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An Analysis of Stock Status of the Greenland Halibut in Subarea 2 and Divisions 3KLMNO Based on Extended Survivors Analysis

by

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Abstract

The catch-at-age data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO were revised at the June 2000 meeting of the Scientific Council of the North Atlantic Fisheries Organization. A separable model has used to examine the structure of the new data set and investigate trends in selection. Extended Survivors Analysis, calibrated using Canadian and European Union survey information, is used to assess the current status of the stock.

Data

Revised catch number, weight and maturity at age data for the Greenland Halibut in Subarea 2 and Divisions 3KLMNO, were presented at the June 2000 meeting of the Scientific Council of the North Atlantic Fisheries Organization (NAFO) (Bowering and Brodie 2000, Morgan and Bowering 2000). The data sets are listed in Tables 1,2, and 3. Updated Canadian and European Union (EU) survey Greenland Halibut catch per unit effort data sets were also made available at the meeting, they are presented in Tables 4 and 5. As in previous assessments of this stock, natural mortality was assumed to be constant at age and in all years at 0.2.

A Separable Virtual Population Analysis of the catch at age data

In a preliminary screening analysis, before the introduction of additional noise resulting from fitting to survey information, a Separable virtual population analysis model was used to examine the structure of the new catch numbers at age data. The development of the Separable VPA procedure has been described by Pope (1977,1979) and Pope and Shepherd (1982). The implementation used for the analysis is described in Darby and Flatman (1994).

The Separable VPA model

Separable VPA determines values of fishing mortality from a matrix of catch-at-age data, on the assumption that the exploitation pattern is constant. The model assumes that fishing mortality-at-age in any year is the product of a year effect, the overall fully exploited fishing mortality in a year (Fo(y)), and an age dependent exploitation pattern effect (S(a)). The fishing mortality-at-age acting in a year is given by

$$F_{(y,a)} = Fo_{(y)}\, S_{(a)}$$

The catch-at-age data are used to derive a matrix of log catch ratios,

$$D_{(y,a)} = \mathrm{Ln}\,(C_{(y+1,a+1)} / C_{(y,a)})$$

removing year class effects by normalising the matrix with respect to recruitment. Given estimates of the overall fully exploited fishing mortality in a year ($\hat{F}o(y)$), and an age dependent exploitation pattern effect ($\hat{S}(a)$), the log catch ratios can be modelled in terms of F and M alone.

$$\hat{D}_{(y,a)} = \mathrm{Ln}\left[\frac{F_{(y+1,a+1)} Z_{(y,a)} \left(1 - e^{-Z_{(y+1,a+1)}}\right) e^{-Z_{(y,a)}}}{F_{(y,a)}\ Z_{(y+1,a+1)} \left(1 - e^{-Z_{(y,a)}}\right)} \right]$$

An iterative procedure is used to estimate $\hat{F}o(y)$ and $\hat{S}(a)$ such that the objective function of the log catch ratio residuals

$$\Psi\,(\hat{F}o, \hat{S}) = \sum_{y,a} w_{(y,a)} \left(D_{(y,a)} - \hat{D}_{(y,a)} \right)^2$$

is minimised. $W_{(y,a)}$ are year and age weights.

Pope (1979) demonstrated that the information contained within a catch data matrix analysed by a Separable VPA is insufficient for the definition of a unique solution. If a unique solution is to be achieved, extra information must be utilised, for example trends in fishing effort or stock biomass indices.

A Separable VPA for the Greenland Halibut in Subarea 2 and Divisions 3KLMNO

Table 6 presents the matrix of log-catch ratio residuals derived from the fit of a Separable VPA model to the Greenland halibut data for ages 5 - 16 and the years 1975 - 1999. The constraints Fo(1999) = 0.2 and S(16) = 1.0, taken from a tuned VPA were used to specify a solution. Row and column totals of weighted residuals are given, as is the grand total, which the algorithm is attempting to minimise. Row and column weights are printed at the edges of the table. When estimating the average selection at age, equal weight was specified for the log catch ratios derived from each pair of years. Although this Separable VPA solution is not unique, it does provide an extremely useful diagnostic filter for examining total catch-at-age data in isolation; high individual residuals and or patterns in the residuals indicating data anomalies. It also provides a method for investigating the variation in selection throughout the history of the fishery.

Often the final un-weighted SSQ value is the result of a few high residuals (>0.5) indicating poor data for that year and age, these usually occur at poorly sampled age groups. The very high negative residual at ages 5/6 in 1976/77 provides a good example, a log residual of -4 is very large. There is a considerable amount of random noise at the oldest ages of the analysis 14 - 16. This noise would be carried forward into any VPA tuning procedure, adding to error resulting from imprecise survey information at the oldest ages. Therefore, in order to reduce their influence on subsequent analyses, the oldest ages were summed to produce a plus group at age 14.

Pattern in the residuals may indicate a systematic lack of fit of the model to the data (i.e. variation in the selection pattern). Year effects run down the columns of the table, age effects across the rows and year class effects follow the cohort diagonals. Figure 1 presents a contour plot / map of the residuals, a useful approach to locating diagnostic patterns.

The contour plot and Table 6 reveal that the residual matrix has very strong year effects at the youngest and oldest ages, especially at ages 6 - 9 in the years 1980 - 1987. Such anomalies in the log catch ratios can be induced by a variety of effects, for example: annual changes in discard practices, growth or spatial pattern and sampling or reading errors within age length keys.

The most prominent feature of the residual map is the change from the light coloured positive residuals at the mid range ages in the early years to the dark negative residuals of the later years. There is an opposite, if noisier, colour change at the oldest and youngest ages. This chequer board effect is strongly indicative of a change in selection pattern across the catch matrix.

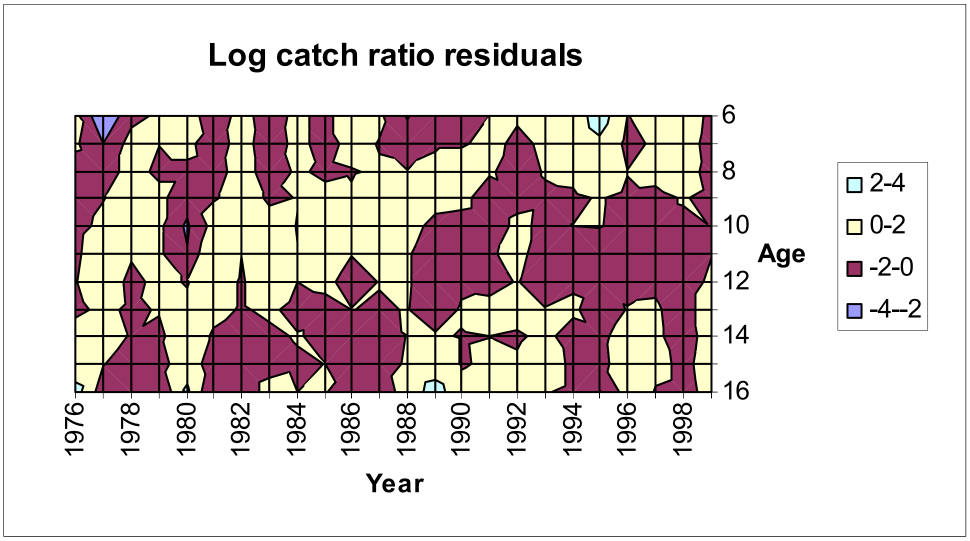

Figure 1. A contour plot of the log catch ratio residuals resulting from the fit a Separable VPA model to the catch at age data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

The change in selection pattern spans the years 1987-1989. It was examined in greater detail by applying year weights to the separable VPA model to estimate selection for the years prior, and subsequent to, 1987. The selection patterns derived from separable models fitted to the time periods 1982-1987 and 1988-1999 are presented in Figure 2. The figure shows a clear difference in the patterns of selection at age between high values at ages 8-10 in the early years towards ages 13-16 in later years.

The pattern of the residuals illustrated in Figure 1, indicates that, rather than a sudden change in selection, there seems to have been a gradual transition towards the oldest ages. Evidence for a trend was therefore examined by setting the year weights such that selection was estimated as a series of four year running means. The results are presented in Figure 3, which illustrates a gradual evolution of selection from a fishery with the highest values at ages 8 - 10, to a fishery with the highest selection at the oldest ages recorded.

There is some evidence from the fishery that a change has taken place in the dominance of the gear type used for the landings. A shift away from a predominantly gill net fishery to a trawl fishery on older ages in deeper water (Bowering pers. comm.); the estimated trend is consistent with this. However, the analyses carried out here have been conditioned on a series of assumptions, namely:

a) a closed population no migration from, or immigration into, the area of the fishery;
b) a constant spatial linkage between the catches and effort
c) constant natural mortality at age and in time;
d) no change in discard practices;
e) the only source of error in the landings data are sampling errors in the catch there is no bias due to unrecorded landings.

Each of these factors, which are assumed to be constants in the model formulation, are confounded with selection in more detailed models. One or a combination of them could be responsible for inducing the pattern estimated by the model. Their effects cannot be separated unless additional information is available for more complex models.

Figure 2 Estimated selection at age relative to the average selection at all age, for two time periods in the fishery for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

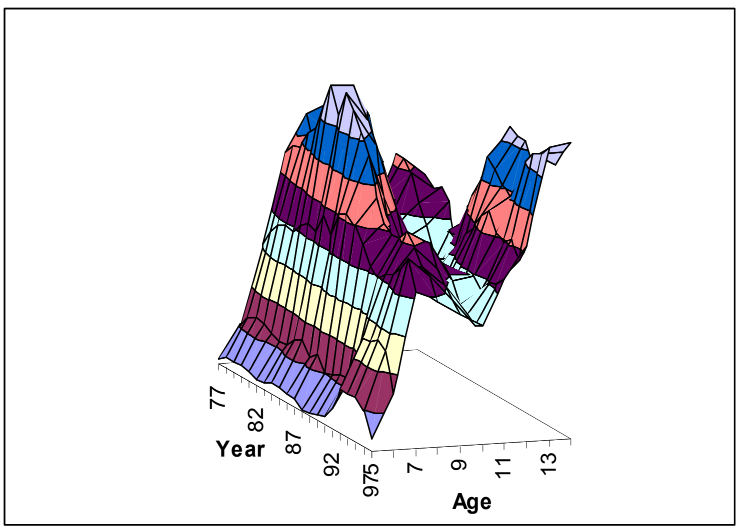

Figure 3 A time series of four year running means of estimated selection at age relative to the average selection at all ages for the Greenland Halibut in Subarea 2 and Divisions 3KLMNO fishery data.

An Extended Survivors Analysis assessment of Greenland Halibut in Subarea 2 and Divisions 3KLMNO

The XSA model

The Extended Survivors Analysis (XSA, Shepherd (1999)) algorithm, implemented in the Lowestoft VPA assessment package (Darby and Flatman, 1994) was used to calibrate a virtual population analysis based on the catch data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO. XSA utilizes the relationship between catch per unit effort (CPUE) and population abundance to estimate catchability. Shepherd (1999) describes the least squares derivation of the equations. For each cohort, the terminal populations, $Pt_{(Ty,Ta)}$, which initialize a VPA iteration, are estimated as:

$$\text{Ln } P_{t(Ty,Ta)} = \frac{\sum_f \sum_{i=Fa}^{i=Ta} [\, w_{(y,i,f)} (\text{Ln } \hat{N}_{(y,i,f)} - \text{Ln } ECZ_{(y,i)})]}{\sum_f \sum_{i=Fa}^{i=Ta} [w_{(y,i,f)}]}$$

where
$$w(_{y,i,f}) = \frac{\theta_{(y,i,f)}\, \tau_{(y)}\, \phi_{(f)}}{\sigma^2_{(y,i,f)}\, ECF_{(y,i)}}$$

and
$$\hat{N}_{(y,a,f)} = \frac{U_{(y,a,f)}}{q_{(a,f)}}$$

Ty and Ta are indices for the final year (y) and oldest age (a) of the cohort. $\hat{N}_{(y,a,f)}$ are fleet (f) based estimates of population size derived from CPUE data (U) and catchability which is assumed to be independent at age and by fleet, log-normally distributed and constant in time. ECF and ECZ are the cumulative exponential fishing and total mortality rates summed from the oldest cohort age back to age a. $\tau(y)$ are the time series weights which can be used to down-weight older data, $\phi(f)$ are the user defined fleet weights (usually set to 1 or 0) and $\theta(y,a,f)$ are missing value weights. $\sigma(y,a,f)$ are the standard errors of the fleet based predictions of population abundance.

Estimates of fleet catchability at the oldest age in a VPA based model are directly dependent on the terminal population or F values used to initialize the underlying VPA. Catchability at the oldest age cannot be determined without the use of additional constraints. XSA imposes the constraint that fleet catchability is constant (independent of age) above a certain age.

A shrinkage constraint, shrinkage to the mean F, can be applied to the estimates of population abundance which initiate the VPA calculations. This was introduced after the Working Group on Methods of Fish Stock Assessment (the Methods Working Group), examined biases in assessment predictions of terminal F and survivors (Anon., 1991, 1993). At each age, the program calculates a mean of the F values for a user defined range of years that precede the final year. The mean F and the total catch in the final year are used to calculate an estimate of the survivors at the end of the year. The value is included in the final weighted average terminal population estimate. The survivors in years prior to the final year are shrunk to a terminal population derived from an average of the F values of a range of ages that precede the oldest true age, and the total catch value for the oldest true age. The weight given to the population estimate derived from the F shrinkage is user defined as a coefficient of variation.

An XSA assessment of Greenland Halibut in Subarea 2 and Divisions 3KLMNO

As a result of the residuals apparent in the fit of the Separable VPA model, discussed previously, a catch at age data range of 1-14+ was chosen for the XSA assessment. In addition to the use of the plus group, the age range used in the XSA analysis differed from the Separable VPA in that commercial catches were recorded at age 4 since 1990 and survey catch per unit effort information was available for ages (1-4) for the whole time series. This information was included in the XSA assessment by extending the age range of the catch numbers, stock and catch weights and natural mortality at age down to age 1.

A preliminary series of model fits to ascertain the optimum XSA structure for a fit to the catch and survey data, resulted in the parameter selections listed in Table 7a. The process of choosing the parameters selections is described in Darby and Flatman (1994) and will not be outlined in detail here. The final model was fitted with catchability constant in time at all ages, independent of age for ages 1 - 11 and, for each fleet, constrained at ages 12 and 13 to the value estimated at age 11. A fishing mortality shrinkage constraint was imposed such that the terminal populations in the final year were shrunk towards the average of the preceding two years and at the oldest age, to the two penultimate ages. The log standard error weight for the fishing mortality means was set at 0.5, as was the minimum standard error threshold.

Initially the model was fitted to the complete range of survey data available, for the EU survey 1991 - 1999 and for the Canadian RV survey 1978 - 1999. However, patterns in the log catchability residuals at the oldest ages (Figures 4a,b and 5) revealed that, as with the previously noted changes in selection at age, there has been an autocorrelated variation in catchability at age in the time series of both surveys. This is most severe in the Canadian RV survey which has shown not only a gradual trend in catchability from year to year but also a severe change in level over the same time period, 1987-1988, that selection changed within the catch at age data. The effect is especially strong at the oldest ages. The cause of the change in catchability and its possible correlation with the change in selection could not be explored in the time available. Detailed information would be required on the spatial distributions of the commercial catch and surveys.

In the XSA model fitted to the surveys it was assumed that catchability was constant during the time of the assessment. As a result of the use of an average catchability for a parameter that appears to have changed its level, estimates of population abundance derived from the Canadian survey are biased. They are over-estimated prior to 1987 and under-estimated subsequently. Therefore, in order to allow the full time series of data to be used for the estimation of population trends, the assumption was made that the Canadian survey catchability changed abruptly in 1998 and the data set was divided into two series covering the catches prior to and post 1987.

The XSA diagnostic output from the final model structure fitted to the three survey time series is presented in Tables 7b,c,d and e. The estimated population numbers, fishing mortality and summary time series are presented in Tables 8, 9 and 10.

The log catchability residuals from the final model fit are plotted in Figures 6 & 7, there is considerable noise. Although dividing the Canadian survey into two series has compensated for the change in the level of catchability, making the assumption of constant catchability more acceptable, it has not removed the autocorrelation.

An examination of the log catchability estimates and the associated standard errors for the two Canadian survey periods (Tables 7 b and c), reveals that at ages 1 - 7 there is no significant difference between the estimates. At ages 8 and older the catchability estimates begin to diverge and they are significantly different at ages 10 and older. This confirms the strong trends in the residual patterns at the oldest ages noted from the diagnostics of the preliminary model fit.

The log standard errors of catchability, approximations to the coefficient of variation of the original data, are generally above 0.5 (50%), indicating a relatively poor model fit. When considered with the unexplained autocorrelation in catchability the results of this assessment are considered to be indicative of trends in the stock dynamics rather than providing absolute estimates. Figures 8 illustrates the estimated stock trends, Figure 9 the stock and recruitment plot.

Stock biomass at ages 5 and older is estimated to have increased during the late 1980's and then declined rapidly during the period of high landings in the early 1990's. Estimated fishing mortality has followed the trend in landings, increasing rapidly in the early 1990's, remaining high as the stock was reduced to its historic lows and then declining to the low levels recorded during 1985 – 1990. The reduction in exploitation has resulted from both a decrease in the recorded landings and an increase in biomass following the high recruitments of the 1993 - 1996 year classes.

Currently the stock biomass is estimated to be close to its historically highest level. However, the assessment is noisy and the data has been manipulated to meet model assumptions. Recent point estimates are therefore uncertain. Greater importance should be given to the trends in the recent estimates rather than comparisons with historic levels. Short and medium term stochastic forecasts based on the population numbers estimated by the XSA analysis and based on an assumption of status quo fishing mortality are given in Mahe and Darby (2000).

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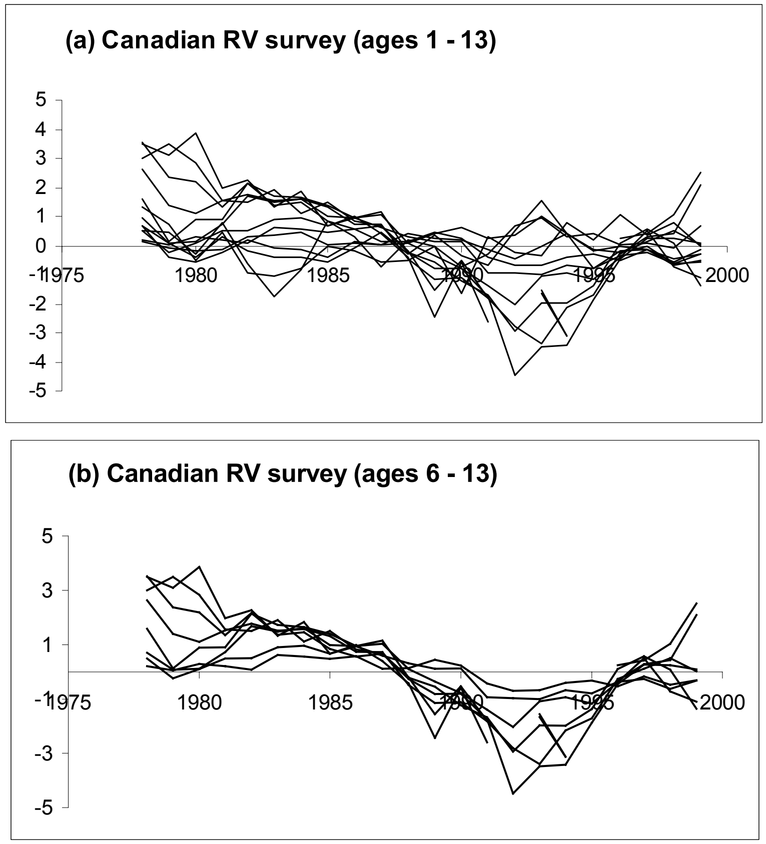

Figure 4(a,b). The log catchability residuals for the Canadian R.V survey derived from the fit of the preliminary XSA based model to the catch at age data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

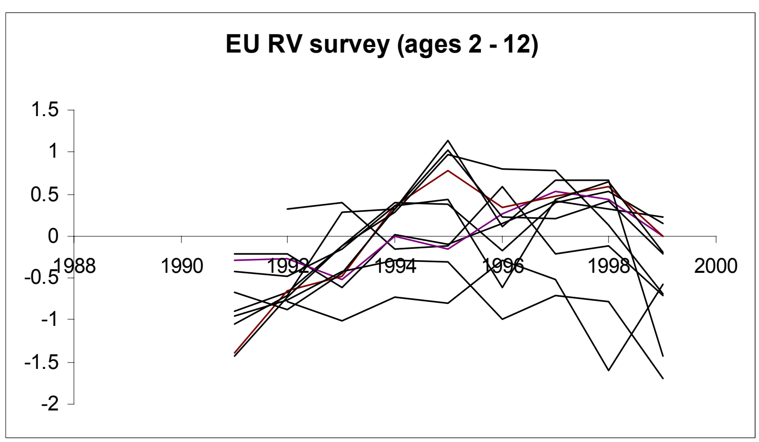

Figure 5. The log catchability residuals for the EU R.V survey derived from the fit of the preliminary XSA based model to the catch at age data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

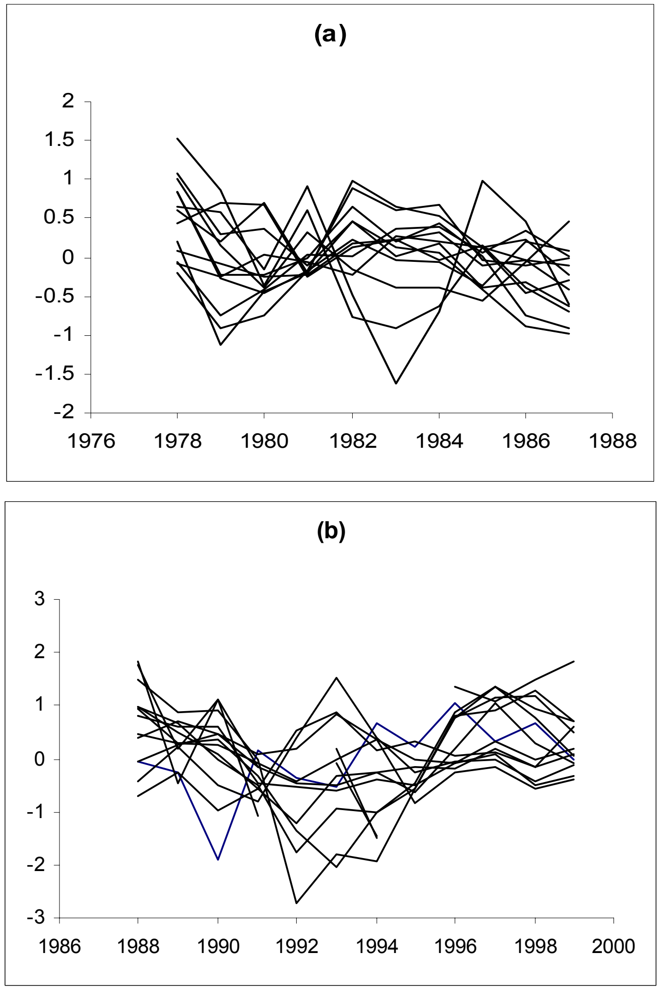

Figure 6. The log catchability residuals for the Canadian R.V survey for the data series 1978 - 1987 (a) and 1998 - 1999 (b), derived from the fit of the final XSA model to the catch at age data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

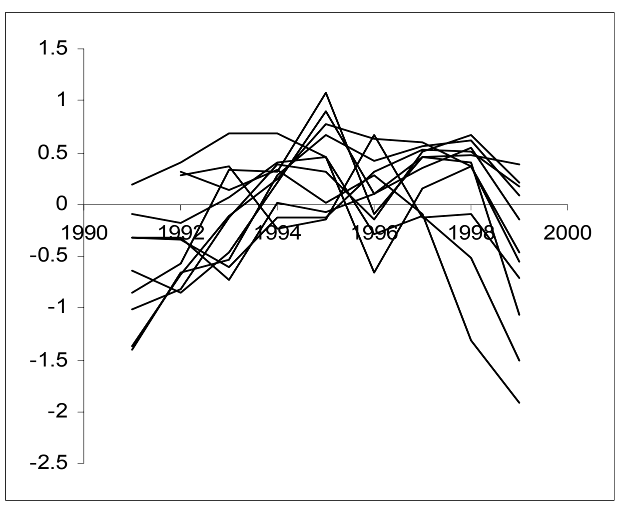

Figure 7. The log catchability residuals for the EU R.V survey derived from the fit of the preliminary XSA based model to the catch at age data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

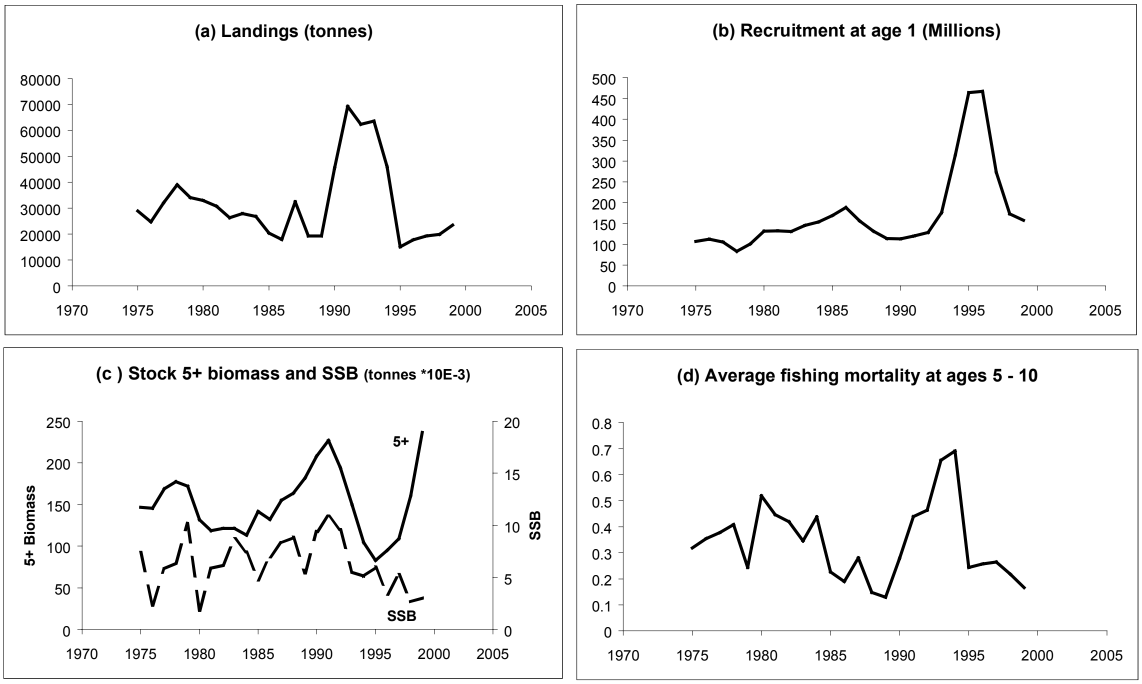

Figure 8. The time series of stock trends for the Greenland Halibut in Subarea 2 and Divisions 3KLMNO

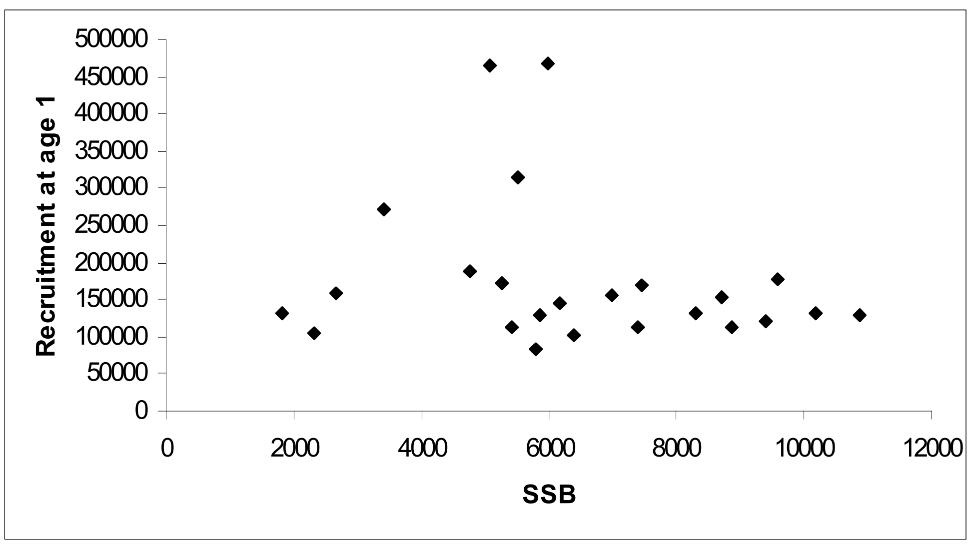

Figure 9. The stock and recruitment plot for the Greenland Halibut in Subarea 2 and Divisions 3KLMNO

Table 1. Catch numbers at age and total landings for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

	YEAR											
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	334	17	534	2982	2386	209	863	269	701	902	1983	280
6	2819	610	5012	8415	8727	2086	4517	2299	3557	2324	5309	2240
7	5750	3231	10798	8970	12824	9150	9806	6319	9800	5844	5913	6411
8	4956	5413	7346	7576	6136	9679	11451	5763	7514	7682	3500	5091
9	3961	3769	2933	2865	1169	5398	4307	3542	2295	4087	1380	1469
10	1688	2205	1013	1438	481	3828	890	1684	692	1259	512	471
11	702	829	220	723	287	1013	256	596	209	407	159	244
12	135	260	130	367	149	128	142	256	76	143	99	140
13	279	101	116	222	143	53	43	163	106	106	87	70
+gp	288	53	84	258	284	27	69	191	175	183	86	117
TONS	28814	24611	32048	39070	34104	32867	30754	26278	27861	26711	20347	17976

	YEAR												
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	95	220	1064	1010	5395	323	190	335	552	297
5	137	296	181	1102	2862	4180	9570	16500	1352	1659	1903	3575	214
6	1902	3186	1988	6758	7756	10922	15928	15815	2342	5197	4169	5407	562
7	11004	8136	7480	12632	13152	20639	17716	11142	3201	6387	7544	5787	861
8	8935	4380	4273	7557	10796	12205	11918	6739	2130	1914	3215	3653	379
9	2835	1288	1482	4072	7145	4332	4642	3081	1183	956	1139	1435	165
10	853	465	767	2692	3721	1762	1836	1103	540	504	606	541	623
11	384	201	438	1204	1865	1012	1055	811	345	436	420	377	343
12	281	105	267	885	1216	738	964	422	273	233	246	161	306
13	225	107	145	434	558	395	401	320	251	143	137	92	145
	349	129	71	318	422	335	182	215	201	89	89	50	151
TONS	32442	19215	19230	45421	69194	62362	63540	46038	15085	17714	19194	19858	2349

Table 2. Catch weights at age for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

	YEAR											
AGE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.609	0.609	0.609	0.609	0.609	0.514	0.392	0.525	0.412	0.377	0.568	0.350
6	0.760	0.760	0.760	0.760	0.760	0.659	0.598	0.684	0.629	0.583	0.749	0.584
7	0.955	0.955	0.955	0.955	0.955	0.869	0.789	0.891	0.861	0.826	0.941	0.811
8	1.190	1.190	1.190	1.190	1.190	1.050	0.985	1.130	1.180	1.100	1.240	1.100
9	1.580	1.580	1.580	1.580	1.580	1.150	1.240	1.400	1.650	1.460	1.690	1.580
10	2.210	2.210	2.210	2.210	2.210	1.260	1.700	1.790	2.230	1.940	2.240	2.120
11	2.700	2.700	2.700	2.700	2.700	1.570	2.460	2.380	3.010	2.630	2.950	2.890
12	3.370	3.370	3.370	3.370	3.370	2.710	3.510	3.470	3.960	3.490	3.710	3.890
13	3.880	3.880	3.880	3.880	3.880	3.120	4.790	4.510	5.060	4.490	4.850	4.950
+gp	5.764	5.144	5.992	5.894	6.077	5.053	7.426	7.359	7.061	7.016	7.010	7.345

	YEAR												
AGE	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.364	0.363	0.400	0.338	0.383	0.430	0.368	0.330	0.363	0.360	0.336	0.373	0.358
6	0.589	0.569	0.561	0.546	0.592	0.577	0.547	0.514	0.531	0.541	0.489	0.543	0.533
7	0.836	0.805	0.767	0.766	0.831	0.793	0.809	0.788	0.808	0.832	0.771	0.810	0.825
8	1.160	1.163	1.082	1.119	1.228	1.234	1.207	1.179	1.202	1.272	1.159	1.203	1.253
9	1.590	1.661	1.657	1.608	1.811	1.816	1.728	1.701	1.759	1.801	1.727	1.754	1.675
10	2.130	2.216	2.237	2.173	2.461	2.462	2.309	2.268	2.446	2.478	2.355	2.351	2.287
11	2.820	3.007	2.997	2.854	3.309	3.122	2.999	2.990	3.122	3.148	3.053	3.095	2.888
12	3.600	3.925	3.862	3.731	4.142	3.972	3.965	3.766	3.813	3.856	3.953	4.010	3.509
13	4.630	5.091	4.919	4.691	5.333	5.099	4.816	4.882	4.893	4.953	5.108	5.132	4.456
+gp	6.454	7.164	6.370	6.391	7.081	6.648	6.489	6.348	6.790	6.312	6.317	6.124	5.789

Table 3. Maturity at age for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

	YEAR											
AGE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
7	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
8	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
9	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
10	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134
11	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422
12	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251
13	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172
+gp	0.7625	0.6971	0.7958	0.7791	0.8054	0.7214	0.7675	0.7665	0.7361	0.7910	0.7228	0.7438

	YEAR												
AGE	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003	0.0000	0.0002
7	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0009	0.0001	0.0005
8	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0027	0.0003	0.0014
9	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0087	0.0014	0.0039
10	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0276	0.0056	0.0110
11	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0422	0.0838	0.0229	0.0308
12	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.2274	0.0881	0.0833
13	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.3172	0.4866	0.2853	0.2064
+gp	0.7460	0.7330	0.6760	0.6840	0.6920	0.6947	0.7037	0.6650	0.7709	0.6868	0.8152	0.7130	0.5634

Table 4. The European Union survey catch numbers at age data set for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Start of fishing	0.5
End of Fishing	0.6

		Numbers at age										
Year	Effort	2	3	4	5	6	7	8	9	10	11	12
1991	1	-1	235	993	1956	1253	2283	545	464	388	122	-1
1992	1	800	286	861	1600	1996	1793	991	473	266	139	67
1993	1	933	599	566	960	1574	1732	1388	905	257	141	51
1994	1	706	1082	1224	1365	2233	2096	1213	689	264	95	54
1995	1	1394	1369	1249	1709	3793	3026	1729	1134	254	68	26
1996	1	4613	1527	2066	3070	4394	2020	1378	392	75	31	35
1997	1	2113	4396	5157	5216	6045	3885	1709	593	200	33	22
1998	1	1268	5149	7835	9168	8821	6334	2339	703	201	27	6
1999	1	426	1904	7178	9818	9599	4382	1544	322	101	8	4

Table 5. The Canadian survey catch numbers at age data set for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Start of fishing	0.8
End of Fishing	1.0

		Numbers at age															
Year	Effort	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1978	1	67133	315362	243378	146864	90817	68595	40908	19170	9940	7366	6469	4117	2683	992	560	365
1979	1	76275	128771	95883	50861	53099	50976	24408	9977	4777	4572	3000	2638	2193	1079	699	624
1980	1	47941	46187	43767	39304	49738	52627	32283	11102	4960	3891	4461	2882	1874	1070	411	231
1981	1	141166	158149	109462	41433	47202	49991	35482	15613	7017	4213	3349	1559	857	446	268	43
1982	1	33748	39589	88918	75651	57104	41105	43097	41244	16566	6765	4129	2714	1929	1975	1257	589
1983	1	12131	34727	71282	75711	71101	51583	50698	39418	15223	4414	3180	2291	1664	1109	495	131
1984	1	31845	50917	70143	74837	103171	61334	42301	27028	13058	6306	2602	1812	1480	1285	677	461
1985	1	192902	113558	65428	54235	66317	69541	42805	17028	7982	5296	2257	1997	874	1002	606	302
1986	1	125257	106161	112555	104606	72301	81840	71749	22142	6546	2380	1856	1668	879	542	555	318
1987	1	36234	81046	212676	99109	75271	53188	47138	25791	9434	2833	1481	1454	754	583	385	204
1988	1	74055	71555	109246	114836	119818	59218	41431	12233	3134	1105	781	463	361	327	236	149
1989	1	52954	95755	174201	174689	108472	87210	38560	9604	2847	747	568	151	35	81	103	31
1990	1	9858	39744	70539	177413	115858	70699	36649	6200	1500	746	640	389	223	155	90	21
1991	1	84583	59211	44644	103158	65701	40331	12485	2383	635	310	181	104	22	8	-1	4
1992	1	52907	188121	148380	95263	38552	22088	10472	1067	140	89	12	-1	-1	15	-1	-1
1993	1	62241	281182	497522	182333	42962	13677	5905	1967	232	32	22	94	41	24	-1	-1
1994	1	359982	189873	171493	112859	51870	9898	4478	1347	172	69	13	17	9	-1	-1	-1
1995	1	342056	397121	122856	39605	50370	15863	3513	920	266	104	49	-1	-1	-1	-1	-1
1996	1	793447	452542	267483	96568	55611	22305	7422	1920	1141	377	178	115	118	42	10	-1
1997	1	222012	486571	398365	192045	89809	40112	17321	5658	1547	493	280	151	100	54	-1	-1
1998	1	199610	216980	265730	188600	92110	38350	17250	4770	1100	580	240	150	140	20	-1	20
1999	1	93492	289040	217037	227676	162884	90149	29589	5048	1100	415	143	86	170	10	-1	-1

Table 6. The Separable VPA diagnostic output, including log catch ratio residuals, annual fishing mortality and selection at age, for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Title : Greenland Halibut in 2+3KLMNO

Separable analysis
from 1975 to 1999 on ages 5 to 16
with Terminal F of .200 on age 8 and Terminal S of 1.000

Initial sum of squared residuals was 379.701 and
Final sum of squared residuals is 163.740 after 76 iterations

Matrix of Residuals

Years Ages	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
5/ 6	0.61	-4.011	-0.512	0.281	1.479	-1.627	0.977	-1.209	0.628	-0.698	1.375	0.387	-2.152
6/ 7	0.25	-2.007	0.761	0.032	0.45	-0.915	0.777	-0.908	0.487	-0.656	0.545	-0.11	-1.246
7/ 8	-0.623	-0.966	0.625	-0.335	-0.313	-0.625	0.61	-0.696	0.185	-0.247	-0.077	0.161	0.102
8/ 9	-0.985	-0.061	0.691	0.541	-1.045	-0.138	0.727	-0.167	0.016	0.393	0.126	0.58	0.556
9/10	-0.698	0.605	0.451	0.456	-2.378	0.823	0.467	0.52	-0.017	0.719	0.284	0.504	0.389
10/11	-0.465	1.687	0.183	0.42	-1.822	1.823	0.026	1.081	0.013	0.81	0.026	0.249	0.123
11/12	-0.029	1.376	-0.524	0.553	-0.115	1.228	-0.234	1.204	0.004	0.304	-0.452	0.037	0.122
12/13	-0.503	0.558	-0.36	0.12	0.331	0.583	-0.161	0.251	-0.494	-0.374	0.012	-0.081	0.034
13/14	1.022	0.646	-0.088	-0.327	1.265	-0.236	-0.964	-0.324	0.116	-0.418	-0.198	-0.782	0.021
14/15	1.009	0.038	-0.656	-0.785	1.439	-1.058	-0.953	-0.633	-0.22	0.004	-0.169	-0.372	0.09
15/16	2.628	-1.198	-1.441	-1.732	2.257	-1.654	-1.153	0.577	-0.001	0.108	-1.061	-0.666	0.529
TOT	0	0	0	0	0	0	0	0	0	0	0	0	0
WTS	1	1	1	1	1	1	1	1	1	1	1	1	1

Years	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	TOT	WTS
5/ 6	-0.459	-1.102	0.057	0.234	0.381	0.923	2.897	-0.033	0.453	1.671	-0.549	0	0.271
6/ 7	-0.156	-0.154	0.419	-0.359	0.25	0.813	1.684	-0.476	0.246	1.204	-0.933	0	0.456
7/ 8	0.397	0.705	0.124	-0.513	0.058	0.168	0.588	0.036	0.347	0.904	-0.612	0	0.753
8/ 9	0.327	0.275	-0.526	-0.291	-0.137	-0.096	0.043	-0.218	-0.338	0.11	-0.384	0	0.81
9/10	-0.292	-0.405	-0.494	0.208	-0.225	0.009	0.034	-0.205	-0.451	-0.289	-0.013	0	0.579
10/11	-0.679	-0.178	-0.096	0.259	-0.417	-0.448	-0.411	-0.755	-0.649	-0.758	-0.02	0	0.481
11/12	-0.888	-0.299	-0.324	0.051	-0.714	-0.172	-0.317	-0.434	-0.123	-0.4	0.147	0	0.655
12/13	-0.678	0.132	0.331	0.432	0.018	0.197	-0.661	0.059	0.084	-0.389	0.557	0	1
13/14	0.128	-0.056	-0.005	-0.127	0.265	-0.411	-0.246	0.521	0.168	-0.397	0.429	0	0.743
14/15	0.694	-0.103	0.19	0.131	0.683	-0.281	-0.322	0.688	0.42	-0.309	0.471	0	0.613
15/16	2.993	0.361	0.783	0.088	0.058	-0.221	-2.08	0.945	-0.119	-0.353	0.351	0	0.29
TOT	0	0	0	0	0	0	0	0	0	0	0	-0.001	
WTS	1	1	1	1	1	1	1	1	1	1	1		

Fishing Mortalities (Fo(y))

	1975	1976	1977	1978	1979
F-values	0.6846	0.4518	0.4734	0.914	0.7164

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
F-values	0.5452	0.4538	0.6396	0.4975	0.6145	0.3497	0.3008	0.5955	0.3115	0.2534

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
F-values	0.6236	0.9562	0.9536	1.1168	0.9641	0.4912	0.3545	0.2691	0.4299	0.2

Selection-at-age (S(a))

	5	6	7	8	9	10	11	12	13	14	15	16
S-values	0.0305	0.2003	0.677	1	0.9283	0.7947	0.7073	0.7098	0.9398	0.962	1.2712	1

Table 7a. The parameter selections specified for the final XSA model for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Lowestoft VPA Version 3.1

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Extended Survivors Analysis

2+3 GHL index file

CPUE data from file d:\data\glh\GHLef98.dat

Catch data for 25 years. 1975 to 1999. Ages 1 to 14.

Fleet	First year	Last year	First age	Last age	Alpha	Beta
CAN RV	1978	1999	1	13	0.8	1
CAN RV	1988	1999	1	13	0.8	1
EU Survey	1991	1999	2	12	0.5	0.6

Time series weights :

Tapered time weighting not applied

Catchability analysis :

Catchability independent of stock size for all ages

Catchability independent of age for ages >= 11

Terminal population estimation :

Terminal year survivor estimates shrunk towards the mean F of the preceeding 2 years.
S.E. of the mean to which the estimates are shrunk = .500

Oldest age survivor estimates for the years 1975 to 1999 shrunk towards1.000 * the mean F of ages 11 - 12
S.E. of the mean to which the estimates are shrunk = .500

Minimum standard error for population estimates from each cohort age = .500

Individual fleet weighting not applied

Tuning converged after 92 iterations

Time series weights

	1	1	1	1	1	1	1	1	1	1

Table 7b. The diagnostics of the XSA fit to the Canadian survey catch per unit effort data for the years 1978 - 1987, for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Log catchability residuals.

Fleet : CAN RV

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0.64	0.58	-0.15	0.92	-0.49	-1.62	-0.71	0.99	0.45	-0.6
2	1.52	0.86	-0.36	0.61	-0.78	-0.9	-0.62	0.12	-0.04	-0.42
3	1.01	0.15	-0.4	0.32	-0.15	-0.38	-0.38	-0.56	-0.07	0.47
4	0.84	-0.27	-0.46	-0.18	0.23	-0.03	-0.05	-0.36	0.19	0.08
5	0.08	-0.09	-0.25	-0.23	0.18	0.22	0.33	-0.1	-0.03	-0.1
6	-0.08	-0.25	0.03	-0.07	-0.23	0.27	0.2	0.12	0.23	-0.23
7	-0.06	-0.74	-0.42	0.04	0.01	0.37	0.38	0.06	0.34	0.02
8	-0.2	-0.9	-0.75	-0.18	0.89	0.61	0.68	-0.04	-0.1	0
9	0.21	-1.13	-0.43	-0.2	0.98	0.66	0.54	0.13	-0.45	-0.29
10	0.84	-0.23	-0.23	-0.01	0.64	0.2	0.44	0.02	-0.75	-0.92
11	1.08	0.3	0.37	-0.11	0.46	0.14	0.05	-0.42	-0.88	-0.99
12	0.43	0.69	0.68	-0.26	0.13	0.22	-0.03	0.16	-0.38	-0.7
13	0.6	0.21	0.71	-0.21	0.46	0.01	0.18	-0.39	-0.31	-0.63

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	8	9	10	11	12	13
Mean Log	-0.6774	-0.0439	0.3422	0.2603	0.4264	0.5595	0.7913	0.8684	0.8016	0.8752	1.0699	1.0699	1.0699
S.E(Log q)	0.8538	0.7857	0.49	0.3734	0.1945	0.2015	0.3546	0.5854	0.6275	0.5652	0.6275	0.46	0.4514

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	4.29	-0.627	-35.97	0	10	3.79	-0.68
2	-1.92	-1.542	33.75	0.03	10	1.41	-0.04
3	1.11	-0.118	-1.57	0.14	10	0.57	0.34
4	0.93	0.115	0.58	0.23	10	0.37	0.26
5	1.1	-0.25	-1.56	0.44	10	0.23	0.43
6	1.89	-1.509	-10.56	0.26	10	0.36	0.56
7	-2.48	-2.835	37.96	0.08	10	0.66	0.79
8	-1.89	-1.656	29.91	0.04	10	1.01	0.87
9	-1.83	-1.631	26.8	0.04	10	1.05	0.8
10	3.31	-0.966	-21.72	0.02	10	1.88	0.88
11	-25.66	-1.016	225.38	0	10	16.08	1.07
12	17.16	-2.031	******	0	10	6.64	1.16
13	1.19	-0.243	-2.58	0.17	10	0.56	1.13

Table 7c. The diagnostics of the XSA fit to the Canadian survey catch per unit effort data for the years 1988 - 1999, for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Fleet : CAN RV 88 - 99

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	-0.05	-0.24	-1.92	0.17	-0.37	-0.52	0.66	0.22	1.05	0.32	0.67	0
2	-0.7	-0.24	-0.97	-0.57	0.53	0.86	0.15	0.31	0.05	0.12	-0.15	0.6
3	-0.42	0.23	-0.5	-0.81	0.4	1.54	0.41	-0.24	-0.04	-0.03	-0.44	-0.11
4	-0.04	0.27	0.47	0.1	0.18	0.84	0.36	-0.83	-0.26	-0.15	-0.56	-0.38
5	0.48	0.28	0.25	-0.1	-0.43	-0.02	0.37	-0.03	-0.08	0.07	-0.48	-0.31
6	0.4	0.71	0.48	-0.17	-0.45	-0.49	-0.26	-0.16	-0.18	0.2	-0.17	0.07
7	0.81	0.6	0.61	-0.46	-0.52	-0.59	-0.39	-0.49	-0.07	0.33	-0.02	0.2
8	0.97	0.51	0.08	-0.56	-1.23	-0.32	-0.24	-0.63	0.19	1.04	0.29	-0.1
9	0.97	0.66	0	-0.48	-1.78	-0.93	-1.01	-0.45	0.86	1.34	0.78	0.05
10	0.94	0.29	0.35	-0.34	-1.37	-2.05	-1	-0.58	0.81	0.92	1.3	0.72
11	1.49	0.88	0.91	-0.01	-2.72	-1.81	-1.93	-0.58	0.78	1.35	0.96	0.69
12	1.75	0.18	1.1	-0.16		0.18	-1.5		0.76	1.14	1.18	0.49
13	1.85	-0.46	1.13	-1.07		-0.07	-1.44		1.36	1.09	1.48	1.84

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	8	9	10	11	12	13
Mean Log	-0.3431	0.3008	0.4571	0.4393	0.2592	-0.0552	-0.273	-1.0116	-1.8091	-2.2415	-2.5243	-2.5243	-2.5243
S.E(Log q)	0.7568	0.5522	0.6116	0.4674	0.3079	0.3778	0.5015	0.6614	0.9538	1.0573	1.4261	1.0612	1.3627

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	0.53	2.555	5.94	0.74	12	0.32	-0.34
2	0.83	0.633	1.78	0.58	12	0.47	0.3
3	1.47	-0.905	-6.18	0.27	12	0.91	0.46
4	1.9	-1.938	-11.16	0.32	12	0.79	0.44
5	1.42	-1.47	-5.1	0.55	12	0.42	0.26
6	0.78	0.907	2.38	0.64	12	0.3	-0.06
7	0.73	1.019	2.96	0.59	12	0.37	-0.27
8	1.35	-0.592	-2.01	0.22	12	0.92	-1.01
9	2.86	-1.099	-11.56	0.03	12	2.71	-1.81
10	2.36	-0.891	-6.04	0.04	12	2.52	-2.24
11	2.6	-0.648	-5.99	0.02	12	3.81	-2.52
12	3.28	-1.065	-10.12	0.03	10	2.97	-2.01
13	-1.46	-1.743	13.8	0.06	10	1.61	-1.95

Table 7d. Diagnostics of the fit to the European Union survey data for the years 1988 - 1999, for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Fleet : EU Survey

Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1										
2			0.27	0.36	-0.24	-0.14	0.67	-0.12	-0.09	-0.72
3		-1.01	-0.81	-0.13	0.39	0.32	-0.15	0.51	0.67	0.21
4		-0.33	-0.32	-0.73	0.02	-0.07	0.11	0.45	0.48	0.38
5		-0.33	-0.34	-0.6	-0.12	-0.12	0.31	0.52	0.51	0.18
6		-1.4	-0.66	-0.54	0.27	0.66	0.42	0.56	0.61	0.09
7		-0.65	-0.86	-0.46	0.21	0.89	0.11	0.35	0.55	-0.14
8		-1.36	-0.68	-0.11	0.24	0.77	0.64	0.59	0.37	-0.46
9		-0.86	-0.57	0.34	0.32	1.08	-0.1	0.45	0.4	-1.06
10		-0.1	-0.18	0.07	0.41	0.46	-0.66	0.16	0.37	-0.55
11		0.19	0.41	0.68	0.68	0.46	-0.29	-0.11	-0.52	-1.5
12			0.32	0.14	0.33	0.01	0.27	-0.1	-1.32	-1.91

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	9	10	11	12
Mean Log	-4.9722	-4.6628	-3.8473	-3.1128	-2.4082	-1.9893	-1.9809	-2.079	-2.5494	-3.3971	-3.3971
S.E(Log q	0.4253	0.5827	0.4079	0.3985	0.7131	0.5768	0.7157	0.7026	0.4082	0.7041	0.9017

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	0.9	0.339	5.67	0.67	8	0.41	-4.97
3	0.6	2.416	7.51	0.84	9	0.28	-4.66
4	0.63	4.253	6.66	0.95	9	0.15	-3.85
5	0.7	1.729	5.54	0.83	9	0.25	-3.11
6	2.55	-1.058	-10.64	0.06	9	1.81	-2.41
7	38.37	-3.371	******	0	9	14.61	-1.99
8	-3.55	-4.985	36.62	0.15	9	1.27	-1.98
9	-6.42	-3.103	52.21	0.02	9	3.13	-2.08
10	1.1	-0.277	1.96	0.5	9	0.48	-2.55
11	0.53	1.733	5.42	0.66	9	0.33	-3.4
12	0.46	1.423	5.55	0.54	8	0.36	-3.68

Table 7e. The XSA estimates of survivors at the beginning of 2000 derived from each survey, their standard errors and the combined weighted average; for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

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

Year class = 1998

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	129140	0.788	0	0	1	1	0
EU Survey	1	0	0	0	0	0	0
F shrinkage r	0	0.5				0	0

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
129140	0.79	0	1	0	0

Age 2 Catchability constant w.r.t. time and dependent on age
Year class = 1997

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	215141	0.464	0.035	0.08	2	0.537	0
EU Survey	56200	0.5	0	0	1	0.463	0
F shrinkage r	0	0.5				0	0

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
115557	0.34	0.47	3	1.392	0

Age 3 Catchability constant w.r.t. time and dependent on age

Year class = 1996

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	145484	0.375	0.133	0.35	3	0.517	0
EU Survey	154175	0.388	0.145	0.38	2	0.483	0
F shrinkage r	0	0.5				0	0

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
149622	0.27	0.09	5	0.318	0

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

Year class = 1995

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	199736	0.3	0.293	0.98	4	0.431	0.001
EU Survey	273363	0.306	0.223	0.73	3	0.413	0.001
F shrinkage r	117876	0.5				0.155	0.002

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
209505	0.2	0.19	8	0.949	0.001

Table 7e(cont). The XSA estimates of survivors at the beginning of 2000 derived from each survey, their standard errors and the combined weighted average; for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Age 5 Catchability constant w.r.t. time and dependent on age

Year class = 1994

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	137638	0.257	0.136	0.53	5	0.447	0.014
EU Survey	265165	0.261	0.108	0.41	4	0.433	0.007
F shrinkage n	69047	0.5				0.12	0.028

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
168354	0.17	0.17	10	0.998	0.011

Age 6 Catchability constant w.r.t. time and dependent on age

Year class = 1993

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	85274	0.229	0.145	0.63	6	0.48	0.058
EU Survey	104266	0.247	0.147	0.6	5	0.411	0.048
F shrinkage n	46671	0.5				0.109	0.104

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
86739	0.16	0.12	12	0.728	0.057

Age 7 Catchability constant w.r.t. time and dependent on age

Year class = 1992

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	28447	0.21	0.089	0.43	7	0.481	0.242
EU Survey	35611	0.229	0.138	0.6	6	0.402	0.198
F shrinkage n	23113	0.5				0.117	0.291

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
30383	0.15	0.08	14	0.54	0.228

Age 8 Catchability constant w.r.t. time and dependent on age

Year class = 1991

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	14658	0.202	0.178	0.88	8	0.476	0.21
EU Survey	18508	0.22	0.13	0.59	7	0.397	0.17
F shrinkage n	7456	0.5				0.126	0.379

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
14766	0.14	0.13	16	0.866	0.209

Table 7e(cont). The XSA estimates of survivors at the beginning of 2000 derived from each survey, their standard errors and the combined weighted average; for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Age 9 Catchability constant w.r.t. time and dependent on age

Year class = 1990

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	8196	0.206	0.15	0.73	9	0.431	0.168
EU Survey	5866	0.223	0.185	0.83	8	0.392	0.228
F shrinkage r	3351	0.5				0.176	0.37

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
6139	0.15	0.13	18	0.856	0.219

Age 10 Catchability constant w.r.t. time and dependent on age

Year class = 1989

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	2443	0.237	0.219	0.92	10	0.326	0.208
EU Survey	1493	0.271	0.186	0.69	8	0.424	0.32
F shrinkage r	1708	0.5				0.25	0.285

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
1813	0.19	0.13	19	0.68	0.271

Age 11 Catchability constant w.r.t. time and dependent on age

Year class = 1988

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	1022	0.265	0.23	0.87	11	0.274	0.265
EU Survey	784	0.272	0.298	1.1	9	0.437	0.334
F shrinkage r	818	0.5				0.289	0.322

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
853	0.2	0.15	21	0.764	0.31

Age 12 Catchability constant w.r.t. time and age (fixed at the value for age) 11

Year class = 1987

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	1	0	0	0	0	0	0
CAN RV	697	0.295	0.182	0.62	12	0.265	0.335
EU Survey	455	0.279	0.267	0.96	9	0.41	0.476
F shrinkage r	844	0.5				0.325	0.284

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
623	0.21	0.14	22	0.667	0.368

Age 13 Catchability constant w.r.t. time and age (fixed at the value for age) 11

Year class = 1986

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV	175	0.895	0	0	1	0.004	0.559

Table 8. The estimates of fishing mortality at age derived from an XSA model fitted to the data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

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Terminal Fs derived using XSA with final year & oldest age shrinkage.

Table 8 Fishing mortality (F) at age

YEAR		1975	1976	1977	1978	1979
	5	0.0068	0.0003	0.0082	0.0491	0.0567
	6	0.0998	0.0153	0.1302	0.1714	0.1984
	7	0.3065	0.1589	0.4055	0.3622	0.4278
	8	0.4455	0.5317	0.6506	0.5596	0.4537
	9	0.5461	0.7369	0.6245	0.5739	0.1524
	10	0.5047	0.6811	0.4426	0.7327	0.1731
	11	0.3398	0.5005	0.1266	0.6642	0.3058
	12	0.2821	0.2022	0.1329	0.3217	0.271
	13	0.3128	0.3536	0.1302	0.3515	0.1991
+gp		0.3128	0.3536	0.1302	0.3515	0.1991
FBAR 5-10		0.3182	0.354	0.3769	0.4082	0.2437

YEAR		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	5	0.0046	0.0204	0.008	0.0172	0.017	0.0376	0.0053	0.0023	0.0048	0.0026
	6	0.0643	0.1297	0.0695	0.1386	0.0729	0.1319	0.0544	0.0451	0.0685	0.0399
	7	0.33	0.4801	0.2699	0.4694	0.3543	0.2678	0.233	0.4084	0.2756	0.2273
	8	0.6776	0.9104	0.5839	0.598	0.8524	0.3725	0.39	0.5919	0.2813	0.2276
	9	0.9596	0.7481	0.8237	0.4874	0.7847	0.3498	0.2632	0.3922	0.1533	0.1442
	10	1.0738	0.3921	0.7583	0.3641	0.5461	0.2013	0.1918	0.2402	0.1011	0.1284
	11	0.6659	0.1712	0.4986	0.1887	0.3791	0.1189	0.1391	0.2365	0.0814	0.1306
	12	0.2167	0.1768	0.2589	0.1061	0.1907	0.1473	0.1459	0.2355	0.0933	0.148
	13	0.1453	0.1046	0.3162	0.1619	0.2116	0.1697	0.1474	0.3686	0.1318	0.1803
+gp		0.1453	0.1046	0.3162	0.1619	0.2116	0.1697	0.1474	0.3686	0.1318	0.1803
FBAR 5-10		0.5183	0.4468	0.4189	0.3458	0.4379	0.2268	0.1896	0.28	0.1474	0.1284

YEAR		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	FBAR 97-99
	4	0.0012	0.0034	0.019	0.0182	0.0948	0.0051	0.0022	0.0021	0.0024	0.0013	0.0019
	5	0.0145	0.0462	0.0818	0.2366	0.4557	0.0309	0.0324	0.027	0.0284	0.0115	0.0223
	6	0.1286	0.1344	0.2488	0.5057	0.7738	0.1055	0.1595	0.1066	0.0998	0.057	0.0878
	7	0.3798	0.3948	0.6306	0.82	0.8262	0.3407	0.4628	0.3662	0.2115	0.2283	0.2687
	8	0.3783	0.6584	0.7957	0.967	0.8924	0.3566	0.3517	0.4491	0.3032	0.209	0.3204
	9	0.3532	0.7571	0.6099	0.8322	0.7229	0.3696	0.2677	0.3657	0.3697	0.2188	0.3181
	10	0.4216	0.6401	0.4171	0.5709	0.4729	0.2575	0.2648	0.2714	0.2959	0.2708	0.2794
	11	0.3048	0.5866	0.3536	0.4755	0.5367	0.2627	0.342	0.369	0.2704	0.3102	0.3165
	12	0.4222	0.5792	0.4872	0.6804	0.3531	0.3454	0.2848	0.3299	0.2344	0.3679	0.3107
	13	0.3807	0.5184	0.373	0.5388	0.5028	0.3676	0.3065	0.27	0.1966	0.3433	0.27
+gp		0.3807	0.5184	0.373	0.5388	0.5028	0.3676	0.3065	0.27	0.1966	0.3433	
FBAR 5-10		0.2793	0.4385	0.464	0.6554	0.6907	0.2435	0.2565	0.2643	0.2181	0.1659	

Table 9. The estimates of population numbers at age derived from an XSA model fitted to the data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

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Terminal Fs derived using XSA with final year & oldest age shrinkage.

Table 10 Stock number at age (start of year) Numbers*10**-3

YEAR	1975	1976	1977	1978	1979
1	106511	112089	105011	83225	101056
2	125261	87204	91771	85975	68139
3	108448	102555	71397	75136	70391
4	67727	88790	83965	58455	61516
5	54596	55450	72695	68745	47859
6	32800	44397	45383	59034	53585
7	24072	24304	35797	32622	40719
8	15235	14506	16975	19538	18592
9	10404	7989	6979	7251	9141
10	4707	4934	3130	3060	3344
11	2693	2327	2044	1646	1204
12	607	1570	1155	1475	694
13	1148	375	1050	828	875
+gp	1177	195	757	955	1730
TOTAL	555386	546684	538109	497943	478843

YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	131332	132042	130318	144880	153369	168685	187923	156209	131283	113870
2	82737	107526	108107	106696	118618	125568	138108	153858	127893	107485
3	55787	67740	88034	88511	87355	97116	102806	113073	125968	104710
4	57631	45675	55460	72077	72466	71520	79512	84171	92576	103134
5	50365	47184	37395	45407	59011	59330	58556	65099	68913	75795
6	37024	41046	37850	30373	36542	47498	46781	47688	53174	56154
7	35975	28426	29519	28909	21649	27815	34084	36274	37323	40653
8	21734	21175	14400	18450	14801	12437	17423	22105	19742	23195
9	9670	9037	6975	6575	8307	5167	7015	9658	10013	12200
10	6426	3033	3501	2506	3307	3103	2982	4415	5342	7033
11	2303	1798	1678	1343	1426	1568	2077	2015	2843	3953
12	726	969	1240	834	910	799	1140	1480	1302	2145
13	433	479	665	784	614	616	564	807	957	971
+gp	220	765	773	1288	1055	606	940	1242	1150	473
TOTAL	492364	506892	515917	548632	579430	621829	679912	698093	678481	651773

YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	GMST 75-97
1	112913	120073	128625	176114	314350	464030	466859	272629	172390	157731	0	154560
2	93229	92446	98308	105309	144190	257368	379915	382232	223210	141141	129140	123404
3	88002	76329	75688	80488	86220	118053	210715	311048	312945	182749	115557	96485
4	85729	72050	62493	61968	65898	70591	96653	172519	254665	256218	149622	74575
5	84439	70103	58790	50202	49821	49071	57503	78961	140944	208003	209505	58220
6	61892	68136	54806	44351	32443	25860	38952	45578	62926	112160	168354	44044
7	44176	44558	48767	34989	21899	12252	19054	27189	33544	46627	86739	30404
8	26515	24738	24581	21252	12616	7848	7135	9821	15434	22227	30383	16678
9	15124	14871	10485	9081	6616	4232	4498	4110	5131	9331	14766	8010
10	8648	8698	5710	4665	3235	2629	2394	2818	2334	2903	6139	4009
11	5064	4644	3755	3081	2158	1651	1664	1504	1759	1421	1813	2179
12	2840	3057	2115	2158	1568	1033	1039	968	851	1099	853	1254
13	1515	1525	1402	1064	895	902	599	640	570	551	623	801
+gp	1101	1141	1180	478	595	717	370	413	308	570	651	
TOTAL	631188	602369	576705	595200	742504	1016235	1287350	1310430	1227011	1142732	914146	

Table 10. The XSA summary table of population and exploitation trends.

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Table 16 Summary (without SOP correction)

Terminal Fs derived using XSA with final year & oldest age shrinkage.

	RECRUITS Age 1	BIOMASS 5+	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 5-10
1975	106511	146691	7392	28814	3.898	0.3182
1976	112089	145539	2322	24611	10.599	0.354
1977	105011	169115	5804	32048	5.522	0.3769
1978	83225	177608	6400	39070	6.105	0.4082
1979	101056	172211	10182	34104	3.349	0.2437
1980	131332	131631	1829	32867	17.970	0.5183
1981	132042	118486	5855	30754	5.253	0.4468
1982	130318	121112	6178	26278	4.254	0.4189
1983	144880	121321	8697	27861	3.203	0.3458
1984	153369	113342	7452	26711	3.584	0.4379
1985	168685	141382	4748	20347	4.285	0.2268
1986	187923	132160	6999	17976	2.568	0.1896
1987	156209	155269	8310	32442	3.904	0.28
1988	131283	163517	8858	19215	2.169	0.1474
1989	113870	181972	5432	19230	3.540	0.1284
1990	112913	208149	9412	45421	4.826	0.2793
1991	120073	227172	10861	69194	6.371	0.4385
1992	128625	194124	9589	62362	6.503	0.464
1993	176114	149177	5526	63540	11.499	0.6554
1994	314350	104345	5082	46038	9.059	0.6907
1995	464030	83122	5998	15085	2.515	0.2435
1996	466859	95281	3401	17714	5.208	0.2565
1997	272629	109193	5276	19194	3.638	0.2643
1998	172390	160633	2656	19858	7.476	0.2181
1999	157731	236550	3025	23492	7.766	0.1659
Arith. Mean	173741	201160	6291	31769	0.2812	0.3407
	(Thousands)	(Tonnes)	(Tonnes)	(Tonnes)		