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

by

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<u>Abstract</u>

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, fishing mortality remains relatively high, and the strength of all year-classes since the 1996 year-class are below 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 2008-2011 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, or if the catches in 2008 and onward are decreased by 15% annually under the Rebuilding Plan.

<u>Introduction</u>

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 2006 NAFO Scientific Council assessment of this stock indicated that exploitable (ages 5+) biomass to be the lowest in the time series; estimated average fishing mortality was amongst the highest in the time series and the strength of recent year-classes was weak (Healey and Mahé, 2006). 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, 2003), 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*".

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%, and 27%, respectively), during the first three years of this rebuilding plan. The estimated catch for 2006 is 23,530 tons.

Catch-at-age

Length sampling provided by EU-Portugal (Vargas et *al*., 2007), EU-Spain (González et *al*., 2007), and Russia (Vaskov et *al*., 2007) for 2006 fisheries are quite similar, all indicating a modal catch length of about 40-44cm. A comparison of the length sampling available for the catches in the past two years indicates no change in the Portuguese or Russian fisheries, but slightly different length compositions in the Spanish and Canadian 2006 catches (see Brodie et *al.*, 2007 and González et *al*. 2007). However, available age-length keys highlight the 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, Canadian age-length keys were applied in place of the Spanish age-length keys. Recent research suggests that despite these inconsistencies, the Canadian, EU and Russian age determination methods may be substantially 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 (2007). Samples from the Canadian fishery were used to derive catch-at-age independently for each gear (see Table 5 of Brodie et al., 2007). The 1998 and 1999 year-classes (ages 7 and 8 in 2006) 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 2006, these age groups accounted for just 9% of the catch numbers, primarily attributable to gillnet mesh size regulations within the Canadian EEZ (see Brodie et al., 2007).

Due to the age-reading discrepancies previously noted, the age distribution of the Spanish, Russian and Portuguese catches are no longer applied to compute catch-at-age. The length samples from these nations are converted to catch-at-age using Canadian age length keys.

No sampling data are available for the 2006 catches taken by EU-Latvia, EU-Lithuania, EU-Estonia, Japan, and the Faroe Islands (EU-Denmark) (2307 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 1975-2006 are given in Table 2. As in the recent past, in 2006 the modal catch was at age 7, corresponding to the 1999 year-class. Catch weights at age (Table 3) are computed as weighted means of the values from national sampling, and indicate no trends over time. However, note that catch weights at age in 2006 at the older ages are lower than those in previous years. 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 2002-2006 is plotted in Figure 2. The sum-of-products is 0.981 for the 2006 data, and is close to 1 for all five years. Note that although the landings for 2005 and 2006 have been almost identical (23, 255 tons versus 23, 531 tons, respectively), the age compositions for these catches are considerably different – in fact, the number of individuals removed increased by 10%. The numbers of age groups 5, 6, 7, and 8 in the catch increased in the 2006 fishery, with corresponding decreases at the remaining ages.

Survey Data

During the previous assessment of this stock, Gonzaléz Costas and Gonzaléz Troncoso (2006) presented a quality evaluation of surveys for Greenland Halibut. 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 2006 assessment:

a) EU 3M - a European Union summer survey in Division 3M from 1995–2006, ages 1 – 12 (Casas and González Troncoso, 2007).
b) Can 2J3K autumn survey, true Campelen data from 1996 - 2006, ages 1 to 14 (Healey, 2007).
c) Can 3LNO spring survey, true Campelen data from 1996 - 2005, ages 1 to 8 (Healey, 2007).

An additional year of data are available from the EU summer 3M survey and Canadian autumn 2J3K survey; the Canadian spring survey in Divisions 3LNO was not completed during 2006 (see Brodie and Stansbury, 2007).

In addition to the survey series that have been used to calibrate the recent assessments, we have included the Canadian autumn survey series from Divisions 3L and 3M, as well as the EU-Spain summer survey in the NRA of Divisions 3NO to evaluate the possibility of including these data into the analytical assessment. The Division 3L index was included in the combined Divisions 2J3KL index in earlier assessments of this stock (e.g. Darby et *al.*, 2004), but during the 2005 assessment this index was replaced by the Division 2J3K results due to survey coverage problems in Division 3L during the fall of 2004 (see Healey and Mahé, 2005; Healey and Dwyer, 2005). The EU-Spain dataset was included in exploratory runs during the 2005 assessment, but was not incorporated into the STACFIS agreed formulation owing to residual patterns over time.

During the 2003 assessment, STACFIS agreed (NAFO, 2003; Darby et a*l.*, 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).

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

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 in these plots yield the correlation coefficients equivalent to those presented by Gonzaléz Costas and Gonzaléz Troncoso (2006). A comparison of these correlation coefficients from each of the indices (Figure 5) Some of the low correlation values noted in 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.

Several comparisons of the standardized indices are presented (Figures 6a-6e) illustrating the consistency of dataset currently used to calibrate the analytical assessment (Figure 6a), but in addition, to evaluate the possibility of adding other available indices to the tuning dataset.

The following combinations of survey data are illustrated:

- All of the available data series (Figure 6a) - excludes Canadian data using the Engels gear (anything prior to 1995) as there are relatively few survey points to compare these data against.
- Canadian Div. 2J3K fall, Canadian Div. 3LNO spring and Spanish Div. 3NO (NRA only) summer surveys (Figure 6b).
- Canadian Div. 3LNO spring and Canadian Div. 3L fall surveys (Figure 6c).
- EU Div. 3M summer and Canadian Div. 3M fall surveys (Figure 6d).
- Canadian Div. 2J3K fall, Canadian Div. 3LNO spring, and EU Div. 3M Summer surveys (Figure 6e).

Observe that the Spanish Div. 3NO is quite variable at the youngest ages, but is generally similar with the Canadian data(Figure 6b); however, the recent increases in the Canadian Div. 2J3K data are not measured in the Spanish survey. The Canadian spring survey in Divs. 3LNO and fall survey in Div. 3M are very consistent (Figure 6c), although some problems are evident at ages 7 & 8. The Canadian Div. 3M fall survey and the EU Div. 3M summer survey indicate broadly similar trends at ages 5-8 (Figure 6d), but at the older ages are indicating an entirely different signal. This reflects the different depth coverage of these two surveys (the Canadian survey extends to almost 1500m, whereas the EU survey has a maximum depth of 730m). The survey data used to calibrate the XSA appears to be fairly consistent through time over a majority of the age groups (Figure 5e). Note 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.

Of the Canadian Division 3L, Canadian Division 3M and Spain Division 3NO (NRA) surveys, the Canadian 3L index was considered to be the best candidate for inclusion in the XSA calibration dataset, as this index is consistent with the Canadian spring index from Divisions 3LNO (see Figure 5c) and also the Canadian Div. 2J3K fall survey data. This index was included as part of the combined Divisions 2J3KL index used in calibrating the XSA up until the June 2005 assessment of this stock. Due to survey coverage deficiencies in this survey during autumn 2004, Healey and Dwyer (2005) determined that the deficiencies were such that the 2004 result could not be considered comparable to the remainder of the time series. If the Division 3L index is to be included in the assessment, there are two options: to add the Division 3L data as an additional index, or to re-institute the combined Division 2J3KL index, with the 2004 value set as missing in the XSA input data. The latter option of reverting to the 2J3KL index was considered undesirable due to the fact that this would force the exclusion of the 2004 index values, detrimentally impacting the estimation of survivors (in recent assessments, the Canadian fall 2J3K index has received the highest weighting in computing estimates of survivors). This solution could be revisited in the future when the 2004 data would be in a more converged part of the SPA.

It was decided to not include the Division 3L index as it is part of the Canadian autumn series and has similar trends to the Division 2J3K index; thereby this index is not considered to be a truly independent source of information.

Despite these concerns, a preliminary analysis which included this index was evaluated with practically-identical results, yet having a stronger retrospective pattern.

In addition to the FLEDA diagnostic plots, we present “bubble plots” of the indices used in tuning the XSA (scaled within each survey-age) in Figure 6. 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 (see Healey (2007) 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, VPA analyses for this stock are still considered appropriate.

Assessment Results

Survey data over 1995-2006 and catch information from 1975-2006 were used to estimate numbers at age using the XSA formulation applied during the 2006 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 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 7 illustrates the exploitable (ages 5+) biomass, average fishing mortality and the age 1 recruitment. (Estimates of 2007 survivors from the XSA are used to compute 2007 biomass assuming the 2007 stock weights are equal to the 2004-2006 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 75 000 t. The 2007 5+ biomass is estimated to be approximately 73 000 tons. This is 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. As a result of high catches in 1991-94, fishing mortality increased considerably. Fbar(5-10) then declined to about 0.20 in 1995 with the substantial reduction in catch but has increased since then and has remained high despite a reduction of effort as catches have exceeded the rebuilding plan quotas. Fbar(5-10) in 2006 is estimated to be 0.59.

Estimated recruitment for all year-classes since the 1996 year-class, that is, all age groups which comprise the majority of the current exploitable biomass, are below the long-term average, as indicated in the previous assessment (Healey and Mahé, 2006). The estimated abundance of the 2003 - 2005 year-classes are the lowest values in the time series. Although the estimated magnitude of the 2003 and 2004 year-classes are consistent in the three survey series (see Estimated Survivors in Table 5b), the two observations of 2005 year-class are not consistent.

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 9. 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, with increasing shrinkage influence at older ages.

Selection patterns of the recent past are plotted in Figure 10. Current results indicate increased selection at age 8 relative to other age groups. This stems from a slight increase in the modal length in the Spanish catch. Recent changes to fishing regulations within the Canadian EEZ have resulted in 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 (2007).

Residual graphics from the XSA analysis are presented in Figures 11 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 11a) 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. Note that all of the residuals in the 2005 and 2006 Canadian fall survey for ages 5 and older are positive due to the increased abundance in these cohorts as compared to the relative abundance at younger ages. Again, the residual bubble plots (Figure 11c) display problematic trends – evidence of cohort tracking and year effects, each of which indicate poor model fit.

Retrospective analysis

A retrospective analysis was conducted to examine the influence of removing successive years' data on the terminal estimates of biomass, fishing mortality and recruitment (Figure 12). Retrospective patterns in stock size 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 (2006 to 2005) in the current assessment is less severe than that noted in the previous assessment (2005 to 2004).

There are some notable features in these retrospective figures. One is 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. However, in the recent past, fishing mortality appears to be over-estimated and biomass underestimated as the estimated recruitment since 2000 has been revised upwards in each successive assessment. The second unusual feature of the retrospective analysis is the changing trend in average fishing mortality between the 2005 assessment and subsequent assessments (Figure 12). 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 0.55 in the current assessment, compared to 0.71 in the 2005 assessment. A comparison of the selection patterns (not shown) also indicates retrospective differences, especially in the terminal year. A final interesting feature of this analysis is that the relative difference between the 1993-1995 cohorts and those in 1998-2001 decreased considerably as data were added to the model.

To gain further insight into such differences, Tables 10 and 11 provide a measure of the sensitivity of the XSA output to the addition of the 2006 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 2006 assessment with changes exceeding 10% in magnitude highlighted. Observe that the one year retrospective differences are driven primarily by revisions to the 1997 - 1999 year-classes, the same age groups indicating increased abundance in the Canadian fall index.

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 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 2007 and average fishing mortality (Figure 14) 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 9) in the combined run.

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 be the lowest in the 1975-2007 time-series.

Based on average weights and partial recruitment for the past 3 years, F_{Max}=0.25 and $F_{0.1}$=0.14. The XSA estimate of average fishing mortality (ages 5-10) for 2006 is 0.59, which is more than double the F_{Max} level, or approximately four times the $F_{0.1}$ level.

Projections

Five-year deterministic and stochastic projections (to January 1, 2012) were considered. This is an increased time-horizon compared to recent assessments which have included three year projections. Considering that 2007 is the final fishing year for which TACs were specified in the FC Greenland Halibut rebuilding plan, we provide projection results for five years. It should be emphasized that 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.

The rebuilding plan TACs for 2004 - 2006 were exceeded by 27%, 22%, and 27% respectively. As such, all projections carried out assume that 20, 000 tons will be removed during 2007 (16, 000 TAC + 25%). No rebuilding plan TACs have been set beyond 2007; during the years 2008 – 2011, four scenarios are evaluated:

i) constant fishing mortality at the F0.1 level (=0.138)
ii) constant fishing mortality at F2006 (=0.533)
iii) constant landings at 16 000 tons (denoted Rebuilding Plan I), and
iv) annual landings reduced by 15%, the maximum possible reduction under the FC rebuilding plan, from the 2007 TAC level. Specifically, removals in 2008 are assumed to be 13 600 tons, and are reduced by 15% in each additional year. (Denoted Rebuilding Plan II).

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 2007 and corresponding CVs are computed from the XSA output. Deterministic projections were conducted assuming a recruitment value fixed at the 1999-2004 geometric mean of the age 1 XSA estimates. For the stochastic projections, recruitment was bootstrapped from the 1975-2004 age 1 numbers from the XSA; more recent recruitment levels were not included as these estimates are less certain. Note that the assumed age 1 recruitment levels have almost no impact in the exploitable biomass in the medium term projections. Scaled selection pattern and corresponding CVs are derived from the 2004 to 2006 average from the XSA. Weights at age in the stock and in the catch and corresponding CVs are computed from the 2004-2006 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. The distribution was assumed 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 (Tables 12, 13) of exploitable biomass (see also Figure 15), fishing yield, and average fishing mortality (Figure 16) are presented. Results indicate that the exploitable biomass will continue to decline if current levels of fishing mortality are maintained. If catches over 2008-2011 are constant at 16 000 tons (Rebuilding Plan I), exploitable biomass remains stable with minimal recovery. Exploitable biomass is projected to increase rapidly if fishing mortality is reduced to the F0.1 level, or if the catches in 2008 and onward are decreased by 15% annually (Rebuilding Plan II).

Table 13 provides growth rates of the exploitable and 10+ biomass in relation to those in 2003, when the rebuilding plan was implemented, and in 2007, the terminal year from the current assessment. Table 14 presents the ratio of the exploitable (5 +) biomass at the end of the projection period in relation to the target identified in the rebuilding plan. Severe declines in the biomass are evident if current levels of fishing mortality are maintained. If catch levels are reduced by 15% annually (Rebuilding Plan II) or 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. Maintaining a fixed catch of 16 000 tons annually, the projected biomass remains below the level when the rebuilding plan was implemented. Note that potential success of the rebuilding plan is much greater under F0.1 or 15% annual reductions in catch (2012 exploitable biomass approximately three-quarters of the rebuilding target) than that under current levels of F or fixed catches of 16 000 tons.

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 17 - 20 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, it is assumed that 20 000 will be removed during 2007 (16 000 ton TAC + 25%).

In addition, probability profiles of the biomass in 2012, the end of projection period (Figure 21) are compared to the 2003 level, 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 2012 being below a reference level. Only the scenarios under F0.1 or 15% annual reduction provide a high (>90%) probability that the exploitable biomass will have recovered to the 2003 level by 2012. Even under the most optimistic scenario, there is a low (<10%) probability that the 2012 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 an all-time 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.

Deterministic and stochastic projections indicate that under the Fisheries Commission rebuilding plan, prospects for stock rebuilding are currently poor. Results indicate that the exploitable biomass will continue to decline if current levels of fishing mortality are maintained. If catches over 2008-2011 are constant at 16, 000 tons, projected exploitable biomass remains stable at a low level with minimal recovery. Exploitable biomass is projected to increase rapidly if fishing mortality is reduced to the F0.1 level, or if the catches in 2008 and onward are decreased by 15% annually.

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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	TAC - FC	Landings
1960			0.9
1961			0.7
1962			0.6
1963			2
1964			4
1965			10
1966			19
1967			27
1968			32
1969			37
1970			37
1971			25
1972			30
1973			29
1974	40		28
1975	40		29
1976	30		25
1977	30		32
1978	30		39
1979	30		34
1980	35		33
1981	55		31
1982	55		26
1983	55		28
1984	55		27
1985	75		20
1986	100		18
1987	100		32
1988	100		19
1989	100		20
1990	50		47
1991	50		65
1992	50		63
1993	50		62
1994	25		51
1995		27	15
1996		27	19
1997		27	20
1998		27	20
1999		33	24
2000		35	34
2001		40	37
2002		44	34
2003		42	35
2004		20*	25
2005		19*	23
2006		18.5*	24
2007		16*	

* TAC specified under FC Rebuilding Plan (FC Doc. 03/13).

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

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

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
1995.9	49.93	51.10	15.13	6.03	6.63	1.99	0.39	0.12	0.02	0.01	0.00	0.00	0.00
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

EU Survey	1	2	3	4	5	6	7	8	9	10	11	12
1991.6	1.62	0.26	0.43	1.31	2.87	1.61	2.75	0.66	0.58	0.44	0.18	0.02
1992.6	2.09	1.57	0.56	1.27	2.30	2.80	2.42	1.31	0.58	0.34	0.17	0.08
1993.6	1.77	1.55	0.97	0.86	1.27	1.92	2.02	1.57	0.97	0.26	0.13	0.05
1994.6	1.78	1.24	1.70	1.79	1.92	2.97	2.66	1.47	0.79	0.27	0.11	0.06
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

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

Table 5a. XSA Settings.

Lowestoft VPA Version 3.1

11/06/2007 17:12

Extended Survivors Analysis

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

CPUE data from file GhalTUN2007.txt

Catch data for 32 years. 1975 to 2006. Ages 1 to 14.

Fleet	First year	Last year	First age	Last age	Alpha	Beta
EU Surve	1995	2006	1	12	0.5	0.6
CAN 2J3K	1996	2006	1	13	0.8	1
CAN 3LN(	1996	2006	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 2006
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 46 iterations

Table 5b. XSA diagnostic results.

Fleet : EU Survey(MNPT)

Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	0.92	0.3	-0.06	-0.11	-1.06	0.22	0.99	0.3	-0.11	0.23	-0.8	-0.84
2	0.18	1.14	0.52	0.16	-0.81	-1.69	-0.08	0.65	-0.45	0.95	-0.11	-0.45
3	0.27	-0.18	0.54	0.93	0.19	-1.29	-0.17	0.28	-1.24	0.71	0.6	-0.64
4	0.1	0.39	0.62	0.96	1.04	-0.33	-0.96	-0.44	-0.51	-0.25	-0.04	-0.58
5	-0.47	0.17	0.52	0.55	0.43	-0.07	-0.8	-0.35	-0.73	0.33	0.29	0.12
6	-0.03	-0.05	0.52	0.64	0.17	0.14	-0.3	-0.47	-0.87	0.14	0.09	0.01
7	0.32	-0.39	0.22	0.83	0.44	0.02	0.08	0.05	-0.84	-0.37	-0.25	-0.12
8	0.38	0.14	0.3	0.46	0.32	0.55	0.81	-0.24	-1.15	-0.71	-0.62	-0.25
9	1.13	0.01	0.52	0.66	-0.07	0.4	-0.56	-0.77	-0.72	0.14	-0.79	0.05
10	0.37	-0.7	0.24	0.23	-0.32	-0.16	-0.92	-0.62	0.09	0.56	0.41	0.83
11	0.32	-0.62	-0.52	-0.31	-1.66	0.46	-1.63	-0.31	-0.29	1.42	1.29	1.85
12	-0.43	0.31	-0.24	-1.4	-2.09	99.99	99.99	-0.6	-0.9	1.41	0.79	2.02
13	No data for this fleet at this age											

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

Age	1	2	3	4	5	6	7	8	9	10	11	12
Mean Log	-10.3466	-10.8038	-10.2937	-9.9016	-8.953	-8.2548	-8.0745	-8.1811	-8.8825	-9.2471	-10.0187	-10.0187
S.E(Log q	0.6469	0.7908	0.7307	0.6362	0.4781	0.4071	0.4394	0.5922	0.6199	0.5455	1.1171	1.2708

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	0.52	2.272	10.88	0.69	12	0.29	-10.35
2	0.61	1.053	11.01	0.42	12	0.48	-10.8
3	0.54	1.104	10.71	0.36	12	0.39	-10.29
4	0.42	2.049	10.53	0.56	12	0.24	-9.9
5	0.85	0.291	9.22	0.29	12	0.43	-8.95
6	1.82	-1.096	6.41	0.15	12	0.73	-8.25
7	1.78	-1.162	6.56	0.18	12	0.77	-8.07
8	12.62	-0.791	-1.76	0	12	7.6	-8.18
9	0.37	1.715	8.41	0.42	12	0.21	-8.88
10	4.68	-1.357	15.8	0.01	12	2.46	-9.25
11	-0.87	-3.046	4.21	0.21	12	0.74	-10.02
12	-1.62	-2.496	0.14	0.1	10	1.63	-10.13

Table 5b XSA diagnostic results (cont).

Fleet : CAN 2J3K Fall(MNPT)

Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	99.99	0.57	-0.49	-0.53	-0.9	-0.01	0.13	0.03	0.36	0.36	0.02	0.46
2	99.99	-0.01	0.33	-0.32	0.15	-0.3	-0.25	-0.18	-0.1	0.32	-0.05	0.42
3	99.99	0.36	0.48	0.28	0.22	-0.01	0.02	-0.27	-0.33	-0.18	-0.45	-0.12
4	99.99	-0.12	0.14	-0.01	0.38	-0.18	0.03	-0.34	-0.33	-0.07	0.02	0.47
5	99.99	0	0.32	-0.16	0.24	0	-0.13	-0.47	-0.34	0.05	0.17	0.31
6	99.99	-0.42	0.48	0.2	0.45	-0.03	0.18	-1.03	-0.58	-0.41	0.47	0.7
7	99.99	-0.79	0.01	0.18	0.82	-0.01	0.27	-1.21	-0.74	-0.32	0.84	0.95
8	99.99	-1.07	0.08	-0.07	0.43	0.05	0.39	-0.99	-0.53	-0.22	0.58	1.37
9	99.99	0.16	0.39	0	0.12	-0.51	0	-0.85	-0.74	0.03	0.41	0.98
10	99.99	-0.28	0.09	0.26	0.6	-0.25	-0.34	-0.84	-0.38	0.46	0.44	0.24
11	99.99	-0.09	0.23	0.09	-0.09	-0.18	-0.09	-1.18	-0.28	-0.46	1.29	0.74
12	99.99	-0.24	0.42	0.27	-0.73	-1.18	-0.8	99.99	-0.07	-0.34	0.71	0.8
13	99.99	0.43	0.04	0.36	1	99.99	0.55	-0.23	-0.32	1.05	0.96	99.99

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

Age	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean Log	-7.7129	-7.799	-8.1775	-8.1724	-8.283	-8.5933	-8.5106	-8.9063	-9.7166	-10.2937	-10.4297	-10.4297	-10.4297
S.E(Log q	0.4634	0.2672	0.303	0.2575	0.2587	0.5432	0.7148	0.7073	0.5352	0.447	0.6333	0.6791	0.6875

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	1.49	-0.846	5.9	0.25	11	0.7	-7.71
2	1.3	-1.072	6.75	0.59	11	0.34	-7.8
3	0.55	3.406	9.53	0.87	11	0.12	-8.18
4	0.87	0.407	8.55	0.51	11	0.23	-8.17
5	1.05	-0.133	8.16	0.47	11	0.29	-8.28
6	1.28	-0.334	8.06	0.14	11	0.73	-8.59
7	2.52	-0.779	6.15	0.03	11	1.84	-8.51
8	-1.8	-1.096	9.31	0.02	11	1.26	-8.91
9	1.84	-0.433	11.07	0.03	11	1.03	-9.72
10	1.48	-0.586	11.66	0.14	11	0.68	-10.29
11	2.35	-1.039	15.2	0.06	11	1.48	-10.43
12	3.74	-1.754	22.16	0.05	10	2.25	-10.55
13	1	-0.011	10.02	0.46	9	0.56	-10

Table 5b XSA diagnostic results (cont).

Fleet : CAN 3LNO Spr(MNPT)

Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	99.99	0.5	0.37	-1.15	-0.87	0.15	-0.18	-0.08	0.5	0.51	0.25	99.99
2	99.99	0.96	1.02	-0.36	-0.6	0.06	-0.33	-0.54	0.76	-0.35	-0.63	99.99
3	99.99	0.86	0.79	0.63	-0.37	-0.3	-0.67	-0.86	0.17	-0.2	-0.06	99.99
4	99.99	0.66	0.52	0.99	-0.02	-0.09	-0.74	-0.89	0.12	-0.15	-0.4	99.99
5	99.99	-0.07	0.32	1.01	0.44	0.02	-0.67	-0.79	-0.21	-0.09	0.05	99.99
6	99.99	-0.42	0.35	1.07	0.38	0.84	-0.06	-1.11	-0.91	-0.64	0.51	99.99
7	99.99	-0.63	-0.17	1.19	0.81	1.17	0.36	-1.25	-1.04	-1.02	0.58	99.99
8	99.99	-2.66	-0.25	1.41	1.24	0.77	0.36	-1.13	-0.75	0.32	0.68	99.99
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	-11.8596	-11.2913	-10.7292	-10.5412	-10.3757	-10.9702	-11.7323	-12.8663
S.E(Log q	0.586	0.661	0.6016	0.6008	0.5234	0.7488	0.9436	1.2401

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	1.48	-0.582	12.06	0.16	10	0.9	-11.86
2	0.38	2.876	11.35	0.73	10	0.18	-11.29
3	0.33	2.927	11.09	0.7	10	0.15	-10.73
4	0.48	1.216	10.82	0.4	10	0.28	-10.54
5	0.63	0.884	10.54	0.42	10	0.34	-10.38
6	0.97	0.029	10.96	0.14	10	0.77	-10.97
7	1.56	-0.339	12.66	0.04	10	1.55	-11.73
8	1.43	-0.11	14.5	0.01	10	1.88	-12.87

Table 5b (cont). XSA Diagnostic results

Terminal year survivor and F summaries :

Age 1 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(N	19360	0.673	0	0	1	0.355	0
CAN 2J3K F	70906	0.5	0	0	1	0.645	0
CAN 3LNO	1	0	0	0	0	0	0
F shrinkag	0	0.5				0	0

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
44699	0.4	0.62	2	1.548	0

Age 2 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(N	14589	0.521	0.171	0.33	2	0.257	0
CAN 2J3K F	35195	0.354	0.2	0.56	2	0.558	0
CAN 3LNO	36073	0.615	0	0	1	0.185	0
F shrinkag	0	0.5				0	0

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
28196	0.26	0.21	5	0.803	0

Age 3 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(N	28909	0.43	0.26	0.61	3	0.244	0
CAN 2J3K F	35505	0.289	0.149	0.52	3	0.542	0
CAN 3LNO	33536	0.46	0.566	1.23	2	0.214	0
F shrinkag	0	0.5				0	0

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
33357	0.21	0.14	8	0.648	0

Table 5b (cont). XSA Diagnostic results

Age 4 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(I	42747	0.361	0.34	0.94	4	0.22	0.005
CAN 2J3K F	45442	0.25	0.211	0.84	4	0.458	0.004
CAN 3LNO .	40597	0.372	0.25	0.67	3	0.207	0.005
F shrinkag	13717	0.5				0.115	0.014

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
38162	0.17	0.17	12	1.006	0.005

Age 5 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(I	42178	0.292	0.161	0.55	5	0.256	0.039
CAN 2J3K F	37394	0.224	0.084	0.38	5	0.438	0.044
CAN 3LNO .	36264	0.32	0.242	0.76	4	0.213	0.046
F shrinkag	23859	0.5				0.092	0.068

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
36757	0.15	0.08	15	0.571	0.045

Age 6 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(I	26066	0.253	0.268	1.06	6	0.277	0.202
CAN 2J3K F	24711	0.208	0.14	0.68	6	0.404	0.212
CAN 3LNO .	21158	0.277	0.114	0.41	5	0.227	0.244
F shrinkag	17828	0.5				0.092	0.283

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
23496	0.13	0.1	18	0.735	0.222

Age 7 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(I	7438	0.228	0.103	0.45	7	0.284	0.907
CAN 2J3K F	7403	0.202	0.16	0.79	7	0.338	0.91
CAN 3LNO .	6496	0.261	0.183	0.7	6	0.194	0.99
F shrinkag	7161	0.5				0.185	0.93

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
7183	0.14	0.07	21	0.513	0.928

Table 5b (cont). XSA Diagnostic results

Age 8 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(N	1265	0.24	0.159	0.66	8	0.248	1.505
CAN 2J3K F	1981	0.216	0.286	1.32	8	0.258	1.175
CAN 3LNO .	1219	0.254	0.189	0.74	7	0.131	1.534
F shrinkag	2742	0.5				0.363	0.962

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
1871	0.2	0.13	24	0.64	1.215

Age 9 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(N	725	0.297	0.137	0.46	9	0.262	0.858
CAN 2J3K F	1547	0.284	0.215	0.76	9	0.302	0.493
CAN 3LNO .	554	0.269	0.198	0.74	8	0.092	1.023
F shrinkag	1085	0.5				0.343	0.646

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
1021	0.21	0.11	27	0.512	0.675

Age 10 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(N	687	0.326	0.254	0.78	10	0.291	0.399
CAN 2J3K F	700	0.3	0.106	0.35	10	0.357	0.393
CAN 3LNO .	446	0.271	0.187	0.69	8	0.051	0.562
F shrinkag	486	0.5				0.301	0.526

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
610	0.21	0.1	29	0.461	0.44

Table 5b (cont). XSA Diagnostic results

Age 11 Catchability constant w.r.t. time and dependent on age
Year class = 1995

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey(N	598	0.344	0.236	0.69	11	0.254	0.187
CAN 2J3K F	563	0.305	0.109	0.36	11	0.395	0.198
CAN 3LNO .	405	0.268	0.236	0.88	8	0.032	0.266
F shrinkag	149	0.5				0.319	0.604

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
370	0.22	0.16	31	0.738	0.287

Age 12 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(N	322	0.413	0.263	0.64	12	0.192	0.124
CAN 2J3K F	279	0.344	0.181	0.53	11	0.389	0.142
CAN 3LNO .	232	0.3	0.278	0.93	7	0.015	0.168
F shrinkag	52	0.5				0.404	0.596

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
145	0.25	0.22	31	0.871	0.257

Age 13 Catchability constant w.r.t. time and age (fixed at the value for age) 11
Year class = 1993

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU Survey(N	119	0.376	0.205	0.55	11	0.16	0.218
CAN 2J3K F	84	0.324	0.196	0.6	10	0.303	0.295
CAN 3LNO .	173	0.329	0.132	0.4	6	0.014	0.155
F shrinkag	74	0.5				0.523	0.33

Weighted prediction :

Survivors at end of yea	Int s.e	Ext s.e	N	Var Ratio	F
84	0.29	0.09	28	0.321	0.296

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

N@A (XSA)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1975	112258	126268	110141	66812	53819	31893	23091	14337	9312	3931	1773	415	720	735
1976	116630	91909	103379	90176	54701	43761	23561	13703	7254	4040	1691	816	218	113
1977	107484	95488	75249	84640	73830	44770	35277	16367	6321	2529	1313	635	433	311
1978	82333	88001	78179	61609	69297	59963	32119	19112	6753	2521	1154	876	402	459
1979	98960	67409	72049	64008	50441	54038	41480	18181	8792	2936	763	290	385	756
1980	130002	81021	55190	58989	52405	39138	36346	22357	9333	6141	1969	365	103	52
1981	131711	106437	66335	45186	48296	42717	30156	21478	9546	2757	1564	695	183	292
1982	130923	107835	87143	54310	36995	38760	30886	15817	7224	3919	1452	1049	441	511
1983	146236	107191	88288	71347	44465	30045	29654	19570	7735	2709	1685	649	627	1030
1984	153319	119728	87761	72284	58414	35771	21381	15411	9223	4257	1592	1190	463	794
1985	167009	125527	98025	71852	59181	47009	27184	12217	5667	3853	2346	935	845	832
1986	186714	136735	102773	80256	58828	46659	33684	16906	6836	3391	2692	1777	676	1126
1987	155857	152868	111950	84143	65708	47911	36175	21777	9235	4267	2350	1983	1328	2049
1988	128730	127605	125158	91657	68891	53673	37505	19660	9745	4996	2722	1577	1369	1646
1989	112785	105395	104474	102471	75042	56135	41061	23345	12133	6813	3669	2047	1196	583
1990	107652	92341	86291	85536	83896	61275	44161	26850	15247	8593	4884	2608	1434	1042
1991	94371	88138	75602	70649	69945	67691	44053	24726	15145	8798	4600	2909	1334	997
1992	70733	77265	72161	61898	57643	54677	48403	24167	10475	5935	3837	2078	1282	1078
1993	83745	57911	63259	59080	49715	43412	34883	20954	8743	4657	3264	2225	1034	464
1994	142441	68565	47413	51792	47457	32044	21131	12529	6372	2958	2151	1718	950	632
1995	171415	116621	56136	38819	37522	23925	11925	7219	4161	2429	1424	1027	1025	815
1996	149826	140343	95481	45960	31490	29497	17469	6867	3983	2336	1500	853	594	367
1997	122514	122667	114903	78173	37457	24281	19448	8523	3891	2396	1456	834	488	314
1998	105933	100306	100431	94075	63700	28945	16107	9096	4069	2155	1413	812	460	253
1999	105832	86731	82124	82226	76522	48918	18806	7951	4142	2033	1275	816	519	537
2000	104278	86648	71009	67237	67052	60707	34961	7606	3078	1890	1101	733	391	312
2001	103256	85376	70941	58137	54804	53062	38317	9464	3242	1639	1070	568	417	198
2002	105587	84539	69900	58082	47193	42844	32438	11354	3085	1740	894	479	282	179
2003	85366	86448	69215	57229	47120	37135	28527	10650	3318	1400	829	406	189	209
2004	60780	69892	70777	56668	45698	34515	20701	8188	2942	1256	679	416	203	172
2005	42064	49762	57223	57948	45584	33739	20806	7410	2970	1226	550	295	174	124
2006	54596	34439	40742	46850	46960	35827	22195	7703	2451	1156	602	229	138	171
2007	0	44699	28196	33357	38162	36757	23496	7183	1871	1021	610	370	145	189

Table 7. XSA estimated fishing mortality at age. The mean is computed over ages 5 – 10.

F @ AGE(XSA)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean
1975	0.000	0.000	0.000	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	0.000	0.000	0.000	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	0.000	0.000	0.000	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	0.000	0.000	0.000	0.000	0.049	0.169	0.369	0.576	0.633	0.995	1.180	0.622	0.943	0.943	0.465
1979	0.000	0.000	0.000	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	0.000	0.000	0.000	0.000	0.004	0.061	0.326	0.651	1.019	1.168	0.841	0.490	0.842	0.842	0.538
1981	0.000	0.000	0.000	0.000	0.020	0.124	0.445	0.890	0.690	0.441	0.200	0.256	0.301	0.301	0.435
1982	0.000	0.000	0.000	0.000	0.008	0.068	0.256	0.515	0.781	0.644	0.605	0.314	0.525	0.525	0.379
1983	0.000	0.000	0.000	0.000	0.018	0.140	0.455	0.552	0.397	0.332	0.148	0.139	0.207	0.207	0.316
1984	0.000	0.000	0.000	0.000	0.017	0.075	0.360	0.801	0.673	0.396	0.332	0.143	0.292	0.292	0.387
1985	0.000	0.000	0.000	0.000	0.038	0.133	0.275	0.381	0.314	0.159	0.078	0.124	0.121	0.121	0.217
1986	0.000	0.000	0.000	0.000	0.005	0.055	0.236	0.405	0.271	0.167	0.106	0.091	0.122	0.122	0.190
1987	0.000	0.000	0.000	0.000	0.002	0.045	0.410	0.604	0.414	0.250	0.199	0.170	0.207	0.207	0.288
1988	0.000	0.000	0.000	0.000	0.005	0.068	0.274	0.283	0.158	0.109	0.085	0.077	0.090	0.090	0.149
1989	0.000	0.000	0.000	0.000	0.003	0.040	0.225	0.226	0.145	0.133	0.142	0.156	0.144	0.144	0.129
1990	0.000	0.000	0.000	0.001	0.015	0.130	0.380	0.373	0.350	0.425	0.318	0.470	0.407	0.407	0.279
1991	0.000	0.000	0.000	0.003	0.046	0.135	0.400	0.659	0.737	0.630	0.594	0.620	0.620	0.620	0.435
1992	0.000	0.000	0.000	0.019	0.084	0.249	0.637	0.817	0.611	0.398	0.345	0.498	0.416	0.416	0.466
1993	0.000	0.000	0.000	0.019	0.239	0.520	0.824	0.990	0.884	0.572	0.442	0.652	0.560	0.560	0.672
1994	0.000	0.000	0.000	0.122	0.485	0.788	0.874	0.902	0.764	0.531	0.539	0.317	0.466	0.466	0.724
1995	0.000	0.000	0.000	0.009	0.041	0.115	0.352	0.395	0.377	0.282	0.312	0.348	0.316	0.316	0.260
1996	0.000	0.000	0.000	0.005	0.060	0.217	0.518	0.368	0.308	0.272	0.388	0.359	0.309	0.309	0.291
1997	0.000	0.000	0.000	0.005	0.058	0.210	0.560	0.539	0.391	0.328	0.384	0.395	0.372	0.372	0.348
1998	0.000	0.000	0.000	0.007	0.064	0.231	0.506	0.587	0.494	0.325	0.349	0.247	0.250	0.250	0.368
1999	0.000	0.000	0.000	0.004	0.032	0.136	0.705	0.749	0.585	0.414	0.353	0.535	0.369	0.369	0.437
2000	0.000	0.000	0.000	0.005	0.034	0.260	1.107	0.653	0.430	0.369	0.461	0.365	0.453	0.453	0.475
2001	0.000	0.000	0.000	0.009	0.046	0.292	1.016	0.921	0.422	0.406	0.604	0.502	0.534	0.534	0.517
2002	0.000	0.000	0.000	0.009	0.040	0.207	0.914	1.030	0.590	0.542	0.589	0.728	0.682	0.682	0.554
2003	0.000	0.000	0.000	0.025	0.111	0.384	1.048	1.087	0.771	0.523	0.489	0.497	0.587	0.587	0.654
2004	0.000	0.000	0.000	0.018	0.103	0.306	0.827	0.814	0.675	0.626	0.635	0.671	0.644	0.644	0.559
2005	0.000	0.000	0.000	0.010	0.041	0.219	0.794	0.906	0.744	0.511	0.674	0.558	0.521	0.521	0.536
2006	0.000	0.000	0.000	0.005	0.045	0.222	0.928	1.215	0.676	0.440	0.287	0.257	0.296	0.296	0.588

Table 8. Stock summary table from XSA analysis (no SOP correction; shrinkage parameters fixed at 0.5).

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

	RECRUITS Age 1	TOTALBIO	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 5-10
1975	112258	132741	9302	28814	3.0975	0.3652
1976	116630	134509	6114	24611	4.0251	0.422
1977	107484	156957	7424	32048	4.3166	0.4237
1978	82333	167765	8677	39070	4.5027	0.4651
1979	98960	162544	9818	34104	3.4736	0.249
1980	130002	130921	5501	32867	5.9751	0.5382
1981	131711	115282	7196	30754	4.2735	0.4351
1982	130923	121301	9195	26278	2.8578	0.3787
1983	146236	122735	12222	27861	2.2795	0.3156
1984	153319	115204	10113	26711	2.6412	0.3867
1985	167009	148085	10389	20347	1.9585	0.2165
1986	186714	138047	11975	17976	1.5011	0.1897
1987	155857	164554	15888	32442	2.0419	0.2875
1988	128730	168993	13752	19215	1.3973	0.1493
1989	112785	182105	8277	20034	2.4203	0.1285
1990	107652	205930	15053	47454	3.1524	0.2787
1991	94371	224362	30050	65008	2.1633	0.4346
1992	70733	192107	23241	63193	2.7191	0.4659
1993	83745	148017	16143	62455	3.8689	0.6716
1994	142441	102654	11981	51029	4.2592	0.7243
1995	171415	76807	10944	15272	1.3955	0.2602
1996	149826	76799	6126	18840	3.0753	0.2905
1997	122514	73913	4749	19858	4.1815	0.3477
1998	105933	87214	3718	19946	5.3653	0.3678
1999	105832	102500	4593	24226	5.2744	0.4367
2000	104278	110700	3355	34177	10.188	0.4755
2001	103256	111664	3793	38232	10.0794	0.5173
2002	105587	98019	4157	34062	8.1949	0.5538
2003	85366	89583	3647	35151	9.6394	0.6541
2004	60780	74852	3090	25486	8.2476	0.5588
2005	42064	75573	2332	23225	9.9593	0.5358
2006	54596	76510	2129	23531	11.0518	0.5875
Arith. Mean	114729	127780	9217	31696	4.6743	0.4097
0 Units	(Thousands)	(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%.

2007/2006 Ratio Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1975	0.999	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	0.999	0.999	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	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1978	0.998	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979	0.998	0.998	0.999	0.999	0.999	1.000	1.000	1.000	0.999	0.999	1.000	0.997	1.000	0.999
1980	0.997	0.998	0.998	0.999	0.999	0.999	1.000	0.999	1.000	1.000	0.999	1.000	1.000	1.000
1981	0.996	0.997	0.998	0.998	0.999	0.999	0.999	0.999	0.999	0.999	0.998	0.997	1.000	1.000
1982	0.994	0.996	0.997	0.998	0.998	0.999	0.999	0.998	0.999	0.998	0.998	0.998	0.998	0.998
1983	0.991	0.994	0.996	0.997	0.998	0.998	0.999	0.998	0.997	0.997	0.996	0.995	0.997	0.997
1984	0.992	0.991	0.994	0.996	0.997	0.998	0.998	0.998	0.997	0.996	0.996	0.995	0.996	0.996
1985	0.993	0.992	0.991	0.994	0.996	0.997	0.998	0.997	0.996	0.995	0.994	0.995	0.994	0.994
1986	0.992	0.993	0.992	0.991	0.994	0.996	0.996	0.997	0.995	0.994	0.994	0.994	0.994	0.994
1987	0.992	0.992	0.993	0.992	0.991	0.994	0.996	0.995	0.995	0.994	0.993	0.993	0.993	0.993
1988	0.995	0.992	0.992	0.993	0.992	0.991	0.994	0.994	0.991	0.993	0.992	0.992	0.992	0.992
1989	0.995	0.995	0.992	0.992	0.993	0.992	0.991	0.992	0.992	0.990	0.992	0.991	0.991	0.990
1990	0.996	0.995	0.995	0.992	0.992	0.993	0.992	0.988	0.990	0.990	0.988	0.991	0.990	0.990
1991	0.997	0.996	0.995	0.995	0.992	0.992	0.992	0.988	0.983	0.986	0.985	0.984	0.985	0.984
1992	0.993	0.997	0.996	0.995	0.995	0.991	0.991	0.989	0.977	0.965	0.973	0.973	0.970	0.970
1993	0.989	0.993	0.997	0.996	0.994	0.995	0.989	0.983	0.974	0.958	0.949	0.962	0.957	0.957
1994	0.993	0.989	0.993	0.997	0.996	0.993	0.991	0.975	0.955	0.940	0.928	0.922	0.931	0.929
1995	0.981	0.993	0.989	0.993	0.996	0.994	0.985	0.979	0.941	0.908	0.902	0.883	0.897	0.896
1996	0.983	0.981	0.993	0.989	0.993	0.996	0.993	0.978	0.969	0.916	0.882	0.870	0.843	0.842
1997	0.996	0.983	0.981	0.993	0.989	0.992	0.995	0.988	0.969	0.958	0.892	0.836	0.826	0.824
1998	1.039	0.996	0.983	0.981	0.993	0.989	0.990	0.991	0.980	0.955	0.942	0.849	0.773	0.771
1999	1.188	1.039	0.996	0.983	0.980	0.993	0.986	0.984	0.984	0.967	0.939	0.920	0.815	0.815
2000	1.077	1.188	1.039	0.996	0.983	0.980	0.992	0.972	0.967	0.972	0.951	0.915	0.871	0.869
2001	1.093	1.077	1.188	1.039	0.996	0.982	0.974	0.976	0.947	0.950	0.961	0.924	0.883	0.880
2002	1.067	1.093	1.077	1.188	1.039	0.995	0.976	0.931	0.942	0.921	0.926	0.930	0.881	0.882
2003	0.891	1.067	1.093	1.077	1.190	1.041	0.994	0.942	0.829	0.900	0.872	0.875	0.863	0.864
2004	0.916	0.891	1.067	1.093	1.079	1.218	1.061	0.984	0.847	0.692	0.842	0.806	0.812	0.808
2005	1.206	0.916	0.891	1.067	1.095	1.088	1.320	1.151	0.965	0.738	0.546	0.739	0.680	0.678
2006		1.206	0.916	0.891	1.068	1.099	1.112	2.158	1.480	0.929	0.628	0.379	0.619	0.658

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%.

2007/2006 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	1.001	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					1.002	1.001	1.000	1.000	1.001	1.001	1.001	1.000	1.001	1.001
1980					1.000	1.000	1.000	1.001	1.001	1.001	1.001	1.001	1.001	1.001
1981					1.000	1.002	1.001	1.001	1.002	1.002	1.003	1.002	1.002	1.002
1982					1.000	1.001	1.001	1.002	1.002	1.003	1.003	1.003	1.003	1.003
1983					1.006	1.002	1.002	1.002	1.003	1.003	1.005	1.004	1.003	1.003
1984					1.000	1.003	1.003	1.003	1.004	1.005	1.005	1.005	1.005	1.005
1985					1.003	1.004	1.003	1.004	1.005	1.006	1.006	1.006	1.006	1.006
1986					1.019	1.004	1.005	1.004	1.006	1.007	1.007	1.007	1.006	1.006
1987					1.000	1.007	1.005	1.007	1.006	1.007	1.008	1.007	1.007	1.007
1988					1.021	1.010	1.007	1.007	1.010	1.008	1.008	1.009	1.008	1.008
1989					1.000	1.008	1.011	1.009	1.009	1.011	1.009	1.010	1.010	1.010
1990				1.000	1.007	1.008	1.010	1.014	1.012	1.012	1.014	1.012	1.013	1.013
1991				1.000	1.009	1.009	1.010	1.017	1.026	1.020	1.020	1.023	1.021	1.021
1992				1.005	1.005	1.010	1.013	1.018	1.032	1.045	1.033	1.035	1.038	1.038
1993				1.005	1.006	1.007	1.017	1.030	1.042	1.059	1.068	1.055	1.060	1.060
1994				1.003	1.005	1.011	1.015	1.041	1.071	1.084	1.102	1.099	1.095	1.095
1995				1.000	1.002	1.007	1.019	1.027	1.076	1.117	1.127	1.158	1.135	1.135
1996				1.022	1.008	1.005	1.009	1.027	1.038	1.106	1.164	1.178	1.219	1.219
1997				1.000	1.012	1.009	1.007	1.016	1.039	1.052	1.146	1.242	1.255	1.255
1998				1.016	1.006	1.013	1.013	1.012	1.027	1.056	1.073	1.201	1.333	1.333
1999				1.026	1.019	1.007	1.021	1.024	1.021	1.042	1.078	1.115	1.273	1.273
2000				1.023	1.018	1.024	1.015	1.041	1.043	1.034	1.066	1.112	1.187	1.187
2001				0.966	1.004	1.021	1.046	1.040	1.070	1.065	1.056	1.107	1.176	1.176
2002				0.844	0.961	1.005	1.040	1.127	1.084	1.113	1.107	1.110	1.194	1.194
2003				0.926	0.831	0.952	1.010	1.109	1.307	1.145	1.189	1.183	1.211	1.211
2004				0.912	0.923	0.790	0.910	1.025	1.257	1.612	1.260	1.339	1.325	1.325
2005				0.936	0.911	0.909	0.618	0.783	1.054	1.461	2.166	1.469	1.612	1.612

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

Name	**Value**	**Uncertainty (CV)**	**Name**	**Value**	**Uncertainty (CV)**
Population at age in 2007			Selection pattern		(2004-2006
N1	Bootstrap (1975-2004)		sH1	0.000	0.000
N2	44699	0.62	sH2	0.000	0.000
N3	28196	0.26	sH3	0.000	0.000
N4	33357	0.21	sH4	0.020	0.579
N5	38162	0.17	sH5	0.113	0.556
N6	36757	0.15	sH6	0.445	0.204
N7	23496	0.13	sH7	1.514	0.038
N8	7183	0.14	sH8	1.739	0.177
N9	1871	0.20	sH9	1.249	0.099
N10	1021	0.21	sH10	0.941	0.198
N11	610	0.21	sH11	0.961	0.430
N12	370	0.22	sH12	0.893	0.451
N13	145	0.25	sH13	0.876	0.382
N14	189	0.29	sH14	0.876	0.382
Weight in the catch	(2004-2006)		Weight in the stock	(2004-2006	
WH1	0.000	0.00	WS1	0.000	0.00
WH2	0.000	0.00	WS2	0.000	0.00
WH3	0.187	0.33	WS3	0.000	0.00
WH4	0.272	0.10	WS4	0.000	0.00
WH5	0.392	0.04	WS5	0.392	0.04
WH6	0.568	0.06	WS6	0.568	0.06
WH7	0.824	0.03	WS7	0.824	0.03
WH8	1.178	0.07	WS8	1.178	0.07
WH9	1.605	0.06	WS9	1.605	0.06
WH10	2.066	0.08	WS10	2.066	0.08
WH11	2.611	0.07	WS11	2.611	0.07
WH12	3.380	0.06	WS12	3.380	0.06
WH13	4.131	0.08	WS13	4.131	0.08
WH14	5.208	0.10	WS14	5.208	0.10
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. Deterministic projections under various catch levels and fishing mortality options. Rebuilding Plan I indicates a fixed annual catch of 16 000 t; Rebuilding Plan II indicates a 15% annual reduction in catches from the 2007 TAC level (16 000 t).

F0.1

Year	5+ Biomass (t)	Yield (t)	Fbar (5-10)
2007		20000	0.445
2008	69883	8057	0.138
2009	77374	10191	0.138
2010	84088	10749	0.138
2011	96257	10612	0.138
2012	109528		

Fcurrent

Year	5+ Biomass (t)	Yield	Fbar (5-10)
2007		20000	0.445
2008	69883	26102	0.588
2009	54735	21224	0.588
2010	45453	16440	0.588
2011	47541	13653	0.588
2012	53864		

Rebuilding Plan I

Year	5+ Biomass (t)	Yield	Fbar (5-10)
2007		20000	0.445
2008	69883	16000	0.305
2009	67411	16000	0.283
2010	65963	16000	0.303
2011	70396	16000	0.346
2012	75610		

Rebuilding Plan II

Year	5+ Biomass (t)	Yield	Fbar (5-10)
2007		20000	0.445
2008	69883	13600	0.250
2009	70422	11560	0.181
2010	74773	9826	0.145
2011	87444	8352	0.120
2012	103032		

Table 13. Biomass growth (%): biomass at the end of the projection period (2012) is compared to the biomass at the beginning of the projection (2007; 73 000 tons) and the biomass in 2003, when the rebuilding plan was instituted (89 500 tons).

F0.1

	Biomass (t)	
	5+	10+
2012 relative to 2007	50%	529%
2012 relative to 2003	22%	377%

Fcurrent

	Biomass (t)	
	5+	10+
2012 relative to 2007	-26%	-30%
2012 relative to 2003	-40%	-47%

Rebuilding Plan I

	Biomass (t)	
	5+	10+
2012 relative to 2007	3%	175%
2012 relative to 2003	-16%	108%

Rebuilding Plan II

	Biomass (t)	
	5+	10+
2012 relative to 2007	41%	427%
2012 relative to 2003	15%	300%

Table 14. 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	0.78
F2006	0.38
Rebuilding Plan I	0.54
Rebuilding Plan II	0.74

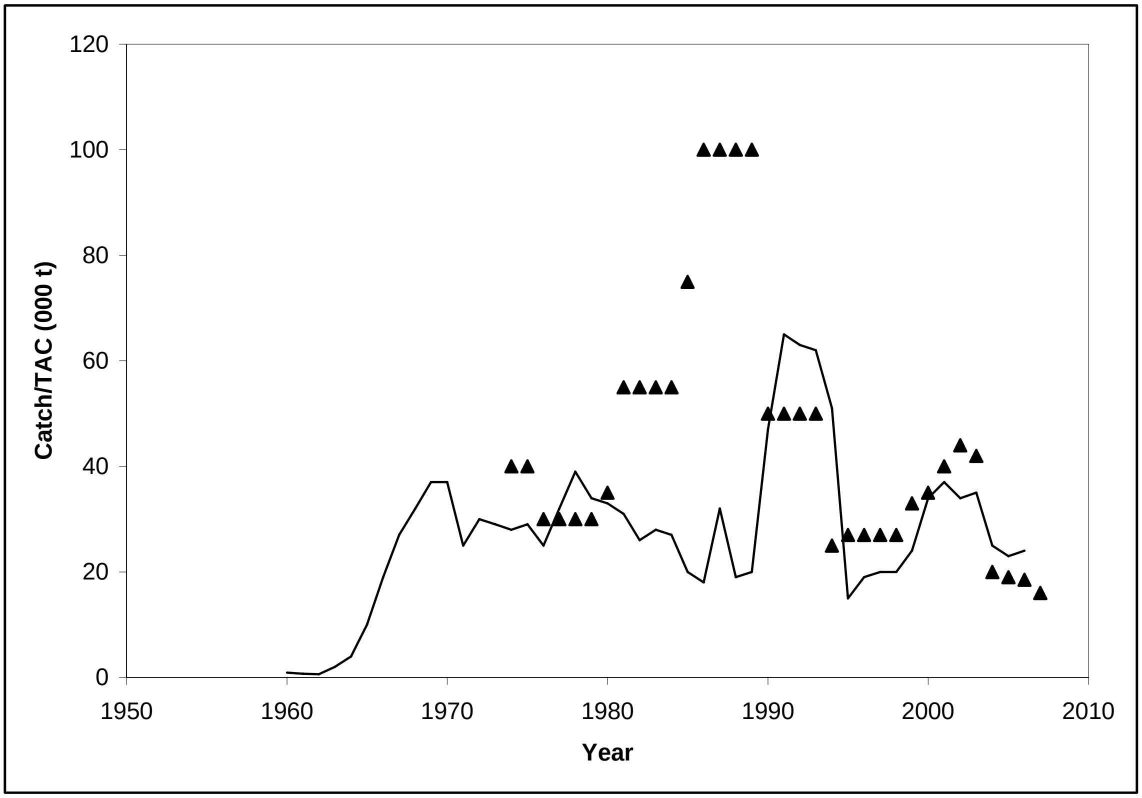


Figure 1 – Catches (line) and TAC (triangle) of Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO.

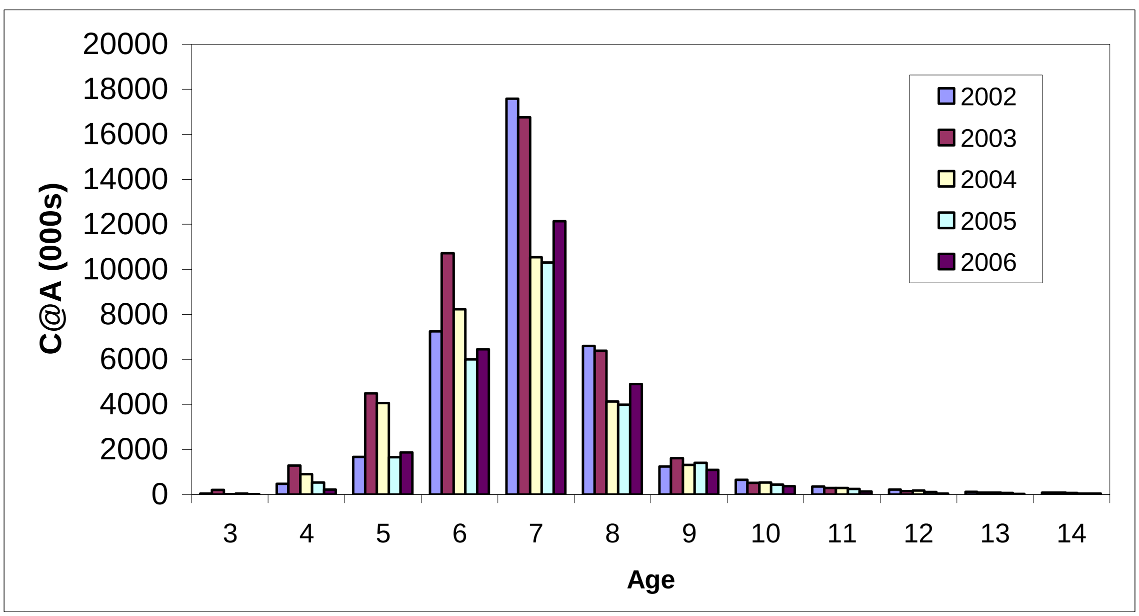
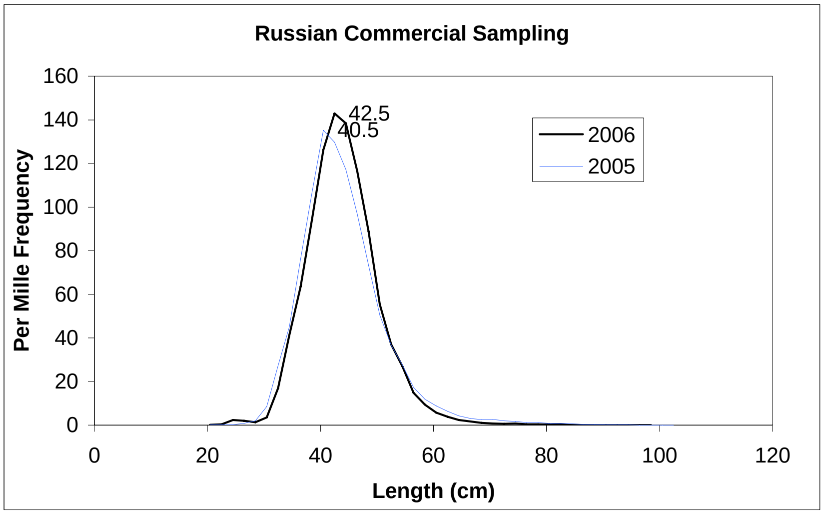
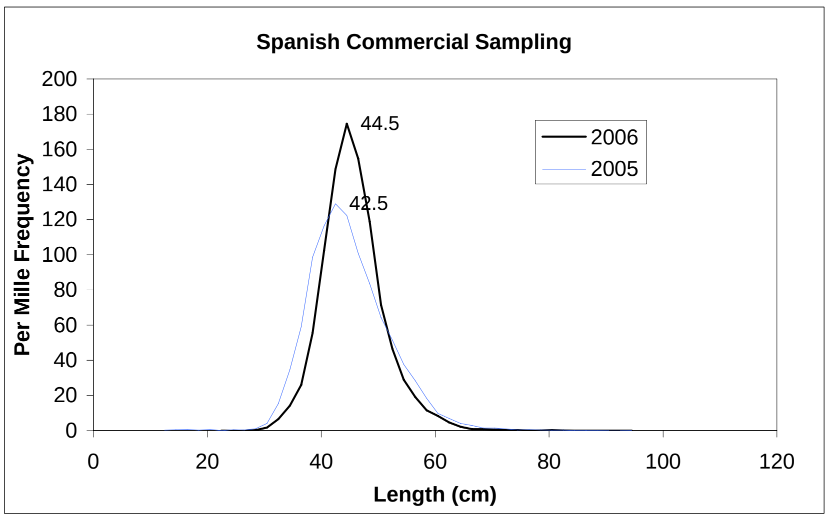


Figure 2 – Total international catch at age (in thousands) in recent period (2002-2006).





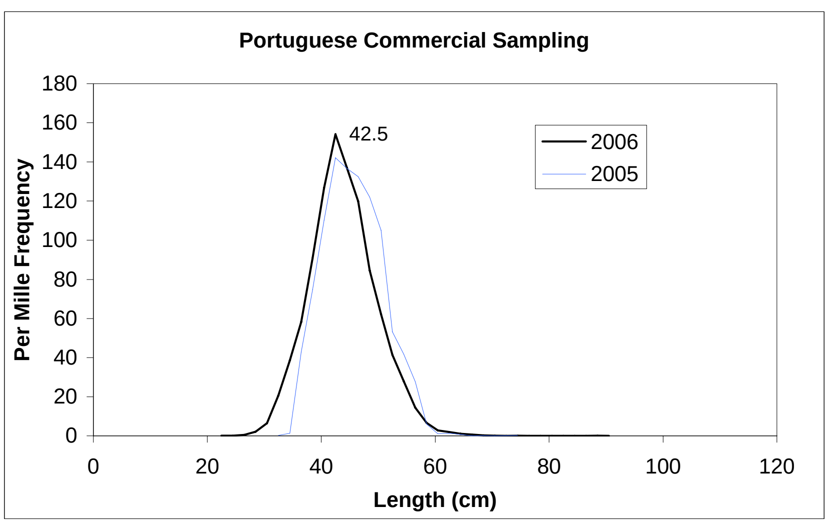
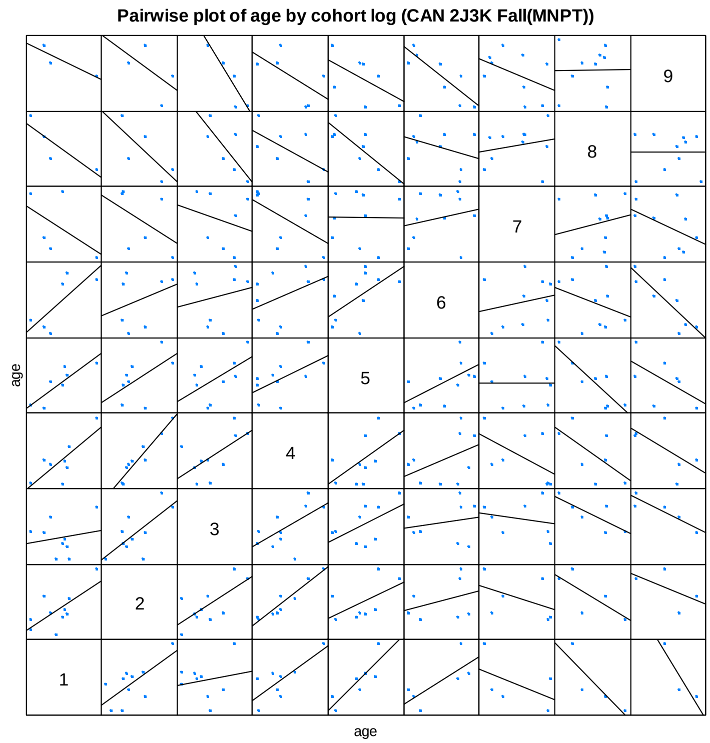


Figure 3 – Available Length Sampling in 2005 and 2006 for fisheries within the NRA. Labels indicate modal length group.



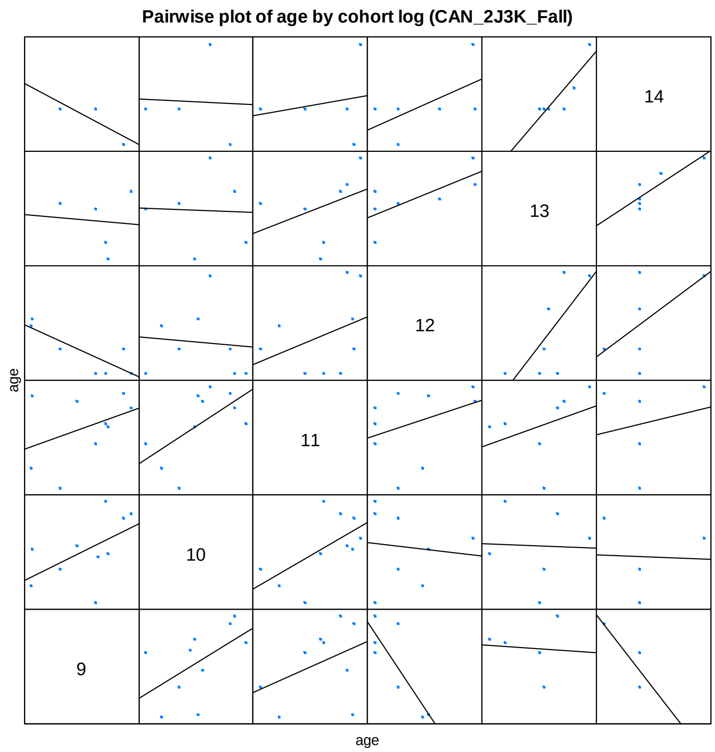


Figure 4a: Pair-wise scatter plot of age-disaggregated survey data (log-scale) from Canadian fall survey in Divs. 2J3K. Points represent comparison of survey data for a common cohort at different ages.

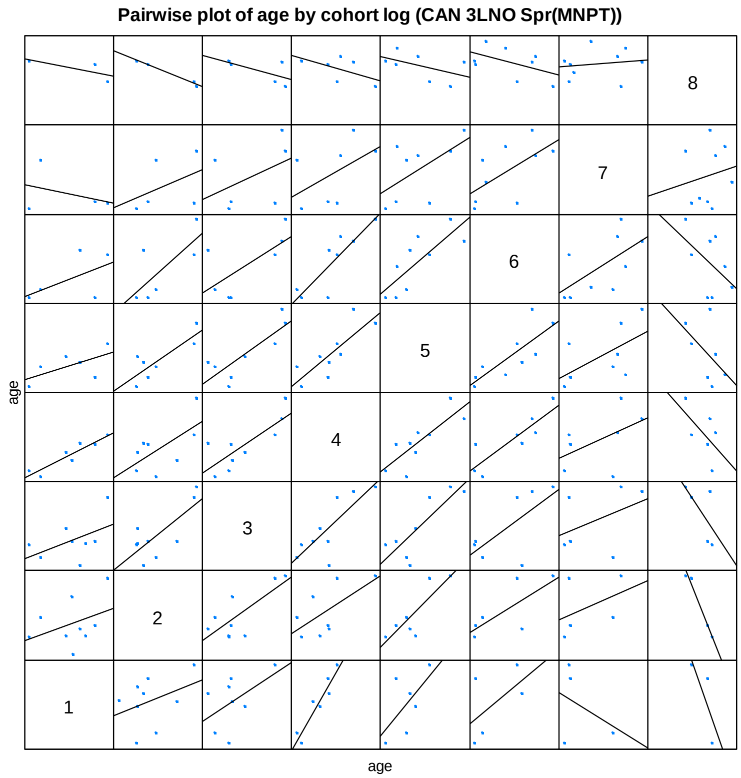


Figure 4b: Pair-wise scatter plot of age-disaggregated survey data (log-scale) from Canadian spring survey in Divs. 3LNO. Points represent comparison of survey data for a common cohort at different ages.

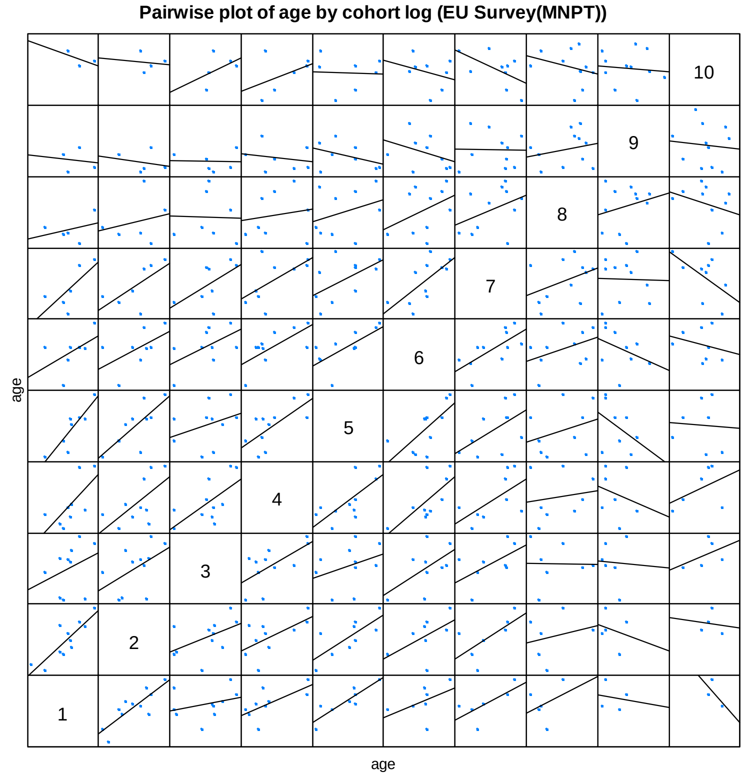
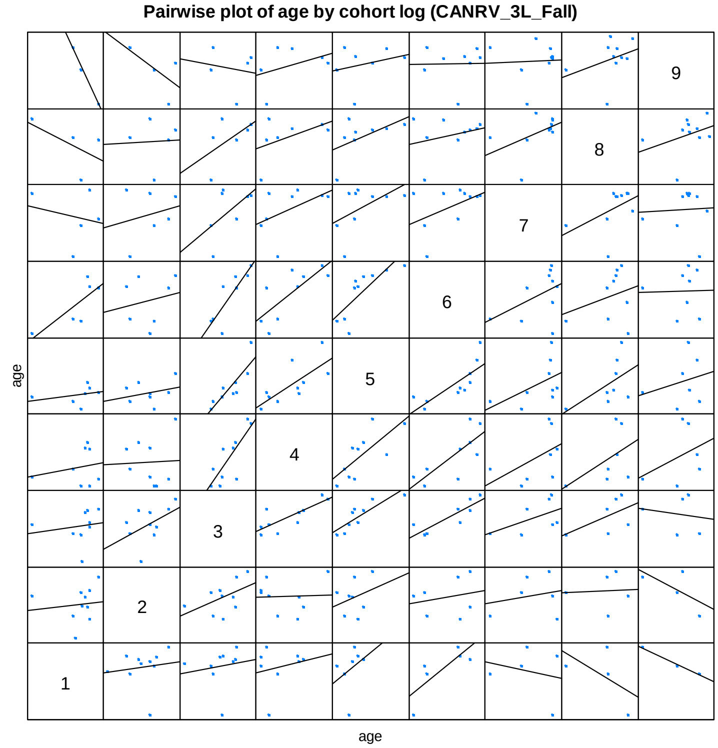


Figure 4c: Pair-wise scatter plot of age-disaggregated survey data (log-scale) from EU summer survey in Div. 3M. Points represent comparison of survey data for a common cohort at different ages.



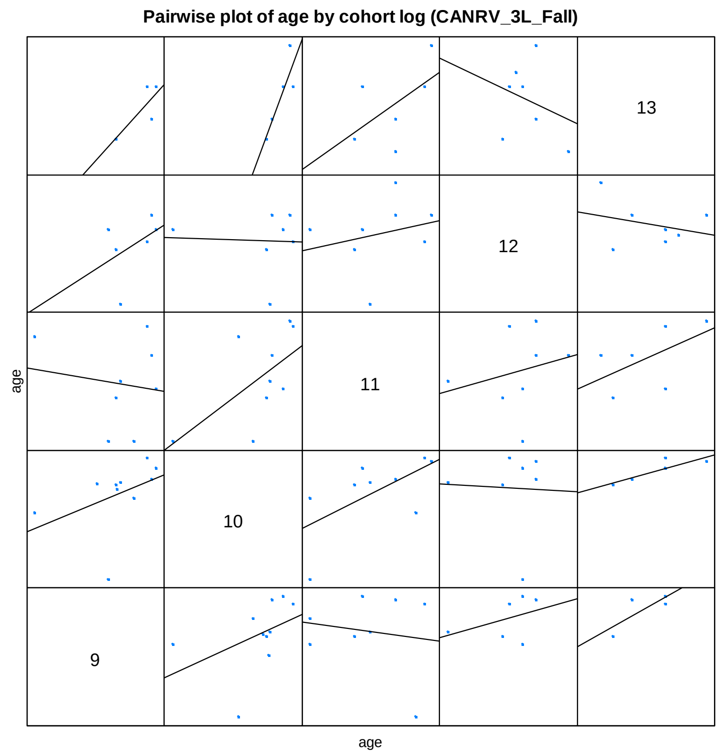
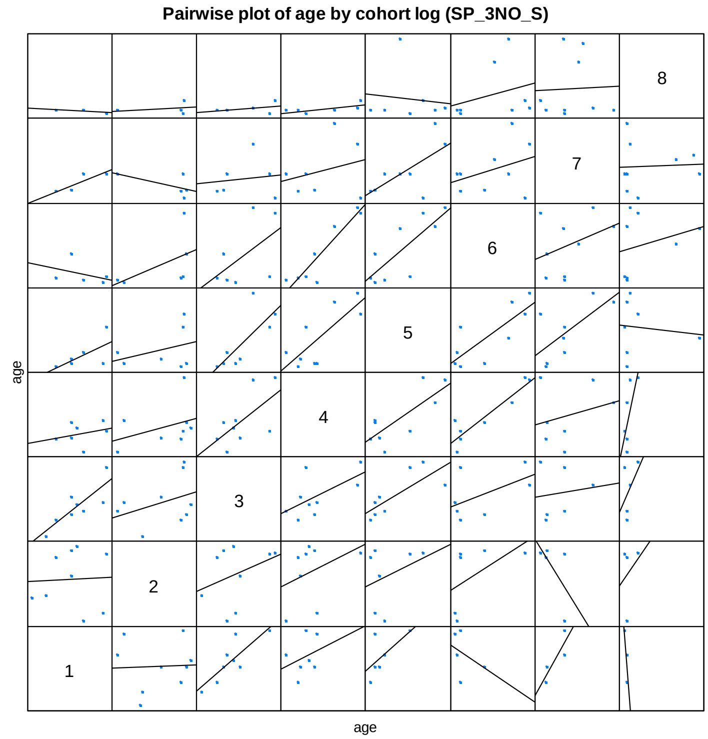


Figure 4d: Pair-wise scatter plot of age-disaggregated survey data (log-scale) from Canadian fall survey in Div. 3L. Points represent comparison of survey data for a common cohort at different ages.



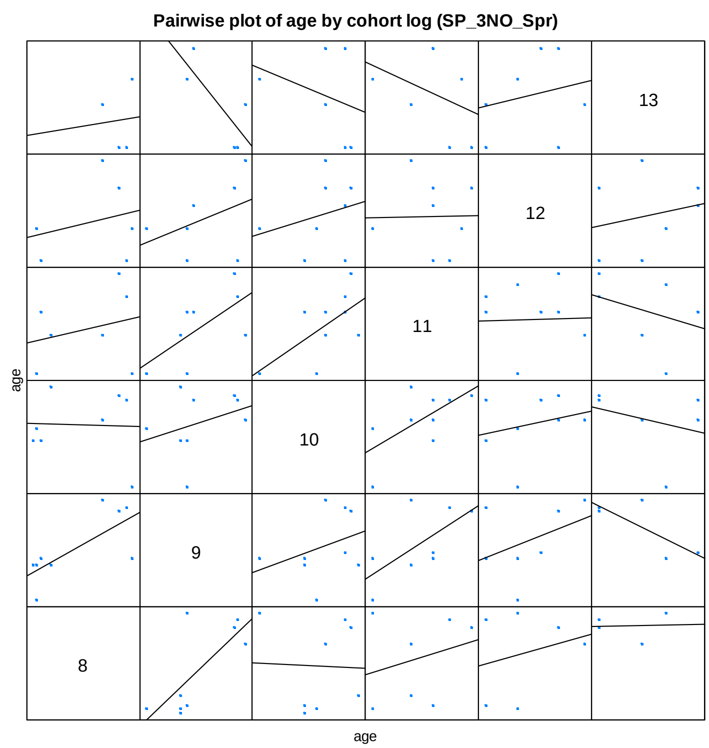
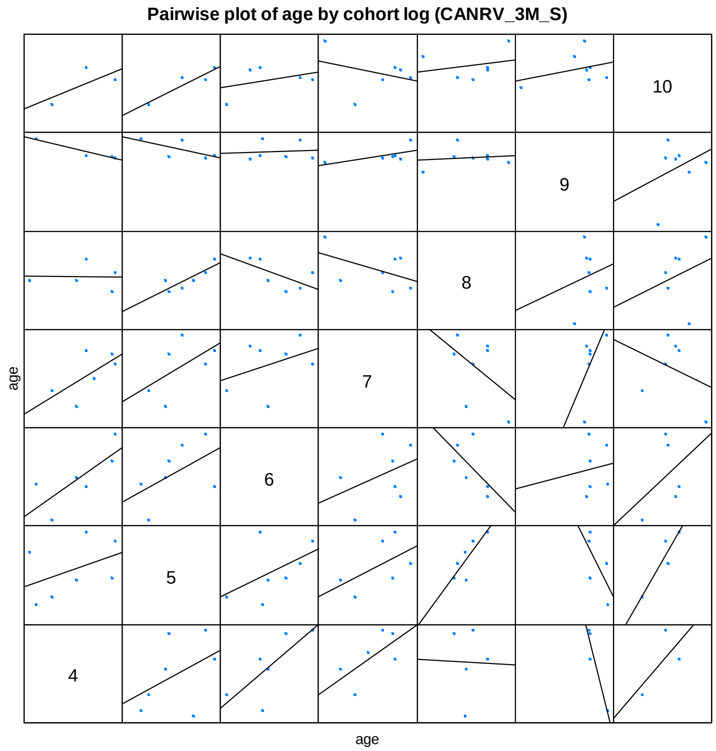


Figure 4e: Pair-wise scatter plot of age-disaggregated survey data (log-scale) from EU-Spain summer survey in the NRA of Divs. 3NO. Points represent comparison of survey data for a common cohort at different ages.



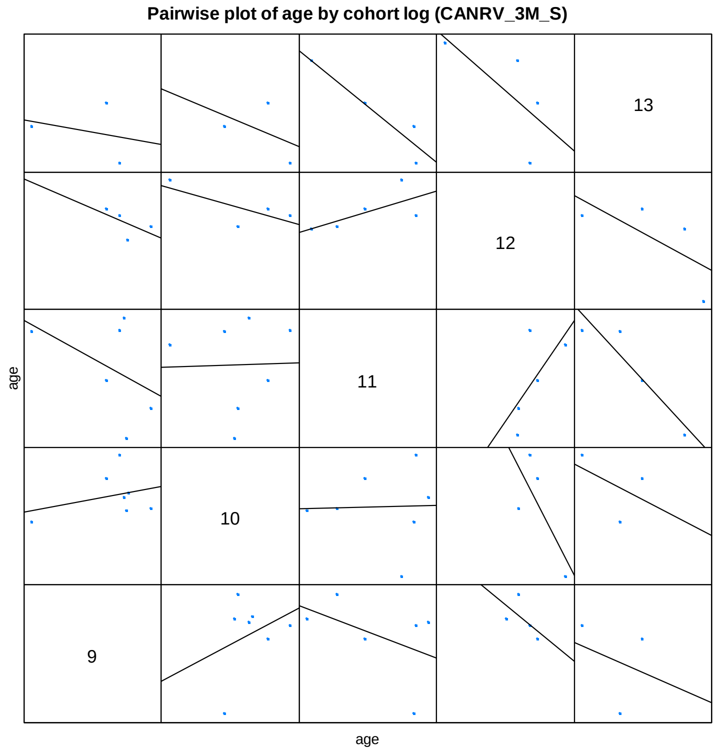


Figure 4f: Pair-wise scatter plot of age-disaggregated survey data (log-scale) from Canadian fall survey in Divs. 2J3K. Points represent comparison of survey data for a common cohort at different ages.

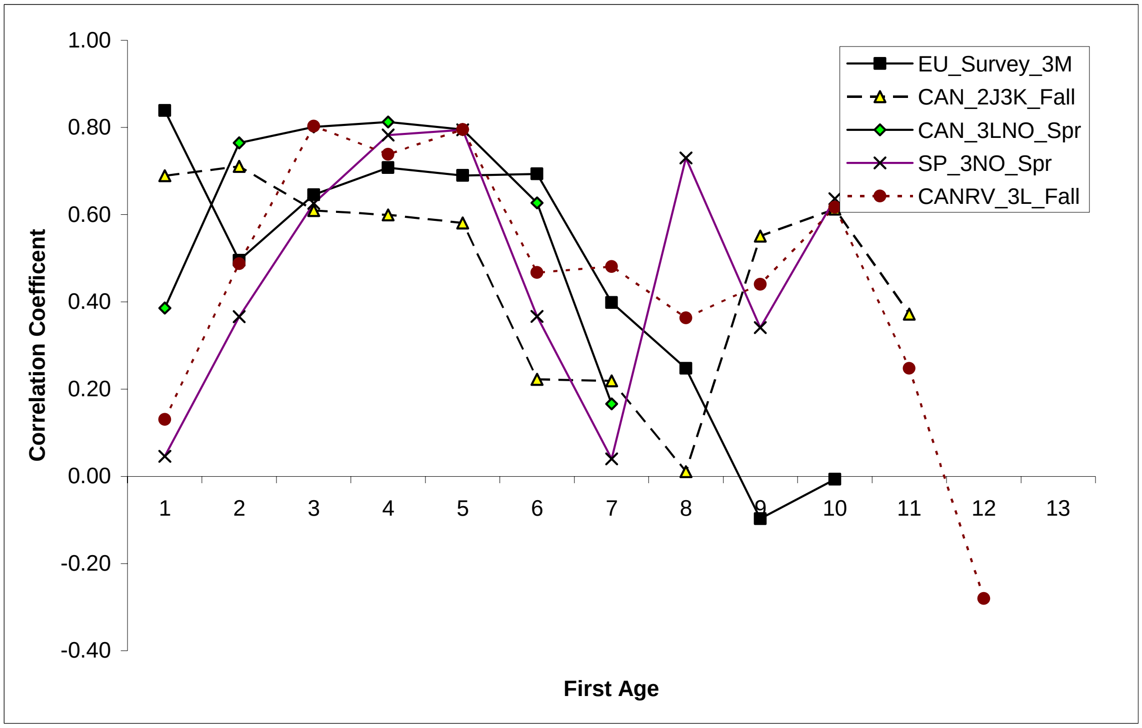


Figure 5 – Correlation coefficients between successive age groups from each survey series included in the VPA analysis. "First Age" identifies the youngest age being considered.

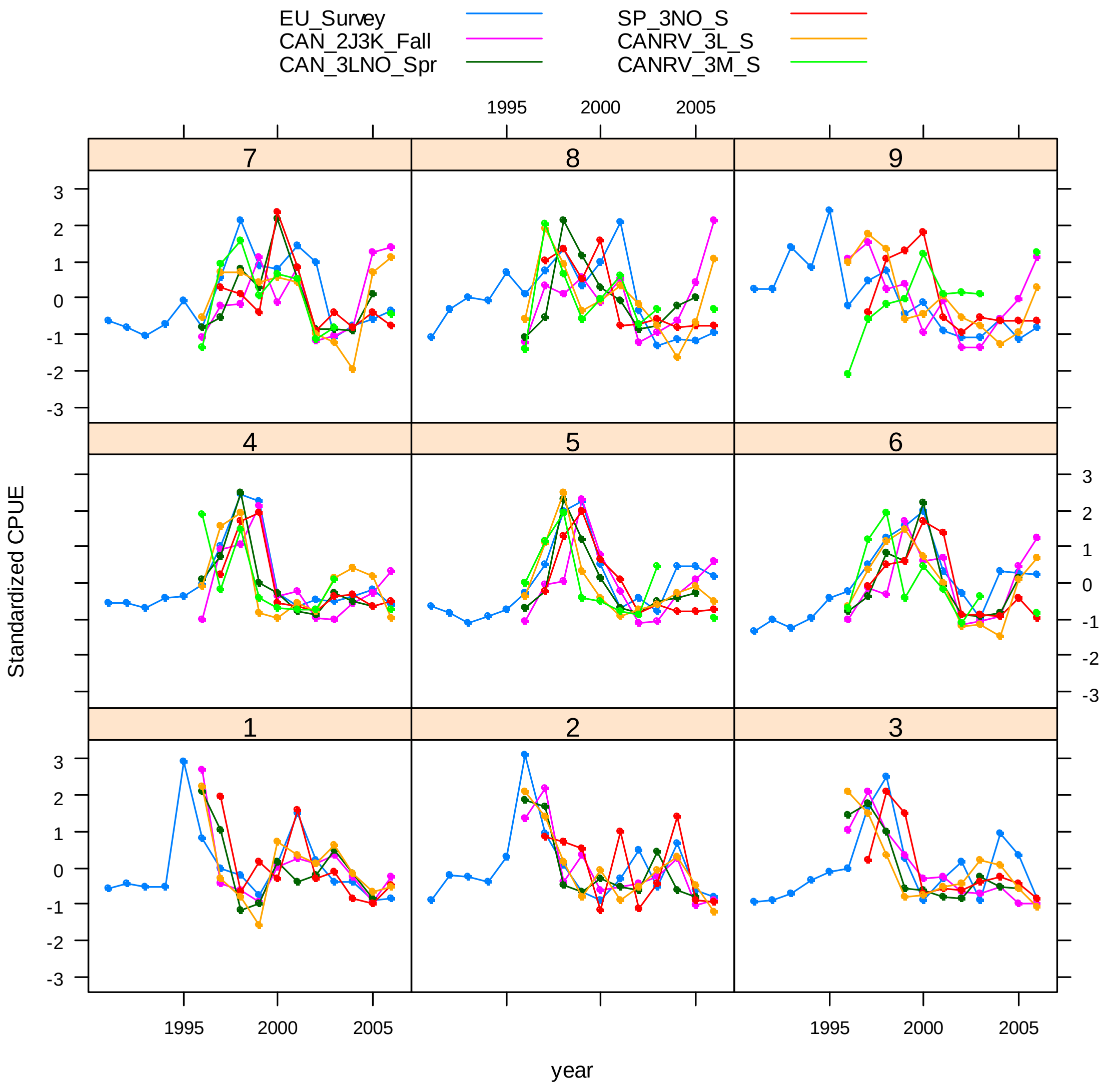


Figure 6a: Standardized age-disaggregated Greenland Halibut survey indices.

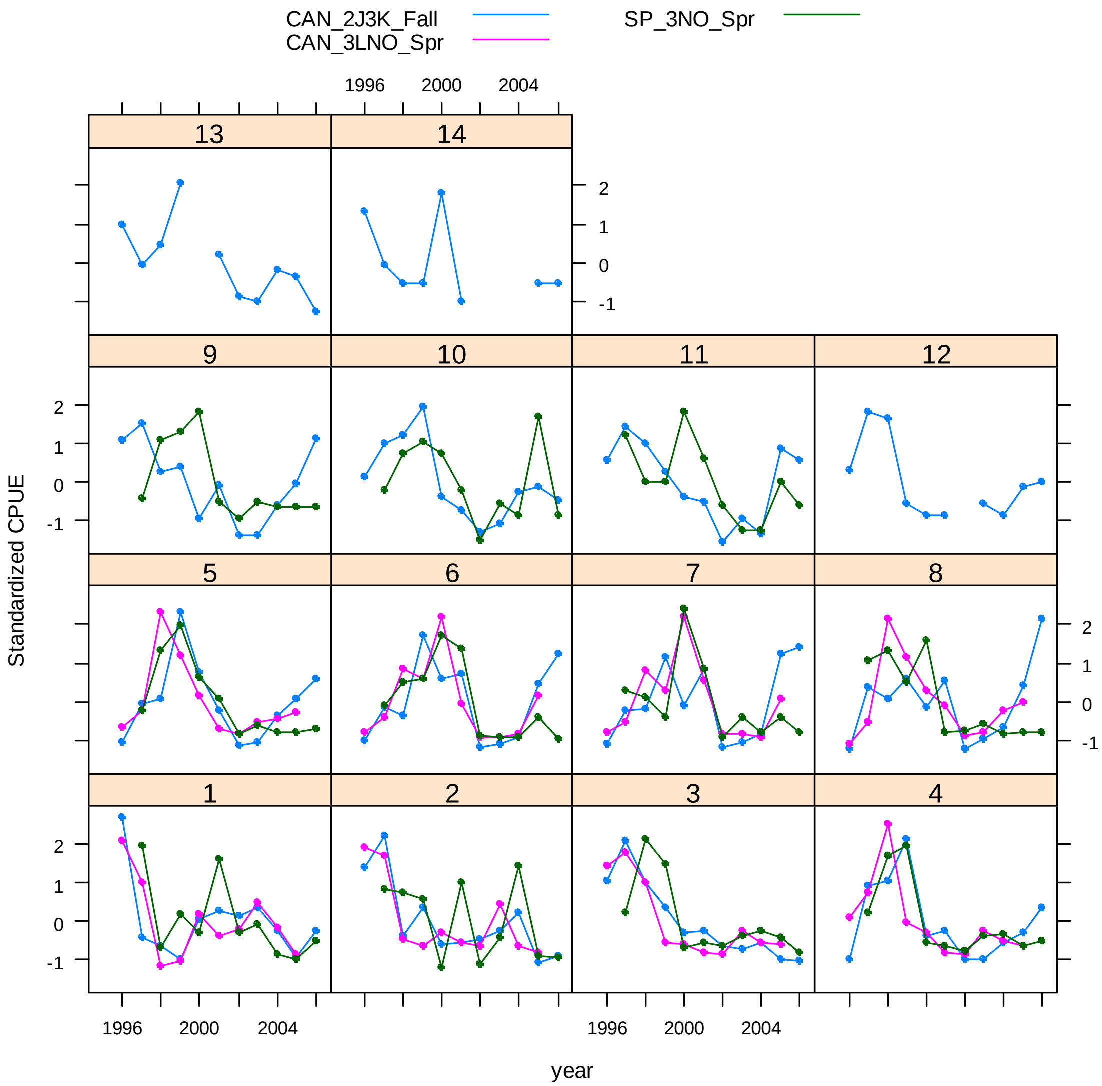


Figure 6b: cont.

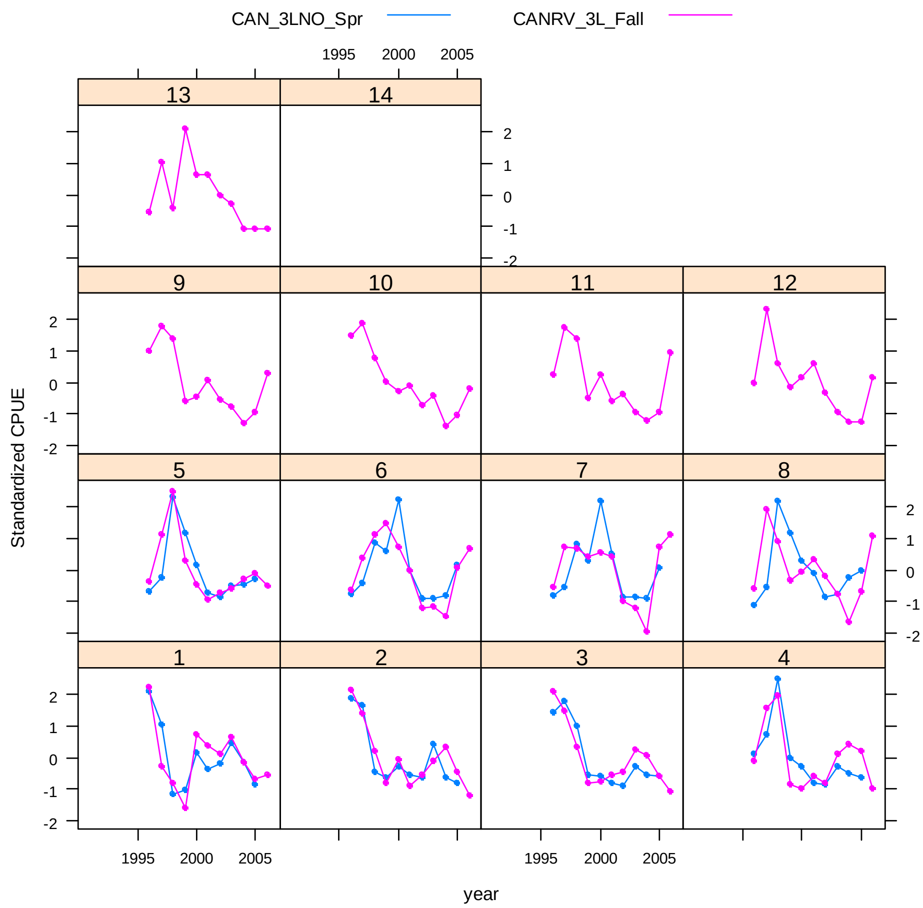


Figure 6c: cont.

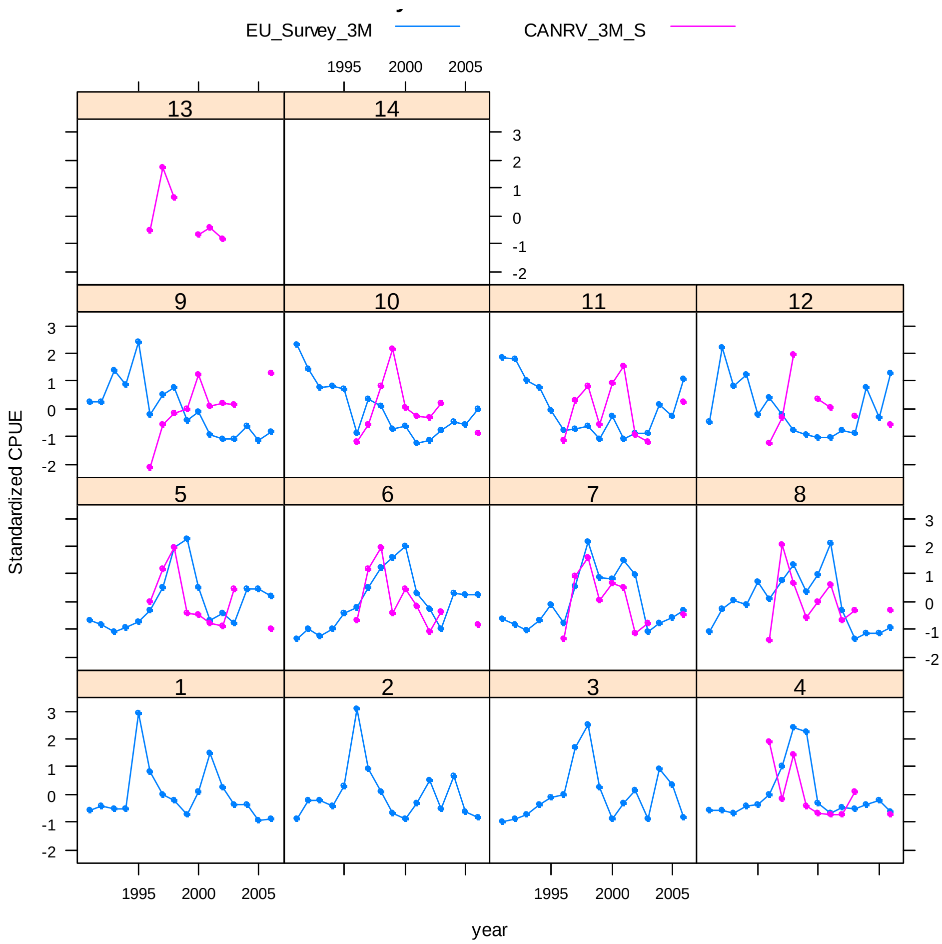


Figure 6d: cont.

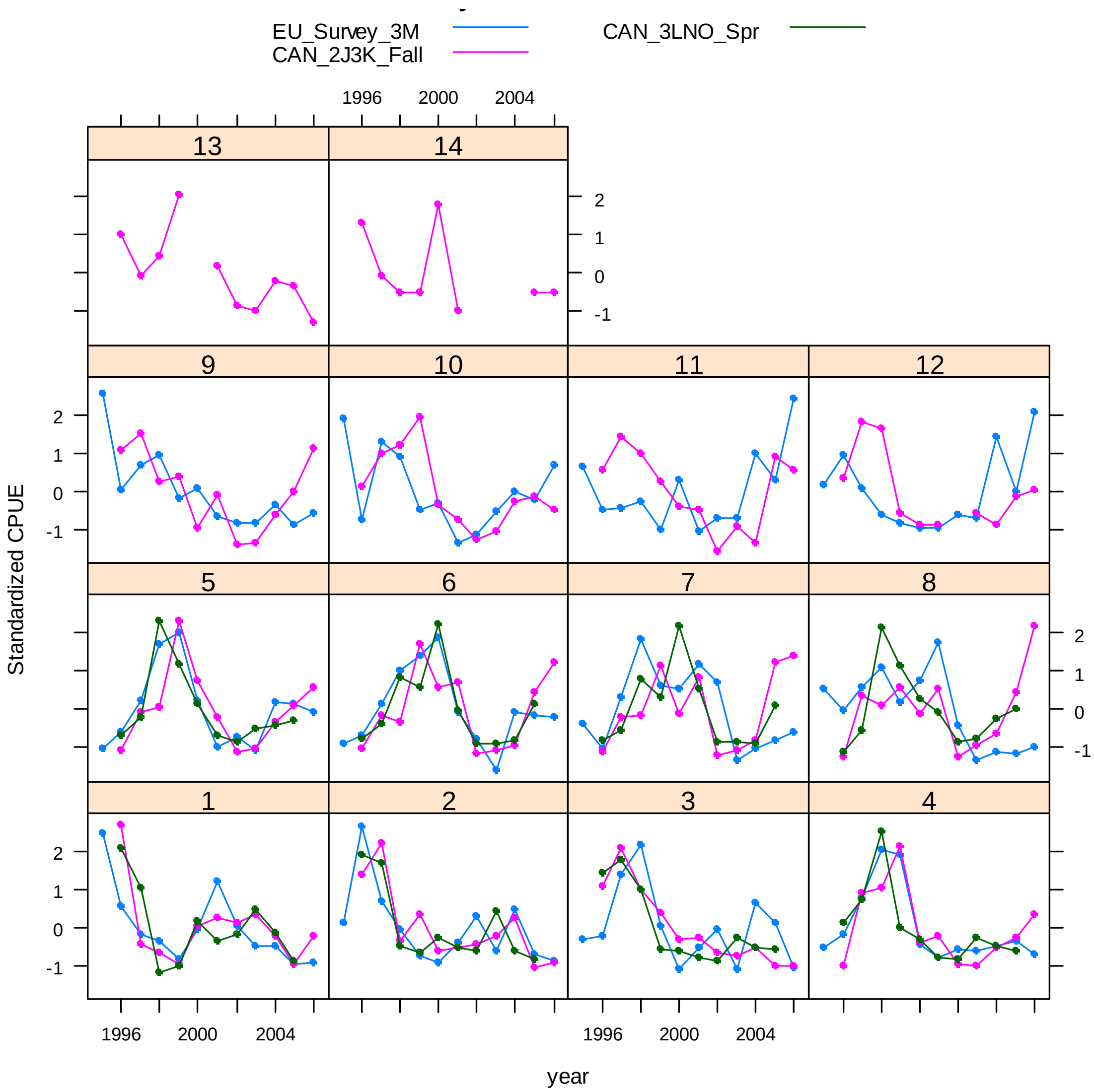


Figure 6e: cont.

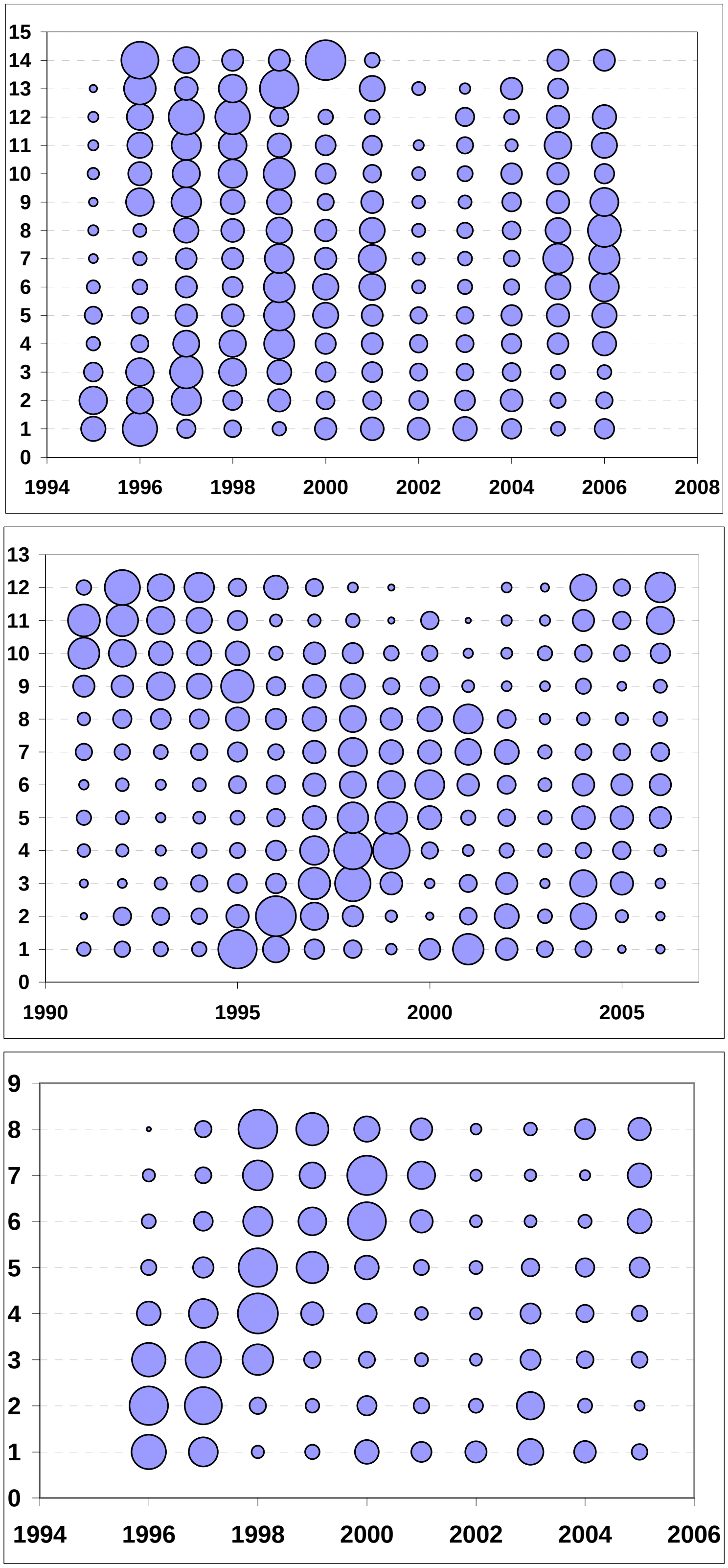


Figure 7. MNPT of Greenland Halibut in the Canadian fall survey of Divisions 2J3K (upper panel), the EU summer survey in Division 3M (middle panel), and Canadian spring surveys in Divisions 3LNO. Bubbles are scaled within each age.

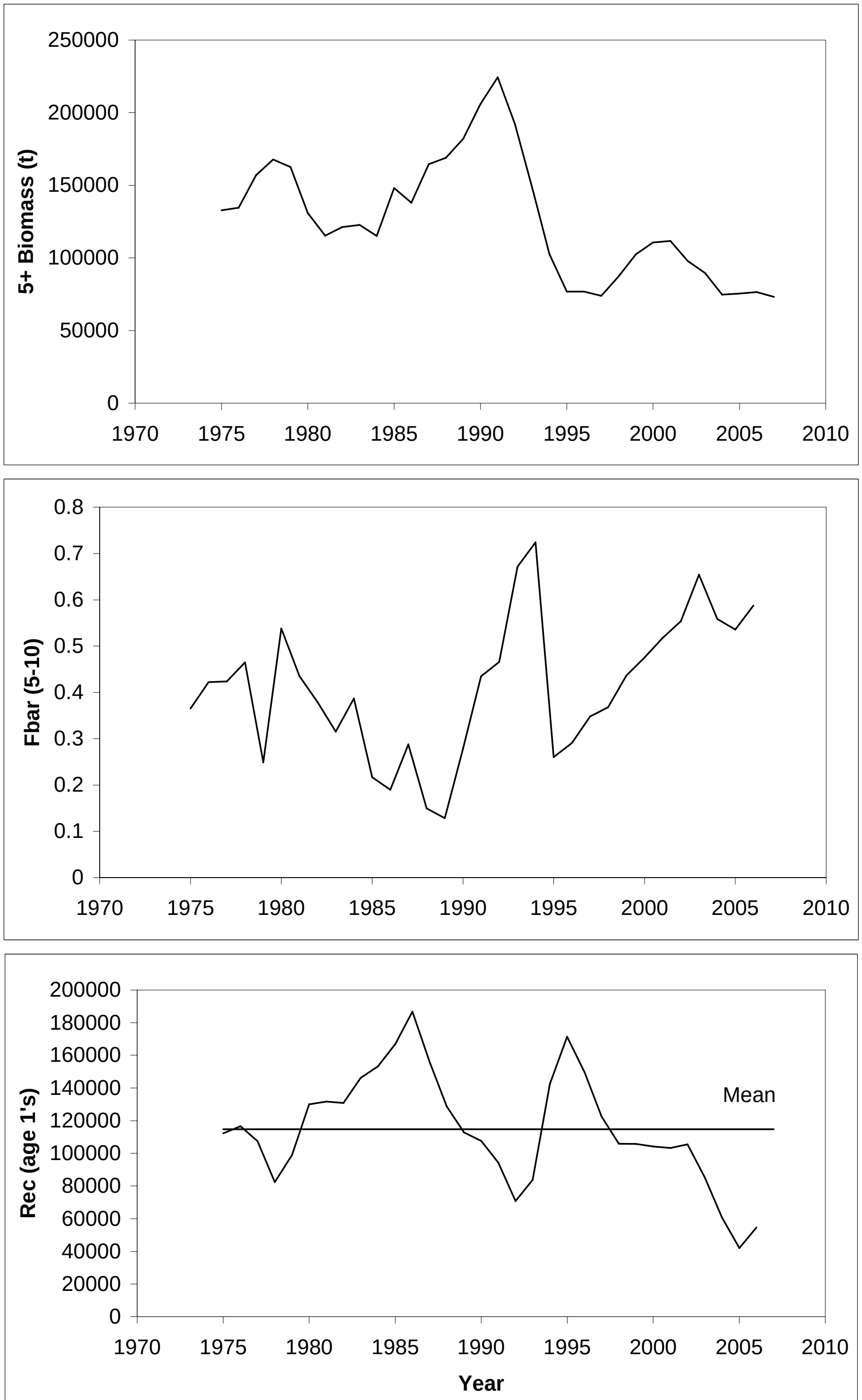
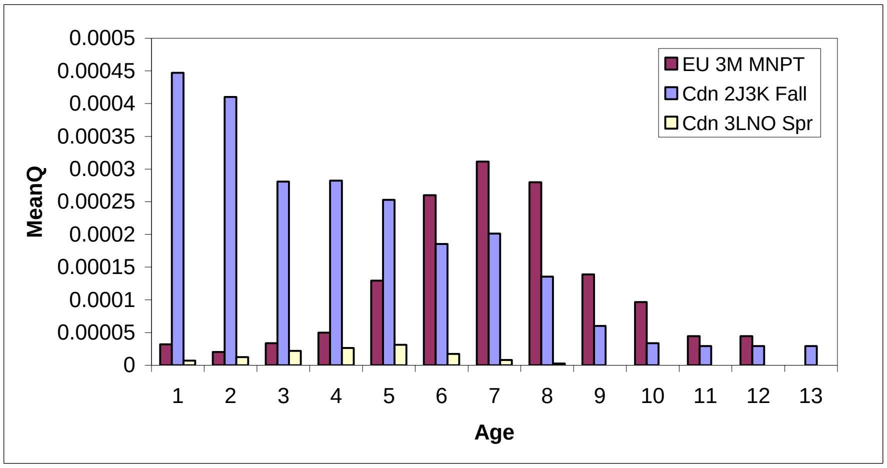
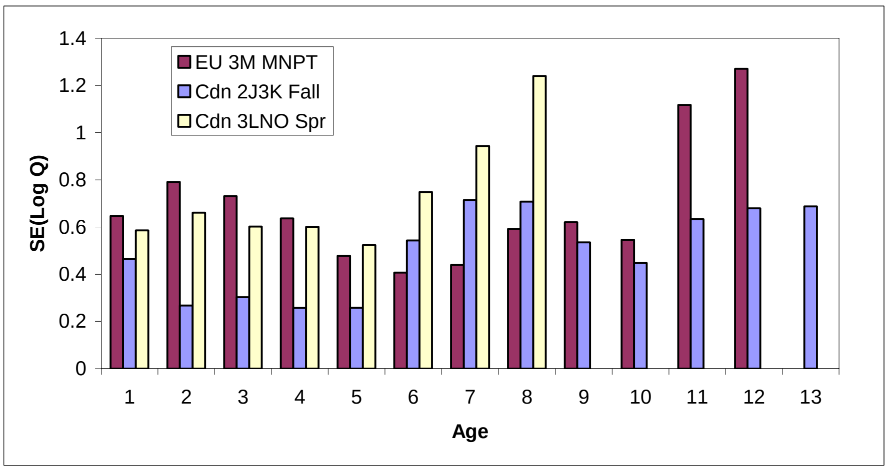


Figure 8. XSA Estimates of exploitable biomass (ages 5+ in tons; upper panel), average fishing mortality (ages 5-10) and recruitment (000's at age 1) for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO.

Catchabilities



SE(Log q)



Shrinkage Scaled Weights

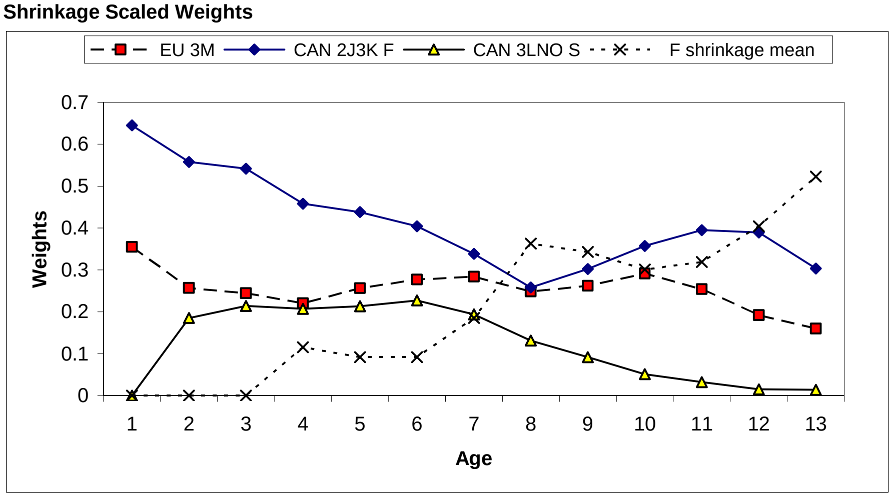


Figure 9. XSA estimated catchabilities, associated standard errors, and the scaled weights used to estimate survivors in the terminal year.

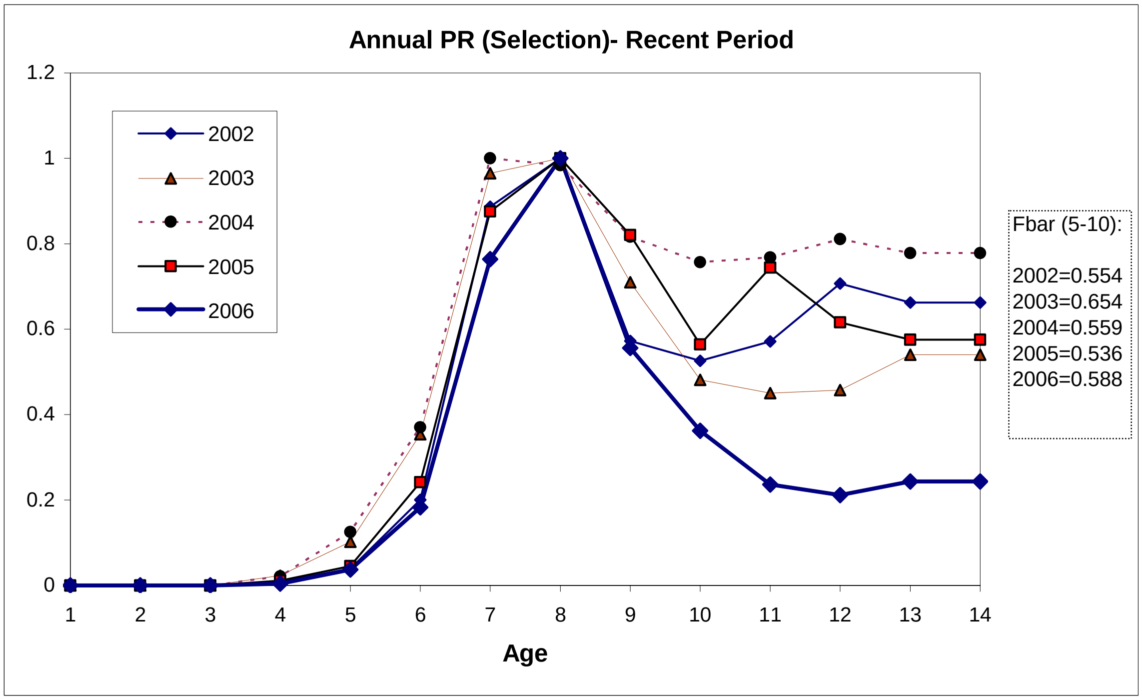


Figure 10. XSA estimated selection pattern in the most recent five years.

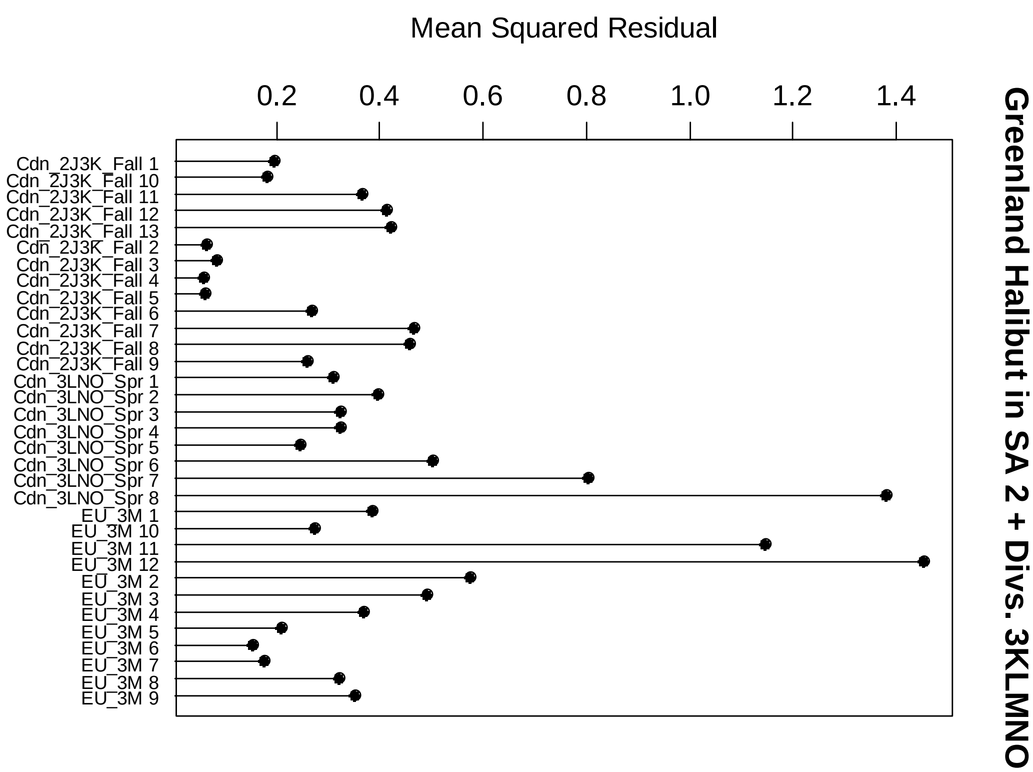
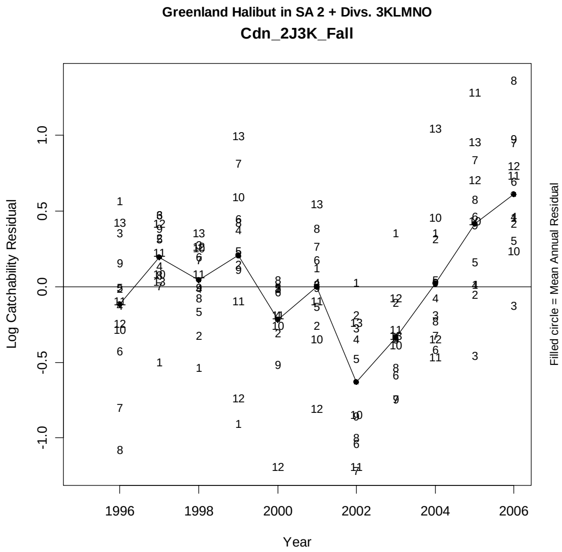
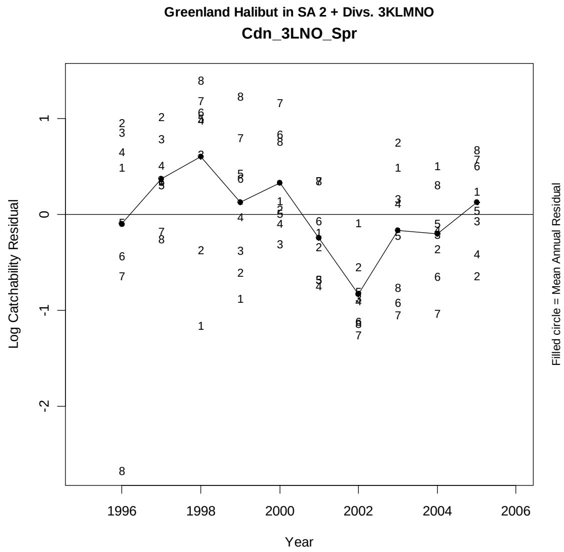


Figure 11a. Mean square residuals from XSA for each survey-age.





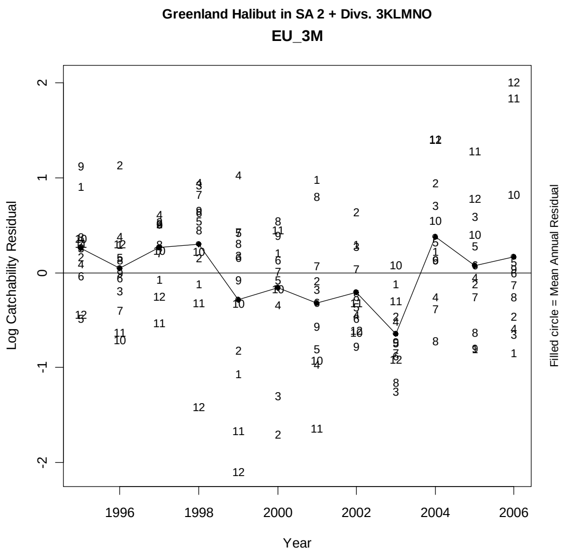


Figure 11b. XSA residuals by survey, age and year. Symbol=age, solid circle=mean annual residual.

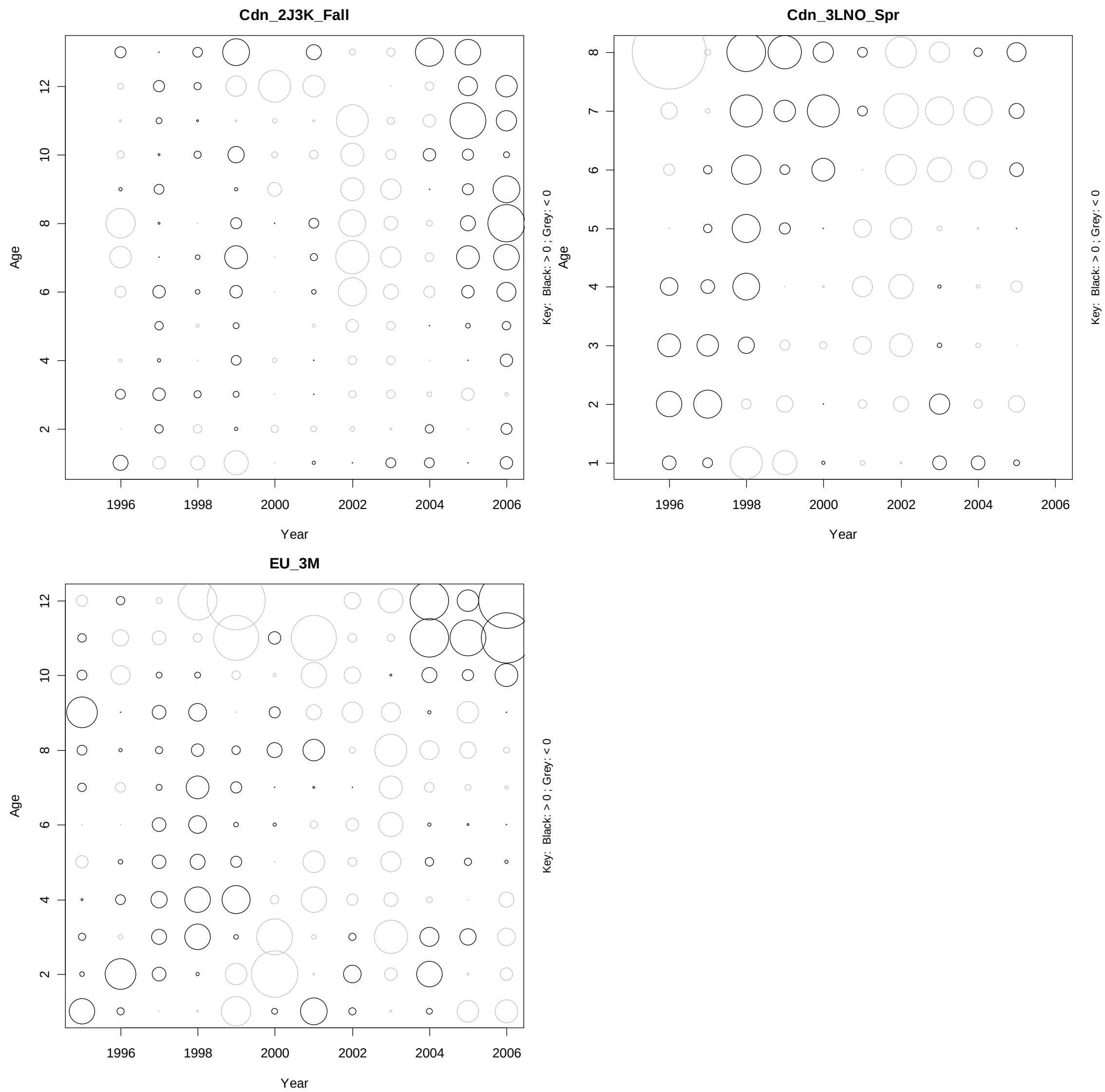


Figure 11c. XSA Residuals (cont.) Black=positive residual; grey=negative residual. Symbols are scaled to the overall maximum residual to permit comparisons across survey series.

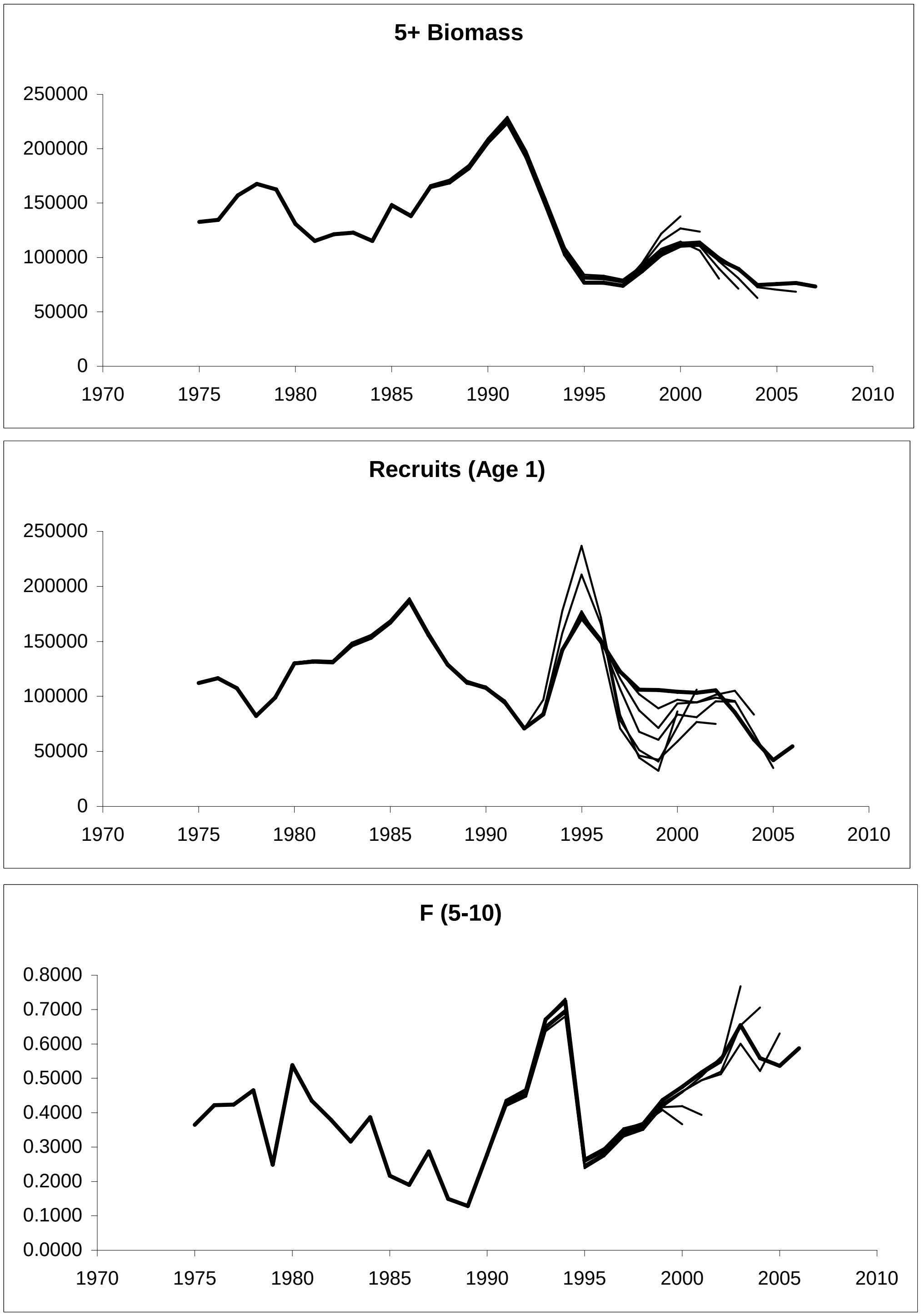


Figure 12 – Retrospective Analysis – 5+ biomass (t), Age 1 recruitment (000s) and average fishing mortality (ages 5-10). Bold lines highlight the current assessment.

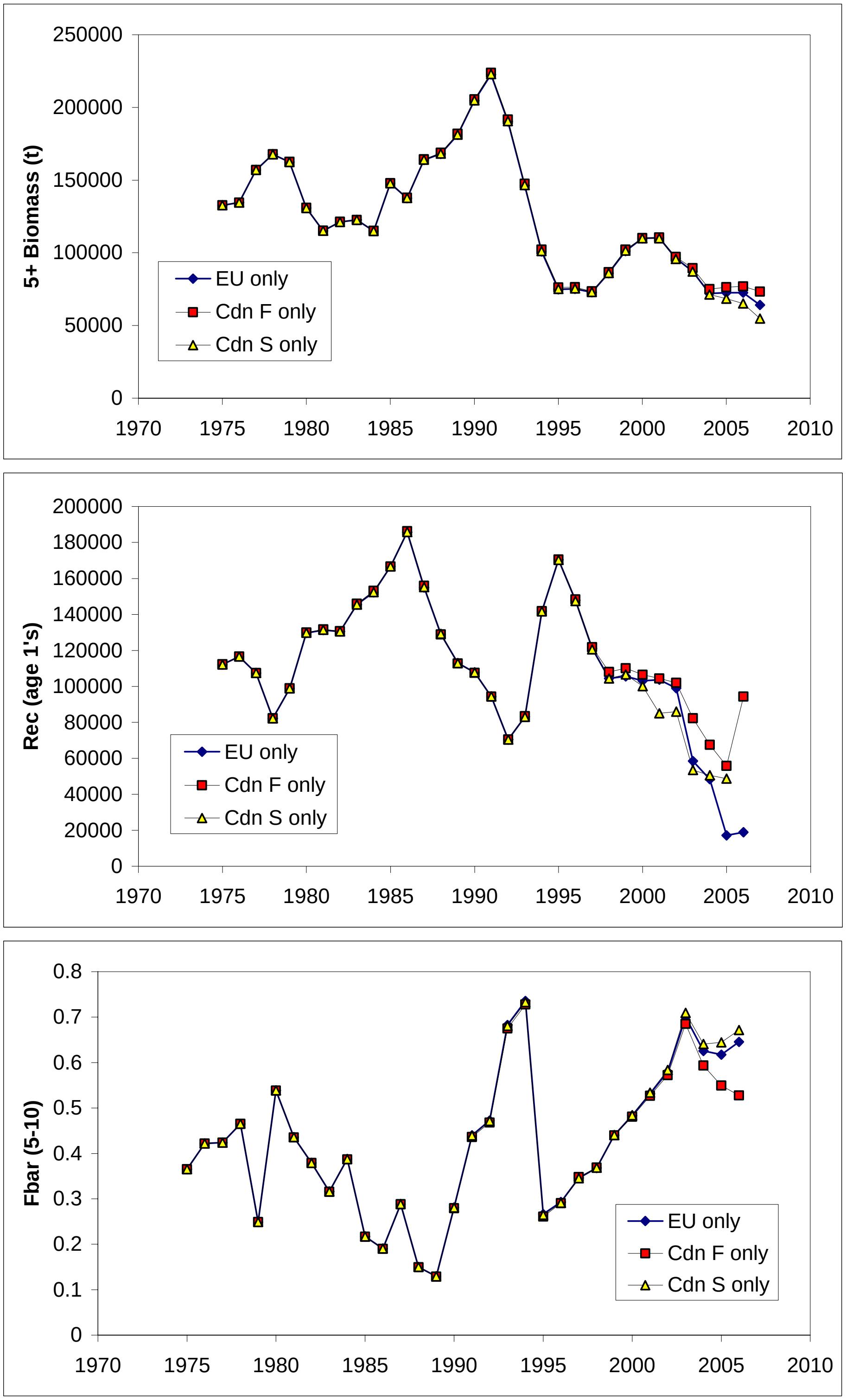


Figure 13. Biomass (5+; tons), Recruitment (age 1; 000s), and average fishing mortality (ages 5-10) from three XSA analyses calibrated using only one of the tuning series.

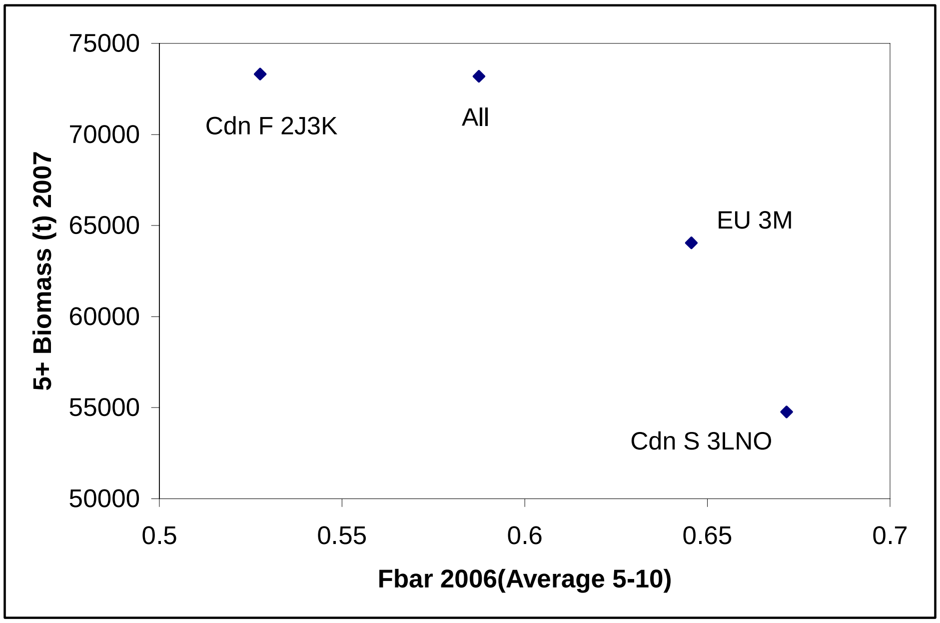


Figure 14. Comparison of exploitable biomass in 2007 and fishing mortality in 2006 for XSA analyses calibrated using a single tuning series. “All” refers to the analysis which includes all three data series.

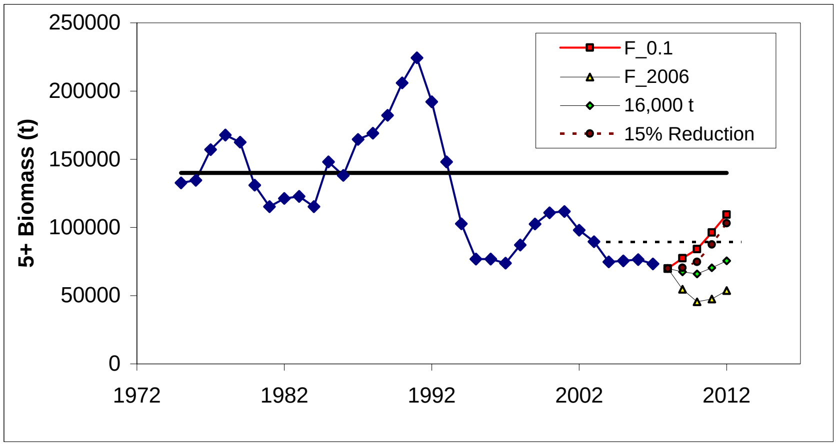


Figure 15. Deterministic projection of 5+ biomass to 2012 (see text for description of projection scenarios). The solid horizontal line represents the rebuilding plan target biomass of 140 000 tons; the dashed horizontal line is the level of the exploitable biomass in 2003, when the FC rebuilding plan was implemented.

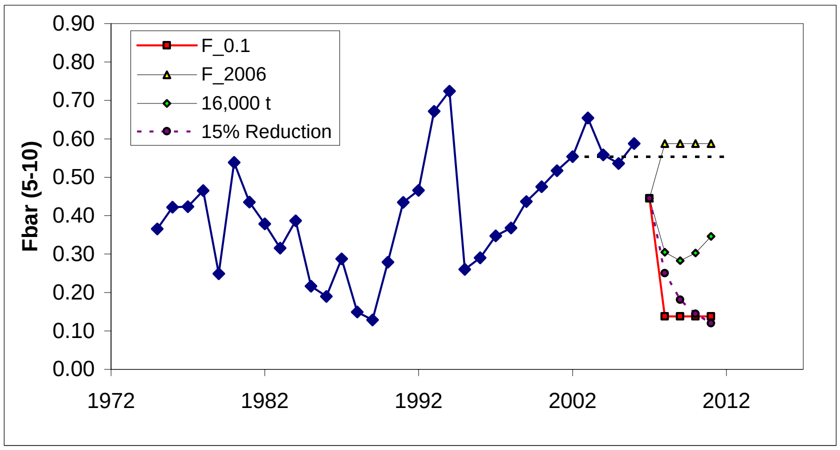


Figure 16. Deterministic projection of average fishing mortality to 2011 (see text for description of projection scenarios). The horizontal dashed line indicates the level of fishing mortality when the rebuilding plan was implemented.

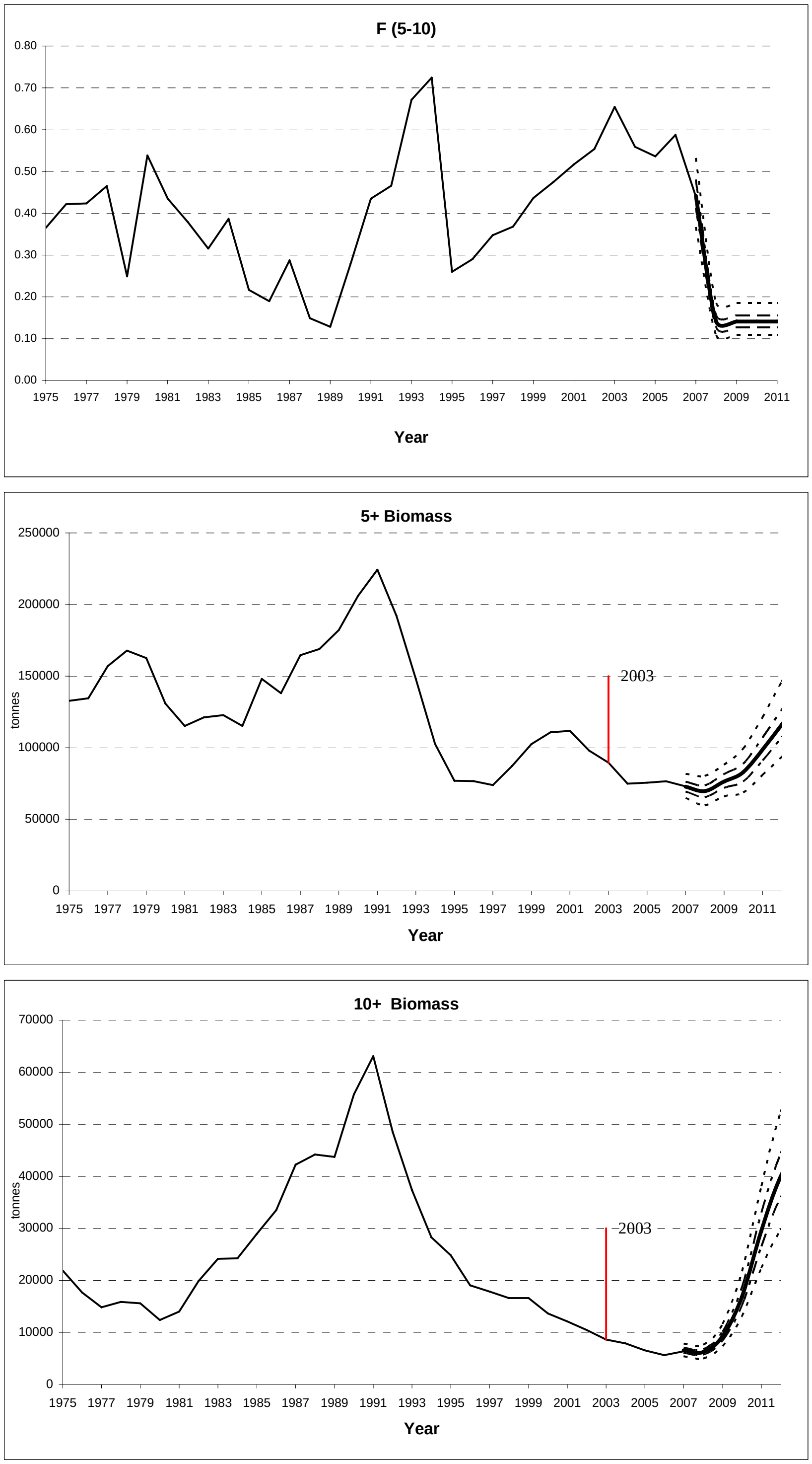


Figure 17. Stochastic projection estimates of average fishing mortality, 5+ biomass, and 10+ biomass over 2008-2012 assuming catches correspond to the F0.1 level. The biomass levels of 2003 (year in which rebuilding plan developed) are highlighted. The 5th, 25th, 50th (thick line), 75th, and 95th percentiles are shown.

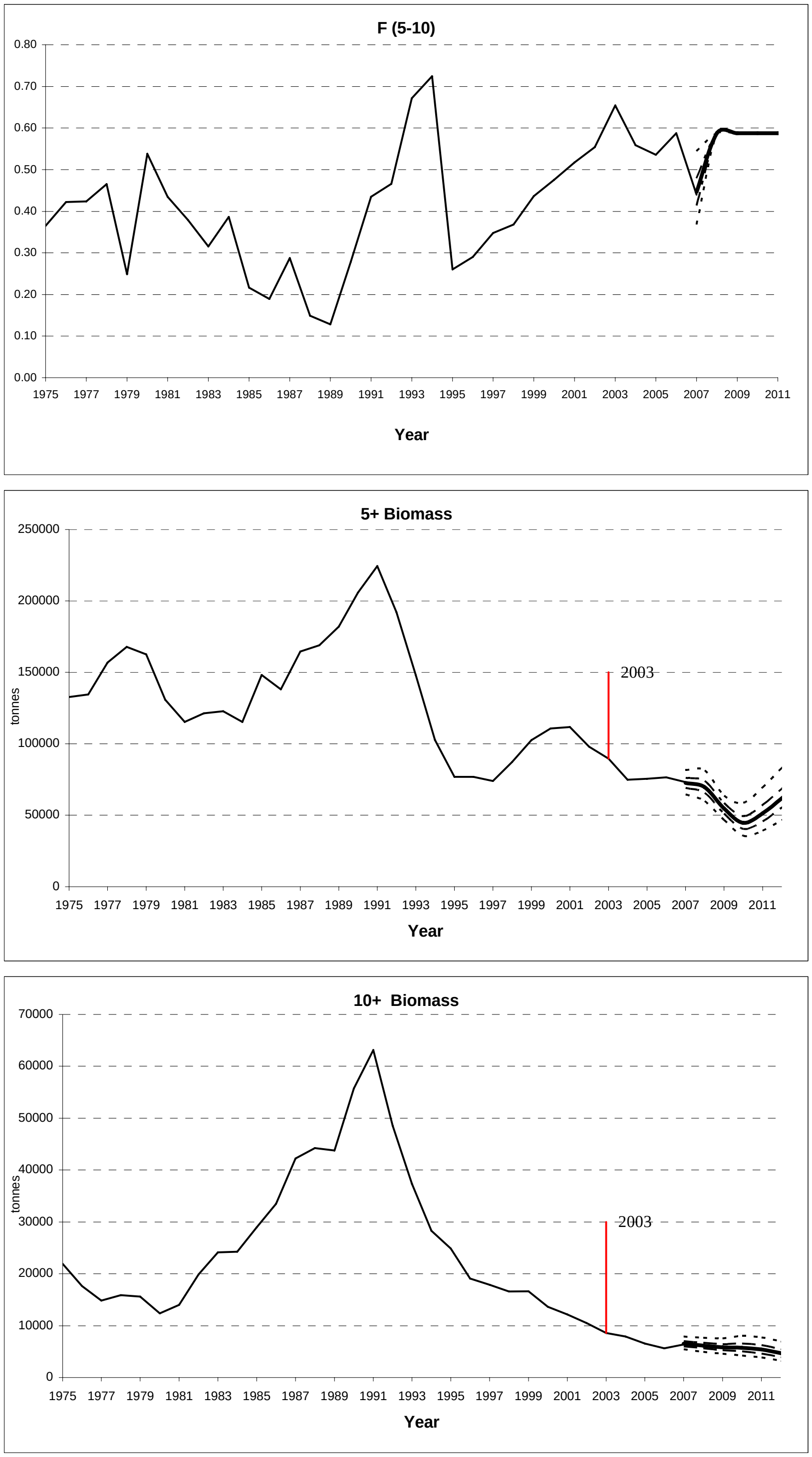


Figure 18. Stochastic projection estimates of average fishing mortality, 5+ biomass, and 10+ biomass over 2008-2012 assuming catches correspond to the F2006 level. The biomass levels of 2003 (year in which rebuilding plan developed) are highlighted. The 5th, 25th, 50th (thick line), 75th, and 95th percentiles are shown.

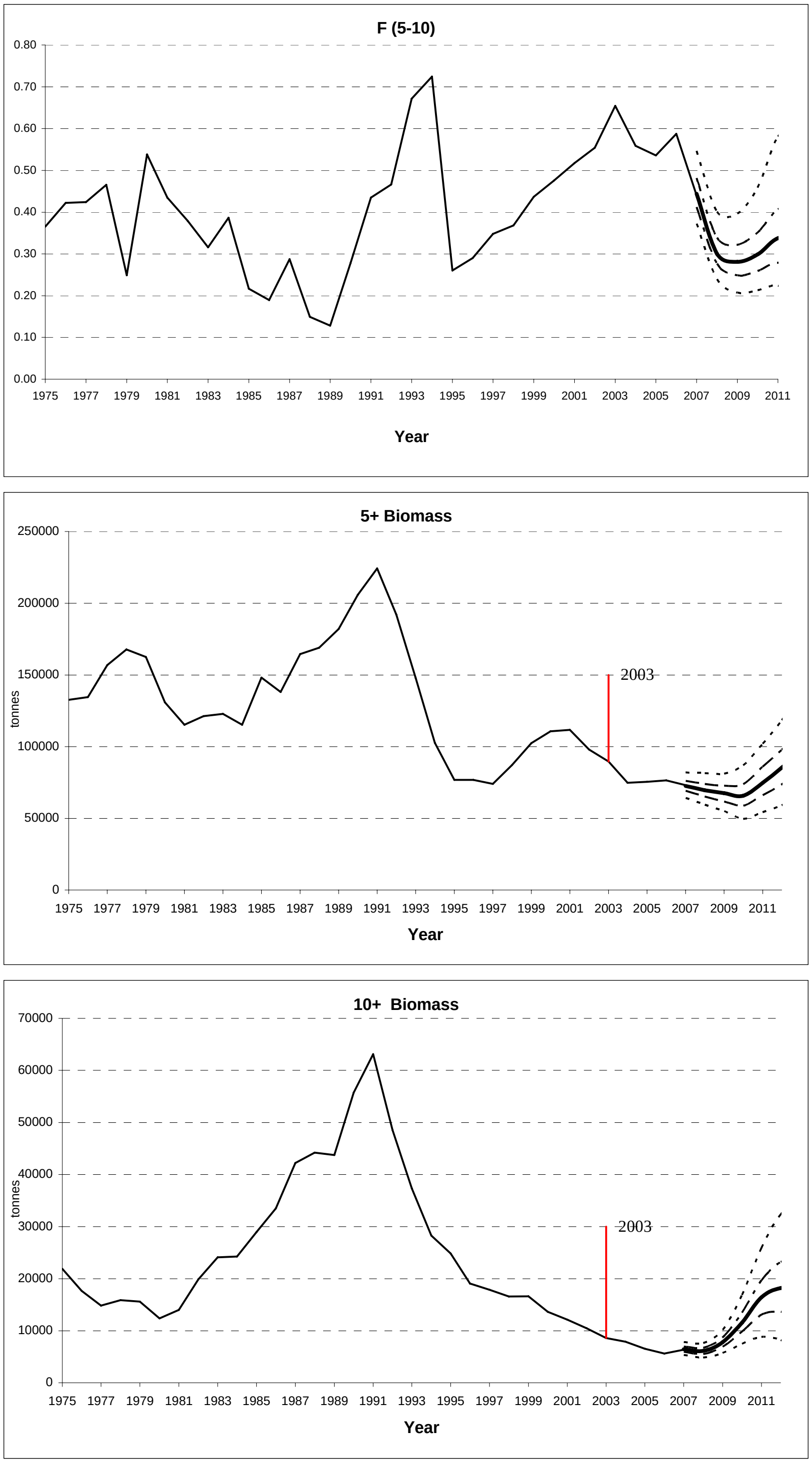


Figure 19. Stochastic projection estimates of average fishing mortality, 5+ biomass, and 10+ biomass over 2008-2012 under Rebuilding Plan I (catches from 2008 onward are fixed at 16 000 tons). The biomass levels of 2003 (year in which rebuilding plan developed) are highlighted. The 5th, 25th, 50th (thick line), 75th, and 95th percentiles are shown.

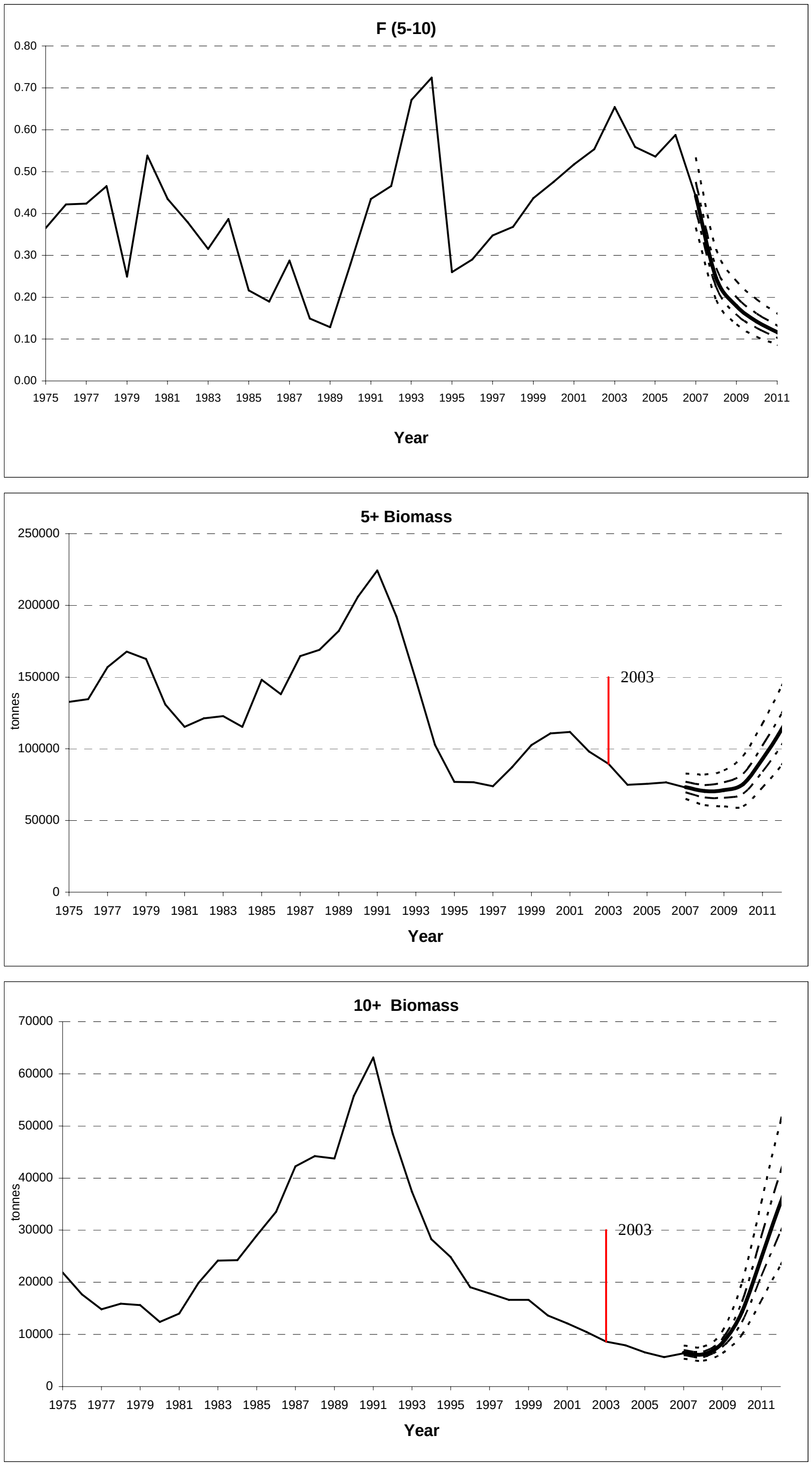


Figure 20. Stochastic projection estimates of average fishing mortality, 5+ biomass, and 10+ biomass over 2008-2012 under Rebuilding Plan II (assuming catches from 2008 onward are reduced by 15% annually from the 2007 TAC level). The biomass levels of 2003 (year in which rebuilding plan developed) are highlighted. The 5th, 25th, 50th (thick line), 75th, and 95th percentiles are shown.

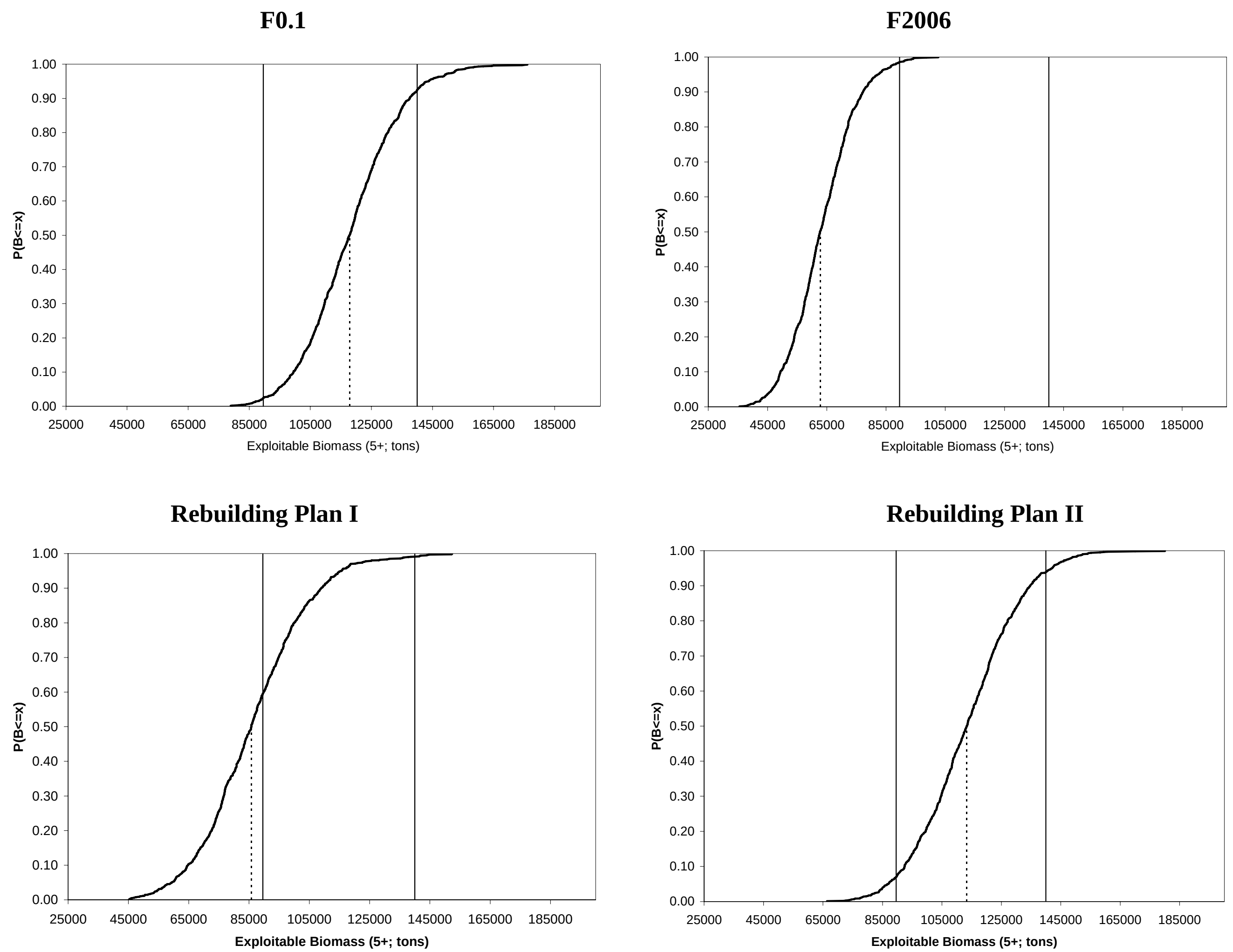


Figure 21. Cumulative probability of exploitable biomass in 2012 for each of the four projection scenarios being below a given level. Vertical lines demarcate the biomass level in 2003 (89 500 tons) and the rebuilding plan target (140 000 tons). The dashed vertical line indicates the median value of the projected exploitable biomass in 2012 under each scenario.