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An Assessment of Stock Status of the Greenland Halibut Resource in NAFO Subarea 2 and Divisions 3KLMNO based on Extended Survivors Analysis

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Abstract

An Extended Survivors Analysis was applied to the commercial catch at age data for Greenland Halibut in NAFO Subarea 2 and Divisions 3KLMNO from 1975-2000 to assess the current status of the stock. The analysis was calibrated using Canadian and European Union research vessel survey data. Stock biomass at ages 5 and older is estimated to have increased during the late-1980s and then declined rapidly during the period of high landings in the early-1990s. Estimated fishing mortality has followed the trend in landings, increasing rapidly in the early-1990s, 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 better than average recruitment of the 1993-1995 year-classes. However, the assessment is considered to be very uncertain with respect to absolute estimates of stock size and it does not match the historic trends in the stock as illustrated by the longest survey series. Nevertheless, the trend in the recent years is believed to be reflective of the stock trajectory.

Data

Revised catch number, weight and maturity at age data for the Greenland Halibut in Subarea 2 and Divisions 3KLMNO for 1975-1999, were presented in detail at the June 2000 meeting of the NAFO Scientific Council (Bowering and Brodie 2000) with an update to include 2000 data presented here. The data sets are listed in Tables 1 and 2. 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 3 and 4. Catch weights at age and stock weight at age are the same and based on commercial data. In the absence of an agreed maturity ogive, the 10+ biomass is used as a proxy for spawning stock biomass. The 5+ biomass was used as an estimate of exploitable biomass. As in previous assessments of this stock, natural mortality was assumed to be constant at age and in all years at 0.2.

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

The details of the methodology of the Extended Survivor Analysis (Shepherd, 1999; Darby and Flatman, 1994) was described in detail in the 2000 assessment document (Darby and Mahé, 2000) and therefore won't be repeated here.

A full investigation of the possible formulation was conducted in 2000. For the 2001 assessment, inclusion or not of the ages 1 and 2 from the survey data as well as the number of years used for the F shrinkage was investigated with respect to estimation of recruitment and the retrospective pattern. The results of the investigation showed that an extension of the year range to 5 years reduced the retrospective pattern. The inclusion of ages 1 and 2 in the calibration data provides 3 estimates of the age 3 survivors at the end of the final

year which is the incoming recruitment. The retrospective pattern of the age 3 estimates is improved with the inclusions of ages 1 and 2 as well as the retrospective pattern in the biomass and F estimates. (Fig. 1).

Therefore the final setting for the XSA were left identical to the 2000 assessment except for the inclusion of age 1 in the EU survey and a shrinkage extended from 2 to 5 years (Table 5a). 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 five 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.

The log catchability estimates, the associated standard errors and the log catchability residuals for the two Canadian survey periods and the EU survey are given in Tables 5 b-c. The log catchability residuals are plotted in Fig. 2 and 3.

The log standard errors of catchability, approximations to the coefficient of variation of the original data, are generally above 0.5 (50%) except for ages 4 to 7 in the Canadian survey and ages 1 and 2 in the EU survey, indicating a relatively poor model fit. The details of the estimation of survivors by fleet are given in Tables 5d. The EU survey is given most of the weight in the estimates of survivors of the 1997 to 1999 year-classes. For those ages, the Canadian survey estimates are much higher. Except for the year-classes 1991 to 1993, the estimates of survivors are not consistent among fleets.

The results of this assessment are given in Tables 6, 7 and 8. Although showing improvement in terms of retrospective pattern, they are still considered to be indicative of trends recent stock dynamics rather than providing absolute estimates of stock size and fishing mortality. Figure 4 illustrates the estimated stock trends and Fig. 5, the stock and recruitment plot using the 10+ biomass as a proxy for spawning stock biomass (SSB).

Stock biomass at ages 5 and older is estimated to have increased during the late-1980s and then declined rapidly during the period of high landings in the early-1990s. Estimated fishing mortality has followed the trend in landings, increasing rapidly in the early-1990s, 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 above average recruitment of the 1993-1995 year-classes.

Currently the stock biomass is estimated to be close to its historically highest level. However, the assessment is noisy and the data have been manipulated to meet model assumptions. Recent absolute 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 Mahé (2001).

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

	Year								
Age	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	334	17	534	2982	2386	209	863	269	701
6	2819	610	5012	8415	8727	2086	4517	2299	3557
7	5750	3231	10798	8970	12824	9150	9806	6319	9800
8	4956	5413	7346	7576	6136	9679	11451	5763	7514
9	3961	3769	2933	2865	1169	5398	4307	3542	2295
10	1688	2205	1013	1438	481	3828	890	1684	692
11	702	829	220	723	287	1013	256	596	209
12	135	260	130	367	149	128	142	256	76
13	279	101	116	222	143	53	43	163	106
+gp	288	53	84	258	284	27	69	191	175
Total Nb	20912	16488	28186	33816	32586	31571	32344	21082	25125
Landings (t)	**28814**	**24611**	**32048**	**39070**	**34104**	**32867**	**30754**	**26278**	**27861**

	Year								
Age	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	95	220	1064
5	902	1983	280	137	296	181	1102	2862	4180
6	2324	5309	2240	1902	3186	1988	6758	7756	10922
7	5844	5913	6411	11004	8136	7480	12632	13152	20639
8	7682	3500	5091	8935	4380	4273	7557	10796	12205
9	4087	1380	1469	2835	1288	1482	4072	7145	4332
10	1259	512	471	853	465	767	2692	3721	1762
11	407	159	244	384	201	438	1204	1865	1012
12	143	99	140	281	105	267	885	1216	738
13	106	87	70	225	107	145	434	558	395
+gp	183	86	117	349	129	71	318	422	335
Total Nb	22937	19028	16533	26905	18293	17092	37749	49713	57584
Landings (t)	**26711**	**20347**	**17976**	**32442**	**19215**	**20034**	**47454**	**65008**	**63193**

	Year							
Age	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	1010	5395	323	190	335	552	297	271
5	9570	16500	1352	1659	1903	3575	2149	2029
6	15928	15815	2342	5197	4169	5407	5625	12583
7	17716	11142	3201	6387	7544	5787	8611	21175
8	11918	6739	2130	1914	3215	3653	3793	3299
9	4642	3081	1183	956	1139	1435	1659	973
10	1836	1103	540	504	606	541	623	528
11	1055	811	345	436	420	377	343	368
12	964	422	273	233	246	161	306	203
13	401	320	251	143	137	92	145	129
+gp	182	215	201	89	89	51	151	104
Total Nb	65222	61543	12141	17708	19803	21631	23702	41662
Landings (t)	**62455**	**51029**	**15272**	**18840**	**19858**	**19946**	**24226**	**34177**

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**
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126
4	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244
5	0.609	0.609	0.609	0.609	0.609	0.514	0.392	0.525	0.412
6	0.76	0.76	0.76	0.76	0.76	0.659	0.598	0.684	0.629
7	0.955	0.955	0.955	0.955	0.955	0.869	0.789	0.891	0.861
8	1.19	1.19	1.19	1.19	1.19	1.05	0.985	1.13	1.18
9	1.58	1.58	1.58	1.58	1.58	1.15	1.24	1.4	1.65
10	2.21	2.21	2.21	2.21	2.21	1.26	1.7	1.79	2.23
11	2.7	2.7	2.7	2.7	2.7	1.57	2.46	2.38	3.01
12	3.37	3.37	3.37	3.37	3.37	2.71	3.51	3.47	3.96
13	3.88	3.88	3.88	3.88	3.88	3.12	4.79	4.51	5.06
+gp	5.764	5.144	5.992	5.894	6.077	5.053	7.426	7.359	7.061

	Year								
Age	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0.126	0.126	0.126	0.126	0.126	0.126	0.09	0.126	0.175
4	0.244	0.244	0.244	0.244	0.244	0.244	0.181	0.244	0.289
5	0.377	0.568	0.35	0.364	0.363	0.4	0.338	0.383	0.43
6	0.583	0.749	0.584	0.589	0.569	0.561	0.546	0.592	0.577
7	0.826	0.941	0.811	0.836	0.805	0.767	0.766	0.831	0.793
8	1.1	1.24	1.1	1.16	1.163	1.082	1.119	1.228	1.234
9	1.46	1.69	1.58	1.59	1.661	1.657	1.608	1.811	1.816
10	1.94	2.24	2.12	2.13	2.216	2.237	2.173	2.461	2.462
11	2.63	2.95	2.89	2.82	3.007	2.997	2.854	3.309	3.122
12	3.49	3.71	3.89	3.6	3.925	3.862	3.731	4.142	3.972
13	4.49	4.85	4.95	4.63	5.091	4.919	4.691	5.333	5.099
+gp	7.016	7.01	7.345	6.454	7.164	6.37	6.391	7.081	6.648

	Year							
Age	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0.134	0.08	0.08	0.161	0.12	0.119	0.176	0
4	0.232	0.196	0.288	0.242	0.206	0.228	0.253	0.254
5	0.368	0.33	0.363	0.36	0.336	0.373	0.358	0.346
6	0.547	0.514	0.531	0.541	0.489	0.543	0.533	0.524
7	0.809	0.788	0.808	0.832	0.771	0.81	0.825	0.787
8	1.207	1.179	1.202	1.272	1.159	1.203	1.253	1.192
9	1.728	1.701	1.759	1.801	1.727	1.754	1.675	1.774
10	2.309	2.268	2.446	2.478	2.355	2.351	2.287	2.279
11	2.999	2.99	3.122	3.148	3.053	3.095	2.888	2.895
12	3.965	3.766	3.813	3.856	3.953	4.01	3.509	3.645
13	4.816	4.882	4.893	4.953	5.108	5.132	4.456	4.486
+gp	6.489	6.348	6.79	6.312	6.317	6.124	5.789	5.531

Table 3. 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**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1991	1	349	-1	235	993	1956	1253	2283	545	464	388	122	-1
1992	1	922	800	286	861	1600	1996	1793	991	473	266	139	67
1993	1	937	933	599	566	960	1574	1732	1388	905	257	141	51
1994	1	832	706	1082	1224	1365	2233	2096	1213	689	264	95	54
1995	1	6165	1394	1369	1249	1709	3793	3026	1729	1134	254	68	26
1996	1	2874	4613	1527	2066	3070	4394	2020	1378	392	75	31	35
1997	1	1597	2113	4396	5157	5216	6045	3885	1709	593	200	33	22
1998	1	1434	1268	5149	7835	9168	8821	6334	2339	703	201	27	6
1999	1	525	426	1904	7178	9818	9599	4382	1544	322	101	8	4
2000	1	1602	147	312	1405	5557	11591	4093	1701	351	98	49	-1

Table 4. 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	0.1

		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
2000	1	322796	182144	139877	99212	111556	65480	19417	3379	670	210	165	17	20	54	-1	-1

Table 5a. 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

G. halibut SA2+3KLMNO Index file: (Combined sexes with plus group)

CPUE data from file GhalTUN2.dat

Catch data for 26 years. 1975 to 2000. Ages 1 to 14.

Fleet	First year	Last year	First age	Last age	Alpha	Beta
CAN RV1	1978	2000	1	13	0.8	1
CAN RV2	1989	2000	1	13	0.8	1
EU Survey	1991	2000	1	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 final 5 years.
S.E. of the mean to which the estimates are shrunk = .500

Oldest age survivor estimates for the years 1975 to 2000
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 71 iterations

Tuning series weights

1	1	1	1	1	1	1	1	1	1

Table 5b. The diagnostics of the XSA fit to the Canadian survey catch per unit effort data for the years 1978 – 1987 (CAN RV1) and 1988-2000 (CAN RV2), for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Log catchability residuals.

Fleet : CAN RV1

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	0.63	0.57	-0.17	0.9	-0.52	-1.65	-0.75	0.96	0.42	-0.63	0.26
2	1.57	0.91	-0.31	0.65	-0.75	-0.87	-0.6	0.15	-0.02	-0.39	-0.33
3	1.04	0.19	-0.37	0.36	-0.12	-0.36	-0.36	-0.54	-0.05	0.49	-0.28
4	0.8	-0.28	-0.46	-0.18	0.23	-0.04	-0.06	-0.37	0.18	0.06	0.12
5	0.03	-0.15	-0.28	-0.24	0.17	0.21	0.31	-0.13	-0.06	-0.13	0.28
6	-0.08	-0.25	0.02	-0.04	-0.2	0.31	0.24	0.15	0.25	-0.21	-0.2
7	-0.05	-0.74	-0.42	0.03	0.04	0.42	0.43	0.11	0.38	0.04	-0.24
8	-0.16	-0.84	-0.72	-0.13	0.91	0.71	0.84	0.09	0.02	0.11	-0.83
9	0.34	-1.03	-0.3	-0.14	1.07	0.71	0.74	0.39	-0.24	-0.08	-1.46
10	1.07	-0.03	-0.12	0.17	0.69	0.32	0.5	0.31	-0.38	-0.63	-1.89
11	1.57	0.51	0.53	-0.05	0.61	0.13	0.12	-0.4	-0.6	-0.6	-1.82
12	0.86	1.31	0.9	-0.1	0.16	0.36	-0.08	0.2	-0.38	-0.39	-1.43
13	1.26	0.71	1.42	0.01	0.61	0.02	0.31	-0.48	-0.29	-0.7	-1.43

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 q	-0.6432	-0.0674	0.324	0.2802	0.4616	0.5468	0.7754	0.7943	0.6588	0.6663	0.8805	0.8805	0.8805
S.E(Log q)	0.8177	0.7589	0.4757	0.3488	0.2097	0.2077	0.3617	0.6314	0.7628	0.7885	0.872	0.7631	0.8608

Fleet : CAN RV2

Age	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	-0.6	-2.27	0	-0.39	-0.57	0.54	-0.03	1.08	0.42	0.67	0.69	0.47
2	-0.59	-1.33	-0.92	0.35	0.83	0.09	0.19	-0.2	0.14	-0.05	0.59	0.9
3	0	-0.72	-1.04	0.17	1.5	0.51	-0.16	-0.02	-0.14	-0.28	0.13	0.05
4	0.14	0.35	-0.01	0.07	0.72	0.45	-0.62	-0.07	-0.03	-0.56	-0.11	-0.32
5	0.24	0.21	-0.14	-0.46	-0.05	0.35	0.15	0.22	0.35	-0.27	-0.24	-0.35
6	0.67	0.45	-0.2	-0.48	-0.5	-0.27	-0.18	0.04	0.56	0.15	0.3	-0.54
7	0.58	0.58	-0.49	-0.54	-0.61	-0.37	-0.47	-0.07	0.7	0.46	0.64	-0.41
8	0.5	0.06	-0.58	-1.25	-0.33	-0.24	-0.57	0.24	1.08	0.86	0.56	-0.35
9	0.68	0	-0.47	-1.78	-0.92	-0.98	-0.4	0.97	1.44	0.87	0.86	-0.26
10	0.36	0.39	-0.3	-1.33	-2.02	-0.97	-0.52	0.89	1.09	1.45	0.85	0.13
11	0.98	0.98	0.02	-2.7	-1.79	-1.91	-0.56	0.83	1.44	1.16	0.87	0.68
12	0.3	1.24	-0.03	99.99	0.22	-1.47	99.99	0.78	1.22	1.29	0.79	-0.68
13	-0.18	1.3	-0.81	99.99	0.03	-1.38	99.99	1.37	1.11	1.58	1.99	-0.08

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 q	0.0231	0.6713	0.691	0.5652	0.3045	-0.0159	-0.2436	-0.9922	-1.8105	-2.2613	-2.5268	-2.5268	-2.5268
S.E(Log q)	0.8921	0.6783	0.6245	0.3928	0.2854	0.4263	0.5407	0.6759	0.9716	1.056	1.4054	0.9817	1.2398

Table 5c. Diagnostics of the fit to the European Union survey data for the years 1991 - 2000, for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

Fleet : EU Survey

Age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	-0.8	0.25	-0.08	-0.84	0.65	0.15	0.18	0.43	0.2	-0.14
2	99.99	0.27	0.49	-0.12	-0.09	0.59	0.08	0.18	-0.55	-0.84
3	-1.13	-0.92	-0.07	0.6	0.5	-0.04	0.5	0.92	0.55	-0.91
4	-0.45	-0.45	-0.86	0.09	0.12	0.28	0.56	0.46	0.63	-0.38
5	-0.46	-0.45	-0.72	-0.24	-0.03	0.53	0.71	0.63	0.17	-0.14
6	-1.53	-0.79	-0.65	0.16	0.55	0.54	0.8	0.82	0.22	-0.12
7	-0.75	-0.95	-0.54	0.16	0.84	0.05	0.61	0.92	0.19	-0.53
8	-1.48	-0.8	-0.21	0.14	0.73	0.58	0.52	0.77	0.04	-0.31
9	-0.89	-0.6	0.31	0.32	1.08	-0.03	0.51	0.45	-0.35	-0.79
10	-0.08	-0.16	0.08	0.42	0.5	-0.6	0.3	0.49	-0.45	-0.5
11	0.15	0.35	0.63	0.61	0.4	-0.31	-0.11	-0.41	-1.41	0.1
12	99.99	0.3	0.1	0.29	-0.05	0.21	-0.1	-1.29	-1.71	99.99
13	No data for this fleet at this age									

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

Age	1	2	3	4	5	6	7	8	9	10	11	12
Mean Log q	-4.7404	-4.7737	-4.5314	-3.7063	-2.9831	-2.2754	-1.8961	-1.8645	-2.0486	-2.5524	-3.3255	-3.3255
S.E(Log q)	0.4853	0.467	0.7432	0.5057	0.4953	0.7739	0.668	0.7247	0.644	0.4242	0.6105	0.8328

Table 5d. 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 = 1999

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV1	1	0	0	0	0	0	0
CAN RV2	309156	0.929	0	0	1	0.231	0
EU Survey	167612	0.509	0	0	1	0.769	0
F shrinkage mean	0	0.5				0	0

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
193074	0.45	0.26	2	0.578	0

Age 2 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 RV1	1	0	0	0	0	0	0
CAN RV2	84206	0.562	0.105	0.19	2	0.287	0
EU Survey	26495	0.357	0.52	1.46	2	0.713	0
F shrinkage mean	0	0.5				0	0

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
36927	0.3	0.4	4	1.314	0

Age 3 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 RV1	1	0	0	0	0	0	0
CAN RV2	95408	0.425	0.202	0.47	3	0.368	0
EU Survey	52841	0.324	0.386	1.19	3	0.632	0
F shrinkage mean	0	0.5				0	0

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
65671	0.26	0.24	6	0.95	0

Age 4 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 RV1	1	0	0	0	0	0	0
CAN RV2	71706	0.324	0.149	0.46	4	0.358	0.003
EU Survey	82253	0.277	0.174	0.63	4	0.491	0.003
F shrinkage mean	70103	0.5				0.151	0.003

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
76442	0.19	0.1	9	0.496	0.003

Table 5d (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 = 1995

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV1	1	0	0	0	0	0	0
CAN RV2	106153	0.272	0.194	0.71	5	0.394	0.017
EU Survey	146219	0.244	0.172	0.7	5	0.488	0.012
F shrinkage mean	52699	0.5				0.118	0.034

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
114224	0.17	0.15	11	0.889	0.016

Age 6 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 RV1	1	0	0	0	0	0	0
CAN RV2	77990	0.239	0.086	0.36	6	0.436	0.136
EU Survey	169115	0.234	0.105	0.45	6	0.453	0.065
F shrinkage mean	77700	0.5				0.111	0.137

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
110727	0.16	0.13	13	0.797	0.098

Age 7 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 RV1	1	0	0	0	0	0	0
CAN RV2	34157	0.22	0.114	0.52	7	0.435	0.445
EU Survey	34526	0.222	0.221	0.99	7	0.423	0.441
F shrinkage mean	38077	0.5				0.142	0.408

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
34847	0.15	0.11	15	0.702	0.438

Age 8 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 RV1	1	0	0	0	0	0	0
CAN RV2	13488	0.213	0.128	0.6	8	0.437	0.2
EU Survey	14998	0.216	0.139	0.64	8	0.416	0.182
F shrinkage mean	5634	0.5				0.147	0.425

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
12394	0.15	0.12	17	0.813	0.216

Table 5d (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 = 1991

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV1	1	0	0	0	0	0	0
CAN RV2	6435	0.214	0.163	0.76	9	0.401	0.128
EU Survey	6212	0.217	0.19	0.88	9	0.427	0.133
F shrinkage mean	1865	0.5				0.172	0.387

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
5123	0.15	0.16	19	1.051	0.159

Age 10 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 RV1	1	0	0	0	0	0	0
CAN RV2	2777	0.249	0.137	0.55	10	0.289	0.159
EU Survey	1400	0.25	0.149	0.6	10	0.464	0.294
F shrinkage mean	1371	0.5				0.247	0.299

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
1698	0.18	0.11	21	0.602	0.248

Age 11 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 RV1	1	0	0	0	0	0	0
CAN RV2	1427	0.267	0.212	0.79	11	0.262	0.21
EU Survey	911	0.273	0.145	0.53	9	0.457	0.312
F shrinkage mean	813	0.5				0.282	0.343

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
992	0.2	0.11	21	0.557	0.289

Table 5d (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 12 Catchability constant w.r.t. time and age (fixed at the value for age) 11

Year class = 1988

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
CAN RV1	1	0	0	0	0	0	0
CAN RV2	412	0.326	0.248	0.76	12	0.258	0.368
EU Survey	340	0.279	0.314	1.12	9	0.368	0.432
F shrinkage mean	443	0.5				0.374	0.347

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
395	0.23	0.15	22	0.662	0.382

Age 13 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 RV1	335	0.854	0	0	1	0.004	0.299
CAN RV2	316	0.366	0.199	0.54	12	0.23	0.314
EU Survey	190	0.282	0.261	0.93	9	0.336	0.479
F shrinkage mean	290	0.5				0.43	0.338

Weighted prediction :

Survivors at end of year	Int s.e	Ext s.e	N	Var Ratio	F
257	0.25	0.12	23	0.498	0.375

Table 6. 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.

Run title : G. halibut SA2+3KLMNO Index file: (Combined sexes with plus group)

At 5/06/2001 19:55

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

Table 8 Fishing mortality (F) at age

YEAR	1975	1976	1977	1978	1979	1980
AGE						
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0.0067	0.0003	0.0081	0.0488	0.0556	0.0046
6	0.0995	0.0151	0.1298	0.1693	0.197	0.063
7	0.3072	0.1584	0.3994	0.361	0.4205	0.3268
8	0.4617	0.5336	0.6474	0.5459	0.4513	0.6576
9	0.5785	0.7874	0.6286	0.5687	0.1472	0.949
10	0.5687	0.7606	0.4995	0.7422	0.1709	1.0054
11	0.3926	0.6153	0.1495	0.832	0.3124	0.6527
12	0.3256	0.2453	0.1777	0.3983	0.3955	0.2228
13	0.3614	0.4334	0.1643	0.5204	0.2651	0.2367
+gp	0.3614	0.4334	0.1643	0.5204	0.2651	0.2367
FBAR 5-10	0.3371	0.3759	0.3855	0.406	0.2404	0.5011

YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
AGE										
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0.0012
5	0.0209	0.0082	0.0176	0.0173	0.0378	0.0053	0.0023	0.0048	0.0026	0.0146
6	0.1311	0.071	0.1419	0.0747	0.1339	0.0547	0.0452	0.0687	0.0399	0.1287
7	0.4678	0.2736	0.4834	0.3651	0.2758	0.2374	0.4112	0.2766	0.2279	0.3801
8	0.8938	0.559	0.6108	0.9042	0.3891	0.4065	0.609	0.2841	0.2287	0.3796
9	0.7044	0.789	0.4529	0.8194	0.3894	0.2795	0.4172	0.1597	0.1459	0.3554
10	0.3839	0.6701	0.3378	0.4843	0.2159	0.2212	0.2597	0.1095	0.1347	0.4286
11	0.1526	0.4825	0.1563	0.3406	0.101	0.1511	0.2831	0.0892	0.1429	0.3235
12	0.1716	0.2249	0.1016	0.1524	0.1285	0.1214	0.2607	0.1157	0.1642	0.4764
13	0.108	0.3043	0.1364	0.201	0.1305	0.126	0.2923	0.1491	0.2319	0.4373
+gp	0.108	0.3043	0.1364	0.201	0.1305	0.126	0.2923	0.1491	0.2319	0.4373
FBAR 5-10	0.4336	0.3952	0.3407	0.4442	0.2403	0.2008	0.2908	0.1506	0.13	0.2812

YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	FBAR 98-
AGE											
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0.0034	0.0192	0.0184	0.1162	0.0071	0.003	0.0028	0.0027	0.0019	0.0032	0.0026
5	0.0464	0.0831	0.2398	0.4633	0.0385	0.0458	0.037	0.0366	0.013	0.0159	0.0218
6	0.1348	0.25	0.5159	0.7918	0.1078	0.2034	0.1553	0.1404	0.0743	0.0979	0.1042
7	0.3952	0.6332	0.8269	0.86	0.3545	0.4766	0.5107	0.3352	0.347	0.4381	0.3735
8	0.6591	0.7969	0.9761	0.9102	0.3832	0.3721	0.4706	0.5012	0.3839	0.2158	0.367
9	0.7619	0.6112	0.8351	0.7387	0.3833	0.2957	0.397	0.3969	0.4478	0.1586	0.3344
10	0.6468	0.4217	0.573	0.476	0.2666	0.2785	0.3097	0.3323	0.2989	0.2479	0.293
11	0.6028	0.3597	0.4839	0.5402	0.2651	0.3585	0.3958	0.3228	0.3641	0.2894	0.3254
12	0.637	0.5106	0.7004	0.3625	0.3489	0.2883	0.3526	0.2579	0.4743	0.382	0.3714
13	0.6349	0.4361	0.5837	0.53	0.3819	0.3108	0.2744	0.2146	0.391	0.3746	0.3267
+gp	0.6349	0.4361	0.5837	0.53	0.3819	0.3108	0.2744	0.2146	0.391	0.3746	
FBAR 5-10	0.4407	0.466	0.6611	0.7067	0.2556	0.2787	0.3134	0.2904	0.2608	0.1957	

Table 7. 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.

Run title : G. halibut SA2+3KLMNO Index file: (Combined sexes with plus group)

At 5/06/2001 19:55

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	1980
	AGE						
	1	108435	110946	102838	81451	98714	129490
	2	126064	88779	90835	84197	66687	80820
	3	109703	103212	72686	74369	68935	54598
	4	67902	89817	84503	59510	60889	56439
	5	55263	55594	73536	69185	48723	49851
	6	32889	44943	45501	59723	53946	37732
	7	24024	24377	36244	32718	41283	36271
	8	14813	14466	17034	19904	18671	22196
	9	9966	7643	6946	7300	9441	9734
	10	4301	4576	2847	3033	3384	6672
	11	2389	1994	1751	1415	1182	2335
	12	537	1321	882	1234	504	708
	13	1017	317	846	605	679	278
	+gp	1041	165	610	696	1340	141
0	TOTAL	558344	548151	537062	495341	474376	487266

	YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
	AGE										
	1	131363	129930	144571	153291	168587	187447	155589	129449	112545	111476
	2	106018	107551	106378	118365	125504	138027	153469	127385	105984	92144
	3	66170	86800	88055	87095	96909	102754	113007	125650	104294	86772
	4	44701	54175	71066	72094	71307	79342	84128	92522	102873	85389
	5	46208	36598	44355	58184	59025	58381	64960	68878	75751	84226
	6	40626	37051	29721	35680	46821	46531	47545	53061	56125	61856
	7	29005	29174	28255	21115	27110	33530	36070	37206	40560	44152
	8	21417	14874	18168	14266	12000	16845	21651	19575	23100	26439
	9	9415	7173	6964	8076	4729	6657	9185	9642	12063	15046
	10	3085	3811	2668	3625	2914	2623	4121	4955	6728	8536
	11	1999	1721	1596	1558	1828	1922	1721	2603	3636	4815
	12	995	1405	870	1118	907	1353	1353	1062	1949	2581
	13	464	687	918	643	786	653	981	854	774	1354
	+gp	742	799	1510	1105	774	1088	1512	1025	377	983
0	TOTAL	502208	511750	545095	576213	619200	677156	695293	673865	646759	625768

	YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	GMST 75-
	AGE												
	1	99015	91806	129077	245376	411825	316080	170670	119660	55089	235820	0	139555
	2	91269	81067	75164	105680	200897	337173	258785	139733	97970	45103	193074	115465
	3	75441	74724	66372	61539	86523	164480	276054	211875	114404	80211	36927	94369
	4	71043	61766	61179	54341	50384	70839	134665	226014	173469	93666	65671	74302
	5	69825	57966	49607	49175	39609	40959	57826	109951	184545	141755	76442	57434
	6	67961	54578	43676	31955	25332	31206	32033	45622	86786	149148	114224	42875
	7	44528	48624	34802	21347	11853	18621	20847	22454	32460	65964	110727	29512
	8	24719	24556	21135	12463	7396	6808	9466	10242	13148	18784	34847	16166
	9	14809	10469	9061	6520	4106	4128	3842	4841	5080	7332	12394	7714
	10	8634	5659	4652	3219	2550	2292	2515	2115	2665	2658	5123	3813
	11	4553	3702	3039	2147	1637	1599	1420	1510	1242	1618	1698	2089
	12	2853	2040	2115	1534	1024	1028	915	783	895	707	992	1174
	13	1312	1235	1002	860	874	592	631	526	495	456	395	736
	+gp	980	1038	450	572	694	366	407	290	511	365	462	
0	TOTAL	576941	519231	501333	596727	844703	996170	970076	895618	768758	843589	652977	

Table 8. The XSA summary table of population and exploitation trends.

Summary (without SOP correction)

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

	RECRUITS Age 1	TOTALBIO 5+ B	TOTSPBIO 10+B	LANDINGS	YIELD/SSB	FBAR 5-10
1975	108435	142679	27712	28814	4.0031	0.3371
1976	110946	142612	22028	24611	11.5239	0.3759
1977	102838	166156	20933	32048	6.4515	0.3855
1978	81451	175118	21130	39070	7.5439	0.406
1979	98714	170375	23143	34104	4.0246	0.2404
1980	129490	132079	15571	32867	22.0007	0.5011
1981	131363	119451	21389	30754	4.8819	0.4336
1982	129930	122170	24768	26278	3.7289	0.3952
1983	144571	123735	29511	27861	2.4124	0.3407
1984	153291	113333	25672	26711	3.1455	0.4442
1985	168587	141500	24524	20347	3.0231	0.2403
1986	187447	131455	27606	17976	1.9918	0.2008
1987	155589	154329	32806	32442	2.9579	0.2908
1988	129449	158587	34662	19215	2.1652	0.1506
1989	112545	177564	39686	20034	3.981	0.13
1990	111476	204396	54554	47454	4.9075	0.2812
1991	99015	223220	62067	65008	6.0051	0.4407
1992	91806	191085	46794	63193	6.4312	0.466
1993	129077	147458	35989	62455	10.8438	0.6611
1994	245376	102581	27322	51029	9.0282	0.7067
1995	411825	77763	24244	15272	2.4279	0.2556
1996	316080	83130	19917	18840	4.9947	0.2787
1997	170670	88444	19671	19858	4.9328	0.3134
1998	119660	122050	17266	19946	6.3875	0.2904
1999	55089	182078	17992	24226	6.0929	0.2608
2000	235820	231897	17383	34177	10.9524	0.1957
Arith. Mean	151175	147125	28244	32100	6.0323	0.347
Units	(Thousands)	(Tonnes)	(Tonnes)	(Tonnes)		

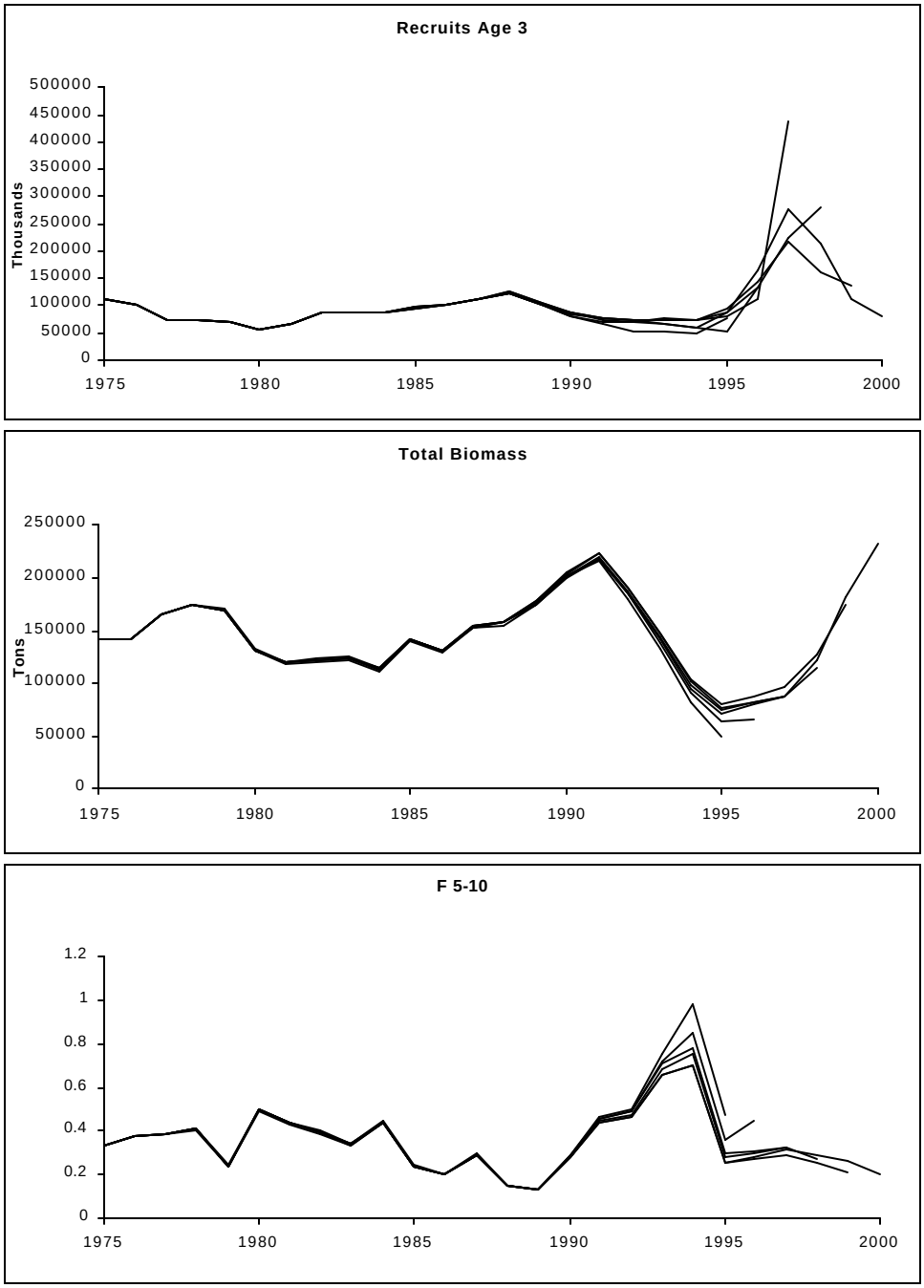

Figure 1. – XSA Retrospective analysis.

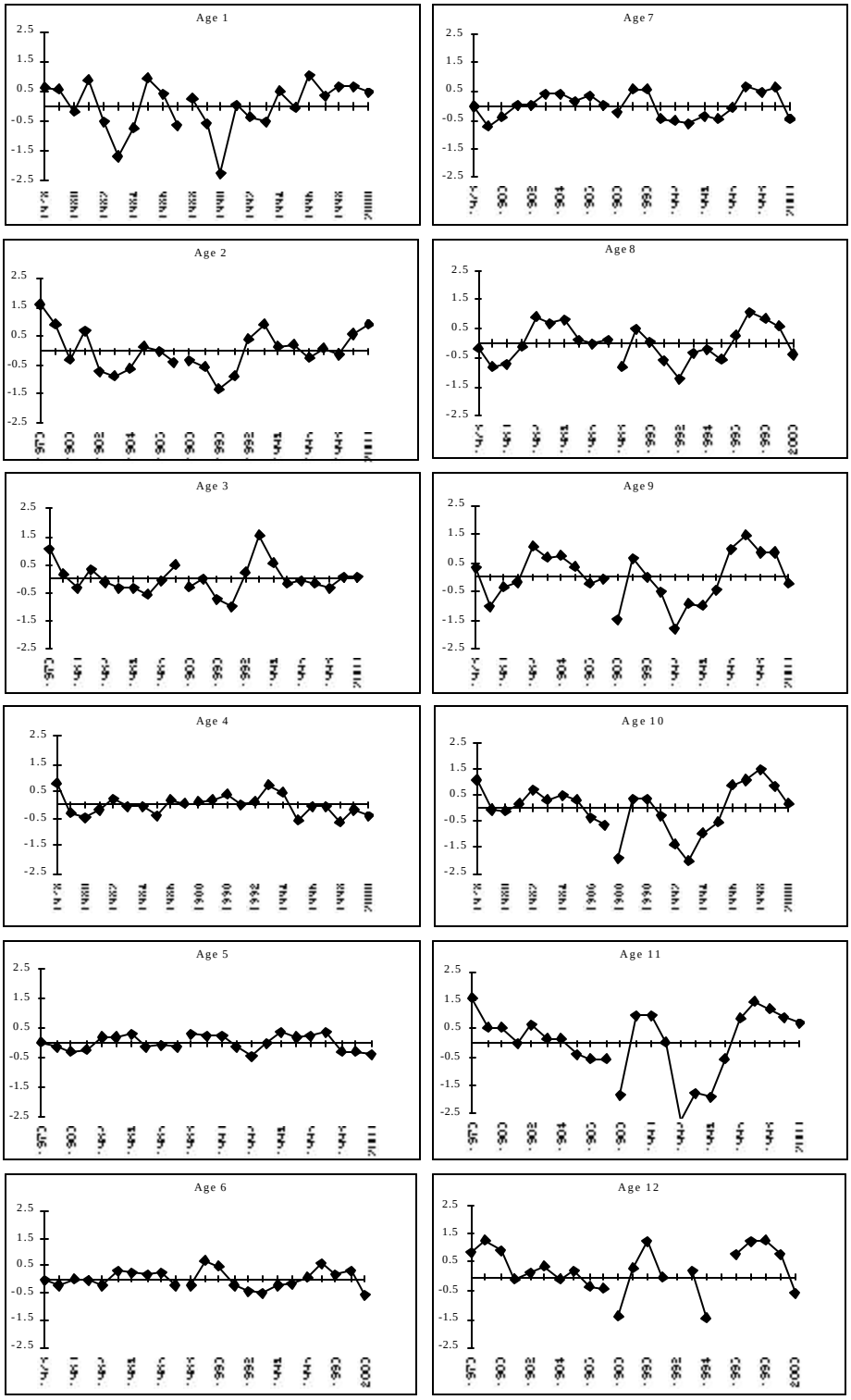

Figure 2. The log catchability residuals for the Canadian R.V survey for the data series 1978 - 1987 and 1998 - 1999, derived from the fit of the final XSA model to the catch at age data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

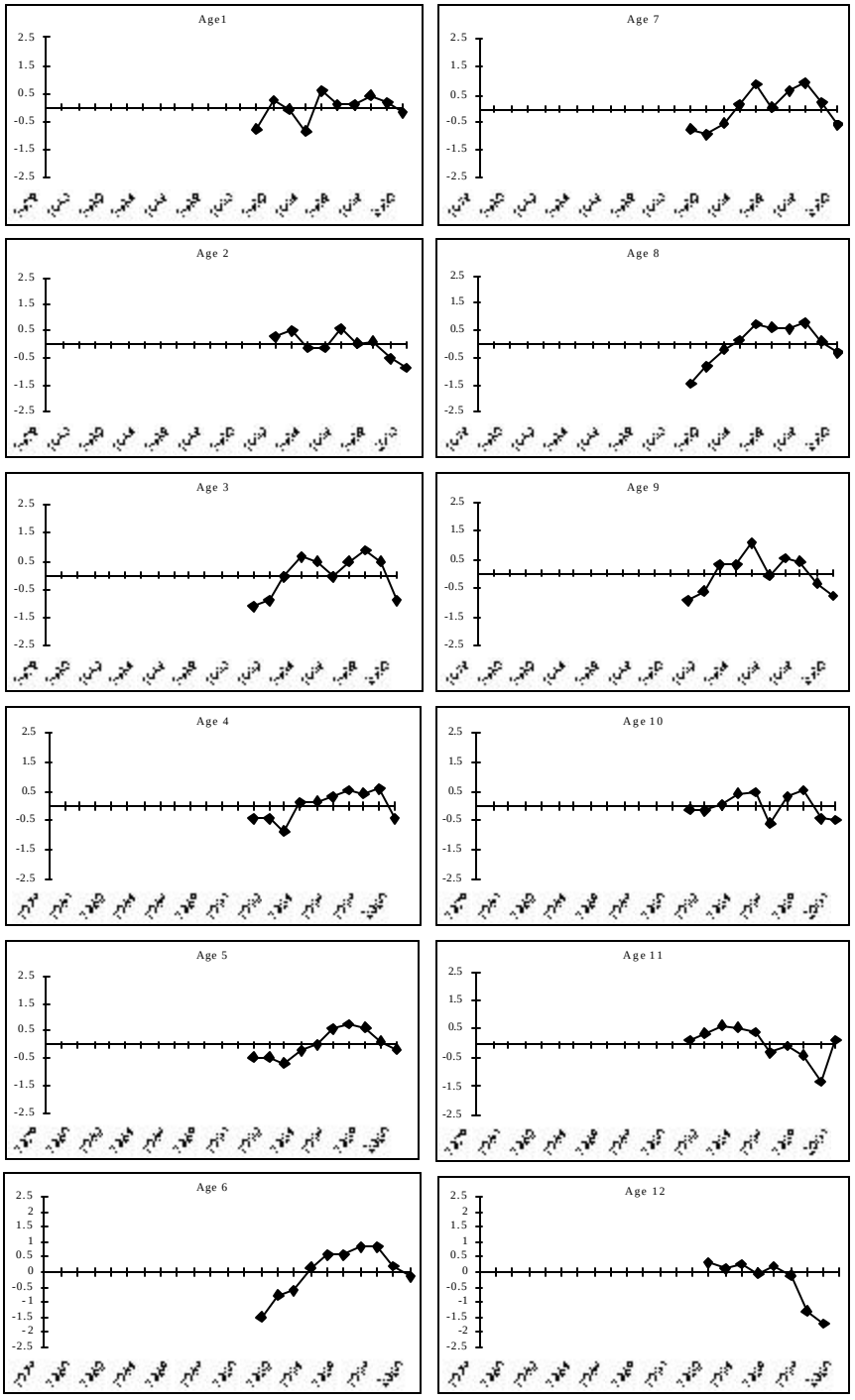

Figure 3. The log catchability residuals for the EU R.V survey derived from the fit of the preliminary XSA based model to the catch at age data for Greenland Halibut in Subarea 2 and Divisions 3KLMNO.

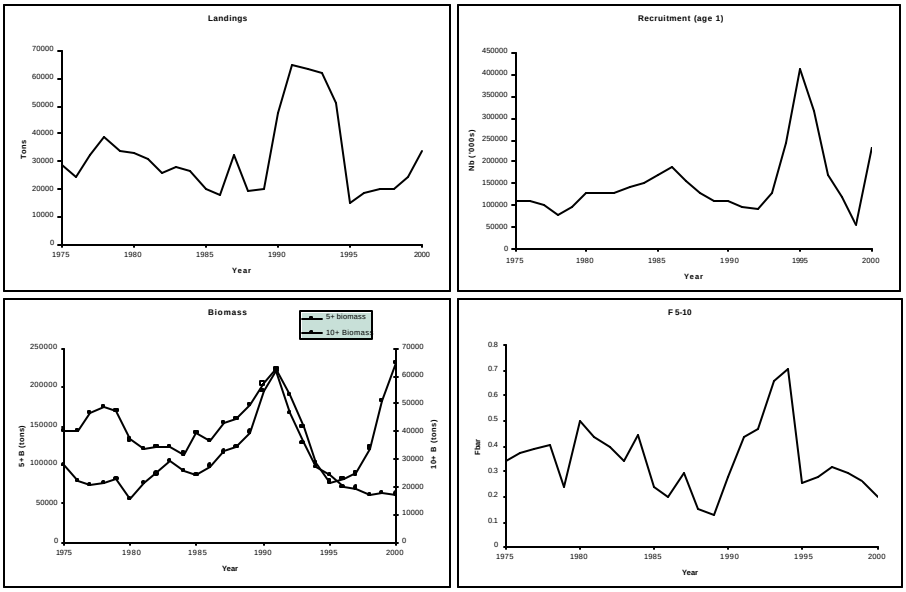

Figure 4. The time series of stock trends for the Greenland Halibut in Subarea 2 and Divisions 3KLMNO

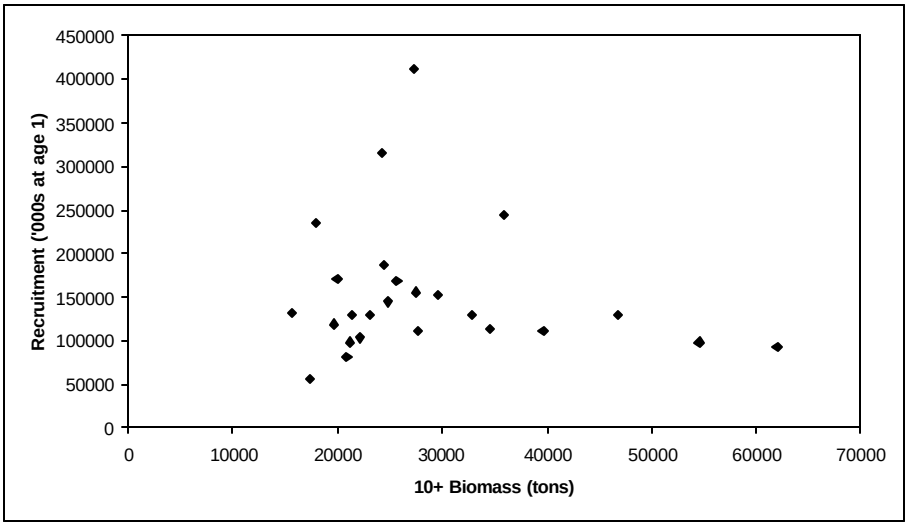

Figure 5. The stock and recruitment plot for the Greenland Halibut in Subarea 2 and Divisions 3KLMNO