XIII-39 East Greenland Shelf: LME #59

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The East Greenland Shelf LME extends along Greenland's east coast to the Eirik Ridge, covering an area of about 319,000 km^2, of which 13.34% is protected (Sea Around Us 2007). It is influenced by the cold East Greenland Current, which flows south along the coast from the polar area. A sub-arctic climate, seasonal ice cover and marked fluctuations in salinity, temperature and phytoplankton characterise this LME. The continental shelf varies in width, from 750 km in the north to 75 km in the south, and a large number of fiords are found. LME book chapters, articles and reports pertaining to this LME include Prescott (1989), Skjoldal *et al*. (1993) and UNEP (2004).

I. Productivity

Changes in sea and air temperature are the principal physical driving forces of this LME. Climatic variability causes large inter-annual variability in ice and hydrographic conditions. This, in turn, affects plankton production and fish recruitment, and can contribute to variations in annual catches of cod and small pelagics. Due to the cover of ice for most of the year, which inhibits the penetration of light, the East Greenland Shelf is considered a Class III, low productivity ecosystem (<150 $gCm^{-2}yr^{-1}$). The melting of sea ice in the summer has significant effects on ecological conditions, causing large amounts of nutrient salts to be transported into the waters around East Greenland. Owing to these climatic factors and to the high latitude of the region, the seasonal phytoplankton production is of short duration and of limited extent. Primary production is conveyed efficiently to higher trophic levels and supports large populations of fish, marine mammals and seabirds.

Oceanic fronts (Belkin *et al.* 2009): The East Greenland Polar Front (EGPF) (Figure XIII-39.1) hugs the shelf break and the Greenland continental slope, and serves as the offshore boundary of this LME. The EGPF waters originate in the Arctic Ocean, which explains their extremely low temperature and salinity. A complicated pattern is formed by the EGPF over the broad Ammassalik Shelf between 63° N and 65° N, where three separate branches of the EGPF are observed. This shelf is known as a major spawning area of cod. Therefore the multiple frontal structure discovered from satellite data is important to the local cod fishery. South of the Denmark Strait, the EGPF is joined by the Irminger Current Front that carries warm and salty waters originated in the North Atlantic Current.

East Greenland Shelf LME SST (Belkin 2009)(Figure XIII-39.2):
Linear SST trend since 1957: 0.51°C.
Linear SST trend since 1982: 0.73°C.

Like many other boreal LMEs, the East Greenland Shelf cooled down in the 1950s-1960s until it reached the all-time minimum of just 0.5°C in 1971 during the passage of the Great Salinity Anomaly (GSA) of the 1970s (Dickson et al. 1988; Belkin et al. 1998). The passage of the GSA'70s is believed to have contributed to the collapse of cod fisheries downstream, off West Greenland and Newfoundland, in the 1980s (Hamilton et al. 2003). Later on, the GSAs of the 1980s and of the 1990s were absent over the East Greenland Shelf, consistent with their local formation in the Labrador Sea (Belkin et al., 1998; Belkin, 2004).

After a quick recovery in 1972, SST rose steadily until present. The all-time maximum SST in 2003 exceeded 2.6°C. The record-breaking SST is consistent with the all-time maximum near-surface air temperature of 1.5°C recorded in Ammassalik on the east coast of Greenland in 2003. The SST maximum of 2003 correlates with the all-time SST maximum of 2004-2005 in the downstream-located West Greenland Shelf LME. In the two nearby LMEs, Iceland Shelf and Faroe Plateau, SST also reached all-time maxima in 2003. Perhaps, it is not accidental that all these anomalies peaked right after El Niño 2002-2003.

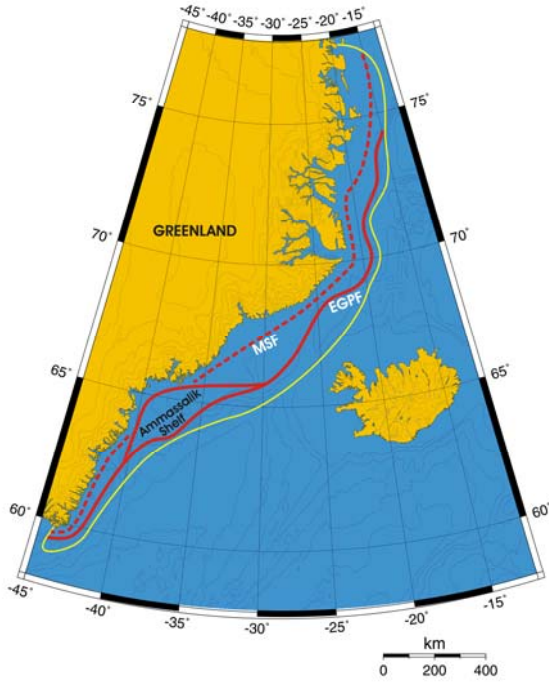

Figure XIII-39.1. Fronts of the East Greenland Shelf LME. EGPF, East Greenland Polar Front; MSF, Mid-Shelf Front (most probable location). Yellow line, LME boundary. After Belkin *et al.* (2009).

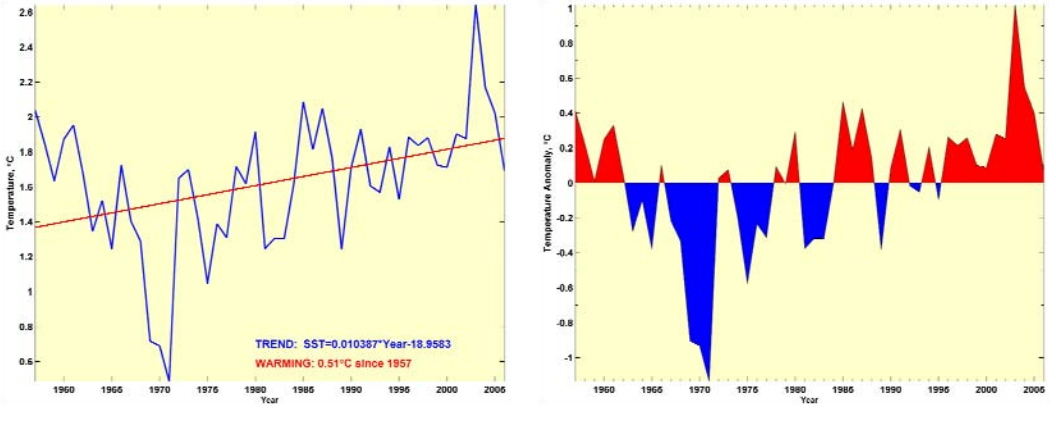

Figure XIII-39.2 East Greenland Shelf annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

East Greenland Shelf LME Chlorophyll and Primary Productivity

The East Greenland Shelf LME is considered a Class III, low productivity ecosystem (<150 $gCm^{-2}yr^{-1}$) (Figure XIII-39.3).

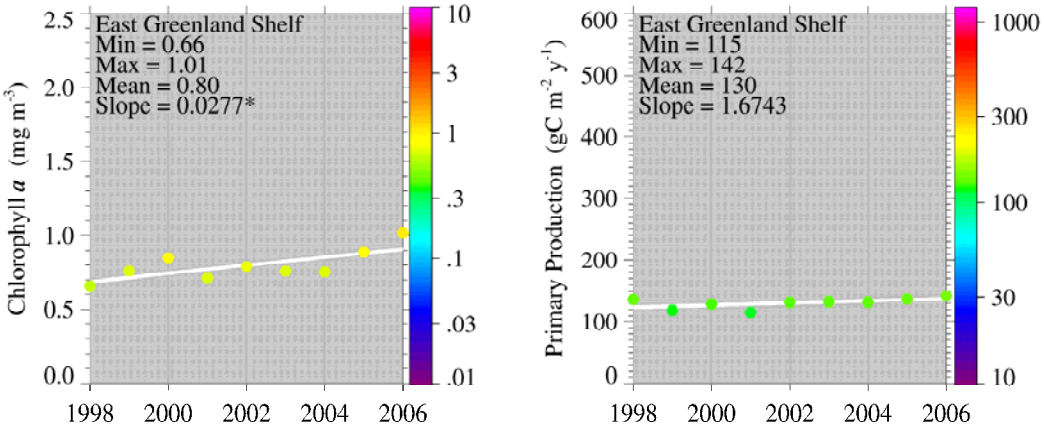

Figure XIII-39.3. East Greenland Shelf trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

Total reported landings[1] from 1950 to 2003 show a series of peaks and troughs (Figure XIII-39.4). Reported landings have fluctuated from a low of 11,000 tonnes in 1983 to a high of 225,000 tonnes in 1996. While historically cod dominated reported landings, in more recent years pelagic fish, notably capelin dominate (Figure XIII-39.4)[2]

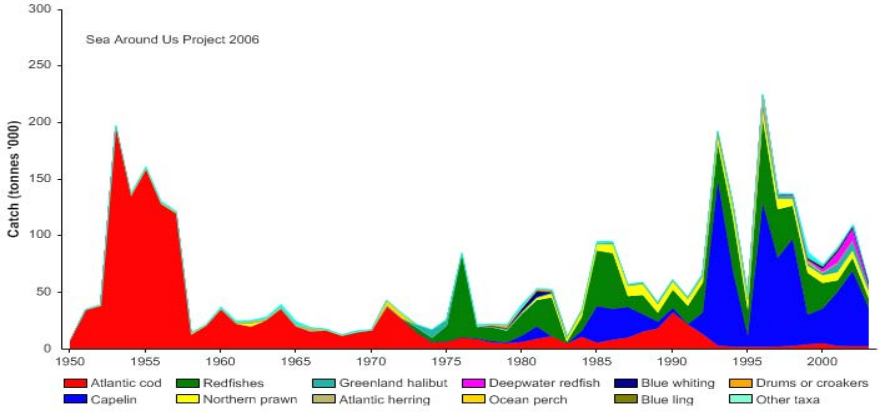

Figure XIII-39.4. Total reported landings in the East Greenland Shelf LME by species (Sea Around Us 2007).

[1] Due to a recent adjustment to the boundaries of the East Greenland Shelf LME, the landings data presented here are based on the 1950-2003 data, computed using the boundaries defined in Figure XIII-39.1. Data for 1950-2004, based on the new LME boundaries, will be available online at www.seaaroundus.org.

[2] 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 this LME reached to 35% of the observed primary production in the mid 1950s, but this relatively high value has not been achieved in recent years, and has remained mostly under 10% (Figure XIII-39.5). The countries with the largest share of the ecological footprint in this LME have changed frequently over the years, with Iceland accounting for the largest footprint in recent years.

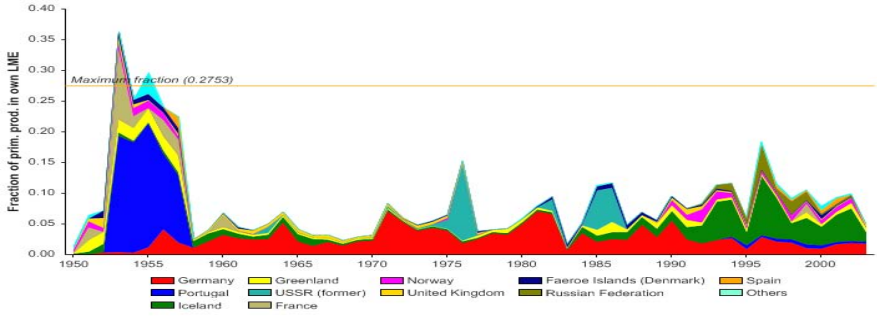

Figure XIII-39.5. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the East Greenland Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Until the early 1970s, the reported landings from this LME and the mean trophic level of the entire fisheries in the region were dominated by cod (i.e., the MTI; Pauly & Watson 2005). With new species coming under exploitation, and the gradual decline of cod landings, a classical 'fishing down' scenario ensued (Pauly *et al.* 1998), with trophic levels declining (Figure XIII-39.6, top), and some compensation through higher landings of species from lower trophic levels (e.g. capelin), the reason for the stability in the FiB index (Figure XIII-35.6, bottom).

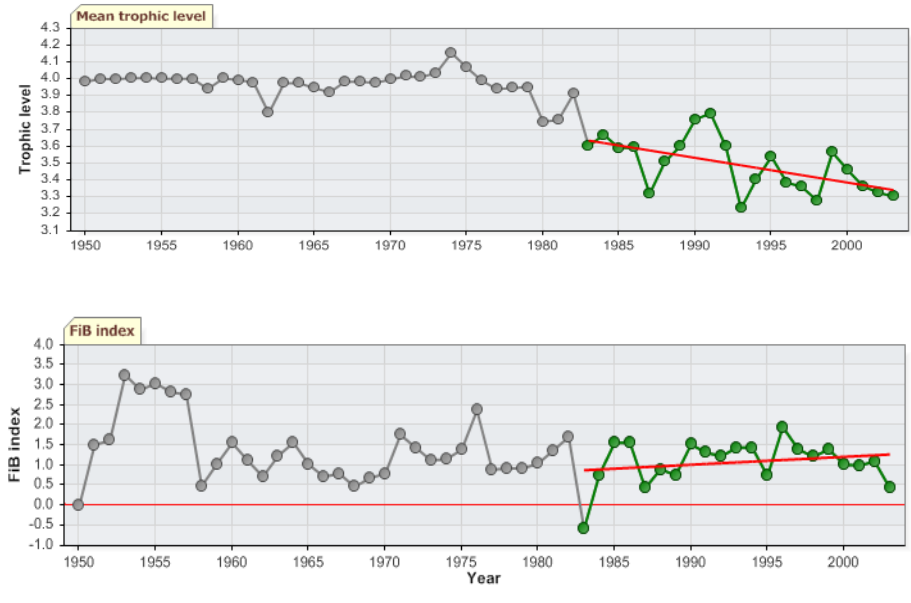

Figure XIII-39.6. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the East Greenland Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate a high proportion of collapsed stocks in this LME (Figure XIII-39.7, top), and a high contribution of these stocks to the reported landings biomass (Figure XIII-39.8, bottom). The jagged appearance of the latter plot reflects fluctuations in the reported landings (Figure XIII-39.4).

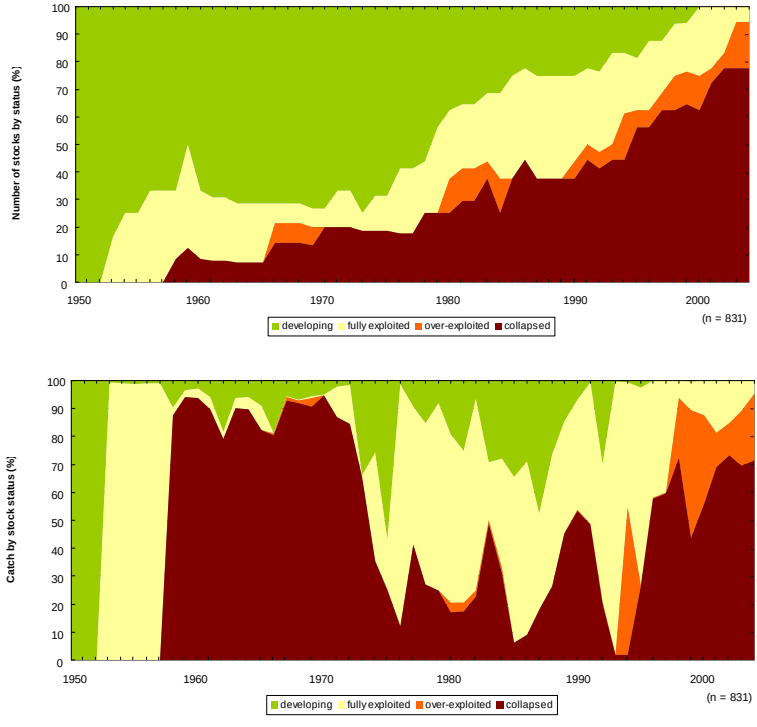

Figure XII-39.7. Stock-Catch Status Plot for the East Greenland Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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).

A stock of some commercial significance was cod, once central to Greenland's economy. This stock collapsed in the early 1990s, with landings falling from about 13,000 tonnes in 1992 to below 4,000 tonnes in the following years. The fluctuations of cod stocks have been linked to changes in sea temperature (see Buch *et al*.1994). Overfishing and its effects on stock size and stock interactions appear to coincide with climatically-driven variability. Atlantic herring was a major species fished in the 1950s and 1960s but it has also almost entirely disappeared in the catch statistics. Today, species landed are mostly capelin, shrimp and redfish. Shrimp (*Pandalus borealis*) is exported. Greenland halibut, Norway haddock, catfish, Atlantic halibut, salmon and char are important to the local economy. Greenland's fishing industry tries to balance the possibilities offered by modern fishing technology with the need to sustain this LME's natural resources. The near-shore quota system differs from the off-shore system for shrimp, cod and Greenland halibut. Marine mammals (five species of seal, walruses and whales) are essential for the survival of the traditional hunting communities, and the meat is traded locally. The whaling industry led to the decimation of several whale species in the region. While the recovery of the overexploited right whale has been very slow, the fin and minke whales have recovered well. Legal measures protect a number of marine species.

III. Pollution and Ecosystem Health

The International Cod and Climate Change Programme studies the response of different cod populations to climate change in various regions of the cod's North Atlantic range. A report by the OSPAR Commission describes the main human pressures in a region of the Arctic Ocean that includes the east coast of Greenland. Owing to this LME's remoteness and low population density, environmental conditions within it are generally good. However, certain activities such as fisheries give cause for concern. In terms of oil pollution, the difficulties associated with taking remedial actions in a cold environment such as this are also of concern. Levels of PCB and DDT are quite high in both biotic and abiotic media around eastern Greenland. For more information about pollutants in the Arctic region including Greenland, the AMAP website (www.amap.no) makes recent reports available. The measurement of 'new' chemicals, in particular brominated and fluorinated compounds in the Arctic environment and evidence of the biological effects of OCs (Organochlorines) in polar bears, glaucous gulls, and northern fur seals are highlights of recent research carried out on POPs in the Arctic (AMAP 2002 Report on POPs). These compounds can adversely affect immune, endocrine and reproductive systems.

The PAME Working Group is involved in assessing changing states of Arctic environments (see also the Governance module). The PAME work plan (2004-2006) will identify indicators of ecosystem health and ecosystem objectives for the Arctic LMEs. In the Arctic, the average extent of sea-ice cover in the summer has declined by 15-20% over the past 30 years. This decline is expected to accelerate, with the near total loss of sea ice in the summer projected for late this century (ACIA 2004). The OSPAR website has information on the protection and conservation of marine biodiversity and ecosystems, eutrophication, hazardous and radioactive substances (www.ospar.org).

IV. Socioeconomic Conditions

The first Europeans arrived in Ammassalik only about 100 years ago. The human population in the region is extremely small, with about 3,500 people living in the 2 towns and 9 settlements of Greenland's east coast. Many are from the traditional Inuit culture, which continues to play an important role in everyday life. The Inuit dependence on fishing and on the harvesting of wildlife formed the basis of their society, culture and economy. Today, the local population continues to be highly dependent on the fish, crustaceans and mussels obtained from the sea, and on the hunting of seals, whales, polar bears and other prey. Fishing accounts for 95% of total exports. Certain mineral deposits may be of future economic interest, including the oil fields near Jameson Island in East Greenland. Diamond, gold, niobium, tantalite, uranium and iron deposits are found on the island.

The PAME Working Group has information on the indigenous and non-indigenous communities living in the Arctic who are heavily dependent on the Arctic living marine resources. All of these groups are represented in the Arctic Council. OSPAR provides information on the offshore oil and gas industry, and the use of the ecosystem approach to the management of human activities (www.ospar.org).

V. Governance

For centuries Greenland belonged to Denmark, but since 1979 has moved towards independence. The Greenland Institute of Natural Resources is responsible for providing scientifically sound management advice to the Greenland government. Investigations on selected fish larvae and zooplankton in relation to hydrographic features is currently undertaken as part of the monitoring programme NuukBasic. The marine component of the monitoring program was initiated in 2005, and is managed by the Center of Marine

Ecology and Climate Effects at Greenland Institute of Natural Resources. Results from the monitoring programme are published in annual reports, as well as peer-reviewed scientific papers when appropriate. Issues that have been identified as important for the management of this LME include the need to improve the scientific basis for linking climatic variability and climate change to the chemical and biological processes and fishing pressure. Greenland participates in the Arctic Council and OSPAR as part of Denmark and the Faroe Islands.

References

ACIA (2004). Arctic Climate Impact Assessment. Impacts of a warming Arctic. Overview report. http://amap.no/workdocs/index.cfm?dirsub=%2FACIA%2Foverview.

AMAP. Arctic Monitoring and Assessment Program. www.amap.no

Belkin, I.M. (2004) Propagation of the "Great Salinity Anomaly" of the 1990s around the northern North Atlantic, *Geophysical Research Letters*, **31**(8), L08306, doi:10.1029/2003GL019334.

Belkin, I.M. (2009) Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I.M., Cornillon, P.C., and Sherman, K. (2009). Fronts in Large Marine Ecosystems. Progress in Oceanography, in press.

Belkin, I.M., Levitus, S. Antonov, J. and Malmberg, S.-A. (1998) "Great Salinity Anomalies" in the North Atlantic, *Progress in Oceanography*, **41**(1), 1-68.

Buch, E., Horsed, S. A. and Hovgard, H. (1994). Fluctuations in the occurrence of cod in Greenland waters and their possible causes. ICES Marine Science Symposia 198:158-174.

Dickson, R.R., J. Meincke, S.-A. Malmberg, and A.J. Lee (1988) The “Great Salinity Anomaly” in the North Atlantic, 1968–1982, *Progress in Oceanography*, **20**(1), 103–151.

Hamilton, L.C., Brown, B.C. and Rasmussen, R.O. (2003) West Greenland's cod-to-shrimp transition: Local dimensions of climate change, *Arctic*, **56**(3), 271-282.

Hansen, P.M. (1949). Studies on the biology of the cod in Greenland waters. Rapports et Proces-Verbaux des Reunions, Conseil International pour l’Exploration de la Mer 123:1-83.

Hardy, R.J., Bamber, J.L., and Orford, S. The delineation of major drainage basins on the Greenland ice sheet using a combined numerical modelling and GIS approach. Hydrological Processes.

Horsted, S.Aa. (1989). Some Features of Oceanographic and Biological Conditions in Greenland Waters, p 456-476 in: Rey L. and Alexander, V. (eds.) Proceedings of the Sixth Conference of the Comite Arctique International 13-15 May 1985. E.J. Brill., Leiden.

NOAA (1991). Report of the ad hoc Committee on Large Marine Ecosystems. NOAA Technical Memorandum NMFS-F/NEC-92.

Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. Nature 374: 255-257.

Pauly, D. and Watson, R. (2005). Background and interpretation of the ‘Marine Trophic Index’ as a measure of biodiversity. Philosophical Transactions of the Royal Society: Biological Sciences 360: 415-423.

Pauly, D., Christensen, V., Dalsgaard, J., Froese R. and Torres, F.C. Jr. (1998). Fishing Down Marine Food Webs. Science 279: 860-863.

Prescott, J.R.V. (1989). The political division of Large Marine Ecosystems in the Atlantic Ocean and some associated seas, p 395-442 in: Sherman, K. and Alexander, L.M. (eds), Biomass Yields and Geography of Large Marine Ecosystems. AAAS Selected Symposium 111. Westview Press, Boulder, United States.

Sea Around Us (2007). A Global Database on Marine Fisheries and Ecosystems. Fisheries Centre, University British Columbia, Vancouver, Canada. www.seaaroundus.org/lme/SummaryInfo.aspx?LME=19

Skjoldal, H.R., Noji, T.T., Giske, J., Fossaa, J.H., Blindheim, J. and Sundby, S. (1993). Mare Cognitum. Science Plan for Research on Marine Ecology of the Nordic seas (Greenland, Norwegian, Iceland Seas) 1993-2000. A regional GLOBEC programme with contributions also to World Ocean Circulation Experiment and Joint Global Ocean Flux Study. Institute of Marine Research, Bergen, Norway.

Stevens, D.P., (1991). A numerical ocean circulation model of the Norwegian and Greenland Seas. Progress in Oceanography 27:365-402.

UNEP (2004). Pedersen, S.A., Madsen, J. and Dyhr-Nielsen, M. Arctic Greenland, East Greenland Shelf, West Greenland Shelf, GIWA Regional Assessment 1b, 15, 16. University of Kalmar, Kalmar, Sweden. www.giwa.net/publications/r1b_15_16.phtml.