ICELAND AND EAST GREENLAND

2.1 Ecosystem overview

2.1.1 Greenland

2.1.1.1 Ecosystem components

Bottom topography, substrates, and circulation

The seafloor drops rapidly from the Greenland coast to depths over 1000 m. In the areas seasonally ice free, the shelf area is rarely more than 75 km wide. The coastline and sub-sea topography are heavily serrated with canyons, and bottom topography is generally rough with hard bottom types.

The strong, cold East Greenland Current dominates the hydrographic conditions along the coast of Greenland. In some years the warmer Irminger Current extends somewhat further west, transporting heat and organisms from Iceland into Greenland waters.

Physical and chemical oceanography (temperature, salinity, nutrients)

East Greenlandic waters are much colder than those surrounding Iceland. The surface layer is dominated by cold polar water, while relatively warm mixed water of Atlantic origin is found at depths between 150 and 800 m up to about 64° N. Mixing and diffusion of heat between these two layers, as well as changes of the relative strength of flow of these two main water components are fundamental in determining physical marine climatic conditions as well as primary and secondary production off western Greenland. Large changes in water temperature regimes have been documented on time-scales of decades or longer in both east and west Greenlandic waters.

In 2005 and 2006 Greenlandic waters were warmer than the long-term average, continuing a trend started earlier in this decade. The warming was stronger in western Greenland than in eastern Greenland, where a strong inflow of Irminger Sea water was present as far north as Fylla Bank, resulting in the warmest temperatures in more than 50 years. However, in the last quarter of 2005 there was a marked cooling of waters around Greenland, declining to near long-term average surface temperatures. This appears to have reversed in 2006, with satellite monitoring data indicating that water temperatures may be increasing again (NASA, 2007). There was also much greater than average melting of glaciers and snow on both coasts of Greenland, increasing the input of freshwater runoff to coastal areas. Between April 2005 and April 2006 ice melted from the Greenland ice sheet at more than two and a half times times the rate in 2003 and 2004 (University of Colorado, 2007).

The west Greenland marine ecosystem is considered to lie between about 60° N, the latitude of Cape Farewell, and about 70° N, the latitude of Disko Island. The near-shore bottom topography is characterized by a continental shelf 60–200 km broad. The physical oceanographic conditions in west Greenland waters are controlled by the large-scale circulation in the North Atlantic: a branch of the warm North Atlantic current circles anti-clockwise in the Irminger Sea off southeast Greenland to join the cold East Greenland Current and around Cape Farewell to form the north-setting West Greenland Current. Under the influence of this relatively warm current, the west Greenland marine ecosystem is Subarctic. Sea ice in winter usually extends no further south than about 66° N. The transport of heat salt and nutrients, as well as plankton, fish eggs, and larvae, to Greenland waters by these dominant North Atlantic current systems and their fluctuations as a consequence of climate change are – together with the runoff of freshwater from land – the major governing processes for the Greenland marine ecosystem (Hunt and Drinkwater, 2005).

For west Greenland there exists a continuous series of temperature and salinity observations spanning more than 50 years, but interdisciplinary research is needed to understand the physical, chemical, and ecological processes that will be affected by climatic change and potentially cause changes in the marine ecosystem.

Investigations in other regions have documented that hydrographic fronts are important to plankton community structure and dynamics. Plankton production at fronts is transferred to higher trophic levels including commercially important fish stocks. Observations of fish catch and distribution of seabirds and marine mammals support the thesis that such sites are of key importance in understanding, as well as exploiting, the production from the west Greenland ecosystem. The coupling between frontal dynamics along the banks at west Greenland has not, on the other hand, been previously investigated, but in particular, knowledge about frontal dynamics and upwelling of nutrients from the deeper parts of the surface layer is needed if the pelagic production is to be understood (Hunt and Drinkwater, 2005).

The deep Greenland Sea is an important area for deep-sea convection of heat in the ocean. The nature and timing of water mass formation in the Greenland Basin plays a significant role in global climate change.
Phytoplankton – timing, biomass/abundance, and major taxonomic composition

The east Greenland Shelf is a low productivity (<150 g C m⁻² yr⁻¹) ecosystem based on SeaWiFS global primary productivity estimates. The melting of the ice in the summer has significant effects on ecological conditions, causing large amounts of nutrients 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. The plankton bloom is dominated by diatoms, but in some years the flagellate Phaeocystis may also contribute. http://na.nefsc.noaa.gov/lme/text/GIWAGreenlandreport.pdf.

The microbial food web in the Arctic has received relatively little attention. However, in high latitude ecosystems the function of these small grazers in coupling the primary production to the fish stocks has to be considered. Recent investigations in Disco Bay and Young Sound and on the banks off west Greenland have documented that bacterioplankton and unicellular zooplankton play a prominent role (Rysgaard et al., 1999; Levrinsen and Nielsen, 2002). Judging from the relative biomass distribution, a large part of the primary production may be channelled through these micro-organisms.

Zooplankton

Zooplankton production in east Greenlandic waters is dominated by Calanus, but late in summer, smaller plankton species may become common. http://na.nefsc.noaa.gov/lme/text/GIWAGreenlandreport.pdf.

These zooplankton, particularly calanoid copepods and krill, are eaten by adult herring and capelin, and by juvenile stages of numerous other fish species as well as by baleen whales. The larvae of both pelagic and demersal fish also feed on eggs and juvenile stages of the zooplankton. In the pelagic ecosystem off Greenland and Iceland the population dynamics of calanoid copepods and to some extent krill are considered to play a key role in the food web as a direct link to fish stocks, baleen whales (Mysticeti), and some important seabirds, such as little auk (Alle alle) and Brünnich’s guillemot (Uria lomvia).

The pelagic ecosystem off west Greenland is poorly known, and baseline studies are therefore necessary before processes such as climate change can be addressed or scenarios modelled. Historically, most research in Arctic pelagic ecology has considered only the larger components of the food web, e.g. the diatoms and calanoid copepods. Research during the last century has documented the annual cycle and population dynamics of Calanus copepods and stressed the key role of these organisms in high latitude distributions. This part of the food web is the direct link to fish stocks. Several key seabird species also rely on Calanus.

From a carbon sediment point of view the composition of the grazer community is also essential. Zooplankton influences carbon dynamics in several ways: by vertical migration, through grazing activity, and as accelerators of sedimentation of organic matter through production of fecal material. An efficient transfer of organic matter produced in the water column to the sea floor through a close pelagic-benthic coupling, together with a low metabolism of benthic fauna, are among the reasons why a high benthic biomass can be maintained in Arctic regions. Despite permanently low temperatures, near-shore Arctic benthic communities mineralize organic matter as efficiently and as rapidly as communities in lower latitudes. Although it represents the link between pelagic production and benthic animal production, virtually no measurements of vertical export exist from west Greenland waters. Furthermore, knowledge of distributional patterns and remineralization potential of the benthos along the west coast is absent. No studies have dealt with growth and production of individual species, and such studies are necessary in order to elucidate the ecological role of macrobenthos in the Arctic food chain (Hunt and Drinkwater, 2005).

Benthos, larger invertebrates (cepalopods, crustaceans, etc.), biogenic habitat taxa

Shrimp biomass off east Greenland and Denmark Strait has been relative stable in the last years considering standardized cpue data, which include most, but not all fleets participating in the fishery (see e.g. NAFO SCS Doc. 04/20). Other information, e.g. survey-based results on shrimp/cod interaction, does not exist for this area.

Fish community

The Greenlandic commercial fish and invertebrate fauna counts fewer species and is characterized by coldwater ones such as Greenland halibut (Hippoglossoides Reinhardtii), northern shrimp (Pandalus borealis), capelin, and snow crab (Chionoecetes opilio). Redfish (Sebastes spp.) are also found, but mainly in Atlantic waters outside the cold waters of the east Greenland continental shelf. Greenlandic waters also contain capelin populations that spawn at the heads of numerous fjords on the western and eastern coasts.

Cod spawn in many west Greenland Fjords and off the banks of southern and eastern Greenland. In some years considerable numbers of larvae drift from Iceland to Greenland and, when mature, these fish return to Iceland to spawn.
The fishable and spawning components of the west Greenland cod are believed to have reached more than 3 and 4 million tonnes respectively in their heyday in the 1940s (Figure 2.1.1.1). The Greenland cod stock collapsed in the 1970s because of worsening climate conditions and overfishing. After 1970, all year classes of cod of any importance at east Greenland have been of Icelandic origin.

Warm conditions have returned since the mid-1990s and, in particular off eastern Greenland, some increase in the abundance of juvenile cod has been observed since the early 2000s. However, recruitment, although improved, has remained below what was seen at comparable hydrographic conditions before, suggesting that other factors might have become more prominent. Possible contributing factors include as the younger age structure of the cod spawning stock at Iceland (reduced egg quality and changed location and timing of larval hatch) and the bycatch of small cod in the increased fishery for northern shrimp. However, the year classes from 2002 and possibly more recently are beginning to support substantial increases in cod biomass off Greenland. Management of this biomass, including decisions on when, where, and how much cod and shrimp to harvest, must take into account the potential for rebuilding spawning biomass off Greenland, the consequences of increased shrimp for the shrimp fishery, and the possibility that as the cod year classes mature they will return to Icelandic waters.

Exploitation of, and research on, offshore fish in west Greenland has been dominated by demersal species. The Atlantic cod fishery is episodic. For example in the 1960s, catches were up to 400 K tonnes year\(^{-1}\), but in 1990 they were close to zero. The most significant fishery since the 1970s has been that for northern shrimp, with catches up to 100 K tonnes year\(^{-1}\) from a biomass estimated by trawl survey to be near 1000 K tonnes. Indications are that the stock has increased continuously during the decade ca. 1994–2004. Surveys in the area indicate that the composition of demersal fish species inhabiting the shelf and continental slope has changed fundamentally since the early 1980s. At the same time, there has been a dramatic change in biomass and size structure of ecologically important species. Today, northern shrimp and Greenland halibut are the only important offshore species fished in the area. In the past, the sandeel was a significant prey for other fishes, seabirds, seals, and whales. Today there are indications that the sandeel is no longer as abundant, and its importance is uncertain. Unless the mechanism underlying these past radical changes in the offshore demersal system can be better understood, the response of the ecosystem to a changing environment will remain unpredictable (Hunt and Drinkwater, 2005).

The pelagic fish community off west Greenland is poorly investigated. Arctic cod and capelin are probably the principal fish species, with squids being the most important pelagic macrofauna. However, juvenile redfish, distributed both demersally and pelagically on the slopes of the banks, compose a huge resource in the west Greenland marine ecosystem, and probably come from stocks in waters east of Greenland. An important task is to determine the structure and function of higher-level components of the pelagic system, and the implications of fishery exploitation on the internal stability of this sub-system.

Birds and mammals: dominant species composition, productivity (esp. seabirds), spatial distribution (esp. mammals)

Seabirds constitute a conspicuous component of the west Greenland ecosystem in winter. At least 3.4 million birds are estimated to winter in the area, not counting unknown numbers, probably also in the millions, of little auks (Alle alle). The winter seabird community is dominated by pursuit-diving Alcidae-Brünnich’s guillemot, black guillemot, little auk, and bottom-feeding eiders: king eiders on the banks and common eiders along the coasts. In summer, the offshore seabird density is lower and mainly consists of wide-ranging surface-feeding fulmars and gulls (kittiwake, glaucous gull, and Iceland gull) (Hunt and Drinkwater, 2005).

Seabirds harvests in west Greenland have been high, in particular Brünnich’s guillemot (>200 000 year\(^{-1}\)) and eiders (>80 000 year\(^{-1}\)), and declines in breeding populations both in Greenland and elsewhere in the Arctic have been ascribed to hunting in west Greenland. It is currently a major management problem to develop locally accepted and sustainable management regimes for seabirds in the west Greenland ecosystem, both in terms of harvest levels and in terms of ensuring that production is not reduced by disturbance in breeding and critical foraging areas.

The west Greenland marine mammal fauna reflects both Atlantic and Arctic influences. North Atlantic whale species occur in west Greenland: minke, fin, sei, and humpback whales mostly feed on small schooling fish or on large invertebrates. Atlantic odontocetes include such cool-water species as the harbour porpoise, the Atlantic white-sided dolphin, the white-beaked dolphin, the killer whale, the long-finned pilot whale, and the northern bottlenose whale. Among Arctic species, the bowhead occurs in west Greenland in winter but in low numbers, belugas and narwhals are also present in the more northerly parts of the west Greenland system in winter, associated with the sea ice (Hunt and Drinkwater, 2005).

The northwest Atlantic stocks of harp and hooded seals are migratory, and pelagic in summer, and are then numerous in west Greenland. Stock size for harp seal is in the range of 6 million, but it is not know what proportion comes to Greenland waters. Ringed and bearded seals are restricted to areas with winter sea ice. Harbour seals and walruses are
found in small numbers in west Greenland. Both these species have been reduced in numbers by hunting and other disturbances (Hunt and Drinkwater, 2005).

**Environmental forcing on ecosystem dynamics**

This section will be developed in future years.

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**Figure 2.1.1.1** Recruitment at age 3, spawning biomass, and fishable biomass of cod off west Greenland.
2.1.2 Iceland

2.1.2.1 Ecosystem components

**Bottom topography, substrates, and circulation**

Iceland is located at the junction of the Mid-Atlantic Ridge and the Greenland–Scotland Ridge just south of the Arctic Circle. The bottom topography of this region is generally irregular, with hard rocky bottom prevailing in most areas. The shelf around Iceland is cut by many sub-sea canyons. It is narrowest off the south coast where in places it extends out only a few km. From there, the continental slope falls away to over 1000 m. Off the west, north, and east coasts, however, the shelf is relatively broad and extends often over 150 km from the coast.

To the south of Iceland the Iceland Basin is separated in the west from the Irminger Sea by the Reykjanes Ridge and in the east from the Norwegian Sea by the Iceland–Faroe Ridge. North of Iceland the Kolbeinsey Ridge stretches to the Jan Mayen Fracture Zone, between Jan Mayen and Greenland, marking the northern limit of the Iceland Sea and separating it from the Greenland Sea. South from Jan Mayen, the Iceland–Jan Mayen Ridge extends to the Iceland–Faroe Ridge, separating the Iceland Sea from the Norwegian Sea (Asthorsson *et al.*, 2007).

The Polar Front lies between Greenland and Iceland and separates the cold and relatively low saline south-flowing East Greenland Current from the Irminger Current, the westernmost branch of the warmer and more saline North Atlantic Current (Figure 2.1.2.1). South and east of Iceland the North Atlantic Current flows towards the Norwegian Sea. The Irminger Current flows northward over and along the Reykjanes Ridge and into the Denmark Strait where it is split. One branch continues northeastward and eastward to the waters north of Iceland and the other branch flows southwestward parallel to the East Greenland Current. In the Iceland Sea north of Iceland a branch out of the cold East Greenland Current flows over the Kolbeinsey Ridge and continues to the southeast along the northeastern shelf brake as the East Icelandic Current. This current is part of a cyclonic gyre in the Iceland Sea.

**Physical and chemical oceanography (temperature, salinity, nutrients)**

Icelandic waters are relatively warm due to Atlantic influence and are generally ice free. Infrequently for short periods in late winter and spring drift ice may come close inshore and even become landlocked off the northwestern and northern coasts. Waters to the south and west of Iceland are usually within the range of 6–10°C whereas on the north Icelandic shelf mixing of Atlantic and Arctic waters means temperatures cool from west (~4–6°C) to east (<4°C). The water masses of the Iceland Sea are much colder than those of the Icelandic shelf.

Hydrobiological conditions are much less variable in the Atlantic water south and west of Iceland than in the waters to the north and east of the country where considerable inter-annual variations of hydrography have been observed. On longer timescales changes in the strength and position of major currents and water masses show some linkages to NAO regime shifts (Figure 2.1.2.2) (Malmberg *et al.*, 1999). However, the atmospheric forces driving the observed seasonal and interannual variations in the ocean climate north of Iceland are also to a considerable extent of local origin. This is probably because the NAO index is mainly related to the westerly winds blowing across the Atlantic at mid-latitudes to the south of Iceland (Asthorsson *et al.*, 2007).

**Broad-scale climate and oceanographic features and drivers**

As pointed out above the NAO has some effect on ocean climate and water mass distributions in these waters, and environmental regimes are thought to have changed several times over the past decades. These regimes are thought to have affected the productivity of many exploited fish stocks, as well as the fish and zooplankton on which they feed. In 2005 the NAO was in a condition of transition. After being strongly positive for several years during the late 1990s it changed to near average conditions at the turn of the 21st century. The position and strength of the Icelandic Low during the past two years appears to be without a clear trend towards a state that is either strongly negative or positive.

**Phytoplankton-timing, biomass/abundance, and major taxonomic composition**

The Iceland Shelf is a high (150–300 g C m⁻² year⁻¹) productivity ecosystem based on SeaWiFS global primary productivity estimates. Productivity is higher in the southwest regions than to the northeast, and higher on the shelf areas than in the oceanic regions (Gudmundsson, 1998). There are marked changes in the spring development of phytoplankton from one year to another, depending on local atmospheric conditions, but spring blooms may start as early as mid-April rather than the more usual mid-May. “Cold” years, with less influence of North Atlantic Current waters to the north of Iceland tend to have lower primary productivity in comparison to years when the influence of the Atlantic water has been as extensive and predominant as in the past decade.
Over the Icelandic shelf diatoms of the genera *Thalassiosira* spp. and *Chaetoceros* spp. typically dominate the phytoplankton spring bloom. During some years the prymnesiophyte *Phaeocystis pachetii* may be abundant in the waters to the north of Iceland in spring. Dinoflagellates of the genera *Ceratium* spp. and *Protoperidinium* spp. increase in abundance after the spring bloom, while diatoms continue to be relatively abundant. In the autumn there is usually a second bloom of diatoms and dinoflagellates (Astthorsson et al., 2007).

**Zooplankton**

In terms of numbers of individuals, copepods dominate the mesozooplankton of Icelandic waters with *Calanus finmarchicus* being the most abundant species, often comprising between 60–80% of net-caught zooplankton in the uppermost 50 m (Astthorsson and Vilhjalmsson, 2002; Astthorsson et al., 2007). Other copepod species occurring regularly over the shelf around Iceland are *Pseudoislanus* spp., *Acartia longiremis* and *Oithona* spp., while some species are more confined to the Atlantic water (e.g. *Temora longicornis, Centropages hamatus*) or to the Polar water (e.g. *Metridia longa, Calanus hyperboreus, Calanus glacialis*) (Gislason and Astthorsson, 2004). The euphausiid *Thysanoessa raschi* is common in fjord areas while *Thysanoessa inermis* is the dominant euphausiid over the shelves. In addition, the euphausiids *Meganyctiphanes norvegica* and *Thysanoessa longicaudata* are mainly found near the shelf edge in oceanic water to the south and west of Iceland (Einarsson, 1945).

Since the early 1960s monitoring of zooplankton biomass in the upper 50 m in Icelandic waters has been carried out on standard transects during May–June (Astthorsson et al., 2007). *Calanus finmarchicus* is the dominant species of the plankton community, and therefore the biomass mainly reflects the biomass of this species. The spring zooplankton biomass generally ranges from ca. 1–10 g dry weight m⁻², with an average of 2–4 g dry weight m⁻². Higher biomass is usually observed in shelf waters off the south and west coasts, in the oceanic waters to the north and northeast of Iceland where Arctic influence is greatest and large Arctic species dominate, and in offshore waters of the Irminger and Norwegian Seas.

Zooplankton biomass time-series in the waters to the north of Iceland show maxima occurring approximately every 7–10 years. Also striking is the collapse in zooplankton biomass during the cold period in the North Atlantic and to the north of Iceland in the 1960s, and it was not until the warm period in the 1990s that biomass levels recovered (Astthorsson and Gislason, 1995).

Zooplankton biomass variability to the north of Iceland is positively related to temperature, which again reflects the inflow of Atlantic water into the area. On average, zooplankton biomass in “warm” years is about 2 times higher than in “cold” years (Astthorsson and Gislason, 1998). Greater inflow of Atlantic water will lead to increased primary production which results in good feeding conditions for zooplankton. The warm temperatures will promote increased growth and faster development times of zooplankton, and the stronger inflow of Atlantic water may advect more zooplankton from the south and west (Astthorsson et al., 2007).

Monitoring series indicate that in the early part of this decade zooplankton biomass was relatively high both north and south of Iceland but began to decline in 2002 in both areas. Zooplankton biomass was near historic lows in the north by 2003 and in the south in 2004 (ICES, 2005). In 2005 and 2006 zooplankton biomass north of Iceland was again above the long-term average, with a decrease in 2007. To the south the zooplankton biomass has been below the long-term average since 2003 (Anon., 2008).

**Benthos, larger invertebrates (cephalopods, crustaceans, etc.), biogenic habitat taxa**

The Greenland–Scotland Ridge represents a biogeographical boundary between the North Atlantic Boreal Region and the Arctic Region and major faunistic changes around Iceland are mainly associated with the ridge. Species diversity of the hyperbenthic family Eusiiridae has been shown to be lower in the deeper parts of the Nordic Seas, i.e. the Norwegian, Greenland, and Iceland Seas compared with areas south of the Greenland–Scotland Ridge (e.g. Weisshappel, 2000). This has been explained partly by a short evolutionary time of the fauna within this environment, but is in particular due to isolation caused by the Greenland–Scotland Ridge, which acts as a barrier against the immigration of species into the Nordic Seas (Svavarsson et al., 1993). Studies, based on material from the BIOICE programme, indicate that in the Iceland Sea and the western part of the Norwegian Sea, the benthic diversity increases with depth to about 320 to 1100 m (shelf slope), below which the diversity again decreases (Svavarsson, 1997). South of the ridge the species diversity has been shown to increase with depth (Weisshappel and Svavarsson, 1998).

The underlying features which appear to determine the structures of benthic communities around Iceland are salinity (as an indicator of water masses) and sediment types. Accordingly, the distribution of benthic communities is closely related to existing water masses and, on a smaller scale, with bottom topography (Weisshappel and Svavarsson, 1998). Also, it has been shown that large differences occur in species composition around the Kolbeinsey Ridge, in the Iceland Sea, with greater abundances and diversity of peracarid crustaceans on the western slope of the ridge, compared with
the east slope (Brandt and Piepenburg, 1994). This will indicate that benthos abundance and diversity is determined by differences in bottom topography and food supply (largely pelagic primary production).

Survey measurements indicate that shrimp biomass in Icelandic waters, both in inshore and offshore waters, has been declining in recent years. Consequently the shrimp fishery has been reduced and is now banned in most inshore areas. The decline in the inshore shrimp biomass is in part considered to be environmentally driven, both due to increasing water temperature north of Iceland and due to increasing biomass of younger cod, haddock, and whiting.

*Lophelia pertusa* was known to occur in 39 places in Icelandic waters (Carlgren, 1939; Copley et al., 1996). The distribution was mainly confined to the Reykjanes Ridge and near the shelf break off the southern coast of Iceland. The depth range was from 114 to 875 m, with most occurrences between 500 and 600 m depth.

Based on information from fishers (questionnaires), eleven coral areas were known to exist close to the shelf break off northwest and southeast Iceland around 1970. Since then more coral areas have been found, reflecting the development of the bottom trawling fisheries extending into deeper waters in the 70s and 80s. At present considerably large coral areas exist on the Reykjanes Ridge and off southeast Iceland (Hornafjarðardjúp deep and Lónsdjúp deep). Other known coral areas are small (Steingrímsson and Einarsson, 2004).

In 2004 a research project was initiated to map coral areas off Iceland (using a Remote Operated Vehicle, ROV), based on the results from questionnaires to fishers on the occurrence of such areas. The aim of the project is to assess the species composition (including *L. pertusa*), diversity, and the status of coral areas in relation to potential damages by fishing practices. In the first survey, intact *Lophelia* reefs were located in two places on the shelf slope off the southern coast of Iceland. Evidence of bottom trawling activities in these areas was not observed.

The database of the BIOICE programme provides information on the distribution of soft corals, based on sampling at 579 locations within the territorial waters of Iceland. The results show that gorgonian corals occur all around Iceland. They were relatively uncommon on the shelf (< 500 m depth) but are generally found in relatively high numbers in deep waters (> 500 m) off southern, western, and northern coasts of Iceland. Similar patterns were observed in the distribution of pennatulaceans off Iceland. Pennatulaceans are relatively rare in waters shallower than 500 m but more common in deep waters, especially off southern Iceland (Guijarro et al., 2006).

Aggregation of large sponges (“ostur” or sponge grounds) is known to occur off Iceland (Klittgard and Tendal, 2004). North of Iceland, particularly in the Denmark Strait, “ostur” was found at several locations at depths of 300–750 m, some of which are classified as sponge grounds. Comprehensive “ostur” and sponge grounds occur off northern and southern Iceland and around the Reykjanes Ridge (Guijarro et al., 2006).

**Fish community**

Icelandic waters are comparatively rich in species and contain over 25 commercially exploited stocks of fish and marine invertebrates. Main species include cod, haddock, saithe, redfish, Greenland halibut and various other flatfish, wolffish, tusk (*Brosme brosme*), ling (*Molva molva*), herring, capelin, and blue whiting. Most fish species spawn in the warm Atlantic water off the southern and southwestern coasts. Fish larvae and 0-group drift west and then north from the spawning grounds to nursery areas on the shelf off northwest, north, and east Iceland, where they grow in a mixture of Atlantic and Arctic water.

Capelin is important in the diet of cod as well as a number of other fish stocks, marine mammals, and seabirds. Unlike other commercial stocks, adult capelin undertake extensive feeding migrations north into the cold waters of the Denmark Strait and Iceland Sea during summer. Capelin abundance has been oscillating over roughly a decadal period since the 1970s, producing a yield of >1600 Kt at the most recent peak. In recent years the stock size of capelin has decreased from about 2000 Kt in 1996/97 to about 1000 Kt in 2006/07 (Anon., 2007). Herring were very abundant in the early 1960s, collapsed, and then increased from 1970 to a historical high level in the last decade. Abundance of demersal species has been trending downward irregularly since the 1950s, with aggregate catches dropping from over 800 Kt to under 500 Kt in the early 2000s.

A number of species of sharks and skates are known to be taken in the Icelandic fisheries, but information on catches is incomplete, and the status of these species is not known. Information on status and trends of non-commercial species are collected in extensive bottom trawl surveys conducted in early spring and autumn, but information on their catches in fisheries is not available.
Birds and mammals: dominant species composition, productivity (esp. seabirds), spatial distribution (esp. mammals)

The seabird community in Icelandic waters is composed of relatively few but abundant species, accounting for roughly one quarter of the total number and biomass of seabirds within the ICES area (ICES, 2002). Auks and petrel are the most important groups, comprising almost three fifths and one quarter of the abundance and biomass in the area, respectively. The most abundant species are Atlantic puffin (Fratercula arctica), northern fulmar (Fulmarus glacialis), common (Uria aalge) and Brunnich’s guillemot (Uria lomvia), black-legged kittiwake (Rissa tridactyla), and common eider (Somateria mollissima). The estimated annual food consumption is about 1.5 million tonnes.

At least 12 species of cetaceans occur regularly in Icelandic waters, and an additional 10 species have been recorded more sporadically. Reliable abundance estimates exist for most species of large whales while such estimates are not available for small cetaceans. In the continental shelf area minke whales (Balaenoptera acutorostrata) probably have the largest biomass. According to a 2001 sightings survey, 67 000 minke whales were estimated in the Central North Atlantic stock region, with 44 000 animals in Icelandic coastal waters (NAMMCO, 2004; Borchers, 2003; Gunnlaugsson, 2003). Minke whales have opportunistic feeding habits, their diet ranging from planktonic crustaceans (krill) to large (> 80 cm) cod. Little information is available on the diet composition of minke whales in Icelandic and adjacent waters, but their annual consumption has been estimated to be of a size equivalent to the total catch of the Icelandic fishing fleet (2M tonnes). Fin whales (Balaenoptera physalus) are mainly distributed along the continental slope and further offshore. The abundance of the East Greenland–Iceland stock of fin whales was estimated at around 23 thousand animals in 2001 (Pike et al., 2003). This stock has been increasing during the last 20 years, mainly in the waters between Iceland and east Greenland. The diet of Icelandic fin whales is known only from the whaling grounds west of Iceland where it consists overwhelmingly of krill, mainly Meganyctiphanes norwegica.

Sei whale (Balaenoptera borealis) abundance is estimated at around 10 thousand animals. This species has a similar distribution and diet in Icelandic waters as fin whales.

Humpback whale (Megaptera novaeangliae) abundance was estimated at around 14 thousand animals in 2001 (Pike et al., 2002). The abundance of this species has been increasing rapidly (10–14% per year) during the last 30 years, but the species was previously very rare. Feeding habits of humpback whales off Iceland are virtually unknown but the species seems to be closely related to the distribution of capelin at certain times of the year. Humpback whales are primarily distributed on the continental shelf area in Icelandic waters.

Sperm whales (Physeter macrocephalus) are a deep-water species, feeding on cephalopods and various fish species. They are relatively common in Icelandic waters, but no reliable absolute abundance estimate is available because of the long diving habits of the species.

Blue whale (Balaenopteur musculus) is the least abundant of the large whales with an estimated stock size of 1–2 thousand animals. This species feeds exclusively on krill.

As mentioned above, no reliable estimates are available for most species of medium-sized and small cetaceans. The exceptions are long-finned pilot whales (Globicephala melas) with an estimated abundance of around 800 thousand animals in the Icelandic–Faroes area, and northern bottlenose whales (40 thousand in the NE Atlantic). Some of these small cetaceans (e.g. white -beaked dolphins (Lagenorhynchus albirostris) and harbour porpoises (Phocoena phocoena) are piscivorous and mainly distributed in coastal waters and may thus have significant interactions with fisheries.

Two species of seals, common seal (Phoca vitulina) and grey seal (Halicoerus grypus) breed in Icelandic waters, while five northern vagrant species of pinnipeds are found in the area (Sigurjónsson and Hauksson, 1994; Hauksson, 1993, 2004). The common seal is observed in coastal areas all around the country, while the grey seal is mainly found off the western, northwestern, and southeastern coasts.

The seal populations at Iceland have been harvested through the centuries, both for food and fur. Hunting of both species combined is currently limited to about 1000 individuals annually, well below the level of ca. 6000 animals of several decades ago. Regular surveys of the common seal and grey seal populations have been undertaken in Icelandic coastal waters since 1980 and 1982, respectively (Anon., 2007). Stock estimates for both species have declined considerably since initial surveys, common seals from about 30 000 individuals to about 10 000 and grey seals from about 9000 to 6000. The steady decrease in population size of both species is mainly considered to be due to over-exploitation (Anon., 2007).
2.1.2.2 Environmental forcing on ecosystem dynamics

The environmental conditions, particularly to the north of Iceland, have a major effect on the biology and distribution of many key species. Around the mid-1990s a rise in both temperature and salinity was observed in the Atlantic water to the south of Iceland. The positive trend has continued ever since and west of Iceland it amounts to an increase of temperature of about 1°C and a salinity of 0.1.

Off central N-Iceland a similar trend is observed, but more irregular since this is an area of variable mixing of warm and cold water masses. Nevertheless, the trend is clear and is indeed larger than in the Atlantic water off west Iceland (the same has been observed off southeastern Iceland as well). The increase of temperature and salinity north of Iceland in the last 10 years is on average about 1.5°C and 1.5 salinity units.

During 2007 temperature and salinity in the upper part of the water column to the south of Iceland were above the long-term average as has been the case since 1997. In the waters to the north of the country temperature and salinity were near the long-term average. Bottom temperature over the shelf has been above average since 2002 and in winter 2003 it was higher than in the previous decades. In May–June 2007 bottom temperature was near or above average all around Iceland (Anon., 2006).

In recent years capelin have both shifted their larval drift and nursing areas far to the west to the colder waters off eastern Greenland. The arrival of adults on the overwintering grounds on the outer shelf off northern Iceland has also been delayed, with migration routes to spawning grounds off southern and western Iceland being located further away from northern and eastern Iceland and not reaching as far west along the southern coast as in most earlier years. This, along with a possible decrease in the stock size of capelin has resulted in a lower food availability of capelin for feeding by the Icelandic cod stock and thus a poorer condition of cod since 2003. There is evidence that the change in the distribution of capelin and thus less overlap in the distribution with cod may be leading to a marked detrimental impact on cod growth (Anon., 2006).

Several southern gadoids such as haddock, saithe, and whiting (Merlangius merlangus) and the monkfish (Lophius piscatorius) are amongst the species that have shown the largest distribution extensions and increases in abundance in recent years. Recruitment investigations on haddock have further demonstrated that, except for 2001, all year classes between 1998 and 2003 have been strong. In fact, the 2003 year class is estimated to be the strongest in 45 years. This increased recruitment and more northerly and northeasterly distribution of haddock may be related to the positive temperature anomaly of recent years (Anon., 2007). Recent shifts in the distribution of the Icelandic summer-spawning herring around Iceland have also been associated with the warming and the same probably applies to the increase of blue whiting in Icelandic waters (Asthorsson et al., 2007).

Icelandic cod has not taken advantage, or not been able to take advantage, of the milder marine climate of Icelandic waters. However, during the last warm epoch, which began around 1920 and lasted until 1965, the Icelandic cod flourished. By the early 1980s the cod had been fished down to a very low level as compared to previous decades and has remained relatively low since. During the last 20 years the Icelandic cod stock has not produced a large year class, the average number of age 3 recruits being about 150 million fish per annum, as compared to 205–210 million recruits in almost any period prior to that, even the cold years of 1965–1971. Migrant cod from Greenland are not included in this comparison. It is not possible to pinpoint exactly what has caused this change, but a very small and young spawning stock is the most obvious common denominator for this protracted period of impaired recruitment to the Icelandic cod stock. Regulations, particularly the implementation of the catch rule in 1993, have resulted in lower fishing mortalities in the past ten years compared to the ten years prior to that and has, despite low recruitment, resulted in almost doubling of the spawning-stock biomass since 1993. This improvement in the SSB biomass has not, however, resulted in a significant increase in production in recent years, despite the increased inflow of warmer Atlantic water.

Asthorsson and Palsson (2006) reported on 22 southern fish species that in past 10 years have been recorded for the first time within the Icelandic 200 mile EEZ. Some of these species were found on common fishing grounds and close to land and are therefore considered to reflect actual changes taking place in the fish fauna around Iceland. Nine of the first-time records (flounder (Platichthys flesus), blue shark (Prionace glauca), violet cuskeel (Brotulotaenia crassa), black devil anglerfish (Melanocetus johnsonii), pink sabertooth (Evermannella balbo), palebelly seasr (Barbantus curvifrons), Lycodes terraenovae, Poromitra megalops, and Chaunax sutkusi) are from more than one location or from different years. Several rare species that used to be recorded only occasionally (or that had not been recorded for a long time) have in recent years been recorded almost annually (twaite shad (Alosa fallax), mackerel (Scomber scombrus), sea lamprey (Petromyzon marinus), and garpike (Belone belone)). In fact, mackerel has in recent years been found in the waters to the east of Iceland in considerable quantities, leading to a fishery in the Icelandic EEZ of more than 30 thousand tonnes in the summer of 2007. Furthermore, several rare southern species have during recent years clearly been extending their distribution to more northern locations (snake pipe fish (Entelurus aequoreus), greater fork-beard (Phycis blennoides), blue antimora (Antimora rostrata)). The changes in fish distribution are believed to be related to
the positive hydrographic anomaly (temperature and salinity), both in the Atlantic water to the south and in the Subarctic waters to the north of Iceland since the middle of the 1990s.

Figure 2.1.2.1  The system of ocean currents around Iceland and in the Iceland Sea.

Figure 2.1.2.2  Temperature deviations north of Iceland 1900–2000, five-year running averages.
Many of the demersal fisheries use mobile gears and fish on hard bottoms. This may potentially cause substantial impacts on seafloor structural habitats and benthos. If the recent changes in distribution of major fish stocks continue, there may be incentives for these fisheries to relocate to new fishing grounds. This could, in turn, potentially increase the amount of habitat altered by these gears, and should be discouraged until information is available on the nature and vulnerability of any new areas to be fished.

The ITQ system used in Icelandic fisheries has a built-in incentive for the fleet to direct effort to more valuable fish (high-grading). When juveniles comprise a high proportion of the fishable biomass of the target stock or the TAC/biomass proportion is relatively high, this may lead to increased discard of the target species. According to extensive discarding measurements carried out in the Icelandic fisheries since 2001 (Pálsson, 2003, 2004) discards as a proportion of landings in weight have been in the range of 0.6–7.1% for the main exploited demersal species (cod, haddock, saithe, redfish, plaice). Reliable information on non-target species taken as bycatch in these fisheries is not available.

2.2.1 References


