4 Faroe Plateau Ecosystem

4.1 Ecosystem overview

4.1.1 Ecosystem Components

Topography, water masses and circulation

The upper layers of the waters surrounding the Faroes are dominated by ‘Modified North Atlantic Water’ which derives from the North Atlantic Current flowing towards the east and northeast (Hansen and Østerhus, 2000) (Figure 4.1.1, upper left panel). This water is typically around 8°C with salinities around 35.25. Deeper than 500–600 m (Figure 4.1.1, lower left panel), the water in most areas is dominated by cold water (T<0°C) with salinities close to 34.9, flowing out of the Nordic Seas through the deepest passages.

In shallow regions, there are strong tidal currents, which mix the shelf water very efficiently. This results in homogeneous water masses in the shallow shelf areas. The well-mixed shelf water is separated relatively well from the offshore water by a persistent tidal front, which surrounds the shelf at about the 100–130 m bottom depth. In addition, residual currents have a persistent clockwise circulation around the islands (Figure 4.1.1, right panel).

The shelf-front provides a fair, although variable, degree of isolation between the on-shelf and the off-shelf areas. This allows the on-shelf areas to support a relatively uniform shelf ecosystem, which in many ways is distinct from off-shelf waters. This ecosystem has distinct planktonic communities, benthic fauna, and several fish stocks. Furthermore, about 1.7 million pairs of seabirds breed on the Faroe Islands and take most of their food from the shelf water.

![Figure 4.1.1](image_url) Bottom topography, circulation, and water masses at the surface (top left panel), at depths greater than about 500 m (bottom left panel) in the area around the Faroes and on the Faroe shelf (right panel). Dashed lines indicate fronts.

Temperature

Due to the strong tidal currents on the Faroe shelf the temperature is constant from surface to bottom in the shallow shelf areas. The temperature ranges from around 6°C in March to 10–11°C in August–September.

In the Northeast Atlantic there has been a general salinity and temperature increase since the early 1990s. The salinity now reaches the previous maximum last observed around 1960, and temperature values exceed records (Holliday et al., 2008). This trend has also been observed on the Faroe shelf, where temperature monitoring since 1992 has revealed a mean annual temperature increase of about 0.07°C year⁻¹, resulting in a temperature increase of about 1°C during this period.
Phytoplankton

The three oceanographic regimes (well-mixed shelf, frontal, and stratified off-shelf) offer different conditions for primary production. While the shallow well-mixed part is relatively well studied, little is known about production cycles and their dependence on environmental conditions in the two other regimes in the region.

One distinguishing feature is the typical earlier spring bloom on the shelf than off the shelf. However, timing and intensity of the bloom can vary greatly from one year to another. This variability has pronounced effects on the ecosystem.

Most of the primary production usually takes place from May to August. The timing of the onset of primary production in spring is, however, highly variably between years (Figure 4.1.3). This variability affects production of food for fish larvae in spring (Gaard 2003; Debes et al., 2005; Debes and Eliasen, 2006), which mainly consists of copepod eggs and nauplii and small copepodites (Gaard and Steingrund, 2001; Nielsen, 2007).

The phytoplankton on the Faroe shelf consists mainly of diatoms during spring and summer. However, during periods with low nutrient concentrations smaller flagellates may be relatively more abundant (Gaard et al., 1998; Debes et al., 2007a).

In 2007 the biomass increase occurred in early spring. However, it decreased already in the beginning of June and remained low for the rest of the season.

Figure 4.1.2  Mean annual temperature on the Faroe shelf, 1992–2007.

Figure 4.1.3  Chlorophyll a concentrations on the central shelf, 1997–2007.
The mean annual primary production on the shelf is around 160–200 g C m$^{-2}$ of which about 50% is estimated to be new production (Debes et al., 2007a). There is a very high interannual variability primary production (Gaard, 2003; Eliasen et al., 2005), and from 1990 to 2007 the new primary production (from spring to mid-summer) has fluctuated by a factor ~5 (Figure 4.1.4). The index for 2007 was slightly below the 1990–2007 average and has been so for the last three years. Except in 2004 the phytoplankton production index has been below average since 2002 (Figure 4.1.4).

![Figure 4.1.4](image)

**Figure 4.1.4** Index of new primary production from spring to mid-summer on the Faroe shelf since 1990. The horizontal line represents the average index in the period 1990–2007.

The main reasons for the high interannual variability in timing and intensity of primary production on the shelf seem to be hydrographical. Modelling (Eliasen et al., 2005; Hansen et al., 2005) and field studies (Debes et al., 2007a) indicate that variable exchange rates between on-shelf and off-shelf waters, causing loss of phytoplankton from the shelf, may be a main controlling factor for biomass increase and the primary production.

The variability in primary production between years (Figure 4.1.4) highly affects production in higher trophic levels in the ecosystem. The primary production is identified as the main driver for biological productivity in the in theshelf ecosystem, including fish and seabirds (Gaard et al., 2002, 2006; Steingrund and Gaard, 2005). Below are described observed effects on fish growth, recruitment and production, behaviour, and catchability.

Primary production variability can thus be used as the first indicator for productive status in the system ~1 year ahead.

**Zooplankton**

While the zooplankton community outside the shelf front is largely dominated by the copepod *Calanus finmarchicus*, the shelf zooplankton community is basically neritic (shelf-related species). During spring and summer the zooplankton in the shelf water is largely dominated by the copepods *Temora longicornis* and *Acartia longiremis*. *C. finmarchicus* is advected from off-shelf and occurs in the shelf water in highly variable abundance between years. Usually the abundance of *C. finmarchicus* is highest in spring and early summer. Meroplanktonic larvae (mainly barnacle larvae) may also be abundant, and decapod larvae and fish larvae and juveniles are common on the Shelf during spring and summer (Gaard 1999, 2003; Debes and Eliasen, 2006).

Reproduction rates of copepods depend largely on their feeding conditions and co-occurring fluctuations have been observed between phytoplankton timing and abundance, and copepod egg production rates, abundance, and composition (Gaard, 1999; Debes et al., 2005, 2008b). This variability affects feeding conditions for fish larvae and pelagic juveniles in general on the shelf (Gaard and Steingrund, 2001; Gaard and Reinert, 2002; Kristiansen, 2007; Nielsen, 2007).

**Fish community**

A total of about 240 fish species are recorded in Faroese waters. Most of these species are, however, rare and are not exploited. The number of commercially exploited species on the Faroe Plateau is about 25. An overview of typical depth distribution of the main species in offshore and shelf areas (deeper than 65 m bottom depth) is shown in Figure
4.1.5. Most of these species spawn locally; however, some species (e.g. redfish and Greenland halibut) have their spawning grounds outside the Faroese area and are apparently common stocks in large parts of the Northeast Atlantic.

![Fish species distribution diagram]

**Figure 4.1.5** Typical depth distribution of fish in areas deeper than ~65 m on the Faroe shelf and in the ocean around the Faroes.

Of pelagic fish blue whiting is the most abundant. After spawning to the west of the British Isles in early spring, they start their feeding migration further north into the Norwegian Sea. They usually enter the Faroe eco-region in late April. They feed mainly on krill, amphipods, and other large zooplankton at depths between 300 and 500 meters, and partly also on the copepod *Calanus finmarchicus* closer to the surface. In late summer and autumn mature individuals migrate southwards again towards the spawning area while juveniles stay in Faroese water and the Norwegian Sea. Mackerel make a similar migration, although they have a more easterly and shallower distribution. Their main food items are *C. finmarchicus* and krill. Norwegian spring-spawning herring may migrate after spawning on the Norwegian shelf in March into the northernmost part of the Faroe eco-region to feed. Later the herring distribution is further north in the Norwegian Sea.

Cod and haddock and saithe are the most commercially important demersal stocks in Faroese waters. Their spawning takes place on the shelf in spring. The saithe spawns mainly in the northeastern and northern part of the shelf slope in February–March, and the offspring is found close to the shores already in May. At an age of about 3 years they migrate into deep habitats, mainly on the upper slope.

Cod spawns in the northern and western part of the shelf, mainly in March. The spawning grounds of the haddock are more disperse than those of cod and saithe and spawning takes place mainly in April. Their offspring is dispersed by the strong currents throughout the shelf area where they feed, mainly on copepods and decapod larvae (Gaard and Steingrund, 2001; Gaard and Reinert, 2002). In July, at lengths of about 4 cm, the cod juveniles migrate into shallow areas close to shore, while the haddock make the transition to a predominantly demersal habitat on the plateau and the banks at depths of 90–200 m. At an age of 1–2 years cod starts its migration to deeper areas on the shelf.

Two ecologically important fish species in the ecosystem are sandeel and Norway pout. After spawning in spring their offspring too is dispersed by the tidal currents throughout the shelf area where they feed on zooplankton. Both species are important food items for seabirds and demersal fish on the shelf and the upper slope, and are important links between zooplankton and higher trophic levels. Especially sandeels occur in variable abundances between years. Neither of these two species is commercially exploited.

Detailed knowledge about variability in food consumption of demersal cod, haddock and saithe in Faroese waters is not conclusive. Saithe feeds on the shelf slope largely on fish (mainly blue whiting and Norway pout) with smaller amounts of krill added to their diet. Cod and haddock show higher diversity in prey items, and predate on benthic fauna as well as fish, with fish being a more prevalent prey item for cod than for haddock. Of the fish prey, sandeel appear to be a key species in the shallow areas. When abundant they are a preferred food item for cod on the shelf and hence, already as 0-group sandeels, affecting the feeding conditions for demersal cod on the shelf. Years with high cod production seem to
be associated with a high abundance of sandeels. In deeper areas on the plateau other species (mainly Norway pout) are more important as prey item for cod. On the slope other species (mainly blue whiting) may be important.

Sandeel recruitment and abundance has been low since the productive years 1999–2001, and is still at a low level. This seems to have affected the growth rates and abundance of cod, and apparently of haddock too.

Despite a marked increase in fishing effort on cod and haddock, the landings have not increased correspondingly. The long-term landings of the cod usually have fluctuated between 20 000 and 40 000 tonnes during the 20th century and of haddock between 12 000 and 25 000 tonnes since the 1950s. The catches of these two main fish stocks have therefore for a long time reached the limit for long-term production within the ecosystem. Variability between years in catches of these species reflects variability in production of the fish stocks.

During the early 1990s the catches of cod and haddock decreased to the lowest on record. The decrease coincided with a severe decrease in productivity in the ecosystem in general, covering all trophic levels, from primary production to fish and seabird feeding conditions, reproduction, and growth rates. The ecosystem productivity increased markedly during the first half of 1990s, and the cod and haddock stocks recovered rapidly, due to increased recruitment success, individual growth rates, and due to low fishing mortality during that period (Gaard et al., 2002; Steingrund et al., 2003; ICES, 2007; Steingrund and Gaard, 2005).

Due to low cod recruitment on the Faroe shelf in recent years the stock has decreased to the same low level as in the early 1990s. The haddock stock is close to average but is decreasing.

Since the monitoring of environmental parameters started in 1990 a clear relationship has been observed, from primary production to the higher trophic levels, which seem to respond quickly to variability in the primary production in the ecosystem.

4.1.2 Major environmental influences on ecosystem dynamics

Fish migration versus age and feeding conditions

After the pelagic phase juvenile cod and saithe migrate into shallow areas while the haddock juveniles are dispersing all over the shelf area. At an age of about 2 years cod gradually migrate into deeper habitats on the shelf. Saithe migrates into deeper waters on the upper shelf slope at an age of about 3 years (Figure 4.1.6).

A high variability in distribution between years is observed, however, for cod. During years with poor feeding conditions adult cod tend to migrate into shallow areas. This seems to affect cod recruitment negatively.

Tagging experiments have shown that migration between Faroe Plateau and neighbouring areas is negligible (Joensen et al., 2005).

![Figure 4.1.6](image)

**Figure 4.1.6** Proportion of cod, haddock and saithe caught inside the 130 m isobath during summer groundfish surveys 1996–2003. (From Steingrund and Gaard, 2005).

Cod and haddock recruitment

Data series for cod since 1961 and since 1970 for haddock show no direct relationship between SSB and recruitment fluctuations on the Faroe plateau. On the other hand, long-term relations between cod and haddock recruitment and
weight-at-age have demonstrated that periods with high weight-at-age occur simultaneously with good recruitment of 2-year-old fish and vice versa (Figure 4.1.7) (Gaard et al., 2002; 2006). This underlines strong simultaneous environmental affects on cod and haddock recruitment and growth rates.

Environmental conditions on the Faroe plateau are highly variable and their strong effects on cod and haddock recruitment clearly overshadow spawning stock effects.

The cod and haddock stocks have proven that when environmental conditions are favourable, they are, even with very small SSB, able to recover quickly. It is, however, when the environmental conditions are poor, that the spawning stock influence on recruitment success most likely is highest. Therefore the importance of spawning stocks should not be underestimated – although it is no guarantee for recruitment success. The recommended $B_{inst}$ for cod and haddock should therefore be more conservative than the observed successful SSBs in the most productive years.

![Figure 4.1.7](image-url)

**Figure 4.1.7** Relationship between recruitment of 2 years old cod and haddock and the mean weight of 2–6 years old cod during 1970–2006 and haddock during 1977–2006 on the Faroe shelf.

Since 1990, when monitoring of environmental parameters in the Faroe shelf ecosystem started, clear co-occurring fluctuations can be observed in primary production and recruitment of cod and haddock. However, the abundance of older cod in shallow areas also affects cod recruitment negatively. During periods with low food abundance (low primary production) adult cod (mainly those with low condition factor) tend to migrate into shallow areas, and this affects cod recruitment negatively. When comparing cod recruitment with a combined positive effect from primary production and a negative effect from abundance of adult cod in shallow areas, a very good correlation ($R^2 \sim 0.8$) is obtained (Steingrund, unpubl. data).

The year class strength of Faroe Plateau cod seems to be determined rather late in life: Recruitment estimates of 2-year-old cod co-fluctuates positively with primary production the year before. These fluctuations indicate that year-class strength is mainly determined when the cod is 1 year old. (Steingrund and Gaard, 2005; Steingrund, unpublished data). The very good relationship between primary production combined with abundance of adult cod in shallow areas and cod recruitment allows prediction of cod stock recruitment earlier than traditional stock assessment methods.

**Cod and haddock growth rates**

Growth rates on cod and haddock on the Faroe plateau are highly variable. Since 1990 the mean growth rates of 2–8 years old cod have fluctuated between 0.3 and 1.6 kg individual$^{-1}$ year$^{-1}$ and the mean growth rates of 2–8 years old haddock between 0.1 and 0.5 kg individual$^{-1}$ year$^{-1}$. No correlation is between the growth rates and the in situ temperature, but good relationship is found between primary production and growth variability of both species (Figure 4.1.8). The growth rates are mainly affected by the highly variable food production. The causal mechanism seems to be a positive relationship between phytoplankton production, zooplankton production and production of food organisms for cod and haddock (e.g., benthic crustaceans, polychaets, and especially sandeels and Norway pout).
Since primary production is rapidly transferred to cod and haddock, they obviously eat young prey items, at least during periods with high growth rates. Detailed analysis of interannual variability in food items for cod and haddock are not available at the present, but the available information indicates that sandeel is a main food item during productive years. In low-productive years they seem to predare more on benthic fauna. Fish furthermore seems to be a more prevalent prey item for cod than for haddock. This may be a reason for why haddock growth variability often is lagging one year behind cod growth variability, especially during low productive periods (Figure 4.1.8).

Figure 4.1.8    Index of new primary production and mean growth rates since the year before, for cod (upper panel) and haddock (lower panel) since 1990.

As pointed out in Section 4.1.1.5 sandeel recruitment and abundance has been at a low level since the productive years 1999–2001. This has affected feeding conditions for especially cod and most likely haddock too.

Weight-at-age for cod and haddock are at present at a very low level (Figure 4.1.7). During the last two years it has stabilized for cod but decreased for haddock in 2006. Consequently, the average growth rate of cod has been slightly higher than expected from the primary production index alone, possible due to the very low cod abundance.

**Fish production**

Fish production in the ecosystem is clearly food limited. Mainly cod production (numbers × individual growth summed up for all age groups) fluctuates relatively well with primary production (Figure 4.1.9). When comparing primary production with production of cod haddock and saithe combined, the correlation is even better.
Since young age groups are the most numerous (mainly in the productive years) the observed variability in cod production in Figure 4.1.9 largely is due to variable abundances of recruits (Figure 4.1.10). The production variability is, thus, affected by variable recruitment (uncertain for the last year) and fishing effort. By combining Figures 4.1.8, 4.1.9, and 4.1.10, the low cod production during the last years seems to be due to low cod abundance and not low growth rates. The figure furthermore illustrates, that in the 1960s and 1970s the proportion of production of older age classes was clearly higher than in recent times. The reason most likely is higher fishing mortalities in the later years.

As cod grow older, they tend to move into deeper areas (Figure 4.1.6), a part of them feeding on the slope outside the shelf front. This may increase production capacity of the cod stocks. However, information is not available at the moment to quantify this potential effect.

**Figure 4.1.10** Production of Faroe Plateau cod, split into age groups.

**Benthos**

Due to strong tidal currents, the seabed in shallow regions on the shelf (except sheltered fjords) consists mainly of sand on stones. In deeper areas is most silt and organic material. The benthic fauna on the shelf is diverse with e.g. polychaetes, decapods, echinoderms, and bivalves as important groups. On the slope coral and sponge areas occur. The coral areas have been reduced due to trawling and therefore the authorities in 2004 have closed three areas for trawling. On the shelf there is local fishery (dredging) for scallops and in inshore areas there is trap fishery for Norway lobster (*Nephrops*).
Ecosystem effects of the fisheries

Trawling activity has caused a significantly reduce the distribution areas of corals (*Lophelia pertusa*) on the shelf and bank slopes. Therefore the Faroese authorities in 2004 have closed three coral areas for trawling.

Since fishery on the Faroe Plateau is effort regulated, discard of commercially fish most likely is small. The level of bycatch of non-commercial species and of non-commercial size in unknown and may be higher, especially during periods of high recruitment.

In addition to effort regulation (limited number of fishing days), spawning grounds are closed for fishing activity, and large areas on the shelf are permanently or periodically closed for trawling. Furthermore, trawling is regulated by mesh sized. The current management regime which limits effort and spatial access for certain gear is likely to be effective for demersal fish stocks (Zeller and Reinert, 2004).

Concluding remarks

The Faroe Islands utilize an effort- and spatial-based system of fisheries management. Successful management of such a system is dependent on information on influences from environmental variables on the fish stocks, individual behaviour, and catchability.

Environmental effects in the Faroe shelf ecosystem are strong may be useful in prediction of cod and haddock recruitment and growth rates as well as in management regulations.

The highly variable environmental conditions on the Faroe plateau have very strong influences on cod and haddock recruitment. Recruitment of 2-year-old cod correlates positively with primary production and negatively with abundance of adult cod in shallow areas the year before. In years with low food abundance cod tend to migrate into shallow areas, affecting cod recruitment negatively. A high correlation is observed between recruitment of 2-year-old cod and environmental conditions for cod (primary production combined with abundance of adult cod in shallow areas) one year before, indicating that recruitment mainly is determined as 1-year-old cod.

Growth rates of cod and haddock are also highly affected by feeding conditions.

Relationship between environmental conditions for cod and haddock (food abundance) and longline catchability may also be useful information from a management perspective. In and effort management regime with a limited number of fishing days, expected catchability changes may need to be incorporated in the advice on fisheries. For cod there is observed a link between primary production and individual growth rates (Figure 4.1.8). The cod growth rates seem to be negatively correlated with the catchability of longlines, suggesting that cod prefer longline baits when natural food abundance is low. Since longliners usually take a large proportion of cod catch, the total fishing mortality fluctuates in the same was as the longline catchability and there is thus a negative relationship between cod growth and mortality.

For haddock there seems a similar mechanism as for cod. Although the catchability for longliners (which take the majority of the catch) as estimated for the longliners logbooks does not follow the expected pattern for the first time of the series (1986–1995), it may be a result of very small catches in that period when the stock biomass was low. The fact that a negative relationship is observed between growth rates and fishing mortality suggests that the same mechanism is valid for haddock as for cod.

It is, however, important to note that the relationship between productivity of the ecosystem and the catchability of longlines depends on age of the fish. The relationship is most clear for fish age 5. For cod age 3 and 4 the relationship is less clear, and for young haddock there apparently is no such relationship between productivity and catchability.

For saithe no clear relationship is observed between catchability for pair trawlers (which take the majority of the catches) and other variables such as primary production, growth, and stock size.

The catchability analysis reported above suggests that natural factors may have a large influence on longline catchability for cod and haddock. In 2006 the primary production was slightly below average.

Considerations for assessments and advice

The primary production in 2007 was below the 1990–2007 average and was close to the 2005 level and no major changes are therefore expected in cod and haddock feeding conditions from 2006 to 2007. The following environmental information should considered implemented in assessment and management advice of the Faroe plateau cod stock and the Faroe haddock stock:
• In effort regulation variable longline catchability for cod and haddock seems to be affected by variable feeding conditions. Variability in catchability is therefore important in management advice. Expected environmental effects on longline catchability for cod and haddock were included in the assessment and the advice for 2007. However, estimated variability in cod and haddock catchability, based on environmental information, and growth rates of cod and haddock, should be considered implemented even further quantitatively, in future assessment work.

• The co-fluctuation between plankton productivity and cod and haddock recruitment and growth rates (weight-at-age) since 1990 should be considered used for improved predictions for recruitment and weight for cod and haddock.

References:

4.2 Human impacts on the ecosystem

4.2.1 Fishery effects on benthos and fish communities

General

Trawling activity has caused a significantly reduction of the distribution areas of corals (*Lophelia pertusa*) on the shelf and bank slopes. Therefore the Faroese authorities in 2004 have closed three coral areas for trawling.

Since fishery on the Faroe Plateau and on the Faroe Bank is effort regulated, discarding of commercially fish most likely is minor. The level of by-catch of non-commercial species and of non-commercial sizes is unknown and may be higher, especially during periods of high recruitment.

In addition to effort regulation (limited number of fishing days), spawning grounds are closed for fishing activity, and large areas on the shelf are permanently or periodically closed for trawling. Furthermore, trawling is regulated by minimum mesh sizes. The current management regime which limits effort and spatial access for certain gear is likely to be effective for demersal fish stocks (Zeller and Reinert 2004).

The total demersal catches decreased from 120 000 t in 1985 to 65 000 t in 1993, increased again to above 150 000 t in 2002 but have since decreased to about 125 000 t in 2007; the demersal catches in 2008 are expected to decline even further. The three most important demersal species are cod, haddock and saithe.

Part of the total international catches of mackerel, Norwegian spring-spawning herring and blue whiting are taken around the Faroe Islands. The catches of these species are reported together with the catches from other areas in the section on widely migrating stocks, see Volume 9.

The main fisheries in Faroese waters are mixed-species, demersal fisheries and single-species, pelagic fisheries. The demersal fisheries are mainly conducted by Faroese fishermen, whereas the major part of the pelagic fisheries are conducted by foreign fishermen licensed through bilateral and multilateral fisheries agreements.

Pelagic Fisheries. Three main species of pelagic fish are fished in Faroese waters: blue whiting, herring and mackerel; several nations participate. The Faroese pelagic fisheries are almost exclusively conducted by purse seiners and larger purse seiners also equipped for pelagic trawling. The pelagic fishery by Russian vessels is conducted by large factory trawlers. Other countries use purse seiners and factory trawlers.

Demersal Fisheries. Although they are conducted by a variety of vessels, the demersal fisheries can be grouped into fleets of vessels operating in a similar manner. Some vessels change between longlining, jigging and trawling, and they therefore can appear in different fleets. The following describes the Faroese fleets first followed by the fleets of foreign nations.

Open boats. These vessels are below 5 GRT. They use longline and to some extent automatic, jigging engines and operate mainly on a day-to-day basis, targeting cod, haddock and to a lesser degree saithe. A majority of open boats participating in the fisheries are operated by part-time fishermen.

Smaller vessels using hook and line. This category includes all the smaller vessels, between 5 and 110 GRT operating mainly on a day-to-day basis, although the larger vessels behave almost like the larger longliners above 110 GRT with automatic baiting systems and longer trips. The area fished is mainly nearshore, using longline and to some extent automatic, jigging engines. The target species are cod and haddock.

Longliners > 110 GRT. This group refers to vessels with automatic baiting systems. The main species fished are cod, haddock, ling and tusk. The target species at any one time is dependent on season, availability and market price. In general, they fish mainly for cod and haddock from autumn to spring and for ling and tusk during the summer. During summer they also make a few trips to Icelandic waters.

Otter board trawlers < 500 HP. This refers to smaller fishing vessels with engine powers up to 500 Hp. The main areas fished are on the banks outside the areas closed for trawling. They mainly target cod and haddock. Some of the vessels are licensed during the summer to fish within the twelve nautical miles territorial fishing limit, targeting lemon sole and plaice.

Otter board trawlers 500-1000 HP. These vessels fish mainly for cod and haddock. They fish primarily in the deeper parts of the Faroe Plateau and the banks to the southwest of the islands.

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Otter board trawlers >1000 HP. This group, also called the deep-water trawlers, target several deep-water fish species, especially redfish, blue ling, Greenland halibut, grenadier and black scabbard fish. Saithe is also a target species and in recent years they have been allocated individual quotas for cod and haddock on the Faroe Plateau.

Pair trawlers <1000 HP. These vessels fish mainly for saithe, however, they also have a significant by-catch of cod and haddock. The main areas fished are the deeper parts of the Faroe Plateau and the banks to the southwest of the islands.

Pair trawlers >1000 HP. This category targets mainly saithe, but their by-catch of cod and haddock is important to their profit margin. In addition, some of these vessels during the summers have special licenses to fish in deep water for greater silver smelt. The areas fished by these vessels are the deeper parts of the Faroe Plateau and the banks to the southwest of the islands.

Gill netting vessels. This category refers to vessels fishing mainly Greenland halibut and monkfish. They operate in deep waters off the Faroe Plateau, Faroe Bank, Bill Bailey’s Bank, Lousy Bank and the Faroe-Iceland Ridge. This fishery is regulated by the number of licensed vessels and technical measures like depth and gear specifications.

Jiggers. Consist of a mixed group of smaller and larger vessels using automatic jigging equipment. The target species are saithe and cod. Depending on availability, weather and season, these vessels operate throughout the entire Faroese region. Most of them can change to longlines.

Foreign longliners. These are mainly Norwegian vessels of the same type as the Faroese longliners larger than 110 GRT. They target mainly ling and tusk with by-catches of cod, haddock and blue ling. Norway has a bilateral fishery agreement with the Faroes for a total quota of these species while the number of vessels can vary from year to year.

Foreign trawlers. These are mainly otter board trawlers of the same type as the Faroese otter board trawlers larger than 1 000 HP. Participating nations are United Kingdom, France, Germany and Greenland. The smaller vessels, mainly from the United Kingdom and Greenland, target cod, haddock and saithe, whereas the larger vessels, mainly French and German trawlers, target saithe and deep-see species like redfish, blue ling, grenadier and black scabbardfish. As for the foreign longliners, the different nations have in their bilateral fishery agreement with the Faroes a total quota of these species while the number of vessels can vary from year to year.

**Catchability analysis**

In an effort management regime with a limited numbers of fishing days, it is expected that vessels will try to increase their efficiency (catchability) as much as possible in order to optimise the catch and its value within the number of days allocated. “Technological creeping” should therefore be monitored closely in such a system. However, catchability of the fleets can change for other reasons, e.g. availability of the fish to the gears. If such effects are known or believed to exist, catchability changes may need to be incorporated in the advice on fisheries.

The primary production of the Faroe Shelf ecosystem may vary by as much as a factor of five and given the link between primary production and recruitment and growth (production) of cod as demonstrated by Steingrund & Gaard (2005), this could have pronounced effects on catchability and stock assessment as a whole. Below are the results from an analysis regarding Faroe Plateau cod, Faroe haddock and Faroe saithe.
Figure 4.2.1.1  Faroe Plateau Cod. Relationship between long line catchability and primary production.

For cod and haddock there seems to be a link between the primary production and growth (Figure 4.1.8). The growth of cod and haddock seems to be negatively correlated with the catchability of longlines, suggesting that cod and haddock attack longline baits to a higher degree when natural food abundance is low. Since longliners usually take a large proportion of the cod and haddock catches, the total fishing mortality fluctuates in the same way as the long line catchability and thus there is a negative relationship between growth and fishing mortality (Figure. 4.2.1.2).

It is, however, important to note that the relationship between the productivity of the ecosystem and the catchability of long lines depends on the age of the fish. For cod, the relationship is most clear for age 5 and older fish; for age 3 and 4, the relationship is less clear. For young haddock there apparently is no such relationship between productivity and catchability.

For saithe no clear relationship was observed between the catchability for the Cuba pair trawlers (pair trawlers take the majority of the catch) and other variables such as primary production, growth and stock size.
The analysis reported above suggests that natural factors may have a larger influence than technological ones, at least for Faroe Plateau cod and Faroe haddock on changes in catchability. In addition, the available data indicate that there has not been sufficient time since the implementation of the effort management system in 1996 to detect convincing changes in catchability. However, from a management perspective, if the hypothesis that catchability is related to productivity is true, and if productivity is low, there is a potential for very high fishing mortality to be exerted on cod and haddock. It could therefore be prudent to consider substantial reductions in fishing effort in periods with low primary productivity.

Figure 4.2.1.2. Faroe Plateau Cod (top) and Faroe haddock (bottom). Relationship between fishing mortality and growth during the last 12 months.
Concluding remarks

The Faroe Islands utilize an effort- and spatial-based system of fisheries management. Successful management of such a system is among other things depending on information on influences from environmental variables on the fish stocks, individual behaviour and catchability.

Environmental effects in the Faroe shelf ecosystem are strong and may be useful in prediction of cod and haddock recruitment and growth rates as well as in management regulations.

The highly variable environmental conditions on the Faroe plateau have very strong influences on cod and haddock recruitment. Recruitment of 2-years old cod correlates positively with primary production and negatively with abundance of adult cod in shallow areas the year before. In years with low food abundance cod tend to migrate into shallow areas, affecting cod recruitment negatively. There is a high correlation between recruitment of 2 years old cod and environmental conditions for cod (primary production combined with abundance of adult cod in shallow areas) one year before, indicating that recruitment mainly is determined as 1 years old cod.

Growth rates of cod and haddock are also highly affected by feeding conditions. Since 1990 the annual mean growth rates of age 2-7 have (average for age 2-7) have varied by a factor of 4 and 6 for cod and haddock, respectively.

Relationship between environmental conditions for cod and haddock (food abundance) and longline catchability may also be useful information from a management perspective. In an effort management regime with a limited number of fishing days, expected catchability changes may need to be incorporated in the advice on fisheries. For cod and haddock there is observed a link between primary production and individual growth rates (Figure 4.1.8), and the growth rates seem to be negatively correlated with the catchability of longlines, suggesting that cod and haddock prefer longline baits when natural food abundance is low. Since longliners usually take a large proportion of the cod and haddock catches, the total fishing mortality fluctuates in the same was as the longline catchability and there is thus a negative relationship between growth and mortality.

It is, however, important to note that the relationship between productivity of the ecosystem and the catchability of longlines depends on age of the fish. The relationship is most clear for fish age 5 and older. For cod age 3 and 4 the relationship is less clear, and for young haddock there apparently is no such relationship between productivity and catchability.

For saithe no clear relationship is observed between catchability for pair trawlers (which take the majority of the catches) and other variables such as primary production, growth and stock size.

The analysis reported above suggests that natural factors may have a large influence on longline catchability for cod and haddock. Based on information on primary production in 2005-2007, which is below average (Figure 4.1.4) there is a potential for increased longline catchability.