Stock Annex: Saithe (*Pollachius virens*) in Division 5.b (Faroes grounds)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Saithe
Working Group	North Western Working Group (NWWG)
Created:	February 2010
Authors:	
Last updated:	
Last updated by:	Luis Ridao, and Petur Steingrund (Faroe Marine Research Institute)

A. General

A.1. Stock definition

Saithe is widely distributed around the Faroes, from shallow inshore waters to depths of 500 m. The main spawning areas are found at 150-250 meters depth east and north of the Faroes. Spawning takes place from January to April, with the main spawning in the second half of February. The pelagic eggs and larvae drift with the clockwise current around the islands until May/June, when the juveniles, at lengths of 2.5-3.5 cm, migrate inshore. The nursery areas during the first two years of life are in very shallow waters in the littoral zone. Young saithe are also distributed in shallow depths, but at increasing depths with increasing age. Saithe enter the adult stock at the age of 3 or 4 years (Jákupsstovu 1999).

Saithe in Division 5.b is regarded as a management unit although tagging experiments have demonstrated migrations between the Faroes, Iceland, Norway, west of Scotland and the North Sea (Jákupsstovu 1999). Jakobsen and Olsen (1987) investigated taggings of saithe at the Finmark coast (off Northern Norway) during the 1960s-1970s. They found that emigration rates to the Faroe area by some 2-3 % of the North-east arctic saithe stock was sufficient to explain the tagging results, and that the emigration likely occurred before sexual maturity. Bearing in mind that the North-east arctic saithe stock is larger than the saithe stock at the Faroes (by a factor of 1 to 6), up to some 20 % of the saithe stock at the Faroes may be of norwegian origin, according to this study. However, it might be expected that the emigration rate of saithe from more southerly locations along the Norwegian coast could be higher than in Jakobsen and Olsen's (1987) study (see Jakobsen (1981) for emigration to the North Sea). On the other hand, the emigration rate in the opposite direction also has to be accounted for. English tagging experiments (Jones and Jónsson, 1971) with Faroe Plateau saithe in the 1960s indicated an emigration rate to the Faroe Bank of 5 % (2 out of 41), North Sea of 15 %, and a rate of 20 % to Iceland (2 % had unknown recapture site). Regarding the migration between Icelandic and Faroese waters, there have been tagged some 18463 juvenile saithe in Icelandic waters in 2000-2005 (Armansson *et al.*, 2007), and 1649 have been recaptured up to now, 7 of them in Faroese waters (Marine Research Institute, Iceland, pers. comm.). This indicates that emigration rate of saithe to Faroese waters might be limited. In conclusion, Faroe saithe seem to receive recruits from own waters as well as recruits from the North-east arctic saithe stock and probably also the North Sea stock. In addition there might be a net emigration to Icelandic waters (Jones and Jónsson, 1971; Jakobsen and Olsen, 1987).

A.2. Fishery

Since the introduction of the 200 miles EEZ in 1977, the saithe fishery has been prosecuted mostly by Faroese vessels. The principal fleet consists of large pair trawlers (>1000 HP), which have a directed fishery for saithe, about 50 - 60% of the reported landings in since 1992. The smaller pair trawlers (<1000 HP) and larger single trawlers have a more mixed fishery and they have accounted for about 10-20% of the total landings of saithe since 1997. The share of landings by the jigger fleet accounts for less than 4% of the total landings since 2000.

Since early-1980s the bulk of catches consists of age groups 4 to 7 while the contribution of older age groups was more substantial from 1961 to 1980 (WD 08)

Nominal landings of saithe in Division 5.b have varied cyclically between 10 000 t and 68 000 t with three distinctive cycles of around 15 years period since 1960.

Catches used in the assessment include foreign catches that have been reported to the Faroese Authorities but not officially reported to ICES. Catches in Subdivision 2.a, which lies immediately north of the Faroes, have also been included. Little discarding is thought to occur in this fishery.

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). Saithe, however, seem to be more affected by the productivity over the outer areas. 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 regulate the abundance of saithe in Faroese waters (Steingrund and Hátún, 2008). When comparing a gyre index (GI) to saithe in Faroese waters there was a marked positive relationship between annual variations in GI and the total biomass of saithe lagged 4 years.

There is a negative relationship between mean weight-at-age and the stock size of saithe in Faroese waters. This could be due to simple density-dependence, where there is a competition for limited food resources. Stomach content data show that blue whiting, Norway pout, and krill dominate the food of saithe, and the annual variations in the stomach fullness are mainly attributable to variations in the feeding on blue whiting. There seemed to be no relationship between the way stomach fullness is related to weights-at-age (í Homrum *et al.* 2009). One explanation for this might be the influx of fish (3 to 5 years old) to Faroese waters from other saithe stocks given that weights-at-age are very similar, e.g. for NEA and Faroe saithe in years when the Faroe saithe stock is large (4 years after a high GI) whereas Faroe saithe has up to two times larger individual weights when the stock size is low.

B. Data

B.1. Commercial catch

In order to compile catch-at-age data, the sampling strategy is to have length, length-age, and length-weight samples from all major gears (jiggers, single trawlers > 1000 HP, pair trawlers < 1000 HP, pair trawlers > 1000 HP and others) during three periods: January-April, May-August and September-December. When sampling was insufficient, length-age and length-weight samples were used from similar fleets in the same time period while avoiding if possible the use of length measurements. Landings were obtained from the Fisheries Ministry and Statistics Faroe Islands. Catch-at-age for fleets covered by the sampling scheme were calculated from the age composition in each fleet category and raised by their respective landings. Fleet based catch-at-age data 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 landing samples.

B.2. Biological

B.3. Surveys

The spring groundfish surveys in Faroese waters were initiated in 1983 with the research vessel Magnus Heinason. 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 first cruise was not conducted and one third of the stations used up to 1991 were fixed. Since 1993 all stations are fixed.

The summer (August-September) groundfish (bottom trawl) survey was initiated in 1996 and covers the Faroe Plateau with 200 fixed stations distributed within the 65 to 520 m contour. Effort for both surveys is recorded in terms of minutes towed (~60 min). Survey data for Faroe saithe are available to the WG from both the spring- (since 1994) and summer- (since 1996) surveys. The usual way was to calculate the index as the stratified mean number of saithe 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 saithe less than 20 cm were considered being 0 years and between 20-40 cm 1 year. 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 in the summer survey.

Both survey indices are available to the Working Group. However the survey series have not been used due to high CVs. In order to address this issue, a data-driven post-stratification analysis was applied in 2008. The analysis suggested that the optimal number of strata to estimate relative stock abundances should be between 5 and 7 for both surveys. The new stratification results in less variable survey estimates while improving year class consistency from one year to the next (Ridao Cruz, L. 2008, WD 5). A similar approach was used at the Benchmark Assessment Workshop (WKROUND) in 2010 (WD 03). In this case one large haul was windsorized to the second largest in the spring series prior to the analysis proper. With these revised survey indices several age-based models were run, e.g., XSA, NTF-Adapt and Separable models. A strong bias was observed in the retrospective pattern for all models and therefore the revised survey series were yet regarded as not suitable for model tuning. However, WKROUND in 2010 noted that the surveys were able to capture annual changes in the range of the spatial distribution of saithe on the Faroe Plateau. This variability (proportion of all 300 hauls containing at least one saithe) was used as a scaling factor of the commercial cpue (based on the pairtrawlers, see later).

Maturity at age data from the spring survey is available since 1983. Some of the 1983-1996 values were revised in 2003 but not the maturities for the 1961-1982 period (Steingrund, 2003). 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. Due to poor sampling in 1988 the proportion mature for that year was calculated as the average of the two adjacent years. At the 2012 working group a model using maturity at age from the Faroese groundfish spring survey was implemented to derive smoothed trends in maturity by age and year. The fitting was done locally and the smoothing level was chosen as a trade-off between retaining the trend in maturities and reducing the data noise.

B.4. Commercial CPUE

The CPUE series from pair trawlers that has been used in the assessment since 2000 was introduced in 1998 (ICES C.M. 1998/ACFM:19), and consists of saithe catch at age and effort in hours, referred to as the pair trawler series. All vessels use 135mm mesh size, the catch is stored on ice on board and landed as fresh fish. The vessels are greater than 1000 HP and have specialized in fishing on saithe and account for 5 000-20 000 t of saithe each year. The tuning series data are based on available logbooks of 4-10 trawlers since 1995. Data are stored in the database at the Faroe Marine Research Institute in Torshavn where they are quality controlled and corrected if necessary. Effort is estimated as the number of fishing (trawling) hours, i.e. from the time the trawl meets the bottom until hauling starts. It is not possible to determine effort in fishing days because day and time of fishing trips are not recorded in the logbooks. The effort distribution of the pair trawlers fleet covers most of the fishing areas in the deeper parts (bottom depth > 150 m) at the Faroes. Distribution of combined trawl catches (single- and pair-trawlers) from logbooks is shown in figure 1.

During 2002-2005 four pairs of these trawlers were decommissioned. In 2004 and 2005 two new pairs of trawlers (>1000 HP) were introduced in the tuning series; one pair had been fishing saithe since 1986 and the other since 1995. These two new pairs showed approximately the same trends as the other pair trawlers in the series during 1999-2003. In 2009 two new pairs of trawlers were used to extend the tuning series. These trawlers were built in 2003 and 2004 and they show the same trends in CPUE as the others, but higher in absolute numbers. At the 2010 benchmark assessment the CPUE series were compiled based on hauls where saithe contributed more than 50% of the total catch, discarding a pair (pair-6) and constraining the spatial distribution to those statistical squares where most of the fishing activity takes place. A GLM model using year, month, pair and depth as explanatory variables (WD 09) was applied to the resulting input data. If 'fishing square' was added as an explanatory variable, the year-effect in the GLM model remained the same. However, 'fishing square' was excluded from the model in order to keep the number of the degrees of freedom as low as possible. In addition to the pairtrawler cpue, which is a measure of saithe density in the core area of saithe, the range of the spatial distribution of saithe was considered when constructing an abundance index for saithe. The pairtrawler cpue was scaled by the proportion of survey survey hauls in March and August (approximately 300 each year, except 100 in 1995) containing at least one saithe. The revised annual indices resulted in a substantial reduction in the bias observed in the retrospective pattern. The WKROUND working group regarded this novel approach to the commercial series as satisfactory.

B.5. Other relevant data

C. Historical Stock Development

The last benchmark assessment for Faroe Island saithe was conducted in 2005. The model explored during that benchmark workshop, an XSA model, was not used for interim assessments or to provide management advice after that workshop because of a retrospective pattern observed in model outputs at that time. It was hypothesized that the retrospective pattern was likely due to changes in selectivity due to changes in fish growth as it was observed that the average weight at age in the catch was dropping. The 2010 benchmark workshop further explored the XSA model as well as an ADAPT, TSA and separable statistical models. The CPUE series that has been used in the assessment since 2000 was introduced in 1998 (ICES C.M. 1998/ACFM:19), and consists of saithe catch at age and effort in hours, referred to as the pair trawler series. The commercial CPUE series was standardized and the density indices were multiplied by an area expansion factor to better represent a measure of total stock abundance (Sec. 6.2.5.2.) These data updates were found to significantly reduce the retrospective pattern previously observed in the assessment. The SSB, F and recruitment estimates generated by both models were comparable and the XSA assessment was adopted as the benchmark assessment because it had been the model historically used for this stock. The model settings are described below. In 2013 the spring groundfish survey (FGFS1) was introduced in the current assessment framework along with the commercial fleet. Spring survey data were considered superior to the summer survey for calibrating the assessment. Commercial catch-at age data (ages 3-14+, years 1961-2012) were calibrated in the XSA model using the spring survey at age data (ages 3-10, years 1993-2012) and the commercial pair-trawl fleet (ages 3-11, years 1995-2012).

Model used: FLXSA, Extended Survivors Analysis for FLR

Software used: FLR, version 2.0

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 ≥ 8.

Terminal population estimation: Survivor estimates shrunk towards the mean F of the final 5 years or the 3 oldest ages. S.E. of the mean to which the estimates are shrunk = 2.000. Minimum standard error for population estimates derived from each fleet = .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	1961-last data year	3 – 14+	Yes
Canum	Catch at age in numbers	1961-last data year	3 – 14+	Yes
Weca	Weight at age in the commercial catch	1961-last data year	3 – 14+	Yes
West	Weight at age of the spawning stock at spawning time.	1961-last data year	3 – 14+	Yes, assumed to be the same data as weight at age in the catch
Mprop	Proportion of natural mortality before spawning	1961-last data year	3 – 14+	No, set to 0 for all ages and years
Fprop	Proportion of fishing mortality before spawning	1961-last data year	3 – 14+	No, set to 0 for all ages and years
Matprop	Proportion mature at age	1983- last data year + 1 (2009)	3 – 14+	Predicted ogives. Data prior to 1983 is average of 1983-1996 values.
Natmor	Natural mortality	1961-last data year	3 – 14+	No, set to 0.2 for all ages and years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Pair trawlers	1995- last data year	3-11

D. Short-Term Projection

Model used: Age structured.

Software used: Multi Fleet Deterministic projection (MFDP1a), prediction with management option table

Initial stock size: Taken from the final VPA run (table 10). Recruitment at age 3 is the geometric mean of the recent 6 years excluding the last recruitment estimate

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

Maturity: In the assessment year is the average of weight in assessment year and previous year. For the two following years after the assessment year an average of the most three recent years is used.

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

Weight at age in the stock: weight-at-age for 3-years old saithe is predicted by the year class strength (number of 3-years old in the stock) with a 3 year time lag (Eq. 1) whereas weight for ages 4 to 8 is estimated by weight-at-age the previous year from the same year class (Eq. 2). Weight for ages 9 to 14+ is an average of the most 3 recent years (Eq. 3)

$W_{3,y} = \alpha N_{3,y-3} + \beta$ for $a = 3$ (Eq. 1)

$W_{a+1,y+1} = \alpha W_{a,y} + \beta$ for $4 \leq a \leq 8$ (Eq. 2)

$W_{a,y} = (W_{a-3,y}\ W_{a-2,y}\ W_{a-1,y})/3$ for $9 \leq a \leq 14+$ (Eq. 3)

Weight at age in the catch: The same value as in the last data year.

Exploitation pattern: Average exploitation pattern in the final VPA for the last two years rescaled to terminal F if pattern is present in recent years, otherwise un-scaled.

Intermediate year assumptions: None

Stock recruitment model used: None

Procedures used for splitting projected catches: None

E. Medium-Term Projections

F. Long-Term Projections

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

Software used: Multi Fleet Yield Per Recruit (MFYPR2a).

Maturity: Average for 1983 to last data year +1 (2009).

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

Weight at age in the stock: Assumed to be the same as weight at age in the catch.

Weight at age in the catch: Average weights from 1983 to last data year.

Exploitation pattern: Average exploitation pattern of the last five years

Procedures used for splitting projected catches: None.

G. Biological Reference Points

In 2014 at the WKMSYREF2 workshop the EqSim simulation framework was used to explore candidates to Fmsy. The work was presented at the NWWG meeting in 2014 and the results agreed with the previous simulations in that estimates of Fmsy are in the range of Fmsy=0.30 and Fmsy=0.34 and not as the present level of Fmsy=0.28. In the 2014 meeting ACOM adopted the EqSim framework and agreed to set Fmsy=0.30. Below it is an excerpt from the WKMSYREF2 report:

The EqSim framework fits three stock-recruit functions (Ricker, Beverton-Holt and Hockey-stick) on the bootstrap samples of the stock and recruit pairs from which approximate joint distributions of the model parameters can be made. The result of this is projected forward for a range of F's values and the last 50 years are retained to calculate summaries. Each simulation is run independently from the distribution of model and parameters. Error is introduced within the simulations by randomly generating process error about the constant stock recruit fit, and by using historical variation in maturity, natural mortality, weight at age, etc.

In the EqSim simulations the Hockey-Stick stock-recruit function were used assuming assessment and autocorrelation errors. Figure 3 illustrates the results of these simulations which suggest that candidates for FMSY are FMSY =0.34 (median yield) and

FMSY =0.30 (F that gives the maximum mean yield in the long term) lie above the current FMSY = Fpa = 0.28 if autocorrelation and assessment errors are included in the simulation framework. If errors are ignored then estimates for FMSY are predicted to FMSY =0.38 (median yield), FMSY =0.35 (maximum mean yield). No Blim is defined for faroe saithe but for the purposes of the analysis a value of Blim=Bpa/1.4 was set for the simulations. A more detailed information of the simulations are available under *http://www.ices.dk/community/groups/Pages/WKMSYREF2.aspx* Below it's the table with the current reference points adopted by the working group and ACOM:

Biological reference points	WKMSYREF2/NWWG/ACOM 2014
Btrigger	55 000 t.
Blim	not defined.
Bpa	55 000 t.
Flim	not defined
Fpa	0.28
Fmsy	0.30

H. Other Issues

Response to technical minutes

2006

Technical minutes suggested that a length based assessment should be attempted. This will be further investigated with Bormicon for next year's meeting, time permitting.

The question of migration has been brought up previously. Although tagging data indicate that saithe migrates between management areas, and some indications are seen in the assessment as well, no attempts have been made to quantify the migration rate of saithe.

Bycatch has been mentioned in the latest technical minutes. The results presented in NWWG 2007 indicate that the bycatch issue is a minor problem in the saithe assessment (ICES C.M. 2007/ACFM:17). Mandatory use of sorting grids in the blue whiting fishery was introduced from April 15, 2007 in the areas west and northwest of the Faroe Islands.

2007

Technical minutes pointed out the problem of variability in weight-at-age and suggested the possibility of using different modelling approaches that the WG could explore in the future. It was discussed whether there was possibility for Faroe Saithe to be part of the benchmark workshop in winter 2008; but this session was already closed for additional participants. Alternatively the group discussed the possibility of working intersessionally to explore usable models for next year's meeting.

2008

Technical minutes pointed out the problem of variability in pelagic/demersal occurrence of saithe, hence the problems in reliability of survey indices (high CV). Commercial CPUE indices were used for tuning. However, declining weight-at-age leading to declining catchability not accounted for in XSA.

At this point, there is no improvement in the 2009 year assessment compared to previous year. In the benchmark assessment the surveys should be closer investigated. The summer survey shows that the spatial distribution of saithe on the Faroe Plateau has become wider. An attempt should be made to incorporate this information into the index of stock size.

I. References

Armansson, H., Jónsson, S.Th., Neilson, J.D., and Marteinsdottir, G. 2007. Distribution and migration of saithe (Pollachius virens) around Iceland inferred from mark-recapture studies. ICES Journal of Marine Science, 64: 1006-1016.

Fryer, Rob. 2010. Time Series Analysis (TSA) of Faroe Saithe. WD 4. WKROUND 2010.

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.

Hátún, H., Payne, M., Beaugrand, G., Reid, P.C., Sandø, A.B., Drange, H., Hansen, B., Jacobsen, J.A., and Bloch, D. 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, in press.

Í Homrum, E., Ofstad, L.H. and Steingrund, P. Diet of Saithe on the Faroe Plateau. WD 12, NWWG 2009. 10 pp.

ICES C.M. 1998/ACFM:19.

Jakobsen, T. 1981. Assessments of the North-East Arctic and North Sea saithe stocks taking into account migration. ICES C.M. 1981/G:36.

Jakobsen, T., and Olsen, S. 1987. Variation in rates of migration of saithe from Norwegian waters to Iceland and Faroe Islands. Fisheries Research, 5: 217-222.

Jákupsstovu, S.H. 1999. The Fisheries in Faroese Waters. Fleets, activities, distribution and potential conflicts of interest with an offshore oil industry.

Jones, B., and Jónsson, J. 1971. Coalfish tagging experiments at Iceland. Rit Fiskideildar, vol. 5, no. 1: 2-27 (1971).

Ridao Cruz, L. 2008. Post-Stratification of the survey indices for Faroese saithe. WD 5, NWWG 2008.

Ridao Cruz, L. 2010. Post-Stratification of the survey indices for Faroese saithe. WD 3, WKROUND 2010.

Ridao Cruz, L. 2010. Length Cohort Analysis (LCA) of Faroe Saithe. WD 5, WKROUND 2010.

Ridao Cruz, L. 2010. Faroese Groundfish Surveys for Saithe in Vb. WD 6, WKROUND 2010.

Ridao Cruz, L. 2010. NTF- ADAPT model for Faroese Saithe. WD 7, WKROUND 2010.

Ridao Cruz, L. 2010. Overview on the Faroese saithe fishery. WD 8, WKROUND 2010.

Ridao Cruz, L. 2010. GLM model diagnostics of Pair-trawl catch rates for saithe in Vb. WD 9, WKROUND 2010.

Steingrund, P. April 2003. Correction of the maturity stages from Faroese spring groundfish survey. WD 14, NWWG 2003.

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., and Gaard, E. (ms). Recruitment in Faroe Plateau cod (Gadus morhua L.) hampered by cannibalism at age 1 but positively related to the contemporary abundance of age 3+ cod at age 2. ICES Journal of Marine Science. (Submitted).

Steingrund, P., and Hátún, H. 2008. Relationship between the North Atlantic Subpolar Gyre and fluctuations of the saithe stock in Faroese waters. WD 20, NWWG 2008. 7 pp.

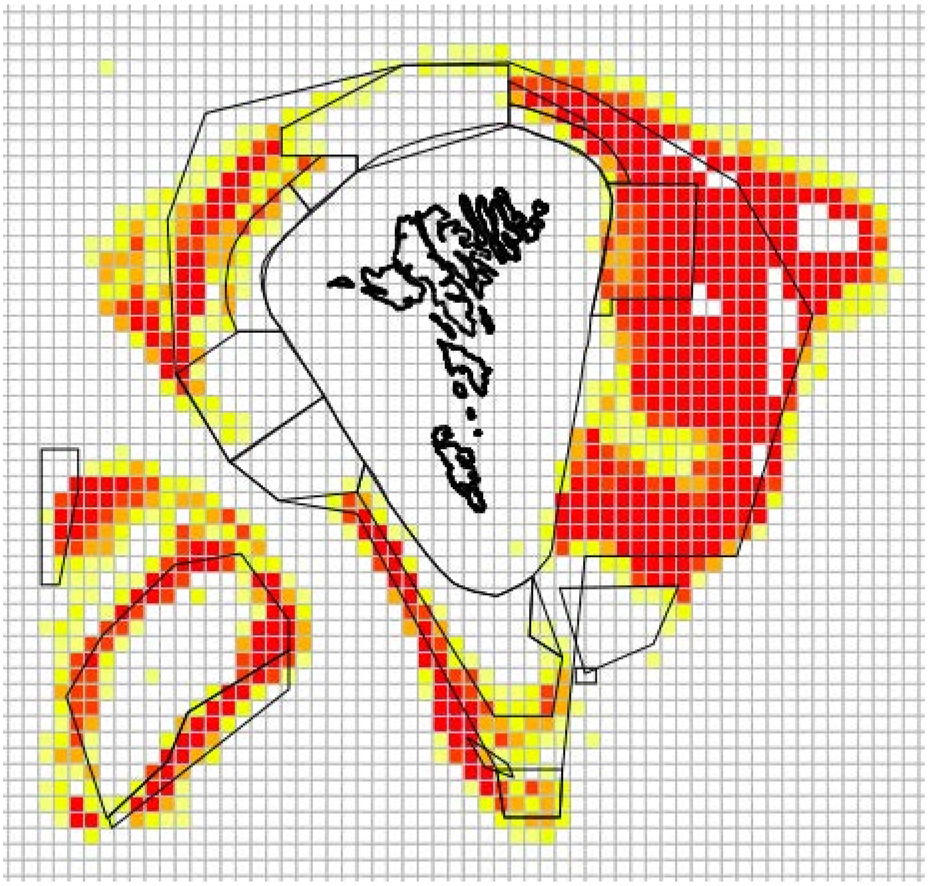

Figure 1. Faroe Saithe 5.b. Effort distribution of pair-trawler fleet (1996-2009)

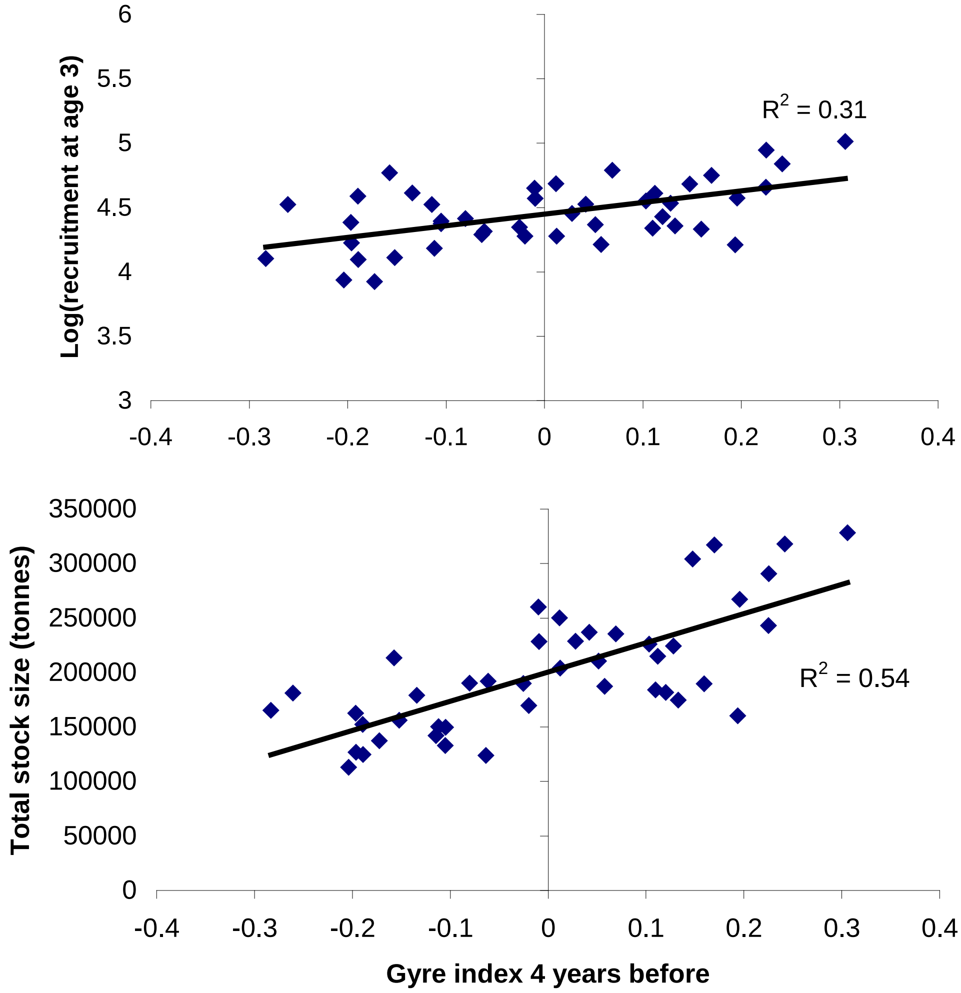

Figure 2. Relationship between the gyre index and both recruitment (top figure) and total stock biomass estimates (bottom figure.) Note that a large gyre index indicates a small subpolar gyre, and, consequently, a large influx of plankton-rich warmer-than-average water to the outer areas (bottom depth > 150 m) around the Faroes, where saithe typically are found.

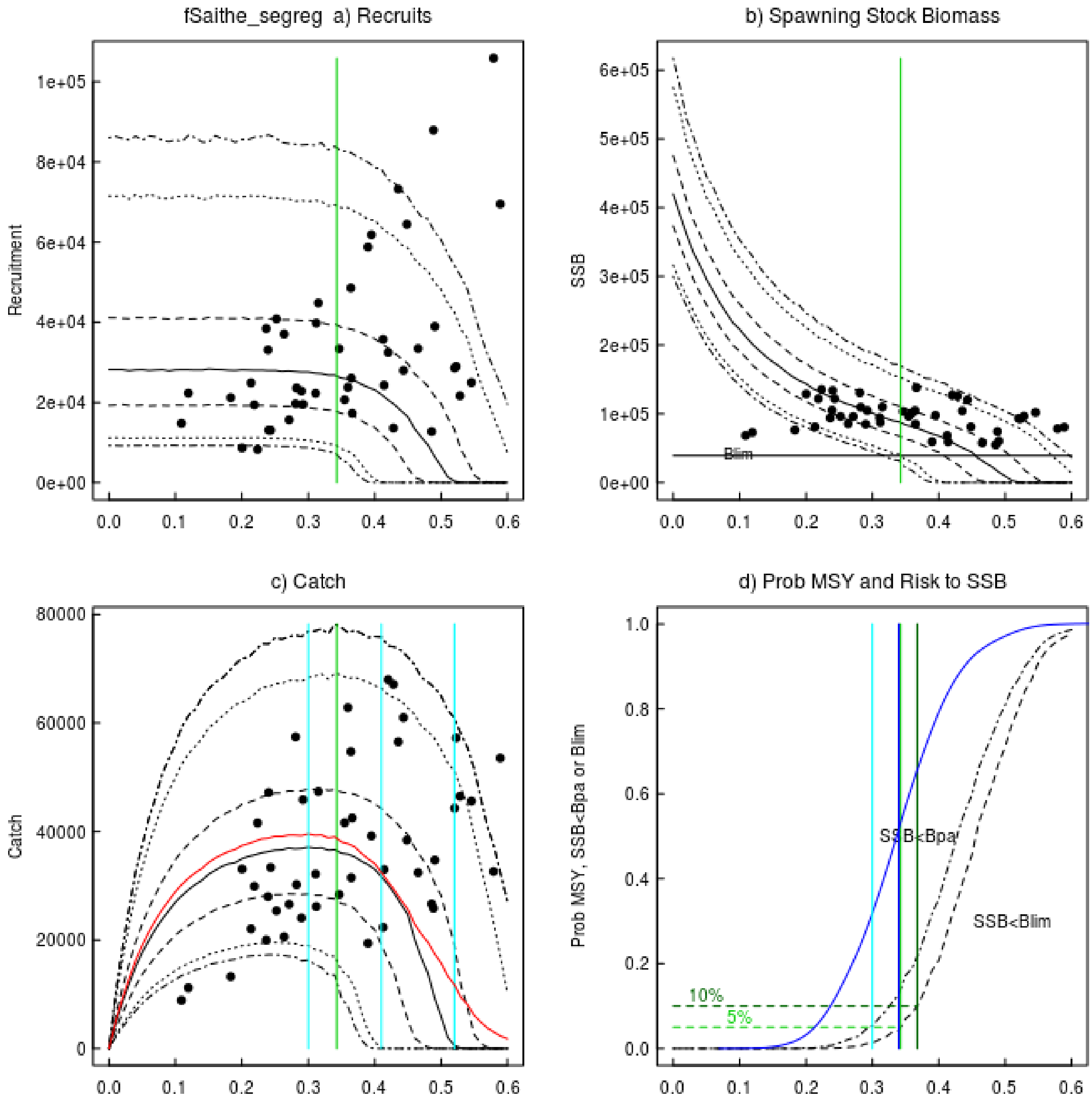

Figure 3. Faroe saithe. EqSim simulation outputs with assessment errors and Hockey-stick function.