XIII-41 Iceland Shelf: LME #19

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The Iceland Shelf LME surrounds the island-nation of Iceland in the northeast Atlantic Ocean. It is characterised by a sub-arctic climate and environment, with seasonal ice cover and marked fluctuations in salinity and temperature off the north coast. Temperature, currents, tides and seasonal oscillations affect productivity in this LME. The area of this LME is 315,500 km^2, of which 0.06% is protected (Sea Around Us 2007). In this highly active geological region, the divergence of two tectonic plates causes the formation of oceanic crust and the crest of the Mid-Atlantic Ridge. LME book chapters and articles pertaining to this LME include Prescott (1989) and Astthorsson & Vilhjalmsson (2002).

I. Productivity

Iceland has a wide volcanic margin marked by broad valleys and a sharply defined slope. For a map of bottom topography around Iceland, see Astthorsson & Vilhjalmsson (2002, p. 220). Three ocean currents (the North Icelandic Irminger Current, the East Icelandic Current, and the Coastal Current move in a clockwise gyre around the island. For a map of ocean currents, see Astthorsson & Vilhjalmsson (2002, p. 221). A complex system of transverse ridges is oceanographically important because it separates the relatively warm and saline waters of the Atlantic from the cold, fresh Arctic waters of the Iceland Sea and Norwegian Sea to the north and northeast.

The Iceland Shelf LME is considered a Class II, moderately high productivity ecosystem (150-300 $gCm^{-2}yr^{-1}$). Extensive primary productivity measurements have been carried out annually in the waters around Iceland for more than four decades (see Thordardottir 1984). For a map of average primary production in Icelandic waters based on data from the period 1958-1982, see Astthorsson & Vilhjalmsson (2002). Climate is the primary force driving the LME. There are marked interannual changes in the spring development of phytoplankton (Gudmundsson, 1998). Studies on zooplankton biomass and species composition have been carried out on standard transects during late May-June in Icelandic waters. The highest biomass is found in the front area between the coastal and the Atlantic water off Iceland's south coast and in the Arctic waters of the East Icelandic Current off the northeast coast. Changes in hydrography impact the food chain through influences on primary production, zooplankton, and the capelin and cod stocks. For a conceptual model of how climatic conditions in Icelandic waters may affect production at lower trophic levels and eventually the yield from the Icelandic cod stock, see Astthorsson & Vilhjalmsson (2002, p. 240).

Oceanic fronts (Belkin et al. 2009). The Irminger Current warm and salty waters arrive on the Iceland Shelf from the south and circulate anticyclonically around Iceland. The Polar and Arctic waters, both relatively fresh and cold, arrive from the north along the North Iceland Front to meet the Irminger waters (carried by the North Icelandic Irminger Current along the Irminger Current-West Iceland Front) over the northwest, north and northeast Iceland Shelf where two major fronts form (Figure XIII-41.1). The western front is located where the Irminger waters meet the western branch of cold, fresh waters headed toward the Denmark Strait. The eastern front is located north and northeast of Iceland where the East Icelandic Current meets the North Icelandic Irminger Current. The eastern front appears to be connected to the Iceland-Faroes Front observed farther east, although this connection is rather tenuous.

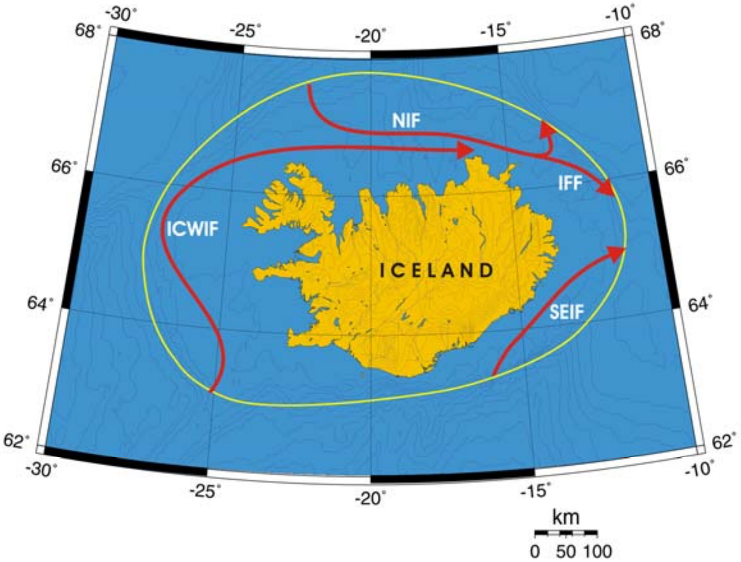

Figure XIII-41.1. Fronts of the Iceland Shelf LME. IFF, Iceland-Faroes Front (located mostly outside this LME; the link between NIF and IFF is rather tenuous); ICWIF, Irminger Current-West Iceland Front; NIF, North Iceland Front; SEIF, Southeast Iceland Front. Yellow line, LME boundary. After Belkin et al. 2009.

Iceland Shelf LME SST (Belkin, 2009)

Linear SST trend since 1957: -0.11°C.
Linear SST trend since 1982: 0.86°C.

The Iceland Shelf experienced a dramatic cooling from the all-time maximum of 7.2°C in 1960 down to the all-time minimum of 5.4°C in 1969 (Figure XIII-41.2). This event heralded the arrival of the Great Salinity Anomaly (GSA) of the 1960s-1970s (GSA'70s; Dickson et al., 1988; Belkin et al., 1998), which had a lasting effect on this ecosystem. This cold anomaly was associated with low salinities and with increased export of sea ice. Ocean currents transported the GSA'70s from the Greenland Sea southward past Iceland, then around the Subarctic Gyre, and eventually back to Iceland and past Iceland into the Norwegian Sea. A map of the circulation in the northern North Atlantic is shown at www.ospar.org.

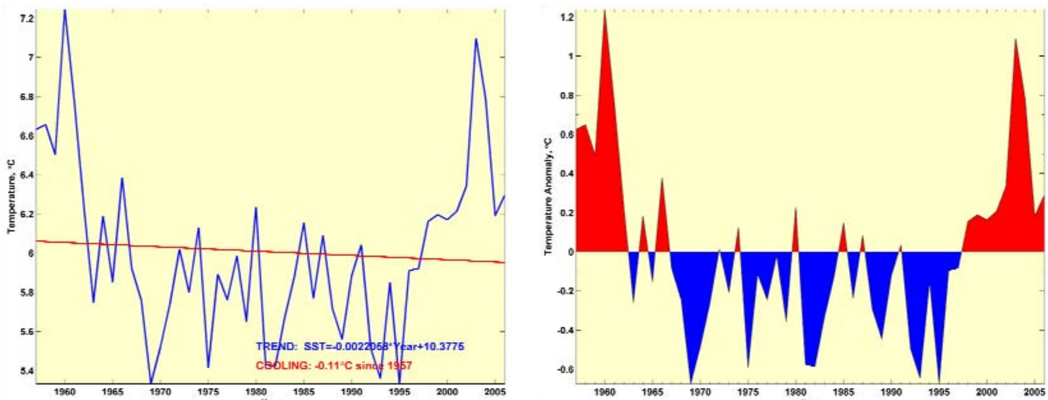

Figure XIII-41.2. Iceland Shelf LME annual mean SST (left) and SST anomaly (right), 1957-2006. After Belkin (2009).

The SST remained low through 1995, the year when SST was as cold as in 1969 (<5.4°C). Then SST abruptly rose through 2003, when it peaked at 7.1°C, a 1.7°C rise in 8 years, thereby posting an average annual warming rate of >0.2°C/year, one of the fastest warming rates observed in the world's oceans.

Iceland Shelf LME Chlorophyll and Primary Productivity: The Iceland Shelf LME is considered a Class II, moderately high productivity ecosystem (150-300 $gCm^{-2}yr^{-1}$).

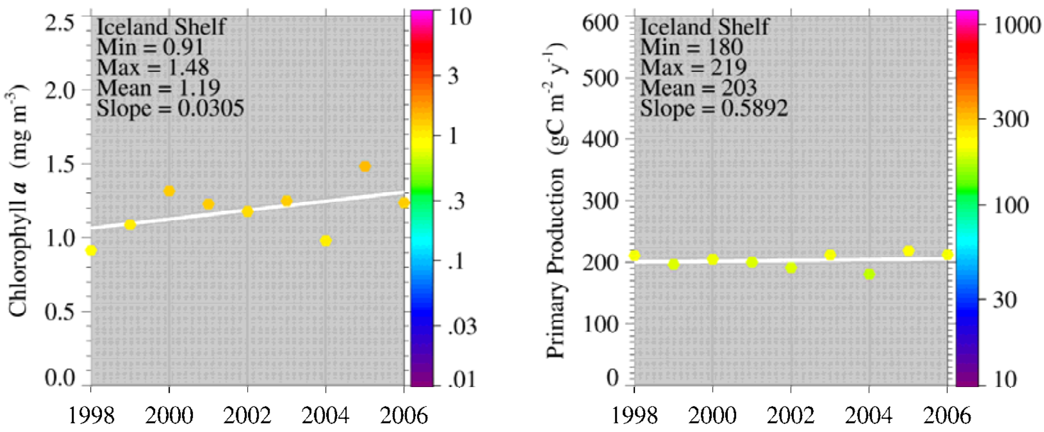

Figure XIII-41-3. Iceland Shelf LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

Total reported landings[1] have increased since 1950, with occasional considerable variation mainly driven by fluctuations in capelin landings, and total reported landings peaked in 1997 at 1.6 million tonnes (Figure XIII-41.4). Landings were driven primarily by Atlantic cod before the 1970s and by herring and especially capelin afterwards (Figure XIII-41.4). Capelin, which in 1997 accounted for over 60% of the total landings, are linked to cod through a tight predator-prey relationship (Jakobsson & Stefansson, 1998). The herring catch peaked at about 615,000 tonnes in 1962, before collapsing in the late 1960s and early 1970s. An important fishery for northern shrimp developed during the 1970s to the 1990s, with landings in the mid-1990s of over 60,000 tonnes[2]. This decline has been attributed to higher predatory pressure by cod and reduced recruitment related to recent warming (Astthorsson et al., 2007)

[1] Due to a recent adjustment to the boundaries of the Iceland Shelf LME, the landings data presented here are based on the 1950-2003 data, computed using the boundaries defined in Figure XIII-41.1. Data for 1950-2004, based on the new LME boundaries, will be available online at www.seaaroundus.org.

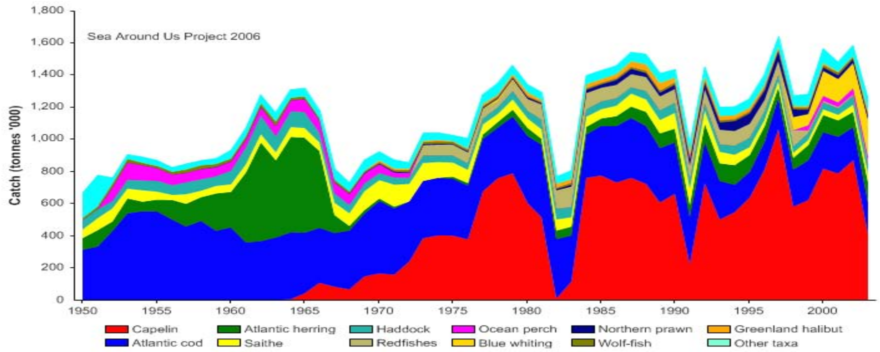

Figure XIII-41.4. Total reported landings in the Iceland Shelf LME by species (Sea Around Us 2007)

No Figure XIII-41.5. Information on the value of reported landings cannot be provided at this stage, due to the recent adjustments in LME boundaries (see note 1 above). Data for values using the newly adjusted boundaries will be available at www.seaaroundus.org**.**

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in the LME exceed the observed primary production (Figure XIII-41.6). Such unrealistically high PPR likely implies that the large portion of the reported landings are supported by primary production from neighbouring marine ecosystems, i.e., large groups of exploited stocks are feeding outside of the Iceland Shelf LME and migrating in (see e.g. FAO 1981). Iceland accounts for almost the entire ecological footprint in the LME since the late 1970s, following a long, well-documented struggle against the exploitation of its shelf area by distant-water fleets (Bonfil *et al.* 1998).

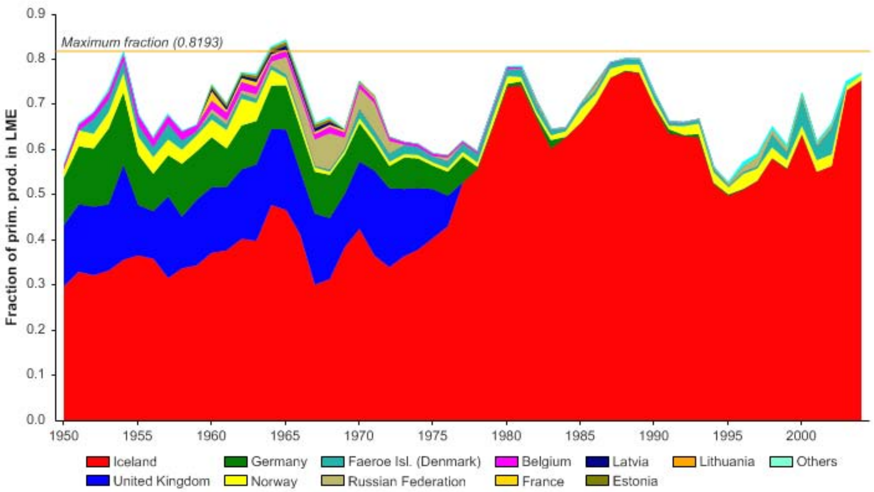

Figure XIII-41.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Iceland Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Both the mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) and the FiB index have declined over the reported period (Figure XIII-41.7). In a detailed analysis on the state of the fisheries in the Iceland Shelf LME, Valtysson & Pauly (2003) stated that the declining TL level reflected increasing interest in pelagic species and invertebrates due to new fishing technology, fish processing technology and marketing, and was also driven by restrictions in groundfish catches due to declining stocks. Note that capelin and herring were never historically harvested simultaneously until the 1980s. Furthermore, the lower trophic level blue whiting has migrated into Icelandic waters because of the warming climate in recent years. These factors help create the appearance of, but not the fact of, ‘fishing down the food web’.

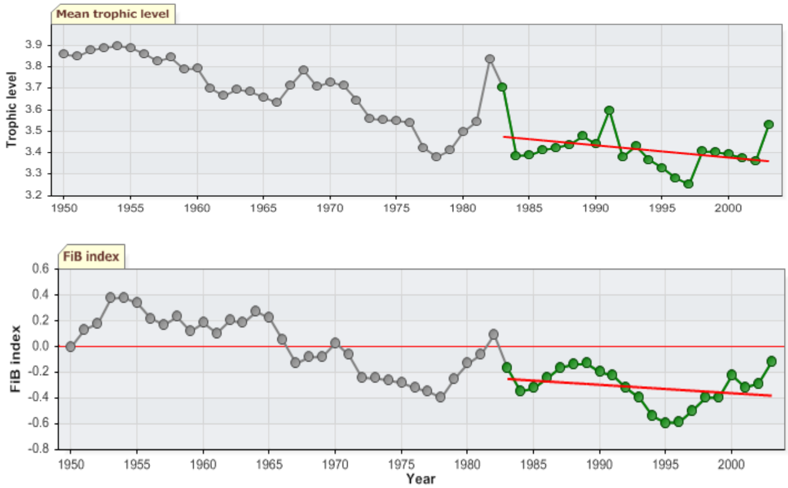

Figure XIII-41.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Iceland Shelf LME (Sea Around Us 2007)

The Stock-Catch Status Plots indicate that the number of overexploited stocks has been increasing over the years, accounting for nearly 90% of the commercially exploited stocks in the region (Figure XIII-41.8, top) with the majority of the reported landings biomass supplied by overexploited stocks (Figure XIII-41.8, bottom).

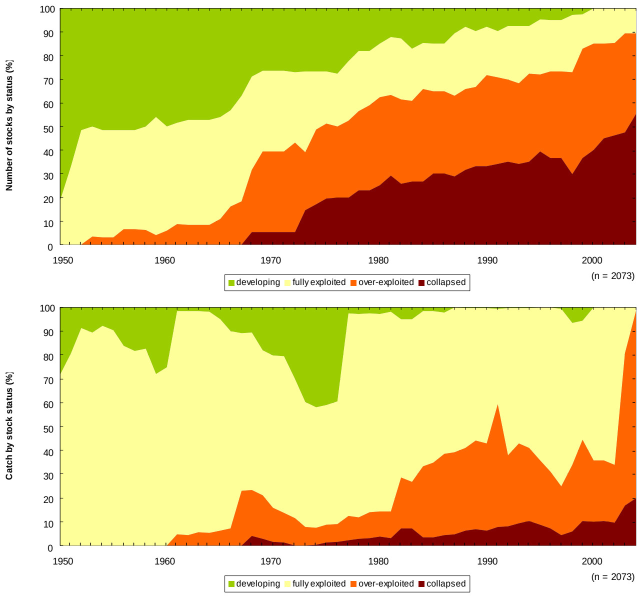

Figure XIII-41.8. The Stock-Catch Status Plots for the Iceland Shelf LME showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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 vol. for definitions).

Fluctuations in salinity, temperature and phytoplankton contribute to variations in annual catches of cod and small pelagics. Actions are underway in Iceland to reduce overexploitation in a joint government-industry effort for achieving long term sustainability in fish stock yields. Intensive fishing is a secondary force, after climate, driving this LME. Changes in fisheries technology have also impacted the total catch from this LME. At the turn of the last century, the fishing industry gradually became more mechanised, which led to a catch increase. See Astthorsson & Vilhjalmsson (2002) for the following: information on fish yields; a graph of demersal fish catches (cod, haddock, saithe, redfish) in 1950-1998; the inshore and offshore shrimp catch in 1964-1998; a graph of the huge fluctuations of herring and capelin from 1950- 1995 (p. 232); the spawning stock biomass and total catch of the Icelandic cod stock from 1955- 1998 (p. 233); a map of feeding areas and spawning grounds of the Icelandic capelin (p. 236); and for a conceptual model of how climatic factors may affect the yield of cod through the food chain. The simplicity of the main trophic links and oscillations between warm and cold climatic regimes dramatically influence fish yield in this LME. For further information on the impact of climate on the Icelandic Shelf LME see Astthorsson *et al*., (2007) and for occurrence of new and rare species in recent years see Astthorsson & Palsson (2006). Fluctuations in temperature and salinity can be related to large-scale changes in the atmospheric circulation over the North Atlantic Ocean (Malmberg *et al*., 1999). See Dickson *et al*. (1988), Belkin et al. (1998) and Belkin (2004) for information on the 'Great Salinity Anomalies' in the Northern North Atlantic. Near shore, hydrographic conditions may vary considerably from year to year mainly due to timing and variations of fresh water runoff.

III. Pollution and Ecosystem Health

Marine pollution appears to be negligible in the fishing grounds of the Iceland Shelf LME. However, the Iceland's Ministry of the Environment reports that in some seasons of the year, the quantity of persistent organic pollutants has been measured above the EU's established critical limits in fish products such as fish oil and fish meal for animal feed. (Report on the Implementation of the GPA 2001-2006 in Iceland, p.11). Although the proportion of inhabitants with sewage treatment has risen from 40% in 1992 to almost 70% in 2005, measurements of faecal bacteria have revealed occasional contamination in the vicinity of Reykjavik. The OSPAR 2005 report reveals that in Iceland the concentration of arsenic in the vicinity of Álftafijord northwest and cadmium in the Hvalfjord southwest has increased since the last measurements and efforts are underway to determine why. Yet, heavy metal contamination in living organisms does not appear to be a problem in the sea around Iceland, largely because of the lack of heavy industry. The concentration of mercury is among the lowest measured in the Northeast Atlantic and has not increased since measurements began. The Ministry recounts that regular warnings concerning shellfish consumption had to be released in the July 2006 when in the west in Hvalfjord and Breiõafjord and in Eyjafjord in the north, the levels of Dinophysis species and the *Pseudo-nizschia pseudodelcatissima* both measured far above reference limits. Causes are being investigated. Of particular concern is the effect of the toxins on humans and on the farmed fish and cultivated shellfish. Nitrogen and phosphorous released into the ocean from Iceland's rivers are routinely measured. Recent legislation requires ship owners to remove ships that run aground within six months following the incident. Iceland's environment laws and their monitoring and assessments, demonstrate their intent to remain one of the cleanest places on earth.

IV. Socioeconomic Conditions

Iceland has a population of nearly 313,000 as of October 2007 according to Statistics Iceland (www.statice.is). Icelanders enjoy a per capita income among the highest in Europe and remain quite dependent on the fishing industry. Foreign fleets, specifically

British, began fishing these waters at the beginning of the 15th Century (Jonsson, 1994). Fishing by foreign fleets (particularly German and British) played an important role in the cod fisheries during the 20th Century (Schopka, 1994) but foreign investment in the fishing industry is no longer allowed. Iceland is one of the few nations in the world today that has been able to build a modern society upon the exploitation of the resources of its surrounding waters. Seafood products constitute about 60% of Iceland's exports. To address fisheries overexploitation, Iceland has successfully introduced a management system to allow stocks to recover (country profiles at <www.fco.gov.uk>). Iceland has diversified its economy away from fishing into other investments: i.e. aluminium smelting, finance and overseas investment—with some 60% of bank profits now coming from overseas operations. The country is self-sufficient in meat and dairy products. Tourism is now a major foreign exchange earner with some 400,000 visitors in 2005-2006. Whale-watching attracts some 20% of visitors to Iceland. In 2006, 70,000-80,000 visitors from Britain alone came to Iceland. Major industries today in Iceland are fish processing, aluminium smelting, ferrosilicon production, geothermal power, tourism, and pharmaceuticals (country profiles at <www.fco.gov.uk>).

V. Governance

Iceland has played a pioneering role in International Law of the Sea. The competition of foreign fishing fleets prompted Iceland to protect its fisheries by extending its territorial limits. The territorial sea was three miles in 1901, and was extended to four miles in 1952. These extensions were early and bold moves for that time. In 1958, the territorial sea was extended to 12 miles, then in 1972, to 50 miles. British protests against these extensions took the form of three 'cod wars' (in 1961, 1972 and 1975). In an arbitration opposing Iceland and Great Britain, the International Court of Justice ruled in favour of Iceland. Finally, in 1975, Iceland extended its limits to 200 miles. The Ministry of Foreign Affairs has information on Iceland's international relations (http://www.mfa.is/). Iceland has at least 8 pieces of legislation for marine conservation and is about to establish its first major marine conservation area. Iceland works closely with ICES to monitor the size of fish stocks (www.ices.dk/indexnofla.asp). There are various restrictions on fisheries. The most common methods are TAC, mesh size and gear restrictions, restrictions on season length and timing and area closures. Often all methods are used in combination but depending on species some may be more important for one species than another. The main aim is to secure sustainable fishing. The management of Icelandic capelin has been approached in a multi-species context since 1980 (Astthorsson & Vilhjalmsson 2002). The immature stock is specifically protected from fishing and the needs of cod, the main predator, are taken into account prior to the final decision on total allowable catch. Steps have been taken to obtain a better understanding of multi-species interactions in this LME (Anon. 1997). The EEA (European Economic Area) Agreement is legally binding for Iceland to harmonize their legislation and regulatory framework with EU environmental legislation. Iceland is party to UNCLOS and the OSPAR Convention. The LRTAP agreement on Long-range Transboundary Air Pollution of POPs has not been ratified by Iceland, but Iceland is party to its protocols on POPs and PAHs. Iceland is party to MARPOL for prevention of pollution from ships, the London Dumping Agreement, the Copenhagen Convention on international Nordic country cooperation on dealing with accidents caused by oils and other hazardous substances, and the Basel convention to control transboundary movement of hazardous wastes and their disposal. Iceland is working with the Arctic Council and with PAME to protect the Arctic marine environment (Iceland, Ministry for the Environment, 2006) and chaired the Arctic Council 2002-2004.

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