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Updated SCAA Base Case Assessment and sensitivities 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 2021 into account. Results are reported for a Base Case corresponding to that considered in 2017, and some sensitivities. 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. New data and recent resource trends are consistent with predictions made in 2017 when a revised management procedure for Greenland halibut was adopted.

NOTE: When investigating the causes for the differences in biomass levels between the 2023 Base Case and survey sensitivity 1 (adding the EU 3L survey), a better minimum in the negative log-likelihood was found. The results have been corrected here, with the changes to the previous version being yellow highlighted. A consequential revision to the MP performance companion paper will follow shortly.

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 and 2021 that are now available, and applies unchanged methodology. Results for one sensitivity that was retained in 2017 as a robustness Operating Model (OM), as well as for two sensitivities on the selection of survey series to include in the model fitting, are presented (see below for details).

The assessments results reported include comparisons to those obtained in 2017.

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**": as for 2017 Base Case
b) "**σ_R=0.6**": Larger recruitment variability: standard deviation of log recruitment =0.6,
c) "**Survey sens1**": Adding the EU 3L survey to the five surveys used in the Base Case, and
d) "**Survey sens2**": Replacing the EU 3NO by the EU 3LNO survey.

Results

2017 vs 2023 Base Cases

Table 1 provides the results, with Hessian-based CVs, for the 2023 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 2023 and the corresponding 2017 Base Case.

Figure 2 shows estimated survey and commercial selectivities for the 2023 Base 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 data available 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.

2023 Base Case vs sensitivities

Figure 6 compares results for the 2023 Base Case with the sensitivity increasing the recruitment variability.

Figure 7 compares biomass, N0 (recruitment) and fishing mortality trajectories for the 2023 Base Case and the two sensitivities regarding the choice of surveys included. Figure 8 shows the corresponding fits to the survey indices and catch-at-age data.

Figure 9 shows retrospective analyses for the 2023 Base Case.

Discussion

Some notable features of the results are as follows:

2017 vs 2023 Base Cases

- 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 recent average strength.
- The fits to abundance indices and catch-at-age data continue to be reasonable.
- New data and recent resource trends are consistent with predictions made in 2017 when a revised management procedure for Greenland halibut was adopted.

2023 Base Case vs sensitivities

- No notable difference between the Base Case and the sensitivity with larger sigma R.
- No notable difference between the Base Case and survey sensitivity 1 (including EU 3L survey).
- No notable difference between the Base Case and survey sensitivity 2 (replacing EU 3NO by EU 3LNO).
- Little by way of changes from the retrospective analyses, except for a scale change prior to 2018.

Table 1. Results from fits of the SCAA 2017 Base Case OM, and 2023 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.

	2017 Base Case		2023 Base Case		2023: "σ_R=0.6"		2023: "survey sens1"		2023: "survey sens2"	
'-lnL:overall	-460.60		-535.05		-510.61		-583.75		-524.87	
	-lnL: index	-lnL: CAA	-lnL: index	-lnL: CAA	-lnL: index	-lnL: CAA	-lnL: index	-lnL: CAA	-lnL: index	-lnL: CAA
Can. Fall 2J3K	-1.73	-63.04	-3.00	-79.74	-4.10	-79.76	-1.31	-79.75	-1.68	-79.46
EU 3M 0-700m	0.77	-33.95	1.14	-34.38	1.28	-34.70	0.99	-34.37	0.76	-34.21
EU 3M 0-1400m	-1.78	-38.61	3.76	-55.94	3.51	-56.31	3.80	-55.21	3.88	-55.60
Can. Spring 3LNO	13.44	-49.69	14.78	-53.47	14.87	-53.44	14.83	-53.64	14.65	-53.63
EU 3L	-	-	0.00	0.00	0.00	0.00	-0.18	-49.63	0.00	0.00
EU 3NO	9.06	-61.99	12.93	-77.92	12.99	-77.96	12.36	-77.67	0.00	0.00
Can. Fall 3LNO	1.21	-59.65	1.19	-70.51	1.68	-70.62	1.17	-70.60	0.59	-70.67
EU 3LNO	-	-	0.00	0.00	0.00	0.00	0.00	0.00	2.51	-57.03
Commercial		-105.16		-119.33		-119.68		-119.79		-119.17
'-lnL:RecRes	7.13		8.12		34.34		7.32		7.40	
-lnL:CatchPen	-76.63		-82.70		-82.71		-82.06		-83.21	
h	**0.80**		**0.80**		**0.80**		**0.80**		**0.80**	
M	**0.12**		**0.12**		**0.12**		**0.12**		**0.12**	
f	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
K^{sp}	753	(0.08)	797	(0.10)	797	(0.10)	726	(0.07)	719	(0.07)
$B^{sp}{}_{1975}$	526	(0.36)	545	(0.18)	545	(0.18)	492	(0.14)	485	(0.14)
$B^{sp}{}_{2016}$	104	(0.37)	85	(0.19)	85	(0.19)	65	(0.30)	74	(0.21)
$B^{sp}{}_{2021}$	-		91	(0.19)	91	(0.19)	77	(0.28)	84	(0.20)
$B^{sp}{}_{2016}/K^{sp}$	0.14	(0.36)	0.11	(0.22)	0.11	(0.22)	0.09	(0.31)	0.10	(0.22)
$B^{sp}{}_{2021}/K^{sp}$	-		0.11	(0.21)	0.11	(0.21)	0.11	(0.29)	0.12	(0.21)
$B^{sp}{}_{2016}/B^{sp}{}_{1975}$	0.20	(0.47)	0.16	(0.26)	0.16	(0.26)	0.13	(0.33)	0.15	(0.25)
$B^{sp}{}_{2021}/B^{sp}{}_{1975}$	-		0.17	(0.26)	0.17	(0.26)	0.16	(0.31)	0.17	(0.24)
$B^{5\text{-}9}{}_{1975}$	159	(0.18)	153	(0.24)	153	(0.24)	157	(0.18)	155	(0.18)
$B^{5\text{-}9}{}_{2016}$	92	(0.16)	86	(0.09)	86	(0.09)	82	(0.11)	84	(0.09)
B5-92021/B5-91975	-		62	(0.13)	62	(0.13)	65	(0.14)	66	(0.13)
$B^{5\text{-}9}{}_{2016}/B^{5\text{-}9}{}_{1975}$	0.58	(0.22)	0.56	(0.26)	0.56	(0.26)	0.52	(0.20)	0.54	(0.19)
$B^{5\text{-}9}{}_{2021}/B^{5\text{-}9}{}_{1975}$	-		0.40	(0.27)	0.40	(0.27)	0.41	(0.22)	0.42	(0.21)
	σ index	σ CAA	σ index	σ CAA	σ index	σ CAA	σ index	σ CAA	σ index	σ CAA
Can. Fall 2J3K	0.22	0.06	0.21	0.06	0.21	0.06	0.23	0.06	0.23	0.06
EU 3M 0-700m	0.26	0.06	0.27	0.05	0.28	0.05	0.27	0.05	0.26	0.05
EU 3M 0-1400m	0.21	0.05	0.30	0.05	0.29	0.05	0.30	0.05	0.30	0.05
Can. Spring 3LNO	0.49	0.09	0.49	0.09	0.49	0.09	0.49	0.09	0.49	0.09
EU 3L	-	-	1.08	0.13	1.08	0.13	0.24	0.09	1.08	0.13
EU 3NO	0.38	0.10	0.41	0.09	0.42	0.09	0.40	0.09	1.07	0.15
Can. Fall 3LNO	0.26	0.09	0.25	0.09	0.26	0.09	0.25	0.09	0.25	0.09
EU 3LNO	-	-	0.25	0.11	1.08	0.11	1.07	0.11	0.28	0.08
Commercial		0.07		0.07		0.07		0.07		0.07

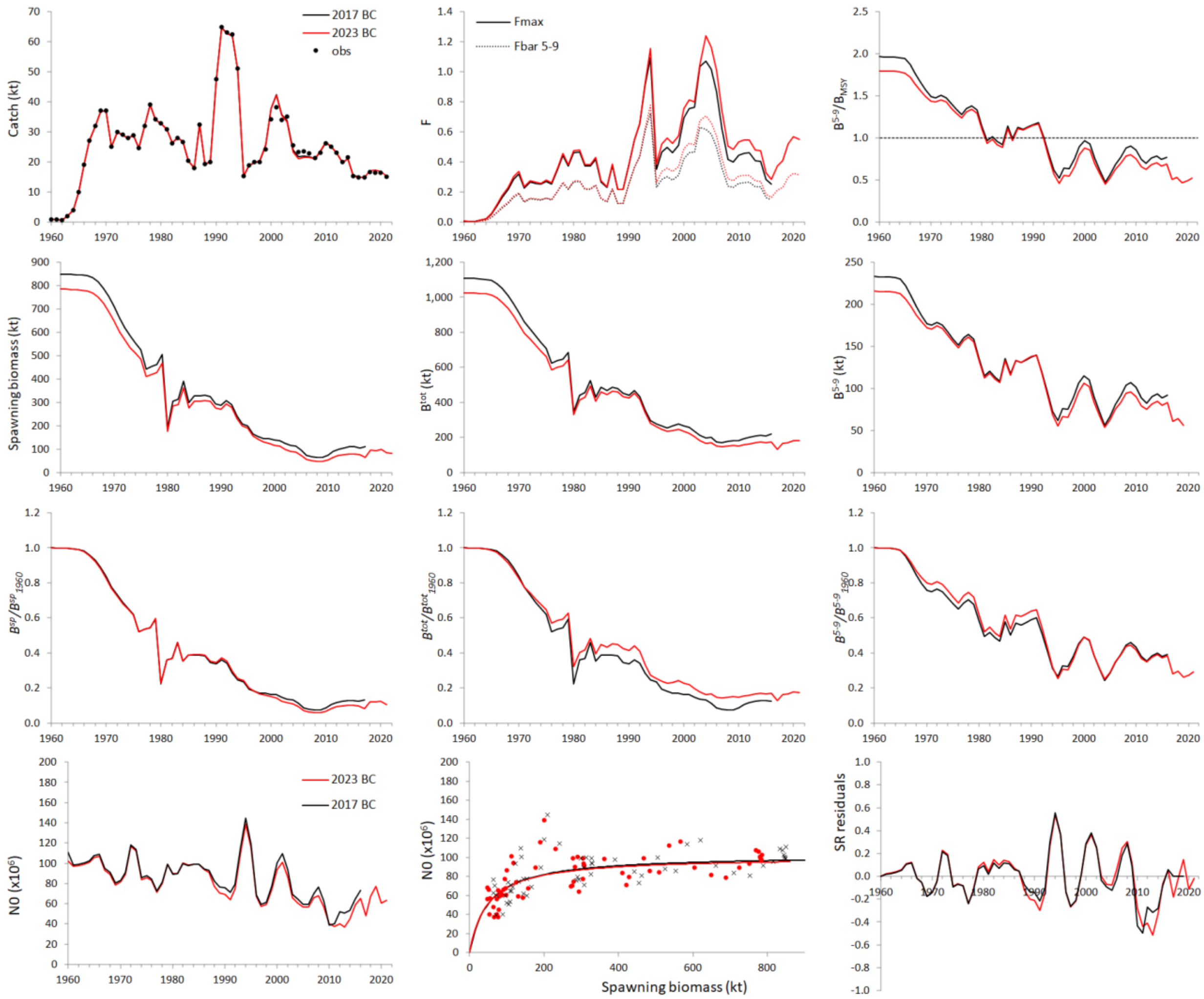

Figure 1. Results for SCAA 2017 (in black) and 2023 (in red) Base Cases. The spawning stock-recruitment plot shows the Beverton-Holt curves estimated. Fmax is the maximum fishing mortality across ages for the year concerned , and Fbar5-9 is the average fishing mortality on fish aged 5 to 9.

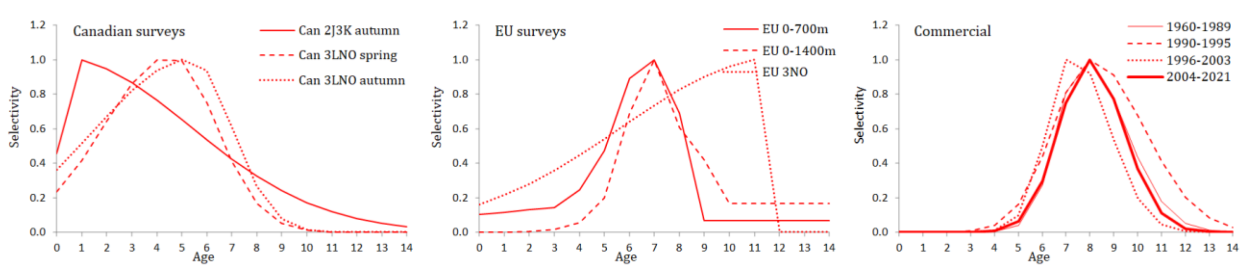

Figure 2. Estimated selectivities for the 2023 Base Case.

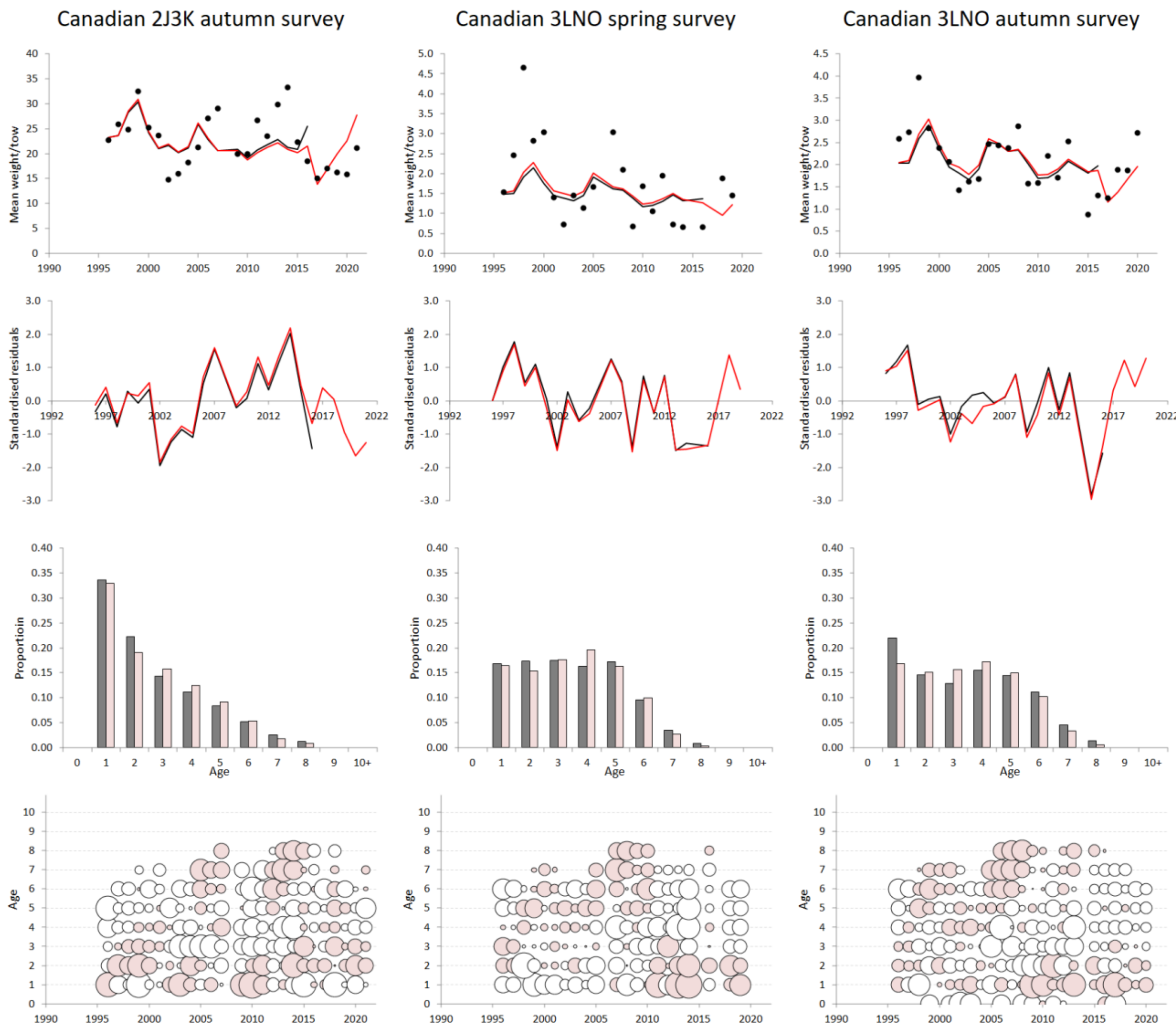

Figure 3a. Fits (and residuals) to the Canadian survey data for the 2017 (in black) and 2023 (in red) Base Cases. The fits and residuals of the CAA data are shown only for the 2023 Base Case. The sizes of the bubbles are proportional to the sizes of the residuals. Positive residuals are shown in pink, while negative residuals are shown in white.

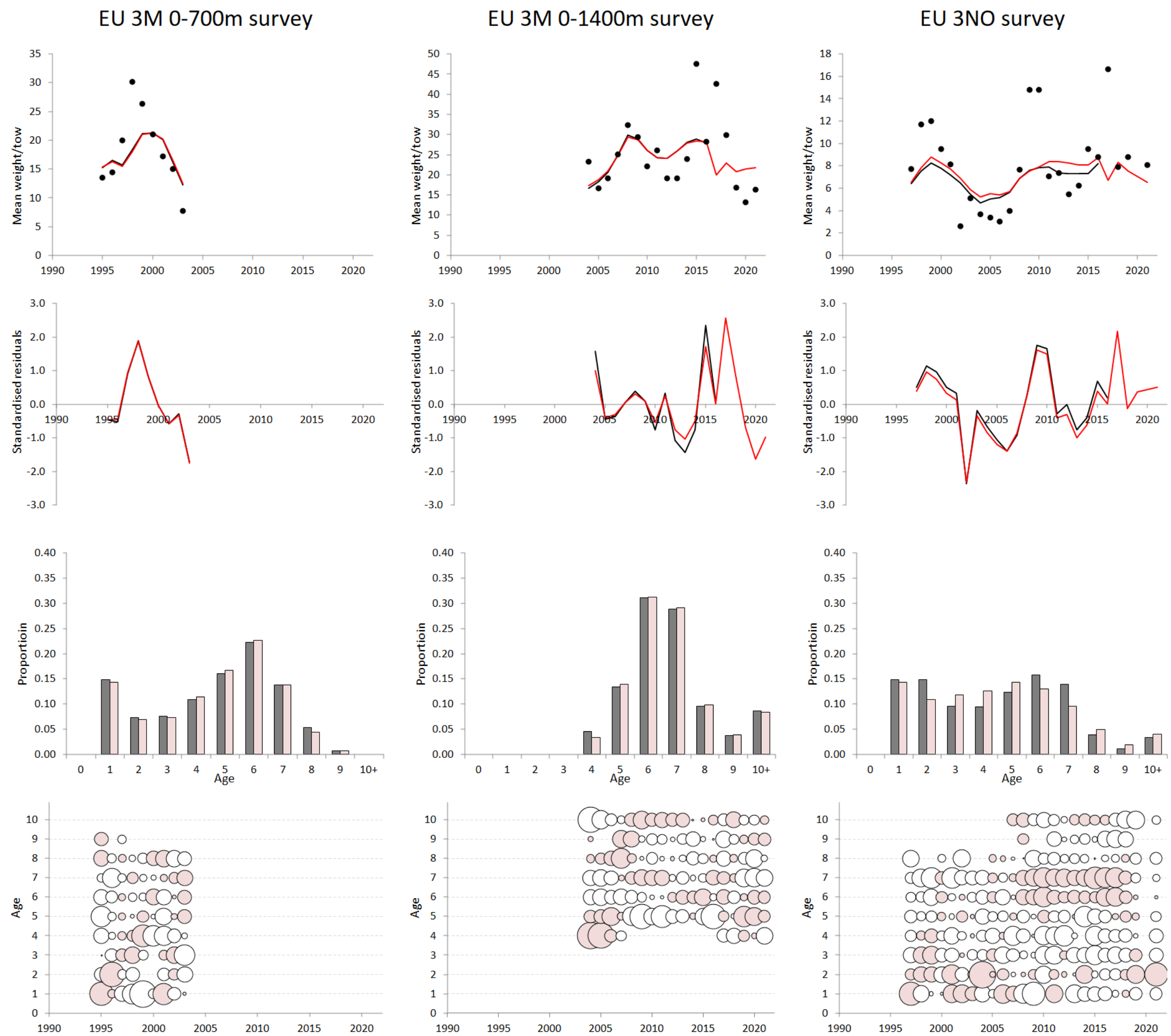

Figure 3b. Fits (and residuals) to the EU survey data for the 2017 (in black) and 2023 (in red) Base Cases. The fits and residuals of the CAA data are shown only for the 2023 Base Case. The sizes of the bubbles are proportional to the sizes of the residuals. Positive residuals are shown in pink, while negative residuals are shown in white.

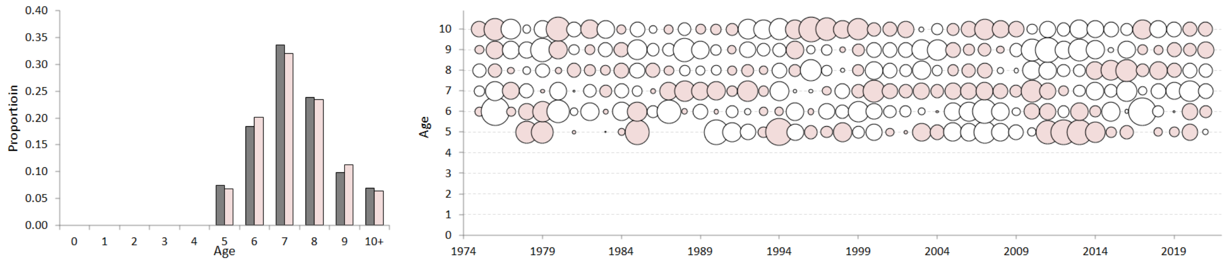

Figure 4. Fits (and residuals) to the commercial CAA data for the 2023 Base Case. The sizes of the bubbles are proportional to the sizes of the residuals. Positive residuals are shown in pink, while negative residuals are shown in white.

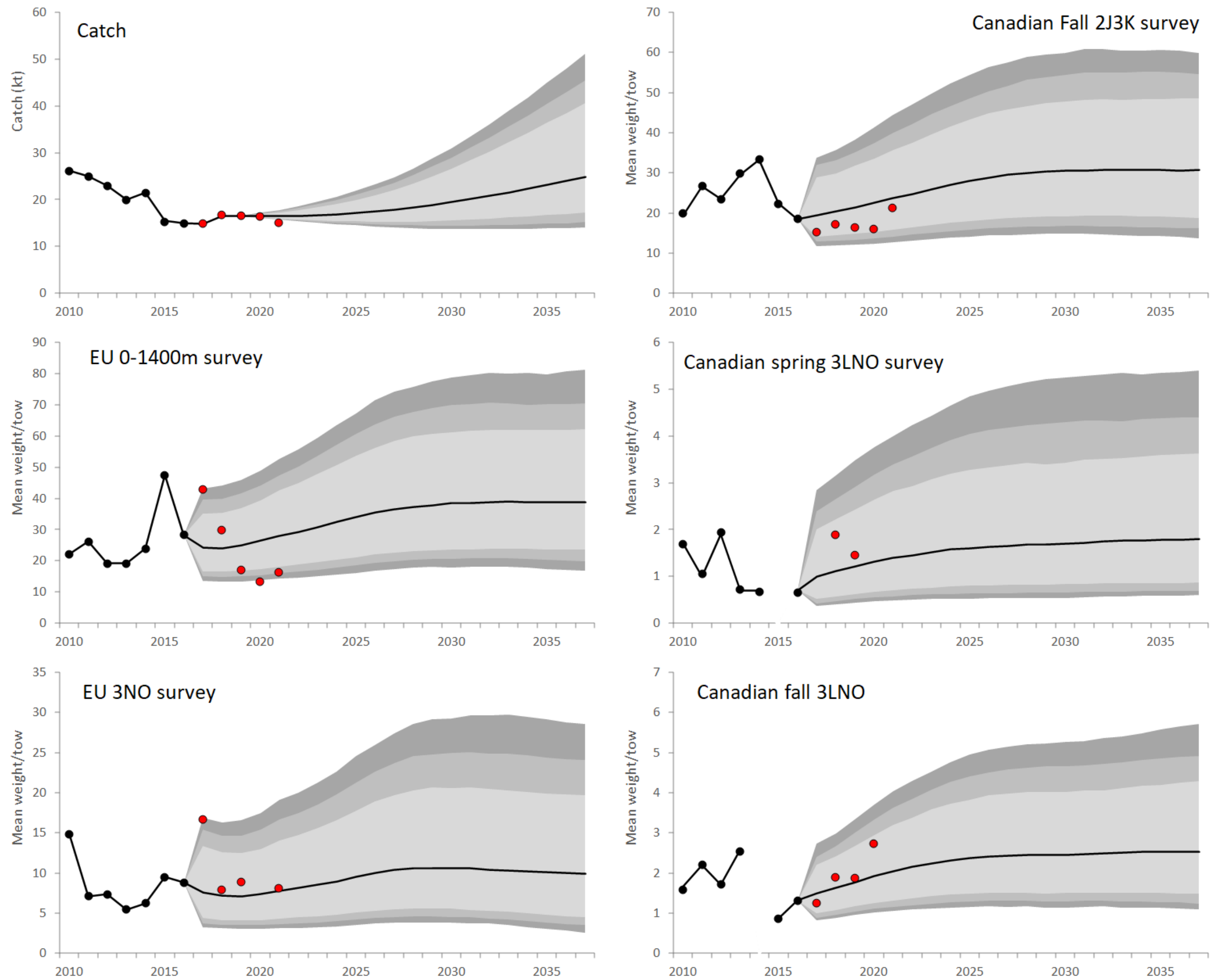

Figure 5. Projection envelopes (95, 90 and 80 percentiles) and medians under the MP adopted in 2017 for the then Base Case OM. Catches and abundance index values observed from 2017 onwards are shown in red; for these, the envelopes take account not only of the uncertainty in future dynamics of the resource (such as variability about the stock-recruitment relationship) but also future observation errors. The probability envelopes have been computed using a 9-point averaging approach from 500 replicates.

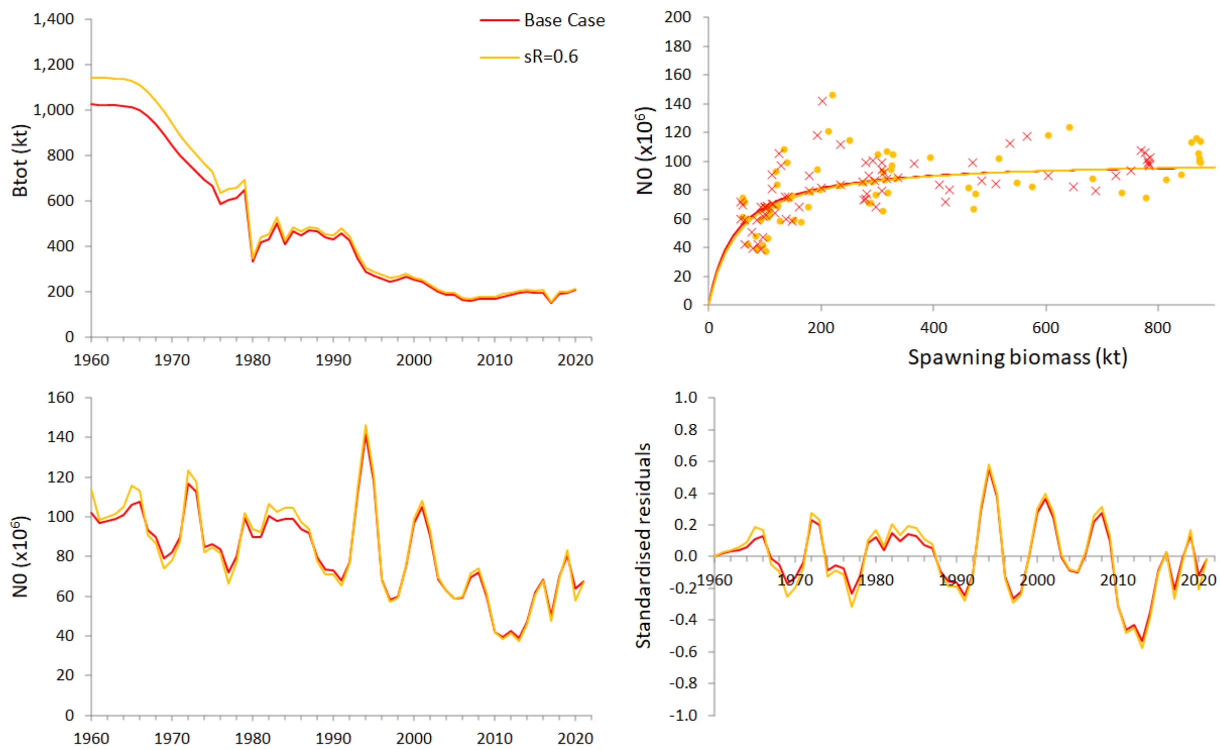

Figure 6. Results for 2023 (in red) Base Case and sensitivity "σ_R=0.6" (in orange). The spawning stock-recruitment plot shows the Beverton-Holt curves estimated.

Figure 7. Results for 2023 Base Case (red), Survey Sens1 (blue) and Survey Sens2 (green).

Figure 8. Fits (and residuals) to the EU 3NO, 3L and 3LNO survey data for the 2023 Base Case and survey sensitivities 1 and 2. The sizes of the bubbles are proportional to the sizes of the residuals. Positive residuals are shown in colour, while negative residuals are shown in white.

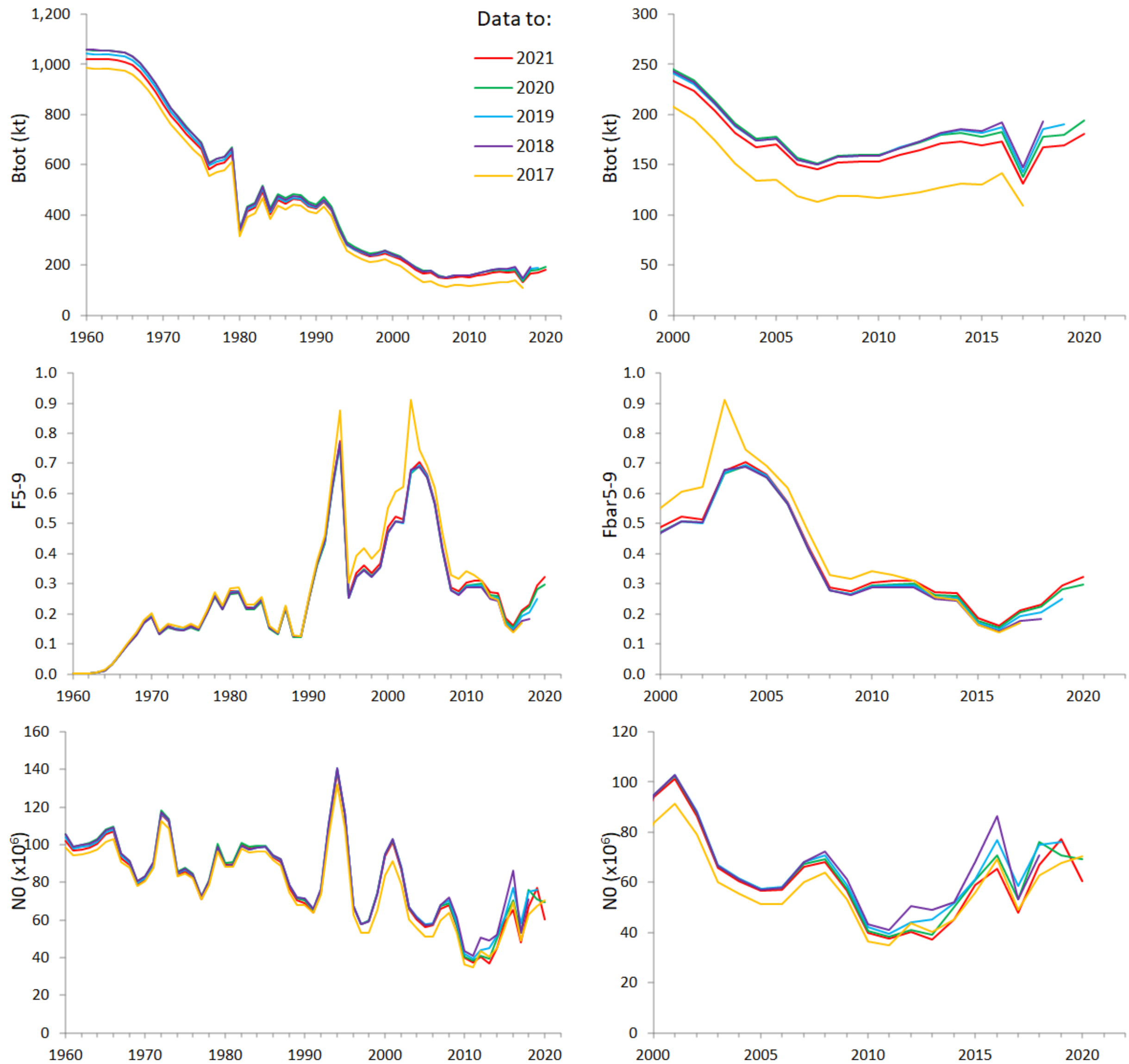

Figure 9. Results of a retrospective analysis for the 2023 Base Case.

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 run.

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).

$Z_{y,a} = F_y S_{y,a} + M_a$ 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:

$$\alpha = \frac{4hR_0}{5h-1} \tag{A.6}$$

and

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

where

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

For baseline run, h is fixed to 0.6 and σ_R=0.4.

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

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

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

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:

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

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:

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

where R_o is the recruitment expected at carrying capacity

and

$$pen^{\vartheta} = \frac{\vartheta^2}{2\sigma_\vartheta^2} \tag{A.12}$$

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:

$I_y^i = \hat{I}_y^i e^{\varepsilon_y^i}$ or $\varepsilon_y^i = ln(I_y^i) - ln(\hat{I}_y^i)$ (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 $N\left(0, (\sigma_y^i)^2\right)$.

The model estimate of survey biomass index is computed as:

$B_y^i = \sum_{a=0}^{m} w_{y,a}^i S_a^i N_{y,a} e^{-Z_{y,a} T^i/12}$ (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:

$-lnL^{\text{survey}} = \sum_i \sum_y \left\{ ln\left(\sqrt{(\sigma_y^i)^2 + (\sigma_{Add}^i)^2}\right) + \frac{(\varepsilon_y^i)^2}{2\left((\sigma_y^i)^2 + (\sigma_{Add}^i)^2\right)} \right\}$ (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 directly in the fitting procedure by its maximum likelihood value (with a minimum estimate of 0.15 imposed to prevent overweighting through overfitting).

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

$lnq^i = \frac{1}{n^i} \sum_y (lnI_y^i - lnB_y^i)$ (A.16)

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:

$-lnL^{CAA} = w^{CAA} \sum_y \sum_a \left[ln(\sigma^{com}) + \left(\sqrt{lnp_{y,a}} - \sqrt{ln\hat{p}_{y,a}}\right)^2 / 2(\sigma_a^{com})^2 \right]$ (A.17)

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

$$\hat{C}_{y,a} = N_{y,a} S_{y,a} F_y \left(1 - e^{-Z_{y,a}}\right)/Z_{y,a} \quad \text{(A.18)}$$

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

$$\hat{\sigma}_a^{com} = \sqrt{\sum_y \left(\sqrt{lnp_{y,a}} - \sqrt{ln\hat{p}_{y,a}}\right)^2 / \sum_y 1} \quad \text{(A.19)}$$

The w^{CAA} weighting factor in equation A.17 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.17), 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.17)) 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:

$$\hat{p}_{y,a}^i = S_a^i N_{y,a} e^{-Z_{y,a} T^i/12} / \sum_{a'} S_{a'}^i N_{y,a'} e^{-Z_{y,a'} T^i/12} \quad \text{(A.20)}$$

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:

$$-lnL^{pen} = \sum_{y=y_1}^{y_2} \left(\varphi_y^2 / 2\sigma_R^2\right) \quad \text{(A.21)}$$

where
φ_y from $N(0, \sigma_R^2)$,
σ_R is the standard deviation of the log-residuals, which is input.

For the baseline run, σ_R=0.4

B.2.7. Catches

$$-lnL^{Catch} = \sum_y \frac{lnC_y - ln\hat{C}_y}{2\sigma_C^2} \quad \text{(A.22)}$$

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

A.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:

$$S_a = \begin{cases} exp\left(-\frac{(a-a_{max})^2}{2\sigma_{left}^2}\right) & \text{for } a \le a_{max} \\ exp\left(-\frac{(a-a_{max})^2}{2\sigma_{right}^2}\right) & \text{for } a > a_{max} \end{cases} \qquad \text{(A.23)}$$

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:

$$S_a = \begin{cases} S_{a+1}\frac{S_{a_1}}{S_{a_1+1}} & a < a_1 \\ \text{estimated freely} & a_1 \le a \le a_2 \\ S_{a_2} & a > a_2 \end{cases} \qquad \text{(A.24)}$$

The double normal selectivity is used for the three Canadian surveys (Can. Autumn 2J3K, Can. Spring 3LNO and Can. Autumn 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. Autumn 2J3K	1	8	9
EU 3M 0-700m	1	9	7
EU 3M 0-1400m	4	10	7
Can. Spring 3LNO	1	8	5
EU 3L	1	10	8
EU 3NO	1	10	6
Can. Autumn 3LNO	0	8	11
EU 3LNO	1	10	6
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)	Year	Landings (t)
1960	900	1980	32867	2000	34177
1961	700	1981	30754	2001	38232
1962	600	1982	26278	2002	34062
1963	2000	1983	27861	2003	35151
1964	4000	1984	26711	2004	25486
1965	10000	1985	20347	2005	23255
1966	19000	1986	17976	2006	23531
1967	27000	1987	32442	2007	22747
1968	32000	1988	19215	2008	21180
1969	37000	1989	20034	2009	23156
1970	37000	1990	47454	2010	26174
1971	25000	1991	65008	2011	24960
1972	30000	1992	63193	2012	22978
1973	29000	1993	62455	2013	19976
1974	28000	1994	51029	2014	21433
1975	28814	1995	15272	2015	15273
1976	24611	1996	18840	2016	14875
1977	32048	1997	19858	2017	14760
1978	39070	1998	19946	2018	16630
1979	34104	1999	24226	2019	16481
				2020	16307
				2021	15039

Table B2. Commercial catch at age matrix (000s) for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO.

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
2020	0	0	1	20	283	1276	3286	2391	2913	2059	1251
2021	0	0	7	39	211	819	3749	3692	2527	2204	983

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.

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	2.854
1976	0	0	0	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.509
1977	0	0	0	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.703
1978	0	0	0	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.909
1979	0	0	0	0.126	0.244	0.609	0.760	0.955	1.190	1.580	3.438
1980	0	0	0	0.126	0.244	0.514	0.659	0.869	1.050	1.150	1.399
1981	0	0	0	0.126	0.244	0.392	0.598	0.789	0.985	1.240	2.400
1982	0	0	0	0.126	0.244	0.525	0.684	0.891	1.130	1.400	2.582
1983	0	0	0	0.126	0.244	0.412	0.629	0.861	1.180	1.650	3.375
1984	0	0	0	0.126	0.244	0.377	0.583	0.826	1.100	1.460	2.751
1985	0	0	0	0.126	0.244	0.568	0.749	0.941	1.240	1.690	3.190
1986	0	0	0	0.126	0.244	0.350	0.584	0.811	1.100	1.580	3.315
1987	0	0	0	0.126	0.244	0.364	0.589	0.836	1.160	1.590	3.444
1988	0	0	0	0.126	0.244	0.363	0.569	0.805	1.163	1.661	3.491
1989	0	0	0	0.126	0.244	0.400	0.561	0.767	1.082	1.657	3.095
1990	0	0	0	0.090	0.181	0.338	0.546	0.766	1.119	1.608	3.010
1991	0	0	0	0.126	0.244	0.383	0.592	0.831	1.228	1.811	3.383
1992	0	0	0	0.175	0.289	0.430	0.577	0.793	1.234	1.816	3.458
1993	0	0	0	0.134	0.232	0.368	0.547	0.809	1.207	1.728	3.231
1994	0	0	0	0.080	0.196	0.330	0.514	0.788	1.179	1.701	3.289
1995	0	0	0	0.080	0.288	0.363	0.531	0.808	1.202	1.759	3.746
1996	0	0	0	0.161	0.242	0.360	0.541	0.832	1.272	1.801	3.409
1997	0	0	0	0.120	0.206	0.336	0.489	0.771	1.159	1.727	3.300
1998	0	0	0	0.119	0.228	0.373	0.543	0.810	1.203	1.754	3.166
1999	0	0	0	0.176	0.253	0.358	0.533	0.825	1.253	1.675	3.195
2000	0	0	0	0	0.254	0.346	0.524	0.787	1.192	1.774	3.125
2001	0	0	0	0	0.249	0.376	0.57	0.83	1.168	1.794	3.177
2002	0	0	0	0.217	0.251	0.369	0.557	0.841	1.193	1.760	2.996
2003	0	0	0	0.188	0.247	0.389	0.564	0.822	1.199	1.651	2.865
2004	0	0	0	0.180	0.249	0.376	0.535	0.808	1.196	1.629	2.907
2005	0	0	0	0.252	0.301	0.396	0.564	0.849	1.247	1.691	2.779
2006	0	0	0	0.129	0.267	0.405	0.605	0.815	1.092	1.495	2.358
2007	0	0	0	0	0.276	0.389	0.581	0.833	1.137	1.500	2.409
2008	0	0	0	0	0.278	0.404	0.617	0.891	1.195	1.605	2.443
2009	0	0	0	0	0.279	0.390	0.599	0.862	1.158	1.611	2.432
2010	0	0	0	0	0.250	0.350	0.570	0.840	1.210	1.650	2.454
2011	0	0	0	0.130	0.210	0.310	0.530	0.850	1.250	1.750	2.627
2012	0	0	0	0.170	0.240	0.300	0.570	0.890	1.280	1.750	2.730
2013	0	0	0	0.140	0.270	0.420	0.630	0.870	1.250	1.830	2.871
2014	0	0	0	0.150	0.240	0.400	0.620	0.890	1.310	1.920	2.955
2015	0	0	0	0.160	0.240	0.410	0.630	0.890	1.220	1.760	2.932
2016	0	0	0	0.219	0.313	0.472	0.669	0.903	1.277	1.821	2.714
2017	0	0.000	0.000	0.000	0.255	0.314	0.517	0.715	1.085	1.366	2.033
2018	0	0	0	0.000	0.301	0.421	0.621	0.876	1.254	1.788	2.752
2019	0	0	0	0.191	0.279	0.414	0.597	0.847	1.191	1.733	2.647
2020	0	0	0.076	0.241	0.275	0.409	0.634	0.866	1.225	1.8	2.901
2021	0	0.088	0.122	0.245	0.32	0.415	0.603	0.851	1.183	1.638	2.636

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 autumn

Year	0	1	2	3	4	5	6	7	8	9	10+	Mean weight (kg) per tow
1996	5.181	103.829	49.985	33.643	10.276	6.603	2.551	0.884	0.202	0.189	0.103	22.66
1997	2.301	29.551	63.090	43.886	21.838	10.670	5.129	2.106	0.675	0.214	0.128	25.89
1998	1.595	25.328	26.234	32.196	22.227	11.112	4.679	2.179	0.596	0.139	0.131	24.82
1999	6.464	15.987	34.422	24.070	28.281	20.042	10.526	3.811	0.703	0.139	0.126	32.48
2000	3.302	38.105	23.180	16.827	13.731	14.540	7.715	2.276	0.531	0.068	0.058	25.17
2001	8.939	46.301	23.339	17.417	14.534	10.326	7.909	3.588	0.727	0.118	0.057	23.67
2002	8.753	42.849	25.482	13.094	9.952	6.311	2.074	0.759	0.200	0.042	0.021	14.78
2003	10.441	47.565	27.904	12.144	9.920	6.627	2.431	0.942	0.283	0.042	0.037	15.95
2004	4.386	33.772	34.542	14.245	13.010	9.406	2.807	1.262	0.378	0.087	0.054	18.17
2005	5.314	16.566	17.086	8.747	14.362	11.410	7.221	4.162	0.698	0.122	0.088	21.24
2006	3.955	33.803	18.904	8.975	18.437	13.671	9.516	4.446	1.214	0.190	0.068	27.02
2007	2.209	32.607	14.510	12.814	18.773	9.573	10.350	6.171	2.140	0.338	0.155	29.12
2009	5.524	50.910	19.258	11.468	8.466	9.961	5.401	3.613	1.401	0.251	0.127	19.99
2010	20.276	47.165	36.268	14.716	9.613	6.876	3.961	2.313	1.074	0.185	0.148	19.92
2011	4.810	43.752	41.888	20.973	18.790	10.318	5.499	3.153	1.257	0.326	0.221	26.74
2012	5.155	12.280	9.609	11.273	11.863	10.957	9.028	4.305	1.692	0.287	0.220	23.50
2013	2.806	23.470	12.194	6.985	6.972	10.983	9.140	7.980	3.966	0.515	0.239	29.79
2014	3.096	22.084	30.408	11.391	4.540	7.956	7.378	8.920	6.621	0.969	0.298	33.34
2015	0.498	17.172	13.979	15.139	7.766	6.815	4.183	3.910	3.918	0.649	0.240	22.29
2016	10.579	29.651	19.467	10.808	8.154	4.826	4.888	3.015	2.092	0.509	0.214	18.54
2017	6.432	30.571	22.750	10.197	8.764	5.719	2.628	1.258	0.962	0.361	0.200	15.10
2018	1.701	14.176	17.045	17.214	8.618	7.004	5.039	2.023	1.028	0.455	0.204	17.05
2019	26.624	16.523	19.526	19.167	12.119	8.817	3.650	1.381	0.406	0.153	0.129	16.28
2020	3.572	24.362	25.318	13.547	8.286	6.244	4.288	1.256	0.620	0.348	0.277	15.84
2021	10.953	23.696	29.206	18.985	7.818	4.810	5.774	3.292	0.883	0.347	0.220	21.15

Canadian 3LNO spring

Year	0	1	2	3	4	5	6	7	8	9	10	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	1.53
1997	0.000	1.163	3.924	5.160	3.227	1.461	0.507	0.099	0.013	0.004	0.000	2.46
1998	0.000	0.237	0.859	3.966	6.334	5.057	1.263	0.332	0.074	0.008	0.003	4.65
1999	0.000	0.302	0.564	1.187	2.034	3.433	1.083	0.243	0.053	0.005	0.004	2.83
2000	0.023	0.793	1.069	1.068	1.506	1.954	2.037	0.556	0.031	0.010	0.006	3.04
2001	0.000	0.575	0.716	0.748	0.677	0.790	0.693	0.242	0.018	0.001	0.000	1.40
2002	0.000	0.648	0.577	0.609	0.587	0.614	0.210	0.049	0.006	0.002	0.001	0.72
2003	0.000	0.931	2.151	1.685	1.581	1.055	0.205	0.049	0.007	0.001	0.000	1.46
2004	0.000	0.676	0.585	1.206	1.209	1.185	0.264	0.042	0.020	0.001	0.002	1.15
2005	0.000	0.353	0.306	1.090	0.946	1.372	0.823	0.206	0.025	0.004	0.000	1.67
2007	0.000	1.595	0.516	0.802	0.399	1.405	1.492	1.121	0.183	0.022	0.003	3.03
2008	0.000	0.443	0.773	0.963	0.713	1.254	0.754	0.637	0.284	0.023	0.008	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	0.68
2010	0.000	0.770	0.656	0.519	0.396	0.844	1.077	0.354	0.143	0.020	0.016	1.68
2011	0.000	1.976	1.411	0.930	0.651	0.624	0.291	0.159	0.097	0.014	0.004	1.06
2012	0.021	0.324	0.803	2.484	1.401	1.160	0.504	0.176	0.060	0.020	0.005	1.94
2013	0.004	1.284	0.679	0.050	0.383	0.607	0.230	0.111	0.044	0.003	0.001	0.73
2014	0.000	1.624	1.188	0.318	0.198	0.240	0.238	0.139	0.058	0.007	0.003	0.66
2016	0.084	0.419	0.555	0.373	0.463	0.295	0.204	0.080	0.052	0.013	0.009	0.66
2018	0.000	3.050	4.395	1.898	1.367	0.899	0.636	0.104	0.094	0.021	0.010	1.88
2019	0.000	4.519	2.103	1.792	1.410	0.894	0.275	0.179	0.047	0.024	0.010	1.45

Canadian 3LNO autumn

Year	0	1	2	3	4	5	6	7	8	9	10	Mean weight (kg) per tow
1996	0.263	5.412	5.066	3.938	1.455	1.042	0.413	0.083	0.004	0.003	0.000	2.58
1997	0.251	1.267	3.446	4.527	3.611	1.725	0.488	0.104	0.039	0.003	0.003	2.73
1998	0.060	0.555	1.811	1.874	2.942	4.071	1.491	0.313	0.083	0.012	0.002	3.97
1999	0.222	0.037	0.617	0.732	1.040	1.970	1.674	0.385	0.037	0.007	0.007	2.82
2000	0.123	1.659	1.338	0.398	0.775	1.172	1.407	0.448	0.036	0.007	0.002	2.37
2001	0.506	1.359	0.673	0.645	1.424	0.774	1.175	0.624	0.049	0.006	0.004	2.06
2002	0.138	1.291	0.936	1.097	1.033	0.928	0.393	0.161	0.039	0.004	0.001	1.42
2003	0.180	1.827	1.107	1.571	1.937	0.927	0.280	0.047	0.017	0.002	0.002	1.62
2004	0.054	1.132	1.397	1.514	1.548	1.200	0.253	0.084	0.012	0.002	0.003	1.68
2005	0.081	0.548	0.926	0.442	1.811	1.477	1.058	0.469	0.064	0.006	0.005	2.47
2006	0.159	0.855	0.497	0.110	0.681	1.338	1.355	0.591	0.130	0.007	0.002	2.43
2007	0.095	0.830	0.467	0.271	0.806	0.608	1.237	0.745	0.213	0.024	0.016	2.38
2008	0.255	0.949	0.280	0.819	1.126	0.900	0.998	0.756	0.438	0.036	0.005	2.87
2009	0.226	2.110	0.228	0.415	0.467	0.869	0.611	0.299	0.137	0.026	0.009	1.57
2010	0.442	1.696	0.466	0.840	0.665	0.695	0.656	0.307	0.107	0.021	0.006	1.59
2011	0.326	1.301	4.134	1.202	2.019	0.932	0.666	0.320	0.057	0.016	0.009	2.21
2012	0.331	0.621	0.198	0.449	1.185	0.934	0.703	0.274	0.080	0.010	0.009	1.71
2013	0.076	2.674	0.951	0.374	0.383	0.998	1.015	0.606	0.264	0.006	0.017	2.53
2015	0.048	0.781	0.601	0.333	0.305	0.252	0.337	0.169	0.099	0.006	0.005	0.87
2016	0.981	1.303	0.438	0.564	0.502	0.630	0.383	0.207	0.093	0.031	0.010	1.31
2017	0.158	2.603	0.861	1.319	0.552	0.570	0.340	0.157	0.088	0.018	0.008	1.25
2018	0.000	3.128	1.810	1.645	0.940	1.138	0.710	0.216	0.061	0.018	0.005	1.89
2019	0.161	3.220	1.964	2.000	1.639	0.994	0.491	0.136	0.035	0.027	0.002	1.87
2020	0.000	4.743	2.589	1.544	2.000	1.512	0.791	0.234	0.104	0.042	0.018	2.71

Table B5. continued

EU 0-700m

Year	0	1	2	3	4	5	6	7	8	9	10	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	0.350	13.52
1996	0.000	5.840	7.970	2.410	3.040	4.200	5.820	2.490	1.620	0.420	0.160	14.42
1997	0.000	3.330	3.780	6.000	6.500	7.110	8.460	4.990	2.150	0.660	0.310	20.01
1998	0.000	2.740	2.130	7.680	11.000	12.330	11.300	7.840	2.620	0.750	0.260	30.13
1999	0.000	1.060	0.700	3.010	10.470	13.410	12.580	5.550	1.820	0.350	0.120	26.37
2000	0.000	3.750	0.290	0.600	2.160	7.090	14.100	5.400	2.320	0.450	0.170	21.08
2001	0.000	8.030	1.430	1.810	0.990	2.790	7.790	6.630	3.210	0.180	0.050	17.25
2002	0.000	4.080	2.940	2.790	1.670	3.790	5.590	5.730	1.280	0.130	0.090	15.05
2003	0.000	2.200	1.000	0.610	1.510	2.480	2.940	1.930	0.470	0.130	0.120	7.73

EU 0-1400m

Year	0	1	2	3	4	5	6	7	8	9	10	Mean weight (kg) per tow
2004	0.000	1.397	2.189	2.924	1.536	6.803	9.156	4.949	1.462	0.727	1.111	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	16.71
2006	0.000	0.449	0.261	0.441	0.907	5.848	8.559	4.680	1.389	0.417	0.898	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	25.10
2008	0.000	0.131	0.065	0.098	0.163	2.026	9.001	12.529	3.177	1.143	1.903	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	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	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	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	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	19.11
2014	0.000	0.016	0.000	0.007	0.163	2.781	8.036	6.873	1.625	0.448	1.527	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	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	28.30
2017	0.000	0.756	0.034	0.023	0.297	4.193	11.500	12.689	4.821	2.112	3.413	42.67
2018	0.000	0.301	0.190	0.212	0.124	2.132	5.989	7.168	3.093	1.579	4.301	29.80
2019	0.000	0.374	0.234	0.196	0.619	3.053	4.417	3.434	1.316	0.903	1.927	16.89
2020	0.000	0.054	0.123	0.310	0.507	2.771	4.708	2.316	0.724	0.666	1.482	13.23
2021	0.000	0.018	0.000	0.025	0.394	2.553	5.998	3.111	1.035	0.677	1.795	16.31

EU 3L

Year	0	1	2	3	4	5	6	7	8	9	10	Mean weight (kg) per tow
2003	0.000	6.024	13.079	10.519	11.294	7.443	3.008	1.029	0.306	0.054	0.297	14.64
2004	0.068	6.713	3.373	7.103	9.680	9.415	2.310	0.461	0.148	0.065	0.125	12.29
2006	0.000	8.387	3.856	2.251	3.290	11.205	7.035	2.341	0.413	0.067	0.250	15.48
2007	0.000	5.451	1.268	2.174	0.767	9.064	8.399	4.064	0.595	0.221	0.262	16.64
2008	0.000	3.762	0.612	5.700	1.627	6.581	10.948	7.809	1.528	0.425	0.731	24.40
2009	0.000	7.080	1.490	1.159	2.498	7.531	8.188	5.758	1.611	0.379	0.691	20.78
2010	0.000	1.272	3.472	2.104	3.296	7.327	8.073	4.497	1.660	0.833	1.227	23.41
2011	0.026	4.495	1.582	1.782	1.550	3.504	5.204	2.344	1.441	0.683	0.942	14.61
2012	0.000	3.138	2.560	8.574	2.387	4.089	5.620	2.280	0.658	0.399	0.699	14.67
2013	0.000	12.866	1.701	1.096	3.947	6.102	6.826	3.255	0.655	0.369	0.779	17.31
2014	0.010	8.427	9.931	2.547	1.425	7.291	6.878	5.441	1.822	0.839	1.274	24.09
2015	0.000	1.509	4.732	2.589	2.627	2.995	8.878	3.895	2.629	0.621	1.679	23.90
2016	0.034	3.644	4.040	5.119	4.027	4.411	3.823	3.756	3.010	0.605	1.955	21.27
2017	0.000	8.299	5.576	17.588	14.598	14.278	8.315	4.669	2.697	0.910	2.119	34.83
2018	0.000	41.529	14.198	6.703	4.895	6.740	4.613	2.455	1.761	0.642	1.880	21.75
2019	0.022	17.912	8.988	22.638	9.461	12.698	6.549	3.442	1.342	0.435	2.056	29.70

EU 3NO

Year	0	1	2	3	4	5	6	7	8	9	10	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	0.154	7.73
1998	0.000	1.711	5.242	9.085	8.468	5.058	2.768	1.097	0.660	0.208	0.199	11.73
1999	0.151	4.380	4.805	7.207	9.307	6.286	2.923	0.775	0.490	0.232	0.244	12.00
2000	0.000	2.917	0.490	0.800	1.389	3.843	4.423	2.562	0.706	0.284	0.339	9.48
2001	0.000	8.869	5.901	1.183	1.070	2.838	3.959	1.559	0.220	0.060	0.249	8.17
2002	0.000	2.860	0.630	1.010	0.680	1.120	0.910	0.430	0.220	0.020	0.080	2.64
2003	0.000	3.520	2.370	1.670	1.890	1.560	0.890	0.770	0.260	0.060	0.150	5.10
2004	0.000	1.200	6.850	2.050	2.030	1.220	0.840	0.510	0.210	0.050	0.100	3.68
2005	0.000	1.070	0.960	1.800	1.030	1.310	1.440	0.680	0.190	0.080	0.160	3.39
2006	0.000	2.290	1.110	0.400	1.540	1.370	0.810	0.520	0.220	0.050	0.080	3.03
2007	0.000	1.830	0.650	0.510	0.330	1.500	1.410	1.030	0.290	0.100	0.170	3.98
2008	0.000	0.640	1.010	0.920	0.710	0.960	2.780	2.570	0.760	0.410	0.350	7.66
2009	0.000	0.570	3.030	2.130	2.540	2.660	4.860	5.580	0.830	0.350	0.490	14.78
2010	0.000	0.380	2.260	0.960	0.750	3.500	5.720	5.290	1.270	0.400	0.630	14.80
2011	0.000	2.260	1.340	0.500	0.640	0.980	2.070	2.180	0.450	0.230	0.490	7.09
2012	0.000	0.090	1.830	1.360	0.450	1.110	1.730	2.030	0.540	0.410	0.690	7.37
2013	0.000	0.280	0.460	0.230	0.820	1.190	1.500	1.230	0.340	0.210	0.610	5.46
2014	0.000	0.530	1.320	0.260	0.150	0.550	1.700	1.790	0.460	0.210	0.690	6.24
2015	0.000	0.950	0.630	0.210	0.220	0.480	1.850	3.460	0.960	0.450	0.800	9.49
2016	0.000	1.130	0.570	0.360	0.470	0.530	1.940	2.660	0.940	0.230	0.830	8.80
2017	0.000	3.450	1.700	0.900	1.120	2.430	4.480	4.720	1.710	0.520	1.060	16.63
2018	0.000	2.450	2.090	1.010	0.840	1.700	1.960	1.680	0.980	0.300	0.510	7.88
2019	0.000	3.390	4.270	4.170	2.820	2.660	2.020	1.280	0.650	0.240	0.810	8.82
2020	0.000	2.400	6.890	1.480	1.110	2.260	2.520	1.310	0.390	0.280	0.730	8.09

EU 3LNO

Year	0	1	2	3	4	5	6	7	8	9	10	Mean weight (kg) per tow
2003	0.000	4.255	6.166	4.530	4.318	3.079	1.452	0.878	0.274	0.056	0.192	7.98
2004	0.026	3.210	5.556	3.987	5.280	3.935	1.396	0.489	0.170	0.054	0.113	6.93
2006	0.000	4.636	2.188	0.999	2.985	4.767	2.959	1.214	0.267	0.064	0.142	7.83
2007	0.000	3.309	0.933	1.158	0.695	4.642	4.139	2.135	0.423	0.146	0.207	9.14
2008	0.000	1.841	0.980	2.613	1.175	3.031	5.845	4.648	1.081	0.439	0.499	14.11
2009	0.000	3.099	2.589	1.701	2.677	4.335	6.153	5.690	1.131	0.403	0.551	17.15
2010	0.000	0.738	2.729	1.447	1.555	5.152	6.693	4.965	1.498	0.572	0.866	18.25
2011	0.010	3.046	1.527	0.974	1.009	1.849	3.298	2.403	0.772	0.369	0.662	9.99
2012	0.000	1.252	2.322	3.933	1.180	2.184	3.142	2.265	0.599	0.420	0.693	10.18
2013	0.000	5.089	0.984	0.565	1.858	3.288	3.493	2.067	0.441	0.292	0.648	10.03
2014	0.004	3.535	4.561	1.297	0.627	3.045	3.804	3.253	0.954	0.451	0.923	13.12
2015	0.000	1.164	2.165	1.166	1.130	1.489	4.572	3.577	1.629	0.509	1.141	15.04
2016	0.013	2.098	2.183	2.023	1.799	1.839	2.743	3.179	1.635	0.394	1.289	13.60
2017	0.000	5.387	4.180	6.555	5.718	7.003	6.138	4.859	2.110	0.702	1.456	23.64
2018	0.000	17.209	6.512	3.530	2.687	3.657	2.918	2.028	1.250	0.452	1.036	13.22
2019	0.006	8.865	6.786	10.603	5.505	6.086	4.310	2.118	0.901	0.328	1.294	16.87