Stock Annex: Cod (*Gadus morhua*) in Subdivision Vb1 (Faroe Plateau)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Cod (*Gadus morhua*) in Subdivision Vb1 (Faroe Plateau)
Working Group	North Western Working Group (NWWG)
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A. General

A.1. Stock definition.

Extensive tagging experiments on the Faroe Plateau (Strubberg, 1916; 1933; Tåning, 1940; Joensen *et al*., 2005; unpublished data) during a century strongly suggest that the cod stock on the Faroe Plateau is isolated from other cod stocks, e.g., from cod on the Faroe Bank and cod at Iceland. Only around 0.1% of recaptured tagged cod are recaptured in other areas than the Faroe Plateau (Joensen *et al*., 2005). The immigration rate from Iceland is even lower. During 1948-86, around 90 000 cod were tagged at Iceland and 11 000 recaptured. Of these, five cod were recaptured in Faroese waters and only three of them on the Faroe Plateau (Jónsson, 1996). Of cod tagged in the North Sea, one specimen has been recaptured at the Faroes (Bedford, 1966).

Icelandic and Faroese tagging experiments suggest that the cod population on the Faroe-Icelandic ridge mainly belongs to the Icelandic cod stock. Faroe Marine Research Institute tagged about 29 000 cod in Faroese waters during 1997-2009 and about 8 500 have been recaptured to March 2009. Of these, one individual was caught on the Icelandic shelf and one on the Faroe-Icelandic ridge. In 2002, 168 individuals were tagged on the Faroe-Icelandic Ridge (Midbank). Twelve have been recaptured so far, 6 at Iceland, 3 on the Faroe-Icelandic Ridge and 0 on the Faroe Plateau (3 had unknown recapture position). The Marine Research Institute in Iceland tagged 25 572 cod in Icelandic waters during 1997-2004 and 3 708 were recaptured to April 2006. Of these, only 13 individuals were recaptured on the Faroe-Icelandic ridge and none on the Faroe Plateau.

Genetic investigations indicate that Icelandic cod might be composed by two components (Pampoulie *et al*., 2006): a western component and an eastern component, which, genetically, is indistinguishable from the Faroe Plateau cod stock (Pampoulie *et al*., 2008). While Faroe Plateau cod is dominated by the Pan I^A allele (above 0.8), the frequency is much lower (between 0.2 and 0.8) for Icelandic populations (Case *et al*., 2005), especially on the Faroe-Icelandic Ridge (0.2). The cod populations in the North Sea are dominated by the Pan I^A allele (as the populations on the Faroe Plateau and the Faroe Bank) but they have a higher frequency of the HbI(1) hemoglobin allele (Sick, 1965). Hence, Faroe Plateau cod have a rather special combination of genetic traits, as they

mainly possess the 'coldwater' hemoglobine allele (Hb-I(2)) and the 'warmwater' $PanI^{A}$ allele.

Cod spawn in February-March at two main spawning grounds north and west of the islands at depths around 90-120 m. The larvae hatch in April and are carried by the Faroe Shelf residual current (Hansen, 1992) that flows clockwise around the Faroe plateau within the 100-130 m isobath (Gaard *et al*. 1998; Larsen *et al.*, 2002). The fry settle in July-August and occupy the near shore areas, which normally are covered by dense algae vegetation. In autumn the following year (*i.e.* as 1 group), the juvenile cod begin to migrate to deeper waters (usually within the 200 m contour), thus entering the feeding areas of adult cod. They seem to be fully recruited to the fishing grounds as 3 year olds. Faroe plateau cod mature as 3-4 year old. The spawning migration seems to start in January and ends in May. Cod move gradually to deeper waters when they are growing older. The diet in shallow water (< 200 m) is dominated by sandeels and benthic crustaceans, whereas the diet in deeper water mainly consists of Norway pout, blue whiting and a few species of benthic crustaceans.

The geographical areas are presented in Figure 3.

A.2. Fishery

The cod fishery on the Faroe Plateau was dominated by British trawlers during the 1950s and 1960s. Faroese vessels took an increasing part of the share during the 1960s. In 1977, the EEZ was extended to 200 nautical miles, excluding most foreign fishing vessels from Faroese fishing grounds. In the 1980s, closed areas (mostly during the spawning time) were introduced and these were extended in the 1990s. Longliners and jiggers fished in shallow (< 150 m) waters, targeting cod and haddock, whereas trawlers exploited the deeper waters, targeting saithe. Small trawlers were allowed to exploit the shallow fishing grounds for flatfish during the summertime. After the collapse in the fishery in the beginning of the 1990s, which contributed to a serious national economic crisis in the Faroes, a quota system was introduced in 1994. It was in charge during 1994-1995, but was replaced by the effort management system in June 1996. The cod stock had by then recovered rapidly, which was in contrast with the scientific expectations.

A.3. Ecosystem aspects

The rapid recovery of the cod stock in the mid-1990s strongly indicated that 'strange things' had happened in the environment. It became clear that the productivity of the ecosystem affected both cod and haddock recruitment and growth (Gaard *et al*., 2002), a feature outlined in Steingrund and Gaard (2005). The primary production on the Faroe Shelf (< 130 m depth), which took place during May-June, varied interannually by a factor of five, giving rise to low- or high-productive periods of 2-5 years duration (Steingrund and Gaard, 2005). The productivity over the outer areas seems to be negatively correlated with the strength of the Subpolar Gyre (Hátún *et al*., 2005; Hátún *et al*., 2009; Steingrund *et al*.,2010), which may reglulate the abundance of saithe in Faroese waters (Steingrund and Hátún, 2008).

B. Data

B.1. Commercial catch

When calculating the catch-at-age, the sampling strategy is to have length, length-age, and length-weight samples from all major gears during three periods: January-April,

May-August and September-December. In the period 1985-1995, the year was split into four periods: January-March, April-June, July-September, and October-December. The reason for this change was that the three-period splitup was considered to be in better agreement with biological cycles (the spawning period ends in April). When sampling was insufficient, length-age and length-weight samples were borrowed from similar fleets in the same time period. Length measurements were, if possible, not borrowed. The number of samples in some years (e.g. 2005 and 2007-2008) was not sufficient to allow the traditional three period splitup for all the fleets, and a two period splitup (January-June and July-December) was adopted for those fleets. In recent years the two period splitup has been used.

The landing values were obtained from the Fisheries Ministry and Statistics Faroe Islands. The catches on the Faroe-Iceland ridge were not included in the catch-at-age calculations, a practice introduced in the 2005 WG. Catch-at-age for the fleets covered by the sampling scheme were calculated from the age composition in each fleet category and raised by their respective landings. The catch-at-age by fleet was summed across all fleets and scaled to the correct catch.

Mean weight-at-age data were calculated using the length/weight relationship based on individual length/weight measurements of samples from the landings.

B.2. Biological

B.3. Surveys

The spring groundfish surveys in Faroese waters with the research vessel Magnus Heinason were initiated in 1983. Up to 1991 three cruises per year were conducted between February and the end of March, with 50 stations per cruise selected each year based on random stratified sampling (by depth) and on general knowledge of the distribution of fish in the area. In 1992 the period was shortened by dropping the first cruise and one third of the 1991-stations were used as fixed stations. Since 1993 all stations are fixed stations. The standard abundance estimates is the stratified mean catch per hour in numbers at age calculated using smoothed age/length keys. In last years assessment, the same strata were used as in the summer survey and calculated in the same way (see below). All cod less than 25 cm were set to 1 year old.

In 1996, a summer (August-September) groundfish survey was initiated, having 200 fixed stations distributed within the 500 m contour of the Faroe Plateau. Half of the stations were the same as in the spring survey.

The abundance index was calculated as the stratified mean number of cod at age. The age length key was based on otolith samples pooled for all stations. Due to incomplete otolith samples for the youngest age groups, all cod less than 15 cm were considered being 0 years and between 15 and 34 cm 1 year (15-26 cm for 2005 because of abnormally small 2 year old fish). Since the age length key was the same for all strata, a mean length distribution was calculated by stratum and the overall length distribution was calculated as the mean length distribution for all strata weighted by stratum area. Having this length distribution and the age length key, the number of fish at age per station was calculated, and scaled up to 200 stations.

The proportion mature was obtained from the spring survey, where all aged individuals were pooled, i.e., from all stations, being in the spawning areas or not. The average maturity at age for 1983 to 1996 was used in years prior to 1983. Some of the 1983-1996 values were revised in 2003 but not the maturities for the 1961-1982 period.

B.4. Commercial CPUE

Two/three commercial cpue series (longliners and pair trawlers) are updated every year, but the WG decided in the benchmark assessment in 2004 not to use them in the tuning of the VPA. The cpue for the longliners was shown to be highly dependent upon environmental conditions whereas the cpue for the pair trawlers could be influenced by other factors than stock size, for example the price differential between cod and saithe. These two/three cpue series are presented in the report although they were not used as tuning series.

B.5. Other relevant data

C. Historical Stock Development

An XSA has been performed during a number of years. The use of tuning indices has, however, varied quite a lot since the mid 1990s. The Faroese spring groundfish survey was excluded as a tuning series in the mid 1990s because the catch-curves in the survey showed an anormal pattern. Two commercial tuning series (single trawlers 400-1000 HP and longliners > 100 GRT) were used during 1996-1998 where the effort was in number of days. In 1999, the tuning series constituted the pairtrawlers > 1000 HP (effort in the number of trawl hours) and the longliners > 100 GRT (effort in the number of hooks set). In 2002, the Faroese Summer Groundfish Survey was used as the only tuning series, as was the case in 2003. A benchmark assessment was performed in the 2004 NWWG, where the Faroese Spring Grounfish Survey was reintroduced, albeit with a modified stratification, i.e., the two surveys were used as the only tuning series. All assessments since then have been update assessments where only minor changes in settings have been made.

Model used: Extended Survivors Analysis.

Software used: Virtual Population Analysis, version 3.2, beta: Windows 95. Copyright: MAFF Directorate of Fisheries Research. License number: DFRVPA31M.DFR.

Model Options chosen:

Time series weights: Tapered time weighting not applied. Catchability analysis: Catchability independent of stock size for all ages. Catchability independent of age for ages >= 6. Terminal population estimation: Survivor estimates shrunk towards the mean F of the final 5 years or the 5 oldest ages. S.E. of the mean to which the estimates are shrunk = 2.00. Minimum standard error for population estimates derived from each fleet = 0.300. Prior weighting not applied.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1959-last data year		Yes
Canum	Catch at age in numbers	1959-last data year	2-10+	Yes
Weca	Weight at age in the commercial catch	1959-last data year	2-10+	Yes

West	Weight at age of the spawning stock at spawning time.	1959-last data year	2-10+	Yes, the same data as for the commercial catch
Mprop	Proportion of natural mortality before spawning	1959-last data year	2-10+	No, set to 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1959-last data year	2-10+	No, so to 0 for all ages in all years
Matprop	Proportion mature at age	1983-last data year +1	2-10+	Yes, but constant values used prior to 1983, i.e., average maturities during 1983-1996
Natmor	Natural mortality	1959-last data year	2-10+	No, set to 0.2 for all ages in all years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Summer Survey	1996- last data year	2-8
Tuning fleet 2	Spring Survey	1994- last data year+1 (shifted to 1993- last data year)	2-9

D. Short-Term Projection

Model used: Age structured.

Software used: MFDP prediction with management option table and yield per recruit routines.

Initial stock size. Taken from XSA for all ages (2-10+).

Natural mortality: Set to 0.2 for all ages in all years.

Maturity: The values observed in the spring survey 2014 are used for 2014 while average maturities 2012-2014 are used in 2015 and 2016.

F and M before spawning: Set to 0 for all ages in all years.

Weight at age in the stock: The same values as weight-at-age in the catch.

Weight at age in the catch: For each age, a regression was performed between the weight-at-age during the whole year and 1) the weight-at-age during January-February or 2) the weight-at-age in the spring survey 1994-2014. The relationship with the higher coefficient of correlation was used as a basis to predict the weight-at-age in 2014. The values for 2015-2016 were set to the 2014 value.

Exploitation pattern: Average for the three last years when there is no trend in the series or rescaled to terminal year when there is a trend in the series.

Intermediate year assumptions: average for the three last years, i.e., not rescaled to the terminal year.

Stock recruitment model used: none.

Procedures used for splitting projected catches: none.

E. Medium-Term Projections

Not performed.

F. Long-Term Projections

Model used: Yield and biomass per recruit over a range of F-values.

Software used: MFYPR version 1.

Maturity: Average for 1983-last data year+1.

F and M before spawning: Set to 0 for all ages and years.

Weight at age in the stock: Same as the weights in the catch.

Weight at age in the catch: Average for 1978-last data year in order exclude the high values in former times.

Exploitation pattern: Average for 2000-last data year (not rescaled to the terminal year) in order to reflect a recent fishing pattern.

Procedures used for splitting projected catches: none.

A long-term simulation model is used, see text in the report.

G. Biological Reference Points

The reference points are dealt with in the general section of Faroese stocks. The reference points for Faroe Plateau cod are the following: B_{pa} = 40kt, B_{lim} = 21kt, F_{pa} = 0.35 and F_{lim} = 0.68.

H. Other Issues

I. References

Bedford, B.C. 1966. English cod tagging experiments in the North Sea. ICES CM 1966/G:9.

Case, R.A.J., Hutchinson, W.F., Hauser, L., Van Oosterhout, C., and Carvalho, G.R. 2005. Macro- and micro-geographic variation in pantophysin (*Pan*I) allele frequencies in NE Atlantic cod *Gadus morhua*. Marine Ecology Progress Series, 301: 267-278.

Gaard, E., Hansen, B., Olsen, B., and Reinert, J. 2002. Ecological features and recent trends in physical environment, plankton, fish and sea birds in the Faroe plateau ecosystem. *In* Large Marine Ecosystem of the North Atlantic (eds K. Sherman, and H.-R. Skjoldal), pp. 245-265. Elsevier. 449 pp.

Hátún, H., Sandø, A.B., Drange, H., Hansen, B., and Valdimarsson, H. 2005. Influence of the Atlantic Subpolar Gyre on the thermohaline circulation. Science, 309: 1841-1844.

H. Hátún, M.R. Payne, G. Beaugrand, P.C. Reid, A.B. Sandø, H. Drange,

B. Hansen, J.A. Jacobsen, D. Bloch. 2009. Large bio-geographical shifts in the north-eastern Atlantic Ocean:

From the subpolar gyre, via plankton, to blue whiting and pilot whales. Progress in Oceanography 80 (2009) 149–162.

Joensen, J.S., Steingrund, P., Henriksen, A., and Mouritsen, R. 2005. Migration of cod (*Gadus morhua*): tagging experiments at the Faroes 1952-65. Fróðskaparrit (Annales Societatis Scientarum Færoensis), 53: 100-135.

Jónsson, J. 1996. Tagging of cod (*Gadus morhua*) in Icelandic waters 1984-1986. Rit Fiskideildar, 14(1): 1-82.

Pampoulie, C., Ruzzante, D.E., Chosson, V., Jörundsdóttir, T.D., Taylor, L., Thorsteinsson, V., Daníelsdóttir, A.K., and Marteinsdóttir, G. 2006. The genetic structure of Atlantic cod (*Gadus morhua*) around Iceland: insight from microsatellite, the *Pan* I locus, and tagging experiments. Canadian Journal of Fisheries and Aquatic Sciences, 63: 2660-2674.

Pampoulie, C., Steingrund, P., Stefánsson, M.Ö., and Daníelsdóttir, A.K. 2008. Genetic divergence among East Icelandic and Faroese populations of Atlantic cod provides evidence for historical imprints at neutral and non-neutral markers. ICES Journal of Marine Science, 65: 65-71.

Sick, K. 1965. Haemoglobin polymorphism of cod in the North Sea and the North Atlantic Ocean. Hereditas, 54 (3): 49-73.

Steingrund, P. and Gaard, E. 2005. Relationship between phytoplankton production and cod production on the Faroe shelf. ICES Journal of Marine Science 62: 163-176.

Steingrund, P., Mouritsen, R., Reinert, J., Gaard, E., and Hátún, H. 2010. Total stock size and cannibalism regulate recruitment in cod (*Gadus morhua*) on the Faroe Plateau. ICES Journal of Marine Science, 67: 111-124.

Steingrund, P., and Hátún, H. 2008. Relationship between the North Atlantic Subpolar Gyre and fluctuations of the saithe stock in Faroese waters. ICES North Western Working Group 2008, Working Document 20. 7 pp.

Strubberg, A.C. 1916. Marking experiments with cod at the Færoes. Meddelelser fra Kommissionen for Danmarks Fiskeri- og Havundersøgelser, serie: Fiskeri 5(2): 1-125.

Strubberg, A.C. 1933. Marking experiments with cod at the Faroes. Second report. Experiments in 1923-1927. Meddelelser fra Kommissionen for Danmarks Fiskeri- og Havundersøgelser, serie: Fiskeri 9(7): 1-36.

Tåning, Å.V. 1940. Migration of cod marked on the spawning places off the Faroes. Meddelelser fra Kommissionen for Danmarks Fiskeri- og Havundersøgelser, serie: Fiskeri 10(7): 1-52.

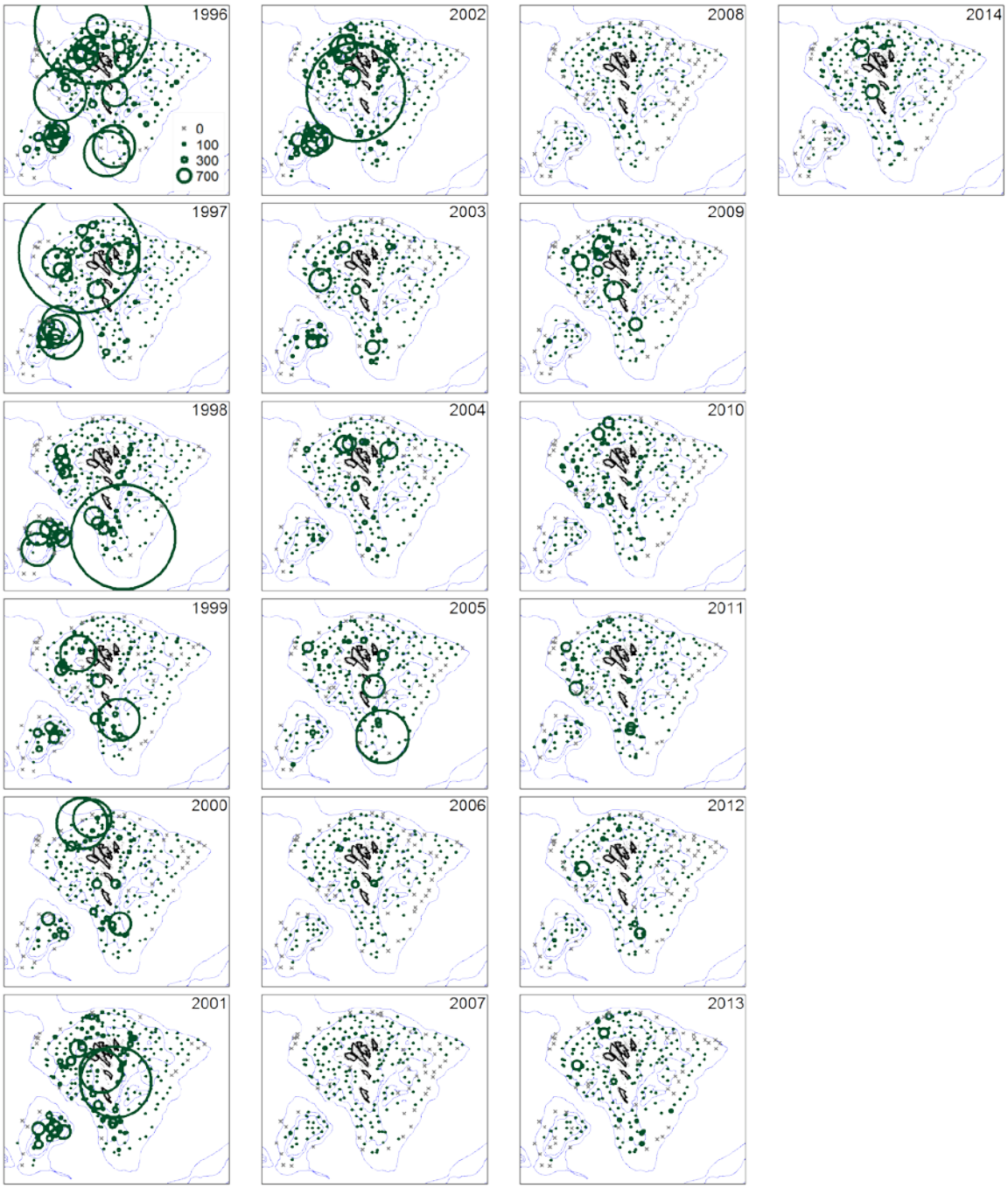

Figure 1. Cod in Division Vb1. The spatial distribution of cod according to the summer survey on the Faroe Plateau (kg per tow). 100, 200 and 500 m depth contours are shown. The figure is continued on the following page.

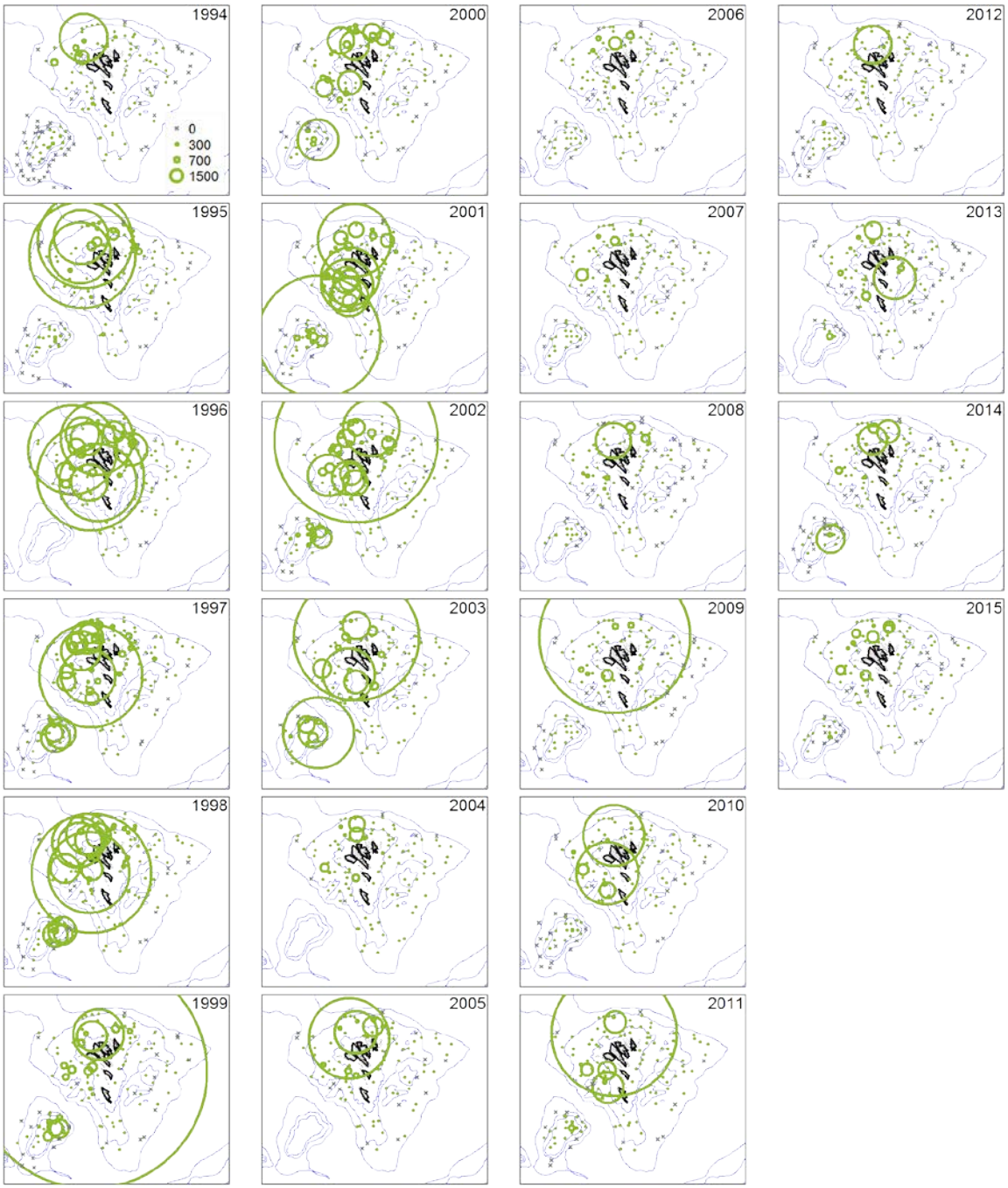

Figure 2. Cod in Division Vb1. The spatial distribution of cod according to the spring survey on the Faroe Plateau (kg per tow). 100, 200 and 500 m depth contours are shown.

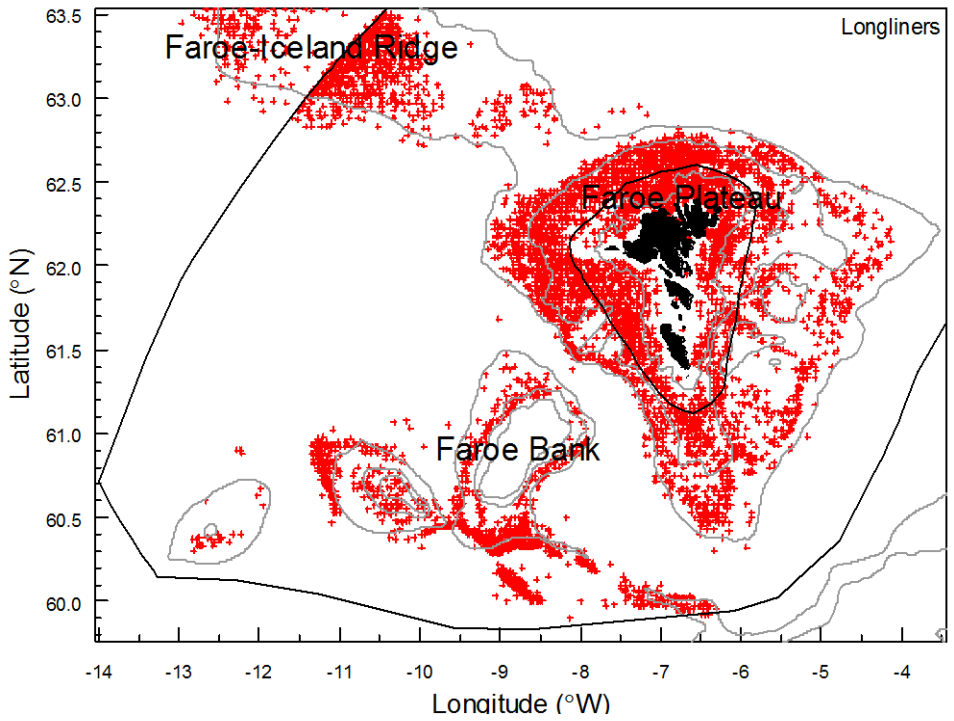

Figure 3. Map of geographical areas often used in the report. The red crosses show the start positions of all longliner settings in 2011.