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Northwest Atlantic Fisheries Organization

Ser. No. N5550 **NAFO SCR Doc. 08/48**

SCIENTIFIC COUNCIL MEETING – JUNE 2008

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

by

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Abstract

Using Extended Survivors Analysis (XSA), estimates of stock status of Greenland Halibut in Subarea 2 and Divisions 3KLMNO are updated with an additional year of catch and survey information. Results indicate that the recent estimates of exploitable (ages 5+) biomass are amongst the lowest in the time series, and fishing mortality remains relatively high despite reductions under the Fisheries Commission Rebuilding Plan. Further, none of the year-classes since the 1996 cohort have been above average. Projections conducted under various catch and fishing mortality options indicate that the exploitable biomass will continue to decline if current levels of fishing mortality are maintained. If catches over 2009-2012 are constant at 16 000 tons, the projected exploitable biomass remains stable with minimal recovery. Of the four projection scenarios considered, exploitable biomass is projected to rapidly increase only if fishing mortality is reduced to the F0.1 level.

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). This assessment updates the estimates of population abundance and of fishing mortality, and medium-term projections are presented which provide the basis for discussion on various catch/management options, including the Fisheries Commission rebuilding plan for this stock.

Results of the 2007 NAFO Scientific Council assessment of this stock indicated that the exploitable (ages 5+) biomass in 2007 was one of the lowest in the estimated time series. Further, estimated average fishing mortality was amongst the highest in the time series and the strength of recent year-classes was weak (Healey and Mahé, 2007). A retrospective analysis indicated that in the recent past, fishing mortality tended to be over-estimated and biomass underestimated 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 2006 assessment also included an evaluation of the reducing the plus-group age, and although there were slight revisions to historic estimates of the exploitable biomass, each analysis provided a consistent assessment of stock status. The XSA model accepted by the Scientific Council was used as a basis for projections and provision of advice. We re-evaluate the status of the stock using the most recent stock surveys and catches.

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). 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*".

During the 2007 assessment, the Scientific Council advised (NAFO, 2007, p. 13) that "*fishing mortality should be reduced to a level not higher than F0.1, or alternatively, catches over the next four years should be reduced by 15% annually from the 2007 TAC (16 000 tons).*" The 2008 TAC was subsequently set at 16 000 tons, higher than that advised by the Scientific Council.

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 1990's into the early part of the 2000's, but have decreased under the FC rebuilding plan. However, estimated catches have exceeded the TAC by considerable margins (27%, 22%, 27% and 42%, respectively), during the first four years of this rebuilding plan. The estimated catch for 2007 is 22,750 tons.

Catch-at-age

Length sampling provided by EU-Portugal (Vargas et *al*., 2008), EU-Spain (González et *al*., 2008), and Russia (Vaskov et *al*., 2008) for 2007 otter trawl fisheries are quite similar (Figure 2), with modal catch length of about 43-46cm. Note, however, that the length sampling for 2007 generally indicates that larger fish were caught compared to 2005 and 2006. This is most strongly apparent in the Russian and Spanish sampling. (See Brodie et *al.*, 2008, 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 these nations 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 (2008). Samples from the Canadian fishery were used to derive catch-at-age independently for each gear (see Table 5 of Brodie et al., 2008). The 1999 and 2000 year-classes (ages 7 and 8 in 2007) dominated the Canadian catch; 70% of the catch (in numbers) came from these two cohorts. Note that the proportion of older individuals has decreased considerably in the Canadian catch – age groups 9 and older accounted for over 20% of the numbers caught in 2004 and 2005 fisheries. However, in 2007, these age groups accounted for less than 14% of the catch numbers, primarily attributable to reductions in the longline catches (only 3t for 2007) and changes to gillnet mesh size regulations within the Canadian EEZ (see Brodie et al., 2008).

No sampling data are available for 2007 catches taken by EU-Lithuania, EU-Estonia, Japan, St. Pierre and Miquelon (EU-France) and the Faroe Islands (EU-Denmark) (1923 t combined catch), all operating in the NAFO Regulatory Area (NRA). 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 operating within the NRA.

Total catch numbers-at-age for 1975-2007 are given in Table 2. As in the recent past, in 2007 the modal catch was at age 7 (the 2000 year-class). In fact, age 7 fish comprise 50% of the total catch numbers-at-age in 2007. Catch weights at age (Table 3) are computed as weighted means of the values from national sampling, and have generally been stable over time. 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 five years (particularly changes at ages 8+), the combined C@A from 2002-2007 is plotted in Figure 3. The sum-of-products is 0.977 for the 2007 data, and is close to 1 for all five years. Note that although the landings for 2005 – 2007 have been almost identical (23.3, 23.5 and 22.7 Kt, respectively), the age compositions for these catches has differed. For example, in 2007, the proportion of catch at ages 5 and 6 is decreased, with corresponding increases in catch numbers at ages 7 and 8. Consequently, there was a slight reduction in total removals (in numbers) in 2007 as compared to 2006.

Survey Data

Previous assessments of this stock have included a quality evaluation of surveys for Greenland Halibut (see Healey and Mahé (2007), Gonzaléz Costas and Gonzaléz Troncoso (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. We have repeated this analysis and investigated the quality of the survey information in more detail using the exploratory data analysis package using the Fisheries Library in R[1] (FLR, www-flr-project.org; see Kell et al., 2007).

The following data series were used to calibrate the XSA during the 2007 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. Retrospective patterns in biomass, fishing mortality and recruitment were less severe when the 1978-1994 data were excluded. Darby et *al.* (2003) also reported improved within survey correlations for the shortened time series. The 1995 data from the Canadian fall survey have also been excluded as the survey coverage in that year was incomplete; several of the deep water strata were not surveyed (see Tables 7-8 of Brodie and Stansbury, 2007).

Results and Discussion

FLEDA

FLR includes an exploratory data analysis library, FLEDA. Amongst the exploratory tools available in this package are pair-wise plots for examining the consistency of survey information across age groups, and an age-by-age comparative plot of multiple (standardized) indices. The data are standardized using the age-specific mean and standard deviation of each index.

Pair-wise plots of the each of the survey indices (by cohort on the log-scale) are presented in Figure 4. The slope of the regression lines between successive ages in these plots yield the correlation coefficients equivalent to those presented by Gonzaléz Troncoso and Gonzaléz Costas (2006). A comparison of these correlation coefficients from each of the indices is presented in Figure 5. The scatterplots reveal that some of the low correlation values noted in

[1] R is a freeware statistical software package available at: http://www.r-project.org.

previous assessments are partially due to one or two outlying points (e.g. ages 6 to 7 in Can 2J3K F index) whereas other problems appear to be systematic.

A comparison of standardized indices illustrating the consistency of dataset currently used to calibrate the analytical assessment is presented in Figure 6. The survey data used to calibrate the XSA appears to be fairly consistent through time over a majority of age groups. Observe that the Canadian Div. 2J3K fall survey is measuring substantial increases in recent years. To some extent, this increasing trend is also present in the other two survey series, but the increases in these surveys are not of the same magnitude as that in the Canadian Div. 2J3K fall survey.

Estimates of survey mortality are computed for each of the surveys used in fitting the XSA (Figure 7). Despite evidence of year-effects, note that the estimated survey mortality has generally been stable or declining in recent years.

To further investigate the consistency of the survey data, we present “bubble plots” of the indices used in tuning the XSA (scaled within each survey-age) in Figure 8. These plots also indicate that there are some difficulties in tracking cohorts in these surveys; note particularly the recent trends in the Canadian fall 2J3K survey index related to changes in catchability. In a sequential population analysis this will be reflected in the catchability residuals and retrospective pattern. Refer to Healey (2007, 2008) for additional discussion on this issue.

These illustrations suggest that the patterns across surveys in the data set currently used to calibrate the assessment are reasonably consistent. This is not to say that the tuning dataset is without problems, as demonstrated in the pair-wise scatter plots. Nonetheless, we rely on the assertion of Healey and Mahé (2006) that XSA uses within cohort information to produce estimates of survivors, and as such, XSA analyses for this stock are still considered appropriate.

Assessment Results

Survey data over 1995-2007 and catch information from 1975-2007 were used to estimate numbers at age using the XSA formulation applied during the 2007 assessment. In addition to exploratory analyses (not shown) conducted during this assessment, previous investigations indicated that the XSA settings used recent assessments are suitable (see Healey and Mahé, (2005), (2006), (2007) for various sensitivity analyses). The XSA settings, diagnostics and results can be found in Table 5. Estimated numbers at age and fishing mortality at age are presented in Tables 6 and 7, with a summary of the estimates presented in Table 8. Figure 9 illustrates the exploitable (ages 5+) biomass, average fishing mortality and the age 1 recruitment. (Estimates of 2008 survivors from the XSA are used to compute 2008 biomass assuming the 2008 stock weights at age are equal to the 2005-2007 average.)

The strong recruiting year-classes of the mid-1980’s, coupled with relatively low fishing mortalities contributed to a substantial increase in the exploitable biomass over 1985-1991. Subsequently, intense fishing pressure and poor recruitment contributed to significant stock declines (on the order of two-thirds reduction) in the early 1990’s. The large 1993-1995 year-classes lead to improvements in the exploitable biomass around the turn of the millennium. Estimates of exploitable biomass since the imposition of the Fisheries Commission rebuilding plan remain relatively low, averaging 84 000 t. The 2008 5+ biomass is estimated to be approximately 79 000 tons. As in recent years, this is amongst the lowest value in the estimated time series.

From 1975-1990, average fishing mortality over ages 5-10 (Fbar(5-10)), although variable, was generally low, particularly so during the late 1980’s. Subsequent trends in Fbar closely mirror the trends in total landings (rapid increase from 1989-90; substantial decline in 1995; increasing into early 2000’s). Estimates of fishing mortality since the imposition of the rebuilding plan have decreased but remain relatively high as the corresponding population estimates of abundance are quite low. Although effort has been reduced under the rebuilding plan, the catches under the rebuilding plan have exceeded the TACs by considerable margins. Fbar(5-10) in 2007 is estimated to be 0.43.

Historical estimates of recruitment indicate two periods with relatively strong year-classes, one during the mid-1980’s and another during the mid-1990’s, each consisting of multiple year-classes. Over the past decade, age 1 recruitment is estimated to be about average over 1998-2002 (these fish are ages 7 to 11 in 2008), with more recent year-classes well below average. In fact, the estimated abundance of the 2003 - 2005 year-classes are the lowest values in the time series, although the abundance estimated independently from each survey is inconsistent (see Estimated Survivors by survey in Table 5b). The estimate for 2007 seems to be an improvement over these extremely low recruitments but should be considered preliminary as it is based on survey information at age 1 only, with very different estimates from each of the three surveys.

The XSA estimated catchabilities (Q), the standard error of Log(Q), and also the scaled weights used to compute the estimates of survivors at each age of the estimated population are presented in Figure 10. Darby and Flatman (1994) suggest that Log(Q) standard errors in excess of 0.5 are indicative of poor fit. In this analysis, the Log(Q) standard errors exceed 0.5 for a majority of index-ages, and in some cases, exceed 1. The scaled weights indicate a dominance of the Canadian fall 2J3K survey over most ages, with increased influence of shrinkage at ages 8 and older.

Selection patterns of the recent past are plotted in Figure 11. Current results (2006 and 2007) indicate increased selection at age 8 relative to other age groups. This stems from increases in the modal length in the catch within several fleets. Recent changes to gillnet fishing regulations within the Canadian EEZ have contributed to a dramatic decline of the relative F at the oldest ages. The majority of the older individuals in the total catch-at-age are taken in the Canadian gillnet fishery; see Brodie et al (2008).

Residual graphics from the XSA analysis are presented in Figures 12 a-c. The trends and patterns are similar to those described in previous assessments of this stock: there are trends in the residuals along the cohorts, plus evidence of year-effects in some of the surveys. The mean squared residual (Figure 12a) is largest for ages 7 and 8 in the Canadian spring survey, and ages 11 and 12 in the EU summer survey. Increasing trends in the mean annual residual in both of the Canadian surveys are cause for concern (Figure 12b). The problems are most severe for the Canadian fall index, with an increasing trend in the residuals through the latter half of this survey. Note that practically all of the residuals from the 2005 – 2007 Canadian fall survey are positive due to the increased abundance in these cohorts as compared to the relative abundance at younger ages. This is problematic considering that this index receives the largest weight in estimating survivors. Again, the residual bubble plots (Figure 12c) illustrate the problematic trends – evidence of cohort tracking and year effects, each of which indicate poor model fit.

Retrospective analysis

A five-year retrospective analysis was conducted to examine the influence of removing successive years' data on the terminal estimates of biomass, fishing mortality and recruitment (Figure 13). Retrospective patterns in stock size and fishing mortality estimates have been problematic in earlier assessments of this stock (see Darby et *al*. 2003). The retrospective results indicate that the recent recruitment estimates have been revised upwards as additional data is included in the model. Trends are evident in the retrospective estimates of fishing mortality, particularly with the estimated fishing mortality in the terminal year. Observe that the magnitude of the one-year retrospective revision to average fishing mortality in the current assessment is less than that noted in the previous assessment.

There are some notable features in the retrospective analyses for this stock. Earlier assessments (e.g. Healey and Mahé (2005)) demonstrated that the direction of the retrospective pattern has reversed over time; during the late 1990's and early 2000's, the successive assessments appear to have underestimated average fishing mortality, and consequently over-estimate the exploitable biomass. This was caused by downwards revisions to the estimated recruitment of the 1993-1995 year-classes. (Note that the assessments prior to June 2003 were based on a different set of tuning indices.) However, in the recent past, fishing mortality appears to have been over-estimated and biomass underestimated. This results from the fact that estimated recruitment over 1997-2001 has been revised upwards in each successive assessment. However, retrospective revisions to the 2002 and 2003 recruitments have not been consistent with respect to the direction of the change. Further, in contrast to the 1997-2001 recruitments, the 2004 recruitment estimate has been revised downward in each subsequent year.

A second unusual feature of the retrospective analysis is the changing trend in average fishing mortality between the 2005 assessment and subsequent assessments. In the 2005 assessment, the estimated of average fishing mortality over ages 5-10 increased between 2003 and 2004. In the subsequent assessments, however, average fishing mortality decreases from 2003 to 2004. The estimate of average fishing mortality for 2004 is 0.49 in the current assessment, compared to 0.71 in the 2005 assessment. A comparison of the selection patterns (not shown) also indicates retrospective differences, particularly over 2005-2007.

To gain further insight into such differences, Tables 9 and 10 provide a measure of the sensitivity of the XSA output to the addition of the 2007 catch and survey data. The tables present ratios of the estimated numbers at age and fishing mortality at age from the current assessment and the 2007 assessment, and changes exceeding 10% in magnitude are highlighted. Observe that the one year retrospective change in average fishing mortality is consistent across ages 5-10.

Robustness
Three additional XSA analyses were conducted which were calibrated using a single tuning index, to gauge the consistency of the estimated stock dynamics. Estimates of exploitable biomass, recruitment and average fishing mortality (Figure 14) have been consistent up until the recent period. The most dramatic differences are in the recent estimates of recruitment from the EU survey and the two Canadian indices, which are based upon a limited number of observations. The estimated exploitable biomass in 2008 and average fishing mortality in 2007 (Figure 15) for each of the single-index analyses are compared with the results using all of the information. Note that the combined trends most closely resemble those from the Canadian fall index as this index receives the highest weighting (refer to Figure 10) in the combined run. Retrospective analyses for each of these “single-index” runs (Figure 16) indicate general consistency of stock status – although the age 1 recruitment estimates, not surprisingly, can be highly variable given the limited information available – as determined from each index.

Further, the sensitivity of results to varying the XSA shrinkage parameters - number of years and the log standard error (refer to Darby and Flatman, 1994 for details) - was also investigated. Comparisons of exploitable biomass, age 1 recruitment and average fishing mortality (Figure 17) indicate some differences in the recent time period. As expected, retrospective trends (Figure 18) increase as the influence of shrinkage is reduced. Also, residual patterns from these analyses (not shown) indicate that the residual problems in this assessment tend are worse for the low shrinkage runs.

Reference Points
Precautionary approach reference points have not previously been defined for this stock. Several of the standard approaches typically available for age-disaggregated assessments are not applicable for this stock given the difficulties in determining the spawner biomass (or appropriate proxy). Limit reference points could not be determined for this stock at this time. However, we note that the exploitable biomass is currently estimated to low (62%) compared to the 1975-2007 time-series average.

Based on average weights and partial recruitment for the past 3 years, F_{Max}=0.34 and $F_{0.1}$=0.18. During the previous assessment, these values were estimated to be 0.25 and 0.14, respectively. The dramatic one year changes are due to much lower average selection and reduced weights at older ages. The XSA estimate of average fishing mortality (ages 5-10) for 2007 is 0.49, which is 44% above than the F_{Max} level, and almost three times the $F_{0.1}$ level.

Projections

In order to evaluate the population trends in the medium term, five-year deterministic and stochastic projections to 2013 were conducted. All projections are contingent on the accuracy of the estimates of survivors. This is especially so for the 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. 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). Attention is also to be drawn on the fact that, as discussed by Patterson et al. (2000), current bootstrapping and stochastic projection methods generally underestimate uncertainty. The percentiles are therefore presented as relative measures of the risks associated with the current harvesting practices. They should not be taken as representing the actual probabilities of eventual outcomes.

All projection scenarios assume a status quo fishing mortality rate for 2008, as the 2008 TAC is unchanged from that in 2007. Using average weights and selection patterns, this produces an assumed catch of approximately 24, 150 tons. (The F2007 catch for 2008 is larger than the 2007 landings of 22 750 t due to higher selection of older, larger fish relative to that in 2007.) For projected catch in years 2009 – 2012, four scenarios with either constant fishing mortality or catch were evaluated:

i) constant fishing mortality at F0.1 (0.180)
ii) constant fishing mortality at F2007 (0.432)
iii) constant landings at 16, 000 tons, and
iv) constant landings at 22, 750 tons.

The projection inputs are summarized in Table 11 with the variability in the projection parameters for the stochastic projections described by the coefficients of variation (column CV in the table). Numbers at age 2 and older at 1st of January 2008 and corresponding CVs are computed from the XSA output. Deterministic projections were conducted assuming a recruitment value fixed at the 2000-2005 geometric mean of the age 1 XSA estimates. For the stochastic projections, recruitment was bootstrapped from the 2000-2005 age 1 numbers from the XSA; more recent recruitment levels were not included as these estimates are less certain. Scaled selection pattern and corresponding CVs are derived from the 2005 to 2007 average from the XSA. Weights at age in the stock and in the catch and corresponding CVs are computed from the 2005-2007 average input data. Natural mortality was assumed to be 0.2 with a CV of 0.15. The stochastic distributions were generated using the @Risk software (www.palisade.com). The distribution was assumed be lognormal for the numbers at age and normal for the other input data.

Deterministic Projection Results

For each of the four scenarios considered, projection results (Table 12) of exploitable biomass (see also Figure 19), fishing yield, and average fishing mortality (Figure 20) are presented. Results indicate that of the scenarios considered, the exploitable biomass will increase throughout the projection period only if fishing mortality is reduced to the F0.1 level. Subsequent to initial declines, the exploitable biomass is projected to increase slightly in each of the F2007 and 16, 000 t projection scenarios by 2011. This is caused by the recruitment of the 2006 year-class to the exploitable biomass. The average fishing mortality under 16 000 t catches, however, continues to increase due to over-exploitation of the weak 2003-2005 year-classes.

If catches of 22, 750 t are taken over 2009 to 2012, the population is projected to decline substantially, with a corresponding increase in fishing mortality. The projected declines under the F2007, 16, 000 t and 22, 750 t are caused by the recruitment of the weak 2003-2005 year-classes into the exploitable biomass.

Tables 13 and 14 provide growth rates of the exploitable and 10+ biomass in relation to those in 2003 (as estimated in the current assessment), when the rebuilding plan was implemented, and in 2008, the terminal year of the assessment. Note that if fishing mortality is reduced to the F0.1 level, the projected biomass grows considerably, due in part to substantial increases in the 10+ age groups.

Table 15 presents the ratio of the exploitable (5 +) biomass at the end of the projection period to the target identified in the rebuilding plan. Note that if catches are maintained at the current TAC level (16 000 t), the biomass in 2013 is projected to be 52% of the target level with only six years remaining in the rebuilding plan.

Stochastic Projection Results

The results of the stochastic projections (average fishing mortality, 5+ biomass and 10+ biomass) conducted under the four scenarios described above are plotted in Figures 21-24, and are similar to those from the deterministic projections. The trend in age 10+ biomass is presented to illustrate the short term development of older portion of the population and should not be considered to represent SSB which is not precisely known. As in the deterministic projections, the status quo fishing mortality (F2007) is assumed to generate 2008 yield.

In addition, probability profiles of the biomass in 2013, the end of projection period (Figure 25) are compared to the 2003 level (as estimated in the current assessment), when the rebuilding plan was implemented, and also to 140 000 tons, the target level identified in the rebuilding plan. These illustrate the risk of the projected exploitable biomass in 2013 being below a reference level. Again, only the F0.1 scenario provides a high (>90%) probability that the exploitable biomass will have recovered to the 2003 level by 2013. Even under this most optimistic scenario, there is a low (<10%) probability that the 2013 biomass will have reached the 140 000 tons target.

Conclusion

The status of this stock is one of considerable concern: recent estimates of exploitable biomass are at quite low and fishing mortality remains high, in spite of the Fisheries Commission rebuilding plan. In addition, all year-classes since the 1996 year-class are estimated to be of below average strength. Projections conducted assuming current fishing mortality, fixed catch of 16 000 tons or fixed catch of 22 750 tons are pessimistic, since the majority of the year-classes which recruit to the exploitable biomass are estimated to be well below average. If a fishing mortality corresponding to F0.1 is achieved, the exploitable biomass is projected to grow in the medium term.

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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	*	

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

Table 3. Catch weights-at-age (kg) matrix 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	0.000	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

Table 4. Survey data (mean numbers per tow) used to calibrate XSA assessment of Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO. Decimalized year reflects the timing of each survey series (e.g. EU Summer survey).

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

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

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

Table 5a. XSA Settings.
Lowestoft VPA Version 3.1

9/06/2008 13:00

Extended Survivors Analysis

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

CPUE data from file GhalTUN2008.txt

Catch data for 33 years. 1975 to 2007. Ages 1 to 14.

Fleet	First year	Last year	First age	Last age	Alpha	Beta
EU Survey	1995	2007	1	12	0.5	0.6
CAN 2J3K	1996	2007	1	13	0.8	1
CAN 3LN(	1996	2007	1	8	0.3	0.45

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 2007
shrunk towards1.000 * the mean F of ages 10 - 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 45 iterations

Table 5b. XSA Diagnostics

Fleet : EU Survey_MNPT

Age	1995	1996	1997
1	1.06	0.45	0.08
2	0.36	1.31	0.7
3	0.32	-0.13	0.59
4	0.22	0.51	0.74
5	-0.42	0.22	0.57
6	0.02	0	0.56
7	0.35	-0.35	0.26
8	0.45	0.21	0.38
9	1.19	0.09	0.59
10	0.39	-0.68	0.29
11	0.33	-0.63	-0.53
12	-0.46	0.31	-0.28
13	No data for this fleet at this age		

Age	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	0	-0.96	0.26	1.07	0.39	0.05	0.59	-0.83	-0.58	-1.57
2	0.33	-0.67	-1.56	-0.01	0.75	-0.32	1.15	0.29	-0.45	-1.89
3	0.97	0.24	-1.27	-0.17	0.22	-1.26	0.72	0.68	-0.37	-0.54
4	1.08	1.16	-0.21	-0.88	-0.37	-0.51	-0.2	0.04	-0.44	-1.14
5	0.6	0.47	-0.03	-0.76	-0.34	-0.74	0.25	0.25	0.11	-0.18
6	0.68	0.21	0.17	-0.27	-0.44	-0.88	0.11	-0.02	-0.04	-0.1
7	0.87	0.47	0.05	0.09	0.06	-0.83	-0.44	-0.35	-0.36	0.19
8	0.54	0.39	0.61	0.86	-0.25	-1.15	-0.71	-0.78	-0.54	-0.01
9	0.74	0.01	0.45	-0.52	-0.74	-0.84	0.06	-0.87	-0.33	0.16
10	0.26	-0.27	-0.11	-0.91	-0.63	0.05	0.26	0.19	0.63	0.52
11	-0.28	-1.64	0.49	-1.61	-0.34	-0.36	1.3	0.73	1.52	1.02
12	-1.43	-2.06	99.99	99.99	-0.6	-0.98	1.26	0.56	1.26	0.89
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
Mean Log	-10.499	-10.9917	-10.3536	-10.0295	-9.0038	-8.3003	-8.114	-8.2594	-8.9642	-9.3011
S.E(Log q	0.7889	0.9651	0.716	0.7135	0.46	0.3991	0.4542	0.6276	0.641	0.4876

Age	11	12
Mean Log	-10.0547	-10.0547
S.E(Log q	1.0085	1.1054

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	0.54	1.649	10.94	0.54	13	0.4	-10.5
2	0.49	1.695	11.15	0.51	13	0.44	-10.99
3	0.63	1.087	10.65	0.44	13	0.45	-10.35
4	0.43	2.608	10.56	0.66	13	0.25	-10.03
5	0.82	0.427	9.34	0.33	13	0.39	-9
6	1.95	-1.234	6.18	0.13	13	0.76	-8.3
7	2	-1.322	6.19	0.14	13	0.88	-8.11
8	-1.63	-1.5	10.45	0.03	13	0.97	-8.26
9	0.27	1.916	8.39	0.38	13	0.15	-8.96
10	1.5	-0.442	10.18	0.07	13	0.76	-9.3
11	-0.79	-2.441	4.57	0.15	13	0.67	-10.05
12	-2.7	-1.571	-3.69	0.02	11	2.76	-10.19

Table 5b. XSA diagnostic results (cont.)

Fleet : CAN 2J3K Fall_MNPT

Age	1995	1996	1997
1	99.99	0.57	-0.49
2	99.99	0.01	0.35
3	99.99	0.33	0.44
4	99.99	-0.19	0.08
5	99.99	0.01	0.34
6	99.99	-0.44	0.46
7	99.99	-0.81	0
8	99.99	-1.09	0.06
9	99.99	0.17	0.38
10	99.99	-0.27	0.13
11	99.99	-0.08	0.24
12	99.99	-0.22	0.41
13	99.99	0.4	0.05

Age	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	-0.56	-0.95	-0.11	0.06	-0.01	0.39	0.58	-0.15	0.58	0.08
2	-0.3	0.13	-0.33	-0.35	-0.24	-0.13	0.36	0.18	0.26	0.07
3	0.24	0.18	-0.08	-0.06	-0.42	-0.44	-0.26	-0.46	0.07	0.45
4	-0.08	0.31	-0.25	-0.07	-0.45	-0.51	-0.21	-0.09	0.42	1.03
5	-0.14	0.25	0.01	-0.12	-0.49	-0.39	-0.07	0.1	0.28	0.22
6	0.18	0.43	-0.06	0.16	-1.06	-0.66	-0.51	0.29	0.58	0.63
7	0.16	0.79	-0.03	0.22	-1.25	-0.8	-0.47	0.65	0.58	0.96
8	-0.09	0.39	0	0.34	-1.12	-0.64	-0.33	0.26	0.88	1.34
9	0	0.12	-0.54	-0.04	-0.91	-0.97	-0.16	0.23	0.45	1.28
10	0.29	0.64	-0.21	-0.33	-0.87	-0.43	0.09	0.18	0	0.76
11	0.15	-0.05	-0.13	-0.04	-1.19	-0.33	-0.58	0.66	0.41	0.94
12	0.26	-0.67	-1.15	-0.76	99.99	-0.13	-0.5	0.48	0.01	0.78
13	0.32	0.96	99.99	0.55	-0.2	-0.32	0.89	0.66	99.99	0.25

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
Mean Log	-7.7275	-7.825	-8.1526	-8.1152	-8.303	-8.58	-8.4988	-8.8935	-9.7212	-10.3436
S.E(Log q	0.4899	0.2642	0.3382	0.4222	0.2598	0.5456	0.7043	0.7312	0.6154	0.4569

Age	11	12	13
Mean Log	-10.4933	-10.4933	-10.4933
S.E(Log q	0.5606	0.6115	0.5713

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	1.99	-1.378	4.07	0.16	12	0.94	-7.73
2	1.28	-1.226	6.85	0.65	12	0.33	-7.82
3	0.96	0.152	8.27	0.59	12	0.34	-8.15
4	3.87	-2.232	-0.17	0.06	12	1.4	-8.12
5	1.15	-0.412	7.92	0.43	12	0.31	-8.3
6	1.17	-0.22	8.25	0.15	12	0.67	-8.58
7	1.55	-0.457	7.62	0.06	12	1.13	-8.5
8	0.85	0.115	8.93	0.06	12	0.65	-8.89
9	1.02	-0.009	9.75	0.03	12	0.66	-9.72
10	0.73	0.461	9.59	0.23	12	0.35	-10.34
11	1	-0.005	10.51	0.17	12	0.59	-10.49
12	1.59	-0.618	13.1	0.11	11	0.97	-10.63
13	0.82	0.628	9.37	0.61	10	0.37	-10.14

Table 5b. XSA diagnostic results (cont.)

Fleet : CAN 3LNO Spr_MNPT

Age	1995	1996	1997
1	99.99	0.42	0.29
2	99.99	0.95	1.01
3	99.99	0.88	0.8
4	99.99	0.74	0.6
5	99.99	-0.07	0.32
6	99.99	-0.48	0.29
7	99.99	-0.79	-0.33
8	99.99	-2.84	-0.42
9	No data for this fleet at this age		
10	No data for this fleet at this age		
11	No data for this fleet at this age		
12	No data for this fleet at this age		
13	No data for this fleet at this age		

Age	1998	1999	2000	2001	2002	2003	2004	2005
1	-1.26	-0.99	-0.04	-0.33	-0.2	0.45	0.65	-0.01
2	-0.36	-0.64	0.01	-0.44	-0.61	0.71	-0.33	-0.42
3	0.64	-0.36	-0.32	-0.7	-0.95	0.11	-0.23	-0.03
4	1.06	0.06	-0.02	-0.7	-0.87	0.08	-0.15	-0.37
5	1.02	0.43	0.02	-0.67	-0.83	-0.26	-0.21	-0.02
6	1.01	0.33	0.77	-0.12	-1.18	-1.02	-0.77	0.31
7	1.03	0.65	1.01	0.18	-1.43	-1.22	-1.26	0.31
8	1.25	1.07	0.59	0.17	-1.37	-0.98	0.09	0.3
9	No data for this fleet at this age							
10	No data for this fleet at this age							
11	No data for this fleet at this age							
12	No data for this fleet at this age							
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
Mean Log	-11.7916	-11.2979	-10.7507	-10.624	-10.3856	-10.917	-11.5791	-12.7013
S.E(Log q	0.6825	0.619	0.5977	0.6026	0.5163	0.7693	1.0921	1.371

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	2.65	-1.044	12.33	0.04	11	1.8	-11.79
2	0.61	1.343	11.31	0.57	11	0.37	-11.3
3	0.66	0.895	10.92	0.43	11	0.4	-10.75
4	0.59	1.259	10.79	0.51	11	0.34	-10.62
5	0.75	0.538	10.5	0.34	11	0.4	-10.39
6	0.99	0.008	10.91	0.12	11	0.8	-10.92
7	1.31	-0.193	12.03	0.04	11	1.5	-11.58
8	0.46	0.418	10.76	0.06	11	0.66	-12.7

Table 5b. XSA diagnostic results (cont.)

Terminal year survivor and F summaries :

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

Year class = 2006

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	13860	0.819	0	0	1	0.204	0
CAN 2J3K	72550	0.51	0	0	1	0.526	0
CAN 3LN(	185987	0.713	0	0	1	0.269	0
F shrinka	0	0.5				0	0

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
66676	0.37	0.63	3	1.7	0

1

Age 2 Catchability constant w.r.t. time and dependent on age

Year class = 2005

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	10933	0.634	0.641	1.01	2	0.196	0
CAN 2J3K	45561	0.357	0.252	0.71	2	0.617	0
CAN 3LN(	36726	0.647	0	0	1	0.188	0
F shrinka	0	0.5				0	0

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
33098	0.28	0.33	5	1.162	0

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

Year class = 2004

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	14975	0.482	0.113	0.23	3	0.208	0
CAN 2J3K	33677	0.291	0.176	0.61	3	0.573	0
CAN 3LN(	30546	0.47	0.089	0.19	2	0.219	0
F shrinka	0	0.5				0	0

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
27852	0.22	0.14	8	0.655	0

Table 5b. XSA Diagnostic results (cont.)

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

Year class = 2003

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	17035	0.404	0.39	0.97	4	0.186	0.005
CAN 2J3K	35063	0.251	0.218	0.87	4	0.482	0.002
CAN 3LNO	19673	0.381	0.342	0.9	3	0.209	0.004
F shrinka	6378	0.5				0.122	0.012

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
22053	0.17	0.22	12	1.269	0.004

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

Year class = 2002

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	33238	0.314	0.251	0.8	5	0.228	0.015
CAN 2J3K	36463	0.224	0.166	0.74	5	0.447	0.014
CAN 3LNO	33250	0.311	0.162	0.52	4	0.233	0.015
F shrinka	7944	0.5				0.092	0.063

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
30374	0.15	0.15	15	1.018	0.017

1

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

Year class = 2001

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	32009	0.266	0.127	0.48	6	0.27	0.1
CAN 2J3K	30019	0.209	0.128	0.61	6	0.434	0.107
CAN 3LNO	31705	0.302	0.254	0.84	5	0.208	0.101
F shrinka	11914	0.5				0.088	0.25

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
28468	0.14	0.11	18	0.768	0.112

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

Year class = 2000

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	11480	0.236	0.217	0.92	7	0.282	0.662
CAN 2J3K	11184	0.201	0.17	0.84	7	0.368	0.675
CAN 3LNO	10286	0.271	0.257	0.95	6	0.201	0.717
F shrinka	8435	0.5				0.15	0.823

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
10621	0.14	0.11	21	0.776	0.701

Table 5b. XSA Diagnostic results (cont.)

Age 8 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
EU Survey	3503	0.24	0.091	0.38	8	0.268	0.875
CAN 2J3K	4050	0.207	0.234	1.13	8	0.309	0.793
CAN 3LNO	3512	0.27	0.311	1.15	7	0.162	0.873
F shrinka	3497	0.5				0.261	0.876

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
3664	0.16	0.1	24	0.609	0.849

Age 9 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
EU Survey	1160	0.291	0.145	0.5	9	0.275	0.673
CAN 2J3K	2116	0.267	0.292	1.09	9	0.306	0.423
CAN 3LNO	884	0.258	0.166	0.64	7	0.099	0.815
F shrinka	1423	0.5				0.32	0.578

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
1449	0.2	0.12	26	0.599	0.57

1

Age 10 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
EU Survey	1016	0.284	0.189	0.67	10	0.336	0.351
CAN 2J3K	1500	0.269	0.158	0.59	10	0.36	0.251
CAN 3LNO	518	0.268	0.161	0.6	8	0.07	0.601
F shrinka	776	0.5				0.234	0.439

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
1046	0.18	0.11	29	0.586	0.342

Table 5b. XSA Diagnostic results (cont.)

Age 11 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
EU Survey	648	0.309	0.225	0.73	11	0.293	0.205
CAN 2J3K	705	0.282	0.167	0.59	11	0.41	0.19
CAN 3LN(	360	0.272	0.173	0.64	8	0.042	0.344
F shrinka	276	0.5				0.255	0.429

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
526	0.19	0.13	31	0.65	0.247

1

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

Year class = 1995

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	568	0.319	0.189	0.59	12	0.271	0.12
CAN 2J3K	545	0.275	0.109	0.4	12	0.455	0.125
CAN 3LN(	422	0.27	0.249	0.92	8	0.029	0.158
F shrinka	125	0.5				0.245	0.458

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
381	0.2	0.15	33	0.767	0.174

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

Year class = 1994

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey	354	0.335	0.185	0.55	12	0.21	0.1
CAN 2J3K	287	0.272	0.116	0.43	12	0.518	0.122
CAN 3LN(	401	0.294	0.293	1	7	0.018	0.088
F shrinka	127	0.5				0.253	0.256

Weighted prediction :

Survivors at end of y	Int s.e	Ext s.e	N	Var Ratio	F
245	0.2	0.11	32	0.54	0.141

Table 6. XSA estimated numbers at age (000s).

	Age													
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14+**
1975	112289	126280	110151	66815	53822	31894	23091	14337	9312	3931	1773	415	720	735
1976	116668	91934	103389	90184	54704	43764	23562	13703	7254	4040	1691	816	218	113
1977	107522	95520	75270	84648	73837	44772	35279	16367	6321	2529	1313	635	433	311
1978	82385	88032	78205	61625	69304	59969	32121	19113	6754	2521	1154	876	402	459
1979	99031	67451	72074	64029	50455	54043	41484	18182	8794	2937	763	290	385	756
1980	130137	81079	55225	59009	52422	39150	36350	22361	9334	6142	1969	365	103	52
1981	131878	106547	66382	45214	48313	42731	30166	21482	9550	2758	1565	696	183	292
1982	131159	107972	87233	54349	37018	38774	30898	15825	7226	3921	1453	1050	441	512
1983	146631	107384	88400	71420	44497	30064	29666	19579	7742	2712	1687	650	628	1031
1984	153784	120051	87919	72376	58474	35797	21396	15421	9231	4262	1594	1192	464	795
1985	167248	125908	98290	71982	59257	47058	27205	12230	5674	3860	2350	937	847	834
1986	187148	136931	103085	80473	58934	46721	33724	16923	6846	3397	2697	1780	677	1128
1987	156283	153224	112109	84399	65886	47997	36225	21810	9249	4276	2355	1987	1331	2054
1988	128757	127954	125449	91787	69100	53819	37576	19702	9772	5007	2729	1581	1373	1650
1989	112950	105417	104760	102709	75149	56306	41180	23403	12167	6835	3679	2052	1199	585
1990	107712	92476	86308	85770	84091	61363	44301	26947	15294	8621	4902	2616	1439	1045
1991	94449	88188	75713	70663	70137	67851	44125	24841	15225	8837	4622	2924	1341	1002
1992	71040	77329	72202	61988	57655	54833	48534	24226	10569	6000	3869	2097	1294	1088
1993	84255	58163	63311	59114	49789	43422	35011	21061	8791	4734	3318	2252	1049	471
1994	143006	68982	47619	51835	47484	32105	21139	12635	6459	2997	2214	1762	971	647
1995	173619	117083	56478	38988	37557	23947	11975	7225	4247	2501	1456	1079	1061	844
1996	151487	142147	95860	46240	31628	29526	17487	6908	3988	2406	1559	880	636	394
1997	124090	124027	116380	78483	37686	24394	19471	8538	3924	2400	1514	882	510	329
1998	110643	101597	101545	95284	63953	29133	16200	9116	4081	2182	1417	860	499	275
1999	112062	90586	83180	83138	77513	49126	18960	8027	4158	2043	1297	819	558	577
2000	117558	91749	74166	68102	67799	61517	35131	7731	3140	1903	1109	751	394	314
2001	112024	96249	75117	60722	55512	53673	38981	9603	3345	1690	1080	575	432	205
2002	111402	91717	78802	61501	49310	43424	32938	11898	3199	1825	936	487	287	182
2003	84400	91208	75092	64517	49919	38867	29002	11060	3763	1493	898	441	196	217
2004	49258	69101	74675	61480	51665	36807	22119	8576	3277	1620	756	472	230	197
2005	50750	40329	56575	61139	49524	38624	22683	8571	3288	1501	848	357	220	157
2006	49376	41551	33018	46320	49573	39052	26195	9239	3402	1416	827	473	189	235
2007	81438	40425	34019	27033	37728	38896	26137	10458	3129	1800	823	554	345	243
2008		66676	33098	27852	22053	30374	28468	10621	3664	1449	1046	526	381	418

Table 7. XSA estimated fishing mortality at age. (Average fishing mortality is computed over ages 5-10.)

	Age													
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14+**	**Fbar(5-10)**
1975	0	0	0	0.000	0.007	0.103	0.322	0.481	0.635	0.644	0.576	0.446	0.560	0.560	0.365
1976	0	0	0	0.000	0.000	0.016	0.164	0.574	0.854	0.924	0.780	0.434	0.720	0.720	0.422
1977	0	0	0	0.000	0.008	0.132	0.413	0.685	0.719	0.585	0.205	0.257	0.351	0.351	0.424
1978	0	0	0	0.000	0.049	0.169	0.369	0.576	0.633	0.995	1.179	0.622	0.943	0.943	0.465
1979	0	0	0	0.000	0.054	0.197	0.418	0.467	0.159	0.200	0.537	0.837	0.529	0.529	0.249
1980	0	0	0	0.000	0.004	0.061	0.326	0.651	1.019	1.167	0.840	0.490	0.841	0.841	0.538
1981	0	0	0	0.000	0.020	0.124	0.445	0.890	0.690	0.441	0.199	0.256	0.300	0.300	0.435
1982	0	0	0	0.000	0.008	0.068	0.256	0.515	0.780	0.644	0.604	0.314	0.525	0.525	0.378
1983	0	0	0	0.000	0.018	0.140	0.454	0.552	0.397	0.331	0.147	0.138	0.207	0.207	0.315
1984	0	0	0	0.000	0.017	0.075	0.359	0.800	0.672	0.395	0.332	0.142	0.291	0.291	0.386
1985	0	0	0	0.000	0.038	0.133	0.275	0.380	0.313	0.159	0.078	0.124	0.121	0.121	0.216
1986	0	0	0	0.000	0.005	0.054	0.236	0.404	0.271	0.166	0.105	0.091	0.121	0.121	0.189
1987	0	0	0	0.000	0.002	0.045	0.409	0.603	0.414	0.249	0.199	0.170	0.207	0.207	0.287
1988	0	0	0	0.000	0.005	0.068	0.274	0.282	0.157	0.108	0.085	0.076	0.090	0.090	0.149
1989	0	0	0	0.000	0.003	0.040	0.224	0.225	0.145	0.132	0.141	0.155	0.143	0.143	0.128
1990	0	0	0	0.001	0.015	0.130	0.379	0.371	0.349	0.423	0.317	0.468	0.406	0.406	0.278
1991	0	0	0	0.003	0.046	0.135	0.400	0.655	0.731	0.626	0.591	0.615	0.616	0.616	0.432
1992	0	0	0	0.019	0.084	0.249	0.635	0.814	0.603	0.392	0.341	0.493	0.412	0.412	0.463
1993	0	0	0	0.019	0.239	0.520	0.819	0.982	0.876	0.560	0.433	0.641	0.549	0.549	0.666
1994	0	0	0	0.122	0.485	0.786	0.874	0.890	0.749	0.522	0.519	0.308	0.453	0.453	0.718
1995	0	0	0	0.009	0.041	0.114	0.350	0.394	0.368	0.273	0.304	0.328	0.303	0.303	0.257
1996	0	0	0	0.005	0.060	0.216	0.517	0.366	0.308	0.263	0.370	0.346	0.286	0.286	0.288
1997	0	0	0	0.005	0.057	0.209	0.559	0.538	0.387	0.327	0.366	0.369	0.353	0.353	0.346
1998	0	0	0	0.006	0.064	0.230	0.502	0.585	0.492	0.320	0.348	0.232	0.228	0.228	0.365
1999	0	0	0	0.004	0.031	0.135	0.697	0.739	0.582	0.411	0.346	0.533	0.338	0.338	0.432
2000	0	0	0	0.004	0.034	0.256	1.097	0.638	0.419	0.366	0.457	0.355	0.450	0.450	0.468
2001	0	0	0	0.008	0.046	0.288	0.987	0.899	0.406	0.391	0.596	0.495	0.510	0.510	0.503
2002	0	0	0	0.009	0.038	0.204	0.891	0.951	0.562	0.510	0.554	0.709	0.664	0.664	0.526
2003	0	0	0	0.022	0.105	0.364	1.018	1.016	0.643	0.481	0.442	0.448	0.558	0.558	0.604
2004	0	0	0	0.016	0.091	0.284	0.748	0.759	0.581	0.448	0.549	0.563	0.540	0.540	0.485
2005	0	0	0	0.010	0.038	0.188	0.698	0.724	0.642	0.396	0.383	0.435	0.387	0.387	0.448
2006	0	0	0	0.005	0.043	0.202	0.718	0.883	0.437	0.343	0.201	0.116	0.207	0.207	0.437
2007	0	0	0	0.004	0.017	0.112	0.701	0.849	0.570	0.342	0.247	0.174	0.141	0.141	0.432

Table 8. Stock summary table from XSA analysis (no SOP correction; shrinkage parameters fixed at 0.5). TOTSPB is the biomass at ages 10 and older.

Terminal Fs derived using XSA with final year & oldest age shrinka

	RE Age 1	TOTALE	TOTSPI	LANDIN	YIELD/S	FBAR 5-
1975	112289	132745	21901	28814	1.3157	0.3652
1976	116668	134515	17670	24611	1.3928	0.422
1977	107522	156967	14817	32048	2.1629	0.4237
1978	82385	167779	15905	39070	2.4565	0.4651
1979	99031	162567	15619	34104	2.1835	0.2489
1980	130137	130949	12403	32867	2.65	0.5381
1981	131878	115319	14026	30754	2.1927	0.435
1982	131159	121359	19874	26278	1.3222	0.3785
1983	146631	122816	24154	27861	1.1535	0.3154
1984	153784	115307	24279	26711	1.1002	0.3863
1985	167248	148263	29003	20347	0.7015	0.2162
1986	187148	138252	33558	17976	0.5357	0.1895
1987	156283	164862	42319	32442	0.7666	0.2869
1988	128757	169413	44314	19215	0.4336	0.1489
1989	112950	182583	43867	20034	0.4567	0.1282
1990	107712	206522	55914	47454	0.8487	0.2776
1991	94449	225176	63402	65008	1.0253	0.4321
1992	71040	193014	49008	63193	1.2894	0.4627
1993	84255	148926	37916	62455	1.6472	0.6659
1994	143006	103612	28899	51029	1.7657	0.7176
1995	173619	77875	25695	15272	0.5944	0.2567
1996	151487	77778	19899	18840	0.9468	0.2883
1997	124090	74714	18439	19858	1.077	0.3463
1998	110643	88131	17210	19946	1.1589	0.3655
1999	112062	103716	17119	24226	1.4151	0.4324
2000	117558	111918	13791	34177	2.4782	0.4684
2001	112024	113461	12424	38232	3.0773	0.5028
2002	111402	100779	10872	34062	3.1329	0.5259
2003	84400	93844	9191	35151	3.8244	0.6044
2004	49258	81929	9342	25486	2.728	0.4851
2005	50750	85460	8558	23225	2.7138	0.4477
2006	49376	88165	7938	23531	2.9643	0.4374
2007	81438	85516	9885	22747	2.3012	0.4318
Arith. Mean	114922	128007	23915	31425	1.6913	0.3969
0 Units	(Thousa	(Tonnes	(Tonnes	(Tonnes)		

Table 9. Retrospective comparison (one year) of numbers at age estimated from XSA. Table entries provide the ratio of the estimated numbers from the current assessment to those estimated in the previous assessment (model formulation unchanged). Shaded entries highlight changes in excess of +/- 10%.

2008/2007 Ratio Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1975	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1976	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1977	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1978	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979	1.001	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1980	1.001	1.001	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981	1.001	1.001	1.001	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.001	1.001	1.000	1.000
1982	1.002	1.001	1.001	1.001	1.001	1.000	1.000	1.001	1.000	1.001	1.001	1.001	1.000	1.002
1983	1.003	1.002	1.001	1.001	1.001	1.001	1.000	1.000	1.001	1.001	1.001	1.002	1.002	1.001
1984	1.003	1.003	1.002	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.002	1.002	1.001
1985	1.001	1.003	1.003	1.002	1.001	1.001	1.001	1.001	1.001	1.002	1.002	1.002	1.002	1.002
1986	1.002	1.001	1.003	1.003	1.002	1.001	1.001	1.001	1.001	1.002	1.002	1.002	1.001	1.002
1987	1.003	1.002	1.001	1.003	1.003	1.002	1.001	1.002	1.002	1.002	1.002	1.002	1.002	1.002
1988	1.000	1.003	1.002	1.001	1.003	1.003	1.002	1.002	1.003	1.002	1.003	1.003	1.003	1.002
1989	1.001	1.000	1.003	1.002	1.001	1.003	1.003	1.002	1.003	1.003	1.003	1.002	1.003	1.003
1990	1.001	1.001	1.000	1.003	1.002	1.001	1.003	1.004	1.003	1.003	1.004	1.003	1.003	1.003
1991	1.001	1.001	1.001	1.000	1.003	1.002	1.002	1.005	1.005	1.004	1.005	1.005	1.005	1.005
1992	1.004	1.001	1.001	1.001	1.000	1.003	1.003	1.002	1.009	1.011	1.008	1.009	1.009	1.009
1993	1.006	1.004	1.001	1.001	1.001	1.000	1.004	1.005	1.005	1.017	1.017	1.012	1.015	1.015
1994	1.004	1.006	1.004	1.001	1.001	1.002	1.000	1.008	1.014	1.013	1.029	1.026	1.022	1.024
1995	1.013	1.004	1.006	1.004	1.001	1.001	1.004	1.001	1.021	1.030	1.022	1.051	1.035	1.036
1996	1.011	1.013	1.004	1.006	1.004	1.001	1.001	1.006	1.001	1.030	1.039	1.032	1.071	1.074
1997	1.013	1.011	1.013	1.004	1.006	1.005	1.001	1.002	1.008	1.002	1.040	1.058	1.045	1.048
1998	1.044	1.013	1.011	1.013	1.004	1.006	1.006	1.002	1.003	1.013	1.003	1.059	1.085	1.087
1999	1.059	1.044	1.013	1.011	1.013	1.004	1.008	1.010	1.004	1.005	1.017	1.004	1.075	1.074
2000	1.127	1.059	1.044	1.013	1.011	1.013	1.005	1.016	1.020	1.007	1.007	1.025	1.008	1.006
2001	1.085	1.127	1.059	1.044	1.013	1.012	1.017	1.015	1.032	1.031	1.009	1.012	1.036	1.035
2002	1.055	1.085	1.127	1.059	1.045	1.014	1.015	1.048	1.037	1.049	1.047	1.017	1.018	1.017
2003	0.989	1.055	1.085	1.127	1.059	1.047	1.017	1.038	1.134	1.066	1.083	1.086	1.037	1.038
2004	0.810	0.989	1.055	1.085	1.131	1.066	1.068	1.047	1.114	1.290	1.113	1.135	1.133	1.145
2005	1.206	0.810	0.989	1.055	1.086	1.145	1.090	1.157	1.107	1.224	1.542	1.210	1.264	1.266
2006	0.904	1.207	0.810	0.989	1.056	1.090	1.180	1.199	1.388	1.225	1.374	2.066	1.370	1.374
2007		0.904	1.207	0.810	0.989	1.058	1.112	1.456	1.672	1.763	1.349	1.497	2.379	1.286

Table 10. Retrospective comparison (one year) of fishing mortality at age estimated from XSA. Table entries provide the ratio of the estimated fishing mortality from the current assessment to those estimated in the previous assessment (model formulation unchanged). Shaded entries highlight changes in excess of +/- 10%.

2008/2007														
Ratio Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1975					1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1976					1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1977					1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1978					1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979					1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1980					1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981					1.000	0.999	1.000	1.000	0.999	0.999	0.999	1.000	0.999	0.999
1982					1.000	1.000	1.000	0.999	0.999	0.999	0.999	0.999	0.999	0.999
1983					1.000	0.999	1.000	0.999	0.999	0.999	0.999	0.999	0.999	0.999
1984					1.000	1.000	0.999	0.999	0.999	0.999	0.998	0.998	0.998	0.998
1985					1.000	0.999	0.999	0.999	0.998	0.998	0.997	0.998	0.998	0.998
1986					1.000	0.998	0.998	0.999	0.998	0.998	0.998	0.998	0.998	0.998
1987					1.000	0.998	0.998	0.998	0.998	0.998	0.997	0.998	0.998	0.998
1988					0.979	0.997	0.998	0.998	0.997	0.997	0.998	0.996	0.998	0.998
1989					1.000	0.997	0.997	0.997	0.997	0.996	0.997	0.997	0.997	0.997
1990				1.000	1.000	0.998	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996
1991				1.000	0.996	0.998	0.998	0.993	0.992	0.994	0.993	0.993	0.993	0.993
1992				1.000	1.000	0.997	0.996	0.996	0.988	0.987	0.990	0.989	0.988	0.988
1993				1.000	0.998	1.000	0.994	0.991	0.991	0.978	0.980	0.984	0.981	0.981
1994				0.999	0.999	0.997	0.999	0.987	0.980	0.983	0.963	0.971	0.972	0.972
1995				1.000	1.000	0.999	0.995	0.999	0.976	0.967	0.974	0.943	0.961	0.961
1996				1.000	0.995	0.999	0.999	0.993	0.998	0.967	0.954	0.964	0.923	0.923
1997				1.000	0.993	0.995	0.998	0.998	0.990	0.998	0.954	0.934	0.949	0.949
1998				0.985	0.997	0.993	0.992	0.997	0.996	0.985	0.997	0.938	0.912	0.912
1999				1.000	0.987	0.996	0.988	0.986	0.995	0.994	0.979	0.995	0.917	0.917
2000				0.978	0.988	0.985	0.991	0.977	0.975	0.992	0.991	0.971	0.992	0.992
2001				0.953	0.987	0.987	0.971	0.976	0.962	0.963	0.987	0.985	0.955	0.955
2002				0.935	0.957	0.985	0.975	0.923	0.952	0.940	0.941	0.974	0.973	0.973
2003				0.888	0.941	0.946	0.972	0.935	0.833	0.920	0.903	0.902	0.951	0.951
2004				0.926	0.879	0.928	0.904	0.932	0.861	0.715	0.865	0.839	0.839	0.839
2005				0.951	0.919	0.861	0.880	0.799	0.864	0.775	0.568	0.779	0.743	0.743
2006				1.020	0.947	0.908	0.774	0.727	0.646	0.780	0.698	0.452	0.699	0.699

Table 11. Input data for deterministic and stochastic projections. See text for recruitment details.

Name	**Value**	**Uncertainty (CV)**	**Name**	**Value**	**ncertainty (CV)**
Population at age i		2008	Selection pattern		(2005-2007
N1	Bootstrap (2000-2005)		sH1	0.000	0.000
N2	66676	0.63	sH2	0.000	0.000
N3	33098	0.33	sH3	0.000	0.000
N4	27852	0.22	sH4	0.014	0.494
N5	22053	0.22	sH5	0.073	0.417
N6	30374	0.15	sH6	0.380	0.280
N7	28468	0.14	sH7	1.608	0.027
N8	10621	0.14	sH8	1.867	0.117
N9	3664	0.16	sH9	1.251	0.181
N10	1449	0.20	sH10	0.820	0.068
N11	1046	0.21	sH11	0.628	0.325
N12	526	0.19	sH12	0.547	0.685
N13	381	0.20	sH13	0.554	0.502
N14	418	0.20	sH14	0.554	0.502
Weight in the catch		(2005-2007)	Weight in the stock		(2005-2007
WH1	0.000	0.00	WS1	0.000	0.00
WH2	0.000	0.00	WS2	0.000	0.00
WH3	0.187	0.99	WS3	0.000	0.00
WH4	0.281	0.06	WS4	0.000	0.00
WH5	0.397	0.02	WS5	0.397	0.02
WH6	0.583	0.04	WS6	0.583	0.04
WH7	0.832	0.02	WS7	0.832	0.02
WH8	1.159	0.07	WS8	1.159	0.07
WH9	1.562	0.07	WS9	1.562	0.07
WH10	2.000	0.08	WS10	2.000	0.08
WH11	2.569	0.06	WS11	2.569	0.06
WH12	3.220	0.07	WS12	3.220	0.07
WH13	3.960	0.07	WS13	3.960	0.07
WH14	4.960	0.05	WS14	4.960	0.05
Natural mortality pattern			Maturity ogive pattern		
M1	0.20	0.15	MT1	0.000	0.000
M2	0.20	0.15	MT2	0.000	0.000
M3	0.20	0.15	MT3	0.000	0.000
M4	0.20	0.15	MT4	0.000	0.000
M5	0.20	0.15	MT5	0.000	0.000
M6	0.20	0.15	MT6	0.000	0.000
M7	0.20	0.15	MT7	0.000	0.000
M8	0.20	0.15	MT8	0.000	0.000
M9	0.20	0.15	MT9	0.000	0.000
M10	0.20	0.15	MT10	1.000	0.000
M11	0.20	0.15	MT11	1.000	0.000
M12	0.20	0.15	MT12	1.000	0.000
M13	0.20	0.15	MT13	1.000	0.000
M14	0.20	0.15	MT14	1.000	0.000

Table 12. Results of Deterministic projections under various catch levels and fishing mortality options.

F0.1

Year	5+ Biomass (t)	Yield (t)	Fbar (5-10)
2008	79050	24154	0.432
2009	67937	10471	0.180
2010	71477	10652	0.180
2011	80184	10389	0.180
2012	90180	10755	0.180
2013	100757		

F2007

Year	5+ Biomass (t)	Yield	Fbar (5-10)
2008	79050	24154	0.432
2009	67937	21252	0.432
2010	58341	16573	0.432
2011	58946	14251	0.432
2012	63078	14169	0.432
2013	68182		

16,000 t

Year	5+ Biomass (t)	Yield	Fbar (5-10)
2008	79050	24154	0.432
2009	67937	16000	0.298
2010	64737	16000	0.343
2011	66507	16000	0.406
2012	68977	16000	0.439
2013	72132		

22,750 t

Year	5+ Biomass (t)	Yield	Fbar (5-10)
2008	79050	24154	0.432
2009	67937	22750	0.475
2010	56517	22750	0.734
2011	49533	22750	1.394
2012	42699	22750	2.798
2013	35401		

Table 13. Exploitable Biomass growth (%) under various projection scenarios. Exploitable biomass (5+) at the end of the projection period (2013) is compared to the biomass at the beginning of the projection (2008; 79 000 tons) and the biomass in 2003, when the rebuilding plan was instituted (93 800 tons).

Exploitable Biomass	F0.1	F2007	16 000t	22 750t
[B(2013)-B(2008)] / B(2008)	27%	-14%	-9%	-55%
[B(2013)-B(2003)] / B(2003)	7%	-27%	-23%	-62%

Table 14. 10+ Biomass growth (%) under various projections. The 10+ biomass at the end of the projection period (2013) is compared to the biomass at the beginning of the projection (2008; 10 900 tons) and the biomass in 2003, when the rebuilding plan was instituted (9 200 tons).

10+ Biomass	F0.1	F2007	16 000t	22 750t
[B(2013)-B(2008)] / B(2008)	199%	4%	38%	-92%
[B(2013)-B(2003)] / B(2003)	253%	23%	63%	-91%

Table 15. Comparison of the biomass at the end of the projection period to the rebuilding plan target of 140 000 tons.

Scenario	Projected Biomass Relative to 140 000t
F0.1	0.72
F2007	0.49
16,000 t	0.52
22,750 t	0.25

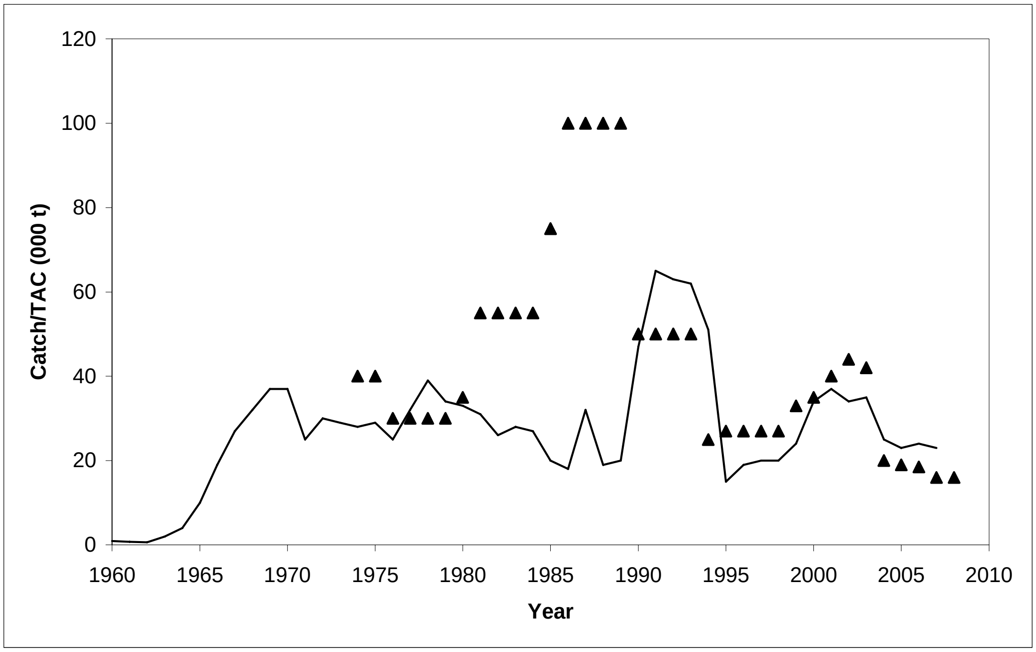


Figure 1 – Catches (line) and TAC (triangle) of Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO.

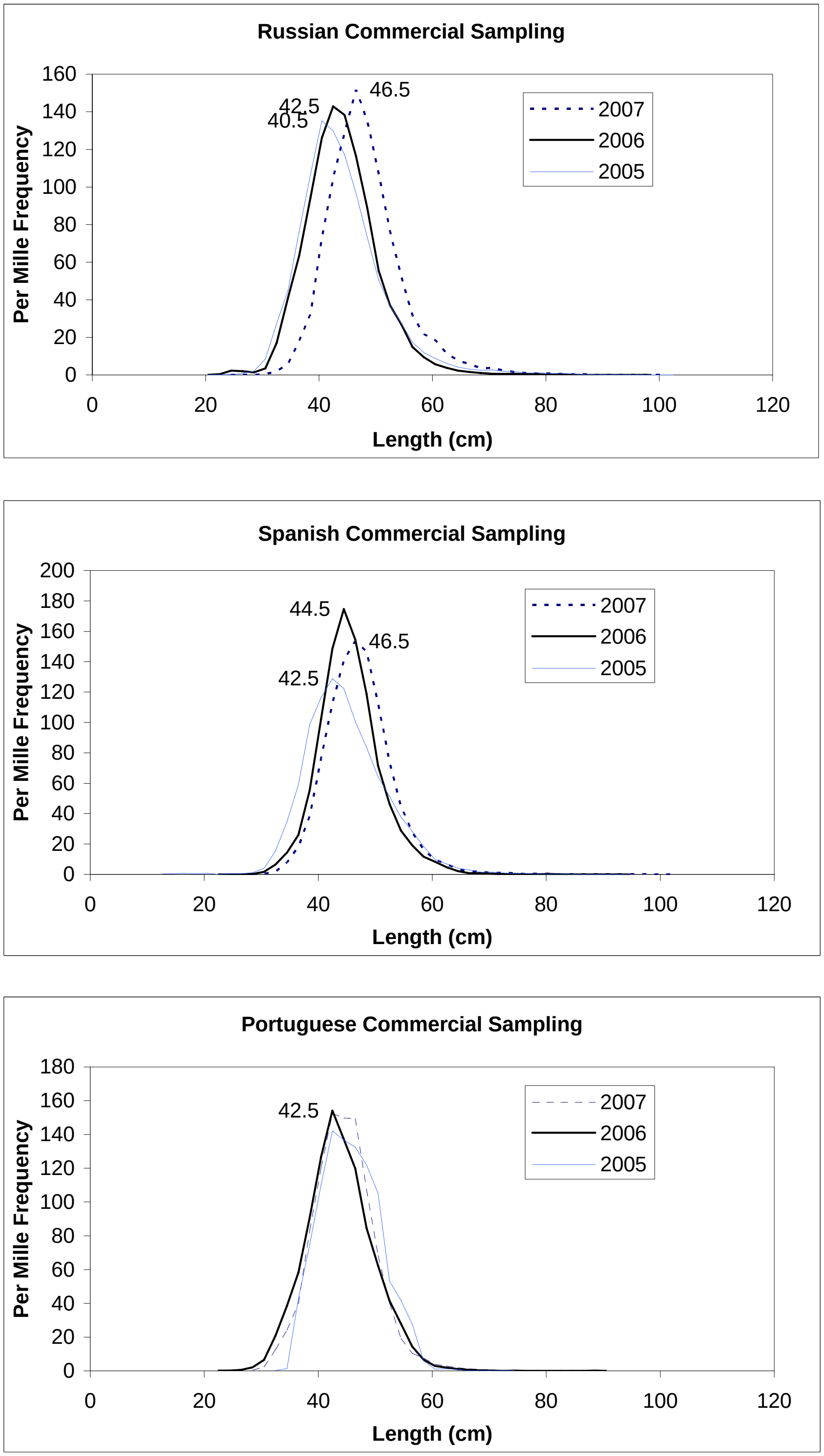


Figure 2 – Available Length Sampling over 2005- 2007 for fisheries within the NRA. Labels indicate modal length group.

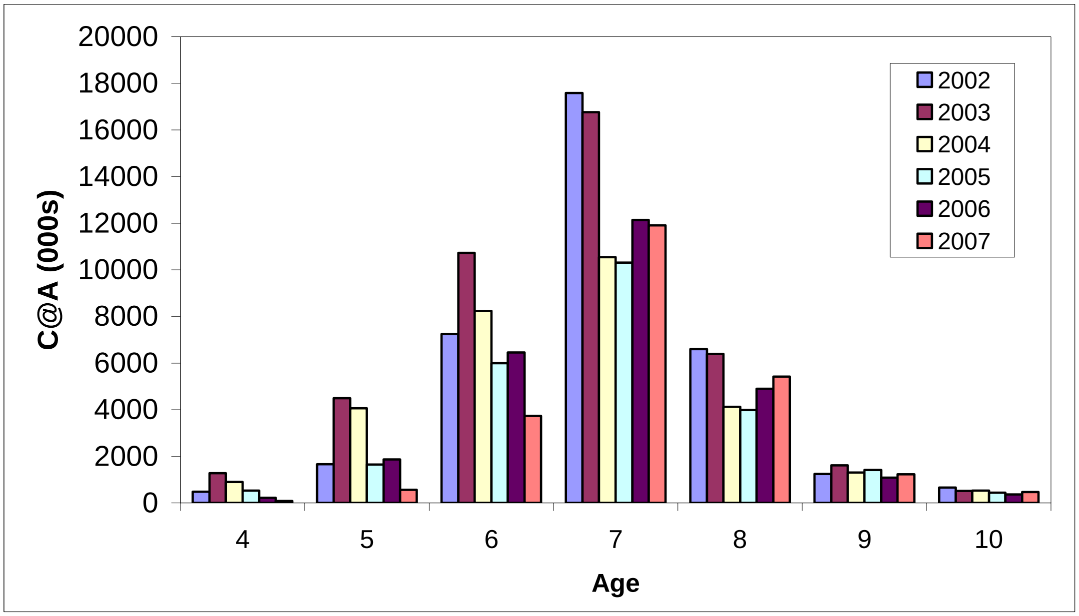
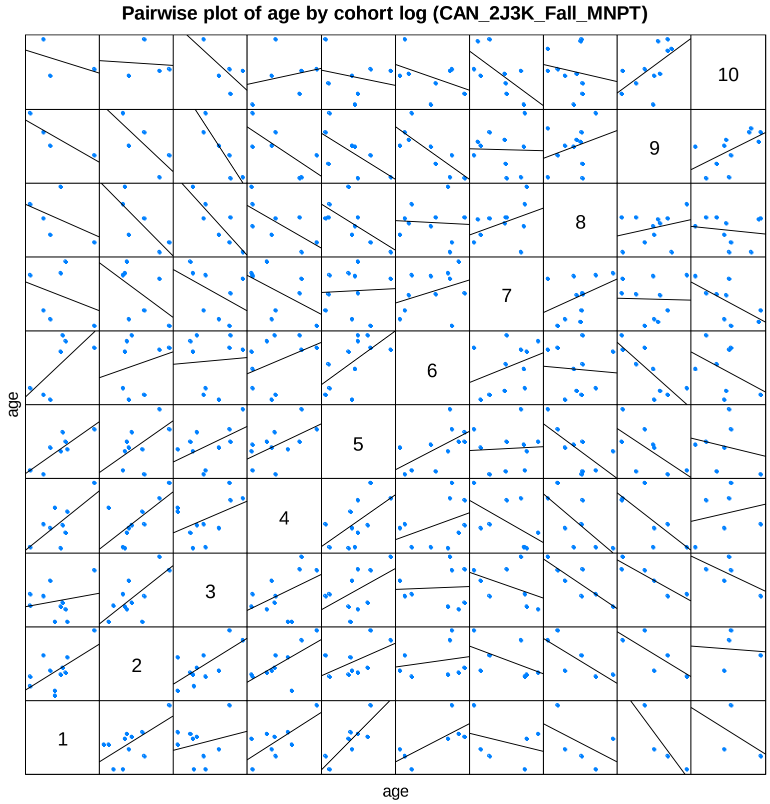


Figure 3 – Total catch at age (in thousands) for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO in recent years (2002-2007).



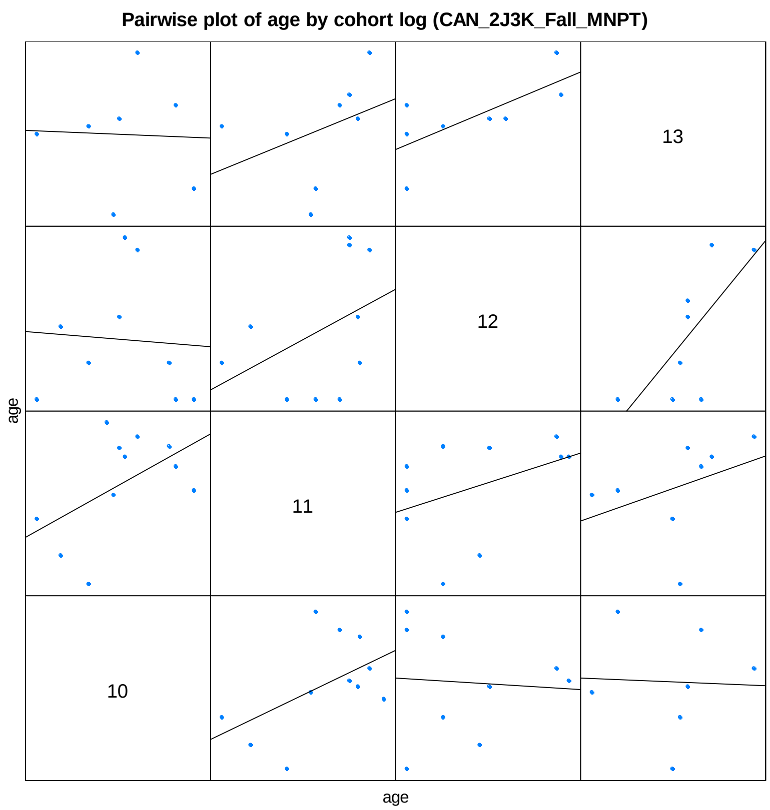


Figure 4a – Pair-wise scatter plot of age-disaggregated survey data (log-scale) from Canadian fall survey in Divs. 2J3K. Points represent comparison of survey data for a common cohort at successive ages.

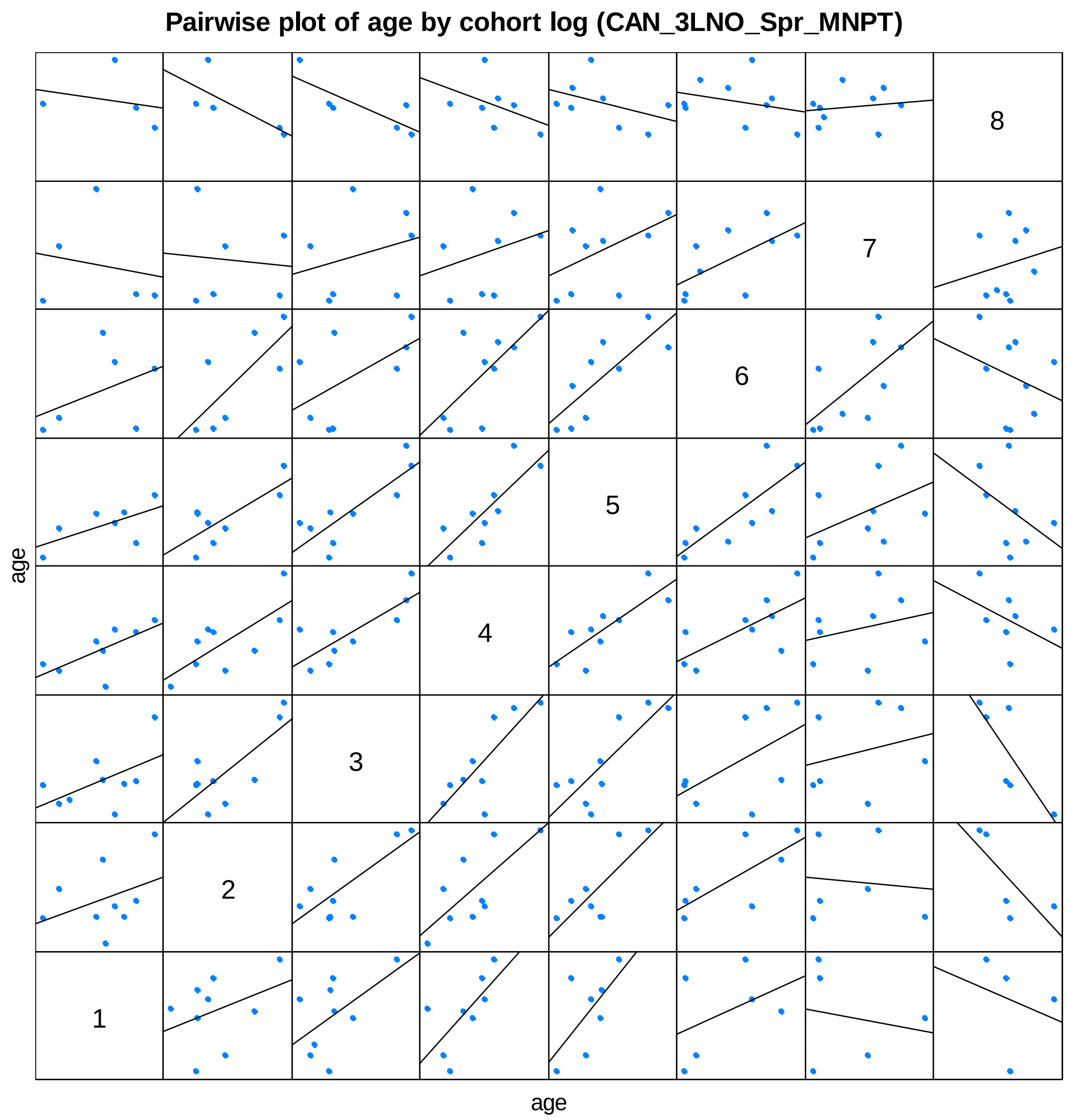


Figure 4b – Pair-wise scatter plot of age-disaggregated survey data (log-scale) from Canadian spring survey in Divs. 3LNO. Points represent comparison of survey data for a common cohort at successive ages.

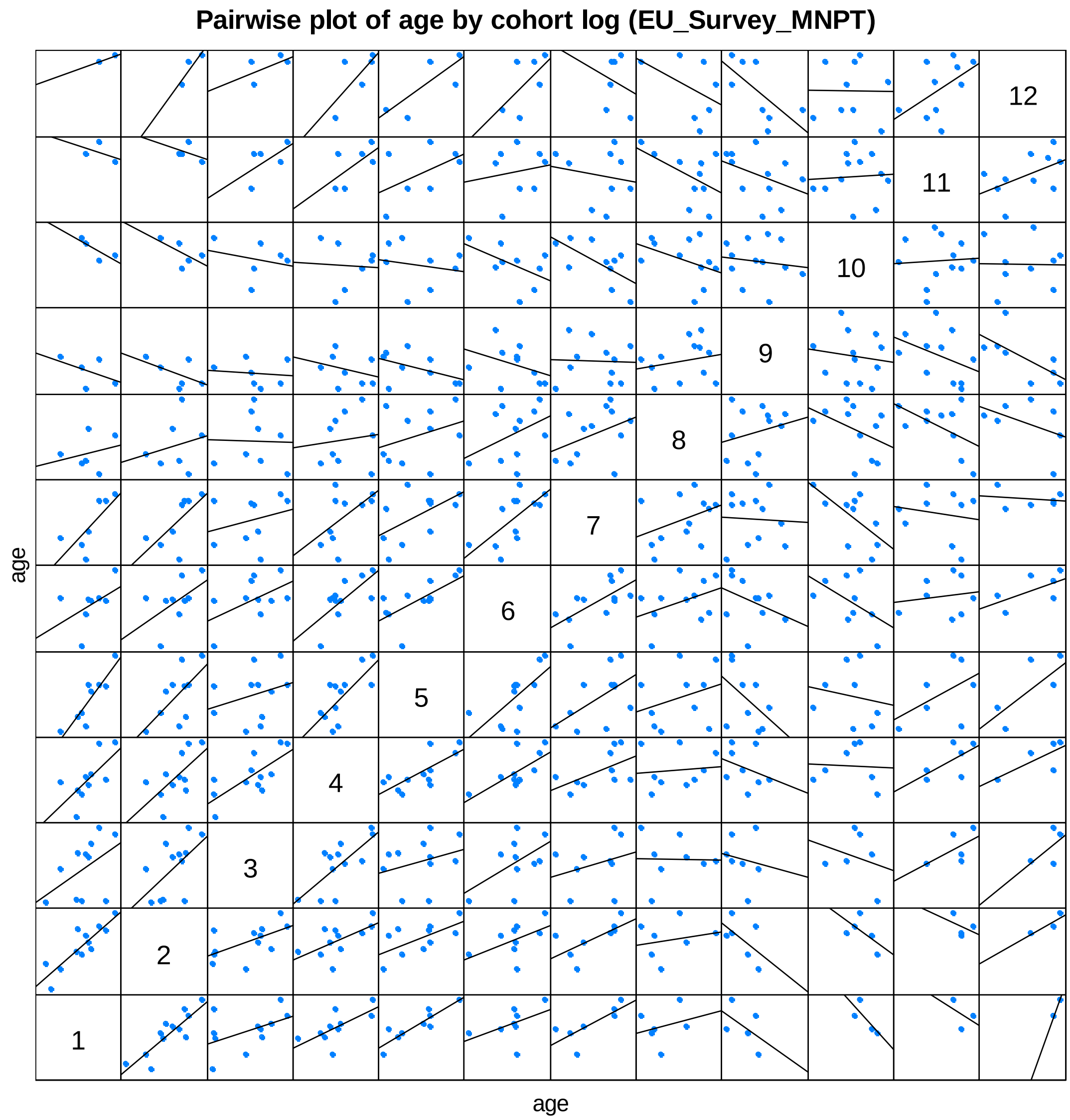


Figure 4c – Pair-wise scatter plot of age-disaggregated survey data (log-scale) from EU summer survey in Div. 3M. Points represent comparison of survey data for a common cohort at successive ages.

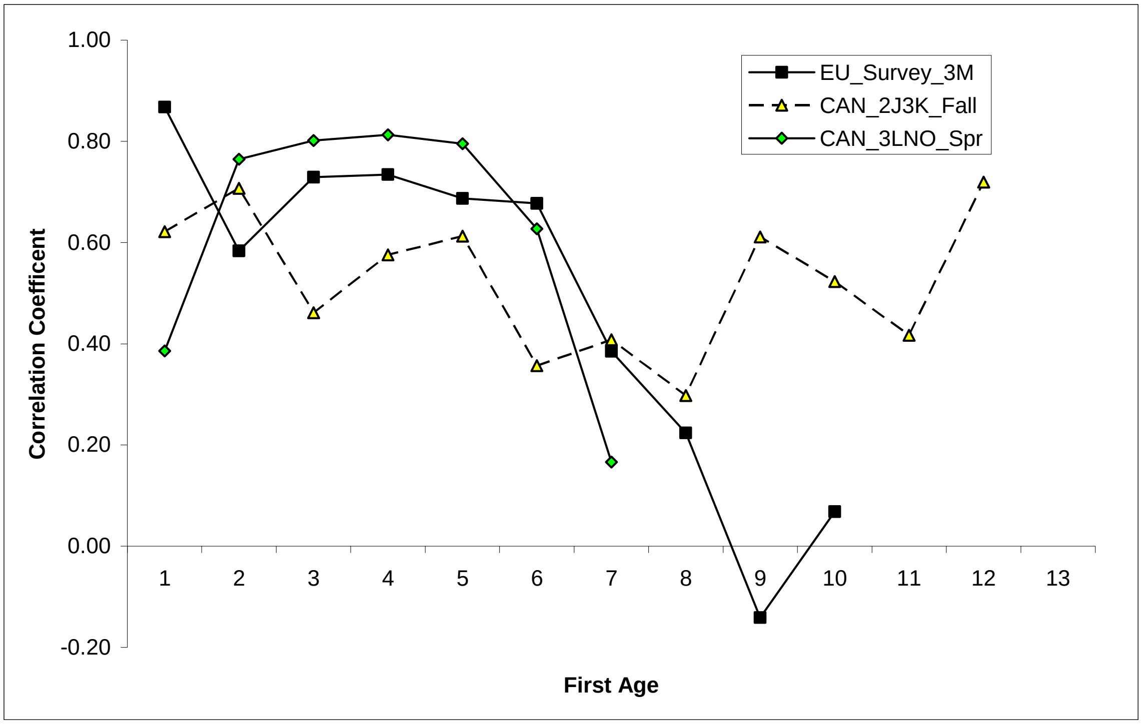


Figure 5 – Correlation coefficients between successive age groups from each survey series included in the VPA analysis. “First Age” identifies the youngest age being considered.

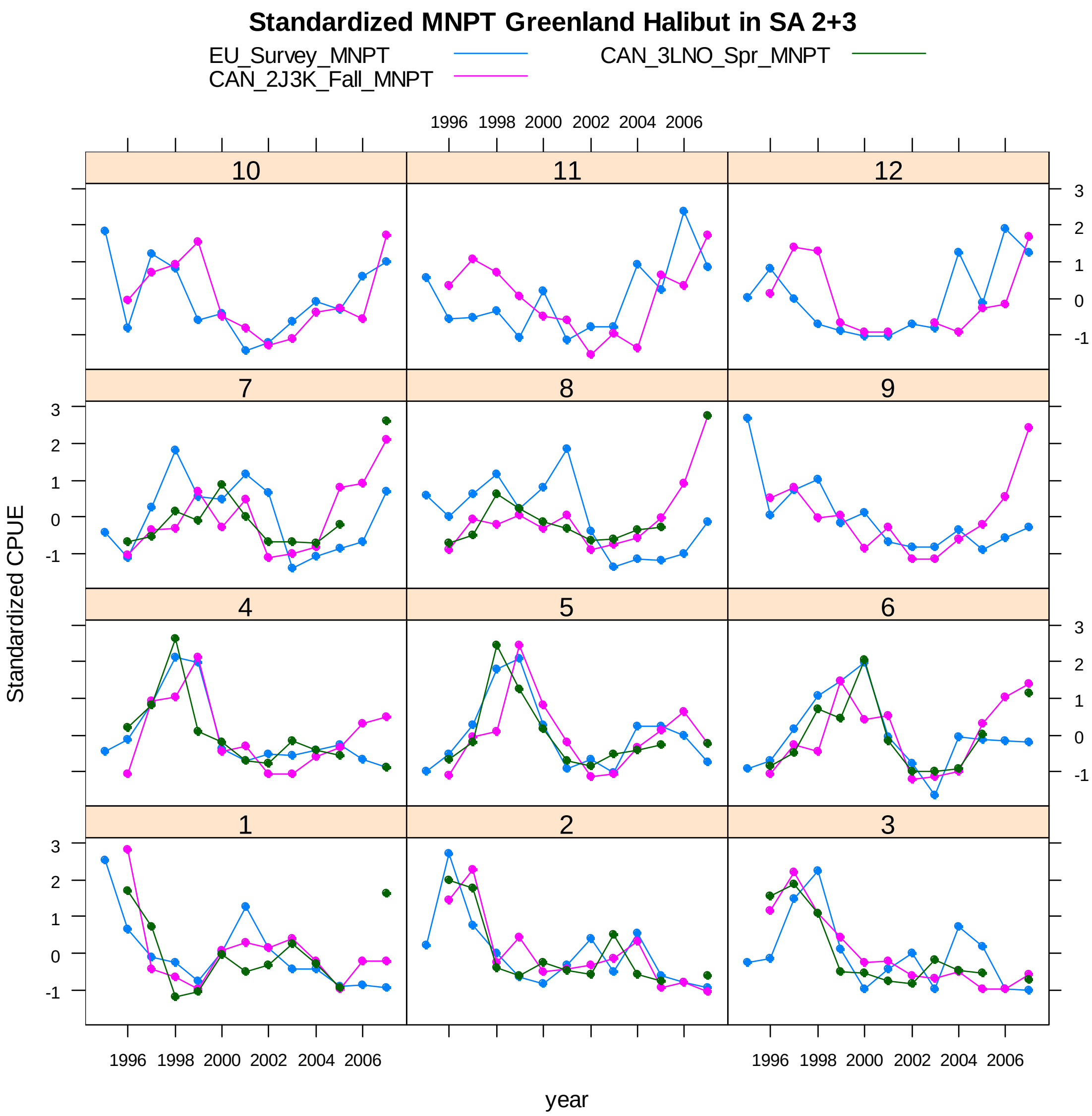


Figure 6 – Standardized age-disaggregated Greenland Halibut survey indices.

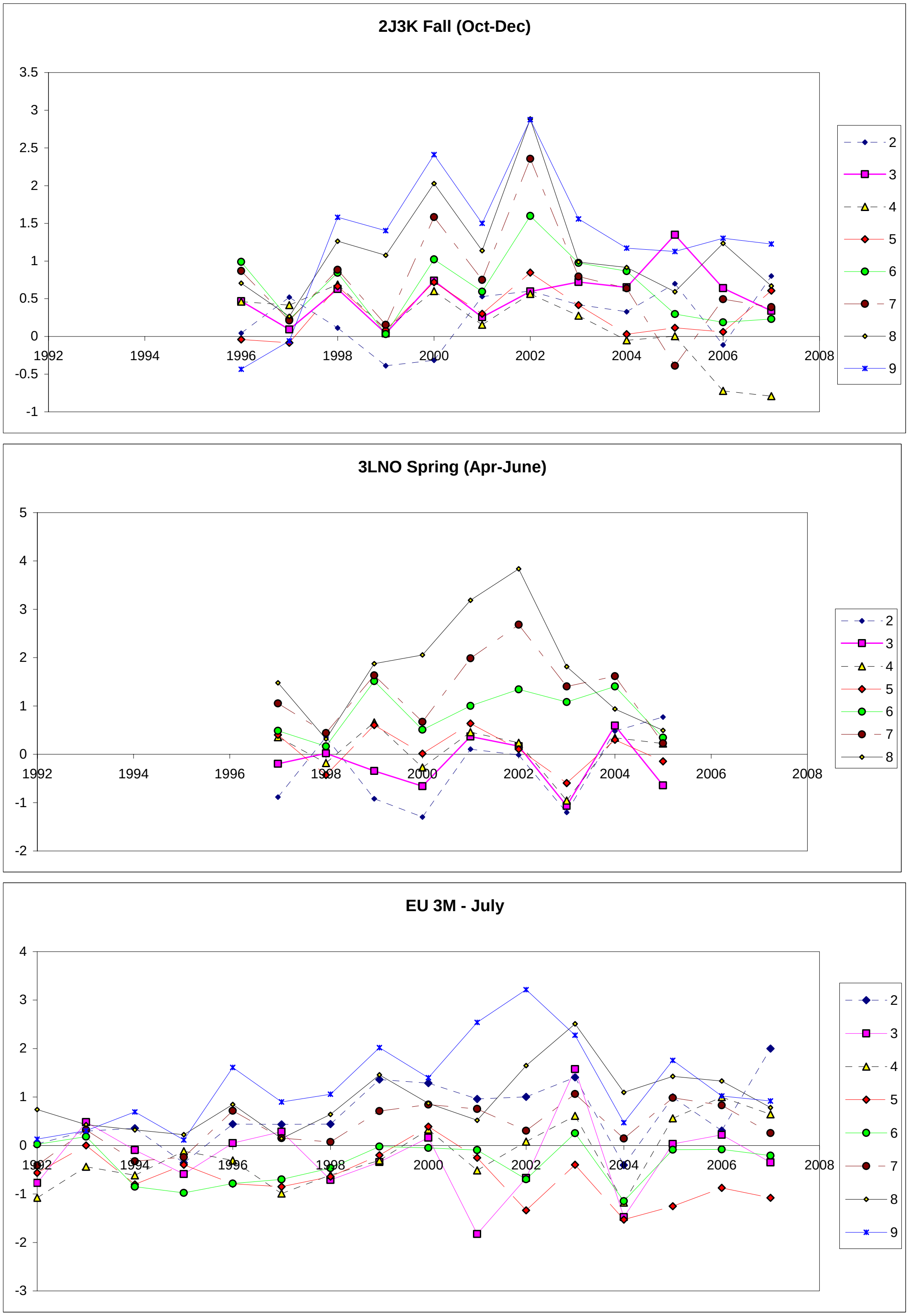
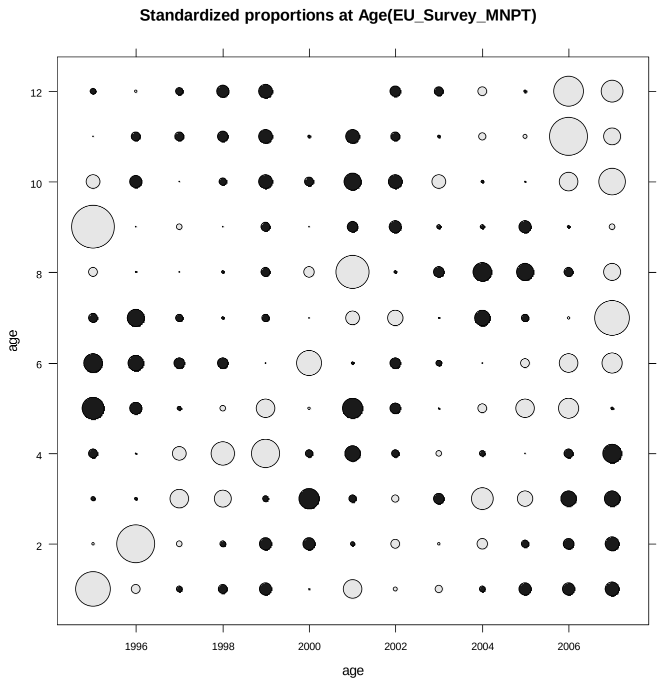


Figure 7 – Survey estimates of total mortality for Greenland Halibut survey indices. (The age a series denotes the total mortality experienced from age (a-1) to age a.)



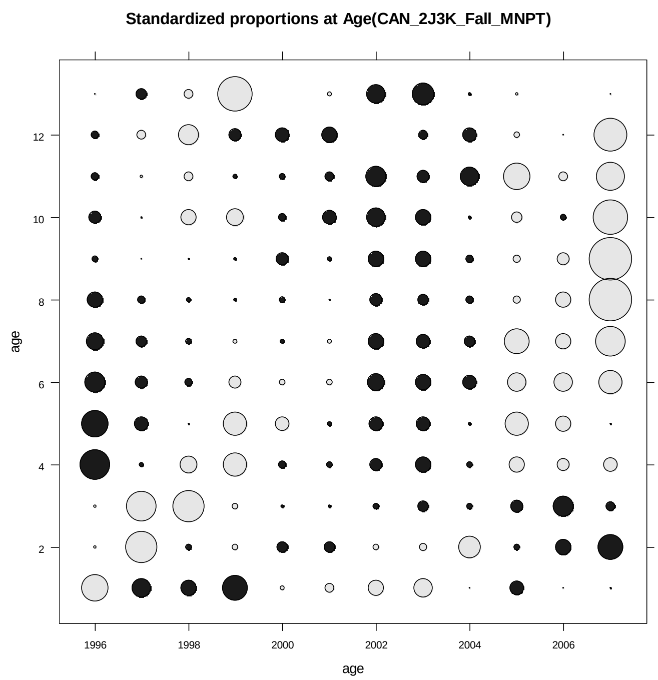


Figure 8 – Standardized age-disaggregated Greenland Halibut survey indices.

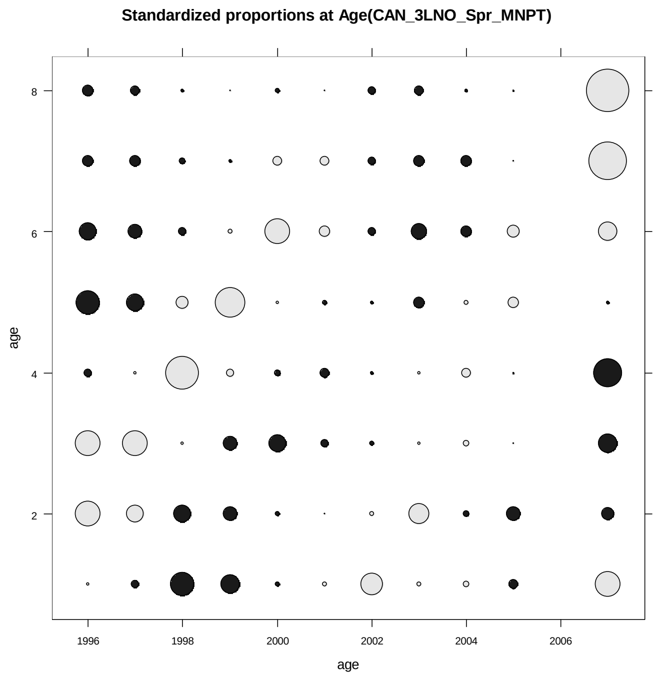


Figure 8. (cont.)

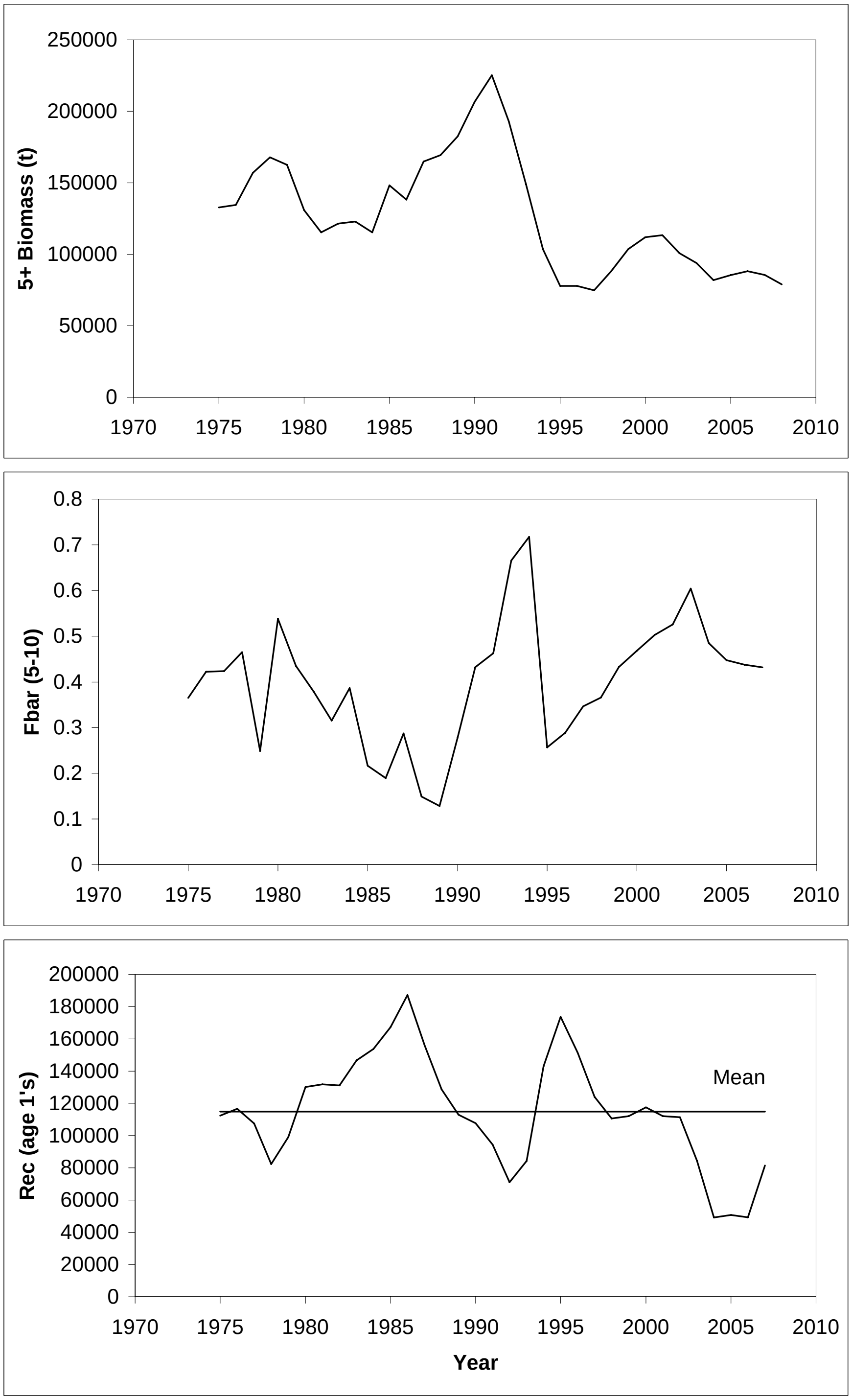
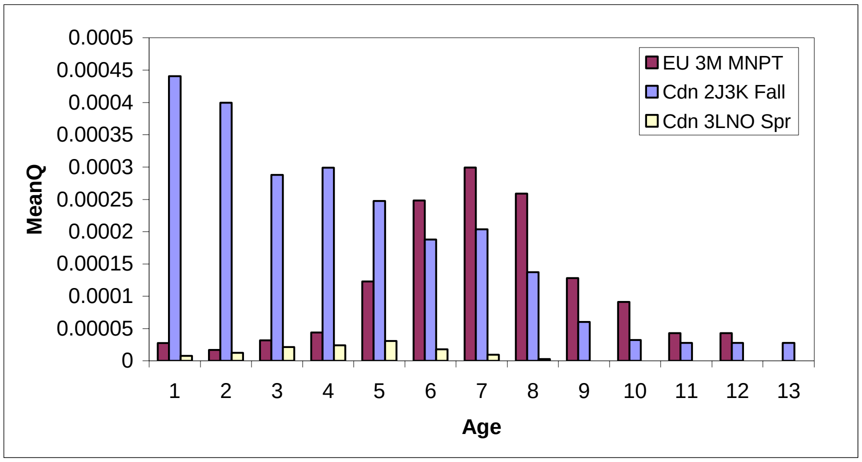
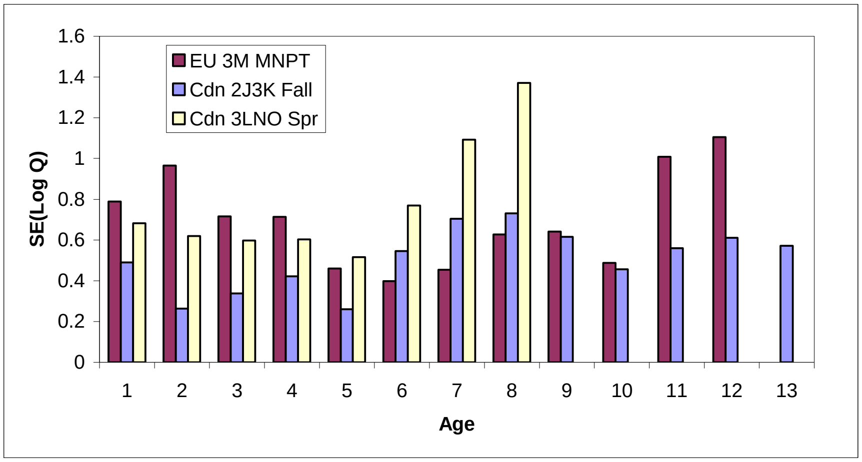


Figure 9 – XSA Estimates of exploitable biomass (ages 5+ in tons; upper panel), average fishing mortality (ages 5-10) and recruitment (000’s at age 1) for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO.

Catchabilities



SE(Log q)



Shrinkage Scaled Weights

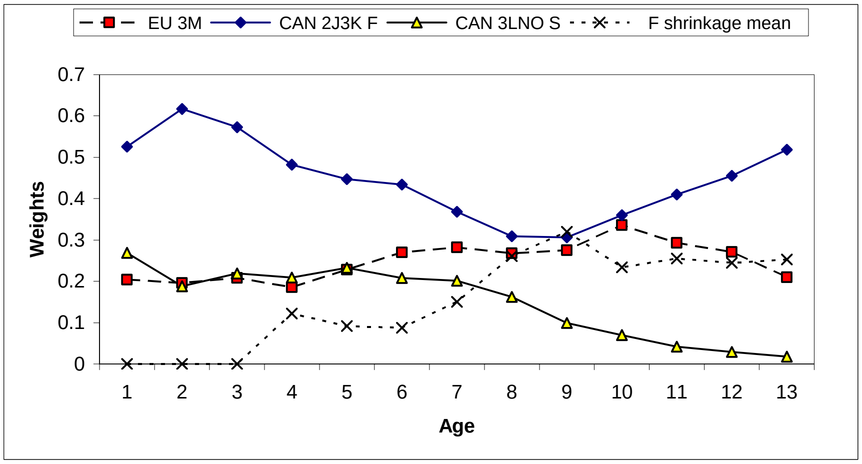


Figure 10 – XSA estimated catchabilities, associated standard errors, and the scaled weights used to estimate survivors in the terminal year.

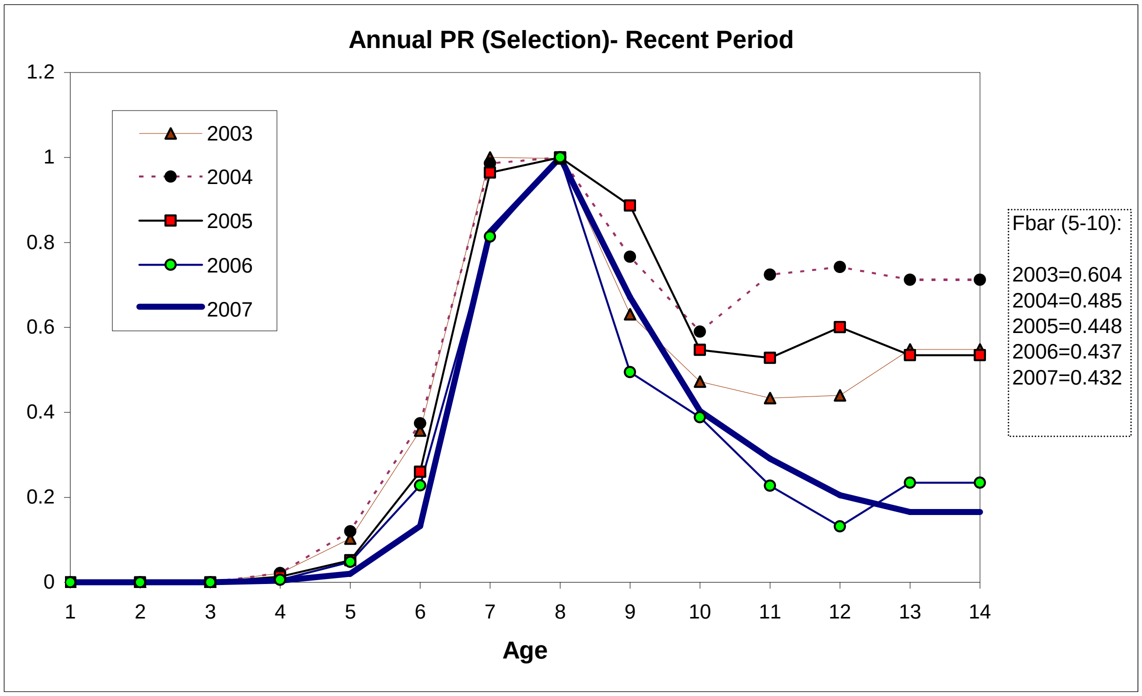


Figure 11 – XSA estimated selection pattern in the most recent five years.

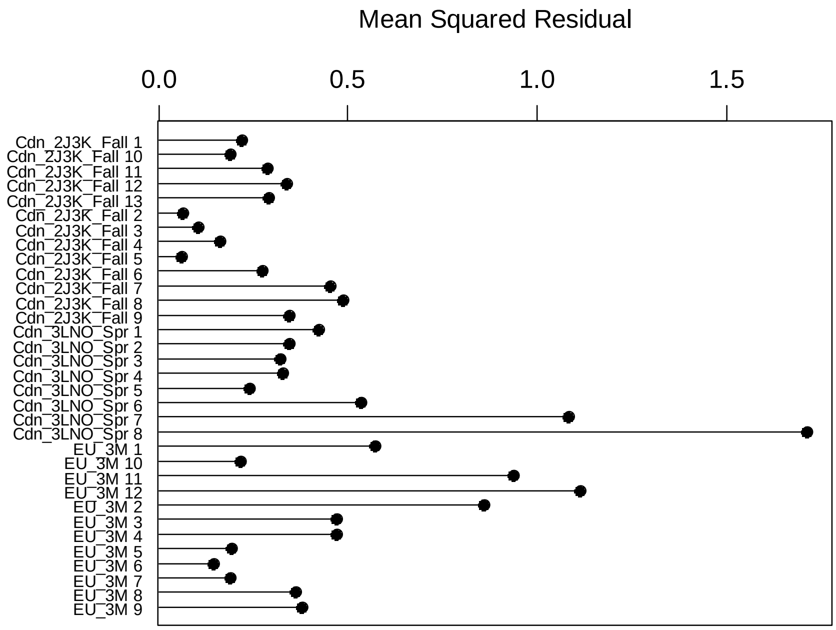


Figure 12a – Mean square residuals from XSA for each survey-age.

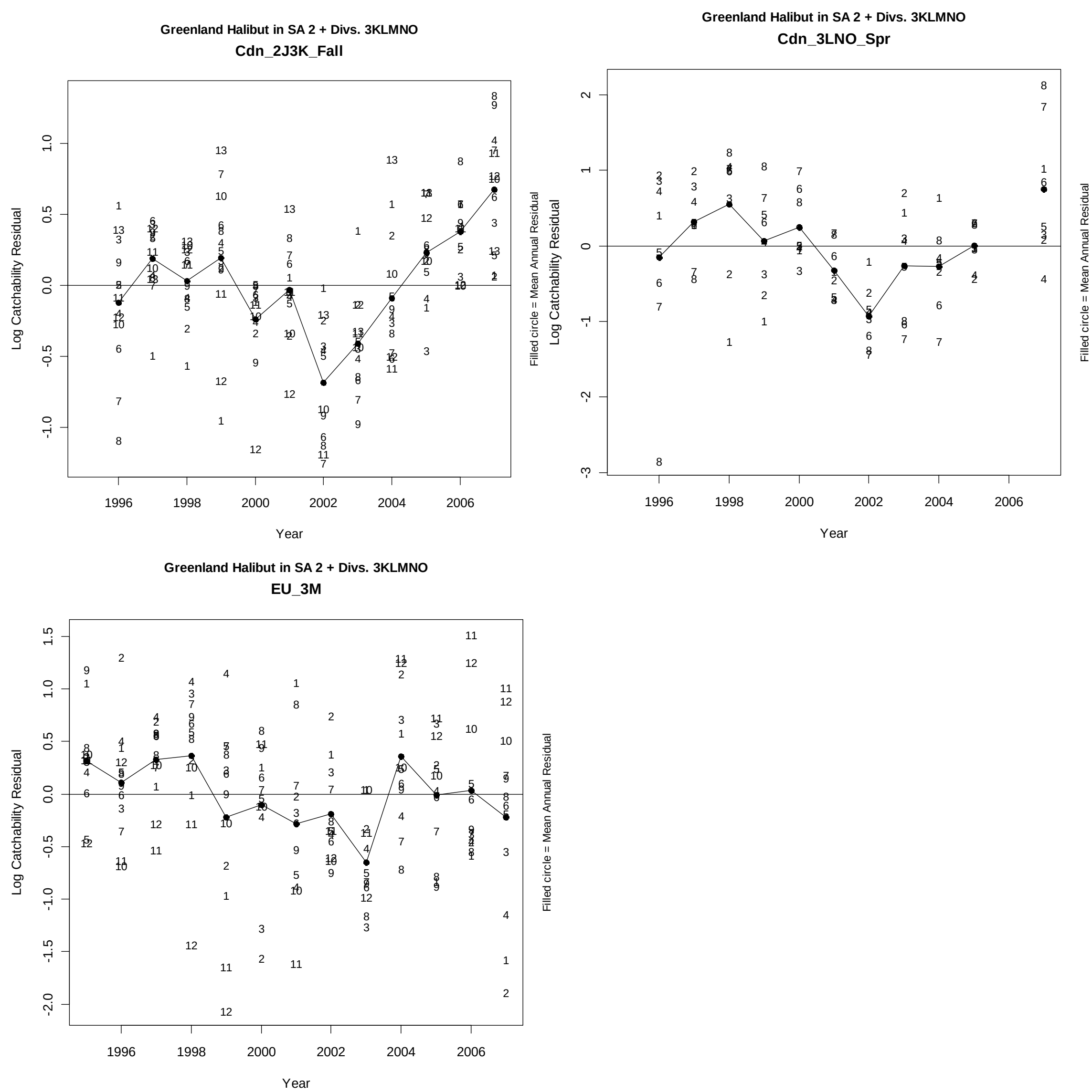


Figure 12b – XSA residuals by survey, age and year. Symbol=age, solid circle=mean annual residual.

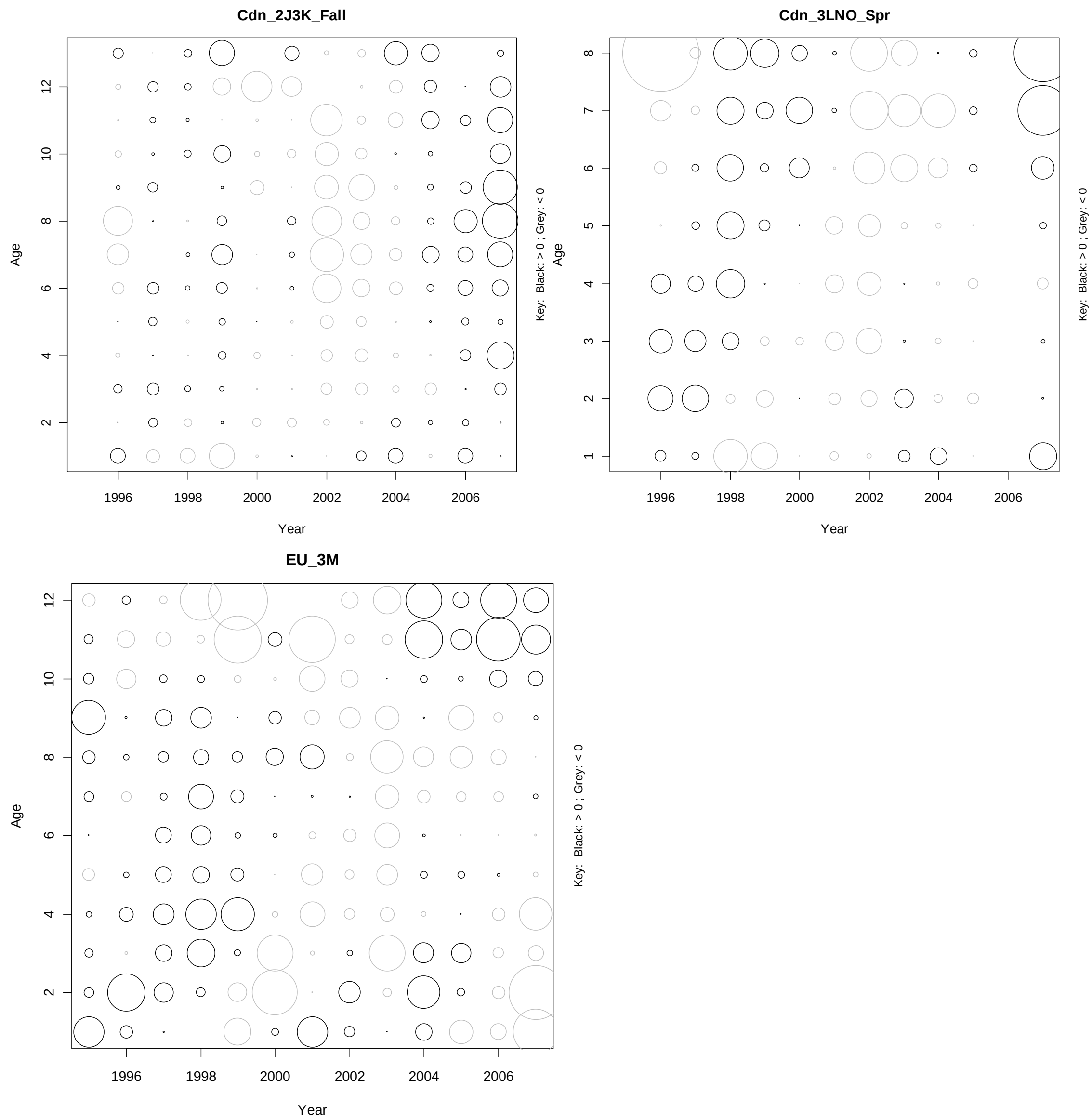


Figure 12c – XSA Residuals (cont.) Black=positive residual; grey=negative residual. Symbols are scaled to the overall maximum residual to permit comparisons across survey series.

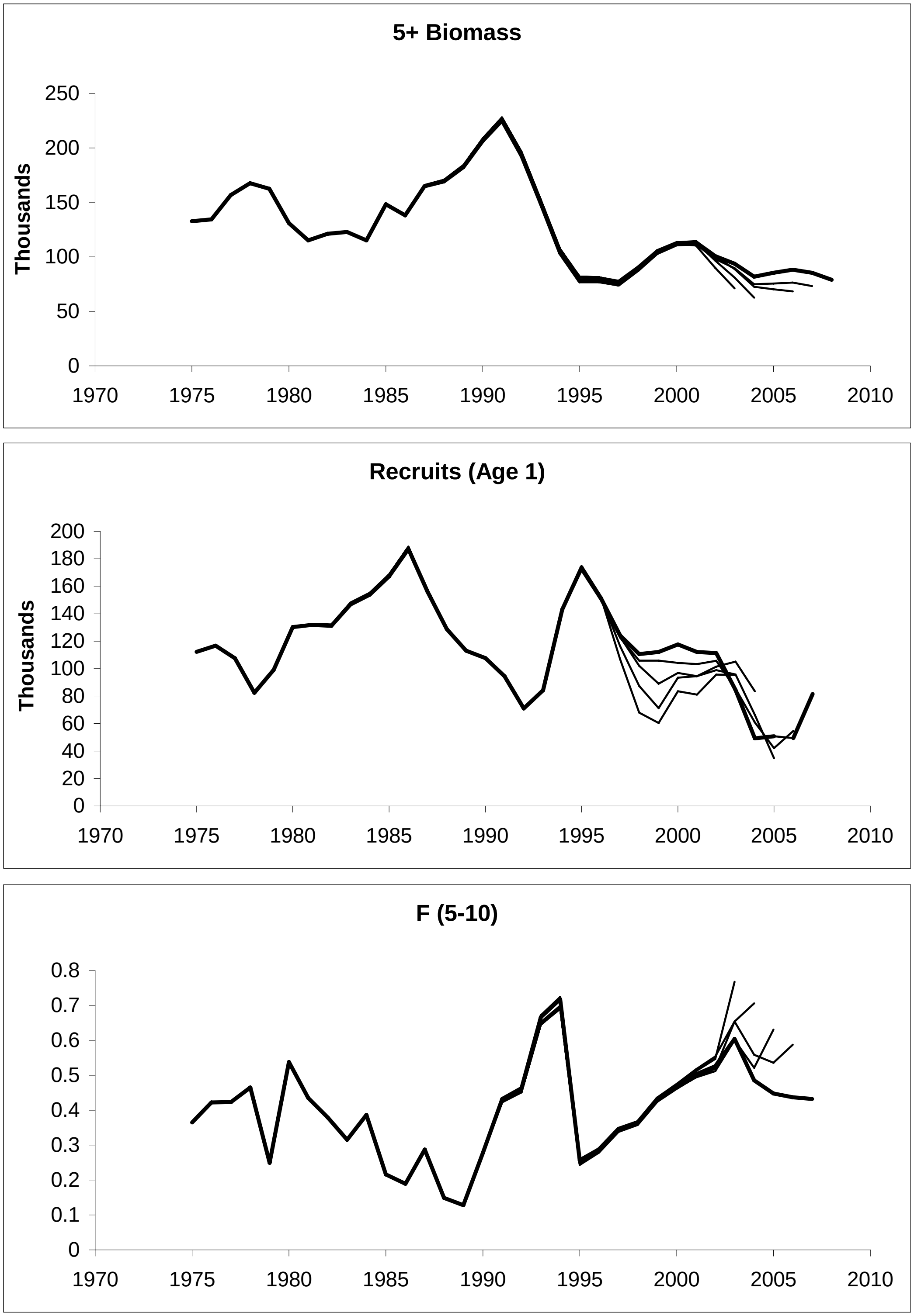


Figure 13 – Retrospective Analysis – 5+ biomass (t), Age 1 recruitment (000s) and average fishing mortality (ages 5-10). Bold lines highlight the current assessment.

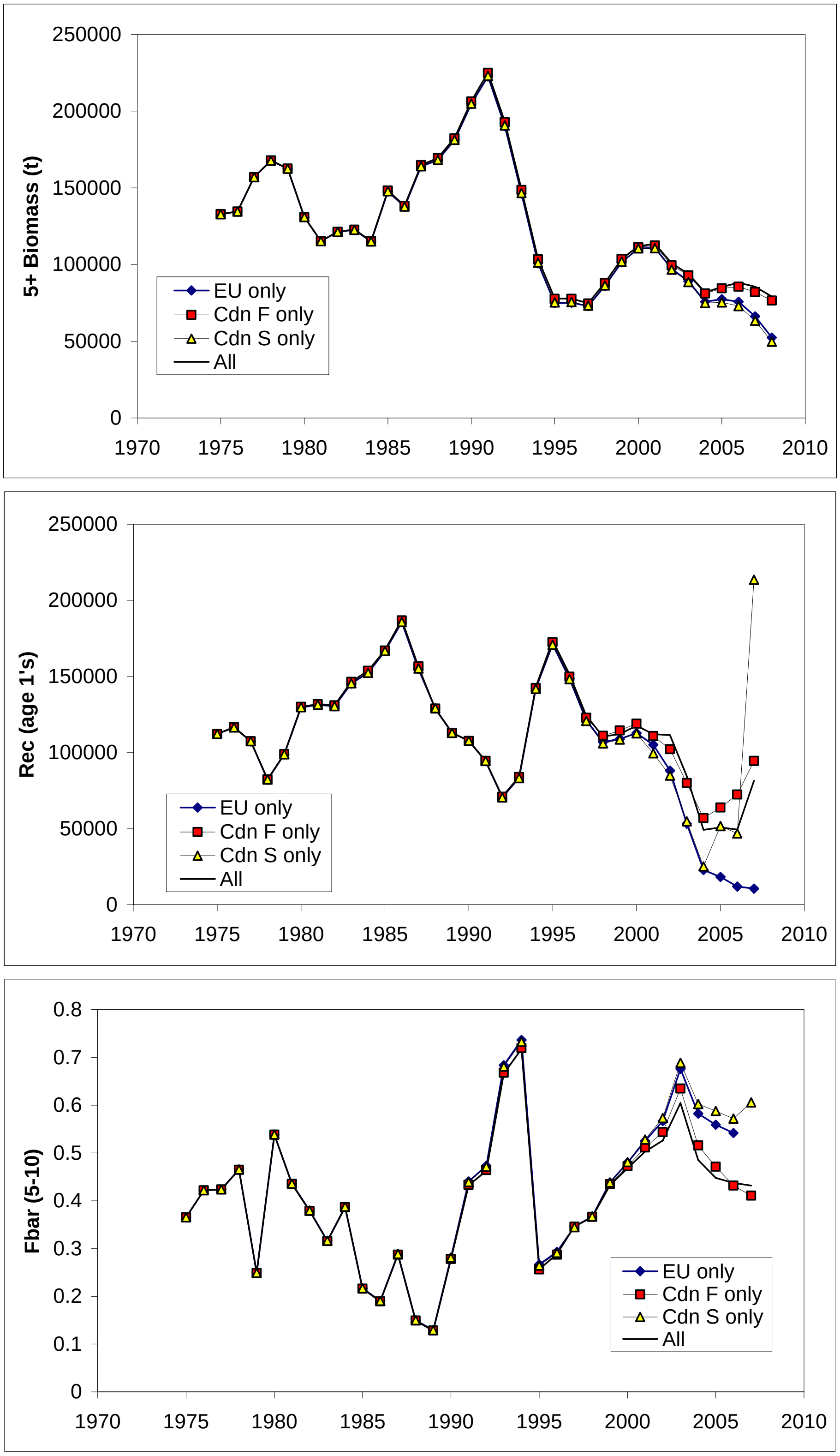


Figure 14 – Biomass (5+; tons), Recruitment (age 1; 000s), and average fishing mortality (ages 5-10) from three XSA analyses calibrated using only one of the tuning series.

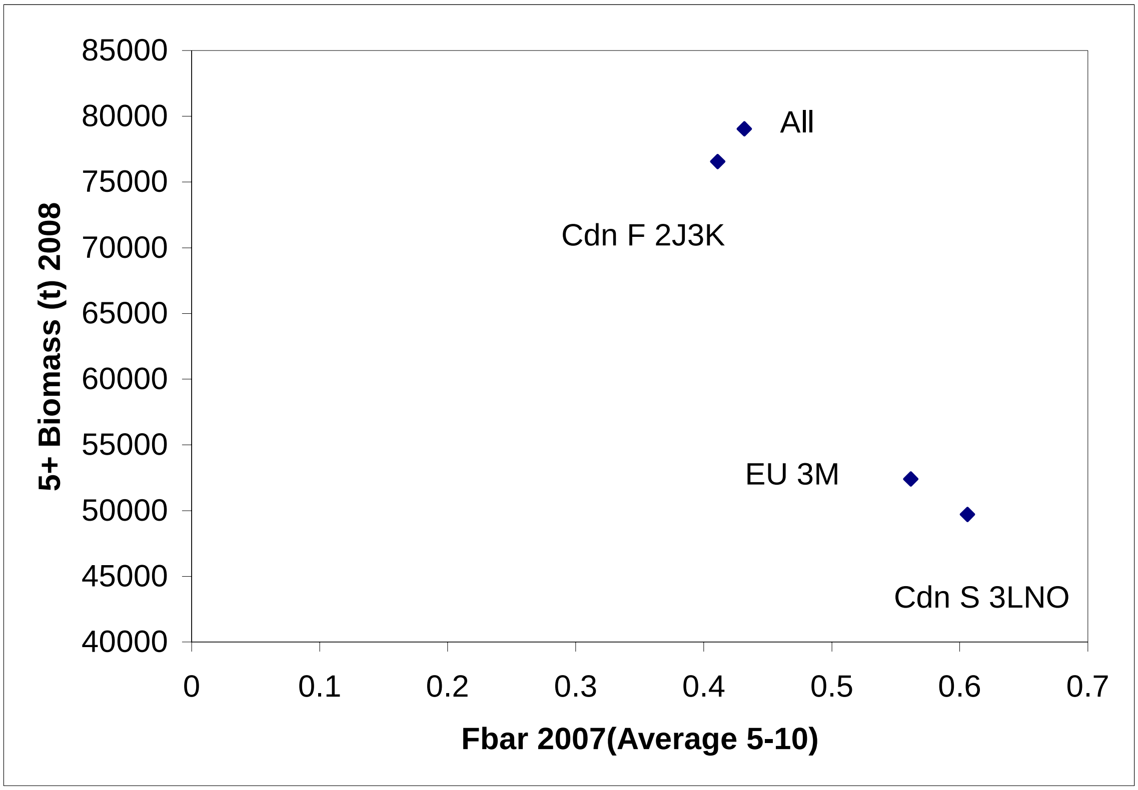


Figure 15 – Comparison of exploitable biomass in 2007 and fishing mortality in 2006 for XSA analyses calibrated using a single tuning series. “All” refers to the analysis which includes all three data series.

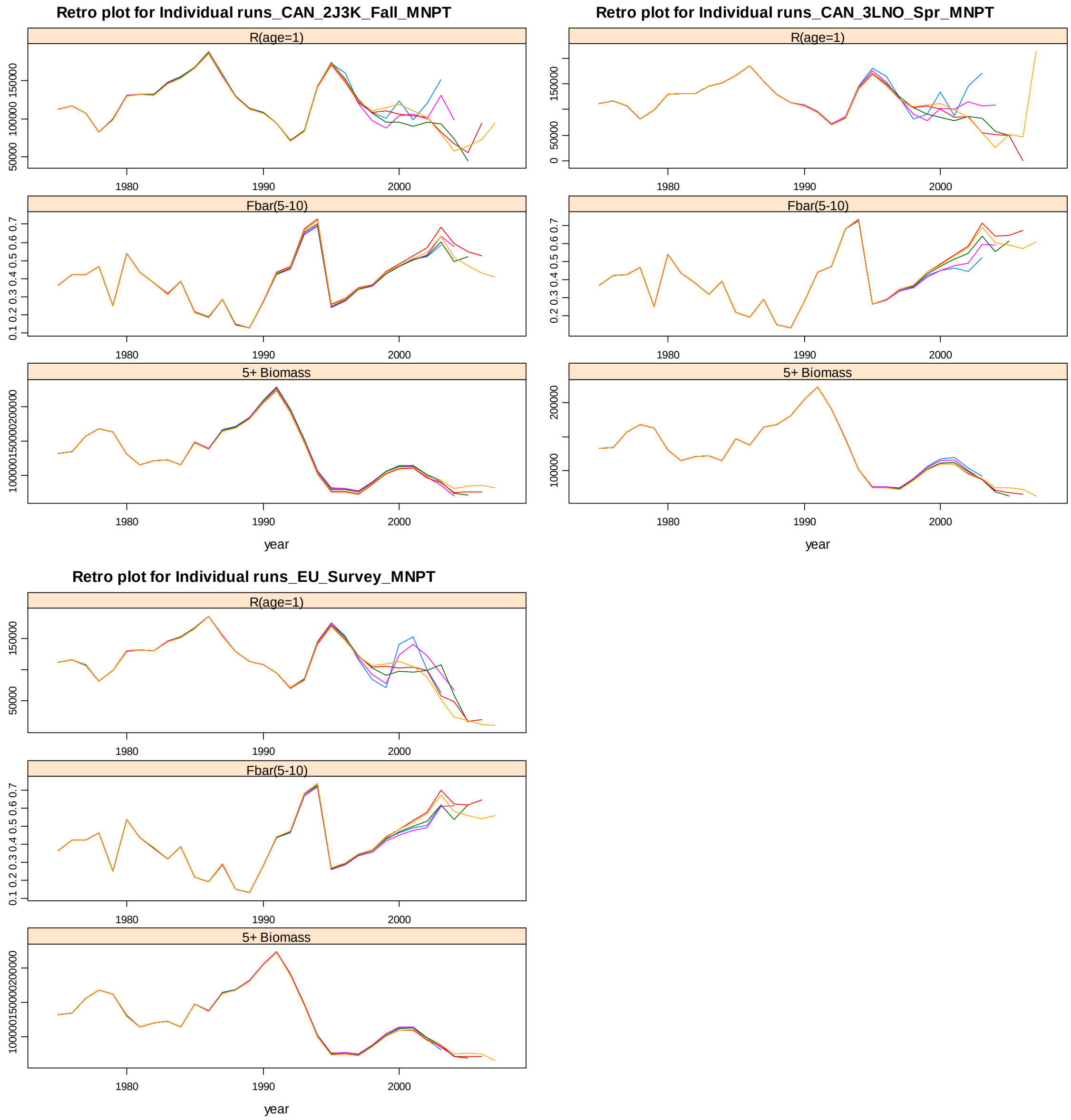


Figure 16 – Retrospective analyses for XSA calibrated using only one of the tuning series

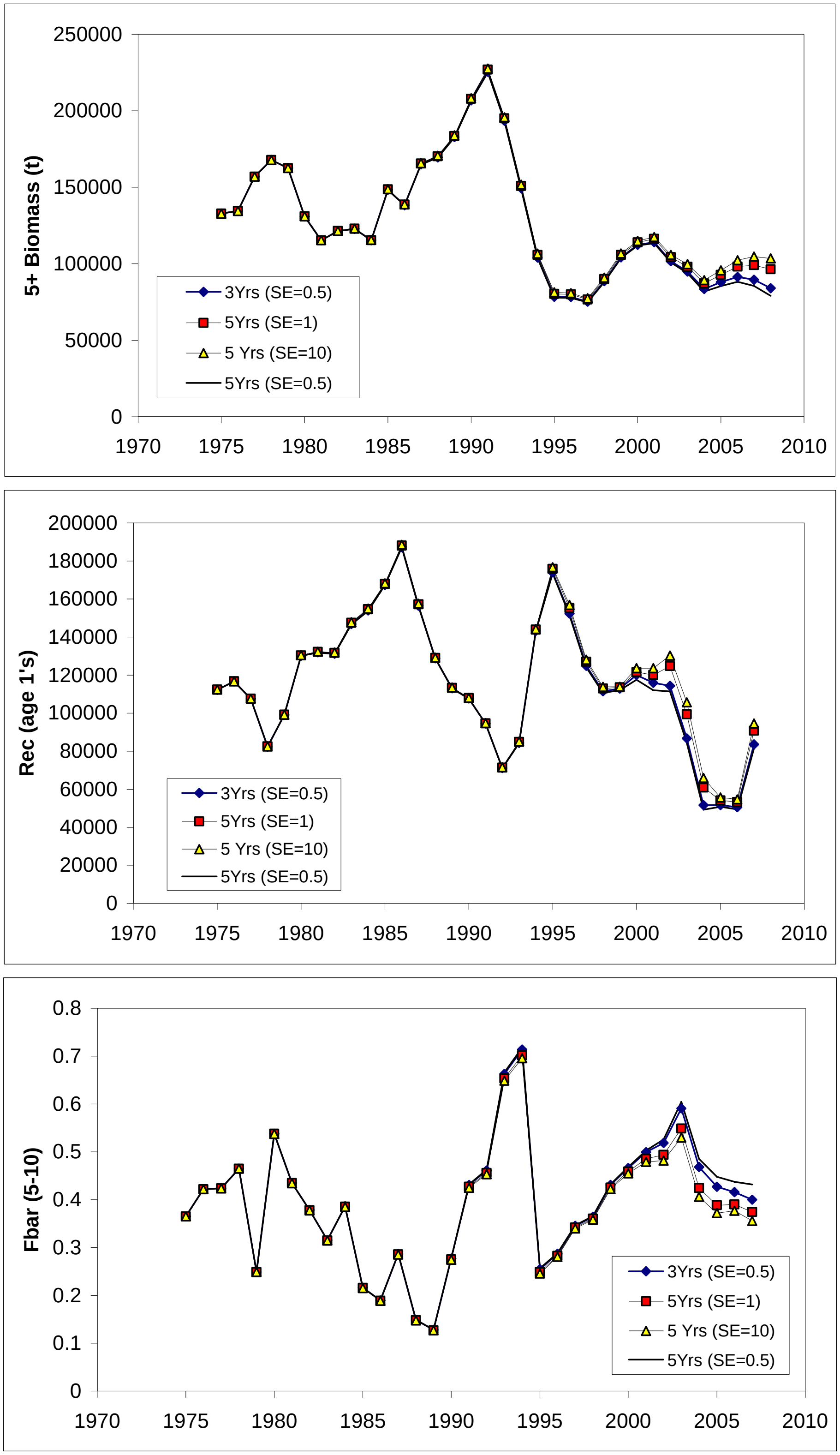


Figure 17 – Biomass (5+; tons), Recruitment (age 1; 000s), and average fishing mortality (ages 5-10) from XSA analyses using varied shrinkage options: identifies the number of years and weighting parameters (lower SE values imply stronger shrinkage) used compute mean F (for each age) to which estimates of survivors are shrunk towards. Current assessment settings corresponds to “5Yrs (SE=0.5)”.

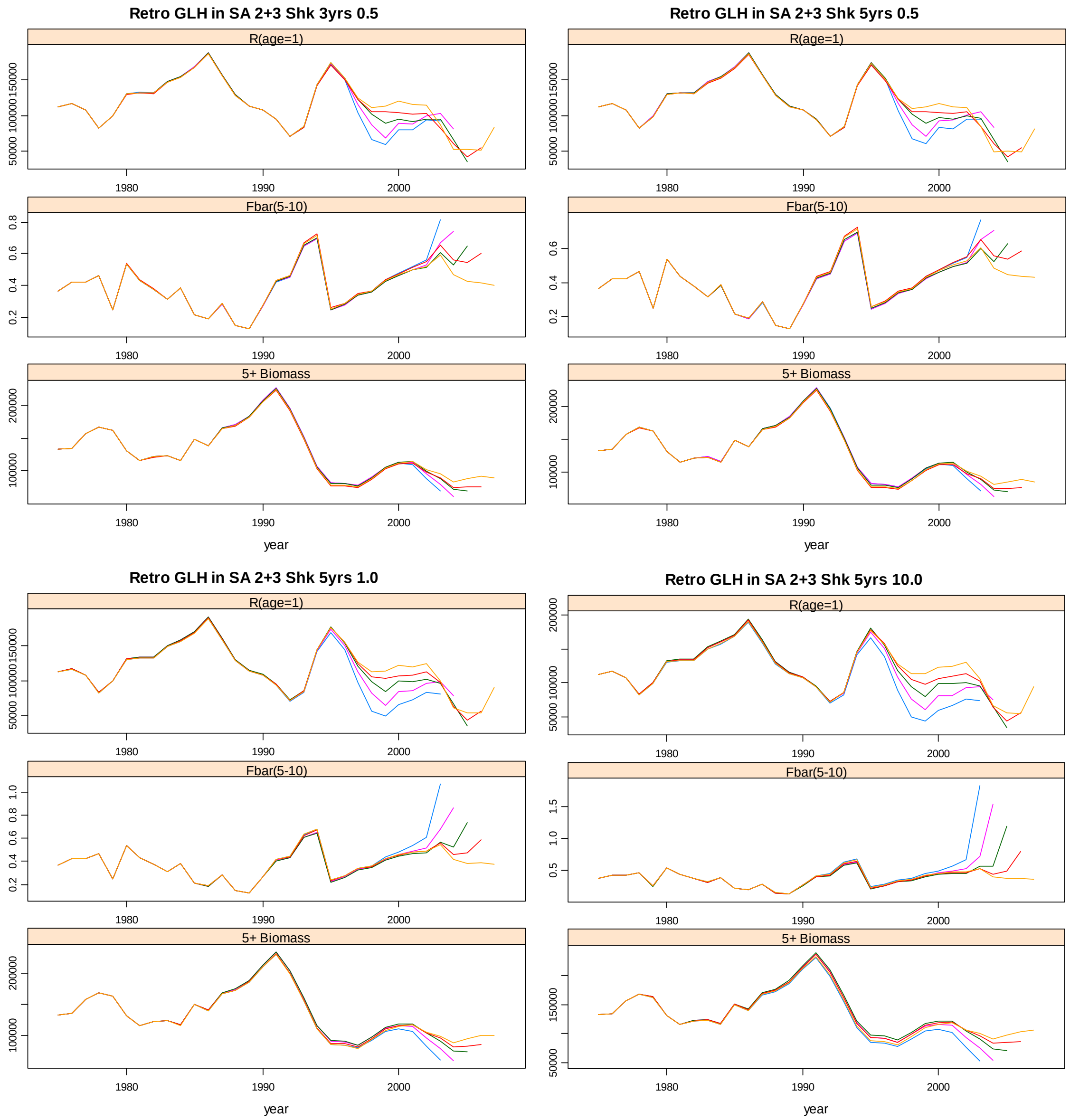


Figure 18 – Retrospective analyses for XSA conducted with various shrinkage comparisons. Panel title identifies the number of years and weighting parameters (lower values imply stronger shrinkage) used compute mean F (for each age) to which estimates of survivors are shrunk towards.

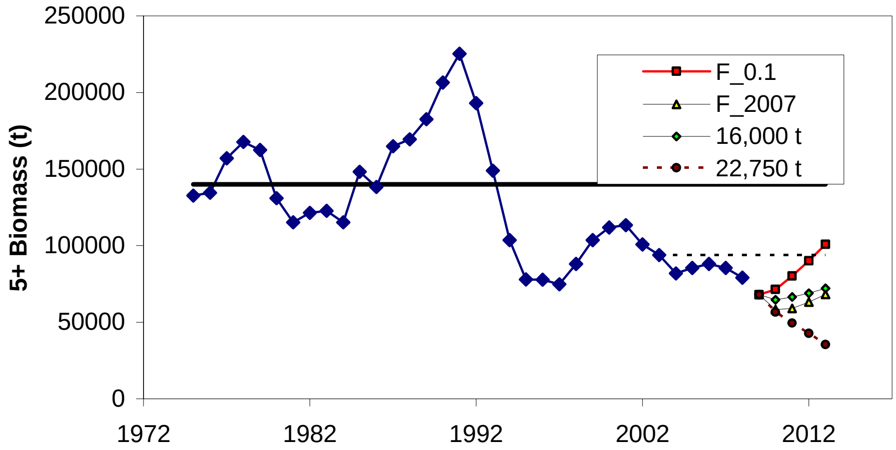


Figure 19 – Deterministic projection of 5+ biomass to 2013 (see text for description of projection scenarios). The solid horizontal line represents the rebuilding plan target biomass of 140 000 tons; the dashed horizontal line is the level of the exploitable biomass in 2003, when the FC rebuilding plan was implemented.

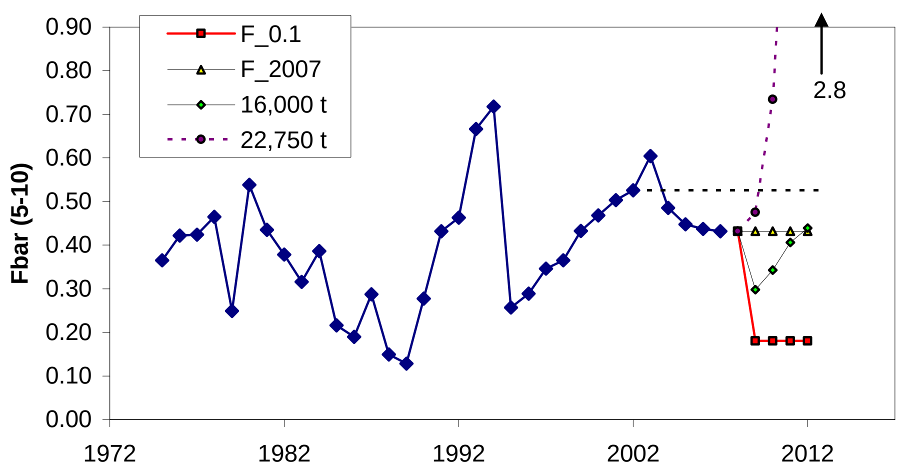


Figure 20 – Deterministic projection of average fishing mortality to 2012 (see text for description of projection scenarios). The horizontal dashed line indicates the level of fishing mortality when the rebuilding plan was implemented.

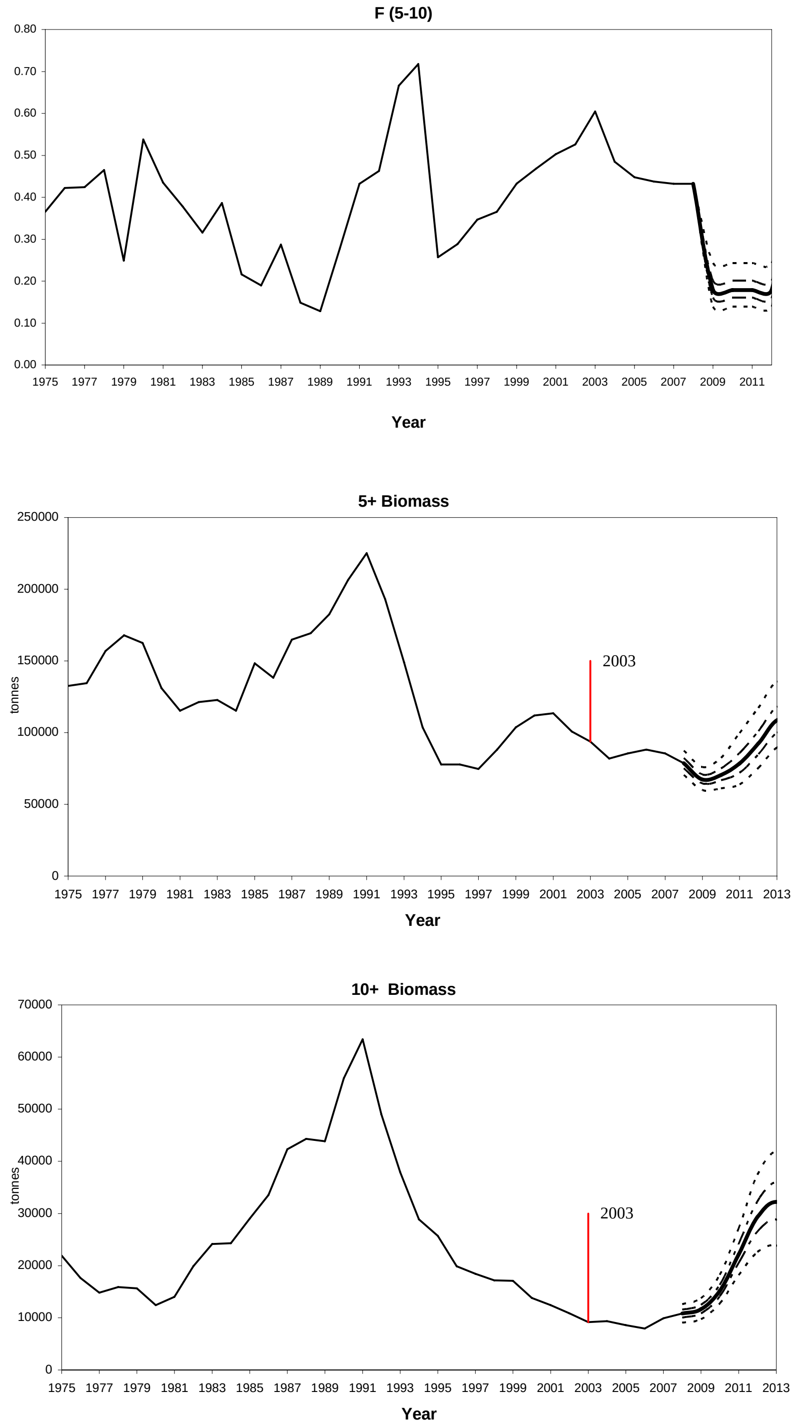


Figure 21 – Stochastic projection estimates of average fishing mortality, 5+ biomass, and 10+ biomass over 2009-2013 assuming catches correspond to the F0.1 level. The biomass level of 2003 (year in which rebuilding plan developed) is highlighted. The 5th, 25th, 50th (thick line), 75th, and 95th percentiles are shown.

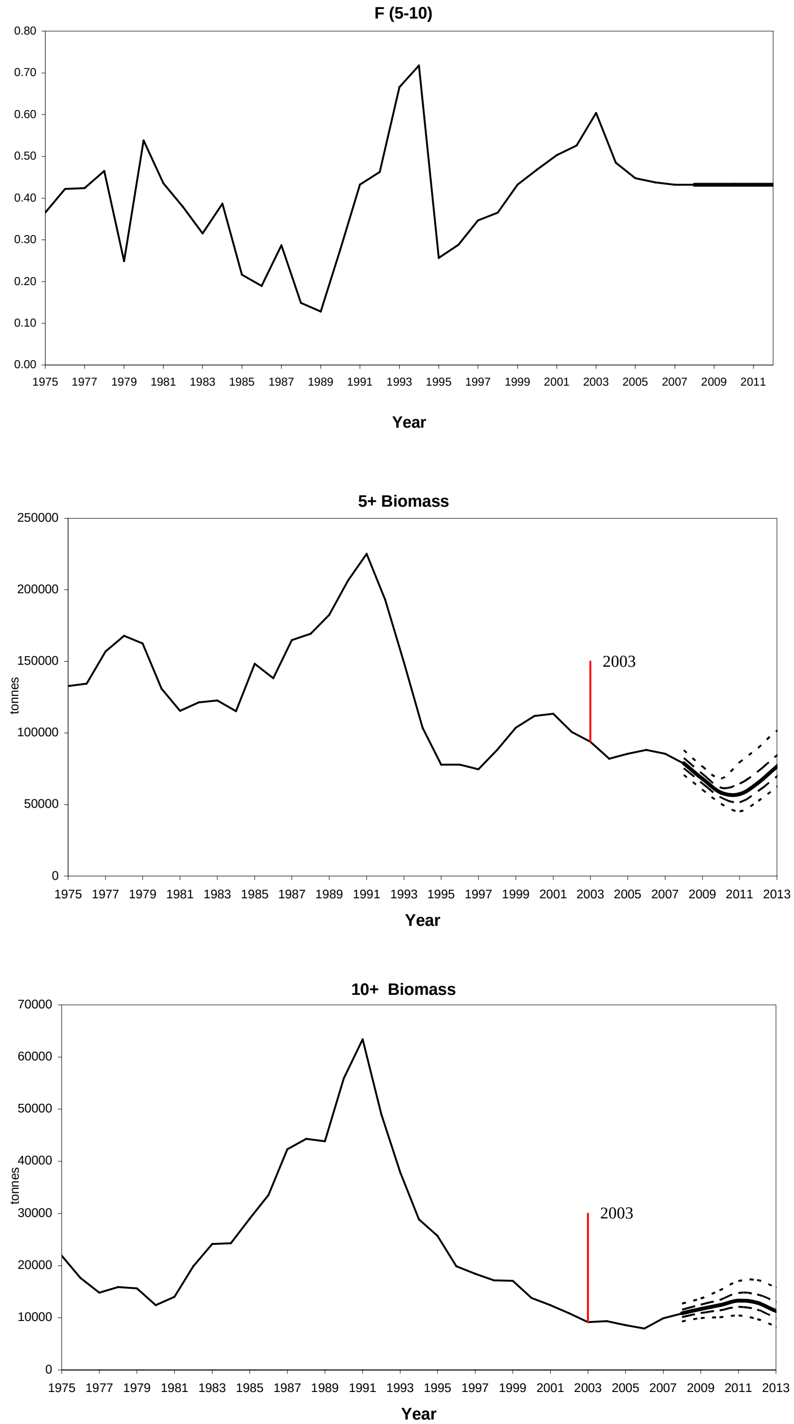


Figure 22 – Projection estimates of average fishing mortality, 5+ biomass, and 10+ biomass over 2009-2013 assuming catches correspond to the F2007 level. The biomass level of 2003 (year in which rebuilding plan developed) is highlighted. The 5th, 25th, 50th (thick line), 75th, and 95th percentiles are shown.

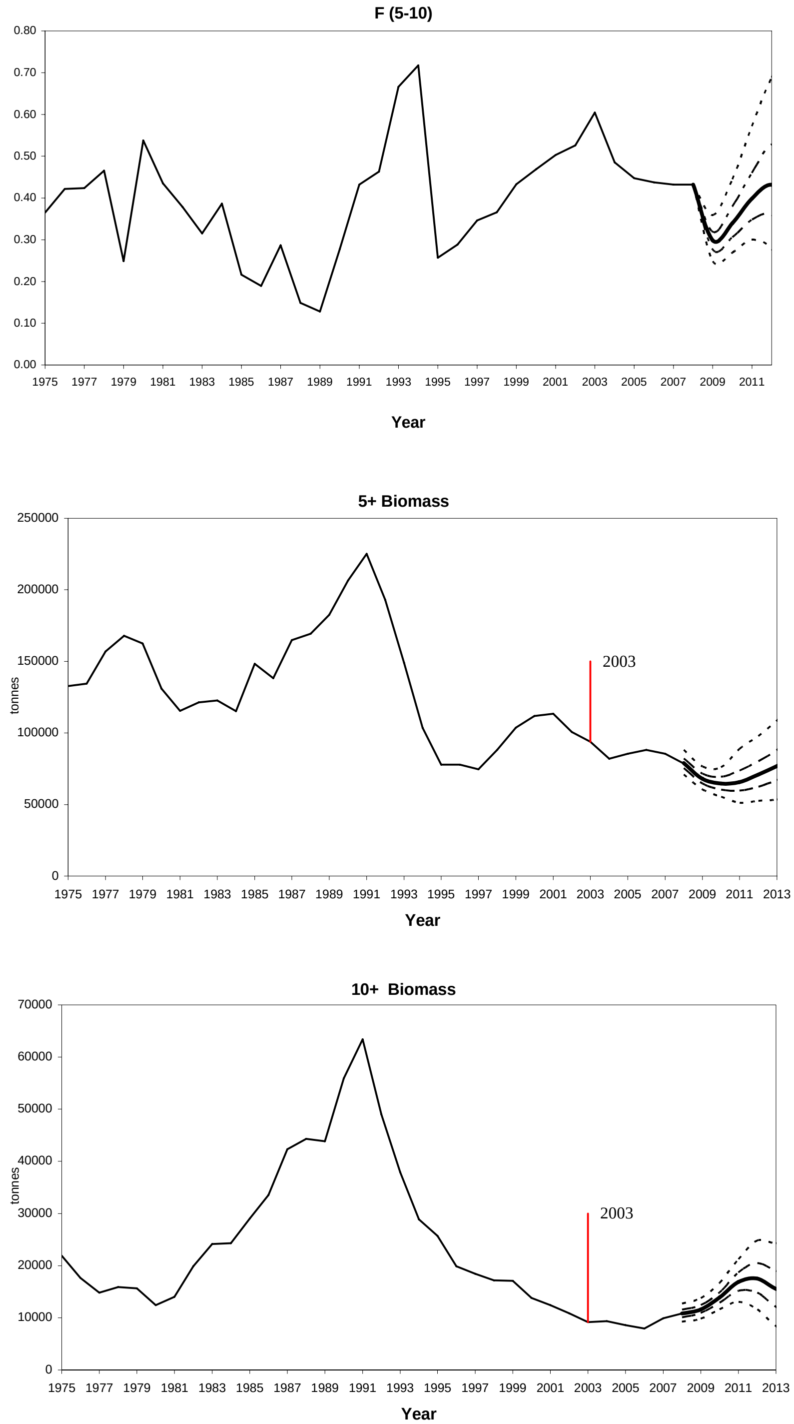


Figure 23 – Projection estimates of average fishing mortality, 5+ biomass, and 10+ biomass over 2009-2013 under constant removals of 16, 000 tons. The biomass level of 2003 (year in which rebuilding plan developed) is highlighted. The 5th, 25th, 50th (thick line), 75th, and 95th percentiles are shown.

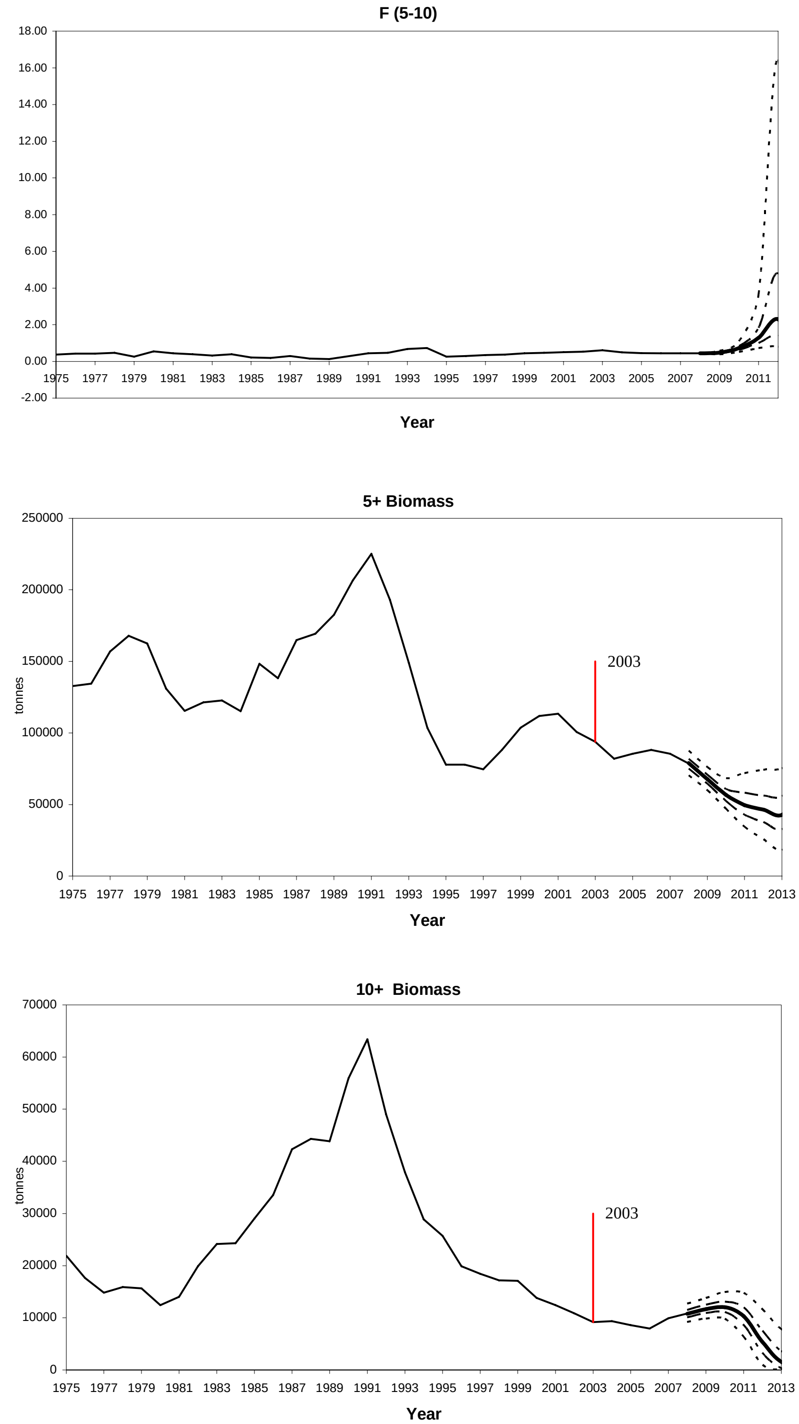


Figure 24 – Projection estimates of average fishing mortality, 5+ biomass, and 10+ biomass over 2009-2013 under constant removals of 22, 750 tons. The biomass level of 2003 (year in which rebuilding plan developed) is highlighted. The 5th, 25th, 50th (thick line), 75th, and 95th percentiles are shown.

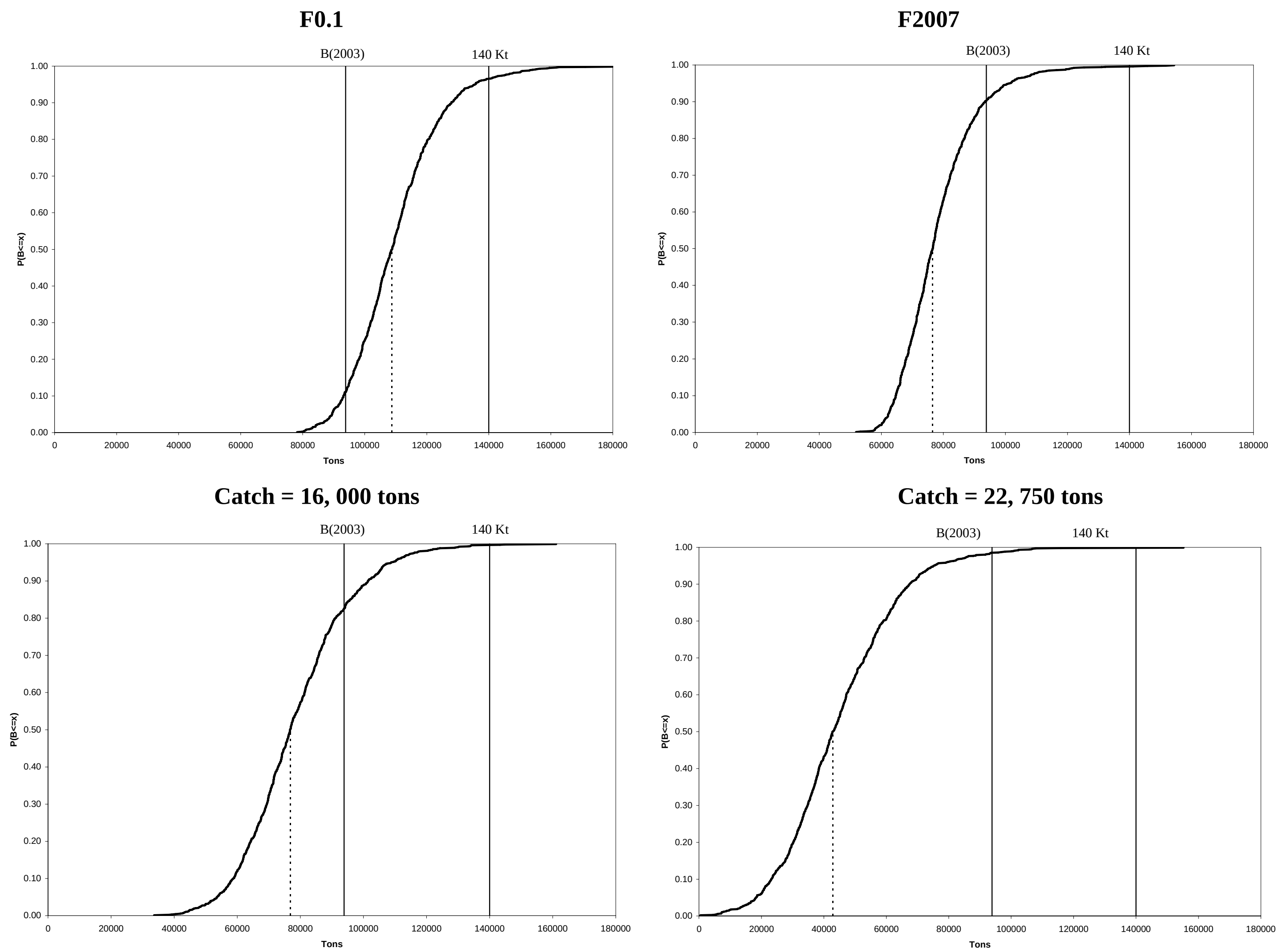


Figure 25 – Probability profile of exploitable biomass in 2013 for each of the four projection scenarios. Solid vertical lines demarcate the biomass level in 2003 (93 800 tons) and the rebuilding plan target (140 000 tons). The dashed vertical line indicates the median projected biomass level in 2013.