# ICES WKFAROE REPORT 2017 

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# Report of the Benchmark Workshop on Faroese Stocks (WKFAROE 2017) 

13-17 February 2017
Copenhagen, Denmark

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

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## Executive summary

The Benchmark Workshop on Faroese Stocks (WKFAROE 2017), convened at two meetings, one data compilation workshop and the final benchmark meeting, both at ICES HQ, Copenhagen. Three stocks were benchmarked: saithe $27.5 \mathrm{~b}, \operatorname{cod} 27.5 \mathrm{~b} 1$, and haddock 27.5 b. The most important conclusions for each stock were:

## Saithe 27.5b

The catch-at-age matrix was extended to last available age as a plus group (15), maturity ogives were revised with a simple 10-year running average and both Faroese groundfish surveys (summer and spring) were incorporated in the assessment model.

The SAM model was adopted as the basis for advice. Reference points were calculated following the benchmark at NWWG 2017.

## Cod 27.5bl

A number of working documents examining potential ecosystem interaction (e.g. cofluctuation of cod recruitment and haddock recruitment, correlations between cod recruitment since 1997 and the amount of sandeels etc.), but none of these were incorporated into the assessment.

The SAM model seems to work well for Faroe Plateau cod and it provides uncertainty estimates for the assessment outputs, including catch figures, which were previously lacking from the XSA model.

The SAM model was adopted as the basis for advice. Reference points were calculated following the benchmark at NWWG 2017.

## Haddock 27.5b

The SAM model seems to work well for Faroe haddock and it provides uncertainty estimates for the assessment outputs, including catch figures, which were previously lacking from the XSA model.

The SAM model was adopted as the basis for advice. Reference points were calculated following the benchmark at NWWG 2017.

A Benchmark Workshop on Faroese Stocks (WKFAROE 2017), chaired by ICES Chair Höskuldur Björnson, Iceland, and external reviewer Chair Jim Ianelli, US and attended by two additional invited external experts Matt Dunn, New Zealand, and Sigurdur Thor Jönsson, Iceland, met at ICES HQ in Copenhagen, Denmark 6-8 December 2016 for a data evaluation meeting and again for a five-day Benchmark meeting 13-17 February 2017 to:
a) 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:
i. Stock identity and migration issues;
ii. Life-history data;
iii. Fishery-dependent and fishery-independent data;
iv. Further inclusion of environmental drivers, multi-species information, and ecosystem impacts for stock dynamics in the assessments and outlook
b) Agree and document the preferred method for evaluating stock status and (where applicable) short term forecast and update the stock annex as appropriate. Knowledge about environmental drivers, including multispecies interactions, and ecosystem impacts should be integrated in the methodology.
If no analytical assessment method can be agreed, then an alternative method (the former method, or following the ICES data-limited stock approach) should be put forward;
c) Re-examine and update (if necessary) MSY and PA reference points according to ICES guidelines (see Technical document on reference points);
d) Develop recommendations for future improving of the assessment methodology and data collection;
e) As part of the evaluation:
i) Conduct physical meeting/correspondence work on data evaluation. Stakeholders are 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 work consider the quality of data including discard and estimates of misreporting of landings;
ii) Following the DE work, produce working documents to be reviewed during the Benchmark meeting at least 7 days prior to the meeting

| Stocks | Stock assessor |
| :--- | :--- |
| Saithe (Pollachius virens) in Division 5.b <br> (Faroes grounds) | Luis Ridao Cruz (luisr@hav.fo) |
| Cod (Gadus morhua) in Subdivision 5.b.1 <br> (Faroe Plateau) | Petur Steingrund (peturs@hav.fo) |
| Haddock (Melanogrammus aeglefinus) in Division 5.b <br> (Faroes grounds) | Jákup Reinert (jakupr@hav.fo) |

## 2 Description of the Benchmark Process

The ICES benchmark on Faroese stocks included the following steps:
1 ) No data call was issued, since all data were known to be directly available to the researchers working in the Faroe Islands.
2 ) One WebEx meeting was held on 29 September to go through the data issues list. External reviewers and chair were invited to attend.

3 ) Data compilation workshop 6-8 December 2016.
4 ) Progress on working documents was discussed via e-mail between the data workshop and the assessment workshop.

Working documents for each stock can be found in Annex 3 to this report.

|  | General |  |  |
| :--- | :--- | :--- | :--- |
| Title | Working Document no. | Description | Contributors |
| Faroe_cod_haddock_ <br> saithe_biomass_ <br> comparison | WD10 | Comparison between cod, <br> haddock and saithe <br> biomasses over time. | Petur Steingrund |


|  |  | SAITHE 27.5B | Contributors |
| :--- | :--- | :--- | :--- |
| Title | Working <br> Document no. | Description | Luis Ridao |
| Faroese Groundfish <br> Surveys for Saithe | WD04 | Exploration of surveys used in <br> the assessment | Maturity ogives for the <br> assessment |
| Faroe Saithe <br> Maturity | WD03 | Exploratory SCA model for <br> saithe 27.5b | Luis Ridao |
| Statistical Stock <br> Assessment Saithe | WD05 | Forecast WAA | Sigurdur Jönsson |
| FaroeSaitheWeigth <br> Prediction.pdf | WD19 | HCR evaluations | Höskuldur <br> Björnson |
| Fsai HCR <br> Evaluations | WD06 | Reference point explorations | Luis Ridao |
| Fsai reference points | WD07 |  |  |


|  | COD 27.5B1 |  |  |
| :--- | :--- | :--- | :--- |
| Title | Working <br> Document no. | Description | Contributors |
| FcodHCREvaluations | WD01 | HCR evaluatons | Höskuldur <br> Björnson |
| FaroePlateauCod_sandeels_ <br> as_extra_tuning | WD08 | Sandeels in cod stomachs <br> as extra tuning | Petur Steingrund |
| FaroePlateauCod_intro | WD09 | Introduction | Petur Steingrund |
| Faroe Plateau cod - influence <br> of plus group | WD12 | Influence of plus-group | Petur Steingrund |
| FaroePlateauCod_feeding_on_ <br> haddock | WD13 | The extent of the feeding <br> of cod on haddock | Petur Steingrund |


| Cod 27.5b1 |  |  |  |
| :---: | :---: | :---: | :---: |
| Title | Working Document no. | Description | Contributors |
| FaroePlateauCod_Predicting_ catchweights | WD14 | Prediction of catch weights | Petur Steingrund |
| FaroePlateauCod_maturities_ 1980_90s_investigated | WD15 | Investigation of maturities | Petur Steingrund |
| FaroePlateauCod_ stockweights_or_catchweights | WD16 | Using catch weights as stock weights | Petur Steingrund |
| FaroePlateauCod_Predicting_ F_in_prognosis | WD18 | Predicting F in prognosis | Petur Steingrund |
| FaroePlateauCod_Natural_ Mortality | WD20 | Investigation of M | Petur Steingrund |


|  | Haddock 27.5b |  | Contributors |
| :--- | :--- | :--- | :--- |
| Title | Working <br> Document no. | Description | Höskuldur Björnson |
| FhadHCREvaluations | WD02 | HCR evaluation | Predictions of weights | Petur Steingrund $\quad$| FaroeHaddock_prediction_of |
| :--- |
| _weights | WD17 $\quad$ WD11 $\quad$| Inputs, survey, |
| :--- |
| previous assessment |$\quad$ Jákup Reinert $\quad$| Faroe haddock |
| :--- |

The first days of the benchmark were devoted to biological parameters, survey indices, and exploration of stock assessment inputs, with some discussion over mixed fisheries and multispecies issues.

The last two days of the benchmark were devoted to finalising the settings for the chosen assessments.

Reference point analyses were complete after the benchmark workshop, in preparation for NWWG 2017.

## 3 Saithe (Pol/achius virens) in Division 5.b (Faroese grounds) - pok.27.5b

3.1 Stock ID and substock structure

The stock structure was not an issue and the perception of stock structure was maintained.
3.2 Issue list

| ISSUE | Problem/Aim | Work needed / POSSIBLE DIRECTION OF SOLUTION | Data needed to be able to do this: are these available / where should THESE COME FROM? | EXTERNAL EXPERTISE needed at benchmark TYPE OF EXPERTISE / PROPOSED NAMES |
| :---: | :---: | :---: | :---: | :---: |
| Tuning series | Commercial series used in the assessment | Include spring and/or summer groundfish surveys | Faroese groundfish surveys (spring and fall) |  |
| Biological <br> Parameters |  |  |  |  |
| Maturity ogives | Maturities are fitted with a global smoother (loess). This causes large revisions in if recent estimates. | Use of a local smoother (spline) which may alleviate large revisions in maturity ogives |  |  |
| Assessment method | Extended survivors analysis (XSA) Changes in catchability and selection pattern | Statistical catch-at-age model which can address changes in selection pattern and catchability as well as stock-recruitment relationships. |  |  |
| Biological <br> Reference Points | Re-evaluations of biomass- and fishing mortality reference points | HCR evaluations. Implementation of management plan should ICES MSY framework deems inappropriate |  | Iceland (Einar, Hoski) |

### 3.3 Scorecard on data quality

A scorecard was not used for this benchmark.

### 3.4 Multispecies and mixed fisheries issues and Ecosystem drivers

No new information was presented at the benchmark meeting. Present assumption maintained.

### 3.5 Stock assessment inputs

### 3.5.1 Catch: quality, misreporting, discards

There were no issues with the catch figures or the assumption that discards were very limited.

Catch-at-age was extended to age $15+$ (plus group).

### 3.5.2 Surveys

Historically, a fisheries-dependant tuning fleet (pair-trawl) was used to calibrate the XSA assessment. At the WKFAROE benchmark group both Faroese groundfish surveys (spring and summer) were explored for use in the SAM model.

Surveys are relatively noisy for saithe but they are nevertheless indicative of trends in stock size.

See more details in WD04 - FaroeseGroundfishSurveysSaithe.pdf (Annex 3).

### 3.5.3 Maturity

Maturity ogives were revised. A 10-year running average is used to estimate maturities to smooth out data noise and at the same time maintaining historical trends.

See more details in WD03 - FaroeSaitheMaturity.pdf (Annex 3).

### 3.5.4 Weight and growth

No changes were made to the former input.
Weights at age in the stock are assumed equal to catch weights.

### 3.5.5 Natural mortality

No changes were made to the former input.

### 3.6 Assessment models

Although a statistical catch-at-age model was presented (WD-05 - StatisticalStockAssessmentSaithe.pdf, see Annex 3)) to the group, the state-space model SAM was adopted as the basis for advice of Faroe saithe.

The workshop explored a number of settings for the SAM fit to saithe 27.5b. SAM offers a flexible way of describing the entire system, with relative few model parameters using random walks (RW) on fishing mortality and stock numbers.

### 3.6.1 SAM Settings and assumptions

The adopted SAM model uses correlated RW on fishing mortalities.

Recruitment was assumed to follow a random walk function.
Different age-specific catchability parameters for ages 3 to 8 and coupled for ages 9 and 10 in both surveys.

Selectivity is allowed to shift gradually. The logarithm of the age specific indices from the spring survey are assumed to be independent Gaussian with a separate variance for age 3 and 4 and a common variance for ages $5-10$. The logarithm of the age specific indices from the spring survey is assumed to follow a multivariate Gaussian distribution with order 1 auto-regressive correlation. The variance parameters for the summer survey are couples in the same way as for the spring survey.

### 3.6.2 Diagnostics

Year-effects are present in the spring survey, e.g. positive and negative residuals in 1998 and 2007 respectively but in general residuals are distributed relatively random in both catches and surveys (Figure 3.5.3.1). The retrospective pattern of F shows periods of overestimation from 2000 to 2010 and years of underestimation since around 2011 (Figure 3.5.3.2) However most of the retrospective runs are within the confidence intervals of the final assessment. In terms of SSB, SAM tends to overestimate the true stock size of the stock but to a lesser extent. The retrospective pattern in recruitment strength has somehow stabilized in comparison with the historical XSA model. Most of the recruitment retrospective runs but two are between the uncertainty levels of the final model.


Figure 3.5.3.1. SAM residuals plots of catch (top), spring (middle) and summer (bottom) surveys.


Figure 3.5.3.2. Retrospective analysis of spawning-stock biomass (tonnes)(top), average fishing mortality over age groups $4-8$ (middle) and recruitment-at-age 3 ('000)(bottom) from the SAM assessment.

### 3.6.3 Results

Given that new input data (revised maturities and fisheries-independent survey data) have been incorporated to the assessment along with a new assessment framework (SAM), results of the historical XSA and SAM cannot be compared directly. The output of both frameworks is however very similar in trends and absolute levels (Figure 3.6.1)


Figure 3.6.1. Estimates of recruitment (top), SSB (middle) and Fbar (bottom) from SAM (black lines and grey shadow areas) and XSA (red lines). Last data point in XSA is the forecast estimate.

### 3.6.4 Final assessment model run

The catch-at-age matrix was extended to last available age as a plus group (15), maturity ogives were revised with a simple 10-year running average and Faroese groundfish surveys were incorporated in the assessment model. SAM was adopted as the basis for advice. See full description in the stock annex.

### 3.7 Short term forecast

The forecast module of SAM is used for short term prognosis. Assumptions for short term prognosis are as follows:

- recruitment is randomly picked from last 5 years (excluding the most recent year-class)
- maturity is the average of last 5 years
- weight-at-age in the forecast years is a status-quo weight predicted by the following model (See WD19 (FarSaitheWeightPrediction) for further details):

$$
\log (C W y, a)=\beta 0+\beta 1^{*} \log (C W y-1, a-1)+\beta 2^{*} \log (S W y, a)
$$

where: CWy,a is catch-weight-at age $a$ and year $y$
SWy, a is stock-weight-at age $a$ and year

- selection pattern is averaged over the most recent 3 years.

The assessment and forecast output is illustrated in Figure 3.7.1.


Figure 3.7.1. Estimates of SSB (top), Fbar (middle) and recruitment (bottom) from adopted SAM run. Black points show estimates for forecast. Grey shadow areas and vertical segments represent uncertainty in estimates.

### 3.8 Reference points

Though some exploratory analysis were looked at during the benchmark (see WD07, Annex 3), reference points were not revised at the benchmark working group but at the NWWG meeting in 2017 according to the ICES guidelines using Eqsim simulation software. See stock annex for a full description of the procedure. The new estimated reference points are presented in the table below:

| BIOLOGICAL REFERENCE POINTS | NWWG 2017 | BASIS |
| :---: | :---: | :---: |
| Btriger | 41400 t . | Bloss |
| Blim | 29571 t. | $\mathrm{B}_{\mathrm{pa}} / 1.4$ |
| $\mathrm{B}_{\mathrm{pa}}$ | 41400 t . | Bloss |
| Flim | 0.7 | Stochastic simulations (ICES, 2017), F50\% F that gives a $50 \%$ probability of SSB $>$ Blim |
| $\mathrm{F}_{\mathrm{pa}}$ | 0.52 | $\mathrm{Flim}^{*}$ *exp( $-1.645^{*}$ sigma) where sigma $=0.18$ |
| FmsY | 0.30 | Stochastic simulations (ICES, 2017). |

Graphical representation of the Eqsim simulations is illustrated in Figure 3.9.1.


Figure 3.9.1. Output from the final Eqsim simulation.

### 3.9 Future research and data requirements

See Section 6.4, 'Recommendations for further work', in the External Reviewer Report (Section 6).

### 3.10 References

See working documents (Annex 3) for relevant references.

4 Cod (Gadus morhua) in Subdivision 5.b.1 (Faroe plateau) - cod.27.5b1

### 4.1 Stock ID and substock structure

The stock structure was not an issue and the perception of stock structure was maintained.
4.2 Issue list

| Issue | Problem/Aim | Work needed / possible direction of solution | Data needed to be able to do this: are these available / where should these come from? | External expertise needed at benchmark type of expertise / proposed names |
| :---: | :---: | :---: | :---: | :---: |
| (New) data to be Considered and/orquantified | Additional M - predator relations | Quantify predation by anglerfish. Scrutinize stock assessment of anglerfish in combination with stomach data (of cod and anglerfish). Densitydependent effects on recruitment, e.g. cannibalism can be investigated by using the estimated stock biomass back to 1710 . | Available at the FAMRI (anglerfish) or in NWWG 2016 (cod) |  |
|  | Prey relations | Sandeels have become scarce because of increased temperature? Benthic crustaceans and Norway pout have become abundant. Do these prey compete or have different response to environmental variables or predation? | Temperature, sandeels O-group data and stomach data of cod, haddock and saithe are available at FAMRI |  |
|  | Ecosystem drivers | Primary production, zooplankton abundance and temperature. Uncertain how this should be addressed. | Available at FAMRI |  |
|  | Other ecosystem parameters that may need to be explored? |  |  |  |
| Tuning series | Spring and summer groundfish survey | Extending the spring survey back in time | Available at FAMRI, but not worked out. Probably not possible in this time frame. |  |
| Discards | None |  |  |  |
| Biological <br> Parameters | Survey lengths, weights, revised maturity estimates | Work up existing data | Available at FAMRI |  |


| Issue | Problem/Aim | Work needed / <br> possible direction of solution | Data needed to be able to do <br> this: are these available / where <br> should these come from? | External expertise needed at benchmark <br> type of expertise / proposed names |
| :--- | :--- | :--- | :--- | :--- |
| Assessment <br> method | Extended survivors <br> analysis (XSA) | No urgent problems, although alternative settings <br> or other models could be investigated. | Expertice available within the ICES <br> community? Local expertice (FAMRI) <br> insufficient |  |
| Biological <br> Reference Points | Evaluate biomass- and <br> fishing mortality reference <br> points | The biomass of Faroe Plateau cod has been <br> estimated back to 1710 in the current NWWG <br> report. | Expertice available within the ICES <br> community? Local expertice (FAMRI) <br> insufficient |  |

### 4.3 Scorecard on data quality

A scorecard was not used for this benchmark.

### 4.4 Multispecies and mixed fisheries issues and Ecosystem drivers

Multispecies interactions were briefly discussed at the benchmark meeting in February 2017.

The relationship between cod and haddock was discussed, i.e. that cod recruitment and haddock recruitment tend to co-fluctuate and whether it was caused by cod feeding on haddock (WD13). It was also noted that the co-fluctuation of the cod and haddock stocks was not apparent prior to around 1963 but that cod and saithe cofluctuated instead (WD10). None of these findings were incorporated into the assessment or forecast.

It was also noted that cod recruitment since 1997 was highly correlated with the amount of sandeels in cod stomachs (WD8). This relationship was not used directly in the assessment, partly because it was not known for how long time this relationship would hold into the future.

### 4.5 Stock assessment inputs

### 4.5.1 Catch: quality, misreporting, discards

There were no issues with the catch figures or the assumption that discards were very limited.

### 4.5.2 Surveys

There were no issues with the surveys.
The extension of the spring groundfish survey data back to the 1980s was not ready for the benchmark. The scanning of outprints to a digital form proved successful as well as the conversion of the format to the current format that can be scrutinised by a computer program for potential errors. The reason for the delay was partly that outprints were lacking for parts of 1989-1992 as well as for a few stations in 1993. The 1983-1988 material seemed, however, to be preserved. Another approach was initiated just prior to the benchmark to search for digital data in the old HP1000 machine. The work to reconstruct the survey information back to 1983 will continue in the future.

### 4.5.3 Maturity

The maturities at age were revised slightly and gave a slightly different average for 1983-1996, which is used for the historic period were no data are available (1959-1982).

See WD15 for further details.

### 4.5.4 Weight and growth

There were no issue with the weights at age in the catches.
Although it was recognised that stock weights at age 2 were probably different from catch weights at age 2 , catch weights were maintained as measures of stock weights for all ages because it made little difference on stock assessment outputs.

See WD16 for further details.

### 4.5.5 Natural mortality

Tagging results from 1997-2015 were investigated (WD 20). They indicated that M could be higher than 0.20 (e.g. 0.28 ) and that there was likely no increase in natural mortality over time (1997-2015). No change in natural mortality was done, however, since this evidence was considered too weak for this purpose.

### 4.6 Assessment models

Although there was no urgent need to replace the traditional XSA assessment model because the assessment output was thought to be data-driven rather than modeldriven, it was decided to adopt the SAM assessment model. The reason was partly that the SAM model provided uncertainty estimates of assessment outputs, including the catch figures. Also, the SAM model provided more options to fine-tune the assessment in addition to the fact that all codes and settings in the program were readily visible and potentially adjustable.

### 4.6.1 Settings and assumptions

A number of settings in the SAM model were explored although only a few are mentioned here. It was attempted to estimate as few different coefficients/parameters in the model as possible in order to provide a rigid model. The specific points were these:

## Recruitment

The age range was extended from 2-10+ to 1-10+. The reason was that the surveys provided abundance indices for age 1 (the age 0 abundance index in the August survey was, however, omitted) and the generic argument to use all available data and let the model treat them instead of disregarding them was followed here. The catch at age 1 was available since 1996 but not readily available before, so catch at age for age 1 was not used.

Recruitment was assumed to follow a random walk function, configuration setting:
\$stockRecruitmentModelCode
[1] 0

## Catchabilities

The catchabilities in the surveys were assumed to be different for ages 1 to 7 and a common catchability for ages 8 and 9 whereas age $10+$ was not estimated. The catchabilities differed between the surveys. No power function was used for the catchabilities. The 'old' settings in the XSA model were that ages 2 to 9 got a separate catchability coefficient and no power function was used. The configuration settings were:
\$keyLogFpar
$[, 1][, 2][, 3][, 4][, 5][, 6][, 7][, 8][, 9][, 10]$
[1,] $\begin{array}{lllllllllll}1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$

$\begin{array}{lllllllllll}{[3,]} & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 15 & -1\end{array}$
\$keyQpow
$[, 1][2][, 3][4][, 5][, 6][, 7][8][, 9][10]$

```
[1,] -1 1
[2,] 
[3,] 
```


## Selectivities

The coefficients for the fishing mortalities were not estimated for age 1 (there was no catch of age 1 in the catch-at-age), and set different for ages $2,3,4,5$ and 6 , and set to a common coefficient for ages $7,8,9$, and $10+$. The configuration below states this (the first row after the labels is catch, the second is the August survey, the third is the March survey, ' -1 ' means that the coefficient is not estimated). The 'old' settings in the XSA model were that each age got a separate fishing mortality, except age $10+$ that got the same value as age 9 . The configuration setting was:

## \$keyLogFsta

$$
[, 1][, 2][, 3][, 4][, 5][, 6][, 7][, 8][, 9][, 10]
$$

[1,] $-1 \begin{array}{llllllllll} & 0 & 1 & 2 & 3 & 4 & 5 & 5 & 5 & 5\end{array}$
[2,] $\quad-1 \begin{array}{llllllllll}1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$
[3,] $\quad-1 \begin{array}{llllllllll} & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$

The F-bar range was kept unchanged, i.e., from age 3 to 7 . The configuration setting was:
\$fbarRange
[1] 37

## Variances

The variance of the fishing mortalities was assumed to be equal for all ages (this was only relevant for the catches). The variance for the population numbers was assumed to be the same for ages 2 to $10+$ and to be different for age 1 . The variance of the survey indices at age was assumed to be the same for ages $2-9$ but different for age 1 ; the surveys had different variances. The setting of a separate variance of age 1 was, in practice, set at the NWWG 2017 meeting. At the WKFAROE meeting in February 2017, all ages had a common variance. The reason for this change was the realisation that age 1 was a poorer index of abundance than ages 2 to 9 , since age 1 cod are only partially distributed in the survey area (many of them are located closer to land). The XSA model did not have options for F , but had a separate variance for each age in the surveys. The configuration settings were:
\$keyVarF

```
[1,] }0
[2,] 
[3,] 
```

\$keyVarLogN
[1] 0111111111
\$keyVarObs
[,1] [2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10]
[1,] 000

[3,] $\quad 3 \quad 4 \quad 4 \quad 4 \quad 4 \quad 4 \quad 4 \quad 4 \quad 4 \quad 4 \quad-1$

## Survey settings

The surveys were tested for autocorrelation between ages, i.e., year effects. It was found that the August survey showed autocorrelation between adjacent ages whereas this was not the case for the March survey. Hence, an AR structure was set for the August survey in the SAM model. This option was not available in XSA. The configuration settings were:

## \$obsCorStruct

## [1] ID AR ID

Levels: ID AR US

## \$keyCorObs

1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10
[1,] NA NA NA NA NA NA NA NA NA
[2,] $00 \times 10 c c c c c c c c$
[3,] NA NA NA NA NA NA NA NA -1

Other settings
The remaining configuration settings were:
\$noScaledYears
[1] 0
\$keyScaledYears
numeric(0)
\$keyParScaledYA
$<0 \times 0$ matrix>
\$keyBiomassTreat
[1] -1-1-1
\$obsLikelihoodFlag

## [1] LN LN LN

Levels: LN ALN
\$fixVarToWeight
[1] 0

### 4.6.2 Diagnostics

The SAM model provided both observation residuals and one-step ahead (OSA) prediction residuals (also known as recursive residuals, or joint sample residuals; Berg and Nielsen (2016)) as shown in figures 4.5.3.1 and 4.5.3.2. For the catches, the most problematic observation residuals appeared to be for the plus group. For the other ages, including the young ages, the observation residuals were 'not so bad'. The OSA residuals also seemed acceptable. A norm for judging residuals is that they are small and random, which appears to be the case here.


Figure 4.5.3.1. Faroe Plateau cod (Subdivision 5.b.1). Observation residuals for the catch, spring survey and the summer survey as estimated by the SAM model.


Figure 4.5.3.2. Faroe Plateau cod (Subdivision 5.b.1). One-step ahead (OSA) residuals for the population numbers and fishing mortality as estimated by the SAM model.

### 4.6.3 Results

The SAM model run with current settings and the XSA model run with pre-2017 settings were very similar with regards to population numbers (Figure 4.6.1). There was a slight difference between the models for age 1 . The F-values were generally higher for age 7+ in the SAM model, but there was little difference in the mean value for younger ages (Figure 4.6.2). However, the yearly fluctuations in the fishing mortalities were less in the SAM model. This is not surprising since the XSA model had a very light shrinkage (2.0) on the F and the SAM model works as a random walk where the current state is affected by the previous state.


Figure 4.6.1. Faroe Plateau cod (Subdivision 5.b.1). Comparison between the results from the current SAM assessment ( 2017 settings) and the XSA assessment (2016 settings). Population number by age and year as well as average values by age over the time period (right, bottom panel).


Figure 4.6.2. Faroe Plateau cod (sub-division 5.b.1). Comparison between the results from the current SAM assessment (2017 settings) and the XSA assessment ( 2016 settings). Fishing mortality by age and year as well as average values by age over the time period (right, bottom panel).

### 4.6.4 Final assessment conclusions

The SAM model seems to work well for Faroe Plateau cod and it provides uncertainty estimates for the assessment outputs, including catch figures. The fact that the uncertainty estimates for the catch figures were rather narrow, at least since 1980, indicates that the catch figures are accurate, which can be expected with the current effort management system. It also provides some indications that there are no major issues with regards to immigration or emigration of cod in this area. The potential replacement of the effort management system with a quota system in 2018 may, however, change this perception in the future and should be followed up.

### 4.7 Short term forecast

The SAM model was used as the assessment tool and for short-term forecast. It was regarded as a benefit that the signal in the historic series was transferred to the short term forecast.

Recruitment: A random recruitment was assumed for the short term forecast where the last 10 years up to the assessment year - 1 were sampled. This option was not available in XSA.

Maturity ogives: The maturity in the assessment year +1 and year +2 was taken as the average of the 1983 up to the assessment year. This procedure differed from the 'old' procedure where the most recent years were used.
Weight at age in the catch in the interim years: The procedure was changed because of potential shortage of manpower at the Faroe Marine Research Institute in the future. Instead of using the January-February weights in the catches in combination with survey weights in the spring, the January-February weights in the catches were not used, because it was expected that these data would probably not be available in the future. The weights in the catch in the assessment year (WCy) were predicted by a regression model having the weights in the March survey (WCy) and the weight in the catch of the same cohort in the catch the year before (WCy-1): WCy $=a^{*} W C y-1+b^{*} W S y+c$. This is done for ages $3-8$ years. The weight of age 2 is estimated by a regression with age 3 the same year, age 9 and age $10+$ is estimated by a regression with age 8 the same year. Regressing age 10+ by age 8 was considered more simple at the NWWG 2017 meeting than regressing age 9 by age 8 and then age $10+$ by age 9 as suggested at the WKFAROE meeting in February 2017.
Weight at age in the stock: The same values as weight-at-age in the catch.
The forecast procedure used starts from the last year's (assessment year) estimate of the state $(\log (\mathrm{N})$ and $\log (\mathrm{F})$ at age). One thousand replicates of the last state are simulated from its estimated joint distribution. Each of these replicates are then simulated forward according to the assumptions and parameter estimates found by the assessment model. In the forward simulations a 5 year average (years up to the assessment year) is used for catch mean weight, stock mean weight, proportion mature, and natural mortality. Recruitment is re-sampled from the last 10 years (up to the year before the assessment year). In each forward simulation step the fishing mortality is scaled, such that the median of the distribution is matching the requirement in the scenario (e.g. hitting a specific $\mathrm{F}_{\mathrm{bar}}$ value or a specific catch). These procedures are different from the 'old' procedure where at most last 3 years, including the assessment year -1 , or the assessment year itself, were used as basis for the short term prediction.

### 4.8 Reference points

Since the assessment model was replaced, it was necessary to recalculate reference points at the NWWG meeting in 2017 (this was not finally conducted during the benchmark).

The Blim was kept unchanged at 21 thousand tonnes, since this previously defined Bloss was the lowest spawning biomass from which the stock had made a recovery. The biomass has been lower in recent years but the stock has not recovered yet.

The $\mathrm{B}_{\mathrm{pa}}=\mathrm{B}_{\text {trigger }}=29226$ tonnes (changed from 40000 tonnes). The uncertainty in the SAM assessment one the final year of SSB was found to be $\sigma=0.20$ and the $B_{p a}$ was found by using the formula $\mathrm{B}_{\mathrm{pa}}=\mathrm{B}_{\lim } \times \exp (\sigma \times 1.645)$. The $\mathrm{B}_{\text {trigger }}$ was, according to ICES
guidelines, set equal to $B_{p a}$ since the stock had not been fished at $\mathrm{FmSy}_{\text {for }}$ for five or more years.
$F_{\text {lim }}=0.90$ (changed from 0.68). Flim was derived from Blim. A stock was simulated with a segmented regression on the spawning stock - recruitment function having the point of inflection at $B_{\lim .}$. Flim was set to the $F$ that, in equilibrium, gave a $50 \%$ probability that SSB $>$ Blim. This simulation was based on a fixed F, i.e., without in-clusion of a Btrigger and without inclusion of assessment/advice errors.
$\mathrm{F}_{\mathrm{pa}}=0.69$ (changed from 0.35). $\mathrm{F}_{\mathrm{pa}}$ was derived from Flim in the reverse of the way $\mathrm{B}_{\mathrm{pa}}$ was derived from $B_{l i m,}$ i.e., $\mathrm{F}_{\mathrm{pa}}=\mathrm{F}_{\lim } \times \exp (-\sigma \times 1.645)$, where $\sigma=0.16$.

The calculations were conducted using EQSIM following ICES guidelines. Decisions made involved the spawning stock - recruitment relationship, the weights at age, the selection pattern and the level of advice error. The full time series (1959-2015) was used as basis for the spawning stock - recruitment relationship where the S-R function was based on the segmented regression (weight 0.61), Ricker (weight 0.36), and Beverton and Holt (weight 0.03). The Ricker curve was included because recruitment at very large stock sizes was low according to extension of stock biomass back to 1710 (ICES, 2016). The autocorrelation between SSB-R data points was approximately 0.55 . The weights at age were based on the last 10 years (2007-2016). The selection pattern was also based on the last 10 years. The selection pattern has been very stable over time, so the use of the last 20 years would not make any big difference for the Fmš. The advice error was estimated from advice sheets back to 1999: $\mathrm{cvF}=0.44$, $\mathrm{phiF}=0.47$, $\operatorname{cvSSB}=0.38$, phiSSB $=0.24$. In total 2000 iterations were performed that projected the stock 200 years into the future, of which, the last 50 years were kept to calculate 'equilibrium' values.

The result of the analyses was that $\mathrm{FMSY}_{\mathrm{M}}=0.23$ (changed from 0.32). The fishing mortality that is associated with a risk of $5 \%$ to fall below $\mathrm{Blim}_{\mathrm{lim}}, \mathrm{F}_{\mathrm{p} 0.5}$, was estimated to be 0.41 , greater than $\mathrm{F}_{\mathrm{MS}}$.

### 4.9 Future research and data requirements

See Section 6.4, 'Recommendations for further work', in the External Reviewer Report (Section 6).

### 4.10 References

Berg, C. W. and Nielsen, A. (2016). Accounting for correlated observations in an age-based statespace stock assessment model. ICES Journal of Marine Science, 73(7), 1788-1797. DOI: 10.1093/icesjms/fsw046

## 5 Haddock (Melanogrammus aeglefinus) in Division 5.b (Faroese grounds) - had.27.5b

### 5.1 Stock ID and substock structure

The stock structure was not an issue and the perception of stock structure was maintained.
5.2 Issue list

| Issue | Problem/Aim | Work needed / <br> possible direction of solution | Data needed to be able to do this: are these available / where should these come from? | $\frac{\text { External expertise needed at }}{\text { benchmark }}$ type of expertise / proposed names |
| :---: | :---: | :---: | :---: | :---: |
| (New) data to be considered and/or quantified | Is the M gestimate of .2 of the right order of magnitude? Should it be investigated? | Quantify predation by other fish stocks, e.g. cod and anglerfish. | Available at the FAMRI (stomach data) |  |
|  | Varying (cyclical) growth and maturity, is it possible to relate this to changes in the environment and stock biomass | Analyse existing data on these issues | Available at FAMRI |  |
|  | Ecosystem drivers | Primary production and temperature. Uncertain how this should be addressed. | Available at FAMRI |  |
|  | Other ecosystem parameters that may need to be explored? |  |  |  |
| Tuning series | Spring and summer groundfish survey | Extend the spring survey back in time | Available at FAMRI |  |
| Discards | None |  |  |  |
| Biological Parameters | Survey lengths, weights, revised maturity estimates | Work up existing data and use weightings of maturity observations | Available at FAMRI |  |


| Issue | Problem/Aim | Work needed / <br> possible direction of solution | Data needed to be able to do this: are these available / where should these come from? | External expertise needed at benchmark <br> type of expertise / proposed names |
| :---: | :---: | :---: | :---: | :---: |
| Assessment method | Extended survivors analysis (XSA) | Present settings of the XSA unchanged for too many years, need to be investigated. Other assessment methods should be investigated | Available at FAMRI | Expertise available within the ICES community? Local expertise (FAMRI) insufficient |
| Biological <br> Reference <br> Points | Evaluate/revise existing biomass- and fishing mortality reference points | Extend present stock biomass estimates back in time, use harvest ratio to evaluate F-reference points, use standard ICES methods | British CPUE data 1906-72 available at FAMRI | Expertise available within the ICES community? Local expertise (FAMRI) insufficient |

### 5.3 Scorecard on data quality

A scorecard was not used for this benchmark.

### 5.4 Multispecies and mixed fisheries issues and Ecosystem drivers

Multispecies interactions were briefly discussed at the benchmark meeting in February 2017. The relationship between cod and haddock was discussed, i.e. that cod recruitment and haddock recruitment tend to co-fluctuate and whether it was caused by cod feeding on haddock (WD13). It was also noted that the co-fluctuation of the cod and haddock stocks was not apparent prior to around 1963 but that cod and saithe co-fluctuated instead (WD10).

It was briefly noted that there was a positive correlation between the amount of sandeels as food for cod or haddock and haddock recruitment (WD08). This relationship was not used directly in the assessment, partly because it was not known for how long time this relationship would hold into the future.

### 5.5 Stock assessment inputs

### 5.5.1 Catch: quality, misreporting, discards

There were no issues with the catch figures or the assumption that discards were very limited.

### 5.5.2 Surveys

There were no issues with the surveys.

The extension of the spring groundfish survey data back to the 1980s was not ready for the benchmark. The scanning of outprints to a digital form proved successful as well as the conversion of the format to the current format that can be scrutinised by a computer program for potential errors. The reason for the delay was partly that outprints were lacking for parts of 1989-1992 as well as for a few stations in 1993. The 1983-1988 material seemed, however, to be preserved. Another approach was initiated just prior to the benchmark to search for digital data in the old HP1000 machine. The work to reconstruct the survey information back to 1983 will continue in the future.

### 5.5.3 Maturity

The maturities were maintained unchanged.

### 5.5.4 Weight and growth

Work was done to extend the yearly values from 1976 and back to 1957 instead of using constant values. However, the sum of product check showed discrepancies with the observed catch by up to $20 \%$. It was proposed to change the catch figures correspondingly, but it was decided to keep the constant weights until more work was done.

The catch weights at age were maintained as measures of weight at age in the stock. It was assumed that adjustments of catch weights to stock weights (from survey weights at age) would not lead to any major change in biomasses, as was observed for cod (WD16).

### 5.5.5 Natural mortality

The natural mortality of 0.2 was maintained.

### 5.6 Assessment models

Although there was no urgent need to replace the traditional XSA assessment model because the assessment output was thought to be data-driven rather than modeldriven, it was decided to adopt the SAM assessment model. The reason was partly that the SAM model provided uncertainty estimates of assessment outputs, including the catch figures. Also, the SAM model provided more options to fine-tune the assessment in addition to the fact that all codes and settings in the program were readily visible and potentially adjustable.

### 5.6.1 Settings and assumptions

A number of settings in the SAM model were explored although only a few are mentioned here. It was attempted to estimate as few different coefficients/parameters in the model as possible in order to provide a rigid model. The specific points were these:

## Recruitment

Recruitment was assumed to follow a random walk function, configuration setting:
\$stockRecruitmentModelCode
[1] 0

## Catchabilities

The catchabilities in the surveys were assumed to be different for ages 1 to 7 and a common catchability for ages 8 and 9 whereas age $10+$ was not estimated. The catchabilities differed between the surveys. No power function was used for the catchabilities. The 'old' settings in the XSA model were that ages 2 to 9 got a separate catchability coefficient and no power function was used. The configuration settings were:
\$conf\$keyLogFpar
$[, 1][, 2][, 3][, 4][, 5][, 6][, 7][, 8][, 9][, 10]$
[1,] $\quad-1 \begin{array}{llllllllll}1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$
$[2] \quad 0 \quad 1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6 \quad 6 \quad-,1 \quad-1$

\$conf\$keyQpow
$[, 1][2][, 3][, 4][, 5][, 6][, 7][8][, 9][, 10]$
[1,] $\quad-1 \begin{array}{llllllllll}1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$
[2,] $\quad-1 \begin{array}{llllllllll}1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$
[3,] $\quad-1 \begin{array}{llllllllll}1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$

## Selectivities

The coefficients for the fishing mortalities were set different for ages $1,2,3,4,5$ and 6 , and set to a common coefficient for ages 7, 8,9 , and $10+$. The R-code below states this (the first row after the labels is catch, the second is the August survey, the third is the March survey, ' -1 ' means that the coefficient is not estimated). The 'old' settings in the XSA model were that each age got a separate fishing mortality, except age 10+ that got the same value as age 9 . The configuration setting was:

## \$conf\$keyLogFsta

$[, 1][, 2][, 3][, 4][, 5][, 6][, 7][, 8][, 9][, 10]$

[2,] $-1 \begin{array}{llllllllll}1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$


The F-bar range was kept unchanged, i.e., from age 3 to 7. The configuration setting was:
\$fbarRange
[1] 37

## Variances

The variance of the fishing mortalities was assumed to be equal for all ages (this was only relevant for the catches). The variance for the population numbers was assumed to be the same for ages 1 to $10+$. The variance of the survey indices at age was assumed to be the same for ages 1-9; the surveys had different variances. The XSA model did not have options for F , but had a separate variance for each age in the surveys. The configuration settings were:
\$conf\$keyVarF
$[, 1][, 2][, 3][, 4][, 5][, 6][, 7][, 8][, 9][, 10]$
[1,] $00 \begin{array}{llllllllll} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$
[2,] $\quad-1 \begin{array}{llllllllll}1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$
[3,] $\quad-1 \begin{array}{llllllllll} & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1\end{array}$
\$conf\$keyVarLogN
[1] 0111111111
\$conf\$keyVarObs

```
[1,] }0
[2,]
[3,] }
```

At the NWWG 2018 it was realized - as found for cod - that the youngest ages (age 1 and 2 in the summer survey and age 1 in the spring survey) should be treated differently than the other ages in the survey leading to following settings:
\$conf\$keyVarObs
$[, 1][, 2][, 3][, 4][, 5][, 6][, 7][, 8][, 9][, 10]$
[1,] $00 \begin{array}{lllllllll} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array} 0$

[3,] $304 \begin{array}{lllllllll} & 4 & 4 & 4 & 4 & 4 & 4 & -1 & -1\end{array}$

## Survey settings

The surveys were tested for autocorrelation between ages, i.e., year effects. It was found that both the March survey and the August survey showed autocorrelation between adjacent ages. Hence, an AR structure was set for the both surveys in the SAM model - the covariance matrix was set to 'correlated' in the August survey and to 'unstructured' in the March survey. This option was not available in XSA. The configuration settings were:
\$conf\$obsCorStruct
[1] ID AR AR
Levels: ID AR US
\$conf\$keyCorObs
1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10
[1,] NA NA NA NA NA NA NA NA NA
[2,] $00 \times 10 c c c c c c c c$
[3,] $1 \begin{array}{llllllllll} & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1\end{array}$

Other settings
The remaining configuration settings were:

## \$conf\$noScaledYears

[1] 0
\$conf\$keyScaledYears
numeric(0)
\$conf\$keyParScaledYA
$<0 \times 0$ matrix>
\$conf\$keyBiomassTreat
[1]-1-1-1
\$conf\$obsLikelihoodFlag

## [1] LN LN LN

Levels: LN ALN
\$conf\$fixVarToWeight
[1] 0

### 5.6.2 Diagnostics

The SAM model provided both observation residuals (Figure 5.5.3.1) one-step ahead (OSA) prediction residuals (Berg and Nielsen (2016); Figure 5.5.3.2). The observation errors showed some year class effects, but were acceptable. The OSA residuals seemed also acceptable. A norm for judging residuals is that they are small and random, which appears to be the case here.


Figure 5.5.3.1. Faroe haddock. Observation residuals from the SAM model.


Figure 5.5.3.2. Faroe haddock. one-step ahead (OSA) prediction residuals from the SAM model.

### 5.6.3 Results

The spawning stock biomass as obtained by the SAM model was lower than the XSA results obtained in 2016, this was prior to 1995 and especially prior to 1970. This feature was discussed at NWWG 2017 but no conclusion was drawn other that it was caused by the difference of the stock assessment models.


Figure 5.6.1. Faroe haddock. Spawning stock biomass as obtained by the SAM model and the XSA model in NWWG 2016.

### 5.6.4 Final assessment conclusions

The SAM model seems to work well for Faroe haddock and it provides uncertainty estimates for the assessment outputs, including catch figures. The fact that the uncertainty estimates for the catch figures were rather narrow (as seen on the www.stockassessment.org homepage) indicates that the catch figures are accurate, which can be expected with the current effort management system. It also provides some indications that there are no major issues with regards to immigration or emigration of haddock in this area. The potential replacement of the effort management system with a quota system in 2018 may, however, change this perception in the future and should be followed up.

### 5.7 Short term forecast

The SAM model was used as the assessment tool and for short-term forecast. It was regarded as a benefit that the signal in the historic series was transferred to the short term forecast.

Recruitment: A random recruitment was assumed for the short term forecast where full data years from 2000 up to the assessment year - 1 were sampled. This option was not available in XSA.

Maturity ogives: The maturity in the assessment year was estimated as the average of the maturity in the assessment year and the year before; year +1 and year +2 was taken as the average of the assessment year and the 2 years before.

Weight at age in the catch: The procedure for estimating weights in the assessment year was changed at the benchmark meeting in February 2017. Instead of using the average of the last 3 years weights for all ages to estimate the weights in the assessment year, it was decided to continue to use this procedure only for age 1 For ages $3-8$ the weights in the catch in the assessment year were predicted by a regression model with spring survey weights. The weight of age 2 is estimated by a regression with age 3 the same year, age 9 and age 10 is estimated by regression with age 8 the same year. A 5 years average including the assessment year was used in the forward simulation.

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

The forecast procedure used starts from the last year's (assessment year) estimate of the state $(\log (\mathrm{N})$ and $\log (\mathrm{F})$ at age). One thousand replicates of the last state are simulated from its estimated joint distribution. Each of these replicates are then simulated forward according to the assumptions and parameter estimates found by the assessment model. In the forward simulations a 5 year average (years up to the assessment year) is used for catch mean weight, stock mean weight, proportion mature, and natural mortality. Recruitment is re-sampled from the last 10 years (up to the year before the assessment year). In each forward simulation step the fishing mortality is scaled, such that the median of the distribution is matching the requirement in the scenario (e.g. hitting a specific $\mathrm{Fbar}_{\mathrm{v}}$ value or a specific catch). These procedures are different from the 'old' procedure where at most last 3 years, including the assessment year -1 , or the assessment year itself, were used as basis for the short term prediction.

### 5.8 Reference points

Since the assessment model was replaced at this benchmark in February 2017, it was necessary to recalculate reference points during the NWWG meeting in 2017 (this was not possible at the benchmark meeting in February).

The Blim was changed from 22000 tonnes to 16780 , i.e. the lowest spawning biomass from which the stock had made a recovery.

The $B_{p a}=B_{\text {trigger }}=22843$ tonnes (changed from 35000 tonnes). The uncertainty in the SAM assessment in the final year of SSB was found to be $\sigma=0.188$ and the $\mathrm{B}_{\mathrm{pa}}$ was found by using the formula $B_{p a}=B_{\lim } \times \exp (\sigma \times 1.645)$. The $B_{\text {trigger }}$ was, according to ICES guidelines, set equal to $B_{\text {pa }}$ since the stock had not been fished at $\mathrm{F}_{\text {MSY }}$ for five or more years.
$F_{\text {lim }}=0.35$ (changed from 0.4). Flim was derived from Blim. A stock was simulated with a segmented regression on the spawning stock - recruitment function having the point of inflection at Blim . Flim was set to the F that, in equilibrium, gave a $50 \%$ probability that SSB $>$ Blim. This simulation was based on a fixed F, i.e., without inclusion of a Btrigger and without inclusion of assessment/advice errors.
$\mathrm{F}_{\mathrm{pa}}=0.26$ (changed from 0.25). $\mathrm{F}_{\mathrm{pa}}$ was derived from Flim in the reverse of the way $\mathrm{B}_{\mathrm{pa}}$ was derived from $B_{\lim }$, i.e., $\mathrm{F}_{\mathrm{pa}}=\mathrm{F}_{\lim } \times \exp (-\sigma \times 1.645)$, where $\sigma=0.185$.

The calculations were conducted using EQSIM following ICES guidelines. Decisions made involved the spawning stock - recruitment relationship, the weights at age, the selection pattern and the level of advice error. The period since 1978 was used as basis for the spawning stock - recruitment relationship where the S-R function was based on the segmented regression (weight 0.7), Ricker (weight 0.24), and Beverton and Holt (weight 0.06). The autocorrelation between SSB-R data points was approximately 0.52. The weights at age were based on the last 20 years. The selection pattern was based on the last 5 years. The advice error was estimated from advice sheets back to 1999: $\mathrm{cvF}=0.48, \mathrm{phiF}=0.37, \mathrm{cvSSB}=0.40$, phiSSB $=0.43$. In total 2000 iterations were performed that projected the stock 200 years into the future, of which, the last 50 years were kept to calculate 'equilibrium' values.

The result of the analyses was that $\mathrm{F}_{\mathrm{MSY}}=0.165$ (changed from 0.25 ). The fishing mortality that is associated with a risk of $5 \%$ to fall below Blim, $\mathrm{F}_{\mathrm{p} 0.5 \text {, was estimated to be }}$ 0.09. The value was in the first simulations 0.13 assuming autocorrelation in the recruitment. At a web-ex meeting in June 2018 it was assumed that there was no autocorrelation in the recruitment that led to $\mathrm{F}_{\mathrm{MSY}}=0.165$.

### 5.8.1 Proposed MSY reference points

No new reference points could be proposed by WKNSEA. It is proposed that the status of the stock in relation to a proxy for Fmsy is determined on an annual basis through the LBI analyses presented in Section 4.7.5.

### 5.9 Future research and data requirements

See Section 6.4, 'Recommendations for further work', in the External Reviewer Report (Section 6).

### 5.10 References

Berg, C. W. and Nielsen, A. (2016). Accounting for correlated observations in an age-based statespace stock assessment model. ICES Journal of Marine Science, 73(7), 1788-1797. DOI: 10.1093/icesjms/fsw046

See working documents (Annex 3) for other relevant references.

## Summary report from external panel

Jim Ianelli, Matthew Dunn and Sigurdur Jönsson were invited external experts for the WKFAROE benchmark of the Faroese cod, haddock, and saithe. The panel reviewed modelling approaches used for assessment concerning suitability for advice at the workshop held at the ICES Headquarters in Copenhagen Denmark, 13-17 February 2017.

The reviewers met with working group participants and made a few requests which were addressed during the workshop. The working group focussed on evaluating alternative assessment applications for comparison purposes and to select the approach most suitable based on scientific understanding of the data as applicable for management advice.

### 6.1 General comments

### 6.1.1 Time varying maturity and body weight at age

As with many stocks assessed within the ICES system, the estimates of annual agespecific maturity and body weights showed substantial variability and often trend. It was agreed to reduce this variability using smoothers. For maturity, the group considered that where historical data and other knowledge indicated variability rather than persistent trend, then an alternative model run should assume constant mean values of maturity at age, and this model should also be used in projections. Although this discounts potential plausible biological changes in the stock (as assumed for e.g., the North Sea cod assessment), it avoids the use of potentially biased values in projections, and ensures historical SSB and projected values are consistent in maturation schedules. The stock weights were assumed equal to catch weights at age, and were generally considered more reliable since sampling for these has been much higher (than maturity at age). In projections, weights at age were assumed to be equal to a recent mean. However, methods for evaluating and capturing the uncertainty and trends in body weights should be included in future advice to the extent practical. A demonstration of a ran-dom-effects approach for cohort and year was developed and is available at https://goo.g1/qfZa2I.

Having Anders Nielsen (the developer of SAM) present for two days of the meeting was extremely beneficial. He noted that accounting for variability in stock weights-atage and maturity (which are assumed fixed) would be useful to include within SAM. He plans to examine the steps and approach to implementing this type of variability within SAM for future versions.

### 6.1.2 Disaggregating fishery data

For the cod and haddock assessments, the models might be improved by splitting the fisheries since there are important nearer-shore longline vessels that likely differ from the trawl vessels targeting these species outside of territorial waters. It was noted that the catch rate trends, relative to the model fit, were substantially different in different fisheries (quite why was unknown). Splitting the fisheries could improve the advice and account for relative sector-specific impacts (i.e., effect on differential catches by gear types on spawning biomass-per-recruit fishing mortality).

### 6.1.3 Natural mortality specifications / estimation

The treatment / specification of natural mortality was based on past practices ( $M=0.2$ across all ages and years). In other ICES regions age and time-varying values are more commonly used (e.g., in the North Sea, derived from multi-species model estimates). An evaluation of alternatives, including stationary age-specific values, should be considered in the next benchmark for these stocks.

### 6.1.4 Consideration of environmental factors

Some characteristics of environmental conditions and potential impacts were presented during the week, and included descriptions and analyses of fish distribution based on tagging data, physical oceanography, changes in prey abundance, and other potential density dependent effects within and between stocks (e.g., cannibalism). Such considerations will likely continue to play a role in the dynamics of these fisheries, and attempts to better understand and incorporate ecosystem impacts on stock dynamics, including catchability and selectivity, should continue.

### 6.2 Stock specific considerations

Overall, the group decided that adopting the SAM assessment framework was most appropriate. In all cases residual plots, sensitivity to data, and retrospective patterns were used as diagnostic tools. The flexibility and statistical rigor of SAM was seen as an improvement over XSA, SCA, and other models under development. The added benefit of having a coordinated interface (in $R$ and on the web) was noted.

### 6.2.1 Cod

### 6.2.1.1 Issues addressed at the benchmark

The previous assessment was based on an application of XSA and used the spring and summer surveys as tuning indices. During the week the group developed a number of model configurations using the SAM framework.

The new framework did not resolve recent retrospective patterns in the model. These patterns were a consequence of a relatively large year class from 2008 that was observed in the surveys at ages $1-2$, but did not appear at age 3 . Plausible hypotheses for their disappearance were discussed (mortality, movement), but no conclusions could be made. The assessment used only fishery independent tuning series. It was noted that the low recent biomass conflicted with CPUE from the main fishery (not used in the model), using longlines, which had been increasing; again plausible hypotheses were discussed for this conflict, but the cause was unknown.

### 6.2.1.2 Use of final stock annex as basis for providing stock advice

The review panel felt able to accept the final model as suitable for providing advice. The XSA model compared similarly with the SAM approach

### 6.2.2 Haddock

### 6.2.2.1 Issues addressed at the benchmark

The group developed a SAM application for this stock and evaluated fits and results on Thursday of the week (the analyst fell ill during the first part of the benchmark). The new method allowed for greater flexibility in specifications and avoided practice of "shifting" time series of estimates.

### 6.2.2.2 Use of final stock annex as basis for providing stock advice

The review panel felt able accept the final SAM model as suitable for use in assessments. Exploration of model settings was pretty limited.

The group noted that, together with cod, future changes in relative abundance should be monitored due to the mixed nature (cod and haddock co-occurring) of this fishery and that this should be a consideration in updating advice to ICES.

### 6.2.3 Saithe

### 6.2.3.1 Issues addressed at the benchmark

The analyst for this stock developed a saithe-specific statistical age-structured assessment program and presented results showing that it compared reasonably with the earlier XSA model that was used. Some modifications of this program were made during the week in addition to developing and testing alternative SAM configurations.

The group discussed the difficulty in obtaining representative samples of saithe, as a result of size and/or age specific shoaling and variable and potentially density dependent vertical movements; a solution to these problem was not forthcoming. The potential for some mixing with other saithe stocks was recognized.

Maturity at age for saithe was seen to be quite variable. Possible causes were argued as being partly due to:

1 ) sampling and sample sizes,
2 ) survey timing (in some years it may be too late in spring for this species), and

3 ) real variability in the spawning ages for saithe.
The relative contribution of these potential causes was unknown. Smoothing the available data was done (see working paper) using splines. This had some unusual residual patterns and the panel recommended developing a simple smooth which treated the maturity at each age independently (the spline assumed no interaction between age and time) and apply that in the base case. Finally, evaluating maturity at age as a more simple mean over time should be presented at least for sensitivity so that the impact on SSB estimates given trends in maturity at age can be evaluated.

### 6.2.3.2 Use of final stock annex as basis for providing stock advice

The review panel felt able to accept the final model as suitable for providing advice and appreciated the efforts made by the analysts to develop alternative methods and conduct sensitivities.

### 6.3 Reference points

The estimation of reference points followed established ICES methodology. Simulations were conducted by different models to evaluate FMSY for cod, haddock and saithe. $B_{\lim }$ and $B_{p a}$ were also investigated. The group discussed the issue of reference period, particularly for cod. Our conclusion was that evidence was weak that a "regime shift" had occurred. Therefore the full period was recommended for reference point estimation and projections.

One consideration explored during the week was how to detect how environmental factors affect stock biomass trends relative to fishing. Code was developed to examine
stock trends projected from estimated historical recruitment but assuming lower constant historical fishing mortalities (including zero fishing). This might be considered as an empirical approach to evaluate depletion estimates due to fishing (noting that this does not assume a stock-recruitment relationship-i.e., the estimated recruitment levels would have occurred at all levels of biomass.
Haddock and cod, and to a lesser extent saithe, are part of a mixed demersal fishery, and ideally the species should not be managed in isolation.

### 6.4 Recommendations for further work

Methods for evaluating and capturing the uncertainty and trends in body weights should be included in future advice to the extent practical.

Splitting the fisheries should be investigated.
Alternatives to constant M should be evaluated, including stationary age-specific values, should be considered in the next benchmark for these stocks.

An attempt should be made to better understand and incorporate ecosystem impacts on stock dynamics, including catchability and selectivity.

Data exist to extend the spring survey back in time, but these were not yet available at the benchmark; the addition of these data would benefit all three assessments.

## Annex 1 List of participants

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## Annex 2 List of stock annexes

| Stock ID | Stock Description | Link |
| :--- | :--- | :--- |
| pok.27.5b | Saithe (Pollachius virens) in Division 5.b (Faroes grounds) | pok.27.5b SA |
| cod.27.5b1 | Cod (Gadus morhua) in Subdivision 5.b.1 (Faroe Plateau) | cod.27.5b1 SA |
| had.27.5b | Haddock (Melanogrammus aeglefinus) in Division 5.b (Faroes <br> grounds) | $\underline{\text { had.27.5b SA }}$ |

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WD01

# Evaluation of Harvest Control Rule for Faroe cod. 

HB
February 23, 2017

## 1 Comments

The Harvest Control Rules (HCR) presented here are all with specified $F_{3-7}$ above certain $B_{\text {trigger }}$. Below $B_{\text {trigger }} \mathrm{F}$ is reduced by the ratio $\frac{S S B_{y+1}}{B_{\text {trigger }}}$ where the year $y$ is the assessment year and $y+1$ advice year. 3 triggers are presented below, $B_{\text {trigger }}=B_{p a}=40, B_{\text {trigger }}=B_{\text {lim }}=21$ and $B_{\text {trigger }}=10$, the last value is practically the same as zero.

## 2 Historical Assessment



Figure 1: Summary of assessment results. Red values indicate prediction based on $F_{m s y}=0.32$

Summary of assessment (figure 1) shows poor recruitment since 2000 leading to reduction in stock size and catch. Fishing mortality has usually been well above $F_{m s y}$ for this stock. The SOP factor $\left(\frac{\text { Landings }}{\sum C N O \times C W T}\right)$ is usually close to 1 except in 1971 and 1972 when it is close to 1.2 . Catch in numbers in those years is scaled up. The same is done in other years but the SOP factor is much closer to 1 in those years.


Figure 2: Mean weight at age in catches. Average values used in precitions shown at the end of each plot.
Mean weight age decreased from 1960-1980 but have not shown any apparent trend since 1980 (figure 2). CV in mean weight at age from 1980-2015 is between 0.12 and 0.17 for ages $3-8$ and first order autocorrelation 0.5-0.6.


Figure 3: Maturity at age. Average values used in predictions shown at the end of each plot.
Maturity at age (figure 3) does not show much variability except for age 3. Values before 1985 are fixed but should not lead to major problems in inference about SSB-Rec function. No problematic trend is observed in those data and skipping variabilty should not lead to major problems.


Figure 4: Selection by age, all values scaled to average 3-7 is 1 .

Selection at age is similar for the commercial fleet and the surveys (figure 4). Age 1 is only observed in the summer survey but the spring survey catches relatively few of the youngest agegroups. (Does not have to say much about the quality of the indices. )

## 3 Assessment Error

HCR evaluations requires appropriate level of assessment error to be included in the simulations. Harvest control rule with biomass trigger point based on SSB requires uncertainty in $F$ in the advice year and uncertainty in SSB in the advice year. The error in $F$ and $S S B$ have high correlation but the CV can be different. Both are affected by uncertainty in numbers at age and prediction error in mean weight at age. The spawning stock is in addition affected by uncertainty in predicting maturity at age and $F$ is affected by selection. The main source of uncertainty affecting both is though uncertainty in numbers at age.

## 4 Recruitment variablitiy

Variability in recruitment is estimated in the model runs with the parameters of the hockey stick SSB-Rec function. The 1st order autocorrelation of residuals can in principle be estimated but the time series is rather short so the value is fixed and sensitivity to different assumptions tested.


Figure 5: Recruitment vs. spawning stock and autocorrelation of recruitment and recruitment residuals. Red lines show predicted recruitment

1st order lag of the autocorrelation of recruitment residuals is estimated around 0.5 (figure 5).

## 5 Final settings

What is described shows the default settings
Recruitment can be generated by hockey stick stock recruitment function with autocorrelated lognormal residuals with $\rho=0.50$. CV is estimated from the data. $R_{\max }$ and $S S B_{\text {break }}$ are estimated.

Stochasticity in mean weight lognormal with $\sigma=0.15$ and $\rho=0.7$ around average of last 20 years. Uncertainty in prediction modelled by assuming same mean weights as last year.

Maturity and selection constant. Variable maturity could be implemented.
CV of assessment error 0.25 and $\rho=0.6$. Estimated $C V$ from the model is $\approx 0.2$, and experience indicates that CV estimated from assessment models tend to be an underestimate?? CV of the assessment error in the year before the assessment year is 0.17 (used for compiling $B_{p a}$ ). If the value of $B_{l i m}$ of 21 thous. tonnes is appropriate $B_{p a}$ should be $21 \times e^{1.645 \times 0.17}=28$ thous tonnes.

Assessment based on separable model, age 2-10 tuned with survey data from 1959. Correlation of residuals in the survey estimated. The estimated selection pattern used in the predictions should be a part of the HCR, changes in selection pattern can not be avoided but should not affect the given advice in each case.

According to ICES guidelines to evaluate $F_{m s y} B_{\text {trigger }}=40 \mathrm{kt}=B_{p a}$ shuld be used when finding $F_{P\left(S S B<B_{l i m}=0.05\right.}$ but not use trigger when finding F leading to maximum yield. $B_{\text {trigger }}=B_{p a}$ turns out to be rather high for this stock (for stability of catches ). In the following text the mimimum of $F$ fulfilling the precautionary criteria and F giving maximum yield will be called $F_{H C R}$

## 6 Results



Figure 6: Scatter of $S S B_{\text {break }}$ and $R_{\text {max }}$

The scatter of SSB-rec pairs (figure 6) shows the normal positive correlation between $R_{\text {max }}$ and $S S B_{b r e a k}$. There are indications that the break point is higher than $B_{\text {lim }}$ but this estimate is confounded with autocorrelation of residuals and possible reduced productivity last $15+$ years. (see below).


Figure 7: Average,median and 10th percentile of catch at "equlibrium". Fifth percentile of SSB is also shown as well as the line that maximizes median of catch, $\mathrm{F}=0.32$ and the line corresponding to maximum yield, The horizontal red and blue lines show $95 \%$ of average and median yield. $B_{\text {trigger }}=10$

The results of the simulations (figure 7) show that median catch is maximized around $F=0.2$ but $F_{P\left(S S B<B_{l i m}=0.05\right.}=0.32$ (higher if $B_{\text {trigger }}=B_{p a}$ ). $F$ that gives $95 \%$ of maximum yield is in the range $0.3-0.32$. The results do therefore lead to $F_{H C R}$ close to the current value of $F_{m s y}$ that is 0.32 .

What is causing the relatively low $F$ giving maximum yield is mean weight at age and selection by age i.e yield per recruit (figure 8). Looking at mean weight of Faroese cod the gain in yield exceeds assumed M until age 10. Comparison of mean weight at age in the spring survey and catches indicates that for age 3 and older catch and survey weights are similar but for age 2 survey weights are approximately $60 \%$ of catch weights (size selection).

The stock - recruitment indicates that estimated $S S B_{\text {break }}$ is well above $B_{\text {lim }}$ (figure 6). Uncertainty in $S S B_{\text {break }}$ is also considerable, leading to risk of reduced recruitment at lower $F$ than when using deterministic SSB-rec relationship.


Figure 8: Yield per recruit as function of fishing mortality using average weight and maturity at age 1996-2015

Analysis of $F_{m s y}$ based on maximising the catches should not include any trigger (ICES 2016) but investigation of $F_{P\left(S S B<B_{l i m}\right)=0.05}$ should. The effect of trigger is demonstrated in figure 9 showing that based on $B_{\text {trigger }}=40\left(B_{p a}\right) F_{P\left(S S B<B_{\text {lim }}\right)=0.05}=0.4$. The adopted $F_{m s y}$ was most likely not based on using trigger at $B_{p a}$, that is relatively new addition to ICES directives, but the adopted might could also be based on maximizing yield ( $95 \%$ of MSY)??


Figure 9: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $B_{\text {trigger }} . C V_{\text {ass }}=0.25$ and $\rho_{\text {rec }}=0.5$.


Figure 10: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $C V_{\text {ass }} . B_{\text {trigger }}=10$ and $\rho_{\text {rec }}=0.6$.
Assumptions about assessment error has some effect on $F_{P\left(S S B<B_{l i m}=0.05\right.}$ (figure 10). The range of values tested is not large or $0.15-0.25$. This range should cover the expected range of the assessment error. The assessment error presented here applies to the uncertainty in the beginning of the assessment year and leads higher uncertainty in realised $F$ especially when $F_{\text {target }}$ is high. The lognormal error used here does also lead to bias in realised F compared to intended. With $F_{\text {target }}=0.32$ and $C V_{\text {ass }}=0.25$ average realised F is 0.358 or $12 \%$ bias. Large part of the effect of increased assessment error is caused by this bias.


Figure 11: Average realised F as function of indended F based on $C V_{\text {ass }}=0.25$ and $B_{\text {trigger }}=10$. The figure does also show $\sigma_{\log \left(F_{y+1}\right)}$

Same results can be presented in a different way (figure 12). The form of the probability density functions is somewhat interesting with the peak somewhat below the target (median) but average higher.


Figure 12: Distribution of realized F for 4 different $F_{\text {target }}$. Results are based on $C V_{\text {ass }}=0.25$ and $B_{\text {trigger }}=10$. The vertical lines show $F_{\text {target }}$ in each panel.

Autocorrelation of recruitment has substantial effect of estimated $F_{\left(P\left(S S B<B_{l i m}=0.05\right)\right.}$ (figure 13). The value
of 0.5 is based on the data since 1959 (the estimate is 0.55 ). The longest period of "correlated" recruitment is since 2000 when recruitment has nearly always been poor.


Figure 13: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $\rho_{\text {rec }} . B_{\text {trigger }}=20, C V_{\text {ass }}=0.25$.

## 7 Productivity change



Figure 14: Recruitment vs. spawning stock in 3 time intervals

Looking at figure 14 changes in productivity (recruitment) can not be ignored. Part of the changes seen can be explained by the spawning stock but when recruitment decreases over some time the spawning stock does also decrease leading to pairs of low SSB low R. Estimating change in productivity (changes in $R_{\max }$ of the hockey stick function) $29 \%$ reduction is estimated when the change occurs in 1988 but $60 \%$ reduction if the change occurs in 2000 table(1. The changes in productity are not so large as $S S B_{b r e a k}$ decreases and $R_{\max }$ (before the change) increases when change in productivity is allowed. Autocorrelation of recruitment recruitment residuals does also decrease ( 0.5 to 0.4 ) when production change in 2000 is included as the long period of poor recruiment after 2000 is partly included in the stock - recruitment function.

|  | Never | 1988 | 2000 |
| ---: | ---: | ---: | ---: |
| Negative log likelihood | -672.60 | -674.40 | -680.17 |
| Estimated SSBbreak | 35.00 | 31.00 | 21.00 |
| $\operatorname{Rmax}(2000) / \operatorname{Rmax}(1959)$ | 1.00 | 0.71 | 0.40 |
| $\operatorname{Rmax}(1959)$ | 16.10 | 18.10 | 17.90 |

Table 1: Effect of allowing changes in $R_{\max }$ in a specified year on negative log-likelihood function and estimated parameters

The changes in 2000 are most obvious and the effect on the log-likelihood (-7.5) considerable for one added parameter (significance level is close to -2).

Rmax(2001+)/Rmax(1959-2000)


Figure 15: Histogram of ratio of $R_{\max }$ after 2000 and before
Histogram of estimated production change after 2000 show that the most likely value is around 0.4 . The lower limit is $e^{-} 1=0.368$ explaining the strange form of the histogram.


Figure 16: Scatter of $S S B_{\text {break }}$ and $R_{\max }$

Allowing production change in the year 2000 leads to different estimate of estimated SSB-Rec relationship (figure 16. The scatter of point is bounded somewhat below $B_{\text {loss }}$. With this type of relationship the value of $B_{\text {lim }}=21$ seems appropriate unlike what can be observed in figure 6 .


Figure 17: Average,median and 10th percentile of catch at "equlibrium". Change in $R_{\max }$ in 2000 estimated. Fifth percentile of SSB is also shown as well as the line that maximizes median of catch, $\mathrm{F}=0.32$ and the line corresponding to maximum yield, The horizontal red and blue lines show $95 \%$ of average and median yield. $B_{\text {trigger }}=B_{\text {lim }}=21$

Comparing the results including the productivity change in 2000 and not including it (figures 17 and 7) shows that $F$ leading to maximum yield is the same but maximum yield is reduced by $50 \%$. F leading to $5 \%$ probability of $S S B<B_{\text {lim }}$ is on the other hand 0.25 instead of 0.32 .

## 8 Conclusions

The current $F_{m s y}$ of 0.32 is a suitable management target if the SSB-recruitment relationship is similar to what it has been since 1959. According to the analysis the rule would be precautionary without any trigger, but maximum yield is obtained at lower $F$ or in the range $0.2-0.24$. Having a trigger at $B_{p a}(40)$ leads and $F=0.32$ leads to approximately $23 \%$ probability of SSB estimated below the trigger that is rather frequent indicating that 40 thous tonnes is rather high trigger.

The value of $B_{\text {lim }}$ is rather low looking at the SSB-rec relationship 1959-2015 without inclusion of autocorrelation or productionchange, the value is closer to 35 thous. tonnes. Including production change in 2000 leads to breakpoint at $B_{\text {loss }}$ that is close to the current $B_{\text {lim }}$ value. If $B_{\text {lim }}$ is 21 thous. tonnes $B_{p a}$ should be 28 thous. tonnes instead of 40 thous. tonnes.

If the recruitment continues to be like it has been since 2000 having $B_{\text {trigger }}=40$ thous. tonnes is muchtoo high but the probability of $S S B<40$ is $67 \%$ if $F=0.32$. A sensible approach in this kind of scenario would be $F \approx 0.25$ and $B_{\text {trigger }}=21$. (The runs do only show 0.24 not 0.25 ). If recruitment will go back to earlier levels this F could lead to relatively large stock, perhaps too large (figure 18)?? If recruitment continues to be like it has been since 2000 probability of $S S B>70$ thous. tonnes is low, even with $F=0.25$ and plenty of time will be available to detect if the recruitment is back at higher level.

But things are perhaps not so complicated. If the SSB-rec relationship is based on data since $1959 B_{\text {lim }}$ should be around 35 thous. tonnes and looking at figure $7 F_{\text {target }}$ to keep the stock with 95 probability above 35 thous. tonnes is around 0.25 that is anyway $F$ giving maximum yield.

## 9 Development with time, based on data from 1959

This section contains some pictures showing development of the stock over time, both with constant $R_{\text {max }}$ and $R_{\max }$ allowed to change in 2000. All figures are based on $B_{\text {trigger }}=B_{\text {lim }}=21$.


Figure 18: Summaries of spawning stock, recruitment and catch when target fishing mortality in 0.32 . The shaded areas show $5,10,25,7590$ and 95 th percentiles and the red line the median. 3 individual runs are shown


Figure 19: Development of spawning stock for 5 different target fishing mortalities. The shaded areas show 5, $10,25,7590$ and 95 th percentiles and the blue lines the median. One individual run is shown. The horizonal lines shows $B_{\text {lim }}=21$ thous. tonnes.


Figure 20: Development of catch for 5 different target fishing mortalities. The shaded areas show $5,10,25,75$ 90 and 95 th percentiles and the blue lines the median. One individual run is shown.

## 10 Development with time, recruitment as observed since 2000.



Figure 21: Summaries of spawning stock, recruitment and catch when target fishing mortality in 0.24 . The shaded areas show $5,10,25,7590$ and 95 th percentiles and the red line the median. 3 individual runs are shown. Change in recruitment after 2000 allowed.


Figure 22: Development of spawning stock for 5 different target fishing mortalities. The shaded areas show 5, $10,25,7590$ and 95 th percentiles and the blue lines the median. One individual run is shown. The horizonal lines shows $B_{\text {lim }}=21$ thous. tonnes. Change in recruitment after 2000 allowed.


Figure 23: Development of catch for 5 different target fishing mortalities. The shaded areas show 5, 10, 25, 75 90 and 95 th percentiles and the blue lines the median. One individual run is shown.

# Evaluation of Harvest Control Rule for Faroe haddock. 

## HB

February 6, 2017

## 1 Comments

The Harvest Control Rules (HCR) presented here are all with specified $F_{3-7}$ above certain $B_{\text {trigger }}$. Below $B_{\text {trigger }} \mathrm{F}$ is reduced by the ratio $\frac{S S B_{y+1}}{B_{\text {trigger }}}$ where the year $y$ is the assessment year and $y+1$ advice year. 3 triggers are presented below, $B_{\text {trigger }}=B_{p a}=35, B_{\text {trigger }}=B_{\text {lim }}=22$ and $B_{\text {trigger }}=10$, the last value is practically the same as zero.

## 2 Historical Assessment



Figure 1: Summary of assessment results. Red values indicate prediction based on $F_{m s y}=0.32$

The summary of assessment (figure 1) shows relatively even recruitment and high fishing mortality from 19571970 but much lower fishing mortality and more variable (haddock like) recruitment since then. The low variability in yearclass size from 1957-1970 is rather untypical for haddock. Average yearclass from 2003-2014 is 7 million at age 1 while the average from 1957-2003 is 34 million or 5 times more. Average catch 1957-2007 was 17.4 thous. tonnes so the recruitment 2003-2014 should not give more than 4000 tons.

Allowing an extra parameter in 1977 scaling down the log of recruitment gives a scaling factor of $e^{-0.945}=$ 0.39 meaning that geometric mean of recruitment after 1977 is $39 \%$ of what it was before. Variability is much higher after 1976 when $\sigma(\log (r))=1.14$ compared to 0.38 for the period 1957-1976. Average recruitment is 22 vs 40 million or $55 \%$ of what it was before 1977 . Therefore the situation before and after 1977 is therefore hardly comparable.

The data before 1976 are based on fixed weights at age(figure 2) so the catch in numbers are scaled as the sum $\left(\sum C N \times C W\right.$ does not represent the "true" landings, that are $10 \%$ lower in the first years. After 1976 variability in catch weights is quite high as is typical for haddock.

Due to these problems the HCR simulations for haddock are based on data since 1976.


Figure 2: Mean weight at age in catches. Average values used in preditions shown at the end of each plot.


Figure 3: Maturity at age. Average values used in predictions shown at the end of each plot.


Figure 4: Summary of assessment results based on data since 1976. Red values indicate prediction based on $F_{m s y}=0.32$

## 3 Recruitment variablitiy

Variability in recruitment is estimated in the model runs with the parameters of the hockey stick SSB-Rec function. The 1st order autocorrelation of residuals can in principle be estimated but the time series is rather short so the value is fixed and sensitivity to different assumptions tested.

Variability is high for this stock as is typical for haddock ( $C V \approx 1.15$ ) leading to long time series required to get an idea about the SSB-R relationship and autocorrelation of the residuals. The spawning stock - recruitment relationship does of course explain minor proportion of the variability in the data.


Figure 5: Recruitment vs. spawning stock and autocorrelation of recruitment and recruitment residuals. Red lines show predicted recruitment

1st order lag of the autocorrelation of recruitment residuals is estimated around 0.6 (figure 5).
Modelling the recruitment residuals as lognormal might be questioned. Autocorrelation and high CV make the timeperiod 1976-2015 rather short for those kind of analysis. The results (figure 6) indicate that extreme values of the theoritical distribution are higher and lower than the real values. The generated recruitment residuals in the model are confined to the range -2 to 2 . The figure does though indicate that the extreme values could be exaggerated.

## log(recruitment)



Figure 6: QQplot of recruitment residuals, $\log (r)$ because Hockey stick is used and $S S B>S S B_{b r e a k}$

## 4 Final settings

Recruitment is generated by hockey stick stock recruitment function with autocorrelated lognormal residuals with $\rho=0.60$. CV is estimated from the data. $R_{\max }$ and $S S B_{b r e a k}$ are estimated. The Hockey stick function does not have any biological explanation but has the feature of not promising increase or decrease in recruitment as long as we are well above $S S B_{\text {break }}$

Stochasticity in mean weight lognormal with $\sigma=0.15$ and $\rho=0.7$ around average of last 20 years. CV for each agegroup (3-8) from 1976-2015 is between 0.13 and 0.2 and first order autocorrelation from $0.5-0.75$. The correlation between adjacent agegroups is between 0.85 and 0.90 . A yearfactor is therefore not the perfect way to model stochasticity in mean weight at age and if it is done the CV should be reduced. The selected value should lead to similar variability in stock biomass due to variability in weight as would be obtained from the data and estimated stock size. Uncertainty in prediction modelled by assuming same mean weights as last year. Density dependence of growth was not obvious from plots of the data (check better!!).

Maturity and selection are assumed to be constant. Selection used to compile TAC should be specified as a part the HCR.

CV of assessment error 0.20 and $\rho=0.6$. Estimated $C V$ from the model is $\approx 0.15$, (compared to 0.2 for cod and 0.23 for saithe) and experience indicates that CV estimated from assessment models tend to be an underestimate?

Assessment based on separable model, age 2-10 tuned with survey data from 1996. Correlation of residuals in the survey estimated. The estimated selection pattern used in the predictions should be a part of the HCR, changes in selection pattern can not be avoided but should not affect the given advice in each case.

According to ICES guidelines to evaluate $F_{m s y} B_{\text {trigger }}=35 \mathrm{kt}=B_{p a}$ shuld be used when finding $F_{P\left(S S B<B_{l i m}\right)=0.05}$ but not use trigger when finding F leading to maximum yield. $B_{\text {trigger }}=B_{p a}$ turns out to be rather high for this stock (for stability of catches ).

## 5 Results



Figure 7: Scatter of $S S B_{\text {break }}$ and $R_{\text {max }}$
The scatter of SSB-rec pairs (figure 7) shows little correlation between $R_{\max }$ and $S S B_{b r e a k}$. There are indications that the break point is close to $B_{\text {lim }}$ or $B_{\text {loss }}$.


Figure 8: Average,median and 10th percentile of catch at "equlibrium". Fifth percentile of SSB is also shown as well as the line that maximizes median of catch, $\mathrm{F}=0.25$ and the line corresponding to maximum yield, The horizontal red and blue lines show $95 \%$ of average and median yield. $B_{\text {trigger }}=10$

The results of the simulations (figure 8) show that average catch is maximized around $F=0.2$, median catch at $F=0.16, F_{P\left(S S B<B_{l i m}\right)=0.05}=0.08$ (higher if $B_{\text {trigger }}=B_{p a}$ ). $F$ that gives $95 \%$ of median yield is in the range $0.13-0.25$.

The combination of high variability in recruitment and relatively high autocorrelation of recruitment residuals leads to probability of periods of only very small yearclasses and therefore very low $F_{P\left(S S B<B_{l i m}=0.05\right.}$. For this stock average SSB is 5 times the fifth percentile of the spawning stock.

The effect of $B_{\text {trigger }}$ is demonstrated in figure 9 showing that even with $B_{\text {trigger }}=35 F_{P\left(S S B<B_{l i m}\right)=0.05}=$ 0.0 .0 ?. The logical interpretation of the results is that $B_{\text {lim }}$ can not be avoided with high probability except with fishing mortality near 0.08 .


Figure 9: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $B_{\text {trigger }} . C V_{\text {ass }}=0.25$ and $\rho_{\text {rec }}=0.6$.
Autocorrelation of recruitment has large effect on estimated $F_{P\left(S S B<B_{l i m}\right)=0.05}$ (figure 10). It is only when $\rho_{\text {rec }}$ is 0.2 or lower that $F_{P\left(S S B<B_{l i m}\right)=0.05}$ is 0.15 .


Figure 10: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $\rho_{\text {rec }} . B_{\text {trigger }}=22$ and $C V_{\text {ass }}=0.6$.

Assumptions about assessment error have relatively smalleffect on $F_{P\left(S S B<B_{l i m}=0.05\right.}$ (figure 11). The range of values tested is not large or $0.15-0.22$. This range should cover the expected range of the assessment error but the assessment of this stock is relatively good. The assessment error presented here applies to the uncertainty in the beginning of the assessment year and leads higher uncertainty in realised $F$ when $F_{\text {target }}$ is high which will most likely not be the case for this stock. The lognormal error used here does also lead to bias in realised F compared to intended. With $F_{\text {target }}=0.20$ and $C V_{\text {ass }}=0.20$ average realised F is 0.205 or $5 \%$ bias.


Figure 11: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $C V_{\text {ass }} . B_{\text {trigger }}=10$ and $\rho_{\text {rec }}=0.6$.


Figure 12: Average realised F as function of indended F based on $C V_{\text {ass }}=0.20$ and $B_{\text {trigger }}=10$. The figure does also show $\sigma_{\log \left(F_{y+1}\right)}$

Same results can be presented in a different way (figure 13). The form of the probability density functions is somewhat interesting with the peak somewhat below the target (median) but average higher. For the higher values of F i.e 0.26 and 0.32 the probability of $B<B_{\text {lim }}$ is not neglible, leading to relatively low $F$ occasionally.


Figure 13: Distribution of realized F for 4 different $F_{\text {target }}$. Results are based on $C V_{\text {ass }}=0.2$ and $B_{\text {trigger }}=10$. The vertical lines show $F_{\text {target }}$ in each panel.

## 6 Productivity change



Figure 14: Recruitment vs. spawning stock in 2 time intervals

Looking at figure 14 changes in productivity (recruitment) around 2000 as noticed for cod can not be excluded. Part of the changes seen can be explained by the spawning stock but when recruitment decreases over some time the spawning stock does also decrease leading to pairs of low SSB low R.

Estimating change in productivity (changes in $R_{\max }$ of the hockey stick function) $36 \%$ reduction is estimated when the change occurs in 2000 . The change is though not significiant for one parameter or a change of -1 in the likelihood function, compared to -8 for cod. But $36 \%$ change in productivity would change much, but this subject will not be investigated further here.

## 7 Conclusions

The current $F_{m s y}$ of 0.25 is in the higher side of range of plausible values when looking at median yield but much too high when looking at $F_{P\left(S S B<B_{l i m}=0.05\right.}$. The probability of a period of poor recruitment is what drives that result and the premises about autocorrelation statistical distribution of recruitment affects the exact values of $F_{P\left(S S B<B_{l i m}=0.05\right.}$. There results do though indicate that avoiding $S S B<B_{l i m}$ with high probability is difficult except with very low F or closing the fisheries when the $S S B<B_{p a}$.

Calculations of median and average yield in figure 8 are based on uncertainty in the stock -recruitment function parameters as well as stochastic autocorrelated recruitment. F in the range 0.15-0.2 and $B_{\text {trigger }}=22$ seems like a good candidate for Harvest Control Rule, it is relatively low F leading to close to maximum yield. The probabilty of being below $B_{\text {lim }}$ is $20 \%$ when $\mathrm{F}=0.2$ and $14 \%$ when $F=0.15$ when the autocorrelation of recruitment is 0.6. With $\rho_{\text {rec }}=0.4$ and $F=0.2, P\left(S S B<B_{\text {lim }}\right)=0.17$

## 8 Development with time, based on data from 1976

This section contains some pictures showing development of the stock over time,


Figure 15: Summaries of spawning stock, recruitment and catch when target fishing mortality in 0.20. The shaded areas show $5,10,25,7590$ and 95 th percentiles and the red line the median. 3 individual runs are shown


Figure 16: Development of spawning stock for 5 different target fishing mortalities. The shaded areas show 5, $10,25,7590$ and 95 th percentiles and the blue lines the median. One individual run is shown. The horizonal lines shows $B_{\text {lim }}=22$ thous. tonnes.


Figure 17: Development of catch for 5 different target fishing mortalities. The shaded areas show 5, 10, 25, 75 90 and 95 th percentiles and the blue lines the median. One individual run is shown.

# Maturity ogives for saithe <br> Luis Ridao Cruz 

February 17, 2017

The WKFAROE working group investigated several models in order to alleviate large fluctuations in maturity ogives for saithe. The method agreed upon in the last benchmark meeting (ICES 2010) was a smoother that caused relatively large revisions in maturity as new data points are available. The WKFAROE group agreed to use a 10 -year moving average which smooths out the noise in maturities and at the same time follows trends in the data. The method causes minimal revisions in maturities as new time series of data are incorporated each year.
Historical maturities (1961-1982) are estimated as mean maurities from 1983 to 1996.
Figure 1 illustrates the observed and fitted maturity ogives for saithe since 1983.


Figure 1: Observed and fitted maturity ogives for saithe since 1983. Average of 1983-1996 are used for historical data.

WD04

# Faroese groundfish surveys for saithe <br> Luis Ridao Cruz 

February 8, 2017

## Background

This document presents an overview of groundfish surveys carried out in faroese waters in the apring (FebruarMarch) and in summer time (August). The surveys design is a classical random stratified design with fixed stations. The number of stations in the spring survey are 100 and the number of stations in the summer are 200. Both survey cover depths from 60 to 500 meters. The coverage of both surveys is however very poor for juvenile saithe, which is largely distributed in coastal areas very close to shore and therefore the surveys do not provide reliable measurements of incoming recruits. Moreover as a result of the schooling nature of saithe variablity in indices is higher than that for species like cod and haddock. The spring survey consists of time series data since 1994 while the summer series were initiated in 1996. Historical data dating back to early 1980's exist but are unfortunately not available for analysis although work is in progress to recover and compile these data in upcoming meetings. Both time series cover to a large degree the traditional fishing grounds of saithe in the Faroe shelf (Figures 7-8). Historically fisheries-dependant indices have been used for tunning the assessment model as a result of insufficient survey data. Given the extended survey indices available at the moment and the reasonable agreement with fisheries data and assessment output it is recommended the adoption of both survey series in the assessment framework. In addition there are problems associated with the use of commercial series as a reliable unbiased index for stock dynammics.

## Catch per unit of effort (CPUE)

Catch rates of both surveys follow the commercial catch-per-unit of effort specially when looking at the log-scale which is how assessments handle the data (Figure 1) There are seasonal effects in the series but both surveys suggest low abundances of saithe in the 1990's, followed by an increase in stock biomass until 2004 and a decline from 2005 to around 2010. Since 2011 both indices are in good agreement and indicate that stock abundances are quite stable. The coefficient of variation (CV) of the summer index (CV=18\%) is higher than the spring survey ( $\mathrm{CV}=13 \%$ ).

## Internal consistency

The internal consistency of the summer survey measured as the correlation between the indices for the same year class in two adjacent years is good with $\mathrm{R}^{2}$ ranging from 0.5 to 0.7 for the best-defined age groups, and $R^{2}$ varying between 0.3 and 0.4 for some other age classes (table 1 , figure 2 ). The internal consistency of the summer index is overall superior to the commercial index. The spring survey shows a weaker internal consistency with $\mathrm{R}^{2}$ ranging from 0.40 to 0.56 for the best-defined ages.(table 1 , figure 3 ).

Table 1: Correlation between the indices for the same year class in two adjacent years in the summer, spring and commercial indices.

| Age groups | Summer | Spring | Commercial |
| :--- | :--- | :--- | :--- |
| age3-4 | 0.33 | 0.36 | 0.29 |
| age4-5 | 0.54 | 0.17 | 0.37 |
| age5-6 | 0.40 | 0.39 | 0.39 |
| age6-7 | 0.60 | 0.56 | 0.67 |
| age7-8 | 0.62 | 0.48 | 0.62 |
| age8-9 | 0.69 | 0.42 | 0.62 |
| age9-10 | 0.59 | 0.41 | 0.43 |
| age10-11 | 0.40 | 0.44 | 0.44 |



Figure 1: CPUE for spring survey (green), summer survey (red) and comercial index (black) on log-scale. Shadow areas show uncertainty in estimates.

## Consistency with the fishery

In order to evaluate the agreement between age-dissagregated survey indices and catch-at-age data a similar procedure as that of the internal consistency is used. We measure the level of consistency between the two series by looking at the correlation age by age. The summer index is considered more reliable than the spring index with a $\mathrm{R}^{2}$ of over 0.7 for age groups $5-10$ and around 0.3 for age classes 3 and 4 (table 2 , figure 4 ). For some age groups (5-7) the summer data is even more reliable than the commercial series and for some other ages ( $8-10$ ) very close in terms of correlation. This is by itself quite remarkable as the commercial tunning index is compiled from the fleet targeting almost exclusively saithe in faroe waters and therefore the agreement between the two series is extremely high (table 2). The consistency between cohorts in the spring and in the catch ranges from 0.5 to 0.77 for age groups 4 to 9 and much lower for ages 3,10 and 11 (table 2, figure 5). Both survey series illustrate the difficulty of measuring recruitment strength (low $\mathrm{R}^{2}$ on age 3 ) of saithe (see background section).

Table 2: Correlation between age-dissagregated indices and catch-at-age data.

| Age | Summer | Spring | Commercial |
| :--- | :--- | :--- | :--- |
| age 3 | 0.27 | 0.22 | 0.58 |
| age 4 | 0.31 | 0.52 | 0.71 |
| age 5 | 0.73 | 0.66 | 0.67 |
| age 6 | 0.80 | 0.77 | 0.71 |
| age 7 | 0.81 | 0.76 | 0.79 |
| age 8 | 0.79 | 0.71 | 0.83 |
| age 9 | 0.74 | 0.62 | 0.76 |
| age 10 | 0.70 | 0.40 | 0.73 |
| age 11 | 0.45 | 0.34 | 0.79 |

The stratified survey design was modified to accomodate for 1 -stratum instead of the current 15 strata. The results (not shown) did not improve substantially in terms of internal diagnostics and agreement with the catch-at-age matrix. Moreover bootstraped indices were compiled for both the 1-stratum and 15 -strata design yielding not significative improvements over the classical method.

## Weight-at-age

Mean weight-at-age from surveys were also compiled (figure 6). Mean catch-weigth-at-age are generally higher than survey weight estimates for age classes 3 to 5 . The discrepancy in absolute values levels off for older age groups. Nevertheless trends in survey mean weights are comparable to mean weights in the catch.


Figure 2: Indices from the summer survey vs. index of the same year class a year later (log-scale). Two-digit numbers in plot Horizontal and vertical blue lines represent the last cohort age pair .


Figure 3: Indices from the springr survey vs. index of the same year class a year later (log-scale). Horizontal and vertical blue lines represent the last cohort age pair .


Figure 4: Correlation between age-dissagregated indices in the summer and catch-at-age data. Horizontal and vertical blue lines represent the last year pair.


Figure 5: Correlation between age-dissagregated indices in the spring and catch-at-age data. Horizontal and vertical blue lines represent the last year pair.


Figure 6: Mean weight-at-age from summer (red) and spring (green) surveys. Black lines represent mean catch-weight-at-age.


Figure 7: Stock distribution. Summer survey (August).


Figure 8: Stock distribution. Spring survey (Februar-March).

WD05

# Statistical Stock Assessment for Saithe (SSAS) <br> Luis Ridao Cruz 

February 9, 2017

The current asessment framework for saithe is a VPA-type model (XSA) tunned with a commercial index. Issues associated with the use of fisheries-dependant tunning data in assessment are well-known (e.g. they may not be a reliable unbiased of stock dinamycs). Moreover XSA is an iterative algorithm with no formal likelihood function and quite sensitive to changes in catchability and therefore not appropiate for noisy survey indices such as those for saithe.

The present document describes an overview of an assessment model which can be used as the basis for ICES advice of saithe. A more detailed description of the model will be provided if the WKFAROE working group concludes its acceptability for advice.

A forward-running separable statistical catch-at-age framework, allowing changes in selectivity to occur in specified years is used (ADMB software). Faroese groundfish surveys as described in working document WD04-FaroeseGroundfishSurveysSaithe were used for tunning the model. Several options were explored such as running the model separately for each survey and fiting different stock recruitmennt functions (Ricker and Hockey-stick).
The periods in which selectivity is allowed to change are 1976 (extension to the EEZ to 200 nm ), 1996 (introduction of the current effort system) and 2010 (in one run an extra selectivity period is added to the model). Catchability in surveys was estimated separately for two distinctive periods (1996-2004 and 2005-2015). The model was fitted to catch-at-age data consisting of measurements since 1961 and ages 3 to $14+$ and to survey catch-at-ge indices (1994-2015 in the spring and 1996-2015 in the summer index) including age groups 3 to 10 . Natural mortality was set to $\mathrm{M}=0.2$ and stock weights were assumed equal to catch-weights.
The estimated parameters are:

- Selection pattern for ages 3-11 (set to 1 for ages 12-14) in 4 periods: 1961-1976, 1977-2010, and 2011 onwards.
- Number of age 3 saithe from 1961 to the present.
- Initial number in each age group (3-14) in 1961.
- Parameters of the stock recruitment function.
- Survey catchability for ages 3-10.

After the estimation is done the estimated variance-covariance matrix is used as proposal distribution in MCMC simulations. The number of runs was set to 1000000 and the parameters values were saved every 1000th time.

All the model runs fit reasonably well the observed catch-at-age data (figures 1-5). The survey catch-at-age residuals have year blocks with residuals being only negative or only positive in some years. The models fitting the Ricker stock-recruitment function were superior to those using a Hockey-stick segmented regression by measuring the Akaike Information Criterion (AIC). Fitting to only one survey index resulted in better models with substantial lower variability in terminal estimates specially average fishing mortality. The best model in terms of AIC was when selection was splitted in 5 different periods. Fihing mortality was however very variable fluctuating by a factor of 2 (figures $6-8$ ). Increasing uncertainty might be caused by model complexity where more parameters are to be estimated.
XSA assesment results are also presented graphically along with another statistical catch-at-age model constructed by IMR Iceland (ADCAM) The results of the three models agree considerably with the SSAS estimates being somehow in between the XSA and ADCAM output. Retrospective plots show a tendency to underestimate average fihing mortality and a subsequent overestimation of stock size (figure 9).


Figure 1: Output from SSAS model with 4 selection periods and using the summer index (blue line). Black and green lines are the XSA and ADCAM results respectively.


Figure 2: Output from SSAS model with 4 selection periods and using both surveys (blue line). Black and green lines are the XSA and ADCAM results respectively.


Figure 3: Output from SSAS model with 5 selection periods and using both surveys (blue line). Black and green lines are the XSA and ADCAM results respectively.


Figure 4: Catch-at-age residuals from SSAS model with 4 selection periods and using both surveys.


ADMB - survey 2 residuals


Figure 5: Survey catch-at-age residuals from SSAS model with 4 selection periods and using both the spring (top graph) and the summer survey (bottom graph).


Figure 6: MCMC results from SSAS model with 4 selection periods and using the summer survey.


Figure 7: MCMC results from SSAS model with 4 selection periods and using both the summer and the spring survey.


Figure 8: MCMC results from SSAS model with 5 selection periods and using both the summer and the spring survey.


Figure 9: Retrospective output from SSAS model with 4 selection periods and using the summer survey.

# Evaluation of Harvest Control Rule for Faroese Saithe. 

HB

February 9, 2017

## 1 Comments

The Harvest Control Rules (HCR) presented here are all with target $F_{4-8}$ above specified $B_{\text {trigger }}$. Below $B_{\text {trigger }} \mathrm{F}$ is reduced by the ratio $\frac{S S B_{y+1}}{B_{\text {triger }}}$ where the year $y$ is the assessment year and $y+1$ advice year. 3 triggers are presented below, $B_{\text {trigger }}=B_{p a}=55, B_{\text {trigger }}=B_{\text {lim }}=\frac{55}{1.3}$ and $B_{\text {trigger }}=10$, the last value is practically the same as zero. $B_{\text {lim }}$ has not been defined for this stock but 55 ( $B_{\text {loss }}$ at some time) was defined as $B_{p a} \cdot \frac{55}{1.3}=42$ could then be defined as $B_{l i m}$

Maturity of this stock as most saithe stocks is poorly sampled and potential HCR should therefore not depend too much on spawning stock.

## 2 Historical Assessment



Figure 1: Summary of assessment results. Red values indicate prediction based on $F_{m s y}=0.3$

The summary of assessment (figure 1) shows low but increasing fishing mortality from 1961-1980. Since then fishing mortality has been variable, between 0.25 and 0.65 . Recruitment is relatively variable ( $C V \approx 0.56$ ) ranging from 14 million to 168 million at age 1. Recruitment after 1990 has been $45 \%$ higher than before on the average but the variability has also been higher.


Figure 2: Mean weight at age in catches. Average values used in preditions shown at the end of each plot.

Mean weight age age has decreased over time (figure 2), especially for the older age groups. On top of this decrease considerable variation has been observed. The lowest mean weight at age was in the years around 2005 when some agegroups were more than 2 years below avearage i.e 6 years old fish was lighter than normal 4 years old fish. Apparently some density dependence can be observed (figure 3)


Figure 3: Mean weight at age of age 6 in catches against biomass of age 3 and older. The numbers show years


Figure 4: Maturity at age. Average values used in predictions shown at the end of each plot.
Maturity at age has also been variable (figure 4). There is positive correlation between maturity and mean weight at age. Maturity at age before 1983 is fixed. A special paper about maturity at age will be introduced at the meeting.

## 3 Recruitment variablitiy

CV of recruitment residuals is estimated in the model runs with the parameters of the hockey stick SSB-Rec function. The 1st order autocorrelation of residuals can in principle be estimated but the time series is rather short so the value is fixed and sensitivity to different assumptions tested.


Figure 5: Recruitment vs. spawning stock and autocorrelation of recruitment and recruitment residuals. Red lines show predicted recruitment

First order lag of the autocorrelation of recruitment residuals is estimated around 0.55 (figure 5).
Modelling the recruitment residuals as lognormal might be questioned. Autocorrelation and high CV make the timeperiod 1961-2015 rather short for those kind of analysis. The results (figure 6) show reasonable fit. The generated recruitment residuals in the model are confined to the range -2 to 2 .

## log(recruitment)



Figure 6: QQplot of recruitment residuals, $\log (r)$ because Hockey stick is used and $S S B>S S B_{\text {break }}$

## 4 Final settings

Recruitment is generated by hockey stick stock recruitment function with autocorrelated lognormal residuals with $\rho=0.55$. CV, $R_{\text {max }}$ and $S S B_{\text {break }}$ are estimated. The Hockey stick function does not have any biological explanation but has the feature of not promising increase or decrease in recruitment as long as we are well above $S S B_{\text {break }}$

Stochasticity in mean weight lognormal with $\sigma=0.15$ and $\rho=0.7$ around average of last 20 years. CV for each agegroup (3-10) from 1980-2015 is between 0.14 and 0.25 and first order autocorrelation 0.5 for age 3 but $0.7-0.8$ for the other agegroups. The correlation between adjacent agegroups for ages $4-10$ is between 0.75 and 0.90. A yearfactor is therefore not the perfect way to model stochasticity in mean weight at age and if it is done the CV should be reduced. The selected value should lead to similar variability in stock biomass due to variability in weight as would be obtained from the data and estimated stock size. Uncertainty in prediction modelled by assuming same mean weights as last year. Density dependence of growth is an issue that should be included.

The selection ssthe average of last 20 years. Maturity and selection are assumed to be constant in the future. Selection used to compile TAC should be specified as a part the HCR.

CV of assessment error 0.27 and $\rho=0.6$. Estimated $C V$ from the model is $\approx 0.23$, (compared to 0.2 for cod and 0.15 for haddock). CV estimated from assessment models tendS to be an underestimate?

Assessment based on separable model, age 2-10 tuned with survey data from from the springsurvey 19942016 and summersurvey 1996-2015. Correlation of residuals in the surveys are estimated. not be avoided but should not affect the given advice in each case.

According to ICES guidelines to evaluate $F_{m s y} B_{\text {trigger }}=55 \mathrm{kt}=B_{p a}$ shuld be used when finding $F_{P\left(S S B<B_{l i m}\right)=0.05}$ but not use trigger when finding F leading to maximum yield. $B_{\text {trigger }}=B_{p a}$ turns out to be rather high for this stock (for stability of catches ).

## 5 Results



Figure 7: Scatter of $S S B_{b r e a k}$ and $R_{\text {max }}$
The scatter of SSB-rec pairs (figure 7) shows no correlation $R_{\max }$ and $S S B_{b r e a k}$. and indications that the break point is close to $B_{\text {loss }}$ i.e no sign of reduced recruitment.


Figure 8: Average,median and 10th percentile of catch at "equlibrium". Fifth percentile of SSB is also shown as well as the line that maximizes median of catch, and the line corresponding to $95 \%$ of maximum yield, The horizontal red and blue lines show $95 \%$ of average and median yield. $B_{\text {trigger }}=10$

The results of the simulations (figure 8) show that average catch and median catch are maximized around $F=0.22$ and $F_{P\left(S S B<B_{l i m}\right)=0.05}=0.24 . F$ that gives $95 \%$ of median yield is in the range $0.15-0.30$.

Low $F$ values are caused by autocorrelation in recruitment, uncertain assessment and relatively low average mean weight at age in predictions (figure 2). There are indications that mean weight at age is density dependent (figure 3) and taking that into account would increase $F_{P\left(S S B<B_{l i m}\right)=0.05}$ but low values of SSB will usually be associated with high mean weight at age.

The effect of $B_{\text {trigger }}$ is demonstrated in figure 9 showing relatively small effect of value of the trigger on $F_{P\left(S S B<B_{l i m}\right)=0.05}$. One of the factors making effect of trigger small is relatively high assessment error that makes use of trigger points less desirable.


Figure 9: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $B_{\text {trigger }} . C V_{\text {ass }}=0.27$ and $\rho_{\text {rec }}=0.55$.
Autucorrelation of recruitment residuals has some effect on $F_{P\left(S S B<B_{l i m}\right)=0.05}$ changing it from 0.24 to 0.27 when $\rho_{\text {rec }}$ changes from 0.2-0.55 (figure 10 .


Figure 10: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $\rho_{\text {rec }} \cdot B_{\text {trigger }}=10$ and $C V_{\text {ass }}=0.27$.
Assumptions about assessment error have similar effect on $F_{P\left(S S B<B_{\text {lim }}=0.05\right.}$ as assumption about $\rho_{\text {rec }}$ (figure 11). The range of values tested is not large or $0.2-0.27$. This range should cover the expected range of the assessment error but the assessment of this stock is uncertain. The assessment error presented here applies to the uncertainty in the beginning of the assessment year and leads higher uncertainty in realised $F$ when $F_{\text {target }}$ is high which will most likely not be the case for this stock. The lognormal error used here does also lead to bias in realised F compared to intended. With $F_{\text {target }}=0.30$ and $C V_{\text {ass }}=0.27$ average realised F is 0.342 or $14 \%$ bias.


Figure 11: Fifth percentile of spawning stock as function of $F_{\text {target }}$ and $C V_{\text {ass }} . B_{\text {trigger }}=10$ and $\rho_{\text {rec }}=0.55$.


Figure 12: Average realised F as function of indended F based on $C V_{\text {ass }}=0.27$ and $B_{\text {trigger }}=10$. The figure does also show $\sigma_{\log \left(F_{y+1}\right)}$

Same results can be presented in a different way (figure 13). The form of the probability density functions is somewhat interesting with the peak somewhat below the target (median) but average higher. For the higher values of F i.e 0.30 and 0.36 the probability of $B<B_{\text {lim }}$ is not neglible, leading to relatively low $F$ occasionally.


Figure 13: Distribution of realized F for 4 different $F_{\text {target }}$. Results are based on $C V_{\text {ass }}=0.27$ and $B_{\text {trigger }}=10$. The vertical lines show $F_{\text {target }}$ in each panel.

## 6 Retrospective runs

Retrospective runs were conducted starting with the assessment year 2001 when the summer survey for the years 1996-2000 and spring survey 1994-2001 are available. For a schooling species like saithe the average $q$ from a survey take relatively long time to settle and the runs should perhaps be repeated fixing the $q$ at current estimates.


Figure 14: Retrospective runs showing average fishing mortality. Each run terminates one year after the assessment year.


Figure 15: Retrospective runs showing average biomass $4+$. Each run terminates one year after the assessment year.


Figure 16: Retrospective runs showing average biomass 4+. Each run terminates in the assessment year.
Uncertainty of the biomass (should change the biomass from $4+$ to $3+$ ) in the assessment year (figure 16) is the uncertainty used in the model. Skipping the last 3 years where assessment has not converged (should really skip more) the average bias in assessment is $19 \%$. and $\sigma\left(\frac{B_{y}, y}{B_{y}, 2016}\right)=0.31$ and $\rho_{\text {ass }}=0.6$ The values used in the HCR simulations $C V=0.27$, and $4 \%$ lognormal bias and $\rho_{\text {ass }}=0.6$. The values from the retros are poorly estimated and the retro should be revisited based on 2016 values og $Q$


Figure 17: Estimated biomass (4+) in the assessment year and in the 2016 assessment


Figure 18: Retrospective pattern of estimated $Q$ in the spring survey. Same for age $8-9$ as for age 7

```
## Error: <text>:2:101: unexpected ')'
## 1: tmp <- rba[rba$age %in% 4:7,]
## 2: ggplot(tmp,aes(assYear,qU2,col=factor(age)))+geom_line(lwd=2)+scale_colour_manual(values=cbbPale
##
```

Figure 19: Retrospective pattern of estimated Q in the summer survey. Same for age 8-9 as for age 7
Survey biomass (figure 20) show very high level of the biomass 2003-2005 with the predicted biomass lower
than the observed one. The survey are fitted via log-residuals so the residuals in biomass are not a direct measure of the fit.


Figure 20: Observed and predicted biomass from the spring survey (blue) and summer survey (red)

## 7 Conclusions

The current $F_{m s y}$ of 0.3 is in the higher side of range of plausible values when looking at median yield and also too high when looking at $F_{P\left(S S B<B_{l i m}\right)=0.05} . \mathrm{F}=0.25$ seems more appropriate value, associated with $B_{\text {trigger }}=$ $B_{l i m}=42$.

Density dependent growth should be modelled. Doing that that might increase estimated $F_{\text {target }} / F_{m s y}$.
Size based selection needs to be investigated. For Icelandic haddock the HCR evaluations were based on density dependent growth and size (mean weight) based selection.

Assessment is relatively unprecise as for all saithe stocks. Use of the Variance-covariance matrix of the survey indices each year should be investigated, downweighting the surveys with high variance.

## 8 Development with time, based on data from 1976

This section contains some pictures showing development of the stock over time,


Figure 21: Summaries of spawning stock, recruitment and catch when target fishing mortality in 0.20 . The shaded areas show $5,10,25,7590$ and 95 th percentiles and the red line the median. 3 individual runs are shown


Figure 22: Development of spawning stock for 5 different target fishing mortalities. The shaded areas show 5, 10, 25, 7590 and 95 th percentiles and the blue lines the median. One individual run is shown. The horizonal lines shows $B_{\text {lim }}=22$ thous. tonnes.


Figure 23: Development of catch for 5 different target fishing mortalities. The shaded areas show 5, 10, 25, 75 90 and 95 th percentiles and the blue lines the median. One individual run is shown.

WD07

# Reference Points for Saithe 

Luis Ridao Cruz

February 10, 2017

Biological reference points (BRPs) for faroe saithe were revised at the WKMSYREF2 workshop, presented to the North-Western Working Group (NWWG) and adopted by ACOM in 2014 (Table 1)

Table 1: Biological reference points for faroe saithe.

| Ref. Points | value |
| :--- | :--- |
| Bpa | 55 kt |
| Btrigger | 55 kt |
| Fpa | 0.30 |
| Fmsy | 0.30 |
| Blim not | not defined |
| Flim not | not defined |

This documents describes stochastic equilibrium simulations performed to re-evaluate BRPs.
Uncertainty is incorporated in parameters such as weight-at-age, maturities and selection pattern which are either re-sampled at random from a specified number of years or fixed over specified years.
Stochascity in the target fishing mortality is done by applying assessment errors.
Uncertainty in the stock-recruitment model is taken into account by applying model averaging using smooth AIC weights (Buckland et al. 1997). The algorithm takes a resample with replacement from the stock and recruit pairs and fit every stock-recruit model under consideration (only Hockey-stick for saithe) and store the AIC. The parameter estimates from the best model are stored and the procedure is again repeated.
The stock at equilibrium is simulated forward for some years ( 200 years and retaining the last 50) and BRPs are calculated. Btrigger (the stock size at which F is linearly reduced) was set to Btrigger=55 kt. Assessment error and autocorrelation were fixed to $\mathrm{Fcv}=0.3$ and $\mathrm{Fphi}=0.5$ respectively and the selection pattern period was chosen from the last three years taken as random and also fixed to average.
Estimates of Fsmy and corresponding catch and spawning stock size (ssb) from the simulations are shown in table 2 and figures 1-2.

Table 2: Fmsy estimates and equlilibrium yield and spawning stock size from EqSim simulations.

| Value | medianMSY | meanMSY |
| :--- | :--- | :--- |
| Fmsy | 0.35 | 0.32 |
| catch | 38055 t | 38133 t |
| sbb | 95958 t | 105519 t |

Another type of simulations were also performed in which the Hockey-stick stock recruitment model was estimated without using smooth AIC weights as described in Buckland et al.
Estimates of Fmsy were in agreement with median Fmsy estimates from EqSim simulations (table 3 and figure 3). Long-term yield and corresponding stock size are however lower than estimates from EqSim. The historical projection of the stock is presented in figure 4.

Table 3: Fmsy estimates and equlilibrium yield and spawning stock size from simulations without Buckland et al.

| Value | medianMSY | meanMSY |
| :--- | :--- | :--- |
| Fmsy | 0.35 | 0.35 |
| catch | 33000 t | 35041 t |
| sbb | 77826 t | 82234 t |





Figure 1: Recruitment, ssb, catch and probability profile from simulations.


Figure 2: Fmsy and long-term yield from simulations.


Figure 3: Fmsy and equilibrium yield and stock size from simulations without smoothed AIC weights in stock recruitment function.


Figure 4: Stock projection from simulations without smoothed AIC weights in stock recruitment function.

## Faroe Plateau cod - can sandeels be used as an extra tuning series?

There is a strong positive correlation between recruitment at age 2 and the amount of sandeels that cod of all ages eat the same year (Figure 1).



Figure 1. Correlation between cod recruitment at age 2 and the amount of sandeels that cod of all ages prey upon the same year.

The question is whether the amount of sandeels in cod stomachs may be used as an extra 'tuning fleet' for age 2 cod in the population.

An XSA was run with sandeels as an extra tuning fleet for age 2 cod. An XSA was run with the same settings as in the NWWG2016 run. The diagnostics of the XSA run is shown below:

Lowestoft VPA Version 3.1

$$
26 / 01 / 2017 \quad 8: 08
$$

Extended Survivors Analysis
COD FAROE PLATEAU (ICES SUBDIVISION Vb1) COD_ind_Surveys_revised

CPUE data from file Surveys_revised_1replacedvalue_sandeels.TXT
Catch data for 57 years. 1959 to 2015. Ages 1 to 10.
Fleet, First, Last, First, Last, Alpha, Beta
year, year, age , age
SUMMER SURVEY , 1996, 2015, 2, 8, .600, . 700
SPRING SURVEY (shift, 1993, 2015, 1, 8, .900, 1.000
SANDEEL IN COD STOMA, 1997, 2015, 2, 2, .300, . 600

Time series weights :
Tapered time weighting not applied

Catchability analysis :

Catchability independent of stock size for all ages
Catchability independent of age for ages >= 6

Terminal population estimation
Survivor estimates shrunk towards the mean $F$
of the final 5 years or the 5 oldest ages.
S.E. of the mean to which the estimates are shrunk $=2.000$

Minimum standard error for population
estimates derived from each fleet $=$. 300

Prior weighting not applied

Tuning converged after 28 iterations
1

Regression weights
, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000

| Fishing mortalities <br> Age, <br> 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015 |
| ---: | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

1
XSA population numbers (Thousands)

| AGE |  |  |  |
| :---: | :---: | :---: | :---: |
| YEAR , | 2, | 3, | 5, |

8 ,
9,
$2006,6.14 \mathrm{E}+03,7.39 \mathrm{E}+03,4.36 \mathrm{E}+03,1.75 \mathrm{E}+03,1.62 \mathrm{E}+03,1.60 \mathrm{E}+03,6.02 \mathrm{E}+02,1.33 \mathrm{E}+02,4.33 \mathrm{E}+01$,
$2007, \quad 7.90 \mathrm{E}+03,5.02 \mathrm{E}+03,5.05 \mathrm{E}+03,2.58 \mathrm{E}+03,1.00 \mathrm{E}+03,7.28 \mathrm{E}+02,5.83 \mathrm{E}+02,1.91 \mathrm{E}+02,3.98 \mathrm{E}+01$,
$2008, \quad 1.01 \mathrm{E}+04,6.47 \mathrm{E}+03,3.66 \mathrm{E}+03,3.02 \mathrm{E}+03,1.45 \mathrm{E}+03,5.38 \mathrm{E}+02,3.35 \mathrm{E}+02,2.46 \mathrm{E}+02,7.98 \mathrm{E}+01$,
$2009, \quad 1.38 \mathrm{E}+04,8.24 \mathrm{E}+03,5.03 \mathrm{E}+03,2.30 \mathrm{E}+03,1.77 \mathrm{E}+03,8.02 \mathrm{E}+02,2.71 \mathrm{E}+02,1.32 \mathrm{E}+02,6.06 \mathrm{E}+01$,
$2010, \quad 5.20 \mathrm{E}+03,1.13 \mathrm{E}+04,5.96 \mathrm{E}+03,2.07 \mathrm{E}+03,1.11 \mathrm{E}+03,8.88 \mathrm{E}+02,3.89 \mathrm{E}+02,1.45 \mathrm{E}+02,5.84 \mathrm{E}+01$,
$2011,2.33 \mathrm{E}+03,4.26 \mathrm{E}+03,7.35 \mathrm{E}+03,3.04 \mathrm{E}+03,9.20 \mathrm{E}+02,4.84 \mathrm{E}+02,2.91 \mathrm{E}+02,1.57 \mathrm{E}+02,6.61 \mathrm{E}+01$,
$2012,3.63 \mathrm{E}+03,1.91 \mathrm{E}+03,3.19 \mathrm{E}+03,3.89 \mathrm{E}+03,1.37 \mathrm{E}+03,4.23 \mathrm{E}+02,2.26 \mathrm{E}+02,1.25 \mathrm{E}+02,8.34 \mathrm{E}+01$,
$2013,9.39 \mathrm{E}+03,2.97 \mathrm{E}+03,1.52 \mathrm{E}+03,2.14 \mathrm{E}+03,1.97 \mathrm{E}+03,6.19 \mathrm{E}+02,1.65 \mathrm{E}+02,9.54 \mathrm{E}+01,3.96 \mathrm{E}+01$,
$2014, \quad 3.95 \mathrm{E}+03,7.69 \mathrm{E}+03,2.39 \mathrm{E}+03,1.08 \mathrm{E}+03,1.45 \mathrm{E}+03,1.08 \mathrm{E}+03,3.48 \mathrm{E}+02,9.98 \mathrm{E}+01,5.55 \mathrm{E}+01$,
$2015,4.18 \mathrm{E}+03,3.23 \mathrm{E}+03,5.94 \mathrm{E}+03,1.48 \mathrm{E}+03,6.30 \mathrm{E}+02,7.38 \mathrm{E}+02,5.69 \mathrm{E}+02,2.07 \mathrm{E}+02,6.91 \mathrm{E}+01$,
Estimated population abundance at 1st Jan 2016
$0.00 \mathrm{E}+00,3.43 \mathrm{E}+03,2.50 \mathrm{E}+03,3.93 \mathrm{E}+03,7.43 \mathrm{E}+02,3.25 \mathrm{E}+02,3.49 \mathrm{E}+02,2.66 \mathrm{E}+02, \quad 1.27 \mathrm{E}+02$,
Taper weighted geometric mean of the VPA populations:
$1.39 \mathrm{E}+04,1.17 \mathrm{E}+04,8.92 \mathrm{E}+03,5.42 \mathrm{E}+03,2.99 \mathrm{E}+03,1.48 \mathrm{E}+03,6.66 \mathrm{E}+02,2.70 \mathrm{E}+02,1.08 \mathrm{E}+02$,
Standard error of the weighted Log(VPA populations) :
, .7110, .6924, .6620, .6663, .6450, .6316, .6645, .711, .8311,

1
Log catchability residuals.

Fleet : SUMMER SURVEY

| Age | , | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | , | No data | for | s fle | at | is age |  |  |  |  |  |
| 2 | , | -.18, | .19, | . 33, | -.88, | .12, | . 66 , | 1.12, | -. 04 , | . 66, | . 53 |
| 3 | , | . 06 , | -. 30, | -. 68, | . 44, | -. 49, | . 00 , | . 54, | -. 40, | . 01 , | . 38 |
| 4 | , | .09, | . 21 , | -. 72 , | -. 24 , | -. 04 , | . 00 , | . 00 , | . 02, | -.27, | . 17 |
| 5 | , | . 59, | -. 15, | . 14, | -.79, | -.87, | -.19, | . 04 , | -. 40 , | . 38 , | . 23 |
| 6 | , | . 08 , | -. 26 , | . 49, | . 03, | -. 74 , | -.67, | -. 42, | -. 77, | . 21 , | . 62 |
| 7 | , | . 20 , | -. 11, | -.44, | . 46 , | -. 03, | -. 40 , | -. 50, | -1.44, | . 07 , | . 44 |
| 8 | , | -. 20 , | -. 34, | . 08 , | . 43 , | -. 26 , | -. 10, | -. 55, | -1.13, | . 16, | . 50 |
| Age | , | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015 |
|  | , | No data | for t | S fle | at | is age |  |  |  |  |  |
|  | , | . 82 , | -. 27 , | -1.79, | -. 15, | . 66, | .13, | -1.71, | -. 64, | . 28 , | . 14 |
|  | , | -. 10, | -. 68, | -. 58, | 1.05, | . 50 , | . 15 , | -.96, | -. 37, | . 70 , | . 70 |
|  | , | -. 25 , | -. 73, | -. 87 , | . 44, | . 81, | . 49, | . 16 , | -1.08, | . 24, | 1.58 |
|  | , | -. 34, | -. 53, | -.11, | . 07 , | . 21 , | . 41, | . 32, | . 38 , | -.17, | . 80 |
|  | , | -. 42, | -. 44, | -. 02, | . 51, | . 18 , | . 14 , | -.21, | . 99 , | .17, | . 53 |
|  | , | -. 10, | -. 73 , | -. 50, | . 44 , | . 38, | . 28 , | -.53, | . 62, | . 06 , | . 39 |
|  |  | -. 02, | -. 51 | -. 53, | . 26 , | . 01 | -. 28 | -. 36, | 32 | -. 02 | -. 06 |

Mean log catchability and standard error of ages with catchability
independent of year class strength and constant w.r.t. time

| Age , | 2, | 3, | 4, | 5, | 6, | 7, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Mean Log q, | -7.8922, | -6.7099, | -6.2966, | -6.0849, | -6.0469, | -6.0469, |
| S.E(Log q), | .7687, | .5526, | .6031, | .4420, | .4876, | .5211, |

Regression statistics :

Ages with $q$ independent of year class strength and constant w.r.t. time.
Age, Slope, t-value, Intercept, RSquare, No Pts, Reg s.e, Mean Q

| 2, | .71, | 1.673, | 8.18, | .64, | 20, | .52, | -7.89, |
| :--- | ---: | ---: | ---: | :--- | :--- | :--- | :--- |
| 3, | .95, | .317, | 6.81, | .67, | 20, | .54, | -6.71, |
| 4, | 1.13, | -.661, | 6.03, | .57, | 20, | .69, | -6.30, |
| 5, | 1.13, | -.822, | 5.88, | .69, | 20, | .50, | -6.08, |
| 6, | 1.12, | -.603, | 5.93, | .60, | 20, | .55, | -6.05, |
| 7, | 1.06, | -.327, | 6.11, | .59, | 20, | .56, | -6.12, |

8, 1.37, -1.979, 6.54, .61, 20, .50, -6.18,


Mean log catchability and standard error of ages with catchability
independent of year class strength and constant w.r.t. time

| Age, | 1, | 2, | 3, | 4, | 5, | 6, | 7, |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Mean Log q, | -8.3513, | -6.9019, | -6.0009, | -5.7163, | -5.7382, | -5.9810, | -5.9810, |
| S.E (Log q), | .7237, | .5628, | .4908, | .4603, | .4231, | .4543, | .4411, |

Regression statistics :

Ages with $q$ independent of year class strength and constant w.r.t. time.
Age, Slope , t-value , Intercept, RSquare, No Pts, Reg s.e, Mean Q

| 1, | 1.00, | -.013, | 8.35, | .55, | 23, | .74, | -8.35, |
| :--- | ---: | ---: | :--- | :--- | :--- | :--- | :--- |
| 2, | 1.00, | -.014, | 6.90, | .65, | 23, | .58, | -6.90, |
| 3, | .89, | .840, | 6.30, | .75, | 23, | .44, | -6.00, |
| 4, | .90, | .794, | 5.96, | .77, | 23, | .42, | -5.72, |
| 5, | .90, | .868, | 5.93, | .79, | 23, | .38, | -5.74, |
| 6, | .89, | .770, | 6.10, | .72, | 23, | .41, | -5.98, |
| 7, | .98, | .189, | 6.18, | .75, | 23, | .39, | -6.18, |
| 8, | .64, | 1.570, | 6.03, | .48, | 23, | .72, | -6.47, |

Fleet : SANDEEL IN COD STOMA


```
Age, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015
    1 , No data for this fleet at this age
    , -.19, -1.93, .49, .59, .22, -. 82, .34, .49, -.09, 1.26
    3, No data for this fleet at this age
    4, No data for this fleet at this age
    5, No data for this fleet at this age
    6 , No data for this fleet at this age
    7 , No data for this fleet at this age
    8 ', No data for this fleet at this age
```

Mean log catchability and standard error of ages with catchability
independent of year class strength and constant w.r.t. time

```
    Age , 2
Mean Log q, -14.5319,
S.E(Log q), .7986,
```

Regression statistics :

Ages with $q$ independent of year class strength and constant w.r.t. time.
Age, Slope, t-value, Intercept, RSquare, No Pts, Reg s.e, Mean Q
2, .91, $.331, ~ 14.04, ~ .47, ~ 19, ~-14.53$,

1

Terminal year survivor and F summaries :
Age 1 Catchability constant w.r.t. time and dependent on age
Year class = 2014

| Fleet, | Estimated, Survivors, | $\begin{aligned} & \text { Int, } \\ & \text { s.e, } \end{aligned}$ | $\begin{aligned} & \text { Ext, } \\ & \text { s.e, } \end{aligned}$ | Var, <br> Ratio, |  | Scaled, Weights, | $\begin{gathered} \text { Estimated } \\ \mathrm{F} \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | 1., | . 000, | . 000, | . 00, | 0 , | . 000 , | . 000 |
| SPRING SURVEY (shift, | 3426., | . 739, | . 000 , | . 00 , | 1, | 1.000, | . 000 |
| SANDEEL IN COD STOMA, | 1., | . 000 , | . 000 , | . 00 , | 0 , | . 000 , | . 000 |
| F shrinkage mean , | 0., | 2.00, |  |  |  | . 000 , | . 000 |

Weighted prediction :

| Survivors, | Int, | Ext, | Nar, | F |
| :--- | :--- | :--- | :--- | :--- |
| at end of year, s.e, | s.e, | Ratio, |  |  |

1
Age 2 Catchability constant w.r.t. time and dependent on age
Year class $=2013$

| Fleet, | Estimated, Survivors, | Int, s.e, | $\begin{aligned} & \text { Ext, } \\ & \text { s.e, } \end{aligned}$ | Var, Ratio, |  | Scaled, Weights, | $\begin{aligned} & \text { Estimated } \\ & \mathrm{F} \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | 2880., | . 788 , | . 000, | . 00, | 1, | . 196, | 048 |
| SPRING SURVEY (shift, | 1666. | . 454 , | . 644, | 1.42, | 2, | . 591, | . 081 |
| SANDEEL IN COD STOMA, | 8818., | .819, | . 000 , | . 00 , | 1, | .181, | . 016 |
| F shrinkage mean | 1578., | 2.00, |  |  |  | . 032, | . 086 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $2504 .$, | .35, | .40, | 5, | 1.147, | .055 |

Age 3 Catchability constant w.r.t. time and dependent on age
Year class $=2012$
Fleet, $\quad$ Estimated, Int, Ext, Var, N, Scaled, Estimated

| SUMMER SURVEY | $6894 .$, | .460, | .198, | .43, | 2, | .311, | .127 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| SPRING SURVEY (shift, | $2985 .$, | .337, | .074, | .22, | 3, | .574, | .273 |
| SANDEEL IN COD STOMA, | $3579 .$, | .819, | .000, | .00, | 1, | .094, | .232 |
| F shrinkage mean , | $2628 .$, | $2.00, \ldots$, |  |  |  | .021, | .305 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | , | Ratio, |  |
| $3929 .$, | .26, | .17, | 7, | .647, | .214 |

Age 4 Catchability constant w.r.t. time and dependent on age

| Fleet, | Estimated, | Int, | Ext, | Var, | N, | Scaled, | Estimated |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , | Survivors, | s.e, | s.e, | Ratio, |  | Weights, | F |
| SUMMER SURVEY | 1676., | . 372 , | . 576, | 1.55, | 3, | . 328 , | . 248 |
| SPRING SURVEY (shift, | 448., | . 276 , | . 115, | . 41, | 4, | . 592, | . 719 |
| SANDEEL IN COD STOMA, | 1218., | .819, | . 000 , | . 00 , | 1, | . 059, | . 328 |
| F shrinkage mean | 835., | 2.00, |  |  |  | . 022, | . 448 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | R' | Ratio, |  |
| $743 .$, | .21, | .28, | 9, | 1.304, | .492 |

Age 5 Catchability constant w.r.t. time and dependent on age
Year class $=2010$

| Fleet, | Estimated, | Int, | Ext, | Var, | N, | Scaled, | Estimated |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , | Survivors, | s.e, | s.e, | Ratio, |  | Weights, | F |
| SUMMER SURVEY , | 399., | . 293, | . 453, | 1.54, | 4, | . 387 , | . 389 |
| SPRING SURVEY (shift, | 278., | .237, | . 219, | . 92 , | 5, | . 561, | . 521 |
| SANDEEL IN COD STOMA, | 458. | .819, | . 000, | . 00 , | 1, | . 036 , | 347 |
| F shrinkage mean | 265., | 2.00, |  |  |  | . 016, | . 540 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | S.e, | Ratio, |  |  |
| $325 .$, | .18, | .20, | 11, | 1.084, | .460 |

1
Age 6 Catchability constant w.r.t. time and dependent on age
Year class $=2009$

| Fleet, | Estimated, Survivors, | $\begin{aligned} & \text { Int, } \\ & \text { s.e, } \end{aligned}$ | $\begin{aligned} & \text { Ext, } \\ & \text { s.e, } \end{aligned}$ | Var, <br> Ratio, | N, | Scaled, Weights, | $\begin{aligned} & \text { Estimate } \\ & \mathrm{F} \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | 316., | . 263, | . 306, | 1.16, | 5, | . 410, | 592 |
| SPRING SURVEY (shift, | 391. | . 221, | .190, | . 86 , | 6, | . 550, | 502 |
| SANDEEL IN COD STOMA, | 154. | .819, | . 000 , | . 00 , | 1, | . 023, | 978 |
| F shrinkage mean , | 302., | 2.00, |  |  |  | . 017, | . 612 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $349 .$, | .17, | .15, | 13, | .914, | .549 |

Age 7 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2008$

| Fleet, | Estimated, | Int, | Ext, | Var, | N, | Scaled, | Estimated |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , | Survivors, | s.e, | s.e, | Ratio, | , | Weights, | F |
| SUMMER SURVEY | 361., | . 262 , | . 053, | . 20, | 6, | . 418, | . 441 |
| SPRING SURVEY (shift, | 210., | . 226 , | . 270 , | 1.19, | 7, | . 554, | . 669 |
| SANDEEL IN COD STOMA, | $330 .$, | . 819, | . 000 , | . 00 , | 1, | . 009, | . 473 |
| F shrinkage mean , | 285., | 2.00, |  |  |  | . 019, | . 532 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $266 .$, | .17, | .15, | 15, | .883, | .560 |

1
Age 8 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2007$

| Fleet, | Estimated, Survivors, | Int, | Ext, | Var, Ratio, |  | Scaled, Weights, | Estimat <br> F |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | $156 .$ | $\begin{aligned} & \text { s.e, } \\ & .242, \end{aligned}$ | $\begin{aligned} & \text { s.e, } \\ & .155, \end{aligned}$ | $.64,$ | 7, | .555, | . 241 |
| SPRING SURVEY (shift, | 99., | . 235, | . 182, | . 77 , | 8, | . 424, | . 358 |
| SANDEEL IN COD STOMA, | 230., | . 819, | . 000 , | . 00 , | 1, | . 006 , | . 170 |
| F shrinkage mean | $66 .$, | 2.00, |  |  |  | . 015, | . 499 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, | Rat |  |
| $127 .$, | .17, | .12, | 17, | .715, | .289 |

Age 9 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2006$

| Fleet, | Estimated, | Int, | Ext, | Var, | N, | Scaled, | Estimated |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , | Survivors, | s.e, | s.e, | Ratio, |  | Weights, | F |
| SUMMER SURVEY , | 42., | . 259, | . 151, | . 58 , | 7, | .569, | . 400 |
| SPRING SURVEY (shift, | 28., | . 258, | . 121, | . 47, | 8 , | . 403, | . 554 |
| SANDEEL IN COD STOMA, | 58., | . 819, | . 000 , | . 00 , | 1, | . 004 , | . 306 |
| F shrinkage mean | 34. | 2.00, |  |  |  | . 024, | . 474 |

Weighted prediction :
$\begin{array}{lllll}\text { Survivors, } & \text { Int, } & \text { Ext, }, ~ & \text { Var, } & \text { F } \\ \text { at end of year, } & \text { s.e, } & \text { s.e, } & \text { Ratio, } & \end{array}$

| at end of year, s.e, | s.e, | Ratio, |  |  |
| :---: | :---: | :---: | :---: | :---: |
| $36 .$, | .19, | .10, | 17, | .535, |

When looking at the scaled weights of the tuning fleets on age 2 , the following numbers were obtained:

```
Age 2 Catchability constant w.r.t. time and dependent on age
Year class = 2013
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline Fleet, & Estimated, Survivors, & \[
\begin{aligned}
& \text { Int, } \\
& \text { s.e, }
\end{aligned}
\] & \[
\begin{aligned}
& \text { Ext, } \\
& \text { s.e, }
\end{aligned}
\] & Var, Ratio, & & Scaled, Weights, & Estimat
F \\
\hline SUMMER SURVEY & 2880., & . 788 , & . 000 , & . 00, & 1 & .196, & . 048 \\
\hline SPRING SURVEY (shift, & 1666., & . 454, & . 644, & 1.42, & 2 & . 591, & 081 \\
\hline SANDEEL IN COD STOMA, & 8818. & .819, & . 000 , & . 00 , & 1 & .181, & . 016 \\
\hline
\end{tabular}
```

The sandeel tuning got approximately the same weight as the summer survey, but the spring survey dominated the tuning of age 2.


Figure 2. Abundance of age 2 with and without sandeel tuning.


Figure 3. Retrospective analysis of the recruitment with and without the sandeel tuning.

The sandeel tuning had a very little impact on the estimates of recruitment, probably except the terminal year (Figure 2). The retrospective analysis of recruitment was probably slightly better with the sandeel tuning (Figure 3).

A relevant question is also whether the positive correlation between cod recruitment and the amount of sandeels in cod stomachs will hold in the future.

## Faroe Plateau cod - intro

Here I briefly show some relevant material for Faroe Plateau cod (sorry for the messy structure of the document). The cod stock has been extremely low the last 10-15 years compared with the last 300 years. The main point is to show that since 2003 the recruitment has been extremely low. The catchability with longlines has increased dramatically after 2005 and there is a close negative relationship between catchability with longlines and recruitment. Also, as shown elsewhere, there is a strong positive correlation between the amount of sandeels in cod stomachs and cod recruitment at age 2 . This points to food availability/cannibalism as a constraining factor of cod recruitment. There is a strong negative correlation between zooplankton biomass in June/July and recruitment of 2 year-old cod+haddock (shifted to $y-1$ ), although the mehanism is unknown.


Figure 1. Faroe Plateau Cod. Catch.


Figure 2. Faroe Plateau Cod. Total stock size.


Figure 3. Faroe Plateau Cod. Spawning stock size.


Figure 4. Faroe Plateau Cod. Recruitment.


Figure 5. Faroe Plateau Cod. Fishing mortality.


Figure 6. Faroe Plateau Cod. Catch composition.


Figure 7. Faroe Plateau Cod. Catch composition in relative terms.

| Fleet | Size | Samples | Lengths | Otoliths | Weights |
| :--- | :--- | ---: | ---: | ---: | ---: |
| Open boats |  | 4 | 794 | 80 | 794 |
| Longliners | $<100$ GRT | 8 | 1,561 | 160 | 1,561 |
| Longliners | $>100$ GRT | 17 | 3,529 | 358 | 3,529 |
| Jiggers |  | 0 | 0 | 0 | 0 |
| Gillnetters |  | 0 | 0 | 0 | 0 |
| Sing. traw lers | $<400 \mathrm{HP}$ | 0 | 0 | 0 | 0 |
| Sing. traw lers | $400-1000 \mathrm{HP}$ | 11 | 1,981 | 200 | 1,981 |
| Sing. traw lers | $>1000 \mathrm{HP}$ | 0 | 0 | 0 | 0 |
| Pair traw lers | $<1000 \mathrm{HP}$ | 0 | 0 | 0 | 0 |
| Pair traw lers | $>1000 \mathrm{HP}$ | 29 | 5,575 | 439 | 4,412 |
| Total |  | 69 | 13,440 | 1,237 | 12,277 |

Figure 8. Faroe Plateau cod. Sampling intensity in 2015.


Figure 9. Faroe Plateau cod. Weights at age.


Figure 10. Faroe Plateau cod. Maturity at age

Faroe Plateau cod


Figure 11. Faroe Plateau cod. Reconstructed biomass back in time


Figure 12. Faroe Plateau cod. Catch per unit effort series.


Figure 13. Faroe Plateau cod. Catch per unit effort series - only longliners.


Figure 14. Faroe Plateau cod. Catchability with longlines.


Figure 15. Faroe Plateau cod. Catchability with longlines and recruitment.


Figure 16. Faroe Plateau cod and haddock. Relationship between zooplankton year y and recruitment of cod + haddock (at age 2 set to $y-1$ ).

## Biomass estimates back in time for cod, haddock and saithe

In this document the biomasses of cod, haddock and saithe are estimated back in time. One point is to show that the total biomass of cod, haddock and saithe has not shown any time trend over the last century. However, the proportion of saithe increased over time, cod decreased over time whereas haddock remained stable. The data are from NWWG 2016.

A speculation is that it could be noted that the Norwegian spring spawning herring stock (NSSH), which partly was located in Faroese waters, collapsed at about the same time as the cod started to show the same stock dynamics as haddock (mid 1960s). When the NSSH recovered in the 1980s it did not show up in Faroese waters as a local spawing population.


Figure 1. Biomass of Faroe cod, haddock and saithe the last century. From NWWG 2016. Note that cod and saithe were at the same level and fluctuated in the same way until around 1963 whereas cod and haddock became more similar after 1963.


Figure 2. Biomass of Faroe cod, haddock and saithe the last century - in relative terms. From NWWG 2016. Note that the proportion of saithe increased steadily over the time period whereas the proportion of cod decreased. Haddock remained stable.

## Introduction

This document is meant to give an overview of the work I have done prior to the Benchmark meeting. Main emphasize has been on the input data, revise existing data and try to find other data not used in the spaly assessments so far. Most important are addition of catch weight at age 1957-1976, where constant weights have been applied so far. The other additions are concerning the spring survey. The tuning series have been expanded back to 1983; although the years 1983-1993 still not are in the accessible database, data were available for the first years and they have now been included. Survey weights at age have not been presented and used for stock assessment; now the weights back to 1994 have been extracted from the database, and based on regressions between catch weights and survey weights attempts have been to extend the series back to 1957.

XSA has been the default assessment tool for this stock for (too) many years. Since the last Benchmark, the settings of the XSA have been the same (according to the ICES rules up to now). These setting have been investigated and a slightly revised assessment is presented.

Commercial weights at age. Several years ago, The Faroe Marine Research Institute received a lot of old fish data from The Aberdeen Marine Laboratory; the catch at age in numbers from this data source were at the last Benchmark used to expand the series back to 1957. Now catch weights at age at data have been extracted and it has also been possible to extend this series back to 1957. For the years 1957-1976 constant weights were applied in former assessments. The revised series is presented on Sharepoint under 06. Datalhaddock Vb in excel format and under the folder same place: tuning files $\ c o m b-t u n-s p r i n g-16-j r . ~ T h e r e ~ s e e m ~ h o w e v e r ~ t o ~ b e ~ s o m e t h i n g ~ w r o n g e ~ w i t h ~ t h e s e ~ o l d ~ w e i g h t s, ~$ because when running the XSA, the sum of product check result in some strange values, so we may stick to the former constant weights for the time being.

## The spring survey

The sampling level 1994-2016 is shown in Table 1.

## Spring surveys 1994-2016 sampling level

| Year | Length | Weight | Maturity | Age |
| ---: | ---: | ---: | ---: | ---: |
| 1994 | 9021 | 630 | 414 | 412 |
| 1995 | 10640 | 512 | 528 | 492 |
| 1996 | 14377 | 924 | 949 | 950 |
| 1997 | 25223 | 1284 | 1283 | 1279 |
| 1998 | 16303 | 4174 | 1134 | 1131 |
| 1999 | 12470 | 2998 | 1121 | 1121 |
| 2000 | 16888 | 5774 | 1011 | 982 |
| 2001 | 13664 | 5959 | 1048 | 1047 |
| 2002 | 12496 | 5469 | 1078 | 1078 |
| 2003 | 10901 | 4851 | 1092 | 1089 |
| 2004 | 7674 | 5052 | 1020 | 1018 |
| 2005 | 11303 | 6348 | 1004 | 1006 |
| 2006 | 9878 | 5303 | 997 | 994 |
| 2007 | 9283 | 6844 | 1025 | 1021 |
| 2008 | 5454 | 3312 | 994 | 987 |
| 2009 | 5407 | 3670 | 1016 | 1016 |
| 2010 | 5605 | 3100 | 1030 | 1030 |
| 2011 | 6042 | 4380 | 1007 | 1005 |
| 2012 | 6805 | 4371 | 1035 | 1032 |
| 2013 | 7839 | 6632 | 1011 | 1007 |
| 2014 | 7140 | 3722 | 1011 | 1008 |
| 2015 | 7476 | 4035 | 1004 | 1002 |
| 2016 | 7925 | 4318 | 1005 | 1007 |

The goal is to sample at least 1000 fishes for age and maturity.
Lenght measurements are taken from every haul, and at least $25 \%$ of them are also weighted. All samples ar taken randomly

## Survey weights

The survey weights 1994-2016 have been calculated (Table 2). The excel version of this table is on the WKFAROE share point site. Based on this and catch weight at age, survey weights at age have been extended back to 1957 from regression of survey and catch weight at age in the period 19942015. For fully recruited ages the fit is ressonable but for the young ages the fit is not good. By simple deleting outliers the fit gets better but the number of observations is in some cases very small. It is questionable if this exercise can be used for something sensible. But the results are presented as excel files under the directory Data and the folder haddock Vb , surwey weights.

Table 2. Faroe haddock. Weight at age (kg) in the spring survey 1994-2016.

| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | 0.025 | 0.032 | 0.079 | 0.106 | 0.031 | 0.04 | 0.04 | 0.034 | 0.04 | 0.051 | 0.066 | 0.032 | 0.091 | 0.031 | 0.029 | 0.039 | 0.034 | 0.027 | 0.031 | 0.034 | 0.031 | 0.03 | 0.023 |
| 2 | 0.238 | 0.161 | 0.188 | 0.166 | 0.281 | 0.198 | 0.198 | 0.263 | 0.305 | 0.16 | 0.212 | 0.175 | 0.194 | 0.198 | 0.235 | 0.26 | 0.288 | 0.221 | 0.211 | 0.274 | 0.254 | 0.263 | 0.217 |
| 3 | 0.711 | 0.673 | 0.543 | 0.432 | 0.382 | 0.586 | 0.586 | 0.654 | 0.712 | 0.52 | 0.418 | 0.347 | 0.383 | 0.447 | 0.534 | 0.558 | 0.674 | 0.713 | 0.511 | 0.588 | 0.715 | 0.707 | 0.673 |
| 4 | 1.189 | 1.298 | 1.437 | 0.917 | 0.788 | 0.75 | 0.75 | 0.955 | 1.336 | 0.889 | 0.743 | 0.592 | 0.55 | 0.721 | 0.723 | 0.877 | 1.049 | 1.059 | 1.017 | 0.968 | 1.137 | 1.24 | 1.168 |
| 5 | 1.4 | 1.788 | 2.025 | 1.907 | 1.13 | 1.11 | 1.11 | 1.24 | 1.866 | 1.492 | 0.954 | 0.915 | 0.786 | 0.914 | 0.911 | 1.096 | 1.266 | 1.305 | 1.356 | 1.473 | 1.27 | 1.539 | 1.681 |
| 6 | 1.605 | 1.941 | 2.529 | 1.999 | 2.18 | 1.452 | 1.452 | 1.607 | 2.349 | 1.921 | 1.401 | 1.122 | 1.024 | 1.024 | 0.956 | 1.262 | 1.467 | 1.434 | 1.492 | 1.748 | 1.672 | 1.712 | 1.887 |
| 7 | 1.794 | 2.139 | 2.524 | 2.134 | 2.006 | 2.106 | 2.106 | 1.938 | 2.496 | 1.208 | 1.746 | 1.595 | 1.258 | 1.262 | 1.128 | 1.331 | 1.505 | 1.584 | 1.621 | 2.095 | 2.103 | 2.075 | 2.27 |
| 8 | 1.993 | 2.341 | 2.586 | 2.718 | 2.965 | 2.781 | 2.781 | 3.125 | 2.69 | 2.249 | 2.162 | 2.123 | 1.994 | 1.456 | 1.494 | 1.535 | 1.6 | 1.557 | 1.592 | 2.013 | 1.994 | 2.06 | 2.82 |
| 9 | 2.383 | 2.512 | 2.847 | 2.549 | 2.668 | 2.98 | 2.98 | 0 | 2.849 | 2.459 | 2.521 | 3.098 | 2.269 | 2.234 | 1.82 | 1.848 | 1.889 | 1.813 | 1.711 | 1.836 | 2.07 | 2.62 | 2.66 |
| 10 | 2.12 | 2.967 | 2.882 | 2.738 | 2.873 | 2.482 | 2.482 | 3.011 | 4.233 | 2.697 | 2.407 | 2.884 | 0 | 0 | 1.318 | 2.079 | 2.333 | 2.044 | 2.01 | 2.084 | 2.119 | 2.23 | 2.465 |
| 11 | 2.671 | 2.777 | 3.489 | 2.813 | 3.103 | 3.969 | 3.969 | 3.303 | 4.956 | 3.331 | 2.69 | 3.696 | 3.125 | 0 | 0 | 0 | 1.995 | 2.148 | 2.068 | 2.048 | 2.395 | 2.267 | 3.156 |
| 12 | 1.952 | 2.68 | 3.151 | 0 | 2.683 | 3.21 | 3.21 | 3.293 | 3.606 | 0 | 0 | 2.867 | 0 | 3.398 | 0 | 0 | 2.259 | 2.844 | 2.238 | 2.658 | 2.682 | 2.267 | 0 |
| 13 | 0 | 0 | 2.422 | 2.911 | 0 | 2.729 | 2.729 | 3.73 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.227 | 0 | 3.028 | 3.24 | 0 |
| 14 | 0 | 2.822 | 0 | 3.551 | 0 | 0 | 0 | 0 | 5.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | , | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Assessment

XSA has been the default assessment method for many years, and since the last Benchmark assessment the settings have been kept constant. There have been some reflections on, what shrinkage should be used. A rather heavy shrinkage of 0.5 have been the preferred but due to the development of the stock parameters there has been a wish to take away the shrinkage which in XSA can be done by using a 2.0 shrinkage. The retrospective analyses of the spaly run (0.5) and one shrunl 2.0 is shown below:


Faroe haddock XSA 2016 spaly 2.0 retro SSB




## Faroe Plateau cod assessment - the influence of the plus group

The influence of the plus group is investigated. Traditionally, ages 10 and older have been put into a plus group. At the WKFAROE benchmark meeting the issue that XSA might not handle plus groups well, especially if there if much fish in the plus group. Hence, as an excercise, the catch at age was extended to age 13 based on the data for 1996-2015. A few fish of age 15 were put into the age 13 category in order to avoid that most of the age 14 and age 15 was composed of zero values. Based on the 1996-2015 period, an average catch per ages 10, 11, 12 and 13 was calculated and together with the known age 10+ numbers for the years 1959-1995, the catch at age was extended to age 13 for this period.

The main result was that there was virtually no difference between the traditional XSA run, i.e., with the 10+ group, and the alternative XSA run with the age 13 true age for the 1979-2015 period. For the 1959-1978 period, the total and spawning biomass was 3000 to 8000 tons lower and the fishing mortality 0.03 to 0.1 higher, see the figures below. The two XSA runs are included in the end of the document.


Figure 1. Comparing recruitment.


Figure 2. Comparing total stock size.


Figure 3. Comparing spawning stock size.


Figure 4. Comparing fishing mortality.


Figure 5. Comparing absolute difference in biomass.


Figure 6. Comparing absolute difference in fishing mortality.


Figure 7. Comparing relative difference in biomass.


Figure 8. Comparing relative difference in fishing mortality.

## Table 1. Report file for the age 13 true age XSA run.

```
Lowestoft VPA Version 3.1
    14/02/2017 10:09
Extended Survivors Analysis
COD FAROE PLATEAU (ICES SUBDIVISION Vb1) COD_ind_Surveys_revised
CPUE data from file Surveys_revised_1replacedvalue.TXT
Catch data for 57 years. 1959 to 2015. Ages 1 to 13.
    Fleet, First, Last, First, Last, Alpha, Beta
SUMMER SURVEY , 1996, 2015, 2, 8, 8, .600, . 700
SPRING SURVEY (shift, 1993, 2015, 1, 8, .900, 1.000
Time series weights :
    Tapered time weighting not applied
Catchability analysis :
    Catchability independent of stock size for all ages
    Catchability independent of age for ages >= 6
Terminal population estimation :
Survivor estimates shrunk towards the mean F
of the final 5 years or the 5 oldest ages.
S.E. of the mean to which the estimates are shrunk = 2.000
    Minimum standard error for population
    estimates derived from each fleet = . 300
    Prior weighting not applied
Tuning converged after }170\mathrm{ iterations
```

1
Regression weights
, $1.000,1.000,1.000,1.000,1.000,1.000,1.000,1.000,1.000,1.000$
Fishing mortalities
Age, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015
$1, .000, .000, .000, .000, .000, .000, .000, .000, .000, .000$
2, .181, . 118, . 050, . 124, . 230, .088, . 029, . 021, . 057, . 075
$\begin{array}{llllllllll}3, & .322, & .312, & .262, & .685, & .471, & .431, & .195, & .136, & .283,\end{array} .214$
5, . 600, . 421, . 385, . 487, .631, . $573, .583, .391, .465, .467$
6, . 759, . 575, .478, . 502, . $907, .565, .730, .363, .429, .526$
7, .868, .583, . 726, .415, .652, .640, .671, .296, .305, . 533
8, .869, $.563, \quad .896, \quad .609, \quad .561, \quad .379, \quad .916, \quad .350, \quad .163, \quad .272$

| 9, | .288, | .588, | .966, | .669, | .954, | .358, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| $10,37.317$, | .130, | 2.124, | .670, | 1.128, | .126, | .403, | .059,$\quad .003, \quad .441$

            11, . 306, . \(000, .120,43.385,70.488, .000, .397, .052, .000, .000\)
    12, . \(000, \quad .575, \quad .000, .000, .000, .000, . .977, .353, .000, .000\)
    1
XSA population numbers (Thousands)
YEAR AG
$2007,7.91 \mathrm{E}+03,5.02 \mathrm{E}+03,5.05 \mathrm{E}+03,2.62 \mathrm{E}+03,1.01 \mathrm{E}+03,7.30 \mathrm{E}+02,6.38 \mathrm{E}+02,2.18 \mathrm{E}+02,4.97 \mathrm{E}+01,2.71 \mathrm{E}+01$,


#### Abstract

$2008, \quad 1.01 \mathrm{E}+04,6.47 \mathrm{E}+03,3.65 \mathrm{E}+03,3.03 \mathrm{E}+03,1.49 \mathrm{E}+03,5.44 \mathrm{E}+02,3.36 \mathrm{E}+02,2.91 \mathrm{E}+02,1.02 \mathrm{E}+02,2.26 \mathrm{E}+01$, $2009,1.39 \mathrm{E}+04,8.28 \mathrm{E}+03,5.04 \mathrm{E}+03,2.30 \mathrm{E}+03,1.77 \mathrm{E}+03,8.29 \mathrm{E}+02,2.76 \mathrm{E}+02,1.33 \mathrm{E}+02,9.74 \mathrm{E}+01,3.17 \mathrm{E}+01$, $2010, \quad 5.26 \mathrm{E}+03,1.14 \mathrm{E}+04,5.99 \mathrm{E}+03,2.08 \mathrm{E}+03,1.10 \mathrm{E}+03,8.91 \mathrm{E}+02,4.11 \mathrm{E}+02,1.49 \mathrm{E}+02,5.93 \mathrm{E}+01,4.09 \mathrm{E}+01$, $2011,2.31 \mathrm{E}+03,4.31 \mathrm{E}+03,7.39 \mathrm{E}+03,3.06 \mathrm{E}+03,9.25 \mathrm{E}+02,4.81 \mathrm{E}+02,2.95 \mathrm{E}+02,1.75 \mathrm{E}+02,6.98 \mathrm{E}+01,1.87 \mathrm{E}+01$ $2012,3.54 \mathrm{E}+03,1.89 \mathrm{E}+03,3.23 \mathrm{E}+03,3.93 \mathrm{E}+03,1.39 \mathrm{E}+03,4.27 \mathrm{E}+02,2.24 \mathrm{E}+02,1.27 \mathrm{E}+02,9.83 \mathrm{E}+01,3.99 \mathrm{E}+01$ $2013,9.38 \mathrm{E}+03,2.90 \mathrm{E}+03,1.51 \mathrm{E}+03,2.18 \mathrm{E}+03,2.00 \mathrm{E}+03,6.35 \mathrm{E}+02,1.68 \mathrm{E}+02,9.36 \mathrm{E}+01,4.16 \mathrm{E}+01,5.79 \mathrm{E}+01$, $2014,2.93 \mathrm{E}+03,7.68 \mathrm{E}+03,2.32 \mathrm{E}+03,1.08 \mathrm{E}+03,1.48 \mathrm{E}+03,1.11 \mathrm{E}+03,3.61 \mathrm{E}+02,1.03 \mathrm{E}+02,5.40 \mathrm{E}+01,2.05 \mathrm{E}+01$ $2015,4.13 \mathrm{E}+03,2.39 \mathrm{E}+03,5.94 \mathrm{E}+03,1.43 \mathrm{E}+03,6.22 \mathrm{E}+02,7.62 \mathrm{E}+02,5.91 \mathrm{E}+02,2.18 \mathrm{E}+02,7.13 \mathrm{E}+01,3.61 \mathrm{E}+01$,


Estimated population abundance at 1st Jan 2016
$0.00 \mathrm{E}+00,3.38 \mathrm{E}+03,1.82 \mathrm{E}+03,3.93 \mathrm{E}+03,7.01 \mathrm{E}+02,3.19 \mathrm{E}+02,3.69 \mathrm{E}+02,2.84 \mathrm{E}+02,1.36 \mathrm{E}+02,3.76 \mathrm{E}+01$,
Taper weighted geometric mean of the VPA populations:
$1.38 \mathrm{E}+04,1.16 \mathrm{E}+04,8.86 \mathrm{E}+03,5.37 \mathrm{E}+03,2.95 \mathrm{E}+03,1.45 \mathrm{E}+03,6.40 \mathrm{E}+02,2.48 \mathrm{E}+02,8.80 \mathrm{E}+01,3.92 \mathrm{E}+01$,
Standard error of the weighted Log(VPA populations) :
.7177, .6992, .6573, .6620, .6363, .6178, .6389, .6704, .8461, 2.1008,

|  | AGE <br> YEAR , |  |
| :--- | :--- | :--- |
| 2006, | $4.19 \mathrm{E}+00$, | $1.65 \mathrm{E}-33$, |
| 2007, | $5.63 \mathrm{E}-17$, | $2.53 \mathrm{E}+00$, |
| 2008, | $1.95 \mathrm{E}+01$, | $4.61 \mathrm{E}-17$, |
| 2009, | $2.21 \mathrm{E}+00$, | $1.42 \mathrm{E}+01$, |
| 2010, | $1.33 \mathrm{E}+01$, | $2.60 \mathrm{E}-19$, |
| 2011, | $1.08 \mathrm{E}+01$, | $2.65 \mathrm{E}-30$, |
| 2012, | $1.35 \mathrm{E}+01$, | $8.86 \mathrm{E}+00$, |
| 2013, | $2.18 \mathrm{E}+01$, | $7.43 \mathrm{E}+00$, |
| 2014, | $4.47 \mathrm{E}+01$, | $1.70 \mathrm{E}+01$, |
| 2015, | $1.68 \mathrm{E}+01$, | $3.66 \mathrm{E}+01$, |

Estimated population abundance at 1st Jan 2016
$2.32 \mathrm{E}+01, \quad 1.38 \mathrm{E}+01$,
Taper weighted geometric mean of the VPA populations:
$1.54 \mathrm{E}+01,5.84 \mathrm{E}+00$,
Standard error of the weighted Log(VPA populations) :

$$
1.7294, \quad 1.6054,
$$

1

Log catchability residuals.

Fleet : SUMMER SURVEY

| Age | , | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 |  | No data for this fleet at this age |  |  |  |  |  |  |  |  |  |
| 2 |  | -.19, | .16, | . 32, | -.89, | .11, | . 64, | 1.09, | -. 05, | . 64, | . 51 |
| 3 |  | . 07, | -. 30 , | -. 70 , | . 45, | -.49, | . 00 , | . 54, | -. 41, | . 01, | . 38 |
| 4 |  | . 10, | . 21 , | -. 72 , | -. 26 , | -.03, | . 00 , | -. 01, | . 02, | -. 29, | . 17 |
| 5 | , | . 60, | -. 14, | . 16, | -.79, | -.89, | -. 17, | . 05, | -. 40 , | . 37, | . 20 |
| 6 | , | .09, | -. 25 , | . 53, | . 06 , | -. 73, | -. 70 , | -.37, | -. 76, | .19, | 59 |
| 7 | , | . 21 , | -. 10, | -. 42, | . 53, | . 02, | -. 39, | -.61, | -1.36, | . 08 , | 39 |
| 8 | , | -. 22 , | -. 37, | .07, | . 44, | -.09, | -.03, | -. 58, | -1.45, | . 39, | . 50 |
| Age | , | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015 |
| 1 |  | No data for this fleet at this age |  |  |  |  |  |  |  |  |  |
| 2 | , | . 80 , | -. 28 , | -1.80, | -.17, | . 64, | . 11, | -1.72, | -.63, | . 27 , | . 44 |
| 3 |  | -.11, | -. 67, | -.57, | 1.05, | . 50 , | .14, | -.97, | -. 36, | . 74, | . 70 |
| 4 | , | -. 26 , | -. 75 , | -.87, | . 44, | . 81 , | . 48, | .15, | -1.09, | . 26, | 1.64 |
| 5 |  | -.33, | -. 53, | -. 13, | . 07, | . 22 , | . 41, | . 31 , | . 37 , | -.19, | . 82 |
| 6 |  | -. 48, | -. 42, | -. 02, | . 48, | . 19, | .17, | -. 20 , | . 97 , | .16, | . 50 |
| 7 |  | -. 18, | -. 85, | -.49, | . 43, | . 30 , | . 28 , | -. 50, | . 61, | . 03, | . 35 |
| 8 |  | -. 18, | -.69, | -.88, | . 27 , | -.02, | -. 40, | -. 38, | . 37, | -.03, | -. 10 |

Mean log catchability and standard error of ages with catchability independent of year class strength and constant w.r.t. time

| Age , | 2, | 3, | 4, | 5, | 6, | 7, | 8 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mean Log q, | -7.8786, | -6.7124, | -6.2999, | -6.0939, | -6.0639, | -6.0639, | -6.0639, |

S.E(Log q), .7709, .5574, .6142, .4457, .4831, .5205, .5151,

Regression statistics :

Ages with $q$ independent of year class strength and constant w.r.t. time.
Age, Slope, t-value, Intercept, RSquare, No Pts, Reg s.e, Mean Q

| 2, | .74, | 1.422, | 8.13, | .63, | 20, | .56, | -7.88, |
| ---: | ---: | ---: | ---: | :--- | :--- | :--- | :--- |
| 3, | .95, | .270, | 6.80, | .66, | 20, | .55, | -6.71, |
| 4, | 1.15, | -.716, | 6.01, | .56, | 20, | .72, | -6.30, |
| 5, | 1.13, | -.828, | 5.88, | .69, | 20, | .51, | -6.09, |
| 6, | 1.10, | -.548, | 5.96, | .60, | 20, | .54, | -6.06, |
| 7, | 1.06, | -.323, | 6.14, | .59, | 20, | .56, | -6.15, |
| 8, | 1.54, | -2.070, | 6.77, | .45, | 20, | .69, | -6.23, |

Fleet : SPRING SURVEY (shift

| Age, | 1993, | 1994, | 1995 |
| ---: | ---: | ---: | ---: |
| 1, | .01, | -.50, | -.39 |
| 2, | -.91, | -.89, | .18 |
| 3, | -.62, | .02, | .12 |
| 4, | -.56, | .00, | .60 |
| 5, | -.57, | .77, | .40 |
| 6, | -.52, | .89, | .53 |
| 7, | -.54, | .48, | .18 |
| 8, | -5.54, | .45, | .21 |


| Age | , | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | , | -. 80 , | -. 74 , | . 69 , | -.42, | . 26 , | . 18 , | -. 49 , | 1.96, | . 98 , | -. 06 |
| 2 | , | -.25, | -. 25 , | . 37 , | . 24 , | .47, | . 74, | -. 26 , | . 24, | . 41, | -1 |
| 3 | , | -. 03, | -.17, | . 07 , | . 06 , | . 20 , | . 31, | . 38 , | -.48, | . 43, | 9 |
| 4 | , | -. 05, | .19, | -. 24 , | -. 54, | -.12, | . 34, | -.02, | -. 24 , | . 26 , | -. 42 |
| 5 | , | -.11, | . 27 , | .19, | -.57, | -.37, | . 10, | . 28 , | -. 39, | . 39, | . 6 |
| 6 | , | -.08, | -.02, | . 26 , | . 42 , | . 34, | .08, | -.22, | -. 42, | . 27 , | -. 5 |
| 7 | , | -. 14, | -. 21 , | -. 18, | . 25 , | -.66, | . 04 , | -.03, | -. 14, | -. 64, | -. 8 |
| 8 |  | -1.47, | . 87 , | . 10, | -1.18, | -1.30, | . 26 , | -. 10, | -. 54, | -. 46 , | -1.05 |
| Age | , | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015 |
| 1 |  | -1.08, | . 12, | . 43, | . 93 , | . 35 , | -.11, | -.03, | -. 35, | -.95, | . 0 |
| 2 |  | -.66, | . 23 , | -.09, | . 76 , | . 54, | -. 20 , | .89, | -. 75, | -. 14, | . 4 |
| 3 |  | -. 84, | . 10, | . 52, | . 33, | . 46 , | . 26 , | 1.13, | -. 53, | -.47, | -. 3 |
| 4 |  | -. 79 , | -. 05, | . 66 , | . 36 , | . 58 , | -. 37, | 1.11, | -. 17, | -.08, | -. |
| 5 |  | -. 35, | -. 17, | . 45 , | . 26 , | . 63, | -. 65, | . 34, | -.09, | .19, |  |
| 6 |  | -. 46 , | -. 04 , | . 04 , | -. 07 , | 1.12, | -. 76, | -. 30 , | -.21, | -.09, |  |
| 7 |  | -. 42, | -. 65, | -.09, | . 07 , | . 63 , | -.33, | -.08, | -. 17, | -. 53, |  |
| 8 |  | .10, | -. 68, | -.03, | .11, | .19, | -1.40, | . 48, | -.02, | -.82, | -1. |

Mean log catchability and standard error of ages with catchability
independent of year class strength and constant w.r.t. time

| Age, | 1, | 2, | 3, | 4, | 5, | 6, | 7, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Mean Log q, | -8.3390, | -6.8897, | -6.0033, | -5.7195, | -5.7478, | -5.9961, | -5.9961, |
| S.E (Log q), | .7011, | .5689, | .4885, | .4580, | .4253, | .4556, | .4673, |

Regression statistics :

Ages with $q$ independent of year class strength and constant w.r.t. time.

Age, Slope, t-value, Intercept, RSquare, No Pts, Reg s.e, Mean Q

| 1, | 1.00, | -.012, | 8.34, | .57, | 23, | .72, | -8.34, |
| :--- | ---: | ---: | ---: | :--- | :--- | :--- | :--- |
| 2, | 1.04, | -.218, | 6.82, | .65, | 23, | .60, | -6.89, |
| 3, | .89, | .834, | 6.30, | .75, | 23, | .44, | -6.00, |
| 4, | .91, | .772, | 5.96, | .77, | 23, | .42, | -5.72, |


| 5, | .90, | .867, | 5.94, | .78, | 23, | .39, | -5.75, |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 6, | .88, | .866, | 6.12, | .72, | 23, | .40, | -6.00, |
| 7, | .97, | .210, | 6.22, | .72, | 23, | .41, | -6.22, |
| 8, | .72, | .904, | 6.22, | .34, | 23, | .94, | -6.57, |

Terminal year survivor and $F$ summaries
Age 1 Catchability constant w.r.t. time and dependent on age
Year class $=2014$


Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $3384 .$, | .72, | .00, | 1, | .000, | .000 |

1
Age 2 Catchability constant w.r.t. time and dependent on age
Year class $=2013$


Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, |
| :--- | :--- | :--- | :--- | :--- |
| at end of year, | s.e, | S.e, | Ratio, |  |

Age 3 Catchability constant w.r.t. time and dependent on age
Year class $=2012$

| Fleet, | Estimated, Survivors, | $\begin{aligned} & \text { Int, } \\ & \text { s.e, } \end{aligned}$ | $\begin{aligned} & \text { Ext, } \\ & \text { s.e, } \end{aligned}$ | Var, <br> Ratio, |  | Scaled, Weights, | $\begin{gathered} \text { Estimated } \\ \mathrm{F} \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | $6866 .$, | . 463 , | . 206 , | . 44, | 2, | . 338, | 128 |
| SPRING SURVEY (shift, | 2962. | . 335 , | . 070, | . 21, | 3 , | .639, | 275 |
| F shrinkage mean | 2628., | 2.00, |  |  |  | . 023, | . 305 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | S.e, | , | Ratio, |  |
| $3925 .$, | .27, | .19, | 6, | .707, | .214 |

1
Age 4 Catchability constant w.r.t. time and dependent on age
Year class $=2011$

| Fleet, | Estimated, | Int, | Ext, | Var, |  | Scaled, | Estimated |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | Survivors, | S.e, | s.e, | Ratio, |  | Weights, | F |
| SUMMER SURVEY SPRING SURVEY (shift, | 1632., | . 377 , | . 588 , | 1.56, | 3, | . 341 , | .254 .727 |
| SPRING SURVEY (shift, | 442., | .275, | .115, | . 42 , | 4, | . 635, | . 727 |
| F shrinkage mean , | 843., | 2.00, |  |  |  | . 024 , | . 445 |

Weighted prediction :
$\begin{array}{lll}\text { Survivors, } & \text { Int, } \\ \text { at end of year, } & \text { s.e, } & \text { Sar, }\end{array}$
$\begin{array}{ccccc}\text { at end of year, s.e, } & \text { s.e, } & \text { Ratio, } & \\ 701 ., & .22, & .30, & 8, & 1.362,\end{array}$


Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $319 .$, | .18, | .21, | 10, | 1.127, | .467 |

1
Age 6 Catchability constant w.r.t. time and dependent on age
Year class $=2009$


Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $369 .$, | .17, | .16, | 12, | .923, | .526 |

Age 7 Catchability constant w.r.t. time and age (fixed at the value for age) 6 Year class $=2008$

| Fleet, | Estimated, Survivors, | $\begin{aligned} & \text { Int, } \\ & \text { s.e, } \end{aligned}$ | $\begin{aligned} & \text { Ext, } \\ & \text { s.e, } \end{aligned}$ | Var, <br> Ratio, |  | Scaled, Weights, | Estimated <br> F |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | 377., | . 261 , | . 051, | .19, | 6, | . 432 , | . 426 |
| SPRING SURVEY (shift, | 227. | . 228 , | . 276 , | 1.21, | 7, | . 549, | . 632 |
| F shrinkage mean , | 295., | 2.00, |  |  |  | . 019, | . 517 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | ---: | ---: | ---: | ---: | ---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $284 .$, | .17, | .16, | 14, | .908, | .533 |

1
Age 8 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2007$


Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $136 .$, | .17, | .13, | 16, | .748, | .272 |

Age 9 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2006$

| Fleet, |  |  | Estimated, | Int, | Ext, | Var, | N, | Scaled, | Estimate |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , |  |  | Survivors, | s.e, | s.e, | Ratio, | , | Weights, | F |
| SUMMER | SURVEY | , | 46., | . 274, | .163, | . 60, | 7, | .537, | . 374 |
| SPRING | SURVEY | (shift, | 30., | . 262 , | . 123 , | . 47 , | 8 , | . 436, | . 533 |

F shrinkage mean ,
34., $2.00,1$,
.027,
.474

Weighted prediction :


Age 11 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2004$

| Fleet, | Estimated, Survivors, | $\begin{aligned} & \text { Int, } \\ & \text { s.e, } \end{aligned}$ | $\begin{aligned} & \text { Ext, } \\ & \text { s.e, } \end{aligned}$ | Var, <br> Ratio, |  | Scaled, Weights, | $\begin{gathered} \text { Estimated } \\ \text { F } \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | 12., | . 295 , | .144, | . 49, | 7, | . 579, | . 000 |
| SPRING SURVEY (shift, | 16., | . 264 , | . 214, | . 81 , | 8, | . 421 , | . 000 |
| F shrinkage mean | 0., | 2.00, |  |  |  | . 000, | . 000 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :--- | :--- | :--- | :--- | :--- | :--- |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $14 .$, | .20, | .13, | 15, | .626, | .000 |

1
Age 12 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2003$

| Fleet, | Estimated, Survivors, | Int, | Ext, s.e, | Var, Ratio, |  | Scaled, Weights, | Estimat <br> F |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | 28., | . 267, | .157, | . 59, | 7, | .553, | 000 |
| SPRING SURVEY (shift, | 33., | . 230, | . 241, | 1.05, | 8, | . 447, | . 000 |
| F shrinkage mean | 0. | 2.00 |  |  |  | . 000, | . 000 |

Weighted prediction :
Survivors, Int, Ext, N, Var, F
$\begin{array}{ccccc}\text { at end of year, s.e, } & \text { s.e, } & \text { Ratio, } & \\ 30 ., & .18, & .14, & 15, & .772,\end{array}$

Table 2. Results from the XSA run with true age 13.

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)

|  | TableYEAR, | Catch numbers at age |  |  |  |  | Numbers*10 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |
|  | AGE |  |  |  |  |  |  |  |
|  | 1, | 0, | 0 , | 0, | 0 , | 0 , | 0, | 0, |
|  | 2, | 2002, | 4728, | 3093, | 4424, | 4110, | 2033, | 852, |
|  | 3, | 4239, | 4027, | 2686, | 2500, | 3958, | 3021, | 3230, |
|  | 4, | 858, | 2574, | 1331, | 1255, | 1280, | 2300, | 2564, |
|  | 5, | 1731, | 513, | 1066, | 855, | 662, | 630, | 1416, |
|  | 6 , | 200, | 876, | 232, | 481, | 284, | 350, | 363, |
|  | 7, | 207, | 171, | 372, | 93, | 204, | 158, | 155, |
|  | 8 , | 50, | 131, | 78, | 94, | 48, | 79, | 48, |
|  | 9, | 10, | 61, | 29, | 22, | 30, | 41, | 63, |
|  | 10, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 11, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 12, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 13, | 0 , | 0, | 0 , | 0 , | 0 , | 0 , | 0 , |
| 0 | TOTALNUM, | 9297, | 13081, | 8887, | 9724, | 10576, | 8612, | 8691, |
|  | TONSLAND, | 22415, | 32255, | 21598, | 20967, | 22215, | 21078, | 24212, |
|  | SOPCOF \%, | 100, | 101, | 91, | 94, | 96, | 98, | 113, |


|  | Table 1 | Catch | bers a | age |  |  |  | ers*10 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0 , | 0, | 0 , | 0, | 0, | 0, | 0, | 0, | 0 , | 0, |
|  | 2, | 1337, | 1609, | 1529, | 878, | 402, | 328, | 875, | 723, | 2161, | 2584, |
|  | 3, | 970, | 2690, | 3322, | 3106, | 1163, | 757, | 1176, | 3124, | 1266, | 5689, |
|  | 4, | 2080, | 860, | 2663, | 3300, | 2172, | 821, | 810, | 1590, | 1811, | 2157, |
|  | 5, | 1339, | 1706, | 945, | 1538, | 1685, | 1287, | 596, | 707, | 934, | 2211, |
|  | 6 , | 606, | 847, | 1226, | 477, | 752, | 1451, | 1021, | 384, | 563, | 813, |
|  | 7, | 197, | 309, | 452, | 713, | 244, | 510, | 596, | 312, | 452, | 295, |
|  | 8 , | 104, | 64, | 105, | 203, | 300, | 114, | 154, | 227, | 149, | 190, |
|  | 9, | 33, | 27, | 11, | 92, | 44, | 179, | 25, | 120, | 141, | 118, |
|  | 10, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 67, | 62, | 103, |
|  | 11, | 0 , | 0, | 0 , | 0 , | 0 , | 0 , | 0, | 23, | 21, | 35, |
|  | 12, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 5, | 5, | 8 , |
|  | 13, | 0 , | 0 , | 0, | 0, | 0 , | 0 , | 0 , | 2, | 2, | 3 , |
| 0 | TOTALNUM, | 6666, | 8112, | 10253, | 10307, | 6762, | 5447, | 5253, | 7284, | 7567, | 14206, |
|  | TONSLAND, | 20418, | 23562, | 29930, | 32371, | 24183, | 23010, | 18727, | 22228, | 24581, | 36775, |
|  | SOPCOF \%, | 109, | 102, | 106, | 109, | 99, | 123, | 125, | 101, | 101, | 97, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
At 14/02/2017 10:14

| Table | 1 | Catch | numbers at | age |  |  |  | bers*10 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | 0 , | 0 , | 0 , | 0, | 0 , | 0 , | 0, | 0 , | 0, | 0, |
| 2, |  | 1497, | 425, | 555, | 575, | 1129, | 646, | 1139, | 2149, | 4396, | 998, |
| 3, |  | 4158, | 3282, | 1219, | 1732, | 2263, | 4137, | 1965, | 5771, | 5234, | 9484, |
| 4, |  | 3799, | 6844, | 2643, | 1673, | 1461, | 1981, | 3073, | 2760, | 3487, | 3795, |
| 5, |  | 1380, | 3718, | 3216, | 1601, | 895, | 947, | 1286, | 2746, | 1461, | 1669, |
| 6 , |  | 1427, | 788, | 1041, | 1906, | 807, | 582, | 471, | 1204, | 912, | 770, |
| 7, |  | 617, | 1160, | 268, | 493, | 832, | 487, | 314, | 510, | 314, | 872, |
| 8, |  | 273, | 239, | 201, | 134, | 339, | 527, | 169, | 157, | 82, | 309, |
| 9, |  | 120, | 134, | 66, | 87, | 42, | 123, | 254, | 104, | 34, | 65, |
| 10, |  | 128, | 6, | 38, | 26, | 12, | 38, | 84, | 70, | 45, | 55, |


|  | 11, | 44, | 2, | 13, | 9, | 4, | 13, | 29, | 24, | 16, | 19, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 12, | 10, | 0 , | 3 , | 2 , | 1, | 3, | 7, | 6 , | 4, | 4, |
|  | 13, | 5, | 0, | 1, | 1, | 0 , | 1, | 2, | 2, | 1, | 2, |
| 0 | TOTALNUM, | 13458, | 16598, | 9264, | 8239, | 7785, | 9485, | 8793, | 15503, | 15986, | 18042, |
|  | TONSLAND, | 39799, | 34927, | 26585, | 23112, | 20513, | 22963, | 21489, | 38133, | 36979, | 39484, |
|  | SOPCOF \%, | 97, | 70, | 100, | 99, | 106, | 104, | 99, | 97, | 97, | 95, |



|  | Table 1 | Catch | numbers at | age |  |  |  | bers*10 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0, | 0, | 0, | 0, | 0 , | 0 , | 0, | 0 , | 0 , | 0, |
|  | 2, | 351, | 200, | 455, | 1246, | 2170, | 3967, | 2099, | 697, | 98, | 504, |
|  | 3, | 5164, | 1278, | 745, | 1044, | 2737, | 3812, | 7354, | 2186, | 673, | 604, |
|  | 4, | 4608, | 6710, | 1558, | 840, | 811, | 2130, | 3405, | 4696, | 1230, | 896, |
|  | 5, | 1542, | 3731, | 5140, | 1164, | 443, | 373, | 1688, | 1979, | 2051, | 1146, |
|  | 6 , | 1526, | 657, | 1529, | 2339, | 700, | 372, | 474, | 657, | 717, | 841, |
|  | 7, | 596, | 639, | 159, | 461, | 840, | 728, | 538, | 182, | 234, | 208, |
|  | 8, | 147, | 170, | 118, | 62, | 108, | 443, | 417, | 94, | 63, | 41, |
|  | 9, | 347, | 51, | 28, | 18, | 8, | 36, | 293, | 118, | 41, | 19, |
|  | 10, | 32, | 96, | 5, | 5, | 1, | 5, | 6 , | 19, | 15, | 20, |
|  | 11, | 10, | 17, | 17, | 2 , | 0 , | 1 , | 0 , | 2, | 19, | 8 , |
|  | 12, | 4, | 5, | 1, | 0 , | 0 , | 0 , | 0 , | 0 , | 1, | 4, |
|  | 13, | 2 , | 2, | 2 , | 1, | 0 , | 0, | 0 , | 0 , | 1, | 0 , |
| 0 | TOTALNUM, | 14329, | 13556, | 9757, | 7182, | 7818, | 11867, | 16274, | 10630, | 5143, | 4291, |
|  | TONSLAND, | 40422, | 34304, | 24005, | 19245, | 21833, | 28577, | 38834, | 25167, | 12840, | 10119, |
|  | SOPCOF \%, | 99, | 101, | 103, | 101, | 104, | 100, | 100, | 100, | 100, | 100, |


| Table YEAR, | 1 | Catch numbers at age |  |  | Numbers*10**-3 |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | 0, | 0 , | 0 , | 0, | 0, | 0 , | 0, | 0 , | 0, | 0 , |
| 2, |  | 1110, | 506, | 287, | 873, | 2113, | 328, | 49, | 55, | 387, | 156, |
| 3, |  | 1097, | 1226, | 761, | 2262, | 2034, | 2343, | 517, | 173, | 518, | 1035, |
| 4, |  | 469, | 723, | 783, | 861, | 861, | 1234, | 1346, | 333, | 286, | 522, |
| 5, |  | 663, | 315, | 430, | 618, | 468, | 365, | 555, | 587, | 499, | 210, |
| 6 , |  | 801, | 289, | 187, | 296, | 481, | 188, | 200, | 175, | 350, | 282, |
| 7, |  | 333, | 255, | 157, | 85, | 178, | 126, | 99, | 39, | 86, | 221, |
| 8, |  | 76, | 85, | 156, | 55, | 58, | 50, | 69, | 25, | 14, | 47, |
| 9, |  | 10, | 20, | 57, | 43, | 33, | 19, | 25, | 15, | 9 , | 23, |
| 10, |  | 1, | 3, | 18, | 14, | 25, | 2, | 12, | 3, | 0 , | 7 , |
| 11, |  | 1, | 0 , | 2, | 2, | 12, | 0 , | 4, | 1, | 0 , | 0 , |
| 12, |  | 0 , | 1, | 0 , | 0 , | 0 , | 0 , | 5, | 2, | 0 , | 0 , |
| 13, |  | 0 , | 0 , | 0 , | 0 , | 1, | 0 , | 0 , | 0 , | 0 , | 0 , |


|  |  |  |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| TOTALNUM, | 4561, | 3423, | 2838, | 5109, | 6264, | 4655, | 2881, | 1408, | 2149, | 2503, |
| TONSLAND, | 9844, | 7511, | 7315, | 9979, | 12757, | 9692, | 7204, | 4473, | 5715, | 7394, |
| SOPCOF \%, | 100, | 100, | 101, | 101, | 100, | 100, | 100, | 100, | 100, | 100, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
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| Table 2 | Catch | weights a | age (kg) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000, | . 0000, | . 0000, | . 0000 , | . 0000, | . 0000 , | . 0000, | . 0000, | . 0000 , |
| 2, | . 9800 , | . 9600, | . 8800 , | 1.0900, | . 9600 , | . 8100, | .6600, | 1.1100, | 1.0800, | . 7900 , |
| 3, | 1.7700, | 1.9300, | 1.7200, | 1.8000, | 2.2300, | 1.8000, | 1.6100, | 2.0000, | 2.2200, | 1.7900, |
| 4, | 2.7500, | 3.1300 , | 3.0700 , | 2.8500, | 2.6900, | 2.9800, | 2.5800, | 3.4100 , | 3.4400 , | 2.9800, |
| 5, | 3.5100 , | 4.0400, | 4.1200, | 3.6700 , | 3.9400 , | 3.5800 , | 3.2600 , | 3.8900, | 4.8000, | 4.2600 , |
| 6 , | 4.8000, | 4.7800, | 4.6500, | 4.8900, | 5.1400, | 3.9400 , | 4.2900, | 5.1000 , | 5.1800 , | 5.4600 , |
| 7, | 6.3200 , | 6.2500 , | 5.5000, | 5.0500 , | 6.4600, | 4.8700, | 4.9500, | 5.1000 , | 5.8800, | 6.2500 , |
| 8 , | 7.5100, | 7.0000, | 7.6700, | 7.4100, | 10.3100, | 6.4800 , | 6.4800, | 6.1200 , | 6.1400 , | 7.5100, |
| 9, | 10.3400, | 11.0100, | 10.9500, | 8.6600 , | 7.3900, | 6.3700 , | 6.9000 , | 8.6600, | 8.6300, | 7.3900, |
| 10, | 11.6500, | 10.6900, | 9.2800, | 14.3900, | 9.3400, | 10.2200, | 11.5500, | 7.5700 , | 7.6200, | 8.1700 , |
| 11, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, |
| 12, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, |
| 13, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, |
| SOPCOFAC, | 1.0905, | 1.0224, | 1.0598, | 1.0851, | . 9943 , | 1.2264, | 1.2481, | 1.0082, | 1.0094, | . 9674 |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
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| Table | Catch | s | age (kg) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000, | . 0000 , | . 0000 , | . 0000, | . 0000, | . 0000 , | . 0000, | . 0000 , | . 0000, | . 0000 , |
| 2, | . 9400, | . 8700 , | 1.1120, | . 8970, | . 9270, | 1.0800, | 1.2300, | 1.3380, | 1.1950, | . 9050 , |
| 3, | 1.7200, | 1.7900, | 1.3850, | 1.6820, | 1.4320, | 1.4700, | 1.4130, | 1.9500, | 1.8880, | 1.6580, |
| 4, | 2.8400, | 2.5300, | 2.1400, | 2.2110, | 2.2200, | 2.1800, | 2.1380, | 2.4030, | 2.9800, | 2.6260, |
| 5, | 3.7000 , | 3.6800 , | 3.1250, | 3.0520, | 3.1050 , | 3.2100 , | 3.1070, | 3.1070 , | 3.6790, | 3.4000 , |
| 6, | 5.2600, | 4.6500, | 4.3630, | 3.6420, | 3.5390, | 3.7000 , | 4.0120, | 4.1100, | 4.4700, | 3.7520 , |
| 7, | 6.4300 , | 5.3400 , | 5.9270, | 4.7190, | 4.3920, | 4.2400, | 5.4420, | 5.0200 , | 5.4880, | 4.2200, |
| 8 , | 6.3900 , | 6.2300, | 6.3480 , | 7.2720, | 6.1000 , | 4.4300, | 5.5630, | 5.6010, | 6.4660, | 4.7390, |
| 9, | 8.5500 , | 8.3800, | 8.7150, | 8.3680 , | 7.6030, | 6.6900 , | 5.2160, | 8.0130, | 6.6280, | 6.5110, |
| 10, | 13.6200, | 10.7200, | 12.2290, | 13.0420, | 9.6680, | 10.0000, | 6.7070 , | 8.0310, | 10.9810, | 10.9810, |
| 11, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, |
| 12, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, |
| 13, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, |
| SOPCOFAC, | .9681, | . 7014 , | .9976, | . 9852, | 1.0585, | 1.0397, | .9949, | . 9669, | .9683, | .9489, |


| Table 2 | Catch | weights at | age (kg) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, | 1.0990, | 1.0930, | 1.0610, | 1.0100, | . 9450 , | . 7790 , | . 9890 , | 1.1550, | 1.1940, | 1.2180, |
| 3 , | 1.4590, | 1.5170, | 1.7490, | 1.5970, | 1.3000, | 1.2710, | 1.3640, | 1.7040, | 1.8430, | 1.9860, |
| 4, | 2.0460, | 2.1600, | 2.3000, | 2.2000, | 1.9590, | 1.5700, | 1.7790, | 2.4210, | 2.6130, | 2.6220, |
| 5, | 2.9360, | 2.7660, | 2.9140, | 2.9340, | 2.5310, | 2.5240, | 2.3120, | 3.1320 , | 3.6540 , | 3.9250 , |
| 6 , | 3.7860, | 3.9080 , | 3.1090 , | 3.4680 , | 3.2730, | 3.1850, | 3.4770, | 3.7230, | 4.5840, | 5.1800, |
| 7, | 4.6990, | 5.4610, | 3.9760 , | 3.7500, | 4.6520, | 4.0860, | 4.5450, | 4.9710, | 4.9760, | 6.0790 , |
| 8 , | 5.8930, | 6.3410, | 4.8960, | 4.6820, | 4.7580, | 5.6560 , | 6.2750, | 6.1590, | 7.1460, | 6.2410, |
| 9, | 9.7000, | 8.5090, | 7.0870 , | 6.1400 , | 6.7040 , | 5.9730, | 7.6190, | 7.6140, | 8.5640, | 7.7820, |
| 10, | 8.8150, | 9.8110, | 8.2870 , | 9.1560, | 8.6890, | 8.1470 , | 9.7250, | 9.5870, | 8.7960, | 8.6270 , |
| 11, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, |
| 12, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, |
| 13, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, |
| SOPCOFAC, | .9617, | .9643, | 1.0056, | . 9776, | .9895, | 1.0584, | 1.0173, | 1.0222, | 1.0127, | 1.0085, |


| Table 2 | Catch | eights at | age (kg) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , | . 0000 , |
| 2, | 1.0160, | . 9010, | 1.0040, | 1.0500, | 1.4160, | 1.1640, | 1.0170, | . 8200, | 1.0370, | . 9860, |
| 3, | 1.7370, | 1.3410, | 1.4170, | 1.5860, | 2.1700, | 2.0760, | 1.7680, | 1.3620, | 1.1540, | 1.3730, |
| 4, | 2.7450, | 1.9580, | 1.8020, | 2.3500, | 3.1870 , | 3.0530, | 2.8050, | 2.1270, | 1.6930, | 1.7600, |
| 5, | 3.8000 , | 3.0120, | 2.2800, | 2.7740, | 3.7950, | 3.9760 , | 3.5290 , | 3.3290, | 2.3630, | 2.2930, |
| 6 , | 4.4550, | 4.1580, | 3.4780 , | 3.2140 , | 4.0480, | 4.3940, | 4.0950, | 4.0920, | 3.8300 , | 3.1380 , |
| 7, | 4.9780, | 4.4910, | 5.4330, | 5.4960, | 4.5770, | 4.8710, | 4.4750, | 4.6700, | 5.1910, | 5.2870, |
| 8 , | 5.2700, | 5.3120, | 5.8510, | 8.2760, | 8.1820, | 5.5630, | 4.6500, | 6.0000 , | 6.3260, | 8.2850 , |
| 9, | 5.5930, | 6.1720, | 7.9700, | 9.1290, | 11.8950, | 7.2770, | 6.2440, | 6.7270 , | 7.6560, | 8.7030 , |
| 10, | 7.4820, | 7.0560, | 8.8020, | 10.6520, | 13.0090, | 12.3940, | 7.4570, | 6.8100, | 9.5730, | 9.5170, |
| 11, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, |
| 12, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, |
| 13, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, |
| SOPCOFAC, | . 9922 , | 1.0078, | 1.0257, | 1.0138, | 1.0422, | 1.0028, | 1.0007, | . 9998 , | . 9986 , | 1.0018, |


| Table | Catch | s | age (kg |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000 , | .0000, | . 0000, | . 0000 , |
| 2, | . 8390, | . 9370, | 1.2090, | . 8050, | 1.0490, | . 8150, | 1.0070, | 1.0110, | 1.0990, | 1.1980, |
| 3, | 1.3040, | 1.3240, | 1.4780, | 1.4310, | 1.6420, | 1.3670, | 1.3150, | 1.5270, | 1.6530, | 1.7330, |
| 4, | 1.9880, | 1.9700, | 2.1040, | 2.2870, | 2.4000, | 2.4130, | 1.8930, | 2.5280, | 2.4660, | 2.7690, |
| 5, | 2.3860 , | 3.0760 , | 2.7140, | 2.7230, | 3.2120, | 3.4930, | 3.1020, | 3.1800 , | 3.0000 , | 3.6500 , |
| 6 , | 3.3300 , | 3.5290 , | 3.8040, | 3.4350 , | 3.6780, | 4.5250, | 4.2790, | 4.6720, | 4.1480, | 4.4030, |
| 7, | 4.6910, | 4.7100, | 4.6690, | 5.0810, | 4.7740, | 5.0760, | 5.5730, | 6.7760 , | 6.4890 , | 5.7680 , |
| 8 , | 7.6350, | 6.4640 , | 5.9150, | 6.2810, | 5.9730, | 6.6310 , | 5.8710, | 6.9660, | 9.3940, | 8.0350, |
| 9, | 9.5240, | 9.4610, | 7.2330, | 8.3120, | 7.0940, | 6.8630 , | 7.4820, | 9.0280, | 9.2360, | 10.3340, |
| 10, | 11.9900, | 9.5090, | 9.5590, | 9.9590, | 9.8000, | 10.0890, | 9.2060, | 10.3240, | 12.1200, | 11.1270, |
| 11, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, | 11.0000, |
| 12, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, | 12.0000, |
| 13, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, | 13.0000, |
| SOPCOFAC, | 1.0041, | 1.0027, | 1.0076, | 1.0075, | 1.0033, | .9997, | . 9988 , | . 9972 , | 1.0012, | . 9989 , |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1) COD_ind_Surveys_revised
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AGE

| 1, | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , | . 0000 , | 0000, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2, | . 1700 , | . 1700 , | . 1700 , | . 1700 , | . 1700 , | . 1700 , | 1700, |
| 3, | . 6400, | . 6400, | .6400, | . 6400, | . 6400, | .6400, | 6400, |
| 4, | . 8700 , | . 8700 , | . 8700 , | . 8700 , | . 8700 , | . 8700 , | 8700 |
| 5, | . 9500, | . 9500 , | . 9500, | . 9500 , | . 9500 , | . 9500 , | . 9500 |
| 6 , | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 7, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 8, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 10, | 1.0000, | 1.0000 , | 1.0000, | 1.0000 , | 1.0000, | 1.0000, | 1.0000, |
| 11, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 12, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 13, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000 |


| Table | 5 | Proportion mature at age |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, |  | . 1700 , | . 1700 , | . 1700 , | . 1700 , | . 1700 , | . 1700 , | . 1700 , | . 1700 , | . 1700 , | . 1700 , |
| 3, |  | .6400, | . 6400 , | . 6400, | . 6400, | . 6400, | . 6400, | . 6400, | . 6400, | .6400, | .6400, |
| 4, |  | . 8700 , | . 8700 , | . 8700, | . 8700 , | . 8700 , | . 8700 , | . 8700 , | . 8700 , | . 8700 , | . 8700 , |
| 5, |  | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500 , | .9500, | . 9500 , |
| 6 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000 , | 1.0000, | 1.0000, |
| 7, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 8, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 10, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 11, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 12, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 13, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |


| Table | 5 | Proportion mature at age |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, |  | . 1700 , | .1700, | .1700, | . 1700, | .1700, | .1700, | . 1700 , | . 0300, | . 0700 , | . 0000, |
| 3 , |  | .6400, | .6400, | . 6400, | . 6400, | .6400, | . 6400, | .6400, | . 7100, | . 9600, | . 5000, |
| 4, |  | . 8700 , | . 8700 , | . 8700, | . 8700 , | . 8700, | . 8700, | . 8700 , | . 9300 , | . 9800, | . 9600, |
| 5, |  | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500, | . 9500 , | . 9500 , | . 9400 , | . 9700 , | . 9600 , |
| 6 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 7, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 8 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 10, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 11, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 12, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 13, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000 |


| Table | 5 | Propo | n mat | at age |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000, | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, |  | . 0000 , | . 0000 , | . 0600 , | . 0500 , | . 0000 , | . 0000 , | . 0600 , | . 0300 , | . 0500 , | . 0900 , |
| 3, |  | . 3800 , | .6700, | . 7200 , | . 5400, | . 6800, | . 7200 , | . 5000, | . 7300 , | . 3300, | . 3500 , |
| 4, |  | . 9300 , | . 9100, | . 9000 , | . 9800 , | . 9000 , | . 8600 , | . 8200, | . 7800 , | . 8800 , | . 3300 , |
| 5, |  | 1.0000, | 1.0000, | . 9700, | 1.0000, | . 9900 , | 1.0000, | . 9800, | . 9100, | . 9600, | . 6600, |
| 6 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | . 9600 , | 1.0000, | 1.0000, | . 9900, | 1.0000, | . 9700 , |
| 7, |  | . 9600 , | 1.0000, | 1.0000, | 1.0000, | . 9800 , | 1.0000, | 1.0000, | 1.0000, | . 9600 , | 1.0000, |
| 8 , |  | .9400, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 10, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 11, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |

12, $1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000$, $13,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000,1.0000$,

| Table | 5 | Propo | $n$ mat | at age |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000 , | . 00000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, |  | . 0400 , | . 0000, | . 0000 , | . 0200, | . 0200, | . 0700, | . 0400 , | . 0000 , | . 0000 , | . 0500 , |
| 3, |  | . 4300, | .6400, | .6200, | . 4300, | . 3900 , | .4700, | . 3700 , | . 2900 , | . 5100, | . 6600, |
| 4, |  | . 7400 , | . 9100, | . 9000 , | . 8800 , | . 6900, | . 8600 , | . 7600 , | . 7900 , | . 7800 , | . 9000 , |
| 5, |  | . 8500, | .9700, | . 9900, | . 9800, | . 9200, | .9400, | . 9700 , | . 8800, | . 9200, | . 9300, |
| 6, |  | . 9400 , | 1.0000, | . 9900, | 1.0000, | . 9900 , | 1.0000, | . 9300, | . 9800, | . 8900, | . 9800 , |
| 7, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | . 9700 , | 1.0000, | . 8700 , | . 9200, |
| 8, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000 , |
| 10, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 11, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 12, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 13, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000 |


| Table | 5 | Proportion mature at age |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000, | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , |
| 2, |  | . 0400 , | . 0000 , | . 1000 , | . 0900 , | . 0800 , | . 0600 , | . 0000 , | . 2400, | . 2400 , | . 2800, |
| 3 , |  | . 5900, | . 4700, | . 7800 , | .6100, | .6100, | . 5100, | . 6300, | . 8200, | . 7300 , | . 4800 , |
| 4, |  | . 8000 , | . 7800 , | . 9100 , | . 8100, | . 7700 , | . 6900, | . 8500 , | . 9500 , | . 9800 , | . 7000 , |
| 5, |  | . 9900 , | . 9100 , | . 9000 , | . 9600 , | . 9400 , | . 8400 , | . 9400 , | .9800, | 1.0000, | . 9500 , |
| 6, |  | . 9900 , | . 9900, | . 9500 , | . 9400 , | . 9700 , | . 9300 , | . 9700 , | 1.0000, | 1.0000, | . 9700 , |
| 7, |  | 1.0000, | . 9700, | 1.0000, | .9600, | 1.0000, | . 9800 , | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 8 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 10, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | . 8300 , | 1.0000, | 1.0000, | 1.0000, |
| 11, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 12, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 13, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD_ind_Surveys_revised
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Terminal Fs derived using XSA (With F shrinkage)

|  | $\begin{aligned} & \text { Table } 8 \\ & \text { YEAR, } \end{aligned}$ | $\begin{aligned} & \text { Fishing } \\ & \text { 1959, } \end{aligned}$ | $\begin{gathered} \text { mortalit } \\ 1960, \end{gathered}$ | $\begin{gathered} \text { Ey (F) at } \\ 1961, \end{gathered}$ | age 1962, | 1963, | 1964, | 1965, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| AGE |  |  |  |  |  |  |  |  |
|  | 1, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
|  | 2, | . 1856 , | . 4637 , | . 3373 , | . 2782, | . 2575 , | . 1144 , | 1155, |
|  | 3, | . 5028, | . 6952 , | . 5265, | . 5041 , | . 4316, | . 3060 , | . 2683, |
|  | 4, | . 4890, | .6627, | . 5198, | . 5034, | . 5276, | . 4830, | . 4638 , |
|  | 5, | . 6571, | .6173, | . 6453, | . 7655 , | . 5474 , | . 5407, | . 6291, |
|  | 6 , | . 4366 , | . 8541, | .6380, | . 6923, | . 6284, | .6361, | . 7027 , |
|  | 7, | . 7023 , | . 8480 , | 1.2034, | . 5746, | . 7280 , | . 9021, | . 6557, |
|  | 8, | . 5135, | 1.5472, | 1.3617, | 1.2713, | .6722, | . 7064 , | . 7843 , |
|  | 9, | 15.2181, | 17.0264, | 16.2828, | 16.0066, | 16.3167, | 16.6291, | 17.0586, |
|  | 10, | .0000, | . 0000 , | . 0000 , | . 00000 , | . 0000 , | . 0000 , | . 0000 , |
|  | 11, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
|  | 12, | . 0000, | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , | . 0000 , |
|  | 13, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 0 FBAR | 3-7, | . 5576, | . 7355 , | . 7066 , | .6080, | . 5726, | . 5736, | 5439 |


|  |  | $\begin{aligned} & \text { Table } 8 \\ & \text { YEAR, } \end{aligned}$ | $\begin{aligned} & \text { Fishing } \\ & \text { 1966, } \end{aligned}$ | $\begin{gathered} \text { mortalit } \\ 1967, \end{gathered}$ | $\begin{array}{ll} \text { ty }(F) \text { at } \\ 1968, \end{array}$ | $\begin{aligned} & \text { age } \\ & 1969, \end{aligned}$ | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| AGE |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 1, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
|  |  | 2, | . 0870 , | . 0812, | . 1026 , | . 1173, | . 0544 , | . 0315 , | . 0472 , | . 0648 , | . 0820 , | . 0803 , |
|  |  | 3 , | . 1867 , | . 2527 , | . 2400 , | . 3121 , | . 2248 , | . 1376 , | . 1508, | . 2366 , | . 1545 , | . 3213 , |
|  |  | 4, | . 2771 , | . 2513, | . 4273, | . 3992 , | . 3752 , | . 2451 , | . 2141, | . 3131 , | . 2095 , | .4273, |
|  |  | 5, | . 4722 , | . 3854 , | . 4837 , | . 4716 , | . 3652 , | . 3998 , | . 2827 , | . 2937, | . 3062 , | . 4269 , |
|  |  | 6, | .6123, | . 6279, | . 5323, | . 4837 , | . 4461 , | . 6231, | . 6468 , | . 2972, | . 4035 , | . 4795 , |
|  |  | 7, | 1.1259, | . 7466 , | . 8427 , | . 6918, | . 4921 , | . 6268 , | . 5688, | . 4146, | . 6883, | . 3829 , |
|  |  | 8, | 1.4240, | 1.7515, | .6174, | 1.2930, | . 7184 , | . 4506 , | . 3878 , | . 4407 , | . 3562 , | . 7103 , |
|  |  | 9, | 16.4120, | 16.2113, | 15.3134, | 2.4537, | 1.2037, | 1.4529, | . 1654 , | . 5994, | . 5449 , | . 5343, |
|  |  | 10, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 8890 , | . 7300 , | 1.0394, |
|  |  | 11, | . 0000 , | . 00000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 9885 , | . 7951 , | 1.3521, |
|  |  | 12, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 6596, | . 5943, | . 8328 , |
|  |  | 13, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 7223, | . 6094 , | . 9034, |
| 0 | FBAR | 3-7, | . 5348 , | . 4528 , | . 5052 , | . 4717 , | . 3807 , | . 4065 , | . 3726 , | . 3110, | . 3524 , | . 4076 , |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
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Terminal Fs derived using XSA (With F shrinkage)

|  |  | Table | 8 | Fishing | mortality | (F) at |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | YEAR, |  | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 1, |  | . 0000, | . 0000, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000, |
|  |  | 2, |  | . 0932 , | . 0474 , | . 0588 , | . 0435 , | . 0551 , | . 0525 , | . 0586 , | . 0993, | . 1074 , | . 0658 , |
|  |  | 3, |  | .1795, | . 3033 , | .1863, | . 2625 , | . 2403 , | . 2927 , | . 2236, | . 4678 , | . 3717 , | . 3551 , |
|  |  | 4, |  | . 3697 , | .5028, | . 4284, | . 4206 , | . 3700 , | . 3432 , | . 3689 , | . 5620, | . 5803, | . 5086, |
|  |  | 5, |  | .5388, | . 7651 , | . 4700, | . 5037, | . 4181, | . 4376 , | . 3925 , | . 6674, | . 6687, | .6158, |
|  |  | 6 , |  | . 5443 , | .6890, | . 4993, | . 5698, | . 5160, | . 5314 , | . 4058 , | . 7977 , | . 4862 , | . 9483 , |
|  |  | 7, |  | . 8446 , | 1.2667, | . 5310, | . 4693, | . 5267, | . 6888, | . 6202, | 1.0843, | . 4923, | 1.3136, |
|  |  | 8 , |  | .7495, | . 9884 , | . 7754 , | . 5584, | . 6990, | . 7687 , | . 5450, | .7439, | . 4851 , | 1.4460, |
|  |  | 9, |  | 1.5997, | 1.1056, | . 8416 , | . 9657, | . 3373 , | . 5949, | 1.1429, | . 7867 , | . 3454 , | . 9276 , |
|  |  | 10, |  | 2.7448, | . 2762 , | 1.2039, | 1.0084, | . 3203 , | . 5859, | 1.1331, | 1.2691, | 1.0000, | 1.6874, |
|  |  | 11, |  | 3.0697 , | . 3256 , | 1.8440, | 1.1236, | . 3963 , | . 6922, | 1.3566, | 1.3267, | 1.2520, | 2.1722, |
|  |  | 12, |  | 15.8181, | . 0000 , | 1.2210, | 14.2087, | . 3309 , | . 5896, | 1.0684, | 1.3038, | . 8292, | 1.4378, |
|  |  | 13, |  | 4.8565, | . 0000 , | 1.1916, | 3.6223, | . 0000 , | . 6521, | 1.0614, | 1.0989, | . 7902 , | 1.5547, |
| 0 | FBAR | 3- |  | . 4954 , | . 7054 , | . 4230, | . 4452 , | . 4142 , | . 4587, | . 4022 , | . 7158 , | . 5198, | . 7483 , |


|  |  | $\begin{aligned} & \text { Table } 8 \\ & \text { YEAR, } \end{aligned}$ | $\begin{aligned} & \text { Fishing } \\ & \text { 1986, } \end{aligned}$ | $\begin{aligned} & \text { mortality } \\ & 1987, \end{aligned}$ | $\begin{aligned} & y \text { (F) at } \\ & 1988, \end{aligned}$ | $\begin{aligned} & \text { age } \\ & 1989, \end{aligned}$ | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | AGE |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 1, | . 0000, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000, |
|  |  | 2, | . 0248, | . 0283, | . 0655 , | .1686, | . 0772 , | . 0322 , | . 0201 , | . 0133, | . 0255 , | . 0700 , |
|  |  | 3 , | . 3548 , | . 2221, | . 3419 , | . 4301 , | . 3425 , | . 1974 , | . 0995 , | . 1021 , | . 1140 , | .1618, |
|  |  | 4, | . 6248, | . 4760 , | . 5688, | . 7196 , | . 6143, | . 4640 , | . 3221 , | . 1856 , | . 1910, | . 4712, |
|  |  | 5, | . 7058 , | . 4881 , | . 5503, | . 7750 , | . 7114 , | . 5596 , | . 3643 , | . 2499 , | . 2481 , | . 2810, |
|  |  | 6 , | . 8324 , | . 5596 , | . 7828 , | . 9667 , | . 7401 , | . 5862 , | . 5648, | . 2155, | . 2172, | . 3576 , |
|  |  | 7, | . 8963, | . 4972 , | . 8097, | 1.0905, | .8627, | . 6231, | .5519, | . 3621 , | .1709, | . 3281 , |
|  |  | 8, | . 8209, | . 7144 , | . 8916 , | 1.1432, | 1.2519, | . 7383, | . 5012, | . 2548 , | . 2440 , | . 2567 , |
|  |  | 9, | . 9240 , | 1.3079, | . 9628, | 1.0167, | . 9288 , | .7939, | . 5628, | . 4004 , | . 2837 , | . 4792 , |
|  |  | 10, | 1.3731, | 1.2402, | 1.6716, | . 4456 , | 1.0100, | . 8840 , | 1.0284, | . 7402 , | . 3577 , | . 8974, |
|  |  | 11, | 2.1245, | 1.7770, 1 | 15.1073, | . 9698 , | 1.1573, | 1.2402, | 2.0215, | . 8496 , | . 3785 , | . 8508, |
|  |  | 12, | 14.2087, | 13.5155, 1 | 13.5155, | . 0000 , | 13.5155, | . 5871 , | 14.2087, | 13.5155, | . 3182, | . 5472, |
|  |  | 13, | 3.9428, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | 3.7149, | . 0000 , | . 0000 , | .6116, |
| 0 | FBAR | 3-7, | . 6828, | . 4486 , | .6107, | . 7964 , | . 6542, | .4861, | . 3805 , | . 2230 , | .1883, | . 3200 , |



|  |  | 5, | .8314, | . 8350, | .6428, | . 3250 , | . 2470 , | . 3142 , | . 8463 , | .8709, | . 7366 , | . 4869 , |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 6 , | .9105, | 1.1231, | 1.0589, | . 6955, | . 3314 , | . 3388 , | . 8511 , | 1.0016, | . 9538, | . 7882 , |
|  |  | 7, | 1.1180, | 1.4262, | .9497, | 1.1826, | .5811, | . 6914, | 1.2456, | . 9929 , | 1.3841, | . 8332, |
|  |  | 8, | . 8937, | 1.2633, | 1.2495, | 1.4058, | 1.0427, | . 7085 , | 1.1948, | . 7512 , | 1.2672, | 1.0219, |
|  |  | 9, | 1.2335, | . 9466 , | .7141, | .6230, | . 6641 , | 1.3779, | 1.7884, | 1.5893, | . 9074 , | 2.8067, |
|  |  | 10, | . 7899 , | 1.7269, | . 2093, | . 2579, | . 0605 , | 1.2716, | . 9262 , | . 5015, | . 9302, | 2.1248, |
|  |  | 11, | .7383, | 1.5175, | 16.5752, | . 1207, | . 0000 , | . 0792, | . 0000 , | . 9697 , | 1.5870, | 74.4876, |
|  |  | 12, | . 7902 , | 1.1001, | . 2955 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | 8.8322, | 26.2982, |
|  |  | 13, | . 8991 , | 1.3285, | 3.8752, | . 5446, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | 2.7376, | . 0000 , |
| 0 | FBAR | 3- | .7010, | . 7880 , | . 6172, | . 5579, | . 3762 , | .4307, | . 8064 , | . 7721, | . 7108 , | .5578, |



Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
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Terminal Fs derived using XSA (With F shrinkage)

| Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |
| AGE |  |  |  |  |  |  |  |
| 1, | 17200, | 14584, | 24588, | 24442, | 25377, | 10542, | 21663, |
| 2, | 13062, | 14082, | 11941, | 20131, | 20012, | 20777, | 8631, |
| 3 , | 11856, | 8883, | 7252, | 6978, | 12479, | 12665, | 15171, |
| 4, | 2452, | 5871, | 3629, | 3507, | 3451, | 6635, | 7636, |
| 5, | 3972, | 1231, | 2478, | 1767, | 1735, | 1667, | 3351, |
| 6 , | 625, | 1686, | 544, | 1064, | 673, | 822, | 795, |
| 7, | 453, | 331, | 587, | 235, | 436, | 294, | 356 , |
| 8, | 138, | 184, | 116, | 144, | 108, | 172, | 98, |
| 9, | 11, | 67 , | 32, | 24, | 33, | 45, | 70, |
| 10, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
| 11, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
| 12, | 0, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
| 13, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
| TOTAL, | 49768, | 46919, | 51166, | 58292, | 64304, | 53620, | 57771, |




|  | Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 12429, | 10832, | 19461, | 4485, | 8178, | 13897, | 12223, | 30740, | 52219, | 16036, |
|  | 2, | 9463, | 10176, | 8868, | 15933, | 3672, | 6696, | 11378, | 10007, | 25168, | 42753, |
|  | 3, | 13269, | 7558, | 8099, | 6800, | 11021, | 2783, | 5308, | 9130, | 8085, | 20087, |
|  | 4, | 20128, | 7619, | 4955, | 4711, | 3621, | 6406, | 1870, | 3934, | 6749, | 5906, |
|  | 5, | 5180, | 8823, | 3875, | 2297, | 1878, | 1604, | 3298, | 1110, | 2676, | 4565, |
|  | 6 , | 1774, | 2094, | 4434, | 1830, | 866, | 755, | 750, | 1876, | 708, | 1709, |
|  | 7, | 441, | 632, | 980, | 1660, | 570, | 338, | 344, | 349, | 1238, | 466, |
|  | 8 , | 290, | 147, | 315, | 357, | 457, | 197, | 149, | 162, | 199, | 854, |
|  | 9, | 86, | 105, | 59, | 106, | 93, | 107, | 77 , | 74, | 103, | 128, |
|  | 10, | 38, | 28, | 23, | 18, | 31, | 30, | 40, | 36, | 40, | 63, |
|  | 11, | 11, | 8, | 7, | 4, | 10, | 9 , | 10, | 12, | 14, | 23, |
|  | 12, | 2, | 1, | 1, | 0 , | 1, | 2, | 2, | 1, | 4, | 8 , |
|  | 13, | 1, | 0 , | 0, | 0 , | 0 , | 0 , | 1, | 0 , | 0 , | 2, |
| 0 | TOTAL, | 63114, | 48022, | 51077, | 38200, | 30398, | 32825, | 35450, | 57431, | 97202, | 92602, |


| Table 10 | Stock number at age (start of year) |  |  |  | Numbers*10**-3 |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 8169, | 7371, | 17755, | 24442, | 36614, | 16227, | 7423, | 4322, | 7286, | 9053, |
| 2, | 13129, | 6688, | 6035, | 14537, | 20012, | 29977, | 13285, | 6077, | 3539, | 5965, |
| 3, | 32637, | 10432, | 5295, | 4529, | 10774, | 14421, | 20953, | 8978, | 4345, | 2809, |
| 4, | 13988, | 22048, | 7384, | 3661, | 2763, | 6345, | 8357, | 10501, | 5372, | 2948, |
| 5, | 3019, | 7283, | 11980, | 4636, | 2237, | 1529, | 3267 , | 3762, | 4348, | 3286, |
| 6 , | 2822, | 1076, | 2587, | 5158, | 2742, | 1431, | 914, | 1148, | 1289, | 1704, |
| 7, | 979, | 929, | 287, | 735, | 2106, | 1612, | 835, | 320, | 345, | 407, |
| 8, | 275, | 262, | 183, | 91, | 184, | 965, | 661, | 197, | 97, | 71, |
| 9, | 541, | 92, | 61, | 43, | 18, | 53, | 389, | 164, | 76, | 22, |
| 10, | 65, | 129, | 29, | 24, | 19, | 8, | 11, | 53, | 27, | 25, |
| 11, | 21, | 24, | 19, | 19, | 15, | 15, | 2, | 4, | 26, | 9, |
| 12, | 8 , | 8 , | 4, | 0 , | 14, | 13, | 11, | 1, | 1, | 4, |
| 13, | 4, | 3, | 2, | 3, | 0 , | 12, | 10, | 9, | 1, | 0 , |
| TOTAL, | 75656, | 56346, | 51621, | 57877, | 77500, | 72604, | 56119, | 35535, | 26753, | 26303, |


| Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |  |  |  | 2016, | GMST 59-** | AMST 59-** |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |  |  |  |
| ${ }_{\text {age }}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1, | 6105, | 7899, | 10093, | 13829, | 5253, | 2302, | 3534, | 9373, | 2919, | 4127, | 0 , | 14508, | 17895, |
| 2, | 7412, | 4998, | 6467, | 8263, | 11322, | 4301, | 1885, | 2893, | 7674, | 2390, | 3379, | 11993, | 14749, |
| 3, | 4428, | 5064, | 3634, | 5035, | 5976, | 7358, | 3225, | 1499, | 2319, | 5932, | 1816, | 9145, | 11073, |
| 4, | 1753, | 2632, | 3037, | 2287, | 2076, | 3052, | 3904, | 2172, | 1071, | 1430, | 3921, | 5656, | 6796, |
| 5, | 1603, | 1011, | 1501, | 1778, | 1093, | 920, | 1382, | 1979, | 1477, | 618 , | 699, | 3070, | 3661, |
| 6 , | 1653, | 713, | 543, | 840, | 896, | 472, | 423, | 629, | 1089, | 758, | 316, | 1470, | 1768, |
| 7, | 634, | 629 , | 322, | 275, | 420, | 299, | 216, | 166, | 357, | 575, | 365, | 645 , | 789, |
| 8, | 145, | 218, | 284, | 122, | 148, | 183, | 130, | 87, | 100, | 214, | 271, | 250, | 317, |
| 9, | 21, | 50, | 102, | 91, | 50, | 69, | 104, | 44 , | 49, | 69, | 133, | 87, | 125, |
| 10, | 1, | 8, | 23, | 32, | 36, | 11, | 39, | 63, | 23, | 32, | 36, | 1, | 42, |
| 11, | 2, | 0 , | 4, | 2, | 13, | 7, | 7 , | 21, | 49, | 19, | 20, | 0, | 13, |
| 12, | 0 , | 1, | 0, | 1, | 0 , | 0, | 6 , | 2, | 17, | 40, | 15, | 0, | 4, |
| 13, | 0 , | 0 , | 0, | 0 , | 1, | 0, | 0 , | 0 , | 0, | 14, | 33, | 0 , | 2, |
| TOTAL, | 23757, | 23223, | 26009, | 32555, | 27285, | 18973, | 14856, | 18929, | 17142, | 16218, | 11002, |  |  |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)


| Table 11 | Spawning | stock | er at | (sp | ng tim | Numbers*10**-3 |  |  | 1974, | 1975, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0, | 0 , | 0 , | 0 , | 0 , | 0, | 0 , | 0, | 0 , |
| 2, | 3015, | 3875, | 2946, | 1490, | 1427, | 1989, | 3567, | 2165, | 5157, | 6294, |
| 3, | 4029, | 8519, | 11011, | 8194, | 4086, | 4166, | 5942, | 10489, | 6255, | 14643, |
| 4, | 8264, | 3721, | 7364, | 9640, | 6675, | 3632, | 4041, | 5687, | 9214, | 5965, |
| 5, | 3735, | 5600 , | 2587, | 4294, | 5782, | 4100, | 2541, | 2917, | 3718, | 6681, |
| 6 , | 1463, | 2008, | 3283, | 1375, | 2309, | 3458, | 2369, | 1651, | 1874, | 2359, |
| 7, | 322, | 649 , | 877, | 1578, | 694, | 1210, | 1518, | 1016, | 1004, | 1025, |
| 8, | 151, | 86 , | 252, | 309, | 647, | 347, | 529, | 704, | 549, | 413, |
| 9, | 36 , | 30, | 12, | 111, | 69, | 258, | 181, | 294, | 371, | 315, |
| 10, | 0 , | 0 , | 0 , | 0 , | 8 , | 17, | 49, | 126, | 132, | 176, |
| 11, | 0 , | 0 , | 0, | 0 , | 0 , | 6 , | 14, | 40, | 42, | 52, |
| 12, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 5, | 11, | 12, | 16, |
| 13, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 4, | 5, | 6 , |

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Terminal Fs derived using XSA (With F shrinkage)
Table 11 Spawning stock number at age (spawning time) Numbers*10**-3
YEAR, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985,

| 1, | 0 , | 0 , | 0 , | 0, | 0 , | 0, | 0, | 0 , | 0 , | 0 , |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2, | 3160, | 1725, | 1826, | 2539, | 3953, | 2372, | 3758, | 754, | 3338, | 0, |
| 3, | 17902, | 8874, | 5072, | 5307, | 7492, | 11531, | 6936, | 12119, | 17890, | 17533, |


| 4, | 11818, | 16651, | 7293, | 4685, | 4542, | 6557, | 9577, | 6598, | 8578, | 10100, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 5, | 3478, | 7300, | 9003, | 4248, | 2750, | 2805, | 4159, | 5858, | 3212, | 3851, |
| 6, | 3757, | 1749, | 2927, | 4849, | 2212, | 1560, | 1561, | 2421, | 2618, | 1389, |
| 7, | 1196, | 1785, | 719, | 1455, | 2246, | 1081, | 751, | 852, | 893, | 1318, |
| 8, | 572, | 421, | 412, | 346, | 745, | 1086, | 445, | 331, | 236, | 447, |
| 9, | 166, | 221, | 128, | 155, | 162, | 303, | 412, | 211, | 129, | 119, |
| 10, | 151, | 27, | 60 , | 45, | 48, | 95, | 137, | 108, | 79, | 75, |
| 11, | 51, | 8 , | 17, | 15, | 14, | 29, | 43, | 36, | 25, | 24, |
| 12, | 11, | 2, | 5, | 2 , | 4, | 7, | 12, | 9, | 8, | 6, |
| 13, | 6 , | 0 , | 2, | 1, | 0 , | 2, | 3 , | 3 , | 2, | 3, |


| Table 11 | $\begin{aligned} & \text { Spawning stock number at age (spawning time) } \\ & 1986,1987, \quad 1988, \quad 1989, \quad 1990, \end{aligned}$ |  |  |  |  | Numbers*10**-3 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  |  |  |  |  | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0, | 0 , | 0 , | 0, |
| 2, | 0, | 0, | 532, | 797, | 0 , | 0 , | 683, | 300, | 1258, | 3848, |
| 3, | 5042, | 5064, | 5831, | 3672, | 7494, | 2004, | 2654, | 6665, | 2668, | 7031, |
| 4, | 18719, | 6933, | 4460, | 4617, | 3259, | 5509, | 1534, | 3069, | 5939, | 1949, |
| 5, | 5180, | 8823, | 3759, | 2297, | 1859, | 1604, | 3232, | 1010, | 2569, | 3013, |
| 6 , | 1774, | 2094, | 4434, | 1830, | 832, | 755, | 750, | 1857, | 708, | 1658, |
| 7, | 423, | 632, | 980, | 1660, | 558, | 338, | 344, | 349, | 1188, | 466, |
| 8, | 273, | 147, | 315, | 357, | 457, | 197, | 149, | 162, | 199, | 854, |
| 9, | 86 , | 105, | 59, | 106, | 93, | 107, | 77, | 74, | 103, | 128, |
| 10, | 38, | 28, | 23, | 18, | 31, | 30, | 40, | 36, | 40, | 63, |
| 11, | 11, | 8, | 7, | 4, | 10, | 9 , | 10, | 12, | 14, | 23, |
| 12, | 2, | 1, | 1, | 0 , | 1, | 2, | 2, | 1, | 4, | 8 , |
| 13, | 1, | 0 , | 0 , | 0 , | 0 , | 0 , | 1, | 0 , | 0 , | 2, |


| $\begin{aligned} & \text { Table } 11 \\ & \text { YEAR, } \end{aligned}$ | Spawning stock number at age (spawning time) |  |  |  |  | Numbers*10**-3 |  |  | 2004, | 2005, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0 , | 0 , | 0 , | 0, | 0, | 0 , | 0 , | 0 , | 0 , |
| 2, | 525, | 0, | 0, | 291, | 400, | 2098, | 531, | 0 , | 0 , | 298, |
| 3 , | 14034, | 6676, | 3283, | 1948, | 4202, | 6778, | 7753, | 2604, | 2216, | 1854, |
| 4, | 10351, | 20064, | 6646, | 3221, | 1907, | 5456, | 6352, | 8296, | 4190, | 2654, |
| 5, | 2566, | 7065, | 11861, | 4543, | 2058, | 1437, | 3169, | 3310, | 4001, | 3056, |
| 6 , | 2652, | 1076, | 2561, | 5158, | 2715, | 1431, | 850, | 1125, | 1147, | 1670, |
| 7, | 979, | 929, | 287, | 735, | 2106, | 1612, | 810, | 320, | 300 , | 374, |
| 8, | 275, | 262, | 183, | 91, | 184, | 965, | 661, | 197, | 97, | 71, |
| 9, | 541, | 92, | 61, | 43, | 18, | 53, | 389, | 164, | 76, | 22, |
| 10, | 65, | 129, | 29, | 24, | 19, | 8 , | 11, | 53, | 27, | 25, |
| 11, | 21, | 24, | 19, | 19, | 15, | 15, | 2, | 4, | 26, | 9 , |
| 12, | 8 , | 8 , | 4, | 0 , | 14, | 13, | 11, | 1, | 1, | 4, |
| 13, | 4, | 3, | 2, | 3 , | 0 , | 12, | 10, | 9, | 1, | 0 , |


| Table 11 | Spawning | stock | er at | (sp | ng tim |  | ers*10 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0 , | 0 , | 0 , | 0 , | 0, | 0 , | 0, | 0, | 0, |
| 2, | 296, | 0, | 647, | 744, | 906, | 258, | 0, | 694, | 1842, | 669, |
| 3 , | 2612, | 2380, | 2835, | 3071, | 3645, | 3753, | 2032, | 1229, | 1693, | 2848, |
| 4, | 1402, | 2053, | 2763, | 1852, | 1598, | 2106, | 3319, | 2064, | 1049, | 1001, |
| 5, | 1587, | 920, | 1351, | 1707, | 1028, | 773, | 1299, | 1939, | 1477, | 587 , |
| 6 , | 1637, | 706, | 516, | 789, | 869, | 439, | 411, | 629, | 1089, | 735, |
| 7, | 634, | 610, | 322, | 264, | 420, | 293, | 216, | 166, | 357, | 575, |
| 8 , | 145, | 218, | 284, | 122, | 148, | 183, | 130, | 87, | 100, | 214, |
| 9, | 21, | 50, | 102, | 91, | 50, | 69, | 104, | 44, | 49, | 69, |
| 10, | 1, | 8 , | 23, | 32, | 36, | 11, | 33, | 63, | 23, | 32, |
| 11, | 2, | 0 , | 4, | 2, | 13, | 7, | 7, | 21, | 49, | 19, |
| 12, | 0 , | 1, | 0 , | 1, | 0 , | 0 , | 6, | 2, | 17, | 40, |
| 13, | 0 , | 0 , | 0 , | 0 , | 1, | 0 , | 0 , | 0 , | 0 , | 14, |

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Terminal Fs derived using XSA (With F shrinkage)


| Table 12 | Stock biomass at age (start of year) |  |  |  |  | Tonnes |  |  | 1974, | 1975, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0, | 0 , | 0 , | 0, | 0 , | 0, | 0 , | 0, | 0, |
| 2, | 17381, | 21881, | 15249, | 9557, | 8060, | 9479, | 13849, | 14137, | 32760, | 29247, |
| 3, | 11143, | 25691, | 29593, | 23046, | 14236, | 11718, | 14948, | 32777, | 21696, | 40954, |
| 4, | 26121, | 13386, | 25986, | 31580, | 20638, | 12439, | 11984, | 22292, | 36433, | 20430, |
| 5, | 13801, | 23815, | 11220, | 16590, | 23979, | 15452, | 8720, | 11943, | 18785, | 29959, |
| 6 , | 7021, | 9596, | 15264, | 6722, | 11870, | 13626, | 10164, | 8418, | 9707, | 12880, |
| 7, | 2037, | 4057 , | 4825, | 7970, | 4482, | 5894, | 7516, | 5181, | 5903, | 6405, |
| 8, | 1137, | 599, | 1932, | 2291, | 6670, | 2251, | 3431, | 4308, | 3374, | 3101, |
| 9, | 377, | 329, | 133, | 963, | 513, | 1645, | 1250, | 2547, | 3201, | 2328, |
| 10, | 0 , | 0 , | 0 , | 0 , | 73, | 174, | 571, | 952, | 1008, | 1439, |
| 11, | 0, | 0 , | 0 , | 0 , | 0 , | 71, | 154, | 445, | 465, | 574, |
| 12, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 63, | 137, | 148, | 188, |
| 13, | 0, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 56, | 63, | 72, |
| TOTALBIO, | 79018, | 99354, | 104202, | 98719, | 90523, | 72749, | 72651, | 103193, | 133543, | 147577, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
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Terminal Fs derived using XSA (With F shrinkage)
Table 12 Stock biomass at age (start of year) Tonnes
YEAR, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985,

| YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0 , | 0, | 0, | 0, | 0, | 0, | 0, | 0, | 0, |
| 2, | 10400, | 11123, | 9409, | 16092, | 3470, | 5216, | 11253, | 11558, | 30050, | 52073, |
| 3, | 19359, | 11465, | 14165, | 10860, | 14327, | 3537, | 7240, | 15558, | 14900, | 39893, |
| 4, | 41183, | 16456, | 11397, | 10364, | 7094, | 10058, | 3327, | 9525, | 17636, | 15486, |
| 5, | 15209, | 24404, | 11292, | 6740, | 4753, | 4048, | 7624, | 3475, | 9776, | 17917, |
| 6 , | 6717, | 8183, | 13785, | 6346, | 2836, | 2404, | 2609, | 6983, | 3244, | 8854, |
| 7, | 2070, | 3451, | 3895, | 6223, | 2651, | 1383, | 1563, | 1736, | 6160, | 2834, |
| 8 , | 1710, | 933, | 1541, | 1671, | 2172, | 1113, | 932, | 999, | 1423, | 5332, |
| 9, | 835, | 889, | 418, | 649, | 625, | 639, | 587, | 561, | 881, | 994, |
| 10, | 339, | 275, | 192, | 169, | 272, | 245, | 385, | 344, | 356, | 547, |
| 11, | 124, | 88, | 73, | 39, | 106, | 103, | 112, | 127, | 154, | 255, |
| 12, | 27, | 13, | 13, | 0 , | 13, | 30, | 27, | 13, | 49, | 94, |
| 13, | 15, | 0 , | 0 , | 0, | 0 , | 0, | 15, | 0 , | 0 , | 31, |
| TOTALBIO, | 97988, | 77281, | 66181, | 59153, | 38320, | 28776, | 35675, | 50880, | 84629 , | 144311, |


| Table 12 | Stock biomass at age (start of year) |  |  |  |  | Tonnes |  |  | 2004, | 2005, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0 , | 0, | 0 , | 0 , | 0, | 0, | 0, | 0, | 0, |
| 2, | 13339, | 6026, | 6059, | 15263, | 28337, | 34893, | 13511, | 4983, | 3670, | 5881, |
| 3, | 56691, | 13989, | 7502, | 7183, | 23380, | 29938, | 37046, | 12228, | 5014, | 3856, |
| 4, | 38398, | 43171, | 13306, | 8603, | 8807, | 19370, | 23443, | 22336, | 9095, | 5189, |
| 5, | 11471, | 21937, | 27315, | 12860, | 8490, | 6078, | 11530, | 12522, | 10275, | 7534, |
| 6 , | 12571, | 4475, | 8998, | 16577, | 11101, | 6287, | 3743, | 4696, | 4937, | 5348, |
| 7, | 4872, | 4174, | 1557, | 4038, | 9641, | 7852, | 3736, | 1492, | 1791, | 2150, |
| 8, | 1449, | 1391, | 1070, | 751, | 1508, | 5366, | 3074, | 1180, | 613, | 586, |
| 9, | 3026, | 568, | 483, | 392, | 217, | 387, | 2428, | 1102, | 582, | 194, |
| 10, | 485, | 911, | 258, | 259, | 245, | 95, | 82, | 363, | 262, | 239, |
| 11, | 233, | 265, | 207, | 214, | 169, | 160, | 19, | 39, | 290, | 97, |
| 12, | 97, | 99, | 52, | 0 , | 169, | 151, | 132, | 17, | 13, | 53, |
| 13, | 48, | 39, | 29, | 34, | 0 , | 150, | 134, | 117, | 15, | 0 , |
| TOTALBIO, | 142680, | 97045, | 66836, | 66174, | 92064, | 110726, | 98877, | 61075, | 36559, | 31129, |


| Table 12 | Stock biomass at age (start of year) |  |  |  |  | Tonnes |  |  | 2014, | 2015, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0, | 0, | 0 , | 0, | 0, | 0, | 0 , | 0, | 0, |
| 2, | 6218, | 4683, | 7819, | 6652, | 11877, | 3505, | 1898, | 2925, | 8433, | 2863, |
| 3, | 5774, | 6704, | 5371, | 7205, | 9812, | 10058, | 4240, | 2289, | 3834, | 10281, |
| 4, | 3485, | 5186, | 6389, | 5230, | 4982, | 7364, | 7391, | 5492, | 2640, | 3960 , |
| 5, | 3825, | 3110, | 4074, | 4841, | 3511, | 3215, | 4288, | 6292, | 4432, | 2255, |
| 6 , | 5505, | 2515, | 2064, | 2885, | 3296, | 2134, | 1811, | 2941, | 4516, | 3337 , |
| 7, | 2976, | 2961, | 1504, | 1398, | 2004, | 1515, | 1204, | 1122, | 2317, | 3315, |
| 8, | 1105, | 1410, | 1680, | 764, | 886, | 1211, | 766, | 608, | 942, | 1723, |
| 9, | 199, | 470, | 735, | 759, | 353, | 473, | 780, | 400, | 451, | 718, |
| 10, | 13, | 76, | 216, | 315, | 352, | 110, | 361, | 648, | 275, | 354, |
| 11, | 27, | 0 , | 42, | 24, | 146, | 74, | 78, | 234, | 535, | 205, |
| 12, | 0 , | 13, | 0 , | 16, | 0 , | 0 , | 66, | 27, | 198, | 478, |
| 13, | 0 , | 0 , | 0, | 0 , | 14, | 0 , | 0 , | 0 , | 0 , | 176, |
| TOTALBIO, | 29127, | 27129, | 29894, | 30090, | 37234, | 29661, | 22884, | 22977, | 28574, | 29665, |

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| 6, | 3624, | 10148, | 3001, | 5246, | 3700, | 4997, | 4522, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 7, | 2888, | 2198, | 4165, | 2135, | 2956, | 2057, | 2604, |
| 8, | 1010, | 1493, | 1149, | 951, | 944, | 1077, | 774, |
| 9, | 87, | 742, | 257, | 162, | 389, | 280, | 563, |
| 10, | 0, | 0, | 0, | 0, | 0, | 0, | 0, |
| 11, | 0, | 0, | 0, | 0, | 0, | 0, | 0, |
| 12, | 0, | 0, | 0, | 0, | 0, | 0, | 0, |
| 13, | 0, | 0, | 0, | 0, | 0, |  |  |



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Terminal Fs derived using XSA (With F shrinkage)

|  | Table 13 | Spawning | stock | biomass at | age (sp | ing t |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0, | 0 , | 0 , |
|  | 2, | 2971, | 1501, | 2030, | 2277, | 3665, | 2561, | 4623, | 1009, | 3989, | 0, |
|  | 3, | 30792, | 15885, | 7024, | 8926, | 10729, | 16951, | 9800, | 23633, | 33776, | 29070, |
|  | 4, | 33564 , | 42128, | 15607, | 10358, | 10084, | 14294, | 20476, | 15855, | 25564, | 26524, |
|  | 5, | 12869, | 26865, | 28136, | 12965, | 8539, | 9005, | 12923, | 18202, | 11817, | 13094, |
|  | 6 , | 19763, | 8133, | 12772, | 17661, | 7830, | 5773, | 6262, | 9950, | 11702, | 5212, |
|  | 7, | 7689, | 9532, | 4261, | 6865, | 9863, | 4584, | 4086, | 4275, | 4899, | 5562, |
|  | 8, | 3656, | 2621, | 2614, | 2517, | 4544, | 4810, | 2473, | 1852, | 1525, | 2117, |
|  | 9, | 1421, | 1855, | 1117, | 1299, | 1233, | 2028, | 2150, | 1691, | 853, | 774, |
|  | 10, | 2059, | 295, | 734, | 590, | 468, | 947, | 918, | 864, | 864, | 819, |
|  | 11, | 561, | 87, | 188, | 162, | 149, | 316, | 475, | 397, | 272, | 261, |
|  | 12, | 133, | 23, | 56 , | 27, | 47, | 89, | 141, | 109, | 94, | 70, |
|  | 13, | 72, | 0 , | 21, | 15, | 0 , | 30, | 44, | 43, | 26, | 36, |
| 0 | TOTSPBIO, | 115549, | 108924, | 74559, | 63662, | 57150, | 61390, | 64371, | 77880, | 95380, | 83538, |


| Table 13 | Spawning | stock | biomass at | age (sp | ing ti |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0 , | 0 , | 0, | 0 , | 0 , | 0 , | 0 , | 0, | 0 , |
| 2, | 0 , | 0 , | 565, | 805, | 0 , | 0, | 675, | 347, | 1503, | 4687, |
| 3 , | 7356, | 7682, | 10199, | 5864, | 9742, | 2547, | 3620, | 11357, | 4917, | 13963, |
| 4, | 38300, | 14975, | 10258, | 10157, | 6385, | 8650, | 2728, | 7430, | 15520, | 5110, |
| 5, | 15209, | 24404, | 10953, | 6740, | 4706, | 4048, | 7472, | 3163, | 9385, | 11826, |
| 6 , | 6717, | 8183, | 13785, | 6346, | 2722, | 2404, | 2609, | 6913, | 3244, | 8588, |
| 7, | 1988, | 3451, | 3895, | 6223, | 2598, | 1383, | 1563, | 1736, | 5914, | 2834, |
| 8 , | 1607, | 933, | 1541, | 1671, | 2172, | 1113, | 932, | 999, | 1423, | 5332, |
| 9, | 835, | 889 , | 418, | 649, | 625, | 639, | 587, | 561, | 881, | 994, |
| 10, | 339, | 275, | 192, | 169, | 272, | 245, | 385, | 344, | 356, | 547, |
| 11, | 124, | 88, | 73, | 39, | 106, | 103, | 112, | 127, | 154, | 255, |
| 12, | 27, | 13, | 13, | 0 , | 13, | 30, | 27, | 13, | 49, | 94, |
| 13, | 15, | 0 , | 0 , | 0 , | 0 , | 0 , | 15, | 0 , | 0 , | 31, |

TOTSPBIO, 72517, 60894, 51892, 38663, 29342, 21162, 20726, 32990, 43345, 54261,

| Table 13 | Spawning | stock | biomass at | age (sp | ing t |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0 , | 0, | 0, | 0 , | 0, | 0, | 0 , | 0 , | 0, |
| 2, | 534, | 0, | 0 , | 305, | 567, | 2443, | 540, | 0 , | 0 , | 294, |
| 3, | 24377, | 8953, | 4652, | 3089, | 9118, | 14071, | 13707, | 3546, | 2557, | 2545, |
| 4, | 28415, | 39286, | 11976, | 7570, | 6077, | 16658, | 17817, | 17645, | 7094, | 4670, |
| 5, | 9750, | 21279, | 27042, | 12603, | 7811, | 5714, | 11184, | 11020, | 9453, | 7007, |
| 6 , | 11817, | 4475, | 8908, | 16577, | 10990, | 6287, | 3481, | 4602, | 4394, | 5241, |
| 7, | 4872, | 4174, | 1557, | 4038, | 9641, | 7852, | 3624, | 1492, | 1558, | 1978, |
| 8 , | 1449, | 1391, | 1070, | 751, | 1508, | 5366, | 3074, | 1180, | 613, | 586, |
| 9, | 3026, | 568, | 483, | 392, | 217, | 387, | 2428, | 1102, | 582, | 194, |
| 10, | 485, | 911, | 258, | 259, | 245, | 95, | 82, | 363, | 262, | 239, |
| 11, | 233, | 265, | 207, | 214, | 169, | 160, | 19, | 39, | 290, | 97, |
| 12, | 97, | 99, | 52, | 0 , | 169, | 151, | 132, | 17, | 13, | 53, |
| 13, | 48, | 39, | 29, | 34, | 0 , | 150, | 134, | 117, | 15, | 0 , |
| OTSPBIO, | 85102, | 81440, | 56233, | 45832, | 46512, | 59332, | 56221, | 41123, | 26833, | 22905, |



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|  | Table 14 | Stock biomass at age with SOP (start of year) |  |  |  |  |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0, | 0, | 0, | 0, | 0, | 0 , | 0, | 0, | 0, | 0, |
|  | 2, | 18955, | 22372, | 16161, | 10370, | 8014, | 11625, | 17286, | 14253, | 33067, | 28293, |
|  | 3, | 12152, | 26267, | 31363, | 25008, | 14155, | 14371, | 18656, | 33046, | 21899, | 39619, |
|  | 4, | 28486, | 13686, | 27540, | 34269, | 20521, | 15256, | 14958, | 22475, | 36775, | 19764, |
|  | 5, | 15050, | 24348, | 11891, | 18002, | 23844, | 18951, | 10883, | 12041, | 18961, | 28982, |
|  | 6 , | 7656, | 9811, | 16177, | 7294, | 11803, | 16711, | 12686, | 8487, | 9798, | 12460, |
|  | 7, | 2221, | 4148, | 5113, | 8648, | 4457, | 7229, | 9381, | 5224, | 5958, | 6196, |
|  | 8 , | 1240, | 612, | 2048, | 2486, | 6632, | 2760, | 4282, | 4344, | 3405, | 3000, |
|  | 9, | 411, | 336, | 141, | 1045, | 511, | 2017, | 1560, | 2568, | 3231, | 2252, |
|  | 10, | 0 , | 0, | 0 , | 0 , | 73, | 214, | 713, | 960, | 1017, | 1392, |
|  | 11, | 0, | 0, | 0, | 0, | 0 , | 86, | 192, | 449, | 470, | 555, |
|  | 12, | 0, | 0, | 0, | 0, | 0, | 0, | 79, | 138, | 149, | 182, |
|  | 13, | 0, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 56, | 64, | 70, |
| 0 | TOTALBIO, | 86170, | 101580, | 110434, | 107124, | 90010, | 89220, | 90676, | 104041, | 134795, | 142765, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
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$$
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$$

Terminal Fs derived using XSA (With F shrinkage)



| Table 14 | Stock | biomass at | age with | SOP (st | of y |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0, | 0 , | 0, | 0 , | 0 , | 0 , | 0, | 0 , | 0 , |
| 2, | 13235, | 6073, | 6215, | 15473, | 29534, | 34991, | 13521, | 4982, | 3665, | 5892, |
| 3 , | 56249, | 14097, | 7695, | 7282, | 24368, | 30021, | 37072, | 12225, | 5007, | 3863, |


|  | 4, | 38099, | 43506, | 13648, | 8721, | 9179, | 19424, | 23459, | 22330, | 9083, | 5198, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 5, | 11381, | 22108, | 28017, | 13037, | 8849, | 6095, | 11538, | 12519, | 10261, | 7547, |
|  | 6 , | 12473, | 4509, | 9229, | 16805, | 11570, | 6304, | 3746, | 4695, | 4930, | 5358, |
|  | 7, | 4834, | 4207, | 1597, | 4093, | 10048, | 7873, | 3738, | 1492, | 1789, | 2154, |
|  | 8 , | 1438, | 1402, | 1097, | 762, | 1572, | 5381, | 3076, | 1180, | 612, | 588, |
|  | 9, | 3003, | 573, | 496, | 397, | 226, | 388, | 2430, | 1102, | 581, | 195, |
|  | 10, | 481, | 918, | 264, | 262, | 255, | 95, | 82, | 362, | 262, | 239, |
|  | 11, | 231, | 267, | 212, | 217, | 176, | 160, | 19, | 39, | 290, | 97. |
|  | 12, | 96, | 100, | 53, | 0 , | 176, | 151, | 132, | 17, | 13, | 53, |
|  | 13, | 48, | 39, | 30, | 35, | 0 , | 150, | 134, | 117, | 15, | 0 , |
| 0 | TOTALBIO, | 141569, | 97799, | 68554, | 67084, | 95954, | 111036, | 98947, | 61061, | 36508, | 31184, |



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Table 15 Spawning stock biomass with SOP (spawning time) Tonnes
YEAR, 1959, 1960, 1961, 1962, 1963, 1964, 1965,

| AGE |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1, | 0, | 0, | 0, | 0 , | 0, | 0 , | 0 , |
|  | 2, | 1893, | 2414, | 1988, | 3232, | 3387, | 3366, | 1520, |
|  | 3, | 13166, | 11636, | 9342, | 9574, | 14832, | 14573, | 15856, |
|  | 4, | 6910, | 17356, | 9876, | 9652, | 10087, | 17865, | 19229, |
|  | 5, | 16653, | 5212, | 10010, | 7259, | 7260, | 6737, | 13554, |
|  | 6 , | 3635, | 10232, | 2721, | 4954, | 3542, | 4909, | 5093, |
|  | 7, | 2897, | 2216, | 3777, | 2017, | 2830, | 2021, | 2933, |
|  | 8 , | 1013, | 1506, | 1041, | 899, | 904, | 1058, | 872, |
|  | 9, | 87, | 748, | 233, | 153, | 372, | 276, | 634, |
|  | 10, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 11, | 0 , | 0 , | 0 , | 0 , | 0, | 0 , | 0 , |
|  | 12, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 13, | 0 , | 0 , | 0, | 0 , | 0 , | 0, | 0 , |
| 0 | TOTSPBIO, | 46255, | 51319, | 38990, | 37740, | 43214, | 50804, | 59691, |


| Table 15 | Spawning | stock | biomass w | SOP | (spawning | time) | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0, | 0, | 0, | 0 , | 0, | 0, | 0, | 0 , | 0, |
| 2, | 3222, | 3803, | 2747, | 1763, | 1362, | 1976, | 2939, | 2423, | 5621, | 4810, |
| 3 , | 7777, | 16811, | 20073, | 16005, | 9059, | 9198, | 11940, | 21150, | 14015, | 25356, |
| 4, | 24782, | 11907, | 23960, | 29814, | 17854, | 13272, | 13013, | 19553, | 31994, | 17195, |
| 5, | 14297, | 23131, | 11297, | 17102, | 22652, | 18003, | 10339, | 11439, | 18013, | 27533, |
| 6 , | 7656, | 9811, | 16177, | 7294, | , 11803, | 16711, | 12686, | 8487, | 9798, | 12460, |
| 7, | 2221, | 4148, | 5113, | 8648, | 4457 , | 7229, | 9381, | 5224, | 5958, | 6196, |
| 8, | 1240, | 612, | 2048, | 2486, | 6632, | 2760, | 4282, | 4344, | 3405, | 3000, |
| 9, | 411, | 336, | 141, | 1045, | 511, | 2017, | 1560, | 2568, | 3231, | 2252, |
| 10, | 0 , | 0 , | 0 , | 0 , | 73, | 214, | 713, | 960 , | 1017, | 1392, |
| 11, | 0 , | 0 , | 0 , | 0 , | , 0, | 86 , | 192, | 449, | 470, | 555, |


|  | 12, | 0, | 0, | 0, | 0, | 0, | 0, | 79, | 138, | 149, | 182, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 13, | 0, | 0, | 0, | 0, | 0, | 0, | 0 , | 56, | 64, | 70, |
| 0 | TOTSPBIO, | 61608, | 70559, | 81555, | 84158, | 74403, | 71467, | 67124, | 76791, | 93737, | 101001, |

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Table 15 Spawning stock biomass with SOP (spawning time) Tonnes
YEAR, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985,

Table 15 Spawning stock biomass with SOP (spawning time) Tonnes
YEAR, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995,

|  | AGE |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1, | 0 , | 0 , | 0, | 0, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 2, | 0 , | 0, | 568, | 787, | 0 , | 0 , | 687, | 354, | 1522, | 4726, |
|  | 3, | 7074, | 7407, | 10256, | 5733, | 9640, | 2695, | 3683, | 11609, | 4979, | 14081, |
|  | 4, | 36832, | 14440, | 10315, | 9929, | 6318, | 9154, | 2776, | 7595, | 15717, | 5154, |
|  | 5, | 14626, | 23532, | 11015, | 6589, | 4657, | 4285, | 7601, | 3233, | 9505, | 11926, |
|  | 6 , | 6460, | 7891, | 13863, | 6204, | 2694, | 2545, | 2654, | 7067, | 3285, | 8661, |
|  | 7, | 1912, | 3328, | 3917, | 6084, | 2571, | 1463, | 1590, | 1775, | 5989, | 2858, |
|  | 8, | 1545, | 900, | 1549, | 1634, | 2150, | 1178, | 949, | 1021, | 1441, | 5377, |
|  | 9, | 803, | 858, | 420, | 634, | 618, | 676, | 597, | 574, | 892, | 1002, |
|  | 10, | 326, | 265, | 193, | 165, | 269, | 260, | 391, | 352, | 360, | 552, |
|  | 11, | 119, | 85, | 73, | 38, | 105, | 109, | 114, | 130, | 156, | 257, |
|  | 12, | 26, | 13, | 13, | 0 , | 13, | 32 , | 27, | 14, | 49, | 95, |
|  | 13, | 14, | 0 , | 0 , | 0 , | 0 , | 0 , | 15, | 0 , | 0 , | 32, |
| 0 | TOTSPBIO, | 69739, | 58718, | 52184, | 37797, | 29035, | 22397, | 21084, | 33724, | 43895, | 54721, |




Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD_ind_Surveys_revised,
At 14/02/2017 10:14
Table 16 Summary (without SOP correction)
Terminal Fs derived using XSA (With F shrinkage)


# Table 3. Report of the XSA with the plus group (= NWWG 2016 run). 

Lowestoft VPA Version 3.1
12/04/2016 8:57

Extended Survivors Analysis

```
COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD ind Surveys revised
CPUE data from file Surveys_revised_1replacedvalue.TXT
Catch data for 57 years. 1959 to 2015. Ages 1 to 10.
    Fleet, First, Last, First, Last, Alpha, Beta
SUMMER SURVEY \(\quad\), \(\quad\) year, year, age , age \(\quad 1996,2015, ~ 2, ~ 8, ~ .600, ~ .700\)
Time series weights :
    Tapered time weighting not applied
Catchability analysis :
    Catchability independent of stock size for all ages
    Catchability independent of age for ages >= 6
Terminal population estimation :
Survivor estimates shrunk towards the mean F
of the final 5 years or the 5 oldest ages.
S.E. of the mean to which the estimates are shrunk = 2.000
    Minimum standard error for population
    estimates derived from each fleet = . 300
    Prior weighting not applied
Tuning converged after 29 iterations
```

1
Regression weights
, $1.000,1.000,1.000,1.000,1.000,1.000,1.000,1.000,1.000,1.000$
Fishing mortalities
Age, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015

| 1, | .000, | .000, | .000, | .000, | .000, | .000, | .000, | .000, | .000, | .000 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 2, | .181, | .118, | .050, | .125, | .231, | .088, | .029, | .021, | .057, | .075 |
| 3, | .326, | .313, | .261, | .687, | .474, | .435, | .195, | .137, | .284, | .215 |
| 4, | .352, | .371, | .337, | .531, | .614, | .597, | .482, | .186, | .350, | .518 |
| 5, | .601, | .426, | .396, | .489, | .627, | .578, | .595, | .400, | .469, | .472 |
| 6, | .808, | .577, | .486, | .524, | .914, | .558, | .741, | .376, | .443, | .533 |
| 7, | .946, | .661, | .730, | .426, | .706, | .650, | .655, | .303, | .320, | .562 |
| 8, | 1.004, | .675, | 1.204, | .616, | .585, | .434, | .946, | .336, | .169, | .290 |
| 9, | .292, | .811, | 1.562, | 1.542, | .978, | .383, | .403, | .542, | .193, | .461 |

1
XSA population numbers (Thousands)

$2006,6.14 \mathrm{E}+03,7.39 \mathrm{E}+03,4.36 \mathrm{E}+03,1.75 \mathrm{E}+03,1.62 \mathrm{E}+03,1.60 \mathrm{E}+03,6.02 \mathrm{E}+02,1.33 \mathrm{E}+02,4.36 \mathrm{E}+01$,
$2007,7.90 \mathrm{E}+03,5.03 \mathrm{E}+03,5.05 \mathrm{E}+03,2.58 \mathrm{E}+03,1.00 \mathrm{E}+03,7.28 \mathrm{E}+02,5.83 \mathrm{E}+02,1.91 \mathrm{E}+02,3.98 \mathrm{E}+01$,
$2008, \quad 1.01 \mathrm{E}+04,6.46 \mathrm{E}+03,3.66 \mathrm{E}+03,3.02 \mathrm{E}+03,1.45 \mathrm{E}+03,5.37 \mathrm{E}+02,3.35 \mathrm{E}+02,2.46 \mathrm{E}+02,7.97 \mathrm{E}+01$,
$2009, \quad 1.38 \mathrm{E}+04,8.24 \mathrm{E}+03,5.03 \mathrm{E}+03,2.31 \mathrm{E}+03,1.77 \mathrm{E}+03,8.02 \mathrm{E}+02,2.71 \mathrm{E}+02,1.32 \mathrm{E}+02,6.05 \mathrm{E}+01$,
$2010,5.24 \mathrm{E}+03,1.13 \mathrm{E}+04,5.95 \mathrm{E}+03,2.07 \mathrm{E}+03,1.11 \mathrm{E}+03,8.88 \mathrm{E}+02,3.89 \mathrm{E}+02,1.45 \mathrm{E}+02,5.84 \mathrm{E}+01$,

```
2011, 2.30E+03, 4.29E+03, 7.34E+03, 3.03E+03, 9.19E+02, 4.86E+02, 2.91E+02, 1.57E+02, 6.60E+01,
2012, 3.53E+03, 1.88E+03, 3.22E+03, 3.89E+03, 1.37E+03, 4.22E+02, 2.28E+02, 1.25E+02, 8.34E+01,
2013, 9.35E+03, 2.89E+03, 1.50E+03, 2.17E+03, 1.97E+03, 6.17E+02, 1.65E+02, 9.68E+01, 3.96E+01,
2014, 2.92E+03, 7.65E+03, 2.32E+03, 1.07E+03, 1.47E+03, 1.08E+03, 3.47E+02, 9.95E+01, 5.66E+01,
2015, 4.12E+03, 2.39E+03, 5.92E+03, 1.43E+03, 6.17E+02, 7.55E+02, 5.68E+02, 2.06E+02, 6.88E+01,
Estimated population abundance at 1st Jan 2016
0.00E+00, 3.37E+03, 1.81E+03, 3.91E+03, 6.97E+02, 3.15E+02, 3.63E+02, 2.65E+02, 1.26E+02,
```

Taper weighted geometric mean of the VPA populations:
$1.39 \mathrm{E}+04,1.16 \mathrm{E}+04,8.91 \mathrm{E}+03,5.41 \mathrm{E}+03,2.99 \mathrm{E}+03,1.48 \mathrm{E}+03,6.66 \mathrm{E}+02,2.70 \mathrm{E}+02,1.08 \mathrm{E}+02$, Standard error of the weighted Log(VPA populations) :

```
, .7233, . 7048, .6634, .6680, .6456, .6312, .6644, .7107, .8305,
Log catchability residuals.
```

| Age | , | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 |  | No data | for t | is flee | at t | his age |  |  |  |  |  |
| 2 | , | -.19, | .17, | . 32 , | -. 90, | .11, | . 64, | 1.10, | -.05, | . 64, | . 52 |
| 3 | , | . 06 , | -. 30 , | -. 68, | . 44, | -. 49 , | . 00 , | . 54, | -. 40 , | .01, | . 38 |
| 4 | , | . 09 , | . 20 , | -. 72, | -.24, | -. 04 , | . 00 , | -.01, | . 02 , | -. 27 , | . 16 |
| 5 | , | . 59, | -. 15, | . 14, | -.79, | -. 87 , | -.19, | . 04, | -. 40 , | . 38 , | . 23 |
| 6 | , | . 08 , | -. 26 , | . 49 , | . 03, | -. 73 , | -.67, | -. 42, | -. 77 , | . 21, | . 62 |
| 7 | , | . 21 , | -. 11, | -. 44 , | . 46 , | -.03, | -. 40 , | -.49, | -1.44, | . 07 , | . 44 |
| 8 | , | -. 20 , | -. 34, | .08, | . 43, | -. 26 , | -. 10, | -.55, | -1.13, | .16, | . 49 |
| Age | , | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015 |
| 1 |  | No data | for t | is flee | t at t | this age |  |  |  |  |  |
| 2 | , | . 80 , | -. 28 , | -1.80, | -. 17, | . 65 , | .11, | -1.72, | -. 63, | . 27, | . 44 |
| 3 | , | -. 10, | -. 68, | -.58, | 1.05, | . 50, | .15, | -.97, | -. 36, | .73, | . 70 |
| 4 | , | -.25, | -. 74, | -. 88 , | . 43, | . 81, | .48, | . 16 , | -1.09, | . 26, | 1.63 |
| 5 | , | -. 34, | -. 53, | -.11, | . 07 , | . 21, | .41, | . 32 , | . 38 , | -.19, | . 82 |
| 6 |  | -.42, | -. 43, | -.01, | . 51, | .18, | .14, | -. 20 , | 1.00, | .18, | . 50 |
| 7 |  | -.09, | -. 73, | -. 50, | . 44, | . 38 , | . 28 , | -. 54, | . 62, | .06, | . 39 |
| 8 |  | -. 02, | -. 50, | -.53, | . 26 , | .01, | -.27, | -. 36, | . 31 , | -.01, | -. 05 |

Mean log catchability and standard error of ages with catchability independent of year class strength and constant w.r.t. time

| Age , | 2, | 3, | 4, | 5, | 6, | 7, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Mean Log q, | -7.8746, | -6.7078, | -6.2936, | -6.0845, | -6.0486, | -6.0486, |
| S.E (Log q), | .7723, | .5560, | .6124, | .4451, | .4861, | .5222, |

Regression statistics

Ages with $q$ independent of year class strength and constant w.r.t. time.

Age, Slope, t-value, Intercept, RSquare, No Pts, Reg s.e, Mean Q

| 2, | .74, | 1.413, | 8.13, | .63, | 20, | .56, | -7.87, |
| :--- | ---: | ---: | ---: | :--- | :--- | :--- | :--- |
| 3, | .95, | .273, | 6.80, | .66, | 20, | .54, | -6.71, |
| 4, | 1.15, | -.719, | 6.00, | .56, | 20, | .71, | -6.29, |
| 5, | 1.13, | -.847, | 5.87, | .69, | 20, | .51, | -6.08, |
| 6, | 1.11, | -.587, | 5.94, | .60, | 20, | .55, | -6.05, |
| 7, | 1.06, | -.327, | 6.11, | .59, | 20, | .56, | -6.12, |
| 8, | 1.37, | -1.958, | 6.54, | .61, | 20, | .49, | -6.18, |

Fleet : SPRING SURVEY (shift

| Age, | 1993, | 1994, | 1995 |
| ---: | ---: | ---: | ---: |
| 1, | .00, | -.51, | -.39 |
| 2, | -.92, | -.90, | .18 |
| 3, | -.62, | .02, | .12 |


| 4 5 6 7 8 | ', | -.56, -.56, -.60, -.36, -4.60, | $\begin{gathered} -.01, \\ .76, \\ .89 \\ .39 \\ .71, \end{gathered}$ | $\begin{array}{r} .59 \\ .39 \\ .52 \\ .19 \\ .09 \end{array}$ |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Age | , | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005 |
| 1 |  | -. 79 , | -. 75, | .69, | -.43, | . 26 , | .18, | -. 50, | 1.97, | . 99 , | -. 07 |
| 2 |  | -. 25 , | -. 24, | . 36, | . 24, | .47, | . 74, | -. 25 , | . 24 , | . 42, | -1.06 |
| 3 | , | -. 04 , | -. 17, | .09, | . 05 , | . 20, | . 31, | . 38 , | -. 47, | .43, | -. 92 |
| 4 | , | -. 06 , | . 18 , | -. 24 , | -. 52, | -. 14, | . 33, | -.02, | -.23, | . 28 , | -. 43 |
| 5 | , | -. 12, | . 25 , | .17, | -.58, | -. 34, | . 08 , | . 27 , | -. 39, | . 41, | -. 60 |
| 6 | , | -.09, | -.03, | . 22 , | . 39, | .33, | .11, | -. 26 , | -. 43, | . 29 , | -. 52 |
| 7 | , | -. 14, | -. 21 , | -.19, | .17, | -. 71, | . 04, | .13, | -. 24 , | -.64, | -. 82 |
| 8 | , | -1.44, | . 92 , | .13, | -1.18, | -1.51, | . 18, | -. 06 , | -. 15, | -. 74 , | -1.05 |
| Age | , | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015 |
| 1 |  | -1.09, | . 12 , | .43, | . 94 , | . 36 , | -.10, | -.03, | -. 35, | -.95, | . 00 |
| 2 |  | -. 66, | . 22 , | -.09, | . 76, | . 54, | -. 20 , | . 89 , | -. 75, | -. 14, | . 40 |
| 3 | , | -.83, | .10, | .51, | . 33, | .47, | . 27, | 1.13, | -. 53, | -. 48, | -. 35 |
| 4 | , | -. 79 , | -.03, | . 66, | . 35 , | . 58, | -. 36, | 1.12, | -. 17, | -.08, | -. 45 |
| 5 | , | -. 36 , | -. 16, | .47, | . 25, | .61, | -. 65, | . 36 , | -.07, | . 19, | -. 36 |
| 6 |  | -.39, | -. 05 , | . 04 , | -.03, | 1.12, | -. 79, | -.29, | -. 19, | -.06, | -. 20 |
| 7 |  | -. 30 , | -. 50, | -. 10, | .09, | . 72 , | -. 33, | -.13, | -.16, | -. 49, | -. 94 |
| 8 |  | . 30, | -. 46, | . 42 , | .11, | . 24, | -1.25, | .51, | -. 08, | -. 79 , | -1.45 |

Mean log catchability and standard error of ages with catchability independent of year class strength and constant w.r.t. time

| Age, | 1, | 2, | 3, | 4, | 5, | 6, | 7, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Mean Log q, | -8.3359, | -6.8864, | -5.9989, | -5.7133, | -5.7378, | -5.9828, | -5.9828, |
| S.E (Log q), | .7023, | .5683, | .4869, | .4573, | .4211, | .4557, | .4400, |

Regression statistics :

Ages with $q$ independent of year class strength and constant w.r.t. time.
Age, Slope , t-value , Intercept, RSquare, No Pts, Reg s.e, Mean Q

| 1, | 1.00, | -.024, | 8.33, | .57, | 23, | .72, | -8.34, |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 2, | 1.04, | -.221, | 6.81, | .65, | 23, | .60, | -6.89, |
| 3, | .89, | .833, | 6.29, | .75, | 23, | .44, | -6.00, |
| 4, | .91, | .756, | 5.95, | .77, | 23, | .42, | -5.71, |
| 5, | .90, | .858, | 5.93, | .79, | 23, | .38, | -5.74, |
| 6, | .89, | .776, | 6.10, | .71, | 23, | .41, | -5.98, |
| 7, | .97, | .199, | 6.18, | .75, | 23, | .39, | -6.18, |
| 8, | .64, | 1.579, | 6.03, | .48, | 23, | .72, | -6.47, |

1

Terminal year survivor and $F$ summaries :
Age 1 Catchability constant w.r.t. time and dependent on age
Year class $=2014$

| Fleet, | Estimated, Survivors, | $\begin{aligned} & \text { Int, } \\ & \text { s.e, } \end{aligned}$ | Ext, | Var, <br> Ratio, |  | Scaled, Weights, | Estimated $F$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY , | 1., | . 000, | . 000 , | . 00 , | 0 , | . 000 , | . 000 |
| SPRING SURVEY (shift, | 3374. | . 717 , | . 000, | . 00, | 1, | 1.000, | . 000 |
| F shrinkage mean | 0., | 2.00, |  |  |  | . 000, | . 000 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, | Ration |  |
| $3374 .$, | .72, | .00, | 1, | .000, | .000 |

1
Age 2 Catchability constant w.r.t. time and dependent on age


Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $1815 .$, | .38, | .35, | 4, | .917, | .075 |

Age 3 Catchability constant w.r.t. time and dependent on age
Year class $=2012$

| Fleet, |  |  | Estimated, | Int, | Ext, | Var, |  | Scaled, | Estimated |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , |  |  | Survivors, | s.e, | s.e, | Ratio, |  | Weights, | F |
| SUMMER | SURVEY | , | 6838., | . 463 , | . 206, | . 44, | 2, | . 338, | . 128 |
| SPRING | SURVEY | (shift, | 2949., | . 334, | . 070, | . 21 , | 3, | . 639, | . 276 |
| F shr | inkage | mean | 2609., | 2.00, |  |  |  | . 023, | . 307 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | , | Ratio, |  |
| $3908 .$, | .27, | .19, | 6, | .708, | .215 |

Age 4 Catchability constant w.r.t. time and dependent on age
Year class $=2011$

| Fleet, | Estimated, | Int, | Ext, | Var, |  | Scaled, | Estimat |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , | Survivors, | s.e, | s.e, | Ratio, |  | Weights, | F |
| SUMMER SURVEY | 1625., | . 376 , | . 587, | 1.56, | 3 , | . 341 , | . 255 |
| SPRING SURVEY (shift, | 439., | . 275 , | .115, | . 42 , | 4, | . 635, | . 730 |
| F shrinkage mean | 833., | 2.00, |  |  |  | . 024 , | . 449 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | S.e, | s.e, | Ratio, |  |  |
| $697 .$, | .22, | .30, | 8, | 1.365, | .518 |

Age 5 Catchability constant w.r.t. time and dependent on age
Year class $=2010$


Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | S.e, | S.e, | Ratio, |  |  |
| $315 .$, | .18, | .21, | 10, | 1.127, | .472 |

1
Age 6 Catchability constant w.r.t. time and dependent on age
Year class = 2009


Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $363 .$, | .17, | .16, | 12, | .924, | .533 |

Age 7 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2008$

| Fleet, | Estimated, | Int, | Ext, | Var, |  | Scaled, | Estimated |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , SURVEY | Survivors, | s.e, | s.e, | Ratio, |  | Weights, | F |
| SUMMER SURVEY , | 361., | . 263 , | . 053, | . 20 , | 6, | . 419, | . 441 |
| SPRING SURVEY (shift, | 210., | . 226, | . 270, | 1.19, | 7, | . 562, | . 669 |
| F shrinkage mean | 285., | 2.00, |  |  |  | . 019, | . 531 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | ---: | ---: | ---: | ---: | ---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $265 .$, | .17, | .16, | 14, | .912, | .562 |

Age 8 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2007$

| Fleet, | Estimated, | Int, | Ext, | Var, |  | Scaled, | Estimated |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| , | Survivors, | s.e, | s.e, | Ratio, |  | Weights, | F |
| SUMMER SURVEY , | 156., | . 243, | . 155, | . 64, | 7, | . 558, | . 241 |
| SPRING SURVEY (shift, | 99., | . 235, | . 180 , | . 77, | 8, | . 427, | 359 |
| F shrinkage mean | 66., | 2.00, |  |  |  | . 015, | . 498 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :---: | :---: | :---: | :---: | :---: | :---: |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $126 .$, | .17, | .13, | 16, | .731, | .290 |

Age 9 Catchability constant w.r.t. time and age (fixed at the value for age) 6
Year class $=2006$

| Fleet, | Estimated, Survivors, | $\begin{aligned} & \text { Int, } \\ & \text { s.e, } \end{aligned}$ | Ext, s.e, | Var, <br> Ratio, |  | Scaled, Weights, | $\begin{gathered} \text { Estimate } \\ \mathrm{F} \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SUMMER SURVEY | 42., | . 259, | . 150, | . 58, | 7, | . 571, | . 402 |
| SPRING SURVEY (shift, | 28., | . 258 , | . 121, | . 47 , | 8, | . 405 , | . 555 |
| F shrinkage mean | 34. | 2.00, |  |  |  | .024, | 478 |

Weighted prediction :

| Survivors, | Int, | Ext, | N, | Var, | F |
| :--- | :--- | :--- | :--- | :--- | :--- |
| at end of year, | s.e, | s.e, | Ratio, |  |  |
| $36 .$, | .19, | .10, | 16, | .548, | .461 |

Table 4. Results from the XSA run with the plus group (= NWWG 2016 run).

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
At 12/04/2016 9:00



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|  | Table YEAR, | Catch numbers at age |  |  | Numbers*10**-3 |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0 , | 0 , | 0, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 2, | 1497, | 425, | 555, | 575, | 1129, | 646, | 1139, | 2149, | 4396, | 998, |
|  | 3, | 4158, | 3282, | 1219, | 1732, | 2263, | 4137, | 1965, | 5771, | 5234, | 9484, |
|  | 4, | 3799, | 6844, | 2643, | 1673, | 1461, | 1981, | 3073, | 2760, | 3487, | 3795, |
|  | 5, | 1380, | 3718, | 3216, | 1601, | 895, | 947, | 1286, | 2746, | 1461, | 1669, |
|  | 6 , | 1427, | 788, | 1041, | 1906, | 807, | 582, | 471, | 1204, | 912, | 770, |
|  | 7, | 617, | 1160, | 268, | 493, | 832, | 487, | 314, | 510, | 314, | 872, |
|  | 8 , | 273, | 239, | 201, | 134, | 339, | 527, | 169, | 157, | 82, | 309, |
|  | 9, | 120, | 134, | 66, | 87, | 42, | 123, | 254, | 104, | 34, | 65, |
|  | +gp, | 186, | 9, | 56, | 38, | 18, | 55, | 122, | 102, | 66, | 80, |
| 0 | TOTALNUM, | 13457, | 16599, | 9265, | 8239, | 7786, | 9485, | 8793, | 15503, | 15986, | 18042, |
|  | TONSLAND, | 39799, | 34927, | 26585, | 23112, | 20513, | 22963, | 21489, | 38133, | 36979, | 39484, |

SOPCOF \%,
98, $\qquad$
$\qquad$ 100,
97,
97,
95,


|  | Table 1 | Catch numbers at age |  |  | Numbers*10**-3 |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0, | 0 , | 0 , | 0, | 0, | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 2, | 1110, | 506, | 287, | 873, | 2113, | 328, | 49, | 55, | 387, | 156, |
|  | 3, | 1097, | 1226, | 761, | 2262, | 2034, | 2343, | 517, | 173, | 518, | 1035, |
|  | 4, | 469, | 723, | 783, | 861, | 861, | 1234, | 1346, | 333, | 286, | 522, |
|  | 5, | 663, | 315, | 430, | 618, | 468, | 365, | 555, | 587, | 499, | 210, |
|  | 6, | 801, | 289, | 187, | 296, | 481, | 188, | 200, | 175, | 350 , | 282, |
|  | 7, | 333, | 255, | 157, | 85, | 178, | 126, | 99, | 39, | 86, | 221, |
|  | 8 , | 76, | 85, | 156, | 55, | 58, | 50, | 69, | 25, | 14, | 47, |
|  | 9, | 10, | 20, | 57, | 43, | 33, | 19, | 25, | 15, | 9, | 23, |
|  | +gp, | 3, | 3, | 19, | 17, | 38, | 2, | 22, | 5, | 1, | 7, |
| 0 | TOTALNUM, | 4562, | 3422, | 2837, | 5110, | 6264, | 4655, | 2882, | 1407, | 2150, | 2503, |
|  | TONSLAND, | 9844, | 7511, | 7315, | 9979, | 12757, | 9692, | 7204, | 4473, | 5715, | 7394, |

SOPCOF \% 100, 100, 101, 101, 100, 100, 100, 100,

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| Table 2 | Catch | eights a | age (kg) |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |
| AGE |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 00000, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, | . 8500, | 1.0000, | 1.0800, | 1.0000, | 1.0400, | . 9700 , | . 9200, |
| 3, | 1.7300, | 2.0300, | 2.2200, | 2.2700, | 1.9400, | 1.8300, | 1.4500, |
| 4, | 3.2300, | 3.3700, | 3.4500, | 3.3500, | 3.5100, | 3.1500, | 2.5700, |
| 5, | 4.4000, | 4.4200, | 4.6900, | 4.5800, | 4.6000, | 4.3300, | 3.7800 , |
| 6 , | 5.8000, | 6.0200 , | 5.5200, | 4.9300, | 5.5000, | 6.0800 , | 5.6900, |
| 7, | 6.3700 , | 6.6500 , | 7.0900, | 9.0800, | 6.7800 , | 7.0000 , | 7.3100, |
| 8 , | 7.3400, | 8.1200, | 9.9100, | 6.5900 , | 8.7100, | 6.2500 , | 7.9300, |
| 9, | 7.8800 , | 11.0000, | 8.0300 , | 6.6600 , | 11.7200, | 6.1900 , | 8.0900 , |
| +gp, | 10.2700, | 10.2700, | 10.2700, | 10.2700, | 10.8200, | 14.3900, | 11.1100, |
| SOPCOFAC, | 1.0030, | 1.0083, | . 9068 , | .9444, | . 9573, | . 9824 , | 1.1262, |


| Table | Catch | weights at | age (kg) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000, | . 0000, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, | . 9800 , | . 9600, | . 8800, | 1.0900, | . 9600 , | .8100, | .6600, | 1.1100, | 1.0800, | . 7900 , |
| 3, | 1.7700, | 1.9300, | 1.7200, | 1.8000, | 2.2300, | 1.8000, | 1.6100, | 2.0000, | 2.2200, | 1.7900, |
| 4, | 2.7500, | 3.1300 , | 3.0700 , | 2.8500, | 2.6900, | 2.9800, | 2.5800, | 3.4100, | 3.4400, | 2.9800, |
| 5, | 3.5100 , | 4.0400, | 4.1200, | 3.6700 , | 3.9400 , | 3.5800 , | 3.2600, | 3.8900 , | 4.8000, | 4.2600 , |
| 6 , | 4.8000, | 4.7800, | 4.6500, | 4.8900, | 5.1400, | 3.9400 , | 4.2900, | 5.1000, | 5.1800, | 5.4600, |
| 7, | 6.3200, | 6.2500 , | 5.5000, | 5.0500, | 6.4600 , | 4.8700 , | 4.9500 , | 5.1000, | 5.8800, | 6.2500, |
| 8, | 7.5100, | 7.0000 , | 7.6700, | 7.4100, | 10.3100, | 6.4800 , | 6.4800 , | 6.1200, | 6.1400 , | 7.5100, |
| 9, | 10.3400, | 11.0100, | 10.9500, | 8.6600, | 7.3900, | 6.3700 , | 6.9000 , | 8.6600, | 8.6300, | 7.3900, |
| +gp, | 11.6500, | 10.6900, | 9.2800, | 14.3900, | 9.3400, | 10.2200, | 11.5500, | 7.5700, | 7.6200, | 8.1700, |
| SOPCOFAC, | 1.0905, | 1.0224, | 1.0598, | 1.0851, | .9943, | 1.2264, | 1.2481, | 1.0134, | 1.0134, | .9709, |

[^0]| Table | Catch | ights | age (kg) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, | . 9400 , | . 8700 , | 1.1120, | . 8970, | . 9270 , | 1.0800, | 1.2300, | 1.3380, | 1.1950, | . 9050 , |
| 3 , | 1.7200, | 1.7900, | 1.3850, | 1.6820, | 1.4320, | 1.4700, | 1.4130, | 1.9500, | 1.8880, | 1.6580, |
| 4, | 2.8400, | 2.5300, | 2.1400, | 2.2110, | 2.2200, | 2.1800, | 2.1380, | 2.4030, | 2.9800, | 2.6260, |
| 5, | 3.7000 , | 3.6800 , | 3.1250, | 3.0520, | 3.1050 , | 3.2100 , | 3.1070 , | 3.1070 , | 3.6790 , | 3.4000 , |
| 6, | 5.2600 , | 4.6500, | 4.3630, | 3.6420, | 3.5390 , | 3.7000 , | 4.0120, | 4.1100, | 4.4700, | 3.7520 , |
| 7, | 6.4300 , | 5.3400 , | 5.9270, | 4.7190, | 4.3920, | 4.2400, | 5.4420, | 5.0200, | 5.4880, | 4.2200, |
| 8 , | 6.3900 , | 6.2300 , | 6.3480 , | 7.2720, | 6.1000 , | 4.4300, | 5.5630, | 5.6010, | 6.4660, | 4.7390, |
| 9, | 8.5500 , | 8.3800 , | 8.7150 , | 8.3680 , | 7.6030, | 6.6900 , | 5.2160, | 8.0130 , | 6.6280, | 6.5110, |
| +gp, | 13.6200, | 10.7200, | 12.2290, | 13.0420, | 9.6680, | 10.0000, | 6.7070 , | 8.0310 , | 10.9810, | 10.9810, |
| SOPCOFAC, | . 9653 , | . 7012 , | . 9965 , | . 9843 , | 1.0584, | 1.0408, | 1.0030, | . 9695 , | .9685, | . 9491 , |


| Table 2 | Catch weights at age (kg) |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000, | . 0000 , | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000 , | . 0000, | . 0000 , |
| 2, | 1.0990, | 1.0930, | 1.0610, | 1.0100, | . 9450 , | . 7790 , | . 9890, | 1.1550, | 1.1940, | 1.2180, |
| 3, | 1.4590, | 1.5170, | 1.7490, | 1.5970, | 1.3000, | 1.2710, | 1.3640, | 1.7040, | 1.8430, | 1.9860, |
| 4, | 2.0460, | 2.1600, | 2.3000, | 2.2000, | 1.9590, | 1.5700, | 1.7790, | 2.4210, | 2.6130, | 2.6220, |
| 5, | 2.9360, | 2.7660, | 2.9140, | 2.9340, | 2.5310, | 2.5240, | 2.3120, | 3.1320, | 3.6540, | 3.9250, |
| 6 , | 3.7860, | 3.9080 , | 3.1090, | 3.4680, | 3.2730, | 3.1850 , | 3.4770, | 3.7230, | 4.5840, | 5.1800, |
| 7, | 4.6990, | 5.4610, | 3.9760, | 3.7500, | 4.6520, | 4.0860, | 4.5450, | 4.9710, | 4.9760, | 6.0790, |
| 8 , | 5.8930, | 6.3410 , | 4.8960, | 4.6820, | 4.7580, | 5.6560, | 6.2750, | 6.1590, | 7.1460 , | 6.2410, |
| 9, | 9.7000, | 8.5090, | 7.0870, | 6.1400, | 6.7040 , | 5.9730, | 7.6190, | 7.6140, | 8.5640 , | 7.7820, |
| +gp, | 8.8150, | 9.8110, | 8.2870, | 9.1560, | 8.6890, | 8.1470 , | 9.7250, | 9.5870, | 8.7960, | 8.6270, |
| SOPCOFAC, | . 9625 , | . 9642 , | 1.0061, | . 9774 , | . 9901 , | 1.0600, | 1.0202, | 1.0225, | 1.0141, | 1.0108, |



| Table 2 | Catch weights at age (kg) |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, | .8390, | . 9370, | 1.2090, | . 8050, | 1.0490, | . 8150, | 1.0070, | 1.0110, | 1.0990, | 1.1980, |
| 3, | 1.3040, | 1.3240, | 1.4780, | 1.4310, | 1.6420, | 1.3670, | 1.3150, | 1.5270, | 1.6530, | 1.7330, |
| 4, | 1.9880, | 1.9700, | 2.1040, | 2.2870, | 2.4000, | 2.4130, | 1.8930, | 2.5280, | 2.4660, | 2.7690, |
| 5, | 2.3860, | 3.0760, | 2.7140, | 2.7230, | 3.2120 , | 3.4930, | 3.1020 , | 3.1800, | 3.0000 , | 3.6500, |
| 6 , | 3.3300, | 3.5290 , | 3.8040 , | 3.4350 , | 3.6780 , | 4.5250, | 4.2790, | 4.6720, | 4.1480, | 4.4030, |
| 7, | 4.6910, | 4.7100, | 4.6690, | 5.0810, | 4.7740, | 5.0760, | 5.5730, | 6.7760 , | 6.4890 , | 5.7680 , |
| 8, | 7.6350, | 6.4640, | 5.9150, | 6.2810 , | 5.9730, | 6.6310 , | 5.8710, | 6.9660 , | 9.3940, | 8.0350, |
| 9, | 9.5240, | 9.4610, | 7.2330, | 8.3120, | 7.0940, | 6.8630 , | 7.4820, | 9.0280, | 9.2360, | 10.3340, |
| +gp, | 11.9900, | 9.5090, | 9.5590, | 9.9590, | 9.8000, | 10.0890, | 9.2060 , | 10.3240, | 12.1200, | 11.1270, |
| SOPCOFAC, | 1.0028, | 1.0043, | 1.0094, | 1.0067, | 1.0047, | . 9997 , | 1.0004, | 1.0004, | . 9990 , | . 9989 , |


| Table | Proportion mature at age |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |
| AGE |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, | . 1700 , | .1700, | . 1700, | . 1700, | . 1700, | . 1700, | .1700, |
| 3, | . 6400, | . 6400, | . 6400 , | . 6400, | . 6400 , | .6400, | . 6400, |
| 4, | . 8700, | .8700, | . 8700, | . 8700, | . 8700, | . 8700, | . 8700, |


| 5, | .9500, | .9500, | .9500, | .9500, | .9500, | .9500, | .9500, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 6, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 7, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 8, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| gp, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |


| Table | 5 | Proportion mature at age |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, | . 0000, |
| 2, |  | . 1700, | .1700, | . 1700, | .1700, | . 1700, | . 1700, | .1700, | .1700, | . 1700, | .1700, |
| 3, |  | . 6400, | .6400, | . 6400, | .6400, | . 6400, | .6400, | .6400, | .6400, | . 6400, | .6400, |
| 4, |  | . 8700 , | . 8700, | . 8700, | . 8700 , | . 8700 , | . 8700 , | . 8700 , | . 8700, | . 8700 , | . 8700 , |
| 5, |  | . 9500 , | . 9500, | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500 , | . 9500 , |
| 6 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 7, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 8 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| +gp, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |

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| Table | 5 | Propor | n mat | at age |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, |  | . 1700 , | .1700, | . 1700 , | . 1700 , | .1700, | . 1700, | . 1700, | . 0300, | . 0700 , | . 0000 , |
| 3, |  | . 6400, | . 6400, | . 6400, | . 6400, | .6400, | . 6400, | . 6400, | . 7100 , | . 9600 , | . 5000, |
| 4, |  | . 8700 , | . 8700 , | . 8700, | . 8700 , | . 8700 , | . 8700 , | . 8700 , | . 9300 , | . 9800 , | . 9600 , |
| 5, |  | . 9500 , | . 9500, | . 9500, | . 9500, | . 9500, | . 9500 , | . 9500 , | . 9400 , | . 9700 , | . 9600 , |
| 6, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000 , | 1.0000, | 1.0000, |
| 7, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 8 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| +gp, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |


| Table | 5 | Proportion mature at age |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000 , | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, |  | . 0000 , | . 0000 , | . 0600 , | . 0500, | . 0000 , | . 0000 , | . 0600 , | . 0300 , | . 0500 , | . 0900 , |
| 3, |  | . 3800, | . 6700, | . 7200, | . 5400, | .6800, | . 7200, | . 5000, | . 7300, | . 3300 , | . 3500 , |
| 4, |  | . 9300, | . 9100, | . 9000 , | . 9800 , | . 9000 , | . 8600 , | . 8200, | . 7800 , | .8800, | . 3300 , |
| 5, |  | 1.0000, | 1.0000, | . 9700 , | 1.0000, | . 9900 , | 1.0000, | . 9800 , | . 9100, | . 9600 , | . 6600, |
| 6, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | . 9600 , | 1.0000, | 1.0000, | . 9900, | 1.0000, | . 9700, |
| 7, |  | . 9600 , | 1.0000, | 1.0000, | 1.0000, | . 9800, | 1.0000, | 1.0000, | 1.0000, | . 9600, | 1.0000, |
| 8, |  | . 9400 , | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| +gp, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |


| Table | 5 | Proportion mature at age |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, |  | . 0400 , | . 0000 , | . 0000 , | . 0200, | . 0200 , | . 0700 , | . 0400 , | . 0000 , | . 0000 , | . 0500 , |
| 3 , |  | . 4300, | . 6400, | . 6200, | . 4300, | . 3900 , | . 4700 , | . 3700 , | . 2900 , | .5100, | . 6600, |
| 4, |  | . 7400 , | . 9100, | . 9000 , | . 8800 , | .6900, | . 8600 , | . 7600 , | . 7900 , | . 7800 , | . 9000 , |
| 5, |  | . 8500, | . 9700, | . 9900 , | . 9800 , | . 9200, | . 9400 , | . 9700 , | . 8800 , | . 9200, | . 9300, |
| 6 , |  | . 9400 , | 1.0000, | . 9900 , | 1.0000, | . 9900, | 1.0000, | . 9300, | . 9800 , | . 8900 , | . 9800 , |
| 7, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | . 9700 , | 1.0000, | . 8700 , | . 9200 , |
| 8 , |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| +gp, |  | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |


| Table | Pro | n m | at age |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , | . 0000, | . 0000 , | . 0000 , | . 0000 , |
| 2, | . 0400 , | . 0000 , | . 1000 , | . 0900 , | . 0800, | . 0600 , | . 0000 , | . 2400 , | . 2400 , | . 2800 , |
| 3, | . 5900, | . 4700, | . 7800 , | .6100, | .6100, | . 5100, | .6300, | . 8200, | . 7300 , | . 4800 , |
| 4, | . 8000, | . 7800 , | . 9100 , | . 8100, | . 7700 , | . 6900, | . 8500, | . 9500 , | . 9800 , | . 7000 , |
| 5, | . 9900 , | . 9100, | . 9000 , | . 9600 , | . 9400 , | . 8400 , | . 9400 , | . 9800 , | 1.0000, | . 9500 , |
| 6 , | . 9900 , | . 9900 , | . 9500 , | . 9400, | . 9700, | . 9300 , | .9700, | 1.0000, | 1.0000, | . 9700 , |
| 7, | 1.0000, | . 9700, | 1.0000, | . 9600 , | 1.0000, | . 9800 , | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 8, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| 9, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, |
| +gp, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | 1.0000, | . 8300, | 1.0000, | 1.0000, | 1.0000, |

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|  |  | 2, | .0829, | . 0789 , | .1010, | .1099, | . 0530, | .0309, | . 0464 , | . 0657 , | . 0816, | . 0774 , |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 3, | .1969, | . 2389 , | . 2318, | . 3063 , | . 2081 , | .1337, | . 1476, | . 2322 , | . 1568 , | . 3193, |
|  |  | 4, | . 2552 , | . 2687 , | . 3949 , | . 3806 , | . 3654 , | . 2225 , | . 2070, | . 3048 , | . 2046 , | .4359, |
|  |  | 5, | . 4499 , | . 3442 , | .5339, | . 4180 , | . 3409 , | . 3845 , | . 2497 , | . 2813, | . 2953, | . 4134, |
|  |  | 6 , | . 5016, | . 5779, | . 4472 , | . 5709, | . 3709 , | . 5572, | . 6058, | . 2526 , | . 3797 , | . 4544 , |
|  |  | 7, | . 9680, | .5203, | . 7132 , | . 5118, | .6559, | . 4651 , | . 4686 , | . 3722 , | . 5330, | . 3504 , |
|  |  | 8, | . 8520 , | 1.0438, | . 3331, | . 8457 , | . 4208, | . 7528 , | . 2464 , | . 3259 , | . 3052 , | . 4485 , |
|  |  | 9, | . 6106 , | . 5556 , | . 4882 , | . 5499 , | .4339, | . 4800 , | . 3578 , | . 3091 , | . 3457 , | . 4235 , |
|  |  | p, | . 6106, | . 5556 , | . 4882 , | . 5499, | .4339, | . 4800 , | . 3578 , | . 3091 , | . 3457 , | . 4235, |
| 0 | FBAR | $3-$ | . 4743 , | . 3900 , | . 4642 , | . 4375 , | . 3882 , | . 3526 , | . 3358 , | . 2886 , | . 3139 , | . 3947 , |

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Terminal Fs derived using XSA (With F shrinkage)



| Table | 8 | Fishing | mortality | (F) at |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
| 1, |  | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, |  | . 0301 , | . 0341 , | . 0866 , | . 0989 , | . 1279, | . 1586, | . 1939, | . 1347, | . 0312, | . 0995 , |
| 3, |  | .1916, | .1459, | . 1719, | . 2922 , | . 3268 , | . 3465 , | . 4930, | . 3177 , | . 1864 , | . 2725, |
| 4, |  | . 4512 , | . 4082 , | . 2665 , | . 2987, | . 3887 , | . 4580, | . 6010, | . 6873, | . 2971, | . 4053, |
| 5, |  | . 8130, | .8299, | .6381, | . 3267 , | . 2539, | . 3104 , | . 8261 , | . 8792, | . 7491 , | . 5004, |
| 6, |  | . 9099 , | 1.0584, | 1.0420, | .6857, | . 3338 , | . 3517 , | . 8322 , | . 9433, | . 9767 , | .8175, |
| 7, |  | 1.1481, | 1.4231, | . 8124 , | 1.1262, | . 5659, | . 7000 , | 1.3642, | .9388, | 1.1465, | .8836, |
| 8, |  | . 9542 , | 1.3855, | 1.2396, | . 9085, | . 9070, | .6738, | 1.2352, | . 9717 , | 1.0737, | .6153, |
| 9, |  | 1.0211, | 1.1287, | . 9235, | . 6112, | . 2657 , | . 9194, | 1.4999, | 1.8512, | 2.0794, | 1.2362, |
| +gp, |  | 1.0211, | 1.1287, | . 9235 , | .6112, | . 2657 , | . 9194 , | 1.4999, | 1.8512, | 2.0794, | 1.2362, |

0 FBAR 3-7, .7028, .7731, .5862, .5459, .3738, .4333, .8233, .7532, .6712, .5758,


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Terminal Fs derived using XSA (With F shrinkage)


| Table 9 | Relative | $F$ at |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, | .1749, | . 2022, | . 2177, | . 2511, | . 1365 , | . 0875 , | . 1382 , | . 2275 , | . 2600 , | . 1962 , |
| 3 , | . 4151 , | .6125, | . 4994 , | . 7000 , | . 5361, | . 3792 , | . 4397 , | . 8044 , | . 4997, | . 8091 , |
| 4, | . 5380, | .6889, | . 8507, | . 8699 , | . 9412 , | .6311, | . 6165, | 1.0561, | .6519, | 1.1045, |
| 5, | . 9485 , | . 8825 , | 1.1501, | . 9553, | . 8780 , | 1.0905, | .7437, | . 9746 , | .9407, | 1.0473, |
| 6 , | 1.0575, | 1.4819, | . 9634 , | 1.3050, | . 9553, | 1.5802, | 1.8043, | . 8752 , | 1.2097, | 1.1514, |
| 7, | 2.0409, | 1.3342, | 1.5363, | 1.1698, | 1.6895, | 1.3190, | 1.3958, | 1.2897, | 1.6980, | . 8877 , |
| 8 , | 1.7962, | 2.6765, | . 7175 , | 1.9329, | 1.0838, | 2.1349, | . 7339 , | 1.1291, | . 9724, | 1.1364, |
| 9, | 1.2874, | 1.4245, | 1.0517, | 1.2569, | 1.1175, | 1.3614, | 1.0656, | 1.0712, | 1.1014, | 1.0730, |
| +gp, | 1.2874, | 1.4245, | 1.0517, | 1.2569, | 1.1175, | 1.3614, | 1.0656, | 1.0712, | 1.1014, | 1.0730, |
| REFMEAN, | . 4743 , | . 3900 , | . 4642 , | . 4375, | . 3882 , | . 3526 , | . 3358 , | . 2886 , | .3139, | . 3947 , |



| Table | Relat | F at |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000, | . 0000, | . 0000 , | . 0000, | . 0000 , | . 0000, | . 0000, | . 0000 , | . 0000, |
| 2, | . 0369, | . 0653 , | . 1097, | . 2084, | . 1168 , | .0629, | . 0437 , | . 0558, | . 1359 , | . 2168, |
| 3, | . 5298, | . 4960, | . 5812, | . 5517, | . 5022, | . 3877 , | . 2174, | .4301, | .6037, | . 5016, |
| 4, | . 9304 , | 1.0676, | . 9282, | . 9561, | . 9537, | . 8734 , | . 7099 , | . 7873, | 1.0203, | 1.4470, |
| 5, | 1.0507, | 1.0893, | . 9038 , | . 9568 , | 1.1999, | 1.1610, | . 7550 , | 1.0741, | 1.3374, | . 8727 , |
| 6 , | 1.2339, | 1.2477, | 1.2732, | 1.2076, | 1.0690, | 1.4488, | 1.3819, | . 8538 , | 1.1904, | 1.1244, |
| 7, | 1.2553, | 1.0995, | 1.3136, | 1.3278, | 1.2752, | 1.1291, | 1.9359, | 1.8547, | . 8482 , | 1.0543, |
| 8 , | . 8082 , | 1.3974, | 1.4224, | 1.3804, | 1.7013, | 1.3941, | .9675, | 2.4390, | 1.7142, | . 7282 , |
| 9, | 1.0658, | 1.1898, | 1.1794, | 1.1786, | 1.2527, | 1.2120, | 1.1596, | 1.4113, | 5.8845, | 2.2887, |
| +gp, | 1.0658, | 1.1898, | 1.1794, | 1.1786, | 1.2527, | 1.2120, | 1.1596, | 1.4113, | 5.8845, | 2.2887, |
| REFMEAN, | . 6691 , | . 4453 , | .6075, | . 7964 , | . 6680 , | . 5151, | . 4607 , | . 2374 , | . 1872 , | . 3219 , |


| Table | Relative | F at |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , | . 0000 , |
| 2, | . 0428 , | . 0441 , | . 1477, | . 1811 , | . 3422 , | . 3661 , | . 2355, | . 1788 , | . 0465 , | . 1728 , |
| 3, | . 2726, | .1888, | . 2932 , | . 5353, | . 8743, | . 7996 , | . 5989, | . 4218, | . 2777 , | . 4732 , |
| 4, | .6420, | . 5280 , | . 4547 , | . 5472 , | 1.0397, | 1.0570, | .7299, | . 9124, | . 4427 , | . 7038 , |
| 5, | 1.1569, | 1.0735, | 1.0886, | . 5985, | .6792, | . 7163 , | 1.0034, | 1.1672, | 1.1161, | . 8690 , |
| 6 , | 1.2947, | 1.3689, | 1.7776, | 1.2561, | . 8930, | . 8116, | 1.0108, | 1.2523, | 1.4553, | 1.4196, |
| 7, | 1.6337, | 1.8408, | 1.3859, | 2.0629, | 1.5138, | 1.6155, | 1.6570, | 1.2463, | 1.7082, | 1.5344, |
| 8, | 1.3577, | 1.7921, | 2.1148, | 1.6642, | 2.4261, | 1.5550, | 1.5002, | 1.2900, | 1.5997, | 1.0685, |
| 9, | 1.4529, | 1.4599, | 1.5755, | 1.1196, | . 7108 , | 2.1220, | 1.8218, | 2.4577, | 3.0982, | 2.1469, |
| +gp, | 1.4529, | 1.4599, | 1.5755, | 1.1196, | . 7108 , | 2.1220, | 1.8218, | 2.4577, | 3.0982, | 2.1469, |
| REFMEAN, | . 7028 , | . 7731, | . 5862 , | . 5459 , | . 3738 , | . 4333, | . 8233, | . 7532 , | . 6712 , | . 5758, |


| Table | Relati | F at |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, | MEAN | **-** |
| AGE |  |  |  |  |  |  |  |  |  |  |  |  |
| 1, | .0000, | .0000, | . 0000 , | . 0000 , | .0000, | . 0000 , | .0000, | . 0000 , | .0000, | . 0000 , | . 000 |  |


|  | 2, | . 2991, | . 2510, | .1139, | . 2344 , | . 3470 , | . 1565, | . 0546 , | .0758, | .1541, | .1629, | .1309, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 3, | . 5373, | . 6656, | .5909, | 1.2919, | . 7110 , | . 7718 , | . 3662 , | . 4870 , | . 7607 , | . 4672 , | . 5716 , |
|  | 4, | . 5809, | . 7910, | . 7630, | 1.0001, | . 9207 , | 1.0593, | . 9024 , | .6638, | . 9380 , | 1.1258, | . 9092 , |
|  | 5, | . 9902 , | . 9064 , | . 8953 , | . 9193, | .9400, | 1.0257, | 1.1150, | 1.4264, | 1.2566, | 1.0254, | 1.2361, |
|  | 6 , | 1.3323, | 1.2289, | 1.0990, | . 9866 , | 1.3700, | . 9904 , | 1.3891, | 1.3403, | 1.1876, | 1.1586, | 1.2289, |
|  | 7, | 1.5592, | 1.4080, | 1.6518, | . 8021 , | 1.0584, | 1.1528, | 1.2273, | 1.0825, | .8571, | 1.2231, | 1.0542, |
|  | 8 , | 1.6546, | 1.4386, | 2.7256, | 1.1591, | . 8776 , | .7695, | 1.7729, | 1.1986, | . 4527, | .6303, | . 7606 , |
|  | 9, | . 4814 , | 1.7273, | 3.5357, | 2.9007, | 1.4669, | . 6799, | . 7544, | 1.9340, | . 5174, | 1.0026, | 1.1513, |
|  | +gp, | . 4814 , | 1.7273, | 3.5357, | 2.9007, | 1.4669, | . 6799, | . 7544, | 1.9340, | . 5174, | 1.0026, |  |
| 0 | REFMEAN, | . 6067 , | . 4695 , | .4419, | .5314, | .6668, | . 5635, | .5338, | . 2804, | . 3732 , | .4599, |  |

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Terminal Fs derived using XSA (With F shrinkage)

| Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |
| AGE |  |  |  |  |  |  |  |
| 1, | 17399, | 14680, | 25227, | 24782, | 26668, | 10100, | 22676, |
| 2, | 13238, | 14245, | 12019, | 20654, | 20290, | 21834, | 8269, |
| 3 , | 12185, | 9027, | 7385, | 7042, | 12907, | 12893, | 16037, |
| 4, | 2634, | 6141, | 3747, | 3616, | 3503, | 6986, | 7823, |
| 5, | 4092, | 1380, | 2699, | 1863, | 1825, | 1710, | 3639, |
| 6 , | 683, | 1784, | 666, | 1245, | 752, | 895, | 830, |
| 7, | 503, | 378, | 668, | 335, | 584, | 358, | 416, |
| 8, | 213, | 225, | 155, | 210, | 190, | 294, | 151, |
| 9, | 29, | 129, | 66, | 56, | 87, | 112, | 169, |
| +gp, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
| TOTAL, | 50976, | 47989, | 52630, | 59804, | 66807, | 55183, | 60009, |


| Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |  | 1974, | 1975, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 28643, | 21475, | 11390, | 10514, | 14569, | 26041, | 15356, | 37229, | 46803, | 22687, |
| 2, | 18566, | 23451, | 17582, | 9325, | 8608, | 11928, | 21320, | 12573, | 30480, | 38319, |
| 3 , | 5999, | 13990, | 17744, | 13012, | 6840, | 6684, | 9469, | 16664, | 9639, | 23000, |
| 4, | 10207, | 4034, | 9020, | 11522, | 7843, | 4548, | 4788, | 6689, | 10816, | 6747, |
| 5, | 4085, | 6475, | 2525, | 4976, | 6447, | 4456, | 2981, | 3187, | 4037, | 7217, |
| 6 , | 1698, | 2133, | 3757, | 1212, | 2682, | 3754, | 2483, | 1901, | 1969, | 2460, |
| 7, | 351, | 842 , | 980, | 1967, | 561, | 1516, | 1760, | 1109, | 1209, | 1103, |
| 8 , | 200, | 109, | 410, | 393, | 965, | 238, | 779, | 902, | 626, | 581, |
| 9, | 80, | 70, | 31, | 240, | 138, | 519, | 92, | 499, | 533, | 378, |
| +gp, | 0 , | 0, | 0 , | 0 , | 0 , | 0 , | 0 , | 400, | 342, | 476, |
| TOTAL, | 69829, | 72579, | 63439, | 53161, | 48654, | 59683, | 59029, | 81153, | 106456, | 102968, |

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| Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |  | 1984, | 1985, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 12208, | 13128, | 18318, | 28804, | 17100, | 27027, | 30732, | 58342, | 21157, | 11616, |
| 2, | 18575, | 9995, | 10748, | 14998, | 23582, | 14000, | 22128, | 25161, | 47766, | 17322, |
| 3, | 29035, | 13853, | 7799, | 8298, | 11759, | 18286, | 10878, | 17086, | 18656, | 35130, |
| 4, | 13683, | 20010, | 8372, | 5282, | 5226, | 7580, | 11228, | 7128, | 8767, | 10538, |
| 5, | 3572, | 7765, | 10190, | 4463 , | 2811, | 2957, | 4413, | 6412, | 3339, | 4023, |
| 6 , | 3908, | 1676, | 2993, | 5433, | 2206, | 1491, | 1564, | 2450, | 2765, | 1412, |
| 7, | 1279, | 1909, | 659, | 1509, | 2723, | 1076, | 694, | 854, | 916, | 1439, |
| 8, | 636, | 489, | 513, | 297, | 789, | 1477, | 440, | 284, | 238, | 466, |
| 9, | 304 , | 274, | 184, | 238, | 122, | 339, | 732, | 207, | 91, | 121, |
| +gp, | 466, | 18, | 154, | 103, | 52, | 150, | 348, | 200, | 174, | 146, |
| TOTAL, | 83665, | 69116, | 59931, | 69424, | 66370, | 74384, | 83159, | 118126, | 103870, | 82212, |


| Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 12108, | 10661, | 19749, | 4441, | 8132, | 13900, | 12320, | 30804, | 52357, | 15991, |
| 2, | 9511, | 9913, | 8729, | 16169, | 3636, | 6658, | 11380, | 10087, | 25220, | 42867, |
| 3, | 13279, | 7597, | 7884, | 6686, | 11214, | 2754, | 5277, | 9132, | 8150, | 20130, |
| 4, | 20181, | 7627, | 4987, | 4535, | 3528, | 6565, | 1846, | 3909, | 6751, | 5960, |
| 5, | 5194, | 8866, | 3882, | 2323, | 1734, | 1527, | 3428, | 1090, | 2655, | 4566, |
| 6 , | 1784, | 2105, | 4469, | 1835, | 888, | 637, | 688, | 1982, | 692, | 1692, |
| 7, | 459, | 640, | 989, | 1688, | 574, | 356, | 247, | 298, | 1325, | 453, |
| 8, | 389, | 162, | 321, | 365, | 480, | 201, | 163, | 83, | 157, | 926, |
| 9, | 102, | 185, | 71, | 111, | 99, | 126, | 80, | 85, | 38, | 93, |
| +gp, | 81, | 69, | 53, | 16, | 50, | 56, | 90, | 96, | 26, | 102, |
| TOTAL, | 63087, | 47826, | 51135, | 38170, | 30336, | 32780, | 35520, | 57567, | 97371, | 92780, |


| Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |  | 2004, | 2005, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 8049, | 7407, | 17868, | 24393, | 36505, | 16074, | 7466, | 4308, | 7182, | 9029, |
| 2, | 13092, | 6590, | 6064, | 14629, | 19972, | 29888, | 13160, | 6112, | 3527, | 5880, |
| 3 , | 32730, | 10401, | 5214, | 4553, | 10850, | 14388, | 20880, | 8875, | 4374, | 2799, |
| 4, | 14024, | 22125, | 7359, | 3595, | 2783, | 6406, | 8331, | 10441, | 5288, | 2972, |
| 5, | 3062, | 7312, | 12043, | 4616, | 2183, | 1545, | 3318, | 3739, | 4300, | 3217, |
| 6, | 2823, | 1112, | 2611, | 5209, | 2726, | 1387, | 927, | 1189, | 1271, | 1664, |
| 7, | 965, | 930, | 316, | 754, | 2148, | 1598, | 799, | 330, | 379, | 392, |
| 8, | 264, | 251, | 184, | 115, | 200, | 999, | 650, | 167, | 106, | 99, |
| 9, | 599, | 83, | 51, | 44, | 38, | 66 , | 417, | 155, | 52, | 30, |
| +gp, | 80, | 192, | 45, | 19, | 5, | 11, | 10, | 27, | 44, | 47, |
| TOTAL, | 75688, | 56403, | 51755, | 57926, | 77409, | 72361, | 55957, | 35344, | 26522, | 26129, |


| Table 10 | Stock number at age (start of year) |  |  |  |  | Numbers*10**-3 |  |  |  |  | 2016, | GMST 59-** | AMST 59-** |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |  |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1, | 6143, | 7896, | 10060, | 13806, | 5244, | 2301, | 3530, | 9349, | 2918, | 4121, | 0, | 14573, | 18032, |
| 2, | 7393, | 5030, | 6465 , | 8237, | 11303, | 4294, | 1884, | 2890, | 7654, | 2389, | 3374, | 12051, | 14865, |
| 3, | 4358 , | 5048, | 3660, | 5033, | 5954, | 7343, | 3218, | 1498, | 2316, | 5917, | 1815, | 9201, | 11174, |
| 4, | 1745, | 2576, | 3024, | 2308, | 2074, | 3034, | 3892, | 2167, | 1070, | 1428, | 3908, | 5710, | 6882, |
| 5, | 1623, | 1004, | 1454, | 1767, | 1111, | 919, | 1368, | 1968, | 1473, | 617 , | 697, | 3116, | 3734, |
| 6 , | 1597, | 728, | 537, | 802, | 888, | 486, | 422, | 617 , | 1080, | 755, | 315, | 1508, | 1829, |
| 7, | 602, | 583, | 335, | 271, | 389, | 291, | 228, | 165, | 347, | 568 , | 363, | 676, | 840, |
| 8, | 133, | 191, | 246 , | 132, | 145, | 157, | 125, | 97, | 100, | 206, | 265, | 277, | 360, |
| 9, | 44, | 40, | 80, | 60 , | 58, | 66 , | 83, | 40, | 57, | 69, | 126, | 110, | 161, |
| +gp, | 13, | 6, | 26, | 23, | 66, | 7 , | 73, | 13, | 6, | 21, | 46, |  |  |
| total, | 23649, | 23102, | 25887, | 32439, | 27231, | 18898, | 14822, | 18804, | 17022, | 16090, | 10908, |  |  |

[^1]| Table 11 | Spawning | stock | number at | age (spa | ing time) |  | bers*10**-3 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |
| AGE |  |  |  |  |  |  |  |
| 1, | 0, | 0 , | 0, | 0, | 0 , | 0, | 0, |
| 2, | 2250, | 2422, | 2043, | 3511, | 3449, | 3712, | 1406, |
| 3 , | 7798, | 5777, | 4726, | 4507, | 8261, | 8252, | 10263, |
| 4, | 2292, | 5342, | 3259, | 3146, | 3048, | 6078, | 6806, |
| 5, | 3887, | 1311, | 2564, | 1770, | 1734, | 1624, | 3457, |
| 6 , | 683, | 1784, | 666, | 1245, | 752, | 895, | 830, |
| 7, | 503, | 378, | 668, | 335, | 584, | 358, | 416, |
| 8 , | 213, | 225, | 155, | 210, | 190, | 294, | 151, |
| 9, | 29, | 129, | 66, | 56, | 87 , | 112, | 169, |
| +gp, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |


| Table 11 | $\begin{aligned} & \text { Spawning stock } \\ & 1966,1967, \end{aligned}$ |  |  |  |  | Numbers*10**-3 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  |  | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0 , | 0, | 0, | 0, | 0, | 0 , | 0 , | 0, | 0 , |
| 2, | 3156, | 3987, | 2989, | 1585, | 1463, | 2028, | 3624, | 2137, | 5182, | 6514, |
| 3, | 3839, | 8954, | 11356, | 8327, | 4378, | 4278, | 6060, | 10665, | 6169, | 14720, |
| 4, | 8880, | 3510, | 7848, | 10024, | 6823, | 3957, | 4165, | 5819, | 9410, | 5870, |
| 5, | 3880, | 6151, | 2398, | 4727, | 6125, | 4233, | 2832, | 3028, | 3836, | 6856, |
| 6, | 1698, | 2133, | 3757, | 1212, | 2682, | 3754, | 2483, | 1901, | 1969, | 2460, |
| 7, | 351, | 842, | 980, | 1967, | 561, | 1516, | 1760, | 1109, | 1209, | 1103, |
| 8 , | 200, | 109, | 410, | 393, | 965, | 238, | 779, | 902, | 626, | 581, |
| 9, | 80 , | 70, | 31, | 240, | 138, | 519, | 92, | 499, | 533, | 378, |
| +gp, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 400, | 342, | 476, |

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Terminal Fs derived using XSA (With F shrinkage)

| Table 11 | Spawning | stock | er a | (spa | g tir | Numbers*10**-3 |  |  | 1984, | 1985, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0, | 0 , | 0 , | 0, | 0 , | 0, | 0 , | 0, | 0 , |
| 2, | 3158, | 1699, | 1827, | 2550, | 4009, | 2380, | 3762, | 755, | 3344, | 0 , |
| 3, | 18582, | 8866, | 4991, | 5310, | 7526, | 11703, | 6962, | 12131, | 17910, | 17565, |
| 4, | 11904, | 17408, | 7284, | 4595, | 4547, | 6594, | 9768, | 6629, | 8592, | 10117, |
| 5, | 3393, | 7377, | 9680, | 4240, | 2670, | 2809, | 4192, | 6028, | 3239, | 3862, |
| 6 , | 3908, | 1676, | 2993, | 5433, | 2206, | 1491, | 1564, | 2450, | 2765, | 1412, |
| 7, | 1279, | 1909, | 659, | 1509, | 2723, | 1076, | 694, | 854, | 916, | 1439, |
| 8, | 636, | 489, | 513, | 297, | 789, | 1477, | 440, | 284, | 238, | 466, |
| 9, | 304, | 274, | 184, | 238, | 122, | 339, | 732, | 207, | 91, | 121, |
| +gp, | 466, | 18, | 154, | 103, | 52, | 150, | 348, | 200, | 174, | 146, |


| Table 11 | Spawning | stock | number at | age (sp | ng ti |  | bers*10 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0 , | 0 , | 0, | 0 , | 0 , | 0, | 0 , | 0 , | 0, |
| 2, | 0 , | 0, | 524, | 808, | 0 , | 0, | 683, | 303, | 1261, | 3858, |
| 3, | 5046, | 5090, | 5676, | 3610, | 7626, | 1983, | 2639, | 6666, | 2689, | 7046, |
| 4, | 18768, | 6941, | 4488, | 4444, | 3175, | 5646, | 1514, | 3049, | 5941, | 1967, |
| 5, | 5194, | 8866, | 3765, | 2323, | 1716, | 1527, | 3359, | 992, | 2549, | 3014, |
| 6 , | 1784, | 2105, | 4469 , | 1835, | 852, | 637, | 688, | 1962, | 692, | 1641, |
| 7, | 441, | 640 , | 989, | 1688, | 563, | 356, | 247, | 298, | 1272, | 453, |


| 8, | 366, | 162, | 321, | 365, | 480, | 201, | 163, | 83, | 157, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 9, | 102, | 185, | 71, | 111, | 99, | 126, | 80, | 85, | 38, |
| $+g p$, | 81, | 69, | 53, | 16, | 50, | 56, | 90, | 96, | 26, |


| Table 11 | $\begin{aligned} & \text { Spawning } \\ & 1996, \end{aligned}$ | stock number at age (spawning time) |  |  |  | Numbers*10**-3 |  |  | 2004, | 2005, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, |  | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0 , | 0 , | 0, | 0 , | 0, | 0 , | 0 , | 0 , | 0, |
| 2, | 524, | 0 , | 0 , | 293, | 399, | 2092, | 526, | 0 , | 0 , | 294, |
| 3 , | 14074, | 6657, | 3233, | 1958, | 4231, | 6762, | 7726, | 2574, | 2231, | 1847, |
| 4, | 10378, | 20133, | 6623, | 3164, | 1920, | 5510, | 6331, | 8249, | 4125, | 2675, |
| 5, | 2603, | 7093, | 11922, | 4523, | 2009, | 1452, | 3218, | 3291, | 3956, | 2992, |
| 6 , | 2653, | 1112, | 2585, | 5209, | 2698, | 1387, | 862, | 1165, | 1131, | 1631, |
| 7, | 965, | 930, | 316, | 754, | 2148, | 1598, | 775, | 330, | 330, | 360, |
| 8, | 264, | 251, | 184, | 115, | 200, | 999, | 650, | 167, | 106, | 99, |
| 9, | 599, | 83, | 51, | 44, | 38, | 66, | 417, | 155, | 52, | 30, |
| +gp, | 80 , | 192, | 45, | 19, | 5, | 11, | 10, | 27, | 44, | 47, |


| Table | Spawning | stock number at age (spawning time) |  |  |  | Numbers*10**-3 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0 , | 0, | 0 , | 0, | 0 , | 0 , | 0, | 0, | 0, |
| 2, | 296, | 0 , | 646, | 741, | 904, | 258, | 0 , | 694, | 1837, | 669, |
| 3 , | 2571, | 2373, | 2855, | 3070, | 3632, | 3745, | 2028, | 1229, | 1691, | 2840, |
| 4, | 1396, | 2009, | 2752, | 1870, | 1597, | 2094, | 3308, | 2059, | 1049, | 999, |
| 5, | 1606, | 914, | 1309, | 1696, | 1044, | 772, | 1285, | 1929, | 1473, | 586, |
| 6, | 1581, | 721, | 510, | 754, | 861, | 452, | 409, | 617, | 1080, | 732, |
| 7, | 602, | 565, | 335, | 260, | 389, | 286, | 228, | 165, | 347, | 568, |
| 8 , | 133, | 191, | 246, | 132, | 145, | 157, | 125, | 97, | 100, | 206, |
| 9, | 44, | 40, | 80, | 60, | 58, | 66, | 83, | 40, | 57, | 69, |
| +gp, | 13, | 6, | 26, | 23, | 66, | 7, | 60, | 13, | 6, | 21, |

[^2]At 12/04/2016 9:00
Terminal Fs derived using XSA (With F shrinkage)

| Table 12 | Stock biomass at age (start of year) |  |  |  |  | Tonnes |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |
| AGE |  |  |  |  |  |  |  |
| 1, | 0 , | 0 , | 0, | 0 , | 0, | 0 , | 0, |
| 2, | 11252, | 14245, | 12981, | 20654, | 21102, | 21179, | 7607, |
| 3, | 21080, | 18324, | 16395, | 15985, | 25040, | 23595, | 23253, |
| 4, | 8508, | 20694, | 12925, | 12113, | 12296, | 22007, | 20104, |
| 5, | 18003, | 6100, | 12656, | 8533, | 8394, | 7404, | 13755, |
| 6 , | 3963, | 10737, | 3675, | 6137, | 4134, | 5442, | 4723, |
| 7, | 3206, | 2516, | 4733, | 3043, | 3959, | 2509, | 3042, |
| 8, | 1563, | 1826, | 1537, | 1384, | 1657, | 1834, | 1194, |
| 9, | 229, | 1420, | 526, | 376, | 1018, | 695, | 1366, |
| +gp, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
| TOTALBIO, | 67803, | 75862, | 65428, | 68225, | 77602, | 84666, | 75043, |


|  | Table 12 | Stock biomass at age (start of year) |  |  |  |  | Tonnes |  |  | 1974, | 1975, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, |  |  |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0, | 0, | 0 , | 0 , | 0 , | 0, | 0, | 0 , | 0, | 0, |
|  | 2, | 18194, | 22513, | 15472, | 10165, | 8264, | 9662, | 14071, | 13956, | 32919, | 30272, |
|  | 3, | 10618, | 27002, | 30520, | 23421, | 15254, | 12032, | 15245, | 33328, | 21400, | 41170, |
|  | 4, | 28070, | 12626, | 27693, | 32837, | 21097, | 13554, | 12352, | 22808, | 37209, | 20105, |
|  | 5, | 14337, | 26158, | 10401, | 18261, | 25402, | 15951, | 9718, | 12397, | 19379, | 30745, |
|  | 6 , | 8150, | 10194, | 17472, | 5926, | 13786, | 14790, | 10654, | 9696, | 10202, | 13434, |
|  | 7, | 2219, | 5261, | 5388, | 9934, | 3621, | 7381, | 8714, | 5658, | 7110, | 6894, |
|  | 8, | 1505, | 764, | 3142, | 2913, | 9953, | 1543, | 5050, | 5521, | 3844, | 4363, |
|  | 9, | 825, | 771, | 345, | 2082, | 1021, | 3305, | 634, | 4319, | 4601, | 2791, |
|  | +gp, | 0 , | 0 , | 0 , | 0, | 0 , | 0 , | 0 , | 3031, | 2603, | 3889, |
| 0 | TOTALBIO, | 83919, | 105289, | 110433, | 105537, | 98398, | 78218, | 76439, | 110713, | 139266, | 153664, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD_ind_Surveys_revised

$$
\text { At } 12 / 04 / 2016 \quad 9: 00
$$

Terminal Fs derived using XSA (With F shrinkage)

|  | Table 12 | Stock biomass at age (start of year) |  |  |  |  | Tonnes |  | 1983, | 1984, | 1985, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, |  |  |  |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0, | 0, | 0, | 0, | 0, | 0, | 0, | 0, | 0, | 0, |
|  | 2, | 17460, | 8696, | 11952, | 13453, | 21861, | 15121, | 27218, | 33666, | 57081, | 15676, |
|  | 3 , | 49940, | 24797, | 10801, | 13957, | 16838, | 26881, | 15371, | 33318, | 35222, | 58246, |
|  | 4, | 38860, | 50624, | 17917, | 11678, | 11602, | 16523, | 24006, | 17129, | 26127, | 27673, |
|  | 5, | 13216, | 28576, | 31843, | 13622, | 8727, | 9492, | 13712, | 19923, | 12283, | 13678, |
|  | 6 , | 20558, | 7792, | 13060, | 19786, | 7805, | 5518, | 6275, | 10068, | 12360, | 5296, |
|  | 7, | 8223, | 10192, | 3906, | 7120, | 11961, | 4560, | 3779, | 4289, | 5028, | 6072, |
|  | 8 , | 4065, | 3045, | 3257, | 2160, | 4815, | 6542, | 2447, | 1593, | 1539, | 2208, |
|  | 9, | 2597, | 2295, | 1602, | 1993, | 927, | 2271, | 3820, | 1661, | 602, | 786, |
|  | +gp, | 6341, | 194, | 1889, | 1343, | 500, | 1503, | 2336, | 1608, | 1916, | 1605, |
| 0 | TOTALBIO, | 161260, | 136211, | 96227, | 85112, | 85038, | 88411, | 98963, | 123255, | 152158, | 131240, |


|  | Table 12 | Stock biomass at age (start of year) |  |  |  |  | Tonnes |  | 1993, | 1994, | 1995, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, |  |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0, | 0 , | 0 , | 0 , | 0, | 0, | 0 , | 0, | 0, | 0 , |
|  | 2, | 10452, | 10835, | 9261, | 16331, | 3436, | 5187, | 11255, | 11650, | 30113, | 52212, |
|  | 3, | 19374, | 11524, | 13789, | 10677, | 14579, | 3500, | 7198, | 15561, | 15020, | 39979, |
|  | 4, | 41290, | 16474, | 11471, | 9976, | 6911, | 10307, | 3285, | 9464 , | 17640, | 15626, |
|  | 5, | 15250, | 24523, | 11312, | 6816, | 4388, | 3855, | 7924, | 3414, | 9701, | 17923, |
|  | 6 , | 6752, | 8228, | 13894, | 6365, | 2906, | 2028, | 2391, | 7379, | 3170, | 8766, |
|  | 7, | 2157, | 3492, | 3932, | 6331, | 2672, | 1454, | 1124, | 1481, | 6593, | 2755, |
|  | 8, | 2292, | 1029, | 1571, | 1707, | 2284, | 1135, | 1022, | 511, | 1122, | 5776, |
|  | 9, | 988, | 1578, | 505, | 680, | 667 , | 753, | 610, | 650, | 326, | 726, |
|  | +gp, | 716, | 678, | 442, | 147, | 434, | 460, | 874, | 924, | 228, | 884, |
| 0 | TOTALBIO, | 99271, | 78362, | 66177, | 59031, | 38276, | 28679, | 35684, | 51034, | 83914, | 144645, |



|  | 2, | 13301, | 5937, | 6088, | 15360, | 28280, | 34789, | 13384, | 5012, | 3657, | 5798, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 3 , | 56852, | 13948, | 7389, | 7221, | 23544, | 29869, | 36917, | 12088, | 5047, | 3843, |
|  | 4, | 38495, | 43320, | 13262, | 8448, | 8870, | 19559, | 23367, | 22209, | 8953, | 5231, |
|  | 5, | 11637, | 22024, | 27457, | 12804, | 8286, | 6142, | 11709, | 12449, | 10160, | 7376, |
|  | 6 , | 12576, | 4624, | 9080, | 16741, | 11034, | 6093, | 3797, | 4866, | 4868, | 5223, |
|  | 7, | 4802, | 4178, | 1716, | 4144, | 9832, | 7785, | 3574, | 1543, | 1968, | 2072, |
|  | 8, | 1392, | 1331, | 1074, | 950, | 1638, | 5556, | 3022, | 1003, | 669, | 817, |
|  | 9, | 3352, | 514, | 409, | 397, | 451, | 482, | 2603, | 1041, | 396, | 258, |
|  | +gp, | 596, | 1356, | 397, | 204, | 61, | 134, | 72, | 182, | 421, | 450, |
| 0 | TOTALBIO, | 143005, | 97233, | 66872, | 66269, | 91995, | 110410, | 98445, | 60392, | 36140, | 31066, |


|  | Table 12 | Stock biomass at age (start of year) |  |  |  |  | Tonnes |  |  |  | 2015, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, |  |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0, | 0, | 0, | 0 , | 0, | 0 , | 0 , | 0 , | 0, | 0, |
|  | 2, | 6202, | 4713, | 7816, | 6631, | 11857, | 3499, | 1897, | 2922, | 8412, | 2862, |
|  | 3, | 5683, | 6684, | 5410, | 7202, | 9776, | 10037, | 4232, | 2288, | 3829, | 10254, |
|  | 4, | 3469, | 5074, | 6362, | 5279, | 4978, | 7321, | 7367, | 5479, | 2639, | 3953, |
|  | 5, | 3871, | 3089, | 3947, | 4812, | 3567, | 3210, | 4242, | 6259, | 4419, | 2253, |
|  | 6 , | 5317, | 2571, | 2044, | 2754, | 3265, | 2198, | 1806, | 2885, | 4481, | 3322, |
|  | 7, | 2822, | 2744, | 1564, | 1375, | 1855, | 1480, | 1269, | 1116, | 2253, | 3275, |
|  | 8, | 1012, | 1237, | 1457, | 830, | 864, | 1042, | 732, | 674, | 935, | 1659, |
|  | 9, | 416, | 376, | 577, | 503, | 415, | 453, | 624, | 358, | 523, | 711, |
|  | +gp, | 156, | 56, | 247, | 232, | 648, | 70, | 670, | 135, | 76, | 231, |
| 0 | TOTALBIO, | 28949, | 26543, | 29423, | 29617, | 37225, | 29310, | 22838, | 22114, | 27567, | 28520, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD_ind_Surveys_revised
At 12/04/2016 9:00
Terminal Fs derived using XSA (With F shrinkage)

|  | Table 13 | Spawning | stock biomass at age (spawning time) |  |  |  |  | Tonnes |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |
|  | AGE |  |  |  |  |  |  |  |
|  | 1, | 0, | 0 , | 0, | 0 , | 0, | 0 , | 0, |
|  | 2, | 1913, | 2422, | 2207, | 3511, | 3587, | 3600, | 1293, |
|  | 3, | 13491, | 11727, | 10493, | 10230, | 16026, | 15101, | 14882, |
|  | 4, | 7402, | 18004, | 11245, | 10538, | 10698, | 19146, | 17491, |
|  | 5, | 17103, | 5795, | 12023, | 8106, | 7975, | 7034, | 13067, |
|  | 6 , | 3963, | 10737, | 3675, | 6137, | 4134, | 5442, | 4723, |
|  | 7, | 3206, | 2516, | 4733, | 3043, | 3959, | 2509, | 3042, |
|  | 8, | 1563, | 1826, | 1537, | 1384, | 1657, | 1834, | 1194, |
|  | 9, | 229, | 1420, | 526, | 376, | 1018, | 695, | 1366, |
|  | +gp, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
| 0 | TOTSPBIO, | 48869, | 54447, | 46439, | 43326, | 49054, | 55362, | 57057, |


| Table 13 | Spawning | stock | biomass at | ge (sp | ing ti |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1966, | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0 , | 0, | 0, | 0, | 0 , | 0, | 0, | 0, | 0, |
| 2, | 3093, | 3827, | 2630, | 1728, | 1405, | 1642, | 2392, | 2372, | 5596, | 5146, |
| 3, | 6796, | 17281, | 19533, | 14989, | 9763, | 7700, | 9757, | 21330, | 13696, | 26349, |
| 4, | 24421, | 10985, | 24093, | 28568, | 18354, | 11792, | 10746, | 19843, | 32372, | 17491, |
| 5, | 13620, | 24850, | 9881, | 17348, | 24132, | 15154, | 9232, | 11777, | 18411, | 29208, |
| 6 , | 8150, | 10194, | 17472, | 5926, | 13786, | 14790, | 10654, | 9696, | 10202, | 13434, |
| 7, | 2219, | 5261, | 5388, | 9934, | 3621, | 7381, | 8714, | 5658, | 7110, | 6894, |
| 8, | 1505, | 764, | 3142, | 2913, | 9953, | 1543, | 5050, | 5521, | 3844, | 4363, |
| 9, | 825, | 771, | 345, | 2082, | 1021, | 3305, | 634, | 4319, | 4601, | 2791, |
| +gp, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 3031, | 2603, | 3889, |

TOTSPBIO, 60629, 73934, 82484, 83487, 82035, 63308, 57180, 83547, 98434, 109566,

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD_ind_Surveys_revised
At 12/04/2016 9:00

Terminal Fs derived using XSA (With F shrinkage)

| Table 13 | Spawning | stock | biomass a | age (sp | ing t |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0, | 0, | 0 , | 0 , | 0, | 0 , | 0, | 0, | 0 , |
| 2, | 2968, | 1478, | 2032, | 2287, | 3716, | 2570, | 4627, | 1010, | 3996, | 0, |
| 3, | 31962, | 15870, | 6913, | 8932, | 10777, | 17204, | 9837, | 23656, | 33813, | 29123, |
| 4, | 33808, | 44043, | 15588, | 10160, | 10094, | 14375, | 20885, | 15930, | 25604, | 26566, |
| 5, | 12555, | 27147, | 30251, | 12941, | 8291, | 9017, | 13026, | 18727, | 11915, | 13131, |
| 6 , | 20558, | 7792, | 13060, | 19786, | 7805, | 5518, | 6275, | 10068, | 12360, | 5296, |
| 7, | 8223, | 10192, | 3906 , | 7120, | 11961, | 4560, | 3779, | 4289, | 5028, | 6072, |
| 8, | 4065, | 3045, | 3257 , | 2160, | 4815, | 6542, | 2447, | 1593, | 1539, | 2208, |
| 9, | 2597, | 2295, | 1602, | 1993, | 927, | 2271, | 3820, | 1661, | 602, | 786, |
| +gp, | 6341, | 194, | 1889, | 1343, | 500, | 1503, | 2336, | 1608, | 1916, | 1605, |
| OTSPBIO, | 123077, | 112057, | 78497, | 66723, | 58887, | 63562, | 67033, | 78542, | 96773, | 84786, |

Table 13 Spawning stock biomass at age (spawning time) Tonnes
YEAR, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995,

| AGE |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1, | 0, | 0 , | 0, | 0, | 0 , | 0 , | 0, | 0, | 0, | 0 , |
| 2, | 0 , | 0 , | 556, | 817, | 0, | 0 , | 675, | 350, | 1506, | 4699, |
| 3, | 7362, | 7721, | 9928, | 5766, | 9913, | 2520, | 3599, | 11359, | 4957, | 13993, |
| 4, | 38399, | 14992, | 10323, | 9777, | 6220, | 8864, | 2694, | 7382, | 15523, | 5157, |
| 5, | 15250, | 24523, | 10973, | 6816, | 4344, | 3855, | 7766, | 3107, | 9313, | 11829, |
| 6, | 6752, | 8228, | 13894, | 6365, | 2790, | 2028, | 2391, | 7305, | 3170, | 8503, |
| 7, | 2070, | 3492, | 3932, | 6331, | 2619, | 1454, | 1124, | 1481, | 6329, | 2755, |
| 8, | 2154, | 1029, | 1571, | 1707, | 2284, | 1135, | 1022, | 511, | 1122, | 5776, |
| 9, | 988, | 1578, | 505, | 680, | 667, | 753, | 610, | 650, | 326, | 726, |
| +gp, | 716, | 678, | 442, | 147, | 434, | 460, | 874, | 924, | 228, | 884, |
| TOTSPBIO, | 73693, | 62241, | 52125, | 38406, | 29270, | 21069, | 20755, | 33068, | 42475, | 54320, |


|  | Table 13 | Spawning | stock | mass | ge (sp | ing ti |  | nes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1996, | 1997, | 1998, | 1999, | 2000, | 2001, | 2002, | 2003, | 2004, | 2005, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0 , | 0 , | 0 , | 0, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , |
|  | 2, | 532, | 0 , | 0, | 307, | 566, | 2435, | 535, | 0, | 0, | 290, |
|  | 3, | 24446, | 8927, | 4581, | 3105, | 9182, | 14039, | 13659, | 3506, | 2574, | 2536, |
|  | 4, | 28486, | 39421, | 11935, | 7435, | 6120, | 16821, | 17759, | 17545, | 6984, | 4708, |
|  | 5, | 9891, | 21363, | 27183, | 12548, | 7623, | 5774, | 11357, | 10955, | 9347, | 6860, |
|  | 6 , | 11821, | 4624, | 8989, | 16741, | 10923, | 6093, | 3532, | 4768, | 4332, | 5118, |
|  | 7, | 4802, | 4178, | 1716, | 4144, | 9832, | 7785, | 3467, | 1543, | 1712, | 1906, |
|  | 8, | 1392, | 1331, | 1074, | 950, | 1638, | 5556, | 3022, | 1003, | 669, | 817, |
|  | 9, | 3352, | 514, | 409, | 397, | 451, | 482, | 2603, | 1041, | 396, | 258, |
|  | +gp, | 596, | 1356, | 397, | 204, | 61, | 134, | 72, | 182, | 421, | 450, |
| 0 | TOTSPBIO, | 85321, | 81714, | 56284, | 45830, | 46396, | 59118, | 56006, | 40542, | 26435, | 22942, |


| $\begin{aligned} & \text { Table } 13 \\ & \text { YEAR, } \end{aligned}$ | $\begin{aligned} & \text { Spawning stock } \\ & 2006,2007, \end{aligned}$ |  |  |  |  |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0 , | 0, | 0 , | 0, | 0, | 0 , | 0, | 0, | 0, |
| 2, | 248, | 0 , | 782, | 597, | 949, | 210, | 0 , | 701, | 2019, | 801, |
| 3, | 3353, | 3141, | 4220, | 4393, | 5963, | 5119, | 2666, | 1876, | 2795, | 4922, |
| 4, | 2775, | 3958, | 5789, | 4276, | 3833, | 5052, | 6262, | 5205, | 2586, | 2767, |
| 5, | 3833, | 2811, | 3553, | 4619, | 3353, | 2696, | 3988, | 6134, | 4419, | 2141, |
| 6 , | 5264, | 2545, | 1942, | 2589, | 3167, | 2044, | 1752, | 2885, | 4481, | 3223, |
| 7, | 2822, | 2662, | 1564, | 1320, | 1855, | 1450, | 1269, | 1116, | 2253, | 3275, |
| 8, | 1012, | 1237, | 1457, | 830, | 864, | 1042, | 732, | 674, | 935, | 1659, |
| 9, | 416, | 376, | 577, | 503, | 415, | 453, | 624, | 358, | 523, | 711, |
| +gp, | 156, | 56, | 247, | 232, | 648, | 70, | 556, | 135, | 76, | 231, |
| TOTSPBIO, | 19879, | 16786, | 20129, | 19359, | 21047, | 18135, | 17848, | 19083, | 20087, | 19729, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD ind Surveys revised At 12/04/2016 9:00

Terminal Fs derived using XSA (With F shrinkage)



Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD_ind_Surveys_revised

$$
\text { At } 12 / 04 / 2016 \quad 9: 00
$$

Terminal Fs derived using XSA (With F shrinkage)

| Table 14 | Stock biomass at age with SOP (start of year) |  |  |  |  |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 1976, | 1977, | 1978, | 1979, | 1980, | 1981, | 1982, | 1983, | 1984, | 1985, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0, | 0, | 0 , | 0 , | 0 , | 0, | 0 , | 0 , | 0, |
| 2, | 16854, | 6098, | 11910, | 13242, | 23138, | 15737, | 27299, | 32638, | 55283, | 14878, |
| 3, | 48206, | 17388, | 10764, | 13738, | 17822, | 27977, | 15417, | 32302, | 34113, | 55279, |
| 4, | 37510, | 35499, | 17855, | 11495, | 12280, | 17197, | 24078, | 16606, | 25304, | 26264 , |


| 5, | 12757, | 20038, | 31732, | 13408, | 9237, | 9879, | 13753, | 19315, | 11896, | 12981, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 6, | 19844, | 5464, | 13015, | 19476, | 8261, | 5743, | 6294, | 9760, | 11971, | 5026, |
| 7, | 7937, | 7147, | 3892, | 7009, | 12660, | 4746, | 3790, | 4158, | 4869, | 5762, |
| 8, | 3924, | 2135, | 3245, | 2126, | 5096, | 6809, | 2455, | 1545, | 1491, | 2096, |
| 9, | 2507, | 1609, | 1597, | 1962, | 981, | 2364, | 3831, | 1610, | 583, | 746, |
| 49p, | 6121, | 136, | 1882, | 1322, | 530, | 1564, | 2343, | 1559, | 1855, | 1523, |


|  | Table 14 | Stock biomass at age with SOP (start of year) |  |  |  |  |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | YEAR, | 1986, | 1987, | 1988, | 1989, | 1990, | 1991, | 1992, | 1993, | 1994, | 1995, |
|  | AGE |  |  |  |  |  |  |  |  |  |  |
|  | 1, | 0 , | 0, | 0, | 0 , | 0, | 0 , | 0, | 0, | 0 , | 0, |
|  | 2, | 10060, | 10448, | 9318, | 15962, | 3402, | 5498, | 11483, | 11912, | 30537, | 52774, |
|  | 3 , | 18647, | 11112, | 13874, | 10436, | 14435, | 3710, | 7344, | 15910, | 15231, | 40409, |
|  | 4, | 39741, | 15885, | 11541, | 9751, | 6843, | 10925, | 3351, | 9676, | 17888, | 15794, |
|  | 5, | 14678, | 23646, | 11381, | 6662, | 4345, | 4086, | 8085, | 3491, | 9837, | 18116, |
|  | 6, | 6499, | 7934, | 13980, | 6221, | 2877, | 2150, | 2439, | 7544, | 3215, | 8860, |
|  | 7, | 2076, | 3368, | 3957, | 6188, | 2646, | 1541, | 1146, | 1514, | 6686, | 2784, |
|  | 8 , | 2206, | 992, | 1581, | 1668, | 2262, | 1203, | 1043, | 523, | 1138, | 5838, |
|  | 9, | 951, | 1521, | 508, | 664, | 660, | 799, | 623, | 665, | 331, | 734, |
|  | +gp, | 689, | 654, | 444, | 144, | 429, | 487, | 891, | 944, | 232, | 893, |
| 0 | TOTALBIO, | 95548, | 75559, | 66584, | 57696, | 37899, | 30399, | 36406, | 52180, | 85094, | 146203, |



| Table 14 | Stock | biomass at | age with | SOP (st | of y |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| YEAR, | 2006, | 2007, | 2008, | 2009, | 2010, | 2011, | 2012, | 2013, | 2014, | 2015, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0 , | 0, | 0, | 0, | 0, | 0, | 0, | 0, | 0, | 0, |
| 2, | 6219, | 4733, | 7889, | 6675, | 11913, | 3498, | 1898, | 2923, | 8404, | 2859, |
| 3, | 5699, | 6713, | 5460, | 7251, | 9822, | 10034, | 4234, | 2289, | 3825, | 10243, |
| 4, | 3479, | 5096, | 6421, | 5314, | 5001, | 7319, | 7370, | 5481, | 2636, | 3949, |
| 5, | 3882, | 3103, | 3984, | 4844, | 3584, | 3209, | 4244, | 6261, | 4415, | 2251, |
| 6, | 5332, | 2582, | 2063, | 2772, | 3280, | 2198, | 1807, | 2886, | 4477, | 3319, |
| 7, | 2830, | 2756, | 1578, | 1384, | 1864, | 1479, | 1269, | 1116, | 2251, | 3271, |
| 8, | 1015, | 1242, | 1470, | 836, | 868, | 1041, | 732, | 675, | 934, | 1657, |
| 9, | 417, | 378, | 582, | 506, | 417, | 453, | 624, | 358, | 523, | 710, |
| +gp, | 156, | 56, | 250, | 233, | 651, | 69 , | 670, | 135, | 76, | 231, |


| TOTALBIO, | 29029, | 26658, | 29698, | 29816, | 37398, | 29300, | 22848, | 22123, | 27540, | 28489, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Run title : COD | FAROE P | PLATEAU | (ICES SUBDIVISION Vb1) |  |  |  | COD_ind_Surveys_revised |  |  |  |
| At 12/04/2016 | 9:00 |  |  |  |  |  |  |  |  |  |
|  | Terminal | 1 Fs der | ived using | XSA (Wi | th F shri | nkage) |  |  |  |  |
| Table 15 | Spawning | $g$ stock b | biomass wi | h SOP ( | (spawning | time) | Tonnes |  |  |  |
| YEAR, | 1959, | 1960, | 1961, | 1962, | 1963, | 1964, | 1965, |  |  |  |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0, | 0, | 0, | 0, | 0, | 0, |  |  |  |
| 2, | 1919, | 2442, | 2001, | 3316, | 3434, | 3537, | 1457, |  |  |  |
| 3 , | 13532, | 11824, | 9514, | 9662, | 15342, | 14835, | 16761, |  |  |  |
| 4, | 7424, | 18153, | 10197, | 9953, | 10241, | 18810, | 19699, |  |  |  |
| 5, | 17154, | 5843, | 10902, | 7656, | 7634, | 6910, | 14716, |  |  |  |
| 6 , | 3975, | 10826, | 3332, | 5796, | 3958, | 5346, | 5319, |  |  |  |
| 7, | 3216, | 2537, | 4292, | 2874, | 3790, | 2465, | 3426, |  |  |  |
| 8, | 1567, | 1841, | 1394, | 1307, | 1586, | 1802, | 1344 , |  |  |  |
| 9, | 230, | 1431, | 477, | 355, | 975, | 683, | 1538, |  |  |  |
| +gp, | 0, | 0, | 0, | 0 , | 0 , | 0, | 0, |  |  |  |
| TOTSPBIO, | 49017, | 54898, | 42109, | 40918, | 46960, | 54390, | 64259, |  |  |  |


| Table 15 | Spawning1966, | stock biomass with SOP (spawning time) |  |  |  |  | Tonnes |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 1967, | 1968, | 1969, | 1970, | 1971, | 1972, | 1973, | 1974, | 1975, |
| AGE |  |  |  |  |  |  |  |  |  |  |
| 1, | 0, | 0, | 0, | 0, | 0 , | 0, | 0 , | 0, | 0, | 0, |
| 2, | 3373, | 3913, | 2788, | 1875, | 1397, | 2014, | 2986, | 2404, | 5671, | 4996, |
| 3 , | 7411, | 17668, | 20701, | 16265, | 9707, | 9444, | 12178, | 21615, | 13879, | 25581, |
| 4, | 26631, | 11231, | 25534, | 31000, | 18250, | 14461, | 13413, | 20108, | 32804, | 16982, |
| 5, | 14853, | 25407, | 10472, | 18825, | 23995, | 18585, | 11522, | 11934, | 18657, | 28357, |
| 6 , | 8888, | 10422, | 18517, | 6431, | 13708, | 18139, | 13297, | 9826, | 10338, | 13043, |
| 7, | 2420, | 5379, | 5710, | 10779, | 3601, | 9052, | 10877, | 5734, | 7205, | 6693, |
| 8, | 1642, | 781, | 3330, | 3161, | 9896, | 1893, | 6303, | 5594, | 3895, | 4236, |
| 9, | 900, | 788, | 365, | 2259, | 1015, | 4054, | 791, | 4377, | 4663, | 2710, |
| +gp, | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 0 , | 3071, | 2637, | 3776, |
| TOTSPBIO, | 66117, | 75591, | 87417, | 90595, | 81570, | 77642, | 71366, | 84663, | 99750, | 106374, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1) COD_ind_Surveys_revised
At 12/04/2016 9:00
Terminal Fs derived using XSA (With F shrinkage)
Table 15 Spawning stock biomass with SOP (spawning time) Tonnes





Table 15 Spawning stock biomass with SOP (spawning time) Tonnes
YEAR, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015,

| AGE |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1, | 0 , | 0 , | 0, | 0 , | 0, | 0 , | 0 , | 0, | 0, | 0, |
| 2, | 249, | 0, | 789, | 601, | 953, | 210, | 0, | 701, | 2017, | 800, |
| 3 , | 3362, | 3155, | 4259, | 4423, | 5991, | 5117, | 2667, | 1877, | 2792, | 4916, |
| 4, | 2783, | 3975, | 5843, | 4304, | 3851, | 5050, | 6264, | 5207, | 2584, | 2764, |
| 5, | 3843, | 2823, | 3586, | 4650, | 3369, | 2696, | 3989, | 6136, | 4415, | 2138, |
| 6 , | 5279, | 2556, | 1960, | 2606, | 3181, | 2044, | 1753, | 2886, | 4477, | 3219, |
| 7, | 2830, | 2673, | 1578, | 1329, | 1864, | 1449, | 1269, | 1116, | 2251, | 3271, |
| 8, | 1015, | 1242, | 1470, | 836, | 868, | 1041, | 732, | 675, | 934, | 1657, |
| 9, | 417, | 378, | 582, | 506, | 417, | 453, | 624, | 358, | 523, | 710, |
| +gp, | 156, | 56, | 250, | 233, | 651, | 69 , | 556, | 135, | 76, | 231, |
| TOTSPBIO, | 19934, | 16858, | 20317, | 19489, | 21145, | 18129, | 17855, | 19090, | 20068, | 19708, |

Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD_ind_Surveys_revised,
At 12/04/2016 9:00
Table 16 Summary (without SOP correction)
Terminal Fs derived using XSA (With F shrinkage)


Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
COD_ind_Surveys_revised,

| At $12 / 04 / 2016$ | $9: 00$ |
| ---: | :--- |
| Table 17 | Summary |

Terminal Fs derived using XSA (With F shrinkage)

| , | RECRUITS, Age 1 | TOTALBIO, | TOTSPBIO, | LANDINGS, | YIELD/SSB, | SOPCOFAC, | FBAR | 3-7, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1959, | 17399, | 68009, | 49017, | 22415, | . 4573, | 1.0030, |  | . 5117, |
| 1960, | 14680, | 76490, | 54898, | 32255, | .5875, | 1.0083, |  | . 6610, |
| 1961, | 25227, | 59328, | 42109, | 21598, | .5129, | . 9068 , |  | . 6059 , |
| 1962, | 24782, | 64433, | 40918, | 20967, | . 5124, | . 9444 , |  | . 5226 , |
| 1963, | 26668, | 74289, | 46960, | 22215, | . 4731, | . 9573, |  | . 4944 , |
| 1964, | 10100, | 83179, | 54390, | 21078, | . 3875 , | . 9824, |  | . 5017, |
| 1965, | 22676, | 84516, | 64259, | 24212, | . 3768 , | 1.1262, |  | . 4909, |
| 1966, | 28643, | 91515, | 66117, | 20418, | . 3088 , | 1.0905, |  | . 4743, |
| 1967, | 21475, | 107649, | 75591, | 23562, | . 3117 , | 1.0224, |  | . 3900, |
| 1968, | 11390, | 117038, | 87417, | 29930, | . 3424, | 1.0598, |  | . 4642 , |
| 1969, | 10514, | 114522, | 90595, | 32371, | . 3573 , | 1.0851, |  | . 4375, |
| 1970, | 14569, | 97841, | 81570, | 24183, | . 2965 , | . 9943 , |  | . 3882 , |
| 1971, | 26041, | 95928, | 77642, | 23010, | . 2964 , | 1.2264, |  | . 3526 , |
| 1972, | 15356, | 95404, | 71366, | 18727, | . 2624 , | 1.2481, |  | . 3358 , |
| 1973, | 37229, | 112192, | 84663, | 22228, | . 2625 , | 1.0134, |  | . 2886 , |
| 1974, | 46803, | 141128, | 99750, | 24581, | . 2464 , | 1.0134, |  | . 3139 , |
| 1975, | 22687, | 149187, | 106374, | 36775, | . 3457 , | . 9709, |  | . 3947 , |
| 1976, | 12208, | 155659, | 118802, | 39799, | . 3350 , | . 9653, |  | .4749, |
| 1977, | 13128, | 95514, | 78576, | 34927, | . 4445 , | . 7012 , |  | .6757, |
| 1978, | 18318, | 95892, | 78224, | 26585, | . 3399 , | . 9965 , |  | . 4259, |
| 1979, | 28804, | 83777, | 65676, | 23112, | . 3519 , | . 9843 , |  | . 4273, |
| 1980, | 17100, | 90005, | 62326, | 20513, | . 3291 , | 1.0584, |  | . 3945 , |
| 1981, | 27027, | 92017, | 66154, | 22963, | . 3471 , | 1.0408, |  | . 4648 , |
| 1982, | 30732, | 99259, | 67233, | 21489, | . 3196 , | 1.0030, |  | . 4138, |
| 1983, | 58342, | 119494, | 76145, | 38133, | .5008, | . 9695 , |  | . 7056 , |
| 1984, | 21157, | 147366, | 93725, | 36979, | .3945, | . 9685 , |  | . 5081 , |
| 1985, | 11616, | 124555, | 80468, | 39484, | . 4907, | . 9491 , |  | . 7014 , |
| 1986, | 12108, | 95548, | 70929, | 34595, | .4877, | . 9625, |  | . 6691, |
| 1987, | 10661, | 75559, | 60015, | 21391, | . 3564 , | . 9642 , |  | . 4453, |
| 1988, | 19749, | 66584, | 52445, | 23182, | . 4420, | 1.0061, |  | . 6075, |
| 1989, | 4441, | 57696, | 37537, | 22068, | .5879, | . 9774 , |  | . 7964 , |
| 1990, | 8132, | 37899, | 28982, | 13692, | . 4724, | . 9901 , |  | . 6680, |
| 1991, | 13900, | 30399, | 22333, | 8750, | . 3918 , | 1.0600, |  | . 5151, |
| 1992, | 12320, | 36406, | 21175, | 6396, | . 3021 , | 1.0202, |  | . 4607 , |
| 1993, | 30804 , | 52180, | 33811, | 6107, | .1806, | 1.0225, |  | . 2374 , |
| 1994, | 52357 , | 85094, | 43072, | 9046, | . 2100, | 1.0141, |  | . 1872 , |
| 1995, | 15991, | 146203, | 54905, | 23045, | . 4197 , | 1.0108, |  | . 3219 , |
| 1996, | 8049, | 142142, | 84807, | 40422, | . 4766 , | .9940, |  | . 7028 , |
| 1997, | 7407, | 98287, | 82600, | 34304, | .4153, | 1.0108, |  | . 7731, |
| 1998, | 17868, | 68735, | 57852, | 24005, | .4149, | 1.0279, |  | . 5862 , |
| 1999, | 24393, | 67192, | 46468 , | 19245, | . 4142, | 1.0139, |  | . 5459 , |
| 2000, | 36505, | 95882, | 48356, | 21833, | . 4515, | 1.0422, |  | . 3738 , |
| 2001, | 16074, | 110713, | 59281, | 28577, | . 4821, | 1.0027, |  | . 4333, |
| 2002, | 7466 , | 98496, | 56035, | 38834, | .6930, | 1.0005, |  | . 8233, |
| 2003, | 4308, | 60397, | 40546 , | 25167, | .6207, | 1.0001, |  | . 7532 , |
| 2004, | 7182 , | 36182, | 26466, | 12840, | . 4851, | 1.0012, |  | . 6712 , |
| 2005, | 9029, | 31218, | 23054, | 10119, | . 4389, | 1.0049, |  | . 5758 , |
| 2006, | 6143, | 29029, | 19934, | 9844, | . 4938, | 1.0028, |  | . 6067 , |
| 2007, | 7896, | 26658, | 16858, | 7511, | . 4455 , | 1.0043, |  | . 4695, |
| 2008, | 10060, | 29698, | 20317, | 7315, | . 3600 , | 1.0094, |  | .4419, |
| 2009, | 13806, | 29816, | 19489, | 9979, | . 5120, | 1.0067, |  | . 5314, |
| 2010, | 5244 , | 37398, | 21145, | 12757, | . 6033, | 1.0047, |  | . 6668, |
| 2011, | 2301, | 29300, | 18129, | 9692, | . 5346 , | .9997, |  | . 5635, |
| 2012, | 3530, | 22848, | 17855, | 7204, | . 4035 , | 1.0004 , |  | . 5338, |
| 2013, | 9349, | 22123, | 19090, | 4473, | . 2343 , | 1.0004, |  | . 2804 , |
| 2014, | 2918, | 27540, | 20068, | 5715, | . 2848 , | . 9990 , |  | . 3732 , |
| 2015, | 4121, | 28489, | 19708, | 7394, | . 3752 , | . 9989 , |  | . 4599 , |
| Arith. |  |  |  |  |  |  |  |  |
| Mean | , 17523, | 79156, | 54811, | 21579, | . 4067 |  |  | . 5069 |
| 0 Units, | (Thousands), | (Tonnes), | (Tonnes), | (Tonnes), |  |  |  |  |

# Covariability in recruitment of Faroe Plateau cod and Faroe haddock: is small haddock a prerequisite for cod recruitment? 

The recruitment of cod and haddock have co-fluctuated since the 1960s (Figure 1), especially if the recruitment of cod at age 2 is compared with recruitment of haddock at age 2 , but shifted to the previous year (Figure 2, Figure 3, Figure 4).

This leads to the question whether cod feed on haddock and if haddock is an important food item of juvenile cod, could it then control the cod recruitment?

In fact cod (of all ages) prey on haddock (of all sizes) and the cod predation rate is highly correlated with the total biomass of haddock (Figure 5). Cod of ages 2-4 years also feed on haddock, nearly in the same amount as the abundance of 1-year old haddock ( 2 -year old haddock shifted to the previous year), see Figure 6 and Figure 7.

If haddock is an important food for juvenile cod then the evidence (that haddock as food for cod may control cod recruitment) seems strong, but that is not the case (Figure 8).

Hence, it might be concluded that cod and haddock recruitment (at age 2 ) are highly correlated, especially when haddock recruitment is shifted one year back in time. Even though cod prey on haddock the amount of 1-year old haddock in juvenile cod stomachs (age 2) is far too low to control cod survival/recruitment by being the main food source for juvenile cod.

Cod cannibalism could be an alternative explanation, for example that adult cod show less cannibalistic behaviour when juvenile haddock and/or sandeels are abundant. One possibility is that the food close to the bottom (e.g. sandeels and juvenile haddock) is the key variable, i.e., the large amounts eaten of Norway pout (Figure 9) by juvenile cod a little higher in the water column don't reduce cannibalism. Another possibility, which might be more likely, is that juvenile cod (age 2) get 'safety in numbers' by staying together with juvenile haddock (age 1), i.e., they are less likely to be cannibalised or predated on when staying together with many juvenile haddock. Large numbers of Norway pout in the water column above will not help in this respect.


Figure 1. Recruitment of Faroe Plateau cod and Faroe haddock.


Figure 2. Recruitment of Faroe Plateau cod and Faroe haddock, haddock is shifted to the previous year.


Figure 3. Recruitment of Faroe Plateau cod and Faroe haddock, haddock is shifted to the previous year, now on a log-scale.


Figure 4. Recruitment of Faroe Plateau cod and Faroe haddock, haddock is shifted to the previous year, now on a log-scale and as scatterplot.


Figure 5. Faroe haddock biomass compared with the partial fulness index (PFI) of cod feeding on haddock.


Figure 6. Faroe Plateau cod, ages 2-4, feeding on Faroe haddock compared with the amount of 1year old haddock available. PFI is partial fulness index.


Figure 7. Faroe Plateau cod, ages 2-4, feeding on Faroe haddock, shown for each age of cod.


Figure 8. Faroe Plateau cod, ages 2-4, feeding on Faroe haddock compared with the total fulness index (except trawl-eaten food and liquid). Note the different scales for PFI on haddock and total content.


Figure 9. Faroe Plateau cod, ages 2-4, feeding on Faroe haddock compared with the feeding on Norway pout. Note the different scales for haddock and Norway pout.

## Predicting Faroe Plateau cod catch weights in the assessment year

In the Faroe Plateau cod stock annex, the catch weights in the assessment year have been estimated by either the March survey weights in the assessment year or the January-February weights in the catch in the assessment year (the one that gave the highest fit).

Due to reduced manpower on the institute, it is expected that the catch weights in January-February in the assessment year will not be available in the future. Therefore, it is explored whether it is feasible to use March survey weights and the catch weights of the same cohort the year before as a new method to estimate catch weights in the assessment year.

Multiple regression analyses were performed for ages 3 to 8 , see tables in the end of this document. In some cases (ages 4 and 8) both variables (surwey weighs and catch weights of the same cohort the year before) were significant, but in most cases only one of the variables (survey weighs) was significant. Nevertheless, the insignificant variables were not thrown of of the model because they still contained some information.

The figure (Figure 1) shows that using the survey weighs in the assessment year in many cases gave a reasonable estimate of the catch weighs in the assessment year. Adding the catch weighs of the same cohort the year before to the model improved the fit slightly in most cases.

The weight of age 2 in the assessment year was estimated by a linear regression with age 3 the same year. The weight of age 3 in the assessment year+1 was was regressed against age 4 the same year (Figure 2). The weight of ages 9 and 10+ in the assessment year and the year after were estimated by ages 8 and 9 , respectively (Figure 2 ).

The consequences for catch, biomass and spawning biomass are shown in Figure 3. The average deviation of observed and predicted values of catch, biomass and spawning biomass was $6 \%$, but certain years it could reach $15 \%$ or more.


Figure 1. Faroe Plateau cod. Prediction of catch weights in the assessment year by using either the weighs of the same cohort the year before (panels to the left), the weight in the March survey in the assessment year (panels to the right) or by using the catch weighs of the same cohort the year before and the March survey weights (panels in the middle).


Figure 1. Faroe Plateau cod. Prediction of catch weights in the assessment year by using either the weighs of the same cohort the year before (panels to the left), the weight in the March survey in the assessment year (panels to the right) or by using the catch weighs of the same cohort the year before and the March survey weights (panels in the middle). (Continued).


Figure 2. Faroe Plateau cod. Prediction of catch weights (ages 2 and 3) in the assessment year or assessment year +1 by using other age groups in the same year.


Figure 2. Faroe Plateau cod. Prediction of catch weights (age 9 or 10+) in the assessment year or assessment year +1 by using other age groups in the same year. Continued.


Figure 3. Faroe Plateau cod. Prediction of catch weights and consequences for catch, biomass and spawning biomass.


| Coefficientsandard Err |  |  | t Stat | P-value Lower 95\%Upper 95\%ower 95.0\% pper 95.0\% |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Intercept | 0.126688 | 0.337973 | 0.374848 | 0.711925 | -0.5807 | 0.834074 | -0.5807 | 0.834074 |
| Survey | 0.319693 | 0.188138 | 1.699247 | 0.105587 | -0.07408 | 0.71347 | -0.07408 | 0.71347 |
| Catch | 0.945581 | 0.317748 | 2.975885 | 0.007765 | 0.280527 | 1.610635 | 0.280527 | 1.610635 |



| Coefficientsandard Err |  |  |  | $t$ Stat | P-value |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Intercept | 0.182218 | 0.332577 | 0.547898 | 0.590141 | -0.51387 | 0.878309 | -0.51387 |
| Survey | 0.581018 | 0.147322 | 3.943861 | 0.000871 | 0.272669 | 0.889367 | 0.272669 |
| 0.889367 |  |  |  |  |  |  |  |
| Catch | 0.539841 | 0.233703 | 2.309944 | 0.032287 | 0.050695 | 1.028987 | 0.050695 |



[^3]

Coefficientsandard Err t Stat P-value Lower 95\%Upper 95\%ower 950\%pper 95.0 \begin{tabular}{llllllllll}
\hline Intercept \& 0.959596 \& 0.394719 \& 2.431083 \& 0.025123 \& 0.133438 \& 1.785753 \& 0.133438 \& 1.785753

 

\hline Survey \& 0.65285 \& 0.139143 \& 4.69193 \& 0.000159 \& 0.36162 \& 0.944081 \& 0.36162 \& 0.944081 <br>
\hline

 

Catch \& 0.135465 \& 0.164283 \& 0.824584 \& 0.41984 \& -0.20838 \& 0.479313 \& -0.20838 \& 0.479313 <br>
\hline
\end{tabular}

|  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| Age 7 |  |  |  |  |  |  |  |  |
| SUMMARY | OUTPUT |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| Regression | Statistics |  |  |  |  |  |  |  |
| Multiple F | 0.577274 |  |  |  |  |  |  |  |
| R Square | 0.333245 |  |  |  |  |  |  |  |
| Adjusted I | 0.263061 |  |  |  |  |  |  |  |
| Standard I | 0.543747 |  |  |  |  |  |  |  |
| Observati | 22 |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| ANOVA |  |  |  |  |  |  |  |  |
|  | df | SS | MS | F | gnificance $F$ |  |  |  |
| Regressio | 2 | 2.807661 | 1.403831 | 4.748119 | 0.021266 |  |  |  |
| Residual | 19 | 5.617547 | 0.29566 |  |  |  |  |  |
| Total | 21 | 8.425208 |  |  |  |  |  |  |

Coefficientsandard Err t Stat $\quad$ P-value Lower 95\%Upper 95\%ower 95.0\%pper 95.0\% $\begin{array}{llllllllll}\text { Intercept } & 2.563424 & 0.95353 & 2.68835 & 0.01455 & 0.567662 & 4.559186 & 0.567662 & 4.559186\end{array}$ | Survey | 0.394995 | 0.183932 | 2.1475 | 0.044868 | 0.01002 | 0.779969 | 0.01002 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

| Catch | 0.123583 | 0.28466 | 0.434142 | 0.669075 | -0.47222 | 0.719382 | -0.47222 | 0.719382 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |



Coefficientsandard Err tStat $\quad$ P-value Lower 95\%Upper 95\%ower 95.0\%pper 95.0\% \begin{tabular}{l|lllllllll}
\& Intercept \& -1.15322 \& 1.537607 \& -0.75001 \& 0.462436 \& -4.37147 \& 2.065029 \& -4.37147 \& 2.065029

 

Survey \& 0.461584 \& 0.138007 \& 3.344637 \& 0.003405 \& 0.172732 \& 0.750437 \& 0.172732 \& 0.750437

 

Catch \& 0.822087 \& 0.299261 \& 2.747056 \& 0.012816 \& 0.195726 \& 1.448448 \& 0.195726 \& 1.448448 <br>
\hline
\end{tabular}

Petur Steingrund, Faroe Marine Research Institute

## Investigating maturity of Faroe Plateau cod in the 1980s and 1990s

According to the stock annex for Faroe Plateau cod the maturities back into the 1950s are set to the average values for 1983 to 1996. Some of the years were revised for age 2 . Here the data are investigated more and new average maturities calculated.

In the Excel file "FaroePlateauCod_maturity_1983_2001_investigated.xlsx" the raw data are provided. Maturity " 0 " is immature, maturity " 1 " is mature and blanks denote no information about these fish. "ALDUR" = age of fish in years.


Based on this table, the following maturities were obtained:

|  |  |  |  |  |  |  |  | No fish |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | Average 1 |
| Age 2 | $0.625^{\prime \prime}$ | 0.403846 | 0 | 0 |  | 0.166667 | 0.045455 | 0 |  | 0.064516 | 0.25 | 0.717647 | 0.174757 | 0.074074 | 0.18014 |
| Age 3 | '0.707071' | $0.957219^{\prime \prime}$ | 0.5 | 0.371795 | 0.647059 | 0.786517 | 0.53125 | 0.684211 | 0.758621 |  | 0.731183 | $0.885246^{\prime \prime}$ | 0.52381 | 0.455621 | 0.638543 |
| Age 4 | "0.928571' | 0.983607 | 0.956522 | $0.926606^{\prime \prime}$ | 0.9125 | 0.906832 | 0.971698 | $0.91358^{\prime}$ | 0.963504 | 0.666667' | $0.77777{ }^{\prime \prime}$ | $0.979275^{\prime \prime}$ | 0.525926 | 0.738824 | 0.867992 |
| Age 5 | '0.941176' | $0.969697^{\prime}$ | 0.961538 | 1 | 1 | 0.974684" |  | 0.985714' | $1{ }^{\prime}$ | 0.966667' | $0.913043^{\prime}$ | 0.991453 | 0.735099 | 0.866995 | 0.950433 |
| Age 6 | 1 | 1 | 1 | 1 | 1 | 1 |  |  | 0.904762 | 1 | 0.992754 |  | 0.968421 | 0.939759 | 0.986121 |
| Age 7 |  | 1 |  | $0.958333^{\prime \prime}$ | 1 |  |  | 0.977273 |  | 1 |  | $0.97872{ }^{\prime \prime}$ | 1 " | 1 | 0.993881 |
| Age 8 | 1 | 1 | 1 | $0.94117{ }^{\prime \prime}$ | -1 | 1 | 0.909091 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.989305 |
| Age 9 | 1 |  | 1 | 1 | 1 | 1 | 1 | 1 | 1 |  | 1 |  | 1 | 1 | 1 |
| Age 10 | 1 | 1 | 1 |  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

This could serve as a basis to determine the maturities from 1959 to 1982.

# Faroe Plateau cod - is it worth to use stock weights that are different from catch weights? 

Stock individual weights have always been set equal to catch weigths. In this working document it is investigated how much the use of stock weights from either the March or August survey will alter the total stock biomass or spawning stock biomass. When calculating the total stock size, the August survey was used to estimate individual weights whereas when calculating the spawning stock size the March survey was used. The stock weights were calculated by multiplying the catch weights by a factor (average of survey weights divided by average of catch weigths for the survey period).

The results shows that the total stock biomass and spawning stock biomass is little influenced by the use of stock weights instead of catch weights. Hence, it is proposed to keep catch weights = stock weights in the future.

Table 1. Faroe Plateau cod. Calculating total stock size by using 1) stock weights = catch weights for all ages, 2) stock weights = August survey weights for age 2 only and all other ages = catch weights, 3) all ages = stock (August survey) weights. Calculating spawning stock size in the same way, except that survey weights from the March survey were used instead of the August survey.

|  | Catch <br> weights <br> only | Stock <br> weights <br> for | Stock <br> weights <br> only | Catch <br> weights | Stock <br> only <br> weights <br> for | Stock <br> weights <br> only |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  |  | TB (t) | TB (t) | TB (t) | SSB (t) | Age 2 <br> SSB (t) |
| 1959 | 67802 | 65323 | 64606 | SSB (t) |  |  |
| 1960 | 75864 | 72725 | 72243 | 48868 | 47678 | 46838 |
| 1961 | 65439 | 62579 | 62192 | 54448 | 53248 | 52434 |
| 1962 | 68222 | 63671 | 63186 | 46450 | 45383 | 44574 |
| 1963 | 77602 | 72952 | 72252 | 43323 | 41538 | 40860 |
| 1964 | 84662 | 79995 | 78952 | 49055 | 47183 | 46337 |
| 1965 | 75050 | 73374 | 72411 | 55358 | 53148 | 52336 |
| 1966 | 83918 | 79909 | 79275 | 57063 | 55999 | 55094 |
| 1967 | 105291 | 100331 | 99376 | 60628 | 58854 | 58058 |
| 1968 | 110430 | 107021 | 106085 | 73936 | 71741 | 70530 |
| 1969 | 105536 | 103296 | 103044 | 82481 | 80979 | 79689 |
| 1970 | 98394 | 96573 | 97838 | 83486 | 82982 | 81503 |
|  |  |  |  | 82031 | 83006 | 81519 |


| 1971 | 78220 | 76091 | 76914 | 63310 | 63641 | 62462 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1972 | 76434 | 73334 | 74248 | 57175 | 57299 | 56126 |
| 1973 | 110712 | 107636 | 108823 | 83545 | 84318 | 82064 |
| 1974 | 139259 | 132006 | 133049 | 98428 | 97395 | 95198 |
| 1975 | 153663 | 146993 | 147580 | 109566 | 108582 | 105789 |
| 1976 | 161267 | 157420 | 157970 | 123084 | 123305 | 119834 |
| 1977 | 136216 | 134300 | 133571 | 112062 | 111294 | 109453 |
| 1978 | 96221 | 93587 | 94427 | 78491 | 78656 | 76961 |
| 1979 | 85113 | 82148 | 83230 | 66723 | 67038 | 65537 |
| 1980 | 85039 | 80222 | 81477 | 58888 | 58760 | 57347 |
| 1981 | 88407 | 85075 | 85943 | 63557 | 63778 | 62193 |
| 1982 | 100062 | 93822 | 94702 | 67214 | 66222 | 64615 |
| 1983 | 123246 | 115828 | 115210 | 78534 | 77973 | 76284 |
| 1984 | 152152 | 139575 | 138594 | 96767 | 94009 | 92079 |
| 1985 | 131243 | 127789 | 125656 | 84790 | 84157 | 82366 |
| 1986 | 99362 | 97059 | 95972 | 73780 | 73346 | 72235 |
| 1987 | 78357 | 75970 | 75934 | 62236 | 62435 | 61283 |
| 1988 | 66173 | 64133 | 64160 | 52120 | 52118 | 51151 |
| 1989 | 58945 | 55347 | 55670 | 38322 | 38516 | 37734 |
| 1990 | 38273 | 37516 | 37572 | 29267 | 29572 | 28887 |
| 1991 | 28677 | 27534 | 27721 | 21068 | 21346 | 20898 |
| 1992 | 35685 | 33205 | 33427 | 20757 | 20863 | 20295 |
| 1993 | 51028 | 48461 | 48143 | 33063 | 32854 | 32113 |
| 1994 | 83916 | 77281 | 76930 | 42477 | 41971 | 41188 |
| 1995 | 144640 | 133136 | 132535 | 54315 | 53172 | 51963 |
| 1996 | 143017 | 140085 | 137843 | 85325 | 84756 | 83240 |
| 1997 | 97228 | 95919 | 95010 | 81709 | 81172 | 79767 |
| 1998 | 66918 | 65576 | 65355 | 56327 | 56287 | 55361 |
| 1999 | 66276 | 62892 | 63175 | 45837 | 46216 | 45420 |
| 2000 | 91998 | 85767 | 85753 | 46399 | 46926 | 45907 |
| 2001 | 110413 | 102748 | 102693 | 59121 | 58809 | 57615 |
| 2002 | 98450 | 95501 | 94471 | 56012 | 56055 | 55040 |
| 2003 | 60390 | 59285 | 58646 | 40541 | 40478 | 39870 |
| 2004 | 36149 | 35343 | 35356 | 26442 | 26612 | 26096 |
| 2005 | 31071 | 29793 | 30018 | 22947 | 23105 | 22618 |
| 2006 | 28959 | 27593 | 27858 | 19889 | 20176 | 19743 |
| 2007 | 26545 | 25506 | 25634 | 16787 | 17120 | 16755 |
| 2008 | 29423 | 27701 | 27884 | 20129 | 20025 | 19609 |
| 2009 | 29612 | 28151 | 28113 | 19353 | 19201 | 18814 |
| 2010 | 37227 | 34614 | 34623 | 21049 | 20840 | 20314 |
| 2011 | 29310 | 28538 | 28296 | 18135 | 18107 | 17761 |
| 2012 | 22843 | 22425 | 22589 | 17852 | 18095 | 17670 |
| 2013 | 22117 | 21474 | 21558 | 19086 | 18872 | 18546 |
| 2014 | 27568 | 25714 | 26015 | 20088 | 19500 | 19124 |
| 2015 | 28525 | 27894 | 28151 | 19733 | 19918 | 19425 |

## Faroe haddock, prediction of weights from the same cohort the year before and survey weights the same year

The current annex method of estimating individual weights in the assessment year (average of last 3 years and probably scaling to last value) is compared with estimates based on survey weights the same year and cohort weights the year before. The results show that using survey weights and/or cohort weighs the year before is more accurately estimating individual weights in the assessment year than the annex method. For most ages, the models including either only survey weights or cohort weights the year before performed well, and including both variables improved the fit slightly more. The survey weights were significant for all ages (Table 1) and cohort weights the year before significant for ages 6 and 7 .

Although not investigated here, prediction of weights the year after the assessment year (ages 4-8) could probably be based on the cohort weights the year before, probably also the ages 5-9 for the year after that. The other ages could be estimated by other means, for example by correlations with other ages the same year.


Figure 1. Faroe haddock. Prediction of weights from the weight of the same cohort the year before (far left), the same cohort the year before and survey weights (March) the same year (middle left), the survey weights only (middle right) and the default (NWWG 2016) method (far right).

Table 1. Faroe haddock. Prediction of weights from the same cohort the year before (here termed 'catch') and the survey weights in the March survey ('survey').

Age 3
SUMMARY OUTPUT

Regression Statistics
Multiple F 0.720573
R Square 0.519226
Adjusted। 0.468618
Standard I 0.093751
Observati 22
ANOVA

|  | $d f$ |  | SS | MS | F |
| :--- | ---: | ---: | :---: | :---: | :---: |
| gnificance $F$ |  |  |  |  |  |
| Regressio | 2 | 0.180352 | 0.090176 | 10.25979 | 0.000952 |
| Residual | 19 | 0.166997 | 0.008789 |  |  |
| Total | 21 | 0.347349 |  |  |  |


|  |  | ficientsandard Err t Stat | t Stat | P-value Lower 95\%Upper 95\%ower 95.0\%pper 95.09 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 0.5 | 0.194955 | 2.720618 | 0.013571 | 0.122353 | 0.938444 | 0.122353 |  |
| Catch | 0.307645 | 0.179869 | 1.710386 | 0.103474 | -0.06882 | 0.684115 | -0.06882 |  |

Age 4
SUMMARY OUTPUT

Regression Statistics
Multiple F 0.901744
R Square 0.813142
Adjusted। 0.793473
Standard! 0.097093
Observati 22

ANOVA

|  | $d f$ |  | SS | MS | F |
| :--- | ---: | :---: | :---: | :---: | :---: |
|  | gnificance $F$ |  |  |  |  |
| Regressio | 2 | 0.779447 | 0.389724 | 41.34074 | $1.2 \mathrm{E}-07$ |
| Residual | 19 | 0.179115 | 0.009427 |  |  |
| Total | 21 | 0.958562 |  |  |  |


| Catch | 0.089583 | 0.14146 | 0.633274 | 0.534104 | -0.2065 | 0.385662 | -0.2065 | 0.385662 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

Age 5
SUMMARY OUTPUT

Regression Statistics
Multiple F 0.921619
R Square 0.849382
Adjusted। 0.833528
Standard : 0.125368
Observati
22
ANOVA

|  | $d f$ | SS | MS | F | gnificance $F$ |
| :--- | ---: | ---: | :---: | ---: | :---: |
| Regressio | 2 | 1.684058 | 0.842029 | 53.57361 | $1.55 \mathrm{E}-08$ |
| Residual | 19 | 0.298627 | 0.015717 |  |  |
| Total | 21 | 1.982685 |  |  |  |


| Coefficientsandard Err |  |  | t Stat | P-value Lower 95\%Upper 95\%ower 95.0\%pper 95.0\% |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Intercept | 0.259623 | 0.128108 | 2.026594 | 0.056973 | -0.00851 | 0.527756 | -0.00851 | 0.527756 |
| Survey | 0.710972 | 0.111468 | 6.378285 | $4.06 \mathrm{E}-06$ | 0.477668 | 0.944277 | 0.477668 | 0.944277 |
| Catch | 0.150495 | 0.127615 | 1.179282 | 0.252843 | -0.11661 | 0.417597 | -0.11661 | 0.417597 |

Age 6
SUMMARY OUTPUT

| Regression Statistics |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Multiple F 0.944582 |  |  |  |  |  |
| R Square 0.892234 |  |  |  |  |  |
| Adjusted। 0.880891 |  |  |  |  |  |
| Standard! 0.126705 |  |  |  |  |  |
| Observati | 22 |  |  |  |  |
| ANOVA |  |  |  |  |  |
|  | df | SS | MS | F | gnificance |
| Regressio | 2 | 2.525465 | 1.262733 | 78.65434 | $6.44 \mathrm{E}-10$ |
| Residual | 19 | 0.30503 | 0.016054 |  |  |
| Total | 21 | 2.830495 |  |  |  |


| Coefficientsandard Err |  |  | Sta | value Lower 95\%Upper 95\%ower 95.0\%pper 95.0\% |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Intercept | 0.195367 | 0.126787 | 1.540913 | 0.139828 | -0.07 | 0.460735 | -0.07 | 0.4 |
| Surve | 0.653986 | 0.094879 | 6.892809 | $1.42 \mathrm{E}-06$ | 0.455401 | 0.852571 | 0.455401 | 0.852571 |
| Catch | 0.243153 | 0.107983 | 2.25177 | 0.036362 | 0.017142 | 0.469165 | 0.017142 | 0.4691 |

Age 7
SUMMARY OUTPUT

Regression Statistics

| Multiple F | 0.89428 |
| :--- | :--- |

R Square 0.799737
Adjusted। 0.778656
Standard ! 0.199723
Observati 22

ANOVA

|  | $d f$ |  | SS | MS | F |
| :--- | ---: | ---: | ---: | ---: | ---: |
|  | gnificance $F$ |  |  |  |  |
| Regressio | 2 | 3.02661 | 1.513305 | 37.93751 | $2.32 \mathrm{E}-07$ |
| Residual | 19 | 0.757899 | 0.039889 |  |  |
| Total | 21 | 3.784509 |  |  |  |

Coefficientsandard Err $t$ Stat $\quad$ P-value Lower 95\%Upper 95\%ower 95.0\%pper 95.09
Intercept $-0.017720 .223109-0.079440 .937513-0.48470 .449249$-0.4847 0.449249
$\begin{array}{llllllllll}\text { Survey } & 0.487612 & 0.12948 & 3.765929 & 0.001308 & 0.216607 & 0.758616 & 0.216607 & 0.758616\end{array}$

| Catch | 0.553567 | 0.129856 | 4.262929 | 0.00042 | 0.281775 | 0.825358 | 0.281775 | 0.825358 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

Age 8
SUMMARY OUTPUT

| Regression Statistics |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Multiple F 0.922706 |  |  |  |  |  |
| R Square 0.851386 |  |  |  |  |  |
| Adjusted। 0.835743 |  |  |  |  |  |
| Standard! 0.17264 |  |  |  |  |  |
| Observati 22 |  |  |  |  |  |
| ANOVA |  |  |  |  |  |
|  | df | SS | MS | F | gnificance |
| Regressio | 2 | 3.244153 | 1.622076 | 54.42403 | $1.36 \mathrm{E}-08$ |
| Residual | 19 | 0.566284 | 0.029804 |  |  |
| Total | 21 | 3.810437 |  |  |  |


|  |  | Coefficientsandard Err | t Stat |  | P-value | Lower 95\%Upper 95\%ower 95.091pper 95.09 |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Intercept | 0.34608 | 0.186079 | 1.859853 | 0.078461 | -0.04339 | 0.735549 | -0.04339 | 0.735549 |
| Survey | 0.608656 | 0.147585 | 4.124102 | 0.000577 | 0.299757 | 0.917556 | 0.299757 | 0.917556 |
| Catch | 0.203551 | 0.177217 | 1.148599 | 0.264977 | -0.16737 | 0.574471 | -0.16737 | 0.574471 |

# Predicting Faroe Plateau cod fishing mortality in the assessment year by use of a negative correlation with growth 

The fishing mortality in the assessment year has traditionally been predicted by the average of the last 3 years and rescaling to the terminal year when there is a trend (either upwards or downwards).

This method has a poor fit (22\%) to the realised data from the current assessment (terminal year is 2015), see Figure 1.

One way to improve the prediction of fishing mortality is to take advantage of the fact that there is a negative correlation between growth (weight increase of 5 cohorts since the last year, ages 2-3, 3-4, $4-5,5-6,6-7$ ) and fishing mortality (F3-7), see Figure 2. The reason seems to be that cod prey more on longline baits when the abundance of natural prey is low and vice versa (Steingrund et al., 2009), and since a large part ( $30-70 \%$ ) of the catch is taken by longlines, this variability affects the total fishing mortality.

When the NWWG 2016 assessment is used as basis for fishing mortalities (i.e., the retrospective pattern is not taken into account), the model using growth explains $65 \%$ of the fit whereas the Annex model explains only 26\% (Figure 3). A similary result is obtained if the retrospective pattern is taken into account (Figure 4).

The modelling of the fishing mortality from growth is superior to the Annex method for the last 20 years, and it may be argued that it is based on a sound mechanistic relationship (Steingrund et al., 2009), but the main disadvantage is that it is uncertain for how long time this relationship will hold into the future. The new management system that is intended to be introduced in 2018 is currently proposed to contain a mixture of quotas and fishing days. This means that the management system probably will dampen the natural variability of longline catchability since that will only work for the fishing day part of the system (around half of the cod catch). It is a question whether the negative relationship between growth and fishing mortality, nevertheless, should be used to estimate fishing mortality in the prognosis, as long as it seems to be superior to the Annex method.

## References

Steingrund, P., Clementsen, D.H., and Mouritsen, R. 2009. Higher food abundance reduces the catchability of cod (Gadus morhua) to longlines on the Faroe Plateau. Fisheries Research 100 (2009) 230-239.


Figure 1. Faroe Plateau cod. Prediction of fishing mortality in the assessment year by using the Annex method by taking average of the last 3 years and rescaling to the terminal year if there is a trend (either upwards or downwards). The retrospective pattern is taken into account, i.e., the assessment is run up to the terminal year.


Figure 2. Faroe Plateau cod. Relationship between growth (average weight increase of 5 cohorts since last year) and fishing mortality. A strong negative relationship is apparent from 1985 and onwards.


Figure 3. Faroe Plateau cod. Prediction of fishing mortality by growth (average weight increase of 5 cohorts since last year) (upper panel) or by the Annex method (lower panel). The retrospective pattern is not taken into account, i.e., the fishing mortalities are taken from the NWWG 2016 assessment.


Figure 4. Faroe Plateau cod. Prediction of fishing mortality by growth (average weight increase of 5 cohorts since last year) (lower panel) or by the Annex method (upper panel). The retrospective pattern is taken into account.

# Simple models for predicting Faroe Saithe cw@age 

SbJ
16 February 2017

## Intro

In the assessment of Faroe Saithe a linear model has been used to predict catch weight at age for age groups 4 to 8 from the weight of the same cohorts one year younger in the previous year. The exercise was initiated to see if adding stock weight at age from the survey would improve the fit, investigate if it would be better to fit on log scale and adding a year effect to the model was also included in the analysis, which can be regarded as a follow-up to the WDs to NWWG in 2010 and 2012 regarding weight prediction for Icelandic saithe (Magnússon 2012, Jónsson \& Steinarsson 2010).

## M\&M

Data for this exercise were taken from cw@a data in 'faroeass.rdata', object 'saidata\$rbya' and stock weight at age in the Faroese spring survey found in text file 'Wya_var_1strata_W.txt', both in the WKFAROE2017 sharepoint data directory.

## Results

## The data



Figure 1. Relationship between the response varible ' cW ' and the predictors 'cWlast' and 'sW', shown on a linear (upper panel) and log scale (lower panel).

## Model fits

We fit 6 models to the data, SPALY, adding the sw@a, including a year factor, and these models repeated on $\log$-scale:
model $1</ \operatorname{lm}(\mathrm{cW} \sim$ cWlast, data = mdata $)$
model $2</ \quad \operatorname{lm}(\mathrm{cW} \sim$ cWlast +sW, data $=$ mdata $)$

```
model 5 </ \(\operatorname{lm}(\mathrm{cW} \sim\) cWlast + sW + factor(year ), data = mdata )
coeff5 </ coefficients(model5)[4:24]
model 7 </ \(\operatorname{Im}(\log (\mathrm{cW}) \sim \log (\mathrm{cWlast})\), data \(=\) mdata \()\)
model \(8</ \operatorname{lm}(\log (\mathrm{cW}) \sim \log (\mathrm{cWlast})+\log (\mathrm{sW})\), data \(=\) mdata \()\)
model9 </ \(\operatorname{Im}(\log (\mathrm{cW}) \sim \log (\mathrm{cWlast})+\log (\mathrm{sW})+\) factor(year \()\), data \(=\) mdata \()\)
coeff9 </ coefficients(model9)[4:24]
Instead of doing model diagnostics we take a look at the sum of squared differences between observed and modelled weight-at-age where 'res' + number indicates the model:
```

apply(pdata[, 12:17],2,function( X$\left.) \operatorname{sum}\left(\mathrm{x}^{\wedge} 2\right)\right)$
\#\# res1 res2 res5 res7 res8 res9
\#\# 8.2083675 .2527972 .6863118 .2421835 .2247562 .193886

## absolute difference

We take a look at the absolute difference against the observed weights:


Figure 2. Prediction errors as difference (kg) from the 6 regression models, on linear (upper panel) and on a log scale (lower panel). Colors indicate ages 4 to 8 . Models from the left are based on the c@a-1 the year before, in the middle with sw@a also, and with the addition of a year factor to the fit on the right.

## relative difference

and the relative difference against the observed weights:


Figure 3. Relative prediction errors from the two regression models, on linear (upper panel) and on log scale (lower panel). Colors indicate ages 4 to 9 . Models from the left are based on the c@a-1 the year before, in the middle with sw@a also, and with the addition of a year factor to the fit on the right.

## year effects



Figure 4. Year factors from the models 5 and 9, on linear and log scale.

## References

Jónsson, S.P. \& B.Æ. Steinarsson 2010. Predicting current or assessment year weight at age in iSaithe landings. ICES NWWG WD 19.

Magnússson, Á. 2012. Icelandic saithe: New model to predict current weight at age. ICES NWWG WD 30.

# Estimating natural mortality rate (M) for Faroe Plateau cod 

In this document, which is written in May 2018 just prior to the finalizing of the WKFAROE report, the natural mortality of Faroe Plateau Cod is investigated by comparing assessment results with tagging returns. Calculations were done at the WKFAROE meeting in February 2017 in the spreadsheet "FaroePlateauCod_tag_returns.xls", but a working document was not written until in May 2018 to facilitate the overview of the work done in the spreadsheet. There was not time at the WKFAROE meeting to check the calculations against the litterature, so the results are of a very preliminary nature. In brief, the results of this exercise showed that the traditional $M$ of 0.2 was in good correspondence with mark-recapture data - and therefore not to be altered at the benchmark. Another finding was that there was no major time trend in the natural mortality rate.

The tagging data are shown in Table 1.
Table 1. Taggings of Faroe Plateau cod 1997-2016 and subsequent recaptures in year 0 to year 4.

| Year | Number tagged in |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| tagged | September/October | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 |
| 1997 | 4349 | 290 | 848 | 163 | 46 | 21 |
| 1998 | 2400 | 119 | 336 | 114 | 56 | 32 |
| 1999 | 1502 | 19 | 206 | 78 | 54 | 16 |
| 2000 | 830 | 43 | 100 | 76 | 23 | 2 |
| 2002 | 2568 | 113 | 402 | 98 | 34 | 8 |
| 2003 | 1112 | 132 | 151 | 56 | 24 | 11 |
| 2004 | 711 | 18 | 88 | 41 | 21 | 7 |
| 2005 | 156 | 6 | 19 | 7 | 2 | 1 |
| 2006 | 1209 | 70 | 183 | 61 | 23 | 19 |
| 2007 | 885 | 98 | 107 | 42 | 36 | 12 |
| 2008 | 1355 | 60 | 188 | 125 | 36 | 15 |
| 2009 | 706 | 52 | 105 | 44 | 14 | 2 |
| 2010 | 1026 | 104 | 132 | 23 | 13 | 6 |
| 2011 | 993 | 64 | 107 | 31 | 22 | 9 |
| 2012 | 500 | 11 | 53 | 46 | 13 | 7 |
| 2013 | 1195 |  | 38 | 194 | 51 | 25 |
| 2014 | 2002 |  |  | 71 | 257 | 99 |
| 2015 | 1583 |  |  |  | 41 | 131 |
| 2016 | 2035 |  |  |  |  | 25 |

The tag loss was assumed to be $5 \%$ since 4 out of 106 cod lost their tags during four months (December 1997 to March 1998). The tagging mortality was set to 0.038 as 161 out of 4288 cod died after 3-12 hours in tanks. It was assumed that local people were more willing to report tags the first two years of the tagging study (1997-1998) compared with the later years (1999-2016) so an extra proportion of 0.2 was added to the reporting rate these years (the reporting rate itself was modelled, see later). The number of tag returns (Table 1) where first divided by the reporting rate and then adjusted downwards by tagging mortality and further downwards by tag loss so the number of alive cod in the sea with tags could be obtained.

The number of tagged cod in the sea was for year 0 (two months November-December) modelled by applying natural mortality (which itself was modelled, see later) in November, then subtracting all recaptures during year 0 on 1st of December, and then applying natural mortality in December. The number of cod at sea year 1 (and subsequent years) was modelled in the same way, applying natural mortality the first 6 months, then subtracting all recaptures during the year, and then applying natural mortality for 6 months. An example is shown in Table 2 and Table 3. Based on these numbers at sea, a total mortality rate ( $Z$ ) was calculated, based on an assumed natural mortality rate and tag reporting rate - and these results were fitted to the $Z$ obtained from the stock assessment in the way that the sum of the squared residuals was minimized (Table 4, Figure 1)

The results are shown in Table 5. It was not possible to fit the model unless M was 0.28 or larger. Table 5 shows that the modelled reporting rate increased with increasing natural mortality rate. The reporting rate is unknown, but is expected to be to be larger than $50 \%$ and lesser than $80 \%$. If the reporting rate is $50 \%$, then Table 5 suggests a natural mortality rate of 0.28 , which is not substantially larger than the traditional 0.2 . Given the uncertainties in these calculations Table 5 indicates that the traditional value of 0.2 can as well be kept for this stock instead of using any other and higher value. A second take-home message is that there was probably no major change of $M$ over time as the lines in Figure 1 did not diverge over time.

Table 2. An example of the number of tagged cod at sea modelled by a natural mortality rate of 0.3 (set value) and a reporting rate of 0.52 (fitted) and the corresponding total mortality ( $Z$ ) calculated by $\ln$ (number first) - $\ln$ (number second year).

| Number of tags at sea: | Z <br> Year 1- |  |  |  |  |  | Year 2- |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | Year 3-

Table 3. Z values assigned to years.

| Z |  | Year labels when mortality happens: |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: |
| Year 1-2 | Year 2-3 | Year 3-4 | Year 1-2 | Year 2-3 | Year 3-4 |
| 0.82 | 0.58 | 0.43 | 1998 | 1999 | 2000 |
| 0.79 | 0.65 | 0.62 | 1999 | 2000 | 2001 |
| 0.75 | 0.64 | 0.78 | 2000 | 2001 | 2002 |
| 0.73 | 1.09 | 0.98 | 2001 | 2002 | 2003 |
| 0.89 | 0.60 | 0.48 | 2003 | 2004 | 2005 |
| 0.93 | 0.88 | 0.91 | 2004 | 2005 | 2006 |
| 0.71 | 0.68 | 0.69 | 2005 | 2006 | 2007 |
| 0.72 | 0.60 | 0.44 | 2006 | 2007 | 2008 |
| 0.89 | 0.75 | 0.64 | 2007 | 2008 | 2009 |
| 0.82 | 0.75 | 1.39 | 2008 | 2009 | 2010 |
| 0.80 | 1.17 | 1.08 | 2009 | 2010 | 2011 |
| 0.90 | 0.93 | 0.78 | 2010 | 2011 | 2012 |
| 0.85 | 0.49 | 0.47 | 2011 | 2012 | 2013 |
| 0.69 | 0.50 | 0.55 | 2012 | 2013 | 2014 |
| 0.64 | 0.93 | 0.71 | 2013 | 2014 | 2015 |
| 0.39 | 1.25 | 1.12 | 2014 | 2015 | 2016 |
|  | 0.43 | 1.45 | 2015 | 2016 | 2017 |
|  |  | 0.43 | 2016 | 2017 | 2018 |

Table 4. $Z$ values from mark-recapture data compared (fitted with) $Z$ values from the stock assessment.

|  |  | F from <br> Number <br> of |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Year | average | soints <br> assessment <br> (F4-7) | Z from <br> stock <br> assessment |  |
| 1998 | 1 | 0.82 | 0.69 | 0.89 |
| 1999 | 2 | 0.69 | 0.61 | 0.81 |
| 2000 | 3 | 0.61 | 0.39 | 0.59 |
| 2001 | 3 | 0.66 | 0.46 | 0.66 |
| 2002 | 2 | 0.94 | 0.91 | 1.11 |
| 2003 | 2 | 0.94 | 0.86 | 1.06 |
| 2004 | 2 | 0.77 | 0.79 | 0.99 |
| 2005 | 3 | 0.69 | 0.65 | 0.85 |
| 2006 | 3 | 0.77 | 0.68 | 0.88 |
| 2007 | 3 | 0.72 | 0.51 | 0.71 |
| 2008 | 3 | 0.67 | 0.49 | 0.69 |
| 2009 | 3 | 0.73 | 0.49 | 0.69 |
| 2010 | 3 | 1.16 | 0.72 | 0.92 |
| 2011 | 3 | 0.96 | 0.60 | 0.80 |
| 2012 | 3 | 0.65 | 0.62 | 0.82 |
| 2013 | 3 | 0.54 | 0.32 | 0.52 |
| 2014 | 2 | 0.74 | 0.40 | 0.60 |
| 2015 | 1 | 0.71 | 0.52 | 0.72 |

Table 5. Results from the calculations of natural mortality.

No fit possible with $\mathrm{M}<0.27$

|  | Sum |  |  |
| ---: | :---: | :---: | ---: |
| Correlation | Residuals | Reporting <br> rate | Natural <br> mortality |
| 0.671451 | 0.306659 | 0.503219 | 0.28 |
| 0.673453 | 0.287822 | 0.520406 | 0.3 |
| 0.675208 | 0.260093 | 0.570385 | 0.35 |
| 0.671869 | 0.253216 | 0.63333 | 0.4 |
| 0.663381 | 0.260234 | 0.714573 | 0.45 |



Figure 1. A time series of total mortality rate $(Z)$ obtained by a mark-recapture experiment and compared (fitted) with Z obtained from the stock assessment. This example is when natural mortality was set to 0.3.


[^0]:    At 12/04/2016 9:00

[^1]:    Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)

[^2]:    Run title : COD FAROE PLATEAU (ICES SUBDIVISION Vb1)
    COD_ind_Surveys_revised

[^3]:    Coefficientsandard Err t Stat P-value Lower 95\%Upper 95\%ower 95.0\% pper 95.0\% \begin{tabular}{l|lllllllll}
    \hline Intercept \& 0.599281 \& 0.437092 \& 1.371062 \& 0.186334 \& -0.31556 \& 1.514125 \& -0.31556 \& 1.514125 <br>
    \hline

 

    Survey \& 0.472431 \& 0.192515 \& 2.45399 \& 0.023948 \& 0.069492 \& 0.87537 \& 0.069492 \& 0.87537

 

    Catch \& 0.470411 \& 0.269641 \& 1.74458 \& 0.097213 \& -0.09395 \& 1.034776 \& -0.09395 \& 1.034776 <br>
    \hline
    \end{tabular}

