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Report of the Benchmark Workshop on Roundfish (WKROUND)

9–16 February 2010

Copenhagen, Denmark

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

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Executive Summary

The WKROUND 2010 Benchmark Workshop was held at ICES Headquarters in Copenhagen, Denmark from 9–16 February 2010. The Workshop was chaired by Richard Methot (USA) with ICES Coordinator Einar Hjörleifsson (Iceland) and involved 26 participants representing 10 nations. The primary objectives of the Workshop were to compile and evaluate data sources and select appropriate assessment models to include in updated Stock Annexes for five stocks: Northeast Arctic saithe, Icelandic saithe, Faroes saithe, northern hake and southern hake. Benchmark workshops are designed to consider stocks under their jurisdiction on a rotational basis, with each stock being analysed in a 3–5 year cycle. The Stock Annexes are the most important product of this process, with each annex containing all relevant information that the benchmark workshop participants have identified as current best practice assessment inputs and models, providing sufficient detail to ensure that future assessment scientists can readily replicate assessments without the need to have been previously involved in such assessments. The Report also details the analyses undertaken during the Benchmark Workshop to inform the Stock Annexes.

This Report consists of the Benchmark Workshop Report and the Stock Annex for each stock in turn, followed by general recommendations arising from the plenary sessions of the Workshop, and four annexes containing supplementary information. The species-specific benchmark reports are split into specified sections dealing with data sources, data quality, environmental and ecosystem issues, stock assessment methods, forecasts, biological reference points, recommended modifications to the stock annex, recommendations on the procedure for assessment updates and recommendations for future work. Sections on industry-supplied data are also included where appropriate. The species-specific Stock Annexes follow the standard ICES format.

The Benchmark was completed and corresponding Stock Annexes were updated for all five stocks. In each case, a preferred assessment model configuration was identified. For two stocks, northern hake and southern hake, new assessment methods were introduced to utilize size composition data after tagging studies invalidated previously utilized age data. Issues requiring further work were identified for all stocks and included in the Benchmark Report.

General recommendations covered a wide range of topics including: evaluation of proxies for F_{msy}, use of preliminary workshops to better prepare assessments for benchmark workshops, development of integrated survey indices from a spatial mosaic of individual surveys, and possible approaches to getting more consideration of environmental factors in stock assessments.

1 Introduction

This Benchmark Workshop was convened according to guidance provided by ACOM. Draft Terms of Reference were set out in the document ACOM36 (Annex 1). The key aspects of the Terms of Reference are:

to compile and evaluate data sources for stock assessments,

to solicit relevant data from industry and other stakeholders, and

to update the relevant Stock Annexes to include what benchmark participants identify as current best practice assessment inputs and methods, providing sufficient detail to ensure that assessment scientists can readily replicate assessments without the need to have been previously involved in such assessments.

Accordingly, the first two days of this Benchmark Workshop were devoted to data compilation, including invited input from stakeholders; and to identifying assessment issues. The next six days then focused on resolving the assessment issues to the extent possible, with a view to revising the Stock Annexes for adoption for the following 3–5 years.

The Workshop was chaired by Richard Methot (USA) with ICES Coordinator Einar Hjörleifsson (Iceland) and Andrew Applegate (USA), Patrick Sullivan (USA) and Daniel Howell (Norway) as invited experts. Other participants included members of the ICES assessment groups (North Western Working Group, Arctic Fisheries Working Group and Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim), industry representatives, and members of the ICES Secretariat. A full list of participants is provided in Annex 2. A numbered list of Working Documents considered by the WK, and subsequently archived by ICES, is given in Annex 3.

2 Northeast Arctic (NEA) Saithe

2.1 Current stock status and assessment issues

A final XSA assessment was accepted by WKROUND2010, which included a 15+ plus group, split tuning-series (1989–2001; 2002–2008), a greatly reduced shrinkage factor, and no downweighting. Total SSB is estimated to have increased from 126 000 mt in 1992 to 667 000 mt in 2007, declining slightly to 612 000 mt in 2008. Landings declined from 213 000 mt in 2006 to 183 000 mt in 2008, less than the TAC constraint. Fishing mortality on ages 4–7 (which represent about 70% of the total catch) declined from 0.59 in 1992 to 0.16 in 2004, increasing to 0.22 in 2008. Recruitment since 2006 has been below average (204 million age 3 fish); following the strong 2002 year class (431 million age 3 fish in 2005).

Fishing mortality in 2008 is below F_{max} (0.32), but well above $F_{35\%SPR}$ (0.10). A more complete analysis of the potential MSY limit or target fishing mortality was not completed until the pre-1989 catch-at-age data could be extended to 15+.

Mainly due the effect of poor recent recruitment, a fishing mortality rate of 0.22 in 2010 is forecast to produce landings of 165 000 mt and result in a January 1, 2011 SSB of 460 000 mt, considerably below the current level.

The latest benchmark assessment was in 2005 and updated in 2009. The XSA model was used to fit the catch data, with trawl fleet (trips with >20% saithe) cpue for ages 4–10 and with the acoustic survey for ages 4–8 as tuning series. Fishing mortality was below F_{pa}, biomass was above B_{pa}, and catch limits were set using short-term projections. Recent SSB had been estimated to be declining from high levels in recent years, although that estimate was revised upward with each successive update assessment. A large retrospective pattern, underestimating SSB and overestimating F, had been observed and not resolved.

In addition, a substantial reduction in mean weights-at-age had been observed (Figure 1), similar to neighbouring saithe stocks. While the cause of the declining weights-at-age was unknown, it was thought that the change in productivity should be reflected in the biological reference points, if it were a semi-permanent feature that was unlikely to quickly revert to the prior pattern.

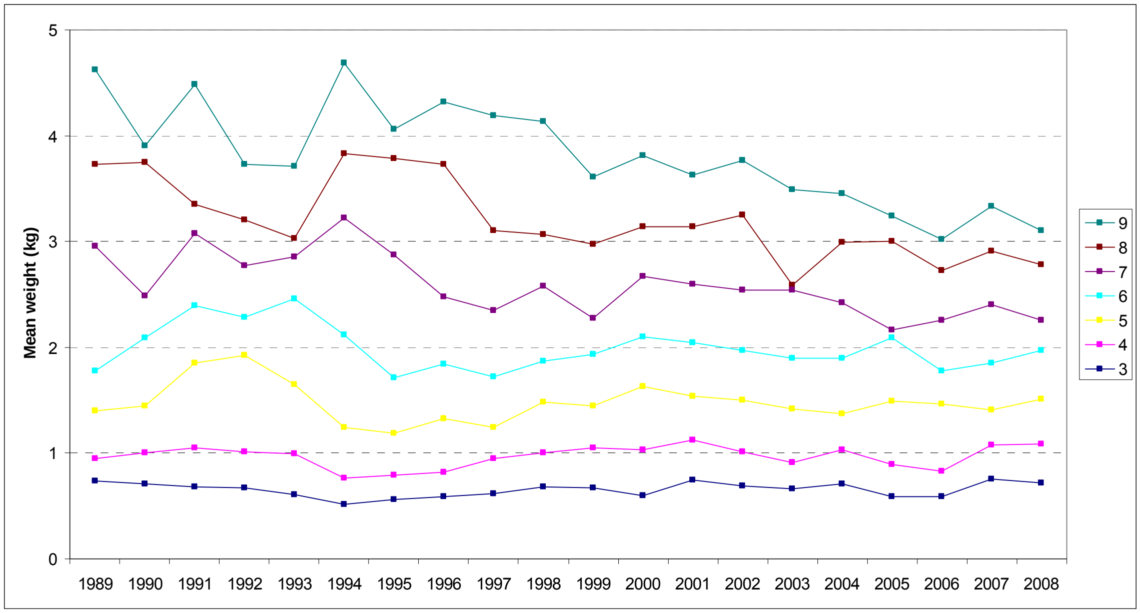

Figure 1. Annual mean weight-at-age in the commercial landings of NEA saithe for ages 3 to 9.

Various sets of cpue data had been used in tuning the XSA model, including a more directed trawl fishery selected as trips with >80% saithe and data from the Norwegian purse-seine fishery. Due to uncertainty about how well these data tracked the apparent stock biomass trend in recent years, these latter cpue time-series had been dropped from the tuning-series and industry proposed using a standard set of seven vessels thought to represent an unbiased data source.

Because the changing mean weights-at-age did not appear to be the major cause of bias, WKROUND 2010 focused on other potential causes of the retrospective pattern and explored various model runs to determine cause. The major cause of the large retrospective pattern appeared to be the relatively large amount of catch in the plus group, which was then extended from 10+ to 15+, although the catch time-series had to be shortened to the period 1989 to 2008, due to the lack of available catch-at-age data before 1989. Other factors included an apparent change in catchability about 2002, the effect that shrinkage had on the assessment and to a lesser extent the effect of downweighting.

2.2 Compilation of available data

2.2.1 Catch and landings data

Commercial landings data allocated to ages 3–10 from 1960 to 2008 were compiled to generate a catch-at-age matrix. Commercial landings data allocated to ages 3–14 from 1989 to 2008 were available at the WKROUND 2010 meeting. Data for these landings came from the ICES database with landings reported by 10 countries including Norway, Russia, and Germany for trips using a variety of gears. Most landings were reported for the Norwegian trawl fishery. Catch in numbers-at-age and weights-at-age were compiled by port sampling programmes for Norway and Germany, and applied to the remaining landings by area and quarter. Discards and recreational landings are believed to occur at relatively small amounts, but were not estimated. Details about how the landings data were derived and processed are described in the stock annex for this report.

2.2.2 Biological data

The weight-at-age in the stock was assumed to be the same as the weight-at-age in the catch. A fixed natural mortality rate (M) of 0.2 was assumed for the assessment, forecasts, and biological reference point estimations. The proportion natural and fishing mortality before spawning was assumed to be zero, based on assumptions or analysis made in previous assessments. In the assessment, the proportion mature at-age (maturity ogive) was analysed using three stanzas. Before 1995, maturity was assumed to have knife edge selectivity at age 6. From 1985 to 2005, a constant maturity ogive was used for all years, based on re-read information on spawning rings, work conducted before the 2005 WG meeting. Since 2005, a three year moving average was applied based on data supplied by Norway. The history and rationale for the selection of biological data are described in more detail within the stock annex for this report.

2.2.3 Tuning time-series data

An annual acoustic survey specially designed to survey saithe abundance has been conducted since 1985 in October and November, covering the Norwegian coastal banks from 62°N to the Russian border. The whole area has been surveyed since 1992 using a fixed transect design with four subareas to estimate total abundance. Since 1995, a Norwegian acoustic survey for coastal cod in September, just before the saithe survey and includes areas not included in the regular saithe survey which often include 2 and 3-year old saithe that have not yet migrated out to the banks. And in autumn 2003, the two surveys were combined, allowing the production of a similar index as before.

The survey mainly covers the grounds where the trawl fishery takes place, normally dominated by 3–5 year old fish. Two year old fish also appear in the survey data but inhabit the fjords and more coastal areas (partially indexed by the coastal cod survey described above), but there may be high interannual availability to the survey of the young ages.

Although the saithe and the coastal cod surveys are conducted with similar gear, but were conducted in a slightly different season and changes in data processing and abundance estimation had taken place. Although the survey index produced comparable results and they were reviewed by previous WGs, WKROUND 2010 is unaware that formal calibration studies had been conducted. Data for calibration analyses are probably unavailable.

Initial XSA runs used the 3–7 age disaggregated acoustic survey index as a single series tuned to the catches in 1994–2008. Subsequent and final runs split the survey time–series into two parts (1994–2001, 2002–2008) to allow the model to estimate separate catchabilities for the special saithe and combined saithe and cod survey[1], as well as account for other methodological changes that may have affected true catchability.

2.2.4 Commercial tuning data

Commercial cpue data from the Norwegian purse-seine fishery and the Norwegian trawl fishery are available for analysis and use as a tuning-series. The quality and performance of a seven vessel fleet, nominated as a tuning-series by industry (see discussion below) was analysed by the Arctic WG and presented to the WKROUND 2010 as a working document, but not used in the assessment because of unresolved uncertainties and variability of the dataset. The effort (hours trawling) for each cpue observation was standardized or calibrated to a standard vessel, but were not standardized with respect to area and season.

Prior analysis of the purse-seine fishery data indicated that it recently become less reliable as an indicator of stock abundance and for this reason had been dropped as a tuning index in the last assessment. Also, in previous assessments, the 2007 cpue data were thought to be an outlier because the trend contradicted the trend for similar ages in the survey data. These and the 2008 data were added back into the cpue tuning-series for this assessment, because WKROUND 2010 believed the data to be informative and decided to let the model to decide how to weight the data. Keeping the data in the model also provides residual information which may be used to identify 'true' outliers, which would otherwise be missing and unestimated.

Commercial cpue for trawl trips with > 20% and > 80% saithe were therefore used as a 4–8 age disaggregate series tuned to the catches in 1994–2008. Subsequent and final runs split the survey time-series into two parts (1994–2001, 2002–2008) to allow the model to estimate separate catchabilities for an earlier and later period. In the latter period, the commercial fleet appeared to target older saithe than before and there also appears to be a southerly shift in the distribution of saithe in the survey. Thus splitting the tuning series allows the XSA model to fit separate catchabilities when there may have been a fundamental shift in how the fishery operates, although no specific time when this shift may have occurred was identifiable.

2.2.5 Industry/stakeholder data inputs

No additional data were supplied by industry during WKROUND 2010 and relevant stakeholders did not attend the meeting, or provide guidance and comments in writing.

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[1] Although the change to the combined cod-saithe survey occurred in 2003, there were other methodological changes in the processing of species and age allocations during this time period that may also have led to a change in catchability. WKROUND 2010 split the time series in 2002 to allow the model to fit separate catchabilities without shortening the latter tuning series to the point in became uninformative. Later assessments might explore making the split in 2003 instead of 2002 as newer data become available.

During prior Arctic WG meetings, industry had recommended using a standard data from a fleet of seven trawl vessels, which had been analysed by the WG, but found to exhibit higher variability with respect to stock trends than the more comprehensive >20% and <80% index that had been used to tune earlier stock assessment models.

The WKROUND 2010 did not formally analyse the industry supplied data, but accepted the Arctic WG recommendations based on working documents supplied to WKROUND 2010. There was, however, no review or discussion on how the industry supplied data had been analysed or whether standardization at the vessel, area, and seasonal level would have modelled other primary effects and provided a better index to be used for tuning.

Industry/stakeholder representatives did not attend the WKROUND 2010 meeting, so were unavailable for background details that might have helped WKROUND2010 make decisions about the use of the commercial cpue and other data, or as an anecdotal validation of trends observed in the assessment.

2.3 Stock identity and migration issues

Some migration had been observed with neighbouring stocks in historical tagging data, but this low migration rate is not thought to have a significant effect on the estimate of NEA stock size and reference points. However, the Icelandic saithe stock assessment includes some periodic immigration events of adult fish from the NEA Saithe stock, identified through changes in mean weight-at-age which were more consistent with NEA Saithe. Historical tagging data from the Barents Sea are also indicative that NEA saithe may periodically emigrate to the Faroe saithe stock area.

2.4 Spatial changes in the fishery and stock distribution

An increasing proportion of the stock has been observed in the southern strata, based on the results of both commercial catch and survey data. In addition, an increasing proportion of the catch is derived from older fish than had occurred previously. A substantial decline in mean weight-at-age has been observed, but this change is accommodated by the use of annual age–length keys, which appear to be adequate at present biological sampling levels.

2.5 Environmental drivers of stock dynamics

The recruitment of saithe may suffer in years with a reduced inflow of Atlantic water (Jakobsen, 1986), possibly as a function of the availability of key prey species to saithe. No formal information or analyses were presented to WKROUND 2010 on this subject, however.

2.6 Role of multispecies interactions

Saithe as juveniles serve as prey for a wide variety of species, including marine mammals. Abundances of predators could be or become a key factor in the productivity of saithe. No formal information or analyses were presented to WKROUND 2010 on this subject, however.

Saithe are piscivorous and could also have an effect on the productivity of other finfish, particularly when saithe are at very high or very low abundance. Again, no formal information or analyses were presented to WKROUND 2010 on this subject.

2.7 Impacts on the ecosystem

No information on the effects of the saithe fishery on the ecosystem was presented to WKROUND 2010.

2.8 Stock assessment methods

As in previous assessments, the NEA saithe data were fit with the XSA implementation of a virtual population analysis (VPA). Model runs were conducted in the DOS version of XSA, but retrospective analyses were conducted in the FLR environment. Slight differences in some results (Fs, numbers and SSB) for the two operational programming environments were observed by WKROUND 2010, which deserve more extensive evaluation but do not change the perception in mortality and biomass trends.

2.9 Stock assessment

WKROUND 2010 identified the very large retrospective pattern (Figure 1) as being the most problematic issue for the assessment and adjusted the model to resolve it. The most fundamental problem was in the way that fish in the plus group are modelled in XSA (and ADAPT) and affects the population size estimates when the catch of the plus group becomes significant. To accommodate this problem, most assessments select a plus group that has a relatively small fraction of the catch at fishing mortality levels observed in the time-series.

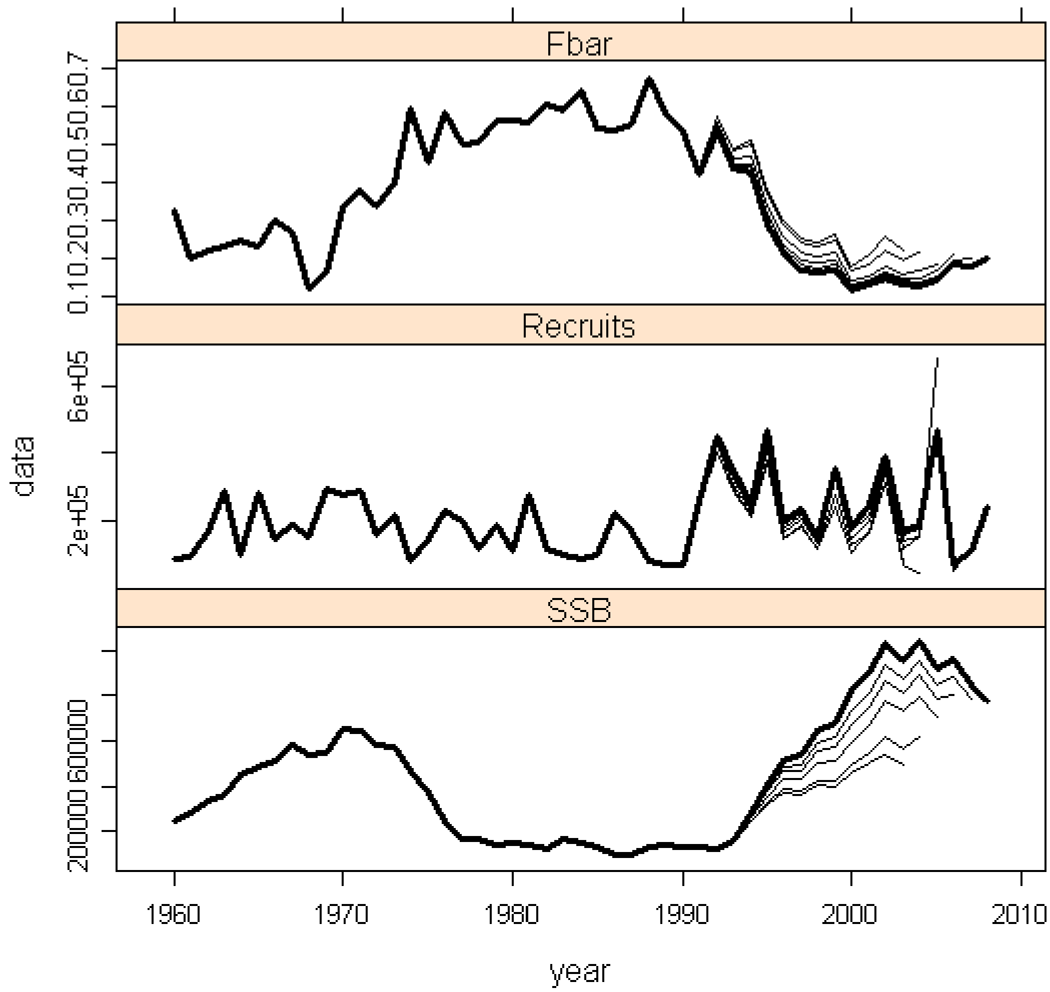


Figure 2. Trends and retrospective pattern for F4–7, recruitment and SSB for an 11+ XSA SPALY run with updated catch at-age and tuning indices through 2008.

The change in mean weights did not appear to be an assessment problem, *per se*, as long as the aging was accurate and saithe at length were assigned to appropriate ages in the age–length keys. The change in mean weights appears to be a fundamental shift in the saithe population to reduced productivity.

Various changes to the tuning-series and catch-at-age matrix were applied individually to examine the effect on the retrospective pattern and other diagnostics. These model revisions included increasing the plus group from 11+ to 15+, splitting the tuning-series in 2002 to allow the XSA freedom to estimate different qs for each time-series, reduce shrinkage to the mean to better allow the model to fit population number to the tuning-series, and not using a tri-cubic downweighting (tapering). In all runs, the reference fishing mortality encompassed ages 4–7, representing about 70% of the catch throughout the assessment (Figure 3). WKROUND 2010 discussed adding age 8 to the reference ages, but the added catch data did not add enough information to F_{bar} compared with the amount of noise added with the estimation of mortality on age 8, a relatively small part of the catch for the early part of the assessment. Residual patterns for the 11+ and 15+ catch-at- age XSA runs (Figure 10) did not appreciably improve even though the retrospective pattern saw a significant improvement.

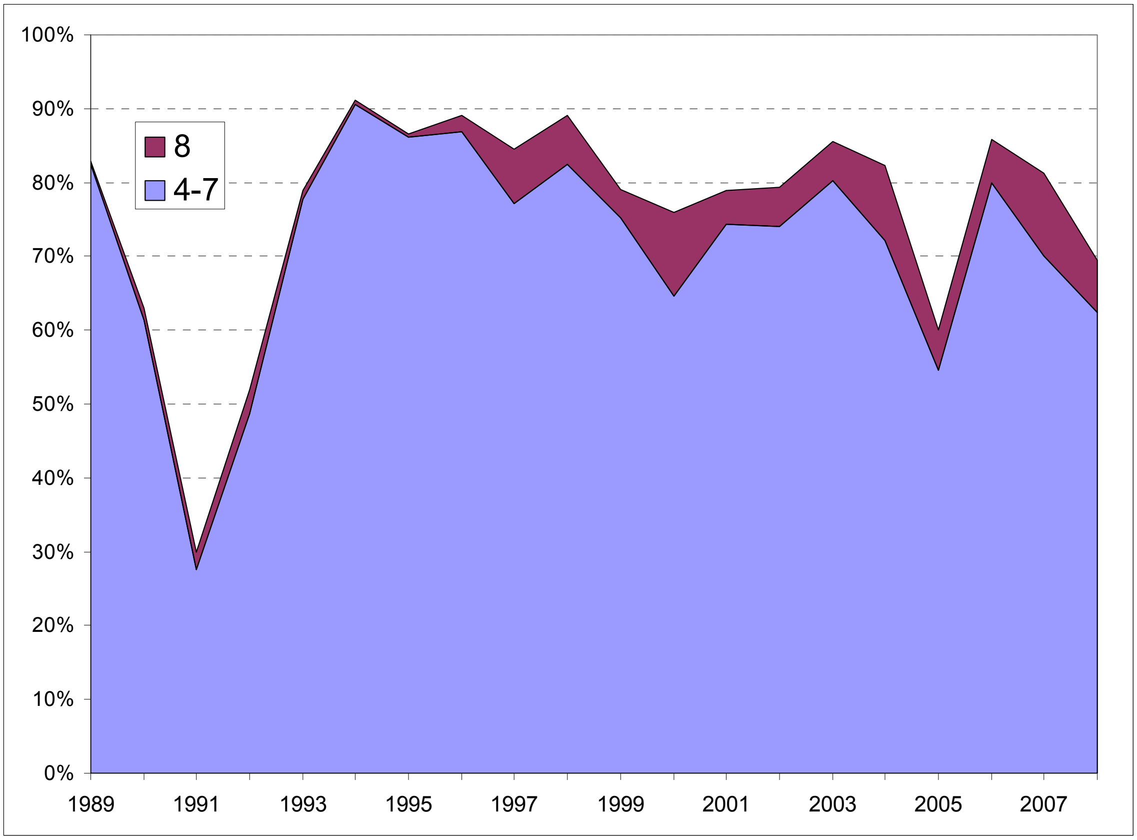


Figure 3. Percent of catch in number by age group.

All four adjustments to the catch-at-age and tuning data treatments were thought individually to improve the assessment, although the two adjustments that had the most effect were increasing the catch-at-age matrix to 15+ and splitting the tuning-series (Figure 4). The retrospective pattern improved and the deviations from the reference series for SSB decreased the value of Mohn's rho, because some of the deviations from the reference became positive (i.e. overestimating SSB). The average deviation from the mean, represented by rho' in fact increased (Figure 9).

Splitting the tuning-series without increasing the catch-at-age to 15+ significantly improved the retrospective pattern, although it may have allowed the model to compensate for the effect of the 11+ catch-at-age data. Retrospective plots for this treatment were not retained, nor were the rho statistics computed, because WKROUND 2010 recommended against using the 11+ catch-at-age as being inappropriate given the known shortcomings of the XSA (and ADAPT) modelling of the plus group.

A single parameter rho was developed by Mohn, 1999 to calculate a quantity to be able to compare the quality of two or more comparable retrospective patterns (see equation and figure below). Rho is the cumulative deviation of the terminal year estimates for each peal from a reference year in the final assessment time-series. When the pattern switches sign, however, Mohn's rho can appear to improve, i.e. become closer to zero, when in fact the average deviation may become larger. To correct for this potential misleading outcome, WKROUND 2010 computed a rho statistic using the squared deviation divided by the reference value. This new value is not meant for hypothesis testing however until its statistical properties are better understood and the appropriate test is identified and applied. Unlike Mohn's rho, the value of this new statistic is always greater than zero and smaller values are generally a better outcome, although the effect of a persistent pattern of over or underestimation should also be considered.

$$\rho = \sum_{y=1}^{npeels} \frac{X_{Y-y,tip} - X_{Y-y,ref}}{X_{Y-y,ref}}$$

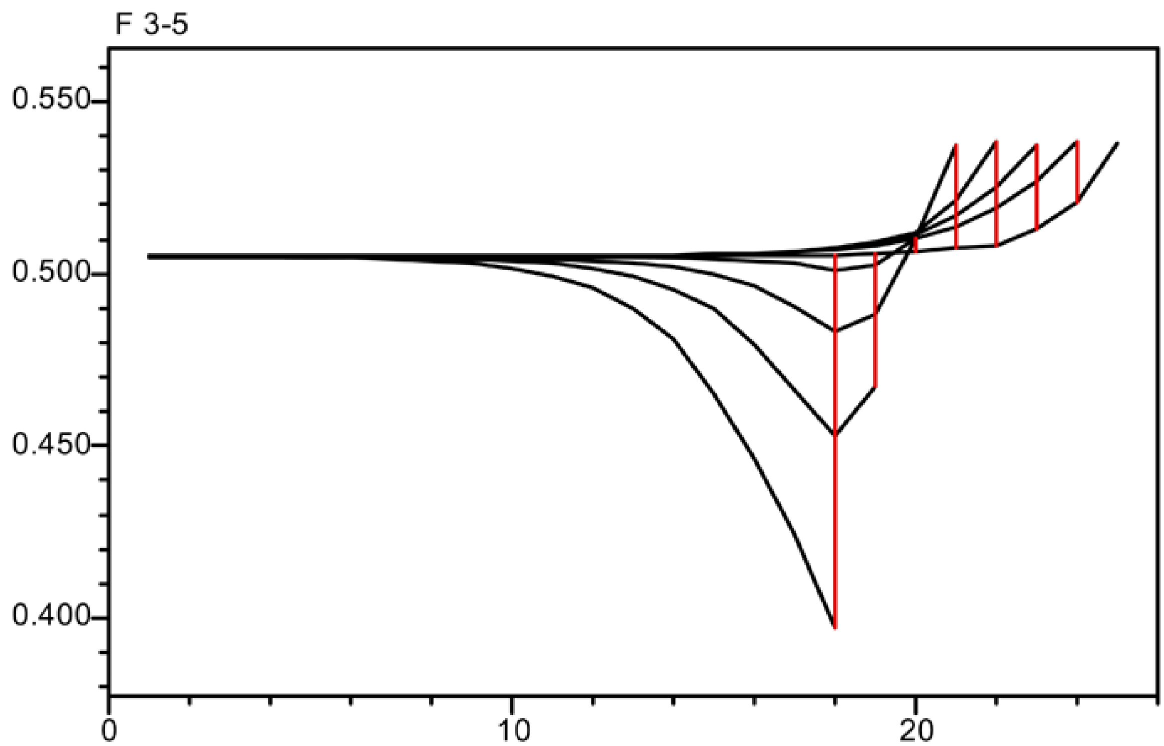


Figure 1. Example of the comparisons made when calculating Mohn rho. There are 25 years in the assessment and seven years used in the calculation of Mohn rho.

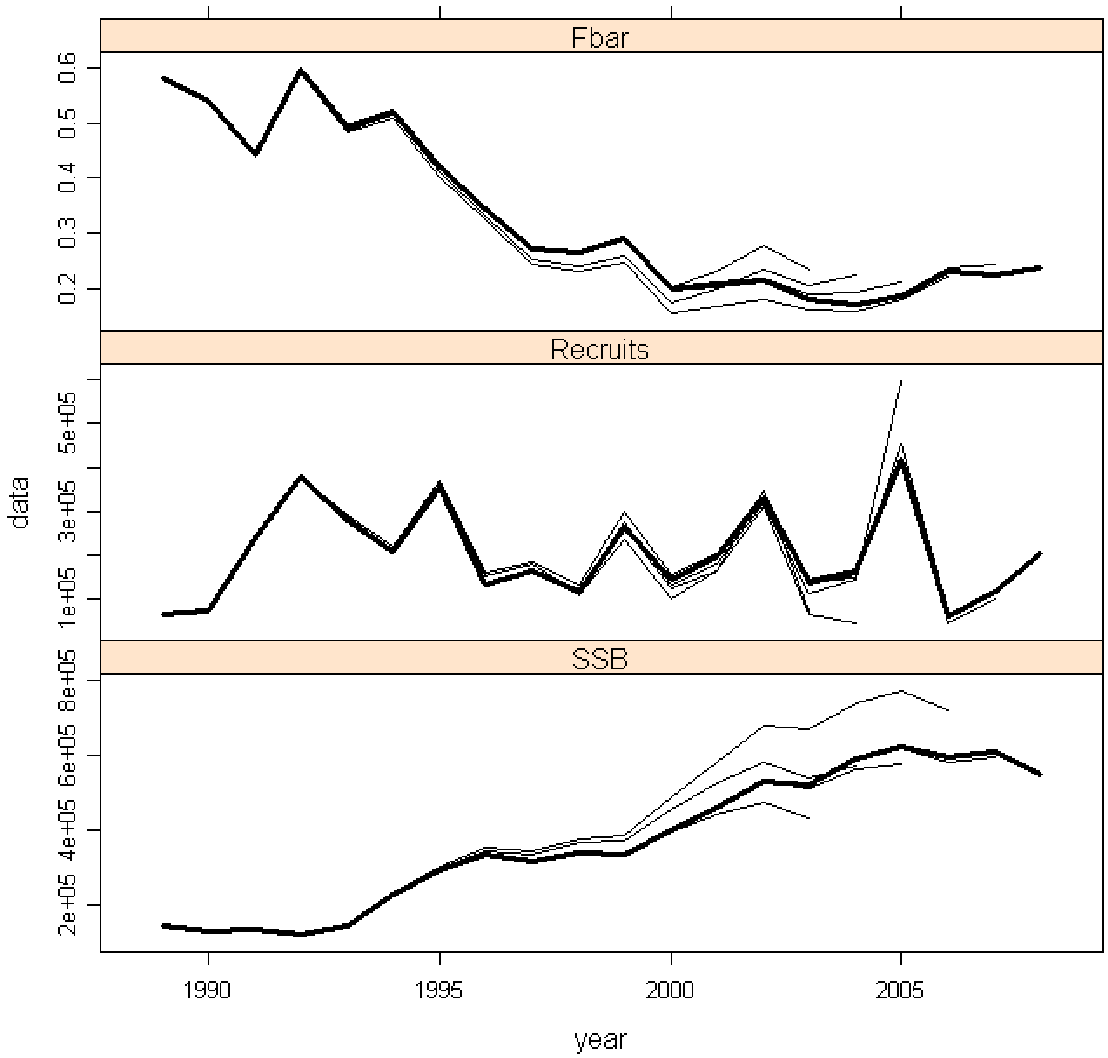


Figure 4. Trends and retrospective pattern for F_{4-7}, recruitment and SSB for a 15+ XSA SPALY run with updated catch-at-age and tuning indices through 2008.

From that point forward, WKROUND 2010 computed successive XSA runs in a stepwise fashion adding the split time-series to the 15+ catch-at-age run, then reducing shrinkage, and then removing the time weighted tapering. WKROUND 2010 found that splitting the tuning-series was justified on the grounds that there had been a shift in catchability around year 2002 and that the survey was redesigned in 2003, and the fishery to a larger degree targeted older ages, possibly in different portions of the stock range as well. The retrospective pattern (Figure 5) was judged as being good for fishing mortality estimation, but it appeared that the model in this configuration appeared to overestimate SSB, which is also reflected in the value of rho and rho' (Figure 9). WKROUND 2010 believed that the overestimation of SSB in this configuration was the result of the high weight (value = 0.5) assigned to shrinkage to the mean in the XSA model.

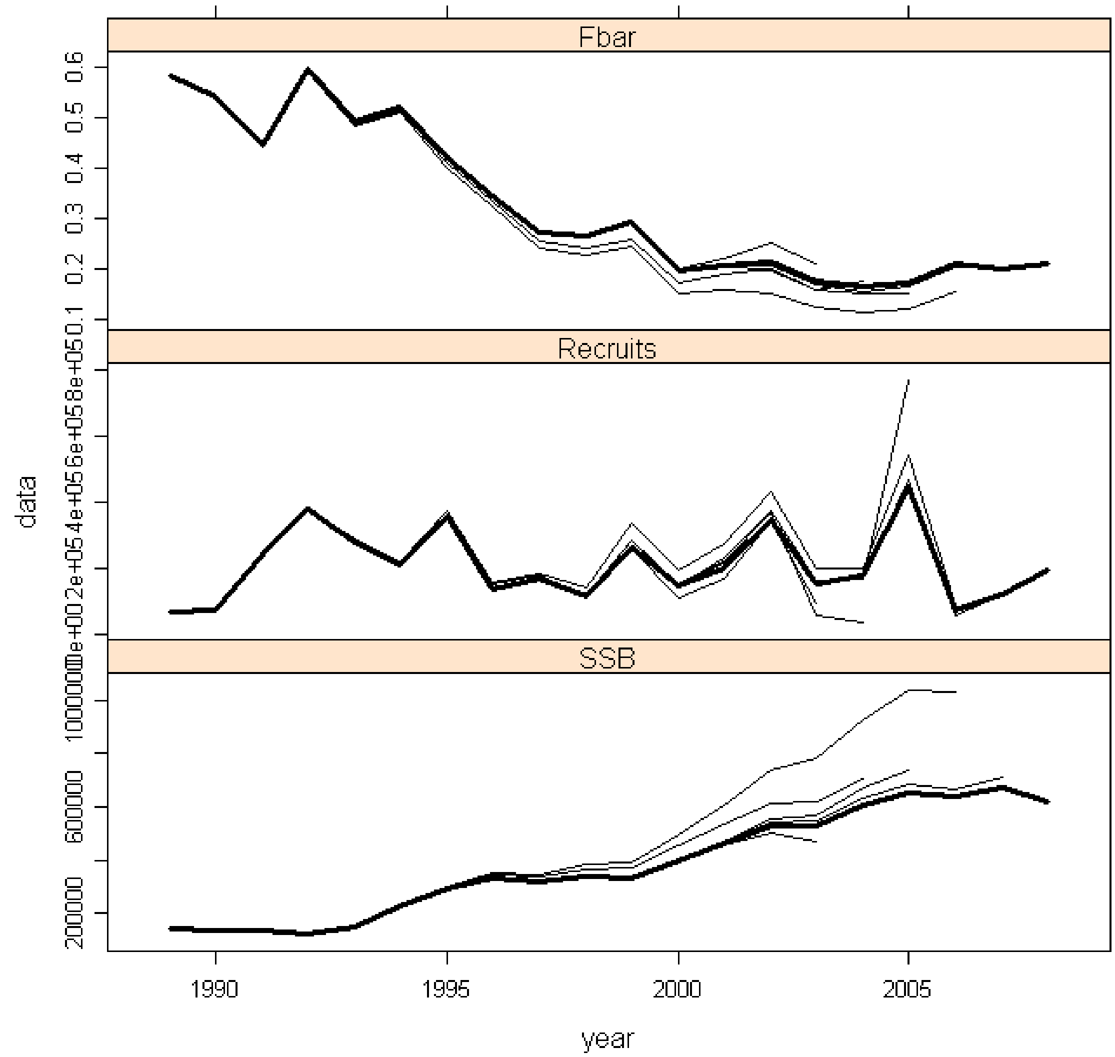


Figure 5. Trends and retrospective pattern for $F_{4\text{-}7}$, recruitment and SSB for a 15+ XSA SPALY and split tuning-series run with updated catch at-age and tuning indices through 2008.

WKROUND 2010 furthermore investigated if the use of a relative high shrinkage of 0.5 used by the Arctic WG was justified with the current run configuration, particularly because much of the retrospective pattern had been resolved by expanding the catch-at-age to 15+. The weighting of the shrinkage to the final survivor estimates with a value of 0.5 was between 51% for age 3 and in excess of 16% for all other ages. Detailed diagnostics indicate that both tuning indices were a relatively good fit to the estimated cohort abundances. Increasing the shrinkage value to 1.5 (decreasing the effect of shrinkage to the mean) allowed the tuning-series to have a greater effect on determining the strength and weaknesses of each cohort, compared with that evident in the catch-at-age data. This 1.5 value reduced the weight of the shrinkage factor to less than 4% for all ages.

The retrospective pattern (Figure 6) once again improved with F_{bar} apparently well estimated and a less problematic overestimation of SSB compared with the previous run. Consequently, the value for rho and rho' decreased to zero (Figure 9).

This run was eventually adopted as the final run configuration, after evaluating the effect of tapering (see below).

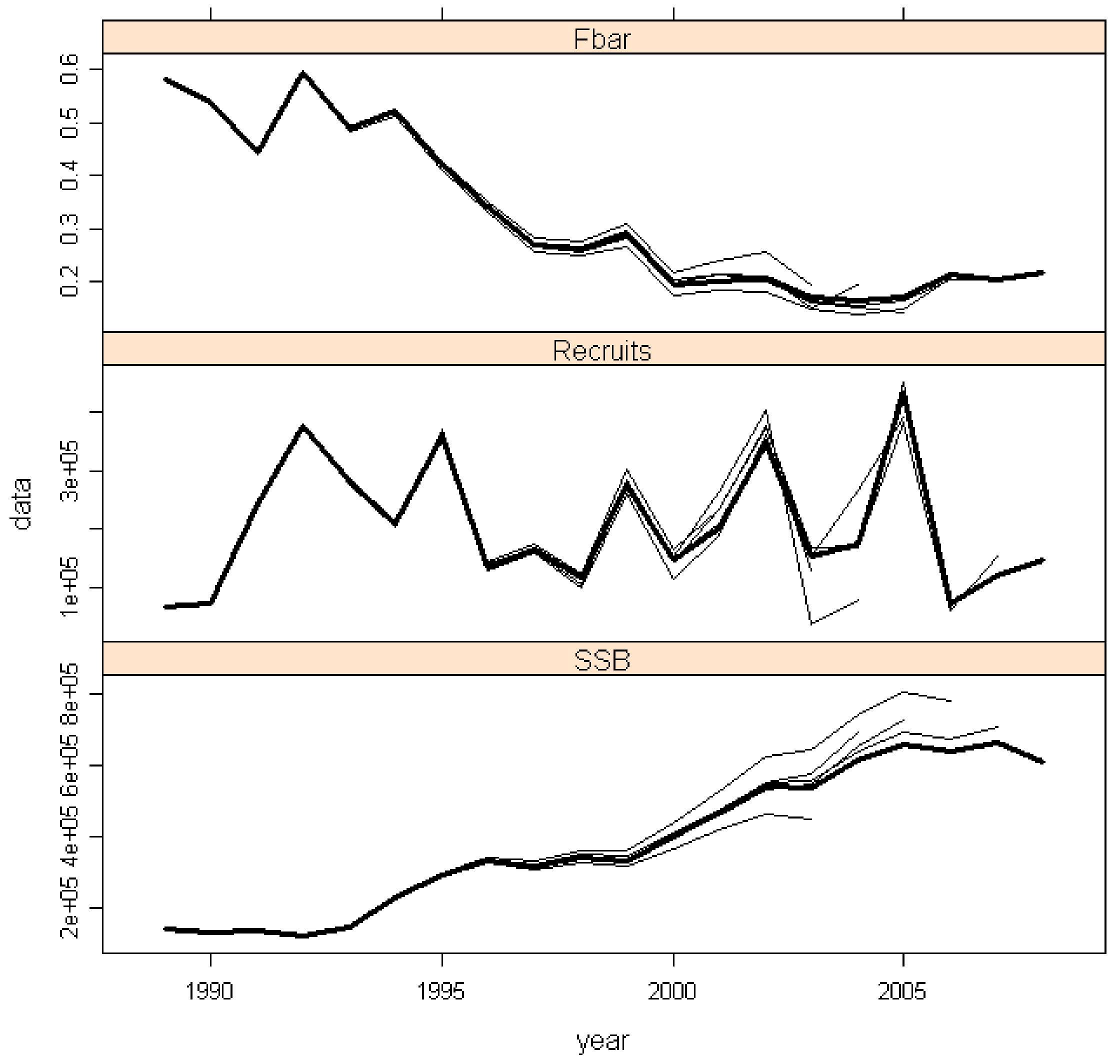


Figure 6. Trends and retrospective pattern for $F_{4\text{-}7}$, recruitment and SSB for a 15+ XSA SPALY, split tuning-series, and low shrinkage (value = 1.5) run with updated catch-at-age and tuning indices through 2008.

The use of a 20-year tricubic downweighting (taper) vs. no taper was also investigated. Although the diagnostics did not substantially improve, removing the taper (run 4) improved the retrospective pattern (Figure 7 and Figure 9) and the effect was confounded by splitting the tuning-series because the q for the pre-2002 portion of the tuning-series would not be used to estimate abundance-at-age in recent years when the tuning-series is split.

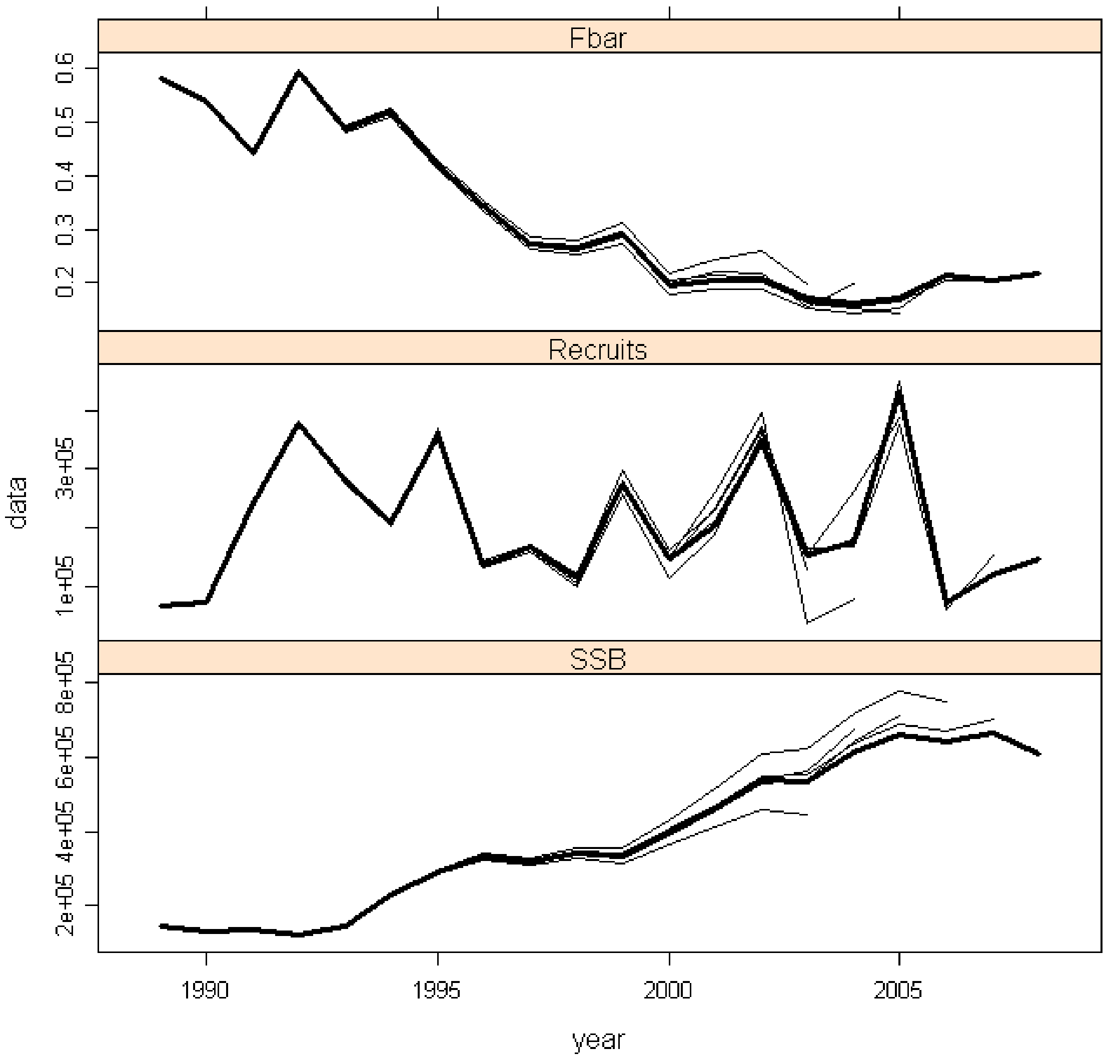


Figure 7. Trends and retrospective pattern for F_{4-7}, recruitment and SSB for a 15+ XSA SPALY, split tuning-series, and low shrinkage (value = 1.5) with tapering run with updated catch-at-age and tuning indices through 2008.

Thus, WKROUND 2010 adopted the configuration using 15+ catch-at-age, a split tuning-series, less shrinkage effect, and no tapering as the final, accepted run. For future update assessments, WKROUND 2010 recommends using this configuration with a longer 15+ catch-at-age series if earlier data out to age 15 can be recovered.

Residual patterns in the final run were apparent in the 1994–2001 portion of the fit, possibly related to the anomalous values for age 6 in 1997, noted in the working documents. The residual pattern for the 2002–2008 fit was relatively good (Figure 11).

Fishing mortality has declined from 0.5–0.6 in the early 1990s to values around 0.2 in the 2000s, but there is an increasing trend since 2004 to 0.22 in 2008 (Table 1). The 1999 and 2002 year classes were relatively strong (346 and 431 million age 3 fish respectively, but the 2003 and 2004 year classes appear to be weak, well below the 204 million age 3 fish average. SSB has increased from low values in the 1990s, but have levelled off since 2005 and were 612 thousand mt in 2009 (Table 1). This XSA assessment formulation may slightly overestimate SSB in the terminal year, as corroborated by overestimation in 4 of the 5 years in the retrospective analysis (Figure 8).

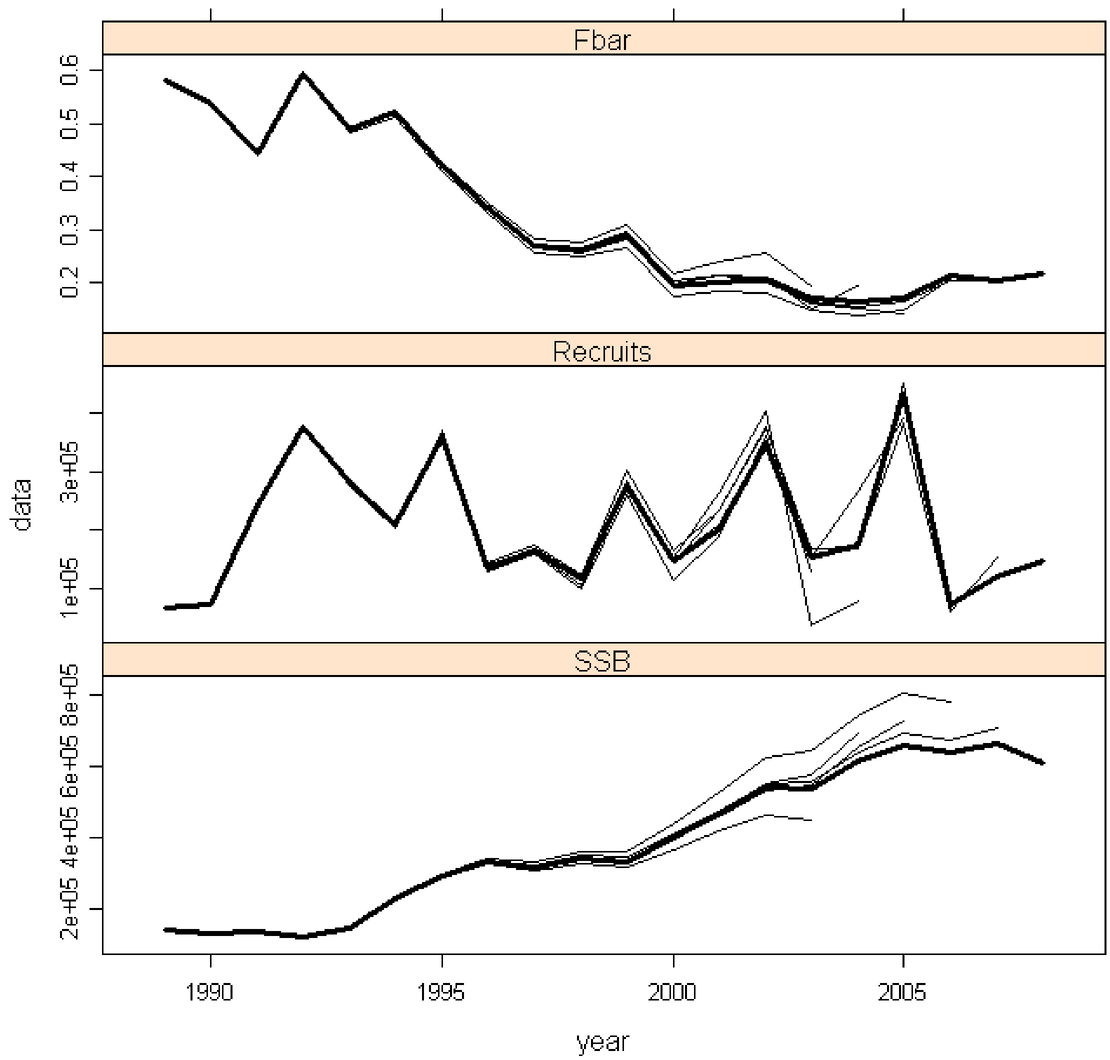


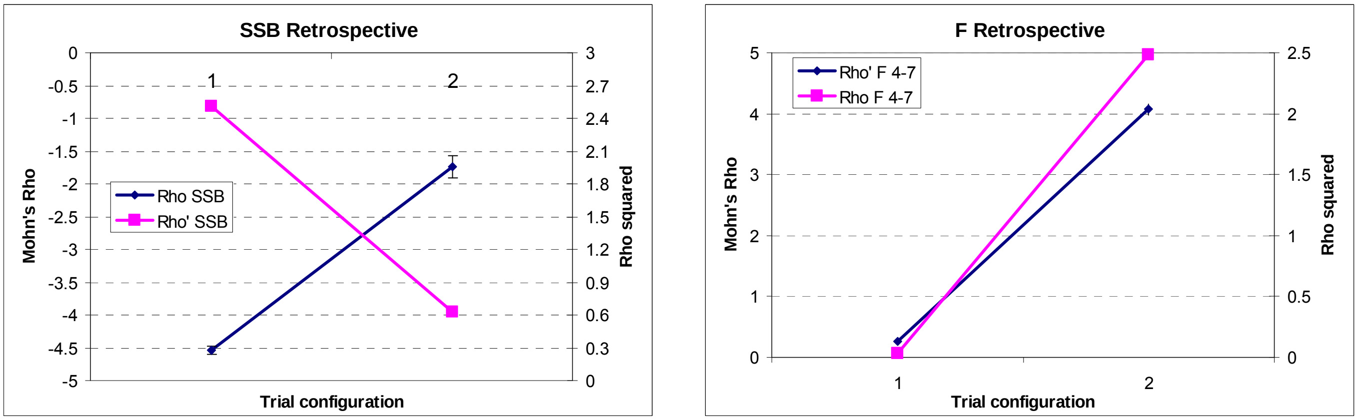
Figure 8. Trends and retrospective pattern for $F_{4\text{-}7}$, recruitment and SSB for a 15+ XSA SPALY, split tuning-series, low shrinkage (value = 1.5), and no tapering final run with updated catch-at-age and tuning indices through 2008.

Table 1. Summary of estimated trends in recruitment, biomass, and fishing mortality for the final XSA run.

	Recruits (age 3)	Total B (mt)	Total SSB (mt)	Landings (mt)	Yield/SSB (kg)	Fbar (4-7)
1989	66,929	323,296	150,974	122,310	0.810	0.585
1990	72,369	263,237	134,268	95,848	0.714	0.543
1991	241,592	359,490	134,728	107,326	0.797	0.442
1992	378,228	549,818	125,625	127,516	1.015	0.594
1993	278,781	645,788	148,022	153,584	1.038	0.489
1994	208,178	585,067	223,810	146,544	0.655	0.518
1995	357,356	712,763	290,853	168,378	0.579	0.420
1996	134,528	723,701	332,880	171,348	0.515	0.343
1997	166,089	712,519	317,671	143,629	0.452	0.274
1998	116,872	751,609	334,216	153,327	0.459	0.266
1999	274,053	800,020	332,894	150,373	0.452	0.291
2000	146,171	838,602	399,486	135,945	0.340	0.196
2001	201,877	914,628	465,448	136,402	0.293	0.203
2002	345,669	1,034,000	538,060	155,246	0.289	0.209
2003	151,619	980,497	537,605	159,757	0.297	0.173
2004	175,357	1,007,107	614,777	162,140	0.264	0.163
2005	430,990	1,135,319	661,487	176,678	0.267	0.172
2006	72,573	1,019,829	644,083	212,670	0.330	0.213
2007	119,259	989,470	667,175	199,206	0.299	0.203
2008	147,094	901,563	611,979	183,444	0.300	0.218

Ages 3–10, 11+;

10 year peal



Ages 3–14, 15+;
3 year peal

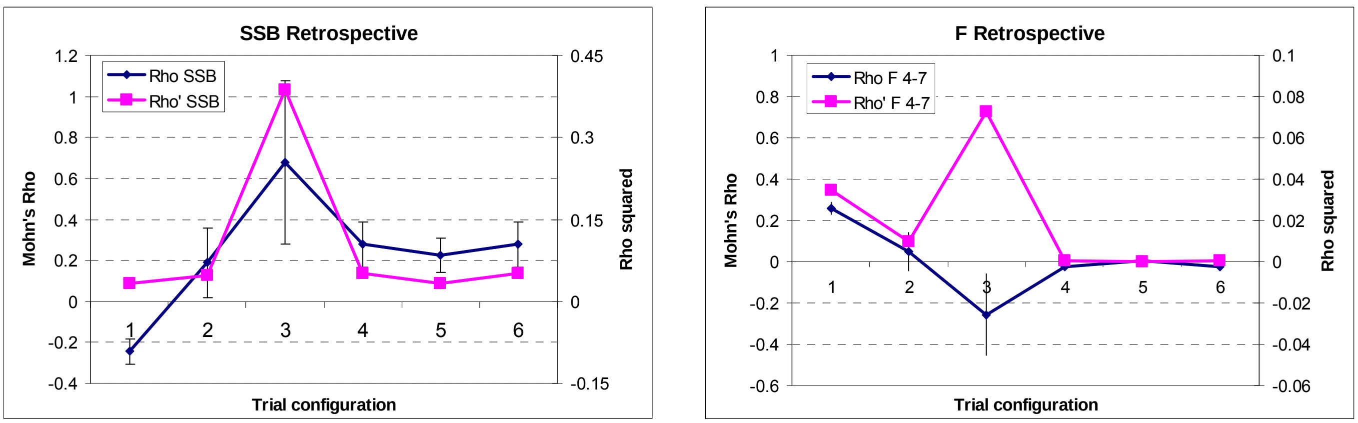


Figure 9. Cumulative retrospective error (Mohn's rho, Mohn, 1999) and the square of deviations for candidate XSA model runs. Treatments include (1) SPALY, (2) SPALY 15+, (3) Split tuning-series 15+, (4) Split tuning-series 15+ without tapering applied, (5) Split tuning-series 15+ with tapering applied, and (6) Final run, Split tuning-series 15+ without tapering applied.

Acoustic survey | Commercial trawl cpue

SPAL Y 11+

SPAL Y 15+

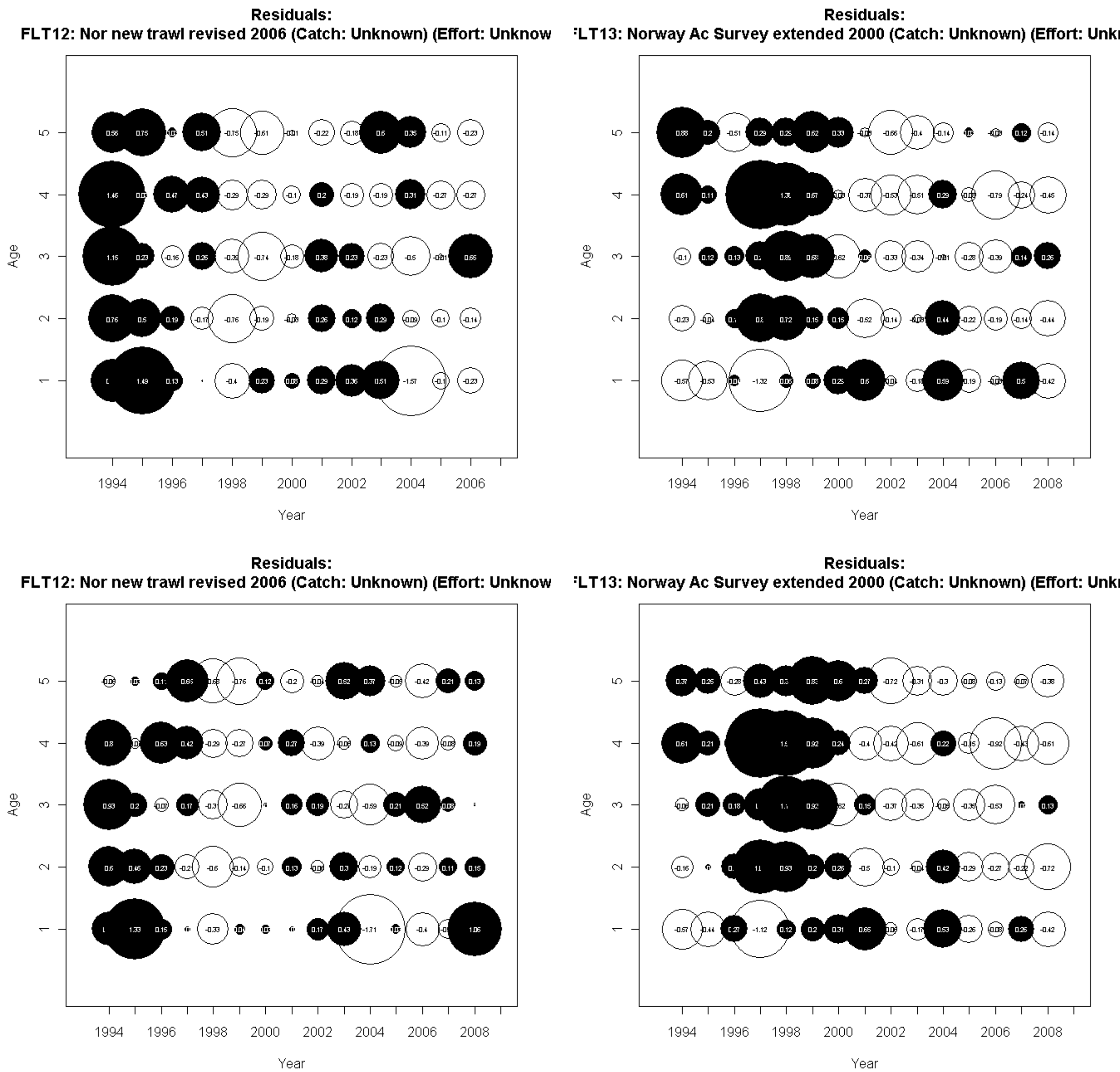


Figure 10. Residuals for combined tuning-series for two SPALY runs with 11+ and expanded 15+ catch-at-age.

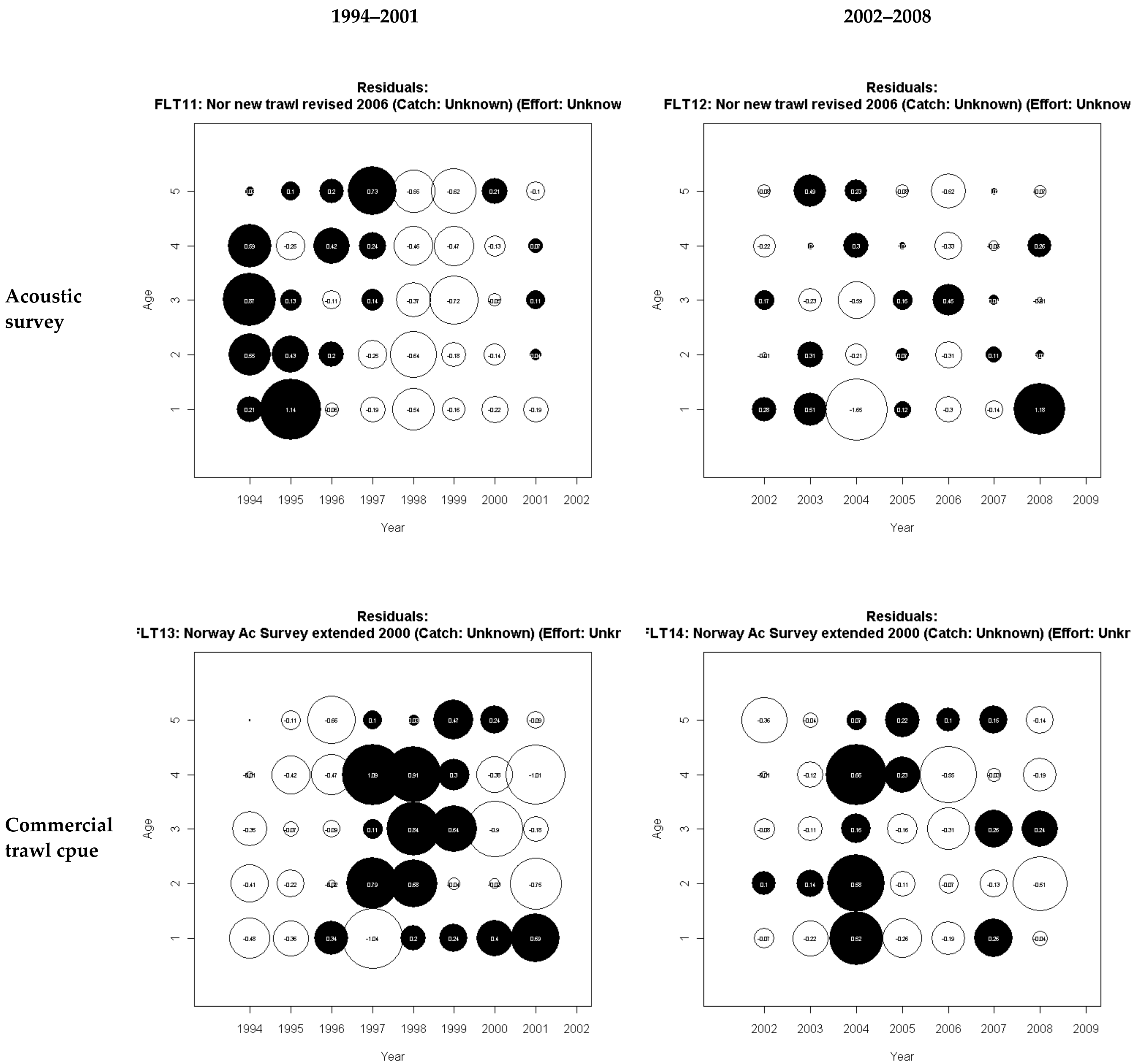


Figure 11. Residuals for split time-series, final run.

2.10 Recruitment estimation

Recruitment was estimated within the XSA model formulation as age 3, tuned to the acoustic survey. Particularly because there is little age 3 in the commercial catch, the recruitment estimate for 2008 is almost entirely based on the estimated age 3 catchability for 2002–2007 applied to the 2008 survey value.

2.11 Forecasts

Short-term forecasts were done using the standard ICES software (MSFOR). The initial stock size was taken from the XSA output, the maturity-at-age was the average of the two last years, the weights-at-age the average of the three last years and the fishing pattern was the average of the three last year age specific fishing mortality for ages 3–10, while ages 11–15+ were given the average fishing mortality for ages 10–13 which were estimated for the last three years in the assessment. This is essentially the same procedure used for yield-per-recruit analysis below, except that the Fs at age are applied for the *status quo* F and (theoretically) to the catch in the transition year (2009). Figure 11 summarizes the results of the forecast.

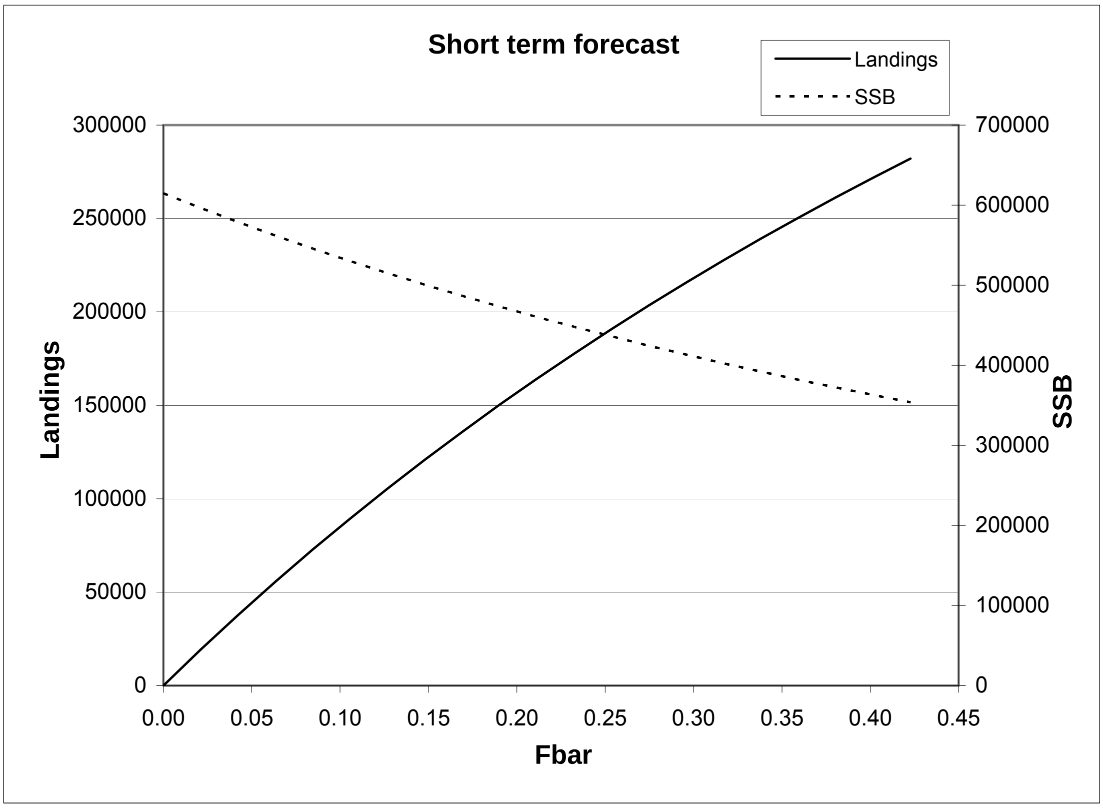


Figure 12. Short-term forecasts of 2010 landings and January 1, 2011 SSB over a range of fishing mortality applied in 2010. Catch in 2009 was assumed to be 165 000 mt (F= 0.2 = 165 000 mt expected landings; TAC constraint = 225 000 mt).

2.12 Biological reference points

The management environment is in a transition between using B_{lim}/B_{pa} and using MSY based reference points and WKROUND 2010 received guidance to estimate MSY and/or develop suitable other types of reference points as a proxy for those based on MSY estimation. In either case, WKROUND 2010 notes that these reference points are and should be thought of as a function of the underlying model of the stock dynamics.

During the 2010 benchmark meeting the 11+ group in the catch matrix was expanded to 11–15+. This and the break of the tuning-series, lowering of the shrinkage and no time tapering in the XSA resulted in a substantially lower stock estimate than had been estimated by prior assessments. The PA reference points therefore have to be re-estimated to evaluate if they need to be changed. However, during the benchmark meeting it was only possible to expand the age span in the catch matrix back to 1989, while the whole time-series goes back to 1960 (Figure 13). Using only the 20 last years in the time-series may affect the estimation of the PA reference points, especially F_{lim} (Figure 14), where the present estimate is based on the whole time-series of weight, maturity and fishing mortality-at-age. Therefore the PA reference point were not re-estimated or evaluated during the benchmark meeting. The aim is to expand the time-series of catch data before the next meeting of the ICES AFWG in April 2010, and re-evaluate the PA reference points at the April 2010 working group meeting.

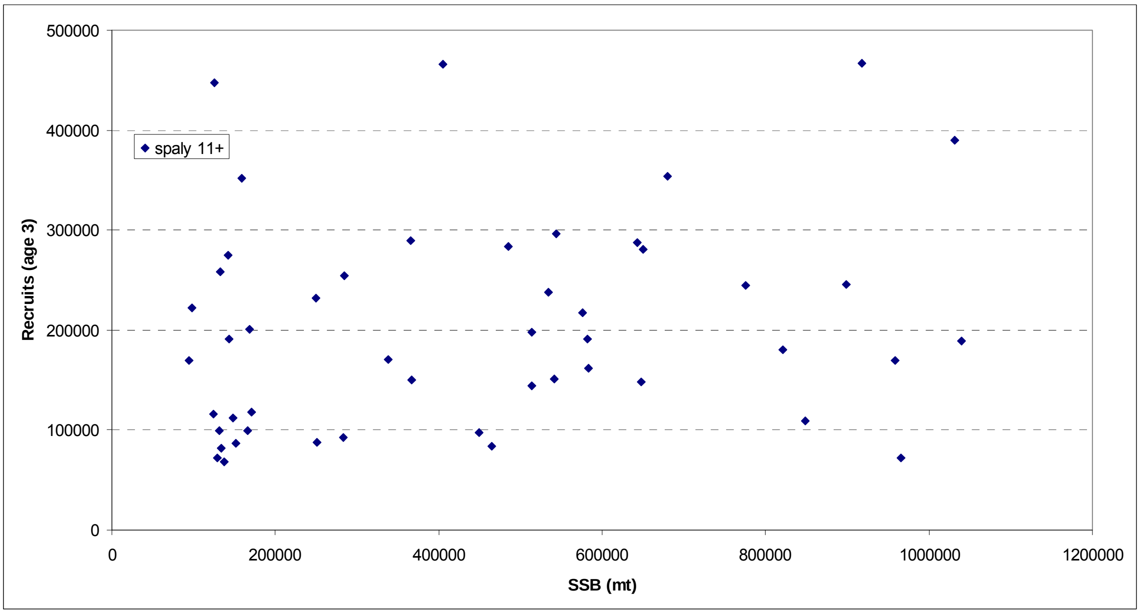


Figure 13. Comparison of 1960–2008 recruitment and SSB estimates for SPALY run, fit to an 11+ catch-at-age matrix.

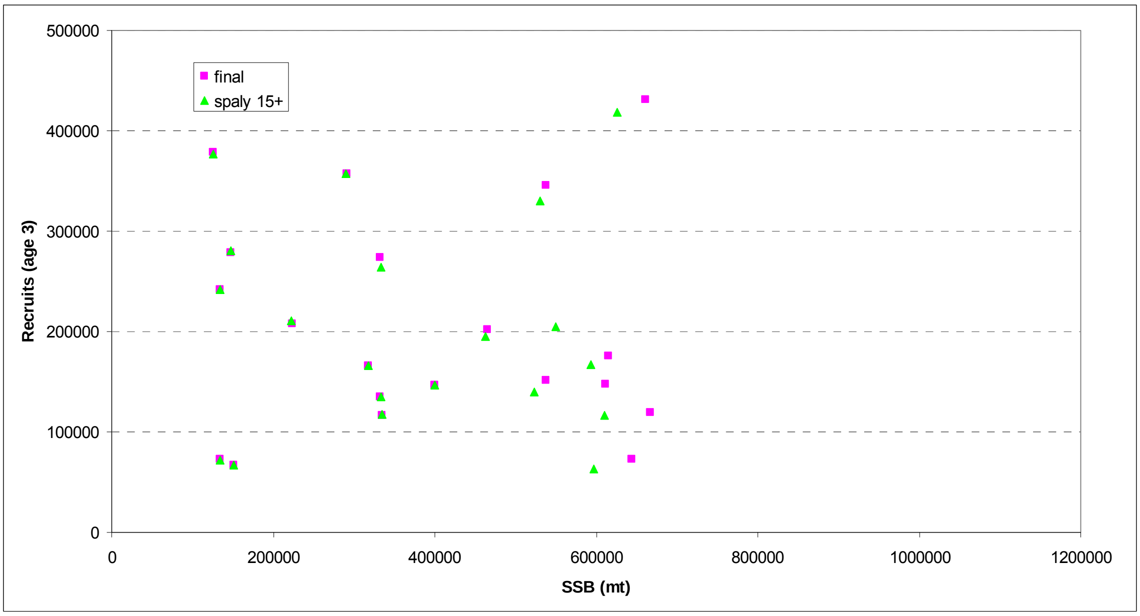


Figure 14. Comparison of 1989–2008 recruitment and SSB estimates for SPALY and final XSA runs, both fit to a 15+ catch-at-age matrix.

WKROUND 2010 computed new yield-per-recruit reference points as potential proxy values for those based on MSY considerations. In this analysis, the long-term (1989–2008) biological parameters (maturity and weight-at-age) were applied, with catches being estimated with a selectivity pattern derived from 2006–2008 F at age estimated by the XSA. Employment of a longer time-series of F at age were evaluated and although the longer series smoothed the interannual variability of the selection pattern, the longer time-series introduced a different selectivity pattern that existed before the fleet began targeting older ages in recent years (Figure 15). As a result, WKROUND 2010 recommended using the last three years in the assessment (2006–2008) to represent the selection pattern in the yield-per-recruit analysis. In this context, the F_{bar} reported by the ICES yield-per-recruit software represents the average selectivity of the reference ages, rather than the average F as labelled in the output. Care should be taken to avoid misinterpretation when the reference age is not fully selected.

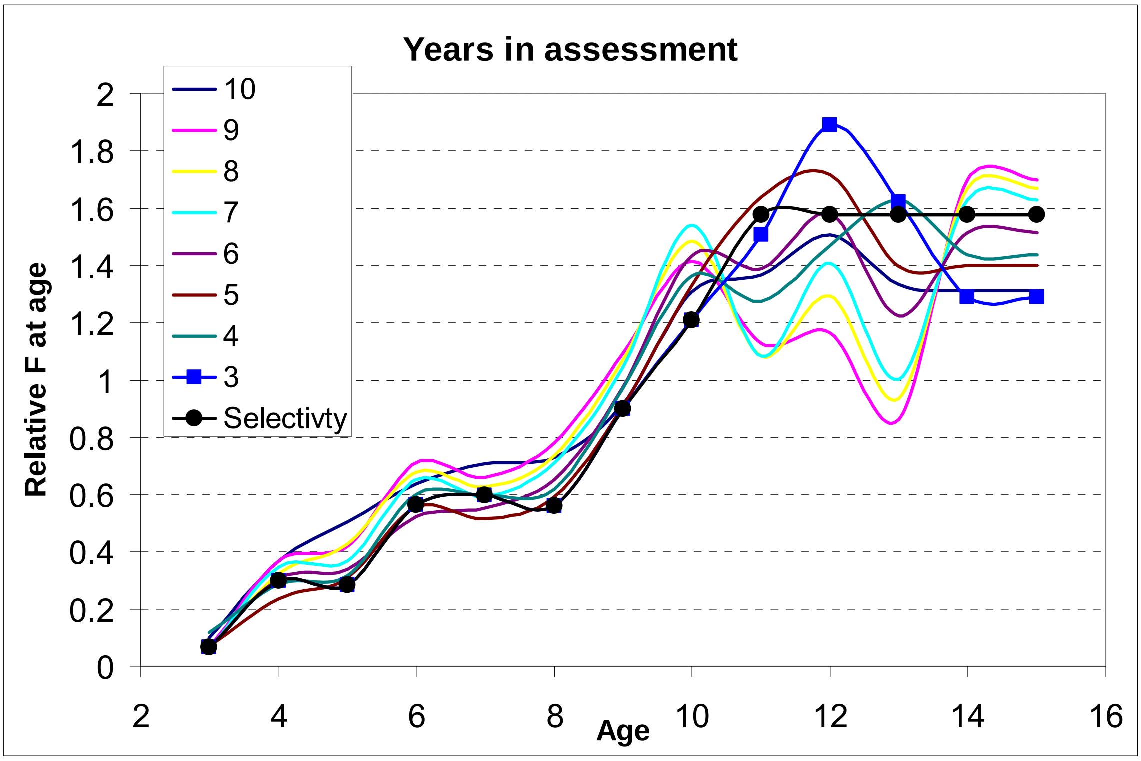
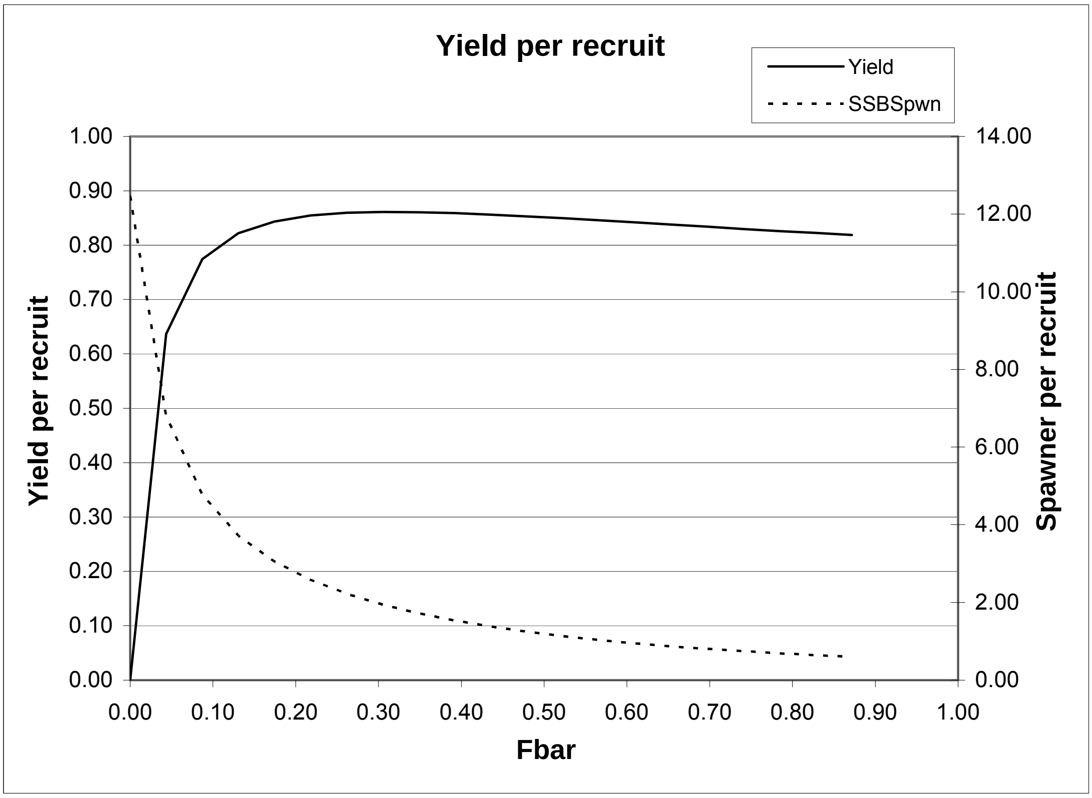


Figure 15. Mean relative F at age for a series of possible choices of assessment years; (3=2006–2008; 10=1999–2008).

F_{max} is estimated to be 0.19, but this value is compatible with the mean F for ages 4–7, which do not appear to be fully selected by the fishery. Absolute F values (seen in older groups) are much higher, but are not representative of the mortality pressure applied to the majority of the catch. In thinking about MSY considerations, the analyst should be aware of and properly evaluate this nuance.

$F_{0.1}$ is estimated to be 0.06, a very low value when compared with other stocks, but again this value represents the mortality value applied by a partially selected range of ages 4–7 that represent about 70% of the catch-at-age. The low value may also be caused by a large step in fishing mortality in the yield-per-recruit calculations, which should be corrected particularly if $F_{0.1}$ is used as the basis for an F_{msy} proxy. Similarly, F35% (sometimes used as an F_{MSY} proxy for other stocks) is estimated at 0.10, but further evaluation of the S/R relationship is warranted before such a value (or other value) is adopted as a suitable proxy for the true F_{MSY}.



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Reference point	F multiplier	Absolute F
FMax	0.7275	0.3171
F0.1	0.1403	0.0611
F35%SPR	0.2323	0.1013
Fmed		0.3000

Weights in kilograms

Figure 16. Yield-per-recruit reference point estimates and estimates of yield-per-recruit and SSB/recruit values over $F_{4\text{–}7}$ ranging from 0 to 1.

2.13 Recommended modifications to the stock annex

The stock annex was revised to describe the new XSA model configuration and how the biological reference point and short-term projections were computed. Medium-term projections were not computed and were therefore removed from the stock annex. When compatible software is available, a bootstrap analysis should be conducted that allows for the catchability coefficients to vary and capture the sampling error a frequency distribution of terminal estimates of F and B. This output should carry through the forecasts to estimate uncertainty about candidate TACs and their probability to exceed reference points given perfect implementation of the limits.

The software to conduct short, medium, and possibly long-term projections should be the same except that for long-term and possibly medium-term projections should apply longer-term biological parameters, reflecting the potential long-term stock productivity. As in previous assessments, the age specific fishing mortality for ages 3–10 were input into the projections for the last three years in the assessment (2006–2008, in this case), but the average fishing mortality for ages 11–15+ were given the average fishing mortality for ages 10–13 which were estimated for the last three years in the assessment. This average removed some of the effects of the more poorly estimated fishing mortality rates for the oldest disaggregated age groups. A bootstrap analysis which inputs the realizations into the projections would not require this *ad hoc* procedure to be applied.

For the yield-per-recruit analysis and biological reference point analysis, a selectivity pattern derived from the fishing mortality-at-age estimated from the XSA assessment results, averaged over the last three years was applied to the range of fishing mortalities (0–2) for which yield, biomass, and catch were estimated. WKROUND 2010 examined the selectivity patterns derived from 3–10 years of assessment data and ratios of median Fs to smooth out the high variability of F at old ages. After examining these analyses, WKROUND 2010 decided to simply average the fishing mortality over ages 11–13 and apply it to ages 11–15+ in the yield-per-recruit analysis, using three years of estimated fishing mortality to represent fishery selectivity. For the yield-per-recruit calculations, 1989–2008 maturation and weight-at-age data were input as biological parameters to reflect the long-term productivity of the stock over a wide range of fishing mortalities.

2.14 Recommendations on the procedure for assessment updates

Update assessments should follow the procedures described in the stock annex (at the end of this Section) and fit the catch data using the XSA model formulation, using age disaggregated acoustic survey and commercial trawl cpue catch-at-age data. It would be desirable to extend the catch-at-age matrix to earlier years as far as reliable data can be generated when developing future update assessments. Tuning-series using commercial cpue data should be developed with standardization modelled using vessel, seasonal (month or quarter), and area as main effects when developing new tuning-series. Such work however may require benchmark review.

2.15 References

Jakobsen, T. 1986. Recruitment and distribution of North-East Arctic saithe in relation to changes in the environment. Pp 213–223 in Loeng, H. (ed.). The effect of oceanographic conditions on distribution and population dynamics of commercial fish stocks in the Barents Sea. Proceedings of the third Soviet-Norwegian Symposium, Murmansk 26–28 May 1986. Institute of Marine Research, Bergen, 1987.

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES Journal of Marine Science, 56: 473–488.

Stock Annex Northeast Arctic Saithe

Quality Handbook **Annex: Saithe in Subareas I and II**

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Saithe in Subareas I and II (Northeast Arctic)
Working Group:	Arctic Fisheries Working Group
Date:	16.03.2010
Revised by:	Sigbjørn Mehl / Åge Fotland

A. General

A.1. Stock definition

The Northeast Arctic saithe is mainly distributed along the coast of Norway from the Kola Peninsula in northeast and south to Stad at 62º N (Figure 1). The 0-group saithe drifts from the spawning grounds to inshore waters. 2–4 years old the saithe gradually moves to deeper waters, and at age 3–6 it is found at typical saithe grounds. It starts to mature at age 5–7 and in early winter a migration toward the spawning grounds further out and south starts.

The stock boundary 62º N is more for management purposes than a biological basis for stock separation. Tagging experiments demonstrate a regular annual migration of mature fish from the North-Norwegian coast to the spawning areas off the west coast of Norway and also to a lesser extent to the northern North Sea (ICES, 1965). There is also a substantial migration of immature saithe to the North Sea from the Norwegian coast between 62º and 66º N (Jakobsen, 1981). In some years there are also examples of mass migration from northern Norway to Iceland and to a lesser extent to the Faroe Islands (Jakobsen, 1987). 0-group saithe, on the other side, drifts from the northern North Sea to the coast of Norway north of 62º N.

A.2. Fishery

Norway accounts for more than 90% of the landings. Over the last ten years about 40% of the Norwegian catch originates from bottom trawl, 25% from purse-seine, 20% from gillnet and 15% from other conventional gears (longline, Danish sine and handline). The gillnet fishery is most intense during winter, purse-seine in summer while the trawl fishery takes place more evenly all year around. Landings of saithe were highest in 1970–1976 with an average of 238 000 t and a maximum of 274 000 t in 1974 (Figure 2). Catches declined sharply after 1976 to about 160 000 t in the years 1978–1984. This was partly caused by the introduction of national economic zones in 1977. The stock was accepted as exclusively Norwegian and quota restrictions were put on fishing by other countries while the Norwegian fishery for some years remained unrestricted. Another decline followed and from 1985 to 1991 the landings ranged from 70 000 to 122 000 t. An increasing trend was seen after 1990 to 171 000 t in 1996, followed by a new decline to 136 000 t in 2000. Since then the annual landings have increased gradually to 212 000 t in 2006, followed by a decline to 199 000 t in 2007 and 183 000 t in 2008. Quotas can be transferred between gears if the quota allocated to one of the gears will not be taken. The target set for the total landings has generally been consistent with the scientific recommendations.

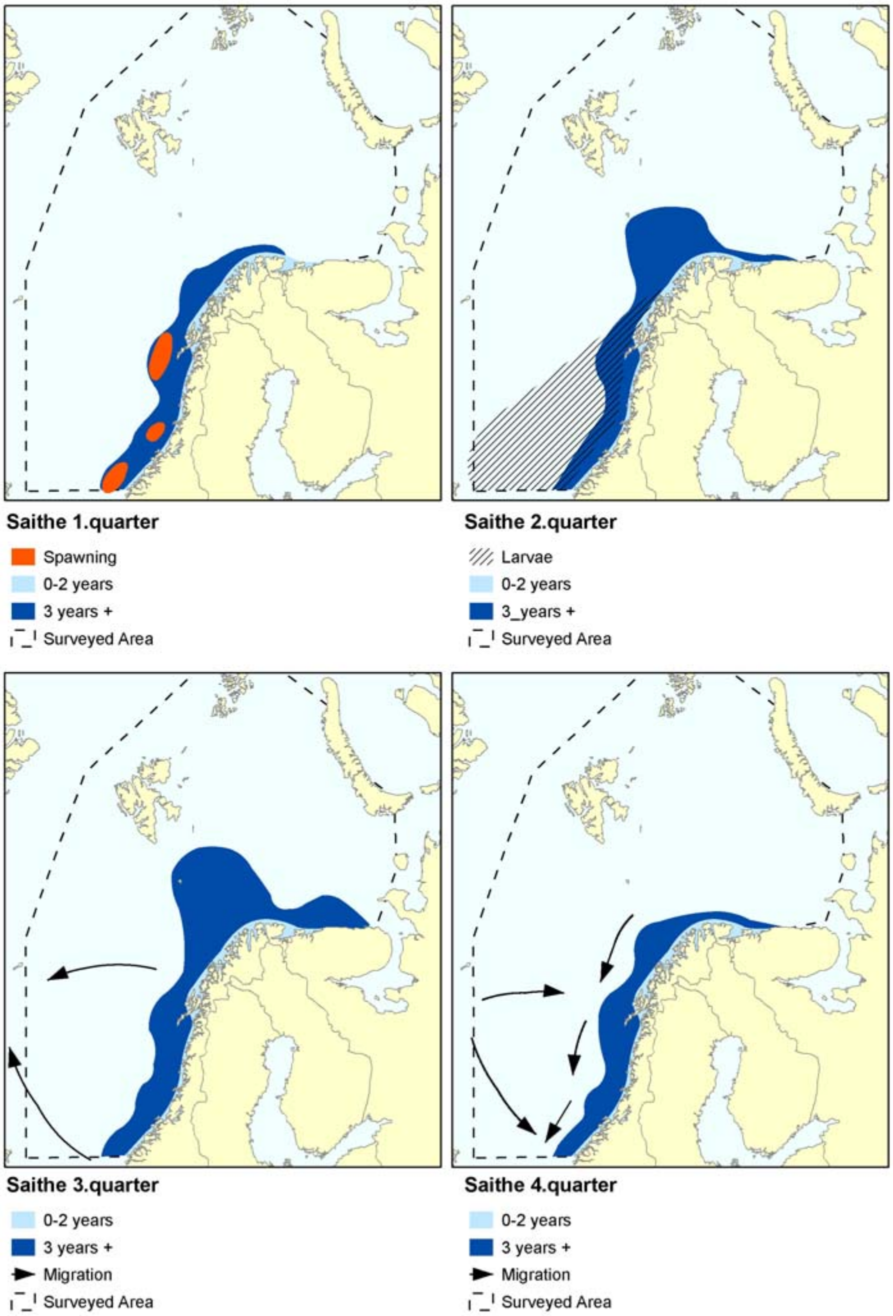

Figure 1. NEA saithe. Distribution of larvae, juveniles, adult spawning areas and the main migration patterns by (a) first quarter, (b) second quarter, (c) third quarter, and (d) fourth quarter.

The number of vessels taking part in the purse-seine fishery has varied between 110 and 429 since 1977, with the highest participation in the first part of the period. There have been some variations from year to year, and many of the vessels that have taken part in the fishery the last decade have accounted for only a small fraction of the purse-seine catches. The annual effort in the Norwegian trawl fishery has varied between 12 000 and 77 000 hours, with the highest effort from 1989 to 1995. Like in the purse-seine fishery there have been rather large changes from year to year.

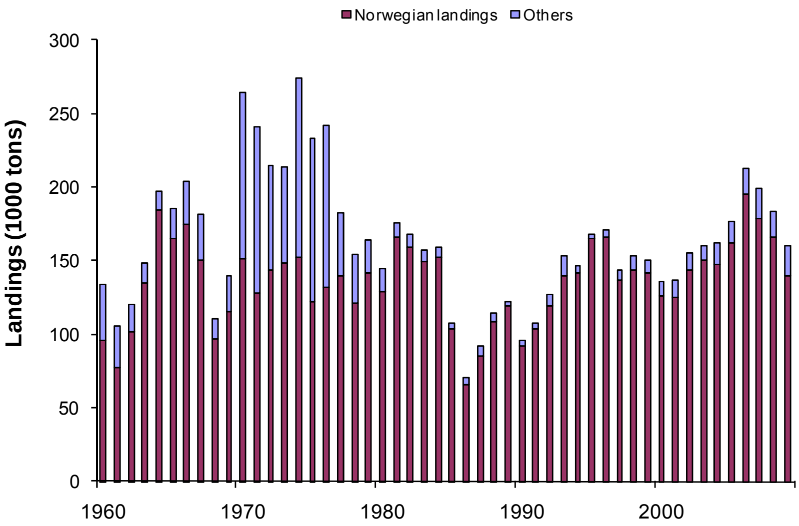

Figure 2. NEA saithe landings 1960–2009. Red part of bars shows the Norwegian landings.

1 March 1999 the minimum landing size was increased from 35–40 cm to 45 cm for trawl and conventional gears, and to 42 cm (north of Lofoten) and 40 cm (between 62° N and Lofoten) for purse-seine, with an exception for the first 3000 t purse-seine catch between 62° N and 66°33′ 30 N, where the minimum landing size still is 35 cm.

A.3. Ecosystem aspects

The recruitment of saithe may suffer in years with reduced inflow of Atlantic water (Jakobsen, 1986).

B. Data

B.1. Commercial catch

Norwegian commercial catch in tonnes by quarter, area and gear are derived from the sales notes statistics of The Directorate of Fisheries. Data from about 20 subareas are aggregated on 6 main areas for the gears gillnet, longline, handline, purse-seine, Danish seine, bottom trawl, shrimp trawl and trap. For bottom trawl the quarterly area distribution of the catches is adjusted by logbook data from The Directorate of Fisheries and the total bottom-trawl catch by quarter and area is adjusted so that the total annual catch for all gears is the same as the official total catch reported to ICES. No discards are reported or accounted for, but there are several reports of discards. In later years there are also reports of misreporting, saithe is landed as cod in a period with decreasing quotas and availability of cod and good availability of saithe.

The sampling strategy is to have age–length samples from all major gears in each area and quarter. There are at present no defined criteria on how to allocate samples of catch numbers, mean length and mean weight-at-age to unsampled catches, but the following general process has been applied: First look for samples from a neighbouring area if the fishery extends to this area in the same quarter. If there are no samples available in neighbouring areas, search for samples from other gears with the most similar selectivity in the same area or in neighbouring areas. The last option is to search in neighbouring quarters, first from the same gear in the same area, and then from neighbouring areas and similar gears. For some gears, areas and quarters length samples taken by the coast guard are applied and combined with an ALK from a neighbouring area, gear or quarter. ALKs from research surveys (shrimp trawl) are also used to fill holes.

Constant weight-at-age values are used for the period 1960–1979. For subsequent years, Norwegian weights-at-age in the catch are estimated from length-at-age by the formula:

Weight (kg) = $(l^3 *5.0+l^2 *37.5+l*123.75+153.125)*0.0000017$,

Where

l = length in cm.

Norway has on average accounted for about 95% of the saithe landings. Data on catch in tonnes from other countries are either taken from ICES official statistics (by ICES area) or from reports to Norwegian authorities. A few countries also supply some additional data. The text table below demonstrates which countries supply which kind of data:

	Kind of data				
Country	Caton (catch in weight)	Canum (catch-at-age in numbers)	Weca (weight-at-age in the catch)	Matprop (proportion mature-by-age)	Length composition in catch
Norway	x	x	x	x	x
Russia	x	x	x		x
Germany	x	x	x		
United kingdom	x				
France	x				
Spain1	x				
Portugal	x				
Poland	x				
Greenland[1]	x				
Faroe Islands[1]	x				
Iceland[1]	x				

[1] **As reported to Norwegian authorities.**

The Norwegian, Russian and German input files are Excel spreadsheet files. Russian input data earlier than 2002 are supplied on paper and later punched into Excel spreadsheet files before aggregation to international data. The data should be found in the national laboratories and with the Norwegian stock co-ordinator.

The national data have been aggregated to international data on Excel spreadsheet files. Age composition data are normally available from Norway, Russia (some areas) and Germany (Division IIA). In some areas Russian length composition has been applied on the Russian landings together with an age–length-key (ALK) and weight-at-age data from the Norwegian trawl landings. Catches from the other countries were assumed to have the same age composition and weight-at-age as the Norwegian trawl landings. In some years the final German and Russian numbers-at-age have been adjusted to remove SOP discrepancies before aggregation to international data. The Excel spreadsheet files used for age distribution, adjustments and aggregations can be found with the Norwegian stock co-ordinator. Since 2007 the national data have also been uploaded to the ICES InterCatch database.

The result files (FAD data) can be found with the stock co-ordinator and at ICES as ASCII files on the Lowestoft format under **w:\acom\afwg\year\Stock\sai_arct**.

B.2. Biological

Weight-at-age in the stock is assumed to be the same as weight-at-age in the catch.

A fixed natural mortality of 0.2 is used both in the assessment and the forecast.

Both the proportion of natural mortality before spawning (Mprop) and the proportion of fishing mortality before spawning (Fprop) are set to 0.

Regarding the proportion mature-at-age, until AFWG 1995 knife-edge maturity-at-age 6 was used for this stock. In the 1996–2004 assessments, an ogive based on analyses of spawning rings in otholiths for the period 1973–1994 was applied for all years. The analysis demonstrated a lower maturation in the last part of the period, and some extra weight was given to this part when an average ogive was calculated. In 2005 a large number of otholiths with missing information on spawning rings were re-read, and new analyses were done for the period 1985–2004. The maturity-at-age had decreased somewhat in the last part of that period, and the 2005 WG decided to use a 3-year running average, reference year being the middle of the 3-year period, for the years from 1985 and onwards (2-year average for the first and last year) (ICES 2005). The ogives used until AFWG 1995 and in 1996–2004 assessments are presented in the text table below.

Age group	2	3	4	5	6	7	8	9	10	11+
Until 1995	0	0	0	0	1	1	1	1	1	1
1996–2004	0	0	0.01	0.55	0.85	0.98	1	1	1	1

B.3. Surveys

In 1985–2002 a Norwegian acoustic survey specially designed for saithe was been conducted annually in October–November (Nedreaas, 1997). The survey covers the near coastal banks from the Varangerfjord close to the Russian border and southwards to Stad at 62° N (Figure 3). The whole area has been covered since 1992, and the major parts since 1988. The aim of conducting an acoustic survey targeting Northeast Arctic saithe has been to support the stock assessment with fishery-independent data of the abundance of the youngest saithe. The survey mainly covers the grounds where the trawl fishery takes place, normally dominated by 3–5(6) year old fish. 2-year-old saithe, mainly inhabiting the fjords and more coastal areas, are also represented in the survey, although highly variably from year to year. In 1997 and 1998 there was a large increase in the abundance of age 5 and older saithe, confirming reports from the fishery. In 1999 the abundance of these age groups decreased somewhat, but was still at a high level compared with the years before 1997 (Mehl, 2000). Abundance indices for ages 2–5 were used for tuning from 1988 onwards, but including older ages as a 6+ group in the tuning-series improved the scaled weights a little and at the 2000 WG meeting it was decided to apply the extended series in the assessment. The results from the survey in autumn 2000 demonstrated a further decrease in the abundance of age 5 and older saithe (Korsbrekke and Mehl, 2000). It is not known how well the survey covers the oldest age groups from year to year, but at least for precautionary reasons the 6+ group was kept in the tuning-series. Before the 2005 WG the 6+ group from the Norwegian acoustic survey was split into individual age groups 6–9 by rerunning the original acoustic abundance estimates. However, this was only possible to do for the years back to 1994. Based on further analysis during the 2005 benchmark assessment, indices for ages 3–7 was used for tuning in the 2005 and later assessments.

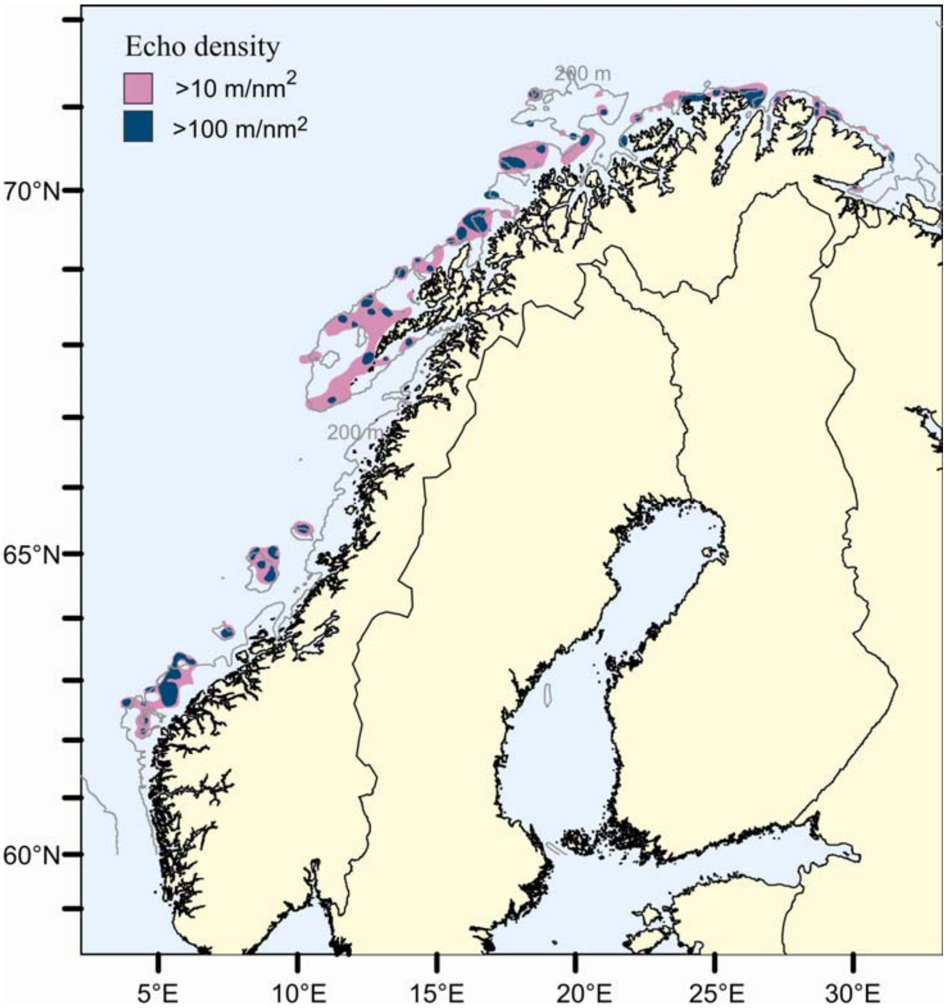

Figure 3. NEA saithe. Distribution of total saithe echo density in the acoustic survey autumn 1998.

In 1995–2002 a Norwegian acoustic survey for coastal cod was conducted along the coast and in the fjords from Varanger to Stad in September, just prior to the saithe survey described above. This survey covers coastal areas not included in the regular saithe survey. Because saithe is also acoustically registered, this survey provides supplementary information, especially about 2- and 3-year-old saithe that have not yet migrated out to the banks. At the WG meeting in 2000 analyses were done on combining these indices with indices from the regular saithe survey in the tuning-series, but it did not influence the assessment much. The WG therefore decided, for the time being, to apply only indices from the longer time-series of the regular saithe survey in the assessment.

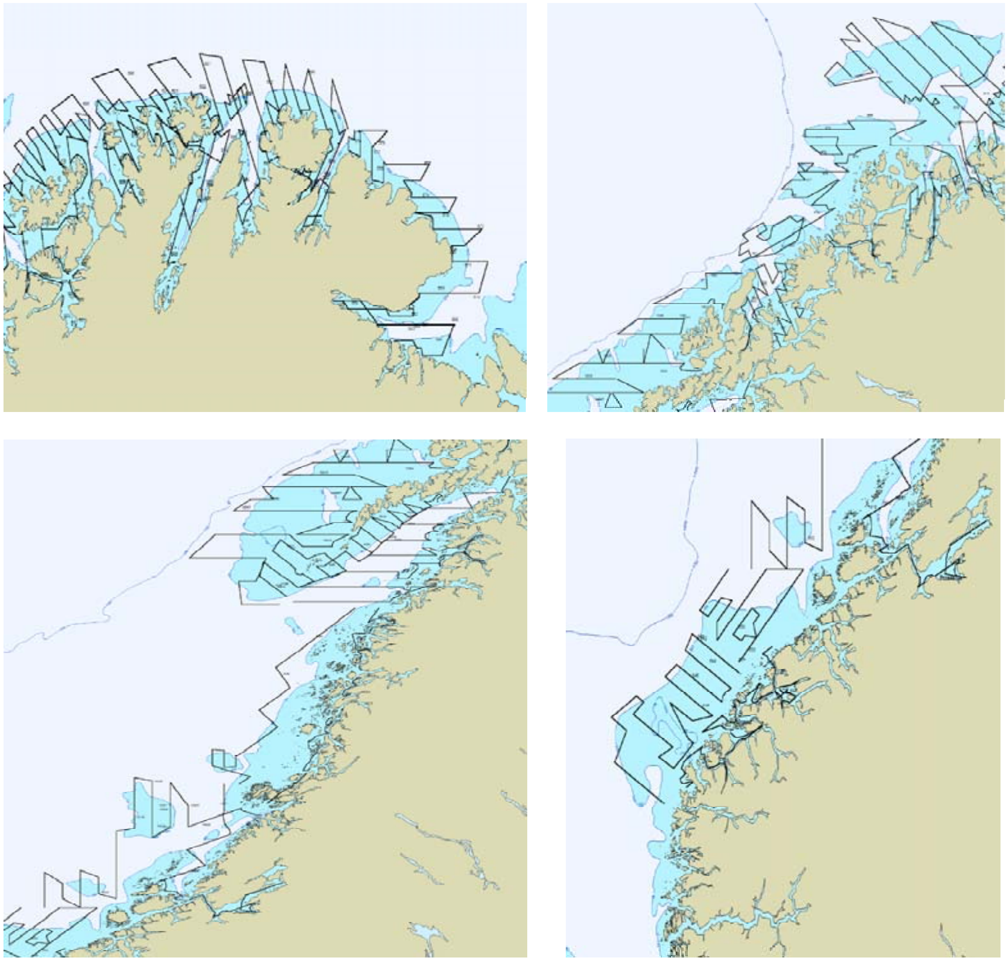

Figure 4. Standard transects in new combined saithe and coastal survey.

In autumn 2003 the saithe- and coastal cod surveys were combined. A new survey was designed, with new stratification and smaller strata based on depth and fish distribution in recent years, and with new and more regular transects (Figure 4). The new course lines had already been partly introduced in the saithe survey in 2001 and 2002. At the 2010 benchmark assessment two alternative survey index series was tested, one for 2001–2008 representing the traditional saithe survey area with new course lines and stratification, and one for 2003–2008 representing the combined saithe and coastal cod survey areas. The new tuning-series gave lower and more stable S. E. Log q residuals than the tuning-series currently used. However, the retrospective trend was still poor and the estimates of F and SSB in the last assessment year were far away from any other analysis. The new series are probably still too short to be used for tuning of the NEA saithe XSA. Until a longer time-series based on the new survey design is established, indices from the whole survey time-series, representing the traditional saithe survey area only, will be applied for tuning. The estimation of these abundance indices is done very much in the same way for the whole time-series and the results for later years should be comparable with earlier years.

B.4. Commercial cpue

Two cpue dataseries have been used, one from the Norwegian purse-seine fishery and one from the Norwegian trawl fishery.

Until 1999 indices of fishing effort in the purse-seine fishery were based on the number of vessels of 20–24.9 m length and the effort (number of vessels) of this length category was raised by the catches to represent the total purse-seine effort. However, the number of vessels taking part in the fishery almost doubled from 1997 to 1998, but due to regulations the catches were almost the same as in 1997. In such a situation the total number of vessels participating in a fishery is clearly not a good measure of effort. Examination of the data demonstrated that many of the vessels that have taken part in the fishery the last decade have accounted for only a small fraction of the purse-seine catches, and these also included most of the vessels that tend not to be involved on a regular basis. Roughly half of the vessels have caught less than 100 tonnes per year, and the sum of these catches represents only about 5–10% of the total purse-seine catch. Therefore the number of vessels catching more than 100 tonnes annually seems to be a more representative and more consistent measure of effort in the purse-seine fishery. These numbers are raised to the total purse-seine catch. The new effort series demonstrated a smaller decrease in later years than the old one and in the XSA runs it gets higher scaled weights. The 2000 WG meeting therefore decided to use the new cpue dataseries in the assessment.

The quality and performance of the purse-seine tuning fleet has been discussed several times in the WG. The effort, measured as number of vessels participating, has been highly variable from year to year. This was partly taken care of by only including vessels with total catch > 100 tonnes. However, with a restricting and changing TAC and transfer of quota, the cpue may change much from year to year without really reflecting trends in the saithe abundance. This is also reflected in the tuning diagnostics of exploratory runs. There are rather large and variable log q residuals and large S.E. log q for all age groups except age 4, which often is the dominant age group in the purse-seine landings. But even for age 4 the S.E. log q is higher than in the Norwegian trawl cpue and acoustic survey indices single fleet tunings. There are strong year effects, and in the combined tuning the purse-seine series get low scaled weights. Mainly based on this the 2005 WG decided to not include the purse-seine tuning fleet in the analysis (ICES 2005). In later years with lower availability of young saithe the TAC has been less restricting, and at the 2010 benchmark assessment exploratory runs were done with updated purse-seine tuning-series. The purse-seine tuning series demonstrated the higher S.E_Log q residuals and lower scaled weights than the other tuning-series and did not perform any better than in previous analysis, and were not reintroduce as a tuning-series in the assessment.

Catch and effort data for Norwegian trawlers were until 2000 taken from hauls where the effort almost certainly had been directed towards saithe, i.e. days with more than 50% saithe and only on trips with more than 50% saithe in the catch. The effort estimated for the directed fishery was raised by the catches to give the total effort of Norwegian trawlers. From 1997 to 1998 the effort increased by more than 50%, but due to regulations the catches were slightly lower in 1998 and the cpue decreased by almost 40% from 1997 to 1998 and stayed low in 1999. This may at least partly be explained by change in fishing strategies in a period with increasing problems with bycatch of saithe in the declining cod fishery due to good availability of saithe. In 2001 new cpue indices by age were estimated based on the logbook database of the Directorate of Fisheries, which has a daily resolution (Salthaug and Godø, 2000). After some initial analyses it was decided to only include data from vessels larger than the median length because they demonstrated the least noisy trends. One single cpue observation from a given vessel is the total catch per day divided by the duration of all the trawl hauls that day. To increase the number of observations during a time period with decreasing directed saithe fishery, all days with 20% or more saithe were included. The effort (hours trawling) for each cpue observation was standardized or calibrated to a standard vessel. Until 2002, first averaging all cpue observations for each month, and then averaging over the year a yearly index was calculated. The cpue indices were divided on age groups by quarterly weight, length and age data from the trawl fishery. From 2003, first averaging all cpue observations for each quarter, and then averaging over the year a yearly index was calculated. The cpue indices were finally divided on age groups by yearly catch in numbers and weight-at-age data from the trawl fishery. The new approach was less influenced by short periods with poor data, while it still evens out seasonal variations.

There was an increase in the total cpue from 1999 to 2003, when it reached the highest level in the time-series going back to 1980. In 2004 the total cpue was almost exactly the same as in 2003, while there was about a 30 % increase from 2004 to 2005. This was caused by an increase in the quarter one cpue. This increase started already in 2003, but was most pronounced in 2005. The increase may be explained by increased availability and catchability of saithe in spawning areas of Norwegian spring-spawning herring, where the saithe feeds on herring during quarter one. A similar increase was not seen in the other areas and quarters. AT the 2005 benchmark assessment an annual cpue series was calculated without quarter one data. This cpue series demonstrated much less variations over the last four years, and the WG decided to use a cpue time-series averaged over quarters 2–4 for tuning (ICES 2005). Due to rather large negative log q residuals in the first part of the new time-series, it was shortened to only cover the period after 1993. Based on exploratory runs done at the 2005 benchmark assessment the age span was set to 4–8.

The estimates of total cpue increased considerably both in 2007 and 2008. The survey (Aglen *et al.*, 2009) demonstrates a larger proportion of saithe in the southern half of the distribution area in the last years, and logbook data reveal that the trawl catches included in the cpue calculations also have become gradually more southerly distributed, i.e. the trawlers follow saithe aggregations that may have become extra available in 2007 and 2008. The biological samples used for dividing total cpue on age groups are, however, from the whole saithe fishery and therefore include age groups that are not numerous in these aggregations. Based on this and the decline in survey indices in the same years and additional analysis, the WG decided to exclude the 2007 and 2008 cpue data in the final assessment (ICES 2008, ICES 2009a).

Further analysis and exploratory runs were presents at the 2010 benchmark assessment. Six different options were tested, included a proposal from the industry. The cpue index based upon 7 vessels proposed by the industry could implement new bias or noise due to lack of quarterly indices and index values out of range. To take account of a time period (2000–2008) with increasing directed saithe fishery (Figure 2b), all days with 80% or more saithe are excluded in some runs. Of the two options A) leaving out quarter 1 in the averaging and use all catches with > 20% saithe for the rest of year (as in the current index) or B) leaving out days with > 20% but < 80% saithe and including quarter 1 in the averaging, option B was chosen because it gave somewhat better diagnostics in the XSA runs and is more consistent regarding how data are selected and direct fishery is treated in the rest of the year. The increase in cpue at the end of the time period was much less for this option and all data years were included in the analysis.

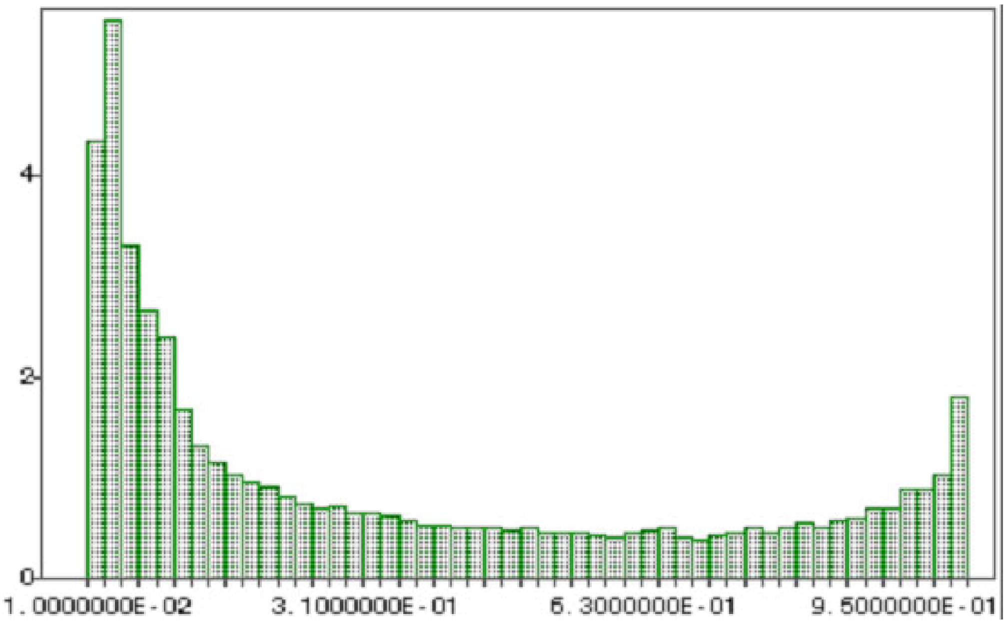

Figure 5a. Distribution of small and large trawl catches of NEA saithe (in percent) 1994–1999.

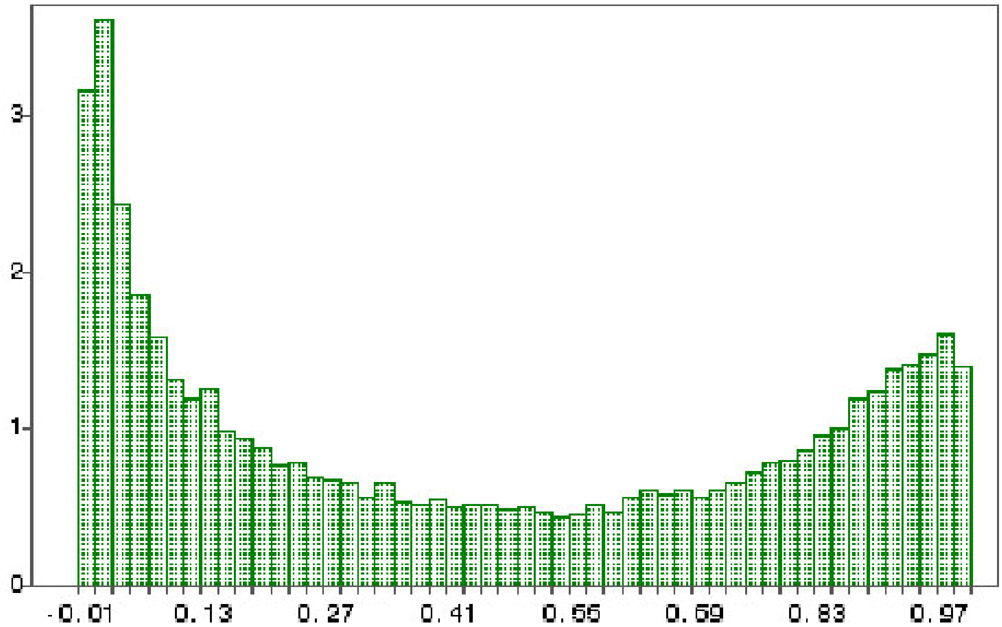

Figure 5a. Distribution of small and large trawl catches of NEA saithe (in percent) 2000–2008.

B.5. Other relevant data

None.

C. Historical stock development

Until the 2005 assessment age 2 was applied as recruitment age in the XSA runs, projections and calculations of reference points. Since the mid 1990s there has been almost no catch of 2 year olds and this age group should in theory be fully protected by the new minimum landing size. 2-year-old saithe, mainly inhabiting the fjords and more coastal areas, are represented in the survey, but highly variable from year to year. The saithe is normally not fully recruited to the survey before at age 3 and in some years at age 4. It is therefore difficult to estimate good recruitment indices, even at age 2. This especially effects the projections. Retrospective XSA analyses demonstrated that applying age 3 as recruitment age implies that one may include more years in the last part of the recruitment time-series. The 2005 WG therefore decided to apply age 3 as recruitment age.

Since about year 2000 the number of old (11+) fish in the catch matrix has been gradually increasing until 2004 and then decreased somewhat, but is still on a high level compared with the years before 2000. VPA based assessment models fitted to datasets with significant numbers in the oldest age and plus group, are extremely sensitive to the method by which fishing mortality at the oldest age is estimated, due to relatively poor VPA convergence at the oldest ages (see ICES 2002, Annex 7). At the 2010 benchmark assessment (WKROUND 2010) the catch matrix was extended to 15+ to avoid some of the potentially plus group problems. This was for the time being only possible to do back to 1989. Exploratory XSA runs demonstrated much better retrospective patterns and lower SSB levels and higher F levels at the end of the time period.

Analysis of the tuning-series indicated that there had been a shift in catchability around year 2002 (Figure 6). The survey was redesigned in 2003, and the fishery to a larger degree targeted older ages. Permanent breaks were made in both tuning-series in 2002. This allows the XSA freedom to estimate different qs. Exploratory XSA runs demonstrated improvement of retrospective patterns and diagnostics, and some year effects were no more apparent. Additional exploratory runs with reduced shrinkage were done to better allow the model to fit population number to the tuning-series. Detailed XSA diagnostics indicated that both tuning indices were relative good in estimating year-class strength at different ages. Therefore lowering the shrinkage, allowing the commercial cpue and survey to determine more of the year classes seemed appropriate (ICES 2009b). The proposed shrinkage of 1.5 lowered the weight of the shrinkage to less than 4 % for all ages. The use of a 20 year tricubic taper against a no-taper was also investigated. Although diagnostics did not substantially improve, it was decided that there were no benefits in keeping the tricubic taper as the splitting up of the tuning-series already had a similar impact on the assessment as the 20 year taper and improved substantially the assessment.

The recommendation from WKROUND 2010 therefore was to run the XSA with a 15+ catch matrix, tuning time-series broken in 2002, reduced shrinkage (S.E. of the mean to which the estimate are shrunk increased from 0.5 to 1.5) and no tapered time weighting. The new model options are shown below.

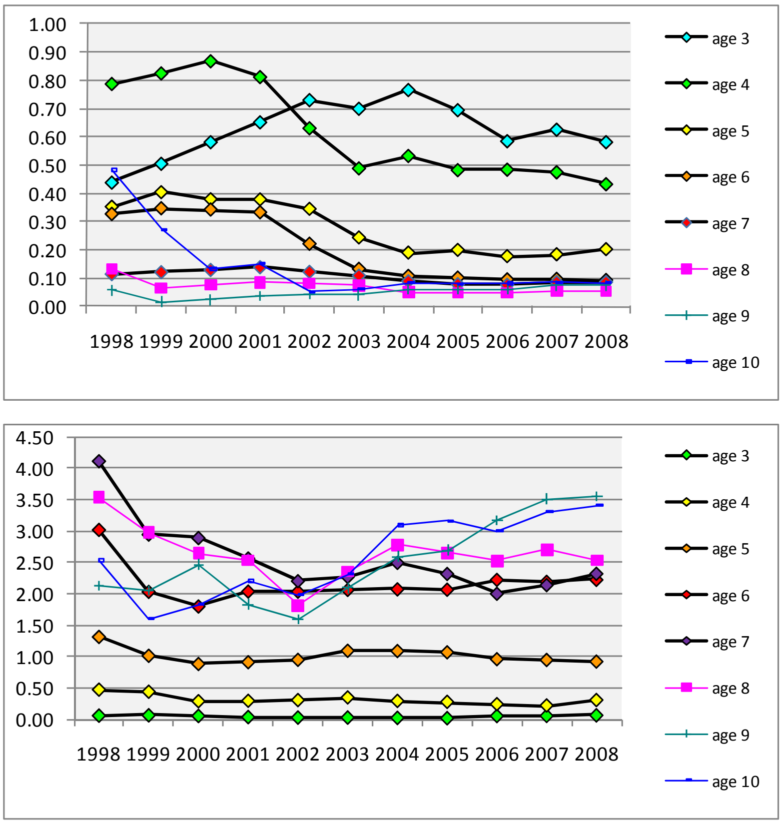

Figure 6. Catchability (index/N) at age in the Norwegian acoustic survey (upper panel) and in the Norwegian trawl cpue series (lower panel).

Until the 2005 assessment age group 3–6 was the reference age group for Fbar and has been applied in the projections and calculations of fishing mortality reference points. Before the mid 1990s 3 year old fish made up a significant part of the landings, and age group 3–6 contributed about 80%. Since the mid 1990s there has been a marked reduction in the landings of 3 year olds, and age group 4–7 contributes more than age group 3–6. This is partly related to transference of quota from purse-seine to conventional gears and partly to better price for larger saithe. In 1999 the minimum landing size was increased, and most of the 3-year-old fish will be below this size the whole year. The 2005 WG therefore decided to apply age group 4–7 as reference age group for Fbar. The fishing mortality PA-reference points therefore were re-calculated.

Due to the increased number of old fish in the catch matrix the 2010 benchmark assessment also investigated the age span for Fbar. Age groups 4–7 still make up most of the landings, and there are more noisy data in older age groups. Therefore it was decided keep Fbar as current.

Model used: XSA

Software used: Lowestoft VPA suite. In AFWG 2009 exploratory assessment runs were conducted in FLR version 2.8.1.

Model Options chosen:

No tapered time weighting applied

Catchability independent of stock size for all ages

Catchability independent of age for ages >= 8

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 estimate are shrunk = 1.500

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	1989 – last data year	3 – 15+	Yes
Canum	Catch at age in numbers	1989 – last data year	3 – 15+	Yes
Weca	Weight at age in the commercial catch	1989 – last data year	3 – 15+	Yes/No - constant at age from 1960 - 1979
West	Weight at age of the spawning stock at spawning time.	1989 – last data year	3 – 15+	Yes/No - assumed to be the same as weight-at-age in the catch
Mprop	Proportion of natural mortality before spawning	1989 – last data year	3 – 15+	No – set to 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1989 – last data year	3 – 15+	No – set to 0 for all ages in all years
Matprop	Proportion mature at age	1989 – last data year	3 – 15+	Yes/No – constant ogive 1960-1984, three year running average since 1985
Natmor	Natural mortality	1989 – last data year	3 – 15+	No – set to 0.2 for all ages in all years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 11	Nor trawl quarter 1–4	1994 – 2001	4–8
Tuning fleet 12	Nor trawl quarter 1–4	2002 – last data year	4–8
Tuning fleet 13	Norway ac survey	1994 – 2001	3–7
Tuning fleet 13	Norway ac survey	2002 – last data year	3–7

For analysis of alternative procedures see WG reports from AFWG 1997–2009.

D. Short-term projection

Model used: Age structured

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

Initial stock size. Taken from the XSA for age 5 and older. The recruitment-at-age 3 in the last data year is estimated using the long-term geometric mean, and numbers-at-age 4 in the intermediate year is calculated applying a natural mortality of 0.2 and the F value estimated by XSA, (advised by RG in 2004).

From AFWG 2009 the numbers-at-age 4 in the intermediate year is calculated applying a natural mortality of 0.2 and the F value estimated by standard Pope's equation for calculation of this y-c at age 4, i.e. N(4)=[N(3)*exp(-M/2)-C(3)] *exp(-M/2), (advised by RG in 2009).

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

Maturity: Constant ogive 1960–1984, three year running average since 1985

F and M before spawning: Set to 0 for all ages in all 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: For weight-at-age in stock and catch the average of the last three years in the VPA is normally used.

Exploitation pattern: The average of the last three years for ages 3–10, and a constant value for age 11 to 15+ calculated as the average of ages 11–13 over the last three years.

Selection pattern for yield-per-recruit: The average selection pattern from the last three years (2006–2008) of the assessment was used.

Intermediate year assumptions: TAC constraint, scaled to a TAC value. If using Sq F for the intermediate year, exploitation patterns described above should be used if there is no trend in F. If a trend in F is observed, the exploitation pattern should be scaled by the Fbar (4–7) to the level of the last year.

Stock recruitment model used: None, the long-term geometric mean recruitment-at-age 3 is used

Procedures used for splitting projected catches: Not relevant

E. Medium-term projections

The issue was not addressed during the 2010 benchmark and no projections were made. Settings previously used are listed below.

Model used: Age structured

Software used: MFDP single option prediction

Initial stock size: Same as in the short-term projections.

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

Maturity: Same as in the short-term projections.

F and M before spawning: Set to 0 for all ages in all 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: Same as in the short-term projections.

Exploitation pattern: Same as in the short-term projections.

Intermediate year assumptions: F-factor from the management option table corresponding to the TAC

Stock recruitment model used: None, the long-term geometric mean recruitment-at-age 3 is used

Uncertainty models used: @RISK for Excel, Latin Hyper cubed, 5000 replications, fixed random number generator

Initial stock size: Lognormal distribution, LOGNORM (mean, standard deviation), with mean as in the short-term projections and standard deviation calculated by multiplying the mean by the external standard error from the XSA diagnostics (except for age 3, see recruitment below)

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

Maturity: Constant ogive 1960–1984, three year running average since 1985

F and M before spawning: Set to 0 for all ages in all 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 weight of the three last years

Exploitation pattern: Average of the three last years, scaled by the Fbar (4–7) to the level of the last year if there is a trend

Intermediate year assumptions: F-factor from the management option table corresponding to the TAC

Stock recruitment model used: specified as a PERT distribution (as special form of the beta distribution) with a *minimum* and *maximum* value as specified. The shape parameter is calculated from the defined *most likely* value.

RiskPertAlt(arg1type, arg1value, arg2type,arg2value, arg3type,arg3value). Specifies a PERT distribution with three arguments of the type *arg1type to arg3type*. These arguments can be either a *percentile* between 0 and 1 or "*min*", "*m. likely*" or "*max*".

Examples: *RiskPertAlt(2%; min; 50%; geomean; 98%; max) specifies a PERT distribution with a minimum of min and a most likely value of geomean and a 98th percentile of max*.

F. Long-term projections

The issue was not addressed during the 2010 benchmark and no projections were made.

G. Biological reference points

	Type	Value	Technical basis
Precautionary approach	Blim	136 000 t	change point regression.
	Bpa	220 000 t	Blim * exp(1.645*σ), where σ=0.3
	Flim	0.58	F corresponding to an equilibrium stock = Blim
	Fpa	0.35	Flim * exp(-1.645*σ), where σ=0.3. This value is considered to have a 95% probability of avoiding the Flim
Targets			0.35 in agreed management plan

(last changed in 2005)

Yield and spawning biomass per Recruit
F-reference points (2009):

	Fish Mort	Yield/R	SSB/R
	Ages 4–7		
Average last 3 years	0.19	0.79	3.22
Fmax			
F0.1	0.16	0.75	3.73
Fmed	0.35	0.84	1.74

HCR evaluation has revealed that candidates for reference points consistent with high long-term yields and a low risk of depleting the productive potential of the stock can be found at F_{pa}.

Due to the change of Fbar from 3–6 to 4–7 and age at recruitment from 2 to 3, the **lim** and **pa** reference points were re-estimated at the 2005 WG. The **lim** reference points were estimated according to the new methodology outlined in ICES CM 2003/ACFM:15. Saithe retrospective XSA-analyses demonstrate that in later years there have been an overestimation of F and underestimation of SSB in the assessment year. The trend may have been the opposite in earlier years, but the length of the tuning-series do not allow for long enough retrospective analysis to verify this. The new methodology (ICES CM 2003/ACFM:15) does not give any advice on how to deal with such situations. The **pa** reference point estimation was therefore based on the old procedure, applying the "magic formula" $\mathbf{B}_{pa} = \mathbf{B}_{lim}$ exp(1.645*σ) and $\mathbf{F}_{pa}$=$\mathbf{F}_{lim}$*exp(-1.645*σ), where σ is a measure of the uncertainty of F estimates (ICES CM 1998/ACFM:10). For NEA saithe a value of 0.3 was applied in both estimates.

In 1994 the WG proposed a MBAL of 150 000 t, based on the frequent occurrence of poor year classes below this level of SSB. The new maturity ogive introduced in 1995 gave somewhat higher historical SSB estimates. 150 000 t was considered to represent a less restrictive MBAL and 170 000 t was found to correspond better with the arguments used in 1994 (ICES 1996/Assess: 4). The Study Group on the Precautionary Approach to Fisheries Management (SGPAFM, ICES 1998/ACFM: 10) also found this to be a suitable level for B_{pa}. However, based on a visual examination of the stock–recruitment plot ACFM later reduced the B_{pa} to 150 000 t (ICES 1998b).

At the 2005 WG parameter values, including the change-point ($\mathbf{S}^* = \mathbf{B}_{lim}$), slope in the origin ($\hat{\alpha}$) and recruitment plateau (**R***), were computed using segmented regression on the 1960–2000 time-series of SSB-recruitment pairs. The values are presented in the text table below. Applying the "magic formula" $\mathbf{B}_{pa} = \mathbf{B}_{lim}$ exp(1.645*σ), gives a $\mathbf{B}_{pa}$ of 223 392 t, rounded to 220 000 t. The WG proposed this as the new $\mathbf{B}_{pa}$ for Northeast Arctic saithe.

From algorithm in Julious (2001)		
S*	$\hat{\alpha}$	R*
136 378	1.27	173 200

$F_{0.1}$ and F_{max} are estimated by the MFDP yield-per-recruit routine, and increased from 0.08 to 0.15 and from 0.14 to 0.3 for $F_{0.1}$ and F_{max}, respectively, in the 1999–2005 assessments, in 2009 assessment to 0.16 and 0.39 for $F_{0.1}$ and F_{max} respectively.

The SGPAFM (ICES 1998/ACFM: 10) suggested the limit reference point F_{lim} = F_{med} for northeast Arctic cod, haddock and saithe. A precautionary fishing mortality (F_{pa}) was defined as $F_{pa} = F_{lim} \cdot e^{-1.645\sigma}$ (σ = 0.2-0.3). The 1998 WG, however, found that setting F_{lim} = F_{med} did not correspond very well with the exploitation history for those fish stocks. It was therefore decided to estimate F_{pa} and other reference points by the PASoft program package (MRAG 1997). The estimates for $F_{0.1}$, F_{max}, and F_{med} were exactly the same as the values already estimated by other routines. The median value for F_{loss} was estimated at 0.43. F_{lim} can be set at F_{loss} (ICES 1998/ACFM:10). The probability of exceeding F_{lim} should be no more than 5% (ICES 1997/Assess: 7). The 5th percentile of the F_{loss} estimated here was 0.30 and the 1998 WG recommended using this value for F_{pa}. ACFM considered the 5th percentile calculated from the PASoft program package to be too unstable for long-term use and re-estimated F_{pa} using the formula $F_{pa} = F_{lim} \cdot e^{-1.645\sigma}$ with σ = 0.3 giving a F_{pa} = 0.26, based on an estimated F_{lim} = 0.45 (ICES 1998c). An updated version of the PASoft program package (Cefas 1999) was available at the 1999 WG and F_{pa} was re-estimated to 0.26. The WG therefore agreed to use this value for a precautionary fishing mortality for saithe (F_{pa} = 0.26).

ICES CM 2003/ACFM:15 proposed that $\mathbf{F}_{lim}$ should be set on the basis of $\mathbf{B}_{lim}$, and $\mathbf{F}_{lim}$ should be derived deterministically as the fishing mortality that will on average (i.e. with a 50% probability) drive the stock to the biomass limit. The functional relationship between spawner-per-recruit and F will then give the F associated with the R/SSB slope derived from the $\mathbf{B}_{lim}$ estimate obtained from the segmented regression. At the 2005 WG arithmetic means of proportion mature 1960–2004, weight in stock and weight in catch 1980–2004 (weights were constant before 1980), natural mortality and fishing pattern 1960–2004 were used for calculating the spawner-per-recruit function using ICES Secretariat yield-per-recruit software. R/SSB = 1.27 from the $\mathbf{B}_{lim}$ estimation gives SSB/R = 0.7874 and a $\mathbf{F}_{lim}$ = 0.58. Applying the "magic formula" $F_{pa} = F_{lim}$ exp(-1.645*σ), gives a F_{pa} of 0.35. The 2005 WG proposed this as the new F_{pa} for Northeast Arctic saithe.

H. Other issues

Harvest control rule

In 2007 Norway asked ICES to evaluate whether a proposal for a harvest control rule for setting the annual fishing quota (TAC) for Northeast Arctic saithe was consistent with the precautionary approach. The harvest control rule contains the following elements:

estimate the average TAC level for the coming 3 years based on $\mathbf{F}_{pa}$. TAC for the next year will be set to this level as a starting value for the 3-year period.

the year after, the TAC calculation for the next 3 years is repeated based on the updated information about the stock development. However, the TAC should not be changed by more than +/- 15% compared with the previous year's TAC.

if the spawning-stock biomass (SSB) at the beginning of the year for which the quota is set (first year of prediction), is below $\mathbf{B}_{pa}$, the procedure for establishing TAC should be based on a fishing mortality that is linearly reduced from $\mathbf{F}_{pa}$ at SSB=$\mathbf{B}_{pa}$ to 0 at SSB equal to zero. At SSB levels below $\mathbf{B}_{pa}$ in any of the operational years (current year and 3 years of prediction) there should be no limitations on the year-to-year variations in TAC.

ICES concluded that the HCR is consistent with the precautionary approach for all simulated data and settings, including a rebuilding situation under the condition that the assessment uncertainty and error are not greater than those calculated from historical data (ICES 2007). This also holds true when an implementation error (difference between TAC and catch) equal to the historical level of 3% is included.

The highest long-term yield was obtained for an exploitation level of 0.32, i.e. a little below the target F used in the HCR (Fpa), and ICES recommended using a lower value in the HCR.

The HCR is expected to rebuild a depleted stock to a level above $\mathbf{B}_{lim}$ within three years.

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3 Icelandic Saithe

3.1 Current stock status and assessment issues

A clear decline in Icelandic saithe stock biomass is evident in estimates for years since 2005 along with an associated rise in fishing mortality since about 2001. The decline in biomass and increase in fishing mortality are apparent across all assessment models explored during this workshop including the benchmark assessment discussed here. The current benchmark analysis includes information from 1980 through 2009 and contains data on catch-at-age from the fishery for fish aged 3 through 10+ and a Spring survey index that runs from 1985 through the present. A shorter time-series from the autumn survey was also examined in various model runs, but was not included in the final benchmark assessment. The model selected for use is a separable statistical catch-age model implemented in ADMB. This differs from the ADCAM model used in the previous assessment. ADCAM is a VPA type model which allows for changes in selectivity at each time-step at the cost of adding many more parameters to the model. To account for changes in fishery selectivity in 1996 a break in selectivity occurs in the model for that time. Over the last three decades, biomasses appear to have peaked twice, once in 1988 and then again at a lower level in 2004. These two peaks were driven, in part, by strong recruitment events. The assessment appears to be of high quality and should be viewed as reliable as a basis for making management decisions for this stock.

Icelandic saithe in area Va are managed as a single stock. Migration of saithe into the area can occur and tagging studies have provided evidence to support this occurring during certain time periods (NWWG 2008). The assessments include migration events that estimate immigration in pre-specified years based on evidence from increases in landings at certain ages and changes in weight-at-age that cannot be predicted from recruitment levels and standard growth generated from age 3 recruitment alone. The possibility of emigration from Icelandic waters has not been explicitly accounted for in the assessment.

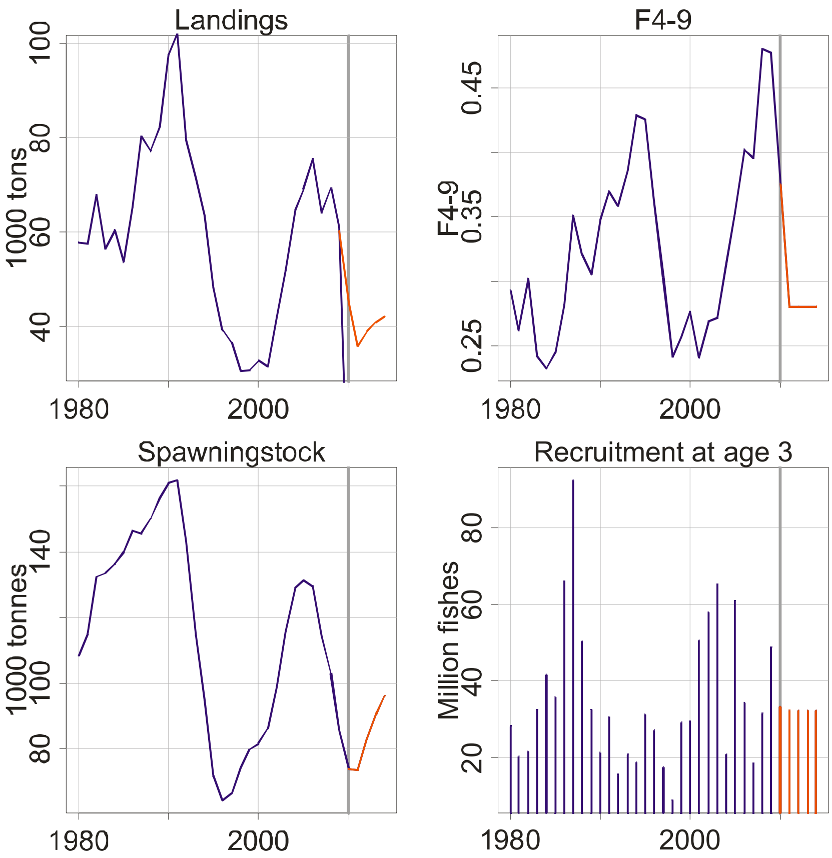


Figure 1 Development of the stock according to the run based on benchmark assessment statistical catch-age model with 2 separable periods and tuned to the spring survey index. The trends shown in red for the period after 2009 are based on projections. The trends shown for 2009 and earlier are model estimates based on the most recent dataseries.

3.2 Compilation of available data

3.2.1 Catch and landings data

Landings of saithe in Icelandic waters in 2009 are estimated to have been 61 334 tonnes (a drop from previous years). Of the landings 46 476 tonnes were caught by trawl, 9364 tonnes caught by gillnets, and 5494 tonnes caught by other means. The domestic advice for the fishing year 2009 (Fishing resulting in Fpa=0.3) was 35 000 tonnes, but the TAC issued was 50 000 tonnes.

Discarding of saithe, estimated annually since 2001 is hardly detectable (Pálsson *et al.*, 2008). The accuracy of the landings statistics are considered reasonable although some bias is likely.

3.2.2 Biological data

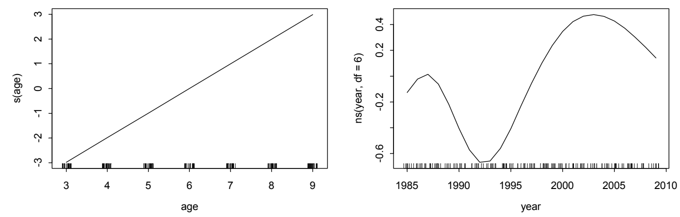
A fixed natural mortality of 0.2 is used both in the assessment and the forecast.

Data on maturity for saithe are available from the Icelandic groundfish Spring survey conducted annually in March since 1985. Spawning of saithe starts late January with a peak in February, just before the survey time. But maturity-at-age data from surveys are considered to give better estimates of maturity-at-age than from landings data, especially if surveys are close to the spawning time. Still, the data from the survey are quite variable and so a model was chosen to derive smoothed trends in maturity-by-age and year. The model was fit to data over ages 3 through 9 using a generalized linear model:

$$logit(P_{a,t}) = \alpha + \beta\ s(age,df=4) + \gamma\ ns(year,df=6)$$

where P is the proportion mature-at-age a in year t and *S* and *ns* are smoothing splines used to increase the flexibility of the model.

The resulting trends by age and year are shown below.



The benchmark assessment of Icelandic saithe was fit to catch data from 1980 to 2009. The following maturity values were applied for spawning-stock biomass calculations by time period:

1980–1985 are the mean model values from 1985–1998

1985–2009 are the values from the model

Projections forward use the 2009 model values. As these latter values are already smoothed there is no need to take an average over some some specified prior time period.

Maturity is set to 1 for fish older than age 9 and set to 0 for fish younger than age 3.

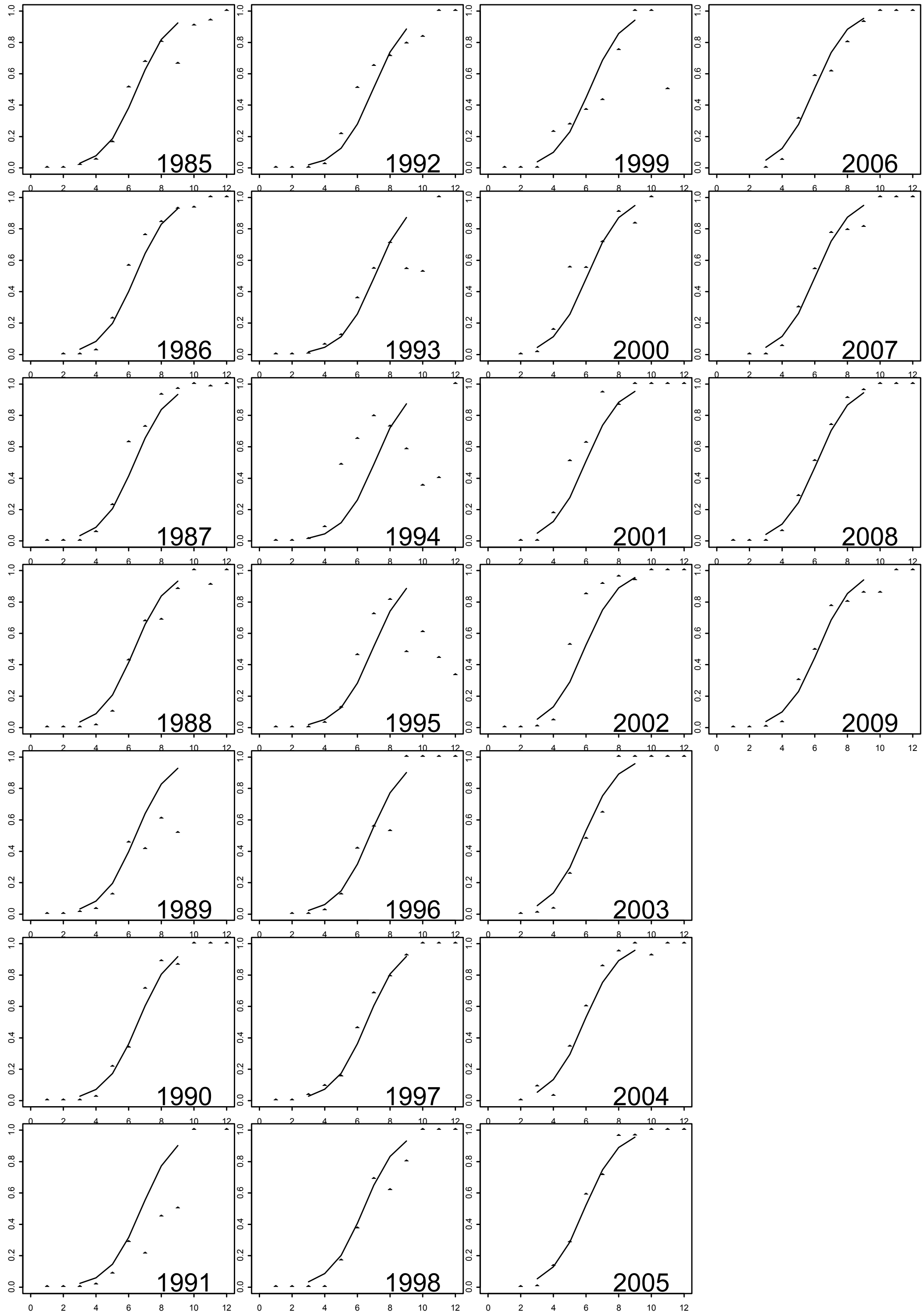


Figure 2. The observed proportion mature-at-age for each year from the autumn survey and the fitted curve as defined by the model described above.

3.2.3 Survey tuning data

Annual survey cruises are conducted by the Marine Research Institute. Two surveys are considered appropriate to saithe. These are the spring survey (March survey) and the autumn survey (October survey). Both are stratified random bottom-trawl surveys. The spring survey focuses on depths shallower than 500 m and has a relatively dense station-net on the shelf (approx 530 stations). The autumn survey has around 380 stations but also covers a much larger area including depths to below 1000 m and is designed to index Greenland halibut and *S. mentella;* as a result the distance between the stations is much greater. The suvey indices have become less variable since 1995 and this likely has improved the quality of assessment results.

3.2.4 Commercial tuning data

Commercial cpue indices are not used for tuning in this assessment. Although these indices have been explored for inclusion in the past, they were not considered for inclusion during this workshop because the cpue data were not standardized and the trends in the cpue may not be a reliable indicator of abundance.

3.2.5 Industry/stakeholder data inputs

No additional information beyond the landings from the commercial fleet was presented for incorporation in the assessment at the Benchmark Workshop.

3.3 Stock identity and migration issues

Migration is known to occur, with immigration likely bringing in new recruits into the population at various ages, an event that apparently varies from year to year and may be related to oceanographic conditions, prey distribution, and neighbouring stock size. Approximately 115 000 saithe have been tagged in the NE-Atlantic in the last century, most of them in the Barents Sea with total returns just under 20 000 (Jonsson, 1996). At Iceland 6000 saithe were tagged in 1964–1965, the recapture rate being 50% (Jones and Jonsson, 1971). Based on recaptures by area approximately 1 in 500 of tagged saithe released outside Icelandic waters were recaptured in Icelandic waters and 1 in 300 released in Icelandic waters were recaptured in distant waters (Jonsson, 1996).

Other evidence of saithe migrations exist, albeit of a more circumstantial nature. Sudden changes in average length or weight-at-age and reciprocal fluctuation in catch numbers-at-age in different areas of the NE-Atlantic have been interpreted as signs of migrations between saithe stocks (Reinsch, 1976; Jakobsen and Olsen, 1987; Jonsson, 1996).

Migration is esimated in the model at age 7 in 1991 by allowing an extra term to be added as “recruitment” at that age. Other post age 3 recruitments occur at other years, but these are typically lower. The timing of events to be included are determined by identifying signigicantly lower mean weights-at-age.

3.4 Spatial changes in the fishery and stock distribution

No new spatial changes in the fishery or stock were reported since the last assessment.

3.5 Environmental drivers of stock dynamics

Changes in the distribution of the large pelagic stocks (blue whiting, Norwegian spring-spawning herring) may affect the propensity of saithe to migrate off shelf and between management units. But, this relationship has not been quantified in a way that can be used to modify the assessment or create more informative projections. However, this phenomenon should be monitored for future data and model development and for incorporation into management considerations.

3.6 Role of multispecies interactions

3.6.1 Trophic interactions

No information about trophic interactions was presented and none were modelled by the assessment.

3.6.2 Fishery interactions

No fishery interactions were included.

3.7 Impacts on the ecosystem

No evidence was presented to indicate whether or not the fishery is impacting the marine environment.

3.8 Stock assessment methods

3.8.1 Models

A separable, forward projection, statistical catch-age model developed in ADModel Builder was used to fit the catch-at-age data from the commercial fleets and incorporates the spring bottom-trawl survey index as a tuning-series. Natural mortality is set at 0.2 for all age groups. Selectivity is estimated to be constant by age over time through the time period 1980–1995 and then is allowed to change to a different set of selectivities by age for the remaining time period 1996–2009. The ADCAM model was used for the assessment between 2007 and the present update. Prior to that a separable catch-age model was used from 2004–2006, an ADAPT model from 2003–2004 and a TSA model before that. Several of these models were examined extensively during the workshop and were found to give results that were not inconsistent with those found under the present benchmark assessment.

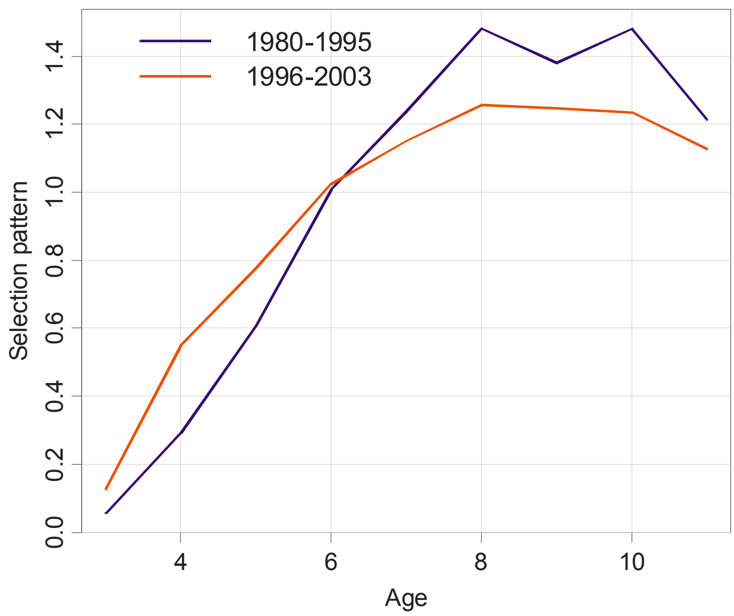


Figure 3. Difference in selection pattern for early and late periods in the statistical catch-age model.

3.8.2 Sensitivity analysis

A number of sensitivity analyses were conducted during the benchmark workshop. These included comparisons of outputs and residuals under alternative models and model configurations, a series of retrospective analyses (discussed below), and runs with and without a break in the time-series of selectivity estimates to account for changes in the fishing behaviour (Figures 4-6).

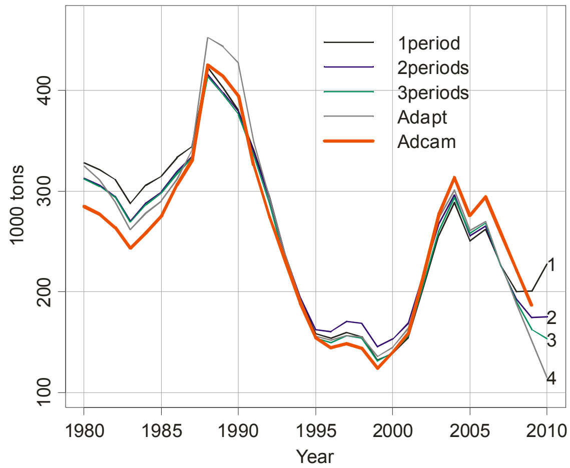


Figure 4. Comparison of 4+ biomass estimates from model runs using the March survey tuning-series, where the model was allowed to fit the data with one, two, or three periods having different selection patterns.

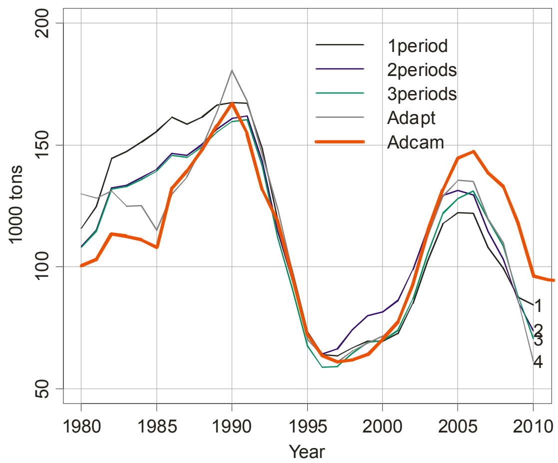


Figure 5. Comparison of spawning-stock biomass estimates from model runs using the March survey tuning-series, where the model was allowed to fit the data with one, two, or three periods having different selection patterns.

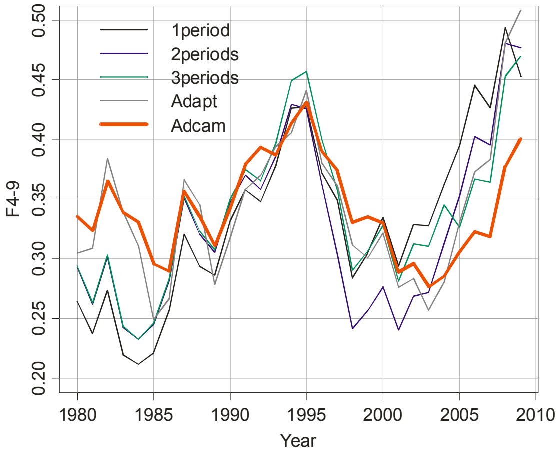


Figure 6. Comparison of F4–9 estimates from model runs using the March survey tuning-series, where the model was allowed to fit the data with one, two, or three periods having different selection patterns.

3.8.3 Retrospective patterns

The magnitude of the retrospective patterns encountered in previous assessments has been reduced by employing the statistical catch-age model. In addition, the number of parameters used in the estimation has been reduced and the overall fit (as demonstrated by a reduction in the negative log-likelihood) has improved. The simpler model is also somewhat easier to interpret in terms of residuals (now including residuals in the catch-at-age series) in terms of model performance.

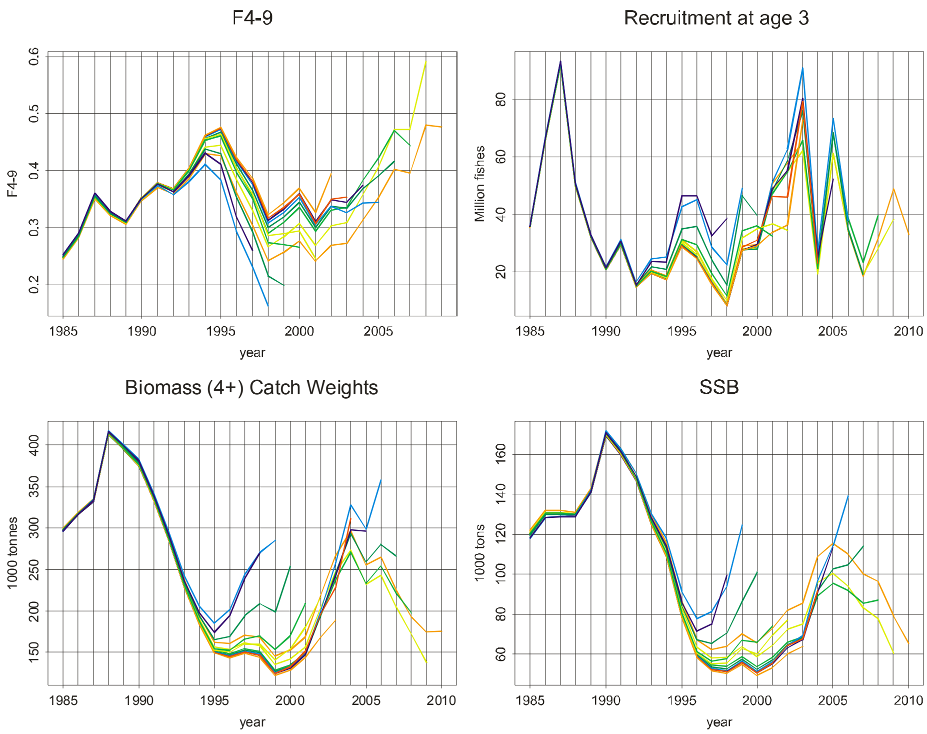


Figure 7. Retrospective pattern from a two period separable model run that is tuned with the March survey index.

3.8.4 Evaluation of the models

The separable statistical catch-age model, with a break in selectivity in 1995, that included only the one survey index (spring), was the model chosen as the best model to apply in annual assessment conducted subsequent years until the next benchmark.

3.9 Stock assessment

Icelandic saithe stock biomass has demonstrated a decline since 2005 and a corresponding increase can be seen in fishing mortality since 2001. These results are revealed in the Table below.

Stock Assessment Output
Provided by Year, Landings, Spawning Stock, and Recruitment-at-Age 3

Year	CatchIn1000tons	Spawningstock	N3
1980	57.6594	108.3700	28183.10
1981	57.5480	114.9870	20196.10
1982	67.8653	132.4800	21539.40
1983	56.5035	133.5130	32427.00
1984	60.4052	136.4140	41561.50
1985	53.7281	140.0110	35704.60
1986	65.2304	146.4710	66203.50
1987	80.2366	145.7610	92464.20
1988	77.2441	150.1430	50200.30
1989	82.3386	156.3530	32530.80
1990	97.5374	160.8980	21272.00
1991	102.2010	161.8750	30484.00
1992	79.5679	143.2150	15439.20
1993	71.5393	114.6780	20712.60
1994	63.5594	94.8093	18627.90
1995	48.2961	71.7787	31206.30
1996	39.3516	64.3194	27050.70
1997	36.6707	66.3543	17356.30
1998	30.6566	74.2130	8756.32
1999	30.8981	79.9457	29002.80
2000	32.7509	81.6031	29446.90
2001	31.5702	86.1335	50483.10
2002	41.9690	98.7560	57937.80
2003	51.8142	115.5800	65281.80
2004	64.6678	129.0880	20736.50
2005	69.0542	131.3170	61078.90
2006	75.4619	129.6170	34117.60
2007	64.2609	114.4960	18507.00
2008	69.4260	103.0300	31527.40
2009	61.1043	85.7135	48810.50

3.10 Recruitment estimation

Recent recruitment appears to be above average for the 1985–2008 time-series, but at a lower level than the strong 2000 and 2002 year classes. This means that upturns in stock biomass are not likely in the short-term as long as fishing mortality remains at historically high levels.

3.11 Short-term and medium-term forecasts

A Markov chain Monte Carlo algorithm, implemented through the ADMB program, was used to make the projections. The projections were made using the final year's estimates from the assessment as starting conditions for the model. Runs were made with and without a spawner-recruit relationship implemented, the latter allowing an equilibrium assessment that approximates what would be found under a simple yield-per-recruit analysis. SSBbreak in stochastic simulation of the Icelandic saithe was estimated at 80 kt (Bloss=65kt). The results of the simulation are shown in Figures 8–12.

Fmsy is estimated to be 0.28 (Figures 10 and 11).

3.12 Biological reference points

The simulations that included the spawner-recruitment relationship in the estimated Fmsy of 0.28 are suitable to allow it to be used as a target fishing mortality.

The estimated breakpoint of 80 kt is a candidate for Btrigger, the point where fishing mortality should be reduced. This breakpoint could also be a candidate for Bpa.

The estimated value of Bloss of 65 kt is a candidate for Blim.

The harvest control rule will probably not be F based but rather set up as a proportion of stock biomass although it will likely lead to the same F that is considered appropriate as Ftarget here.

Reference Point Approach	SSB (1000t)	F	Yield (1000t)
Fmsy	120	0.28	54.9
F0.1	174	0.19	53.7
F0.35	153	0.22	54.0

The simulations used a trigger SSB below which the intended fishing mortality will be reduced linearly to 0. For Icelandic saithe the estimated breakpoint in hockey stick regression is 80 kt which is a natural candidate for Btrigger.

The estimated SSBbreak seems like a reasonable candidate for Btrigger. Fmsy in simulations taking into account most sources of uncertainty was estimated at 0.28 a candidate for Fmsy and Ftarget.

Figure 12 shows the cumulative probability distribution of the spawning stock in 2069 with F = 0.28, with and without a reduction in effort occurring below the trigger point of 80kt. Uncertainty in the estimation of the trigger point is taken into account so that when F is overestimated SSB is underestimated by the same amount.

The analysis reveals that there is a minor change in the profile at low SSB but inclusion of the trigger point indicates that the probability of being below Btrigger is around 7% instead of 15%.

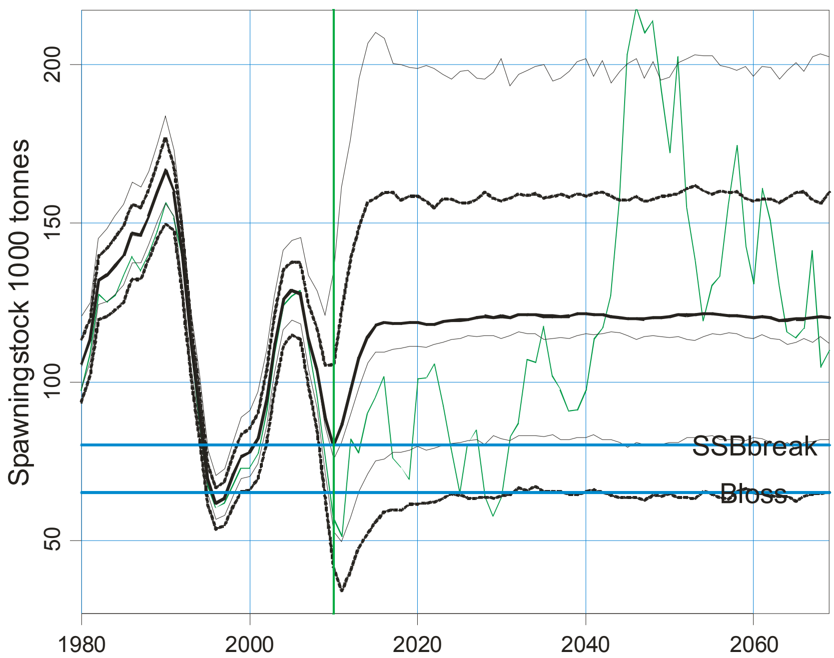


Figure 8. Development of the spawning stock from the benchmark assessment statistical catch-age model with split periods of constant selectivity and spring survey tunning index. The forward simulations were based on fishing mortality of 0.28. The lines are 5th percentile, 16th percentile, median, mean, 84th percentile and 95th percentile. Only one realization is also shown.

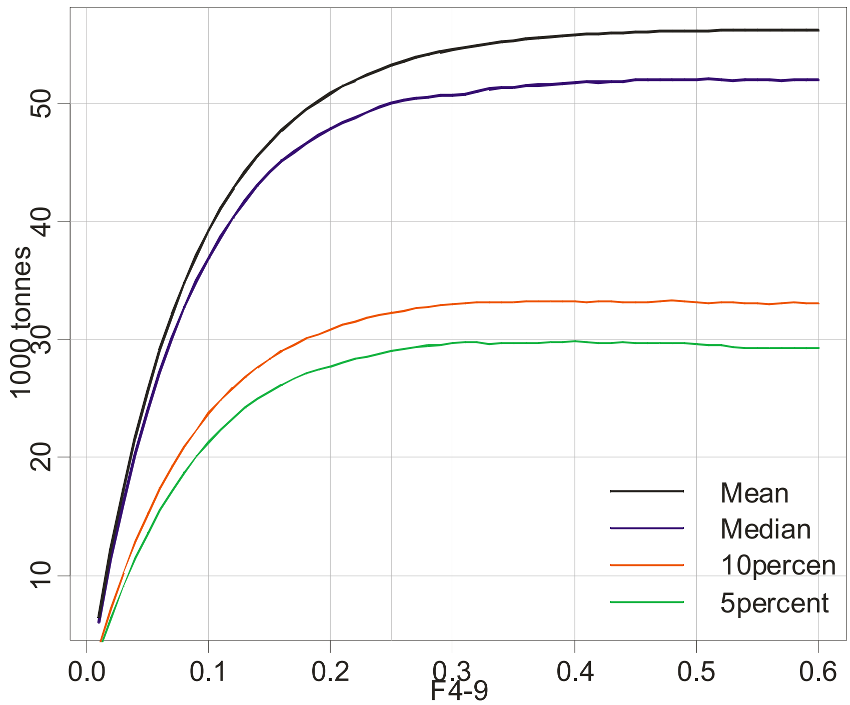


Figure 9. Equilibrium yield over a range of constant fishing mortality under the assumptions of no SSB-Recruitment function. This roughly corresponds to a yield-per-recruit analysis. The Figure shows mean, median, 10th percentile and 5th percentile.

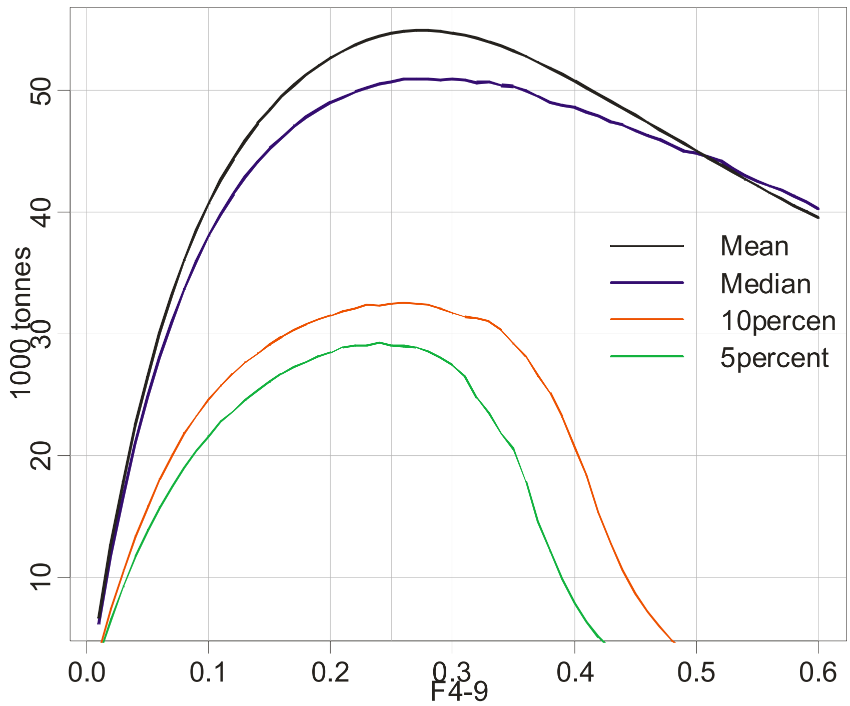


Figure 10. Equilibrium yield plotted over a range of constant fishing mortality with the assumption of a hockey stick SSB-Recruitment function. The figure shows mean, median, 10th percentile and 5th percentile.

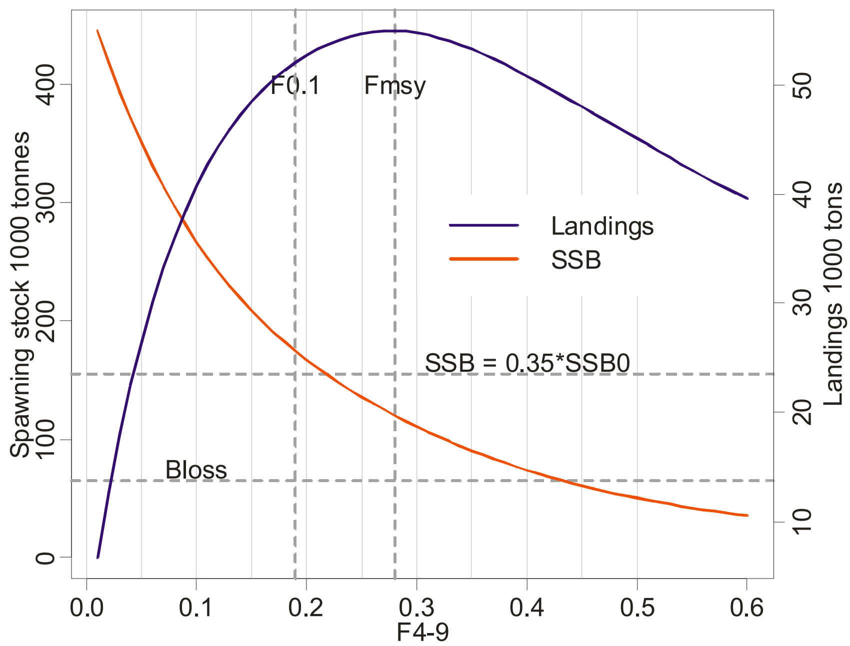


Figure 11.Yield and SSB as functions of fishing mortality.

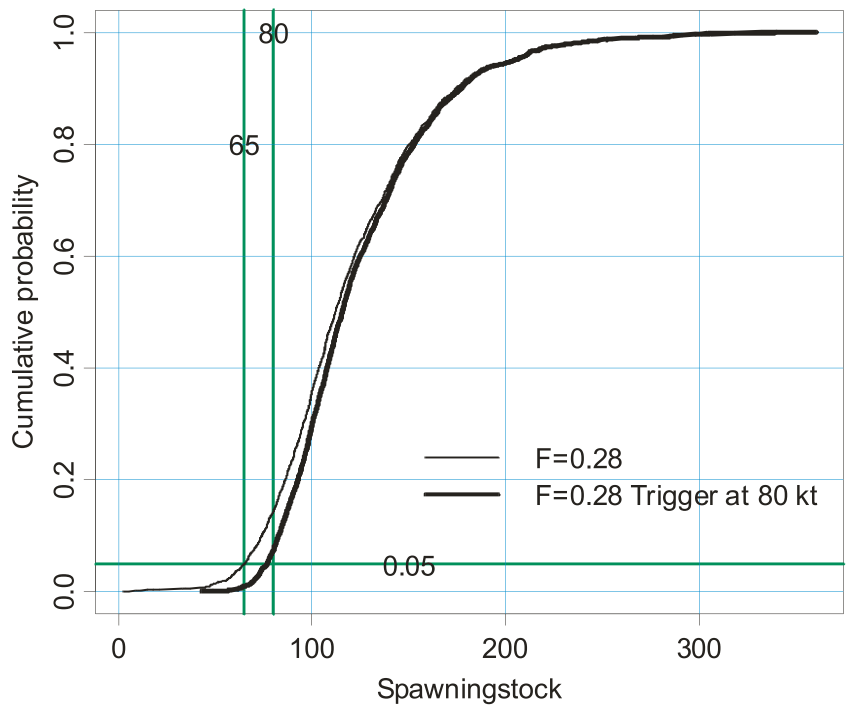


Figure 12. Cumulative probability of the spawning stock in 2069.

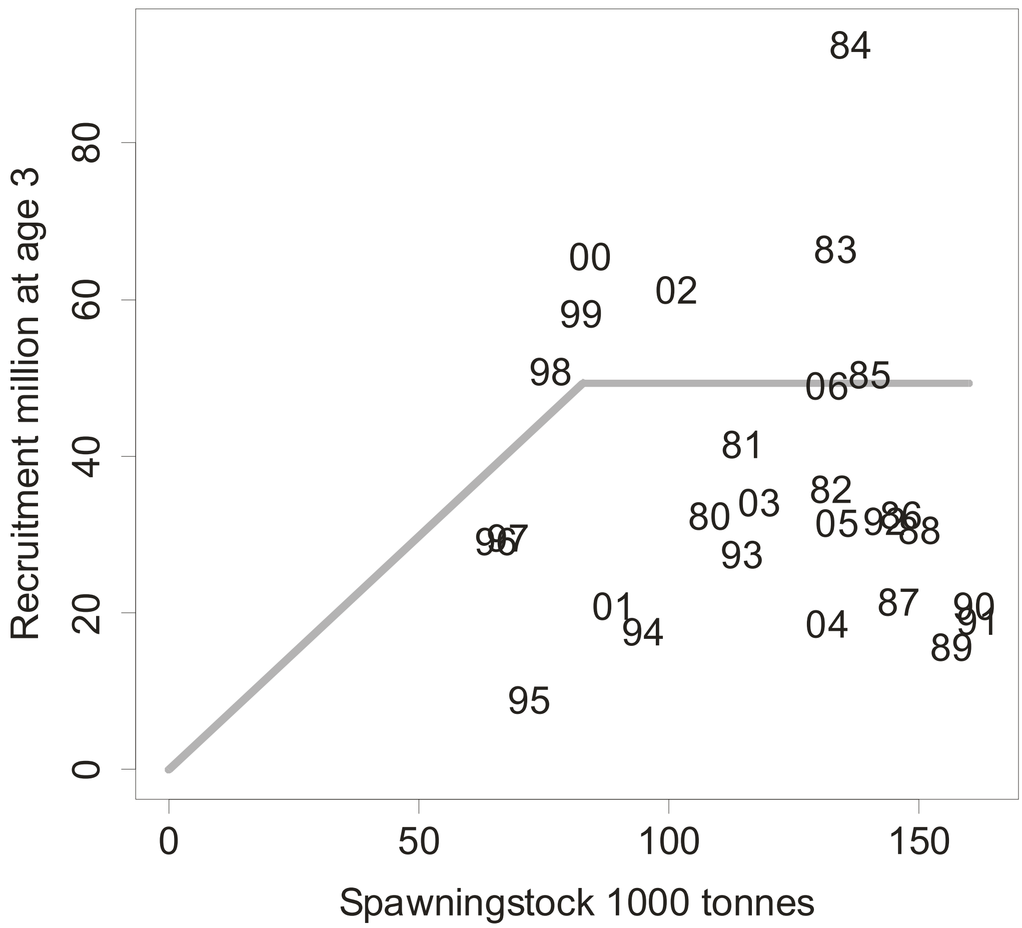


Figure 13. Icelandic saithe recruitment vs. spawning stock. The numbers represent year class. The inflection (SSBbreak) is at 80 kt.

3.13 Recommended modifications to the stock annex

No stock annex existed for this stock prior to the 2010 Benchmark meeting.

3.14 References

ICES. 2008. Report of the North-Western Working Group (NWWG). ICES CM 2008 /ACOM:03.

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.

Jones, B. W., and Jonsson, J. 1971. Coalfish tagging experiments at Iceland. Rit. Fiskideildar, 5:1–27.

Jonsson, S. T. 1996. Saithe on a shelf. Two studies of *Pollachius virens* in Icelandic waters. Masters thesis, University of Bergen. 151 pp.

Reinsch, H. 1976. Kohler und Steinkohler. A. Ziemsen Verlag, Vittenberg Lutherstadt. 158 pp. (In German).

Stock Annex Saithe in Icelandic waters (Division Va)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Saithe in Icelandic waters (Division Va)
Working Group:	NWWG
Date:	16.2 2010
Revised by:	Asta Gudmundsdottir, Einar Hjörleifsson and Höskuldur Björnsson.

A. General

A.1. Stock definition

Saithe in Icelandic waters (Division Va) is managed as a one unit, though taggings have demonstrated that in some years saithe migrates from distinct waters into Icelandic waters and vice versa. Saithe is both demersal and pelagic. They can be found all around Iceland, but are most common in the warm waters south and southwest off Iceland. Spawning starts late January with a peak in February in shallow water (100–200 m) off the southeast, south and west coast of Iceland. The main spawning area is considered to be south/southwest off Iceland (Selvogsbanki, Eldeyjarbanki). The larvae drift clockwise all around Iceland and mid-June juveniles can be found in many coves, bays and harbours then about 3–5 cm long. At age 2 they move to deeper waters in winter. Saithe becomes mature at age 4–7.

According to available data approximately 115 thousand saithe were tagged in the NE-Atlantic in the last century, most of them in the Barents Sea with total returns just under 20 thousand (S. T. Jonsson, 1996). At Iceland 6000 saithe were tagged in 1964–1965, the recapture rate being 50% (Jones and Jonsson, 1971). Based on recaptures by area approximately 1 in 500 of tagged saithe released outside Icelandic waters was recaptured in Icelandic waters and 1 in 300 released in Icelandic waters was recaptured in distant waters (S. T. Jonsson, 1996). For comparison, cod long-term average rate of emigration from Icelandic waters is 1 in 2000 tagged fish (J. Jonsson, 1996), a rate almost an order of magnitude lower.

Other evidence of saithe migrations exist, albeit of a more circumstantial nature. Sudden changes in average length or weight-at-age and reciprocal fluctuation in catch numbers-at-age in different areas of the NE-Atlantic have been interpreted as signs of migrations between saithe stocks (Reinsch, 1976; Jakobsen and Olsen, 1987; S.T. Jonsson, 1996). Because mean weight-at-age decreases along an approximately NW-SENE gradient, migration of e.g. northeast arctic saithe to Icelandic waters will, theoretically, be detectable as a reduction in size-at-age in the Icelandic saithe catches. Catch curves from some year classes, from different areas show some reciprocal variations. Inspection of the data based on the above indicate that the most likely years and ages for immigration are as follows: Age 10 in 1986, age 7 in 1991, age 9 in 1993 and the 1992 year class as age 7 saithe in 1999 and 8 in 2000.

A recent tagging programme was conducted in Icelandic waters in 2000–2004 from which ~1750 of ~16 000 tags released have been returned. The number of returns from areas other than the Icelandic EEZ has now reached 10 or around 2.5% of the recaptures outside the management area of the stock. Most were tagged at eastern localities and recaptured in Faroes waters, with a pulse of tags recovered in early 2006. Other foreign returns have come from areas west of Scotland and east of Greenland. Figure A.1.1 shows the total returns from this tagging programme (2007 ICES NWWG).

A.2. Fishery

Annual landings and overview of the major fleets

Annual estimates of landings of saithe from Icelandic waters are available since 1905 (Figure A.2.1). The historical information is largely derived from Statistical Bulletin, with unknown degree of accuracy. The more recent landings (from 1980 onward) statistics are from the Directorate of Fisheries as annually reported to ICES.

After WWII the fishery was initially dominated by foreign fleets, mainly English and German trawlers. The former were primarily targeting cod and catching saithe as a bycatch, while the latter were more directly targeting saithe as well as redfish. The domestic fleet has more or less been the sole exploiter of the saithe resource since 1978, following the expansion of the Icelandic EEZ from 50 to 200 miles in 1975.

Information on landings of the Icelandic fishing fleet by fishing gear is available since 1974, with the exception of the years 1979–1981 (Figure A.2.2). Largest portion of the catch is taken by trawl; with gillnet fisheries playing a secondary role. The importance of the gillnet fisheries has declined, being between 13–43 % in the period 1974–1995, but only around 10% of the total landings since then.

Information from captains logbook records, available since 1991 demonstrate that gillnet and trawl fisheries are of mixed nature (see WD 04). Between 40–80% of the annual bottom-trawl landings based on hauls where saithe is reported as catch constitutes 75% or more of the catches. During the 1990s an increasing portion of the total annual saithe trawl landings was taken as bycatch, with the trend somewhat reversing in the since then. The less important gillnet fishery in terms of landings are somewhat more of a mixed species fisheries compared with the trawl fishery. Here between 20–80% of annual gillnet catches are from settings where saithe constitutes 75% or more of the catches. Relatively speaking the gillnet fishery became more of a bycatch fisheries in 1996–2006 compared with that observed in the 1991–1995 (in a period when catches were higher). Since 2003 until 2008 the gillnet fishery, according to the logbook records have become increasingly a targeted fishery.

In the pelagic fishery a small amount of bycatch of saithe (~1%) has been reported in the blue whiting fishery in the Icelandic EEZ (NWWG report in 2009).

Attempts have been made at estimating discarding in the Icelandic fisheries since 2001 (Pálsson *et al*., 2008) based on a method using length measurements taken by observers on board and measurements taken of landed fish. Discarding of saithe is hardly detectable, while that observed e.g. for haddock has been around 8% of landings in numbers.

Spatial and temporal distribution catches

The saithe fishery in Icelandic waters is largely limited to the southern and western shores of Iceland (Figure A.2.3), with an increase in share of the catches taken in the southeast and in the northwest relative to that obtained in the southwest (WD 04). The gillnet fishery occurs over a relatively narrower geographic range and in shallower water relative to the bottom-trawl fishery. The saithe fishery takes place more or less continuously throughout the whole year; although catches in November through January tend to be lower than in other months and somewhat higher in March.

Fleet composition

The fishing fleet operating in Icelandic waters consists of a diverse boat types and sizes, operating various types of gear. The largest share of the saithe catches (76% in 2008) are taken with trawler larger than 40 BRT. The bulk of the gillnet catches are taken by 13 boats in the size classes 30–41 BRT. The top 50 trawler and boats took around 85% of the total saithe catch in 2008. The remainder of the saithe catch come from myriads of smaller boats, using handlines, jigging and Danish seine. These boats are largely targeting cod, haddock and flatfish with saithe being only a bycatch.

Management

The fisheries in Icelandic waters have since 1984 been managed under a TAC system, where each boat owns a certain percentage of the TAC. The management year is from start of September to end of August in the following year. The system is an ITQ system, allowing free transferability of quota between boats. This transferability can either be on a temporary (one year leasing) or a permanent (permanent selling) basis. This system has resulted in boats having quite diverse species portfolios, with companies often concentrating/specializing on particular group of species. The system allows for some but limited flexibility with regards converting a quota share of one species into another within a boat, allowance of landings of fish under a certain size without it counting fully in weight to the quota and allowance of transfer of unfished quota between management years. The objective of these measures is to minimize discarding, which is effectively banned. Landings in Iceland are restricted to particular licensed landing sites, with information being collected on a daily basis time by the Directorate of Fisheries (the native enforcement body). All fish landed has to be weighted, either at harbour or inside the fish processing factory. The information on landing is stored in a centralized database maintained by the Directorate and is available in real time on the Internet (www.fiskistofa.is). Insignificant amount of the saithe caught in Icelandic waters is landed in foreign ports. The accuracy of the landings statistics are considered reasonable although some bias is likely.

All boats operating in Icelandic waters have to maintain a logbook record of catches in each haul. The records are available to the staff of the Directorate for inspection purposes as well as to the stock assessors at the Marine Research Institute.

A system of instant area closure is in place for many species, including saithe. The aim of the system is to minimize fishing on smaller fish. For saithe, an area is closed temporarily (for 3 weeks) for fishing if on-board inspections (not 100% coverage) reveal that more than 25% of the catch is composed of fish less than 55 cm in length. No minimum landing size of any fish species exist in Icelandic waters. The minimum allowable mesh size is 135 mm in the trawl fisheries, with the exception of targeted shrimp fisheries in waters north of the island.

The Marine Research Institute has issued a recommended annual TAC since 1984, with advice also given by ICES since 1987. The set TAC has often been set higher than the advice and no formal harvest control rule exists for this stock. The landings (by quota year) have in 6 out of 25 years exceeded the national TAC by more than 10%. With the exception of 1995 and 1996 the landings in other years have been closed to or lower than the national TAC.

A.3. Ecosystem aspects

Changes in the distribution of the large pelagic stocks (blue whiting, Norwegian spring-spawning herring) may affect the propensity of saithe to migrate off shelf and between management units. This is poorly documented but well .known.

Significant changes in the length and weight-at-age have been observed in the Icelandic saithe. It is unknown if these factors are fisheries or environmentally driven.

B. Data

B.1. Commercial catch

Sampling from the Icelandic fleet

Sampling of size and age composition of saithe in the Icelandic fisheries only started in 1974 (Figures B.1.1 and B.1.2). In the years 1974 to 1977, the sampling was rather limited, with less than 50 independent samples taken each year. Thereof otoliths were taken in 15 samples or less, annually. In the years 1978 and 1979 a significant sampling occurred from the fisheries, with the primary objective to establish the relationship between length and weight. Since 1980 regular sampling, with the objective to calculate annual catch in number has taken place. During 1980–1998 the number of independent samples were 50–100 per year but have increased significantly in recent years being above 200 in the last four years. This increase is in part due to random samples taken by the staff of the Directorates of Fisheries, partly aimed at studying potential discarding.

Over the period the 1980–1998 the number of length measurements in each sample was around 200. Thereof, 100 fish were sampled for otoliths/age. In 1999 there was a change in the protocol within each sample, where the number of fish measured was reduced to 150, with 50 fish being weighted and sampled for otoliths. This did not result in fewer individuals being sampled, due to the increase in the sampling intensity that occurred at the same time. Systematic gutted weight measurements of fish sampled for otoliths commenced in 1995.

The sampling protocol by the staff of the Marine Research Institute has in the last years been linked to the progression of landings within the year. The system is fully computerized (referred to as "Sýnó" by the natives) and directly linked to the daily landings statistics available from the Directorate of Fisheries. For each species, each fleet/gear and each landing strata a certain target of landings value behind each sample is prespecified. Once the cumulative daily landings value pass the target value an automatic request is made to the sampling team for a specific sample to be taken. The system as such should thus take into account seasonal variability of the landings of any species. An overview of the cumulative landings of the saithe and the cumulative sampling of saithe seem to be in reasonable sync (Figure B.1.3), although there seem to be lesser sampling intensity in summer, possibly associated with summer holiday of the staff. The sampling design is not per se linked to the geographical distribution of the fisheries. However the fishing location of the fish measured at harbour is known with reasonably accuracy, because fishing date is registered for each fish boxes and can hence be linked to geographic location of the fishing at that date, based on the captain's logbook record. An overview of the sampling of Saithe based on this information (Figures B.1.4 and B.1.5) shows that overall, the geographical sampling intensity mirrors the geographical distribution of the fisheries (see Figures A.2.3).

Calculation of catch in numbers

The calculation of the annual catch in number of the Icelandic saithe has since 1989 been based on only 2 métiers, trawl and gillnet, with no splitting by season or geographic distribution of fishing. Catches in other gears (longline and Danish seine) are included with the trawl gear. For the saithe the length–distribution are compiled into bins of 5 cm and used as such in the length–age key. The parameters used to convert length to weights are:

Cond = 0.024498

Power = 2.7567

Otherwise the calculations of calculation of annual catch in number and weight-at-age for saithe have since 1980 been calculated in the same way as was done for other species assessed by age based methods at the Marine Research Institute. What follows is a general description of the algorithm used in the calculations in the unix software package (referred to as PAX: “Population Assessment in uniX”):

PAX is a menubased system where one has among other things the options of fetching data from a centralized database; calculate catches in numbers; make cpue indices and run a vpa program. It was first written late eighties and has been updated several times since then. Most of the modules in the system are prelude shellscrips which are run in unix/linux. Now the most used unit is the catches in numbers calculations. That module will be described here.

Catch in numbers are calculated for each area, a sason and a gear combination and then combined to total catches in numbers over all areas, seasons and gears.

Length distributions

Data used are length–frequency samples taken in area **r**, season **t** and gear **g**.

L_l is the number of fish at length *l*.

One has the option to run the length distributions on 1 cm or 5 cm basis. If the latter one is chosen, a temporary variable *lemultfj* is assigned the value $l * L_l$ to be able to calculate the correct mean length in the length distribution. Then the grouping in 5 cm intervals is done in the way that the numbers get the middle value from the interval. As an example the values in the range 10-14 and 15-19 are assigned 12 and 17 respectively. Lengths are then in fact either

$$l \in \{1,2,3,...\} \, or \, l \in \{2,7,12,17,...\}$$

Age–length and maturity keys

Data used are age-determined data from otolith samples in area **r**, season **t** and gear **g**. If no otolith samples exist from this area, season and gear combination, they have to be borrowed from other season or gear for the same area or from other areas.

K_{la} is the number-at-length *l* and at age *a*, *a*>0.

M_{la} is the number mature-at-length *l* and at age *a*, *a*>0.

IM_{la} is the number immature-at-length *l* and at age *a*, *a*>0.

A fish is assigned to IM_{la} if it has a maturity value 1 in the database otherwise it is assigned to M_{la} .

Multiply the age–length and maturity keys with the length–distribution

Sum of the numbers at length *l* over all ages:

$$K_{l.} = \sum_a K_{la}$$

Make a new key with the number of fish:

$$C_{la} = \frac{K_{la}}{K_{l.}} \cdot L_l$$

And new maturity keys:

$$CM_{la} = \frac{M_{la}}{M_{la} + IM_{la}} \cdot C_{la} \text{ and } CIM_{la} = \frac{IM_{la}}{M_{la} + IM_{la}} \cdot C_{la}$$

Average length and weight

In this step average length and weight-at-age are calculated. For each area, season and gear the condition factor (*cond*) and the power (*power*) in a length–weight relationship are input data.

$$\tilde{w}_{la} = C_{la} \cdot cond \cdot \exp(power \cdot \log(l)) \quad \text{(the weight in each cell)}$$

$$\tilde{l}_{la} = C_{la} \cdot l$$

Note that in the above 2 equations l is a midpoint if 5 cm grouping has been chosen.

The total frequency in the key is:

$$C_{..} = \sum_l \sum_a C_{la}$$

and total weight

$$\tilde{w}_{..} = \sum_l \sum_a \tilde{w}_{la}$$

So the mean weight in this area, season and gear combination is

$$\overline{w} = \frac{\tilde{w}_{..}}{C_{..}}$$

The ratio of weight and number by age from the total:

$$ratio\_w_a = \sum_l \tilde{w}_{la} / \tilde{w}..$$

$$ratio\_C_a = \sum_l C_{la} / C..$$

The mean weight and mean length-at-age and ratio mature-at-age are:

$$\overline{w}_a = \frac{\sum_l \tilde{w}_{la}}{\sum_l C_{la}}$$

$$\bar{l}_a = \frac{\sum_l \tilde{l}_{la}}{\sum_l C_{la}}$$

$$ratio\_M_a = \frac{\sum_l CM_{la}}{\sum_l (CM_{la} + CIM_{la})}$$

if the denominator > 0 otherwise the *ratio_M_a is set to -1.*

Catches in numbers

Input data for this module is the landings in tons (*catch*) for each area, season and gear.

The total number of fish caught is:

$$C_{tot} = \frac{catch}{\overline{w}}$$

The catches in numbers and weight by age is then

$$C_a = C_{tot} \cdot ratio\_C_a$$
$$W_a = C_a \cdot \overline{w}_a$$

To derive the total catches in numbers and weight summation is done over all areas, seasons and gears.

Historical catch in numbers and weight-at-age: 1960–1979

Tabulated annual catch in numbers-at-age of the Icelandic saithe catches can be found from 1960 onwards, with the earliest record found in the Report on the Saithe (Coalfish) Working Group 1976 (ICES C.M. 1976/F:2). However, it is obvious that the Coalfish working group members had compiled these historical numbers (from 1960 onward) already by 1973 (Report of the Saithe (Coalfish) Working Group, ICES C.M. 1973 / F: 10), this being deduced from the resulting VPA analysis done by the 1973 group, where a tabulation of stock in numbers and fishing mortality-by-age is given for the period 1960–1970. From the various recent ICES assessment reports dealing with Icelandic saithe, it can be deduced that the catch in numbers as originally reported in the Coalfish reports have remained unchanged, i.e. no later revisions were done to the calculated numbers.

Description on how the annual age composition of the catch for the period 1960–1980 were compiled by the ICES Working Group at the time are very limited and the calculation cannot be repeated. Number of annual samples, fish measured and age composition by fleet (countries) is not stated in the ICES assessment report from this time. In the 1973 Coalfish report it is noted that catch in numbers for Icelandic saithe in this early period were based only on samples from the German and English fleet. In the report it is then stated: "As a result it had to be assumed that the catches of the countries for which no data were available had the same age composition as the countries for which data were available. For each year the available age distributions of national catches were summed and the resultant age composition was then raised by the ratio of total landed weight of all countries to landed weight of countries for which age composition were known." However, in the same report it is further noted that "young saithe recruited first to the Icelandic purse-seine and trawl fisheries, then to the English trawl fishery and finally to the German trawl fishery". Given this, the approach of raising the catch composition from the German/UK age distribution to the total landings will most likely lead to a bias in the total catch-at-age distribution to some unknown degree. In particular since the Icelandic fleet took the largest share of the catches from 1967 onwards (Figure A.2.1). The earliest account where age composition from the Icelandic fleet is used as a part of the total annual catch-at-age matrix is in 1977 (Report of the Saithe (Coalfish) Working Group. ICES C.M. 1978/G:3). This is understandable because samples from the Icelandic fleet prior to that year are very limited (see above).

No information is provided in the early working group reports on how weight-at-age in the catches was derived. In all cases, annual weight-at-age used is a constant value over the time period. However, as early as 1973 (Report of the Saithe (Coalfish) Working Group. ICES C.M: 198–73/F:10) it was noted that ".. in the English data there was a clear trend of reducing length at age over the past 10–12 years for saithe …. The rate of reduction of average length has been about 1 cm per year, and over the period of 10 or 12 years this is equivalent to more than a year's growth. Similar but less marked trend is apparent in the German data." Given this observation, the use of a constant weight-at-age over this time period is obviously wrong. In addition it explains the significant discrepancy between sumproduct of catch numbers and weight-at-age vs. that of the total landings exist, particularly in the early part of the time-series. The catch weight-at-age has historically been used in the calculation of SSB. Using the constant weight-at-age results in significantly higher historical maximum SSB (Figure B.1.6, based on a simple VPA model) than if weights scaled so that the sumproducts of catch in number and weight-at-age are the same as the total landings (see WD02 for details of how rescaling was done).

Given that:

- The that samples of the catch composition from the Icelandic fleet is not available in the early time period;
- Fixed weight-at-age used in the early time period;
- Sumproduct discrepancy;
- Consequences different derivations have on the perception on the dynamic range.

data information prior to 1980 is not used, albeit at the cost of loosing information on the dynamic history of the stock and its response to fisheries. However, based on the VPA model (Figure B.1.6) the dynamic range of SSB in the period observed from 1980 is within the range observed in the long time-series.

B.2. Biological

A fixed natural mortality of 0.2 is used both in the assessment and the forecast.

The proportion of natural mortality before spawning (Mprop) and the proportion of fishing mortality before spawning (Fprop) are set to 0.

Weight-at-age in the stock is assumed to be the same as in the landings. For predicting next year's weights the catch weights from last year are used. If a large year class occurs having a low mean weight account should be taken in the short-term predictions.

Maturity-at-age is based on measurements obtained in the Icelandic groundfish spring survey (Figure B.2.1) using a smother (see below). Spawning of saithe starts late January with a peak in February, just before the survey time. The survey time is thus close to the spawning time making visual detection of maturity stages optimal. Maturity-at-age data from surveys are considered to give better estimates of maturity-at-age in the stock than those from landings data, in particular because of limited ungutted samples in the landings (Figure B.1.2).

Because the annual survey estimates of maturity-at-age are very noisy (Figure B2.1.) a model to smooth the maturity data is used. All fish at age 10 and older are set as mature. The model fitted (using Splus) is:

$$\text{logit}(P_{a,t}) = \alpha + \beta\, s(\text{age},df=4) + ns(\text{year},df=6)$$

where P is the proportion mature-at-age a in year t. S and ns are smoothing splines used to increase the flexibility of the model. Results for two age groups, 5 and 7, are shown in Figure B.2.2 along with the mean proportion mature for the same age groups from the survey data.

B.3. Surveys

An account of the Icelandic March (Spring, 1985–onwards) and October (Fall, 1996–onwards) groundfish surveys were provided as a WD for the Benchmark 2010 (WD-03). The WD is a translation of a citable report (http://www.hafro.is/Bokasafn/Timarit/rall_2007.pdf) written in the native language. It will be formally published in non-native speaking language in spring 2010. In summary, the surveys design is a classical random stratified design with fixed stations with time. With the caveat that experienced captains given the freedom to choose particular stations within a certain predefined geographical constraint determined by the scientist. The number of stations in the spring survey is 530; the number of stations in the fall is 380. The spring survey covers depth to 500 meters, but the fall survey covers depths down to 1200 m.

The longer spring survey time-series covers to a large degree the traditional fishing grounds of saithe (Figure A.2.3). The shorter fall survey covers almost the entire distributional range of the fisheries (Figure B.3.1), although with only half the station density. The covarge of both surveys is however very poor for juvenile saithe, which are thought largely to inhabit coastal areas very close to shore. Hence the surveys do not provide reliable measurements of incoming recruits.

The survey indices for saithe that are used as tuning indices are derived using conventional methods. Year effects, particularly in the earlier period are very apparent in the survey biomass indices (Figure B.3.2) and result in age based indices, when plotted as "consistency plots" to look very non-informative (Figures B.3.3 and B.3.4). The "year effect" seen in the surveys is largely thought to be a result of the schooling nature of the species, with an accompanying high cv estimates in the survey abundance indices. However, there are indication that the surveys are able to track cohorts to some degree, in particular when catch curves of survey indices are plotted on the log-scale, the scale that the model "sees the data" (Figure B.3.5). Hence, in order to use the information in the cohort signal from the surveys for species such as Icelandic saithe in an assessment framework some measures must unfortunately be made to allow for the year effect in the survey to be "a parameter" in the model.

B.4. Commercial cpue

Catch per unit of effort are routinely calculated during the annual assessment process (Figure B.4.1). The overall trend in catch rates demonstrate similar trend with time, irrespective of how the indices are derived (mean, median, <50% or >50% saithe per haul), but the absolute values differ. The indices increased sharply from 2000–2004 but have decreased since then, but are still above the level in 1988–2000. Although this trend corresponds roughly with the perceived stock dynamics, the cpue for Icelandic saithe has not been considered a reliable unbiased index to be used quantitatively as a tuning series in an analytical model.

C: Modelling framework (historical stock development)

Historical account of models used for saithe assessments

In the 1980s and early 1990s a traditional VPA was used for assessing the Icelandic saithe. The input terminal F for the VPA was estimated by various data sources and different *ad hoc* methods.

From 1993–2001 both XSA (except in 1999 and 2000) and TSA were run and compared. In all years cpue data were used as tuning-series in XSA. Only catch data were used running TSA, except in 1997 and 1999 where cpue data were used as well. The decision taken each year was to use the terminal Fs estimated by TSA as input values for a traditional VPA.

In 2002 survey indices for saithe from the Icelandic groundfish survey in spring were used for the first time in an assessment. XSA, TSA and an ADAPT model were used. The conclusion was the same as in last year's, Fs taken from TSA and put into a traditional VPA.

In 2003 Icelandic saithe was not assessed by ICES. Domestic TSA, ADAPT and camera (a separable model implementation in ADMODEL builder) were used as assessments programmes. The decision taken this time was to use camera as the final run.

In 2004–2006 camera was used as a final run by ICES, but other models like TSA, cadapt (ADAPT type model implemented in ADMODEL builder), AMCI (a "flexible" separable model) and ADCAM (a forward running statistical catch-at-age model implemented in ADMODEL builder, allowing for "random walk" in Fay) were un as well. In 2006 XSA was also run again.

In 2007 Icelandic saithe was not assessed by ICES. Domestic TSA, camera and ADCAM were run. The use of camera was rejected due to shifts in the age composition of the landings and it was not considered realistic to assume a fixed selection pattern for the whole assessment period like camera did. Then ADCAM was adopted and since then it has been the assessment program giving the final results each year. For comparison TSA has also been run every year.

Current model used-adopted at the Benchmark 2010

A forward running separable statistical catch-at-age model, allowing changes in selectivity to occur in specified years is used. The software used is ADMODEL builder, adapted to the saithe by Höskuldur Björnsson, MRI. The source code and an LINUX executable version are stored by ICES. The model is set up so that both stock assessment and predictions are run at the same time. The code is to a large extent the same as was used by ICES for the HCR evaluation of Icelandic cod in December 2009.

Operating model

The operating model is the virtual world, which is supposed to reflect the true system in the evaluation framework. The virtual world here is very simple with constant M, no length based parameters, etc.

The biological model is a simple single-species age structured population following the classical exponential stock-equation:

$$N_{a+1,y+1} = N_{ay} e^{-\left(F_{ay} + M_{ay}\right)}$$

The age groups in the model are 1 to 14 years with age 3 the youngest age in the landings. In the settings here the oldest group (14 years) is not a plus group!

Migration events are estimated at specific year and ages and are then added to the number in stock at the beginning of the year. The size of migration events is estimated as an additional parameter, equivalently as annual recruitment estimates.

Catches are taken according to the catch-equation:

$$\hat{C}_{ay} = \frac{F_{ay}}{F_{ay} + M_{ay}} \left(1 - e^{-(F_{ay} + M_{ay})}\right) N_{ay}$$

$$\hat{C}_y = \sum_a \hat{C}_{a,y} W^c_{a,y}$$

Fishing mortality by year and age is modelled as:

$$F_{ay} = s_a F_y$$

The time period that where catch-at-age data are available can be divided in a number of subperiods with the selection pattern s_a estimated separately for each period. The selection pattern of ages 11–14 is assumed to be identical and defined as 1.

Spawning is assumed to occur at the beginning of the year so no mortality takes place before spawning. This is not strictly correct but a good approximation

The spawning stock is then calculated by

$$SSB_y = \sum_a N_{y,a} W^{ssb}_{y,a} \; p_{y,a}$$

where $p_{y,a}$ is the proportion mature by year and age.

The predicted recruitment is (in the Benchmark 2010) calculated as a simple hockey-stick given the data available at the time.

Reference biomass is calculated from

$$B^{ref}_y = \sum_{a=4}^{a=14} N_{ay} W^c_{ay}$$

where W^c_{ay} are the mean weight-at-age in the landings.

Observation model and objective functions

The model parameters are estimated by minimizing a negative log-likelihood that is the sum of 4 components.

1) Landings in numbers

$$\Psi_1 = \sum_{a,y} \frac{\log \dfrac{C_{ay} + \delta_a}{\hat{C}_{ay} + \delta_a}}{2(\Omega_1 \sigma_a)^2} + \log(\Omega_1 \sigma_a)$$

where Ω_1 is an estimated parameter but the pattern of the measurement error with age σ_a is read from the input files. The values δ_a are input from file. They are supposed to reflect the value where the error goes from being lognormal to multinomial. Typical value could be corresponding to 5 otoliths sampled.

2) Landings in tonnes

$$\Psi_2 = \sum_{a,y} \frac{\log \frac{C_y}{\hat{C}_y}}{2\Omega_2^{\ 2}} + \log \Omega_2$$

where C_y are the "real" landings in tonnes in year y, $\hat{C}_y$ the modelled landings and Ω_2 the assumed standard error of the landings. The value of 0.05 was used for Ω_2 in these runs. The likelihood component Ψ_2 is somewhat redundant as it is already incorporated in Ψ_1. Leaving Ψ_2 out will on the other hand lead to unacceptable deviation between observed and predicted landings in numbers.

3) Survey abundance in numbers

Initially the survey likelihood was calculated by

$$\Psi_3 = \sum_{a,y} \frac{\log \frac{I_{ay} + \delta_a^s}{\hat{I}_{ay} + \delta_a^s}}{2(\Omega_3 \sigma_a^s)^2} + \log\left(\Omega_3 \sigma_a^s\right)$$

where Ω_3 is an estimated parameter but the pattern of the measurement error with age σ_a^s is read from the input files. The values δ_a^s are input from file and are similar to δ_a in Ψ_1. The predicted survey numbers $\hat{I}_{ay}$ are calculated from the equation $\hat{I}_{ay} = q_a N_{ay}^{b_a}$. The parameters q_a are estimated, but the parameters b_a are set to all set one as the survey indices are considered too noisy to estimate those extra parameters.

For Icelandic saithe year effects are apparent in the survey and were taken into account by modelling the survey residuals by a multivariate normal distribution.

$$\Gamma = \log \frac{I_{ay} + \delta_a^s}{\hat{I}_{ay} + \delta_a^s}$$

a=2:10 is the vector of survey residuals in a given year.

$$\Psi_3 = 0.5 \sum_y \log\det \Theta_6 + \Gamma_y^{\ T} \Theta_6^{-1} \Gamma_y$$

The matrix Θ_6 is calculated from the equation. $\Theta_{6ij} = \Omega_3^2 \sigma_i^s \ \sigma_j^s \ \kappa^{abs(i-j)}$ where κ is an estimated parameter and the parameters Ω_3 and σ_a^s are explained above. When the value κ is high the equation approaches modelling the survey indices as a year factor.

4) Stock – recruitment parameters

$$\Psi_4 = \sum_{a,y} \frac{\log \frac{N_{1y}}{\hat{N}_{1y}}}{2\Omega_4^{\ 2}} + \log \Omega_4$$

where $\hat{N}_{1y}$ is the estimated recruitment from the stock–recruitment function and Ω_4 is an estimated parameter. Ω_4 can be set as a function of SSB (usually increasing with smaller SSB) but that option was not used in the simulations in the 2010 Benchmark. Autocorrelation of the residuals are quite high for saithe exemplified by periods of good and bad recruitment. The modelling of the autocorrelation is done in the same way as the modelling of the yearfactor in the survey.

$$\Gamma_y = \log \frac{N_{1y}}{\hat{N}_{1y}}$$

y=1980:2009 is the vector of recruitment residuals in a given year.

$$\Psi_4 = 0.5 \sum_y \log\det\Theta_7 + \Gamma_y{}^T \Theta_7^{-1} \Gamma_y$$

The matrix Θ_7 is calculated from the equation. $\Theta_{7ij} = \Omega_4^2\ \rho^{abs(i-j)}$ where ρ is an estimated parameter and the parameters Ω_4 explained above.

The stock–recruitment models used were either constant recruitment or Hockeystick recruitment with the breakpoint estimated.

5) Overall objective function

The total objective function to be minimized is ρ is in used to in a first order AR model in future predictions. The estimated value is 0.45 and inclusion of it does not have much effect on the outcome of prognosis.

$$\Psi = \sum_{i=1}^{i=4} \Psi_i$$

Parameter estimated

The estimated parameters in most of the runs are:

- Effort F_y for each year 1980–2009;
- Selection pattern s_a for ages 3–10 (set to 1 for ages 11–14) in 2 periods, 1980–1995 and 1996–2009;
- Number of age 2 saithe 1980 to the present;
- Initial number in each age group (2-14) in 1980.
- Migration events. Age 7 1991 is always include but diagnostics by allowing migration event at age 7 in 1999 is sometimes checked;
- Parameters of the stock recruitment function (2–4 depending on the function used). In addition CV in the stock recruitment function is estimated;
- Catchability the survey q_a for ages 1–7 with 8–10 same as 7. 3 CV parameters Ω_1 Ω_3 and Ω_4, parameter κ for modelling yearblocks in the survey and parameter ρ to model recruitment residuals.

After the estimation is done the estimated variance-covariance matrix was used as proposal distribution in MCMC simulations (see Admodel builder manuals). The number of runs was between 300 000 and 1 000 000 and the parameters values were saved every 250th or 500th time. The saved chain was then used in prediction.

Prediction model

Natural mortality was fixed to 0.2.

Stochasticity in future weight-at-age in the stock (W_{ay}^{s}), the catch (W_{ay}^{c}) and spawning stock (W_{ay}^{ssb}) are modelled as:

$$W_{ay}^{s} = \hat{W}_{ay}^{s} e^{E_y^w}$$

$$W_{ay}^{c} = \hat{W}_{ay}^{c} e^{E_y^w}$$

$$W_{ay}^{ssb} = \hat{W}_{ay}^{ssb} e^{E_y^w}$$

where,

$$E_y^w = \left(\rho_w E_{y-1}^w + \sqrt{1-\rho_w{}^2}\,\varepsilon_y \right)$$

$$\varepsilon_y = N(0,1)$$

The mean values of $\hat{W}_{ay}^{s}$, $\hat{W}_{ay}^{c}$ and $\hat{W}_{ay}^{ssb}$ in the 2010 Benchmark were the most recently observed values from 2009. The selection of those "average value" has considerable effect on the outcome and the selected values are around 12% below the average from the long term. Expert judgement by WG, based on future patterns may change the basis used.

In the prediction recruitment is generated by the estimated stock–recruitment function (Hockey-Stick in the 2010 Benchmark). Added to the estimated recruitment is random lognormal noise with CV estimated by the assessment part of the model. Autocorrelated residuals in recruitment are modelled in the same way as autocorrelated stochasticity in mean weight-at-age.

The selection pattern used in the 2010 Benchmark prediction is the selection pattern of the last "selection period" (1996–2009). This may change if different selection pattern is considered appropriate by the WG for years where data have not yet observed. No stochasticity is modelled in the selection pattern but the uncertainty in the estimated selection pattern is transferred to the prediction.

Assessment error is modelled as autocorrelated lognormal noise as done for the stochasticity in weight.

$$\tilde{F}_y^{ref} = F_y^{ref} e^{E_y^b}$$

Where,

$$E_y^b = \left(\rho E_{y-1}^b + \sqrt{1-\rho^2}\,\varepsilon_y \right)$$

When the stock is below $B_{trigger}$ intended fishing mortality was reduced by linear reduction in fishing mortality according to:

$$F_y^{ref} = F_y^{ref0-} \frac{SSB_y}{B_{trigger}}.$$

(as suggested in the ACOM "default" approach in the new MSY concept.)

The above implementation means that error in estimation of SSB is taken into account, when fishing mortality is underestimated and vice versa. The ultimate goal in using this assessment framework is to implement HCR based on biomass that leads to a definition of target fishing mortality in relation to the ICES Fmsy concept. Given that uncertainty in the assessment and the short-term prediction is already taken into account, the estimates of the Fmsy proxy derived here are not comparable with that derived from a deterministic approach.

Of note is that no implementation error is included in the simulations.

CV of residuals in the catch and the survey estimated, with and one multiplier estimated the survey and one for the catch. The *a priori* set age group patterns (σs) and stabilizers (εs) are given in the text table below: δ_a is set to 0.7% of the total catch in numbers each year.

AGE	CATCH	SURVEY	SURVEY
Group	σ_a	δ_a^s	σ_a^s
1			
2		1	0.50
3	0.17	0.5	0.30
4	0.13	0.5	0.22
5	0.11	0.5	0.19
6	0.10	0.5	0.16
7	0.10	0.3	0.19
8	0.10	0.3	0.24
9	0.11	0.3	0.35
10	0.12	0.3	0.45
11	0.15		
12	0.19		
13	0.26		
14	0.37		

Linear catchability relationship for all age groups in survey.

Weights and maturity have been given with matrices based on different data to produce alternative versions/flavours of stock and SSB biomass.

Migration is estimated for 1 events, *i. e.* for age group 7 in 1991. 4 other events are hypothesized, i.e. age 10 in 1986, 9 in 1993, 7 in 1999 and 8 in 2000, but were not used in the Benchmark 2010. The timing of these migration events and the age groups included are determined/based on loose indications from deviations from 'normal' weight-at-age, *i. e.* abnormally low. Potential future migrations will be evaluated using the same procedure.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1980–onward		Yes
Canum	Catch at age in numbers	1980–onward	3–14	Yes
Weca	Weight at age in the commercial catch	1980–onward	3–14	Yes
West	Weight at age of the spawning stock at spawning time.	1980–onward	3–14	Weca is used as West.
Mprop	Proportion of natural mortality before spawning	1980–onward	3–14	No, kept fixed at 0.
Fprop	Proportion of fishing mortality before spawning	1980–onward	3–14	No, kept fixed at 0.
Matprop	Proportion mature at age in the survey	1980–onward	3–14	Yes, but modelled with a smoother.
Natmor	Natural mortality	1980–onward	3–14	No, kept fixed at 0.2.

The input data used in the 2010 Benchmark are archieved on the 2010 Benchmark SharePoint site.

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Icelandic spring groundfish survey	1985–onward	1–10

D. Short-term projection

Model used/software used: The same software is used for forward projections as the assessment. For parameter settings and input data see Chapter C.

E. Medium-term projections

Model used/software used: The same software is used for forward projections as the assessment. For parameter settings and input data see Chapter C.

F. Long-term projections

Model used/software used: The same software is used for forward projections as the assessment. For parameter settings and input data see Chapter C.

G. Biological reference points

The following reference points (taken from the 2009 stock summary sheet) have been used as the basis of the advice in the precautionary framework:

	Type	Value	Technical basis
Precautionary approach	Blim	90Kt.	Bloss estimate in 1998
	Bpa	150 Kt.	Observed low SSB values in 1978–1993
	Flim	Not defined.	
	Fpa	0.3	Fishing mortality sustained for 3 decades.

Targets	Fy	Not defined.

(unchanged since 1998)

Note: taking into account the strong reductions in mean weight-at-age and change in fishing pattern, the F_{pa} as defined in 1998 now corresponds to a lower fishing mortality than 0.3. Under the current conditions F_{pa} corresponds to a value of 0.22. B_{pa} has been calculated based on of inappropriate historical weight-at-age. Therefore it cannot be used as basis for advice.

The time-series used has been shortened to 1980–onwards in 2010 Benchmark. In addition the maturity 0-gives now used are based on maturity derived from the survey, not from the catches as done in 1998. The result is that the SSB has been scaled downwards relative to calculated in 1998. Because of the new MSY framework being established by ICES the above reference points, established in 1998 were not addressed by 2010 Benchmark. Within the developing MSY-framework in ICES an Fmsy proxy for the stock of 0.28 and Btrigger of 80 kt were considered as a suitable candidate by the 2010 Benchmark.

I. References

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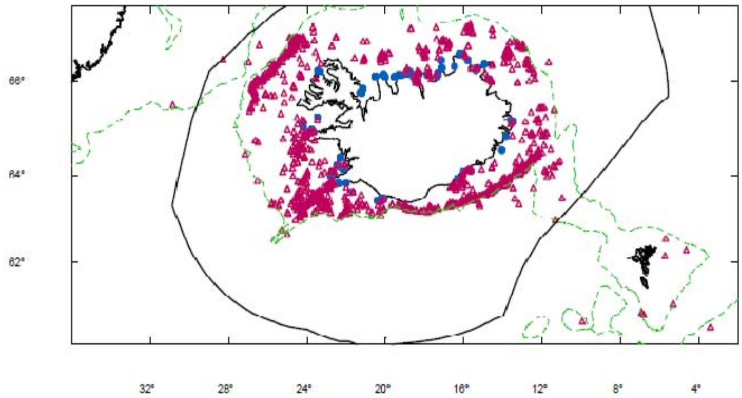


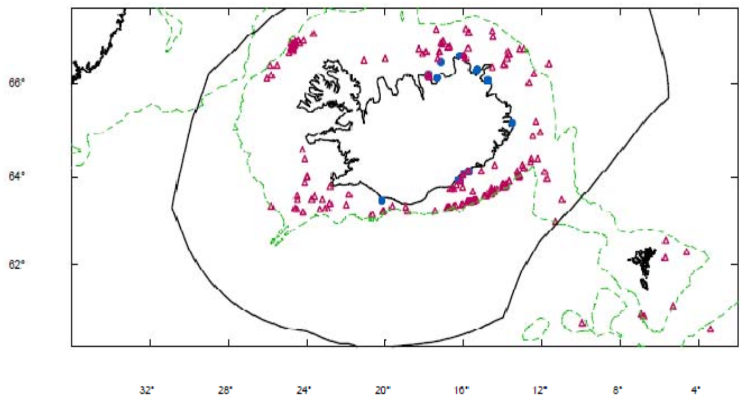


Figure A.1.1. Results from taggings in 2000–2004. Total returns, above; returns after more than 560 days at liberty (the shortest period at liberty in the recaptures from the Faroes) from the set of stations from which tags were recaptured at the Faroes or on the Faroe-Iceland Ridge, below. Blue dots denote tagging locality, violet triangles recapture location, the 500 m isobath and approximate Icelandic EEZ boundary are also shown.

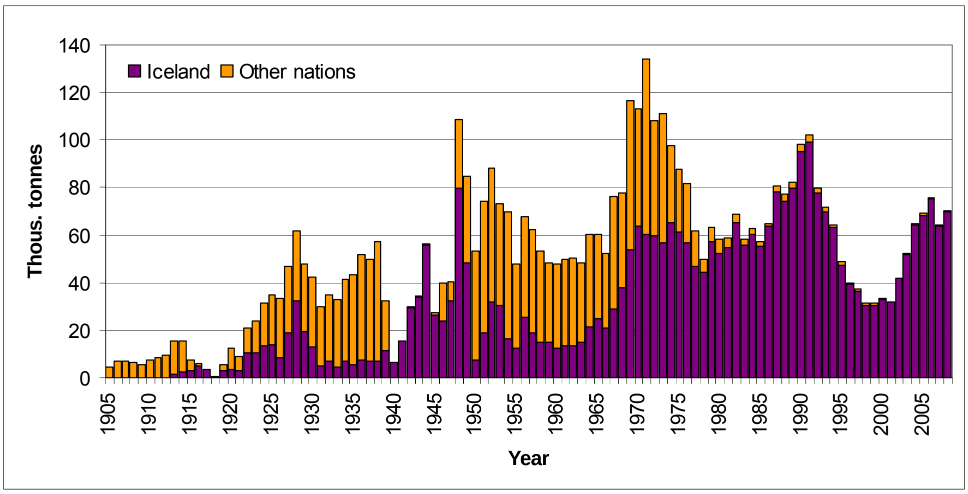


Figure A.2.1. Saithe in Va. Landings in thousand tonnes in the years 1905–2008.

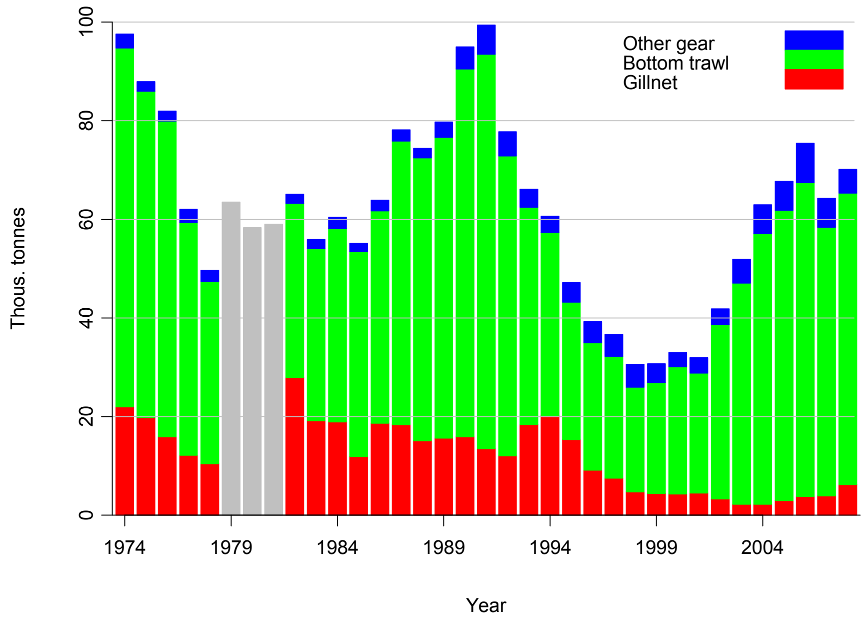


Figure A.2.2. Saithe in Va. Annual landings by gear type 1974–2008.

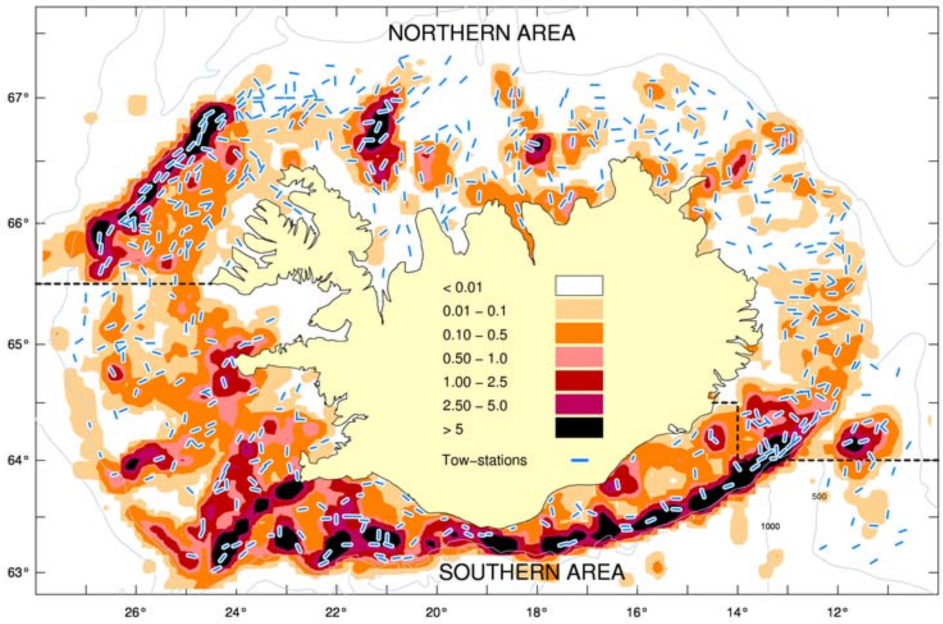


Figure A.2.3. Contour-plot of the distribution of commercial catches of saithe in Va (tonnes/square mile) in 2008, blue lines are tow-stations in the Spring Survey (March). The 500 and 1000 m depth contours are shown.

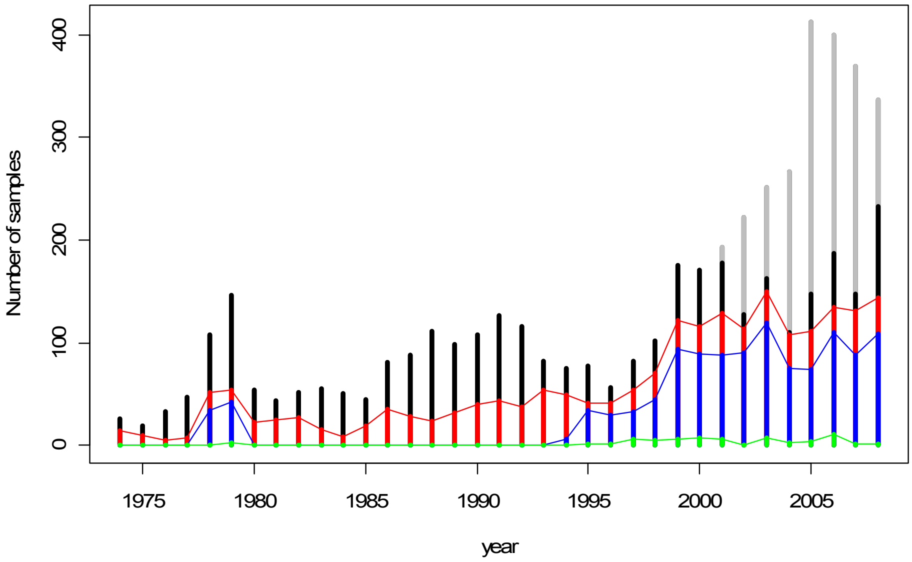


Figure B.1.1. Saithe in Va. Number of annual samples from the Icelandic fishing fleet 1974–2008. The grey bars refer to the total number of samples (including from the discarding programme), black bars refer to number of samples (excluding those from the discarding programme), the red bars to the number of samples where otoliths were taken, blue bars to the numbers sampled for gutted weight and green bars to numbers sampled for ungutted weight.

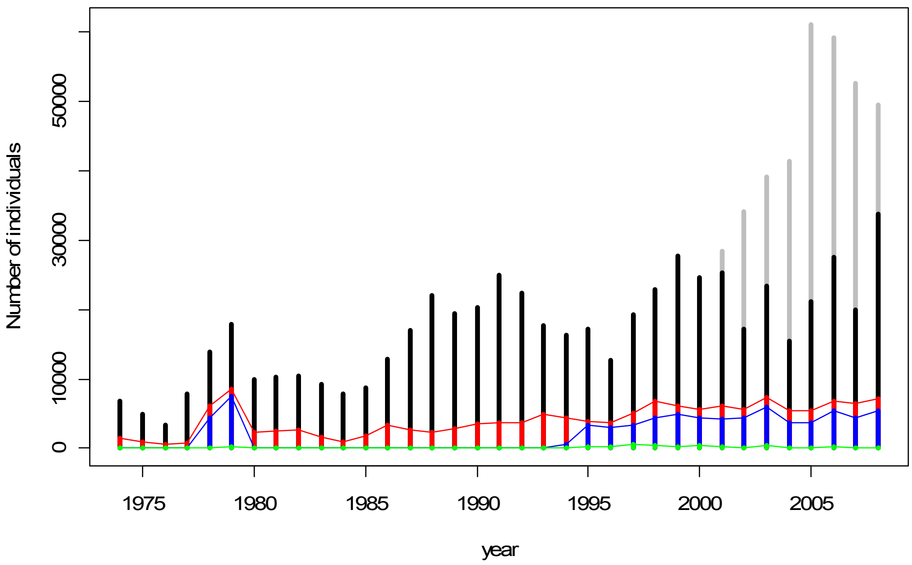


Figure B.1.2. Saithe in Va. Number of individual fish measurements from the Icelandic fishing fleet 1974–2008. The grey bars refer to the total number of measurements (including from the discarding programme), black bars refer to number of samples (excluding those from the discarding programme), the red bars to the number of samples where otoliths were taken, blue bars to the numbers sampled for gutted weight and green bars to numbers sampled for ungutted weight.

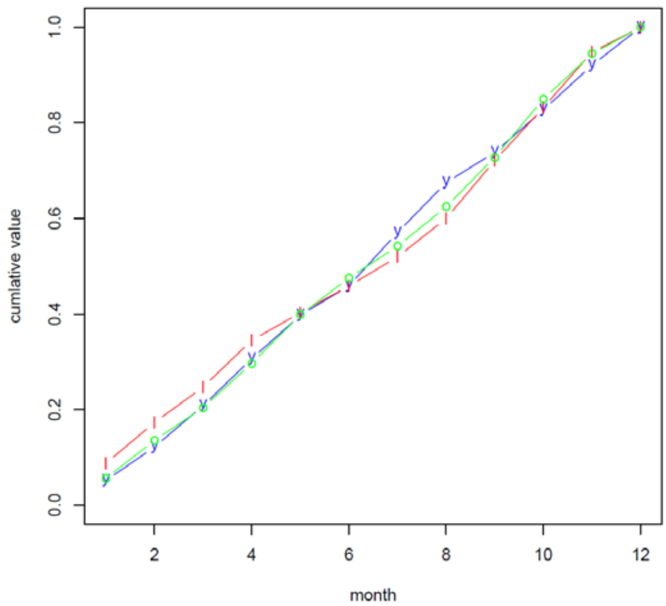


Figure B.1.3. Saithe in Va. Cumulative plot of landings (y: blue) and length (l: red) and otolith (o: green) sampling by month over the period 2005 to 2008.

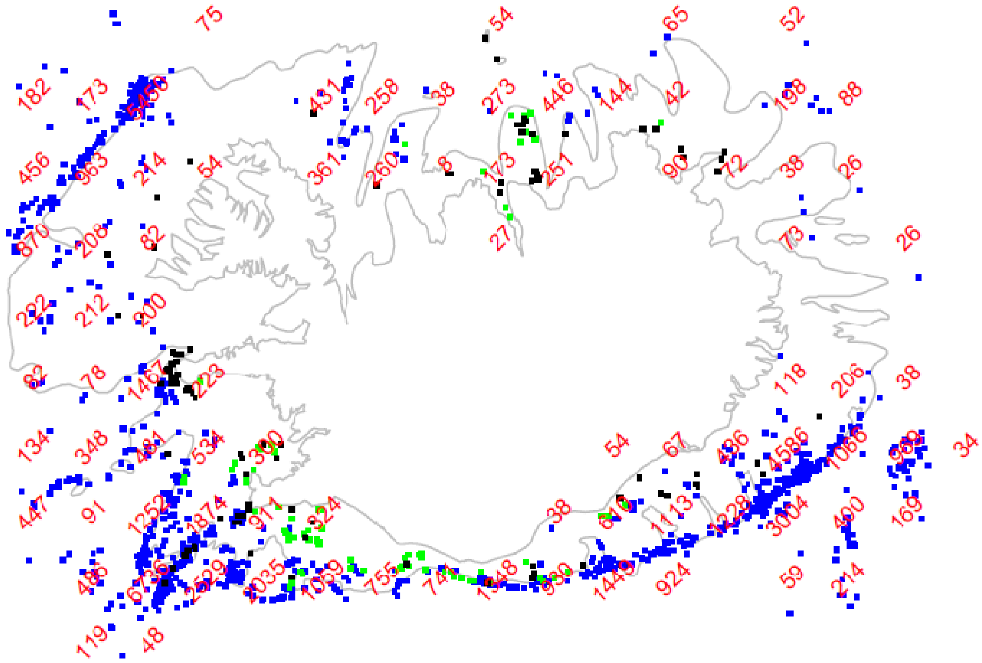


Figure B.1.4. Length samples: Location and average annual number sampled by statistical square for in 2005 to 2008. Blue dots indicate trawl sample, green gillnet samples and black dots other gear.

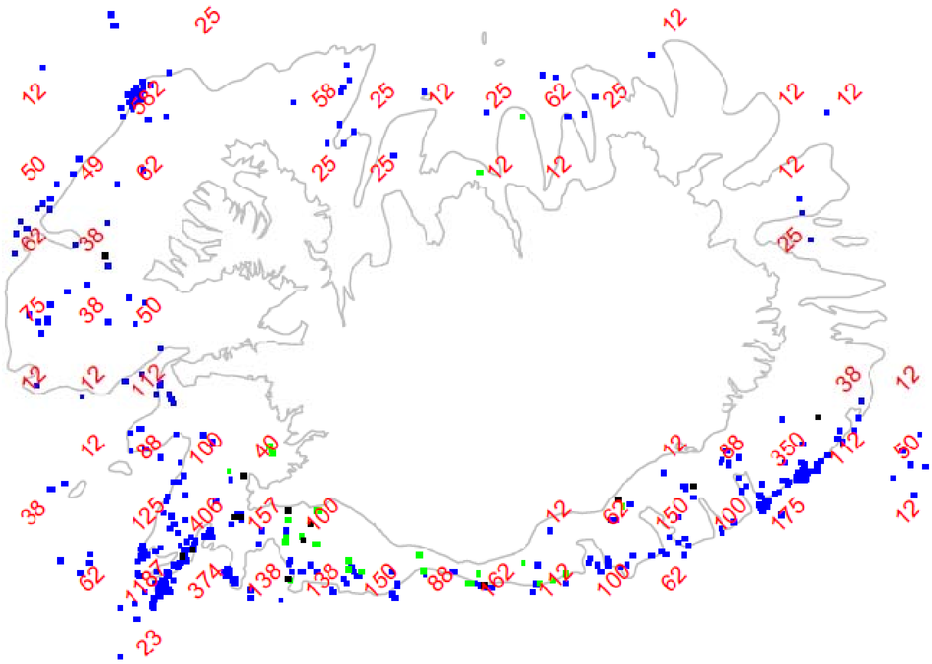


Figure B.1.5. Saithe in Va. Otolith samples: Location and average annual number sampled by statistical square for in 2005 to 2008. Blue dots indicate trawl sample, green gillnet samples and black dots other gear.

Figures B.1.6. Saithe in Va. Comparison of SSB trajectory based on constant weight-at-age (blue) matrix in period prior to 1979 and one where weights in that period were rescaled (red).

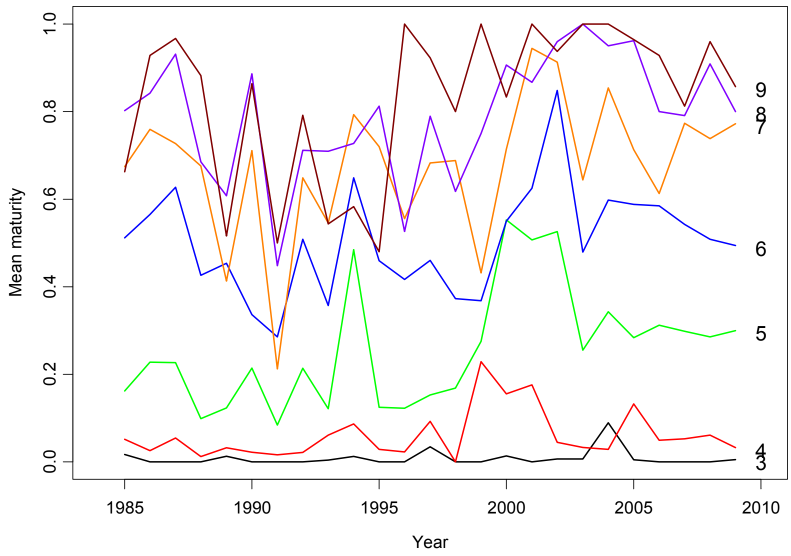


Figure B.2.1. Saithe in Va. Proportion mature-at-age by year in the spring survey (SMB).

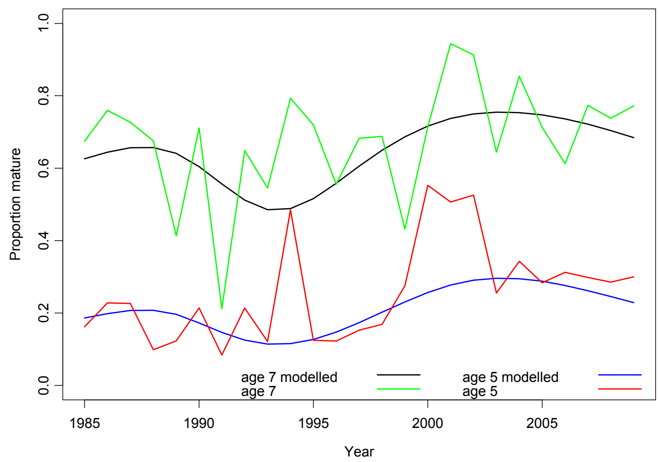


Figure B.2.2. Saithe in Va. Proportion mature-at-age 5 and 7 from the raw survey data and the modelled values from the smoothed glm model.

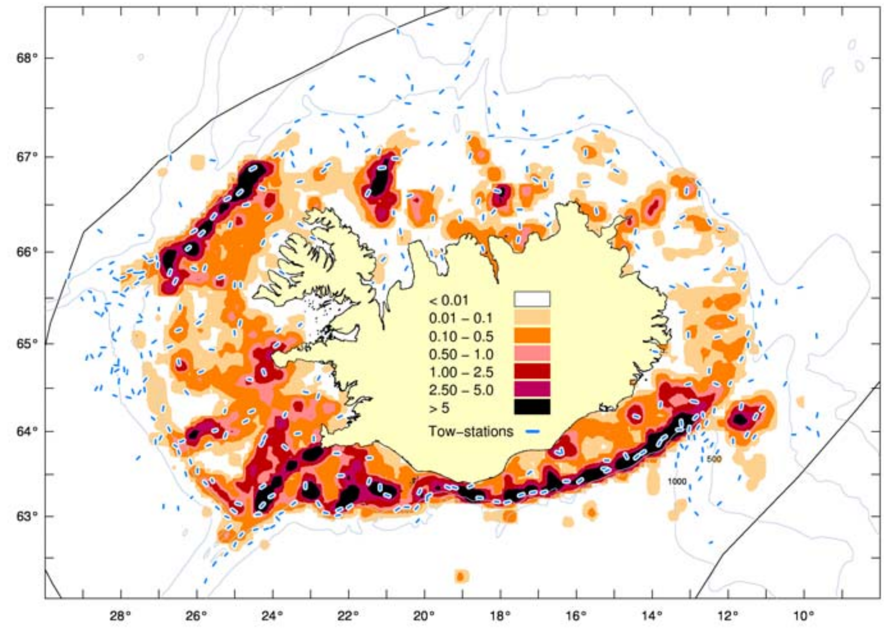


Figure B.3.1. Contour-plot of the distribution of commercial catches of saithe in Va (tonnes/square mile) in 2008, blue lines are tow-stations in the Autumn Survey (October). The 500 and 1000 m depth contours are shown.

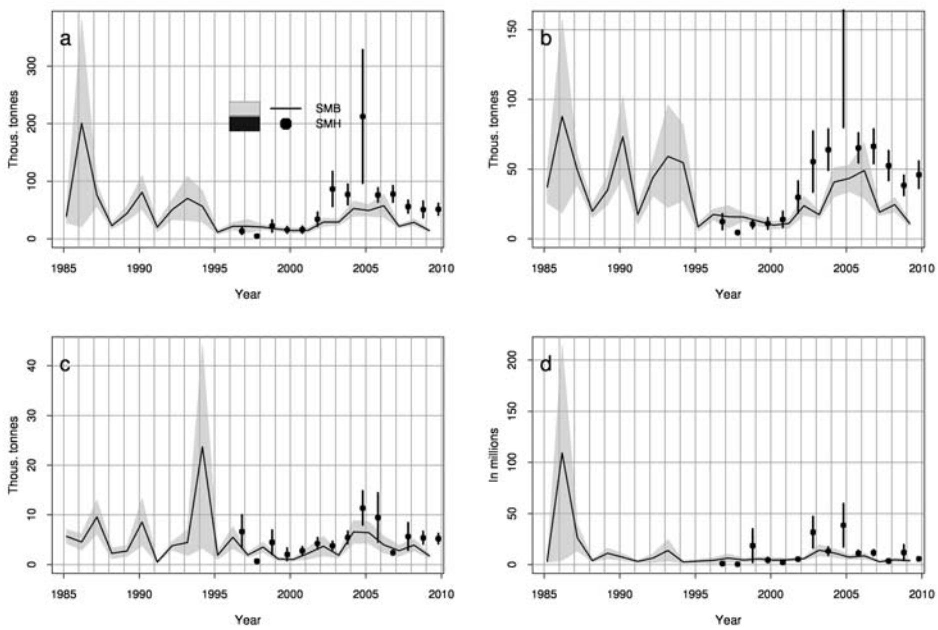


Figure B.3.2. Saithe in Va. Shown are a) total biomass indices, b) biomass indices larger than 55 cm, c) biomass indices larger than 90 cm and d) abundance indices smaller than 55 cm. The lines with shades show the Spring survey indices from 1985 (SMB) and the points with the vertical line show the Autumn survey (SMH) from 1997. The shades and vertical line indicate +/- 1 standard error.

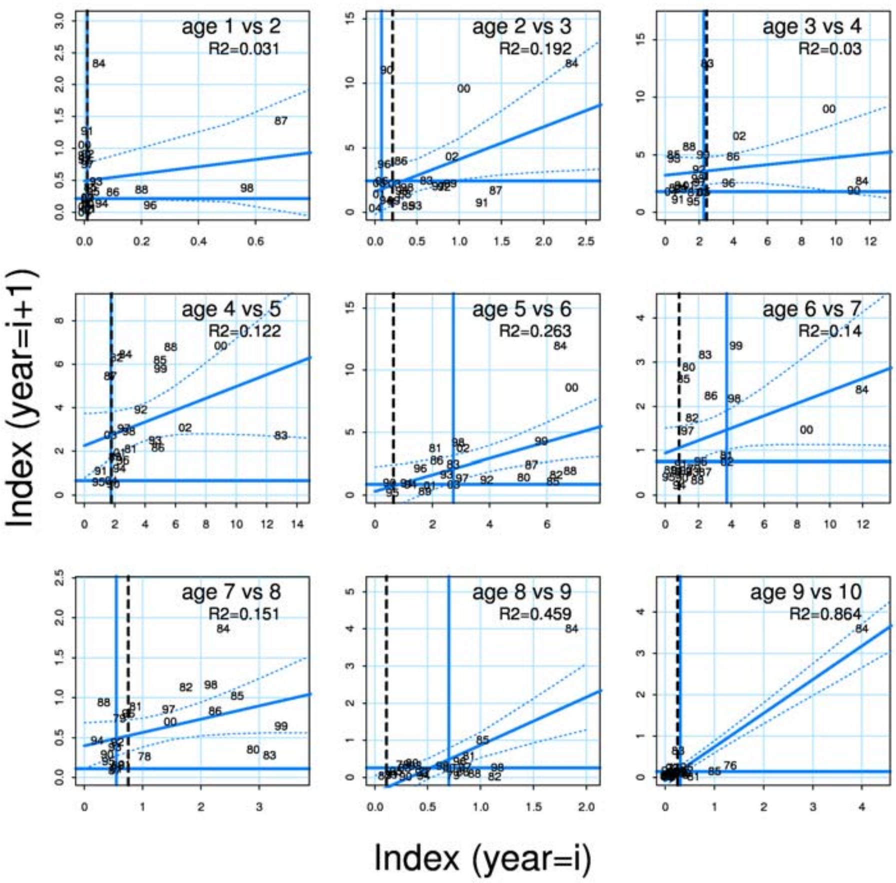


Figure B.3.3. Saithe in division Va. Indices from the Spring Survey vs. index of the same year class in survey a year later. The cross represents the last cohort age pair and the dotted vertical line is the value from the 2009 for the younger age in the pair plot.

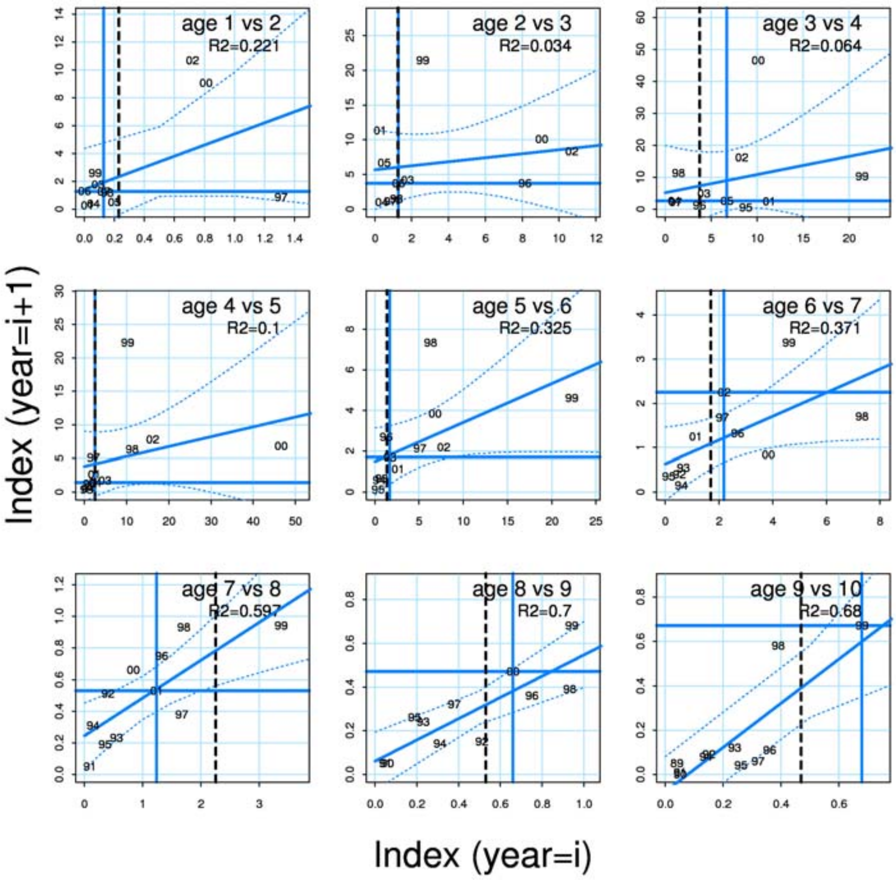


Figure B.3.4. Saithe in division Va. Indices from the Autumn survey vs. index of the same year class in survey a year later. The cross represents the last cohort age pair and the dotted vertical line is the value from the 2009 for the younger age in the pair plot.

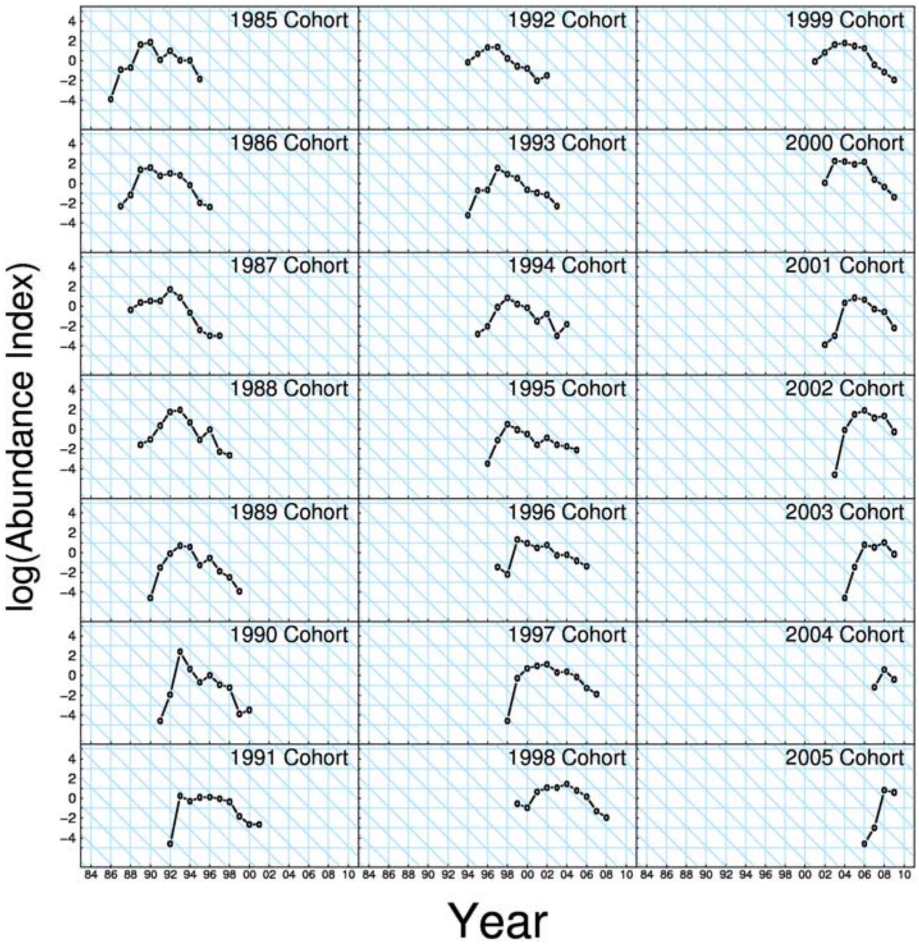


Figure B.3.5. Saithe in division Va. Catch curves from the Spring Survey. The grey lines show Z=1.

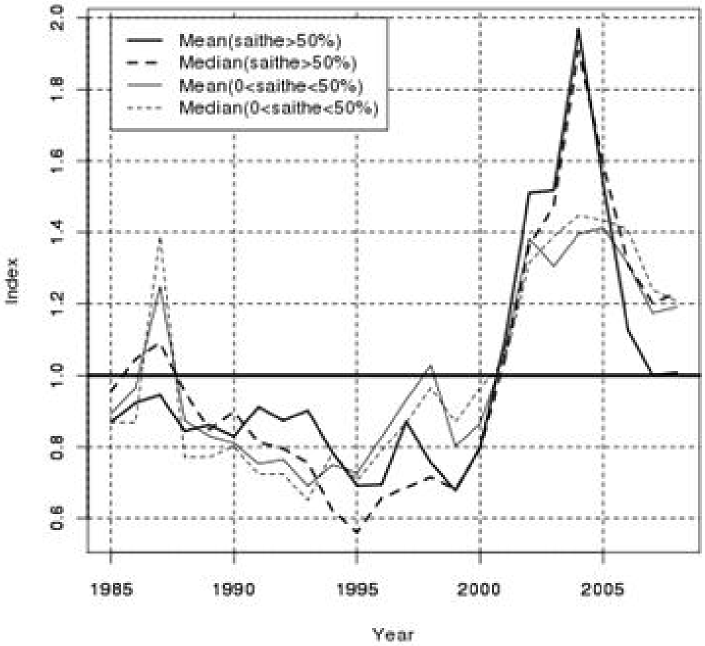


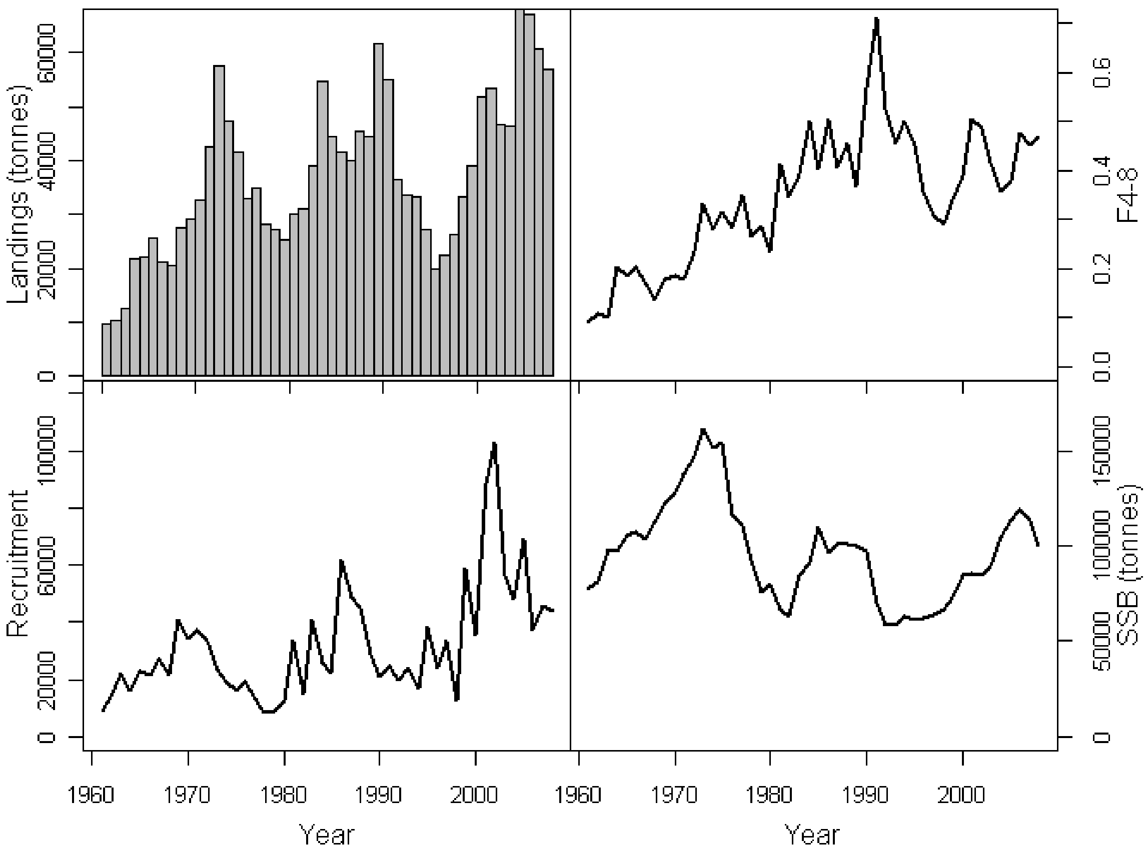
Figure B.4.1. Saithe in Va. Cpue where saithe is > 50% and < 50% of the catches in each tow. Shown are mean and median values and the long-term mean. The numbers are scaled to the mean of the time-series. The figure is taken from the NWWG Report in 2009.

4 Faroe Islands Saithe

4.1 Current stock status and assessment issues

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 model in association with updated catch-at-age data. The commercial cpue series was also updated, standardized and the density indices were multiplied by an area expansion factor to better represent a measure of total stock abundance. 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.

Landings over the last four years have decreased slightly, but remain at the highest levels observed over the history of this fishery. Average fishing mortality has nevertheless remained fairly stable over this time period due to increases in stock biomasses supported by strong recruitment over the last decade. Recruitment is beginning to return to average levels again and this would suggest that stock biomass will drop in subsequent years as well.



4.2 Compilation of available data

4.2.1 Catch and landings data

Landing information on Faroe Island saithe used in the benchmark assessment covers the years from 1961 through 2008. Landings of saithe in Faroe Island waters in 2008 were estimated to have been 57 025 tonnes (indicating a continuing drop in annual landings from record high levels). The catch-at-age information collected from the landings represents ages 3–12+ and this is the age range that is represented in the XSA model.

4.2.2 Biological data

Natural mortality was set at 0.2 for all ages over all years.

Maturity-at-age information was developed from spring survey data, which are available from 1983 onward. Smoothed ogive models fit, described in the stock annex (Section B.3) to these data were used in spawning-stock biomass calculations.

4.2.3 Survey tuning data

There are two annual groundfish surveys conducted in Faroese waters. The spring survey was initiated in 1983, while the summer survey began in 1996. The design of this survey, which uses a fixed station statistical design, has not been modified since 1993. Neither survey dataset is used in the benchmark XSA assessment due to high CVs and strong bias observed in several age-based models, e.g. XSA, NTF-Adapt and Statistical models (Stock annex, Section B.3).

4.2.4 Commercial tuning data

At the 2010 benchmark assessment the commercial cpue series was compiled based on hauls where saithe contributed to 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 took place. A GLM model using year, month, pair and depth as explanatory variables was applied to the resulting input data. In addition, an annual scaling factor taking into account the spatial distribution of saithe derived from survey indices (proportion of approximately 300 hauls containing at least one saithe in March and August) was multiplied to average predicted catch rates. The revised annual indices resulted in a substantial reduction in the bias observed in the retrospective pattern. The benchmark working group regarded this novel approach to developing the commercial series as reasonable. Another potential way of combining the GLM and a spatial factor is to estimate an annual Gini Coefficient to the cpue data to derive an index that incorporates spatial variability.

4.2.5 Industry/stakeholder data inputs

No additional information beyond the landings from the commercial fleet was presented for incorporation in the assessment at the benchmark workshop.

4.3 Stock identity and migration issues

Saithe in Division Vb 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 Northeast arctic saithe stock was sufficient to explain the tagging results, and that the emigration likely occurred before sexual maturity. Bearing in mind that the Northeast arctic saithe stock is larger than the saithe stock at the Faroes (by a factor of 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. Regarding the migration between Icelandic and Faroese waters, there have been 18463 juvenile saithe tagged in Icelandic waters in 2000–2005 (Armansson *et al*., 2007), and 1649 have been recaptured up to now, seven of them in Faroese waters (Marine Research Institute, Iceland, pers. comm.). This indicates that emigration rate of juvenile saithe to Faroese waters might be limited, but that the emigration rate of adult saithe (>70 cm long) might be more important. In conclusion, Faroe saithe seem to receive recruits from its own waters as well as recruits from the Northeast arctic saithe stock and probably also the North Sea stock.

4.4 Spatial changes in the fishery and stock distribution

No spatial changes in the fishery or stock distribution were noted during this benchmark.

4.5 Environmental drivers of stock dynamics

According to existing literature the productivity of the ecosystem clearly affects 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), over the period May through 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 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. No effort was made to incorporate these environmental factors into the assessment, but inclusion in future models may be useful to reduce uncertainty and help develop responsive harvest control rules.

4.6 Role of multispecies interactions

4.6.1 Trophic interactions

Food availability for other gadoid stocks (e.g. cod and haddock) may be reduced if the saithe stock were to increase. This increase would likely decrease individual growth for cod, which will tend to move to nearshore areas and prey on juveniles (1-year-old cod), thus imparing recruitment (to 2-year-old cod) (Steingrund *et al.*, 2010). Hence, a large stock of saithe may hamper the recruitment of cod, and there may exist a trade-off between the Fmsy for saithe and cod.

4.6.2 Fishery interactions

None were presented or discussed.

4.7 Impacts on the ecosystem

No evidence was presented to indicate that the fishery is impacting the marine environment adversely in a significant way.

4.8 Stock assessment methods

4.8.1 Models

An XSA (a VPA type model) was adopted for this benchmark review. The model uses information on landings-at-age, and standardized commercial spatially adjusted cpue indices to assess the state of the population.

4.8.2 Sensitivity analysis

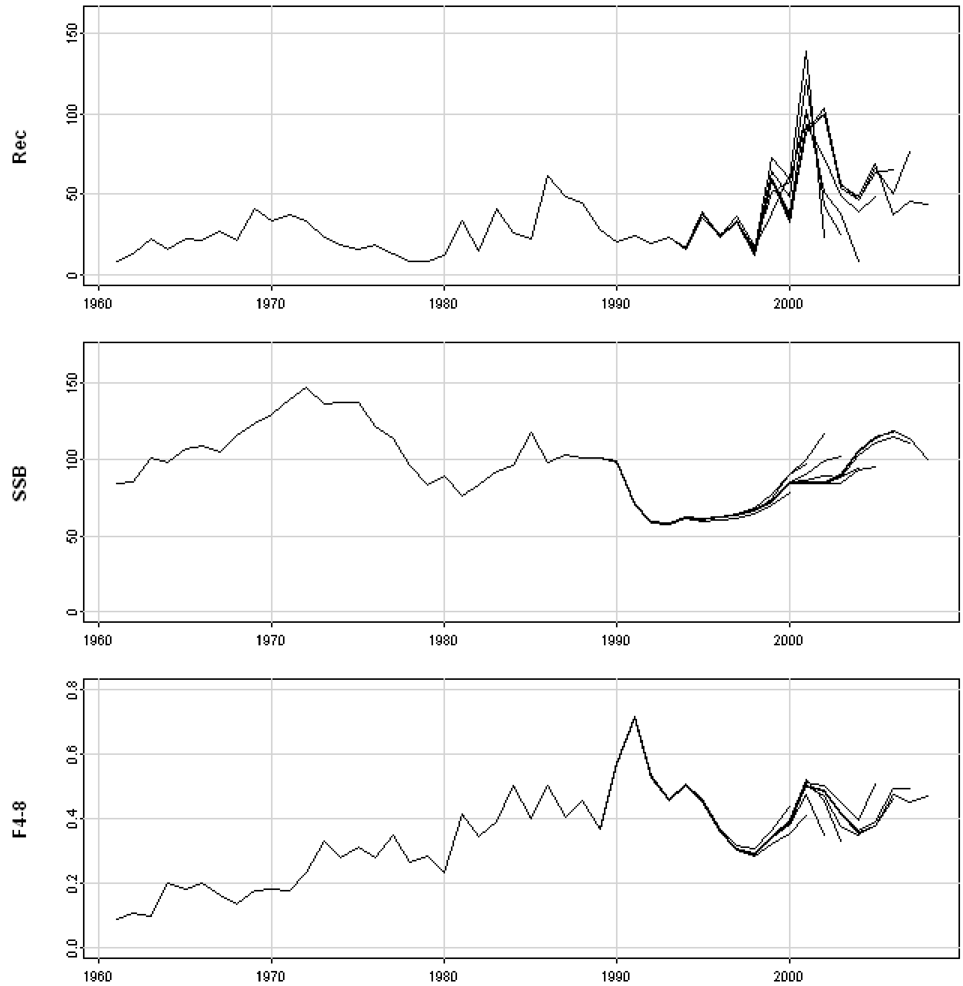
Several models were initially tested, then the data were updated and a final set of comparison runs using XSA and ADAPT were made. The results were found to be reasonably comparable and so the XSA was adopted as the benchmark assessment as it had already been used for several years on this fishery.

Terminal Year Estimates in 2008

Model	N3	SSB	F	Type	Class
Adapt	270 mills.	94 000 t.	0.51	Pair-trawl tunning	Age-based VPA model
Adapt – N3 Adjusted (see Section 3.10)	44 mills.	94 000 t.	0.51	Pair-trawl tunning	Age-based VPA model
XSA	277 mills.	99 600 t.	0.47	Pair-trawl tunning	Age-based VPA model
XSA– N3 Adjusted (see Section 3.10)	44 mills.	99 600 t.	0.47	Pair-trawl tunning	Age-based VPA model

4.8.3 Retrospective patterns

Although some retrospective pattern still remains, updating the data input to the model, specifically with regard to catch-at-age and the commercial cpue tuning index, has significantly improved the magnitude of the pattern and would appear to facilitate reasonable application of model findings to management actions. Recruitment estimates for 2008 remain highly uncertain.



4.8.4 Evaluation of the models

As stated above, model performance appears good and adequately represents stock status. But environmental drivers (also discussed above), which are not explicitly included in the assessment, could decrease uncertainty in future projections of stock trends.

4.9 Stock assessment

Spawning stock biomass has fluctuated between 60 000 and 150 000 tonnes over the last five decades. Recent increases in landings were supported by several years of strong recruitment. Recruitment has subsequently declined, but still remains above the time-series average. Fishing mortality has remained stable in recent years but above the long-term average. High fishing mortality and observed slow growth in year classes since 1996 might limit an increase in SSB despite the recent high recruitment.

Stock Assessment Summary

Given by year, recruitment, total biomass, spawning-stock biomass, landings, yield per SSB and average fishing mortality over ages 4–8.

Year	Rec	TB	SSB	Land	ySSB	Fbar
1961	9046	115934	77760	9592	0.11	0.091
1962	13663	121530	80703	10454	0.14	0.108

1963	22430	155468	97861	12693	0.14	0.1
1964	16191	159586	97540	21893	0.23	0.201
1965	22803	172603	105041	22181	0.23	0.183
1966	21830	182212	106838	25563	0.24	0.203
1967	26878	180952	103935	21319	0.2	0.166
1968	21514	186522	112680	20387	0.18	0.135
1969	40797	214057	122822	27437	0.23	0.179
1970	34135	223022	127718	29110	0.24	0.183
1971	37284	227016	138091	32706	0.22	0.177
1972	33606	236348	146870	42663	0.29	0.233
1973	23281	250539	161893	57431	0.35	0.333
1974	18896	226852	151780	47188	0.31	0.281
1975	16305	211575	154087	41576	0.27	0.313
1976	18910	164382	116650	33065	0.27	0.282
1977	12939	152909	110673	34835	0.3	0.351
1978	8414	134621	93250	28138	0.3	0.266
1979	8631	105141	75651	27246	0.35	0.285
1980	12449	116195	80291	25230	0.32	0.233
1981	33324	132643	66741	30103	0.47	0.413
1982	15211	130137	63278	30964	0.51	0.345
1983	40971	171779	84311	39176	0.46	0.392
1984	25957	185465	91279	54665	0.6	0.502
1985	22180	182006	109969	44605	0.43	0.402
1986	61680	233867	96455	41716	0.46	0.503
1987	48460	248411	100962	40020	0.41	0.405
1988	44822	260007	100717	45285	0.45	0.455
1989	28500	228128	100425	44477	0.46	0.367
1990	20684	190691	97233	61628	0.65	0.568
1991	24809	149436	70669	54858	0.78	0.71
1992	19549	123632	58821	36487	0.59	0.526
1993	23741	132974	58769	33543	0.56	0.456
1994	16819	126785	62678	33182	0.52	0.501
1995	38648	152425	61248	27209	0.44	0.451
1996	24249	162303	62451	20029	0.31	0.358
1997	33418	180887	63809	22306	0.35	0.306
1998	12727	165211	66939	26421	0.39	0.289
1999	58781	213044	73325	33207	0.44	0.339
2000	35639	225956	84962	39020	0.45	0.388
2001	88098	290695	85399	51786	0.61	0.504
2002	102960	328176	84685	53546	0.63	0.485
2003	56357	316980	89139	46555	0.52	0.416
2004	48102	304286	104912	46355	0.44	0.358
2005	68952	318106	113820	68008	0.6	0.376
2006	37374	267299	118971	67103	0.57	0.476
2007	45506	242999	113733	60819	0.54	0.45
2008	44000	228461	99668	57025	0.57	0.469

4.10 Recruitment estimation

Recruitment estimates are notoriously unreliable in any type of assessment model. To stabilize recruitment estimates in the most recent years, recruitment-at-age 3 is calculated as the geometric mean of the recruitments observed from 1995 to 2007.

4.11 Short-term and medium-term forecasts

Fishing mortality above 0.3 in 2010 causes projected SSB on January 1, 2011 to decline below the 100,000 mt assessment estimate for January 1, 2009, assuming that catch in 2009 is about 50 000 tonnes.

2009						
Biomass	SSB	FMult	FBar	Landings		
213206	91221	1.0000	0.4652	50071		
2010					2011	
Biomass	SSB	FMult	FBar	Landings	Biomass	SSB
204078	80282	0.0000	0.0000	0	248957	113409
.	80282	0.1000	0.0465	5674	242876	108631
.	80282	0.2000	0.0930	11078	237094	104115
.	80282	0.3000	0.1396	16228	231592	99845
.	80282	0.4000	0.1861	21138	226356	95807
.	80282	0.5000	0.2326	25822	221370	91988
.	80282	0.6000	0.2791	30292	216620	88373
.	80282	0.7000	0.3256	34559	212092	84951
.	80282	0.8000	0.3722	38637	207775	81711
.	80282	0.9000	0.4187	42534	203655	78642
.	80282	1.0000	0.4652	46261	199723	75734
.	80282	1.1000	0.5117	49827	195967	72978
.	80282	1.2000	0.5582	53241	192378	70364
.	80282	1.3000	0.6048	56511	188947	67884
.	80282	1.4000	0.6513	59644	185664	65532
.	80282	1.5000	0.6978	62649	182523	63298
.	80282	1.6000	0.7443	65532	179515	61177
.	80282	1.7000	0.7908	68300	176633	59162
.	80282	1.8000	0.8374	70957	173870	57248
.	80282	1.9000	0.8839	73512	171220	55427
.	80282	2.0000	0.9304	75967	168676	53695
Input units are thousands and kg - output in tonnes						

4.12 Biological reference points

In order to consider how F_{MSY} should be evaluated, a brief summary of existing reference points is given, as well as proposals for changes that are found in NWWG report. The stock size of Faroe saithe has fluctuated regularly between 110 and 330 thousand tonnes during the last 49 years (Figure 1, the period 1961–1963 is omitted from the Figure). When the stock is small, the weights tend to be large and *vice versa*. The total stock size is highly correlated with hydrographic conditions southwest of the Faroes some 4 years before, whereas the recruitment demonstrates a weaker correlation (Figure 2). There appears to be a negative relationship between the size of the spawning stock and subsequent recruitment, and the relationship is different for small-stock and large-stock situations (Figure 3).

In order to evaluate reference points, small-stock situations (1991–1998) and large-stock situations (2002–2007) are compared, as well as the entire period (1961–2007).

The yield-per-recruit is much higher for small-stock periods than for large-stock periods (Figure 4), as well as spawning stock per recruit (Figure 5). Fmax is 0.43 for small-stock periods as well as for the entire period, whereas it is 0.30 for large-stock periods.

Table 1 summarizes current and alternative reference points. The current Fpa is lower than any of the three proposed Fmax values. One canditate for the F_{MSY} is the average of 0.43 and 0.30, i.e. 0.36 (taking rounding of the former values into account). $B_{trigger}$ could be set at the current Blim of 60 thousand tonnes. The $F_{0.1}$ of 0.15 seems too low to be a candidate for F_{MSY}. The current Fpa also seems too low if the goal is to maximize yield.

Table 1. Reference points for Faroe Saithe for consideration during the February 2010 benchmark assessment. Bold figures indicate reference points established entirely under previous benchmark.

Reference point	Small stock	Large stock	All sizes	Remarks
	1991–1998	2002–2007	1961–2007	
Reference Points using Previous Benchmark Results				
Blim	60	60	60	NWWG07: Recommends using Bpa
Flim	0.40	0.40	0.40	
Flim	0.48	0.81	0.65	New SSB per R applied to old Blim
Bpa	85	85	85	
Fpa	0.28	0.28	0.28	
Fpa	0.33	0.53	0.46	New SSB per R applied to old Bpa
Reference Points using 2010 Benchmark Results				
Blim	50	50	50	Based on NWWG07 algorithm
Flim	0.54	1.00	0.77	New SSB per R applied to new Blim
Fmax	0.43	0.30	0.43	
F0.1			0.15	
Average Recruits	24	60	32	

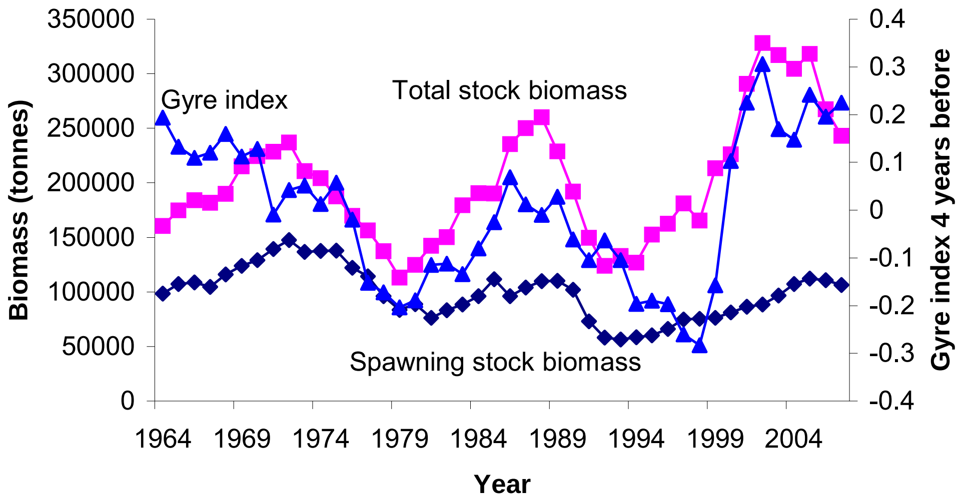


Figure 1. Stock development of Faroe saithe and its relation to the gyre index. Note that a large gyre index indicates a small Subpolar Gyre, and, consequently, a large influx of plankton-rich warmer-than-average water to the outer areas (bottom depth >150 m) around the Faroes, where saithe typically are found.

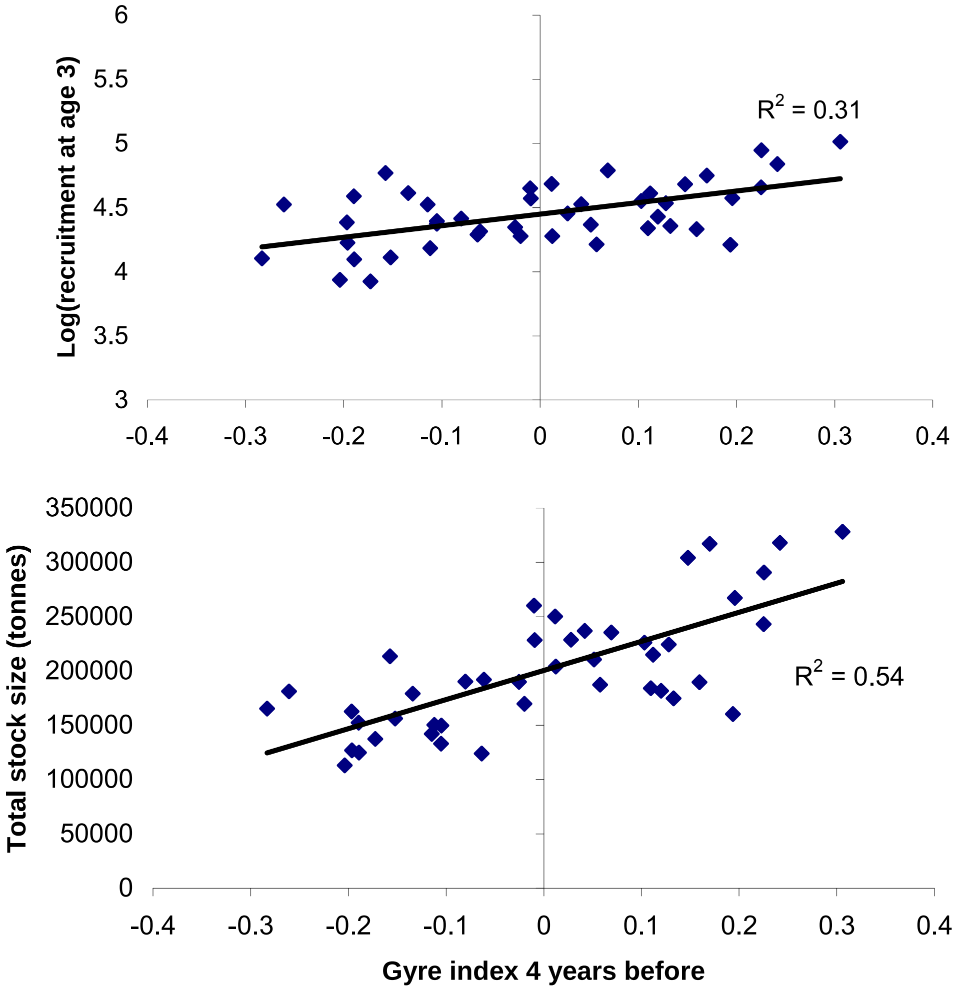


Figure 2. Relationship between the gyre index and recruitment as well as total stock size. Note that a large gyre index indicates a small Subpolar Gyre, and, consequently, a large influx of plankton-rich warmer-than-average water to the outer areas (bottom depth >150 m) around the Faroes, where saithe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

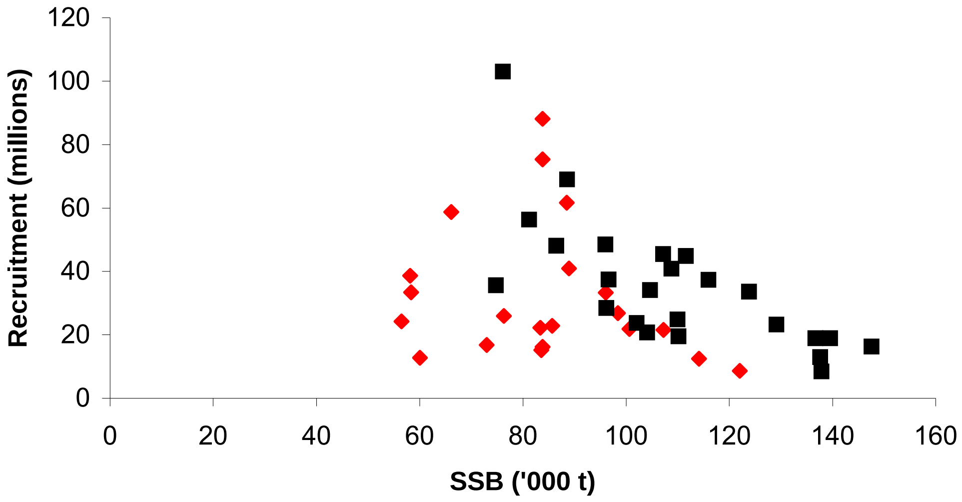


Figure 3. Spawning stock biomass recruitment relationship for Faroe saithe. Red diamonds indicate small stock sizes (total biomass less than 180 thousand tonnes) whereas black squares indicate larger stock sizes.

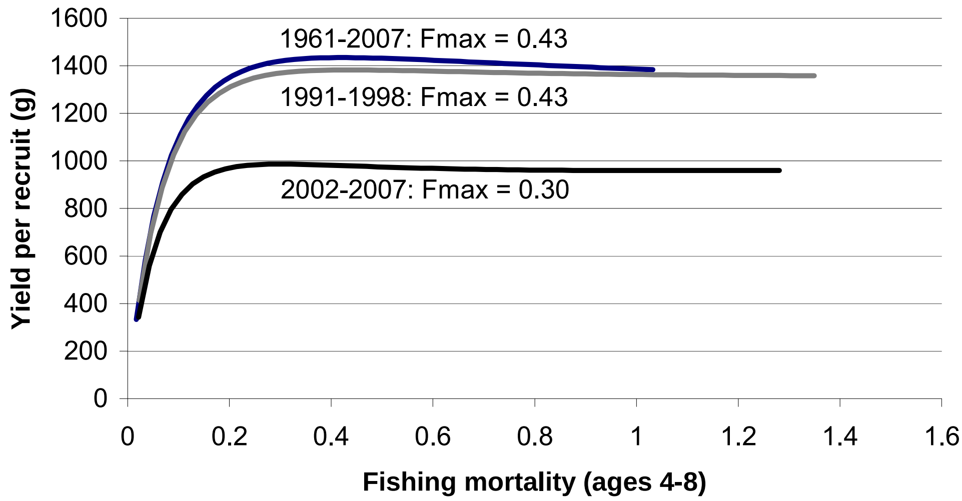


Figure 4. Yield-per-recruit calculations for small stock size (1991–1998), large stock size (2002–2007) and the whole assessment period (1961–2007), except the last year.

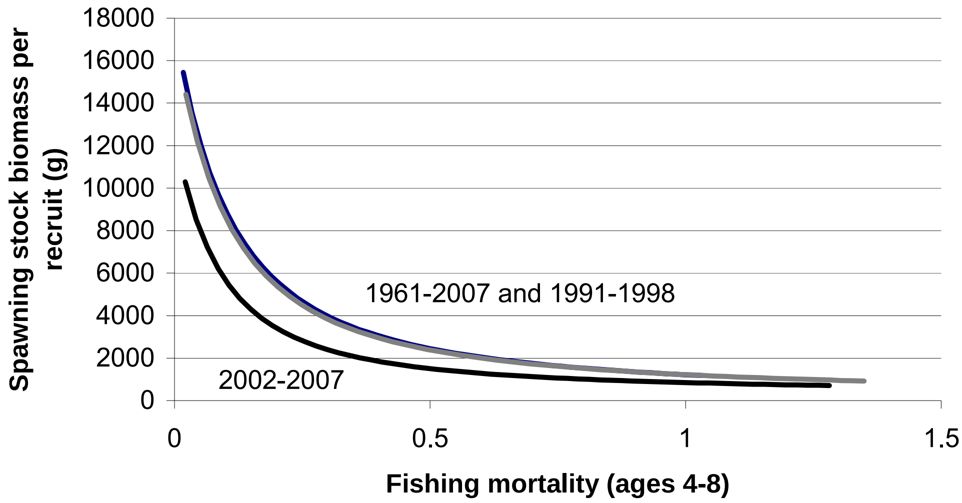


Figure 5. Spawning stock biomass per recruit calculations for small stock size (1991–1998), large stock size (2002–2007) and the whole assessment period (1961–2007), except the last year.

4.13 Recommended modifications to the stock annex

The 2010 updated stock annex appears to be complete and accurate.

4.14 Recommendations on the procedure for assessment updates

Regarding biological reference points it might be suggested that a Management Strategy Evaluation (MSE) be considered for examination of harvest control strategies for Faroe Island saithe. We've established a range of F reference points including F0.1 and Fmax for this stock. The most appropriate F level is probably somewhere in the middle. A MSE approach would not only be useful from a management strategy view point under stationary assumptions, but also allow exploration of the influence of environmental drivers have on long-term management actions. The presentation on MSE given by Dorleta Garcia at this workshop using XSA applied to Northern Hake might be used as a model for how to do this type of reference point and harvest control rule evaluation.

4.15 Industry supplied data

No industry supplied data (other than landings) were used during this workshop.

4.16 References

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Stock Annex Faroe Saithe (Division Vb)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Faroe saithe (Division Vb)
Working Group:	North-Western Working Group
Date:	Feb 2010
Revised by	Luis and Petur

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 Vb 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 Northeast arctic saithe stock was sufficient to explain the tagging results, and that the emigration likely occurred before sexual maturity. Bearing in mind that the Northeast 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, 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 18 463 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 Northeast 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 pairtrawlers (>1000 HP), which have a directed fishery for saithe, about 50–60% of the reported landings in since 1992. The smaller pairtrawlers (<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 (WD08).

Nominal landings of saithe in Division Vb 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 Iia, 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 reveal 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, pairtrawlers <1000 HP, pairtrawlers >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 were 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 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. Because 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, WD05). A similar approach was used at the Benchmark Assessment Workshop (WKROUND) in 2010 (WD03). 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. A model presented at the WKROUND workshop (WD06) was utilized to smooth the maturity ogives (Eq 1.) The model kept the major trends in the observed data while smoothing out the maturity-at-age matrix.

$$M = \frac{M_{\text{inf}}}{1 + \exp\left(-k\left(age - age50\right)\right)} \qquad \text{Eq. 1}$$

where M is the proportion mature and Minf, k and age 50 are parameters estimated by the model.

B.4. Commercial cpue

The cpue series from pairtrawlers 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 pairtrawler series. All vessels use 135 mm 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 5000–20 000 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 pairtrawlers 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 pairtrawlers) 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 demonstrated approximately the same trends as the other pairtrawlers in the series during 1999–2003. In 2009 two new pairs of trawlers were used to extend the tuning series. These trawlers were build in 2003 and 2004 and they reveal 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 (WD09) 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 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

An XSA has been performed during a number of years. The use of tuning indices has varied. 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 pairtrawler series. At the benchmark assessment workshop in 2010 (WKROUND 2010) the XSA and NTF-Adapt (WD07) frameworks were used as the main assessment tools. Given their similarities in terms of stock estimates and retrospective patterns and not the least the approach (VPA-type models) it was not a matter of great concern to choose between both models: The XSA was adopted as the basis for advice. Input data for the XSA run are located at the URL of the WKROUND 2010 website (http://groupnet.ices.dk/benchmark2010/round2010/default.aspx→Data→Faroe saithe→Input Data XSA).The model settings are described below.

Model used: Extended Survivors Analysis (XSA)

Software used: Virtual Population Analysis (VPA), version 3.1

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 – 12+	Yes
Canum	Catch at age in numbers	1961–last data year	3 – 12+	Yes
Weca	Weight at age in the commercial catch	1961–last data year	3 – 12+	Yes
West	Weight at age of the spawning stock at spawning time.	1961–last data year	3 – 12+	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 – 12+	No, set to 0 for all ages and years
Fprop	Proportion of fishing mortality before spawning	1961–last data year	3 – 12+	No, set to 0 for all ages and years
Matprop	Proportion mature at age	1983–last data year + 1 (2009)	3 – 12+	Predicted ogives. Data prior to 1983 is average of 1983-1996 values.
Natmor	Natural mortality	1961–last data year	3 – 12+	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 geometric mean of 1995–2007.

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

Maturity: First year (2009) is average of the last data year (2008) and last data year +1 (2009). The two next years (2010–2011) is average of three latest years (2007–2009).

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

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

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 three years, not rescaled.

Intermediate year assumptions: None

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: 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 1961 to last data year.

Exploitation pattern: Average exploitation pattern of the last five years.

Procedures used for splitting projected catches: None.

Periods with small stock and large stock situations were considered in the WKROUND 2010.

G. Biological reference points

Biological reference points for saithe in Division Vb are as follows:

B_{lim} = 60 000 t

B_{pa} = 85 000 t

F_{lim} = 0.40

F_{pa} = 0.28

For Faroe saithe, the highest recruitment has been observed at or near the lowest SSB. The NWWG in 2007 therefore suggested that Bloss should be used as Bpa, not Blim. The working group recommended that Bpa for saithe be set at Bloss = 60 000 t and that Blim be set at an arbitrarily lower value (45 000–50 000t) until more stock and recruitment data pairs are observed below Bloss. NWWG 2009 reiterated those recommendations. Fishing mortality reference points need to be further considered.

H. Other issues

I. References

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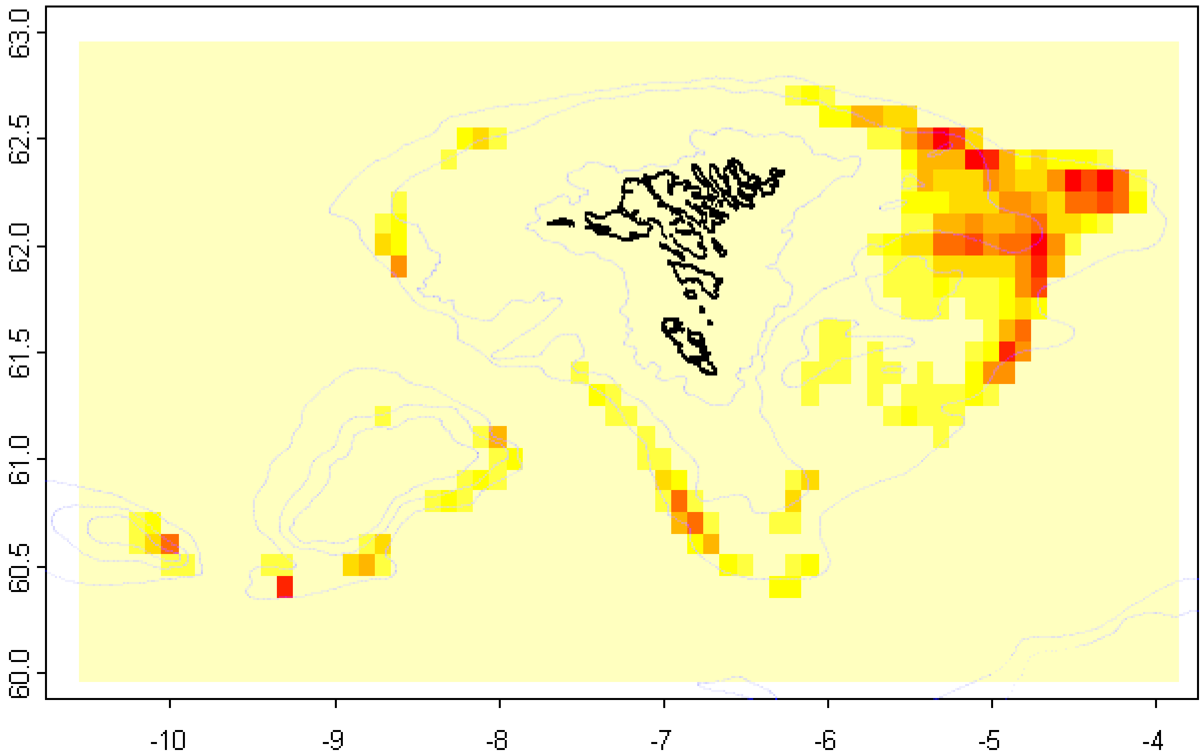


Figure 1. Faroe Saithe Vb. Distribution of combined trawl catches (single and pairtrawlers) from 1995–2008 (logbooks.) Depth contour lines of 100, 200 and 400m are shown.

5 Northern Hake

5.1 Current stock status and assessment issues

The northern hake stock appears to have been reduced in abundance prior to 1990 and to have remained at a relatively stable, but low, abundance level due to annual fishing mortality rate (F averaged over ages 1–5 equivalent to lengths 15–80cm) near 1.0 throughout the 1990s. An increase in abundance began about 2004 due to somewhat lower catches corresponding to larger recruitments at about that time. Direct evidence of the increase is the upward trend in relative abundance observed in all three contemporary trawl surveys (EVHOE in the Bay of Biscay and Celtic Sea, SP-PGFS in the Porcupine Bank and IGFS in the waters surrounding Ireland). At the start of 2008, the stock has a spawning biomass of 64 947 mt and the F has declined to 0.45. This rate still exceeds the new calculations of Fmax (0.29) and F0.1 (0.20), but spawning biomass is expected to increase at F=0.45 because this F level is well below the average F level of the previous decade. If the future fishing rate was reduced to F0.1 and recruitment remained at the median level since 1990, then a medium-term forecast would have spawning biomass increasing to over 300 000 mt and annual landings around 70 000 mt.

Issues considered in this benchmark relate to:

1) Results of published tagging studies definitively indicate that the past age determination methods were overestimating age approximately twofold. This invalidates the age data used in previously age-based stock assessments and indicates that growth is faster than previously estimated. In addition, these findings suggest that higher natural mortality rates should be used in assessments.

The new assessment shifts to a length-based approach using the Stock Synthesis assessment model. This approach allows direct use of the quarterly length–composition data from each of seven fishing fleets and it allows explicit modelling of a retention process that partitions total catch into discarded and retained portions.

Data since 1990 indicate a very small proportion of fish larger than 60 cm, even though Linf is near 130 cm. After considering sensitivity analyses regarding the degree to which this pattern might be due to dome-shaped partial recruitment vs. historical fishing mortality levels, the panel concluded that the best model configuration would set the two fishing fleets with the most persistent occurrence of large hake to have asymptotic selectivity. The conclusion is supported by catch size composition data from the 1980s which indicated that larger fish were commonly landed by the fleets during the decade just prior to 1990, which is the start year of the assessment model.

The information on faster growth and younger ages supported investigation of larger values for natural mortality. Preliminary model runs were conducted at M=0.2, 0.3 and 0.4. The fit of the assessment model to the size composition and survey index data was better at M=0.4 and the panel concluded that this level of M was the best value to use for this assessment.

The assessment is limited in its ability to precisely estimate current stock abundance and mortality because the modelled time period, 1990–2008, does not exhibit strong contrasts in the available data. Future assessments should attempt to extend the modelled time period back to about 1960 to improve the model's ability to determine the degree to which historical levels of fishing reduced hake abundance. The downward trend during the 1980s in the catch of larger hake should provide information regarding the level of fishing mortality that caused this decline.

5.2 Compilation of available data

5.2.1 Catch and landings data

The quarterly fishery landings, discard, and size composition (LFD) was organized into 7 categories (fleets) for use in the assessment model. These are described in the Table below. The distribution of catch among the principal fleet categories has shifted over time. Largest recent increases have been among the gillnet, longline and "others" fleets. The "others" fleet tends to be more northern in its distribution.

Fleets	Description	FU	Landings (quarterly)	Discards (quarterly)
SPTRAWL7	Spanish trawl in VII	04	1990–2008 (LFD + Weight)	1994, 1999, 2000, 2003–2008 (LFD + Weight)
FRNEP8	French trawl targeting *Nephrops* in VIII	09	1990–2008 (LFD + Weight)	2003–2008 (LFD + Weight)
SPTRAWL8	Spanish trawl in VIII	14	1990–2008 (LFD + Weight)	2005–2008 (LFD + Weight)
TRAWLOTH	All other trawl in VII and VIII	05 + 06 + 08 + 10	1990–2008 (LFD + Weight)	
GILLNET	Gillnet all countries	03 + 13	1990–2008 (LFD + Weight)	
LONGLINE	Longline all countries	01 + 02 + 12	1990–2008 (LFD + Weight)	
OTHERS	Everything else all countries	15 + 16 + 00	1990–2008 (LFD + Weight)	

5.2.2 Biological data

Conventional tagging of European hake (de Pontual *et al*., 2003) recently opened new avenues for a better understanding of the species biology and population dynamic which have remained controversial for decades. The first tagging results provided evidence of substantial growth underestimation (by a factor ~2) due to age overestimation, (de Pontual *et al*., 2006), thus challenging the internationally agreed age estimation method. More tagging efforts, both off the Northwest Iberian Peninsula (Piñeiro *et al*., 2007) and the Mediterranean Sea (Mellon-Duval *et al*., 2010), have recently proved that growth underestimation was not a regional issue. Besides, Ifremer sustained a large tagging effort in the Bay of Biscay from 2004 to 2007 which confirmed the fast growth hypothesis and the concerns with the current otolith-based age estimation methodology. Over the 27 700 released tagged fish (Total Length range at tagging: 13–64 cm), 1199 fish have been returned until now (time at liberty from 1 to 1066 days, maximum TL of the recoveries: 67 cm). New insights derived from these experiments are presented in WD7. Briefly, the available tagging data are still limited; lack of large fish in particular, with significant time at liberty, which impedes the concomitant estimation of L_∞ and K parameters of the von Bertalanffy models. However growth estimation has been refined with respect to previous studies by using realistic L_∞ values. The resulting estimates have good precision (determined by bootstrap estimation) and provide additional strong evidence of fast growth behaviour of the species. In parallel, the accuracy and precision of the otolith-based age estimation method has been assessed by exploiting otoliths recovered from tagged fish through recent international otolith exchange and workshop carried under the ICES auspices. Interpretation of tagged material resulted in a general shift towards younger ages (from 0–10 to 1–5 years) for the same otolith/fish collection and the overall results of the workshop confirmed that the previous internationally agreed ageing method is neither accurate nor precise and provide overestimation of age (ICES 2010). At this time, a replacement ageing method with sufficient precision and accuracy is not available.

5.2.3 Survey tuning data

Four surveys provide relative indices of hake abundance over time. The FR-RESSGASCS survey were conducted in the Bay of Biscay from 1978 to 2002, the FR-EVHOES survey conducted in the Bay of Biscay and in Celtic Sea with a new design since 1997, the SP-PGFS survey conducted on the Porcupine Bank since 2001, and the Irish Groundfish Surveys beginning in 2003 in the west of Ireland and the Celtic Sea. The EVHOE, RESSGASCS, and IGFS surveys principally collect hake less than 50 cm (ages 0, 1, and 2). Only the Porcupine survey commonly collects hake above 75 cm. However, the survey at Porcupine Bank demonstrates an increasing occurrence of small hake (<20 cm) beginning in 2004 and is dominated by these small fish in 2006–2008. Because this survey covers a relatively small portion of the range of northern hake, it is unclear the degree to which this increase in young fish represents localized vs. widespread increases in recruitment.

5.2.4 Commercial tuning data

No commercial fleet tuning data were proposed for use in the model. This decision is supported by the availability of tuning data from several survey fleets and the limited degree to which commercial cpue data can be standardized over time.

5.2.5 Industry/stakeholder data inputs

A representative from a stakeholder group described studies on gear methodology to reduce the bycatch of hake in the *Nephrops* trawl fishery.

5.3 Stock identity and migration issues

Hake are distributed principally from Spain through the British Isles and previous genetic studies have not found evidence of distinct stocks. A boundary between the northern and southern stocks has been established near the Spain-France border. No migration studies were presented, but the spatial distribution of recruitment as observed in the surveys indicates the possibility of some mixing of recruits with the southern stock. In addition, the increasing trend of recruitment in the survey on Porcupine Bank in the north indicates that recruitment events are not uniformly distributed throughout the range of the stock.

5.4 Spatial changes in the fishery and stock distribution

No changes were noted.

5.5 Environmental drivers of stock dynamics

No evidence of environmental drivers was presented in this benchmark. Such patterns should be considered in future, particularly because of the possible northward shift in recruitment.

5.6 Role of multispecies interactions

No multispecies interactions were discussed at this benchmark workshop.

5.7 Impacts on the ecosystem

No ecosystem impacts were directly examined. However, with northern hake at a level of biomass that is only 5% of its calculated unfished level of spawning-stock biomass, it seems highly probable that some shift in species interactions has occurred.

5.8 Stock assessment methods

5.8.1 Models

The Stock Synthesis (SS) assessment model (Methot, 2009) was selected for use in this assessment. This model is commonly used for assessments of groundfish, tunas, and pelagic fish in the US and Australia and is beginning to be used in ICCAT exploratory assessments. SS is written in ADMB (www.admb-project.org) and is a forward simulating, age and size-based model that is capable of being fit with a wide variety of assessment data. The model version used for this assessment is 3.10 (January 2010). Features of the model configuration included:

1) Quarterly time-steps from 1990 through 2008

7 fishing fleets and 7 survey indices

Annual recruitment-at-age 0 was partitioned among the four quarters according to estimated parameters and with the fraction occurring in quarter 2 allowed to fluctuate annually. In final model runs, the fraction allowed to recruit in quarter 4 was set to a nil level.

The annual recruitments are estimated as deviations from a spawner-recruitment curve. The fixed parameters of this curve included a steepness of 0.999 because the time-series was too short and with insufficient contrast to estimate the degree for curvature in the relationship, and included a recruitment variability level (sigmaR) of 0.7. Estimated parameters included the virgin level of recruitment (which also is the mean level of recruitment because steepness was fixed at 0.999) and it included an offset from this mean recruitment level for the initial equilibrium period.

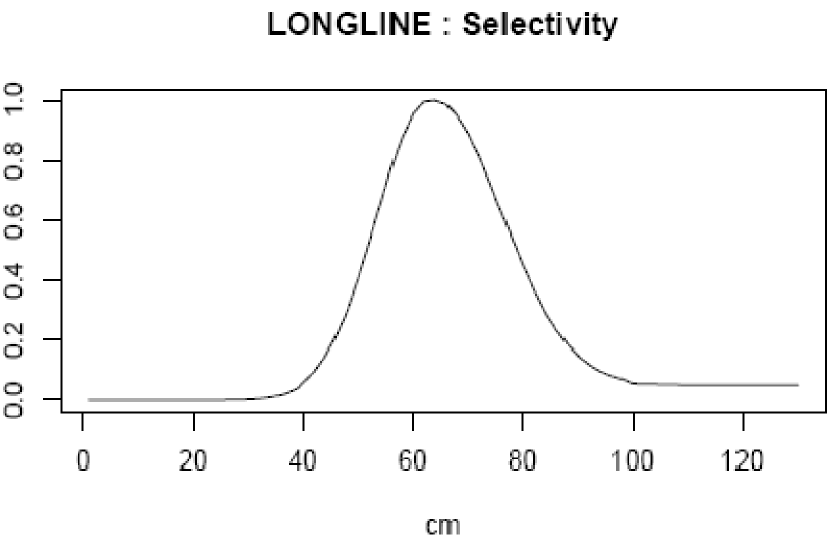
Recruitment estimates extended back to 1985 in order to provide estimates of initial age composition fluctuations superimposed on the initial equilibrium age composition.

Average annual catch by fleet from 1980–1989 used as the initial equilibrium catch from which the model estimated the initial equilibrium F for each fleet.

Discard amount and discard size composition for three fleets (Spanish trawl 7, French *Nephrops*, and Spanish trawl 8) was included.

Retention function to separate total catch into discard and retained portions for these 3 fleets was estimated from a 2 parameter logistic curve for each fleet. The parameters of the curves for Sptrawl7 and SPtrawl8 were allowed to change (shift to larger size at retention) beginning in 1998 due to changes in enforcement of minimum landing sizes.

The selectivity pattern for each fishing fleet was calculated from the "double normal" selectivity pattern 24 available in the SS software. This pattern uses up to 6 parameters to calculate two half-normal curves on either side of a plateau with estimated width.



The catchability coefficient for each tuning fleet's cpue was estimated as a time-invariant parameter.

The RESSGASCS survey was conducted quarterly and a noticeable shift in mean cpue was noted among the quarters. Therefore, each quarter's data were defined as a separate survey (with its own catchability parameter) and all four quarters were set up to share the same selectivity pattern.

5.8.2 Sensitivity analysis

Selectivity pattern: A preliminary set of model runs indicated that results were sensitive to the degree of flexibility allowed in the shape of the fishery selectivity-at-length patterns. If all fleets are allowed to be dome-shaped, the model cannot unambiguously determine the degree to which large fish exist but are never caught, vs. a result in which these large fish have reduced abundance but remain catchable. Three approaches were used to resolve this issue. First, examination of size composition data from the 1980s indicated that the percentage of large fish in the catch was much higher during the early 1980s and declined to a much lower level by 1990. This indicated that the old fish are catchable when they exist. Second, model runs were conducted with a profile on fixed levels for the degree of domed selectivity for selected fleets. These runs confirmed that the best fit to the size composition data occurred with the maximum domed pattern but the biomass increased to unrealistically high levels when the pattern was fully domed. Third, the overall average size composition of each contemporary fleet was examined and it was found that two fleets, "other trawls in VII and VIII" and "others", had the lowest slope of the right hand side of the length composition. These two fleets were assigned an asymptotic selectivity pattern (two parameter logistic function) and all other fleets were modelled with the flexible double normal pattern. This change stabilized model performance.

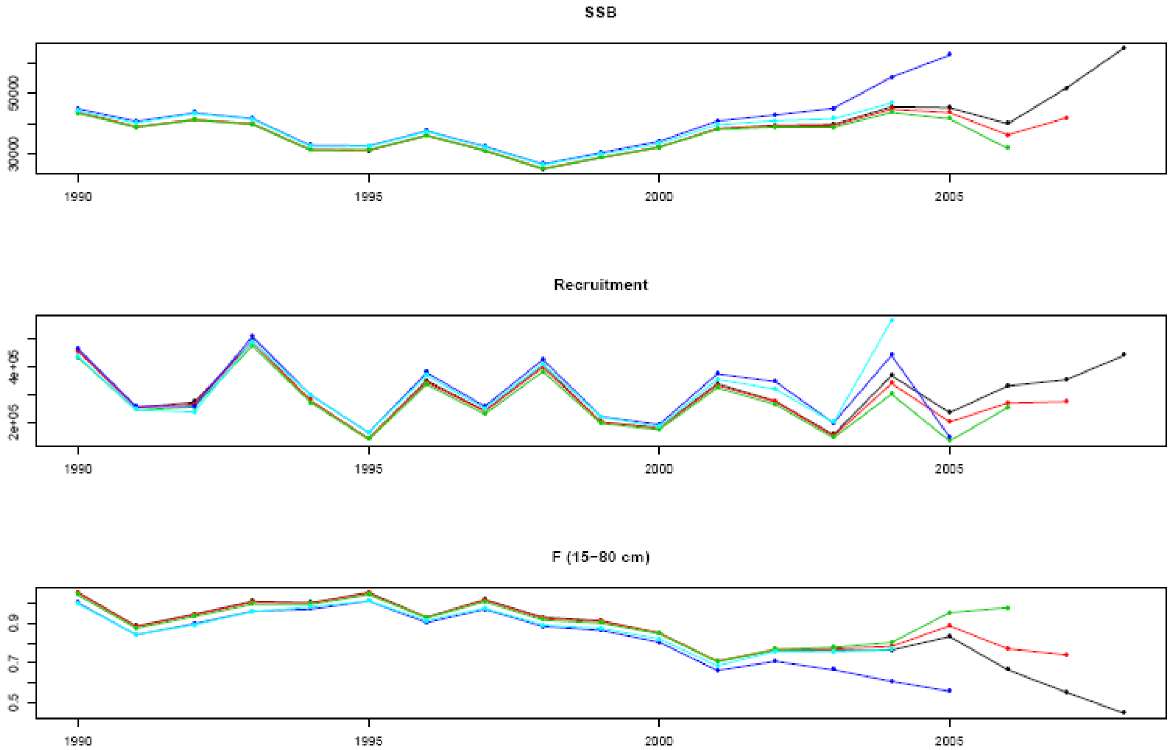
Fishing mortality method: SS allows fishing mortality rates to be modelled as simple scaling coefficients that automatically adjust to match the landed catch exactly, or as model parameters such that the degree of fit to the landed catch becomes part of the log likelihood function. Early model runs used the first method and slow model convergence was observed. Final model runs used the second method, which resulted in nearly 600 model parameters to define these quarterly F values for each fleet. This was done using a standard error of 0.10 (in log-scale) for the fit to the landed catch.

Natural mortality: Model runs were conducted at M=0.2, 0.3 and 0.4. The best fit of the model to the data occurred at M=0.4. In addition, the finding of age overestimation based on the tagging and otolith studies supported the panel's conclusion that the new model should use a value of M higher than the value of 0.2 used previously. An M value of 0.4 was used in all subsequent model runs for both northern and southern hake.

Iterative adjusted of data variance: Initial model runs were conducted with input standard errors set to measured values for the survey cpue and for the discard observations, and to a nominal level of 125 as the effective sample size for the length composition observations. Final model runs set all discard standard errors (in log-scale) equal to 0.5 because the measured standard errors appeared to vary erratically and some with exceptionally small standard errors were dominating the fit of the model. Input standard errors for the survey cpues were adjusted upwards to better match the average deviation between the model and the data. Size composition sample sizes were adjusted downwards to achieve an approximate match between these input variance scalars and the model's general fit to the data. In addition, data from the Porcupine survey were further downweighted to acknowledge the more limited spatial extent of this survey. The final input data variance levels are documented in the stock annex.

5.8.3 Retrospective patterns

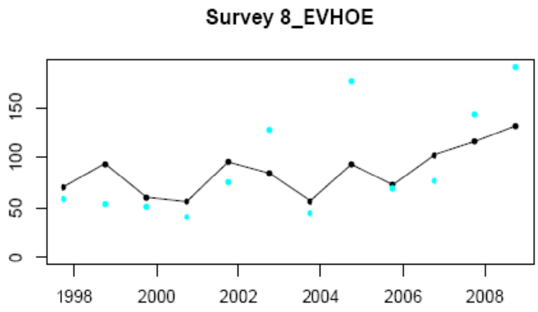
Sensitivity of model results to exclusion of recent data is expected because of the relatively short survey tuning index time-series, the recent increases in the survey indices and the small number of ages in the stock. The patterns demonstrated below indicate that current estimates have uncertainty, but do not exhibit a directional pattern that would indicate a bias.

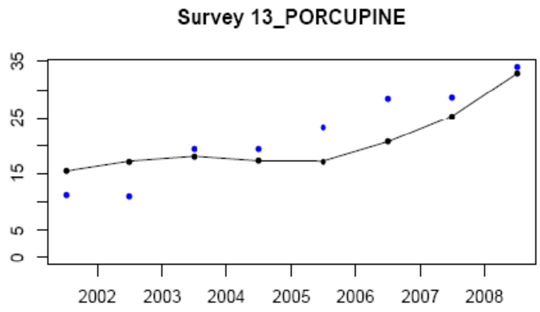


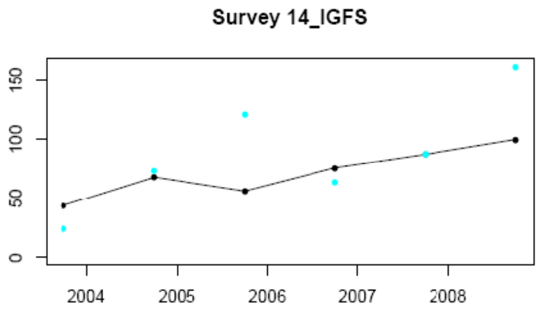
5.8.4 Evaluation of the models

The panel concluded that the final model configuration adequately matched the patterns in the data and that the sensitivity analyses provide adequate understanding of major factors affecting model performance and results. The panel accepted the final model configuration documented in the stock annex as a suitable basis for assessment of northern hake stock status.

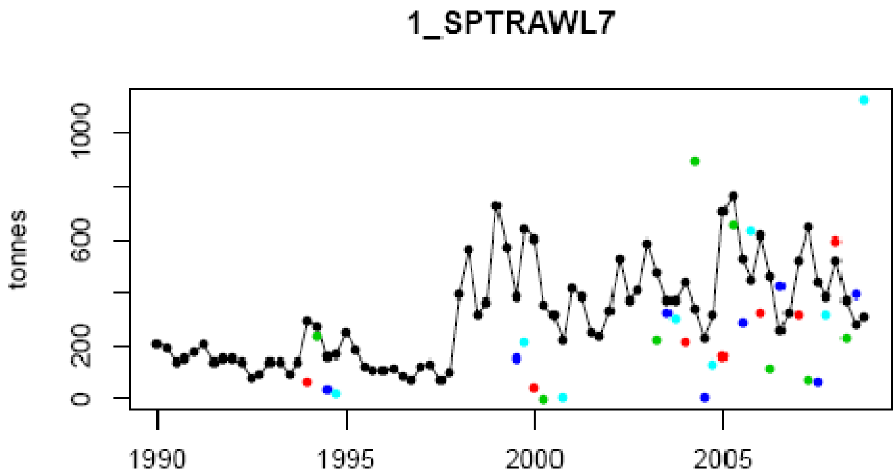
Direct evidence of the increase in recruitment and spawning biomass and decrease in F is the upward trend in relative abundance observed in all three contemporary trawl surveys (EVHOE in the Bay of Biscay and Celtic Sea, SP-PGFS in the Porcupine Bank and IGFS in the waters surrounding Ireland). These trends and the model's corresponding estimates are shown in the Figure below.

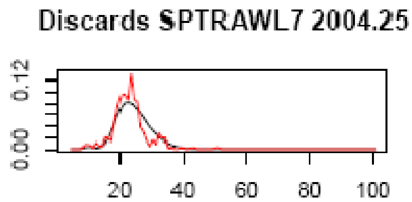


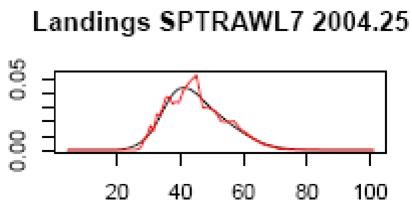




The assessment model includes estimation of a size-selectivity function which partitions the total catch into discarded and retained portions. The figures below show the model's fit to the total discard for the Spanish trawl fleet in unit 7, and demonstrate an example of the fit to the size composition of discards and landings in the first quarter of 2004.





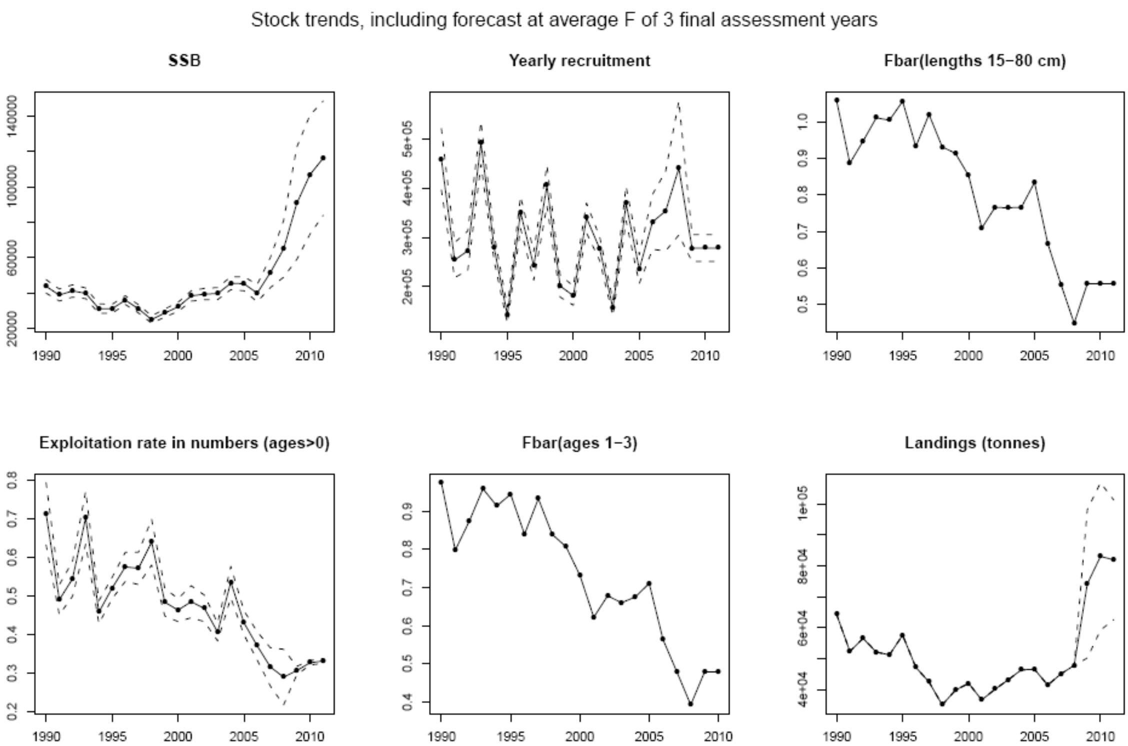


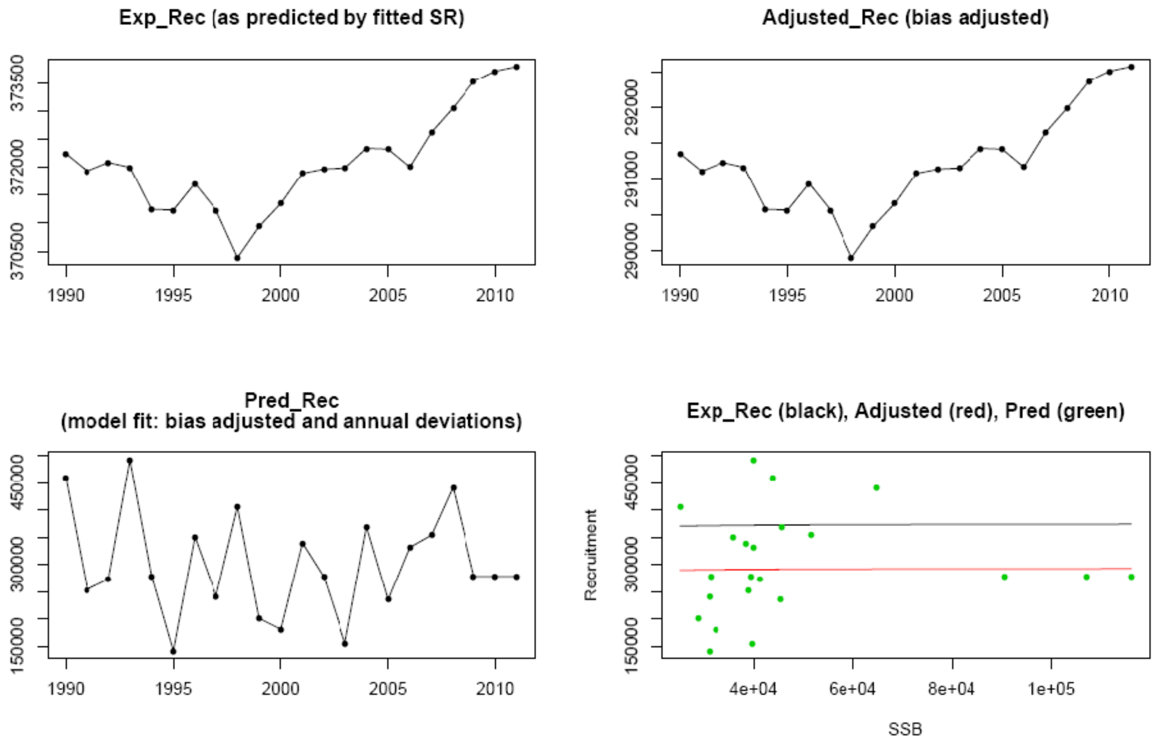
5.9 Stock assessment

The level of spawning-stock biomass averaged 37 000 mt during 1990–2006 then increased to near 65 000 mt in 2008. Although this percentage increase in SSB appears dramatic, the level of SSB is still only about 6% of the 1 170 000 mt level that would exist if the observed mean level of recruitment was unfished. The fishing mortality statistic is calculated as the average annual F for sizes 15–80 cm. This measure of F is nearly identical with the average F for ages 1–5. Values of F averaged near 1.0 during the 1990s and declined to 0.45 in 2008. These results are tabulated below. The Table and Figures extend through a 3 year forecast at the current F level.

The confidence intervals are parametric results from the assessment model calculated from the inverse Hessian matrix. These confidence intervals are expected to underestimate actual uncertainty because some model factors are held constant (particularly natural mortality and the asymptotic selectivity for some fleets). The wide confidence interval for forecast landings level should be interpreted as the range of landings that could occur if F was held constant and recruitment fluctuated.

Year	Rec	B total	SSB	Landings	Landings/ SSB	F (15-80 cm)
1990	459198	72233	43779	64287	1.47	1.06
1991	253796	65002	38873	52375	1.35	0.89
1992	272843	68137	41172	56617	1.38	0.95
1993	491977	60322	39870	52144	1.31	1.01
1994	278821	54230	31220	51259	1.64	1.01
1995	141831	60746	31080	57621	1.85	1.06
1996	350960	55832	35998	47210	1.31	0.93
1997	241938	47651	31064	42465	1.37	1.02
1998	405834	45264	25016	35060	1.4	0.93
1999	201058	50060	28690	39814	1.39	0.92
2000	181368	56289	32168	42026	1.31	0.85
2001	339635	56461	38358	36675	0.96	0.71
2002	277032	59350	39416	40107	1.02	0.77
2003	155990	64850	39689	43162	1.09	0.76
2004	369014	68164	45553	46417	1.02	0.77
2005	235442	65615	45246	46550	1.03	0.83
2006	331558	66452	39948	41467	1.04	0.67
2007	353792	78930	51639	45098	0.87	0.55
2008	441262	100088	64947	47823	0.74	0.45
Forecast at average F of 2006-2008						
2009	278164	134272	90753	74242	0.818	0.56
2010	278300	151529	107002	83055	0.776	0.56
2011	278360	151801	116204	81960	0.705	0.56





5.10 Recruitment estimation

The yearly recruitment time-series is demonstrated in Section 5.9 above. Fluctuations appear to be without substantial trend. Because spawning biomass during 1990–2008 varied over a narrow and low range, it is not feasible to observe a relationship between mean recruitment and spawning biomass.

5.11 Short-term and medium-term forecasts

Short and medium-term forecasts can be conducted within the SS assessment model. By doing these forecasts within the assessment model, it is possible to estimate confidence intervals on these quantities, as shown in the Figures displayed in the section above. The software allows for forecasts using 3-year average F levels and specified F levels such as F35%. In conducting these forecasts and updating reference points in future assessments, the ratio of F among fleets should be updated to reflect conditions expected during the forecast period. Median recruitment levels are used for these forecasts.

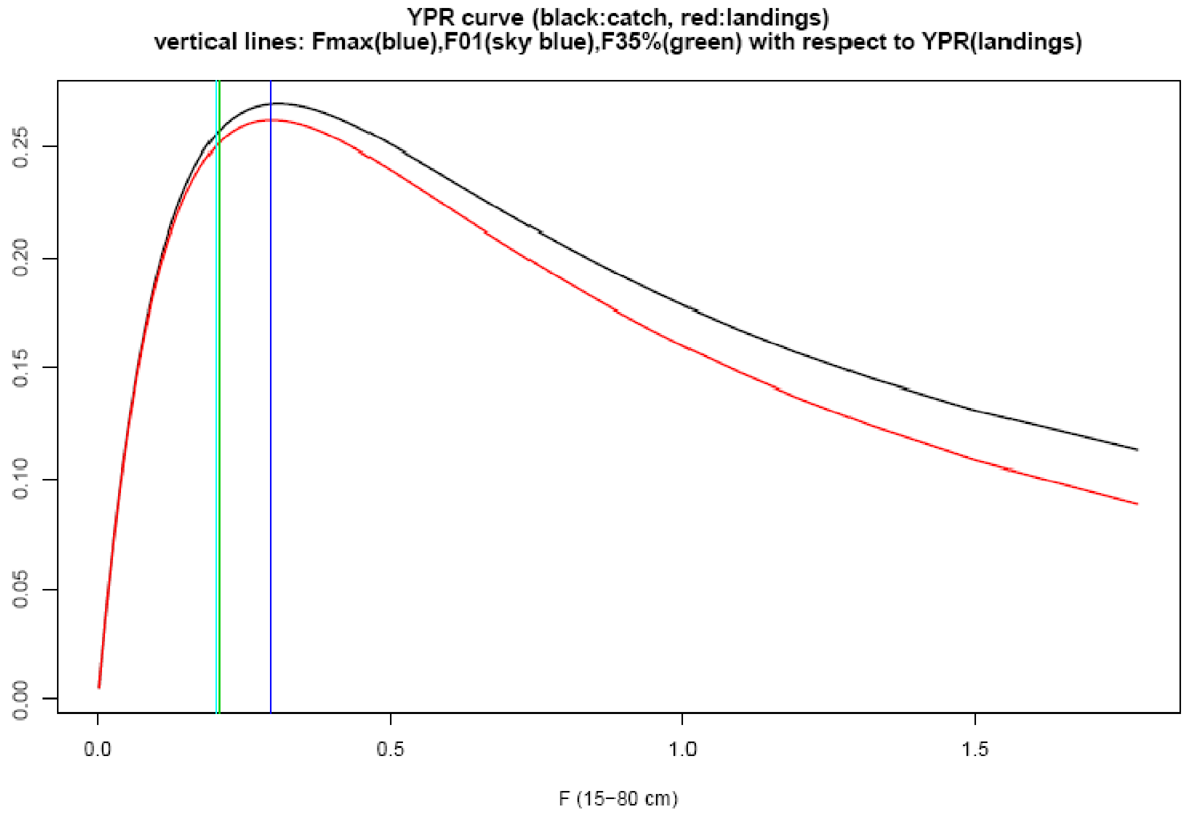
5.12 Biological reference points

This assessment represents a complete re-start relative to the previous assessment which was based on age data now demonstrated to be biased. Thus, all reference points should be redone. In particular, the absolute level of spawning biomass has shifted to a lower scale, so Blim and Bpa values will need to be recast in terms of the new assessment. The lowest level of spawning biomass is now estimated to have been 25 000 mt in 1998. The panel does not recommend that this single lowest year be selected as Blim. The average biomass during 1990–2005 (36 000mt) was only 3% of the biomass level that would have occurred if these recruits had been unfished. Blim probably should not be lower than this 36 000 mt level.

The time-series of spawning biomass and recruitment does not have sufficient contrast to allow direct estimation of Fmsy. Reference points of F0.1, Fmax and F35%

were calculated within the SS assessment model to provide a range of potential proxies for Fmsy. F35% is the fishing rate that would reduce spawning biomass per recruit to 35% of its unfished level. F35% and F0.1 produce very similar results. Fmax is higher and corresponds approximately to a F24% level.

	SPR	YPR	F(15-80 CM)
Fmax	0.24	0.269	0.29
F0.1	0.36	0.253	0.20
F35%	0.35	0.255	0.21



5.13 Recommended modifications to the stock annex

The previous stock annex needed to be substantially updated to document the size composition, discard, and survey data as used in this assessment using stock synthesis. The new annex presents the model configuration and results.

5.14 Recommendations on the procedure for assessment updates

Because this is a new assessment using software that is new to the ICES arena, the current model configuration should be open to some adjustment in subsequent assessment updates. Adjustments that should be considered within the scope of an update include: revision of input data variances to more completely tune the model; introduction of some degree of time-varying selectivity to better account for trends in some remaining residual patterns, and extension of the time-series back 10–30 years to include historical catches more precisely and to include size composition data from the 1980s. It is also advisable to consider a higher penalty (comparable to XSA shrinkage) on recruitment deviations near the end of the time-series because their unconstrained estimates are highly susceptible to fluctuations in survey indices.

More substantial changes that could be considered in a subsequent benchmark would include more explicit treatment of the spatial pattern of the stock, fishery and surveys. One possibility would be a composite of existing surveys so that the model was examining a single more comprehensive survey rather than a set of spatially limited surveys.

5.15 Industry supplied data

No additional data were supplied by industry representatives.

5.16 References

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Stock Annex Northern Stock of Hake

Quality Handbook Stock Annex

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Northern Stock of Hake (Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d)
Working Group:	Assessment of Southern Shelf Stocks of Hake, Monk and Megrim
Date:	15 February 2010
Revised by	

A. General

A.1. Stock definition

European hake (*Merluccius merluccius*) is widely distributed over the Northeast Atlantic shelf, from Norway to Mauritania, with a larger density from the British Islands to the south of Spain (Casey and Pereiro, 1995) and in the Mediterranean and Black sea. Although, as demonstrated by genetic studies (Plá and Roldán, 1994; Roldán *et al*., 1998), there is no evidence of multiple populations in the Northeast Atlantic, ICES assumes since the end of the 1970s two different stock units: the so called Northern stock, in Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d, and the Southern stock in Divisions VIIIc and IXa, along the Spanish and Portuguese coasts. The main argument for this choice was that the Cap Breton canyon (close to the border between the Southern part of Division VIIIb and the more Eastern part of Division VIIIc, i.e. approximately between the French and Spanish borders) could be considered as a geographical boundary limiting exchanges between the two populations.

Hake spawn from February through to July along the shelf edge, the main areas extending from the north of the Bay of Biscay to the south and west of Ireland (Figure 1). After a pelagic life, 0-group hakes reach the bottom in depths of more than 200 m, then moving to shallower water with a muddy seabed (75–120 m) by September. There are two major nursery areas: in the Bay of Biscay and off southern Ireland.

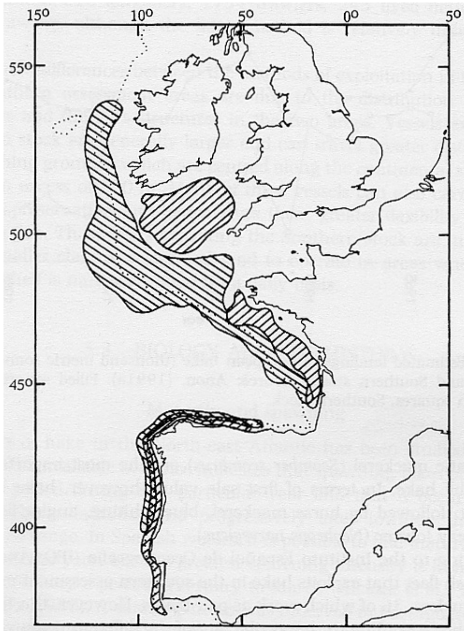

Figure 1. Main spawning and nursery areas. Spawning areas sloping downwards from left to right; Nursery areas sloping downwards from right to left. (from Casey and Pereiro, 1995)

A.2. Fishery

A set of different Fishery Units (FU) has been defined by the ICES Working Group on Fisheries Units in Sub-areas VII and VIII in 1985, in order to study the fishing activity related to demersal species (ICES, 1991a). To take into account the hake catches from other areas, a new Fishery Unit was introduced at the beginning of the nineties (FU 16: Outsiders). This Fishery Unit was created on the basis of combination between mixed areas and mixed gears (trawl, seine, longline, and gillnet). The current FU are defined as follows:

Fishery Unit	Description	Sub-area
FU1	Long-line in medium to deep water	VII
FU2	Long-line in shallow water	VII
FU3	Gillnets	VII
FU4	Non-*Nephrops* trawling in medium to deep water	VII
FU5	Non-*Nephrops* trawling in shallow water	VII
FU6	Beam trawling in shallow water	VII
FU8	*Nephrops* trawling in medium to deep water	VII
FU9	*Nephrops* trawling in shallow to medium water	VIII
FU10	Trawling in shallow to medium water	VIII
FU12	Long-line in medium to deep water	VIII
FU13	Gillnets in shallow to medium water	VIII
FU14	Trawling in medium to deep water	VIII
FU15	Miscellaneous	VII & VIII
FU16	Outsiders	IIIa, IV, V & VI
FU00	French unknown	

The main part of the fishery is currently conducted in six Fishery Units, three of them from Subarea VII: FU 4, FU 1 and FU 3, two from Subarea VIII: FU 13 and FU 14 and one in Subareas IIIa, IV, V and VI : FU16.

From the information reported to the Working Group, Spain accounted in recent years for the main part of the landings (around 60%) followed by France (around 25%), UK, Denmark, Ireland, Norway, Belgium, Netherlands, Germany, and Sweden contributing to the remaining.

The minimum landing size for fish caught in Subareas IV, VI, VII and VIII is set at 27 cm total length (30 cm in Division IIIa).

From 14th of June 2001, an Emergency Plan was implemented by the Commission for the recovery of the Northern hake stock (Council Regulations N°1162/2001, 2602/2001 and 494/2002). In addition to a TAC reduction, 2 technical measures were implemented:

A 100 mm minimum mesh size has been implemented for otter trawlers when hake comprises more than 20% of the total weight of marine organisms retained on board. This measure did not apply to vessels less than 12 m in length and which return to port within 24 hours of their most recent departure.

Two areas have been defined, one in Subarea VII and the other in Subarea VIII, where a 100 mm minimum mesh size is required for all otter trawlers, whatever the amount of hake caught.

Council Regulation (EC) No. 1954/2003 established measures for the management of fishing effort in a biologically sensitive area in Subareas VIIb, VIIj, VIIg, and VIIh. Effort exerted within the biologically sensitive area by the vessels of each EU Member State may not exceed their average annual effort (calculated over the period 1998–2002).

There are explicit management objectives for this stock under the EC Reg. No 811/2004 implementing measures for the recovery of the northern hake stock. It is aiming at increasing the quantities of mature biomass to values equal to or greater than 140 000 t. This is to be achieved by limiting fishing mortality to 0.25 and by allowing a maximum change in TAC between years of 15%.

According to ICES in 2007, the northern hake stock has met the SSB target in the recovery plan of 140 000 t for two consecutive years (2006 and 2007). Article 3 of the recovery plan indicates that, in such a situation, a management plan should be implemented.

An annual one-month fishing activity stop has been implemented by the Spanish administration since 2004. In 2008, a specific national regulation established a 90-days stop to be distributed from August 2008 to December 2009. Independently of these regulations, some Spanish fleets stopped their activity during some weeks in June 2008 to protest against the increase of petrol prices.

In Subarea VIII, for 2006, 2007 and 2008, otter trawlers using a square mesh panel are allowed to use 70 mm mesh size in the area, mentioned above, where 100 mm minimum mesh size is required for all otter trawlers. (EC Reg. No. 51/2006; EC Reg. 41/2007).

Furthermore, there was a ban on gillnets in Divisions VIa,b and VIIb,c,j,k fishing at more than 200 m of depth (EC Reg. No 51/2006) during the first semester of 2006.

A.3. Ecosystem aspects

Although a comprehensive study on the role of hake in its ecosystem has not yet been carried out, some partial studies are available. Hake belongs to a very extended and diverse community of commercial species including megrim, anglerfish, *Nephrops*, sole, sea bass, ling, blue ling, greater forkbeard, tusk, whiting, blue whiting, *Trachurus* spp, conger, pout, cephalopods (octopus, *Loligidae*, *Ommastrephidae* and cuttlefish), and rays. The relative importance of these species in the hake fishery varies largely in relation to the different gears, sea areas, and countries involved.

Hake is preyed upon by sharks and other fish. Cannibalism on juveniles by adults is also quoted. Adults feed on fish (mainly on blue whiting and other gadoids, sardine, anchovy, and other small pelagic fish); juvenile hake prey mainly upon planktonic crustaceans (above all euphausids, copepods, and amphipods).

Ecological factors or environmental conditions impacting on hake population dynamics are not taken into account at present in the assessment or in the management.

B. Data

B.1. Commercial catch

B.1.1. Landings

The Spanish landings data are based on sales notes and Owners Associations data compiled by IEO; and Basque Country sales notes and Ship Owners data compiled by AZTI. French landings data are based on logbook and auction hall sales.

From 1978 to 1989, landings in weight are available by year, gear (trawl, gillnets and longline), country (UK, France and Spain) and ICES Divisions (DIVISION IVa + SUBAREA VI, DIVISION VII and DIVISIONS VIII a+b). From 1990 to present, for most of the years, landings in weight by FUs and countries are available on a quarterly basis. In 1992, only data from Spain is available by FU and on a quarterly basis (Table 1).

Table 1. Landings-in-weight (and their level of aggregation) available to the Working Group.

	1978 TO 1989	1990-1991	1992	1993 TO PRESENT
By Gear, Country and ICES Divisions	X			
By FU		X	X	X
By year	X		X	
By quarter		X	X*	X

*** For Spain only**

From 1978 to 1989, length–frequency distributions are available by year, gear, country and ICES Divisions. From 1990 to present, length compositions of the landings are not available for all Fishery Units, quarters and countries. Only the main FUs/Countries are sampled. Table 2 presents, as an example, the length distributions available for 2008.

Table 2. Length–frequency distributions provided to the Working Group in 2008.

FU	France	Ireland	Spain	UK(EW)	Scotland	Danemark
01			Quarterly			
03	Quarterly		Quarterly	Quarterly		
04			Quarterly	Quarterly		
05	Quarterly			Quarterly		
06				Quarterly		
09	Quarterly					
10	Quarterly					
12	Quarterly		Quarterly			
13	Quarterly		Quarterly			
14			Quarterly			
15		Quarterly				
16			Quarterly		Quarterly	Yearly

B.1.2. Discards

Until 2002, the only discards series available and used by the WG were those of the French artisanal and coastal trawl fisheries in the Bay of Biscay, estimated on the basis of the length compositions obtained during FR-RESSGASC surveys. The RESSGASC survey used for their estimation ended in 2002.

EU countries are now required under the EU Data Collection regulation to collect data on discards.

A new sampling programme of discards in the French *Nephrops* trawlers fishery of the Bay of Biscay started in June 2002. Estimates obtained by this programme (see Table 3 below) were significantly different (by a factor 2 to 10) from previous estimates for that fishery (estimates are from 532 t in 2006 to 1597 t in 2005). Such discrepancies could be explained by changes in the sampling, changes in the discarding practices, variations in the abundance of small fish or by a combination of the three. The CVs associated with these estimates are around 20%.

Discards are available for Danish trawlers and seiners fishing in Subarea IV from 1995 to 2004 and for gillnetters from 1995 to 2008. Their values are quite variable from year to year from 100 to 800 t.

Additional information on discards was available for the Irish otter trawlers fishery in Subareas VI and VII from 1999 to 2001 and for 2004 and 2005 (values from 32 to 650 t, not raised after 2005) and for UK-EW from 2000 to 2008 (raised only to the trip level).

Estimates of discards for the Spanish trawl fleets operating in the ICES Subarea VII and Divisions VIIIabd are available for 1988, 1989, 1994, from 1999 to 2001 and from 2003 to 2008. In Subarea VII, an increase in estimated discards rate was observed from 2003 to 2008 when compared with previous years. Discards were estimated to vary from very small amounts to more than 1000 t in 2003–2005 and over 2000 t in 2008. CVs were highly variable from 20% to more than 100%. The current raising procedure based on landings is not considered satisfactory and will be revised in the near future. This may lead to important revision in discards estimates for those fleets. Fixed gears were also sampled in order to design the Spanish Discards Sampling Programme, but no relevant discards were observed (Pérez *et al*., 1996).

Table 3. Summary of discards data available (weight (t) in bold, numbers ('000) in italic).

Fleet/metier sampled	Corresponding Fishery Units	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Spanish Trawl in VII	FU 4	**612**	**137**	**245**	NA	**1254**	**1089**	**1099**	**965**	**718**	**2141**
		4124	*1175*	*2354*	NA	*16143*	*10654*	*13376*	*5786*	*5554*	*25059*
French Nephrops trawl in VIIIabd	FU9	**565**	**341**	**417**	**172**	**1035**	**1359**	**1597**	**532**	**767**	**858**
		9139	*7421*	*6407*	*2992*	*23676*	*39550*	*37740*	*18031*	*24277*	*18245*
French trawl in VIIIabd	FU10	**211**	**169**	**100**	**142**	NA	NA	NA	NA	NA	NA
		3053	*3013*	*1439*	*2253*	NA	NA	NA	NA	NA	NA
Spanish trawl in VIIIabd	FU14	NA	NA	NA	NA	NA	**30**	**489**	**206**	**471**	**352**
		NA	NA	NA	NA	NA	*451*	*8475*	*3397*	*10002*	*7153*
Irish trawl and seine in VII	FU15	**190**	**650**	**194**	NA	NA	**32**	**94**	*	*	*
		1868	*892*	*1046*	NA	NA	282	*629*	*	*	*
UK (EW) trawl in IV and VII	FU16 + 4 + 5	NA	*	*	*	*	*	*	*	*	*
		NA	*	*	*	*	*	*	*	*	*
Spanish trawl in VI	FU16	NA	NA	NA	NA	NA	NA	NA	NA	NA	**6**
		NA	NA	NA	NA	NA	NA	NA	NA	NA	*11*
Danish trawl and seine	FU16	**42**	**21**	**142**	**354**	**242**	**206**	**814**	**610**	**255**	**190**
		29	*38*	*483*	*691*	*479*	*775*	NA	NA	*849*	*642*
Total Weight from sampled fleet (t)		**1620**	**1319**	**1098**	**668**	**2531**	**2716**	**3278**	**1702**	**1957**	**3547**
Total Number from sampled fleets ('000)		*18213*	*12539*	*11730*	*5935*	*40299*	*51712*	*60220*	*27215*	*39833*	*51110*

* sampled but not raised

During the 2003 assessment, the Working Group noted that, although some improvement in discard data availability had been observed (number of fleets sampled and area coverage), sampling does not cover all fleets contributing to hake catches and discard rates of several fleets are simply not known. Furthermore, when data are available, it was not possible to incorporate them into the assessment in a consistent way. As reconstructing an historical series was found problematic, discard estimates were removed from the full time-series of catch data. From 2003 to 2008, the assessment was thus conducted on landings only. After 2008 Working Group assessment, discards estimates from several sampled fleets were used in the assessment. This includes the French *Nephrops* trawl in VIIIabd discards data from 2003 to present, the Spanish trawl in VII in 1994, 1999, 2000, 2003 to present and the Spanish trawl in VIII abd from 2005 to present.

B.2. Biological

Mean weight-at-length are estimated from a fixed length–weight relationship (W(g)= 0.00513*L(cm)^3.074; ICES, 1991b).

The parameters of the time invariant logistic maturity ogive, for both sexes combined are: L_{50} = 42.85 cm and slope = - 0.2 (ICES, 2010b WD8).

Conventional tagging of European hake (de Pontual *et al*., 2003) recently opened new avenues for a better understanding of the species biology and population dynamic which have remained controversial for decades (see e.g. Belloc, 1935; Hickling, 1933). The first tagging results provided evidence of substantial growth underestimation (by a factor ~2) due to age overestimation, (de Pontual *et al*., 2006), thus challenging the internationally agreed age estimation method. More tagging efforts, both off the Northwest Iberian Peninsula (Piñeiro *et al*., 2007) and the Mediterranean Sea (Mellon-Duval *et al*., 2010), have recently proved that growth underestimation was not a regional issue. Besides, Ifremer sustained a large tagging effort in the Bay of Biscay from 2004 to 2007 which allowed confirming both the relevance of the fast growth hypothesis and the issues of the otolith-based age estimation current methodology. An ICES workshop (ICES, 2010a) confirmed that the previous internationally agreed ageing method is neither accurate nor precise and provides overestimation of age. A replacement ageing method with sufficient precision and accuracy is currently not available. Conversion from length-to-age using an age–length key and the use of an assessment model relying on a catch-at-age matrix and abundance indices at age as was done until 2008 becomes then problematic. This leads the Working Group to consider the use of a length-based stock assessment model.

In the absence of a direct estimate of natural mortality, a constant value of 0.4 was assumed for all age classes and years. It must be noted that this is a larger value than the one used in assessments conducted until 2008 where M was set to a value of 0.2. The rationale for this higher value is that if hake growths about two times faster, the hake longevity is reduced by about a half (from age ~20 to ~10), thus impacting on natural mortality (Hewitt and Hoening, 2005).

B.3. Surveys

Several research-vessel surveys cover part of the geographical distribution of the Northern hake stock (Figure 2).

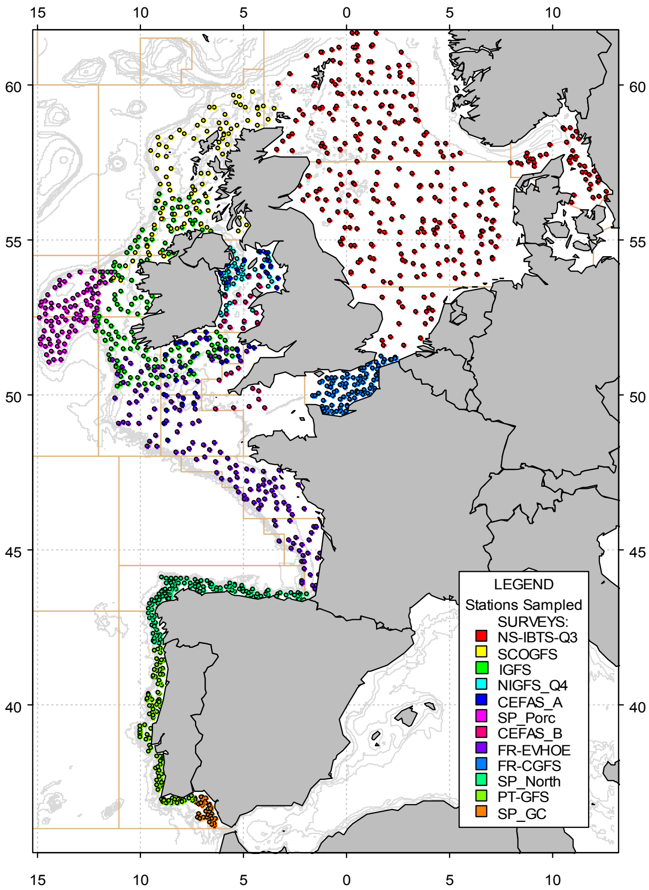

Figure 2. Map of East Atlantic groundfish surveys: stratification and trawling positions.

Abundance indices are available from the following research-vessel surveys:

Abundance indices used in the SS3 assessment:

French Evhoe groundfish survey (FR-EVHOES): years 1997–present. The survey occurs in autumn. The survey uses a GOV trawl with a 20 mm codend liner. It covers the shelf of both the Bay of Biscay and the Celtic Sea.

French Ressgasc groundfish survey (FR-RESSGASCS): years 1978 to 2002. Over the years 1978–1997 the FR-RESSGASCS surveys were conducted with quarterly periodicity. They were conducted twice a year after that (in spring and autumn). Survey data prior to 1987 have been excluded, because there was a change of vessel at that time. Weather conditions encountered by FR-RESSGASCS in 2002 gives to this index a poor reliability and it was decided not to use it. The survey uses a 25 m "Vendéen type" bottom trawl. It covers the Bay of Biscay. The survey ended in 2002.

Spanish Porcupine groundfish survey (SP-PGFS): years 2001 to present. The area covered by this survey is the Porcupine bank extending from longitude 12° W to 15° W and from latitude 51° N to 54° N, covering depths between 180 and 800 m. The cruises are carried out every year in September on board R/V "Vizconde de Eza", a stern trawler of 53 m and 1800 Kw. Numbers-at-age for this abundance index are estimated from otoliths collected during the survey.

Irish Groundfish Surveys: years 2003 to present. This survey is conducted on board the *R.V. Celtic Explorer* in autumn in the west of Ireland and the Celtic sea. The survey uses GOV 36/47 (Grande Ouverture Verticale).

Abundance indices not used in the SS3 assessment:

UK WCGFS survey (UK-WCGFS): years 1988 to 2004. This survey was conducted in March in the Celtic sea. It does not include the 0-age group. Numbers-at-age for this abundance index are estimated from length compositions using a mixed distribution by statistical method. The survey ended in 2004.

B.4. Commercial cpue

Commercial cpues indices provided to the ICES Working Group are not used in the current SS3 assessment. Landings-per-unit-effort time-series are available from the following fleets:

Trawlers from A Coruña and Vigo fishing in Sub-area VII (SP-CORUTR7 and SP-VIGOTR7), pairtrawlers from Ondarroa and Pasajes fishing in Sub-area VIII (SP-PAIRT-ON8 and SP-PAIRT-PA8)

The A Coruña trawler fleet, targeting mainly hake, operates in deeper waters close to the slope in Division VIIb-c, j–k, while the trawler fleet from Vigo, targeting megrim, works in shallower waters in Division VIIj–h and catch hake as bycatch. Both pairtrawler fleets from Ondarroa and Pasajes are targeting hake in the Bay of Biscay.

Ondarroa "Baka" trawlers fishing in Subareas VI, VII and Division VIIIa,b,d, Pasajes "Bou" trawlers fishing in Subarea VIII, longliners from A Coruña, Celeiro and Burela fishing in VII, longliners from Avilés in VIIIa,b,d and trawlers from Santander in VIIIa,b,d.

Lpue values of Spanish gillnetters that started to fish hake in Subareas VII and VIII in 1998 are also provided. It is to be noted that only a small number of ships are involved in the gillnet fishery which makes lpues very sensitive to small changes in the number of trips. It is also noted that for gillnetters and longliners, lpues expressed in kg/day may not be the most appropriate.

Lpue data from two French fleets (Les Sables and Lesconil) fishing in Divisions VIIIa,b,d are also available from Logbooks. Due to important reductions in the availability of logbook information in recent years for both fleets, lpue values for the years 1996 onwards have low reliability. No data have been provided for those two fleets after 2003.

B.5. Other relevant data

C. Historical stock development

Model currently used: Stock Synthesis 3 (SS3), (Methot, 2005).

Software used: Stock Synthesis V3.10, Richard Methot, NOAA Fisheries Seattle, WA.

Recent assessments and sensitivity analysis carried out.

An attempt to use a non-equilibrium surplus production model (ASPIC) was carried out in the 2004 WG (ICES, 2005) and preliminary fits of a length based stock assessment model have been presented in 2007 and 2008.

In the 1998 WG it was found that the SSB estimates for 1985–1987 were very sensitive to the q plateau options between age 5, 6, and 7 (which is the last true age). To reduce this effect, it was decided to extend the ten years window to a twelve-year period in order to tune to the longest available and well behaved fleet dataseries. In the 1999 and 2000 assessments, SSB estimates for 1985–1987 were still sensitive to the extent of the tuning period, and the longest (13 years and 14 years respectively) provided the best pattern for these years, whereas other estimates were very similar for other years. In 2001 assessment, it was decided to use the whole tuning data available and a taper time weighting to reduce the influence of the older years. At that time, this choice did not change radically the estimates of trends in F and SSB and those settings were maintained in 2002 to 2003 assessments.

In 2004, the group investigated again the influence of the taper time weighting and runs were conducted without taper and compared with the base-case run using a tricubic taper over a 20 year period. While the group agreed on the rationale behind the use of a taper to down-weight the years for which we may have less confidence, it expressed concerns over the large influence the use of this option has on the perception of the stock dynamics and the inability of the model to account, in a satisfactory manner, for uncertainty in the data.

Due to uncertainties in hake aging, in 2005, 2006 and 2007, the group also conducted a sensitivity analysis using a simulated ALK assuming a faster growth. In each of these years, several runs were thus conducted (An Update from the previous year and a Simulated ALK, see below).

In WGHMM 2007, an update runs from 2006 has been carried out and the SP-PGFS survey was added to the surveys used to tune the model.

WKROUND 2010 (ICES, 2010b) reviewed the uses of the Stock Synthesis assessment model.

Current assessment

The assessment is a length-based approach using the Stock Synthesis assessment model. This approach allows direct use of the quarterly length composition data and explicit modelling of a retention process that partitions total catch into discarded and retained portions.

The underlying population can be partitioned in time to include as many seasons within a year as required. This is important where temporal aspects of biology (like growth in the case of Hake), or fishing activity dictate finer than annual-level representation, however all the basic input data must then be partitioned to the level of the underlying dynamics.

Recruitment is based on a Beverton–Holt function parameterized to include the equilibrium level of unexploited recruitment (R0) and the steepness (h) parameter, describing the fraction of the unexploited recruits produced at 20% of the equilibrium spawning biomass level. Annual deviations can be estimated for any portion of the modelled time period (or the whole period), and the expected recruitments are bias-corrected to reflect the level of variability (sigmaR, an input quantity) allowed in these deviations.

Growth is described through a von Bertalanffy growth curve with the distribution of lengths for a given age assumed to be normally distributed. The CV of these distributions is structured to include two parameters which can be estimated or fixed, defining the spread of lengths at a young and old age with a linear interpolation between. In addition to growth, the relationships between weight and length, fecundity and length as well as maturity-at-length are all generalized to allow parameters to be estimated or fixed, temporally invariant or not. All model parameters can vary over time either as a function of annual deviations about a mean level, user defined 'blocks' of years in which the parameters differ or a combination of the two.

All model expectations for comparison with data are generated as observations from a 'fleet', either a fishery or a survey/index of abundance. Each fleet has unique characteristics defining relative selectivity across age or size, and can be structured to remove catch or collect observations at a particular time of the year or season. All fleets may be considered completely independent, or parameters may be shared among fleets where appropriate via 'mirroring'.

A suite of selectivity curves including logistic-based shapes of up to eight parameters, power functions and nonparametric forms can be explored through relatively simple modification of the input files.

Kinds of data that model expectations can be fit to include: absolute or relative abundance, length–frequency distributions, age frequency distributions (either total or conditional by length), length-at-age, body weight, and proportion discard. Each of these can be from the retained, discarded or total removals by a specific fleet. Each source has an error distribution (either normal, lognormal or multinomial) associated with it, described by either an input sample size or standard deviation.

Input data for SS3

The overall fishery prosecuting the northern stock of hake has been categorized into 7 "fleets", 4 of which use trawl gears, whereas the remaining three use gillnet, longline and a combination of several gears (Table 4). They are based on a combination of the Fishery Units described above. For each fleet, estimates of landings in weight and length–frequency distributions are available. For some fleet only, discards in weight and length–frequency distribution are used.

Table 4. Fleets characteristics and data available for SS3 (Length–Frequency distribution (LFD) and weight of landings and discards).

FLEETS	DESCRIPTION	FU	LANDINGS (QUARTERLY)	DISCARDS (QUARTERLY)
SPTRAWL7*	Spanish trawl in VII	04	1990–2008 (LFD + Weight)	1994, 1999, 2000, 2003–2008 (LFD + Weight)
FRNEP8	French trawl targeting *Nephrops* in VIII	09	1990–2008 (LFD + Weight)	2003–2008 (LFD + Weight)
SPTRAWL8	Spanish trawl in VIII	14	1990–2008 (LFD + Weight)	2005–2008 (LFD + Weight)
TRAWLOTH	All other trawl	05 + 06 + 08 + 10	1990–2008 (LFD + Weight)	
GILLNET	Gillnet all countries	03 + 13	1990–2008 (LFD + Weight)	
LONGLINE	Longline all countries	01 + 02 + 12	1990–2008 (LFD + Weight)	
OTHERS	Everything else all countries	15 + 16 + 00	1990–2008 (LFD + Weight)	

*** FU04 (and consequently SPTRAWL7) landings and discards contain small amount from area VI as, in some cases, the sampling programme does not allow to make the distinction between area VII and VI.**

For the two Spanish trawl fisheries, it is thought that discarding became much more substantial starting from 1998. For the French *Nephrops* fishery, discarding is thought to have occurred already from 1990. The remaining 4 fisheries (TRAWLOTH, GILLNET, LONGLINE, OTHERS) are assumed not to discard any fish.

Several surveys provide relative abundance indices of abundance and length distributions (Table 5).

Table 5. List of surveys used in SS3.

SURVEYS	AREA	YEARS	QUARTER
EVHOE	Bay of Biscay and Celtic Sea	1997–2008	4
RESSGASC	Bay of Biscay	1990–1997 1998–2001	1, 2 ,3 and 4 2 and 4
PORCUPINE	Porcupine Bank	2001–2008	3
IGFS	North, West and South of Ireland	2003–2008	4

No commercial fleet tuning data are used.

SS3 settings (input data and control files):

Years: 1990 to 2008, 1 area, 4 seasons, both sexes combined

Initial equilibrium catch: annual average of ten years (1980–1989) for each fishery.

Variability for landings, discards and survey abundance indices are entered as standard deviation in log-scale, as follows:

Landings (tonnes): 10% variability

Discards (tonnes): 50% variability

Survey abundance indices: variability externally estimated. As the latter represents only the surveys internal variability, extra variability was added (increment to CV in SS3 control file) according to how representative each survey was felt to be of stock abundance. Surveys' CV were increased by 0.1 (EVHOE), 0.2 (RESSGASC, IGFS), 0.3 (Porcupine).

Length compositions were assigned the following sampling sizes in the SS3 input data file, on the basis of how representative they were felt to be:

Landings: 125 for all fleets, except SPTRAWL7 for which 50 was used for 1990-1997 and 200 was used from 1998 onwards

Discards: 50 for SPTRAWL7 and SPTRAWL8, 80 for FRNEP8

Surveys: 125

The following multipliers were subsequently applied to the latter sample sizes in the SS3 control file:

Landings and discards: 0.5 for all fleets, except LONGLINE to which a factor of 1 was applied

Surveys: 1 (EVHOE), 0.525 (RESSGASC, IGFS), 0.35 (Porcupine)

M=0.4.

Von Bertalanffy growth function: Linf=130 cm, K and mean length-at-age 0.75 estimated. Same growth parameters apply to all fish (across morphs, years, etc)

Maturity ogive: length-based logistic, externally estimated and assumed constant over time

Recruitment allocation for Quarter 2 to 3 estimated with respect to Quarter 1. Quarter 2 allocation is time-varying, with annual deviates. Quarter 4 allocation set to 0.

Beverton–Holt stock–recruitment relationship: steepness h=0.999, sigma_R=0.7, R0 estimated.

Recruitment deviations starting in 1985.

F estimation method = 2 (F by fishery and quarter treated as unknown parameters)

Surveys catchabilities constant over time.

RESSGASC survey entered as 4 separate surveys (1 per quarter). Catchabilities are quarter-specific but all quarters use the same selectivity-at-length.

Selectivity only length-based (no age selectivity considered)

Selectivity-at-length uses Pattern 24 (double normal function, with 6 parameters) for fleets SPTRAWL7, FRNEP8, SPTRAWL8, GILLNET, LONGLINE and all surveys. TRAWLOTH and OTHERS use Pattern 1 (logistic function, with 2 parameters). When Pattern 24 is used, parameter P5 is not used except for SPTRAWL7 and SPTRAWL8.

Selectivity-at-length constant over all years.

Retention patterns for fisheries with discards: length-logistic with asymptotic retention = 1 in all cases, and unknown L50 and slope. For SPTRAWL7 and SPTRAWL8, two different patterns of retention over time are assumed, one for years 1990–1997 and the another one from 1998 onwards.

D. Short-term projection

Model used: length and age-based.

Software used: Forecast module in SS3.

Initial stock size. Taken from the SS3 in the last assessment year.

Natural mortality: Set to 0.4 for all ages in all years.

Growth model: Von Bertalanffy model, with parameters estimated in the assessment model.

Maturity-at-length: The same ogive as in the assessment is used for all years.

Weight-at-length in the stock and in the catch: The same length–weight relationship as in the assessment model.

Exploitation pattern: Average of the final 3 assessment years (with the possibility of scaling to final year F).

Intermediate year assumptions: *status quo* F

Stock–recruitment model used: Beverton–Holt Stock Recruitment relationship estimated in the assessment, with deviances chosen so that recruitment in the projection years approximately matches the geometric mean of estimated recruitment from 1990 until the final assessment year minus 2.

E. Medium-term projections

No medium-term projections are conducted for this stock.

F. Long-term projections

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

Software used: Forecast module in SS3

Selectivity pattern: Average of final 3 assessment years.

Stock and catch weights-at-length: Same length–weight relationship as in the assessment model

Maturity: Fixed maturity ogive as used in assessment

G. Biological reference points

In 2003, ACFM updated precautionary reference points following a revision of the assessment model and input data in recent years. These values all should be re-evaluated based on results from WKROUND 2010.

	WG 1998	ACFM 1998	ACFM 2003
Flim	No proposal	0.28 (= Floss WG 98)	0.35 (= Floss WG 03)
Fpa	No proposal	0.20 (= Flim*e-1.645*0.2)	0.25 (= Flim*e-1.645*0.2)
Blim	No proposal	120 000 t (~ Bloss= B94)	100 000 t (~ Bloss= B94)
Bpa	119 000 t (=Bloss= B94)	165 000 t (= Blim*e1.645*0.2)	140 000 t (= Blim*e1.645*0.2)

H. Other issues

None.

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6 Southern Hake

6.1 Current stock status and assessment issues

Southern hake stock comprises the Atlantic coast of Iberian Peninsula corresponding to the ICES Divisions VIIIc and IXa. Southern hake is one of the most important target species for the fleets operating in the Atlantic coast of the Iberian Peninsula. Historical yields declined from 30 000 t at the beginning of the 1970s to a minimum of 6700 t in 2002, increasing thereafter to 16 000 t in 2008. In 2003, the International Council for the Exploitation of the Sea (ICES) classified the stock as being outside safe biological limits and advised a rebuilding plan. Accordingly, a recovery plan was introduced by the European Commission in 2006 (Reg. EC No 2166/2005) aiming at rebuilding the spawning-stock biomass to 35 000 t, which corresponds to the precautionary spawning-stock biomass reference point estimated by ICES.

Based on the most recent estimates of SSB (in 2009), ICES classifies the stock as suffering reduced reproductive capacity. Based on the most recent estimate of fishing mortality (in 2008) ICES classifies the stock as at risk of being harvested unsustainably. Fishing mortality has increased in recent years and is currently near Flim. SSB and recruitment have increased in recent years, but recruitment in 2008 is lower than in previous years and estimated to be poor (the lowest in the 27-year time-series).

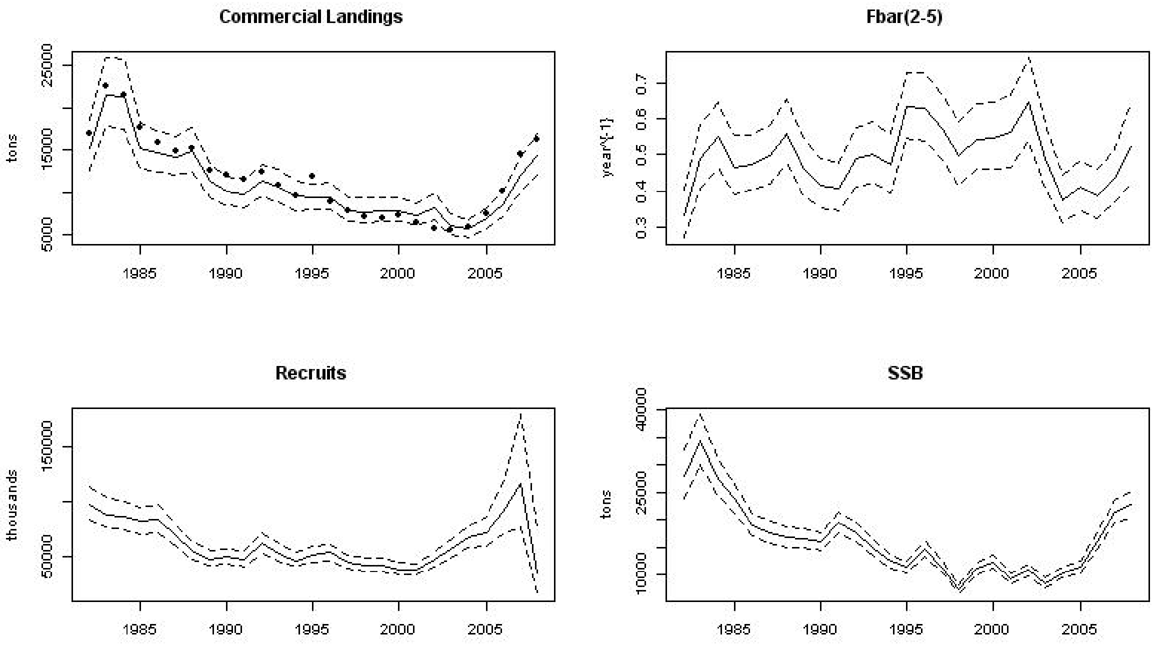

Figure 1. Hake: Southern stock (Divisions VIIIc and IXa). Landings, fishing mortality, recruitment, and SSB from 2009 assessment.

It should be noted that for both the northern and southern hake new assessment models have been developed to avoid the reliance on age-based data. The two new models are considered to be an improvement on the previous method given the problems related to age data described below. However both are new, complex, and significantly different from the previous models. It is therefore likely that refinements and updates will be required over the coming years to both models and further consideration given to the data used. The panel considers that ICES should be flexible in allowing model improvements during the Assessment Working Groups and on an intersessional basis. ICES should therefore ensure that resources are in place to evaluate these improvements.

Issues considered in this benchmark relate to:

1) The northern and southern hake stocks described in this report are managed and assessed separately. However these stocks are adjacent, and are considered to have similar biology with an unknown degree of migration between the two areas. As a consequence the stock structures, and the issues facing the two stocks, are similar. The stock assessment teams have worked to increase the robustness of the two assessments by coordinating their efforts and borrowing strength between the two stocks during the WKROUND meeting.

Results of published tagging studies for the related northern (de Puntual *et al.*, 2006) and southern (Piñeiro *et al.*, 2007; Piñeiro *et al.*, 2009) hake stock indicate that the past age determination methods were overestimating age approximately twofold. This invalidates the age data used in previously age-based stock assessments and indicates that growth is faster than previously estimated. In addition, following Hewitt and Hoenig, 2005, these findings suggest that higher natural mortality rates should be used in assessments.

The new assessment shifts to a length-based approach using the Gadget assessment model. This approach allows the direct use of length structured data. It provides an assessment of the stock, and provides a simulation tool for investigating the growth and biology of the stock.

Catch data since 1990 indicate a very small proportion of fish larger than 60 cm for both hake stocks, even though L_∞ is near 130 cm. After considering sensitivity analyses regarding the degree to which this pattern might be due to dome-shaped partial recruitment vs. historical fishing mortality levels, the panel concluded that the best model configuration would set the fishing fleets with the most persistent occurrence of large hake to have asymptotic selectivity. The rationale for this is discussed in the sensitivity section of this document.

The information on faster growth and younger ages supported investigation of larger values for natural mortality. Investigative model runs were conducted for both hake stocks at M=0.2, 0.3 and 0.4. The fit of the assessment model was better with M=0.2; however the k estimated at this level of natural mortality was approximated 0.08, which was considered unrealistic regarding the information about faster growth. Furthermore, in the case of Northern hake the best fit was obtained with M=0.4 and k was not influenced by distinct M, which was considered a robust estimate. The level of natural mortality adopted for Southern hake was 0.4, borrowing strength from the northern stock.

The assessment is limited in its ability to precisely estimate current stock abundance and mortality because the modelled time period, 1982–2008, does not exhibit strong contrasts in the available data. Future assessments should attempt to extend the modelled time period back to about 1960 to improve the model's ability to determine the degree to which historical levels of fishing reduced hake abundance. The downward trend in the catch of larger hake during the 1980s should provide information regarding the level of fishing mortality that caused this decline.

It should be noted that forward simulation models need to include an initial population, which may be modelled differently from the full dynamics of the forward simulation model. As a result the first years of the model run should be considered to be a "burn-in" period, and the results should be treated with caution. If it is desired to focus on the biomass in the early 1980s then consideration should be given to extending the start of the model run further back in time. Additionally it should be noted that there is considerably more data used in tuning the later part of the model run than for the early part, thus the confidence in the early part must be lower.

6.2 Compilation of available data

Following WGHMM 2009, some data (or lacking data) generating uncertainty in past assessment were reviewed and incorporated to this new assessment approach. These are:

Cadiz landings from 1982 to 2008

Discards from 1992 to 2008

Standardized Portuguese trawl cpue

Maturity ogives.

Apart of this new data, GADGET needs inputs in a fine seasonal scale, in this case by quarter.

6.2.1 Catch and landings data

Landings

The landings data used in the Southern Hake assessment are based on: (i) Portuguese sales notes compiled by the National Fisheries and Aquaculture Directorate; (ii) Spanish sales notes and owners' associations' data compiled by IEO; and (iii) Basque Country sales notes and Ship Owners data compiled by AZTI.

All landings since 1994 were reviewed and computed by quarter. From 1982 to 1993 annual landings were split by quarters assuming the same quarter distribution than in 1994 Landings from the Gulf of Cadiz were compiled and included on the assessment. Before 1994 they were splitting by quarters in the same way than total landings.

Landings length distributions were available by quarter after 1994. Before that we assume that the existing annual length distribution was caught in the middle of the year.

Discards

A Spanish Discard Sampling Programme is being carried out in Divisions VIIIc and IXa North since 1993. The series provides information on discarded catch in weight and number and length distributions for Southern hake. Spanish sampling was carried out in 1994, 1997, 1999-2000 and 2003 onwards. The number of trips sampled by the Spanish programme was distributed by three trawl fleets: Baca otter trawl, Pair trawl and HVO (High Vertical Opening) trawl. Total discards were estimated raising sampling with effort. This series was revised and computed by quarter from 2004 onwards.

The Portuguese Discard Sampling Programme started in 2003 (second semester) and is based on a quasi-random sampling of co-operative commercial vessels. Two trawl fleets are sampled in this programme: Crustacean Trawl and Fish Trawl fleets. The total number of trips, performed by each fleet is used to estimate discards. This seems to be the best sampling variable to use, as there is no correlation between landings and discards. The discards estimation method was revised to take into account fishing hours as auxiliary variable and include outliers analysis (see Southern hake WD 2).

Both series of discarded weights were rebuilt back to 1992 based on the relations between (i) discards and surveys, and (ii) discards and landings (see Southern hake WD 4), with the aim of integrating them in assessment models. Before 2004 quarterly discards distributions were estimated based on 2004-2008 mean quarter distribution.

6.2.2 Biological data

The main hake growth studies comes from Northern hake, providing evidence of substantial growth underestimation (by a factor ~2) due to age overestimation (de Pontual *et al.*, 2006), thus challenging the internationally agreed age estimation method. Recent tagging efforts from Southern stock (Piñeiro *et al.*, 2007) proved that growth underestimation was not a regional issue and similar growth rates were obtained in Galician area. Nevertheless, recovered tags from Southern Stock are scarce and a common approach for growth in both stocks was suggested based on tags information and modelling experiences run along the WHROUND (fix Linf=130 and estimate k with M=0.4). A common international length–weight relationship for the whole period has been used since 1999 (a=0.00000659, b=3.01721).

European hake presents indeterminate fecundity and asynchronous development of the oocytes and it is a serial or batch spawner. Duration of spawning season at the population level may differ between areas (Domínguez-Petit, 2007); but a latitudinal gradient exists such that the latest peaks of spawning occur in higher latitudes. Males mature earlier than females. L50 varies between areas; in the Atlantic populations is between 40-47 cm (Domínguez-Petit, 2007) Besides, temporal fluctuations in size-at-maturity within the population have been also observed what probably reflects changes in growth rate (Domínguez *et al.*, 2008). Changes in maturity parameters affect stock reproductive potential, because smaller and younger females have different reproductive attributes than larger and older individuals.

6.2.3 Survey tuning data

The Spanish October groundfish (SP-GFS) survey uses a stratified random sampling design with half hour hauls and covers the northwest area of Spain from Portugal to France during September/October since 1983 (except 1987).

Two groundfish surveys are carried out annually in the Gulf of Cadiz - in March, from 1994, and in November (SP-GFS-caut), from 1997. A stratified random sampling design with 5 bathymetric strata, covering depths between 15 and 700 m, is used in this area, with one hour hauls. Hake otoliths have been collected since 2000 and ALKs are available since then.

The Portuguese Autumn GFS has been carried out in Portuguese continental waters since 1979 on board the RV “Noruega” and RV “Capricórnio”. Recent work on calibration of these vessels demonstrated a higher catchability of Capricórnio, in particular at lower sizes, as a consequence these years were calibrated. The main objective of this survey is to estimate hake's abundance indices to be used in stock assessment (Anon., 2008). A stratified sampling design was used from 1989 until 2004. In 2005 a new hybrid random-systematic sampling design was introduced, composed by a regular grid with a set of additional random locations (Jardim and Ribeiro Jr., 2007;

Jardim and Ribeiro Jr., 2008). The tow duration was 60 minutes until 2001 and reduced to 30 minutes for the subsequent years, based on results of an experiment demonstrating no significant differences in the mean abundance and length distribution between the two tow durations (Cardador, personal communication, 2007).

The Portuguese July groundfish (P-GFS-jul) survey has not been conducted since 2002.

A new survey, the Portuguese February groundfish, and has been carried out since 2005, with the aim of covering hake's spawning season.

6.2.4 Commercial tuning data

Effort series are collected from Portuguese logbooks and compiled by IPIMAR, and from Spanish sales notes and Owners Associations data and compiled by IEO.

Spanish landings, lpue and effort are available for Coruña trawl (SP-CORUTR), Coruña pair trawl (SP-CORUTRP), Vigo/Marin trawl (SP-VIMATR), Santander trawl (SP-SANTR), Cadiz Trawl and. Only the cpue from A Coruña trawl was used because there is not confidence on the temporal consistence on the other series as abundance indices.

The Portuguese trawl (P-TR) fleet cpue was standarized using a GLM model with Gamma residuals, a "log" link function and explanatory variables year, zone, engine power, métier, percentage of hake in the catch, level of total catch and level of fishing effort. A working document presented to the benchmark documents the procedure (Southern hake WD 1).

6.2.5 Industry/stakeholder data inputs

Cpues series presented before were built with the collaboration of different fishing organizations.

6.3 Stock identity and migration issues

Southern hake stock comprises the Atlantic coast of Iberian Peninsula corresponding to the ICES Divisions VIIIc and IXa. The Northern limit is in the Spanish–French boundary and the Southern one in Gibraltar Strait. These boundaries were defined based on management considerations without biological basis. Atlantic and Mediterranean European hake are usually considered as different stocks due to the differences in biology (i.e. growth rate or spawning season) of the populations in both areas. In the North Eastern Atlantic, there is no clear evidence of the existence of multiple hake populations, although Roldán *et al.*, 1998 based on genetic studies states that "*the data (…) indicate that the population structure within the Atlantic is more complex than the discrete northern and southern stocks proposed by ICES*". It is likely that there is a degree of transfer between the southern and northern hake stocks, and recent studies on population genetics support that (Balado *et al.*, 2003; Pita *et al.*, 2010), however there is at present a lack of data to quantify the amount of migrations between stocks.

6.4 Spatial changes in the fishery and stock distribution

No evidence concerning spatial changes in the fishery and stock distribution was presented during this benchmark. However considering the lack of consistency of the current stock definition we cannot exclude movements from or towards the stock area. Particularly uncertain is the dynamics in the south of the Iberian Peninsula (Algarve and the Gulf of Cádiz) with relation to the north of Africa.

6.5 Environmental drivers of stock dynamics

No evidence of environmental drivers was presented in this benchmark. Such patterns should be considered in future, particularly because of the possible northward shift in recruitment.

6.6 Role of multispecies interactions

This subject was not discussed during the benchmark. The information available can be consulted in the stock annex, based on information from previous years.

6.6.1 Trophic interactions

Hake is known to be a cannibalistic species (Velasco, 2007), and there could be expected to be a variable induced mortality depending on the availability of other prey species. However this has not been considered during the current assessment. Hake is a highly ichthyophagous species with euphausiids although decapod prawns are an important part of its diet for smaller hake (>20 cm). In Galicia and the Cantabrian Sea hake is one of the apex predators in the demersal community (Velasco *et al.*, 2003). Its diet at >30 cm is mainly composed of blue whiting, while other species such as horse mackerel and clupeids are only important in shallow waters and in smaller individuals that also feed on other small fish. Along the Portuguese coast the diet of hake is mainly composed of crustaceans (particularly decapods) and fish. The main food items include blue whiting, sardine, snipefish, decapods and mysids. Cannibalism in the diet of hake is highly variable depending on predator size, alternative prey abundance, year or season. Cannibalism in stomach content observations ranged from 0 to 30% of total volume, with mean values about 5% this values produces a high natural mortality in younger ages (Cerviño *et al.*, 2009).

6.6.2 Fishery interactions

Hake in divisions VIIIc and IXa is caught in a mixed fishery by the Spanish and Portuguese fleets that include trawls, pair-trawls, gillnetters, longliners and artisanal fleets.

The Spanish trawl fleet uses mainly two gears, pair trawl and bottom trawl. The percentage of hake present in the landings is small as there are other important target species (i.e. anglerfish, megrims, Norway lobster, blue whiting, horse mackerel and mackerel). During recent years there has been an increase in Spanish trawlers using a new High Vertical Opening gear towed by single vessels and targeting the pelagic species listed above. In contrast, the artisanal fleet is very heterogeneous and uses a wide variety of gears; traps, large and small gillnet, longlines, etc. The trawl fleet landings length composition, since the implementation of the minimum landing size in 1991, has a mode around 29–31 cm depending on the year. Artisanal fleets target different components of the stock depending on the gear used. Small gillnets catch smaller fish than gillnets and longlines, which target mainly large fish and have length composition with a mode above 50 cm. Hake is an important component of the catch for these fleets mainly due to the high prices that reaches in the Iberian markets.

Hake is caught by the Portuguese fleet in the trawl and artisanal mixed fisheries together with other fish species and crustaceans. These include horse mackerel, anglerfish, megrim, mackerel, Spanish mackerel, blue whiting, red shrimp (*Aristeus antennatus*), rose shrimp (*Parapenaeus longirostris*) and Norway lobster. The trawl fleet comprises two distinct components - the trawl fleet catching demersal fish (70 mm mesh size) and the trawl fleet targeting crustaceans (55 mm mesh size). The fleet targeting fish species operates along the entire Portuguese coast at depths between 100 and 200 m. The trawl fleet targeting crustaceans operates mainly in the southwest and south in deeper waters, from 100 to 750 m. The most important fishing harbours from Northern Portugal are: Matosinhos, Aveiro and Figueira Foz, from Central Portugal are: Nazaré, Lisboa and Sines and Southern Portugal are: Portimão and Vila Real Santo António. The artisanal fleet lands hake mainly in the fishing harbours of the Centre. The main fishing harbours are Póvoa do Varzim (North), Sesimbra (Centre) and Olhão (South). Landings recorded by month reveal that the majority of the hake landings occur from May until October for both fleets.

6.7 Impacts on the ecosystem

No ecosystem impacts were directly examined. However, with southern hake at a level of biomass that is s small fraction of its probable unfished level of spawning-stock biomass, and considering hake is a top predator, it seems highly probable that some shift in species interactions has occurred.

6.8 Stock assessment methods

6.8.1 Models

The Gadget assessment model (Begley and Howell, 2004; Frøysa *et al*., 2002) was selected for use in this assessment. This model is currently used for assessments of tiger prawns in Mozambique, and tusk, redfish (experimental) and cod (auxiliary model) within ICES. Gadget is written in C++, running in UNIX, and is freely available for download (together with source code and full documentation) from http://www.hafro.is/gadget. This website is hosted by the Marine Research Institute of Iceland, and expected to remain online in the long term. Gadget is a tool for producing forward simulation age and size-based models, possibly including multispecies, multifleet or multi-area structure. Gadget has been designed to use a wide variety of assessment data structured by length and/or age. For this assessment only length-structured data were used, thus avoiding the age data that is believed to be unreliable.

The model version used for this assessment is 2.1.06. Features of the model configuration included:

1) Quarterly time-steps from 1982 through 2008;

Fleets:

- 1.1) One fishing fleet (split into two time periods 1982–1993 and 1994–2008);
- 1.2) Cadiz fleet from 1982–2004 (05-08 Cadiz data were integrated in previous fleet due to recent change in Cadiz landings selection pattern);
- 1.3) one discard fleet from 1992–2008;
- 1.4) two cpue series and
- 1.5) three survey indices.

Annual recruitment-at-age 0 was partitioned among the first two quarters according to an estimated parameter but with the proportion assumed to be constant over time. Analysis was conducted demonstrating that allowing this proportion to vary annually produced no strong trends or differences in model results, but did incur a large increase in the number of parameters to estimate;

The annual recruitments are estimated for each year. No reliable spawner–recruit relationship exists, and no attempt was made to close the life cycle within the model. Instead the number of recruits was estimated within the model as the recruitment that produced the population that best fit the overall data;

Initial population by numbers was estimated for the initial population in 1982;

The growth was modelled as a von Bertanlanffy process. The slope parameter was estimated, while the L_∞ parameter was set at 130 cm, based on an analysis of the largest fish recorded in the historical catch;

The reported landings for the fleet, and the estimated discards, were taken as exact and the model was set to match these catch sizes;

The selectivity pattern for each fishing fleet was calculated from the "Exponential L50" selectivity pattern within Gadget. This assumes an asymptotic selectivity, with all fish above a certain size being fully selected, and is described further in Section 6.8.2 below;

The surveys were allowed to have asymmetric dome shaped selectivity (The "AndersenSuitFunc" from Gadget);

All catchabilities were assumed to be constant through time, except as noted above that the commercial fleet was allowed to estimate different selectivities before and after the start of 1994.

6.8.2 Sensitivity analysis

Likelihood profiling/sensitivity analysis: A sensitivity test on the optimized parameter set to examine if the model had reached an optimum. Each parameter was varied in turn by up to ±50%, with all other parameters remaining constant. The resulting sensitivity curves limited at ±5%, represent slices through the likelihood surface around the solution. As can be seen in Figure 2 all of the parameters have reached an optimum, although there is (as expected with this sort of model) a wide degree of difference between the parameters. This analysis provides evidence that the model has reached an optimum (although there is of course no guarantee that it has reached the global optimum).

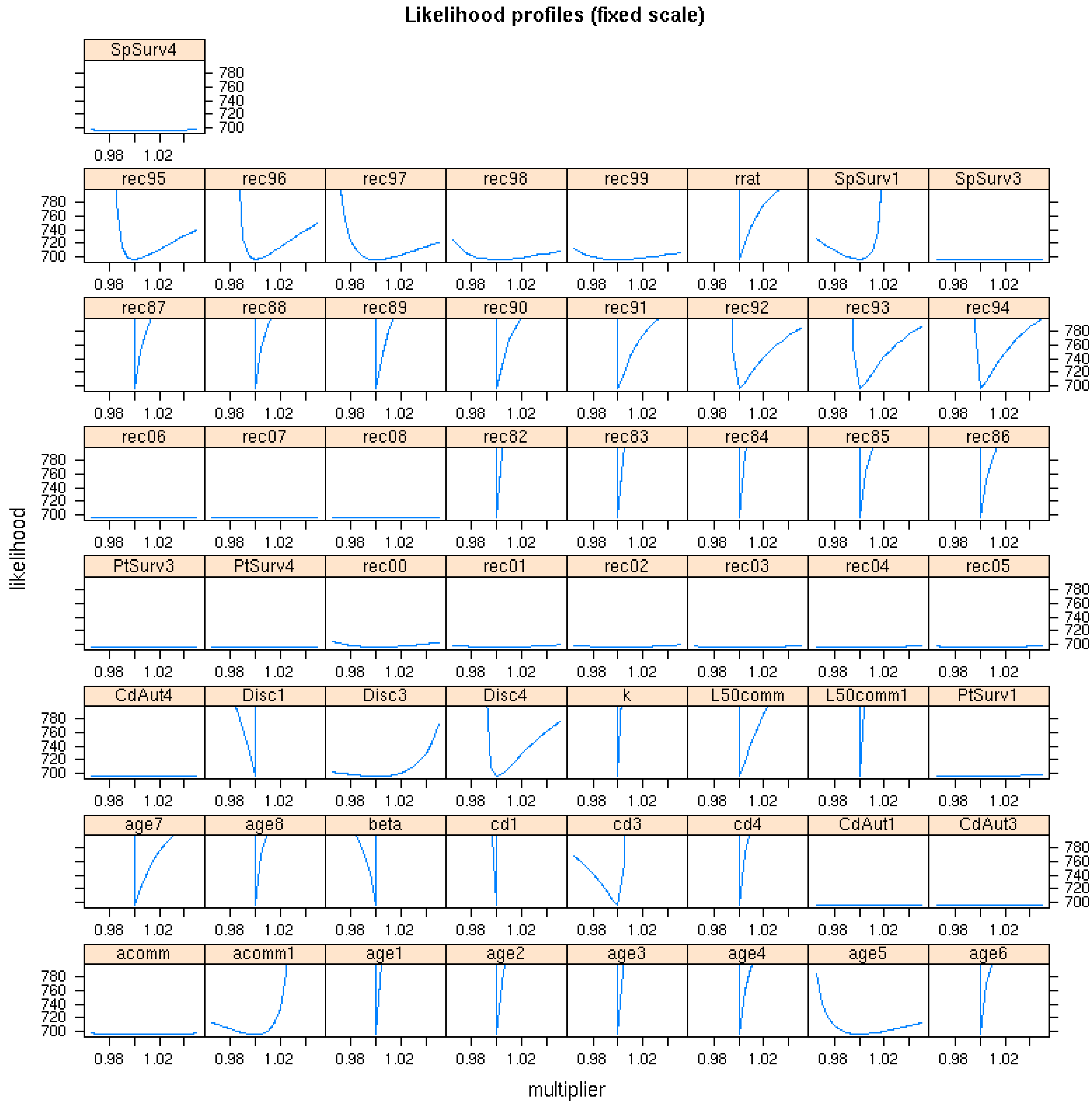

Figure 2. Sensitivity analysis showing that an optimum has been reached.

<u>Selectivity pattern:</u> The choice of selectivity pattern for the commercial fleet was found to have large effects on the modelled population in both the northern and southern hake. The sensitivity arises because there is few data on large fish (>70 cm) in the population. Setting dome shaped selectivities for the commercial fishing permitted the model to generate arbitrarily large populations of large old fish, because these were then never caught in the fleet or the survey, and there was thus no penalty in the objective function from increasing this population. Setting an asymptotic selectivity ensured that model treated the zero values for large fish in the catches as reflecting zeros (or near zeros) in the population. In effect a judgement was made that the zeroes in the catch reflected a low level of large fish in the population. The justification for this choice of asymptotic selectivity was that in the early part of the time-series (1982–1990) large fish were being caught. It therefore seems likely that if such large fish were present in significant numbers in the present population they would also be vulnerable to fishing, and would be seen in the data. Additionally the modelled population produced with the dome shaped selectivity was found to be unrealistically high, and was considered to be a model artefact. Selecting asymptotic

selectivity stabilized the model. Similar issues were found in the northern hake, and resolved in similar way.

Fishing mortality method: The Stock Synthesis model in the northern hake was found to optimize more easily by allowing the model to treat the reported catch in tonnes as an additional dataset to fit, without a requirement to match the catches exactly. This was not found to be necessary for the southern hake model, where catches are assumed to be exact. This assumption should be examined further in future.

Natural mortality: The finding of age overestimation based on the tagging and otolith studies supported the panel's conclusion that the new model should use a value of M higher than the value of 0.2 used previously. Sensitivity testing in both the northern and southern hake suggested that a value of M=0.4 produced a more consistent fit to the data, with consistent biological parameters between the northern and southern hake for k and M (Hewitt and Hoenig, 2005). A value of 0.4 was used for M in all subsequent model runs for both northern and southern hake.

Weighting of datasets: The procedure for assigning the weights in the objective function is described in the Stock Annex, along with the weighting values used. A sensitivity test was conducted by assigning weights in two different ways, and the modelled populations were found to be consistent. The weights used therefore seem suitable for use in a stock assessment.

6.8.3 Retrospective patterns

Retrospective patterns were conducted for the previous four years. Each retrospective run requires re-optimization of the model, and computer time constraints prevented more runs being conducted. The results are presented in Figure 3. Note that retrospective patterns in a forward simulation model such as gadget are different from those from a VPA-based model. In particular a new data point suggesting more (or less) fish in the last year will result in the recruitment being raised (lowered) in previous years to be able to simulate this population, and may also alter growth or selectivities throughout the model. There is no "convergence" in the past, and thus a new year's data could result in differences throughout the time-series. The retrospective pattern in the last 3 years appears to demonstrate a trend to overestimate F and underestimate SSB. The retrospective patterns in SSB are small, indicating that this part of the model is relatively insensitive to new years of data. However the estimate of F (age1–3) and recruitment have proven to be more variable to recent data points, indicating that the modelled population of small fish is more sensitive to variations in the different datasets.

A similar pattern was observed in last assessment (WGHMM, 2009) and three probable causes were proposed then: (1) growth underestimation, (2) migrations and (3) change in selection pattern. The persistence of the retrospective pattern after changing the growth suggests this is not the main cause of that. There was not any available information to think on an important change of selection or migrations in recent years; however this result raises the question again. Based on the model fitted, we may observe a change in the length distribution landings fit in years 2006–2008 compared with previous years, where the model targets larger fish than those observed, suggesting than a change in selection pattern may be driven this pattern. However, it should be noted that the retrospective pattern is based on only a few years of data concerning mostly newly recruited fish, and a certain amount of random noise is to be expected. Further research is required to find the main cause of the retrospective pattern.

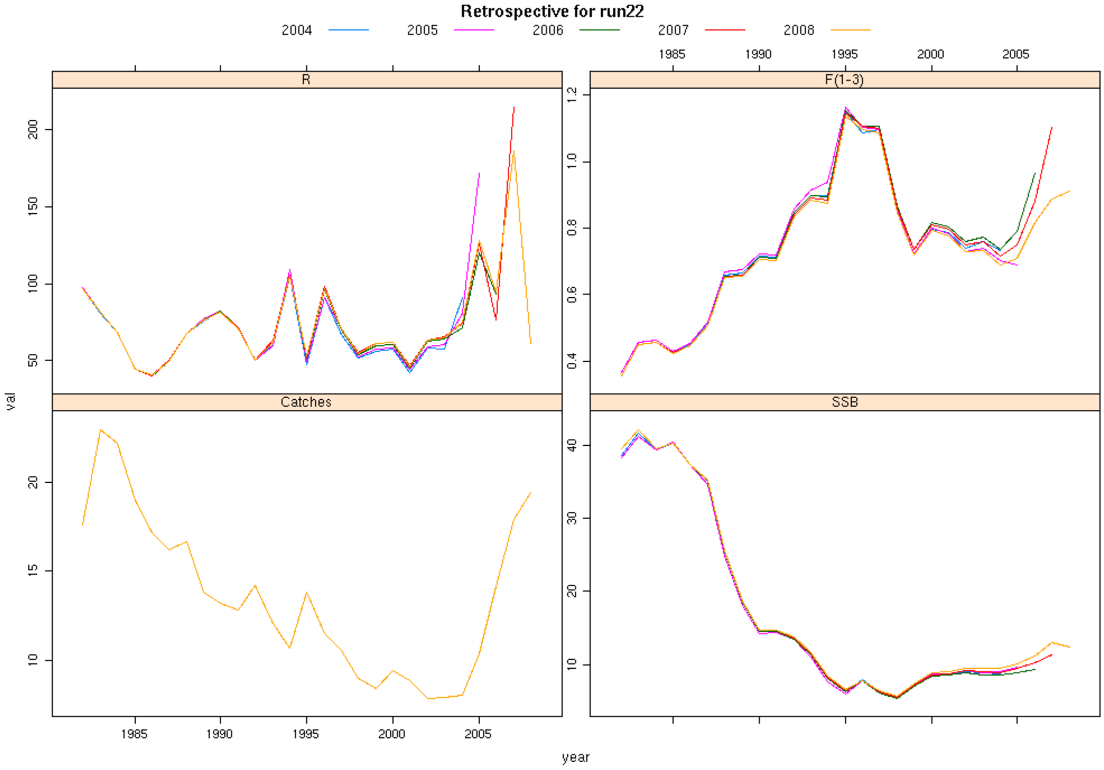

Figure 3. Retrospective runs for the southern hake.

6.8.4 Evaluation of the model

The panel concluded that the final model configuration adequately matched the patterns in the data and that the sensitivity analyses provide adequate understanding of major factors affecting model performance and results. The panel considered that the model was successful in producing stock simulations while avoiding the use of the problematic age data. The panel accepted the final model configuration documented in the stock annex as a suitable basis for assessment of southern hake stock status.

The model is capable of estimating SSB with relatively small residual patterns, and thus can be considered to give a reasonably reliable picture of stock status. However the recruitment of young fish, and hence F resulting from fishing on the younger ages has proven sensitive to the inclusion of updated years of data (see Section 6.8.3 for discussion). As a result the values used as the basis for short-term forecasts have a higher degree of uncertainty. Finally, it should be noted that although the overall stock size may be similar to that generated by previous assessments, the internal stock dynamics are different. If the stock has the higher growth rates estimated by the two hake models, then this has implications for stock recovery potential.

The model has been allowed to select asymmetric dome shaped selectivities for the surveys and the discards, and asymptotic selectivity for the commercial fleet (with different selectivity before and after the end of 1993). This asymptotic selectivity is based on an assumption that lager fish would be available to the fishery if they were in the population, and the models for both northern and southern hake have proven to be sensitive to this. The selectivity patterns are all estimated to physically reasonable values.

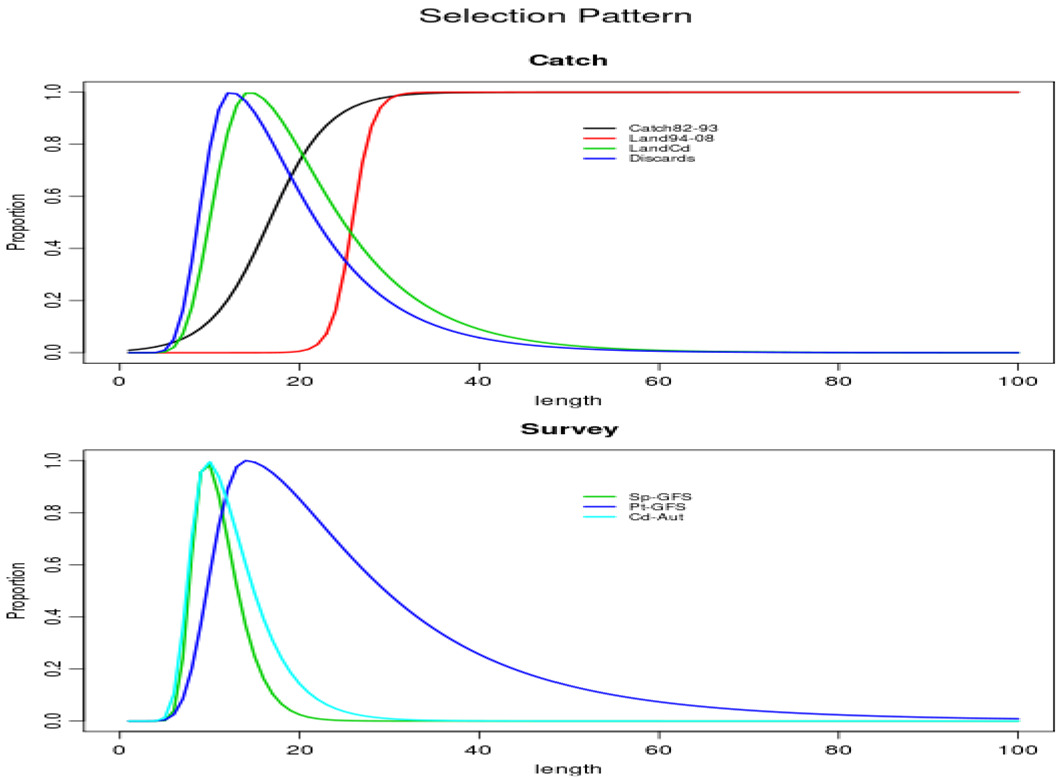

Figure 4. Selection pattern in the fisheries (above) and the survey (below)

6.9 Stock assessment

The spawning-stock biomass is modelled to have been well over 30 000 tonnes, although this is in the "burn-in" period of the model and the precise value should therefore be treated with caution. Subsequently the SSB fell as below 6000 tonnes in the late 1990s. The SSB has since recovered to around 13 000 tonnes, but this is still less than half the biomass seen in the early 1980s.

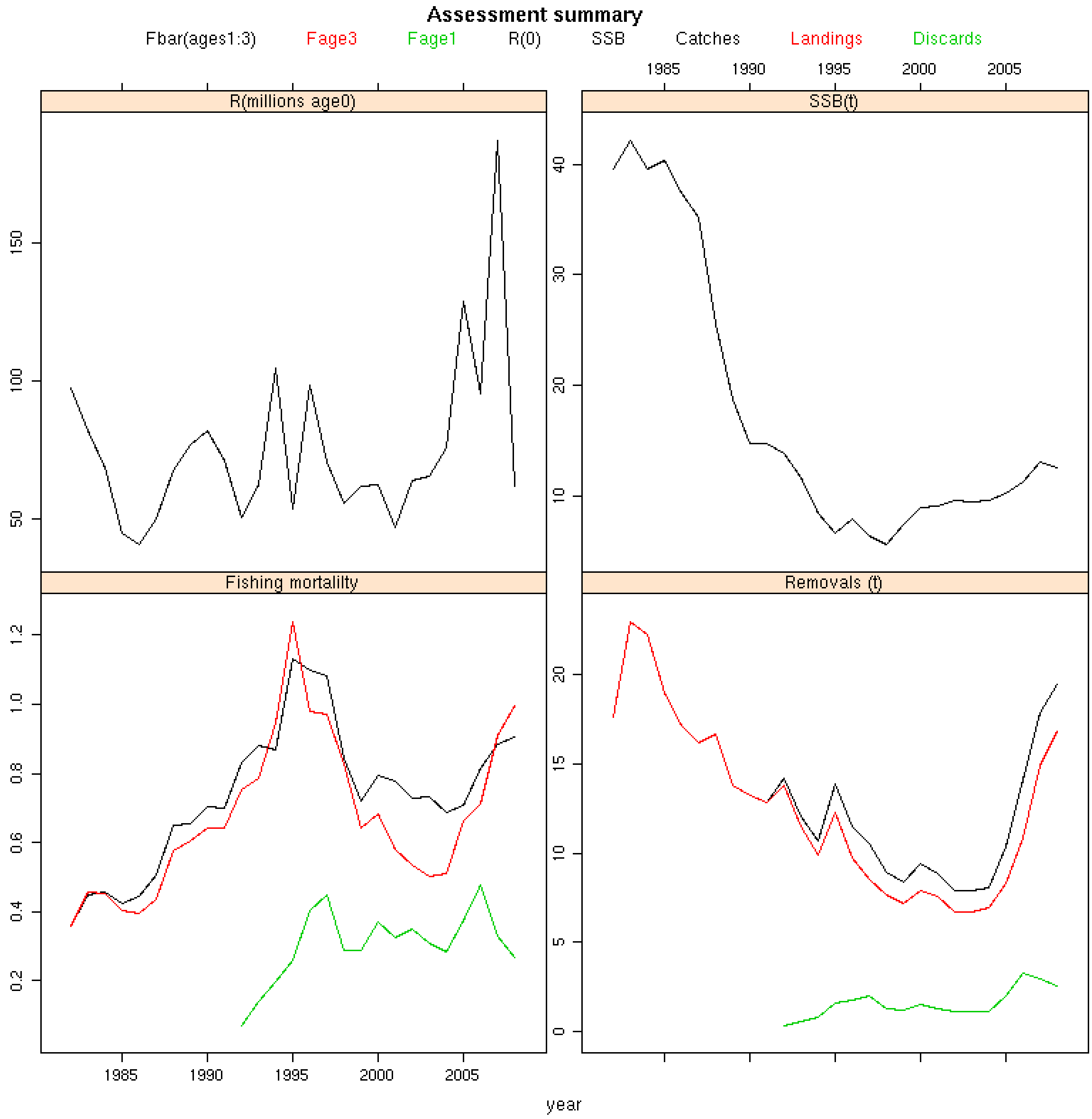

Figure 5. Hake: Southern stock (Divisions VIIIc and IXa). Recruitment, fishing mortality, SSB and catch based on the Benchmark assessment.

6.10 Recruitment estimation

The yearly recruitment time-series is shown in the Figure above. Fluctuations appear to be without substantial trend until recent years, when several good recruitment years are modelled to have occurred.

6.11 Short-term and medium-term forecasts

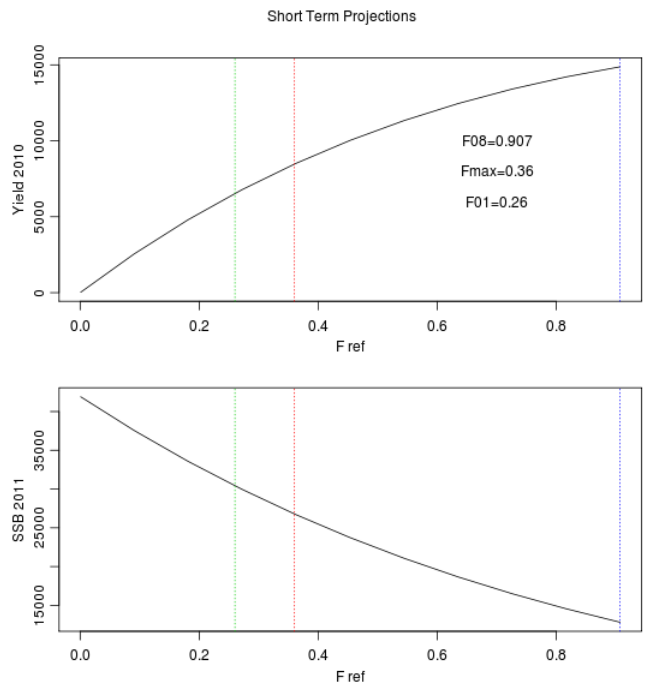

Figure 6. Short-term forecast.

Short-term forecast was based on similar assumptions than those proposed in last assessment. Maturity was set equals to arithmetic mean of last 3 years; Weight-at-age in the stock and in the landings was modelled in GADGET with VB parameters and length–weight relationship parameters. Exploitation pattern for landings follows the logistic selection parameters estimated by GADGET; and in the discards follows the Andersen (asymmetric) selection parameters estimated by GADGET. Procedures used for splitting projected catches are driven by the different selection functions, where yield is calculated from the landings "fleet".

Fishing in 2010 at a level equivalent than those estimated in 2008 should produce a yield near to 15 000 t in 2010 and an increase of SSB in 2011 near to 15 000 t. If F in 2010 decreases to Fmax (60% less than current F), yield in 2010 may drop below 10 000 t, and SSB in 2011 would be well over 25 000 t.

6.12 Biological reference points

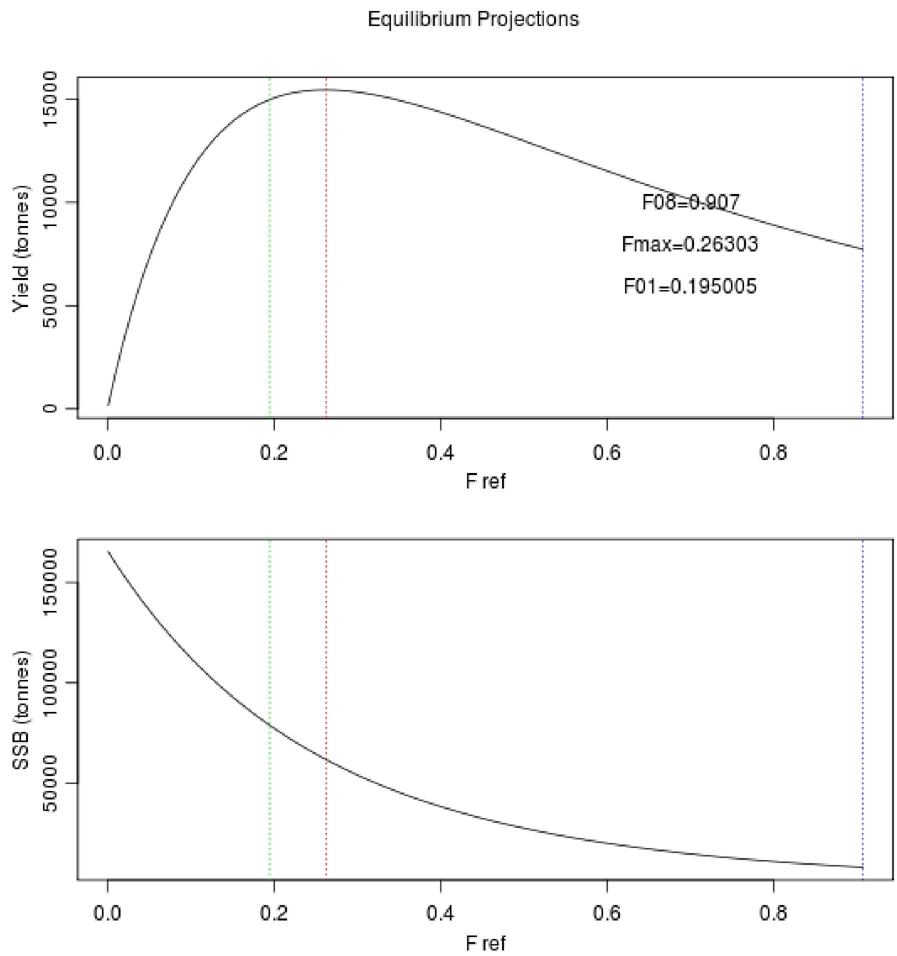

Figure 7. Yield and spawning stock assuming a recruitment equal to the mean of the years 1989–2008.

Long-term projection were performed following the guidelines used last year, but instead of using an equilibrium fit, a forward projection with recruitment equal to the mean of the years 1989–2008, until 2100 was performed. Maturity was set equal to the arithmetic mean of last 3 years; Weight-at-age in the stock and in the landings was modelled in GADGET with VB parameters and length–weight relationship parameters. Exploitation pattern for Landings follows the logistic selection parameters estimated by GADGET; and in the discards follows the Andersen (asymmetric) selection parameters estimated by GADGET. Procedures used for splitting projected catches are driven by selection functions for landings and discards.

The yield plot (Figure 7) demonstrates a clear maximum making Fmax relatively well estimated Fmax = 0.26, around 60% of the current F.

6.13 Recommended modifications to the stock annex

The previous stock annex should be substantially updated to document the use of the Gadget model instead of the previous assessment model. The annex should also describe the size composition data for catches, endations on the procedure for assessment updates.

The procedure carried out within the benchmark and described in the Stock Annex is considered to represent a valid approach to conducting update assessments for the southern hake.

Because this is a new assessment using software that is new to the ICES arena, the current model configuration should be open to some adjustment in subsequent assessment updates. Adjustments that should be considered within the scope of an update include: introduction of some degree of time-varying selectivity to better account for trends in some remaining residual patterns, and extension of the time-series back to include historical catches more precisely and to consider appropriate weighting on the different datasets.

More substantial changes that could be considered in a subsequent benchmark would include more explicit treatment of the spatial pattern of the stock, fishery and surveys. Another possibility would be a disaggregation of the existing commercial fleet. Neither of these lists is meant to be prescriptive, development of the model should follow issues arising during research and assessment on this stock.

We therefore recommend that ICES puts in place resources to support thorough review of possible changes and updates to the modelling procedure during the assessment working groups until the next benchmark for the this stock.

The Workshop recommends that the gadget model, in its current form, is ready for use in stock assessment and management. The Workshop recommends that further development work be conducted to improve the models, both for assessment purposes and as simulation tools to improve our understanding of the stock biology.

The model presented here was considered by WKROUND to represent a step forward in assessing the southern hake stock by removing the reliance on age-based data. The same position has been reached in the northern hake. Effort has been focused on creating viable, stable models. There are however a number of areas where further investigation and model development would be beneficial. Where possible these should be conducted on an ongoing basis and incorporated into the assessment process rather than wait for the next benchmark for this work to be done. Larger changes should be worked on incrementally and brought to the next benchmark. Some possible issues are mentioned here, but this list should not be considered exhaustive. The panel considers that ICES should be flexible in allowing model improvements during the Assessment Working Groups and on an intersessional basis.

The model currently does not model maturation, instead a maturity ogive is used to post-process the results to produce SSB. The model is capable of directly modelling maturation by age and/or length if data are available on the proportion mature by length. This could be implemented in the model to give a direct estimate of SSB, without otherwise affecting model dynamics.

If the biomass in the early time period is considered important, then it may be worth considering moving the start of the model run to an earlier date. This would remove the time period of interest in the early 1980s from the "burn-in" period of the model, and thus increase confidence in the results. Further improvements may be gained if more datasets are available for the early part of the time-series, thus improving the tuning of the parameters during the first part of the model.

The retrospective patterns in F seem to demonstrate variability of recent years. This could be investigated further. It is possible that this may be due to outlying data in 2006, in which case one would expect that the differences should reduce over time. However the nature of the fishery, with high catches from young ages, a short lived species, and multiple datasets may well dictate that such retrospective patterns are inevitable.

A revision of the southern hake model to include cannibalism would address some of the uncertainty surrounding the current assumption of M being constant over ages and time. This could be done by creating dynamically linked multispecies models or by incorporating prey species abundance within a single species cannibalism extension of the current gadget model.

6.14 Industry supplied data

6.15 References

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Stock Annex Southern Hake

Quality Handbook Stock Annex Southern Hake

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Southern hake (Division VIIIc IXa)
Working Group:	WGHMM
Date:	February 2010
Revised by	Santiago Cerviño, Ernesto Jardim and Daniel Howell

A. General

A.1. Stock definition

Southern hake stock comprises the Atlantic coast of Iberian Peninsula corresponding to the ICES Divisions VIIIc and IXa. The Northern limit is in the Spanish–French boundary and the Southern one in Gibraltar Strait. These boundaries were defined based on management considerations without biological basis.

Atlantic and Mediterranean European hake are usually considered as different stocks due to the differences in biology (i.e. growth rate or spawning season) of the populations in both areas. In the North Eastern Atlantic, there is no clear evidence of the existence of multiple hake populations, although Roldán *et al.*, 1998 based on genetic studies states that "*the data (…) indicate that the population structure within the Atlantic is more complex than the discrete northern and southern stocks proposed by ICES*". It is likely that there is a degree of transfer between the Southern and Northern hake stocks, and recent studies on population genetics support that (Balado *et al.*, 2003; Pita *et al.*, 2010), however there is at present a lack of data to quantify the amount of migrations between stocks.

A.2. Fishery

Hake in Divisions VIIIc and IXa is caught in a mixed fishery by the Spanish and Portuguese fleets (trawls, gillnetters, longliners and artisanal fleets).

The Spanish trawl fleet is quite homogeneous and uses mainly two gears, pair trawl and bottom trawl. The percentage of hake present in the landings is small as there are other important target species (i.e. anglerfish, megrims, Norway lobster, blue whiting, horse mackerel and mackerel). During recent years there has been an increase in Spanish trawlers using a new High Vertical Opening gear towed by single vessels and targeting the pelagic species listed above. In contrast, the artisanal fleet is very heterogeneous and uses a wide variety of gears; traps, large and small gillnet, longlines, etc. The trawl fleet landings length composition, since the implementation of the minimum landing size in 1991, has a mode around 29–31 cm depending on the year. Artisanal fleets target different components of the stock depending on the gear used. Small gillnets catch smaller fish than gillnets and longlines, which target mainly large fish and have length composition with a mode above 50 cm. Hake is an important component of the catch for these fleets mainly due to the high prices that reaches in the Iberian markets.

Hake is caught by the Portuguese fleet in the trawl and artisanal mixed fisheries together with other fish species and crustaceans. These include horse mackerel, anglerfish, megrim, mackerel, Spanish mackerel, blue whiting, red shrimp (*Aristeus* *antennatus*), rose shrimp (*Parapenaeus longirostris*) and Norway lobster. The trawl fleet comprises two distinct components - the trawl fleet catching demersal fish (70 mm mesh size) and the trawl fleet targeting crustaceans (55 mm mesh size). The fleet targeting fish species operates along the entire Portuguese coast at depths between 100 and 200 m. The trawl fleet targeting crustaceans operates mainly in the southwest and south in deeper waters, from 100 to 750 m. The most important fishing harbours from Northern Portugal are: Matosinhos, Aveiro and Figueira Foz, from Central Portugal are: Nazaré, Lisboa and Sines and Southern Portugal are: Portimão and Vila Real Santo António. The artisanal fleet lands hake mainly in the fishing harbours of the Centre. The main fishing harbours are Póvoa do Varzim (North), Sesimbra (Centre) and Olhão (South). Landings recorded by month reveal that the majority of the hake landings occur from May until October for both fleets.

A.3. Ecosystem aspects

European hake presents indeterminate fecundity and asynchronous development of the oocytes (Andreu, 1956; Murua *et al*., 1998; Domínguez-Petit, 2007). It is a serial or batch spawner (Murua *et al*., 1996). Duration of spawning season at the population level may differ between areas (Pérez and Pereiro, 1985; Alheit and Pitcher, 1995; Ungaro *et al*., 2001; Domínguez-Petit, 2007); but a latitudinal gradient exists such that the latest peaks of spawning occur in higher latitudes. In general, adults breed when water temperatures reach 10º or 12ºC, changing their bathymetric distribution depending on the region they are in and the local current pattern, releasing eggs at depths from 50 to 150 m (Murua *et al*., 1996; 1998; Alheit and Pitcher, 1995). In general males mature earlier than females. Size-at-maturity is determined by density-dependent factors like abundance or age–length population structure and density independent factors like environmental conditions or fishing pressure (Domínguez *et al*., 2008). L50 varies between areas; in the Atlantic populations is between 40–47 cm (Lucio *et al*., 2002; Piñeiro and Saínza, 2003; Domínguez-Petit, 2007) and in the Mediterranean ones between 25 and 40 cm (Alheit and Pitcher, 1995; García-Rodríguez and Esteban, 1995; Ungaro *et al*., 2001). Besides, temporal fluctuations in size-at-maturity within the population have been also observed what probably reflects changes in growth rate (Domínguez *et al*., 2008). Changes in maturity parameters affect stock reproductive potential, because smaller and younger females have different reproductive attributes than larger and older individuals (Solemdal, 1997; Trippel *et al*., 1997). Maternal physiological status, spawning experience (recruit or repeat spawners) or food rations during gametogenesis are all known to alter fecundity, egg and larval quality, as well as duration of the spawning season (Hislop *et al*., 1978; Kjesbu *et al*., 1991; Trippel, 1999; Marteinsdottir and Begg, 2002). Change in stock structure entails a compensatory response of age/size-at-maturity because depletion of large fish can be compensated by increased egg production by young fish (Trippel, 1995).

Hake recruitment indices have been related to environmental factors. High recruitments occur during intermediate oceanographic scenarios and decreasing recruitment is observed in extreme situations. In Galicia and the Cantabrian Sea, generally moderate environmental factors such as weak Poleward Currents, moderate upwelling and good mesoscale activity close to the shelf lead to strong recruitments. Hake recruitment leads to well-defined patches of juveniles, found in localized areas of the continental shelf. These concentrations vary in density according to the strength of the year class, although they remain generally stable in size and spatial location. These authors have related the year-on-year repetition of the spatial patterns to environmental conditions. In the eastern, progressively narrowing, shelf of the Cantabrian Sea, years during which there is massive inflow of the eastward shelf edge current produce low recruitment indices, due to larvae and prerecruits being transported away from spawning areas to the open ocean.

In Portuguese continental waters the abundance of small individuals is higher between autumn and early spring. In the Southwest main concentrations occur at 200–300 m depth, while in the South they are mainly distributed at coastal waters. In the North of Portugal recruits are more abundant between 100–200 m water depths. These different depth-areas associations may be related with the feeding habits of the recruits, because the zooplankton biomass is relatively higher at those areas.

Hake is a highly ichthyophagous species with euphausiids although decapod prawns are an important part of its diet for smaller hake (>20 cm). In Galicia and the Cantabrian Sea hake is one of the apex predators in the demersal community, occupying together with anglerfish one of the highest trophic levels (Velasco *et al.*, 2003). Its diet at >30 cm is mainly composed of blue whiting, while other species such as horse mackerel and clupeids are only important in shallow waters and in smaller individuals that also feed on other small fish. Along the Portuguese coast the diet of hake is mainly composed of crustaceans (particularly decapods) and fish. The main food items include blue whiting, sardine, snipefish, decapods and mysids. Cannibalism in the diet of hake is highly variable depending on predator size, alternative prey abundance, year or season. Cannibalism in stomach content observations ranged from 0 to 30% of total volume, with mean values about 5% this values produces a high natural mortality in younger ages. An age–length assessment with GADGET taken into account cannibalism was presented in 2009 WGHMM (WD07). Natural mortality estimation for ages 0 and 1 are substantial reaching values about 1 for age 0 and 0.5 for age 1. Projections reveal differences in recovery trajectories when compared with a model without cannibalism.

B. Data

B.1. Commercial catch

Landings

The landings data used in the Southern Hake assessment are based on: (i) Portuguese sales notes compiled by the National Fisheries and Aquaculture Directorate; (ii) Spanish sales notes and owners' associations data compiled by IEO; and (iii) Basque Country sales notes and Ship Owners data compiled by AZTI.

All landings since 1994 were reviewed and computed by quarter. From 1982 to 1993 annual landings were split by quarters assuming the same quarter distribution than in 1994.

Landings from the Gulf of Cadiz were compiled and included on the assessment by quarter, following the same procedure as for other landings.

The length distributions of landings were also computed by quarter after 1994. For the previous period it was assumed that the existing annual length distribution was caught in the middle of the year.

Discards

A Spanish Discard Sampling Programme is being carried out in Divisions VIIIc and IXa North since 1993. The series provides information on discarded catch in weight and number and length distributions for Southern hake. Spanish sampling was carried out in 1994, 1997, 1999–2000 and 2003 onwards. The number of trips sampled by the Spanish programme was distributed by three trawl fleets: Baca otter trawl, Pair trawl and HVO (High Vertical Opening) trawl. Total discards were estimated raising sampling with effort. This series was revised and computed by quarter from 2004 onwards.

The Portuguese Discard Sampling Programme started in 2003 (second semester) and is based on a quasi-random sampling of co-operative commercial vessels. Two trawl fleets are sampled in this programme: Crustacean Trawl and Fish Trawl fleets. The discards estimation method was revised to take into account fishing hours as auxiliary variable and include outlier analysis (see Southern hake WD02).

Both series of discarded weights were rebuilt back to 1992 based on the relations between (i) discards and surveys, and (ii) discards and landings (see Southern hake WD04), with the aim of integrating them in assessment models.

B.2. Biological

The sampling of commercial landings is carried out by the Fisheries Institutes involved in the fishery assessment (AZTI, IEO and IPIMAR) since 1982, except in the Gulf of Cadiz were length distribution are available only since 1994.

The length composition sampling design follows a multistage stratified random scheme by quarter, harbour and gear.

An international length–weight relationship for the whole period has been used since 1999 (a=0.00000659, b=3.01721).

Age information (otoliths) are collected by IEO, AZTI and IPIMAR and ages determined based on the recommendations of WKAEH (WKAEH, 2009). However, due to doubts on growth patterns and unstable ageing criteria, a von Bertalanffy growth model with t0=0, Linf=130 cm and k~0.16 is used. The growth parameters were decided based on (i) tagging data collected for the north stock, and (ii) k estimates by the assessment models carried out during the Benchmark WK.

Natural mortality was assumed to be 0.4 year-1, instead of the past 0.2. The rationale is that if hake growths about two times faster, the hake longevity is reduced around half (from age ~20 to ~10). Hewitt and Hoening, 2005 estimate a relationship among longevity and M that produces a figure around 0.4. This value was set equal for all ages.

Maturity proportions-at-length was estimated with sexes combined from IEO sampling. Data available from IPIMAR and AZTI since 2004 were not considered due to inconsistencies with the IEO data. Maturity-at-length used to estimate population mature biomass was estimated with a logistic function for years 1982 to 2008 (Southern hake WD03).

B.3. Surveys

The **Spanish October** groundfish (SP-GFS) survey uses a stratified random sampling design with half hour hauls and covers the northwest area of Spain from Portugal to France during September/October since 1983 (except 1987).

Two groundfish surveys are carried out annually in the **Gulf of Cadiz - in March**, from 1994, and in **November (SP-GFS-caut)**, from 1997. A stratified random sampling design with 5 bathymetric strata, covering depths between 15 and 700 m, is used in this area, with one hour hauls. Hake otoliths have been collected since 2000 and ALKs are available since then.

The **Portuguese October groundfish (P-GFS-oct)** has been carried out in Portuguese continental waters since 1979 on board the RV "Noruega" and RV "Capricórnio". Recent work on calibration of these vessels revealed a higher catchability of Capricórnio, in particular at lower sizes; as a consequence these years were calibrated. The main objective of this survey is to estimate hake's abundance indices to be used in stock assessment (Anon., 2008). A stratified sampling design was used from 1989 until 2004. In 2005 a new hybrid random-systematic sampling design was introduced, composed by a regular grid with a set of additional random locations (Jardim and Ribeiro Jr., 2007; Jardim and Ribeiro Jr., 2008). The tow duration was 60 minutes until 2001 and reduced to 30 minutes for the subsequent years, based on results of an experiment demonstrating no significant differences in the mean abundance and length distribution between the two tow durations (Cardador, personal communication, 2007).

The **Portuguese July groundfish** (**P-GFS-jul)** survey has not been conducted since 2002.

A new survey, the **Portuguese February groundfish**, and has been carried out since 2005, with the aim of covering hake's spawning season.

B.4. Commercial cpue

Effort series are collected from Portuguese logbooks and compiled by IPIMAR, and from Spanish sales notes and Owners Associations data and compiled by IEO.

Landings, lpue and effort are available for Coruña trawl (SP-CORUTR), Coruña pair trawl (SP-CORUTRP), Vigo/Marin trawl (SP-VIMATR), Santander trawl (SP-SANTR), Cadiz Trawl and Portuguese trawl (P-TR) fleets. Tuning data table (below) demonstrates details about these surveys as well as which of them are used in the assessment model.

The cpue series (1989–2008) of Portuguese trawlers is standardized using a GLM model with Gamma residuals, a "log" link function and explanatory variables year, zone, engine power, métier, percentage of hake in the catch, level of total catch and level of fishing effort. A working document presented to the benchmark documents the procedure (Southern hake WD01).

B.5. Other relevant data

Tagging data from Ifremer have been used to help estimating Bertalanffy's growth parameters.

C. Historical stock development

Until 2009 this stock was assessed with VPA models based on ages estimated from ALK. Tagging studies evaluated in 2009 indicate that the ages used in the VPA models were based on incorrect criteria and are not accurate. This finding resulted in the decision to use a length-based assessment model. The GADGET model was introduced as a suitable length-based model and reviewed by WKROUND.

C.1. Description of gadget

Gadget is a shorthand for the "Globally applicable Area Disaggregated General Ecosystem Toolbox", which is a statistical model of marine ecosystems. Gadget (previously known as BORMICON and Fleksibest). Gadget is an age–length structured forward-simulation model, coupled with an extensive set of data comparison and optimization routines. Processes are generally modelled as dependent on length, but age is tracked in the models, and data can be compared on either a length and/or age scale. The model is designed as a multi-area, multifleet model, capable of including predation and mixed fisheries issues, however it can also be used on a single species basis. Gadget models can be both very data- and computationally intensive, with optimization in particular taking a large amount of time. Worked examples, a detailed manual and further information on Gadget can be found on www.hafro.is/gadget. In addition the structure of the model is described in Begley and Howell, 2004, and a formal mathematical description is given in Frøysa *et al.*, 2002.

Gadget is distinguished from many stock assessment models used within ICES (such as XSA) in that Gadget is a forward simulation model, and is structured be both age and length. It therefore requires direct modelling of growth within the model. An important consequence of using a forward simulation model is that the plus groups (in both age and length) should be chosen to be large enough that they contain few fish, and the exact choice of plus group does not have a significant impact on the model.

Setup of a gadget run

There is a separation of model and data within Gadget. The simulation model runs with defined functional forms and parameter values, and produces a modelled population, with modelled surveys and catches. These surveys and catches are compared with the available data to produce a weighted likelihood score. Optimisation routines then attempt to find the best set of parameter values Growth is modelled by calculating the mean growth for fish in each length group for each time-step, using a parametric growth function. In the hake model a Von Bertanlanffy function has been employed to calculate this mean growth. The actual growth of fish in a given length cell is then modelled by imposing a beta-binomial distribution around this mean growth. This allows for the fish to grow by varying amounts, while preserving the calculated mean. The beta-binomial is described in Stefansson, 2001. The beta-binomial distribution is constrained by the mean (which comes from the calculated mean growth), the maximum number of length cells a fish can grow in a given time-step (which is set based on expert judgement about the maximum plausible growth), and a parameter β, which is estimated within the model. In addition to the spread of growth from the beta-binomial distribution, there is a minimum to this spread due by discretization of the length distribution.

Catches

All catches within the model are calculated on length, with the fleets having size-based catchability. This imposes a size-based mortality, which can affect mean weight and length-at-age in the population (Kvamme, 2005). A fleet (or other predator) is modelled so that either the total catch in each area and time interval is specified, or this the catch per time-step is estimated. In the hake assessment described here the commercial catch and the discards are set (in kg per quarter), and the surveys are modelled as fleets with small total landings. The total catch for each fleet for each quarter is then allocated among the different length categories of the stock according to their abundance and the catchability of that size class in that fleet.

Likelihood data

A significant advantage of using an age–length structured model is that the modelled output can be compared directly with a wide variety of different data sources. It is not necessary to convert length into age data before comparisons. Gadget can use various types of data that can be included in the objective function. Length distributions, age–length keys, survey indices by length or age, cpue data, mean length and/or weight-at-age, tagging data and stomach content data can all be used. Importantly this ability to handle length date directly means that the model can be used for stocks such as hake where age data are sparse or considered unreliable. Length data can be used directly for model comparison. The model is able to combine a wide selection of the available data by using a maximum likelihood approach to find the best fit to a weighted sum of the datasets.

Optimisation

The model has two alternative optimizing algorithims linked to it, a wide area search simulated annealing Corona *et al.*, 1987 and a local search Hooke and Jeeves algorithm (Hooke and Jeeves, 1961). Simulated annealing is more robust than Hooke and Jeeves and can find a global optima where there are multiple optima but needs about 2–3 times the order of magnitude number of iterations than the Hooke and Jeeves algorithm. The model is able to use both in a single run optimization, attempting to utilize the strengths of both. Simulated annealing is used first to attempt to reach the general area of a solution, followed by Hooke and Jeeves to rapidly home in on the local solution. This procedure is repeated several times to attempt to avoid converging to a local optimum. The algorithms are not gradient based, and there is therefore no requirement on the likelihood surface being smooth. Consequently neither of the two algorithms returns estimates of the Hessian.

Likelihood weighting

The total objective function to be minimized is a weighted sum of the different components. Selection of the weights is based on expert knowledge of the quality of the data and the space-time coverage of each dataset, and the internal variance of the dataset. An internal weight based on individual adjustments of the model (var) is used to reflect the variability of the dataset. This was done by optimizing the model to each dataset in turn, and inverting the resulting objective score to use as a weight for that dataset. This has the effect of assigning high weights to low variance datasets, and low weights to low variance ones. It also normalizes the weighted contribution of the different datasets. These weights were then adjusted to account for the length of the dataseries, the coverage of the area inhabited by the stock, and an expert judgement about the relative quality of the different data. The final column (% weight) in the table below gives the final weighted contribution of each dataset to the optimized objective function.

Finding these weights is a lengthy procedure, but it does not generally need to be repeated for each assessment. Rather, the current weights can be used for several years. The weighted contribution of the datasets in a new assessment should be computed, and compared with the previous year. Provided the relative contributions are similar then the model results should be comparable between years.

C.2. Settings for the hake assessment

Population is defined by 1 cm length groups, from 1–130 cm and the year is divided into four quarters. The age range is 0 to 15 years, with the oldest age treated as a plus group. Recruitment happens in the first and second quarter. The length-at-recruitment is estimated and mean growth is assumed to follow the von Bertalanffy growth function with Linf=130 and k estimated by the model.

An international length–weight relationship for the whole period has been used since 1999 (a=0.00000659, b=3.01721).

Natural mortality was assumed to be 0.4 year^{-1}

The commercial landings are modelled as two fleets (1982–1993 and 1994–2008) with a selection pattern described by a logistic function. Cadiz data are modelled as an independent fleet from 1982–2004 (Andersen function, see gadget manual for more information) and added to landings fleet from 2005–2008. Discards from 1992–2008 follows an Andersen function. The same function was used for Spanish survey, Cádiz survey and Portuguese survey. The surveys, on the other hand, are modelled as fleet with constant effort and a nonparametric selection pattern that is estimated for three 15 cm length groups.

Data used for the assessment are described below

DESCRIPTION	PERIOD	BY QUARTER	AREA	LIKELIHOOD COMPONENT
Length distribution of landings	1994–2008	YES	Iberia	Land1.ldist
Length distribution of landings	1982–1993	NO	Iberia	Land.ldist
Length distribution of landings in Cadiz	1994–2008	YES	Gulf of Cadiz	cdLand.ldist
Length distribution of Spanish GFS	1982–2008	-	North Spain	SpDem.ldist
Length distribution of Spanish GFS	1989–2008	-	Portugal	PtDem.ldist
Length distribution of Spanish GFS in Cadiz	1990–2008	-	Gulf of Cadiz	CdAut.ldist
Length distribution of discards	1994, 1998, 1999, 2004–2008	YES	Iberia	Disc.ldist
Abundace index of Spanish GFS of 4–19 cm individuals	1982–2008	-	North Spain	SpIndex15cm.1
Abundace index of Spanish GFS of 20–35 cm individuals	1982–2008	-	North Spain	SpIndex15cm.2
Abundace index of Spanish GFS of 36–51 cm individuals	1982–2008	-	North Spain	SpIndex15cm.3
Abundace index of Portuguese GFS of 4–19 cm individuals	1989–2008	-	Portugal	PtIndex15cm.1
Abundace index of Portuguese GFS of 20–35 cm individuals	1989–2008	-	Portugal	PtIndex15cm.2
Abundace index of Portuguese GFS of 36–51 cm individuals	1989–2008	-	Portugal	PtIndex15cm.3
Abundace index of Spanish trawlers from A Coruña of 4–19 cm individuals	1994–2008	YES	North Spain	Spcpue15cm.1
Abundace index of Spanish trawlers from A Coruña of 20–35 cm individuals	1994–2008	YES	North Spain	Spcpue15cm.2
Abundace index of Spanish trawlers from A Coruña of 36–51 cm individuals	1994–2008	YES	North Spain	Spcpue15cm.3
Standardized abundace index of Portuguese trawlers of 4–19 cm individuals	1989–2008	YES	Portugal	Ptcpue15cm.1

Description	Period	By quarter	Area	Likelihood component
Standardized index of Portuguese trawlers of 20–35 cm individuals	1989–2008	YES	Portugal	Ptcpue15cm.2
Standardized index of Portuguese trawlers of 36–51 cm individuals	1989–2008	YES	Portugal	Ptcpue15cm.3

Description of the likelihood components weighting procedure and % of contribution to the final total likelihood

Likelihood component	Var	Quarters	Quality	Area	Multiplicative Weight	%
Land1.ldist	0.66	44	2	1	133.2	0.2
Land.ldist	0.91	72	3	0.9	213.9	0.32
cdLand.ldist	2.5	52	2	0.1	4.2	0.01
SpDem.ldist	0.87	27	4	0.5	62.3	0.09
PtDem.ldist	0.39	24	4	0.4	99	0.15
CdAut.ldist	0.38	10	4	0.1	10.4	0.02
Disc.ldist	1.04	36	1	0.9	31.2	0.05
SpIndex15cm.1	4.84	9	4	0.5	3.7	0.01
SpIndex15cm.2	0.98	9	4	0.5	18.3	0.03
SpIndex15cm.3	1.2	9	4	0.5	15	0.02
PtIndex15cm.1	3.75	8	4	0.4	3.4	0.01
PtIndex15cm.2	1.34	8	4	0.4	9.5	0.01
PtIndex15cm.3	0.52	8	4	0.4	24.5	0.04
Spcpue15cm.1	2.37	5	2	0.5	2.1	<0.01
Spcpue15cm.2	0.23	5	2	0.5	21.5	0.03
Spcpue15cm.3	1.55	5	2	0.5	3.2	0.01
Ptcpue15cm.1	0.46	6.67	2	0.4	11.6	0.02
Ptcpue15cm.2	1.39	6.67	2	0.4	3.8	0.01
Ptcpue15cm.3	0.76	6.67	2	0.4	7	0.01

The parameters estimated are:

The number of fish by age when simulation starts. (ages 1 to 8) .8 params

Recruitment each year. (1982 to 2008). 27 params

The growth rate (k) of the von Bertalanffy growth model.

Parameter β of the beta-binomial distribution.

The ratio between recruitment in the first and second quarter.

The selection pattern of:

- the commercial catches (1982–1993). 2 params
- Landings (1994–2008) . 2 params
- Cadiz landings (1982–2004) . 3 params
- Discards (1992–2008) . 3 params
- Spanish Survey . 3 params
- Portuguese Survey. 3 params
- Cadiz autumn Survey . 3 params

Catchability of:

- Spanish Survey (3 groups from 4 cm by 15 cm) .3 params
- Portuguese Survey. (3 groups from 4 cm by 15 cm) .3 params
- Spanish cpue (3 groups from 25 cm by 15 cm) .3 params
- Portuguese cpue (3 groups from 25 cm by 15 cm) .3 params

69 parameters in total.

The estimation can be difficult because of some or groups of parameters are correlated and therefore the possibility of multiple optima cannot be excluded. The optimization was started with simulated anneling to make the results less sensitive to the initial (starting) values and then the optimization was changed to Hooke and Jeeves when the 'optimum' was approached. Multiple optimization cycles were conducted to ensure that the model had converged to an optimum, and to provide opportunities to escape convergence to a local optimum.

The model fit were analysed with the following **diagnostics**:

Profiled likelihood plots. To analyze convergence and problematic parameters.

Plot comparing observed and modelled proportions in fleets (catches, landings or discards). To analyze how estimated population abundance and exploitation pattern fits observed proportions.

Plot for residuals in catchability models. To analyse precision and bias in abundance trends.

D. Short-term projection

Model used: Age-length forward projection

Software used: GADGET (script: predict.st.sh)

Initial stock size: abundance-at-age and mean length for ages 0 to 15+

Maturity: arithmetic mean of last 3 years

F and M before spawning: NA

Weight-at-age in the stock: modelled in GADGET with VB parameters and length–weight relationship

Weight-at-age in the catch: modelled in GADGET with VB parameters and length–weight relationship

Exploitation pattern:

Landings: logistic selection parameters estimated by GADGET.

Discards: Andersen (asymmetric) selection parameters estimated by GADGET.

Intermediate year assumptions: F = last assessment year F

Stock–recruitment model used: geometric mean of years 1989–2007

Procedures used for splitting projected catches: driven by selection functions and provide by GADGET.

E. Medium-term projections

NA.

F. Long-term projections

Model used: Age–length forward projection until 2100

Software used: GADGET (script: predict.lt.sh)

Maturity: arithmetic mean of last 3 years

F and M before spawning: NA

Weight-at-age in the stock: modelled in GADGET with VB parameters and length–weight relationship

Weight-at-age in the catch: modelled in GADGET with VB parameters and length–weight relationship

Exploitation pattern:

Landings: logistic selection parameters estimated by GADGET.

Discards: Andersen (asymmetric) selection parameters estimated by GADGET.

Stock–recruitment model used: geometric mean of years 1989–2007

Procedures used for splitting projected catches: driven by selection functions.

G. Biological reference points

Unchanged since 2004

	Type	Value	Technical basis
Precautionary approach	B_{lim}	25 000 t	The level below which there are indications of impaired recruitment.
	B_{pa}	35 000 t	~ B_{lim} *1.4
	F_{lim}	0.55	F_{loss}
	F_{pa}	0.40	~ F_{lim} * 0.72
Targets	F_y	0.27	EC Recovery plan.

H. Other issues and further work

It should be noted that new assessment model have been developed to avoid the reliance on age-based data. The two new models are considered to be an improvement on the previous method given the problems related to age data described below. However both are new, complex, and significantly different from the previous models. It is therefore likely that refinements and updates will be required over the coming years to both models and further consideration given to the data used. The panel (WKROUND, 2010) considers that ICES should be flexible in allowing model improvements during the Assessment Working Groups and on an intersessional basis. ICES should therefore ensure that resources are in place to evaluate these improvements

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7 Recommendations from the Workshop

Recommendations from the Plenary

Recommendation	To whom
Linkage of assessments to environmental and ecosystem conditions The ToR asked that the panel to "consider the possible inclusion of environmental drivers for stock dynamics in the assessments and outlook." Some of the stock annexes describe changes that could be the result of environmental or ecosystem drivers. These include the changes over time in the body weight-at-age of saithe and changes in the spatial distribution of recruitment to northern hake. In some cases there was speculation about possible causes of these observed changes. Several of the newer assessment approaches are amenable to inclusion of environmental time-series as data on temporal changes in important model factors, such as natural mortality, catchability, and growth. However, none of the assessments proposed linking such observed stock changes to environmental drivers in order to improve the accuracy or precision of the assessment. The panel briefly considered possible steps to improve the degree to which environmental factors are directly considered in the assessments. One step is to commission specific work to elucidate the factors and develop relevant time-series. Another is to conduct management strategy evaluations to determine the needed precision of such relationships in order to realize improvements in the assessment.	ACOM/SCICOM
Benchmark preparation Several of the assessments evaluated in this benchmark were not sufficiently developed in advance of the workshop. As a result, valuable time was devoted to getting basic model configurations established instead of being able to delve into more complete sensitivity analyses. Where new methods, such as Stock Synthesis and GADGET, are being used, it is especially important that preliminary workshops be conducted. These workshops could invite experts in these methods to assist in establishment of a sound model foundation.	ACOM
Integration of multiple tuning indices It is unusual for the spatial extent of a stock to be covered by a single research survey and it is common for an assessment to utilize several surveys each of which covers only a portion of the range of the stock. Where these multiple indices exhibit contrary trends, it is possible that each is providing a true reflection of the stock in its subarea and none provides a fully accurate characterization of the trend in the stock as a whole. One approach to dealing with this situation is spatial modelling of stock dynamics. Spatial models are a large step in model complexity and require information about rates of fish movement among the modelled subareas. Alternatively, combination of a spatial mosaic of surveys into a single integrated index of the entire stock offers an more immediately feasible approach to dealing with this situation. A paper describing this approach was submitted for future consideration.	ACOM
Benchmark process The benchmark process is conceived such that the stock annex is the 'recipe' for the assessment, the benchmark is the 'making of' the recipe and subsequent EG reports are the resulting annual cake. This is a logical process, but it does not clearly identify where the prototype cake tasted by the benchmark appears. The benchmark sections on stock status and assessment results need to have an assessment result to refer to. WKROUND 2010 included in its benchmark report sufficient detail about the results of each current assessment so that future EG reports will have a basis for comparison. The WKROUND 2010 panel recommends that ICES clarify this aspect of the benchmark process for future panels.	ACOM

RECOMMENDATION	TO WHOM
F_{msy} proxies This benchmark was the first since the ACOM decision to move towards a Fmsy basis for management advice. Technical guidance on calculation of Fmsy is not planned until the WKFRAME workshop in March 2010. Thus, WKROUND 2010 attempted to provide advice on biological reference points that are relevant to Fmsy, but did not attempt to make strong recommendations with regard Fmsy. In general, the panel concluded that calcualtion of F35%, F0.1 and Fmax could provide a suitable range to bracket Fmsy when Fmsy cannot be directly calculated. Fmax should be considered as an upper limit to Fmsy and even then it should only be considered when the yield curve has a distinct peak at Fmax. Although there was not a unanimous opinion on this approach, some members thought that Fmax could be used as a target only when biomass is well above Bpa, above Bmsy, or above ½ the estimated carrying capacity. Others were concerned that use of high F at high biomass levels would introduce rapid declines in biomass and high fluctuations in catch. Most importantly, the panel recommends that management strategy evaluations be conducted to evaluate the likely performance of whichever Fmsy proxy is chosen. Such evaluations were conducted for Icelandic saither and for the previous assessment of northern hake, providing valuable insights about the consequences of various F target levels. These evaluations can provide information about expected future stock levels, catch levels, and year-to-year variability. However, is important to consider total fisheries induced mortality (including discards and bycatch) as well as target F in such an analysis, otherwise the resulting yield will fall below MSY, and the precautionary principle may not be satisfied. More importantly, MSE analysis provide more information about a true MSY mortality policy in the context of the available data, the uncertainties associated with the assessment model, natural variability, and necessary lags in the assessment process and management implementation.	ACOM ADGMSY (May 2010)
Model comparisons Due to the lack of appropriate aging, both hake assessments required length-based assessment models to estimate population size and mortality rates. The northern hake assessment utilized the Stock Synthesis model, which is commonly used for assessments in the US, and the southern hake assessment utilized the GADGET model, which has been used in a few ICES assessments. The workshop made a substantial effort to configure the two assessments as comparably as possible and the panel is confident that the two models produce comparable results. However, it would be advisable to arrange for a more direct comparision between the two models in which each analysed the same dataset.	ACOM WGHMM
ICES scorecard A template for a scorecard to evaluate data quality and other factors was presented at WKROUND 2010. There was insufficient time during the workshop to complete these scorecards. The panel recommends that these scorecards be completed by the stock coordinators prior to future benchmark workshops in order to provide organized information about the quality of data being used in the assessment to the panel and participants. This scorecard should become a regular section of all Stock Annexes.	PGCCDBS Assessment Groups
Commercial cpue data as tuning series In many cases, commercial logbook data were employed to develop age disaggregate tuning series, modelled as an auxilary index of abundance. Sometimes the data were filtered via ad hoc choices to remove irrelevant information, but failed to take into account or adjust for changes in seasonal or geographical fishing patterns (possibly related to quota management), changes caused by technological improvements or variations in fishing costs, or changes caused by vessel and crew replacement. WKROUND2010 strongly recommends that commercial cpue indices used for tuning series be standardized via statistical models to take these factors into account, whenever possible.	ACOM

RECOMMENDATION	TO WHOM
Stakeholder participation While the members of WKROUND2010 understand the difficulty that stakeholders may have attending a remote meeting (for some), the assessment process would benefit from involvement, knowledge, and advice of stakeholders who could qualify and/or validate the interpretation of data used in the assessment. With modern technology, it would not be difficult to allow stakeholder participation at remote sites at specific times to allow this type of interaction and dialogue.	ACOM
Retrospective analysis Retrospective analysis of the performance of stock assessment models should become a routine and required component of any benchmark assessment. The retrospective pattern can be used to objectively and quantatively compare the performance of the model to estimate terminal year stock size and mortality, as was done for the NEA saithe assessment. And although a retrospective pattern does not reveal the source of bias, it reveals that the assessment model may not be fitting the data appropriately. This retrospective analysis and statistic may also be used as one of many diagnostics to compare model performance when different assessment models are employed to assess a stock, wheras retrospective comparisons between different stocks would be meaningless. Retrospective bias may arise from a variety of sources, including changes in unreported catch, changes in natural mortality, changes in growth, changes in catchability, or as in the case of NEA saithe an inaccurate mathematical treatment of the plus group.	ACOM

Annex 1. WKROUND Terms of Reference

2009/2/ACOM36 A Benchmark Workshop on Roundfish [WKROUND] (External Chair: Richard Methot, USA) and ICES coordinator: Einar Hjörleifsson (Iceland) and three invited external experts: Andrew Applegate (USA), Patrick Sullivan (USA), Daniel Howell (Norway) will be established and will meet in ICES HQ, Copenhagen, Denmark, 9–16 February 2010 to:

Evaluate the appropriateness of data and methods to determine stock status and investigate methods for short-term outlook taking agreed or proposed management plans into account for the stocks listed in the text table below. The evaluation shall include consideration of fishery-dependent, fishery-independent, and life-history data currently being collected for use in the current assessment work and the proposed assessment;

Agree and document preferred method for evaluating stock status and (where applicable) short-term outlook and update the assessment handbooks as appropriate;

Develop recommendations for future improving assessment methodology and data collection;

As part of the evaluation:

conduct a one day data compilation workshop. Stakeholders shall be invited to contribute data (including data from non-traditional sources) and to contribute to data preparation and evaluation of data quality. As part of the data compilation workshop consider the quality of data including discard and estimates of misreporting of landings;

consider the possible inclusion of environmental drivers for stock dynamics in the assessments and outlook;

evaluate the role of stock identity and migration;

evaluate the role of multispecies interactions on the assessments.

Stock	Assessment Lead
Faroe saithe (Division Vb)	Luis Ridao Cruz
Icelandic saithe (Division Va)	Höskuldur Björnsson
Northeast Arctic saithe (Subareas I and II)	Sigbjorn Mehl
Northeast Arctic haddock (Subareas I and II)	Sondre Aanes
Northern stock of hake (Division IIIa, Subareas IV, VI and VII, and Divisions VIIIabd)	Michel Bertignac
Southern stock of hake (Divisions VIIc and IXa)	Santiago Cervino

The Benchmark Workshop will report for the attention of ACOM by 2 March 2010.

Note: The NEA haddock was withdrawn from consideration prior to the start of the Benchmark Workshop.

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Annex 3. List of Working Documents

NEA Saithe

WD3. AFWG 2009. Norwegian Coastal Survey 2008. Asgeir Aglen, Erik Berg, Sigbjørn Mehl og Knut Sunnanå.

WD4. AFWG 2007. Evaluation HCR NEA Saithe. Sigbjørn Mehl, Åge Fotland, Bjarte Bogstad, Knut Korsbrekke and Harald Gjøsæter.

WD7. WKROUND 2010. Observer Programme for Juvenile Northeast Arctic Saithe. Sigbjørn Mehl.

WD8. WKROUND 2010. NEA Saithe XSA Runs with Different Survey Tuning-Series. Sigbjørn Mehl and Åge Fotland.

WD9. WKROUND 2010. Maturity-at-Age for NEA Saithe. Åge Fotland.

WD10. WKROUND 2010. Exploratory XSA Runs for NEA Saithe (using FLR). Sigbjørn Mehl and Åge Fotland

WD11. Catchability for NEA Saithe. Åge Fotland.

WD12. Cpue in the Norwegian NEA Saithe Trawl Fishery. Åge Fotland, Irene Huse, Sigbjørn Mehl.

Icelandic Saithe

WD1. Revising Catch in Numbers for Saithe in Va 1974–1978. Gudmundur Thordarson.

WD2. Revising Catch in Number for Saithe in Va. Gudmundur Thordarson.

WD3. Saithe in Va as Observed in the Icelandic Groundfish Surveys. Gudmundur Thordarson.

WD4. Short Overview in the Icelandic Saithe Fishery. Asta Gudmundsdottir and Einar Hjörleifsson.

WD5. Composition of the Icelandic Saithe Catches. Asta Gudmundsdottir, Björn Ævarr Steinarsson and Einar Hjörleifsson.

WD6. Time-Series Assessment of Icelandic Saithe. Guðmundur Guðmundsson

WD7. Stock Assessment of Saithe in Va using ADCAM on Data from 1980–2008. Höskuldur Björnsson and Sigurður Þór Jónsson.

Faroe Saithe

WD3. Post-Stratification of Survey Indices. Luis Ridao Cruz.

WD4. Time-Series Analysis (TSA). Rob Fryer.

WD5. Length Cohort Analysis (LCA). Luis Ridao.

WD6. Faroese Groundfish Surveys (FGFSs). Luis Ridao Cruz.

WD7. NTF-ADAPT Model. Luis Ridao Cruz.

WD8. Overview in the Faroese Saithe Fishery. Luis Ridao Cruz.

WD9. Generalised Linear Model (GLM) Diagnostices of Pair-Trawl Data. Luis Ridao Cruz.

Northern Hake

WD1. Description of the First Tagging Experiment. Hélène de Pontual, Michel Bertignac, André Battaglia, Gérard Bavouzet, Philippe Moguedet, and Anne-Laure Groison.

WD2. Analysis of Tagging Data obtained from Further Tagging Experiment.

WD3. Simulation of the Impact of a Bias in Age Estimation on the Assessment. Hélène de Pontual, Anne Laure Groison, Carmen Pinêiro, and Michel Bertignac.

WD4.Status of SS3 Assessment of Northern Hake. Michel Bertignac and Carmen Fernández.

WD5. Spanish Discards in VII. Pérez N., H. Araujo and C. Fernández.

WD6. French Discards (*Nephrops* Trawling in VIII). Lise Guerineau, Marie Joëlle Rochet and Michel Bertignac.

WD7. Tagging Data: Update of Data Analysis. Hélène de Pontual, Aurélie Jolivet, François Garren, Michel Bertignac.

WD8. New Maturity Ogives for Northern Hake. Iñaki Quincoces.

WD9. The Effect of Wrong Growth Perception in the Management. Dorleta Garcia and Iñaki Quincoces.

Southern Hake

WD1. Southern Hake in ICES Division IXa: Cpue Standardization of the Portuguese Commercial Trawl. Fátima Cardador and Ernesto Jardim.

WD2. Southern Hake Discards. Ana Cláudia Fernandes, Ernesto Jardim, Manuela Azevedo and Graça Pestana.

WD3. Maturity Ogives Analysis of European Hake from Southern Stock. Rosario Dominguez-Petit, Santiago Cerviño, Fran Saborido-Rey, María Saínza, and Ernesto Jardim.

WD4. Rebuilding the Historical Series Southern Hake Catches. Ernesto Jardim, Santiago Cerviño.

WD5. Southern Hake Benchmark Assessment. Santiago Cerviño, Ernesto Jardim and Daniel Howell

WD6. Hake Cpue Conversion Factor from Bottom Trawl CAR into Bottom Trawl NCT. Manuela Azevedo and Fátima Cardador.

Annex 4. Stakeholder input for the Report

Delphine Ciolek, CNPMEM (French National Committee for Marine Fisheries and Sea Farming), representing the South Western Waters Regional Advisory Council in this meeting.

First of all, the SWWRAC thanks ICES for inviting her to this Benchmark Workshop. Unfortunately, Antonio Cabral wasn't there as expected, so there are no comments on the Southern Hake.

On the Northern Hake

This year, French fishers weren't able to submit any additional data. But it is not always the case. The French sector already conducted studies, for example, the ASCGG[2] (Selectivity improvement in bottom *Nephrops* trawls operating in the Bay of Biscay) or OFFEP (Observation on French gillnet vessels).

Some precise questions established with Michel Bertignac (Ifremer) were sent to producers' organizations and CLPMEM (French Local Committee for Marine Fisheries and Sea Farming). But it is difficult for them to answer, especially when hake is only a bycatch.

The major problem is the confidence that the sector can place in the data used in the evaluation: French and Spanish fishers are indeed very suspicious; the one towards the others about the landings that are reported to the Commission. This problem could be resolved by a control reinforcement in both Member States.

What we will keep in mind, thanks to the Workshop, is the importance of the data quality and the need to get more data on discards. A good thing would be that a few fishers could fill-in logbooks with more details that normally required on the discards in one or two French ports.

Concerning XSA or SS3, the sector encourages choosing the most appropriate model to the stock reality (apparently, SS3).

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[2] French fishermen implement this program to reduce bycatch and undersized hake catch. They adopted a squared mesh panel in 2004, which is an obligation in the EC regulation since 2006.