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Updated SCAA Base Case Assessment for Greenland Halibut

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Summary

The Statistical Catch-at-Age (SCAA) assessment methodology applied to the Greenland halibut resource in 2017 is updated to take further data now available for the years 2017 to 2019 into account. Results are reported for a Base Case corresponding to that considered in 2017, and some sensitivities related to uncertainties about some recent catch-at-age data. Apart from a slight downward shift in the overall biomass scale, results are essentially unchanged from those in 2017, and the sensitivity runs show little difference from the Base Case. There has been a recent slight downward trend in exploitable biomass, but this is likely to reverse quite soon given that the estimates of incoming recruitment are of above average strength. New data and recent resource trends are consistent with predictions made in 2017 when a revised management procedure for Greenland halibut was adopted.

Introduction

This document reports an update of the 2017 Statistical Catch-at-Age (SCAA) assessment of Greenland halibut that takes account of the further data from 2017 to 2019 that are now available, applying unchanged methodology. A number of sensitivity runs are conducted to check the impact of different choices for some very recent catch-at-age data which have yet to be finalised.

The assessments results reported include comparisons to those obtained in 2017, as well as to the projections made at that time to provide probability envelopes for future indices of abundance and some resource dynamics quantities.

Methods

The SCAA methodology for the assessment of Greenland halibut is set out Appendix A, and is identical to that applied in 2017. The updated data to which this methodology is applied are listed in Appendix B.

The following Base Case and sensitivity tests were run:

a) **Base Case**: Includes all commercial and survey CAA data in 2018 and 2019, though the 2018 commercial ALK is applied to the 2019 commercial CAL data to provide the 2019 commercial CAA
b) **Sens1**: As a) Base Case, but excluding the 2019 Canadian fall 2J3K survey CAA data
c) **Sens2**: As a) Base Case, but excluding the 2018 and 2019 Canadian fall 2J3K survey CAA data
d) **Sens3**: As a) Base Case, but excluding the 2019 commercial CAA data
e) **Sens4**: As a) Base Case, but replacing the 2019 commercial CAA data by an alternative vector (computed using a 2015-2018 average ALK instead of the 2018 ALK)

Results

Table 1 provides the results, with Hessian-based CVs, for the 2020 Base Case and sensitivities specified above, together with the corresponding results for the 2017 Base Case.

Figure 1 provides estimated trajectories for various biomass components, fishing mortality and recruitment, as well as showing a spawning stock-recruitment plots, and comparing results for the 2020 and the corresponding 2017 Base Case.

Figure 2 shows estimated survey and commercial selectivities for the 2020 Case Case.

Figures 3 and 4 shows fits of the Base Case assessment to the various survey abundance indices and catch-at-age data sets. Comparative fits for the 2017 Base Case assessment are also shown for the various abundance indices.

Figure 5 compares results for the 2020 Base Case and sensitivities, as well as providing confidence intervals for the Base Case estimates.

Figure 6 shows a retrospective analysis for the 2020 Base Case.

Figure 7 compares data and 2020 Base Case results from 2017 onwards with probability envelopes predicted at the time of the 2017 Base Case assessment based on application of the Management Procedure (MP) adopted at that time.

For ages 5-9 which are considered to be those available to the commercial fleet, and taking account of the current commercial selectivity vector over that age range, Fmsy = 0.237 and Bmsy = 116.8 kt; these compare with 2019 values of 0.226 and 70.5 kt respectively. An increase in this F from 2016 to become closer to Fmsy by 2019 was projected in 2017 to be expected under the MP adopted then.

Discussion

Some notable features of the results are as follows:

- In the main, the precision of estimates is not that good, and has scarcely (if at all) improved given three further years of data.
- Apart from a slight downward shift in overall biomass scale, results are essentially unchanged from those in 2017.
- There has been a recent slight downward trend in exploitable biomass, but this is likely to reverse quite soon given that the estimates of incoming recruitment are of above average strength.
- The general slight upward trend over recent years in spawning biomass is continuing.
- The fits to abundance indices and catch-at-age data continue to be reasonable.
- The sensitivities to changes in the recent catch-at-age data have essentially no impact except for slight changes in very recent recruitment estimates. Sensitivity test 4 involving changes to the 2019

commercial catch-at-age data results in an upward shift in the biomass scale which in some years can exceed 20% for spawning biomass, but is rather less for other biomass components.

- There is no indication of any retrospective patterns.
- New data and recent resource trends are consistent with predictions made in 2017 when a revised management procedure for Greenland halibut was adopted.

Table 1. Results from fits of the SCAA 2017 Base Case OM, and 2020 Base Case OMs and sensitivities Hessian-based CVs are shown in parentheses. Note that the overall log likelihood values shown are not comparable because the datasets for the various assessments are not the same. Values shown in **bold** are fixed on input. B5-9 is the biomass of fish aged 5 to 9, Fbar5-9 is the average fishing mortality on fish aged 5 to 9.

	2017 Base Case		2020 Base Case		2020 Sens1		2020 Sens2		2020 Sens3		2020 Sens4	
-lnL:overall	-460.60		-514.19		-510.90		-507.58		-511.29		-513.90	
-lnL: survey biomass												
Can 2J3K fall	-1.73		-2.35		-2.36		-2.52		-2.34		-2.40	
EU 0-700m	0.77		0.18		0.17		0.18		0.14		0.08	
EU 0-1400m	-1.78		-0.04		-0.03		-0.06		0.00		0.55	
Can 3LNO spr	13.44		13.04		13.04		13.08		13.00		13.00	
EU 3NO	9.06		10.54		10.54		10.54		10.55		10.46	
Can 3LNO fall	1.21		1.15		1.15		1.18		1.09		0.99	
-lnL: commercial CAA	-105.16		-112.57		-112.56		-112.56		-109.47		-112.37	
-lnL: survey CAA												
Can 2J3K fall	-63.04		-73.30		-69.98		-66.50		-73.38		-73.35	
EU 0-700m	-33.95		-33.76		-33.76		-33.78		-33.77		-33.71	
EU 0-1400m	-38.61		-49.14		-49.14		-49.15		-49.10		-49.09	
Can 3LNO spr	-49.69		-53.48		-53.47		-53.59		-53.51		-53.47	
EU 3NO	-61.99		-73.81		-73.81		-73.91		-73.82		-73.76	
Can 3LNO fall	-59.65		-67.78		-67.79		-67.72		-67.80		-67.78	
h	**0.80**	-	**0.80**		**0.80**		**0.80**		**0.80**		**0.80**	
M	**0.12**	-	**0.12**		**0.12**		**0.12**		**0.12**		**0.12**	
ϕ	0.00		0.00		0.00		0.00		0.00		0.00	
K^{sp}	753.31	(0.08)	608.70	(0.08)	608.31	(0.08)	610.43	(0.08)	607.73	(0.08)	763.18	(0.08)
$B^{sp}{}_{1975}$	525.9	(0.36)	442.4	(0.37)	442.2	(0.37)	442.0	(0.37)	441.1	(0.37)	466.6	(0.36)
$B^{sp}{}_{2016}$	104.30	(0.37)	77.28	(0.35)	77.01	(0.36)	77.16	(0.35)	76.44	(0.36)	81.38	(0.33)
$B^{sp}{}_{2016}/K^{sp}$	0.138	(0.36)	0.127	(0.34)	0.127	(0.34)	0.126	(0.34)	0.126	(0.35)	0.107	(0.32)
$B^{sp}{}_{2016}/B^{sp}{}_{1975}$	0.198	(0.47)	0.175	(0.47)	0.174	(0.47)	0.175	(0.47)	0.173	(0.47)	0.174	(0.45)
$B^{sp}{}_{2019}$			111.44	(0.31)	111.05	(0.31)	111.42	(0.31)	110.38	(0.32)	138.59	(0.30)
$B^{sp}{}_{2019}/K^{sp}$			0.18	(0.30)	0.18	(0.30)	0.18	(0.30)	0.18	(0.31)	0.18	(0.29)
$B^{sp}{}_{2019}/B^{sp}{}_{1975}$			0.25	(0.45)	0.25	(0.45)	0.25	(0.44)	0.25	(0.45)	0.30	(0.43)
$B^{5\text{-}9}{}_{1975}$	159.04	(0.18)	154.95	(0.18)	154.85	(0.18)	155.26	(0.18)	154.71	(0.18)	161.14	(0.18)
$B^{5\text{-}9}{}_{2016}$	91.51	(0.16)	78.06	(0.15)	77.94	(0.15)	78.12	(0.15)	77.51	(0.15)	78.60	(0.15)
$B^{5\text{-}9}{}_{2016}/B^{5\text{-}9}{}_{1975}$	0.575	(0.22)	0.504	(0.21)	0.503	(0.21)	0.503	(0.21)	0.501	(0.21)	0.488	(0.21)
$B^{5\text{-}9}{}_{2019}$			70.45	(0.14)	70.43	(0.14)	70.22	(0.14)	70.01	(0.15)	72.59	(0.14)
$B^{5\text{-}9}{}_{2019}/B^{5\text{-}9}{}_{1975}$			0.45	(0.21)	0.45	(0.21)	0.45	(0.21)	0.45	(0.21)	0.45	(0.21)

Figure 1. Results for SCAA 2017 (in black) and 2020 (in red) Base Cases. The spawning stock-recruitment plot shows the Beverton-Holt curves estimated, together with the replacement lines. Fmax is the maximum fishing mortality across ages for the year concerned.

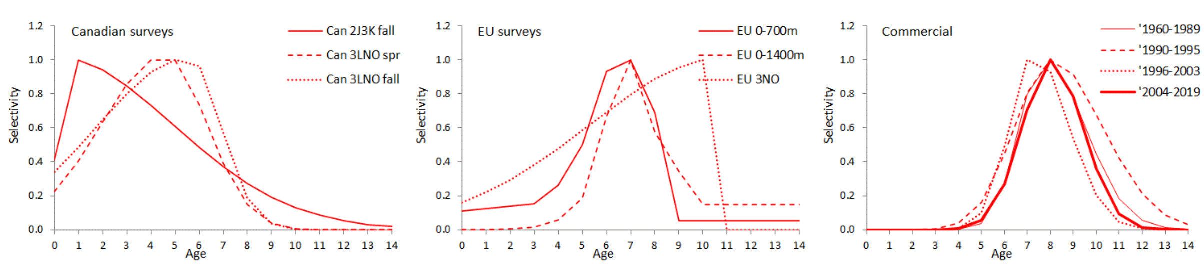

Figure 2. Estimated selectivities for the 2020 Base Case.

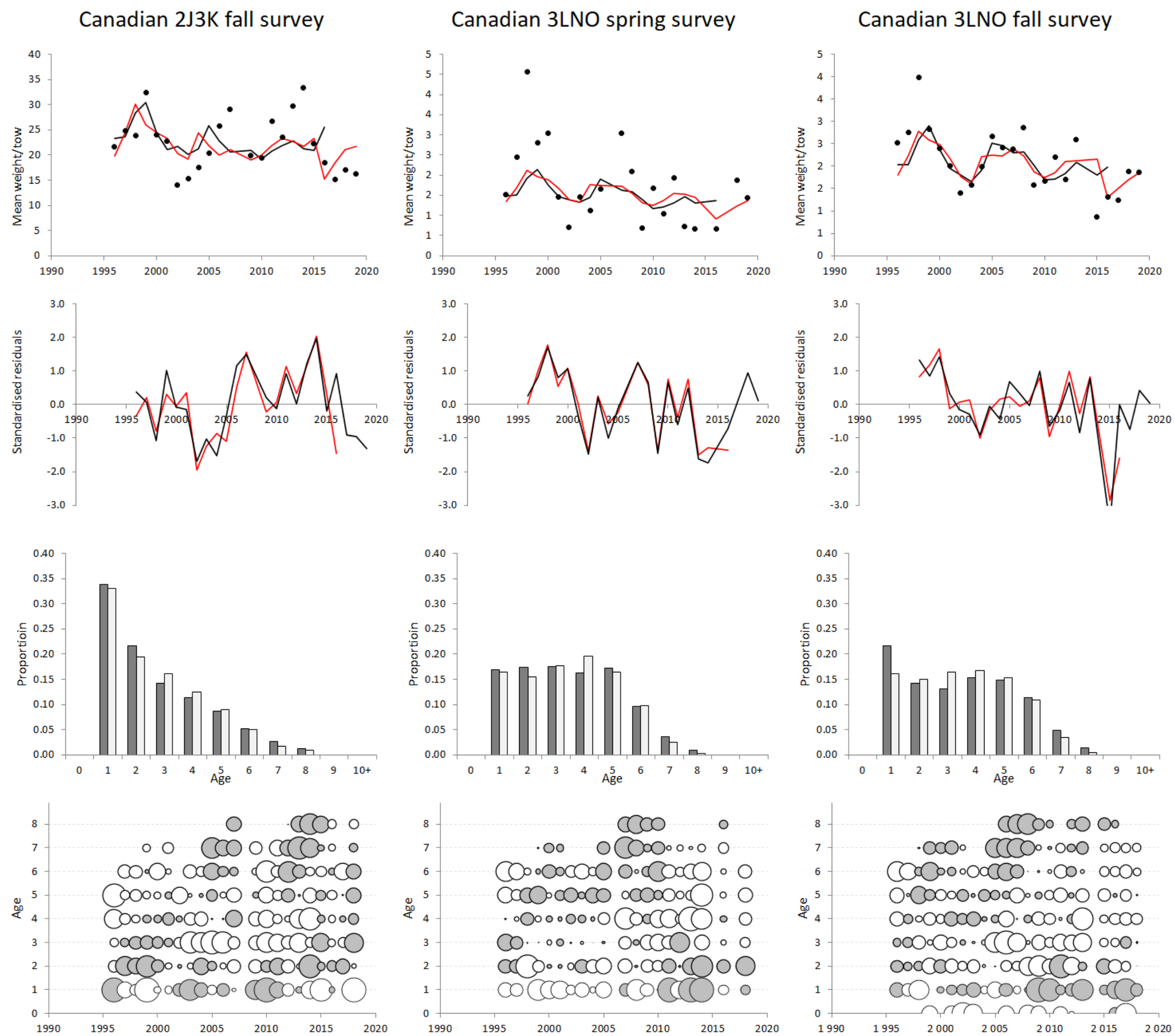

Figure 3a. Fits (and residuals) to the Canadian survey data for the 2017 (in black) and 2020 (in red) Base Cases. The fits and residuals of the CAA data are only shown for the 2020 Base Case. The sizes of the bubbles are proportional to the sizes of the residuals. Positive residuals are shown in grey, while negative residuals are shown in white.

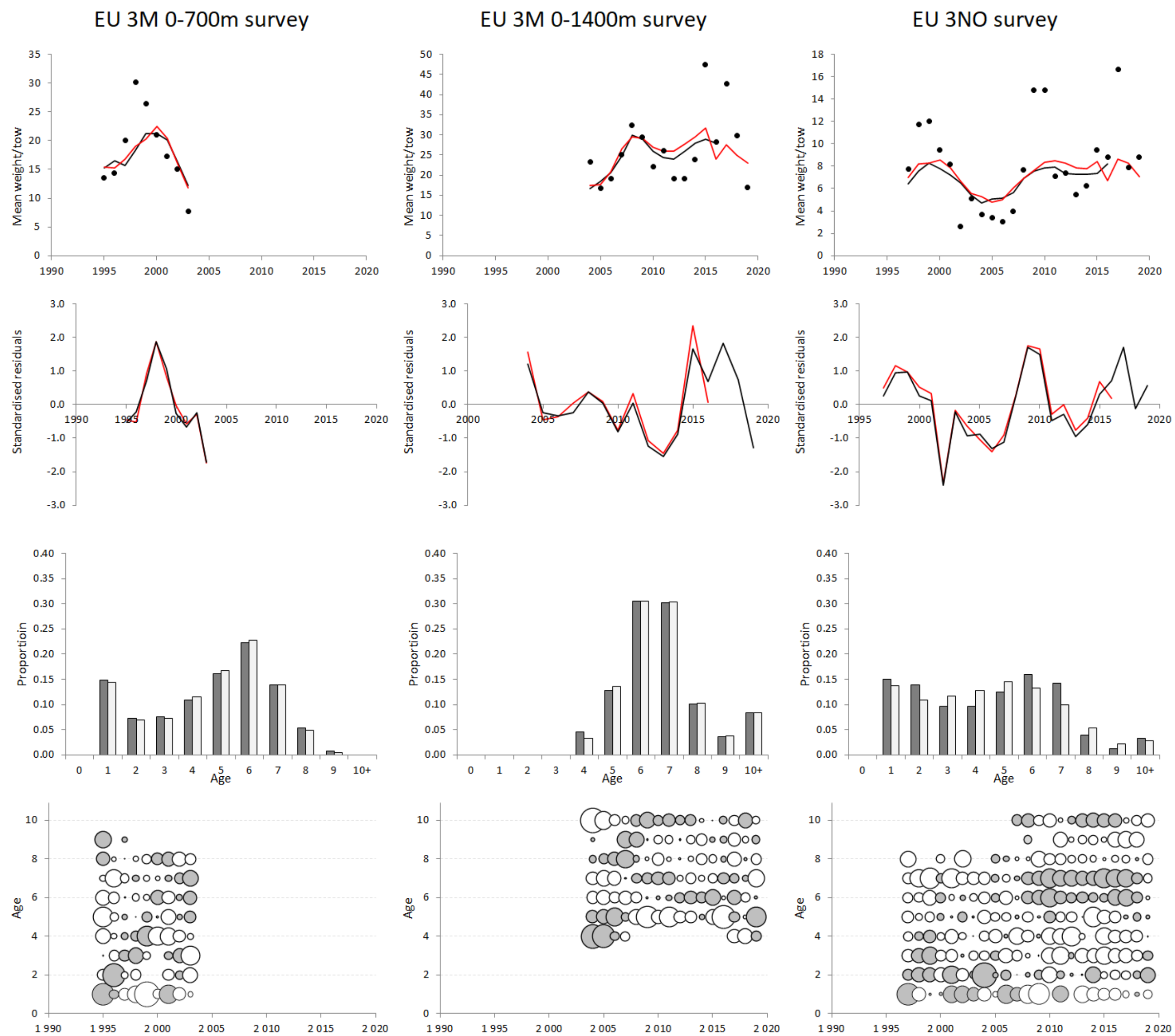

Figure 3b. Fits (and residuals) to the EU survey data for the 2017 (in black) and 2020 (in red) Base Cases. The fits and residuals of the CAA data are only shown for the 2020 Base Case. The sizes of the bubbles are proportional to the sizes of the residuals. Positive residuals are shown in grey, while negative residuals are shown in white.

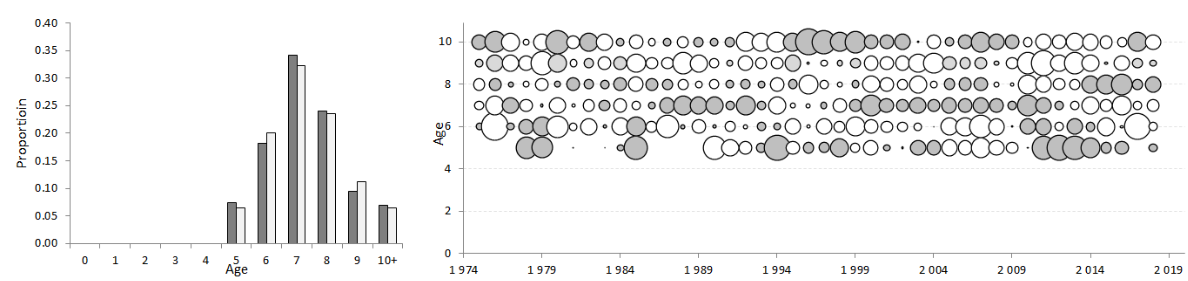

Figure 4. Fits (and residuals) to the commercial CAA data for the 2020 Base Case. The sizes of the bubbles are proportional to the sizes of the residuals. Positive residuals are shown in grey, while negative residuals are shown in white.

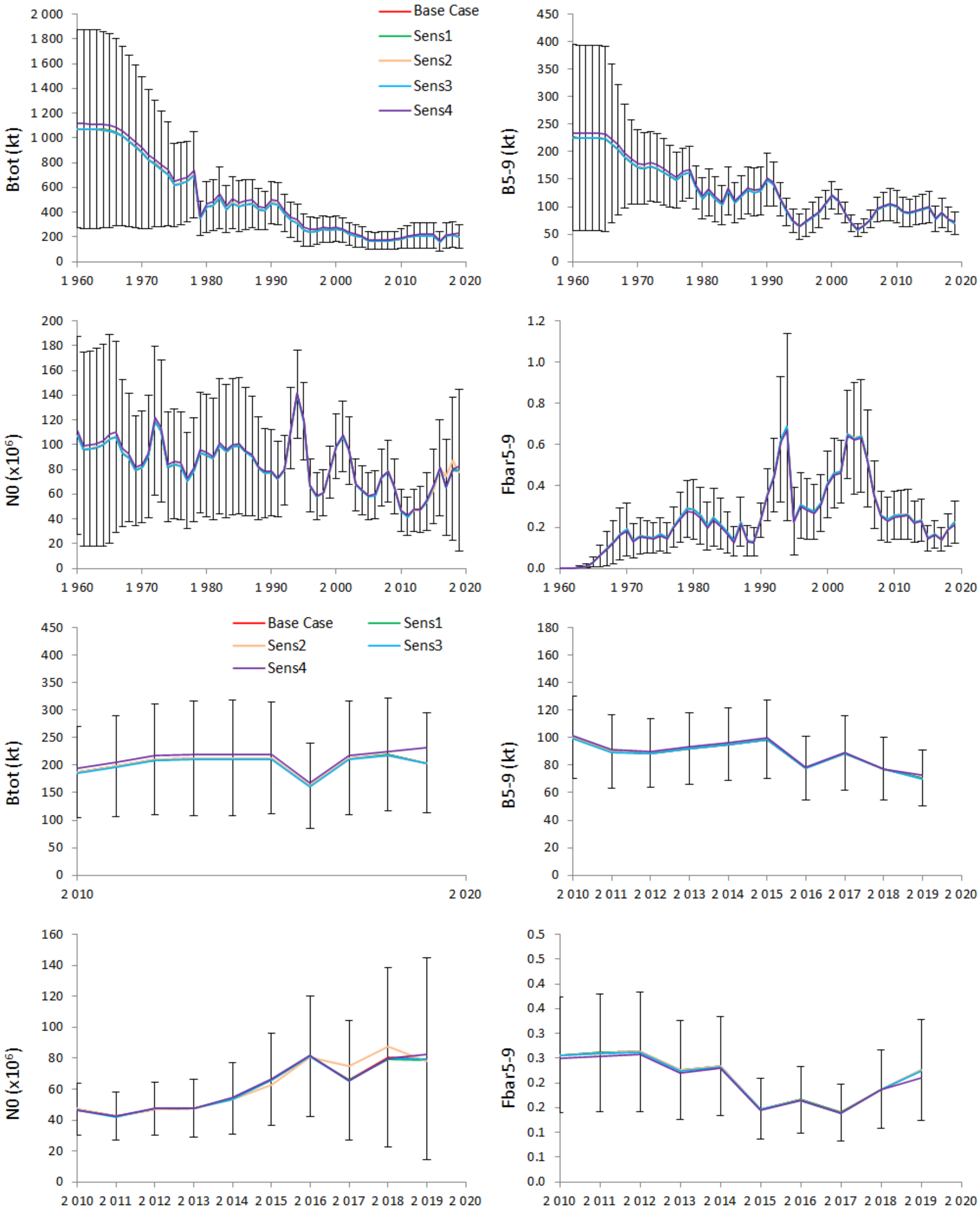

Figure 5. Results for 2020 Base Case (red), Sens1 (green), Sens2 (orange), Sens3 (blue) and Sens4 (purple). The error bars (+- 2 standard errors) are for the Base Case.

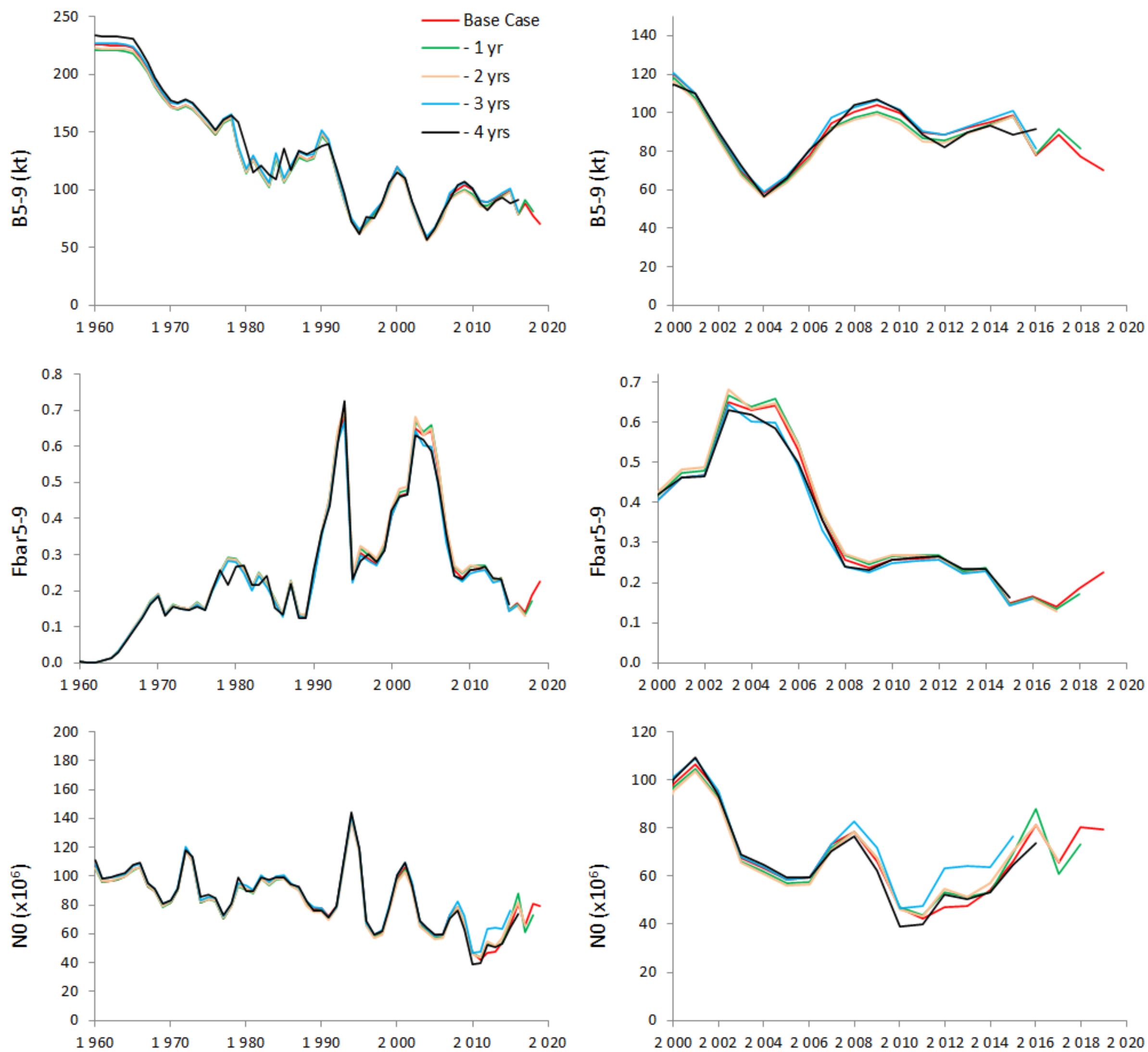

Figure 6. Results of a retrospective

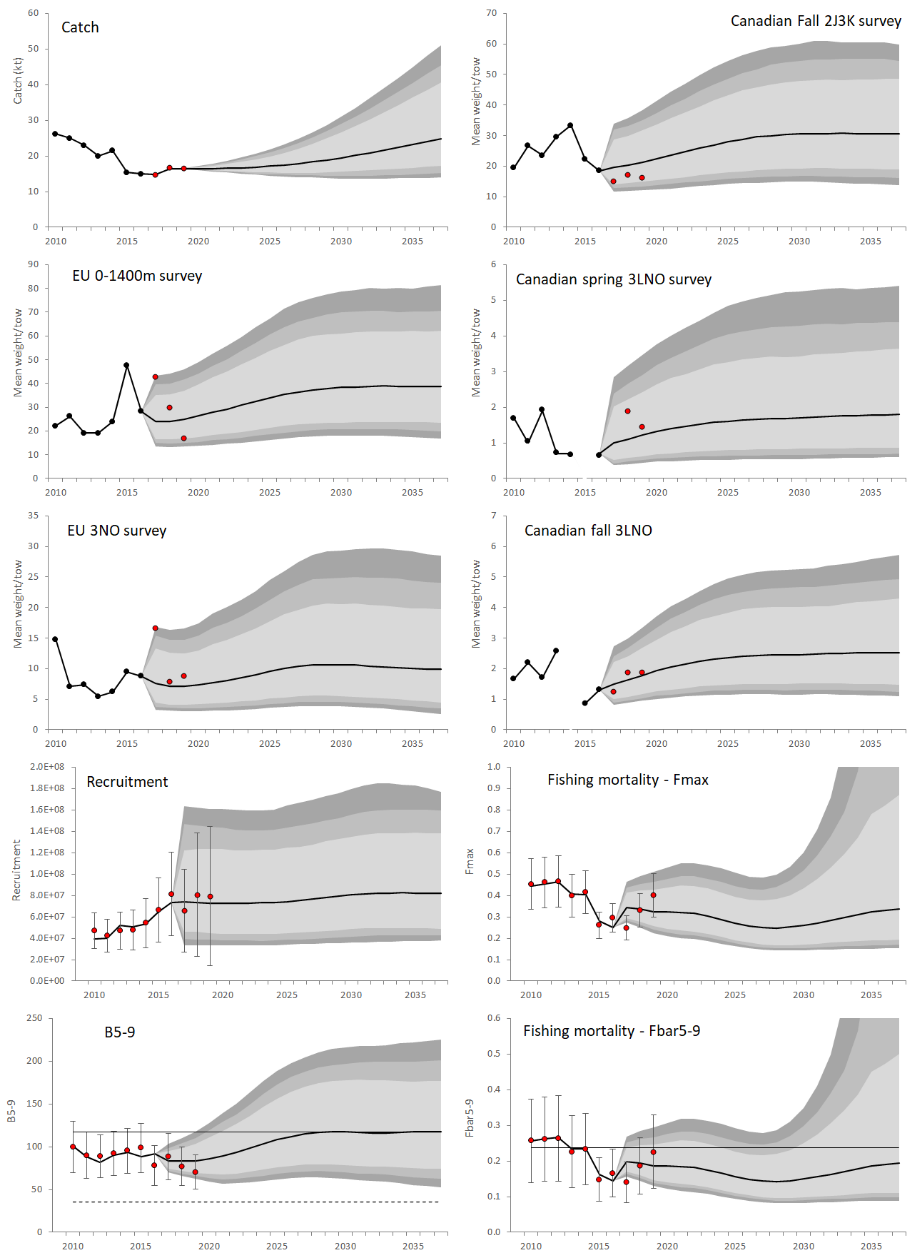

Figure 7. Projection envelopes (95, 90 and 80 percentiles) and medians under the MP adopted in 2017 for the then Base Case OM. Catches and abundance index values observed from 2017 onwards are shown in red; for the abundance indices the envelopes take account not only of the uncertainty in future dynamics of the resource but also future observation errors. For recruitment, fishing mortality (Fmax and Fbar5-9) and B5-9 estimates (dots) are throughout from the 2020 Base Case (and shown with +- 2 stdev error bars), whereas the lines are for the 2017 Base Case OM. Bmsy and Blim (=0.3Bmsy) are shown as full and dashed horizontal lines respectively in the B5-9 plot and Fmsy is shown as a full horizontal line in the Fbar5-9 plot. The probability envelopes have been computed using a 9-point averaging approach from 500 replicates.

Appendix A

Algebraic details of the Statistical Catch-at-Age Model

The text following sets out the equations and other general specifications of the Statistical Catch-at-Age (SCAA) assessment model applied to Greenland halibut, followed by details of the contributions to the (penalised) log-likelihood function from the different sources of data available and assumptions concerning the stock-recruitment relationship. Quasi-Newton minimization is applied to minimize the total negative log-likelihood function to estimate parameter values (the package AD Model Builder™, Otter Research, Ltd is used for this purpose).

Where options are provided under a particular section, the section concludes with a statement in **bold** as to which option was selected for the baseline Operating Model (OM0) selected.

A.1. Population dynamics

A.1.1 Numbers-at-age

The resource dynamics are modelled by the following set of population dynamics equations:

$$N_{y+1,0} = R_{y+1} \quad \text{(A.1)}$$

$$N_{y+1,a+1} = N_{y,a}e^{-Z_{y,a}} \quad \text{for } 0 \le a \le m-2 \quad \text{(A.2)}$$

$$N_{y+1,m} = N_{y,m-1}e^{-Z_{y,m-1}} + N_{y,m}e^{-Z_{y,m}} \quad \text{(A.3)}$$

where

$N_{y,a}$ is the number of fish of age a at the start of year y,

R_y is the recruitment (number of 0-year-old fish) at the start of year y,

m is the maximum age considered (taken to be a plus-group = 14).

$Z_{y,a} = F_yS_{y,a} + M_a$ is the total mortality in year y on fish of age a, where

M_a denotes the natural mortality rate for fish of age a,

F_y is the fishing mortality of a fully selected age class in year y, and

$S_{y,a}$ is the commercial selectivity at age a for year y.

A.1.2. Recruitment

The number of recruits (i.e. new 0-year olds) at the start of year y is assumed to be related to the spawning stock size (i.e. the biomass of mature fish) by Beverton-Holt stock-recruitment relationship, allowing for annual fluctuation about the deterministic relationship.

$$R_y = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} e^{\left(\varphi_y - (\sigma_R)^2/2\right)} \quad \text{(A.4)}$$

where

α and β are spawning biomass-recruitment relationship parameters,

φ_y reflects fluctuation about the expected recruitment for year y, which is assumed to be normally distributed with standard deviation σ_R (which is input in the applications considered here); these residuals are treated as estimable parameters in the model fitting process.

B_y^{sp} is the spawning biomass at the start of year y, computed as:

$$B_y^{sp} = \sum_{a=1}^{m} f_a\, w_{y,a}^{strt} N_{y,a} \quad \text{(A.5)}$$

where

$w_{y,a}^{strt}$ is the mass of fish of age a during spawning, and

f_a is the proportion of fish of age a that are mature.

In order to work with estimable parameters that are more biologically meaningful, the stock-recruitment relationship is re-parameterised in terms of the pre-exploitation (virgin) equilibrium spawning biomass B_0 and the steepness, h, of the stock-recruitment relationship, which is the proportion of the virgin recruitment R_0 that is realised at a spawning biomass level of 20% of the virgin spawning biomass:

$$\alpha = \frac{4hR_0}{5h-1} \qquad \text{(A.6)}$$

and

$$\beta = \frac{B_0(1-h)}{5h-1} \qquad \text{(A.7)}$$

where

$$R_0 = B_0 \Big/ \left[\sum_{a=1}^{m-1} f_a w_{y_0,a}^{strt} exp\left(-\sum_{a'=0}^{a-1} M_{a'}\right) + f_m w_{y_0,m}^{strt} \frac{exp\left(-\sum_{a'=0}^{m-1} M_{a'}\right)}{1-exp(-M_m)}\right] \qquad \text{(A.8)}$$

For baseline run, *h* is fixed to 0.8 and ⍰R=0.4.

A.1.3. Total catch and catches-at-age

The total catch by mass in year y is given by:

$$C_y = \sum_{a=0}^{m} w_{y,a}^{mid} C_{y,a} = \sum_{a=0}^{m} w_{y,a}^{mid} N_{y,a} S_{y,a} F_y \left(1 - e^{-Z_{y,a}}\right) \big/ Z_{y,a} \qquad \text{(A.9)}$$

where

$w_{y,a}^{mid}$ denotes the mass of fish of age a landed in year y,

$C_{y,a}$ is the catch-at-age, i.e. the number of fish of age a, caught in year y.

A.1.4. Initial conditions

As the first year for which catch data are available for the Greenland halibut stock considered does not correspond to the first year of (appreciable) exploitation, one cannot necessarily make the conventional assumption in the application of SCAA's that this initial year reflects a population (and its age-structure) at pre-exploitation equilibrium. For the first year (y_0=1960) considered in the model therefore, the starting numbers-at-age 0 are estimated directly and an average fishing mortality is applied for ages 1 to m:

$$N_{y_0,a} = \begin{cases} N_{y_0,0} & \text{for } a = 0 \\ N_{y_0,a-1} e^{-(M_{a-1}+\vartheta)} & \text{for } 1 < a < m \\ N_{y_0,m-1} e^{-(M_{m-1}+\vartheta)} \big/ \left(1 - e^{-(M_m+\vartheta)}\right) & \text{for } a = m \end{cases} \qquad \text{(A.10)}$$

where ϑ⍰⍰characterises the average fishing proportion over the years immediately preceding y_0. Bounds of (0; 1) are imposed on ϑ⍰⍰

The following penalties are added to the total negative log-likelihood:

$$pen^{N_0} = \frac{\left(lnN_{y_0,0} - lnR_o\right)^2}{2\sigma_R^2} \qquad \text{(A.11)}$$

where R_o is the recruitment expected at carrying capacity

and

$$pen^{\vartheta} = \frac{\vartheta^2}{2\sigma_\vartheta^2} \qquad \text{(A.12)}$$

with $\sigma_\vartheta = 0.1$

A.2. The (penalised) likelihood function

The model can be fit to (a subset of) survey biomass indices, and commercial and survey catch-at-age and catch-at-age data to estimate model parameters (which may include residuals about the stock-recruitment function, facilitated through the incorporation of a penalty function described below). Contributions by each of these to the negative of the (penalised) log-likelihood (-lnL) are as follows.

A.2.1. Survey biomass data

The likelihood is calculated assuming that a survey biomass index is lognormally distributed about its expected value:

$$I_y^i = \hat{I}_y^i e^{\varepsilon_y^i} \quad \text{or} \quad \varepsilon_y^i = ln(I_y^i) - ln(\hat{I}_y^i) \qquad \text{(A.13)}$$

where

I_y^i is the survey index for survey i in year y,

$\hat{I}_y^i = \hat{q}^i \hat{B}_y^i$ is the corresponding model estimate, where

$\hat{q}^i$ is the constant of proportionality (catchability) for the survey biomass series i, and

ε_y^i from $N\left(0, \left(\sigma_y^i\right)^2\right)$.

The model estimate of survey biomass index is computed as:

$$B_y^i = \sum_{a=0}^{m} w_{y,a}^i S_a^i N_{y,a} e^{-Z_{y,a}T^i/12} \qquad \text{(A.14)}$$

where

S_a^i is the survey selectivity for age a, which is taken to be year-independent.

T^i is the month in which the survey is taking place (see Table App.A1), and

$w_{y,a}^i$ denotes the mass of fish of age a from survey i in year y.

Note: Only catch weights-at-age (Appendix B, Table B3) are available, so that $w_{y,a}^{strt} = w_{y,a}^{mid} = w_{y,a}^i$.

The contribution of the survey biomass data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-lnL^{\text{survey}} = \sum_i \sum_y \left\{ ln\left(\sqrt{\left(\sigma_y^i\right)^2 + \left(\sigma_{Add}^i\right)^2}\right) + \frac{\left(\varepsilon_y^i\right)^2}{2\left(\left(\sigma_y^i\right)^2 + \left(\sigma_{Add}^i\right)^2\right)} \right\} \qquad \text{(A.15)}$$

where

σ_y^i is the standard deviation of the residuals for the logarithm of index i in year y, and

σ_{Add}^i is the square root of the additional variance for survey biomass series i, which is estimated in the model fitting procedure, with an upper bound of 0.5.

In this case, however, external estimates of σ_y^i (from survey sampling variance) are not available. So homoscedasticity of residuals is assumed, so that estimation of additional variance falls away and $\sigma_y^i = \sigma^i$ is estimated in the fitting procedure by its maximum likelihood value (with a minimum estimate of 0.15 imposed to prevent overweighting through overfitting):

$$\sigma^i = \sqrt{\frac{1}{n^i} \sum_y \left(lnI_y^i - ln\left(q^i B_y^i\right)\right)^2} \qquad \text{(A.16)}$$

The constant of proportionality q^i for survey biomass index i is estimated by its maximum likelihood value:

$$lnq^i = \frac{1}{n^i} \sum_y \left(lnI_y^i - lnB_y^i\right) \qquad \text{(A.17)}$$

A.2.3. Commercial catches-at-age

The "sqrt(p)" method is used to compute the contribution of the catch-at-age data to the negative of the log-likelihood function. The formulation mimics a multinomial form for the error distribution by forcing near-equivalent variance-mean relationship for the error distributions:

$$-lnL^{CAA} = w^{CAA} \sum_y \sum_a \left[ln(\sigma^{com}) + \left(\sqrt{lnp_{y,a}} - \sqrt{ln\hat{p}_{y,a}}\right)^2 / 2(\sigma_a^{com})^2 \right] \quad \text{(A.18)}$$

where

$p_{y,a} = C_{y,a} / \sum_{a'} C_{y,a'}$ is the observed proportion of fish caught in year y that are of age a,

$\hat{p}_{y,a} = \hat{C}_{y,a} / \sum_{a'} \hat{C}_{y,a'}$ is the model-predicted proportion of fish caught in year y that are of age a,

with

$$\hat{C}_{y,a} = N_{y,a} S_{y,a} F_y \left(1 - e^{-Z_{y,a}}\right) / Z_{y,a} \quad \text{(A.19)}$$

and

σ_a^{com} is the standard deviation associated with the catch-at-age data, which is estimated in the fitting procedure by:

$$\hat{\sigma}_a^{com} = \sqrt{\sum_y \left(\sqrt{lnp_{y,a}} - \sqrt{ln\hat{p}_{y,a}}\right)^2 / \sum_y 1} \quad \text{(A.20)}$$

The w^{CAA} weighting factor in equation A.18 may be set to a value less than 1 to down-weight the contribution of the catch-at-age data (which tend to be positively correlated between adjacent age groups) to the overall negative log-likelihood compared to that of the survey biomass data.

Commercial catches-at-age are incorporated in the likelihood function using equation (A.18), for which the summation over age a is taken from age a_{minus} (considered as a minus group) to a_{plus} (a plus group).

For the baseline run, $w^{CAA} = 0.2$.

A.2.4. Survey catches-at-age

The survey catches-at-age are incorporated into the negative of the log-likelihood in an analogous manner to the commercial catches-at-age, assuming an "adjusted" lognormal error distribution (equation (A.18)) where:

$p_{y,a}^i = C_{y,a}^i / \sum_{a'} C_{y,a'}^i$ is the observed proportion of fish of age a in year y for survey i,

$\hat{p}_{y,a}^i$ is the expected proportion of fish of age a in year y in the survey i, given by:

$$\hat{p}_{y,a}^i = S_a^i N_{y,a} e^{-Z_{y,a} T^i / 12} / \sum_{a'} S_{a'}^i N_{y,a'} e^{-Z_{y,a'} T^i / 12} \quad \text{(A.21)}$$

For the survey CAA, w^{CAA} is also set to 0.2

A.2.5. Stock-recruitment function residuals

The stock-recruitment residuals are assumed to be lognormally distributed. Thus, the contribution of the recruitment residuals to the negative of the (now penalised) log-likelihood function is given by:

$$-lnL^{pen} = \sum_{y=y_1}^{y_2} \left(\varphi_y^2 / 2\sigma_R^2\right) \quad \text{(A.22)}$$

where

φ_y from $N(0, \sigma_R^2)$,

σ_R is the standard deviation of the log-residuals, which is input. σ_R=0.4

B.2.7. Catches

$$-lnL^{Catch} = \sum_y \frac{lnC_y - ln\hat{C}_y}{2\sigma_C^2} \qquad (A.23)$$

where
C_y is the observed catch in year y,
$\hat{C}_y$ is the predicted catch in year y (equation A.9), and
$\sigma_C = 0.1$ is the input CV input.

A.3. Estimation of precision
Where quoted, CV's or 90% probability interval estimates are based on the Hessian.

A.4. Model parameters

B.4.1. Fishing selectivity-at-age:
For the surveys, the fishing selectivities are either estimated separately for ages a_1 to a_2 or are modelled by a double normal shape:

$$S_a = \begin{cases} exp\left(-\frac{(a-a_{max})^2}{2\sigma_{left}^2}\right) & \text{for } a \leq a_{max} \\ exp\left(-\frac{(a-a_{max})^2}{2\sigma_{right}^2}\right) & \text{for } a > a_{max} \end{cases} \qquad (A.24)$$

where σ_{left}, σ_{right} and a_{max} are estimable parameters.

When the fishing selectivity is estimated separately for ages a_1 to a_2, the selectivity is taken to increase exponentially from age 0 to a_1-1 and to remain flat above a_2:

$$S_a = \begin{cases} S_{a+1}\frac{S_{a_1}}{S_{a_1+1}} & a < a_1 \\ \text{estimated freely} & a_1 \leq a \leq a_2 \\ S_{a_2} & a > a_2 \end{cases} \qquad (A.25)$$

The double normal selectivity is used for the three Canadian surveys (Can. Fall 2J3K, Can. Spring 3LNO and Can. Fall 3LNO) as well as the EU 3NO survey. For the EU 3M surveys (0-700m and 0-1400m), the selectivities are estimated separately for ages 1 to 9 and 4 to 10 respectively (ages a_1 and a_2 above).

The commercial fishing selectivities are modelled by a double-normal shape. For the baseline run, the selectivity is estimated for each of four periods: 1960-1989, 1990-1995, 1996-2003 and 2004+.

A.4.2. Other parameters

Stock-recruit standard dev.			
σ_R	0.4		
Model plus group			
m	14		
CAA minus and plus groups	a_{minus}	a_{plus}	T^i
Can. Fall 2J3K	1	8	9
EU 3M 0-700m	1	9	7
EU 3M 0-1400m	4	10	7
EU 3M70 0-1400m	4	10	7
Can. Spring 3LNO	1	8	5
EU 3L	1	10	8
EU 3NO	1	10	6
Can. Fall 3LNO	0	8	11
Commercial	5	10	
Natural mortality:			
M	0.12, age-independent		
Proportion mature-at-age:			
f_a	100% mature at age 10		
Weight-at-age:			
$w_{y,a}^{strt}$	input, ages 0-10+		
$w_{y,a}^{mid}$	input, ages 0-10+		
$w_{y,a}^{i}$	input, ages 0-10+		

Appendix B

The data

Table B1. Landings (tons) for Greenland Halibut in Sub-area 2 and Div. 3KLMNO.

Year	Landings (t)	Year	Landings (t)
1960	900	1990	47454
1961	700	1991	65008
1962	600	1992	63193
1963	2000	1993	62455
1964	4000	1994	51029
1965	10000	1995	15272
1966	19000	1996	18840
1967	27000	1997	19858
1968	32000	1998	19946
1969	37000	1999	24226
1970	37000	2000	34177
1971	25000	2001	38232
1972	30000	2002	34062
1973	29000	2003	35151
1974	28000	2004	25486
1975	28814	2005	23255
1976	24611	2006	23531
1977	32048	2007	22747
1978	39070	2008	21180
1979	34104	2009	23156
1980	32867	2010	26174
1981	30754	2011	24960
1982	26278	2012	22978
1983	27861	2013	19976
1984	26711	2014	21433
1985	20347	2015	15273
1986	17976	2016	14875
1987	32442	2017	14760
1988	19215	2018	16630
1989	20034	2019	16481

Table B2. Catch at age matrix (000s) for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO. The alternative indicated for 2019 is as used for sensitivity test Sens4.

Year	0	1	2	3	4	5	6	7	8	9	10+	
1975	0	0	0	0	0	334	2819	5750	4956	3961	3092	
1976	0	0	0	0	0	17	610	3231	5413	3769	3448	
1977	0	0	0	0	0	534	5012	10798	7346	2933	1563	
1978	0	0	0	0	0	2982	8415	8970	7576	2865	3008	
1979	0	0	0	0	0	2386	8727	12824	6136	1169	1344	
1980	0	0	0	0	0	209	2086	9150	9679	5398	5049	
1981	0	0	0	0	0	863	4517	9806	11451	4307	1400	
1982	0	0	0	0	0	269	2299	6319	5763	3542	2890	
1983	0	0	0	0	0	701	3557	9800	7514	2295	1258	
1984	0	0	0	0	0	902	2324	5844	7682	4087	2098	
1985	0	0	0	0	0	1983	5309	5913	3500	1380	943	
1986	0	0	0	0	0	280	2240	6411	5091	1469	1042	
1987	0	0	0	0	0	137	1902	11004	8935	2835	2092	
1988	0	0	0	0	0	296	3186	8136	4380	1288	1007	
1989	0	0	0	0	0	181	1988	7480	4273	1482	1688	
1990	0	0	0	0	95	1102	6758	12632	7557	4072	5533	
1991	0	0	0	0	220	2862	7756	13152	10796	7145	7782	
1992	0	0	0	0	1064	4180	10922	20639	12205	4332	4242	
1993	0	0	0	0	1010	9570	15928	17716	11918	4642	4438	
1994	0	0	0	0	5395	16500	15815	11142	6739	3081	2871	
1995	0	0	0	0	323	1352	2342	3201	2130	1183	1610	
1996	0	0	0	0	190	1659	5197	6387	1914	956	1405	
1997	0	0	0	0	335	1903	4169	7544	3215	1139	1498	
1998	0	0	0	0	552	3575	5407	5787	3653	1435	1222	
1999	0	0	0	0	297	2149	5625	8611	3793	1659	1568	
2000	0	0	0	0	271	2029	12583	21175	3299	973	1332	
2001	0	0	0	0	448	2239	12163	22122	5154	1010	1368	
2002	0	0	0	37	479	1662	7239	17581	6607	1244	1450	
2003	0	0	0	203	1279	4491	10723	16764	6385	1614	1111	
2004	0	0	0	17	897	4062	8236	10542	4126	1307	1164	
2005	0	0	0	40	534	1652	5999	10313	3996	1410	912	
2006	0	0	0	10	216	1869	6450	12144	4902	1089	627	
2007	0	0	0	0	88	570	3732	11912	5414	1230	785	
2008	0	0	0	0	29	448	3312	10697	5558	1453	595	
2009	0	0	0	0	61	476	3121	8801	7276	1949	846	
2010	0	0	0	0	146	825	5077	11202	6171	2134	841	
2011	0	0	0	430	690	1385	4101	7257	3953	1255	715	
2012	0	0	0	1216	706	1982	3422	7618	5529	1992	1143	
2013	0	0	0	125	460	1744	3873	3997	3255	787	330	
2014	0	0	0	119	259	1007	3041	3583	4626	910	288	
2015	0	0	0	59	89	429	1237	4037	5546	1571	331	
2016	0	0	0	39	116	445	1294	2457	6072	1399	445	
2017	0	0	0	0	2	38	442	2688	4623	2922	1671	
2018	0	0	0	0	117	516	1582	2671	4587	2923	830	
2019	0	0	0	0	221	752	2038	3168	4288	2605	947	
2019	0	0	0	15.77	161.9	981.2	1836	3364	4510	2334	1021	alternative

Table B3. Catch weights-at-age (kg) matrix for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO. Pre-1975 weights-at-age are taken as the 1975-1979 average. The alternative indicated for 2019 is as used for sensitivity test Sens4.

Year	0	1	2	3	4	5	6	7	8	9	10+	
1975	0	0	0	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.509	
1976	0	0	0	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.703	
1977	0	0	0	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.909	
1978	0	0	0	0.126	0.244	0.609	0.760	0.955	1.190	1.580	3.438	
1979	0	0	0	0.126	0.244	0.514	0.659	0.869	1.050	1.150	1.399	
1980	0	0	0	0.126	0.244	0.392	0.598	0.789	0.985	1.240	2.400	
1981	0	0	0	0.126	0.244	0.525	0.684	0.891	1.130	1.400	2.582	
1982	0	0	0	0.126	0.244	0.412	0.629	0.861	1.180	1.650	3.375	
1983	0	0	0	0.126	0.244	0.377	0.583	0.826	1.100	1.460	2.751	
1984	0	0	0	0.126	0.244	0.568	0.749	0.941	1.240	1.690	3.190	
1985	0	0	0	0.126	0.244	0.350	0.584	0.811	1.100	1.580	3.315	
1986	0	0	0	0.126	0.244	0.364	0.589	0.836	1.160	1.590	3.444	
1987	0	0	0	0.126	0.244	0.363	0.569	0.805	1.163	1.661	3.491	
1988	0	0	0	0.126	0.244	0.400	0.561	0.767	1.082	1.657	3.095	
1989	0	0	0	0.090	0.181	0.338	0.546	0.766	1.119	1.608	3.010	
1990	0	0	0	0.126	0.244	0.383	0.592	0.831	1.228	1.811	3.383	
1991	0	0	0	0.175	0.289	0.430	0.577	0.793	1.234	1.816	3.458	
1992	0	0	0	0.134	0.232	0.368	0.547	0.809	1.207	1.728	3.231	
1993	0	0	0	0.080	0.196	0.330	0.514	0.788	1.179	1.701	3.289	
1994	0	0	0	0.080	0.288	0.363	0.531	0.808	1.202	1.759	3.746	
1995	0	0	0	0.161	0.242	0.360	0.541	0.832	1.272	1.801	3.409	
1996	0	0	0	0.120	0.206	0.336	0.489	0.771	1.159	1.727	3.300	
1997	0	0	0	0.119	0.228	0.373	0.543	0.810	1.203	1.754	3.166	
1998	0	0	0	0.176	0.253	0.358	0.533	0.825	1.253	1.675	3.195	
1999	0	0	0	0.000	0.254	0.346	0.524	0.787	1.192	1.774	3.125	
2000	0	0	0	0	0.249	0.376	0.57	0.83	1.168	1.794	3.177	
2001	0	0	0	0.217	0.251	0.369	0.557	0.841	1.193	1.76	2.996	
2002	0	0	0	0.188	0.247	0.389	0.564	0.822	1.199	1.651	2.865	
2003	0	0	0	0.180	0.249	0.376	0.535	0.808	1.196	1.629	2.907	
2004	0	0	0	0.252	0.301	0.396	0.564	0.849	1.247	1.691	2.779	
2005	0	0	0	0.129	0.267	0.405	0.605	0.815	1.092	1.495	2.358	
2006	0	0	0	0.000	0.276	0.389	0.581	0.833	1.137	1.500	2.409	
2007	0	0	0	0	0.278	0.404	0.617	0.891	1.195	1.605	2.443	
2008	0	0	0	0	0.279	0.390	0.599	0.862	1.158	1.611	2.432	
2009	0	0	0	0	0.250	0.350	0.570	0.840	1.210	1.650	2.454	
2010	0	0	0	0.13	0.210	0.310	0.530	0.850	1.250	1.750	2.627	
2011	0	0	0	0.170	0.240	0.300	0.570	0.890	1.280	1.750	2.730	
2012	0	0	0	0.140	0.270	0.420	0.630	0.870	1.250	1.830	2.871	
2013	0	0	0	0.150	0.240	0.400	0.620	0.890	1.310	1.920	2.955	
2014	0	0	0	0.160	0.240	0.410	0.630	0.890	1.220	1.760	2.932	
2015	0	0	0	0.219	0.313	0.472	0.669	0.903	1.277	1.821	2.714	
2016	0	0	0	0.000	0.255	0.314	0.517	0.715	1.085	1.366	2.033	
2017	0	0.000	0.000	0.000	0.301	0.421	0.621	0.876	1.254	1.788	2.752	
2018	0	0	0	0.191	0.279	0.414	0.597	0.847	1.191	1.733	2.647	
2019	0	0	0	0.191	0.279	0.414	0.597	0.847	1.191	1.733	2.27	
2019	0	0	0	0.156	0.275	0.423	0.611	0.859	1.238	1.808	2.726	alternative

Table B4. Proportion mature-at-age for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO.

1	2	3	4	5	6	7	8	9	10	11	12	13	14+
0	0	0	0	0	0	0	0	0	1	1	1	1	1

Table B5. Survey catch-at-age data (numbers) and biomass indices (mean weight (kg) per tow) for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO.

Canadian 2J3K fall

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Mean weight (kg) per tow
1996	4.916	98.682	47.817	32.012	9.539	6.283	2.466	0.836	0.191	0.179	0.039	0.024	0.012	0.017	0.006	21.58
1997	2.182	28.049	58.624	43.608	21.130	10.368	5.007	1.998	0.641	0.203	0.055	0.032	0.022	0.009	0.003	24.80
1998	1.518	23.348	25.071	31.191	21.866	10.859	4.452	2.066	0.565	0.132	0.059	0.028	0.021	0.013	0.004	23.83
1999	6.464	15.987	34.422	24.070	28.281	20.042	10.526	3.811	0.703	0.139	0.072	0.021	0.006	0.025	0.002	32.48
2000	3.081	38.595	22.088	16.483	13.287	13.895	7.267	2.167	0.503	0.064	0.030	0.015	0.004	0.000	0.006	24.01
2001	8.491	43.897	22.721	16.997	14.071	9.765	7.591	3.403	0.692	0.112	0.023	0.014	0.004	0.011	0.001	22.69
2002	8.302	40.670	24.082	12.504	9.679	6.027	1.974	0.719	0.190	0.039	0.013	0.004	0.000	0.003	0.000	14.07
2003	9.938	45.701	26.672	11.689	9.490	6.389	2.271	0.893	0.268	0.040	0.017	0.010	0.006	0.002	0.000	15.31
2004	4.152	32.486	32.930	13.888	12.312	9.209	2.684	1.198	0.358	0.083	0.032	0.006	0.004	0.008	0.002	17.46
2005	5.068	16.057	16.153	8.557	13.845	10.976	6.848	3.960	0.662	0.116	0.034	0.027	0.009	0.007	0.008	20.34
2006	3.753	32.341	17.980	8.502	17.600	13.028	9.113	4.177	1.151	0.180	0.028	0.024	0.010	0.000	0.002	25.73
2007	2.209	32.607	14.510	12.814	18.773	9.573	10.350	6.171	2.140	0.338	0.076	0.039	0.024	0.009	0.007	29.12
2009	5.493	50.624	19.149	11.404	8.421	9.889	5.395	3.591	1.393	0.250	0.077	0.024	0.008	0.008	0.009	19.88
2010	19.536	50.935	39.247	14.815	9.450	6.736	3.767	2.197	1.022	0.176	0.068	0.043	0.016	0.005	0.010	19.47
2011	4.810	44.135	42.063	20.973	18.790	10.318	5.499	3.153	1.257	0.326	0.128	0.061	0.023	0.000	0.009	26.74
2012	5.155	12.280	9.609	11.273	11.863	10.957	9.028	4.305	1.692	0.287	0.108	0.054	0.022	0.014	0.022	23.50
2013	2.760	24.568	12.713	6.855	7.465	10.779	9.071	7.837	3.905	0.506	0.145	0.044	0.017	0.020	0.009	29.65
2014	3.096	22.084	30.407	11.391	4.540	7.956	7.378	8.920	6.621	0.969	0.199	0.040	0.024	0.008	0.029	33.34
2015	0.498	17.172	13.979	15.139	7.766	6.815	4.183	3.910	3.918	0.649	0.140	0.063	0.007	0.009	0.023	22.29
2016	10.579	29.651	19.467	10.808	8.154	4.826	4.888	3.015	2.092	0.509	0.103	0.057	0.022	0.005	0.026	18.54
2017	6.431	30.571	22.787	10.203	8.765	5.724	2.636	1.262	0.962	0.365	0.124	0.035	0.013	0.007	0.021	15.10
2018	1.701	14.329	17.225	17.291	8.620	7.004	5.039	2.023	1.028	0.455	0.089	0.056	0.043	0.011	0.005	17.05
2019	26.624	16.523	19.526	19.167	12.120	8.816	3.650	1.381	0.406	0.153	0.129	0.000	0.000	0.000	0.000	16.29

Canadian 3LNO spring

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Mean weight (kg) per tow
1996	0.000	1.623	4.246	4.605	2.186	0.828	0.285	0.057	0.001	0.000	0.000	0.000	0.000	0.000	0.000	1.53
1997	0.000	1.162	3.924	5.160	3.227	1.461	0.507	0.099	0.013	0.004	0.000	0.000	0.000	0.000	0.000	2.46
1998	0.000	0.233	0.843	3.891	6.215	4.963	1.239	0.326	0.072	0.008	0.003	0.000	0.000	0.000	0.000	4.56
1999	0.000	0.293	0.553	1.150	1.986	3.395	1.092	0.243	0.050	0.005	0.001	0.002	0.001	0.000	0.000	2.81
2000	0.023	0.793	1.069	1.068	1.506	1.954	2.037	0.556	0.031	0.010	0.001	0.001	0.003	0.001	0.000	3.04
2001	0.000	0.565	0.714	0.739	0.676	0.796	0.716	0.279	0.023	0.001	0.000	0.000	0.000	0.000	0.000	1.46
2002	0.000	0.642	0.572	0.603	0.581	0.608	0.208	0.049	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.72
2003	0.000	0.926	2.140	1.665	1.571	1.057	0.206	0.051	0.008	0.001	0.000	0.000	0.000	0.000	0.000	1.45
2004	0.000	0.662	0.572	1.181	1.184	1.161	0.259	0.041	0.020	0.001	0.001	0.000	0.001	0.000	0.000	1.12
2005	0.000	0.353	0.306	1.090	0.946	1.372	0.823	0.206	0.025	0.004	0.000	0.000	0.000	0.000	0.000	1.67
2007	0.000	1.595	0.516	0.802	0.399	1.405	1.491	1.121	0.183	0.022	0.002	0.001	0.000	0.000	0.000	3.03
2008	0.000	0.443	0.772	0.963	0.713	1.254	0.754	0.637	0.284	0.023	0.006	0.000	0.000	0.000	0.001	2.10
2009	0.000	0.266	0.220	0.192	0.385	0.450	0.260	0.134	0.070	0.007	0.003	0.000	0.000	0.000	0.000	0.68
2010	0.000	0.770	0.656	0.519	0.396	0.844	1.077	0.354	0.143	0.020	0.013	0.001	0.000	0.001	0.000	1.68
2011	0.000	1.960	1.397	0.921	0.645	0.618	0.289	0.157	0.096	0.013	0.003	0.001	0.000	0.000	0.000	1.05
2012	0.021	0.324	0.803	2.484	1.401	1.160	0.504	0.176	0.060	0.020	0.003	0.001	0.001	0.000	0.000	1.94
2013	0.004	1.284	0.679	0.050	0.383	0.607	0.230	0.111	0.043	0.003	0.001	0.000	0.000	0.000	0.000	0.73
2014	0.000	1.624	1.188	0.318	0.198	0.239	0.238	0.139	0.058	0.006	0.001	0.001	0.000	0.000	0.000	0.66
2016	0.084	0.419	0.555	0.373	0.463	0.295	0.204	0.080	0.052	0.013	0.008	0.000	0.000	0.000	0.000	0.66
2018	0.000	3.050	4.395	1.897	1.367	0.899	0.636	0.104	0.094	0.021	0.010	0.001	0.000	0.000	0.000	1.88
2019	0.000	4.520	2.103	1.792	1.410	0.893	0.275	0.179	0.047	0.024	0.010	0.000	0.000	0.000	0.000	1.45

Canadian 3LNO fall

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Mean weight (kg) per tow
1996	0.252	5.273	4.920	3.838	1.411	1.000	0.403	0.083	0.003	0.003	0.000	0.000	0.000	0.000	0.000	2.516
1997	0.242	1.224	3.329	4.462	3.633	1.879	0.475	0.110	0.037	0.002	0.000	0.001	0.001	0.000	0.000	2.762
1998	0.058	0.531	1.762	1.864	2.988	4.104	1.502	0.320	0.080	0.011	0.002	0.000	0.000	0.000	0.000	3.980
1999	0.221	0.037	0.617	0.732	1.040	1.970	1.674	0.385	0.037	0.007	0.005	0.002	0.001	0.000	0.000	2.822
2000	0.119	1.762	1.238	0.388	0.783	1.207	1.346	0.467	0.039	0.006	0.001	0.001	0.000	0.000	0.000	2.395
2001	0.488	1.396	0.618	0.681	1.385	0.747	1.145	0.606	0.049	0.006	0.003	0.000	0.000	0.001	0.000	2.014
2002	0.133	1.283	0.902	1.037	1.011	0.913	0.394	0.165	0.036	0.005	0.000	0.001	0.000	0.000	0.000	1.401
2003	0.174	1.786	1.071	1.546	1.871	0.909	0.278	0.047	0.016	0.002	0.002	0.000	0.000	0.000	0.000	1.588
2004	0.057	1.179	1.318	1.563	1.686	1.511	0.389	0.098	0.011	0.002	0.000	0.002	0.001	0.000	0.000	1.986
2005	0.077	0.601	0.887	0.504	1.764	1.580	1.140	0.563	0.063	0.006	0.004	0.000	0.000	0.000	0.000	2.671
2006	0.157	0.846	0.489	0.120	0.676	1.330	1.354	0.591	0.127	0.007	0.002	0.000	0.000	0.000	0.000	2.424
2007	0.095	0.830	0.466	0.271	0.806	0.608	1.237	0.745	0.213	0.024	0.013	0.001	0.002	0.000	0.000	2.376
2008	0.255	0.949	0.280	0.819	1.126	0.900	0.998	0.756	0.438	0.036	0.004	0.001	0.000	0.000	0.000	2.868
2009	0.232	2.150	0.237	0.424	0.469	0.875	0.613	0.300	0.137	0.026	0.008	0.000	0.000	0.000	0.001	1.582
2010	0.438	1.945	0.620	0.858	0.675	0.675	0.670	0.311	0.110	0.021	0.005	0.001	0.000	0.000	0.000	1.663
2011	0.326	1.301	4.134	1.201	2.019	0.932	0.666	0.320	0.056	0.016	0.005	0.002	0.001	0.002	0.000	2.206
2012	0.331	0.621	0.198	0.449	1.185	0.934	0.703	0.274	0.080	0.010	0.004	0.003	0.001	0.000	0.000	1.712
2013	0.076	2.773	1.002	0.370	0.408	1.021	1.058	0.619	0.257	0.006	0.005	0.007	0.005	0.000	0.000	2.589
2015	0.048	0.781	0.601	0.333	0.305	0.252	0.337	0.169	0.099	0.006	0.004	0.000	0.001	0.000	0.000	0.869
2016	0.981	1.303	0.438	0.564	0.502	0.630	0.383	0.207	0.093	0.031	0.008	0.000	0.002	0.000	0.000	1.314
2017	0.158	2.603	0.861	1.319	0.552	0.570	0.340	0.157	0.088	0.018	0.003	0.003	0.000	0.002	0.000	1.246
2018	0.000	3.128	1.810	1.645	0.940	1.138	0.710	0.216	0.061	0.018	0.001	0.004	0.000	0.000	0.000	1.887
2019	0.161	3.220	1.964	2.000	1.639	0.994	0.491	0.136	0.035	0.027	0.002	0.000	0.000	0.000	0.000	1.872

Table B5. continued

EU 0-700m

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Mean weight (kg) per tow
1995	0.000	12.410	2.540	2.230	1.910	2.660	5.100	3.770	2.120	1.310	0.260	0.070	0.020	0.000	0.010	13.52
1996	0.000	5.840	7.970	2.410	3.040	4.200	5.820	2.490	1.620	0.420	0.090	0.030	0.040	0.000	0.010	14.42
1997	0.000	3.330	3.780	6.000	6.500	7.110	8.460	4.990	2.150	0.660	0.220	0.030	0.020	0.020	0.020	20.01
1998	0.000	2.740	2.130	7.680	11.000	12.330	11.300	7.840	2.620	0.750	0.200	0.030	0.010	0.020	0.000	30.13
1999	0.000	1.060	0.700	3.010	10.470	13.410	12.580	5.550	1.820	0.350	0.100	0.010	0.000	0.000	0.010	26.37
2000	0.000	3.750	0.290	0.600	2.160	7.090	14.100	5.400	2.320	0.450	0.110	0.050	0.000	0.000	0.000	21.08
2001	0.000	8.030	1.430	1.810	0.990	2.790	7.790	6.630	3.210	0.180	0.040	0.010	0.000	0.000	0.000	17.25
2002	0.000	4.080	2.940	2.790	1.670	3.790	5.590	5.730	1.280	0.130	0.060	0.020	0.010	0.000	0.000	15.05
2003	0.000	2.200	1.000	0.610	1.510	2.480	2.940	1.930	0.470	0.130	0.100	0.020	0.000	0.000	0.000	7.73

EU 0-1400m

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Mean weight (kg) per tow
2004	0.000	1.397	2.189	2.924	1.535	6.803	9.156	4.949	1.462	0.727	1.111	0	0	0	0	23.33
2005	0.000	0.358	0.533	2.092	1.729	5.284	6.790	3.416	0.985	0.260	0.884	0	0	0	0	16.71
2006	0.000	0.449	0.261	0.441	0.907	5.848	8.559	4.680	1.388	0.417	0.898	0	0	0	0	19.17
2007	0.000	0.253	0.049	0.392	0.294	3.839	9.090	8.568	2.883	0.719	1.201	0	0	0	0	25.10
2008	0.000	0.131	0.065	0.098	0.163	2.026	9.000	12.529	3.177	1.143	1.903	0	0	0	0	32.35
2009	0.000	0.049	0.008	0.033	0.082	1.127	6.803	11.426	3.545	0.931	2.156	0	0	0	0	29.44
2010	0.000	0.031	0.007	0.024	0.112	1.999	6.008	7.830	2.502	0.980	1.629	0	0	0	0	22.13
2011	0.000	0.000	0.000	0.008	0.090	1.854	6.697	8.486	2.565	1.111	2.344	0	0	0	0	26.15
2012	0.000	0.000	0.007	0.038	0.163	2.421	5.777	5.002	1.919	0.751	1.780	0	0	0	0	19.20
2013	0.000	0.005	0.000	0.012	0.321	2.110	7.033	4.525	1.638	0.525	1.806	0	0	0	0	19.11
2014	0.000	0.016	0.000	0.007	0.163	2.781	8.036	6.873	1.624	0.448	1.527	0	0	0	0	23.92
2015	0.000	0.033	0.008	0.008	0.123	2.540	14.848	14.040	4.615	1.666	3.071	0	0	0	0	47.52
2016	0.000	0.172	0.016	0.008	0.008	0.580	4.876	9.237	3.937	1.470	2.205	0	0	0	0	28.30
2017	0.000	0.756	0.033	0.023	0.297	4.193	11.500	12.689	4.821	2.112	3.412	0	0	0	0	42.67
2018	0.000	0.301	0.189	0.212	0.124	2.132	5.989	7.168	3.093	1.579	4.301	0	0	0	0	29.80
2019	0.000	0.374	0.234	0.196	0.619	3.053	4.417	3.434	1.316	0.902	1.927	0	0	0	0	16.89

EU 3NO

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Mean weight (kg) per tow
1997	0.000	9.922	5.523	3.489	3.806	2.242	1.966	1.223	0.601	0.073	0.051	0.049	0.017	0.008	0.029	7.73
1998	0.000	1.711	5.242	9.085	8.468	5.058	2.768	1.097	0.660	0.208	0.084	0.034	0.032	0.019	0.030	11.73
1999	0.151	4.380	4.805	7.207	9.307	6.286	2.923	0.775	0.490	0.232	0.087	0.030	0.046	0.030	0.051	12.00
2000	0.000	2.917	0.489	0.800	1.389	3.843	4.423	2.562	0.706	0.284	0.078	0.058	0.036	0.045	0.122	9.48
2001	0.000	8.869	5.901	1.183	1.070	2.838	3.959	1.559	0.220	0.059	0.046	0.040	0.050	0.049	0.063	8.17
2002	0.000	2.911	0.641	1.023	0.695	1.139	0.922	0.440	0.227	0.016	0.011	0.019	0.019	0.006	0.021	2.64
2003	0.000	3.564	2.399	1.685	1.910	1.578	0.903	0.776	0.264	0.061	0.036	0.013	0.069	0.008	0.023	5.10
2004	0.000	1.218	6.957	2.086	2.060	1.238	0.849	0.514	0.210	0.047	0.026	0.011	0.025	0.019	0.024	3.68
2005	0.000	1.069	0.968	1.810	1.038	1.319	1.441	0.681	0.189	0.076	0.058	0.025	0.032	0.023	0.023	3.39
2006	0.000	2.307	1.118	0.408	1.553	1.383	0.815	0.520	0.225	0.049	0.025	0.017	0.019	0.005	0.012	3.03
2007	0.000	1.813	0.645	0.509	0.324	1.481	1.397	1.021	0.286	0.100	0.091	0.034	0.029	0.000	0.017	3.98
2008	0.000	0.620	0.986	0.899	0.693	0.935	2.702	2.503	0.736	0.402	0.153	0.099	0.033	0.024	0.041	7.66
2009	0.000	0.700	3.216	2.212	2.614	2.725	4.940	5.667	0.847	0.354	0.190	0.138	0.029	0.022	0.121	14.78
2010	0.000	0.374	2.207	0.935	0.729	3.419	5.582	5.159	1.235	0.390	0.260	0.239	0.043	0.024	0.051	14.80
2011	0.000	2.199	1.303	0.482	0.617	0.947	2.009	2.121	0.433	0.225	0.239	0.052	0.057	0.019	0.098	7.09
2012	0.000	0.084	1.800	1.343	0.443	1.091	1.707	2.003	0.535	0.401	0.336	0.108	0.054	0.056	0.118	7.37
2013	0.000	0.273	0.453	0.229	0.806	1.175	1.477	1.215	0.331	0.206	0.243	0.134	0.088	0.028	0.087	5.46
2014	0.000	0.513	1.284	0.257	0.145	0.544	1.652	1.745	0.452	0.208	0.230	0.183	0.107	0.051	0.101	6.24
2015	0.000	0.934	0.615	0.202	0.212	0.473	1.811	3.382	0.940	0.435	0.345	0.192	0.096	0.026	0.119	9.49
2016	0.000	1.082	0.542	0.344	0.454	0.508	1.857	2.547	0.895	0.224	0.282	0.122	0.173	0.084	0.144	8.80
2017	0.000	3.373	1.664	0.880	1.097	2.377	4.380	4.618	1.678	0.510	0.385	0.229	0.219	0.109	0.103	16.63
2018	0.000	2.353	2.001	0.973	0.804	1.635	1.883	1.609	0.939	0.292	0.221	0.135	0.044	0.042	0.060	7.88
2019	0.000	3.337	4.200	4.099	2.773	2.619	1.983	1.255	0.642	0.239	0.518	0.142	0.075	0.023	0.034	8.82