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An Assessment of Greenland Halibut *(Reinhardtius hippoglossoides)* in NAFO Subarea 2 and Divisions 3KLMNO.

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Abstract

Recent assessments of this stock have used extended survivors analysis (XSA) to estimate population numbers and fishing mortality. In 2008, the Canadian survey of Divisions 2J3K was not completed and investigations into the comparability of the 2008 data to those of previous years were conducted. Due to the importance of the areas missed during the 2008 survey, it was determined that it would be inappropriate to use the 2008 Canadian survey results for Divs. 2J3K in any XSA analyses. Given the survey-specific weighting used to estimate survivors, and considering the unavailability of the Canadian fall survey data, it was considered inappropriate to update the XSA analysis. Projections from the previous assessment are provided which replace assumed 2008 catches applied in the previous assessment with the actual 2008 catch-at-age. Results indicate that if catches over 2009-2012 are constant at 16 000 tons, the projected exploitable biomass remains stable with minimal recovery. Exploitable biomass is projected to rapidly increase if fishing mortality is reduced to the F0.1 level, but remains well below the Rebuilding Plan target by 2013.

Introduction

Recent assessments of Greenland Halibut in Subarea 2 and Divisions 3KLMNO have been based on the application of the Extended Survivors Analysis model (XSA; Shepherd, 1999) fitted within the Lowestoft assessment suite (Darby and Flatman, 1994).

Results of the 2008 NAFO Scientific Council assessment of this stock indicated that the exploitable (ages 5+) biomass in 2008 was one of the lowest in the estimated time series. Further, estimated average fishing mortality remained relatively high and the strength of recent year-classes was confirmed to be weak (Healey and Mahé, 2008). A retrospective analysis indicated that in the recent past, fishing mortality tended to be over-estimated and biomass under-estimated as estimated magnitude of the 1996-2000 cohorts had been revised upwards with each successive assessment. Three "single index" analyses were considered, tuning the XSA with each of the three data series in turn to evaluate the consistency of the estimates. Further, the 2008 assessment included an evaluation of the shrinkage settings applied in the assessment. Healey (2009a) gives a chronology of the analytical assessments of this resource, with attention given to the model settings applied and/or the data sets used to estimate stock status.

Coverage issues with the 2008 Canadian fall survey led to STACFIS agreeing that these data were not comparable to those of previous years (refer to Healey and Brodie, 2009 for further detail). Hence, it was considered that updating the XSA assessment using the data available would be inappropriate. The XSA model accepted by the Scientific Council in 2008 was used as a basis for projections and provision of advice. We re-evaluate the status of the stock using the most recent survey and catch data.

In 2003, Fisheries Commission established a fifteen year rebuilding plan for this stock (NAFO, 2003a), with the intent to: "*take effective measures to arrest the decline in the exploitable biomass and to ensure the rebuilding of this biomass to reach a level that allows a stable yield of the Greenland halibut fishery over the long term*". The plan states that "*the objective of this programme shall be to attain a level of exploitable biomass 5+ of 140,000 tonnes on average*", and in an attempt to improve the rebuilding prospects for this stock, TACs were set at 20, 19, 18.5, 16 ('000 tons), respectively, for the years 2004-07 (Figure 1). The plan also notes that subsequent TAC levels "*may be adjusted by the Scientific Council advice*" but "*shall not be set at levels beyond 15% less or greater than the TAC of the preceding year*". The 2008 and 2009 TACs were set at 16 Kt.

Input Data

Catches

Catches increased from low levels in the early-1960s when the fishery began to over 36 000 tons in 1969, ranged from 18 000 tons to 39 000 tons until 1990 (Table 1, Figure 1), when an extensive fishery developed in the deep water of the NAFO Regulatory Area (Bowering and Brodie, 1995). The total catch estimated by STACFIS for 1990-94 was in the range of 47 000 to 63 000 tons annually, although estimates in some years were as high as 75 000 tons. Beginning in 1995, TACs for the resource were established for the entire stock unit by the Fisheries Commission (previous TACs were set autonomously by Canada), and the catch declined to just over 15 000 tons in 1995. Catches increased through the late 1990s into the early part of the 2000s, but have decreased under the FC rebuilding plan. However, estimated catches have exceeded the TAC by considerable magnitudes (27%, 22%, 27%, 42%, and 32% respectively), since the inception of this rebuilding plan. The estimated catch for 2008 is 21,180 tons.

Catch-at-age

Length sampling for otter trawl fisheries in the NRA (Figure 2) were provided by EU-Portugal (Vargas et *al*., 2009), EU-Spain (González et *al*., 2009), and Russia (Skryabin et *al*., 2009). Each of these fleets have shown a general increasing trend in the lengths of fish caught in recent years, and the modal length of fish caught in 2008 was again slightly larger in Russian and Portuguese fisheries. The length distribution of the 2008 Spanish fishery is quite similar to the 2007 sampling information. (See Brodie et *al.*, 2009, for Canadian sampling information.) Available age-length keys indicate a difference between Spanish and Canadian age interpretations (see Alpoim et *al*., 2002; Darby et *al*., 2003). At a given age, the Spanish data have greater mean lengths than Canadian data. Until the differences can be resolved, the length samples from nations fishing in the NRA are converted to catch-at-age using Canadian age length keys. Recent research suggests that in addition to these inconsistencies, the Canadian, EU and Russian age determination methods may be underestimating ages (Treble et *al*., 2005). A workshop on age determination methods for Greenland Halibut was held in early 2006 (Treble and Dwyer, 2006), but consensus on age-readings for this species has not been attained; active research on this problem continues.

Computation of Canadian catch-at-age is described by Brodie et al (2009). Samples from Canadian fisheries were used to derive catch-at-age independently for each gear (see Table 5 of Brodie et *al*., 2009). The 2000 and 2001 year-classes, fish aged 7 and 8 in 2008, dominated the Canadian catch; 80% of the catch (in numbers) came from these two cohorts. The proportion of older individuals has decreased considerably in the Canadian catch in recent years, reflecting changes in gear composition: much less of the Canadian catch is now taken by deep-water (large mesh) gillnets, which selects older, larger fish.

No sampling data are available for 2008 catches taken by EU-Estonia, Japan, and the Faroe Islands (EU-Denmark). Limited sampling information was available for St. Pierre and Miquelon (EU-France). The combined catch from these nations is 2049 tons. A catch-at-age was developed for these fleets under the assumption that the age-composition was similar to that of the combined Spanish, Portuguese and Russian fisheries.

Total catch numbers-at-age for 1975-2008 are given in Table 2. As in the recent past, in 2008 the modal catch was at age 7 (the 2001 year-class). In fact, age 7 fish comprise 50% of the total catch numbers-at-age in 2008. Catch weights at age (Table 3) are computed as weighted means of the values from national sampling, and have changed little over time for the age groups which comprise the majority of catches. However, at older ages (10+), there is evidence of a slight decrease in mean weights at age over the past decade. To illustrate changes in the age composition of the catch over the past six years, the total catch-at-age from 2003-2008 is plotted in Figure 3. The sum-of-products is 1.048 for the 2008 data, and is close to 1 for all five years. Note that although the landings for 2005 – 2008 have not changed considerably (ranging from 21.2 - 23.5 Kt), the age compositions for these catches has differed. For example, in 2007 and 2008, the proportion of catch at ages 5 and 6 is substantially lower, with corresponding increases in catch proportions at ages 7 and 8.

Survey Data

Previous assessments of this stock have included a quality evaluation of surveys for Greenland Halibut (see Healey and Mahé (2007), González Troncoso and González Costas (2006)). Each of the survey series considered indicated similar results: the correlation between survey measurements at successive ages are very consistent up to ages 5 to 6; but for older ages, the correlations are quite weak, even negative in some instances.

The following data series were used to calibrate the XSA during the 2008 assessment:
a) EU 3M - a European Union summer survey in Division 3M from 1995–2007, ages 1 – 12 (Vázquez and González Troncoso, 2008).
b) Can 2J3K autumn survey, true Campelen data from 1996 - 2007, ages 1 to 13 (Healey, 2008).
c) Can 3LNO spring survey, true Campelen data from 1996 - 2007, ages 1 to 8 (Healey, 2008).

During the 2003 assessment, STACFIS agreed (NAFO, 2003b; Darby et *al.*, 2003) to exclude survey data from 1978-1994 from the calibration dataset to exclude time periods when changes in survey catchability were apparent.

Healey and Brodie (2009) document the coverage deficiencies of the 2008 Canadian fall survey. Of particular importance for assessing this stock is the abundance index within Divs. 2J3K which has been used in calibrating recent analytical assessments. During 2008, several strata within Divs. 2J3K were only partially covered with fewer sets completed than planned. Other strata were incomplete (i.e. less than two sets per stratum) and were not used to compute estimates of abundance and biomass. There were 5 strata in Div. 2J with less than two successful tows completed. In Div. 3K, there were 15 such strata, 9 of which were the "inshore" strata, which are closest to the coast and are generally insignificant with regards to estimating total Greenland Halibut abundance or biomass, although mean estimates would be biased. In all, 20 strata out of 86 strata of Divs. 2J3K (2J: 40; 3K: 46) were not completed (Fig. 4). This amounts to 11% of the total stratified area in Divs. 2J3K.

Estimates of total abundance and biomass of Greenland Halibut in Divs. 2J3K from Canadian surveys are provided in Table 4. Healey (2009b) provides full detail on Greenland Halibut results from Canadian surveys. Over the 1996-2007 period, these estimates are compared to those computed from only those strata not completed during the fall of 2008. We exclude 1995 from this exercise as the deep-water strata were not completed in that year. Approximately 1-4% of the total abundance index was measured within the 20 strata not covered in 2008 (Fig. 5). However, the contribution of these affected strata to the biomass index ranges from 6-13%. These differences between abundance and biomass suggest that more large Greenland Halibut are captured in the affected strata. This is not a surprising outcome considering that most of the deepest (> 1000m) strata in Divs. 2J3K were not completed in 2008, and larger Greenland Halibut are typically found in deeper waters.

Given this magnitude of potential bias in the total abundance and biomass indices, and considering that the mean numbers per tow (MNPT) data from Divs. 2J3K have been used in recent assessments to calibrate the XSA, potential biases in the age dis-aggregated MNPT data were explored. The stratified MNPT estimates for Divs. 2J3K were compared to a series of MNPT data which were constructed using only the survey information from those strata that were covered in the fall 2008 survey. Specifically, the data from the 20 strata not completed in 2008 were omitted from the MNPT series computed over 2001-2007. Each series of MNPT estimates (Table 5) were compared by computing the relative difference between the values at each age and year (Table 6). Results indicate constant biases for fish aged 0-5 years old because young Greenland Halibut are infrequently captured in the strata not completed in 2008. The magnitude of the relative difference during 2007 differs from other years at these ages because the inshore strata of Div. 3K (refer to Healey, 2009b) were not covered in 2007. At ages 6 and older (particularly ages 8+), the magnitude and sign of the percent relative difference is quite variable.

With respect to the analytical assessment, consideration was given to adjusting the MNPT data for the youngest age groups, and treating the older ages as missing data within XSA and is discussed further in the **Assessment** section below.

The Flemish Cap (Division 3M) has been surveyed by the EU each summer since 1988, and the mean numbers per tow data for 0-730m over 1995-2007 were used to calibrate the recent XSA assessments (e.g. Healey and Mahé, 2008). The maximum depth surveyed over 1988-2003 was 730m, but beginning in 2004 this survey was extended down to 1460m. Gonzaléz Troncoso et al. (2009) illustrate differences in trends between the (age-aggregated) survey results from depths 0-730m and 0-1460m over 2004-2008. Results (from Casas and Gonzaléz Troncoso, 2009; see Figure 6) indicate that the biomass index from 0-730m has been stable over 2004-2008. However, the index for depths 0-1460m has shown consistent increases through 2005-2008, and has increased by 100% in just four years.

We compare the mean numbers per tow at age for depths of 0-730m (Casas and Gonzaléz Troncoso, 2009) to the mean numbers per tow at age over depths 0-1460m (Gonzaléz Troncoso, pers. comm.), with a view to understanding the implications (if any) of using the mean numbers per tow data for depths 0-730m in last year's assessment. As an example, Figure 7 presents the percent relative difference between each set of mean numbers per tow (using data from 0-730m and 0-1460m) at ages 5-8, the ages which dominate the EU Flemish Cap survey results. The trend and magnitude of the differences between the two data series clearly indicates that mean numbers per tow data for all depths surveyed be formally incorporated into analytical assessments as soon as practically possible. This finding illustrates limitations in using survey data from only a portion of the stock area as an index of the total stock.

The Canadian spring survey in Divs. 3LNO covers depths ranging from 0-732m, and results from this survey (ages 1-8 only) have also been used to calibrate the XSA in recent years. This survey was fully completed in 2008. Both the abundance (Figure 8) and biomass indices declined compared to the 2007 values, although confidence intervals are relatively large particularly for the biomass index (further detail in Healey, 2009b).

Mean numbers per tow from the Canadian fall survey in Divs. 2J3K, the Canadian spring survey in Divs. 3LNO and the EU Flemish Cap survey (0-732 m) are provided in Table 7. Graphical displays of the age compositions of each survey (Figure 8) illustrate some of the problems of cohort consistency noted in previous assessments (e.g. Healey and Mahé, 2009). There are examples of cohorts tracking well at young ages (<6 years old), yet not being consistently measured by the same survey at older ages. There are other cohorts which were not detected as being strong at young ages, but appear to be relatively strong at older ages. These features within the survey data exacerbate the retrospective patterns which have been noted in recent assessments.

<u>Assessment</u>

As noted in previous sections, the impact of the incomplete survey coverage of the Canadian fall survey was reviewed during the assessment (see also Healey, 2009b, Healey and Brodie, 2009). It was determined that the coverage deficiencies within Divs. 2J3K were such that the 2008 mean numbers per tow index from Divs. 2J3K could not be considered comparable to that of previous years. This survey index has been used to calibrate the XSA in recent years, along with the Canadian spring Div. 3LNO and EU Flemish Cap (0-730m) data. The algorithm within XSA which estimates survivors generates and applies a weighting to estimates of terminal year survivors at each survey-age. In recent assessments of this stock (e.g. Healey and Mahé, 2008), the Canadian Div. 2J3K index has received the majority of the weight used to estimate the survivors. It is therefore critical to the XSA assessment that the indices from this survey are consistent from year to year. STACFIS concluded that it would not be appropriate to update that analytical assessment as the Canadian Div. 2J3K data for 2008 were not comparable to those from previous years.

Results of the 2008 NAFO Scientific Council assessment of this stock indicated that the exploitable (ages 5+) biomass in 2008 was one of the lowest in the estimated time series. Estimates of average fishing mortality have decreased since 2003 and the strength of the year-classes about to enter the exploitable biomass was estimated to be very weak (Healey and Mahé, 2008). A retrospective analysis indicated that in the recent past, fishing mortality tended to be over-estimated and biomass under-estimated, as estimated recruitment since 2000 has been revised upwards in each successive assessment. Three “single index” analyses were considered, tuning the XSA with each of the three data series in turn to evaluate the consistency of the estimates. Further, the 2008 assessment also included an evaluation of the shrinkage parameters applied in recent assessments. The XSA model accepted by the Scientific Council in 2008 was used as a basis for projections and provision of advice during the current assessment.

Update of 2008 Projections

STACFIS concluded, after lengthy discussion and with the exception of one member[1], that revising the projections conducted during the 2008 assessment would give a better basis for advice than the other available options but emphasizes that the amount of uncertainty associated with these projections is thereby amplified.

Projections are contingent on the accuracy of the estimates of survivors. This is especially so for deterministic projections, which do not include uncertainties around the XSA estimates of terminal year survivors. In particular, assessments of year-class strength of this stock have been subject to retrospective revisions (see Healey and Mahé, 2008). Further, as the projection period lengthens, an increasing proportion of the age composition is comprised of year-classes that may be poorly estimated (limited survey data available) or are assumed (recruits in the projection period).

Deterministic projections corresponding to management options of 16, 000t and F0.1 were updated from those provided during the 2008 assessment. Each of these projections use the 2008 catch-at-age in the first projection year, whereas the projections provided last year included an assumed catch-at-age computed from the status quo fishing mortality. Note that in the F0.1 projection, a status quo catch of 21 178 tons is assumed caught in 2009, with subsequent catches (2010-2012) corresponding to a fishing mortality of F0.1. The 16, 000 ton projection assumes that removals are 16, 000 tons annually over 2009-2012. Recruitment was fixed at the 2000-2005 geometric mean of the age 1 2008 XSA estimates. Scaled selection patterns are derived from the 2005 to 2007 average from this XSA. Weights at age in the stock and in the catch are computed from the 2005-2007 average input data. Natural mortality was fixed at 0.2 throughout. Given that the additional projection uncertainty noted previously could not be accounted for in the stochastic projection of stock dynamics, it was considered inadvisable to provide updated stochastic projections. These will be provided when the analytical assessment is updated in future years.

The updated projection results using data available from the 2008 fishery (see Table 8 and Figure 9) indicate that the stock will not increase to the exploitable biomass target in the FC rebuilding plan in the near term. Projections conducted assuming a fixed catch of 16 000 tons do not result in improvements in the 5+ biomass, since the majority of the year-classes which recruit to the exploitable biomass during the projection period are estimated to be well below average. However, if a fishing mortality corresponding to F0.1 is achieved, the exploitable biomass is projected to grow in the medium term.

Conclusion

The total catch for 2008 was estimated to be 32% greater than the 16,000 ton rebuilding plan TAC. Data from the EU survey of the Flemish Cap indicate stability in the biomass index for the portion of the survey which has been used in recent analytical assessments (0-730m). However, survey information from deeper depths, covered since 2004, suggest considerable increases in biomass. Results from the Canadian spring survey of Divisions 3LNO indicate decreases in abundance and biomass compared to the 2007 levels.

The analytical (XSA) assessment could not be updated during this assessment as the Canadian survey of Divisions 2J3K was not completed. An update of the deterministic projections conducted during the 2008 assessment indicates that the exploitable biomass will not recover to the FC rebuilding plan target in the near term.

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[1] A “Minority Report” on this approach was filed by the Japanese representative during the Scientific Council Meeting. Refer to the 2009 Scientific Council report for full detail (NAFO, 2009).

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Table 1. Landings and Total Allowable Catches (all in 000 tons) for Greenland Halibut in Sub-area 2 and Div. 3KLMNO. TACs were set autonomously by Canada until 1994. Since 1995, the TAC has been established by NAFO's Fisheries Commission.

Year	**TAC - Canada (000 t)**	**TAC - FC (000 t)**		**Landings (t)**
1975	40			28814
1976	30			24611
1977	30			32048
1978	30			39070
1979	30			34104
1980	35			32867
1981	55			30754
1982	55			26278
1983	55			27861
1984	55			26711
1985	75			20347
1986	100			17976
1987	100			32442
1988	100			19215
1989	100			20034
1990	50			47454
1991	50			65008
1992	50			63193
1993	50			62455
1994	25			51029
1995		27		15272
1996		27		18840
1997		27		19858
1998		27		19946
1999		33		24226
2000		35		34177
2001		40		38232
2002		44		34062
2003		42		35151
2004		20	*	25486
2005		19	*	23255
2006		18.5	*	23531
2007		16	*	22747
2008		16	*	21178
2009		16	*	

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

	Age													
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14+**
1975	0	0	0	0	334	2819	5750	4956	3961	1688	702	135	279	288
1976	0	0	0	0	17	610	3231	5413	3769	2205	829	260	101	53
1977	0	0	0	0	534	5012	10798	7346	2933	1013	220	130	116	84
1978	0	0	0	0	2982	8415	8970	7576	2865	1438	723	367	222	258
1979	0	0	0	0	2386	8727	12824	6136	1169	481	287	149	143	284
1980	0	0	0	0	209	2086	9150	9679	5398	3828	1013	128	53	27
1981	0	0	0	0	863	4517	9806	11451	4307	890	256	142	43	69
1982	0	0	0	0	269	2299	6319	5763	3542	1684	596	256	163	191
1983	0	0	0	0	701	3557	9800	7514	2295	692	209	76	106	175
1984	0	0	0	0	902	2324	5844	7682	4087	1259	407	143	106	183
1985	0	0	0	0	1983	5309	5913	3500	1380	512	159	99	87	86
1986	0	0	0	0	280	2240	6411	5091	1469	471	244	140	70	117
1987	0	0	0	0	137	1902	11004	8935	2835	853	384	281	225	349
1988	0	0	0	0	296	3186	8136	4380	1288	465	201	105	107	129
1989	0	0	0	0	181	1988	7480	4273	1482	767	438	267	145	71
1990	0	0	0	95	1102	6758	12632	7557	4072	2692	1204	885	434	318
1991	0	0	0	220	2862	7756	13152	10796	7145	3721	1865	1216	558	422
1992	0	0	0	1064	4180	10922	20639	12205	4332	1762	1012	738	395	335
1993	0	0	0	1010	9570	15928	17716	11918	4642	1836	1055	964	401	182
1994	0	0	0	5395	16500	15815	11142	6739	3081	1103	811	422	320	215
1995	0	0	0	323	1352	2342	3201	2130	1183	540	345	273	251	201
1996	0	0	0	190	1659	5197	6387	1914	956	504	436	233	143	89
1997	0	0	0	335	1903	4169	7544	3215	1139	606	420	246	137	89
1998	0	0	0	552	3575	5407	5787	3653	1435	541	377	161	92	51
1999	0	0	0	297	2149	5625	8611	3793	1659	623	343	306	145	151
2000	0	0	0	271	2029	12583	21175	3299	973	528	368	203	129	104
2001	0	0	0	448	2239	12163	22122	5154	1010	495	439	203	156	75
2002	0	0	0	479	1662	7239	17581	6607	1244	659	360	224	126	81
2003	0	0	0	1279	4491	10723	16764	6385	1614	516	290	144	76	85
2004	0	0	0	897	4062	8236	10542	4126	1307	529	289	184	87	75
2005	0	0	0	534	1652	5999	10313	3996	1410	444	244	114	64	46
2006	0	0	0	216	1869	6450	12144	4902	1089	372	136	47	32	40
2007	0	0	0	88	570	3732	11912	5414	1230	472	163	80	41	29
2008	0	0	0	29	448	3312	10697	5558	1453	393	115	46	26	15

Table 3. Catch weights-at-age (kg) matrix for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO.

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14+**
1975	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	5.764
1976	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	5.144
1977	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	5.992
1978	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	5.894
1979	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	6.077
1980	0.000	0.000	0.126	0.244	0.514	0.659	0.869	1.050	1.150	1.260	1.570	2.710	3.120	5.053
1981	0.000	0.000	0.126	0.244	0.392	0.598	0.789	0.985	1.240	1.700	2.460	3.510	4.790	7.426
1982	0.000	0.000	0.126	0.244	0.525	0.684	0.891	1.130	1.400	1.790	2.380	3.470	4.510	7.359
1983	0.000	0.000	0.126	0.244	0.412	0.629	0.861	1.180	1.650	2.230	3.010	3.960	5.060	7.061
1984	0.000	0.000	0.126	0.244	0.377	0.583	0.826	1.100	1.460	1.940	2.630	3.490	4.490	7.016
1985	0.000	0.000	0.126	0.244	0.568	0.749	0.941	1.240	1.690	2.240	2.950	3.710	4.850	7.010
1986	0.000	0.000	0.126	0.244	0.350	0.584	0.811	1.100	1.580	2.120	2.890	3.890	4.950	7.345
1987	0.000	0.000	0.126	0.244	0.364	0.589	0.836	1.160	1.590	2.130	2.820	3.600	4.630	6.454
1988	0.000	0.000	0.126	0.244	0.363	0.569	0.805	1.163	1.661	2.216	3.007	3.925	5.091	7.164
1989	0.000	0.000	0.126	0.244	0.400	0.561	0.767	1.082	1.657	2.237	2.997	3.862	4.919	6.370
1990	0.000	0.000	0.090	0.181	0.338	0.546	0.766	1.119	1.608	2.173	2.854	3.731	4.691	6.391
1991	0.000	0.000	0.126	0.244	0.383	0.592	0.831	1.228	1.811	2.461	3.309	4.142	5.333	7.081
1992	0.000	0.000	0.175	0.289	0.430	0.577	0.793	1.234	1.816	2.462	3.122	3.972	5.099	6.648
1993	0.000	0.000	0.134	0.232	0.368	0.547	0.809	1.207	1.728	2.309	2.999	3.965	4.816	6.489
1994	0.000	0.000	0.080	0.196	0.330	0.514	0.788	1.179	1.701	2.268	2.990	3.766	4.882	6.348
1995	0.000	0.000	0.080	0.288	0.363	0.531	0.808	1.202	1.759	2.446	3.122	3.813	4.893	6.790
1996	0.000	0.000	0.161	0.242	0.360	0.541	0.832	1.272	1.801	2.478	3.148	3.856	4.953	6.312
1997	0.000	0.000	0.120	0.206	0.336	0.489	0.771	1.159	1.727	2.355	3.053	3.953	5.108	6.317
1998	0.000	0.000	0.119	0.228	0.373	0.543	0.810	1.203	1.754	2.351	3.095	4.010	5.132	6.124
1999	0.000	0.000	0.176	0.253	0.358	0.533	0.825	1.253	1.675	2.287	2.888	3.509	4.456	5.789
2000	0.000	0.000	0.000	0.254	0.346	0.524	0.787	1.192	1.774	2.279	2.895	3.645	4.486	5.531
2001	0.000	0.000	0.000	0.249	0.376	0.570	0.830	1.168	1.794	2.367	2.950	3.715	4.585	5.458
2002	0.000	0.000	0.217	0.251	0.369	0.557	0.841	1.193	1.760	2.277	2.896	3.579	4.407	5.477
2003	0.000	0.000	0.188	0.247	0.389	0.564	0.822	1.199	1.651	2.166	2.700	3.404	4.377	5.409
2004	0.000	0.000	0.180	0.249	0.376	0.535	0.808	1.196	1.629	2.146	2.732	3.538	4.381	5.698
2005	0.000	0.000	0.252	0.301	0.396	0.564	0.849	1.247	1.691	2.177	2.705	3.464	4.264	5.224
2006	0.000	0.000	0.129	0.267	0.405	0.605	0.815	1.092	1.495	1.874	2.396	3.139	3.747	4.701
2007	0.000	0.000	0.000	0.276	0.389	0.581	0.833	1.137	1.500	1.948	2.607	3.057	3.869	4.954
2008	0.000	0.000	0.000	0.278	0.404	0.617	0.891	1.195	1.605	2.038	2.804	3.247	4.232	4.721

Table 4. Estimates of total abundance, biomass from Divs. 2J3K, the abundance and biomass from the strata not completed during the fall 2008 survey, and the annual percentage of abundance/biomass from the affected strata.

	Total Biomass, Abundance, Divs. 2J3K						Totals from the 2J3K strata not covered F2008							
	Biomass			Abundance			Biomass			Abundance				
Year	Div. 2J	Div. 3K	Divs. 2J3K	Div. 2J	Div. 3K	Divs. 2J3K	Div. 2J	Div. 3K	Divs. 2J3K	Div. 2J	Div. 3K	Divs. 2J3K	% Abun	% Biom
1996	64772	120336	185107	678016	1063373	1741388	2807	7602	10409	3365	12737	16102	0.9%	5.6%
1997	82095	130547	212642	517293	956834	1474127	4264	18827	23091	4482	34842	39325	2.7%	10.9%
1998	62111	142196	204307	329415	709549	1038964	6176	20548	26724	7051	36369	43420	4.2%	13.1%
1999	87147	175632	262779	470904	698691	1169595	3702	12743	16444	4562	16404	20965	1.8%	6.3%
2000	54858	143329	198187	326101	644371	970472	3693	10922	14615	5193	22386	27579	2.8%	7.4%
2001	65777	128721	194497	446712	649233	1095946	3656	20749	24405	4584	34135	38719	3.5%	12.5%
2002	53590	67000	120590	409089	484453	893542	3148	5858	9006	4765	10202	14968	1.7%	7.5%
2003	59769	71453	131222	493875	478268	972143	4140	7514	11654	5583	17811	23394	2.4%	8.9%
2004	59135	90509	149644	424743	512769	937512	2998	7151	10149	3791	16818	20609	2.2%	6.8%
2005	61078	112580	173658	348995	351981	700976	2179	10817	12996	2411	17973	20384	2.9%	7.5%
2006	105925	110175	216099	533728	372466	906194	2225	10002	12227	2348	14343	16691	1.8%	5.7%
2007	57733	179096	236830	293637	598731	892368	6082	10159	16241	6057	10178	16236	1.8%	6.9%
2008	37444	121955	159399	210076	394570	604647								

Table 5. Upper table: Mean numbers per tow at age computed by including only those strata covered during the 2008 fall survey. Lower table: Mean numbers per tow at age computed from all survey data.

Age (yrs)						2001	2002	2003	2004	2005	2006	2007	2008
0						9.01	8.82	10.53	4.41	5.36	3.99	2.23	9.15
1						46.21	43.12	48.23	34.10	16.81	34.09	32.87	15.98
2						23.87	25.52	27.97	34.68	16.92	19.06	14.63	11.71
3						17.66	13.22	12.19	14.56	8.98	9.00	12.92	8.20
4						14.74	10.25	9.96	12.89	14.55	18.65	18.93	9.57
5						10.24	6.37	6.69	9.61	11.56	13.78	9.65	7.57
6						7.79	2.08	2.39	2.78	7.18	9.62	10.38	6.25
7						3.33	0.76	0.91	1.22	4.12	4.39	6.13	3.51
8						0.62	0.20	0.26	0.36	0.67	1.21	2.11	1.68
9						0.11	0.04	0.04	0.08	0.12	0.18	0.33	0.20
10						0.02	0.01	0.01	0.03	0.04	0.03	0.07	0.03
11						0.01	0.00	0.01	0.01	0.03	0.02	0.04	0.02
12						0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.00
13						0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00
14						0.00			0.00	0.00	0.00	0.01	0.00
15									0.00	0.00		0.00	
16									0.00	0.00		0.00	
17										0.00		0.00	
18										0.00			
19										0.00			
20													
Ages 0-20	0.00	0.00	0.00	0.00	0.00	133.63	110.41	119.19	114.75	86.33	114.04	110.33	73.87
Ages 1-4	0.00	0.00	0.00	0.00	0.00	102.48	92.11	98.35	96.23	57.26	80.80	79.35	45.46
Ages 5+	0.00	0.00	0.00	0.00	0.00	22.14	9.47	10.31	14.11	23.72	29.24	28.75	19.26
Ages 6-9	0.00	0.00	0.00	0.00	0.00	11.84	3.08	3.59	4.44	12.08	15.40	18.95	11.64

Age (yrs)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
0	4.92	2.18	1.52	6.46	3.09	8.49	8.30	9.94	4.15	5.07	3.75	2.21	9.15
1	98.68	28.05	23.35	15.99	38.57	43.90	40.67	45.70	32.49	16.06	32.34	32.61	15.98
2	47.82	58.62	25.07	34.42	21.94	22.72	24.08	26.67	32.93	16.15	17.98	14.51	11.71
3	32.01	43.61	31.19	24.07	16.43	17.00	12.50	11.69	13.89	8.56	8.50	12.81	8.20
4	9.54	21.13	21.87	28.28	13.20	14.07	9.68	9.49	12.31	13.84	17.60	18.77	9.57
5	6.28	10.37	10.86	20.04	13.76	9.77	6.03	6.39	9.21	10.98	13.03	9.57	7.57
6	2.47	5.01	4.45	10.53	7.21	7.59	1.97	2.27	2.68	6.85	9.11	10.35	6.25
7	0.84	2.00	2.07	3.81	2.16	3.40	0.72	0.89	1.20	3.96	4.18	6.17	3.51
8	0.19	0.64	0.57	0.70	0.50	0.69	0.19	0.27	0.36	0.66	1.15	2.14	1.68
9	0.18	0.20	0.13	0.14	0.06	0.11	0.04	0.04	0.08	0.12	0.18	0.34	0.20
10	0.04	0.06	0.06	0.07	0.03	0.02	0.01	0.02	0.03	0.03	0.03	0.08	0.03
11	0.02	0.03	0.03	0.02	0.02	0.01	0.00	0.01	0.01	0.03	0.02	0.04	0.02
12	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.02	0.00
13	0.02	0.01	0.01	0.03	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00
14	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ages 0-20	203.02	171.93	121.20	144.57	116.98	127.80	104.20	113.38	109.36	82.33	107.89	109.64	73.87
Ages 1-4	188.05	151.41	101.48	102.76	90.14	97.69	86.93	93.55	91.62	54.61	76.42	78.70	45.46
Ages 5+	10.05	18.34	18.20	35.35	23.75	21.62	8.97	9.90	13.58	22.65	27.72	28.73	19.26
Ages 6-9	3.67	7.85	7.22	15.18	9.93	11.80	2.92	3.47	4.32	11.59	14.62	19.00	11.64

Table 6. Percent relative difference in the two series of mean numbers per tow at age in Table 5. Percent relative difference was computed via:

% Relative Diff - (A-B)/A

Age (yrs)	2001	2002	2003	2004	2005	2006	2007	Avg
0	-6%	-6%	-6%	-6%	-6%	-6%	-1%	-5%
1	-5%	-6%	-6%	-5%	-5%	-5%	-1%	-5%
2	-5%	-6%	-5%	-5%	-5%	-6%	-1%	-5%
3	-4%	-6%	-4%	-5%	-5%	-6%	-1%	-4%
4	-5%	-6%	-5%	-5%	-5%	-6%	-1%	-5%
5	-5%	-6%	-5%	-4%	-5%	-6%	-1%	-5%
6	-3%	-5%	-5%	-4%	-5%	-6%	0%	-4%
7	2%	-5%	-2%	-2%	-4%	-5%	1%	-2%
8	11%	-6%	4%	0%	0%	-5%	1%	1%
9	2%	3%	8%	0%	1%	-2%	1%	2%
10	-4%	-8%	29%	13%	-3%	4%	3%	5%
11	14%	0%	0%	0%	-4%	0%	3%	2%
12	-25%		0%	-25%	33%	-10%	13%	-2%
13	-9%	0%	0%	-13%	0%		0%	-4%

where
A = MNPT using all data
B = MNPT computed using data only from the strata completed during 2008.

Table 7. Survey abundance indices (mean numbers per tow) of Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO. Decimalized year reflects the timing of each survey series (e.g. EU Summer survey). Only those survey series and age ranges

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2J3K Fall	1	2	3	4	5	6	7	8	9	10	11	12	13
1996.9	98.68	47.82	32.01	9.54	6.28	2.47	0.84	0.19	0.18	0.04	0.02	0.01	0.02
1997.9	28.05	58.62	43.61	21.13	10.37	5.01	2.00	0.64	0.20	0.06	0.03	0.02	0.01
1998.9	23.35	25.07	31.19	21.87	10.86	4.45	2.07	0.57	0.13	0.06	0.03	0.02	0.01
1999.9	15.99	34.42	24.07	28.28	20.04	10.53	3.81	0.70	0.14	0.07	0.02	0.01	0.03
2000.9	38.57	21.94	16.43	13.20	13.76	7.21	2.16	0.50	0.06	0.03	0.02	0.00	0.00
2001.9	43.90	22.72	17.00	14.07	9.77	7.59	3.40	0.69	0.11	0.02	0.01	0.00	0.01
2002.9	40.67	24.08	12.50	9.68	6.03	1.97	0.72	0.19	0.04	0.01	0.00	0.00	0.00
2003.9	45.70	26.67	11.69	9.49	6.39	2.27	0.89	0.27	0.04	0.02	0.01	0.01	0.00
2004.9	32.49	32.93	13.89	12.31	9.21	2.68	1.20	0.36	0.08	0.03	0.01	0.00	0.01
2005.9	16.06	16.15	8.56	13.84	10.98	6.85	3.96	0.66	0.12	0.03	0.03	0.01	0.01
2006.9	32.34	17.98	8.50	17.60	13.03	9.11	4.18	1.15	0.18	0.03	0.02	0.01	0.00
2007.9	32.61	14.51	12.81	18.77	9.57	10.35	6.17	2.14	0.34	0.08	0.04	0.02	0.01
2008.9 *	15.98	11.71	8.20	9.57	7.57	6.25	3.51	1.68	0.20	0.03	0.02	0.00	0.00

* Incomplete survey coverage, index not representative.

EU Survey	1	2	3	4	5	6	7	8	9	10	11	12
1995.6	12.41	2.54	2.23	1.91	2.66	5.10	3.77	2.12	1.31	0.26	0.07	0.02
1996.6	5.84	7.97	2.42	3.04	4.20	5.82	2.49	1.62	0.42	0.09	0.03	0.04
1997.6	3.33	3.78	6.00	6.50	7.11	8.46	4.99	2.15	0.66	0.22	0.03	0.02
1998.6	2.74	2.13	7.69	11.00	12.33	11.30	7.84	2.62	0.75	0.20	0.03	0.01
1999.6	1.06	0.70	3.01	10.47	13.41	12.58	5.55	1.82	0.35	0.10	0.01	0.00
2000.6	3.75	0.29	0.60	2.17	7.09	14.10	5.40	2.32	0.45	0.11	0.05	0.00
2001.6	8.03	1.43	1.81	0.99	2.79	7.79	6.63	3.21	0.18	0.05	0.01	0.00
2002.6	4.08	2.94	2.80	1.67	3.79	5.59	5.73	1.28	0.13	0.06	0.02	0.01
2003.6	2.20	1.00	0.61	1.51	2.48	2.94	1.93	0.47	0.13	0.10	0.02	0.01
2004.6	2.19	3.29	4.37	1.97	6.97	7.80	2.54	0.64	0.29	0.13	0.08	0.05
2005.6	0.54	0.81	3.18	2.50	6.89	7.59	2.92	0.61	0.11	0.12	0.06	0.02
2006.6	0.68	0.40	0.65	1.17	5.98	7.46	3.31	0.77	0.22	0.18	0.13	0.06
2007.6	0.42	0.09	0.57	0.34	3.44	7.37	5.76	1.51	0.31	0.21	0.08	0.05
2008.6	0.20	0.10	0.15	0.19	1.50	5.70	6.16	1.13	0.35	0.26	0.12	0.05

3LNO Spr	1	2	3	4	5	6	7	8
1996.4	1.62	4.24	4.60	2.18	0.83	0.28	0.06	0.00
1997.4	1.16	3.92	5.16	3.23	1.46	0.51	0.10	0.01
1998.4	0.22	0.81	3.85	6.19	4.96	1.24	0.33	0.07
1999.4	0.29	0.55	1.15	1.98	3.39	1.09	0.24	0.05
2000.4	0.79	1.07	1.07	1.51	1.95	2.04	0.56	0.03
2001.4	0.57	0.71	0.74	0.68	0.80	0.72	0.28	0.02
2002.4	0.64	0.57	0.60	0.58	0.61	0.21	0.05	0.01
2003.4	0.93	2.14	1.66	1.57	1.06	0.21	0.05	0.01
2004.4	0.66	0.57	1.18	1.18	1.16	0.26	0.04	0.02
2005.4	0.35	0.31	1.09	0.95	1.37	0.82	0.21	0.03
2006.4			**Survey not completed**					
2007.4	1.595	0.516	0.802	0.399	1.405	1.491	1.121	0.183
2008.4	0.443	0.772	0.963	0.713	1.254	0.754	0.637	0.284

Table 8. Deterministic Projection of exploitable biomass, yield and average fishing mortality in the near term under catches corresponding to a fishing mortality of F0.1 (upper table), and under constant catches of 16 000 tons (lower table).

F0.1 - Status quo catch in 2009

Year	5+ Biomass (t)	Yield	Fbar (5-10)
2008	79050	21178	0.414
2009	71579	21178	0.392
2010	62332	8807	0.180
2011	72496	9214	0.180
2012	83457	9988	0.180
2013	94691		

16,000 t

Year	5+ Biomass (t)	Yield	Fbar (5-10)
2008	79050	21178	0.414
2009	71579	16000	0.274
2010	68635	16000	0.313
2011	70580	16000	0.369
2012	73194	16000	0.399
2013	76506		

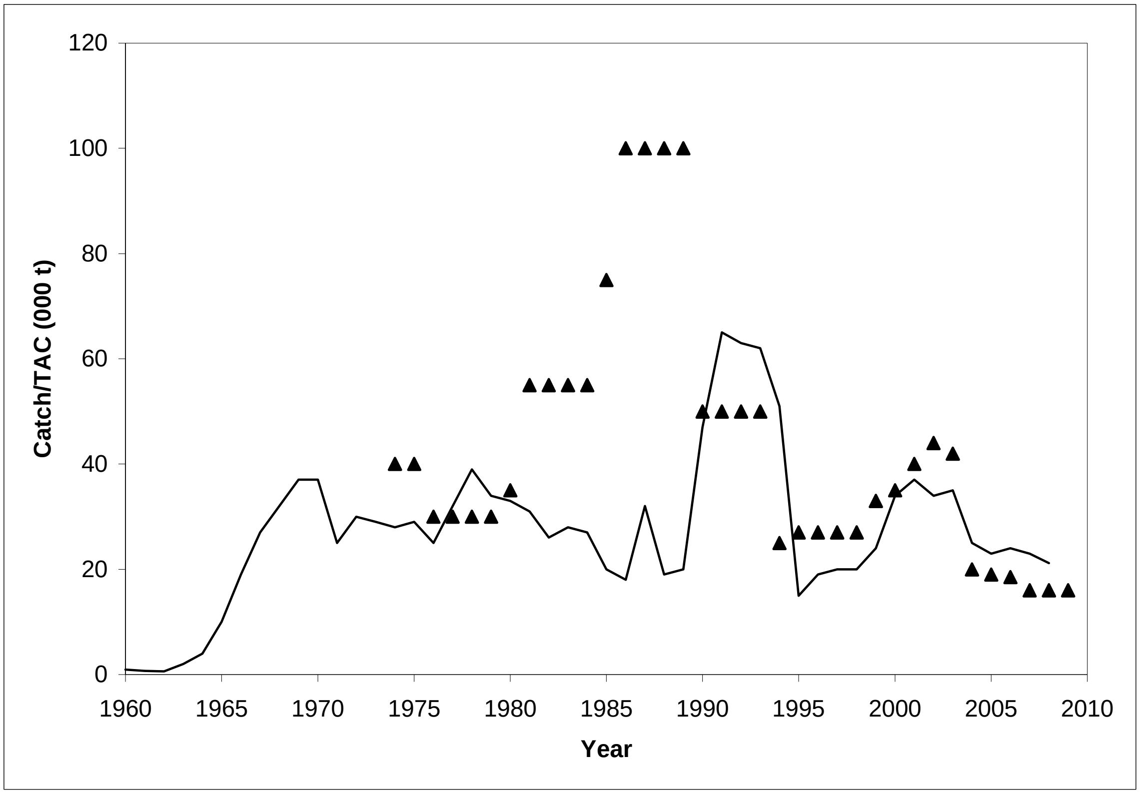


Figure 1. Catches (line) and TAC (triangle) of Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO. Each plotted in units thousands of tons.

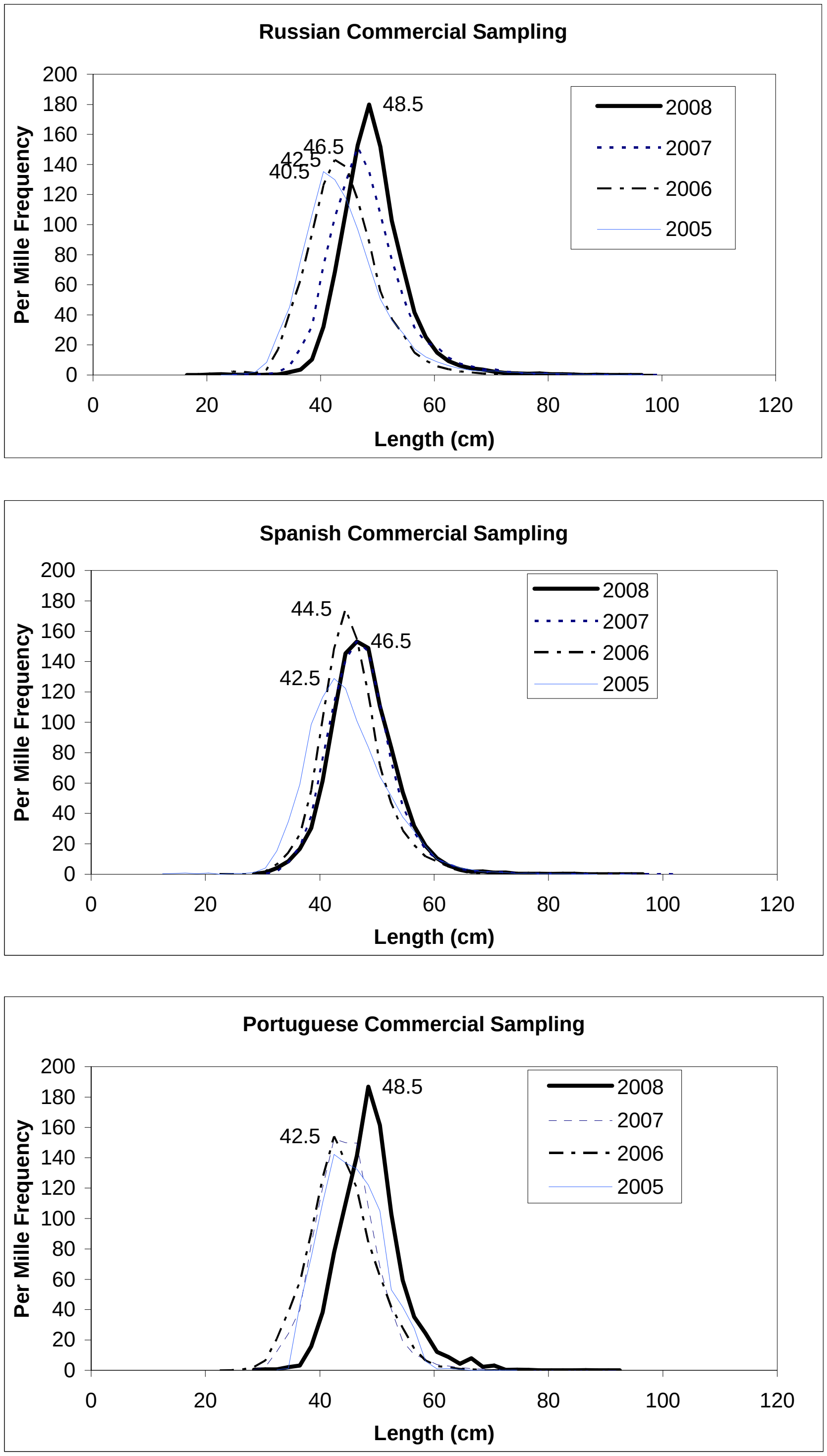


Figure 2. Available Length Sampling over 2005- 2008 for fisheries within the NRA. Labels indicate modal length group.

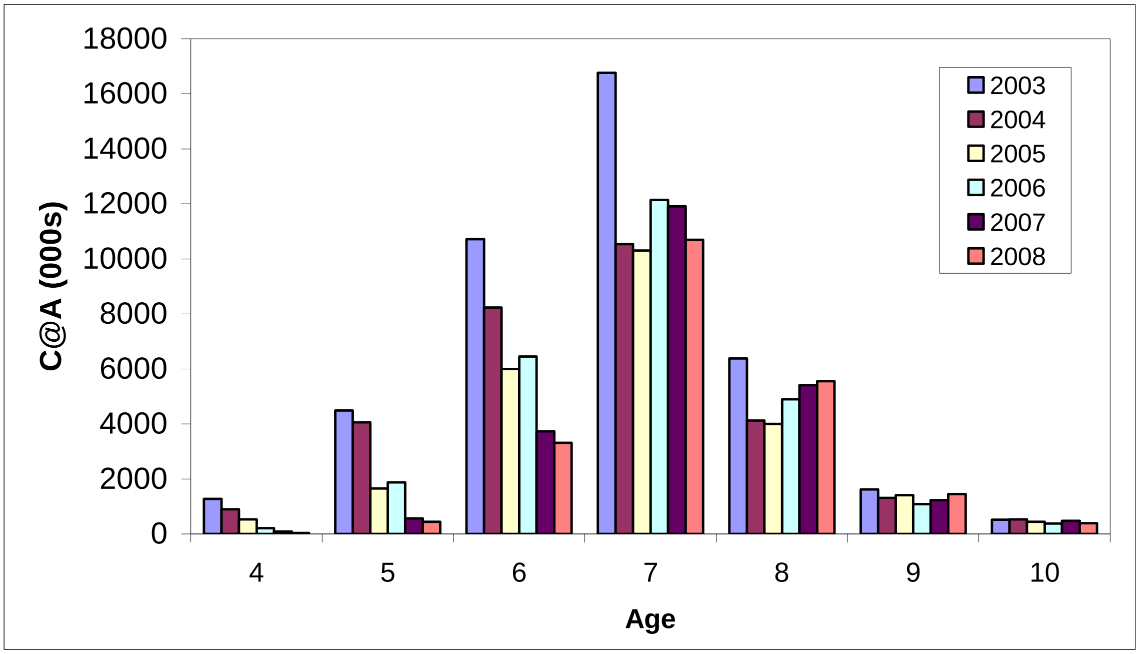
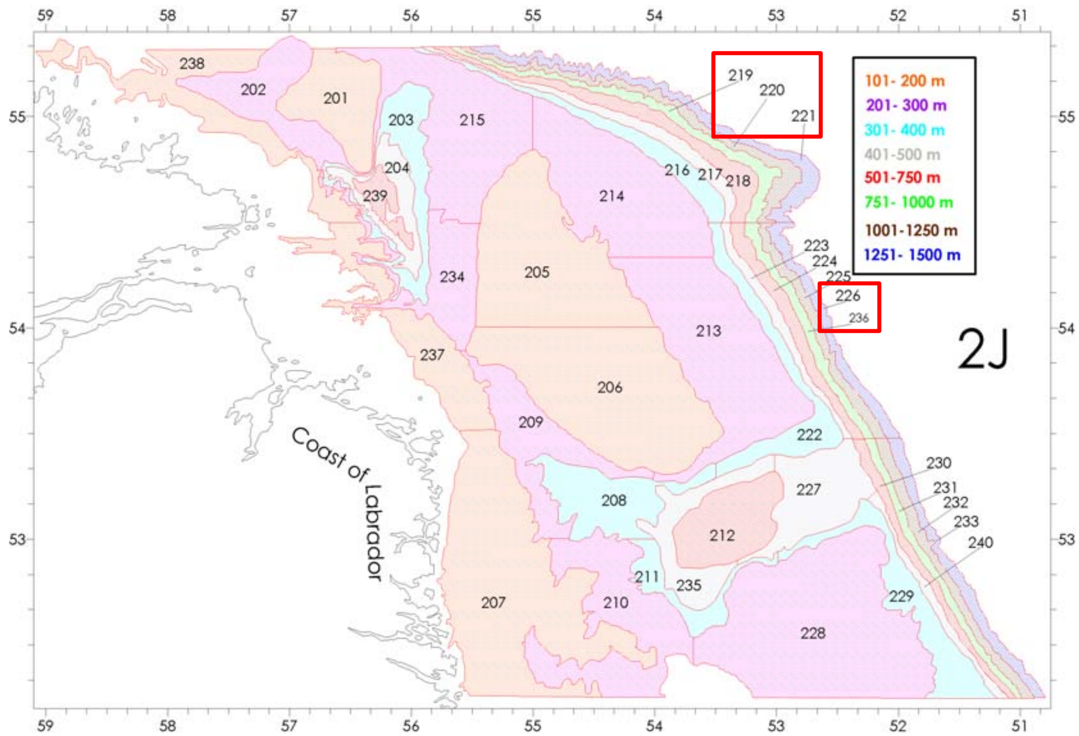


Figure 3. Total catch at age (in thousands) for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO in recent years (2003-2008).



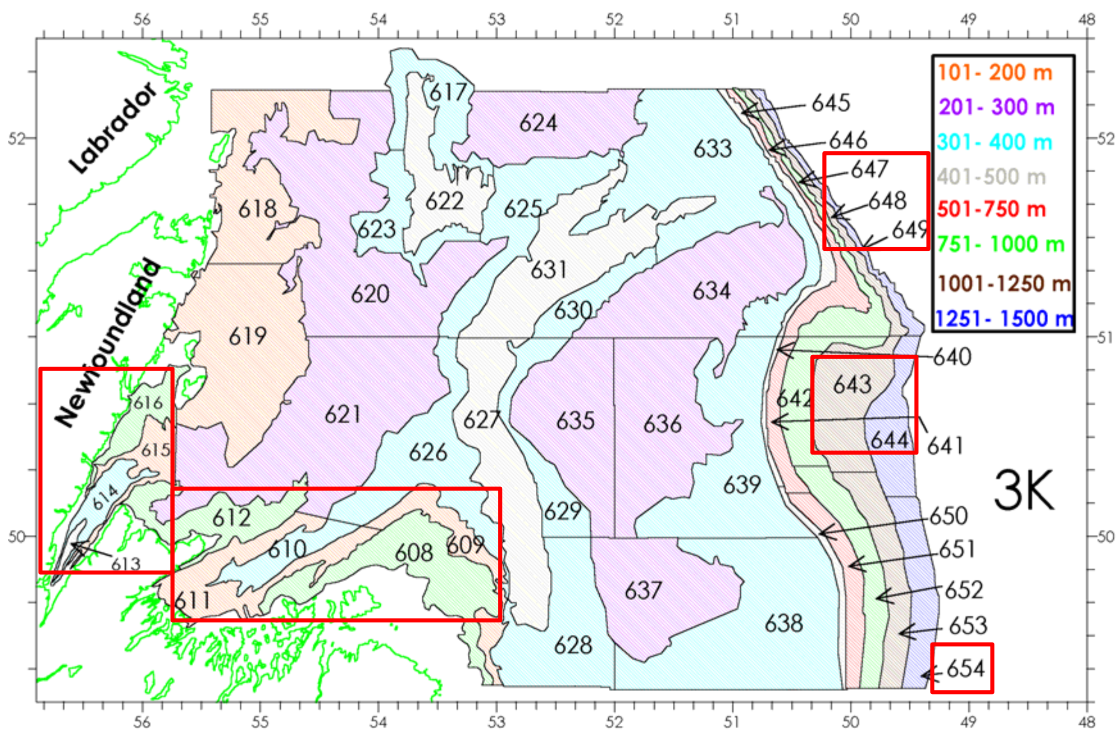


Figure 4. Survey stratification of Divs. 2J3K for Canadian multi-species surveys. Stratum colouring identifies depth range. Stratum numbers inside shaded boxes were not covered during the fall 2008 survey.

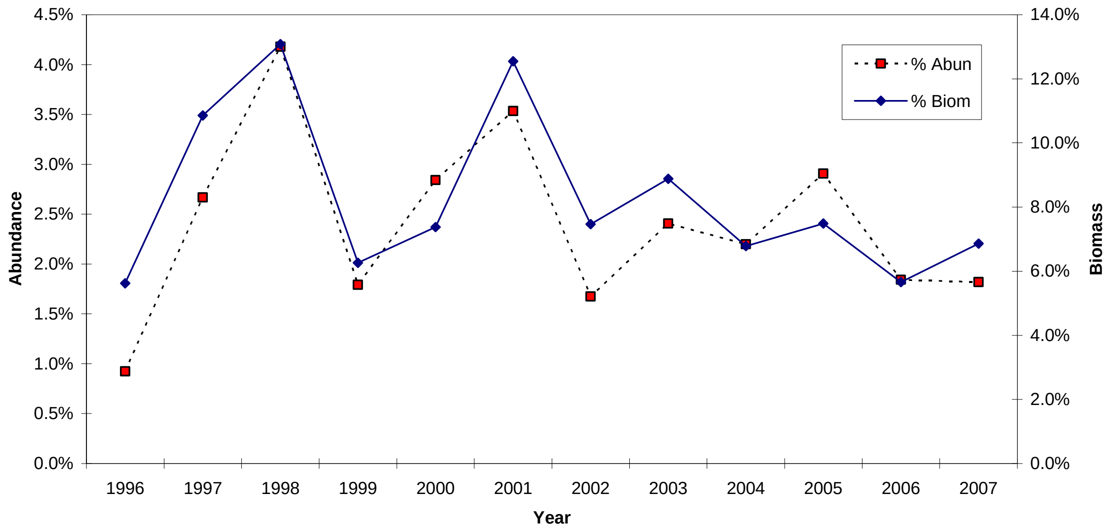


Figure 5. Percentage of abundance and biomass index of Divs. 2J3K from Canadian fall surveys measured in those strata not covered in the fall 2008 survey.

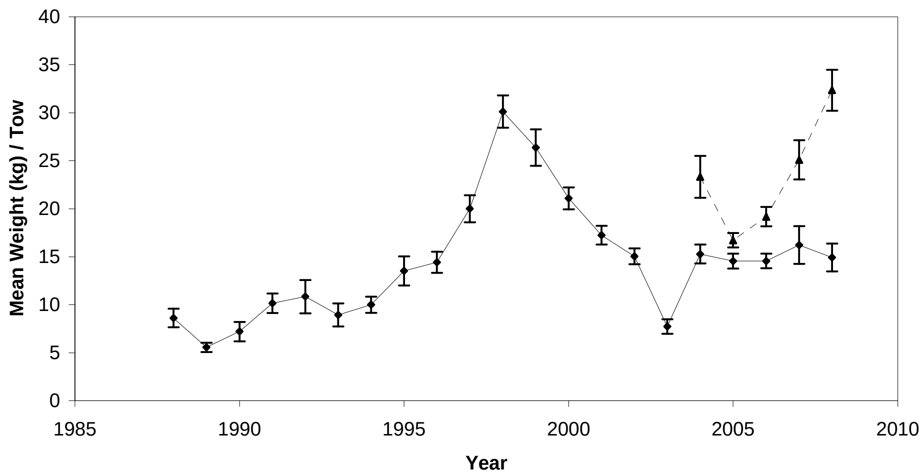


Figure 6. Biomass index (mean catch per tow ± 1 S.E.) from EU summer surveys in Div. 3M. Solid line: biomass index for depths <730 m. Dashed line: biomass index for all depths <1460 m.

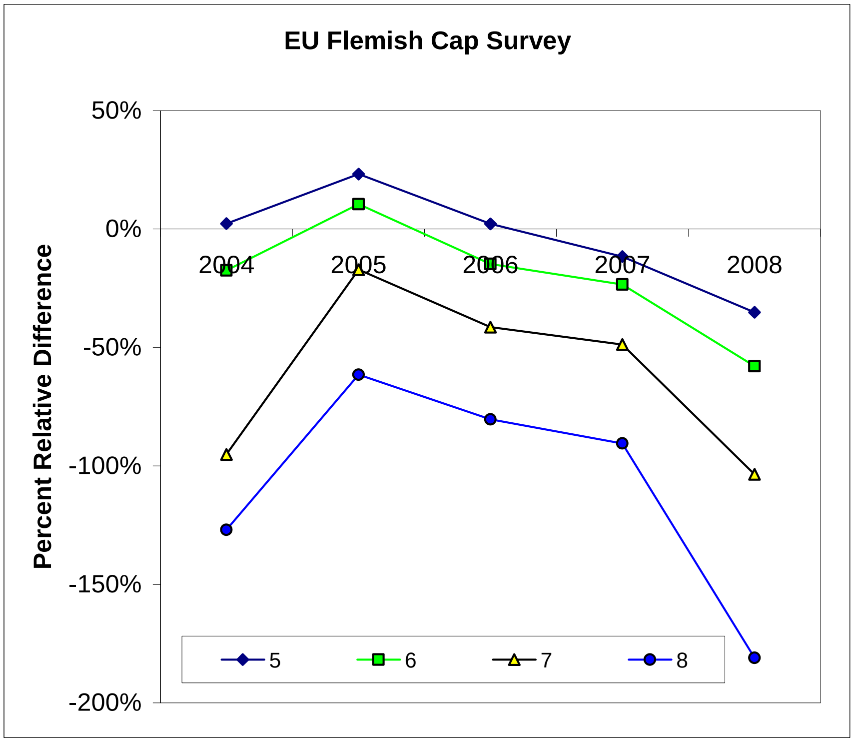
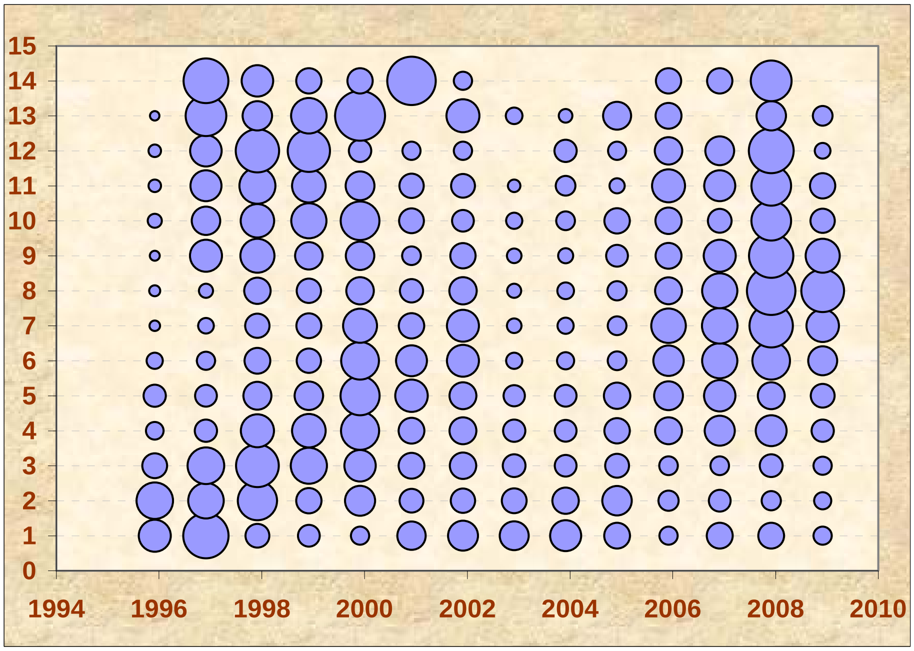


Figure 7. Percent relative difference in EU Flemish Cap mean numbers per tow (MNPT) data from 0-730m and 0-1460m. Percent relative difference computed as (A-B)/A where A= MNPT 0-730m, and B=MNPT 0-1460m.



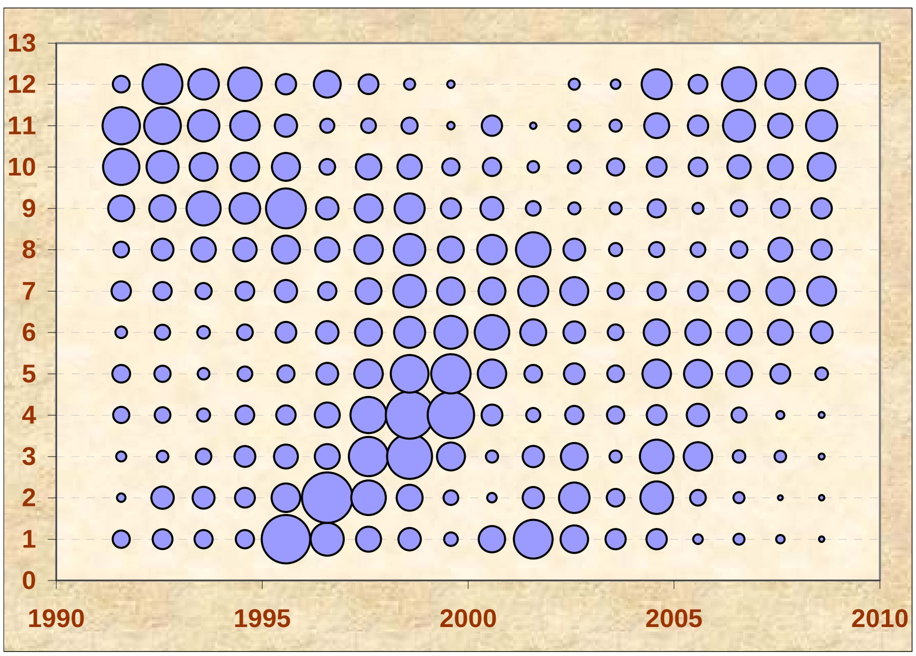
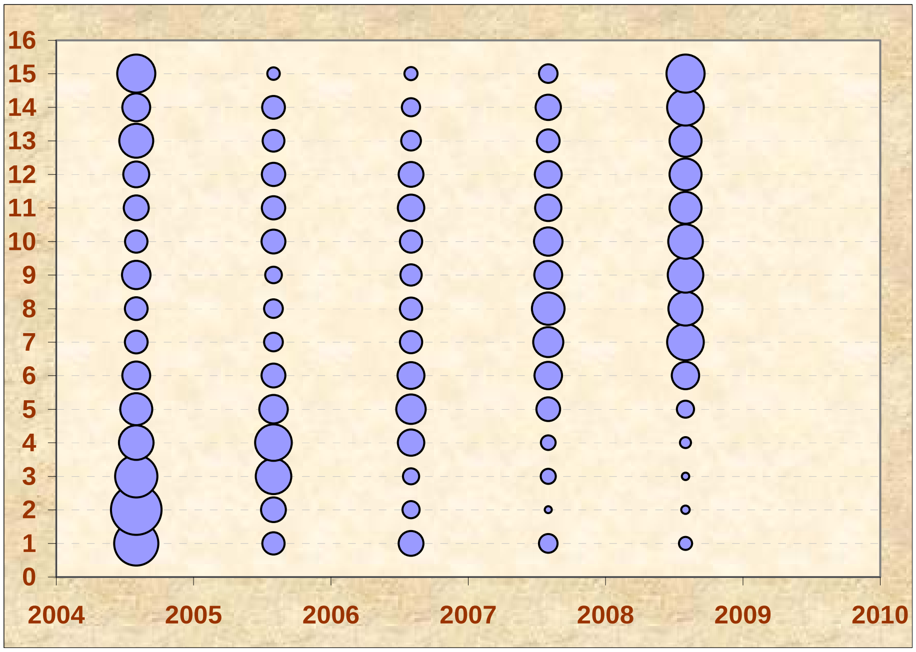


Figure 8. “Bubble” plots of mean numbers per tow at age from selected survey indices. Bubble sizes within a given age are re-scaled by the time-series mean of the index at that age. Upper panel: Canadian fall survey in Divisions 2J3K (note that 2009 data not comparable to earlier years); lower panel: EU Flemish Cap summer survey, depths 0-730m.



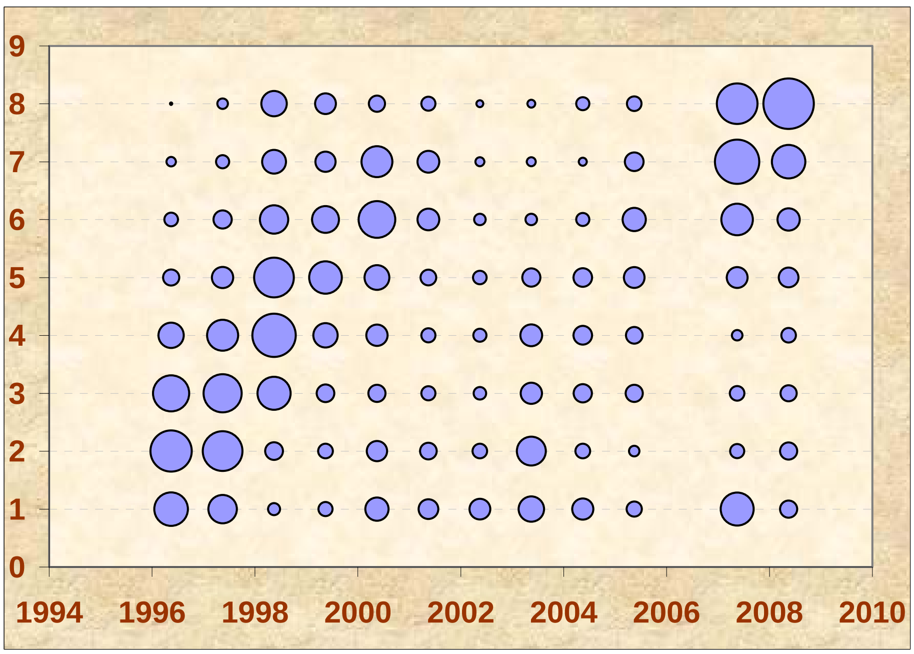


Figure 8 (cont.). Upper panel: EU Flemish Cap summer survey, depths 0-1460m; lower panel: Canadian spring survey of Divisions 3LNO.

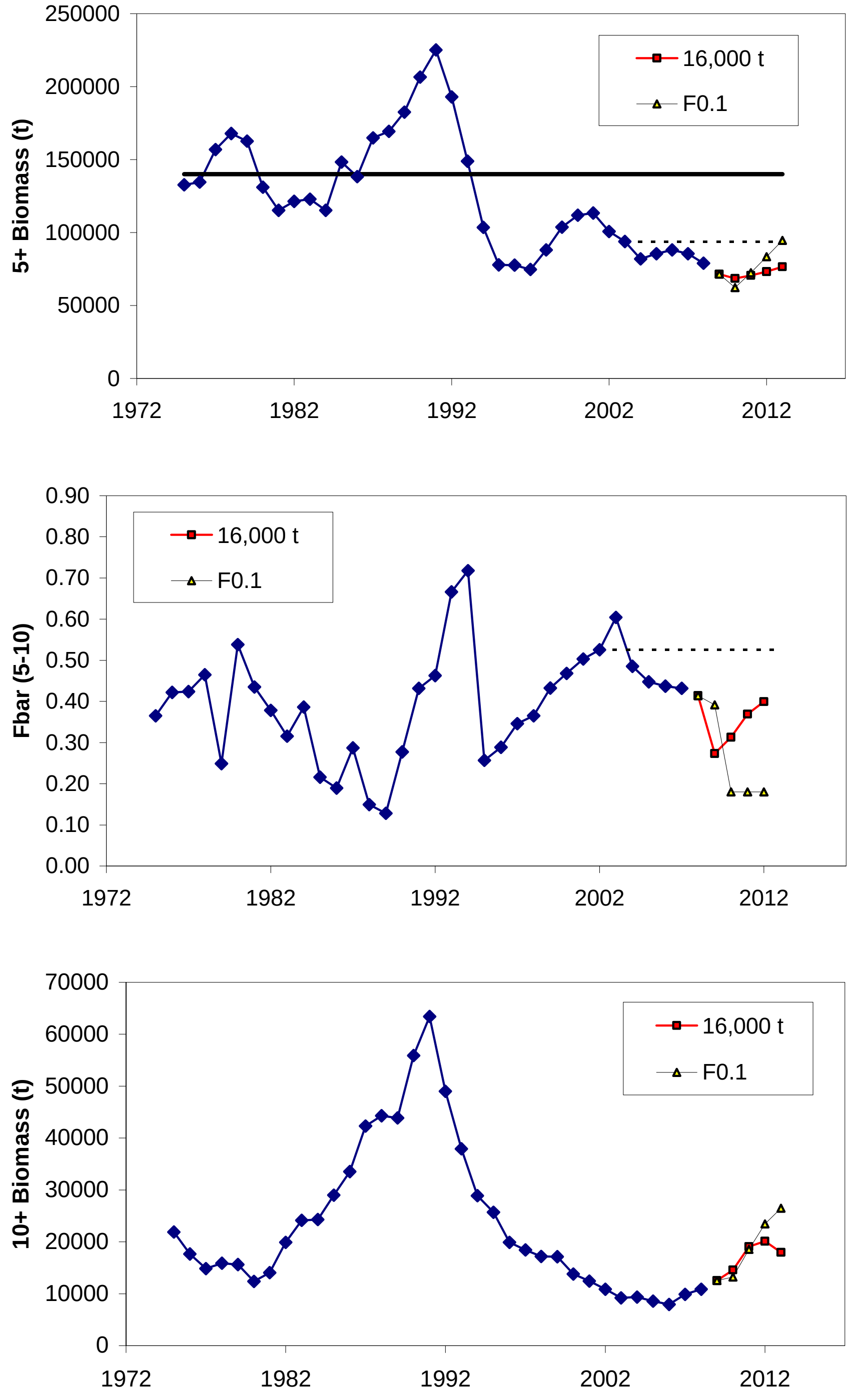


Figure 9. Projections of the accepted 2008 XSA assessment results (diamonds) under management options of constant 16, 000 ton removals (circles) and catches corresponding to a fishing mortality of F0.1 (triangles). Panels (top to bottom) are exploitable biomass (tons), average fishing mortality (ages 5-10) and 10+ biomass (tons).