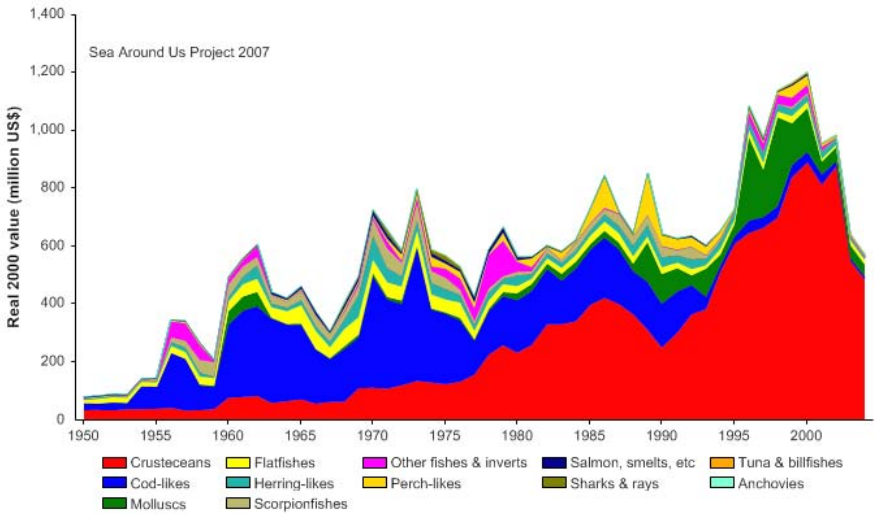


Figure XIX-60.5. Value of reported landings in the Scotian Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME exceeded the observed primary production in the mid 1970s, but has declined in recent years (Figure XIX-60.6). The extremely high PPR recorded in the mid 1970s was likely due to the accumulated biomass of cod stocks being exploited and not from exploitation of annual surplus production. Canada accounts for almost all of the ecological footprint in this LME (Figure XIX-60.6), although in the 1960s and 1970s, a number of European countries also had a large share.

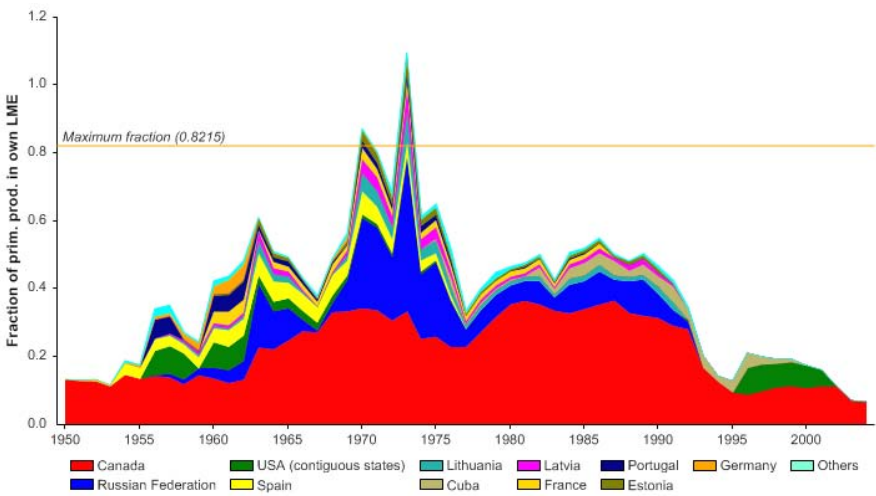


Figure XIX-60.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Scotian Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) remained high until the early 1990s, when the cod stock collapsed (Figure XIX-60.7, top), a clear case of 'fishing down' of the food web (Pauly *et al.* 1998, 2001). The FiB index showed a similar trend (Figure XIX-60.7, bottom), suggesting that the reported landings did not compensate for the decline in the MTI over that period.

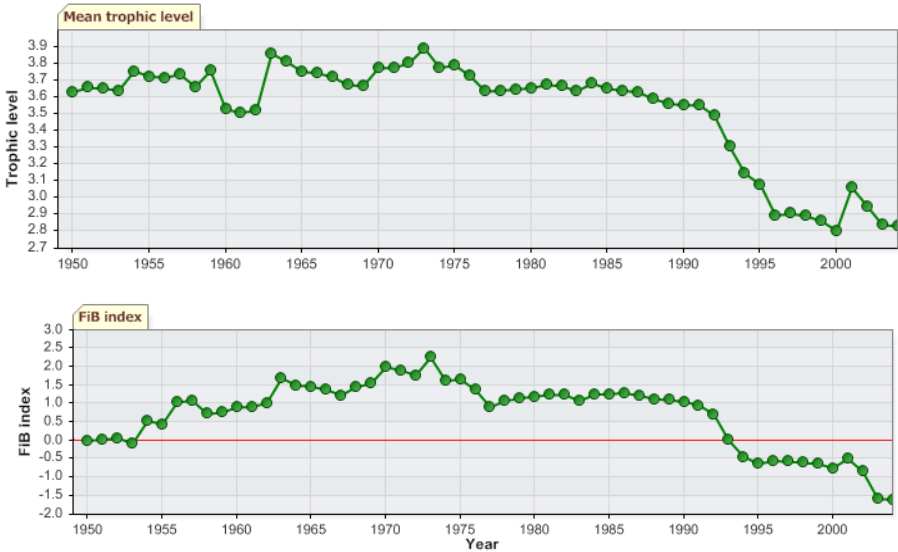


Figure XIX-60.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Scotian Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plot shows that over 90% of commercially exploited stocks in the LME are either overexploited or have collapsed (Figure XIX-60.8, top) with less than 30% of the reported landings biomass supplied by fully exploited stocks (Figure XIX-60.8, bottom).

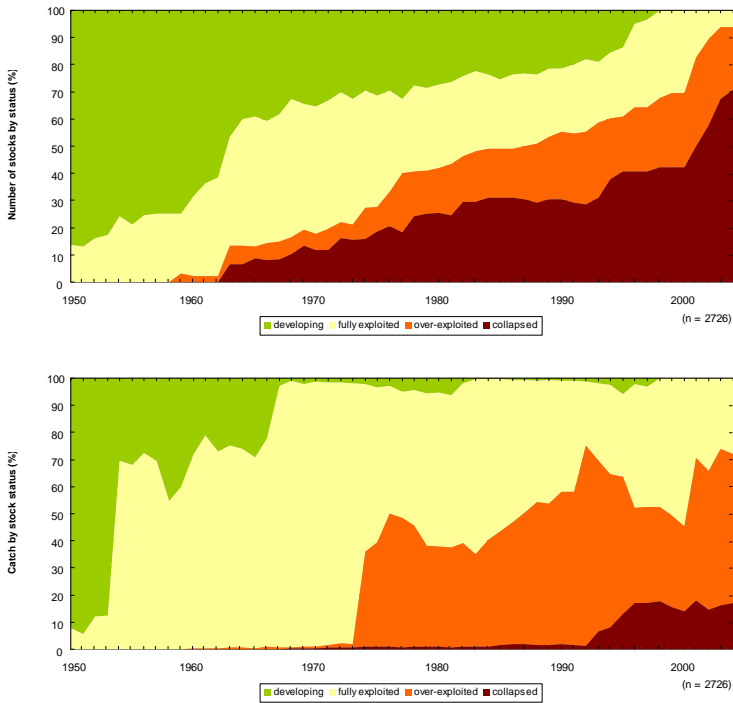


Figure XIX-60.6. Stock-Catch Status Plots for the Scotian Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al.*, this volume, for definitions).

There have been significant declines in abundance and sizes for many commercially exploited fish species (Zwanenburg 2000), indicating that the limits of exploitation had been reached (Pauly *et al.* 2001). The decrease in size, related to fishing effort, occurred both on the eastern and western shelves. Fishing effort increased rapidly with the establishment of Canada's 200-mile EEZ in 1977. Recent analyses of changes in the productivity and biomass yields of the Scotian Shelf LME revealed the consequences of the removal of top predators on the trophic structure of an ecosystem (Choi *et al.* 2004, Frank *et al.* 2005). The dominant change in the biomass yield was a sharp decline in groundfish landings and biomass from the mid-1980s through the mid-1990s. The trawlable demersal biomass declined from 450,000 tonnes in 1973 to less than 15,000 tonnes in 1997. Coincident with this decline was an increase of pelagic fish as well as of shrimp and snow crab. At the lower trophic levels, increases were observed for a 40-year period from 1960 to 2000 in phytoplankton concentrations based on colour index values from CPR, and in the increase in numbers of zooplankters, less than 2 mm in length. The principal fisheries are now directed toward pelagic fish and macroinvertebrates, and are dominated by herring, shrimp and snow crab.

A management scheme taking into account species interaction and biomass production is being initiated to address the overexploitation of the LME's main fisheries (cod, haddock, flounder, and other demersal fish). When the cod fishery collapsed on the Eastern shelf, a cod moratorium was imposed in 1993 and remains in effect. Overfishing led to a number of fishery closures in the early 1990s.

III. Pollution and Ecosystem Health

For information on marine pollution and the protection of this LME's offshore environment, consult the Fisheries and Oceans Canada site at www.mar.dfo-mpo.gc.ca. The report section on Ocean Disposal and Marine Environmental Quality, Scotian Shelf: An Atlas of Human Activities (2005), lists illegal spills and discharges such as the chronic introduction of oil from vessel traffic, marine debris, chemical contaminants from vessels and offshore hydrocarbon development activities, and the introduction of invasive species and pathogens through ballast water as significant ongoing environmental concerns. Also listed are shipwrecks and post-war chemical and unexploded ordinance dump sites that need new assessments for risk. There have been several large-scale environmental emergencies, including the wreck of the Arrow oil tanker and other vessel sinkings. The DFO reports no concentrations of heavy metals above the PEL (probable effects level) on the Scotian Shelf.

Hollingworth recognized the need to assess the wider ecological costs of over exploitation of the fisheries resource (2000). The International GLOBEC Cod and Climate Change Programme studies the response of different cod populations to climate changes in various regions of the cod's North Atlantic range, including the Scotian Shelf. The ESSIM project (Eastern Scotian Shelf Integrated Management Project) described in its first Ecosystem Status Report for the Eastern Scotian Shelf (DFO 2003) the shift in the ecosystem from groundfish to pelagic species and invertebrates (see also Zwanenburg et al. 2006). O'Boyle and Jamieson (2006) point to an ongoing paradigm shift in ocean management, exemplified by explicit consideration of the impacts of all ocean sectors on the marine environment, both separately and in aggregate. The authors recommend adaptive management, and include both conceptual and operational level management goals to achieve ecosystem-based management. Climate change is a priority issue, and on 12 December 2007 the Government of Canada announced at the UN Climate Change Conference in Indonesia new mandatory regulations for industry for emissions reduction. Industries must submit air emissions data to the Government of Canada within the next six months as part of the "toughest plan in Canadian history" to clean up air, tackle climate change and protect our environment" said Environment Minister John Baird. The air emissions action is part of Canada's "Turning the Corner: An Action Plan to Reduce Greenhouse Gases and Air pollution launched in April 2007.

IV. Socioeconomic Conditions

The Nova Scotia Department of Finance, Economics and Statistics, reports that the population of Nova Scotia on 1 October 2007 was 935,106 persons of whom 452,000 were employed and per capita income in 2006 was \$29,459. Health Canada posts a report by Dr. Ronald Colman (2005) on the socioeconomic gradient in health in Atlantic Canada based on evidence from Newfoundland and Nova Scotia 1985-2001 finding high socioeconomic inequality in health in Newfoundland and Glace Bay and Kings County, Nova Scotia compared to Canada as a whole, Europe and Australia. Income was found to be the most important contributor to socioeconomic inequality in health; education and economic status also contributed to health status (Colman 2005).

The trophic cascade changed the structure of the Scotian Shelf LME from an economic perspective, with the recent value of shrimp and crab landings exceeding the previous

value of the demersal fishery. With regard to other marine resources, the Canada-Nova Scotia offshore petroleum Board is responsible for the regulation of petroleum affairs in the province. The presence of oil raises issues of multiple uses of the marine environment.

V. Governance

Federal jurisdiction over Canada's coastal and inland fisheries dates to the Constitution Act of 1867. In 1979 the federal government established the Department of Fisheries and Oceans. However, the provinces are responsible for certain areas of fisheries jurisdiction, including fish processing and the training of fishermen (The Canadian Encyclopedia at www.thecanadianencyclopedia.com). In November 2007 the DFO announced a new framework for the management of fisheries resources. Drivers for the new management framework include the need to certify that Canadian seafood products are sustainably harvested, domestic legislation including Bill C-45, and International agreements and protocols signed by Canada. The Framework and the international agreements emphasise the Precautionary Approach, the Ecosystem Approach, and Sustainable Development.

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