Stock Annex: Saithe (*Pollachius virens*) in subareas 1 and 2 (Northeast Arctic)

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Saithe

Working Group: Arctic Fisheries Working Group (AFWG)

Created:

Authors:

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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 towards 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 show 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 currently accounts for more than 87% 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 seine and handline). The gillnet fishery is most intense during winter, purse-seine in the summer months while the trawl fishery takes place more evenly all year around. 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. 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. Landings of saithe were highest in 1970-1976 with an average of 239,000 t and a maximum of 265,000 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 67,000 to 123,000 t. After 1991 landings increased and ranged between 136,000 t (in 2000) and 212,000 t (in 2006), followed by a decline to 132 000 t in 2015.

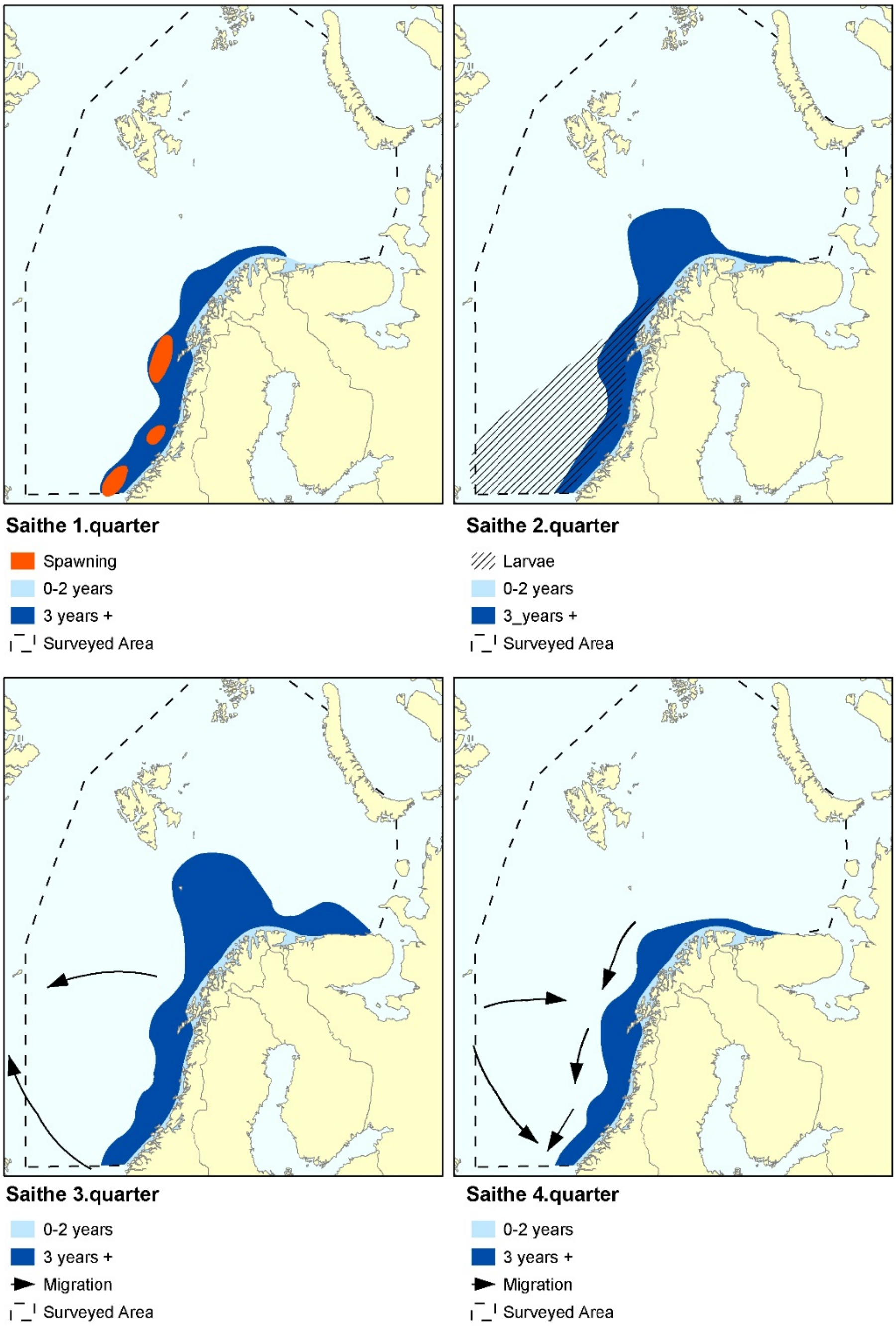

Figure 1. NEA saithe. Distribution of larvae, juveniles, adult spawning areas and the main migration patterns by (a) first quarter, (b) second quarter, (c) third quarter, and (d) fourth quarter.

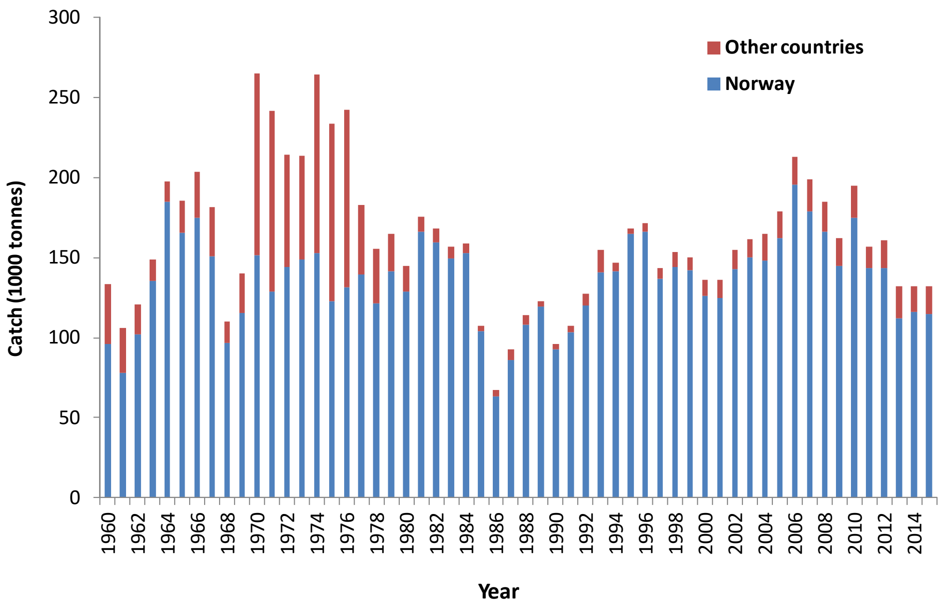

Figure 2. NEA saithe landings 1960-2015. Blue bars shows the Norwegian landings.

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 to 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. The alternative method applied for cod and haddock (ECA, Hirst *et al.* 2004, 2005) produce unrealistic high weights at age compared to the method currently applied for NEA saithe (ICES 2007/ACFM:16).Present sampling coverage may also be too poor for ECA to perform adequately.

Constant weight at age values is used for the period 19601979. 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 84% of the saithe landings. Data on catch in tonnes from other countries are either uploaded to InterCatch by the respective countries or taken from ICES official statistics (by ICES area) or from reports to Norwegian authorities. A few countries have supplied and still supply some additional data. The table below shows which countries are asked to supply data to ICES InterCatch (IC), see AFWG Data Call for more details.

Country	Aggregation level of the InterCatch data	Landings (quantity)	Age comp landings	Length comp landings	Mean weight at age in the landings
Faroe Islands	A	IC	IC		IC
France	A	IC	IC		IC
Germany	A	IC	IC		IC
Greenland	A	IC	IC		IC
Iceland	A	IC	IC		IC
Ireland	A	IC	IC		IC
Netherlands	A	IC	IC		IC
Norway	A	IC	IC		IC
Poland	A	IC	IC		IC
Portugal	A	IC	IC		IC
Russia	A	IC	IC		IC
Spain	A	IC	IC		IC
Sweden	A	IC	IC		IC
United Kingdom	A	IC	IC		IC
Faroe Islands	A	IC	IC		IC

The Norwegian and Russian input files are Excel spreadsheet files. Russian input data earlier than 2002 were 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. Data on numbers and weight at age are normally available only from Norway (from Russia (some areas) until 2008 and Germany (Division IIA until 2013). 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, either by the national co-ordinators or by the stock co-ordinator.

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 showed 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 otoliths with missing information on spawning rings were reread, 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 C.M. 2005/ACFM:20). 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

Since 2008 a rather large reduction in proportion mature fish was observed for age groups 5-8. In the same period there was an increase in weight at age for most of these age groups, and both TSB and SSB decreased considerably over the same period. There was no corresponding reduction in the level of recruitment. Therefore, a strong decrease in maturity-at-age can hardly be justified (given that at least main trends in recruitment are captured by the assessment) and it seems reasonable to use a constant maturity ogive from 2007 and onwards, based on the average 2005-2007. This was introduced at AFWG 2014 (ICES CM 2014/ACOM:05). However, it needs to be further investigated what has caused the impression of this dramatic change in maturity in the sampled data. Maybe the samples are not representative for the stock or spawning zones are not a robust indicator for maturity.

B.3. Surveys (NOcoast-Aco-4Q)

In the period 1985-2002 a Norwegian acoustic survey specifically designed for saithe was conducted annually in October-November (Nedreaas 1997). The survey covered 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 was to support the stock assessment with fishery-independent data of the abundance of the youngest saithe. The survey mainly covered the grounds where the trawl fishery took place, normally dominated by 3 - 5(6) year old fish. 2-year-old saithe, mainly inhabiting the fjords and more coastal areas, were also represented in the survey, although highly variable 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 to 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 showed 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.

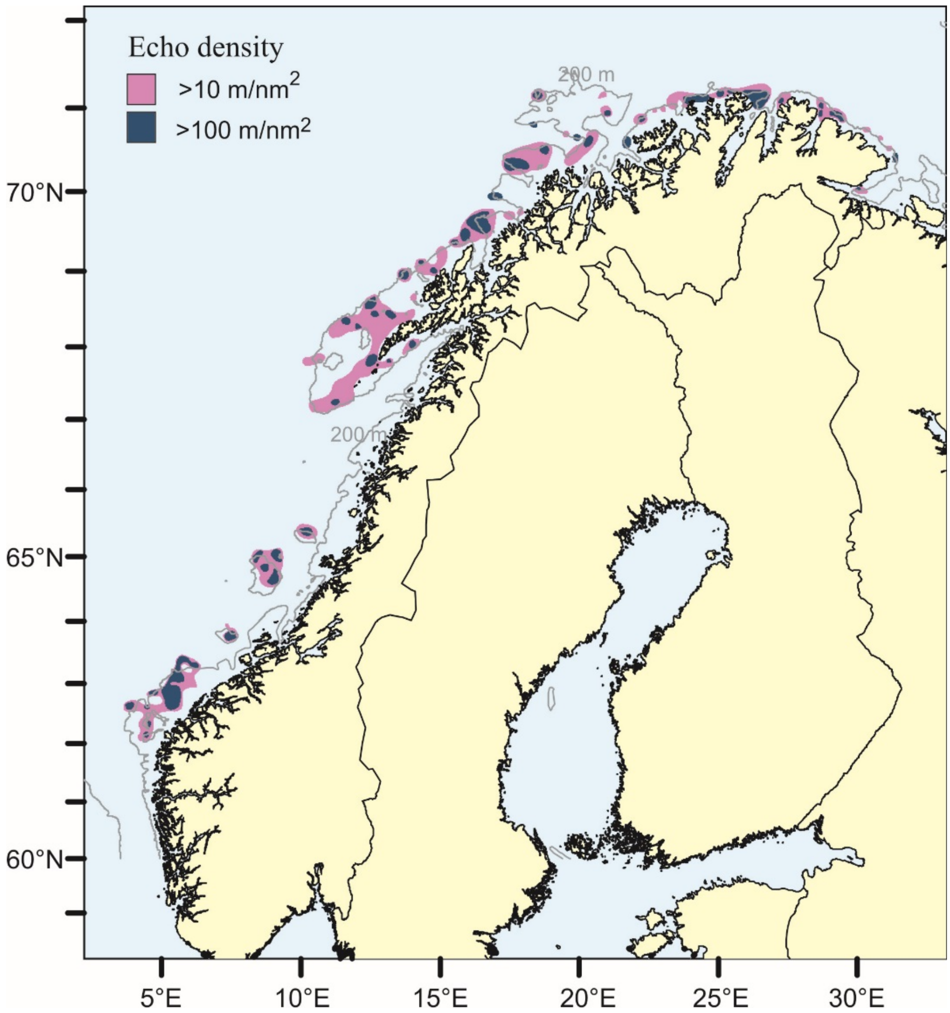

Figure 3. NEA saithe. Distribution of total saithe echo density in the acoustic survey autumn 1998.

From 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 covered coastal areas not included in the regular saithe survey. Because saithe is also acoustically registered, this survey provided supplementary information, especially about 2- and 3-year-old saithe that had 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, and 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.

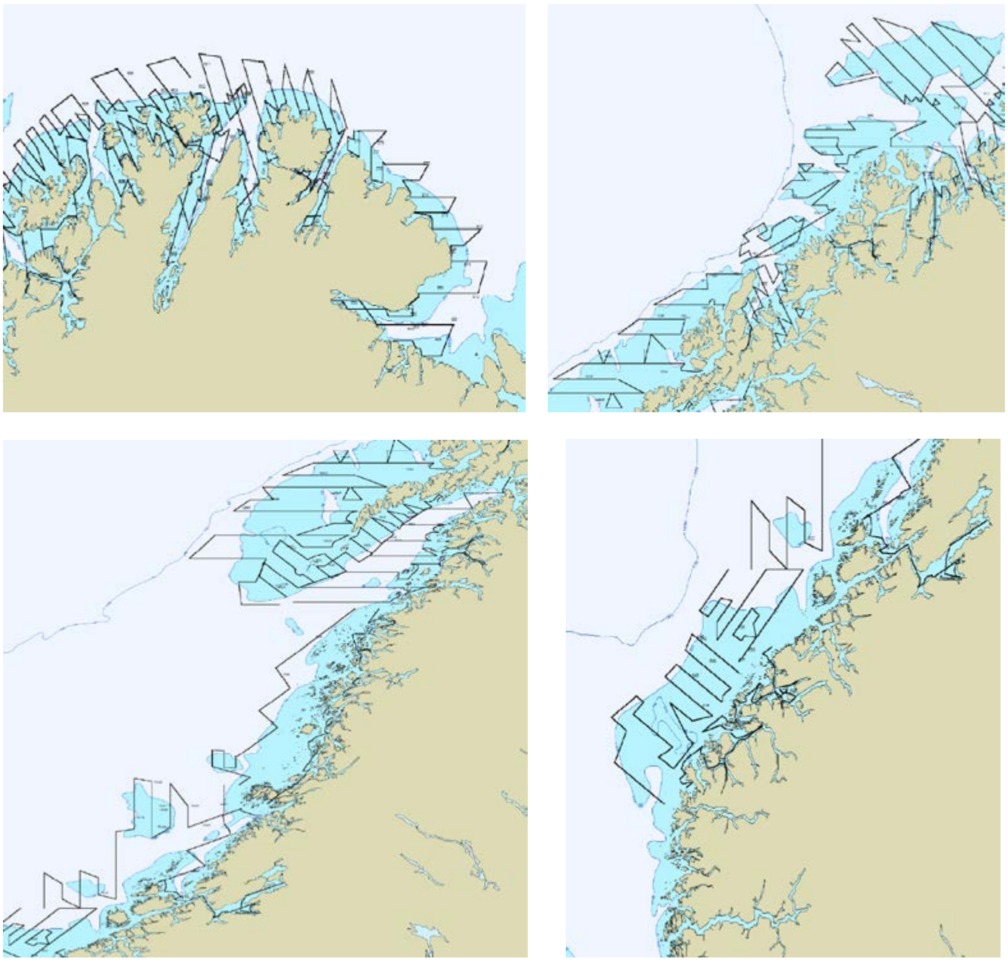

Figure 4. Standard transects in new combined saithe and coastal survey conducted since 2003.

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 were 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. These new series were too short to be used for tuning of the NEA saithe XSA. The estimation of survey time-series 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.

It seems unclear whether the changes in survey design made in 2003 were substantial enough that the decision on splitting or not splitting the survey time-series in the assessment could be taken a priori, i.e. not based on assessment model results. In the SAM model run at the 2014 Interbenchmark Assessment (ICES CM 2014/ACOM:53) with split time-series, catchability estimates were significantly different before and after 2002, justifying the split of time-series. Also, the residual pattern for later part of the survey is improved when the time-series since 2002 is treated separately. However, the retro pattern becomes better if both time-series are combined and SAM results are sensitive to whether to split the survey time-series or not. Thus, the issue of splitting the survey time-series or not remains a source of uncertainty in this assessment, although the split can be justified by the model performance. The 2014 Interbenchmark Assessment (ICES CM 2014/ACOM:53) decided to continue to use split time-series,

B.4. Commercial cpue

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

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 was 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 got low scaled weights. Mainly based on this the 2005 WG decided to not include the purse-seine tuning fleet in the analysis (ICES C.M. 2005/ACFM:20). In following years with a 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 showed 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 was therefore not reintroduced 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 since they showed 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 showed 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 C.M. 2005/ACFM:20). 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) shows a larger proportion of saithe in the southern half of the distribution area in the last years, and logbook data showed that the trawl catches included in the cpue calculations also had become gradually more southerly distributed, i.e. the trawlers follow saithe aggregations that may have become more 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 C.M. 2008/ACOM:01, ICES 2009/ACOM:01).

Further analysis and exploratory runs were presented at the 2010 benchmark assessment. Six different options were tested, including a proposal from the industry. The cpue index based upon 7 vessels proposed by the industry could introduce a new bias or noise due to lack of quarterly indices and index values out of range. To take account for 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.

In Woking Documents to the 2010 Benchmark Assessment and the 2014 Interbenchmark Assessment the historic changes made to the cpue index are described. The fishing patterns had changed considerably over the years. From the very beginning of the time-series the trend in cpue and the trend in the acoustic survey contradict each other.

The fishing pattern of the Norwegian fleet changed again considerably in recent years. The sensitivity runs clearly showed that the residual pattern got worse (strong year effects) when using both tuning series in SAM. SAM tried to fit something in between both contradicting data sources. Therefore, it had to be decided whether one data source was more reliable or whether both data sources should be taken into account leading to a fit in between both extremes.

Given that cpue series should not be used when larger changes in fishing patterns occur (selectivity, spatial distribution of the fleet, change between targeted and bycatch fishery) the 2014 Interbenchmark Assessment recommended to leave out the cpue time-series in its current form for now (ICES CM 2014/ACOM:53). Another reason was that the proportion of catches covered by the index had decreased steadily between 2002 and 2011 further questioning the representativeness of the cpue index. However, it may be worth to try alternative cpue indices (e.g. one index for the targeted fishery only and one index for the fishery with saithe bycatches) until the next benchmark.

B.5. Other relevant data

None.

C. Assessment: data and method

Model used: State-space assessment model SAM (https://www.stockassessment.org; Nielsen & Berg 2014).

Software used: AD Model Builder (ADMB) and R.

Model Options chosen: # Min Age (should not be modified unless data are modified accordingly)

3

Max Age (should not be modified unless data are modified accordingly)

12

Max Age considered a plus group (0=No, 1=Yes)

1

The following matrix describes the coupling

of fishing mortality STATES

Rows represent fleets.

Columns represent ages. flat F from age group 8

1	2	3	4	5	6	6	6	6	6
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Use correlated random walks for the fishing mortalities

(0 = independent, 1 = symmetrical correlation estimated, 2=AR(1)-correlation estimated)

2

Coupling of catchability PARAMETERS

0	0	0	0	0	0	0	0	0	0

```
1	2	3	4	4	0	0	0	0	0
5	6	7	8	8	0	0	0	0	0
# Coupling of power law model EXPONENTS (if used)
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
# Coupling of fishing mortality RW VARIANCES
1	1	1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
# Coupling of log N RW VARIANCES
1	2	2	2	2	2	2	2	2	2
# Coupling of OBSERVATION VARIANCES
1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	0	0	0	0	0
3	3	3	3	3	0	0	0	0	0
# Stock recruitment model code (0=RW, 1=Ricker, 2=BH, ... more in time)
2
# Years in which catch data are to be scaled by an estimated parameter
0
# first the number of years
# Then the actual years
# Them the model config lines years cols ages
# Define Fbar range
4	7
```

Input data types and characteristics: (table below is just an example; adapt the description of input accordingly)

Type	Name	Year range	Age range	Variable from year-to-year Yes/No
Caton	Catch in tonnes	1960 – last data year		Yes
Canum	Catch-at-age in numbers	1960 – last data year	3 – 12+	Yes
Weca	Weight at age in the commercial catch	1960 – last data year	3 – 12+	Yes/No - constant at age from 1960 - 1979

West	Weight at age of the spawning stock at spawning time.	1960 – last data year	3 – 12+	Yes/No - assumed to be the same as Weca
Mprop	Proportion of natural mortality before spawning	1960 – last data year	3 – 12+	No – set to 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1960 – last data year	3 – 12+	No – set to 0 for all ages in all years
Matprop	Proportion mature at age	1960 – last data year	3 – 12+	Yes/No – constant ogive 1960-1984, three year running average 1985-2006, constant from 2007
Natmor	Natural mortality	1960 – last data year	3 – 12+	No – set to 0.2 for all ages in all years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Norway ac survey	1994 – 2001	3–7
Tuning fleet 2	Norway ac survey	2002 – 2015	3–7

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 SAM for age 4 and older. The recruitment-at-age 3 in the last data year was until 2008 estimated using the long-term geometric mean, and numbers-at-age 4 in the intermediate year were calculated applying a natural mortality of 0.2 and the F value estimated by XSA (advised by RG in 2004).

Since AFWG 2009 up to 201 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).

During the 2015 AFWG assessment (ICES CM 2015/ACOM: 05), analyses were performed to investigate if the last year recruitment value from SAM could be used instead of the long-term GM. This issue was not discussed at the IBP when SAM was adopted as assessment model. Estimates of recruitment for 2004-2013 from the 2015 assessment “R_sam2015”, last year recruitment estimates from 10 retrospective runs “R_term” and GMs calculated from the retrospective runs “R_gm” were used in the analyses. To validate the two methods, we assumed that “R_sam2015” is the “truth” and retrospective estimates by SAM and GM were compared to this by the mean squared error method;

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(\hat{Y}_i - Y_i)^2.$$

where Ŷi is "Rterm" or "R_gm" and Yi is "R_sam2015" for the 10 years of retrospective runs. The calculated MSE's showed that the retrospective runs of SAM (MSE(Rterm=1.16E+09)) gave better estimates of recruitment than the geometric mean (MSE(R_gm=7.86E+09), Figure 5). Based on this analysis, estimates of the recruiting year class (3 year olds in the last data year) from the SAM were accepted for the last year. The analysis software R-script is uploaded on the AFWG 2015 SharePoint.

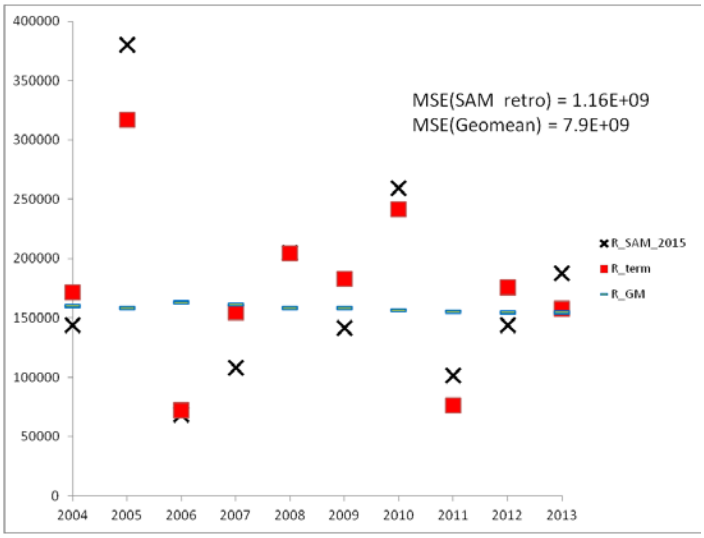

Figure 5: Recruitment estimates from SAM_2015, and R_term and R_gm from 10 retrospective runs of SAM.

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

Maturity: Constant ogive 1960-1984, three year running average 1985-2006, reference year being the middle, constant after 2007

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.

Selection pattern for yield-per-recruit: The average selection pattern from the last three years 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 F_{bar} (4-7) to the level of the last year.

Stock recruitment model used: None, the long-term geometric mean recruitment-at-age 3 for all years (from SAM model for current assessment year) is used in forecast

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.

F. Long-Term Projections

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

G. Reference Points

G.1. Biological reference points

In 2010 the age span was expanded from 11+ to 15+ and important XSA parameter settings were changed (ICES CM 2010/ACOM: 36). LIM reference points were re-estimated at the 2010 WG according to the methodology outlined in ICES CM 2003/ACFM: 15, while the PA reference point estimation was based on the old procedure (ICES CM 1998/ACFM: 10). The results were not very much different from the previous analyses performed in 2005 (ICES CM 2005/ACFM: 20), and since the Harvest Control Rule (HCR) is based on the PA reference points, it was decided not to change the existing LIM and PA reference points. Figure 6 shows that in the whole time-series the XSA estimates from the 2013 assessment are within the confidence limits of the SAM estimates both for F4-7 and SSB. Therefore no new reference points were estimated.

	TYPE	VALUE	TECHNICAL BASIS
Management Plan	Trigger SSBMP	220 000 t	B_{pa}, F is linearly reduced from FMP at SSB = B_{pa} to 0 at SSB equal to zero.
	FMP	0.32	Average TAC for the coming 3 years based on FMP.
MSY	MSY $B_{trigger}$	not defined	
Approach	F_{MSY}	not defined	
	Blim	136 000 t	Change point regression.
Precautionary	B_{pa}	220 000 t	B_{lim} * exp(1.645*σ), where σ = 0.3.
Approach	F_{lim}	0.58	F corresponding to an equilibrium stock = Blim.
	F_{pa}	0.35	F_{lim} * exp(−1.645*σ), where σ = 0.3. This value is considered to have a 95% probability of avoiding the Flim.

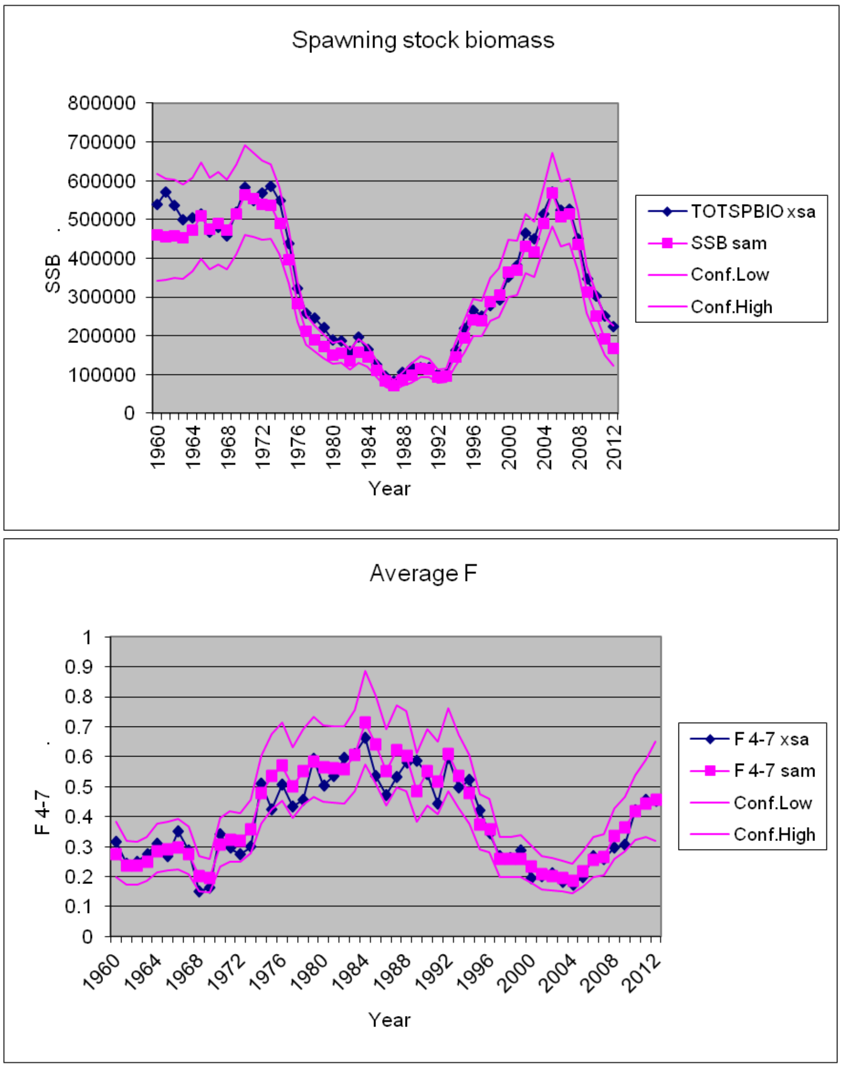

Figure 6. $F_{4\text{-}7}$ and SSB from SAM run with IBP settings and final XSA in AFWG 2013.

G.2. Biomass reference points

At the 2010 WG, parameter values, including the change-point, were computed using segmented regression on the 1960–2005 time-series of SSB-recruitment pairs. The maximum likelihood estimate of the spawning-stock biomass at which recruitment is impaired (change point) was 118,542 t. Applying the "magic formula" $B_{pa} = B_{lim} \exp(1.645^*\sigma)$, with a value of 0.3 for σ, gave a B_{pa} of 194,176 t. However, as explained above, it was decided to still use the existing values of B_{lim} = 136,000 t and B_{pa} = 220,000 t.

G.3. Fishing mortality reference points

F_{lim} was set on the basis of B_{lim} (ICES CM 2003/ACFM: 15). The functional relationship between spawner-per-recruit and F gave the F associated with the R/SSB slope derived from the B_{lim} estimate obtained from the segmented regression. Arithmetic means of proportion mature 1960–2009, weight in stock and weight in catch 1980–2009 (weights were constant before 1980), natural mortality and fishing pattern 1960–2009 were at the 2010 WG used for re-calculating the spawner-per-recruit function using ICES Secretariat yield-per-recruit software. R/SSB = 1.48 from the B_{lim} estimation gave SSB/R = 0.676 and a F_{lim} = 0.59. Applying the "magic formula" $F_{pa} = F_{lim} \exp(-1.645^*\sigma)$, gave a F

0.36, for a ing values of 0.3. As explained above, it wa
F_{lim} = 0.58 and F_{pa} = 0.35.

Yield and SSB per recruit were based on the parameters in Table 5.7.1 and are presented in Table 5.6.1. F0.1, F_{max} and F35%SPR were estimated to be 0.13, 0.27 and 0.14, respectively, which are similar to last year's estimates. The plot of SSB vs. recruitment is shown in Figure 5.1.1. These points are FMSY candidates, but the estimates, especially of F_{max}, are unstable for this stock. When the HCR was re-evaluated in 2011, the highest long-term yield was obtained for an exploitation level of 0.20.

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 $\mathbf{F_{MP}}$. 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 $\mathbf{F_{MP}}$ 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 historic data (ICES 2007). This also holds true when an implementation error (difference between TAC and catch) equal to the historic level of 3% is included.

In 2011 (ICES CM 2011/ACOM: 05) the evaluation was repeated taking into account the changes made to the assessment after the 2010 benchmark assessment (ICES CM 2010/ACOM: 36). The analyses indicate that the HCR still is in agreement with the precautionary approach (Mehl and Fotland, WD 11 2011).

The fishing mortality used the harvest control rule (FMP) was in 2007 set to F_{pa}=0.35. In June 2013, after the ICES advice for 2014 for this stock had been given, FMP was reduced to 0.32.

The HCR is expected to rebuild a depleted stock to a level above B_{lim} within three years.

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